Sherco Solar RFP Appendix B – Technical Specifications

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1. Introduction

1.1. Definitions

1.1.1. Owner / Buyer: Xcel Energy

1.1.2. Contractor: EPC (Engineer, Procure, Construct) Contractor

1.1.3. Seller: Developer or EPC Contractor

1.1.4. Engineer / Engineer of Record: (EOR) EPC Contractor

1.1.5. Quality Assurance Representative (QAR): The Owner reserves the right to engage an individual, partnership or corporation, to perform independent testing, inspection, and analysis to verify the Contractor is supplying a product in compliance with all contractual requirements, including this specification. The QAR shall be qualified by training and experience and hold certifications or documentation of their qualifications. The QAR shall be selected by the Owner and be fully independent of the contractor.

1.1.6. Testing Agency: The Contractor shall employ an independent, accredited testing agency. The testing agency shall be employed by the Contractor, at no cost to the Owner. The testing agency shall complete all testing as documented in contract documents, including this specification.

1.1.7. Geotechnical Engineer: A qualified person licensed to perform geotechnical engineering and investigate, employed by the Contractor, at no cost to the Owner. The Geotechnical Engineer must be a licensed, professional engineer in the state where the project is located.

1.1.8. Utility: Owner of the transmission line for the interconnection agreement.

1.2. Project Description

The Sherco solar project shall be 75 MWAC or larger facility and shall utilize the Sherco 345 kV interconnection as described in the Sherco Solar Resource RFP document.

Contractor to provide all engineering, labor, procurement of materials and equipment, and supervision required for the complete design and installation of a fully functional, and operational solar photovoltaic (PV) facility with an O&M building as described in Appendix S, that is in full compliance with Owner's requirements, applicable codes, standards, laws and regulations. The described facility, as further detailed in the solar technical specifications, shall be designed for a 30-year operating life based on normal operation, and the performance of maintenance, repairs, and the replacement of parts according to manufacturers' recommendations and standard industry practices.

Contractor shall provide all materials (unless provided by Owner), and full system installation of all components, including photovoltaic modules, DC electrical systems including inverters, DC combiner boxes, mounting systems, weather station, remote monitored security cameras, Data Acquisition System (DAS) and electrical interconnection to the local Utility.

Contractor shall commission the component systems of the facility and coordinate interconnection and start-up with Utility. Contractor shall provide comprehensive on-site construction management at all times for the facility when work is conducted.

The facility shall be designed and arranged to make maximum use of the available space as defined in the documents and drawings provided in Attachment 7. The design of the facilities shall be to maximize the annual megawatt hours (MWh) over a 30-year operating life based on measured actual site conditions, and adjusted for evaluated operating, maintenance, and replacement costs.

It is anticipated that the sites will require grading modification for storm water collection and runoff features. Installations shall be pile supported design with direct buried electrical cabling below grade. The transition from PVC raceway above grade to direct buried cables shall include PVC conduit extending below grade to a PVC conduit sweep where the cable transitions to direct buried.

The base design capacity range of the facilities considered shall be capable of a 0.95 lead/lag power factor at the interconnect, unless otherwise indicated by the site interconnect agreement. See Section 9 for base design facilities greater than 75 MVA connecting at high-voltage (HV) transmission voltage levels. The facility will interconnect with the point of interconnection specified voltage distribution lines/substation or transmission lines/substation adjoining or on the facility property. The PV Solar installation shall be single axis tracker design, as dictated by Owner requirements. The module racking foundations shall be adequate for the wind and snow loading specified in Attachment 3. Medium voltage collection lines from each module shall be direct buried as described in this specification.

1.3. Engineering

In all cases, installed components shall carry a Nationally Recognized Testing Laboratories (NRTL) listing for their intended use and application (e.g. – UL, CSA, ETL) and shall be appropriate for the local climate and exposure. All components shall be installed per manufacturer guidelines and in a manner that upholds the manufacturer's warranty.

1.3.1. Transformers shall meet or exceed current US Department of Energy transformer efficiency standards.

1.3.2. Contractor shall consider existing site conditions (including any wetland, waterway, habitat, endangered/threatened species, flood, cultural) with respect to soil characteristics, site clearing, grubbing, grading and drainage to minimize site disturbance.

1.3.3. Contractor shall review the geotechnical evaluation report and shall take all relevant construction measures to accommodate the site conditions provided in the report, based on their professional experience. The geotechnical evaluation report is provided in the contract documents for information purposes only. Specifications provided in the geotechnical evaluation report shall be incorporated into the contract documents under the direction of the EOR. The Facility shall meet all applicable seismic requirements.

1.3.4. Contractor shall install power and communications infrastructure within the system to service the Owner DAS (Data Acquisition System). Layout of this infrastructure shall be in accordance with DAS specification and subject to Owner review and approval.

1.3.5. Contractor shall be responsible for coordinating telecommunications service to the system with telecommunications provider, where such coordination is allowed. Where such coordination is prohibited by the telecommunications provider, Contractor shall assist Owner in their coordination efforts with the telecommunications provider. Contractor is responsible for providing Owner with remote access to data (and physical access to the extent provided herein) to the revenue grade meter and DAS, and weather stations (as applicable). The PV system operation shall be monitored by measurement and data acquisition equipment that conforms to the standards set forth in IEC-61724, PV System Performance, sections 1, 2 and 3. Contractor may use the performance data solely to validate the system integrity and production performance.

1.3.6. Contractor shall review and comply with all environmental studies, glare/glint study, flood studies, cultural resource studies, habitat/species studies, wetlands studies, geotechnical data, and surveys for the project. Contractor shall verify all designs incorporated all results, conclusions, and recommendations from those reports, including all permit conditions and order points.

1.4. Standards

At a minimum, Contractor shall confirm that the facility is constructed in accordance with the most current, locally adopted version of the following standards, as applicable. In the case where standards have conflicting requirements, Contractor must notify the Owner.

All codes and standards required by the local Authority Having Jurisdiction (AHJ), including but not limited to:

1.4.1. ACI - American Concrete Institute

- ACI 318 latest edition, Building Code Requirements for Structural Concrete and Commentary.
- ACI 117, Specification for Tolerances for Concrete Construction and Materials.
- ACI 306, Cold Weather Concreting.
- ACI 305, Hot Weather Concreting.
- ACI 301, Standard Specifications for Structural Concrete.
- ACI 351.1R Grouting between Foundation and Support of Equipment and Machinery

1.4.2. AISC - American Institute of Steel Construction:

- AISC Steel Construction Manual
- AISC Specification for Structural Steel Buildings.
- AISC Code of Standard Practice for Steel Buildings and Bridges.

1.4.3. ASTM - American Society for Testing and Materials

- ASTM A36 Specification for Structural Steel.
- ASTM A992 Standard Specification for Structural Steel Shapes
- ASTM A780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
- ASTM A325 Specification for High-Strength Bolts for Structural Steel Joints.
- ASTM A307 Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.
- ASTM C 94 Standard Specification for Ready-Mixed Concrete
- ASTM F959 Specification for Compressible-Washer-Type Direct Tension Indicators for use With Structural Fasteners.
- ASTM E94 Guide for Radiographic Testing.
- ASTM E142 Methods for Controlling Quality of Radiographic Testing.
- ASTM E164 Practice for Ultrasonic Contact Examination of Weldments.
- ASTM E165 Practice for Liquid Penetrant Inspection Method.
- ASTM E709 Practice for Magnetic Particle Examination.
- ASTM E1799 – Standard Practice for Visual Inspections of Photovoltaic Modules
- ASTM E1802 – Standard Test Methods for Wet Insulation Integrity Testing of Photovoltaic Modules
- ASTM E1830 – Standard Test Methods for Determining Mechanical Integrity of Photovoltaic Modules
- ASTM E2047 – Standard Test Method for Wet Insulation Integrity Testing of Photovoltaic Arrays
- ASTM E2848 – Standard Test Method for Reporting Photovoltaic Non- Concentrator System Performance

1.4.4. AWS - American Welding Society:

- AWS D1.1 Structural Welding Code – Steel
- AWS D-1.2Structural Welding Code-Aluminum
- Welding Handbook RP69
- Research Council on Structural Connections:
  - Specification for Structural Joints Using ASTM A325 or A490 Bolts

1.4.5. ANSI - American National Standards Institute

- ANSI C37.90 – IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus
- ANSI Z21.83 – Solar Photovoltaic Performance Safety

1.4.6. ASCE - American Society of Civil Engineers

- ASCE 7 – Minimum Design Loads for Buildings and Other Structures ASTM -

1.4.7. ASHRAE – American Society of Heating, Refrigerating, and Air Conditioning Engineers

1.4.8. IBC - International Building Code

1.4.9. ICEA – Insulated Cable Engineers Association

1.4.10. IEC - International Electrotechnical Commission –

- IEC 61646 – Thin-film Terrestrial Photovoltaic (PV) modules Design Qualification and Type Approval
- IEC 61683 – Photovoltaic Systems Power Conditioners – Procedure for Measuring Efficiency
- IEC 61727 – Photovoltaic (PV) Systems – Characteristics of the Utility Interface
- IEC 61829 – Crystalline Silicon Photovoltaic (PV) Array – On site Measurement of I-V characteristics
- IEC TS 61836 – Solar Photovoltaic Energy Systems Terms and Symbols
- IEC 61215 – Terrestrial photovoltaic (PV) modules - Design qualification and type approval - Part 1-1: Special requirements for testing of crystalline silicon photovoltaic (PV) modules
- IEC 61724-1,2,3 - Photovoltaic System Performance Monitoring – Guidelines for Measurement, Data Exchange and Analysis
- IEC 62446-1 - Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance - Part 1: Grid connected systems - Documentation, commissioning tests and inspection
- IEC-62804 - Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation

1.4.11. IEEE - Institute of Electrical and Electronics Engineers

- IEEE 928 – Recommended Criteria for Terrestrial PV Power Systems
- IEEE 1374 – Guide for Terrestrial PV Power System Safety
- IEEE 1547 – Standards for Interconnecting Distributed Resources with Electric Power Systems

1.4.12. IFC – International Fire Code, with local amendments

1.4.13. ISA - Instrumentation Society of America

1.4.14. NEC - National Electrical Code

1.4.15. NEMA - National Electrical Manufacturers Association

1.4.16. NESC – National Electrical Safety Code (if required by AHJ, Incentives, or other governing authorities)

1.4.17. NETA - National Electrical Testing Association

1.4.18. NFPA – National Fire Protection Agency

- NFPA 1 – National Fire Code

1.4.19. OSHA - Occupational Safety and Health Act

1.4.20. UL - Underwriters Laboratories

- UL – Underwriter's Laboratories for all equipment when such standards exist

    - UL 1703 – Flat Plate Photovoltaic Modules and Panels
    - UL 1741 - Inverters, Converters, Controllers and interconnection System Equipment for Use with Distributed Energy Resources
    - UL 2703 –Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels
    - UL 3703 – Standard for Solar Trackers
    - UL 61730 – Photovoltaic (PV) Module Certification

System electrical design shall be NEC compliant to the greatest extend possible and in accordance with all applicable legal requirements.

1.5. Interconnection Agreement

The Contractor shall be responsible for obtaining the interconnection agreement from the Utility. Contractor will coordinate with the Utility and provide all necessary work, support, and materials for interconnection of the facility on the Owner side of the Point of Common Coupling (POCC) as defined in the Owner scope in the Interconnection Agreement, and as defined in the electrical drawings and site plan.

1.5.1. Contractor shall coordinate facility construction and interconnection with the Utility.

1.5.2. Contractor shall support and accommodate all necessary work for interconnection of the facility by the Utility.

1.5.3. Contractor shall be responsible for all work associated with the interconnection to the Utility on the Owner side of the POCC as defined in the Owner scope in the Interconnection Agreement, and as defined in the electrical drawings and site plan attached to this specification. If interconnection utilizes existing equipment, Contractor to determine suitable point of interconnection that complies with all Applicable Permits, the Interconnection Agreement and Utility requirements. The facility shall include switchgear (if applicable), circuit breakers, disconnect switches, surge arrestors, relay and protective systems, recloser/pad- mounted breaker (as applicable), revenue grade metering, supports, foundations, grounding systems, auxiliary control power, access roads (if applicable), utilities, and other related equipment for a complete and functioning system as required by the Utility and/or independent system operator.

1.6. General Site Work

All work performed must be in accordance with the most stringent requirements of this specification, and the applicable Authority Having Jurisdiction (AHJ).

1.6.1. Site Preparation

1.6.1.1. Contractor shall provide a plot plan identifying access, egress, laydown and storage areas, and turn-around ratios required for deliveries.

1.6.1.2. Contractor shall provide lay down area that meets relevant codes and standards.

1.6.1.3. Contractor shall be responsible for traffic control, when applicable, stabilized construction entrances, secure entrance gate.

1.6.1.4. The system, laydown, and storage shall consider existing site conditions (including any wetland, waterway, habitat, endangered/threatened species, flood, cultural) with respect to soil characteristics, site clearing, grubbing, grading and drainage to minimize site disturbance.

In areas with field drain tile all tile shall be located prior to construction and re-routed as needed to avoid all underground structures such as solar mounting pilings, fence posts, collection cable, and substation footings. All tile breaks or re-routes shall be documented by GPS and photos showing the location. All repairs shall be of equal capacity or greater and completed to the satisfaction of the landowner and warranted for 5 years.

1.6.1.5. A preconstruction visual survey documenting the conditions of the facility property will be performed, documented with appropriate images and delivered to Owner no later than five days prior to construction mobilization.

1.6.1.6. Site Maintenance During Construction

1.6.1.7. All temporary access roadways used by Contractor shall be constructed and maintained by Contractor in serviceable condition.

1.6.1.8. The Contractor shall maintain all Stormwater Pollution Prevention Plan (SWPPP) Best Management Practices during the entire course of the construction period, and until the construction stormwater permit, and/or local erosion control permit, is terminated.

1.6.1.9. Contractor shall be responsible for temporary erosion and sediment control requirements above and beyond those developed in the SWPPP that are deemed necessary by site conditions or AHJ.

1.6.1.10. The Contractor shall coordinate all activities with any adjacent property owners and local authorities to the satisfaction of the owner and local authorizes.

1.6.1.11. A post-construction survey documenting the conditions of the facility's property will be performed, documented with appropriate images and submitted to Owner within five days after the last heavy truck has traversed the road.

1.6.1.12. A final post-construction survey documenting the condition of the facility property after all construction trucking activity for the project will be delivered to Owner within ten days after the last heavy truck has traversed the road.

1.6.1.13. Contractor shall be responsible for design and implementation of dust suppression and erosion control measures at the facility.

1.6.1.14. Contractor shall supply and be responsible for the delivery and drainage of water necessary for Contractor's performance of the work, including dust suppression. Consumption costs shall be paid by Contractor.

1.6.1.15. Excavating, Trenching, Boring, Filling and Backfilling

1.6.1.16. Excavation, trenching, boring and backfill activities shall be completed as recommended in the contract documents.

1.6.1.17. Contractor shall be responsible for performing all operations in connection with underground (or above ground) DC and AC cabling and equipment pads.

1.6.1.18. Contractor shall be responsible for performing all excavation, filling, and backfilling operations for the equipment pads and buildings.

1.6.1.19. Contractor shall be responsible for the collection and containment of spoils during excavation activities. Spoils not used for backfill upon completion of construction are to be disposed of by the Contractor in compliance with all applicable laws, regulations, and codes.

1.6.1.20. Spoils from any source shall not be placed in or near ditches, swales, canals, or impoundments, or any location susceptible to erosion from high water, flooding, or storm water runoff.

1.6.2. Site Restoration

1.6.2.1. All site development areas disturbed during construction, including laydown, parking, temporary roadways and temporary office trailers shall be restored and stabilized with a pollinator friendly native plant community in accordance with the approved grading plan, SWPPP, and/or erosion control plans.

Contractor shall be responsible for compliance with the site's construction stormwater permit requirements, and local erosion control requirements, if applicable, until permit(s) can be closed out or terminated.

1.6.2.2. Post-Construction Soil Stabilization (as applicable)

1.6.2.3. A soil stabilization plan utilizing a regionally appropriate native seed mix shall be reviewed and approved by Owner and AHJ prior to implementation by Contractor.

1.6.2.4. The soil stabilization plan shall define the seed mix to be utilized in the areas to be stabilized along with data sheets describing the materials planting and methods to be used.

1.6.2.5. Materials shall be installed per manufacturer's recommendations. An as-built report should be prepared indicating final seed mix, installation methods, date performed and photographic documentation of conditions after planting

1.6.2.6. Materials shall be installed suitable to seasonal conditions.

Areas inside of the arrays will employ native low growth, organic vegetative ground cover as approved by the AHJ, where and when local conditions would support its growth. Contractor shall maintain for a period sufficient to facilitate self-sustaining vegetation in accordance with the SWPPP requirements.

To facilitate successful native plant establishment, contractor shall perform yearly maintenance for the first three years. Maintenance will consist of monitoring weed growth and soil moisture during the first growing season and mow any weedy growth higher than 18 inches to a height of 4 to 6 inches and/or provide water if droughty conditions are present. Contractor shall mow the site in early spring for the second and third years after planting. Contractor shall leave the site in the same or better condition that what was found at the commencement of **construction. Areas affected by construction will be cleaned of all construction materials and stabilized in accordance with the SWPPP and/or erosion control plan. Contractor shall repair and replace any affected irrigation systems and leave them fully operational to the satisfaction of the Owner's representative. Trees and stumps shall be removed for all solar arrays.**

1.6.3. General and Temporary Construction Facilities

1.6.3.1. Contractor shall be responsible for establishing and maintaining all restroom, office and meeting areas for the duration of the construction and commissioning portion of the project. Contractor shall provide a work space for the Owner's representatives.

1.6.3.2. Contractor shall provide temporary facilities consisting of washing stations and sanitary facilities.

1.6.3.3. Contractor shall maintain on-site dumpsters and personnel to maintain a clean and rubbish-free work site.

1.6.3.4. Contractor shall provide temporary electrical and network/internet services for its use during construction and consumption costs shall be paid by Contractor.

1.6.3.5. Contractor shall be responsible for supplying or connecting to existing site water source for its use during construction for drinking, personal/equipment washing and dust suppression.

1.6.3.6. Contractor shall fix, at his/her own expense all damaged pavement, utility lines, concrete, and landscape that is damaged as a result of construction activities at an equal or better condition than existed prior to operations.

2. Solar Equipment

2.1. Solar PV Field

2.1.1. All equipment specified by Contractor shall be approved by Owner.

2.1.2. The area available for the solar PV arrays is limited by a Contractor-provided geotechnical evaluation, landscape, protected areas, and other site constraints specified in a Contractor-provided American Land Title Association (ALTA) Survey or equivalent.

2.1.3. Design parameters other than those specified in this document shall be defined by Contractor and approved by the Owner.

2.1.4. PV module row pitch (post-to-post) shall be adequate to allow access for customary maintenance vehicles, such as a pick-up truck, equipment, and personnel.

2.1.5. PV module tilt angle shall be adequate to allow proper water/snow shedding.

2.1.6. PV module strings – groups of PV modules electrically connected in series – shall be designed in accordance with the inverter manufacturer’s maximum DC voltage input specifications and applicable code requirements for maximum operating DC voltage.

2.1.7. PV module arrays – groups of PV arrays electrically connected in parallel – shall be designed in accordance with the inverter manufacturer’s maximum DC current and power input specifications and applicable code requirements for maximum operating DC current and power.

2.2. Photovoltaic Modules

2.2.1. PV modules shall be designed to produce electricity for a minimum of 30 years under the environmental conditions of the site.

2.2.2. The electricity generation capabilities of the modules shall meet or exceed the capabilities defined by the module electrical data sheet of the product.

2.2.3. Annual degradation shall be specified by the manufacturer.

2.2.4. PV modules shall comply with the following parameters to ensure maximum quality and performance.

2.2.4.1. The module manufacturer shall be as agreed upon by Contractor, Owner or Owner's representative per Attachment 9**.**

2.2.4.2. Specification Sheet

a. The manufacturer/supplier shall provide detailed electrical and mechanical specification sheets for the module.

b. The manufacturer shall provide the estimated annual degradation of their module and justify the value provided with historical production data.

c. The maximum allowable annual degradation for modules used on this Facility shall be 0.55 percent per year.

d. Minimum Load Capacity (Snow Load) shall be 5400 Pa or greater.

2.3. Technology

2.3.1.1. The cell technology for the PV module shall be either monocrystalline or polycrystalline silicon, or thin film.

2.3.2. Codes and Standards

2.3.2.1. Modules shall either be UL listed or certified by an OSHA-approved testing agency to meet the UL 1703 specification.

2.3.2.2. The certificates of factory/laboratories tests and compliance to the codes and standards referenced by the manufacturer shall be provided to Owner.

2.3.2.3. The modules shall be provided with a permanent label indicating, at a minimum, the following information:

2.3.2.3.1. Make/model

2.3.2.3.2. Electrical characteristics, including open circuit voltage (Voc); short circuit current (Isc); maximum power point voltage (Vmpp); maximum power point current (Impp); nameplate power (W), and maximum series fuse size

2.3.2.3.3. Temperature coefficients of Isc, Voc and nameplate power

2.3.2.3.4. Nominal power conditions (STC, NOCT, etc.)

2.3.2.3.5. Environmental operating conditions

2.3.2.3.6. Compliance with applicable standards (UL, IEC, CE, etc.)

2.3.2.3.7. Warnings of electrical hazard

2.3.2.3.8. Maximum system voltage

2.3.2.3.9. Maximum Load Capacity

2.3.2.3.10. Date and location of manufacture, manufacturing code

2.3.2.3.11. Serial number

2.4. Module Design and Construction

2.4.1. All modules shall be new and unused. In order to maintain the homogeneity of the system, all cells and modules used throughout the facility shall be supplied by the same manufacturer, be of the same make and model types, and shall have the same nameplate power rating.

2.4.2. The modules shall include factory installed power conductors at least No.12 American Wire Gauge (AWG), rated at 1500 VDC, with clearly defined polarities, weather-proofed, UV resistant/outdoor rated and with locking-type plug-in connectors of single polarity and with same environmental and electrical ratings as the power conductors.

2.4.3. All modules shall be of the same type shall have the same connectors.

2.4.4. The modules shall include a grounding lug, grounding hole, or some other tested grounding attachment mechanism (applicable for framed modules only).

2.4.5. Grounding attachment must specifically be approved by the AHJ.

2.4.6. The module framing, where provided, shall be corrosion-resistant, resistant to damage from snow, wind, hail and windblown dust and sand.

2.4.7. PV modules, at minimum, shall be supplied with a 10-year defects warranty and a minimum 25-year performance degradation warranty.

2.4.8. PV modules damaged during shipping and construction shall be replaced by the Contractor.

2.4.9. Contractor shall provide reports on PV panel delivery at site. The report shall include inspection and acceptance of the panels along with serial numbers for tracking.

2.4.10. Required Spare Parts

2.4.11. Contractor shall provide 0.25 percent of the modules installed to be kept as spares at a minimum with an option to purchase up to 1.0% of the modules installed to be kept as spares.

2.4.12. Unless the O&M building is large enough, Contractor shall provide storage on site for the spare panels in weather- tight shipping containers or Owner-approved equivalent.

2.5. PV Module Mounting System

2.5.1. The PV module mounting systems for typical single axis tracking (SAT) arrays shall meet the following specifications:

2.5.1.1. The design specifications for the foundations of the module mounting system ("mounting system") shall be provided by Contractor as part of the mounting system design specifications for either fixed or SAT systems.

2.5.1.2. The mounting system foundation shall be designed to withstand the site-specific constraints provided in the contract documents, (ground-mounted system) without replacement or compromising its structural integrity for a minimum of 25 years.

2.5.1.3. The foundation shall be designed to comply with all the environmental conditions of the site.

2.5.1.4. The mounting system shall be designed to withstand wind speeds up to the maximums specified by applicable codes, over its specified operating lifetime, without compromising its structural integrity.

2.5.1.5. The mounting system and modules shall have provisions to be continuously bonded and grounded to the ground grid system of the array.

2.5.1.6. The mounting system shall be certified by UL or another approved testing agency to meet the requirements of UL Subject 2703.

2.5.1.7. If a SAT system is provided, it shall be certified by UL or another approved testing agency to meet the requirements of UL Subject 3703.

2.5.1.8. If a SAT system is provided, it must satisfy minimum site requirements for mechanical and electrical equipment ground clearances.

2.5.2. In addition to meeting the requirements of the mounting system, Contractor shall:

2.5.2.1. Provide detailed information on the materials and design of the mounting system.

2.5.2.2. Provide a detailed structural analysis of the foundations and demonstrate that the design conforms to the applicable standards and codes and the contract documents.

2.5.2.3. Demonstrate that the modules will stay attached to the mounting structure under all environmental conditions specified by applicable codes.

2.5.2.4. Ensure that the design of the mounting structure specifies the attachment of the PV modules to mounting structure in accordance with the mounting specifications provided by the PV module manufacturer.

2.5.2.5. Submit all structural designs and calculations for the mounting system to Owner for review prior to purchase of any mounting system equipment.

2.5.2.6. Prepare a design to mitigate the effects of corrosive soils on the structural support system for the design life, which includes concreting around posts, adding a sacrificial layer to the structural steel members, galvanizing, and/or coating the structural steel members with epoxy coating.

2.5.2.7. Provide a detailed description of the method of installation for the mounting system.

2.5.3. Required Manufacturer's Warranties- Single Axis Tracker Mounting System

2.5.3.1. The module mounting manufacturer shall provide a product warranty of at least 10 years on structural components.

2.5.3.2. Tracker drive and control system shall be warrantied a minimum 5 years, with options for extension.

2.5.4. Required Spare Parts- Single Axis Tracker Mounting System

2.5.4.1. All necessary hardware for at least two PV module racks shall be provided as spare parts.

2.6. Combiner Boxes

2.6.1. Each combiner box shall include a fused connection between all underground DC circuit wiring from PV strings to provide over-current and short-circuit protection.

2.6.2. The ungrounded DC circuit wiring from PV strings (if any) shall be connected to a terminal block and bus bar.

2.6.3. The combiner box output circuit (homerun) shall be provided with a load-break disconnect switch with exterior lockable handle, rated for the voltage and current of the combined PV strings.

2.6.4. The string fuses and fuse holders shall be finger-safe and rated according to the string DC current and voltage, and environmental conditions.

2.6.5. The power terminal blocks shall be rated for use with copper conductors and rated for continuous duty at 1500 VDC and 90°C conductor and terminal temperature ratings.

2.6.6. The combiner box shall be equipped with a mechanical ground lug and bus, rated for terminations with copper grounding conductors.

2.6.7. The combiner enclosure shall be outdoor-rated, weatherproof, NEMA 3R or NEMA 4 or NEMA 4X, and the doors shall be easily interchangeable.

2.6.8. The manufacturer shall supply a fully assembled combiner box and shall provide detailed drawings, specifications sheets, mounting instructions, and maintenance requirements of its product.

2.6.9. Each combiner box shall provide “touch-safe” power circuit terminations and include provisions for bolted terminations of the output power circuit to the inverter.

2.6.10. Surge protective devices, per UL 1449, shall be installed at the line side of the main disconnect switch.

2.6.11. Conduit entries into the combiner box shall be from the side or bottom to prevent water ingress.

2.6.12. Each combiner box shall include a provision for a padlock, including a padlock and key.

2.6.13. All padlocks shall be keyed the same. Tags and zip ties may be used as an alternate.

2.6.14. The combiner box door shall be interlocked with a load-break disconnect switch in such a manner that the door cannot be opened when the switch is “closed.” In addition, the switch shall not be capable of being placed in the “closed” position unless the combiner box door is fully closed.

2.6.15. An external door interlock defeat mechanism shall be provided to allow authorized personnel access to the interior of the combiner box while the switch is in the closed position for periodic inspection, troubleshooting, and electrical field measurements.

2.6.16. The combiner box shall be listed to UL 1741 to 1500 VDC, and rated for an operating temperature range of -40°C to +50°C.

2.6.17. Each combiner box shall be suitable for application of permanent labels in the field and shall include electrical warning labels.

2.6.18. All information and warnings required by the National Electrical Code sections 690 and 705 shall be provided on a permanent label attached to each combiner.

2.6.19. Arc Flash PPE requirements shall be provided on a permanent label attached to each combiner.

2.6.20. As an alternate, provide monitoring of string circuit currents.

2.6.21. Required Manufacturer’s Warranties:

2.6.21.1. Combiner boxes shall have a manufacturer's warranty of at least 5 years.

2.6.22. Required Spare Parts:

2.6.22.1. Contractor shall provide at least 1 spare combiner box for every 2 MW AC of installed capacity.

2.6.22.2. Each combiner box shall include 10% spare fuses of each size and type.

2.7. Recombiner Boxes (if required)

2.7.1. Recombiner boxes shall provide a main DC disconnecting means.

2.7.2. Recombiner boxes shall be connected directly before the inverter input via throat connection.

2.7.3. Recombiner boxes shall also meet the following requirements:

2.7.3.1. Rated for 1500 VDC

2.7.3.2. Up to 24 input circuits with configurations up to 1200 A

2.7.3.3. Overcurrent protection (fuses or breakers)

2.7.3.4. If fuses are used, load break disconnects shall be provided that meet the provisions of NFPA-70-2011 (NEC) 690.16(A) and (B) (fuses: disconnecting means and fuse servicing).

2.7.3.5. 90°C rated terminals

2.7.3.6. Continuous duty rated

2.7.3.7. NEMA 3R or NEMA 4 or NEMA 4X

2.7.3.8. Each recombiner box shall include a provision for a padlock, including a padlock and key.

2.7.3.9. All padlocks shall be keyed the same. Tags and zip ties may be used as an alternate with permission of owner.

2.7.3.10. Ground bus

2.7.3.11. As an alternate, provide monitoring of PV output circuit currents.

2.7.4. Each recombiner box shall be suitable for application of permanent labels in the field and shall include electrical warning labels.

2.7.5. All information and warnings required by the National Electrical Code sections 690 and 705 shall be provided on a permanent label attached to each combiner.

2.7.6. Required Manufacturer's Warranties

2.7.6.1. Recombiner boxes shall have a manufacturer's warranty of at least 5 years.

2.7.7. Required Spare Parts

2.7.7.1. Each recombiner shall include 10% spare fuses of each size and type.

2.8. Solar PV Inverters

2.8.1. Inverters shall meet the following requirements:

2.8.1.1. The inverters shall include the necessary DC circuit breakers/disconnect switches, AC circuit breakers/disconnect switches, local controls, remote SCADA system interface (or web-based interface if Owner approved), grid operator control interfaces, and accessories necessary for the inverter to meet all code requirements and function properly as part of a power generation facility.

2.8.1.2. Environmental ratings: -40° to +50°C (-40° to 122°F), Humidity: 15 % - 95%, non-condensing, 6,500 feet elevation.

2.8.1.3. Power factor capability at the point of interconnection shall be at least 0.95 and able to be actively controlled.

2.8.1.4. Power factor capability shall be compliant with the interconnection requirements.

2.8.1.5. Inverters shall include flicker mitigation.

2.8.1.6. Central inverters shall have a nameplate rating greater than or equal to 1 MW AC, unless otherwise approved by Owner.

2.8.1.7. Upon preliminary selection of the inverter make and model, Contractor shall deliver to Owner a location where this inverter in operation.

2.8.1.7.1. Inverter manufacturer shall provide access for a site visit at this location by Owner or Owner’s representative to perform sound level testing. (If required)

2.8.1.7.2. Inverter must meet sound level requirements prior to proceeding with this equipment selection.

2.8.1.8. Inverter maximum input voltage shall be 1500 Vdc, unless otherwise approved by Owner.

2.8.1.9. Inverters shall be IEEE 1547 compliant except for anti-islanding and grid disturbance behavior.

2.8.1.10. Output current harmonics shall contain <3% total harmonic distortion (THD) at rated power output, per IEEE 519, utilizing site check meter. The site check meter shall be capable of providing voltage and harmonic data to the 50th harmonic.

2.8.1.11. .

2.8.1.12. Inverter California Energy Commission (CEC) efficiency shall be >97% without medium voltage step-up transformer.

2.8.1.13. Inverters located outdoors shall be enclosed in lockable, NEMA 3R enclosures, at a minimum.

2.8.1.14. The Contractor’s design shall include an analysis of the maximum anticipated operating temperature to ensure that the manufacturer's recommended operating temperature is not exceeded.

2.8.1.15. Enclosure shall have a door interlock system to prohibit the door(s) from being opened while energized.

2.8.1.16. Inverters shall incorporate a non-load-break, two (2)-pole, lockable disconnect switch for main DC power disconnect for maintenance personnel safety, or other Owner approved method.

2.8.1.17. Inverter output shall be protected by an AC output circuit breaker with short and long time adjustable over current protection.

2.8.1.17.1. This circuit breaker shall be externally operated, or Contractor shall furnish an external on/off (start/stop) switch. (If required by Owner, or per local requirements.) 115 VAC electrical outlets at all work locations

2.8.1.18. Inverters shall be capable of rated output at 50ºC (122ºF) ambient or higher without derating.

2.8.1.19. Inverters shall employ a maximum power point tracking scheme to optimize inverter efficiency over the entire range of PV panel output for the given site design conditions.

2.8.1.20. Inverters shall be equipped with all hardware for data collection and communication to the central SCADA server, including the ability to write to the control registers to reset inverter and modify AC output parameters, including power factor and maximum power.

2.8.1.21. Data collection points shall be integrated into the inverter monitoring and communications package.

2.8.1.22. Inverter Data collection points included shall be (at a minimum):

- AC Voltage
- DC Voltage
- AC Current
- DC Current
- Real Power (kW)
- Reactive Power (kvar)
- Apparent Power (kVA)
- Energy (kWh)
- Alarms
- Inverter status and faults (including ground fault interrupts)

2.8.2. Required Manufacturer's Warranties

2.8.2.1. The inverter manufacturer shall provide a warranty of at least 10 years, with Owner option to extend.

2.8.3. Required Spare Parts

2.8.3.1. The manufacturer shall provide the necessary spare parts for the first two years of operation.

2.8.4. Disconnect Switches

2.8.4.1. Disconnect switches shall meet the following requirements:

- 600 VAC
- Continuous current rating as specified on the drawings (minimum 30 A)
- Three-pole
- NEMA 3R enclosure
- High conductivity copper
- Visible blades
- Positive, quick-make, quick-break mechanisms
- Operating handle whose position is easily recognizable, and which can be locked in the OFF position with multiple padlocks.
- The ON and OFF positions shall be clearly marked.
- Door interlock that prevents the door from being opened while the operating handle is in the ON position.
- All AC service disconnects shall include integrated or compatible adjacent surge protection.
- Conform to NEMA KS1
- UL listed.

Manufacturer's Standard Warranties shall apply

2.9. Meteorological Monitoring Station(s)

2.9.1. Contractor shall supply and install one stand-alone central meteorological monitoring station (met station) at the site for each 25 MWAC of generation. The met station for each 25 MWAC block shall be spaced to provide accurate data for the site.

2.9.2. The met station shall include all instrumentation and sensors necessary to comply with the requirements set forth below in Attachment 2,12, 16, and 17..

2.9.3. The met station shall include a datalogger that can record data from all required instruments and sensors.

2.9.4. The met station datalogger shall include a backup power system, which may or may not be connected to the SCADA System UPS system, to allow for stand-alone operation for at least fifteen days.

2.9.5. The met station datalogger shall have at least a fifteen-day on-board non-volatile data storage capacity.

2.9.6. The met station datalogger shall be capable of sampling data at a rate of at least once per minute.

2.9.7. Five-minute averages of the one-minute data samples shall be recorded every five minutes.

2.9.8. The access to the datalogger shall be password protected and Contractor shall provide the required software, cables and instruction manual to connect to the port and access the data.

2.9.9. The meteorological monitoring station shall include a communications port compatible with a standard laptop computer running Windows OS or Owner approved operating system to be able to read and download data on site.

2.9.10. The pyranometers used shall be Class A pyranometer and shall be a Hukseflux SR-30 or equivalent.

2.9.11. Weather station items shall be as listed:

2.9.11.1. Datalogger with battery backup and Modbus TCP/IP communications

2.9.11.2. Ambient Air Temperature and Relative Humidity

2.9.11.3. Global Horizontal Irradiance Pyranometer

2.9.11.4. Plane of Array Pyranometer (2 minimum)

2.9.11.5. Back of Monitor Temperature Sensors (minimum 10, site size dependent)

2.9.11.6. Precipitation Gauge and Meter

2.9.11.7. Anemometer, Wind Speed and Direction

2.9.11.8. Panel Auxiliaries – Lighting and Receptacle

2.9.12. Optional Solar Resource Monitoring Equipment**:**

2.9.12.1. RaZON+ All in One Solar Monitoring System and Mounting Tripod

2.10. GROUNDING SYSTEMS

2.10.1. All grounding systems shall be designed and provided as required by NEC, NESC, IEEE, and local code requirements.

2.10.2. All grounding systems shall comply with the following:

2.10.2.1. Ground loops shall be provided under/around major electrical equipment.

2.10.2.2. The grounding system shall consist of bare copper conductor and copper-clad steel or stainless-steel ground rods.

2.10.2.3. The system shall be designed to protect personnel and equipment at the facility from the hazards that occur during power system faults and lightning strikes.

2.10.2.4. For ground grids below grade, each junction of the grid shall be bonded with either exothermic welds or irreversible compression connections.

2.10.2.5. Major items of equipment such as inverters and transformers shall have integral ground buses connected to the grounding electrode system.

2.10.2.6. Contractor shall route a grounding conductor parallel to all power conductors operating above 50 volts.

2.10.2.7. The module DC system grounding electrode(s) shall be common with, or bonded to, the AC grounding electrode as indicated in NEC Article 690.4

2.10.2.8. Module grounding shall follow module manufacturer recommendations for grounding.

2.11. POWER AND CONTROL WIRING

2.11.1. Cables shall be selected with an insulation level applicable to the system voltage for which they are used and ampacities suitable for the load being served.

2.11.2. The type of cable used shall be determined by individual circuit requirements, temperature, and individual equipment manufacturer’s recommendations.

2.11.3. Current carrying conductors shall be copper only.

2.11.4. All exposed wiring shall be clearly indicated as sunlight or UV resistant.

2.11.5. DC Cables – Type I

2.11.6. Type I DC cables shall include those used for: Interconnecting PV modules

2.11.6.1.1. Connecting PV module strings to combiner boxes

2.11.6.1.2. Type I DC cables shall be sized in accordance with the NEC requirements for "Solar Photovoltaic Systems" (Article 690) and shall be rated according to the maximum system voltage.

2.11.6.2. Copper conductor is required for all cables from module to module or combiner.

2.11.6.3. Conductors shall be sized accordingly considering any ambient temperature or ampacity de-rate factors and voltage drop considerations.

2.11.6.4. DC cabling shall be sized to not exceed a maximum voltage drop of 2 percent total from PV to module to inverter at Standard Test Conditions.

2.11.6.5. PV Wire is recommended for DC string cables, Owner approval required for alternative DC cable types or PV wire harnesses.

2.11.6.6. If the DC system is ungrounded, PV Wire is required for all conductors that are not enclosed in raceway.

2.11.6.7. DC cable may be direct buried and shall have a minimum insulation that meets the NEC requirement for "Wet Locations." If the DC system is ungrounded, PV Wire is required for all direct buried DC cable.

2.11.6.8. Schedule 80 PVC conduit shall be used for transitions "entering" and "exiting" the cable trench to meet NEC 300.5(D) requirements.

2.11.6.9. DC conductors installed underground or in concrete slabs in PVC conduit are acceptable.

2.11.6.10. Schedule 80 PVC conduit shall only be used above ground to allow immediate transition to metallic raceway.

2.11.6.11. Schedule 40 PVC shall only be used below ground or in concrete slabs.

2.11.6.12. Cable insulation levels shall be rated according to the maximum system voltage.

2.11.6.13. Insulation and jacket materials on all DC conductors, regardless of location, shall be made from thermoset materials such as XLP.

2.11.6.14. No thermoplastic insulation or jacket materials are permitted for DC conductors.

2.11.6.15. Cable insulation type shall be sunlight resistant, rated for wet locations, and have a temperature rating of 90°C or better.

2.11.6.16. Exposed DC string wiring shall be secured at intervals of approximately 24 inches, on center, maximum.

2.11.7. DC Cables – Type II

2.11.7.1. Type II DC cables shall include those used for:

- Connecting combiner boxes to recombiner boxes or inverters
- Connecting recombiner boxes to inverters

2.11.7.2. Conductors shall be sized accordingly considering any ambient temperature or ampacity de-rate factors and voltage drop considerations.

2.11.7.3. DC cabling shall be sized to not exceed a maximum voltage drop of 2 percent total from PV module to inverter at Standard Test Conditions.

2.11.7.4. Aluminum conductor may be used for conductors from combiner to inverter if the conductor is AWG 1/0 or larger. Otherwise copper conductor is required.

2.11.7.5. DC cable may be direct buried and shall have a minimum insulation that meets the NEC requirement for "Wet Locations." If the DC system is ungrounded, PV Wire is required for all direct buried DC cable.

2.11.7.6. Schedule 80 PVC conduit shall be used for transitions "entering" and "exiting" the cable trench to meet NEC 300.5(D) requirements.

2.11.7.7. DC conductors installed underground or in concrete slabs in PVC conduit are acceptable.

2.11.7.8. Schedule 80 PVC conduit shall only be used above ground to allow immediate transition to metallic raceway.

2.11.7.9. Schedule 40 PVC shall only be used below ground or in concrete slabs.

2.11.7.10. Cable insulation levels shall be rated according to the maximum system voltage.

2.11.7.11. Insulation and jacket materials on all DC conductors, regardless of location, shall be made from thermoset materials such as XLP.

2.11.7.12. Thermoplastic insulation or jacket materials shall not be permitted for DC conductors.

2.11.7.13. Cable insulation type shall be rated for wet locations and have a temperature rating of 90°C or better.

2.11.8. Low Voltage AC Power Cables

2.11.8.1. Low Voltage (LV) AC Power Cables shall include those used for connecting inverter output terminals to step-up transformer input terminals

2.11.8.2. Aluminum conductor may be used for conductors for LV AC Power Cable if the conductor is AWG 1/0 or larger.

2.11.8.3. Otherwise copper conductor is required.

2.11.8.4. All power and control cables shall be UL listed.

2.11.8.5. Cables shall be routed in UL listed wireway, conduit, direct buried PVC conduit, or underground duct banks.

2.11.8.6. A maximum of 1 percent AC voltage drop is acceptable between inverter AC output and step-up transformer LV AC input.

2.11.8.7. A maximum of 3 percent AC voltage drop is acceptable in other AC circuits not associated with solar power production.

2.11.8.8. Less than 600 V AC applications

2.11.8.9. Cable insulation levels shall be rated 600 V.

2.11.8.10. Conductors installed in PVC conduit are acceptable.

2.11.8.11. Low voltage power cables for loads up to 480 volts AC and control cables (i.e., 120 volts ac) shall have copper conductor with 600-volt class insulation.

2.11.8.12. Power cables shall be Type XHHW-2 with concentric-lay, uncoated copper, strand B conductor, rated for normal maximum operating temperature of 90°C in wet and dry applications, cross-linked thermosetting polyethylene insulation, and conforming to ICEA S-95-658 (NEMA WC 70).

2.11.9. Auxiliary Power Cables

2.11.9.1. Auxiliary power cables shall include those used for Lighting, electrical receptacles, computers, programmable logic controllers (PLCs), and heating/ventilation.

2.11.9.2. Auxiliary power cables for loads up to 480 volts AC and control cables (i.e., 120 volts ac) shall have copper conductor with 600-volt class insulation.

2.11.9.3. All power and control cables shall be UL listed.

2.11.9.4. Cables shall be routed in UL listed wireway, conduit, direct buried PVC conduit, or underground duct banks, as required.

2.11.9.5. A maximum of 3 percent AC voltage drop is acceptable in AC circuits not associated with solar power production.

2.11.9.6. Power cables shall be Type XHHW-2 with concentric-lay, uncoated copper, strand B conductor, rated for normal maximum operating temperature of 90°C in wet and dry applications, cross-linked thermosetting polyethylene insulation, and conforming to ICEA S-95-658 (NEMA WC 70).

2.11.10. Control System Cables

2.11.10.1. Control cables shall include those used for system control, alarms, contacts, etc.

2.11.11. Shall be type XHHW-2 with concentric-lay, uncoated copper, strand B conductor, rated for normal maximum operating temperature of 90°C in wet and dry applications, cross-linked thermosetting polyethylene insulation, and conforming to ICEA S-95-658 (NEMA WC 70). Multi conductor cable assemblies with XLPE insulation and an overall CPE jacket, 600V. Tray rated, suitable for direct burial. Analog Instrumentation Cables

2.11.11.1. Analog instrumentation cables shall meet the following requirements:

2.11.11.1.1. Twisted Shielded Pair type

2.11.11.1.2. No less than 16 AWG seven-strand

2.11.11.1.3. Concentric-lay

2.11.11.1.4. Uncoated copper conductor

2.11.11.1.5. Rated for normal maximum operating temperature of 90°C dry and 75°C wet applications

2.11.11.1.6. Polyvinyl chloride insulation not less 15 mils average thickness

2.11.11.1.7. Twisted pair of 1-1/2 inch to 2-1/2 inch (38.10 mm - 63.5 mm) lay

2.11.11.1.8. Shield consisting of combination aluminum-polyester tape and seven-strand

2.11.11.1.9. 20 AWG minimum tinned copper drain wire

2.11.11.1.10. With shield applied to achieve 100 percent cover over insulated conductors

2.11.11.1.11. Jacket thickness of 4 mils minimum

2.11.11.1.12. Conductor color identification with one black conductor and one white conductor

2.11.11.1.13. Conforming to UL 62 for Type TFN, and UL 1277 for vertical-tray flame test requirements.

2.11.12. Fiber Optic Cables

2.11.12.1. Fiber optic cable shall meet the following requirements:

2.11.12.1.1. Multi-mode or single-mode (per Owner’s requirement)

2.11.12.1.2. 6 strand minimum

2.11.12.1.3. Double armor (corrugated steel tape), double jacket, when direct buried

2.11.12.1.4. Single armor (corrugated steel tape), single jacket when installed in conduit

2.11.12.1.5. Black polyethylene inner and outer jacket.

2.11.12.1.6. Nominal wall thickness of 0.06 inches.

2.11.12.1.7. Gel filled

2.11.12.1.8. Overall water swellable barrier tape with 25 percent overlap

2.11.12.1.9. Tensile load (installation) of 600 lbs.

2.11.12.1.10. Minimum bending radius 20 times cable diameter Operating temperature -40°C to 70°C

2.11.13. Category 5e or Category 6 Cables

2.11.13.1. Category 5e or Category 6 cable shall meet the following requirements:

2.11.13.1.1. Sunlight, oil, and gas resistant

2.11.13.1.2. Industrial grade

2.11.13.1.3. 4 bonded pairs, 22 AWG

2.11.13.1.4. Solid copper conductor

2.11.13.1.5. Polyolefin insulation

2.11.13.1.6. Black PVC jacket, 0.03 inches

2.11.13.1.7. UL listed Operating temperature of -25°C to 75°C

2.12. Testing

2.12.1. PV STRING OPEN-CIRCUIT VOLTAGE TESTING

2.12.1.1. Open-circuit voltage (Voc) string testing shall be conducted in order to assess overall module and string performance.

2.12.1.2. The Contractor shall perform a follow up infrared scan with a drone 90 days after energization.

2.12.1.3. The test shall be conducted and witnessed by at least two qualified technicians using best practices and the following procedure:

2.12.1.4. The test shall be conducted during periods of irradiance greater than $\mathbf{400}\ \frac{W}{m^2}$

2.12.1.5. Inspect string fuses for appropriate use and correct sizing

2.12.1.6. Measure and record the following for every string:

2.12.1.6.1. String number and combiner box location (or similar relevant string identification)

2.12.1.6.2. Measurements made every five (5) or fifteen (15) minutes

2.12.1.6.3. Time of test and weather conditions

2.12.1.6.4. Module back sheet temperature at a location representative of the strings being tested

2.12.1.6.5. Plane-of-Array (POA) irradiance measurement for area of strings being tested

2.12.1.6.6. Open-circuit voltage (Voc) measurement of every string within each combiner box.

2.12.1.6.7. Measurement shall be made using a voltmeter with the suitable voltage rating and accuracy of at least 0.5%

2.12.1.6.8. Each measured string Voc shall be within 5% from the expected Voc (Voc-expected) and within 5% of adjacent strings under identical temperature and irradiance conditions.

2.12.1.7. The expected Voc shall be calculated using the following equation:

$$Voc - expected = r \cdot Voc - ref \cdot [1 + (J \cdot (Tmod - Tmod - ref)]$$

Where:

$Voc - expected$	= expected open-circuit voltage of the string
$Voc - ref$	= module open-circuit voltage at reference conditions
r	= number of modules in series in tested string
J	= module open-circuit temperature coefficient $(℃ - 1)$
$Tmod$	= measured module backsheet temperature $(℃)$
$Tmod - ref$	= back of module temperature at reference conditions

2.12.2. Comparisons between all measured and expected Voc shall be analyzed in a spreadsheet which shall include the following PASS/FAIL tests for each string:

2.12.2.1. String Voc-measured is within 5% of Voc-expected

2.12.2.2. String Voc-measured is within 5% of the Voc-measured of adjacent strings

2.12.2.3. Strings that fail either test shall be investigated for module defects, loose connections, disconnected modules, or other possible defects tested)

2.12.2.4. Ambient temperature

2.12.2.5. Wind speed

2.12.2.6. Weather conditions

2.12.2.7. Correct polarity shall be verified

2.12.3. Using an IV curve tracer, perform the curve trace using the manufacturer's instructions.

2.12.4. The curve tracer shall be configured to record at least 10 current-voltage data points and record the following values:

2.12.4.1.1. Maximum power (Pmax)

2.12.4.1.2. Voltage at maximum power (Vmp)

2.12.4.1.3. Current at maximum power (Imp)

2.12.4.1.4. Open circuit voltage (Voc)

2.12.4.1.5. Short circuit current (Isc)

2.12.4.1.6. Fill Factor (FF)

2.12.5. Short-circuit current test: Each measured string short-circuit current shall be greater than the expected short-circuit current (Isc-expected) derived using the following equation:

$$Isc - expected = K \cdot Isc - ref \cdot (GGref)$$

Where:

$ISC - expected$	= Expected short-circuit current of the string
$ISC - ref$	= Short-circuit current at Standard Test Conditions (STC) as shown on module datasheet
K	= 0.95 (uncertainty and soiling factor)
G	= Measured Irradiance $\frac{W}{m^2}$
$Gref$	= $1000\ \frac{W}{m^2}$

2.12.6. LOW VOLTAGE INSULATION RESISTANCE TESTING

2.12.6.1. All low voltage (LV) direct current (DC) and alternating current (AC) cables shall be tested for insulation resistance in accordance with the NETA-ATS.

2.12.6.2. Measured insulation resistance values shall be adjusted to a 20°C reference in order to determine acceptance with NETA-ATS.]

2.12.6.3. All insulation resistance acceptance criteria shall be proposed by Contractor for approval by Owner.

2.12.6.4. Any test results that fail to be in accordance with the NETA-ATS, or do not meet the accepted criteria, shall be documented as a deficiency on the test report.

2.12.6.5. Corrective action shall follow the identification of a failed test, followed by re-testing.

2.12.7. LOW VOLTAGE CABLE TESTING

2.12.7.1. Low voltage cables shall include only those designed to operate at or below 1500 V.

2.12.7.2. All low voltage cables shall be inspected and tested in accordance with NETA-ATS, Section 7.3.

2.12.7.3. Test Values shall be in accordance with NETA-ATS, Section 7.3.2.

2.12.7.4. Note: NETA-ATS, states that Section 7.3.2 is for low-voltage cables up to a 600 Volt Maximum.

2.12.7.5. This Section shall also be used for cables with voltages up to 1000 Volts

2.12.7.6. Test voltages applied in the field shall not exceed the maximum test voltage of NETA- ATS, Table 100.1

2.12.7.7. Verify uniform resistance for all parallel conductors

2.12.8. POLARITY VERIFICATION

2.12.8.1. All circuits shall be verified to have the correct polarity according to the design drawings.

2.12.9. INVERTER COMMISSIONING

2.12.9.1. Inverters shall be commissioned by the inverter manufacturer, or an authorized representative of the manufacturer, using the manufacturer's specified procedures.

2.12.9.2. Commissioning reports shall be in a format provided by the manufacturer.

2.12.9.3. At a minimum, inverter commissioning shall meet the following requirements:

2.12.9.3.1. Inverters shall be fully operational after commissioning completion

2.12.9.3.2. All shipping and packing materials shall be removed from inverter cabinets

2.12.9.3.3. Fuses and air filters shall be checked, verified as correct and in place

2.12.9.3.4. Torque wrench marks shall be recorded

2.12.9.3.5. Software updates and data acquisition communication shall be tested and functional

2.12.9.3.6. Noise level study shall indicate inverter meets the manufacturer's specifications.

2.12.9.3.7. Confirm glycol mixture is adequate for the ambient design conditions if required.

2.12.10. METEOROLOGICAL MONITORING STATION TESTING

2.12.10.1. All meteorological monitoring station equipment shall be commissioned, calibrated and tested using the manufacturer's specified procedures with accuracy being compared to the manufacturer's specifications.

2.12.10.2. Current calibration certificates for each installed instrument shall be provided to Owner.

2.12.10.3. Test reports shall be in a manufacturer provided format if available.

2.12.10.4. The following instrumentation, if it is part of the metrology equipment specified by Owner, shall be tested, at a minimum:

2.12.10.5. Solar irradiance measurement device, as applicable, e.g.:

2.12.10.5.1. Global horizontal irradiance (GHI)

2.12.10.5.2. Plane of array (POA) irradiance

2.12.10.5.3. RaZON solar monitor system, as applicable

2.12.10.6. Anemometer (wind speed), as applicable

2.12.10.7. Module temperature, as applicable

2.12.10.8. Ambient temperature, as applicable

2.12.10.9. Precipitation gauge, as applicable

2.12.10.10. Data-logger and communications equipment, as applicable

2.13. Data Acquisition System - (Data Logger Monitoring System)

An overall data acquisition site monitoring system shall be provided separately, or shall be integrated into the Weather Station referenced herein for

2.13.1. The manufacturer of the system shall be included in Attachment 9 PV Solar Equipment Suppliers List or approved by the Owner. Each inverter will be equipped with a condition-based monitoring system. The inverter monitoring system shall connect to the site data logger. Power metering data shall be provided to the data logger to provide revenue grade accuracy metering data and provide alerts for discrepancies with inverter readings. The data logger shall provide wireless communication to allow for secure remote access of the information via the internet, or Owner approved equivalent method.

2.13.2. Hardware

2.13.2.1. The data collection / signal processing unit shall be installed in a serviceable location in the inverter and connected.

2.13.2.2. All cables shall be oil and grease resistant, cold weather flexible, and routed in trays, conduit or raceways that provide protection to the cable.

2.13.3. Data logger and software shall meet the following requirements:

2.13.3.1. Ability to communicate with other devices via Modbus TCP, OPC, PI, or similar protocols

2.13.3.2. Capable of quickly running the provided analysis software

2.13.3.3. Capable of storing 1 year of data

2.13.3.4. Unrestricted access without user count based licensing

2.13.3.5. Analysis software shall be preinstalled and meet the following requirements:

a. Unrestricted access without individual user licensing

b. High level display to view all status on 1 page

c. Record data at least once per day

d. Local alarm function with remote notification

e. Access to all raw data

2.13.4. Minimum Features

2.13.4.1. Solar operation and control from a secure, web-based monitoring system.

2.13.4.2. Main control server with 1-year minimum data storage

2.13.4.3. Secure remote access server

2.13.4.4. Backup power supply

2.13.4.5. All applicable software licenses

2.13.4.6. Automatic backup software

2.13.4.7. Software to modify screens

2.13.4.8. System monitoring screen(s) including the display of all alarms and statuses along with a 1-line overview of breaker position and MWs, volts, amps, and VARs at all metered locations

2.13.4.9. Remote Alarm Notification

2.13.4.10. Power curtailment at the substation level

2.13.4.11. Actual possible power signal the value of which is based on actual on-site solar speed

2.13.4.12. Power ramp rate control

2.13.4.13. System VAR

2.13.4.14. System voltage

2.13.5. Products

2.13.5.1. The solar and associated equipment provided by the manufacturer shall be new and shipped directly from the factory to the project site and shall comply with all Occupational Safety and Health Administration (OSHA) regulations

2.13.6. Execution

2.13.6.1. The solar panels shall be assembled and commissioned in strict compliance with the solar panel manufactures requirements and procedures.

2.13.6.2. All panels and associated array components shall be cleaned internally and externally and free of surface coating scratches, chips, etc. and the subject scratches, chips, etc. repaired prior to being lifted into place. All damage shall be repaired in strict compliance with manufacturer requirements.

2.13.7. Testing and Inspection

2.13.7.1. All facility components will be commissioned and tested in strict compliance with manufactures requirements and procedures

2.13.8. Submittals

2.13.8.1. All supplier commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to solar facility assembly, inspection, commissioning and testing shall be submitted to Owner

2.13.8.2. Contractor and Subcontractor(s) commissioning and testing procedures, checklists, inspection reports, punch lists and other records related to solar panel assembly, inspection, commissioning and testing shall be submitted to Owner

3. Civil Technical

Work under this specification applies to the construction of the roadways, foundations, and drainage.

3.1. Road and Foundation Grading Specifications

3.1.1. All grading shall conform to county grading ordinances, storm water permit requirements, and other applicable laws and applicable standards pertaining thereof.

3.1.2. The Contractor shall perform the grading work, including the exercise of supervisory control during construction, to ensure compliance with all plans, specifications, and codes. Subject to soil conditions, the Contractor shall install geotextile membrane at the discretion of the geotechnical engineer of record on the compacted subgrade prior to placement of road material. The road base course material thickness shall be a minimum of 12 inches and adjusted to accommodate construction traffic and to meet all other requirements as specified in this agreement if geotextile membrane is not used.

3.1.3. Structural fill shall be defined as any fill area receiving permanent loading from an external source, i.e. equipment foundation. Structural fill shall be compacted to a minimum of 95% of the maximum dry density per ASTM D698. Fill materials designated as structural fill shall be placed in lifts not exceeding 6 to 8 inches thick for cohesive soils (containing silts and clays) and 12 inches for cohesionless soils. In-place moisture content of compacted structural fill shall be at or above the optimum moisture content for cohesive soils and plus or minus 3 percentage points of the optimum moisture content for cohesionless soils as per ASTM D698.

3.1.4. Prior to placing structural fill, the existing ground shall be cleared of brush, roots/organic matter, debris and standing water. All unsuitable material shall be placed in non-structural fill areas. Granular fill soil (soils with less than 10 percent passing the No. 200 sieve) is suitable for imported structural fill material and shall be approved by the Engineer prior to use.

3.1.5. Borrow source for structural fill shall be approved by Owner. Structural fill shall be granular soil, free of deleterious material including expansive and organic material, rocks greater than 3 inches in diameter, debris, ice, and frozen soil, and shall be approved by the engineer prior to transport. Structural fill shall be placed on compacted native soil. Depth of the structural fill and compaction requirements shall be according to the contract documents.

3.1.6. Compaction tests shall be taken as required by contract documents. In the event of failed tests, the affected lift of material shall be reworked, recompacted and retested. Contractor shall not place additional fill until acceptable test results are obtained.

3.1.7. Positive drainage is required to drain water away from all footing or load-bearing structures. Drainage shall be directed to natural drainage ways and shall be graded according to the contract documents.

3.1.8. Access and Maintenance Road locations shown on maps may be altered to avoid sensitive vegetation. “AS BUILT” drawings conforming to Owner drawing standards shall be provided upon completion to reflect road and equipment foundation pad modifications made during construction.

3.1.9. Access roads shall be restricted from use by the general public. Signs at all entrances shall indicate “NO TRESPASSING, AUTHORIZED PERSONNEL ONLY. DANGER – HIGH VOLTAGE”. Sign size, content, location, etc. shall be approved by Owner prior to installation. The integrity of the sign shall be designed to withstand all seasonal and earthly elements including but not limited to sun, wind, snow, ice, rain, acidic soils, etc.

3.1.10. All work will be constructed, tested and inspected in compliance with the Project Quality Assurance Plan outlined in Attachment 4.

3.1.11. Site Access Roads shall be designed and constructed such that all uses during operations produce a maximum rut depth of 1.5 inches. Site Maintenance Roads shall be designed and constructed such that all uses during construction produce a maximum rut depth of 3 inches. Roadways shall also be maintained by the Contractor in acceptable condition for a standard 2-wheel drive ½ ton class truck to safely navigate the entire road to perform site inspections.

3.1.12. Contractor shall meet or exceed all recommendations in the contract documents.

3.1.13. Roads damaged during construction shall be repaired to reflect their condition prior to construction.

3.1.14. Road design shall consider water runoff patterns that will exist after construction is complete such that road material will not wash into fields or block, restrict, or divert water flow during heavy rains.

3.1.15. Access roads shall extend to the inverter access door. The road surface area shall be sufficient for a maintenance truck to complete a 3-point turn.

3.1.16. Access roads shall be designed for emergency vehicle access.

3.2. Definition Key

3.2.1. "Site Access Road" is defined as a road used to access the solar facility from a state or county road or an existing access road and extends from the state or county road to immediately within the perimeter fencing to inverters. This shall also include the access road to the substation.

3.2.2. "Site Maintenance Road" is defined as a road/access corridor within the solar facility perimeter fence and between solar arrays used to maintain the solar panels, arrays, etc. Site Maintenance Roads may be compacted native soil roads.

3.2.3. Contractor shall submit to the Owner all QA/QC plan records, all testing and inspection results, compaction test results for road base material, including location, dry density and moisture content.

3.2.4. Contractor shall submit to the Owner grain size analysis test results for road base material, including location and moisture content.

3.2.5. Contractor shall submit to the Owner copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents, and testing and inspection requirements included in this document.

3.3. Products

3.3.1. Aggregate base course and cap material: Shall be as specified in the contract documents or otherwise approved by owner. At a minimum, road base material shall consist of an aggregate base course material with less than 10 percent particles passing the No. 200 sieve with a nominal maximum aggregate size of 1 ½ inches, free of deleterious, frozen and debris-laden materials.

3.3.2. Geotextile Membrane: Shall meet the requirements of the design documents. The engineer of record shall follow the manufacturer's recommendations for aggregate base thickness to be used during construction.

3.3.3. Culvert: Those located in State or County road Right-of-Ways shall be PVC or corrugated metal pipe and shall meet the requirements as directed by the State Department of Transportation and/or the County Engineer in which the project is located. Culverts on project property shall be PVC or corrugated metal pipe and shall meet the required specifications of the construction drawings.

3.4. Execution

3.4.1. Where new Site Access Roads are planned for agricultural areas, all topsoil shall be stripped through the root zone.

3.4.2. The entire Site Access Road subgrade shall be proof-rolled prior to placement of the aggregate base to identify unsuitable areas of subgrade and observed and documented by the QAR. The method to scarify, dry and recompact subgrade will not be allowed unless the material is proven not to contain organic material and/or material unable to remain compacted during or after a rain event.

3.4.3. All trees, stumps, brush, and debris within the grading areas shown in the design document shall be removed. Tree branches overhanging the drive zone of the Site Access Road shall be trimmed back to the edge of the Site Access Road.

3.4.4. Permanent Culverts: Shall be installed per the manufacturer's recommendations. The area where culverts are to be installed shall be cleared and grubbed. Organic materials shall be removed and replaced with recommended bed material. Provide a minimum cover over culverts of 12 inches.

3.4.5. Compaction of the sub-grade for roads, crane pads and foundations shall be the more stringent of the design documents or 95% of Modified Proctor (ASTM D1557).

3.4.6. Compaction of the road base and top course shall be as required by the design documents or to a minimum of 95% of Modified Proctor (ASTM D1557).

3.4.7. Road base course material shall be placed in layers not exceeding 6 inches in loose depth.

3.5. Testing and Inspection

3.5.1. All testing and inspections shall be performed as required by the design documents but at a minimum as indicated and described in this section.

3.5.2. All testing and inspection records shall be sent to the engineer of record for review. A copy of all testing and inspection records and any recommendations made by the engineer shall be sent to the Owner. Review of testing and inspection records does not alleviate the Contractor from the responsibility of correcting defective areas or work.

3.5.3. Soils used for Fill Material shall be tested for Grain Size Analysis and classification (ASTM D6913 and D2487), Atterberg Limits (ASTM D4318), Moisture Content (ASTM D2216), Standard Proctor Tests (ASTM D698), and Modified Proctor Tests (ASTM D1557).

3.5.4. Compacted Subgrade: Site access road shall be proof-rolled the full length in the presence of a geotechnical engineer or qualified and approved representative with a loaded tandem axle dump truck having a minimum gross weight of 25 tons. Subgrade shall be corrected if rutting greater than 1.5 inches and/or "pumping" of the subgrade occurs. Site Maintenance roads shall be recompacted if rutting greater than 3.0 inches occurs. Aggregate Base and Top Course: Shall be proof-rolled the entire road length.

4. Fencing

4.1. Site Fencing – For Solar Facilities Not Located Within Existing Security Fences

4.1.1. Chain link fence is the Owner standard. This type of fence is covered by the following standard and is considered a protective barrier for unattended facilities, a security barrier for the public and the first line of defense as a wildlife deterrent.

4.1.2. Manual entrance gates shall be two 8-feet wide gates that latch and lock at the center.

4.1.3. The solar array fence height is 7 feet high: 6 feet fabric plus a minimum of 1-foot vertical height of barbed wire, mounted at 45-degree angle, pointing outward from the facility. The substation fence shall be 10 feet high without barbed wire.

4.1.4. Contractor shall provide and install the fence to the configuration and details as shown on the permit set of plans.

4.1.5. Contractor shall provide fencing for construction equipment, laydown, and storage as necessary and according to applicable AHJ requirements.

4.1.6. The site fencing shall be grounded.

4.2. Security

4.2.1. 2” diamond chain link fence for the solar arrays and 1" diamond chain link fence for the substation shall be used to deny good toe hold and make climbing over the fence more difficult for unauthorized access from the public.

4.2.2. 45° outrigger with three stands of barbed wire to make climbing over the fence more difficult for the public and to legally declare the facility fences as security barriers.

4.2.3. A 7-foot fence height is the security requirement for the solar array. The substation fence height shall be 10 feet in total height.

4.2.4. Two eight -foot manual swing gates shall be installed at the access road. A personnel gate shall be located near the access road.

4.3. Fencing Material and Application

4.3.1. The height of a standard fence including the barbed wire shall be 7 feet above the rough grade.

4.3.2. The fence fabric shall be 1" or 2” diamond mesh chain link style as required, galvanized as follows:

4.3.2.1. Galvanized - Number 9 AWG (American Wire Gauge), galvanized after weaving, Class II, Conforming to ASTM A392, “Zinc-Coated Steel Chain-Link Fence Fabric”.

4.3.2.2. Barbed wire top guards, consisting of 3 or 4 strands of barbed wire, shall be mounted on outriggers directed outward at a 45-degree angle. The barbed wire should be equally spaced about 6” inches apart. Outriggers should be at least 18” or 24” long to insure 1’-0” vertical height over the top rail of the fence. Wire material to be either galvanized as follows:

4.3.2.2.1. Galvanized - 12 1/2 gauge with 14 gauge 4 barb, 5-inch spacing, conforming to ASTM A121, Class 3 “Zinc-Coated Steel Barb Wire.”

4.4. Fence Framework

4.4.1. Fence posts, top rail, and braces shall be compliant with ASTM F1043 or ASTM F1083.

4.4.2. Intermediate line posts shall be a minimum of 2 1/2” galvanized Schedule 40 pipe (2 7/8” O.D.)

4.4.3. 5.79 lbs. per foot with sufficient length to be driven into the ground a minimum of 4 feet deep.

4.4.4. Corner and terminal posts shall be a minimum of 2 1/2” galvanized Schedule 40 pipe (2 7/8” O.D.) standard pipe, 5.79 lbs. per foot. Posts shall be of sufficient length to be set in concrete at a minimum of 5 feet deep.

4.4.5. Gate posts shall be galvanized standard weight pipe of the following size for single swing gates or one leaf of the double gate. Posts shall be of sufficient length to be set in concrete at a minimum of 5 feet of depth.

Up to 6’ wide	2 7/8” O.D.	5.79 lbs. per foot.
Over 6’ to 13’	4” O.D.	9.11 lbs. per foot.
Over 13’ to 18’	6 5/8” O.D.	18.97 lbs. per foot

4.4.6. Top rail and braces shall be 1 5/8” O.D. 2.27 lbs. per foot. All pipe shall be galvanized to conform to ASTM A120 covering “Black and Hot-Dipped Zinc-Coated (galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.”

4.4.7. Gates shall be galvanized 1.90-inch O.D. pipe, 2.72 lbs. per foot, complete with hinges, stops, rests, and latching devices of a type to accommodate a padlock.

4.4.8. Fittings and latches shall be of appropriate specifications for their functions.

4.4.9. All pipe shall be galvanized to conform to ASTM A120 covering “Black and Hot-Dipped Zinc-Coated (galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.”

4.4.10. Latch for double gate shall allow opening one half of the gate without disturbing anchorage of the second half.

4.4.11. Hardware fittings and braces shall be in compliance with applicable industry standards for complete and proper installation of the fence standard. Galvanizing shall conform to ASTM A153 “Zinc-Coating Hot-Dip Iron and Steel Hardware.”

4.4.12. Each shipment of fence shall be inspected by the Contractor and the Owner to determine whether the galvanizing meets the specifications under which it was purchased.

4.5. Installation of Chain Link Fencing

4.5.1. Installation shall be made in a professional manner by skilled persons experienced in the erection of this type of fence and comply with ASTM F 567 Standard Practice for Installation of Chain-Link Fence. The fence shall be erected on lines and to grades as provided in the design documents. Fence shall follow the ground line unless otherwise specified. Line posts shall be spaced not more than 10 feet apart and shall be driven into the ground, 4 feet minimum, without concrete. All gate, corner and terminal posts shall be set in concrete foundations to a minimum depth of 60 inches. The diameter of the foundation is to be a minimum of 9 inches, except for gate posts, on which the minimum diameter shall be three times the outside diameter of the post. The foundation shall be 3000 P.S.I. concrete or greater.

4.5.2. All foundations shall extend to the finished grade and shall slope away from the post to assure proper drainage. The top shall be the same diameter as the remainder of the foundation and shall be neat in appearance. The fabric and the barbed wire shall be stretched to proper tension between the terminal posts and securely fastened to the frame work members as covered in the material specifications. The bottom of the fabric shall be held uniformly to the existing grade elevation.

5. Electrical System

5.1. DESIGN REQUIREMENTS

5.1.1. All construction work and the completed electrical system shall be in accordance with and conform to applicable provisions of Schedule A.

5.1.2. All equipment shall be new materials and free of defects shall be installed and appropriately listed and NEMA rated. Where applicable, utility-grade equipment shall be used. All new equipment shall have identification tags installed.

5.1.3. Array must be sized to operate within the current, voltage and power limits approved and warranted by the inverter manufacturer. The temperature-adjusted voltage must remain within the inverter limits at historical record low temperature for the location in which it is installed.

5.1.4. Wires must be sized to keep the total voltage drop below 2 percent on the DC conductors from the array to the inverter including existing wire whips on the PC modules, and 2 percent on the AC conductors from the inverter to the point of interconnection. Total drop not to exceed 4 percent.

5.1.5. Electrical design shall include the design of equipment grounding and lightning and sure protection for the entire PV facility.

5.1.6. Design and specify all communications hardware and software required for system protection and remote monitoring and control, and facility security system. The security cameras shall be remotely monitored and controlled.

5.1.7. The electrical system shall be designed to minimize power losses from nameplate generation at the panel through the inverter, and switchgear to the substation or distribution line breaker.

5.1.8. The latest adopted edition of the National Electric Code (NFPA 70, NEC), and National Electric Safety Code (NESC), ANSI C2-1997 shall be followed except where the Utility standards and/or local regulations are more stringent, in which case the most stringent requirement shall govern. Intermediate grounds-4 per mile will not be provided.

5.1.9. All work shall be constructed, tested and inspected in compliance with the Project Quality Assurance requirements.

5.2. AC System

5.2.1. AC Cabling - Cabling for AC systems should be designed to provide a safe and cost-effective means of transmitting power from the inverters to the transformers and beyond. Cables shall be rated for the correct voltage and have conductors sized, considering the operating currents and short-circuit currents. Design shall consider as follows:

0.1.1.1 Cable must be rated for the maximum expected voltage

0.1.1.2 Conductor shall be able to pass the operating and short circuit safely.

0.1.1.3 Cabling sized to avoid voltage drop

0.1.1.4 Insulation should be adequate for the environment of installation

0.1.1.5 Earthing and bonding

0.1.1.6 Installation methods and mechanical protection of the cable

5.2.2. Step-up Transformers

0.1.1.7 Transformer shall be sized based on the output power from the PV arrays with sufficient capacity.

0.1.1.8 Transformer efficiency standards set forth in the Department of Energy “Energy Conservation Program for Commercial Equipment: Distribution Transformers Energy Conservation Standards; Final Rule”.

0.1.1.9 Transformers shall be supplied with a no-load tap changer with high voltage taps capable of operating at 2, 2.5% above and below nominal voltage at full rating.

0.1.1.10 Transformers shall be either dry-type or less-flammable oil insulating liquid.

0.1.1.11 Enclosure finish shall be a powder coat designed for a 25-year service life.

0.1.1.12 Accessories to include liquid level and pressure/vacuum gauges, dial-type thermometer with SPDT alarm contacts, pressure relief valve, and a drain valve with sampler.

5.2.3. Switchgear – Switchgear and protection systems shall be included to provide disconnection isolation, earthing and protection. On the output side of the inverters, provision of a switch disconnector shall be provided to isolate the PV array.

5.2.3.1. Switchgear shall be located outdoors; Enclosure shall be NEMA 4 and lockable.

5.2.3.2. Switchgear shall include an auxiliary compartment containing all instrument transformers associated with the protective relays and 120/240V control power transformer (CPT).

5.2.3.3. Communication hardware shall be included.

5.2.3.4. Relay current transformers shall be C400 accuracy class.

5.2.3.5. Medium voltage protective device and relaying shall be provided.

5.2.4. Grounding and Surge Protection – Grounding should be provided to protect against electric shock, fire hazard and lightning. The grounding of a solar PV system shall include array frames, inverters, lightning and surge protection. Design guidelines should be considered:

5.2.4.1. Ground rods should be placed close to junction boxes.

5.2.4.2. A continuous earth path is to be maintained throughout the PV array.

5.2.4.3. Cable runs should be kept as short as possible.

5.2.4.4. Surge suppression devices can be installed at the inverter end of the DC cable and at the array junction box.

5.2.4.5. Inverter models may include internal surge arrestors.

5.3. DC System

5.3.1. DC components shall be rated to allow for thermal and voltage limits. DC system comprises the following constituents:

5.3.1.1. Array of PV modules

5.3.1.2. DC cabling (module, string, and main cable)

5.3.1.3. DC connectors (plugs and sockets)

5.3.1.4. Junction boxes/combiner boxes

5.3.1.5. Disconnect/switches

5.3.1.6. Protection devices

5.3.1.7. Earthing

5.3.2. PV Array Design – Multiple PV modules shall be installed in sufficient quantity to form a complete PV solar array generating system to generate the projected mega-watts, alternating current (MWac). Design of the arrays should optimize efficiency and should consider the following:

5.3.2.1. Minimize ohmic losses

5.3.2.2. Inverter voltage limits

5.3.2.3. Minimize string voltage drops

5.3.2.4. Maximum number of strings shall not lead to yield loss

5.3.3. Combiner Boxes – Combiner boxes are needed at the point where the individual strings forming an array are marshalled and connected in parallel before leaving for the inverter through the main DC cable. Junctions should be made with screw terminals and must be of high quality to ensure lower losses and prevent overheating.

5.3.4. Fuses/Miniature Circuit Breakers – String fuses or miniature circuit breakers are required for over-current protection. They must be rated for DC operation.

5.3.5. DC Switching – DC switches provide a manual means of electrically isolating entire PV arrays, which is required during installation and maintenance. DC switches must be:

5.3.5.1. Double-pole to isolate both the positive and negative PV array cables

5.3.5.2. Rated for DC operation

5.3.5.3. Capable of breaking under full load

5.3.5.4. Rated for system voltage maximum current

5.3.5.5. Equipped with safety signs.

5.3.6. Inverter – Sizing of the inverter should range within limits of $\mathbf{0.9} < \boldsymbol{Power\ ratio} < \mathbf{1}$. Sizing should be obtained from the inverter manufacturers.

5.3.7. DC Cabling – The selection and sizing of DC cables shall be designed for solar PV installations

5.3.7.1. Module and string cables – single conductor, double-insulated cables are preferable for module connections. Using such cables helps protect against short circuits.

5.3.7.2. Cables shall be resistant to ultraviolet (UV) radiation and weather if laid outdoors without protection.

5.3.7.3. Cables should be rated to the highest temperature they may experience.

5.3.7.4. Appropriate de-rating factors for temperature, installation method and cable configuration should also be applied.

5.3.7.5. Main DC cable – the overall voltage drop between the PV array and the inverter should be minimized and reduce losses. A benchmark voltage drop of less than 2 percent (at STC) shall be used.

5.3.8. Cable management

5.3.8.1. Over-ground cables such as module cables and string cables need to be properly routed and secured to the mounting structure, either using dedicated cable trays or cable ties. Cables should be protected from direct sunshine, standing water and abrasion by the sharp edges of support structures. Split loom shall be installed to protect the cable against sharp edges. They should be kept as short as possible.

5.3.8.2. Plug cable connectors to be touch-proof.

5.3.8.3. The laying of DC cables in trenches must comply with national code and consider specific ground conditions.

5.3.8.4. Cables shall be listed and identified as PV wire per NEC.

5.4. Communication System:

5.4.1. The facility monitoring system and the security system shall require a communications medium with remote access. Contractor shall provide a cellular or DSL link for remote monitoring.

5.4.2. Contractor shall procure and install all materials and equipment necessary to complete the communication (data collection) cable installation. This includes, but is not limited to fiber optic cable, conduit, pull boxes, terminations, connectors, and panels.

5.4.3. Communication tests shall be performed to demonstrate its ability to meet the requirements of its intended use. Fiber loops shall also be tested and provide loop functional check sheets for each communication circuit.

5.4.4. Documentation shall include test results and materials provided.

5.5. Meteorological Stations

0.1.2 Sufficient number of meteorological stations shall be provided to measure meteorological data to evaluate facility performance. The stations shall be capable of collecting the data points and sample frequency. Station shall have capability of recording and storing environmental conditions without AC power for two (2) days.

5.6. Supervisory Control and Data Acquisition (SCADA)

5.6.1. Contractor shall provide engineering workstation providing local control.

5.6.2. SCADA system composed of integral operator human-machine interface (HMI), input/output (I/O) and remote telemetry units (RTU) hardware, firmware, and software, internal control/communications devices designed to industry standards shall provide for remote monitoring, alarm management, control and historical trending of the monitored equipment.

5.6.3. Communication shall be transmitted via ANSI compliant optic or wireless communications infrastructure for web and client interface.

5.6.4. Points to be monitored by the SCADA system shall include, at a minimum:

5.6.4.1. Meteorological stations

a. Reference cell temperature
b. Reference cell Irradiance
c. Ambient Air Temperature
d. Wind Speed
e. Wind Direction
f. Global Horizontal Irradiation
g. Rain
h. Module Temperature

5.6.4.2. Inverters

a. AC Voltage
b. DC Voltage
c. AC Current
d. DC Current
e. kW
f. kWh

5.6.4.3. Metering – System shall monitor and store data from the facility site meter on an interval from between five (5) to twenty (20) seconds.

5.6.4.4. Trackers (if applicable) remote monitoring and control

5.6.4.5. Facility switchgear

5.7. Underground Power Distribution Installation

5.7.1. High voltage cables shall be pulled to the distribution line and tied off to the termination structure with a Kellems grip, or equivalent.

5.7.2. Contractor shall use a minimum cable insulation rated 133% of distribution voltage.

5.7.3. Contractor shall obtain all necessary permits for road bores or trench crossings.

5.8. Underground Power Distribution Feeder Grounding

5.8.1. Grounding transformers are to be supplied on the collection system. Each feeder shall contain at least one grounding transformer, and each grounding transformer shall be interchangeable with another. Grounding transformers shall be sized per Owner distribution standards, and to keep the collection feeder voltage rise during a fault on the feeder to less than 1.39 pu voltage as per IEEE C62.92.1-2000.

5.8.2. An analysis of the maximum transient overvoltage along the feeder collection circuits under a fault shall be performed to determine the appropriate ratings and placement of the grounding transformers on the collection circuits. The analysis shall be provided to Xcel for review.

5.8.3. Arrestors shall be placed on each feeder at the substation, and along the collection circuit at the end of each string, and as needed between to limit the voltage rise during fault conditions, or other events that can cause transient over-voltages.

5.9. Conduit and Wire

5.9.1. Contractor shall keep phasing and color-coding of phases consistent throughout the project.

5.9.1.1. The minimum bending radius of primary cable is twelve (12) times the overall diameter of the cable. The minimum bending radius of secondary and service cable is eight (8) times the overall diameter of the cable. In all cases the minimum radius specified is measured to the surface of the cable on the inside of the bend. No cable bend shall be made within six (6) inches of a terminal base.

5.9.1.2. A pull rope shall be installed in all empty conduits All exposed ends of conduit shall be plugged during construction to prevent the entrance of foreign matter and moisture into the conduit. Burrs or sharp projections, which might damage the cable, shall be removed. Riser shield or conduit shall extend at least eighteen (18) Inches below grade at all riser poles or as shown on the drawings. If full round conduit is used as a riser shield, an end bell shall be installed on the lower end to prevent damage to the cable.

5.9.1.3. Each cable in a switch, sectionalizing cabinet, transformer, etc. shall be identified by circuit number, phase and location of the opposite end with permanent plastic or corrosion resistant metal tags. Close to each cable termination, Contractor shall also mark the cable termination phase designation on the cabinet.

5.9.1.4. At each medium voltage junction box or inverter foundation, a minimum of 10 feet of slack cable shall be coiled in the transformer vault or buried as close as possible if a vault is not used

5.9.1.5. Conduit duct seal shall be used to prevent rodent infestation. Spray foam insulation shall not be used.

5.10. Direct Burial Installation of Cables

5.10.1. The bottom of the trench receiving conduit or direct-buried cable should be smooth, undisturbed, well-tamped earth without exposed rocks. When excavation is in rock or rocky soils, the conduit or cable should be laid on a protective layer of well-tamped backfill. Backfill should be compacted to 95% standard proctor per ASTM D698.

5.10.2. All cables shall be buried a minimum depth of 3 feet to the top of cable/conduit, or as specified by the design engineer, local code requirement, whichever is greater. Communication cable shall be buried at the same depth as the power cable, except in the case when the manufacturer requires that ground cable be buried above power cable. In that case the communication cable shall be buried at the same level as the ground cable.

5.10.3. A minimum bend radius of twelve (12) times the outside diameter of the cable shall be followed.

5.10.4. Cable separation distance shall always be maintained as specified by the product documentation and engineered drawings.

5.10.5. Sufficient slack shall be left at all risers, transformer pads, pedestals and terminal points so that movement of cable after backfilling shall not cause damaging strain on the cable or terminals.

5.10.6. All debris shall be removed from the fill before placing it back in the trench. Cable trenches shall be mechanically compacted six (6) feet minimum from all riser poles, pads, pedestals and terminal points. All disturbed area shall be restored as to not cause ground settling greater than 1” below the undisturbed elevation.

5.10.7. Cable caps (3M) shall be supplied when cables are waiting to be terminated in the field after installation.

5.11. Medium Voltage Splices/Terminations/Connections

5.11.1. Splices

5.11.1.1. Cable splices shall be of the pre-molded rubber, cold-shrink type, of the correct voltage rating and shall be installed in accordance with the splice manufacturer’s instructions. Splices that depend solely on tape for a moisture barrier shall not be used.

5.11.1.2. Electrical works design shall minimize the number of splices required.

5.11.1.3. No bends shall be permitted within twenty-four (24) inches of the end of a splice.

5.11.1.4. The cable or circuit numbers and the exact location of all splices shall be noted on the As-Built Drawings and Documentation shall include GPS locations of each splice.

5.11.1.5. Splicing in ducts is not allowed.

5.11.1.6. The location of each splice shall be marked with single or stacked locating marker balls depending upon the depth of cable burial.

5.11.1.7. A marker ball detection device compatible with the marking balls installed shall be provided.

5.11.2. Primary Cable Terminations and Stress Cones: Prefabricated stress cones or terminations shall be installed in accordance with the manufacturer’s instructions at all primary cable terminals. They shall be suitable for the size and type of cable that they are used with and for the environment in which they will operate. Any indication of misfit, such as a loose or exceptionally tight fit, shall be called to the attention of the Owner. The outer conductive surface of the termination shall be bonded to the system neutral. A heat-shrink or cold-shrink sleeve shall be installed to seal between the body if the termination and the cable jacket.

5.11.3. Special Precautions for Cable Splices and Terminations: A portable covering or shelter shall be used when splices or terminations are being prepared and when prefabricated terminations are being switched. Since cleanliness is essential in the preparation and installation of primary cable fittings, care shall be exercised to prevent the transfer of conducting particles from the hands to insulating surfaces. Mating surfaces shall be wiped with a solvent such as denatured alcohol to remove any possible accumulation of dirt, moisture or other conducting materials. A silicone grease or similar lubricant shall be applied afterwards in accordance with the manufacturer’s recommendations. Whenever prefabricated cable devices are opened, the un-energized mating surfaces shall be lubricated with silicone grease before the fittings are reconnected.

5.11.4. Secondary and Service Connections:

5.11.4.1. A suitable inhibiting compound shall be used with all secondary and service connections.

5.11.4.2. All secondary cable connections located below grade or in secondary pedestals shall be made with pre-insulated secondary connector blocks. Diving bells with open terminals, insulating boots or moisture barriers that depend solely on tape are not acceptable.

5.11.4.3. If the secondary phase terminals are threaded studs, the connection shall be made with a pre-insulated secondary transformer connection block. If the transformer secondary phase terminals are insulated cable leads, connection shall be made with a pre-insulated secondary connector block or with a secondary prefabricated splice when the transformer leads continue directly to the service.

5.11.4.4. Transformer secondary spades shall be taped or otherwise insulated. Boots used for insulation shall be taped so that they cannot be readily slipped off.

5.11.4.5. The secondary connections and insulation shall have accommodations for all future and existing service as shown on the plans and specifications

5.12. Pedestals

5.12.1. Where required, pedestals stakes shall be driven vertically into the bottom of the trench before cables are placed, and shall be located as shown on the drawings. Pedestal posts and supporting stakes shall be in place before the cable is installed. All pedestals should be approximately at the same height above finish grade.

5.13. Equipment Pads

5.13.1. The site for the pad shall be adjacent to but not over the trench backfill zone. The site shall be cleared of all debris and excavated to the specified depth. Native soil excavation bottoms shall be observed for cleanliness and suitability by a licensed, geotechnical engineer or designated representative prior to Structural Fill placement. Structural Fill, as defined in this specification, shall be added per plans and compacted to 95% of the maximum dry density of a standard Proctor (ASTM D698). The pad shall be installed level at the specified elevation.

5.13.2. As an alternative, the inverter skids can be mounted on driven pile foundations designed per the site conditions.

5.14. Transformers

5.14.1. Transformers shall be handled carefully to avoid damage to the finish and shall be positioned in accordance with the plans and specifications. Only qualified and experienced personnel shall be allowed to make connections and cable terminations.

5.15. Grounding

5.15.1. All neutral conductors, ground electrodes, and groundable parts of equipment shall be interconnected. All interconnections shall be made as shown on the design documents. Ground rods shall be installed at all equipment locations as shown in the design documents. All underground ground connections shall be exothermically welded. Clamps shall not be used to make underground ground connections.

5.16. Equipment Enclosures

5.16.1. Excavations for sleeve-type sectionalizing cabinet pads and other below grade enclosures shall be made so as to disturb the surrounding earth as little as practical. Enclosures shall be installed with side walls plumb and without any panel distortion. When installation is complete, the cover of the enclosure shall not be lower than and not more than two (2) inches higher than specified grade. Soil in the immediate vicinity shall be tamped and sloped away from the enclosure. The excess soil shall be spread evenly over the surface of the ground to the design requirements.

5.17. Warning Signs

5.17.1. Each equipment enclosure shall display a “Caution” sign placed so that it is visible to anyone attempting entry to the enclosure. Also, the equipment inside the enclosure shall display a “Danger” sign so that it is visible when the enclosure is open. Cable markers which indicate the presence of underground electrical facilities shall be installed at all road crossing locations.

5.18. Cleanup, Disposal and Restoration

5.18.1. All excess excavated material debris, such as boulders, broken concrete, trees, shrubs, roots, lumber, and any other items resulting from the construction operation, shall be removed and the site restored to its original appearance.

5.18.2. All areas in which trenching takes place shall be restored to the original condition. This includes gravel, concrete and asphalt surfaces.

5.18.3. Construction areas shall be de-compacted to a workable condition for farming to the extent practicable and vegetation cover re-established where disturbed by the work.

5.19. Underground Power Distribution Testing

5.19.1. Power Cable Acceptance Testing

5.19.1.1. Installations of power cable including terminations are to be acceptance tested using DC or low frequency AC high potential (Hipot) testing, and at a minimum to include the following tests**:**

5.19.1.1.1. Continuity: After installation of the cable and prior to the high potential test specified below, a simple continuity test shall be conducted on the system. This can be accomplished by grounding the conductor at the source and checking for continuity from the end of each tap with an ohmmeter.

5.19.1.1.2. High Potential: After successful continuity tests of the distribution voltage collection system, high potential tests on each length of cable, with terminations in place but disconnected from the system. The installation shall withstand a minimum of fifteen (15) minutes DC test potential or as recommended by the cable and connector manufacturers. The voltage may either be increased continuously or in steps to the maximum test value.

5.19.1.1.3. If increased continuously, the rate of increase of test voltage should be approximately uniform and increasing to maximum voltage in not less than ten (10) seconds or more than sixty (60) seconds.

5.19.1.1.4. If applied in steps, the rate of test voltage increase from one step to the next should be approximately uniform. The duration at each step shall be long enough for the absorption current to attain reasonable stabilization (one minute minimum). Current and voltage readings should be taken at the end of each step duration. The number of steps should be from five to eight.

5.19.1.1.5. Cable sheath testing shall be included for medium voltage cable.

5.19.1.2. If more than three failures of any component occur within six months of commercial operation, then partial discharge shall be performed on all similar components.

5.19.1.3. Other Test and Inspections: All other tests and inspections described in the Project Quality Assurance Plan.

5.19.1.4. After completion of a test and before handling the cable, the conductor shall be grounded to permit any charge to drain to earth.

5.19.2. Ground Loop Testing

5.19.2.1. Measure ground loop resistance to remote earth using the three-point method and verify the measured results conform to the requirements of the inverter supplier and the design documents.

5.19.3. Pad – Mount Transformer Testing

5.19.3.1. The following transformer checks and tests shall be completed on all units:

5.19.3.1.1. Inspection of satisfactory mechanical installation including proper torque on bolts, labeling and grounding.

5.19.3.1.2. Insulation resistance test between windings and from each winding to ground.

5.19.3.1.3. Calculate Polarization Index

5.19.3.1.4. Field test of transformer turns ratio test on all taps

5.19.3.1.5. Routine and Design tests specified for Class I power transformers identified in IEEE C57.12.00 2010 table 18.

5.19.3.1.6. Oil analysis for visual inspection, gas, liquid screen, and Karl Fischer moisture at minimum.

5.19.3.1.7. All other test and inspections described in the Project Quality Assurance Plan.

5.20. Submittals

5.20.1. Contractor shall submit to the Owner copies of all completed forms and documentation of all tests, studies, and inspections. Submittals required in the sections that refer to this section shall conform to the requirements of the definitive project agreement and to the following additional requirements:

5.20.1.1. Project Schedule

5.20.1.2. Interface Matrix

5.20.1.3. Construction Plan

5.20.1.4. Design Drawings shall include but not limited to:

5.20.1.4.1. Site plan showing infrastructure layouts, PV arrays locations.

5.20.1.4.2. Overall single line diagrams

5.20.1.4.3. Schematics Diagram

5.20.1.4.4. Wiring Diagram

5.20.1.4.5. Medium voltage and low voltage switch gear line diagrams

5.20.1.4.6. Riser diagrams showing connection to utility AC disconnects and main electrical switchboard

5.20.1.4.7. Indicate conduits, power and communication wires, and combiners, disconnects, inverters, meter, etc.

5.20.1.4.8. Provide PV system(s) power production calculations and total system(s) rating.

5.20.1.4.9. Complete point to point PV System interconnection diagram identifying all DC and AC components.

5.20.1.4.10. Combiner box schedule

5.20.1.4.11. Bill of materials.

5.20.1.4.12. Cable Schedule

5.20.1.4.13. Mounting frame and module layout

5.20.1.4.14. Inverter locations and foundation/housing

5.20.1.5. Control Systems

5.20.1.6. Protection Systems

5.20.1.7. Auxiliary power requirements

5.20.1.8. System Performance Reports: System study shall use software modeling program such as PVsyst for the sizing, simulation, and data analysis of complete PV systems. Output reports shall provide yearly energy production, performance, and energy gains and losses.

5.20.1.9. Medium voltage ampacity report: The purpose of the cable ampacity study is to determine if the calculated cable ampacity is greater than the load on any given cable in the collection system.

5.20.1.10. Low voltage ampacity report: The purpose of the low voltage cable ampacity study is to determine a safe operating ampacity the system can maintain.

5.20.1.11. Insulation coordination study: The purpose of the insulation coordination study is to ensure the insulation coordination requirements have been met per IEEE Std. C62.22-2009.

5.20.1.12. Effective grounding report: The purpose of the effectively grounded system study is to determine if the collection system is effectively grounded as defined by IEEE Standard C62.92.1-2000.

5.20.1.13. Ground grid analysis report: The purpose of the ground grid analysis study is to calculate the touch and step potential and certify that the proposed ground grid will meet or exceed IEEE Std. 80 safety requirements and the inverter manufactures touch potential requirements.

5.20.1.14. Fault current report: The purpose of the fault current analysis and coordination study is to determine the maximum fault current on each section of cable or conductor in the collection system and determine the maximum amount of time the conductor can withstand the fault before the cable is damaged.

5.20.1.15. Power factor report: The purpose of the power factor study is to calculate the power factor over a range of plant outputs to ensure the power factor of the solar facility meets Utility's required power factor range while staying within the power factor limitations of the installation.

5.20.1.16. Energy loss report: The purpose of the energy loss evaluation is to calculate the annual energy loss as a percentage of solar facility production to the distribution voltage bus at the solar facility substation/switching station.

5.20.1.17. Arc flash report: The purpose of the arc flash hazard assessment is to calculate the arc flash incident energy at various points of the solar facility and switchyard under all operating configurations to ensure the worst possible set of results is captured at each location. Applicable standards include IEEE 1584 NFPA 70E.

5.20.1.18. Harmonics report: The purpose of this report is to confirm the solar facility will meet interconnection harmonic requirements under all configurations of the solar facility and interconnection substation.

5.20.1.19. Oil sample analysis report for each padmount transformer

5.20.1.20. Manufacturer's Catalog Data: Submittals for each manufactured item shall include current manufacturer's descriptive literature of cataloged products, equipment drawings, diagrams, performance and characteristic curves, and catalog cuts. Handwritten and typed modifications and other notations not part of the manufacturer's preprinted data will result in the rejection of the submittal. Should manufacturer's data require supplemental information for clarification, the supplemental information shall be submitted as specified for certificates of compliance.

5.20.1.21. Bill of Materials: for major equipment

5.20.1.22. Instructions: Where installation procedures or part of the installation procedures are required to be in accordance with manufacturer's instructions, submit printed copies of those instructions prior to installation. Installation of the item shall not proceed until manufacturer's instructions are received. Failure to submit manufacturer's instructions shall be cause for rejection of the equipment or material.

5.20.1.23. Operation and Maintenance Manuals: Comply with the requirements of the technical sections

5.20.1.24. Operation and Maintenance Manuals for Electrical Works: Submit operation and maintenance manuals for electrical works that provide basic data relating to the design, operation, and maintenance of the electrical system. This shall include:

5.20.1.25. Single-line diagram of the "as-built" electrical works

5.20.1.26. Schematic diagrams of electrical control system

5.20.1.27. Manufacturers' operating and maintenance manuals on active electrical equipment, as applicable.

5.20.1.28. Operating Instructions: Submit text of proposed operating instructions for each system.

5.21. Products

5.21.1. General

5.21.1.1. All materials equipment, and workmanship shall conform to the applicable chapters of the National Electrical Code (NEC), the National Electrical Safety Code (NESC), and the terms and conditions of the Transmission Provider's and other Authorities having lawful jurisdiction pertaining to the work required.

5.21.1.2. All products shall be capable of compliance with all OSHA lockout requirements

5.21.1.3. Underground cable shall be as required by final design. Provide all rubber termination and splice materials.

5.21.1.4. Padmounted transformer(s) as described in the padmount transformer technical specification which is a part of the document.

5.21.1.5. Junction box medium voltage terminations shall utilize "T" type connectors that will allow for the easy relocation of surge arrestors.

5.21.1.6. Pedestals for padmount transformers shall be fiberglass, pre-cast, or cast-in-place concrete.

5.21.1.7. Junction boxes shall be pad mounted within the confines of the power substation.

5.21.1.8. Junction boxes, such as DC combiner boxes, located within the solar array may be pad mounted or mounted to deep foundation post(s).

5.21.2. Condition of Products

5.21.2.1. Except as otherwise indicated, provide new electrical products free of defects and harmful deterioration at the time of installation. Provide each product complete with trim, accessories, finish, guards, safety devices and similar components specified or recognized as integral parts of the product, or required by governing regulations. Unless otherwise indicated by the plans or specifications or approved in writing, the materials and equipment furnished under these specifications shall be the standard products of manufacturers regularly engaged in the production of such equipment and shall be the manufacturers' standard design.

5.21.3. Uniformity

5.21.3.1. Where multiple units of a product are required for the electrical work, provide identical products by the same manufacturer without variations.

5.22. Grid Connection

5.22.1. Factors should be considered during the project development process. The study should evaluate any unforeseen that may impact the viability of the project.

5.22.2. Proximity – The distance from the site to the grid connection point. In order to ensure the grid connection does not adversely affect project economics, it is necessary to carry out a feasibility study to assess power evacuation and transmission line routes.

5.22.3. Availability – The grid availability is the percentage of time that the network is able to accept power from the solar PV facility. The annual energy yield from a facility may be significantly reduced if the grid has significant downtime. Availability statistics should be evaluated.

5.22.4. Capacity – The capacity of the grid to accept exported power from a solar facility will depend on the existing network infrastructure and current loading of the system. The substation and export line capacity shall be sized for the capacity.

5.22.5. Utility requirements – Technical requirements for connection shall comply with Utility company codes and interconnection requirements which may include.

5.22.5.1. Limits on harmonic emission

5.22.5.2. Limits on voltage flicker

5.22.5.3. Limits on frequency variation

5.22.5.4. Fault level requirements

5.22.5.5. System protection

5.23. Execution

5.23.1. Coordination of Electrical Works

5.23.1.1. It is recognized that the electrical drawings are diagrammatic in showing certain physical relationships that must be established within the Electrical Works and in its interface with other work, including utilities and mechanical work, and that such establishment is the exclusive responsibility of the Contractor.

5.23.1.2. Arrange all electrical work in a neat, well-organized manner. Indoor conduit and similar services shall be installed running parallel with the primary lines of the building construction and with a minimum of 7 feet of overhead clearance where possible.

5.23.1.3. Arrange all electrical work with adequate access for operation and maintenance

5.23.1.4. Electrical connections shall be tightened to torque specifications stated by the equipment manufacturer.

5.23.2. Quality Control Testing

5.23.2.1. Upon completing installation of all systems and equipment, but prior to electrical substantial completion, the Contractor shall conduct an operational test of all equipment, controls, and devices installed or modified by the Contractor.

5.23.2.2. Contractor shall notify Owner in writing a minimum of three (3) days in advance of any test. This operational testing is in addition to testing required in separate sections of this specification. Where possible, combination of this testing and other testing required should be accomplished to minimize travel requirements.

5.23.3. Labeling

5.23.3.1. Install permanent labels on all electrical panels, cabinets, disconnects, motor starters, major equipment, or components. Weatherproof labels shall be either laminated black-phenolic plastic with white engraved letters, or engraved (or embossed) stainless steel nameplates. Lettering for panels and equipment shall be a minimum of 1/2 in. high. Labels shall be permanently installed by gluing or screwing to equipment covers. Labels shall show panel or load name and the circuit it is fed from.

6. Inverter Foundation (If Used)

6.1. Excavation, Backfill and Compaction

6.1.1. General

6.1.1.1. Ensure foundation site is graded in accordance with the design documents

6.1.1.2. All work shall be constructed, tested and inspected in compliance with the Project Quality Assurance Plan and as indicated in the design documents.

6.1.2. Submittals

6.1.2.1. Grain size analysis, natural moisture content and standard proctor maximum dry density test data for common fill soil materials.

6.1.2.2. Compaction test results indicating location of test, dry density and moisture content of placed fill.

6.1.2.3. Copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents, and Testing and Inspection requirements included in this document.

6.1.3. Products

6.1.3.1. Lean Concrete: as required by the design documents.

6.1.3.2. Common Fill: Soil free of organic or deleterious material.

6.1.4. Execution

6.1.4.1. Excavate soils to the limits according to the design documents.

6.1.4.2. Prior to placing a protective lean concrete surface, a geotechnical engineer or qualified representative shall inspect and approve the subgrade conditions and record the soil type encountered, groundwater conditions, or other subsurface conditions. The observations taken should confirm the subgrade conditions are consistent with the reference geotechnical information. If the subgrade is destabilized by foot or construction traffic, the surface must be re-inspected prior lean concrete placement. Water should not be allowed to pond on the exposed subgrade.

6.1.4.3. To protect the subgrade, place a lean concrete surface, and fill to the lines and levels indicated on the drawing. It is recommended that the surface be placed as level as possible to facilitate placement of the reinforcing steel and embedment ring.

6.1.4.4. Backfill and Compaction. Place and compact common fill materials to the limits, depth and percent compaction indicated in the contract documents

6.1.4.5. Grade the site in accordance with drawings to prevent water from ponding over the foundation while maintaining the maximum depth of fill specified on the design documents.

6.1.4.6. Restore the site in accordance with the definitive project agreement.

6.1.5. Testing and Inspection

6.1.5.1. Obtain samples of common fill materials and perform the laboratory testing specified in the contract documents.

6.1.5.2. For placed and compacted fills, provide one test per lift per 2,500 square feet, indicating the reporting requirements of ASTM D6938.

6.1.5.3. All other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents.

6.2. Cast in Place Concrete and Steel Reinforcing

6.2.1. General

6.2.1.1. Concrete work shall be in general compliance with all applicable codes and specifications including the following:

a. ACI 318 latest edition, Building Code Requirements for Structural Concrete and Commentary

b. ACI 301, Standard Specifications for Structural Concrete

c. ACI 308, Standard Specification for Curing Concrete

d. ACI 309, Consolidation of concrete guide

6.2.1.2. All work shall be constructed, tested and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents.

6.2.2. Submittals

6.2.2.1. Final mix design meeting the concrete specifications. Concrete mix designs shall be certified by a professional engineer and include the backup documentation required by ACI 301.

6.2.2.2. Product data for admixtures including aggregates, cements and other additives in the concrete mix. Curing of concrete shall be according to the latest ACI standards of practice/recommendations.

6.2.2.3. Mill reports for the reinforcing steel confirming the grade and strength of the reinforcing steel used on the project is as specified in the design documents.

6.2.2.4. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and, Testing and Inspection requirements included in this document.

6.2.3. Products

6.2.3.1. As specified by design documents

6.2.4. Execution

6.2.4.1. Place reinforcement and concrete in accordance with the final design dimensional tolerances.

6.2.4.2. Reinforcement shall be clean and free of rust, mud, debris and foreign material

6.2.4.3. Provide necessary chairs and standees to support rebar and prevent movement or deflection of the mats during placement of concrete.

6.2.4.4. Prevent formwork from moving during placement of concrete.

6.2.4.5. Place concrete in accordance with ACI 301.

6.2.4.6. Place successive lifts of concrete as quickly as possible to insure proper consolidation of concrete between successive lifts.

6.2.4.7. Foundation reinforcement and concrete shall be placed over a lean concrete working surface clear of debris, ponding of water, standing mud, and organic material.

6.2.4.8. Consolidate concrete in accordance with ACI 309 preventing the formation of joints, voids or honeycombing.

6.2.4.9. Create a smooth and level surface on top of concrete footings, equipment pads, and pedestal.

6.2.4.10. Cure concrete in accordance with ACI 308Apply curing compound as soon as bleeding has stopped, and free water is no longer evident at the surface.

6.2.5. Testing and Inspection

6.2.5.1. Cast compressive strength test specimens in accordance with ACI 318.

6.2.5.2. Laboratory strength test of specimens at 7 and 28 days or as required in design documents and the minimum required by ACI 318.

6.2.5.3. Casting and testing of cylinders in excess of 7 and 28 days will be the sole cost of the contractor.

6.2.5.4. Perform a minimum of one air test per concrete truck.

6.2.5.5. Perform a minimum of one slump test per cylinder test.

6.2.5.6. Perform all other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents.

6.2.5.7. All concrete, reinforcement, anchor bolts, embed plates, formwork, etc. shall be inspected per the current International Building Code (IBC), Chapter 17, “Special Inspections.”

6.3. Anchor Bolts and Embedment Plates

6.3.1. General

6.3.1.1. Products, execution and testing are specified to provide durable anchor bolts per most applicable codes and standards set for the solar industry.

6.3.1.2. All work shall be constructed, tested and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents.

6.3.2. Submittals

6.3.2.1. Product data for anchors and hardware

6.3.2.2. Mill certificates for anchors indicating the yield strength.

6.3.2.3. Mill certificates for the embedment ring indicating the material meets the minimum strength requirements.

6.3.2.4. Tension test data for anchor bolts that are tested indicating bolt location and tension value.

6.3.2.5. Copies of all completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and Testing and Inspection reports.

6.3.3. Products

6.3.3.1. As required by design documents.

6.3.4. Execution

6.3.4.1. The final engineered dimensional tolerances shall be adhered to for all installations.

6.3.4.2. Use a template ring to set anchor bolt plumbness and position. Ensure the template ring is set in accordance with the specified construction tolerances.

6.3.4.3. Place and level the embedment ring in accordance with the specified tolerances.

6.3.4.4. Insure the embedment ring is properly anchored to prevent movement.

6.3.4.5. After placement of concrete and at the final elevation, seal the space between the anchor bolt and the anchor bolt sleeve to prevent water from entering the sleeve annulus prior to setting of equipment and grouting of baseplate.

6.3.4.6. After setting of the equipment and grouting the baseplate anchor bolts shall be tensioned according to the specified tensioning procedure to a force as specified in the final design. The tensioning device for the anchor bolts should be calibrated in accordance with the approved procedure described in the Project Quality Assurance Plan on a regular basis to insure required tensions are achieved.

6.3.5. Testing and Inspection

6.3.5.1. After all bolts have been tensioned or torqued; a minimum of 10% shall be tested to verify that the final design tension has been achieved by use of an approved testing procedure.

6.3.5.2. All work shall be constructed, tested and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents.

6.4. Grout

6.4.1. General

6.4.1.1. The grout selected must cure to the required strength as specified in the design documents.

6.4.1.2. All work shall be constructed, tested and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents.

6.4.2. Submittals

6.4.2.1. Manufacturers' product data for grout

6.4.2.2. Grout cube strength test results

6.4.2.3. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan, the design documents and Testing and Inspection reports.

6.4.3. Product

6.4.3.1. Non-Shrink Grout: Pre-packaged grout conforming to design documents

6.4.4. Execution

6.4.4.1. Mix, place and cure grout in accordance with manufacturer's instructions

6.4.5. Testing and Inspection

6.4.5.1. Cast grout cubes and perform laboratory strength testing at 3 and 28 days or in accordance with design documents.

6.4.5.2. All other tests and inspections described in the Project Quality Assurance Plan and as indicated in the design documents.

6.5. Miscellaneous Concrete Embeds

6.5.1. General

6.5.1.1. All work shall be constructed, tested and inspected as described in the Project Quality Assurance Plan and as indicated in the design documents.

6.5.2. Submittals

6.5.2.1. Documentation stating that electrical conduit and grounding grid have been installed in accordance with the manufacturer requirements.

6.5.2.2. All completed forms and documentation of all tests and inspections described in the Project Quality Assurance Plan and design documents.

6.5.3. Product

6.5.3.1. Electrical Conduit: In accordance with manufacturer requirements.

6.5.3.2. Grounding Grid: In accordance with manufacturer requirements.

6.5.4. Execution

6.5.4.1. Verify the location of miscellaneous concrete embedments and ensure they are properly secured to prevent movement during concrete placement.

6.6. Miscellaneous Submittal Requirements

6.6.1. Documentation from the Structural Engineer of record confirming that they have reviewed the testing and inspection records and that the work was performed in conformance and compliance with the design documents. The review does not relieve the Contractor of the work due to errors contained in those documents.

6.6.2. Submit copies of testing and inspection records

7. Infrastructure Facilities Layout

7.1. Not used

8. Solar Generator Step-up Transformer, Three-Phase Padmount Loop Feed

Note: Engineer of record shall review this specification to identify and report inconsistencies within the specification and areas where the specification may not be compatible with the overall solar facility design.

8.1. Codes and Standards

8.1.1. All transformers shall conform to the applicable standards of ANSI, ASTM, IEEE, NEC, NEMA, and NFPA ll materials and devices shall be in accordance with the applicable requirements of the Federal "Occupational Safety and Health Administration" Standards

8.1.2. In case of conflict between the requirements of the various parts of these documents, the requirements of the different parts shall govern in the following sequence: Mandatory governmental regulations, codes and standards, this Specification and the referenced industry codes and mid standards

8.2. Enclosure Construction

8.2.1. The exterior color of the transformer shall be the manufacturer's standard color.

8.2.2. The transformer doors shall be equipped to latch in the open position.

8.2.3. Each door shall open 180°

8.2.4. Heavy 18" stainless steel door rods

8.2.5. All compartment door-latching bolts shall be self-aligning, captive, penta-head and be in accordance with Figure 1 of IEEE C57.12.28

8.2.6. The penta-head cylinder and hasp shall have ½ inch (minimum) holes for padlocking.

8.2.7. The transformer connection compartment shall be arranged so that the high-voltage section shall be separated from the low voltage section by a vertical steel barrier.

8.2.8. An automatic pressure-relief valve shall be installed in the low-voltage compartment.

8.2.9. A pressure vacuum gauge shall be located in the low voltage compartment.

8.2.10. A liquid level gauge shall be located in the low voltage compartment.

8.2.11. A dial type thermometer with maximum temperature indicator shall be installed in the low voltage compartment.

8.2.12. A drain valve and sampler shall be installed such that it is enclosed in and accessible by opening an external lock box. The lock box and hasp shall have ½-inch (minimum) holes for padlocking.

8.2.13. The transformer nameplate shall be located on the inside of the low voltage cabinet door and shall contain data listed in Table 7 of IEEE Standard C57.12.00-2010, under Nameplate. The serial number of the transformer shall also be indicated on the low voltage tank wall. The nameplate shall also include the volume of insulating fluid in gallons and the statement "INSULATING FLUID IS NON-PCB CONTAMINATED." Taps shall be listed in actual voltage rather than percent of nominal. All protective devices, such as fuses and isolation links shall be identified on the nameplate schematic.

8.2.14. All bushings, terminals, and switches shall be identified on the tank wall in yellow stencil or decal.

8.2.15. To preclude exposing internal parts designed to be under oil, the transformer shall be capable of operation without derating when placed on a flat surface up to five degrees out of level in any direction.

8.2.16. The termination cabinets shall be a minimum of 36 inches deep.

8.2.17. A clear barrier on top and front of low voltage circuit breaker.

8.2.18. Dielectric fluid shall be PCB-free mineral oil.

8.2.19. There shall be a minimum of 2 grounding pads in the high voltage compartment and low voltage compartment. Bronze, vice type (Fargo GC-208 or approved equivalent) grounding lugs shall be installed in each ground pad and shall accommodate a 1/0 conductor.

8.2.20. The high voltage bushing pattern shall be, at a minimum, as shown in IEEE C57.12.26 figures 2 and 3.

8.2.21. The low voltage bushing pattern shall be, at a minimum, as shown in IEEE C57.12.26 figures 3 and 4a.

8.2.22. Core ground shall be accessible through a hand hole.

8.3. Service Conditions Class I power transformer

8.3.1. The padmount transformers will be used as Photovoltaic solar inverter step-up transformers in a multi inverter solar facility.

8.3.2. Multiple transformers will be connected in parallel to the same distribution voltage collector circuit and/or branch of the collector circuit.

8.3.3. Approximately 4 MW of Photovoltaic generation will be connected on one circuit.

8.3.4. Design elevation = 1,000 meters a.s.l

8.3.5. Design ambient temperature max = +40°C

8.3.6. Ambient temperature min = -40°C

8.3.7. The transformer shall be connected to the inverter, and other transformers, in such a way that the transformer(s) may be subject to abnormally high voltages associated with an inverter load rejection and other transient conditions. Therefore, the transformer shall be designed to withstand the voltage stress associated with 1.4 times the rated voltage applied to the transformer terminals for 5 seconds.

8.3.8. The transformer will be designed to withstand voltage excursions associated with substation breaker closing.

Table 8.1 Transformer Specifications

Feed configuration	Loop feed
kVA	10% at 25°C greater than the maximum generation level allowed by the inverters.
Phases	3
Frequency	60 Hz
Maximum average temperature rise above ambient	65°C at rated kVA for the combination of connections and taps that gives the highest average temperature rise
Maximum (hottest spot) temperature rise above ambient	80°C at rated kVA for the combination of connections and taps that gives the highest average temperature rise
High voltage	Per One-line or per Engineer of record
Low voltage	XXX grounded Y [Engineer of Record to specify]

High voltage taps	Two full-capacity taps above nominal-rated voltage in 2.5% steps. Two full-capacity taps below nominal-rated voltage in 2.5% steps.
High voltage BIL	xx kV (per site requirements, EOR to specify)
Low voltage BIL	xx kV (per site requirements, EOR to specify)
* Neutral BIL, grounded Y	xx kV
* Neutral BIL, impedance grounded Y	xx kV
Low voltage bushing	Per Engineer of Record
Target impedance	As specified by the Engineer of Record
Losses:	
** No load losses @ 20°C	**
** Load losses @ 85°C	**
High voltage bushings	Six XXX-amp dead break or load break bushing [Engineer of Record to specify]
Low voltage bushings	Engineer of record to specify
Low voltage bushings supports	Engineer of record to specify
	*Engineer of Record is to specify grounded Y or Impedance grounded Y neutral BIL requirements
	**

8.4. Auxiliary Equipment and Accessories

8.4.1. Internal expulsion cartridge fuse x3

8.4.2. Parallel oil-immersed partial range current limiting fuse x6

8.4.3. Hook stick operable, two position, amp rating per EOR, under oil, loop feed switches. Switch positions shall be labeled “open” and “closed.” Switch position labels shall be readable from 2 feet away. (Engineer of Record to specify amp requirements.)

8.4.4. Hook stick operable tap change switch located at an accessible location which does not require reaching behind cables. The tap change switch shall snap into each voltage setting. The switch shall be visible indicating from 2 feet. Provisions, such as a spring loading locking pin or set screw shall be made to assure that accidental operation of the tap changer will not occur.

8.4.5. Low voltage surge arrestor: Ferraz Shawmut surge arrestor or Owner approved equal. The low voltage surge arrestor shall be mounted in an easily viewable and accessible location and shall not be mounted behind cables.

8.4.6. Low voltage power breaker. ABB SACE Emax, or equivalent, as specified by the Engineer of Record.

8.5. Documentation

8.5.1. Factory recommended spare parts list

8.5.2. Shop drawings

8.5.3. Operations and maintenance manual(s)

8.5.4. Certified factory test reports

8.6. Shipment and Storage

8.6.1. Transformer shall be shipped in a manner that they are protected from damage, and with provisions for safely moving them onto and off the shipping vehicle.

9. High Voltage Interconnection (Power Substation) and Transmission

Introduction: It is the intent of this section to provide general specifications for the procurement, installation and testing of a high voltage substation with the goal of interconnecting a large-scale solar facility. The interconnection of such facility consists of building an on-site high voltage substation, typically consisting of a (1) main high voltage Breaker, (1) main GSU (Generation Station Unit) Transformer, and two or more medium voltage vacuum breakers receiving the power coming out of the solar feeders. Up to two solar feeders can be connected to a medium voltage vacuum breaker. Each solar feeder is able to carry up to 20 or 25 MW of solar power. On the high voltage side, typically an H-frame structure is erected to connect an overhead transmission line (exclusive for the solar site), to the Point of Interconnection (POI) approved and indicated by the local Utility. In case the transmission line runs underground, dead-end pole structures are erected.

9.1. General

9.1.1. Section includes general provisions for the electrical Installation.

9.1.2. Related Sections

9.1.2.1. All sections included in this project.

9.1.3. System Description

9.1.3.1. The work covered by this specification shall include furnishing all labor, material, equipment and services to construct and install the complete electrical system as shown on drawings and specifications.

9.1.4. Design Drawings

9.1.4.1. The Engineer of Record drawings shall serve as the working drawings. They indicate the general layout of the complete electrical system.

9.1.4.2. Field verification of scale dimensions on plans is directed since actual locations, distances and levels will be governed by actual field conditions.

9.1.4.3. The Contractor shall also review architectural, structural and mechanical drawings to avert possible installation conflicts. Should drastic change from original plans be necessary to resolve such conflicts, the contractor shall notify the Engineer of Record, and secure written approval and agreement on necessary adjustments before the installation is started.

9.1.4.4. Discrepancies shown on different plans, or between plans and actual field conditions, or between plans and specifications, shall promptly be brought to the attention of the Engineer of Record for a decision.

9.1.4.5. All items not specifically mentioned in the specifications or noted in the drawings, but which are obviously necessary to make a complete working installation shall be included.

9.1.5. Temporary Power

9.1.5.1. The Contractor shall furnish, install, maintain, and remove after construction is completed a temporary power and lighting system.

9.1.6. Safety Precautions

9.1.6.1. The Contractor shall furnish and place proper guards for prevention of accidents.

9.1.6.2. Contractor shall provide and maintain any other construction required to secure safety of life or property, including the maintenance of sufficient lights.

9.1.7. Submittals

9.1.7.1. The Contractor shall submit detailed dimensioned shop drawings covering all items of equipment, data for each type of product used in the project. No equipment should be ordered until these shop drawings and/or data sheets have been approved.

9.1.8. Closeout Submittals

9.1.8.1. The Contractor shall keep a complete set of drawings at the site of work for the express and only purpose of noting thereon on a continuous basis all changes in construction, layout or conduit, ducts, etc., which are affected during construction due to field conditions, change orders, etc.

9.1.8.2. This set of provisional record drawings shall be kept up to date with all changes noted thereon, and these provisional record drawings shall be submitted for the inspection and approval of the Engineer of Record at least five days prior to any partial monthly payment.

9.1.8.3. Upon termination of the work, the Owner shall furnish a complete set of copies, on which the Contractor shall, in a neat and workmanlike manner, make a complete record of all changes and revisions to the original work. These drawings shall be delivered to and be approved by the Engineer before final liquidation of the contract.

9.1.9. Manuals

9.1.9.1. The Contractor shall provide the Owner with four bound copies of Instruction Manuals on the operation and maintenance of each piece of equipment installed, including: inspection, maintenance, cleaning, grounding, precaution and operation.

9.1.9.2. At the time the manuals are given, the Contractor shall supply the Owner with four copies of the equipment manufacturer's recommended spare parts list.

9.1.9.3. The Contractor shall provide four copies of the time current curves of each protective device furnished.

9.1.10. Delivery, Receiving and Storing

9.1.10.1. All electrical materials, equipment and accessories required to complete the work shall be delivered to, received, unloaded and stored by the Contractor until they are installed.

9.1.10.2. Prior to shipment, all items shall be protected or crated to prevent damage during shipment and handling. Wooden covers shall protect equipment flange faces. Contractor shall perform all required uncrating, unpacking, cleaning and inspection prior to installation.

9.1.10.3. All items shall be inspected as soon as they are received to determine if any damage has occurred in transit. Damaged items shall be repaired or replaced immediately to prevent delay in the construction schedule.

9.1.10.4. All items shall be properly protected during all phases of the work. Materials, equipment and accessories, which are not weatherproof, shall be protected against weather damage during storage. The Contractor shall be responsible for the safekeeping of all items during receiving, storing and installation.

9.1.10.5. Defective equipment or equipment damaged in the course of relocation, installation, or test shall be replaced or repaired in a manner meeting with the approval of the Owner.

9.2. Products

9.2.1. Electrical materials shall be new and products of recognized manufacturers and as noted on the drawings and/or stated in these specifications.

9.2.2. It is the intent of these specifications to establish quality standards of materials and equipment installed. Hence, specific items are identified by manufacturer, trade name or catalog designation.

9.2.3. Substitutions

9.2.3.1. Should the Contractor propose to furnish material and equipment other than those specified as permitted by the “similar to” or “approved equal” clauses, he shall submit a written request for any or all substitutions to the Owner representative. Such a request shall be accompanied with complete description (manufacturer, brand name, catalog number, etc.) and technical data for all items.

9.2.3.2. Acceptance or rejection of the proposed substitutions shall be subject to approval of the Owner representative. If requested the Contractor shall submit samples of both the specified and the proposed items for inspection.

9.2.3.3. Contractor shall be responsible for notifying any other Contractor whose work should become affected due to the substitution of a piece of equipment other than that which is incurred by the other trades due to the substitution.

9.2.4. Labor

9.2.4.1. All workmanship shall be first class and performed by persons qualified in this trade.

9.2.4.2. Insofar as is it possible, the Contractor shall keep the same foremen and workmen throughout the project duration.

9.2.5. Supervision

9.2.5.1. During the entire progress of the job, the Contractor shall have a competent experienced engineer and all necessary assistants. This engineer shall not be changed during the progress of the job without the consent of the Owner representative.

9.2.6. Sleeves, Openings, And Inserts

9.2.6.1. The Contractor shall furnish and install all sleeves or openings through floor or walls required for passage of all conduits or ducts installed by him.

9.2.6.2. The Contractor shall furnish and install all inserts and hangers required to support bus ducts, conduits, pull boxes, luminaires, etc.

9.2.6.3. If the sleeves, hangers, inserts, etc. are improperly installed, the Contractor shall do all necessary cutting and patching at this own expense, to rectify the errors.

9.2.7. Cutting and Patching

9.2.7.1. Cutting of walls, partitions, floor and roof that may be necessary for this installation shall be done in a neat workmanlike manner. Openings shall be cut only large enough to facilitate the installation.

9.2.7.2. Cutting of structural members or cutting that in any manner weakens the structure is forbidden.

9.2.7.3. Patching shall be done with the same type of material as was removed. The completed patching work shall restore the surface to its original appearance. Rubble and excess patching material shall be promptly removed from the premises.

9.2.7.4. Patching of waterproofed surfaces shall be done in a manner, which shall render the area completely waterproof.

9.2.8. Excavation and Backfill

9.2.8.1. All excavation trenching and backfilling required for properly installing the electrical duct systems shall be provided as part of the electrical work unless otherwise stated in the specifications or on the drawings.

9.2.8.2. Trenches shall be dug to the proper alignment and required depth only so far in advance of pipe laying as required to permit orderly progress of the work. Trenches shall be only wide enough to permit satisfactory joining of piping.

9.2.8.3. All excavations shall be kept free of water by pumping or other approved means, during progress of the work and until the excavations are backfilled. Backfilling shall be done immediately after the work has been inspected and approved.

9.2.8.4. Where sub-grade soils are unstable and cannot properly support piping, trenches shall be excavated at least six inches deeper than required, backfilled with an approved fill material to the proper elevation and compacted.

9.2.8.5. Special conditions for anchors, supports, thrust blocks, etc., shall be as indicated on the drawings.

9.2.8.6. Backfilling shall not be done until testing has been satisfactorily completed and approved and all concrete appurtenances have been properly cured.

9.2.8.7. Backfill shall be select material, free from rock larger than four inches in diameter and free from deleterious material. The backfill shall be tamped in layers not exceeding six inches in depth and shall be sufficiently damp to permit thorough compaction on each side of the pipe to provide solid support and backing against the external surface, to an elevation of at least 12 inches above the top of the pipe. The balance of the fill shall contain no rock larger than eight inches in its largest dimension and free from deleterious matter. The balance shall be compacted thoroughly by puddling or flooding, or by tamping if the material does not consolidate readily by puddling.

9.2.8.8. All excess excavated material not used for backfill shall be removed from the site.

9.2.9. Field Quality Control

9.2.9.1. All material and workmanship shall be subject to inspection, examination and test by the Owner representative or QAR at any and all times during construction.

9.2.9.2. After the installation is completed, the Contractor shall conduct an operating test for approval. The equipment shall be demonstrated to operate in accordance with the requirements of these specifications. The test shall be performed in the presence of the Owner representative.

9.2.9.3. The Contractor shall furnish promptly, without additional charge, all reasonable facilities, labor, materials and equipment for the safe and convenient inspection and tests that may be required by the Owner representative.

9.2.9.4. The electrical installation shall meet the approval of the local Power Utility Authority and the Contractor shall furnish a Certificate of this approval.

9.2.10. Cleaning and Painting

0.1.2.1 All equipment, luminaires, conduits, ducts and other exposed work shall be thoroughly cleaned. All plated, polished or painted work shall be bright and clean.

0.1.2.2 All equipment shall have factory standard finish unless otherwise called by technical specification for special treatment. Painting Contractor shall provide other painting.

9.2.11. Guarantee of Work

0.1.2.3 All the work herein specified shall be guaranteed free from labor and material defects for one year after the work is received. The Contractor shall deliver a document covering the terms of this guarantee to the Owner.

9.3. Outdoor Potential Transformer Procurement Specification

9.3.1. General

9.3.1.1. Outdoor inductive type potential transformer (PT), oil insulated (PCB free), of the two-bushing type (full insulation for line-to-line connection). The PT shall be built in accordance with ANSI Standard C57.13-1993 and all applicable NEMA Standards. Manufacturer shall include with proposal mounting layout. The potential transformer shall be supplied with primary terminal connectors suitable for 4/0 stranded conductor. Shall provide two secondary windings (X, Y). The insulator shall include an oil sight glass to see the oil level. The PT's nuts, bolts, and washers shall be made of stainless steel.

9.3.2. Products

Table 9.1 Electrical Characteristics

Item	Description	Requirement
1	System Voltage Line to Line	As indicated on Single Line
2	Insulation class	As indicated on Single Line
3	Basic insulation level	As indicated on Single Line
4	Creepage distance	Based on Standards.
5	Power capacity	As indicated on Single Line
6	Ratio	As indicated on Single Line
7	Accuracy	As indicated on Single Line

9.3.2.1. Construction Requirements

9.3.2.1.1. The transformer shall be constructed for the site environment to where it will be installed. The contractor shall reach out to the owner in order to obtain site environmental conditions. Supporting Pedestal, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures ASCE 7.

9.3.2.1.2. Submit all components and anchorage design and drawings for approval.

9.3.3. Execution

9.3.3.1. Routine tests

9.3.3.1.1. Each PT shall receive the following routine test:

- Applied voltage dielectric test between windings and between winding and ground
- Induced Voltage test
- Accuracy test
- Polarity test
- Ratio test
- Power Factor test

9.3.3.1.2. The supplier shall submit the Routine Test reports for each PT to the Owner representative.

9.4. Substation Class Post Insulators

9.4.1. General

9.4.1.1. Section includes outdoor station class post insulators for high voltage systems.

9.4.2. Construction

9.4.2.1. General

9.4.2.1.1. Manufacturers: Those approved by the owner.

9.4.2.1.2. Strength Station Post Insulators:

9.4.2.1.3. Single piece high strength porcelain body with externally attached hardware. Drop forged steel, malleable iron or ductile iron, hot dipped galvanized caps and bases, porcelain caps, hot dipped galvanized bases with interchangeable bolt holes and bolt circle. Provide adapter plates and spacers as required for mounting holes.

9.4.2.1.4. Maximum recommended working load shall be less than forty percent (40%) of the publishing rating under normal operating conditions.

9.4.2.1.5. Voltage rating: as indicated on single line diagrams.

9.4.2.1.6. Finish color shall be Gray 70.

9.4.2.1.7. Acceptable manufacturers: Lapp, Ohio Brass, Joslyn. Loading

- Mounting structure is specified or shown on drawings shall be designed so after the complete equipment is installed the supporting pedestal, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures ASCE 7.

9.5. GOAB Switch

9.5.1. General

9.5.1.1. This specification describes Gang Operated Air Break (GOAB) switch for Substation application. The switch shall be furnished with operating mechanism, mounting bolts, terminal lugs, channel bases, insulators, and provisions for mounting key interlocks. The maximum height shall be 12 ft for the hook switches.

9.5.1.2. The GOAB switch type shall be Vertical Break, Single End Break unless specified differently by the owner.

9.5.2. References:

9.5.2.1. All work shall be in accordance with all applicable codes and standards to include, but not limited to, the following:

9.5.2.1.1. The GOAB shall be built following the latest applicable ANSI/IEEE NEMA requirements.

9.5.2.1.2. ASTM Standard and the herein included

9.5.2.1.3. The following standards shall form part of this specification unless otherwise stated:

- ANSI C29.9 Wet-Process Porcelain Insulators
- IEEE C37.30 IEEE Standard Requirements for High- Voltage Switches
- ANSI C37.32 Schedules of Preferred Ratings, Manufacturing Specification, and Application Guide for High Voltage Air Switches
- ANSI C37.34 Test Code for High-Voltage Air Switches
- ASTM 123 Zinc Coating (Hot Dip) on Iron and Steel Hardware
- NEMA SG6 Power Switching Equipment

9.5.3. Products

9.5.3.1. Conducting Parts Characteristics

9.5.3.1.1. Conducting Parts shall be fabricated with high conductivity copper and copper alloy (or bronze) casting parts. The GOAB shall be designed to limit the temperature rise to 30ºC over an ambient of 40ºC (as per NEMA standard). Switch ratings shall be in accordance to single line diagram.

9.5.3.1.2. All jaws contacts shall be silver to copper and designed so that wiping action is provided with a minimum of roughening or wear on the silver surfaces. Wear of contacts shall not result in diminished contact performance due to reduction of contact pressure. The number and size of contact fingers shall be sufficient to ensure adequate transfer of rated current from the blade to the jaw. All contacts shall be self-aligning and self- adjusting and designed to ensure firm positive contact.

9.5.3.1.3. Each switch blade shall conform one solid piece and shall be so assembled that no part can move relative to another. Ends of switch blades shall be completely close except for drain holes. Switch blades shall be high conductivity copper alloy and of tubular construction.

9.5.3.1.4. Terminal pads on each end of the switch shall be located at the same height above the insulator terminal pads shall have flat, machined surfaces. Terminal pads shall have NEMA Standard.

9.5.3.1.5. The contact fingers shall maintain pressure during normal and short circuit operation without back-up springs or other pressure compensating devices. The hinge contact fingers shall be in continuous contact with the switch blade thought the complete opening and closing operation.

9.5.3.1.6. To increase pressure during short circuit conditions contacts shall be high pressure, self-wiping, reverse loop female type.

9.5.3.1.7. Contact surface between jaws (fingers) and blades shall be copper to silver or silver to silver.

9.5.3.2. Switch Base

9.5.3.2.1. Bases shall be constructed with rigid galvanized steel.

9.5.3.2.2. The switch shall have provisions to adjust for installation irregularities during the field.

9.5.3.2.3. To make adjustments, the switch shall include 4 leveling bolts on the base of each insulator.

9.5.3.3. Insulators

9.5.3.3.1. Porcelain, grey, voltage and BIL as indicated on single line diagram.

9.5.3.3.2. Bearings used at the rotating insulator and operating mechanism shall be made with stainless steel balls and races and will be sealed, permanently lubricated to provide maintenance free operation.

9.5.3.4. Operating Mechanism

9.5.3.4.1. The operating mechanism shall be swing handle, worm gear. The operating mechanism shall include outboard bearings, bell cranks, horizontal and vertical operating rods, pipe guides, pipe coupling, ground strap, grounding clamp, arching horn, grounding operator platform and operating handle. Operating mechanism shall include provision for padlocking ½” Ø shackle in the Close and Open positions with Closed and Open indicators.

9.5.3.4.2. The use of worm gear operator transmission will be 4:1 ratio, sealed, maintenance free.

9.5.3.4.3. The operating mechanism shall include auxiliary switch (for remote status indication).

9.5.3.4.4. The auxiliary switch shall be mounted on the vertical operating rod.

9.5.3.4.5. Key interlock system shall be supplied with the associated main breaker.

9.5.3.4.6. Grounding operator platform shall be made of aluminum checkered plate, 36” X 24”.

9.5.3.4.7. The vertical operating rod shall be 1-1/2” Ø, rigid galvanized steel.

9.5.3.5. Connectors

9.5.3.5.1. Terminal connectors shall be furnished with each GOAB switch. The terminal connectors shall be for conductors or tubing with the diameter specified in the drawing or requisition.

9.5.3.6. Grounding Blades

9.5.3.6.1. The grounding blades shall be furnished on the line side of the GOAB switch and shall be gang operated, 3 pole and single throw.

9.5.3.6.2. The operating mechanism of the grounding blades and the associated air disconnect shall be mechanically interlocked.

9.5.3.6.3. The grounding blades shall be pivoted on the structure mounted. Shall be furnished complete with outboard bearing, bell crank, horizontal and vertical operating rods, pipe guides, grounding operator platforms, ground straps, grounding clamp and operating handle, etc. Operating mechanism shall have provisions for padlocking, ½” Ø shackle in the closed and open position. Grounding blades shall be equipped with strap and terminal lug for connecting 4/0 stranded copper grounding conductor.

9.5.3.6.4. Grounding operator platform shall be made of aluminum checkered plate, 36” X 24”.

9.5.3.7. Mounting

9.5.3.7.1. The attachment components and anchors shall be stainless steel or other material approved by the Owner. Mounting structure is specified or shown on drawings and shall be designed so after the complete equipment is installed the supporting pedestal, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures ASCE 7.

9.5.3.7.2. Submit all components and anchorage design and drawings for approval.

9.5.3.8. Materials and Workmanship

9.5.3.8.1. The equipment shall be new and of standard commercial, first-grade quality as to materials, workmanship, and design, in accordance with the best engineering practice, and shall be such as has been proven to be suitable for the intended purpose. All welding shall be done by welders experienced in the process to be in a manner evidencing good workmanship.

9.5.3.9. Packing and Shipping

9.5.3.9.1. All parts and materials shall be protected with wooden crate, properly sized and fabricated to protect the unit from damage during transportation and subsequent storage. Conducting parts, insulators and base must be supplied fully assembled (per phase) inside wooden crates. Additional materials shall be packed in weather proof boxes and identified with weather proof labels.

9.5.3.9.2. All materials, elements, parts and hardware shall be shipped in flatbed trailers and stored in such a way so that they can be unloaded by finger lifts. Deliveries in containers or closed platforms where finger lifts cannot be used will not be accepted.

9.6. Lightning Arresters

9.6.1. General

9.6.1.1. This specification covers the minimum requirements for the design, manufacturing and testing of metal oxide, outdoor, station class lightning arresters. The lightning arrester shall meet or exceed the requirements and comply with the test established in the latest applicable ANSI and NEMA Standards.

9.6.1.2. The equipment described in the specification requires qualification.

9.6.2. Products

9.6.2.1. Construction

9.6.2.1.1. The housing shall be constructed of polymeric material (silicon rubber) with glass reinforced epoxy collar. It shall maintain a clean and moisture free atmosphere for its internal components.

9.6.2.1.2. The Manufacturer shall stamp the arrester nameplate with the factory measure dielectric-loss (watt loss) for each unit supplied. The plate shall be made of aluminum or suitable for coastal environment.

9.6.2.1.3. The lightning arresters shall have the minimum units per stack. The manufacturer shall specify number of units per stack, mounting dimensions, size, weight and electrical characteristics.

9.6.2.1.4. Each arrester shall be provided with terminals for connecting line and ground conductors.

9.6.2.1.5. Arresters shall be designed for application of 60 Hz and average daily temperature as indicated on site environmental conditions.

9.6.3. Loading

9.6.3.1. The attachment components and anchors shall be stainless steel or other material approved by the owner. Mounting structure is specified or shown on drawings shall be designed so after the complete equipment is installed supporting pedestal, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures ASCE 7.

9.6.3.2. Submit all components and anchorage design and drawings for approval.

9.7. Liquid-Filled Power Transformers (GSU) Procurement Specification

9.7.1. General

9.7.1.1. This specification covers the main power transformers GSU. Transformers shall be designed for continuous duty over a minimum design life of 30 years at full rated load in any mode (self-cooled or under forced cooling).

9.7.2. Attached Data Sheets

9.7.2.1. The appended project specific data sheet forms an integral part of this specification.

9.7.3. Applicable Standards

9.7.3.1. Unless otherwise specified, the transformer and all associated equipment shall conform to the latest revision of all applicable standards including but not limited to the standards listed in this section.

9.7.3.2. American National Standards Institute (ANSI)

9.7.3.2.1. C57.12.10 - Safety Requirements: 230 KV and Below, 833/958 Through 8333/10,417 KVA Single-Phase, and 750/862 Through 60,000/80,000/100,000 KVA Three-Phase Without Load Tap Changing; and 3750/4687 Through 60,000/80,000/100,000 KVA with Load Tap Changing

9.7.3.2.2. C57.12.70 - Terminal Markings and Connections for Distribution and Power Transformers

9.7.3.2.3. C57.12.80 - Standard Terminology for Distribution and Power Transformers

9.7.3.2.4. C57.12.90 - Standard Test Code for Liquid-Immersed Distribution, Power, and regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers

9.7.3.2.5. C57.13 - Standard Requirements for Instrument Transformers

9.7.3.2.6. C57.19.00 - Standard General Requirements and Test Code for Outdoor Power Apparatus Bushings

9.7.3.2.7. C57.19.01 - Standard Performance Characteristics and Dimensions for Outdoor Power Apparatus Bushings

9.7.3.2.8. C57.91 - Guide for Loading Transformers

9.7.3.2.9. C57.93 - Guide for Installation of Liquid-immersed Power Transformers

9.7.3.2.10. C57.98 - Guide for Transformer Impulse Tests

9.7.3.2.11. C57.100 - Standard Test Procedure for Thermal Evaluation of Liquid-Immersed Distribution & Power Transformers

9.7.3.2.12. C57.109 - Guide for Liquid-Immersed Transformer Through-Fault Current Duration

9.7.3.2.13. C57.113 - Guide for Partial Discharge Measurement in Liquid-Filled Power Transformers and Shunt Reactors

9.7.3.2.14. C57.115 - IEEE Guide for loading Mineral-Oil Immersed Power Transformers Rated in excess of 100 MVA (650 C Winding Rise)

9.7.3.2.15. C57.120 - Loss Evaluation Guide for Power Transformers and Reactors.

9.7.3.2.16. C57.131 - Standard Requirements for Load Tap Changers

9.7.3.2.17. C62.11 - Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1kV)

9.7.3.2.18. C62.22 - Guide for the Application of Metal-Oxide Surge Arresters for Alternating

9.7.3.2.19. Current Systems

9.7.3.2.20. Z55.1 - Gray Finishes for Industrial Apparatus and Equipment.

9.7.3.3. American Society for Testing and Maintenance (ASTM)

9.7.3.3.1. D3487 - Standard Specification for Mineral Insulating Oil for Use in Electrical Apparatus

9.7.3.4. National Electrical Manufacturers Association (NEMA)

9.7.3.4.1. TR1 - Transformers, Regulators, and Reactors

9.7.3.4.2. ICS 1 - General Standards for Industrial Controls and Systems

9.7.3.4.3. ICS 2 - General Standards for Industrial Control Devices, Controllers, and Assemblies

9.7.3.4.4. ICS 6 - Enclosures for Industrial Controls and Systems

9.7.3.4.5. MG1 - Motors and Generators

9.7.3.5. The Bidder shall clearly identify any deviation from the specification, accompanying data sheet or an applicable ANSI/IEEE, NEMA or CSA standard in the Bid. If such a statement is not provided, it will be considered as the Bidder's confirmation of total compliance with the specification and standards.

9.7.4. Construction

9.7.4.1. Core and Coil Design

9.7.4.1.1. The transformer core shall be of circular (non-rectangular) design. However, a wound core is not necessary. The coils shall be copper. The core and coil designs shall be standard, proven designs for the manufacturer.

9.7.4.1.2. The manufacturer shall be prepared to submit at the Owner's request, a list of at least 10 installations of similar size, voltage configuration and core and coil design that have been operating satisfactorily within the continental United States for a minimum of 5 years.

9.7.4.1.3. Core ground bushing shall be accessible without opening the tank.

9.7.4.2. Oil Preservation System

9.7.4.2.1. The transformer shall be provided with a conservator type oil preservation system. The conservator shall be provided with a membrane system to minimize potential exposure of the oil to moisture.

9.7.4.2.2. As an option, the manufacturer may provide a regulated nitrogen blanket system only if this system is provided with a Nitrogen generation system that shall operate to fully protect the oil without the changing of Nitrogen bottles as a maintenance procedure.

9.7.4.3. Impedance

9.7.4.3.1. Unless specified otherwise in the accompanying data sheets, the transformer shall be designed with standard base impedance as specified by ANSI C57.12.

9.7.4.4. Limitation of Transformer Capacity

9.7.4.4.1. Nothing in this specification shall be construed as permitting any component (main or auxiliary) of the transformer and associated equipment to limit the use and rating of the transformer to values below those permitted by ANSI/IEEE/CSA standards. For example, bushings, C.T.'s (including secondary windings, etc.), shall not limit the overloading capability of the transformer and shall permit safe overload operation of the transformer per ANSI C57.92 and IEEE C57.115.

9.7.4.5. Instrument Transformers

9.7.4.5.1. Bushing CTs shall be provided per the data sheet.

9.7.4.5.2. The CT secondary resistance shall not exceed 0.0025 Ohms per turn.

9.7.4.6. Surge Arresters

9.7.4.6.1. The transformer shall be equipped with station class surge arresters for all windings which have bushings brought out. These arresters shall be provided with brackets for mounting directly to the transformer tank.

9.7.4.6.2. The arresters shall be selected by the transformer manufacturer such that they are suitable for both the system TOV and each winding BIL (lowest BIL if the winding has graded insulation).

9.7.4.6.3. The Bidder shall furnish the maximum MCOV that can provide an 80% protective margin for the lowest BIL of each winding and shall furnish calculations establishing the adequacy of the MCOV and Discharge Voltage chosen by the Bidder.

9.7.4.6.4. Each arrester shall be supplied with a terminal cap to accommodate a standard NEMA four-hole terminal conductor.

9.7.4.7. Bushings

9.7.4.7.1. All bushings with rated voltage less than or equal to 35kV shall be ANSI 70 porcelain and shall be suitable for hot collar testing.

9.7.4.7.2. All bushings of rated voltage greater than 35kV shall be ANSI 70 porcelain, oil filled, draw lead condenser type bushings with a capacitance tap and weather tight plugs to cover the probe test connection point when not in use.

9.7.4.7.3. Bushings shall have bronze threaded studs. Stud connectors shall be furnished by Contractor.

9.7.5. Grounding

9.7.5.1. Provisions shall be made for the neutral ground lead (grounded-wye applications) and for the surge arrester ground lead consisting of brackets, welded to the transformer, at no more than 3'-0" spacing, beginning at a point 1'-0" above the transformer base and ending at a point 1'-0" below the transformer cover. Brackets shall have (1) 9/16" diameter hole for termination of grounding equipment. The holes shall be aligned vertically.

9.7.5.2. Stainless steel grounding pads shall be provided on all 4 corners of the tank.

9.7.6. Control Cabinet and Control Wiring

9.7.6.1. The transformer shall be equipped with a NEMA 4 control cabinet. All customer connections to transformer control and auxiliary power devices shall be via molded terminal blocks (GE EB-25 or equal) in the control cabinet.

9.7.6.2. All Owner connections to current transformers shall be via shorting type molded terminal blocks (GE EB-27 or equal) in the control box. The control cabinet shall be equipped with thermostatically controlled heaters to prevent condensation from accumulating inside.

9.7.6.3. Terminal blocks for control wiring, where applicable, shall be 12-point, 600-volt, 30 amperes equipped with strap screw contacts and a white marking strip. All conductors shall have a permanently affixed identification band on each end that clearly identifies the conductor with its representation on the associated schematic and wiring diagrams.

9.7.6.4. A door operated light shall be provided.

9.7.6.5. The control cabinet shall have hinged doors with three-point latching system and mechanical stops to allow doors to remain open when necessary and mounted with anti-vibration pads. All external circuits shall enter the bottom of the cabinet through conduit. The cabinet shall be provided with a gasketed removable blank bottom plate that can be drilled or punched in the field for entry of the conduits.

9.7.6.6. The Control Cabinet shall be provided ground bus and grounded via minimum 4/0 copper conductor to tank grounding pad. All hinged doors and panels shall be electrically bonded to the cabinet using flexible braided conductors.

9.7.6.7. All openings shall be equipped with fine mesh filters and stainless steel rodent/insect screens.

9.7.6.8. A storage holder for the transformer drawings shall be provided on the inside of the cabinet door.

9.7.6.9. One (1) 120V AC, 20 ampere, GFI single phase duplex receptacle shall be provided. An additional 120V AC, duplex receptacle shall also be provided.

9.7.6.10. The control circuit contacts and associated equipment that are meant/specified for use in

9.7.6.11. DC circuits shall be suitable for operation at 125 Volts DC.

9.7.6.12. Galvanized rigid metal conduit or galvanized intermediate metal conduit shall be used for all control and other low voltage wiring whenever such wiring is located outside of cabinets. Cable having all heat and light stabilized materials, moisture and heat resistant or wires installed in liquid tight conduit will be permitted between the raceway and a device. All control wiring inside the control cabinet/s shall be installed inside plastic wire way with removable cover.

9.7.6.13. All control wiring shall be minimum 12 AWG except for C.T. circuits which shall be 10 AWG Wire shall be stranded copper with synthetic insulation, rated at 600 volt and 1050 C minimum. No more than two wires shall be terminated at any one terminal point. Insulation compound shall be flame retardant, oil and moisture retardant, having physical and electric properties appropriate for the application.

9.7.6.14. Control and power wiring shall be terminated with heavy duty crimp type ring tongue terminals with an insulating sleeve.

9.7.6.15. All electrical devices, including fans, control relays, alarm/trip contacts, current transformer secondary, etc., which mount on or in the transformer shall be factory-wired complete to and within the below named devices and terminals so that the only field connections necessary for operation shall be the main auxiliary power supply conductors for the fans and auxiliary equipment and the attachment of incoming control conductors and C.T. leads to the terminals. There shall be adequate room inside the control cabinet for connection of all interconnecting wiring without crowding. The Bidder shall provide all wiring necessary for all equipment specified and wiring for future equipment where such wiring is specified.

9.7.7. Cooling System

9.7.7.1. The transformer shall be equipped with a forced air cooling system consistent with the data sheet. The system shall consist of 2 sets of fans, the first of which shall increase the transformer's output rating to 133% of self-cooled, the second of which shall increase the transformer's output rating to 167% of self-cooled.

9.7.7.2. The cooling groups shall be connected to operate as independent groups through a manually operated selector switch that changes the order in which the groups are energized so operating time can be equalized by periodic operation of the switch. Valves shall be provided for each cooling group's radiators so each may be removed for maintenance without de-energizing the transformer.

9.7.7.3. Tank and radiators shall be designed for full vacuum.

9.7.7.4. Cooling fan motors shall be rated for the voltage indicated in the accompanying data sheet and shall be rated for 60 Hz and Class F insulated with Class B temperature rise.

9.7.7.5. Fan Blades shall be one piece and cast of an alloy that requires no painting. Fans shall have "OSHA fan Guards".

9.7.8. Protection and Monitoring Devices

9.7.8.1. Sudden pressure rise device (63SPR) with seal-in relay (63SPR-X) having 2 alarm and 2 trip contacts

9.7.8.2. Winding temperature thermometer (49T) with alarm and trip contacts. Hottest spot winding temperature detector/indicator shall be furnished with separate relay/s for each stage of forced cooling. The relay/s shall control the fans. The winding temperature detection system shall consist of a low voltage current transformer, shunt, heating coil and detector bulb. Construction shall be per ANSI C57.12.10.

9.7.8.3. Oil temperature thermometer (26Q) with alarm and trip contacts

9.7.8.4. Oil level device (71Q) with alarm and trip contacts

9.7.8.5. Tank pressure relief device (63PR) with alarm contacts

9.7.8.6. Tank oil preservation system high / low pressure device (63VP) with high and low pressure alarm contacts

9.7.8.7. Fan power under voltage relays with alarm contacts

9.7.8.8. All gauges shall be visible and readable completely from the ground. All gauges with re- settable pointers shall be mounted 5'+/-6" above the transformer base to permit resetting from the ground. Level gauges shall provide a visual indication of liquid level and shall have two sets of electrical contacts, one of which shall close at high level and one shall close at low level. Construction and installation shall conform to ANSI C57.12. Pressure – vacuum gauges shall include a pressure test connection (air test valve).

9.7.8.9. Buchholz relays with alarm and trip contacts shall be provided (minimum 2 of each).

9.7.9. Welding

9.7.9.1. Welding procedures and welders shall be qualified in accordance with ASME Section IX and AWS D1.1 certification for structural (non-pressure) boundary welds. Contractor shall prepare and maintain on file at the manufactures plant the following documents for Owner review:

9.7.9.1.1. Welding and Repair Procedure

9.7.9.1.2. Cleaning and Painting Procedure

9.7.9.1.3. Shipping Preparations and Shipping Procedure

9.7.10. Accessories

9.7.10.1. Lifting lugs and jacking pads sized for the full-assembled weight of the transformer filled with oil

9.7.10.2. Detachable radiators with sealing valves on the main tank

9.7.10.3. Mounting brackets for HV and LV surge arresters

9.7.10.4. Drain / sampling valve

9.7.10.5. Stainless steel nameplates per IEEE C57.12.00

9.7.11. Color

0.1.2.4 The transformer shall be painted ANSI 61 or 70 gray.

9.7.12. Shipping

9.7.12.1. The transformer shall be shipped FOB job site.

9.7.12.2. The transformer shall be free of rust, scale, manufacturing residue and foreign material to the extent that it can be put into operation without further cleaning.

9.7.12.3. The transformer shall be shipped without oil and with radiators and bushings removed.

9.7.12.4. Openings shall be securely sealed against the entrance of moisture and foreign material. The Contractor shall furnish the oil in a tanker truck at the job site.

9.7.12.5. If the transformer is to be shipped without oil, it shall be filled with dry air. The dew point shall be measured and recorded prior to shipment.

9.7.12.6. Machine-finished or bright surfaces shall be coated with a suitable corrosion-preventative compound and suitably wrapped or otherwise protected against shipping damage.

9.7.12.7. Contractor shall pay attention to the proper packaging and bracing of the equipment to ensure its safe arrival at the job site. Precautions required for handling and storing the equipment shall be clearly indicated on the outside of the containers.

9.7.12.8. Contractor shall be responsible for equipment damage due to improper preparation for shipment and shall repair or replace such damaged equipment expeditiously at their expense.

9.7.12.9. The transformer shall be properly prepared for shipment and shall be fitted with an impact recorder capable of recording X, Y and Z axes.

9.7.13. Optional Prices

9.7.13.1. The supplier shall quote optional prices for the following:

9.7.13.2. Unload the unit onto the Owner provided pad

9.7.13.3. Assembly, oil fill, and test the unit

9.7.14. Factory Testing and Inspection

9.7.14.1. Each unit provide per this specification shall have all factory tests designated as "Routine" in Table 17 of ANSI / IEEE C57.12.00. Certified reports of these tests shall be provided to the Owner immediately upon completion of factory testing, to be no later than the shipping date of the transformer. In addition, the Contractor shall be prepared to produce upon request certified reports of any tests identified by Table 17 of ANSI / IEEE C57.12.00 as design tests or type tests.

9.7.14.2. The Owner reserves the right to inspect the unit at the factory and witness all factory testing at no additional cost other than the travel and local room / board expenses for the Owner's designated representative(s). The Contractor must notify the Owner at least 3 weeks prior to the commencement factory testing and within 1 week, the Owner shall confirm that they will either witness the testing or waive the requirement for inspection / witness test.

9.7.14.3. The Owner reserves the right to perform tests at his own expense to prove compliance with this Specification. If, during a test performed by the Owner, the equipment fails as a result of design or fabrication error, or for any other cause which is the responsibility of the Contractor, the Contractor shall determine the cause of failure and resubmit acceptable proof of performance. The Contractor shall be charged for all subsequent modifications and tests made for acceptance of the equipment.

9.7.15. Loss Evaluation

9.7.15.1. If called for on the data sheets accompanying this specification, the supplier shall provide guaranteed loss values at no-load and load levels as defined by ANSI C57.120 with their proposal. The evaluation factors are defined on the data sheets accompanying this specification.

9.7.15.2. If a loss evaluation is called for, the evaluation shall be performed by the Owner. During factory testing, the transformer losses will be measured per ANSI / IEEE standards; if the losses exceed the guaranteed values then a loss payment shall be calculated using the evaluation factors listed on the data sheets. The loss payment shall be reduced from the amount of the payment from the Owner to the Contractor for the transformer.

9.7.16. Warranty

9.7.16.1. Transformer performance guarantees shall be provided on the following:

9.7.16.2. No Load losses (nominal tap)

9.7.16.3. Full load losses (nominal tap)

9.7.16.4. No PCB (Polychlorinated Biphenyl) content of insulating liquid (to be clearly stated on name plate).

9.7.16.5. The Contractor shall warrant the transformer specified herein to be free from defects in design, materials, and workmanship. The warranty shall cover all expenses to repair or replace all defective portions of the transformer as well as any other components of the transformer that are damaged by failures caused by defective portions of the transformer.

9.7.16.6. In the event that the transformer must be removed from the project site for repairs, then Contractor shall be responsible for all costs to remove the transformer from the site, transport it to the repair facility. After repairs, the Contractor shall, at its own expense, return the transformer to the job site, and reinstall it in its operating position. In no event shall the warranty for the transformer specified herein be for a period of less than 12 months after energization or 18 months after shipment, whichever is shorter. If the Contractor's standard warranty is less than 5 years, the Contractor shall quote an option to extend the warranty to 5 years.

9.7.17. Drawings and Manuals

9.7.17.1. The Contractor shall supply drawings to the Owner in electronic format for approval.

9.7.17.2. Approval drawings may be provided either in AutoCAD dwg format or Adobe PDF format.

9.7.17.3. Each document shall identify, near the title block, Owner's specification number, project name, and applicable equipment tag number.

9.7.17.4. At least 4 weeks prior to shipment of the transformer, the Contractor shall provide certified drawings to the Owner in AutoCAD dwg format. At least one complete paper copy of all certified drawings shall be shipped with each transformer.

9.7.17.5. The Contractor shall supply 6 copies of complete operating and maintenance manuals that are specific to the unit being supplied. If the Contractor must supply generic sections of the manual, irrelevant sections of the manual shall be clearly identified as such.

9.7.17.6. All drawings and Manuals shall pertain specifically to the transformer being supplied and shall be in English.

9.7.17.7. Dimensions shown on all drawings and documents shall be in Imperial Units.

9.7.17.8. Outline drawings shall indicate the center of gravity and structural loading requirements.

9.7.18. Quality Control

9.7.18.1. The Contractor shall provide project specific quality control plan to control the quality of the items and services to meet the requirements of the specification, referenced codes and standards and other contract documents. Contractor- furnished materials, parts, components, services and associated documentation are subject to review by the Owner. Contractor shall perform quality control and inspection during assembly.

10. Data Sheet

Project			**Date**	
Transformer #	T1			
Main Transformer Ratings				
Transformer Continuous MVA (ONAN/ONAF/ONAF)	XXX/XXX/XXX/		2-Winding or 3-Winding Transformer	2
Transformer Rated Rise Temp (Degrees C)	65 ℃		Nominal H-X Imdedance - % on ONAN Basis	8.5% (typical)
Windings and Bushings				
HV Winding Connection (Delta or Grounded Wye)	As per single-line diagram		HV Winding Nominal Voltage (kV)	As per single-line diagram
HV Winding BIL (kV)	As per single-line diagram		HV Bushing Type	Oil-filled w/ Capacitance
HV Bushing	Cover			
XV Continuous MVA (OA/FA/FA/)	Same as Overall Transformer Rating		XV Winding Connection (Delta or Grounded Wye)	As per single-line diagram
XV Winding Nominal Voltage (kV)	As per single-line diagram		XV Winding BIL (kV)	As per single-line diagram
XV Bushing Type	Bulk Porcelain		XV Bushing BIL (kV)	As per single-line diagram
Creepage Distance (Std or Extended)	Standard		If Extended Creepage, Specify Distance	N/A
TV Windings Required	Yes		TV Winding Function	
TV Winding Rated MVA (ONAN/ONAF/ONAF)	35% of Transformer ONAN Rating		TV Winding Nominal Voltage (kV)	13.8
TV Winding Configuration	Delta		TV Winding BIL (kV)	110
TV Winding Broken Delta with 2 – Bushings Brought Out and Link Bar to Complete Delta Across Bushings?	N/A		TV Winding Embedded?	N/A
Bushing Current Transformers				
HV Bushings CTs / Phase	As per single-line diagram		XV Bushings CTs / Phase	As per single-line diagram
HV Bushing CTs	As per single-line diagram		SV Bushing CTs – Top	As per single-line diagram
HVN Bushing CT Qty	As per single-line diagram		XVN Bushing CT Qty	As per single-line diagram
HVN Bushing CT	As per single-line diagram		XVN Bushing CT	As per single-line diagram
TV Bushings required	0		TV Bushing Type / Rating	N/A
TV Bushing CTs				
Tap Changing Equipment				
Automatic LTC Required	Y		LTC Location	Control Board
LTC Range	As per LTC manufacturer		LTC # of Steps	As per LTC manufacturer
LTC Control			LTC Remote Position Indication	Y
DETC Required	Y		DETC Location	HV
DETC Taps Above Normal	2 x 2.5% FCAN		DETC Taps Below Normal	2 x 2.5% FCBN
Surge Arresters				

HV SA Type	Gapless Station Class		HV SA MCOV Rating	As per single-line diagram
XV SA Type	Gapless Station Class		XV SA MCOV Rating	As per single-line diagram
Loss Evaluation Factors – All Loss Evaluations to be Performed per the Methodology of the Latest Version of ANSI C57.120.				
Loss Evaluation Required	Y		No-Load Loss ($ / kW)	
			Full Load-Loss ($ / kW)	
Additional Requirements				

11. High Voltage SF6-Insulated Circuit Breaker procurement Specification

11.1. General

11.1.1. Summary

11.1.1.1. Section includes high voltage outdoor, dead tank, low pressure SF6-insulated circuit breaker and associated equipment in freestanding cubicle.

11.1.2. References

11.1.2.1. All work shall be in accordance with all applicable codes and standards to include, but not limited to, the following:

11.1.2.2. NEC – National Electrical Code

11.1.2.3. OSHA – Occupational Safety and Health Act

11.1.2.4. UL – Underwriters Laboratories

11.1.2.5. ANSI – American National Standards Institute

11.1.2.6. NEMA – National Electric Manufacturers Association

11.1.2.7. NETA – International Electrical Testing Association

11.1.2.8. IEC – International Electro technical Commission

11.1.2.9. IEEE – Institute of Electrical and Electronic Engineers

11.1.3. Submittals

11.1.3.1. Shop Drawings: Indicate outline dimensions, enclosure construction, lifting and supporting points, anchor bolt hole locations and recommended minimum bolt size, ground lug location, weight center of gravity, shipping weights, electrical rating, schematic and point to point wiring diagrams. Diagrams and breaker drawings shall be provided in AUTOCAD format in addition to the hard copies.

11.1.3.2. Project Record Documents: submit data for components and accessories.

11.1.3.3. Test Reports: Indicate procedures and results for specified factory and field testing and inspection.

11.1.3.4. Installation Instructions: Submit manufacturer's installation

11.1.4. Closeout Submittals

11.1.4.1. Project Record Documents: Include copy of manufacturer's certified drawings.

11.1.4.2. Factory Test Reports: Manufacturer shall submit certified test reports of production tests as soon as the tests are completed satisfactorily. The following factory tests shall be made on the circuit breaker:

11.1.4.2.1. Tests in accordance with ANSI C37.09, including a 60 Hz AC HIPOT completely assembled 3-pole breaker.

11.1.4.2.2. A complete wiring and control circuit tests and checks with complete verification of all circuits.

11.1.4.3. Operation and Maintenance Data: Submit operating instructions for manually and electrically opening and closing switches, and include instructions for contact replacements, switch adjustment, and lubrication.

11.1.4.4. Spare Parts: Provide spare parts list, including parts location and diagram or drawing.

11.1.5. Qualifications

11.1.5.1. Manufacturer specializing in manufacturing products specified in this section with a minimum of three years of experience.

11.1.5.2. Testing agency specializing in testing products specified in this section with a minimum of three years of experience.

11.1.6. Delivery, Storage and Handling

11.1.6.1. Manufacturer shall be solely responsible for the adequacy of the preparation for shipment of materials.

11.1.6.2. The breaker shall be shipped fully assembled except extension legs. The breaker shall have at least 5 psig SF6 gas during shipment. Owner does not have to evacuate at site during commissioning of the breaker. The Contractor shall supply SF6 gas to top it off at site.

11.1.6.3. Accept circuit breaker on site. Inspect for damage.

11.1.6.4. Lift only using lugs provided. Handle carefully to avoid damage to internal components, enclosure and finish.

11.1.6.5. Protect products from weather and moisture by covering with plastic or canvas and by maintaining heating within enclosure.

11.1.6.6. The breaker shall be delivered with the bushing terminals protected with conducting grease. Sun resistant plastic material shall be installed on factory to protect the terminals and the bushing (down to CT's) for prolonged outdoor storage.

11.1.6.7. On site Owner training shall be provided on the purchase order.

11.1.7. Maintenance Materials

11.1.7.1. Furnish a complete set of special maintenance tools, spare parts and accessories as required, including but not limited to the following:

11.1.7.1.1. SF6 Gas Bottle fully charged.

11.1.7.1.2. SF6 Gas Leakage Detector.

11.1.7.1.3. SF6 Gas Filling Device (complete with vacuum pump, if required).

11.1.7.1.4. Moisture Detector.

11.1.7.1.5. High Voltage and current Test adapter.

11.1.7.1.6. Two (2) Sets of Gaskets.

11.1.7.1.7. One (1) Spare Bushing.

11.1.7.2. The tools shall be new and engraved with the purchase order number and equipment number when unique only to one component.

11.1.8. Testing

11.1.8.1. The Contractor shall submit factory performed time travel test and graphic records for individual breakers. The manufacturer shall also provide the expected values, maximum and minimum limits, acceptable for the following tests:

11.1.8.1.1. Main contact opening time measured from test initiation.

11.1.8.1.2. Delta main contact opening time within the breaker (open- contact synchronization).

11.1.8.1.3. Open and close over-travel.

11.1.8.1.4. Open and close rebound.

11.1.8.1.5. Main contact closing time measured from test initiation (contact make).

11.1.8.1.6. Delta main contact closing time within the breaker (close-contact synchronization).

11.1.8.1.7. Contact wipe.

11.1.8.1.8. Total travel (stroke).

11.1.8.1.9. Open and close velocity.

11.1.8.1.10. Reference points for Zone 1 velocity.

11.1.8.1.11. 1 Reference points for Zone 2, if available.

11.1.8.1.12. 1 Trip free dwell time within a phase.

11.1.8.1.13. 1 Trip free dwell time within the breaker.

11.1.8.1.14. 1 Trip free main contact opening time measured from test initiation.

11.1.8.1.15. 1 Reclose dead time within a phase.

11.1.8.1.16. 1 Reclose dead time within the breaker.

11.1.8.1.17. 1 Main contact reclosing time measured from test initiation.

11.1.8.1.18. 1 Delta main contact reclosing time within the breaker.

11.1.8.1.19. 1 Open current.

11.1.8.1.20. 20 Close current.

11.1.9. Warranty

11.1.9.1. Provide manufacturer’s standard warranty and indicate duration of this warranty.

11.2. Products

11.2.1. General

11.2.1.1. Product Description: Sulphur hexafluoride (SF6) gas-insulated circuit breaker and associated equipment for outdoor installation. The circuit breaker shall be completely factory assembled.

11.2.1.2. Except as otherwise stated herein, all equipment noted in this Section shall comply with the latest applicable codes and standards of the International Electrotechnical Commission (IEC) and ANSI standards as far as applicable. As a minimum the following individual Codes and Standards shall apply:

a. IEC 56-4 – High Voltage Alternating Current Circuit Breakers.

b. IEC 129 – Alternating Current Disconnectors and Earthing Switches.

11.2.1.3. Manufacturers: ABB, SIEMENS, AEG, or equivalent approved by Owner

11.2.1.4. The circuit breaker shall be constructed for the outdoor site conditions where it will be installed. Breakers supporting frames, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures.

11.2.1.5. Submit all components and anchorage design and drawings for approval.

11.2.2. Ratings

11.2.2.1. The Circuit Breaker and associated equipment shall comply with the following requirements or ratings:

11.2.2.1.1. Operating Voltage (RMS KV): as indicated on single line KV

11.2.2.1.2. Rated frequency: 60 Hz

11.2.2.1.3. Current Rating: as indicated on single line.

11.2.2.1.4. Continuous: As indicated on single line.

11.2.2.1.5. Minimum Symmetrical Interrupting Capacity: As indicated on single line.

11.2.2.1.6. Close and Latching Capability: As suggested by manufacturer.

11.2.2.1.7. Insulation Level: as indicated on single line.

11.2.2.1.8. Bushings Basic Impulse Level: as indicated on ingle line.

11.2.2.1.9. Low Frequency Withstand: as indicated on BIL tables.

11.2.2.1.10. Rated Full Wave Impulse Withstand Peak Voltage: as indicated on BIL Tables.

11.2.2.1.11. Operating Voltages: as indicated on single line.

11.2.2.1.12. Closing: 125 Vdc.

11.2.2.1.13. Tripping: 125 Vdc.

11.2.2.1.14. Auxiliary Power Voltage: 120/240 Vac, 1ø, 60 Hz.

11.2.2.1.15. Rated Voltage Range Factor (K): 1

11.2.2.1.16. Rated Permissible Tripping Delay Time (seconds): 1

11.2.2.1.17. Minimum Creepage Distance of Bushings (inches): Required as per maximum operating voltage.

11.2.2.1.18. Ambient Temperature: as indicated by the site environmental conditions.

11.2.3. Circuit Breaker Control

11.2.3.1. Trip Circuit Requirements:

11.2.3.1.1. The breaker shall be furnished with two trip coils.

11.2.3.1.2. Fused disconnect switches or molded case circuit breakers shall be provided for the trip circuits.

11.2.3.1.3. Trip circuit operating voltage shall be 125 Vdc. Trip circuits shall operate properly within a range of 70 to 140 Vdc as measured at the circuit breaker.

11.2.3.2. Closing Circuit Requirements:

11.2.3.2.1. A fused disconnect switch or molded case circuit breaker shall be provided for the closing circuit.

11.2.3.2.2. Closing circuit operating voltage shall be 125 Vdc. Closing circuit shall operate properly within a range of 90 to 140 Vdc as measured at the circuit breaker.

11.2.3.3. Breaker Wiring:

11.2.3.3.1. All control devices and alarms shall be connected to terminal blocks located in the breaker control cabinet.

11.2.3.3.2. Current transformer leads shall be connected to short circuiting type terminal blocks located in the breaker control cabinet. The short-circuiting strips of these blocks shall be grounded. All current transformer leads shall be #12 AWG.

11.2.3.3.3. All terminal blocks shall have a screw and all wiring terminations shall be made using ring tongue connectors.

11.2.3.3.4. All terminal blocks shall be adequate to receive #10 AWG wire control cable terminals.

11.2.3.3.5. All control wiring shall be #14 AWG minimum type SIS.

11.2.3.3.6. Legible sleeve type wire markers shall be provided at each end of wires over six inches in length.

11.2.3.4. Auxiliary Switches:

11.2.3.4.1. Provide multi-contact auxiliary switches.

11.2.3.4.2. Ten (10) contacts type A and ten (10) contacts type B shall be provided in addition to those normally provided for the circuit breaker operation. Type A means normally open, Type B means normally closed.

11.2.3.5. Trip and Close Devices:

11.2.3.5.1. A local trip and close station shall be provided in the breaker control cabinet. The trip button shall include provisions at a terminal block for connections to block the automatic reclosing sequence.

11.2.3.5.2. The breaker shall be equipped with a position indicator in the cabinet which is visible from the outside of the breaker. Indications of OPEN/CLOSE shall be green-open and red-closed.

11.2.3.5.3. The breaker shall have a mechanical operation counter which is visible from the outside of the cabinet.

11.2.3.5.4. A manual trip device shall be furnished, accessible from the control cabinet. Also, an auxiliary electrical contact shall be included in the close circuit to prevent closing until manually reset. The manual trip device shall not require an external power source to trip the circuit breaker. The trip device shall trip all three poles simultaneously.

11.2.3.5.5. The circuit breaker’s trip-1, trip-2 and close control schemes shall have provisions to be wired by the Owner from separate DC circuits from the Owner’s source. No fuse or MCB’s are required to protect control schemes inside control cabinet. Provisions for key interlock system shall be provided.

11.2.3.6. Control Cabinet:

11.2.3.6.1. The breaker control cabinet shall be outdoor weatherproof design, 316 stainless steel gauge 14 NEMA 4X including hinged doors for full opening with provisions for holding doors for full opening in the open position and a handle with three-point latch and padlocking provisions for holding doors in closed position.

11.2.3.6.2. All breaker controls, terminal blocks, etc. shall be consolidated in the control cabinet, including current transformer secondary.

11.2.3.6.3. The Owner shall furnish a 60 Hz, 120 Vac, single phase power supply to the breaker. The Manufacturer shall furnish appropriate terminals in the control cabinet for terminating the Owner's single-phase service and fused disconnect switches or circuit breakers for the control circuit.

11.2.3.6.4. The control cabinet shall be furnished with suitable strip heaters, with thermostat, to prevent condensation.

11.2.3.6.5. The control cabinet shall be equipped with a weather proof, separately fused, 15 A 125 V, 2 poles, 3 wires polarized, grounded, duplex GFCI outlet, connected to the 120 VAC power supply. The outlet shall be mounted on a convenient location on the control cabinet housing and shall be accessible from the outside without opening the cabinet. A lighting fixture suitable for the connection of an incandescent lamp of not less than 60 Watts, connected to the 120 VAC power supply, shall be provided inside the control cabinet.

11.2.3.6.6. The control cabinet shall be in an accessible location mounted at a convenient operating height.

11.2.3.6.7. All wiring and connections within the control cabinet shall be readily accessible for maintenance.

11.2.3.6.8. The control cabinet shall have a removable steel plate for entrance of up to eight conduits of 2" Ø, through which the power and control cables will enter by separate conduits.

11.2.3.6.9. Control cabinet shall be furnished with a keyless lock suitable for ½" Ø padlock shackle.

11.2.3.6.10. Any access inside of the control cabinet shall be by means of hinged doors.

11.2.3.6.11. Control cabinet doors shall have windows to see breaker position indication (open/close) and the SF6 gas pressure gauge.

11.2.3.6.12. A Ground Bus for the individual connection of the neutral secondary wires from the CT's shall be supplied on a convenient and accessible location at the bottom of the control cabinet with provision to be connected to the substation – ground mat.

11.2.3.7. Interrupters

11.2.3.7.1. The interrupters shall be single break and single pressure units. The interrupter contacts shall be made of a material highly resistant to burning, pitting, and blistering caused by material electric arcs. The motion and travel of these contacts shall be adjustable. The contacts shall be easily replaceable. The circuit breaker shall be able to perform at least twenty full rated fault interruptions without requiring maintenance.

11.2.4. Current Transformers

11.2.4.1. The circuit breaker shall have a quantity of twelve (12) multi- ratio, bushing type current transformers, 2 per bushing. The bushing current transformers shall conform to the following requirements:

11.2.4.1.1. Bushing current transformers shall conform to ANSI Standard C.57.13 1978 or latest revision thereof. The accuracy shall be C400. Ratio shall be as indicated on single lines.

11.2.4.1.2. Continuous Thermal Current Rating Factor (R.F.): 2.0.

11.2.4.1.3. Insulation test: At least 100 MEGA OHMS.

11.2.4.2. All of the CT taps shall be provided wired to individual shorting type terminal blocks Marathon Series 1500. These terminal blocks shall be supplied on a convenient, visible and easily accessible location inside the control cabinet. Also, the CT taps and ratios shall be clearly described on its nameplate.

11.2.4.3. In addition, three (one per load side bushing) fixed or multi ratio metering grade or C400 accuracy class CT'S shall be provided capable to handle a burden of 0.1 ohms.

11.2.5. Operating Mechanism

11.2.5.1. The circuit breaker operating mechanism shall be mechanically and electrically trip free, and shall be spring drive type. The spring drive mechanism shall be capable of storing enough energy to complete an open-close-open cycle when the AC power is lost. The mechanism shall have provisions to be manually charged with a hand crank. The mechanism shall have the necessary dry contacts for a spring charge alarm. This alarm shall have a time delay permitting the mechanism charge the spring.

11.2.5.2. The operating mechanism shall be charged by means of a universal motor, with an AC/DC nominal voltage of 120 VAC/115 VD. Also, the mechanism can be charged manually.

11.2.5.3. The operating mechanism shall provide blocking of TRIP and CLOSE operations when the SF6 gas pressure is too low to perform a proper operation. A low-pressure contact alarm shall be provided prior to this blocking function.

11.2.5.4. The operating mechanism shall have provisions for the connection of a motion transducer for timing test equipment, compatible either with DOBLE equipment.

11.2.5.5. Hydraulic shock absorbers in the mechanism shall dampen the closing and opening operations, protecting the mechanism from undue mechanical stress.

11.2.6. Bushings

11.2.6.1. Bushings shall be hollow, one-piece porcelain, BIL as indicated on single line, filled with SF6 gas common to the breaker tanks. The materials shall be homogeneous free from laminations, cavities or other flaws affecting its mechanical strength or dielectric quality.

11.2.6.2. Bushings shall be ANSI 70 Light Gray in color.

11.2.6.3. Terminals shall be 2" Ø IPS to NEMA pad flexible.

11.2.6.4. Each bushing shall be designed to withstand all the mechanical stresses resulting from the circuit breaker operation and shall be designed for easy replacement in the field.

11.2.6.5. Bushing shall be in accordance with the applicable ANSI Standards C37.010-1999.

11.2.7. Circuit Breaker Tank and Piping

11.2.7.1. Interrupter tank shall be steel construction.

11.2.7.2. All pressure switches, valves, relays, etc. shall be readily accessible and located in suitable, outdoor, weather tight enclosures.

11.2.7.3. All gas piping, fittings, gauges, and other connections shall be made leak tight. Valves used in gas systems shall have seats designed to insure a leak tight breaker with low maintenance requirements.

11.2.7.4. Breaker tanks containing SF6 gas pressure shall be designed, built, and tested to meet applicable standards.

11.2.8. Frame and Painting

11.2.8.1. The circuit breaker shall have all three poles mounted on a Hot-Dip Galvanized Steel frame with legs which bolt directly to the foundation.

11.2.8.2. Two NEMA 2-hole drilled and tapped copper or stainless steel ground pads shall be provided, one each on opposite sides and ends of breaker.

11.2.8.3. The circuit breaker shall be painted with ANSI 70 light gray color. All exposed bolts, washers and nuts shall be stainless steel or must be steel coated.

11.2.9. SF6 Gas

11.2.9.1. The SF6 gas used in the circuit breaker shall comply with the ASTM standard

11.2.9.2. Submit the Material Safety Data Sheet of the gas.

11.2.9.3. One (1) bottle of gas per circuit breaker shall be provided to fill the unit for a proper operation.

11.2.9.4. The maximum allowable gas leakage rate shall be less than 1% per year, guaranteed for ten years.

11.2.9.5. The circuit breaker shall be equipped with pressure relays with adjustable set points to actuate alarms for SF6 gas when pressure is lower than normal, and to prevent operation when pressure reaches a value below acceptable limits. Pressure switch shall be temperature compensated.

11.2.10. Nameplate

11.2.10.1. Provide a breaker nameplate mounted inside the breaker control cabinet with the following data:

11.2.10.1.1. Manufacturer’s name and address.

11.2.10.1.2. Breaker Type and model number.

11.2.10.1.3. Breaker serial number.

11.2.10.1.4. Rated nominal and maximum voltages.

11.2.10.1.5. Rated voltage factor K.

11.2.10.1.6. Rated continuous current.

11.2.10.1.7. Rated symmetrical interrupting capacity at maximum rated

11.2.10.1.8. Voltage.

11.2.10.1.9. Rated frequency.

11.2.10.1.10. Rated BI

11.2.10.1.11. Quantity of insulating medium.

11.2.10.1.12. Operating ranges of control circuit voltages.

11.2.10.1.13. Date of manufacture.

11.2.10.2. Provide a current transformer nameplate with the following data:

11.2.10.2.1. CT ratios.

11.2.10.2.2. CT connection.

11.2.10.2.3. Drawing number of saturation and phase angle, and ration correction factor curves if metering accuracy.

11.3. Protection and Control Prefabricated/Prewired Building

11.3.1. General

11.3.1.1. Summary

a. Section includes a protection and control prefabricated / prewired building for the associated high and medium voltage circuit breakers and related substation components as shown on drawings.

11.3.1.2. References

a. All work shall be in accordance with all applicable codes and standards to include, but not limited to, the following:

- NEC – National Electrical Code
- OSHA – Occupational Safety and Health Act
- UL – Underwriters Laboratories
- ANSI – American National Standards Institute
- NEMA – National Electric Manufacturers Association
- NETA – International Electrical Testing Association
- IEEE – Institute of Electrical and Electronic Engineers

11.3.1.3. Submittals

11.3.1.3.1. Shop Drawings: Indicate outline dimensions, enclosure construction, foundation bolt holes, support weight, mounting details, available conduit space, clearance for accessibility, cable terminated space, shipping splits, lifting and supporting points, electrical single and three line diagrams, AC and DC systems schematic diagrams and equipment electrical ratings.

11.3.1.3.2. Seismic Design Structural Calculations: Submit structural calculations signed and sealed by a Professional Engineer.

11.3.1.3.3. Project Record Documents: submit data for components and accessories.

11.3.1.3.4. Test Reports: Indicate procedures and results for specified factory and field testing and inspection.

11.3.1.3.5. Installation Instructions: Submit manufacturer’s installation instructions covering all equipment.

11.3.1.4. Closeout Submittals

11.3.1.4.1. Project Record Documents: Include copy of manufacturer’s certified drawings.

11.3.1.4.2. Operation and Maintenance Data: Submit operating instructions for the prefabricated building components as follows but not limited to:

- Protection relays and control cabinets
- Batteries and battery chargers
- Remote Terminal Unit (RTU)
- Dynamic System Monitor, if requested by owner.
- HVAC units
- Lighting fixtures
- Communication rack (Equipment to be provided by PREPA)

11.3.1.4.3. Spare Parts: Provide spare parts list, including parts location and diagram or drawing.

11.3.1.5. Qualifications

11.3.1.5.1. Manufacturer specializing in manufacturing products specified in this section with a minimum of 10 years of experience.

11.3.1.5.2. Testing Agency specializing in testing products specified in this section with a minimum of three years of experience.

11.3.1.6. Delivery, Storage and Handling

11.3.1.6.1. Deliver in the indicated maximum width, shipping splits, individually wrapped for protection and with shipping skids.

11.3.1.6.2. Accept building on site. Inspect for damage.

11.3.1.6.3. Lift only using lugs provided. Handle carefully to avoid damage to internal components, enclosure, and finish.

11.3.1.6.4. Protect products from weather and moisture by covering with plastic or canvas and by maintaining heating (when specified) within enclosure.

11.3.1.7. Field Measurements

11.3.1.7.1. Verify field measurements prior to fabrication.

11.3.1.8. Maintenance Materials

11.3.1.8.1. Furnish a complete set of special tools required for installing, operating and maintaining the equipment furnished under these specifications.

11.3.2. Products

11.3.2.1. General

11.3.2.1.1. Manufacturers: Schweitzer or other previously approved by the owner.

11.3.2.2. Building

11.3.2.2.1. Outdoor Hot-Dip Galvanized Gauge 14 Walk-in type enclosure layout as shown on drawings.

- The building shall be equipped with guarded interior lighting fixtures, duplex GFI protected receptacles. Totally prewired to the AC utilities distribution panel board. The doors shall be provided with panic latches and provisions for external padlocking. The building shall be provided with an air conditioning unit. Building ceiling and walls shall be provided with insulation to avoid water condensation.
- The building shall be constructed for the site conditions where it will be installed.
- Building Supporting Frames, their attachments and anchorages shall be designed as to withstand wind and seismic forces calculated as per minimum design loads for buildings and other structures ASCE 7.
- Submit all components and anchorage design, calculations and drawings for approval. Structural calculations and drawings shall be signed and sealed by a Professional Engineer.

11.3.2.3. Control and Protection Panel Assembly

11.3.2.3.1. General

- These specifications describe the substation protection and control system. The equipment outlined in these specifications consists of protection and control relays, Vac and Vdc distribution panels and other auxiliary equipment. The protection and control system will be sheltered in the prefabricated building.
- The design, furnish, delivery, installation, testing and commissioning of the control and protection assembly will be part of the project.
- The assembly shall conform to the latest applicable standards of ANSI, IEEE, NEMA and NEC including but not limited to:
    - ANSI C37.1 Standard Definition, Specification and Analysis of Systems Used for Specification and Analysis of Systems Used for Supervisory Control, Data Acquisition and Automatic Control
    - ANSI C37.2 Standard for Electrical Power System Device Function Numbers
    - ANSI C37.11 S t a n d a r d Requirement for Electrical Control for AC High Voltage Circuit Breakers rated on a Symmetrical Current Basis or a Total Current Basis
    - ANSI C57.13 Standard Requirements for Instrument Transformers
    - ANSI C63.2 Electromagnetic Noise and Field Strength, 10 kHz to 40 GHZ
    - ANSI Y14.15 Drafting Practices for Electrical and Electronics Diagrams
    - ANSI Y32.2 Graphic Symbols for Electrical and Electronic Diagrams.
    - ANSI C37.90 Relays and Relay Systems Electric Power

Apparatus Associated with:

- ASTM D2472 Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strips
- ISA S18.1 Annunciator Sequences and Specifications
- OSHA 29 CFR Occupational Safety and Health Standards for the Part 1926 Construction Industry

11.3.2.3.2. Relays & Control

- Protection and control equipment will be provided as shown in the enclosed Plans Drawing and One Line Diagram. The protection relays and auxiliary relays will be installed on separate cabinets in the prefabricated building. In addition, a Remote Terminal Unit (RTU) shall be supplied if specified and indicated by the owner.
- Relays shall be digital, multifunction, microprocessor-based, standard type flush or semi-flush mounted on the panels and must comply with ANSI/IEEE Standard C.37.90: Relays and Relays Systems Associated with Power Systems Apparatus. Type and settings, with test blocks and plugs, shall be as indicated:
    - Shall provide all necessary equipment for testing relays, including card extenders, software, and communications equipment. Must also provide DOBLE test plan for relay test using DOBLE relay test set and DOBLE protection software.
    - Metering shall be provided through a meter approved by the owner. Three phase metering is required. As minimum Amps, Volts, MWatts, and MVars shall be provided. These values should be shown on the relay under normal conditions. Meters shall be placed in the front panel and at an adequate height (about 66 inches).
    - A power quality meter shall also be installed. This meter shall be capable of measuring harmonics, THD, and individual harmonic contributions.
    - Relays and meters shall be capable of communicating with the RTU or SCADA RTAC Relay via fiber optic local area network IEEE 802.3 with DNP 3.0 and/or through a fiber optic DNP 3.0 network. DNP 3.0 communication can be implemented via an intermediate device capable of providing this functionality, like SEL-3354 or approved equal. All DNP 3.0 IEDs shall be certified.
    - All relays and or protection systems to be used shall be approved by the owner.
- The control voltage and power supply voltage of relays shall be 125 VDC.
- Protection system shall be as shown on the one line and schematic diagram.

11.3.2.3.3. Remote Terminal Unit (RTU)

- If requested by the owner, an RTU shall be supplied by the manufacturer. The prefabricated control building manufacturer shall leave enough room, next to the control panels, to be able to mount an RTU unit.

11.3.2.3.4. Cabinets (Protection)

- All cabinets shall be made with galvanized stretcher rolled steel gauge
  - All steel surfaces to be painted shall receive a phosphate or equivalent treatment prior to application of paint. External and internal surfaces shall be coated with at least one coat of corrosion-resisting paint. The preferred color for the interior finish shall be Light Gray No. 61 (Munsell Notation 8.3G6.10/0.54).
- Each cabinet shall be completely fabricated, wired and assembled by the supplier at his factory. Each cabinet furnished shall be fully equipped and completely wired to the terminal blocks specified herein for all control and monitoring required by the ultimate installation.
- All cabinet doors shall be hinged on the left or right side, equipped with a three-point latching system operated with a single handle. Door shall also be equipped with an automatic brace system to hold the door open at least 90 degrees from the closed position. Hinges for doors, and interior swinging panels, shall not permit sagging due to weight of the door or panel or any devices mounted thereon.
- An engraved nameplate shall be furnished for each device mounted on the cabinet including each relay, switch, breaker, indicating light, and control switch. Nameplate material shall be 3-ply plastic white surface and black core, Nameplates shall be 1/8 inch thick with 5/8 height and ¼ inch letter engraved through the top lamination to the black interior.
- Each cabinet shall be dust tight and gasket construction. Each cabinet shall be a rigid, self-supporting and self-contained welded or bolted metal enclosed steel structure.
- Each cabinet shall include heaters equipped with thermostat control and protective grills to prevent accidental contact by personnel.

11.3.2.3.5. Wiring and Control Cabinet Design

- All protection and control cabinets will be completely wired, tested, and ready for field installation. External cables for connection to breakers, transformers, etc. Control cables will enter through the top of the cabinet. The Contractor will provide the necessary cutouts and space to allow cable access, with cable glands to connect the cable shield properly.
- Wiring shall conform to NEC requirements. Current and insulation rating shall meet the requirements of the control circuits.
- Wiring shall be neatly arranged, firmly laced and secured to the panel or supported by suitable brackets as required. Splicing of wires is not acceptable.
- Internal control wiring will be installed in approved horizontal and vertical wiring channels with removable covers for each access.
- All field wiring shall terminate on terminal blocks with numbering strips to identify each terminal or fuse block. All required jumpers shall be located opposite to the field terminations on the terminal block. Each terminal screw shall carry no more than two wires.

- Terminal blocks shall be suitably mounted, not less than 12 inches above the bottom panel. The terminal strips shall be mounted vertically, unless otherwise specified or shown on the drawings. Terminal blocks shall be arranged in a series of rows. Panel wiring and field wiring shall be segregated from one another by the rows of terminal blocks. No devices, or other material, shall obstruct access to the terminal blocks for connections of terminals or for installation of control cables. Terminal blocks shall be mounted on stand-off supports to the top of the block is flush with the top of the plastic wiring ducts. All interface terminal blocks (to connect to other cabinets and equipment or to DCS, etc.) shall be numbered in sequence without interrupting sequence by terminal block name.
- Completely separated and isolated circuits must be used for control, tripping, alarms and auxiliary devices. The controls and protection for each circuit breaker shall also contain as a minimum the following equipment within the cabinet.
    - Terminal blocks and terminations for each control wire connected to the circuit breaker disconnect switches, and grounding switches. A maximum of two wires per terminal will be permitted.
    - The following separate DC circuits are required:
    - One 125 Vdc, two-pole miniature circuit breaker (MCB) for breaker control and trip circuit #1.
    - One 125 Vdc, two-pole MCB for breaker trip circuit #2.
    - One two-pole MCB for each motor.
    - Terminal blocks and termination of all wires associated with electrical interlocking schemes.
    - Terminal blocks for alarm circuits and miscellaneous remote control functions.
    - Terminal blocks for all spare contacts of circuit breaker.
    - A total of 10% spare terminal blocks.
    - Test switches shall be provided for any AC or DC circuit for any IED (protection meters, etc.) according to its application (voltage, current and voltage and current combination type).
- Each control circuit shall be protected by a two-pole circuit breaker (CB) with auxiliary N/C contacts. The auxiliary contacts of all CB’s of the same circuit type shall be wired in series to a group alarm terminal.
- Wiring shall be terminated by insulated terminals with brazed barrels. Crimping shall be done with a ratchet-type crimping tool. Wiring shall be marked at both ends at the device and at the terminal block or other device).
- A duplex convenience outlet rated 120 V AC, 15 A, with ground fault interrupter shall be provided inside the breaker control cabinets.
- A connection point providing 120V/AC, three phases, shall be provided in one of the control cabinets for the use of maintenance and testing personnel.
- Cable schedules indicating origin and destination of all control and miscellaneous external (not prefabricated) wires shall be provided.

- Cable indexes indicating wire number, wire color, conduit number, and wire use for all control and miscellaneous external (not prefabricated) wires shall be provided.
- All wiring shall meet the following minimum requirements: 90°C, 600-volt switchboard wire, type SIS, 41 strand, tinned copper with PVC wire markers machine stamped sleeves or stamped wires on both ends. Each wire end to be stamped with wire destination. Minimum sizes for AC and DC power and control cables shall be as follows:
  - 120/240 VAC Power #12 AWG or 4mm2
  - 125 VDC Control #14 AWG or 4mm2
  - 120 VAC Potential (PT) #10 AWG or 6mm2
  - Trip and Close Control #12 AWG or 4mm2
  - Current Transformer #10 AWG or 6mm2
- Wiring of relays in the same panel shall be made by direct interconnection. Wiring between different panels shall be made via terminal blocks in each panel.
- All panel-mounted devices shall be sufficiently supported to prevent distortion and warping of the equipment bearing panel or sub-panels. All the terms of equipment called for in these specifications shall be installed in the cabinets.
- Equipment mounted within a cabinet shall be mounted on sub- panels or equipment stand-offs and be easily accessible. No bolts shall protrude through the sides of the cabinet for mounting devices inside the cabinet.
- Shielded control cables shall be grounded at one point.
  - A flat copper bar ground bus shall be installed. The bus shall be drilled for a NEMA 2-hole lug for connection of the station ground cable. All instruments and devices requiring grounding shall be connected to the ground bus by copper conductors via compression type lugs.

11.3.2.3.6. Interlocking

- Electrical and mechanical interlock sequence of operation shall be defined to prevent incorrect sequential operation and/or equipment malfunction that might result in equipment damage and personal injury. The mechanical interlock for circuit breakers and auxiliary switches shall be the type of Kirk Key or approved equal.

11.3.2.3.7. Battery Banks and Battery Chargers

The prefabricated building will include one (1) Battery Bank and one (1) Battery Charger, unless specified differently by the owner. The Charger will be supplied from a VAC load center via disconnecting switches. The battery bank shall be tied with a circuit breaker. The battery bank shall have the capacity to supply the whole substation. The system shall comply with the following:

- Equipment for the battery system must comply with the latest version of ANSI/IEEE 485 and ANSI-C2.
- The battery system shall be rated to provide backup power for the complete facility.
- Batteries shall be Lead Acid.

- The battery and battery charge shall be sized to provide backup power for eight (8) hours and six (6) open/close operations per switching device (breakers, etc.), unless specified differently by the owner.
- The station battery shall be housed in a separate room in the Prefabricated Building with a door to the outside. There shall be no direct access from the battery room to the control room.
- Forced ventilation shall be provided to limit hydrogen build up and acid fumes.
- A containment barrier shall be provided to hold acid spills inside the battery room.
- Battery chargers shall be located in the main control room, separate from the battery room.
- Battery room lighting fixtures shall be gas tight type.
- An eye shower shall be installed outside the battery room, next to the battery room door.
- The battery charger must be provided with at least the following accessories:
    - AC voltage failure alarm relay and DC low voltage alarm relay with contacts connected to a terminal block for easy connection to external circuiting.
    - Contacts for ground detector alarm wired to terminal blocks for easy connection to an external circuit.

11.3.2.3.8.

11.3.2.3.9. **Production Tests**

- All products shall be tested and inspected as part of the regular manufacturing procedure and in accordance with ANSI C37.20, paragraph 5.3 for Switchgear Assemblies. Testing shall include but not be limited to the DC Transient test and the Surge Withstand Capacity test in accordance with the latest version of IEEE 472 (ANSI C37.90a).

11.3.2.3.10. Additional Testing

- The following test shall be performed to the assembled control panel:
    - Verify all wiring between cubicles and relay panels.
    - Verify relay general performance operation.
    - Injection testing of all relays and meter to verify correct operation.
    - The entire above test must be performed on the fully assembled control panel at manufacturer location. The owner reserves the right to witness tests. The Manufacturer shall notify the owner at least four (4) weeks prior to the date of test. The owner may waive the witness of test and in substitution request certified test results.

11.3.2.3.11. Accessories

- The following accessories shall be supplied, but not housed:
    - Identification nameplates for each relay in the front and rear side of the panels and each test switches and other devices in the panels.

- Any software for relay settings, test and calibration shall be provided.

11.3.2.3.12. Information Required with Proposals

- The Manufacturer shall submit with his proposal sufficient information to show the general design of the equipment offered and to permit an engineering comparison with equipment offered by other Manufacturers. He shall furnish the following specific information:
  - Drawings showing outline dimensions and arrangements
  - Descriptive catalog information
  - List of exceptions, if any, to the specifications
  - Catalog descriptions of standard equipment the Bidder proposes to use
  - Names of manufacturers of component parts not provided by the Protection and Control Prefabricated / Prewired Building Manufacturer.
  - List of names and locations of previous projects supplied with a Remote Control Unit using CDC and DNP communication protocols.
  - DNP 3.0 Certificate

11.3.2.3.13. Spare Parts

- The Manufacturer shall submit with his proposal an itemized list of spare parts with prices for every item.

11.4. Conductors: High Voltage Cable

11.4.1. General

11.4.1.1. Summary

11.4.1.1.1. Section includes high voltage cables to be installed in conduits and ducts; and cable splices and terminations.

11.4.1.2. References

11.4.1.2.1. All work shall be in accordance with all applicable codes, standards, and regulations to include, but not limited to, the following:

- NEC – National Electrical Code
- OSHA – Occupational Safety and Health Act
- UL – Underwriters Laboratories
- ANSI – American National Standards
- ASTM – American Society for Testing and Materials
- NEMA – National Electrical Manufacturers Association
- ICEA – Insulated Cable Engineers Association
- IEEE – Institute of Electrical and Electronic Engineers
- AEIC – Association of Edison Illuminating Companies.
- NETA – International Electrical Testing Association

11.4.1.3. System Description

11.4.1.3.1. Provide high voltage cables, splices and cable terminations as indicated on Drawings.

11.4.1.4. Submittals

11.4.1.4.1. Product Data: Submit for each conductor, splice and cable termination.

11.4.1.5. Qualifications

11.4.1.5.1. Manufacturer specializing in manufacturing products specified in this section with a minimum of three years' experience.

11.4.1.6. Delivery, Storage, And Handling

11.4.1.6.1. All materials furnished under this section shall be new and unused.

11.4.1.6.2. Cables shall be delivered to the job in standard reels with approved tags noting length, cable size, insulation type and manufacturer's name. Cable ends shall be sealed prior to shipment.

11.4.1.6.3. All materials shall be protected from weather and damage during storage and handling at the job.

11.4.1.6.4. If factory seals are cut off, new tape seals must be applied to prevent moisture entry into cable.

11.4.1.6.5. Whenever possible, the factory applied lagging (protective cover) should be left in place until removal is necessary. Additional covering may be used, if cable is to be stored for long periods outdoors or in excessively dirty dusty areas.

11.4.1.6.6. Store reels of cable on a firm surface, paved if possible, or on planking to prevent settling into soft ground. The storage area should have good drainage.

11.4.1.6.7. Use fencing or other barriers to protect cables and reels against damage by vehicles or other equipment moving about in the storage areas.

11.4.1.6.8. Reels of cable must not be dropped from any height, particularly from trucks of other transporting equipment.

11.4.1.6.9. Lift reels using following methods: Crane or boom type equipment: insert shaft (heavy rod or pipe) through reel hubs and lift with slings on shaft, preferably utilizing spreader or yoke to reduce or avoid sling pressure against reel head. Fork lift type of equipment may be used to move smaller, narrower width reels. Fork tines should be placed so that lift pressure is on reel heads, not on cable, and must reach all the way across reels so lift is against both reel heads.

11.4.1.6.10. Reels may be moved short distances by rolling. Reels should be rolled in the direction indicated by arrows painted on reel head. Surfaces over which the reels are to be rolled should be firm, clear of debris, and clear of protruding stones, humps, etc. which might damage the cable if the reel straddled them.

11.4.2. Products

11.4.2.1. General

11.4.2.1.1. For entire high voltage cable installation, some of the following types, as noted on Drawings, shall be used:

- Single Conductor, shielded, TR-XLP Extra Clean insulation
- Single Conductor, shielded, EPR insulation.

11.4.2.1.2. The cable shall be designed with an insulation that can stand the continued stress of an additional 10% of the cables nominal kV rating phase to phase.

11.4.2.1.3. The cable shall meet the applicable requirements of the Insulated Cable Engineering Association (ICEA) Standard No. S-66-524 for tree retardant cross-linked polyethylene or S-68-516 for Ethylene Propylene Rubber supplemented by the specifications of the Association of Edison Illuminating Companies (AEIC) Bulletin No. CS87-87 and CS6-87 respectively.

11.4.2.1.4. Cable shall have permanent identification of manufacturer and classification visible on the outer jacket.

11.4.2.2. Conductor

11.4.2.2.1. The conductor shall be compressed; water tight type, concentric laid, stranded, Class B, and shall be made of annealed uncoated copper wires. The interstices between wires shall be filled with a watertight compound. The filling compound shall be a high viscosity polymeric based thermoplastic compound, which adheres to metals and polymeric materials, and compatible with semiconducting, and insulation materials.

11.4.2.2.2. Size of conductor should be based on load flow calculations considering permissible voltage drops.

11.4.2.3. Insulation

11.4.2.3.1. The insulation shall be extra clean, tree retardant XLP or EPR

11.4.2.4. Shielding

11.4.2.4.1. Conductor shall be covered with a layer of extruded semiconducting material.

11.4.2.4.2. Insulation shielding shall be extruded and shall consist of black, semiconducting thermoset material applied directly over the insulation.

11.4.2.5. Extrusion and Curing

11.4.2.5.1. The conductor shielding, insulation, and insulation shielding shall be extruded utilizing a simultaneous triple extrusion process in clean room environment.

11.4.2.5.2. Dry curing method is mandatory.

11.4.2.5.3. A polyvinyl chloride (PVC) jacket shall be applied over the copper shielding tapes.

11.4.2.6. Factory Tests

11.4.2.6.1. All tests shall be made on the cable in accordance with the requirement call for in the Standards on Article 2.1 C of these specifications.

11.4.2.6.2. The supplier or manufacturer shall provide the qualification test results described in Section L of AEIC CS7-87 or CS6-87 as applicable. The cable shall not be considered or evaluated without these qualification test results.

11.4.2.6.3. The manufacturer shall state clearly that it has manufactured and tested the cable in accordance with these specifications and shall inform the Owner or any deviation from them.

11.4.2.7. Terminations

11.4.2.7.1. Cable terminations shall be factory-manufactured kits to suit the specific type and size of the cable.

11.4.2.7.2. The local Power Utility Authority shall approve Cable terminations.

11.4.2.8. Lubrication for Cable Installation

11.4.2.8.1. Cable pulling lubricants used to reduce the coefficient of friction between the cable and the containing conduit or duct shall be compatible with the materials of construction of the cable.

11.4.3. Execution

11.4.3.1. Examination

11.4.3.1.1. Verify conduit, duct, pull boxes and manholes are ready to receive cable.

11.4.3.1.2. Verify routing and termination locations of cable prior to rough in.

11.4.3.2. Installation

11.4.3.2.1. Thoroughly swab all conduits by rodding and brushing before pulling in cables.

11.4.3.2.2. Thoroughly mandrel and swab all conduits before pulling in cables. Use rod equipped with brass knuckle- joint fittings, so the rod can be joined and disjoined. Push rod into duct and couple other rods. Repeat coupling rods until rods extend from manhole to manhole. Repeat rodding of duct until duct is clear of obstruction. If obstructions are encountered, use proper cleaning tool to eliminate obstructions.

11.4.3.2.3. Pull cables into raceway at same time.

11.4.3.2.4. Cable shall be installed in accordance with manufacturer’s recommendation. At no time during or after installation shall the cable be bent to a radius smaller than manufacturer’s recommendation.

11.4.3.2.5. Use suitable manufacturer approved lubricants. Cable pulling compound shall be applied at the beginning of the cable entry into the conduit and at each manhole along the conduit run.

11.4.3.2.6. Use suitable manufacturer approved pulling equipment. Sustain cable-pulling tensions below manufacturers recommended limits. A tension-monitoring device must be used during the pulling system to ensure that the cable maximum pulling tension is not exceeded. This must be a continuous monitoring device so that cable pulling is not interrupted.

11.4.3.2.7. Attachment to the cable can be accomplished with any of the commercially available devices (Kellemps grips, Greenlee wire grip, etc.) or by factory-made pulling eyes. If the pull is through wet or damp locations, the cable ends must be positively sealed to prevent moisture entry and resealed after pulling.

11.4.3.2.8. Factory applied seals on cable ends may be disrupted during the pulling operation and, therefore, should be checked and replaced, if the cables are not going to be spliced or terminated right after pull-in. This is especially important for underground runs where cable ends may be left in manholes, which are subject to flooding.

11.4.3.2.9. Contractor shall pump dry all manholes prior to cable installation. Install cables in manholes or pull boxes along wall providing longest route.

11.4.3.2.10. Roller tracks and/or cable guides shall be placed in each manhole to ensure that the manufacturer’s minimum bending radius is not exceeded and to protect the cables during the transition from top to bottom or bottom to top conduit positions within a given manhole.

11.4.3.2.11. Arrange cables in manholes or pull boxes to avoid interference with conduit or duct entrances.

11.4.3.2.12. Install, terminate, and splice cables in accordance with cable manufacturer’s recommendations. Splices shall be permitted only when necessary. All splicing shall be approved by the local Power Utility. Cable splices shall be made by certified cable splicers with a minimum of 10 years’ experience in splicing cables of this type.

11.4.3.2.13. Support cables to galvanized steel channels and porcelain insulators.

11.4.3.2.14. Cable shields on all splices and terminations and grounding conductor at all manholes shall be properly connected to the ground rods.

11.4.3.2.15. Fireproof cables in manholes using fireproofing tape in half-lapped wrapping. Extend fireproofing 1 inch into duct.

11.4.3.3. Field Quality Control

11.4.3.3.1. Inspect exposed cable sections for physical damage.

11.4.3.3.2. Inspect cable for proper connections.

11.4.3.3.3. Inspect shield grounding, cable supports, and terminations for proper installation.

11.4.3.3.4. Perform inspections and test listed in NETA, Section 7.3.3 (Cables: Medium Voltage), Section 7.13 (Grounding System)

11.4.3.3.5. All testing shall be performed according to the manufacturer's instructions and test value limitations indicated by testing equipment company or cable manufacturer.

11.4.3.3.6. The reference Standards are available as follows:

11.4.3.3.7. International Electrical Testing Association (NETA)

11.4.3.3.8. PO Box 687, Morrison, CO 80465

11.4.3.3.9. Tel: (303) 697-8441; Fax: (303) 697-8431

11.4.3.3.10. E-mail: neta@netaworld.org – Web site: www.netaworl.org

11.4.3.3.11.

11.4.3.3.12. If any cable fails or tests, in the opinion of the testing agency, show unacceptable cable defects, all cables in that conduit between the nearest pulling points on each side of the failure shall be withdrawn. If, in the opinion of the testing agency, other cables that have been installed in the same duct are not damaged, they may be reinstalled, but the failed cable shall be replaced with new cable without additional charge.

11.4.3.3.13. After replacement of the faulty cable and any other damaged cables, all cables or the circuit in that conduit shall be retested. If a cable fails again or if tests, in the opinion of the testing agency, show unacceptable cable defects, all cables shall be replaced without charge and this procedure shall be repeated until tests proved satisfactory.

11.4.3.4. Protection of Installed Construction

11.4.3.4.1. Protect installed cables from entrance of moisture.

11.4.3.5. Cleaning

11.4.3.5.1. Clean interior of manholes and pull boxes to remove dust, debris and other material.

11.5. Grounding Systems for Substations

11.5.1. General

11.5.1.1. Summary

11.5.1.1.1. Section includes all necessary conductors, rod electrodes, exothermic connections, mechanical connections and additional accessories to construct a ground grid that provides a grounding system for a Substation.

11.5.1.2. References

11.5.1.2.1. All work shall be in accordance with all applicable codes and standards to include, but not limited to, the following:

- NEC – National Electrical Code
- OSHA – Occupational Safety & Health Act
- UL – Underwriters Laboratories
- ANSI – American National Standards
- NEMA – National Electric Manufacturers Association
- NETA – International Electrical Testing Association
- IEEE – Institute of Electrical and Electronics Engineers
- LOCAL POWER UTILITY

11.5.1.3. System Description

11.5.1.3.1. Provide materials and labor to ground electrical systems as shown on Drawings to include but not limited to, the following:

- Substation Structure
- Transformers, Switchgears, Air Interrupter Switches, Circuit Breakers, and additional equipment included in the Substation.
- Substation Fence and access doors.
- Raceway system
- Center point of delta-wye Transformers.

11.5.1.3.2. Provide a complete ground-grid enclosing the substation and including the fence within the ground-grid are Except as otherwise indicated on Drawings:

- The perimeter conductor of the grid will be parallel to the fence line at not less than three (3) feet outside the fence.
- Cross conductors shall be provided interconnecting the perimeter conductor in both directions. Exothermic connections shall be used in the points of crossing of all conductors.
- The ground-grid shall be installed at least 18 inches below the ground level. The depth of the crushed-stone (minimum resistivity of 3000 ohms-meter) layer that will cover the ground-grid area is not included in this minimum buried dimension.
- Provide ground electrodes, connected to the ground-grid, in the points of connection of the down conductor from the surge arresters, the transformer neutral and the plate where the air interrupter switch will be operated. Provide additional ground electrodes as indicated on Drawings.

11.5.1.3.3. The system shall be in accordance with ANSI/IEEE Std. 80 – Guide for Safety in ac Substation Grounding.

11.5.1.4. Performance Requirements

11.5.1.4.1. Grounding System Resistance: 5 ohms maximum except as otherwise indicated on Drawings.

11.5.1.5. Submittals

11.5.1.5.1. Product Data: Submit data for each type of product used.

11.5.1.5.2. Test Reports: Indicate overall resistance to ground, resistance of the individual ground rods. Report values greater than 5 ohms for remedial action.

11.5.1.6. Closeout Submittals

11.5.1.6.1. Project Record Documents: Record actual locations of components and grounding electrodes.

11.5.1.7. Delivery, Storage, And Handling

11.5.1.7.1. All material shall be new, unused and delivered in original manufacturer's packaging.

11.5.1.7.2. Protect from weather and construction traffic, dirt, water, chemical and mechanical damage, by storing in original packaging.

11.5.2. Products

11.5.2.1. General

11.5.2.1.1. Except as otherwise indicated, provide electrical grounding and bonding systems indicated on Drawings; with assembly of materials, including, but not limited to: cables, connectors, solderless lug terminals, grounding electrodes and plate electrodes, bonding jumper braid, and additional accessories needed for a complete installation.

11.5.2.1.2. All materials shall be listed and approved for the intended application.

11.5.2.2. Manufacturers

11.5.2.2.1. Subject to compliance with requirements, provide grounding and bonding products of one of the following manufacturers (for each type of product):

- Blackburn (T&B)
- Burndy Corporation.
- Cadweld Div; Erico Products Inc.
- Copperweld.
- East Jordan Iron Works (ground test boxes).
- Josam Manufacturing Company (ground test boxes).
- OZ Gedney Div; General Signal Corp.
- Penn-Union.
- Thomas and Betts Corp.
- Stewart R. Browne (clamps).
- 1 Sherman (lugs and connectors).
- 1 Kearney (lugs and connectors).

11.5.2.3. Cable

11.5.2.3.1. Soft drawn, copper, bare or insulated (as indicated), stranded with 95% conductivity.

11.5.2.3.2. Ground Cable to be sized in accordance with NEC Tables.

11.5.2.4. Bonding Jumper Braid

11.5.2.4.1. Stainless Steel braided tape, constructed of 30-gauge bare stainless steel wires and properly sized for indicated applications.

11.5.2.5. Ground Electrodes

11.5.2.5.1. Ground Rods: shall be ¾ inch by 10-foot copper clad steel unless otherwise specified on Drawings.

11.5.2.5.2. Ground Test Boxes: shall be 8 inch diameter by 24 inch long concrete pipe with belled end, and a cast iron cover with legend “ground” embossed on top.

11.5.2.6. Connections

11.5.2.6.1. Exothermic connections (cadweld or approved equal) shall be the standard method of splicing ground wire underground.

11.5.2.6.2. Provide ground clamp connectors for joining ground cable to pipe or plate. Clamps shall be fabricated of high-strength metals to provide corrosion-resistant permanently tight connection.

11.5.3. Execution

11.5.3.1. Examination

11.5.3.1.1. Verify existing conditions under which electrical grounding and bonding connections are to be made. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to installer.

11.5.3.1.2. Verify that final backfill and compaction has been completed before driving rod electrodes.

11.5.3.2. Installation

11.5.3.2.1. Install ground-grid as indicated on Drawings.

11.5.3.2.2. Exothermic welds shall be made strictly in accordance with the weld manufacturer's written recommendations. Welds which are "puffed up" or which show convex surfaces indicating improper cleaning are not acceptable.

11.5.3.2.3. Install rod electrodes at locations indicated on drawings. The rod electrode shall be driven full length into the earth. The maximum resistance of a driven ground shall not exceed 5 ohms. If this resistance cannot be obtained with a single rod, a sufficient number of additional rods shall be installed not closer than 6 feet in center so that the resultant resistance will be within that limit.

11.5.3.2.4. Install ground test boxes for grounding electrodes with detachable cable connections at locations indicated on the drawings. Install well box top flush with the finished grade.

11.5.3.2.5. Ground the substation fence at each gate post and corner post and at intervals not exceeding 10 feet. Bond each gate section to the fence post through a 1/8-inch by one- inch flexible braided copper strap and clamps.

11.5.3.2.6. Connect surge arrester down conductor, substation structure, air interrupter switch operator, transformer tank, metal-clad switchgear and enclosures of additional equipment to the ground- grid.

11.5.3.2.7. The ground connection of the electric system neutral shall be made in each substation as shown on the drawings. An insulated neutral conductor must be carried from the switchgear neutral bus back to the transformer neutral. The insulated neutral wire must not be grounded on the downstream side of the switchgear in the feeders.

11.5.3.3. Field Quality Control

11.5.3.3.1. Inspect and test in accordance with NETA.

11.5.3.3.2. Grounding and Bonding: Perform inspections and tests listed in NETA section 7.13

11.5.3.3.3. Perform ground resistance testing in accordance with IEEE 14

11.5.3.3.4. Perform leakage current tests in accordance with NFPA 9

11.5.3.3.5. Perform continuity testing in accordance with IEEE 142

11.5.3.3.6. Perform ground resistance measurement for each piece of equipment.

- An independent testing contractor engaged in the business of electrical acceptance testing similar to the inspections and tests specified shall perform the testing. Contractor shall have at least five years of experience
- The testing contractor shall submit proof of qualifications to the Owner. Proof shall include but not be limited to:
- Name of the required registered electrical engineer.
- Certified International Electrical Testing Association (NETA) test technician.
- Experience as a testing laboratory for a minimum of five years.
- Equipment available for use in this project.

11.5.3.3.7. Test in cooperation with other affected contractors. The Owner shall approve the schedule of tests. Three-day notice shall be given prior to testing, unless otherwise necessary or specified.

11.5.3.3.8. All testing shall be performed according to the manufacturer's instructions and test value limitations indicated by testing equipment company or equipment manufacturer.

11.5.3.3.9. The reference Standards are available as follows:

- NETA Grounding System Tests

  International Electrical Testing Association (NETA)
  PO Box 687, Morrison, CO 80465
  Tel: (303) 697-8441; Fax: (303) 697-8431
  E-mail: net@netaworld.org – Web site: www.netaworld.org

- IEEE Std. 142, IEEE Std 81, and IEEE Std. 80

  Institute of Electrical and Electronic Engineers (IEEE)
  IEEE Customer Service Center
  445 Hoes Lane
  P.O. Box 1331
  Piscataway, NJ 08855-1331
  Tel: (732) 981-0060; E-mail: ieee.org/shop

- NFPA 99

  National Fire Protection Association
  1 Battery March Park, Quincy MA 02269-9101
  Tel: (800) 344-3555

11.6. Acceptance Testing

11.6.1. General

11.6.1.1. Summary

11.6.1.1.1. Section includes Acceptance Testing for the electrical equipment in a substation.

11.6.1.2. Applicable References

11.6.1.2.1. All inspections and field tests shall be in accordance with the latest edition of the following codes, standards, and specifications except as provide otherwise herein.

- ASTM – American Society for Testing and Materials
- ANSI – American National Standards Institute
- IEEE – Institute of Electrical and Electronic Engineers
- ICEA – Insulated Cable Engineers Association
- NETA – International Electrical Testing Association
- NEMA – National Electrical Manufacturer's Association
- NEC – National Electrical Code
- NFPA – National Fire Protection Association
- OSHA – Occupational Safety and Health Administration
- 10.UL – Underwriters Laboratories, Inc.

11.6.1.3. Equipment and Systems to Be Tested

- 11.6.1.3.1. Transformers
- 11.6.1.3.2. Cables and Wires
- 11.6.1.3.3. Metal-Enclosed Busways
- 11.6.1.3.4. Outdoor Bus Structures
- 11.6.1.3.5. Switches
- 11.6.1.3.6. Circuit Breakers
- 11.6.1.3.7. Switchgear and Switchboard Assemblies
- 11.6.1.3.8. Instrument Transformers
- 11.6.1.3.9. Metering
- 11.6.1.3.10. Protective Relays
- 11.6.1.3.11. Ground-Fault Protection System
- 11.6.1.3.12. Surge Arrestors
- 11.6.1.3.13. AC Motors
- 11.6.1.3.14. AC Generators
- 11.6.1.3.15. Motor Control
- 11.6.1.3.16. Adjustable Speed Drive Systems
- 11.6.1.3.17. Emergency Systems
- 11.6.1.3.18. Uninterruptible Power Systems
- 11.6.1.3.19. Capacitors
- 11.6.1.3.20. Direct-Current Systems
- 11.6.1.3.21. Grounding Systems.

11.6.1.4. System Description

11.6.1.4.1. The work covered by this specification shall include furnishing all labor, material, equipment and services to perform de acceptance tests for the complete electrical system.

11.6.1.4.2. Preliminary acceptance tests are defined as those tests and inspections required to determine that the equipment involved may be energized for final operations tests.

11.6.1.4.3. Final acceptance will depend upon equipment performance, characteristics, ant their compliance with the intended design as determined by system operational tests defined in this and other sections of these specifications.

11.6.1.4.4. Use the standards of the industry such as IEEE, NEMA, ANSI, IPCEA, NETA and guides in testing the equipment.

11.6.1.5. Qualifications

11.6.1.5.1. The testing shall be performed by an independent testing contractor engaged in the business of electrical acceptance testing similar to the inspections and tests specified. Testing laboratory shall have a minimum of five years of experience.

11.6.1.5.2. The testing contractor shall submit proof of qualifications to the Owner. Proof shall include but not be limited to:

- Name of the required registered professional engineer.
- Qualifications of test personnel: Minimum of two years supervised field experience, or certified National Electrical Testing Association (NETA) test technician.
- Experience as a testing laboratory for a minimum of five years.
- Equipment available for use on this project.

11.6.1.5.3. Membership in the NETA may be submitted in addition to the above list to substantiate qualifications.

11.6.1.6. Test Procedure

11.6.1.6.1. The Owner will provide a set of project electrical documents to assist in ascertaining the extent of the project testing.

11.6.1.6.2. The testing laboratory shall be responsible for tests and test record for each item to be tested.

11.6.1.6.3. Test in the presence of the Owner's representative at the option of the Owner.

11.6.1.6.4. Report immediately to the Owner any system, material, or workmanship which is defective, in compliance with the specifications.

11.6.1.6.5. Provide necessary test equipment and be responsible for setting- up test equipment, wire checks of factory wiring, and any other preliminary work in preparation for the electrical acceptance tests.

11.6.1.6.6. Having a calibration program which maintains applicable test instrumentation within rated accuracy. Accuracy shall be traceable to the National Bureau of Standards. Calibration frequency shall be in accordance with the following schedule:

11.6.1.6.7. Field instruments: six months maximum

11.6.1.6.8. Laboratory instruments: 12 months maximum.

11.6.1.6.9. Dated calibration shall be visible on equipment.

11.6.1.6.10. Test in cooperation with other affected subcontractors. The schedule of tests shall be approved by the Owner's representative. Three-day notice shall be given prior to testing, unless otherwise necessary or specified.

11.6.1.6.11. Advice the manufacturer's representative of tests performed on their equipment. Give a minimum of ten-calendar-day notice to permit him to witness the equipment under test, should be desire.

11.6.1.6.12. Certain pieces of equipment have the services of a manufacturer's service engineer who will assist in performing the tests on the equipment. When this service is provided, he will verify and sign each report form.

11.6.1.6.13. Tests shall be non-destructive and shall not exceed the manufacturer's recommended limit for the equipment being tested.

11.6.1.6.14. Where required for the validity of tests of safety of equipment and personnel, isolate equipment to be tested from the system.

11.6.1.6.15. All testing shall be performed according to the manufacturer instructions and test value limitation indicated by testing equipment company or equipment manufacturer.

11.6.1.7. Test Report

11.6.1.7.1. Incorporate a record of inspections and tests into the test report.

11.6.1.7.2. The test report shall be bond and certified by the testing laboratory.

11.6.1.7.3. The Owner will specify the number of test report copies needed and these shall be received no later than 30 days after completion of project. At the discretion of the Owner's representative, due to the installation scheduling of specific items of equipment or for other reasons, testing may be subdivided into several smaller packages. In that case, one copy of a test report shall be submitted no later than 30 days after completion of each test package, and an inclusive test report containing the package reports shall be submitted in the quantity and the time specified above for the complete project.

11.6.1.7.4. Include the following in the test report:

- Summary of the project.
- Description of the equipment tested.
- Description of test performed.

- List of test equipment used and calibration dates.
- Test results.
- Conclusions and recommendation, if any.

11.6.1.7.5. Where adjustment, modifications, or repairs are made to equipment in order to meet the equipment and/or system specifications, the test results and reports shall indicate the "as left" condition.

11.6.1.7.6. The test forms shall include but not be limited to the following:

- Name plate catalog number, serial number, and rating.
- Desired performance or performance range.
- Measure performances.
- Test equipment used.
- Test personnel and date.
- Any discrepancies or repairs made.

11.6.1.7.7. Test forms that are different than NETA copyrighted test report forms shall be approved by the Owner's representative.

11.6.1.8. Visual Inspection

11.6.1.8.1. Prior to testing, equipment shall be visually inspected to determine that there is no physical damage, loose bolts or missing parts, and the equipment is supplied in agreement with the contract documents, and properly installed and connected.

11.6.1.9. Environmental Conditions

11.6.1.9.1. Temperature

- Test results shall be corrected to 20°C both actual ambient temperature test reading and calculated, corrected to temperature, test values shall be reported.
- Test shall not be made on any equipment when the insulation temperature is below 0°C.

11.6.1.9.2. Humidity

- Test shall not be made on any equipment where the relative humidity is above 70 percent. Deviations of this requirement will only be made by the Owner's representative, if it can be demonstrated that the higher humidity will not affect the test or that the higher humidity can be accounted for adequately in interpreting the test results.

11.6.2. Execution

11.6.2.1. Transformers

11.6.2.1.1. Dry Type Air-Cooled, 600 volt and below – Small (167 kVA Single- Phase, 500 kVA Three-Phase, and Smaller).

- Perform inspection and tests listed in NETA, Section 7.2.1.1

11.6.2.1.2. Dry-Type Air-Cooled, All above 600 Volt and 600 Volt and Below- Large (Greater than 167 kVA Single-Phase and 500 kVA Three-Phase)

- Perform inspection and tests listed in NETA, Section 7.2.1.2
- Perform any additional test required by local power Utility.

11.6.2.1.3. Liquid-Filled

- Perform inspection and test listed in NETA, Section 7.2.2
- Perform any additional test required by local power Utility.

11.6.2.2. Cables

11.6.2.2.1. Low-Voltage, 600 Volt Maximum

- Perform inspection and test listed in NETA, Section 7.3.2

11.6.2.2.2. Medium-Voltage, 69 kV Maximum

- Perform inspection and test listed in NETA, Section 7.3.3
- Perform any additional test require by the local power Utility.

11.6.2.2.3. High-Voltage

- Perform inspection and test listed in NETA, Section 7.3.4
- Perform any additional test required by local power Utility.

11.6.2.3. Metal-Enclosed Busways

11.6.2.3.1. Perform inspection and test listed in NETA, Section 7.4.

11.6.2.4. Outdoor Bus Structures

11.6.2.4.1. Perform inspection and test listed in NETA, Section 7.21

11.6.2.4.2. Perform any additional test required by the local power Utility.

11.6.2.5. Switches

11.6.2.5.1. Low-Voltage

- Perform inspection and test listed in NETA, Section 7.5.1.1

11.6.2.5.2. Medium-Voltage, Metal-Enclosed

- Perform inspection and test listed in NETA, Section 7.5.1.2
- Perform any additional test required by local power Utility.

11.6.2.5.3. High and Medium Voltage, Open

- Perform inspection and test listed in NETA, Section 7.5.1.3
- 2 Perform any additional test required by local power Utility.

11.6.2.5.4. Oil Switches: Medium-Voltage

- Perform inspection and test listed in NETA, Section 7.5.2
- Perform any additional test required by local power Utility.

11.6.2.5.5. Vacuum Switches: Medium Voltage

- Perform inspection and test listed in NETA, Section 7.5.3
- Perform any additional test required by local power Utility.

11.6.2.5.6. SF6 Switches: Medium Voltage

- Visual and Mechanical Inspection
  1. Inspect for physical damage and compare nameplate data with plans and specifications
  2. Inspect anchorage, alignment and grounding.
  3. Perform all mechanical operation and contact blade alignment tests on both the circuit switcher and its operating mechanism in accordance with manufacturer’s instruction.
  4. Check tightness of bolted bus joints by calibrated torque wrench method. Refer to manufacturer’s instruction for proper foot pound level.
- Electrical Tests
  1. Measure contact resistance
  2. Perform switcher travel time test if unit is properly equipped for this test.

3. Circuit switcher shall be tripped by operation of each protective device.
4. Perform insulation resistance test on each pole to ground.
5. Perform AC or DC over potential test on each pole to ground and pole to pole.
6. Perform insulation resistance test on all control wiring at 1000 volts DC (Do not perform this test on wiring connected to solid state relays).
7. All tests indicated in this section shall be verified with equipment manual and manufacturer instructions and recommendations.

11.6.2.6. Circuit Breakers

11.6.2.6.1. Low-Voltage: Insulated/Molded Case

- Perform inspection and test listed in NETA, Section 7.6.1.1

11.6.2.6.2. Low-Voltage: Power

- Perform inspection and test listed in NETA, Section 7.6.1.2

11.6.2.6.3. Medium-Voltage: Air

- Perform any additional test required by local power Utility.

11.6.2.6.4. Medium-Voltage: Oil

- Perform inspection and test listed in NETA, Section 7.6.2.2
- Perform any additional test required by local power Utility.

11.6.2.6.5. Medium-Voltage: Vacuum

- Perform inspection and test listed in NETA, Section 7.6.2.3
- Perform any additional test required by local power Utility.

11.6.2.6.6. Medium-Voltage: SF6

- Perform inspection and test listed in NETA, Section 7.6.2.4
- Perform any additional test required by local power Utility.

11.6.2.6.7. High-Voltage: Oil

- Perform inspection and test listed in NETA, Section 7.6.3.1
- Perform any additional test required by local power Utility.

11.6.2.6.8. High-Voltage: SF6

- Perform inspection and test listed in NETA, Section 7.6.3.2
- Perform any additional test required by local power Utility.

11.6.2.7. Switchgear and Switchboard Assemblies

11.6.2.7.1. Perform inspection and test listed in NETA, Section 7.1

11.6.2.8. Instrument Transformers

11.6.2.8.1. Perform inspection and tests listed in NETA, Section 7.10

11.6.2.9. Metering

11.6.2.9.1. Perform inspection and tests listed in NETA, Section 7.**11**

11.6.2.10. Protective Relays

11.6.2.10.1. Perform inspection and tests listed in NETA, Section 7.9

11.6.2.10.2. Perform any additional test required by latest PREPA regulations.

11.6.2.11. Ground-Fault Protection System

11.6.2.11.1. Perform inspection and tests listed in NETA, Section 7.14

11.6.2.12. Surge Arrestors

11.6.2.12.1. Low-Voltage Surge Protection Devices

- Perform inspections and tests listed in NETA, Section 7.19.1

11.6.2.12.2. Medium and High-Voltage Surge Protection Devices

- Perform inspections and tests listed in NETA, Section 7.19.2

11.6.2.13. AC Motors

11.6.2.13.1. Perform inspection and test listed in NETA, Section 7.15.1.1

11.6.2.14. AC Generators

11.6.2.14.1. Perform inspection and test listed in NETA, Section 7.15.2.1

11.6.2.15. Motor Control

11.6.2.15.1. Motor Starters: Low Voltage

11.6.2.15.2. Motor Starters: Medium Voltage

- Perform inspection and test listed in NETA, Section 7.16.1.2

11.6.2.15.3. Motor Control Centers: Low and Medium Voltage

- Perform inspection and tests listed in NETA, Section 7.16.2.1

11.6.2.16. Adjustable Speed Drive Systems

11.6.2.16.1. Perform inspection and test listed in NETA, Section 7.17

11.6.2.17. Emergency Systems

11.6.2.17.1. Engine Generator

- Perform inspection and test listed in NETA, Section 7.22.1

11.6.2.17.2. Automatic Transfer Switches

- Perform inspection and test listed in NETA, Section 7.22.3

11.6.2.18. Uninterruptible Power Systems

11.6.2.18.1. Perform inspection and test listed in NETA, Section 7.22.2

11.6.2.19. Capacitors

11.6.2.19.1. Perform inspection and test listed in NETA, Section 7.20.1

11.6.2.20. Direct-Current Systems

11.6.2.20.1. Batteries

- Perform inspection and test listed in NETA, Section 7.18.1

11.6.2.20.2. Battery Chargers

- Perform inspection and test listed in NETA, Section 7.18.2

11.6.2.21. Grounding Systems

11.6.2.21.1. Perform inspection and test listed in NETA, Section 7.13

11.6.2.22. References

11.6.2.22.1. The reference Standards are available as follows:

- International Electrical Testing Association (NETA)
  P.O. Box 687, Morrison, CO 80465
  Tel: (303)697-8441; Fax (303)697-8431
  E-mail: neta@netaworld.org – Web site: www.netaworld.org

12. Attachment 1: Deliverables (Documentation after Award)

12.1. Drawings and Specifications

Table 12.1 Owner Drawing List

Sheet	Title	Equip. Spec Review	30% Design Review	Equipment Drawing Review	60% Design Review	90% Design review	As-Builts
-	Coversheet		Yes			Yes	
S100	Structural General Notes		No		Yes		Yes
S101	Racking details		Yes			Yes	
S102	Racking assembly details		Yes			Yes	
S103	Racking configuration		Yes			Yes	Yes
S300	Existing site topos		Yes				Yes
S301	Final site grades		No		Yes		Yes
S302	Fence plan		No		Yes		Yes
S3202	Fencing details		No		Yes		
E100	Legend & specifications		Yes			Yes	Yes
E101	Site Plan - Electrical	Yes	Yes			Yes	Yes
E102	Partial Site Plan - Electrical		Yes			Yes	
E103	Partial Site Plan - Electrical		Yes			Yes	
E104	Substation Detail Drawings		Yes			Yes	Yes
E105	Transmission Line Drawings		Yes			Yes	Yes
E106	Transformer Detail Drawings		Yes			Yes	Yes
E300	One Line Diagram	Yes	Yes			Yes	Yes
E301	Array Circuit Schematic		Yes			Yes	Yes
E302	Cable schedule		No		Yes	Yes	Yes
E303	Communication wiring		No		Yes	Yes	Yes
E400	Interconnect Detail		Yes			Yes	Yes
E401	Trench detail		Yes			Yes	
E402	Grounding plan		Yes			Yes	Yes
E403	Grounding details		Yes			Yes	
O1	Engineer studies and calculations		Yes			Yes	
O2	Startup & commissioning plan				Yes		Yes
O3	Performance test procedure					Yes	Yes
O4	QA/QC plan		Yes			Yes	
O5	Inspection test plan		Yes			Yes	
O6	O&M Manual					Yes	Yes

O7	Construction schedule		Yes		Yes	Yes	
O8	Engineered Equipment Specs	Yes					
O9	Manufacturer's Drawing			Yes		Yes	Yes

12.1.1. Drawings Furnished by Contractor to Owner: Contractor shall prepare and furnish necessary fabrication and erection drawings for installation by others. The Contractor shall submit digital media containing digital copies of all data and drawings compatible with AutoCAD Plant Design Suite or Bentley Open Plant required to perform the work. All drawings shall be transmitted electronically to the Owner. The drawings required and their descriptions are as follows: All physical outlines as required showing the overall size and space requirements (including that required for dismantling and maintenance) and the inter-relationship of the various components. All angles shall be indicated. Cross sections and details as required satisfying the Owner that all components conform to these requirements including design and physical arrangement. All information required by the Owner for the design and location of all connecting Owner furnished structural, mechanical, or electrical items, such as steel supports, anchor bolts, piping, etc. Weight of the equipment and distribution of the static, live, wind, and other loads. Equipment assembly drawings. Erection drawings of Contractor's furnished equipment. Details of special features. The project location and Owner's purchase order number shall be shown on all drawings, including sub-supplier drawings. When of necessity, non-reproducible material is furnished; three (3) copies shall be transmitted to the Owner. Drawings will be examined promptly for general arrangement, general dimensions and suitability and returned with or without comments or suggestions. The Owner has the right to make minor changes and changes required for compliance with these specifications at no change in the Purchase Order price. SUCH REVIEW SHAL NOT RELIEVE THE CONTRACTOR OF RESPONSIBILITY FOR THE ACCURACY OR CORRECTNESS OF ITS WORK OR FOR THE PROPER CONSTRUCTION AND SUCCESSFUL PERFORMANCE OF THE EQUIPMENT IN ACCORDANCE WITH THE CONDITIONS SPECIFIED IN THE CONTRACT. After the first drawing submittal, all drawing changes shall be clearly marked or circled by the Contractor and identified with a complete description in the revision block of the drawing. "General Revision, Per Owner's Marked Print" is not a complete description and is not acceptable. If the Owner's comments or suggested changes are all incorporated into the drawings, then the Contractor may release the drawings for construction. Fabrication or construction shall not be performed until the Owner has returned all drawings related to that work with approval. If the Owner's comments or suggested changes are all incorporated into the drawings, then the Contractor may release the drawings for construction. Fabrication or construction shall not be performed until the Owner has returned all drawings related to that work with approval.

12.2. Operation and Maintenance Manuals

12.2.1. The Contractor shall furnish one (1) hard copy and one electronic set of Owner approved installation, operation, and maintenance instructions and final design approval. The manuals shall include but are not limited to the following:

12.2.1.1. A description of the equipment or engineered system, including major components.

12.2.1.2. Operating theory and enough information to assist the operators and maintenance personnel to properly care for the equipment.

12.2.1.3. Operating instructions, which includes, but is not limited to, proper start-up and shutdown instructions, upset and emergency instructions, operating adjustments, general operating and maintenance procedures, trouble-shooting guides and personnel safety instructions, including warnings for maintenance.

12.2.1.4. Recommended spare parts list.

12.3. Xcel Energy Drawing Standards: The Contractor shall comply with the following drawing standards in the Appendix.

12.3.1. EEC 7.970 W01 Rev. 1.6 Drawing Deliverable Standards

12.3.2. EEC 7.970W01 Rev. 1.6 NSP Title Block

13. Attachment 2: Performance Guarantees

13.1. Functional Tests

13.1.1. The equipment shall be tested for performance prior to commercial operation. This process shall verify the installed system is performing per the design based on the current weather variables.

13.1.2. Prior to the performance test, the Contractor shall perform functional tests. As part of the commissioning process of the newly constructed solar array, the Contractor shall perform a functional test on each of the circuits to verify that they are all operating as expected and designed.

13.1.3. The Contractor shall start up and commission each of the inverters and ensure they are running under their MPPT (Maximum Power Point Tracking) range for optimal performance. The Contractor shall perform an infrared scan to confirm site DC system health prior to conducting the performance tests. The Contractor shall perform repairs or replacements for each string that is not performing as designed.

13.2. Availability Test

13.2.1. This portion of the performance test shall be conducted after the Contractor completes the functional tests and is required for commercial operation. The Availability Test shall be conducted in accordance with the standard outlined in Attachment 16 Availability Test.

13.3. Capacity Test

13.3.1. The Capacity Test shall be conducted prior to commercial operation per the detailed test procedures in Attachment 17 - Capacity Test. The basis for the Capacity Test procedures is ASTM E2848 – Standard Test Method for Reporting Photovoltaic Non- Concentrator System Performance

13.3.2. The performance test boundary for the solar array shall be Contractor supplied weather station and the production power meter or other meter shown on the one-line in interconnection agreement in Attachment 8: Interconnection Agreement with One-line Diagram.

13.3.3. The weather data and MWh (megawatt hour) output data shall be recorded during the test with the Owner approved DAS software. The measured total MWh output during the test shall be the actual output of the solar array. The measured total MWh output shall include the accuracy of the production power meter, line loss between inverters and meter and temperature coefficient correction factor (defined by panel manufacturer).

13.3.4. The weather data recorded during the test shall be entered in the PVsyst or equal model included in the As-Built design. The PVsyst model or another numerical model shall be used to calculate the expected MWh output over the duration of the test. The solar irradiance input in the PVsyst model shall be corrected for the accuracy of the weather station pyranometers.

13.3.5. This portion of the performance guarantee shall be met if the actual measured MWh output is greater than or equal to the expected MWh output calculated by PVsyst or another numerical model. If the actual measured MWh out is less than the expected MWh output, the Contractor shall repair or replace components as required and retest the solar facility to meet this portion of the performance guarantee.

13.3.6. This portion of the performance test may be suspended and restarted due to transient weather conditions as mutually agreed to by the Owner and Contractor. The data collected during the test suspension shall be excluded from the performance calculations. The test suspension period shall not extend the overall test period.

13.4. Production Test

13.4.1. The Contractor shall complete a PVsyst model or Owner approved model based upon the final design of the system and 30-year historical weather data for the area that shall provide an expected monthly production estimate for each of the 12 months of the year. The Contractor shall track the monthly production and compare it to the predicted values and the actual observed weather data to ensure the system is preforming as expected from month to month for the two-year warranty period.

13.4.2. The Contractor shall also perform the Performance Ratio Test in Attachment 12: Production Test - Facility Performance Ratio Test Specification to fulfill the performance guarantee requirements.

13.4.3. The purpose of a Performance Ratio Test is to compare the Measured Performance Ratio of the facility to its Expected Performance Ratio at the Test on Completion (upon taking over of the facility) and during two years of the warranty period.

14. Attachment 3: Site and Ambient Conditions and Reference Materials

14.1. Summary

1.1 Attachment 3 outlines the site conditions used as the basis for performance guarantees, performance tests, and equipment design for the facility site.

14.2. Location

14.2.1. Contactor to specify solar project location.

14.3. Ambient Design Criteria (Contractor to provide per site location.)

14.3.1. Meteorology

14.3.1.1. Local Instrumentation data is used for design wet-bulb temperature, dry-bulb temperature, wind, and other design criteria.

14.3.1.1.1. Temperature and Humidity:

14.3.1.1.2. Maximum Summer Extreme Temperature: degrees F

14.3.1.1.3. Minimum Winter Extreme Temperature: degrees F

14.3.1.1.4. Summer Design Dry Bulb Temperature up to: degrees F

14.3.1.1.5. Summer Design Wet Bulb Temperature: degrees F

14.3.1.1.6. Winter Design Dry Bulb Temperature Down to: degrees F

14.3.1.1.7. Indoor Temperatures

14.3.1.1.8. Summer Design Temperature (Ventilated Areas)

14.3.1.1.9. Winter Design Temperature (Heated Areas)

14.3.1.1.10. Winter Design Temperature (Freeze Protection)

14.3.1.1.11. Precipitation and Snow:

14.3.1.1.12. Annual precipitation in the site vicinity is expected to average xx inches. Annual snowfall in the vicinity averages xx inches.

14.3.1.1.13. Rain Fall Depths (in)

	100 – Year	25 – Year	10 – Year
1 hour			
6 hour			
24 hour			

14.3.1.2.

14.3.1.3. Elevation/Barometric Pressure: The standard barometric pressure adjusted to the facility elevation of xx feet is xx psia.

14.3.1.4. Wind Speed

- Structures shall be designed for wind loads in accordance with the currently adopted local building codes, IBC, and ASCE 7.
- The minimum exposure classification shall be "C".
- Pressure coefficients shall be determined in accordance with ASCE 7
- Wind tunnel design Procedures shall be completed according to ASCE 7, Chapter 31.

14.3.2. Seismic Design

14.3.2.1. Seismic design shall be in accordance with the current local building codes and the IBC. The soil shall be classified as Site Class “D”, unless indicated otherwise in the project geotechnical investigation report.

15. Attachment 4: QAQC (Including Inspection Test Plans)

15.1. Introduction

15.1.1. The purpose of this Quality Management Plan (QMP) is to provide minimum performance standards for Quality Assurance/Quality Control (QA/QC) during the construction of the Project. Procedures and processes will be adjusted to account for the various types of equipment installed and topography of the site. Minimum guidelines will be outlined and will serve as a baseline for the EPC Contractors, prime contractors and/or Subcontractors assigned to the project. Specific requirements shall be put forth in the agreement between the relevant contractors but shall be no less stringent than the minimum requirements set forth in this document.

15.1.2. Specifications and quality standards defined by OEM provider and material suppliers shall supplement the requirements set forth in this document and where conflicts between this document and OEM suppliers exist the installer shall default to the more stringent requirements.

15.1.3. All standards are to be defined and agreed prior to construction start and if necessary shall be modified exclusively through written change order to the scope of work.

15.1.4. Noncompliance to any of the requirements set forth in this document or the design, specifications shall be documented and adjudicated using the Noncompliance Report process. RFIs shall not be used to document and adjudicate deviations to the quality requirements.

15.2. General Requirements

15.2.1. All requirements shall follow the standard order of precedence for construction projects. Where there is disagreement between requirements, the more stringent of standards shall apply. These requirements shall not supersede any requirements dictated by applicable codes or standards of the applicable Authority Having Jurisdiction (AHJ) for the project.

15.3. Project Quality Policy

15.3.1. It is the responsibility of the installation contractor to provide and maintain an effective PQP, in compliance with the contract documents, applicable codes and standards, while providing a safe work environment for employees and subcontractors. The contractor shall ensure the performance of pre-planning, inspection and, when required, testing of all work included in this project. Tests and inspections will be performed to validate the quality of materials, workmanship, and functional requirements mandated by the O&M provider and contract documents. Results of tests and inspections will be documented on the appropriate forms. Contractor shall insist subcontractors and suppliers shall have a written quality program of their own that equals or exceeds the contractor's own quality program. Subcontractor/supplier may adopt Contractor’s quality program; which subcontractor or supplier will adapt to their work.

15.4. Team

15.4.1. Quality Management Team

15.4.1.1. The quality management team will include a designated representative from each stakeholder in the project including the Owner, consultant, third-party inspectors, Contractor and Subcontractors.

15.4.1.2. These team members will be identified early in the project and remain in their respective roles throughout the project.

15.4.1.3. Although it is not necessary to have meetings involving the entire team at one time, members will attend meetings and inspections related to their area of expertise and will verify the quality of the work under their scope on the project.

15.4.2. Personnel

15.4.2.1. Each project will assign quality management duties to suit the size and complexity of the project and assigned staff. This QA/QC plan will identify staff responsibilities. Dual roles may be assigned for small projects. The following is a suggested general assignment of quality management responsibilities for a typical project:

15.4.2.1.1. Project Manager (PM)

The PM is charged with the overall responsibility for the successful completion of the project. The PM's responsibilities include, but are not limited to:

- **i.** Preparing the QMP with assistance of the other members of the project management team.
- **ii.** Initiating pre-installation meetings with Subcontractors.
- **iii.** Monitoring and reporting project progress.
- **iv.** Interfacing with Owner and resolving disputes and complaints.
- **v.** Initiating actions to mitigate quality concerns.
- **vi.** Directing third-party consultants.
- **vii.** Establishing internal review processes for all QMP documents being sent externally.
- **viii.** Establishing documentation procedures.

15.4.2.1.2. Project Superintendent (PS)

The PS coordinates Contractor and Subcontractor activities on the site. The PS's responsibilities include, but are not limited to:

- **i.** Overall responsibility for the site and the site personnel.
- **ii.** Participating in the development of the QMP.
- **iii.** Participating in pre-installation meetings with Subcontractors.
- **iv.** Supervising field personnel for compliance with contract scope and quality requirements.
- **v.** Enforcing implementation of QMP and quality control measures.
- **vi.** Coordinating day-to-day site inspection activities.
- **vii.** Coordinating Contractor's and the Owner's third-party consultants

15.4.2.1.3. Project Engineer (PE)

The PE is responsible for documentation and information flow. The PE's responsibilities include, but are not limited to:

- **i.** Participating in the development of the QMP.
- **ii.** Maintaining and distributing the most current contract documents and approved modifications.

iii. Managing QMP related documents such as inspection reports, photographs, deficiency notices, etc.
iv. Documenting quality-related activities such as pre-installation meetings, first work quality control inspections, deficiency log management, etc.
v. Monitoring subcontractor verification that materials delivered to the site are in accordance with the contract documents and approved submittals.

15.4.2.1.4. Site Quality Manager (SQM)

The SQM's responsibilities include, but are not limited to:

i. Assisting the project management team with the development and execution of the QMP.
ii. Establishing and documenting quality control procedures.
iii. Initiating the pre-installation meetings with Subcontractors and Project team members.
iv. Coordinating Subcontractor communication.
v. Performing and documenting inspections of the Project.
vi. Monitoring Subcontractor compliance with the QMP.

15.4.2.1.5. Subcontractor (SUB)

i. Subcontractor will provide a quality manager for their scope of work.
ii. Subcontractor will resolve deficiencies within 5 business days.
iii. Subcontractor will verify that all materials delivered to the site are approved and correct.
iv. Subcontractor will attend all pre-installation and first work inspections.
v. Subcontractor will provide mockups as required by their contract.

15.5. Quality Control and Assurance

15.5.1. Pre-Installation Meetings

15.5.1.1. Schedule meetings as tasks in the construction schedule and add to submittal schedule.

15.5.1.2. Develop site specific checklists to confirm that the quality requirements for the installation / construction of the project.

15.5.1.3. Use the site-specific checklists for first work inspections and during regularly scheduled site walks.

15.5.2. First Work Inspections

15.5.2.1. Schedule inspections as tasks in the construction schedule and add to submittal schedule.

15.5.2.2. Use checklists and pre-installation meeting minutes to confirm that the work being reviewed meets project requirements.

15.5.3. Site Observations / Issues / Resolution

15.5.3.1. Assigned staff (PS, SQM, SUB) will walk the project regularly and record and transmit deficiencies.

15.5.3.2. All non-compliant work will be resolved in 10 working days.

15.5.4. Testing and Inspection program

15.5.4.1. Review the testing standards specified for equipment installed. Confirm that OEM recommendations are appropriate for the specific project.

15.5.4.2. Review inspection requirements and develop a protocol for notification and resolution of inspection deficiencies.

15.5.4.3. Verify all tools used for testing and inspection is has been calibrated within 12-months.

15.5.4.4. See Appendix B for IMTE Calibration List.

15.5.5. Digital Photographic record

15.5.5.1. Maintain a digital photographic record of installation to begin on day one of construction.

15.5.5.2. Sub-contractors will also maintain a photographic record of all work and existing conditions.

15.5.6. Sub-Contractor requirements and responsibilities

15.5.6.1. Digital photo record of their work.

15.5.6.2. Provide a Quality Management Plan for their work.

15.5.6.3. Provide QA/QC inspections daily/weekly as determined by site specific needs.

15.5.6.4. Install all equipment according to OEM and/or project specifications.

15.5.6.5. Maintain up-to-date punch list and status of punch-list work on-going.

15.5.6.6. Completion of punch-list items.

15.5.6.7. QA/QC punch-list items.

15.5.7. Acceptance (Punch List and Closeout)

15.5.7.1. Completion lists and Punch List

15.5.7.2. As-Built documents

15.5.7.3. Warranties

15.5.7.4. Commissioning

15.5.7.5. Turnover

15.5.8. Electrical Distribution & Communication Components

15.5.8.1. Vaults & Junction boxes

15.5.8.1.1. All electrical and communication above and below ground utility service vaults and junction boxes will be identified. Vaults and junction boxes shall be installed plumb and level and have proper drainage. Manufacturer instructions and recommendations will be followed for proper installation.

15.5.9. Sitework - Roads

15.5.9.1. Roads shall be constructed per the project design. Roads shall be compacted to the requirements based on the soils report, and the Engineer of Record. Testing shall be performed at the recommend intervals by the third-party testing company.

15.5.10. Sitework - Trenches

15.5.10.1. General

15.5.10.1.1. Trenches shall be constructed in conformity with Applicable Law. Trenches shall be constructed with applicable stepping/benching or feature adequate shoring to ensure a safe working environment.

15.5.10.1.2. All cable trenches must follow straight lines between staked points to the greatest extent possible.

15.5.10.1.3. Secondary and service trenches must extend in a straight line from takeoff points wherever possible. The trenches must be dug so that the bottom has a smooth grade. Large rocks, stones and gravel more than ¾ of an inch must be removed from the bottom of the trench.

15.5.10.1.4. Compaction reports shall be provided to the EOR and available for Owner's review.

15.5.10.2. AC / DC PV trenches

15.5.10.2.1. DC PV cable trenches shall be free of rocks, gravel, building rubble, metal, chemically active materials and organic debris prior to installation of cables. Trenches shall feature bedding no less than 3" when bedding is required and compacted to a percentage as determined by the Engineer of Record. Bedding should consist of native materials and if necessary, filtered to achieve the particle size distribution per the Plans and Specifications.

15.5.10.3. Trench backfill and compaction

15.5.10.3.1. The trenches then shall be backfilled with material excavated from the trench or other suitable materials as required. All backfill materials shall be reasonably free of organic materials and rocks ¾ of an inch diameter or larger so as not to cause subsidence or prevent excavation with hand shovels.

15.5.10.4. Non-Trafficable Areas

15.5.10.4.1. For trenches in non-trafficable areas the backfill shall be placed in recommended lifts from the geotechnical report or by the third-party inspector. Trenches shall be compacted to the minimum specifications called out by the EOR or the geotechnical report. Backfill shall be compacted to and tested at intervals not less than 1000'.

15.5.10.5. Trafficable Areas

15.5.10.5.1. For trenches under roads or other locations where vehicles will cross the trench backfill shall be placed in recommend lifts from the geotechnical report or from the third-party inspector. Backfill shall be compacted to minimum requirements stated by the EOR at intervals not less than 1000’.

15.5.11. Foundations

15.5.11.1. Racking Foundations (rotation)

15.5.11.1.1. Square or rectangular racking foundation piles or tubes shall be installed with a rotation of no greater than that allowed by the racking manufacturer.

15.5.11.2. Racking Foundations (plumb)

15.5.11.2.1. Racking foundations shall be installed at a variance of no greater than the degrees from plumb in either the North- South and/or East-West directions as allowed by the racking manufacturer.

15.5.11.3. Racking Foundations (embedment)

15.5.11.3.1. The embedment of racking foundations shall be determined and defined in the design documentation. Racking foundations shall not be installed where the top of the foundation interferes with PV modules or restricts vertical adjustment of the racking table/sub-array.

15.5.11.4. Racking Foundations (row-row spacing)

15.5.11.4.1. Row-Row spacing shall be determined and defined in the design documentation.

15.5.11.5. Inverter SS Foundation

15.5.11.5.1. Inverter SS foundations shall be installed in accordance with the design documentation. Pile foundations shall be installed to design height as specified by the EOR, rotation from true North shall be no greater than that allowed by the EOR.

15.5.11.5.2. Inverter SS foundations shall be galvanized or otherwise protected from corrosion.

15.5.12. Racking

15.5.12.1. General

15.5.12.1.1. Racking shall conform to the manufacturer’s recommendations or the design documents. The installation of the racking system will follow the guidelines specified in the manufacturer’s installation manual.

15.5.12.2. Racking Fastener Requirements

15.5.12.2.1. All racking fasteners shall comply with the racking manufacturer’s recommendations and requirements. If such requirements are not specified, torque values shall not exceed ASME requirements for the fastener type, size and materials.

15.5.13. Cabling

15.5.13.1. General

15.5.13.1.1. All cable shall be visually inspected upon arrival at the site to ensure cable has not suffered physical damage during shipment. Testing of suspect cable can be undertaken to confirm if observed physical damage has resulted in permanent conductor damage. Visual inspection shall also confirm delivered cable conforms to the purchase specifications.

15.5.13.1.2. All cable shall be tested per applicable testing standards defined by the Institute of Electrical and Electronics Engineers (IEEE), Insulated Cable Engineers Association (ICEA) and International Electrotechnical Commission (IEC).

15.5.13.2. AC & DC Cable installation (visual & mechanical inspection)

15.5.13.2.1. All cable shall be visually inspected for damage upon delivery acceptance, during storage, before installation and prior to backfill of underground cable. Under no circumstances shall damage cable insulation be acceptable for any installation.

15.5.13.2.2. Cable reels shall be inspected prior to cable installation to ensure objects will not damage cable insulation during installation processes. The inside surface of wooden reel flanges shall be inspected and free of objects such as nails, screws, staples, wood burrs and chips.

15.5.13.2.3. All torque values for electro-mechanical connections will be verified with a 10% random check by Contractor.

15.5.14. Underground Electrical Collection System

15.5.14.1. Medium voltage cable must be inspected during installation. If a trenching installation method is used, the cables, fiber, ground wire and warning tape shall be inspected during and after they have been installed in the trench and prior to backfill. Inspection should cover cable and reel information, damage to cable, spacing, depth, bedding requirements, etc. Verification that cable meets approved submittal documents (cable manufacturer, size, etc.) must occur at each inspection.

15.5.14.2. Red-line drawings must be updated and reviewed by the subcontractor on a regular basis. Red-line drawings must be submitted to the Engineer of Record who will create the final as built drawings per contract requirements.

15.5.14.3. AC and DC Low Voltage cable must be tested after installation for phase or polarity markings and confirmed by continuity tests.

15.5.14.4. MV terminations and cable splices, shall be installed by qualified persons using approved methods and materials by the Engineer of Record and termination/splice manufacturer and located per project specifications. The termination/splice shall be inspected during cable preparation, before heat shrink is installed and after the heat shrink is installed. The company performing the terminations/splices shall protect the area of work from blowing dirt and dust to reduce the chances of contamination.

15.5.14.5. Insulation-resistance tests (“Megger”) will be completed on all low and medium voltage AC and DC power cables, unless otherwise specified. Megger testing procedures must meet NETA and IEEE requirements and shall be reviewed by the Engineer of Record, and Owner’s Project Engineer.

15.5.14.6. Very Low Frequency (VLF) testing will be performed on branch circuit feeder cable runs and performed in accordance with NETA and IEEE requirements.

15.5.14.7. Inspect bolted electrical connections for high resistance using one or more of the following methods:

15.5.14.7.1. Low-resistance ohmmeter

15.5.14.7.2. Verify tightness using a calibrated torque wrench

15.5.14.7.3. Perform a thermographic survey

15.5.14.8. Inspect shield grounding, cable supports and terminations.

15.5.14.9. Verify cable bends meet or exceed ICEA and manufacturer’s minimum bending radius.

15.5.15. Cable Terminations

15.5.15.1. All compression type cable terminations will be made in accordance with manufacturer recommended processes, terminals, mechanical crimp equipment and compression dies. Terminations will be made in accordance with all applicable electrical codes and standards. Terminations will be inspected prior to circuit energization.

15.5.16. Cable Conduit

15.5.16.1. All conduits shall feature bell-end fittings or smooth transitions.

15.5.16.2. All conduits shall use sweeps that maintain the minimum bending radius of the cable whenever the conduit changes direction.

15.5.17. Disconnect DC cables

15.5.17.1. All wires must have an identification label applied. The label must be legibly printed and of such material as to remain in place for a minimum of 10 years.

15.5.17.2. Any un-terminated and unused cable must be identified and labeled accordingly. Unused cable must be secured and electrically isolated in such a way as to not be hazardous to qualified service personnel working on or inside the enclosure.

15.5.17.3. The quality of DC cable installation and termination will be inspected inside each disconnect box. Items, such as, wire bend radius, wire lay or routing, labeling, wire strip length, and pull tension will be observed. Loose wire strands from PV source circuits or DC feeder cables will not be tolerated and will be promptly corrected. All screw type wire terminals, including ground terminals, will be torque checked and marked accordingly.

15.5.17.4. Anti-oxidizing compounds will be applied to appropriate aluminum/aluminum and aluminum/copper/tinned copper lug type terminations. Each will require a specific type of compound. Ground terminations provided above ground are not required to have anti-oxidizing compound applied.

15.5.18. Fiber Optic Cable Installation

15.5.18.1. Labeling

15.5.18.1.1. Each cable is to be permanently labeled at each end with a unique cable number. In addition, labels shall be affixed to the cable/inner duct at every transition of a vault, hand hole, riser closet, or major pull box.

15.5.18.2. Fiber Termination Standards

15.5.18.2.1. The terminal ends of all fibers cable strands shall be field connectorized. The connectors shall be mounted on bulkheads and installed in enclosures called Fiber Integration Centers (FIC). The choice of termination method must be in accordance with the Engineer of Record.

15.5.18.3. Fiber Cable Testing

15.5.18.3.1. Installation and termination:

15.5.18.3.2. All single mode and multi-mode fiber strands shall be tested end-to-end for bi-directional attenuation, 850 nm/1300 nm for multimode and 1310 nm/1550 nm for single-mode fibers. Tests should be conducted in compliance with EIA/TIA-526-14 or OFSTP 14, Method B, according to the manufacturer's instructions for the test set being utilized.

15.5.18.3.3. Tests must ensure that the measured link loss for each strand does not exceed the "worst case" allowable loss defined as the sum of the connector loss (based on the number of mated connector pairs at the EIA/TIA-568 B maximum allowable loss of 0.75 dB per mated pair) and the optical loss (based on the performance standard above, Section 2.1.1 and Section 2.2.1).

15.5.18.3.4. After termination, each fiber shall be tested with an OLTS / OTDR for length, transmission anomalies, and end-to- end attenuation. Results are to be recorded and supplied to the Engineer of Record and the Owner's project engineer. Test results will be supplied in the form of hard-copy printouts or photographs of screen traces.

15.5.18.3.5. After termination and bulkhead mounting, each terminated fiber is to be tested for end-to-end loss with a power meter/light source. Results are to be recorded and supplied to the Engineer of Record and the project engineer. Test results will be supplied in the form of hard-copy printouts or photographs of screen traces.

15.5.18.3.6. The maximum allowable attenuation for any splice or termination is 0.3 dB. (Or OEM spec).

15.5.18.3.7. The contractor or sub-contractor shall review all end faces of field terminated connectors with a fiber inspection scope following the final polish. Connector end faces with hackles, scratches, cracks, chips and or surface pitting, shall be rejected and re-polished. Terminated connectors will be replaced if re-polishing will not remove the end face surface defects. The recommended minimum viewing magnifications for connector ends are 100X for multi- mode fiber and 200X for single-mode fiber.

15.5.19. Electrical

15.5.19.1. General

15.5.19.1.1. The purpose of this section is to establish the quality assurance methods and procedures for installation, examination, testing and acceptance of electrical equipment and material during construction, installation, and pre-commissioning.

15.5.19.1.2. Prior to execution of work, a planning meeting shall be held.

15.5.19.1.3. All equipment, materials, products, design and construction shall be incompliance with contract documents, design drawings and specifications and the requirements of this section.

15.5.19.1.4. Contractor shall comply with manufacturers' installation instructions. If manufacturers' instructions conflict with the Agreement, the Project Manager shall request clarification through the RFI process before proceeding. Store and protect material and equipment prior to installation per manufacturer's instructions. Submit manufacturer's operation and maintenance manuals and information to Owner and provide instruction to Owner per contract documents.

15.5.19.1.5. All testing and installation shall comply with applicable and/or specified standards, tolerances, codes, or requirements. It is the responsibility of contractor to ensure equipment is properly tagged and marked as required by applicable codes and specifications.

15.5.19.1.6. Pre-commission energization of electrical equipment will be conducted only when specified and only with permission from contractor and owner. All lockout and tagout procedures shall be followed. All parties shall be informed of energization before it takes place. Contractor shall have and maintain zip-tie type LOTO; gang clasps and locks will be used for special conditions on site for LOTO purposes.

15.5.19.1.7. Factory acceptance test reports shall be provided and submitted to Contractor and the Engineer of Record for review and approval. These tests include but are not limited to medium voltage cable, transformers, and fiber optical cable.

15.5.19.1.8. Perform system functional testing after component acceptance testing is complete to verify that all equipment and systems will operate properly. Notify owner/customer in advance to allow them to witness.

15.5.19.1.9. Functional test reports will be submitted to Contractor within the time specified, not to exceed ten (10) calendar days of completion, indicating observations, results of tests and compliance with the Agreement. Reports indicating non-compliance with the Agreement shall be submitted to Contractor within ten (10) calendar days of completion.

15.5.19.1.10. If necessary to comply with manufacturers' warranty terms or if specified in contract documents, arrange for material or equipment suppliers or manufacturers to provide qualified staff personnel (field representative) to perform certain work scopes such as inverter commissioning.

15.5.19.1.11. Contractor must comply with NEC, NESC, NETA, and applicable ASTM/ANSI requirements unless more stringent testing protocol(s) are required or established by the contract documents. Comply with local utility company requirements or owner's/customer's standards as applicable. Provide and document independent electrical inspection from local authority having jurisdiction for NEC compliance.

15.5.19.1.12. Subcontractors shall provide installation procedures, specific to the activity, when the work being installed crosses over or under any live overhead lines, transmission lines, substations, fiber optic lines, gas lines, utility lines, canals, aqueducts, water mains, public roads or rail roads.

15.5.20. Receiving, Storage, Testing and Inspection

15.5.20.1. The purpose of this section is to ensure that receiving, inspection and testing requirements as required by applicable codes, standards or regulatory bodies, and project contract documents, are fulfilled by the contractor. All work including direct and indirect purchased material and equipment within the scope of work described by the project contract, is covered by this procedure.

15.5.20.2. All incoming material and equipment shall be subject to a receiving observation upon arrival. The receiving observation shall be performed to assess the condition of the item(s) being received including verification of quantities, model numbers, and serial numbers, and mark numbers, compliance with the contract or other documents. Visual observation or non-destructive testing for damage or deterioration, and compliance with applicable design tolerances will also be completed.

15.5.20.3. A photographic record shall be made of all incoming materials and equipment which are damaged, deteriorated or suspected of damage or deterioration. Small damages (paint scuffs, discoloration, small dings, rough surfaces, etc.) shall be noted and evaluated on an individual basis.

15.5.20.4. All deliveries shall be logged into documentation management programs or a suitable delivery log on regular intervals.

15.5.20.5. All testing, including welding, shall be performed in accordance with applicable codes, standards or regulatory bodies. Test reports shall be generated by the party performing the test and provided to contractor within ten (10) calendar days of completion. Copies of all tests results and reports are to be provided to Owner’s project engineer within 30 days of receipt.

15.5.20.6. During the term of storage, material / equipment shall be maintained as required by the contract documents. If special storage requirements are necessary, the supplier or owner, if applicable, will provide information for proper storage.

15.5.21. Site Fencing

15.5.21.1. Verify all posts are installed plumb and true. End, corner and pull posts are firmly anchored and supported. Fabric and tension wires shall be tight and secure. Fabric to be continuous between stretch bars. Wire ties / hog rings shall be the same material as fencing fabric.

15.5.21.2. Gates shall be installed plumb, level and secure. Gates shall swing and move freely without binding. Verify gate stops are installed, plumb and secure.

Appendix A – IMTE Calibration List

Trade/User	Tool	Measurement Type	Tool Tolerance
Pile Driving	Digital Level	Degrees	±1.5°
Racking	Torque Wrench	Ft-lbs or nm	4:1 or Greater
String Testing	Voc / Isc	V & mA	±1V , ±10mA
Megger	Insulation tester	Ohms	25ohm, 4:1 or Greater

Appendix B – QAQC Checklists

Panel Delivery
Receipt of panels
Inspection of panels upon receipt
Tracking of received panels
Acceptance of received panels

AC & Fiber Trenching QAQC
Verify Trenching Width and Depth (30"x Max. 54" Deep) Verify Trench Bedding (3" Min.)
Verify Bedding is Free of Rock/ Debris Prior to Placement of Cable Verify AC Conductor Size and Quantity
Verify Horizontal Spacing of Conductors (2" Min.)
Verify Horizontal Spacing Between Different Circuits in the Same Trench (4" min) Confirm All Conductors are not Visually Damaged
Verify Vertical Spacing of Conductors (6" Min.)
Verify Warning Tape is Properly Placed (12" Below Grade) Verify Compaction is Per the Plans and Specifications
Verify Fiber Cable Conductor Size and Quantity
Verify Fiber Cable Conductor Spacing from AC Conductor (6") Verify Correct Size Ground Wire

QAQC DC WIRE TRENCHING CHECKLIST
Verify Trenching Width and Depth (Min. 30"x Max. 42")
Verify Bedding is Free of Rocks/Debris Prior to Placement of Wire Verify DC Conductor Size and Quantity
Verify Horizontal Spacing of Conductors (Min. 2") Confirm Conductors are Not Visually Damaged Verify Vertical Spacing of Conductors (Min. 4")
Verify Warning Tape is Properly Placed (12" Below Grade) Verify Compaction Per the Plans and Specifications

QAQC IES TRENCHING CHECKLIST
Verify Trenching Depth matches of the depth of the conductors coming into the IES Pad Verify Conduit Layout Spacing is Correct
Verify the Number of Conduits is Correct Verify the Size and Type of Conduit is Correct
Verify the Conduit Stub Ups have an End Bell on the Ends to Protect the Cable Verify the Conduit is Plumb and Level
Verify the Height of the conduit so it makes it into the Cabinet in the Transformer or Skid Verify the Conduit is not damaged before backfilling
Verify Bedding is Free of Rock/Debris Prior to Placement of Wire Verify Warning Tape is Properly Placed (12" Below F.G.)
Verify Proper Compaction Per the Plans and Specifications

QAQC IES GROUNDING CHECKLIST
Verify IES Grounding Layout per Blymyer Drawings Verify Depth of Ground Ring (30" min.)
Verify Ground Ring Connection
Verify Depth of Ground Rod (9'-6" min.)

QAQC INVERTER SKID PILES/ WELDING CHECKLIST
Verify Pile Embedment (3'-2" Max. Projection Above F.G.)
Verify Pile Size (W6x7)
Verify Pile Spacing and Orientation Per Blymyer Drawings Verify Plate Size (8"x8"x.5")
Verify Weld Plates are Installed and Level Verify Plates Have 3-(3/16") Field Fillet Welds

Verify Skid is Set with The Transformer and Inverters Orientated Per Plan Specifications Verify If A Shim Has Been Inserted Between Inverter and Plate

QAQC PILE INSTALLATION CHECKLIST
Verify Corner Piles Are in Proper Location
Verify Correct Row Spacing: 23'-0" (GCR 28.6%) Verify Correct Pile Spacing Per Blymyer Drawings
Verify Correct Array Pile Size, Projection, and Embedment Verify Correct Motor Pile Size, Projection, and Embedment Verify Pile Sizes Are in Correct Location
Verify Motor Row Alignment Check Top for Damage/ Paint

QAQC RACKING INSTALLATION CHECKLIST
Verify Torque Tube Size, Gauge, Elevation and Alignment
Verify Bearing Housing Assembly is Visually Leveled and Aligned with the Torque Tube and Piles per the Racking Install Manual
Verify BHA Rail is seated and flush with torque tube
Verify No Gaps between (BHA) Bearing Housing Assembly, BHA Mounting Bracket and the Pile Verify the Right Size Bobtail Pins and Collars are Installed in the Right Locations
Verify Motor is Orientated on East Side of Slew Gear
Confirm All Bolts on Slew Gear Assembly are Torqued Per Nextracker Manual and have Torque Marks Verify Installed BOMs have been galvanized
Verify SPC Box Aligned, Secured, and Orientated on South Side of Slew Gear
Verify the Interior Rows have an Interior Slew Gear and the Exterior Rows have an Exterior Slew Gear Verify Antenna is Connected to SPC Box
Verify Damper Location, Mounting Spacing, and Orientation
Verify All Bolted Connections are Torqued to Right Value and Marked per the Racking Install Manual Verify End Caps are Installed

QAQC MODULE INSTALLATION CHECKLIST
Verify Module Is Centered Over Torque Tube Verify Module Spacing from Middle of Slew Gear
Verify the Right Module Wattage is in Right Location Verify the Right Type of Rail is Installed in Right Location
Verify All Rails are Leveled Within 0 Degrees Relative to the BHA Module Rails Before Fastening Verify Holes in Module Frames Align with the Holes on the Rail
Verify Module is Aligned on Both Sides and Fasten with the Right Size Bobtail Pin and Collar Verify Torque Marks on All Module Rail Straps
Verify Modules are Not Visually Damaged

QAQC STRING WIRE CHECKLIST
Verify all wires are fully plugged in and clicked closed Verify No Wires are Hanging
Verify Zip Ties are Properly Installed with a Minimum of ¼" of tail Verify Wire is Not Sagging
Verify No Sharp Edges Near Wire

QAQC DISCONNECT SWITCH CHECKLIST
Verify DS Piles Are in The Correct Location and Elevation Verify Disconnect Switch Location
Verify Stub Up Location
Verify Switch Height (Min 1'-6") above ground Verify Disconnect Switch String Count
Verify Disconnect Switch Has a Name Plate and Free of Damage Vertical Stub Up Conduit is Not Damaged and Plumb
Verify Outside of Switch Is Not Damaged

Verify Correct Disconnect Switch Pile Size and Embedment Verify Switch is Plumb

15.5.22. Civil

15.5.22.1. The testing requirements identified in this section apply to all civil work for the Project including access roads, foundations, collection, transmission, substation, electrical equipment enclosure, O&M building, etc.

15.5.22.2. Earthwork

15.5.22.2.1. All common, select, or granular fill material shall be qualified by testing to assure minimum gradation requirements. Material selected for use as fill, shall be sampled and a gradation test performed in accordance with ASTM C136. A gradation test shall be performed at a frequency of one for each source or each 10,000 cu. yds. of fill placed. On-site excavated material or imported material from other sources must be tested.

15.5.22.2.2. Soils used for Fill Material shall be tested for Grain Size Analysis (AASHTO T27), Atterberg Limits (AASHTO T89 and T90), Moisture Content (AASHTO T265), Proctor Tests (AASHTO T99), and LA Abrasion Tests (AASHTO T96). Tests shall be performed at a frequency of one for each source or 10,000 cubic yards of filled placed.

15.5.22.2.3. For placed and compacted fills for wind turbine foundations, provide one relative moisture and compaction test per lift indicating test location, dry density, moisture content and % proctor maximum dry density.

15.5.22.2.4. For placed and compacted fills for other locations, provide the greater of 3 relative moisture and compaction tests per lift or 1,000 cubic yards placed, indicating test locations, dry density, moisture content and % Proctor maximum dry density.

15.5.22.2.5. Compaction tests shall be taken as required by the Design Documents. In the event of failed tests, Contractor shall not place additional fill until acceptable test results are obtained.

15.5.22.3. Crane Pads

15.5.22.3.1. Provide adequate testing, as specified by Engineer of Record, to ensure field subgrade bearing capacities meet or exceed main erection crane bearing pad and critical lift requirements.

15.5.22.4. Access Roads

15.5.22.4.1. Compacted Subgrade

a. Access roads shall be proof-rolled the full length in the presence of a geotechnical engineer or qualified and approved representative with a loaded tandem axle dump truck having a minimum gross weight of 25 tons. Subgrade shall be corrected if rutting greater than 1.5 inches and/or “pumping” of the subgrade occurs.
b. The method to scarify, dry and recompact subgrade shall not be allowed unless the material is proven not to contain organic material and/or material unable to remain compacted during or after a rain event.
c. The requirements set forth in Section 15.5.22.5 shall be met if access road subgrade is cement stabilized.

15.5.22.4.2. If applicable Nuclear Density Tests (AASHTO T310) shall be taken every 500 linear feet of road or a minimum of 3 tests per access road.

15.5.22.4.3. Aggregate Base and Top Course

a. Entire road length shall be proof-rolled. Where geogrid membrane is used, a Dynamic Cone Penetrometer (DCP) test (ASTM D6951) shall be taken at a frequency of 1 for every 500 lineal feet of road. A DCP test shall also be taken at a frequency of 1 for every 500 lineal feet of road in areas where an initial proof-roll test has failed. A sieve analysis shall be taken for placed base material and cap material at a frequency of 1 for every 2500 cu yd. A minimum of 2 standard Proctors should be performed on the road base and top course aggregate materials.

15.5.22.5. Cement Stabilization

15.5.22.5.1. Density tests shall be taken at the rate of one test every 1,000 square yards (i.e., approximately seven tests per eight ft. pass per mile).

15.5.22.5.2. Subgrade strength testing by DCP shall be done randomly for every 300 LF in each pass of the reclaimer. After at least two days of production, or when the engineer of record deems the procedure satisfactory, the testing may be increased to every 500 LF. Subgrade strength testing shall be done at 24 hours (plus or minus 4 hours) from the time of final compaction of the stabilized material. A minimum of 15 CBR is required prior to proof rolling by Contractor.

15.5.22.5.3. Additional subgrade strength testing by DCP shall be done at two to seven days from the time of final compaction on a 500 LF spacing. The test must confirm a CBR of 20 is achieved. If a CBR of 20 is not achieved, additional gravel surfacing will be required and the cement content for future stabilization will be adjusted.

15.5.22.5.4. Prior to placement of gravel surface, the subgrade shall be proof-rolled.

15.5.22.6. Concrete Works

15.5.22.6.1. All concrete, reinforcement, anchor bolts, embed plates, formwork, etc. shall be inspected per the current International Building Code (IBC), Chapter 17, “Special Inspections.”

15.5.22.6.2. General Concrete Tests

a. Tests shall be conducted by an independent third-party in accordance with ASTM standards. The location, date, mix, temperature, slump and percent air shall be recorded. Concrete deliveries that do not meet the design specifications shall be rejected.

b. Cast cylinders at least once per day, between batches of differing concrete mix designs, or for every 150 cubic yards of concrete placed. Perform laboratory strength testing per ASTM C39 at 7, 14, and 28 days.

c. Perform a minimum of one air test in accordance with ASTM C231 per set of strength test cylinders cast.

d. Perform a minimum of one slump test in accordance with ASTM C143 per set of strength test cylinders cast.

e. Cast a minimum of nine grout cubes for each foundation and perform laboratory strength testing in accordance with ASTM C109 at 3 and 28 days.

f. Each test cylinder shall be identified by number and record each concrete truck number, date and time batched, number of yards, additives in the mix, the time the concrete was placed, and the structure number of the foundation poured. These records shall be reviewed by the Engineer of Record and submitted to Owner. Test reports shall be labeled in a manner that will allow each test cylinder to be identified with a particular day, time, concrete truck, and structure number.

g. A report of each test cylinder break shall be e-mailed to the Engineer of Record, Owner, and concrete supplier within 2-business days from date of test.

h. Concrete that appears to be of low strength, as evaluated by ACI 214R - Guide to Evaluation of Strength Test Results of Concrete, shall be replaced at no additional cost to Owner.

15.5.23. Electrical

15.5.23.1. Collection

15.5.23.1.1. Upon completing installation of all systems and equipment, but prior to electrical substantial completion, Contractor shall conduct an operational test of all equipment, controls, and devices installed or modified by Contractor.

15.5.23.1.2. Contractor shall notify Owner in writing a minimum of three (3) Business Days in advance of any test. This operational testing is in addition to testing required in separate sections of this specification. Where possible, combination of this testing and other testing required should be accomplished to minimize travel requirements.

15.5.23.1.3. Power Cable Acceptance Testing

Installations of power cable including terminations are to be acceptance tested using D-C or low frequency AC high potential (Hipot) testing, and at a minimum to include the following tests. After completion of a test and before handling the cable, the conductor shall be grounded to permit any charge to drain to earth.

a. Continuity -After installation of the cable and prior to the high potential test specified below, a simple continuity test shall be conducted on the system. This can be accomplished by grounding the conductor at the source and checking for continuity from the end of each tap with an ohmmeter.

b. Cable Jacket Integrity Test -Cable Jacket integrity testing shall be performed on all collection cables. Defects or damage to cable jackets shall be repaired using a cable OEM approved method, or the damaged cable section shall be replaced.

c. High Potential - After successful continuity tests of the 34.5 KV collection system, high potential tests on each length of cable, with terminations in place but disconnected from the system. The installation shall withstand a minimum of fifteen (15) minutes D-C test potential or as recommended by the cable and connector manufacturers. The voltage may either be increased continuously or in steps to the maximum test value.

d. If increased continuously, the rate of increase of test voltage should be approximately uniform and increasing to maximum voltage in not less than ten (10) seconds or more than sixty (60) seconds.

If applied in steps, the rate of test voltage increase from one step to the next should be approximately uniform. The duration at each step shall be long enough for the absorption current to attain reasonable stabilization (one minute minimum). Current and voltage readings should be taken at the end of each step duration. The number of steps should be from five to eight.

Once VLF testing has been completed a test voltage shall be applied to the collection feeder riser conductors. Every switchgear in that feeder should then be checked with a multimeter to verify collection phasing. This test can only be conducted once all collection cable has been terminated and landed for each feeder.

e. If more than three failures of any particular component occur within six months of commercial operation, then partial discharge testing shall be performed on all similar components.

f. Other Test and Inspections: All other tests and inspections described in the Project Quality Assurance Plan.

15.5.23.1.4. Padmount Transformer Testing

a. The following transformer checks and tests shall be completed on all units:

b. Inspection of satisfactory mechanical installation including proper torque on bolts, labeling and grounding.

c. Insulation resistance test for winding to winding and each winding to ground. Calculate Polarization Index.

d. Field test of transformer turns ratio test on all taps.

e. Routine and Design tests specified for Class I power transformers identified in IEEEC57.12.00 2010 table 18

f. Oil analysis for visual inspection, gas, liquid screen, and Karl Fischer moisture at minimum.

g. All other test and inspections described in the Project Quality Assurance Plan.

15.5.23.1.5. Quality Control Testing

Upon completing installation of all systems and equipment, but prior to electrical substantial completion, Contractor shall conduct an operational test of all equipment, controls, and devices installed or modified by Contractor.

Contractor shall notify Owner in writing a minimum of three (3) Business Days in advance of any test. This operational testing is in addition to testing required in separate sections of this specification. Where possible, combination of this testing and other testing required should be accomplished to minimize travel requirements.

15.5.23.2. Transmission Line

15.5.23.2.1. A visual inspection of phasing and overall construction shall be conducted by all interested parties prior to energization.

15.5.23.2.2. Ground resistance testing.

15.5.23.2.3. OPGW

a. Pre-installation Acceptance Testing

Contractor will require the cable manufacturer to ship the cables such that both cable ends are exposed allowing for testing in both directions

After the fiber optic cables are received, but prior to Contractor installing the cables, Contractor shall make sure there has been a bidirectional OTDR test of the cables on the reels. All fibers shall be tested.

All testing shall be done at both optical wavelengths 1300 and 1550 nanometers and results recorded and copies of the testing supplied to Owner. These tests shall be compared with the reel tests performed by the manufacturer. Contractor shall immediately report any discrepancies, defects or anomalies to the supplier and is responsible for any replacement costs incurred.

b. Installed Testing

After installing the fiber optic cables and after all required splicing and termination work, Contractor shall perform a final bidirectional OTDR test on each cable segment. All terminated fibers shall be tested from termination to termination.

Testing shall be performed for each fiber at two wavelengths (1300 and 1550 nanometers). The OTDR shall have a hardcopy feature and digital storage media compatible with standard software such as Excel or Word.

Each OTDR trance shall be identified by fiber ID (tube/color or number), end points (by site name), and launch point. Contractor shall completely investigate any discrepancies, defects or anomalies, as indicated by Owner immediately. Any damage to the fiber optic cables detected during final testing shall be repaired by Contractor at Contractor's sole expense.

In addition to OTDR testing, an optical attenuation test shall be performed on selected fiber circuits. This test shall be performed at 1300 and 1550 nanometers, using a calibrated light source and optical power meter.

Any cable that is tested with negative performance characteristics will be replaced or adjusted as necessary.

Copies of the test results shall be submitted to Owner and Engineer of Record for review and approval prior to final acceptance.

15.5.24. Substation

15.5.24.1. Tests

15.5.24.1.1. Upon completing installation of all systems and equipment, but prior to electrical substantial completion, Contractor shall conduct an operational test of all equipment, controls, and devices installed or modified by Contractor.

15.5.24.1.2. Contractor shall notify Owner in writing a minimum of three (3) Business Days in advance of any test. This operational testing is in addition to testing required in separate sections of this specification. Where possible, combination of this testing and other testing required should be accomplished to minimize travel requirements.

15.5.24.1.3. For the following sections, the term “function” or “function testing” means applying the appropriate inputs (voltage, current, pressure, temperature, etc.) to a device, and verifying all required responses or outputs. Testing shall be completed on the specified equipment after it is fully assembled and installed at its permanent location. The types of tests covered by this criteria document include, but are not be limited to the following:

15.5.24.1.4. In general, all equipment will require the following:

a. Inspection - Visual and mechanical inspections shall be performed.
b. Verify the nameplate data against the design criteria and the "Bill of Materials".
c. Check that there are no broken or cracked parts or other physical damage. Check that screws are tight. This includes relays, synchronizers, cases, and covers.
d. Check devices for moisture or damage from moisture and foreign materials that could inhibit the proper operation and functioning of the devices.
e. Check for proper contact alignment and travel, disc rotation for freedom of movement, target operation, etc. Adjust mechanical alignments per the manufacturer's specification.

15.5.24.2. Grade Tolerances

15.5.24.2.1. Grade for “rough grade” elevations shall be established to a tolerance of ± 5/8”. Horizontal plan dimensions shall be maintained within 0.05 feet of plan location. Road elevations and line shall be located within the same tolerance limits.

15.5.24.3. Structural Steel Erection

15.5.24.3.1. Contractor shall accommodate all inspection and testing activities of high-strength bolted connections and field-welded connections by Owner. Contractor shall perform tests and prepare test reports as required to ensure the complete and finished erection of steel structures.

15.5.24.3.2. Contractor shall document all non-conformances, deficiencies, or deviations identified during the inspection and test process in detail through their non-conformance reporting process and submit to the Company for review and approval of the resolution. Deficiencies revealed through inspections and laboratory tests which are determined to be in non-compliance with this Specification shall be corrected at Contractor's expense. Additional tests shall be performed at Contractor's expense, as necessary, to remove a non-compliance of the original steel erection.

15.5.24.3.3. Bolted Connections

- Field bolted connections shall be inspected in accordance with AISC specifications using the turn of the nut method.

15.5.24.3.4. Field Welded Connections

a. Contractor shall perform inspection and testing of field welded connections during the erection of the structural steel. The following activities shall be performed:

b. Visual inspection of all welds for weld profile and surface defects.

c. Instrument inspection of selected welds to check for defects and discontinuities which are not visible on the surface involving one or more of the following methods:
    - Ultrasonic Inspection: ASTM E 164.
    - Magnetic Particle Inspection: ASTM E 709; performed on root pass and on finished weld. Cracks or zones of incomplete fusion or penetration are not acceptable.
    - Radiographic Inspection: ASTM E 94 and ASTM E 142; minimum quality level "2-2T."
    - Contractor shall record the types and locations of any defects found in field welds and will outline work to be performed by Contractor to correct all deficiencies in field welded connections.

15.5.24.4. Individual Equipment Testing

15.5.24.4.1. Power Transformers

a. Main Power Transformers shall be tested from the field device to the EEE.

b. See for more information.

15.5.24.4.2. Circuit Breakers

a. Physical Testing
    - Fill with gas (SF-6 breakers only) and have SF-6 tested as required.
    - Connect operating Linkage (for independent pole breakers)
    - Perform Hi-Pot vacuum bottles and check measurements (vacuum breakers only)

- Perform visual and operational check of mechanism
- Perform timing and velocity tests
- Perform power factor test on individual bushings and overall power factor
- Sniff/soap for leaks on gas breakers
- Measure contact resistance

b. Control Testing
- Perform current transformer (CT) Tests
- Local checks at the breaker:
- Check function of heater circuit.
- Check function of controls (trip, close, block trip/close, dual trip coil, anti-pump, etc.)
- Check alarms to terminal blocks
- Check labeling of fuses, switches and relays
- Check calibration of relays at breaker
- Wire check AC circuit
- Calibrate relaying
- All associated breaker failure relays
- All associated sync-check and voltage monitoring relays
- All associated reclosing relays
- Any synchronous pole operation controls
- All associated PLC/DCS alarm and control schemes

15.5.24.4.3. Circuit Switchers and Motor Operated Disconnect Switches

a. Physical Testing
- Verify pole synchronism. Switches should be adjusted to manufacturer tolerances.
- For Circuit Switcher and interrupter type devices, perform insulation resistance tests on each pole in accordance with the manufacturer's recommendations.
- Measure the contact resistance across each closed switchblade.
- High-Pot vacuum bottles
- Power factor test on individual bushings and overall power factor
- Check and align switch/fuse combinations
- Verify that expulsion limiting devices are present on all holders having expulsion type elements.
- All problems shall be resolved and all adjustments completed prior to driving the piercing bolts.
- For Circuit Switchers, interrupters, and similar devices, check the timing of the shunt trips and the mechanical trips on the attachments.

b. Control Testing (MOD’s and Circuit Switchers Only)
- Check function of heater circuit.

- Check local function of limit switches.
- Verify proper cam positioning.
- Check local function of interlocks.
- Check function of controls from control house.
- Test and document EMS control and status

15.5.24.4.4. Capacitor Banks

a. Physical Testing
   - Measure and record capacitance of strings/series groups with capacitance meter.
   - Verify equipment is properly grounded

b. Control Testing
   - Perform Current Transformer (CT) Tests
   - Perform VT testing
   - Perform capacitance value check - by voltage method (fuseless only) verify equal voltage distribution across each can
   - Perform wire check of AC circuits
   - Calibrate relaying
   - Verify metering calibration
   - Verify function of control circuits
   - Test alarms to annunciator and to RTU/PLC (remote terminal unit) inputs
   - Test and document EMS analog, control, alarms and status

15.5.24.4.5. Transmission Line Relaying

a. Control Testing
   - Wire check AC circuits
   - Check Line VTs
   - Perform manufacturer’s acceptance tests for all line relays
   - Calibrate relaying, and verify settings for all line relays
   - Set up pilot relaying and transfer trip equipment common to all piloted systems
   - Apply settings
   - Perform “back to back” local function tests
   - Perform “end to end” piloted relaying and transfer trip tests
   - Record installed signal receive levels
   - Check alarms to annunciator and EMS
   - Tone equipment
   - Carrier equipment
   - Verify metering calibration
   - Function relaying control circuits
   - Perform tuning of carrier equipment on ungrounded line
   - Test and document EMS analog, control, alarms and status

- Download as-left relay setting files and turn as-left setting files over to Owner.

15.5.24.4.6. SCADA Systems and Annunciators

a. SCADA Tests
   - Set-up Remote Terminal Unit (RTU) equipment
   - Function test all control, indication, alarm, and analog points in the RTU, to and from the EMS. Verify SCADA descriptions match inputs.
   - Test for connection and functionality to the Turbine Supplier's SCADA system.

b. Traditional Annunciator Tests
   - Check all points including spares along to verify operation of lights, bells, cutoffs, and resets.
   - Verify labeling matches print and is to standard

c. Programmable display panel tests
   - Load configuration software
   - Verify labels are correct in both the schematic and settings spreadsheet.
   - Save final configuration to disk to leave on site.
   - Supply final configuration files to Owner.

15.5.24.4.7. Substation Batteries & Chargers

a. Physical Testing
   - Clean, lubricate and install inter-cell connectors.
   - Torque inter-cell connectors to manufacturer's specifications
   - Measure and record resistance of inter-cell connectors
   - Test DC voltage (float & equalize)
   - Measure temperature and specific gravity of each cell.
   - Perform a battery discharge test per IEEE 450 (if required)

b. Control Testing
   - Check loss of AC alarm
   - Calibrate battery monitoring relay
   - Test alarms to annunciator and to RTU/PLC inputs
   - Test and document EMS alarms
   - Verify DC lighting system (if required)
   - Verify correct coordination of charger with vent fan operation (if required)

15.5.24.4.8. Station Aux./ Transfer Switches/Load Centers

a. Check all circuit connections immediately prior to energization

b. Energize equipment one stage, section, circuit, or piece at a time to minimize the damage in the event of an equipment failure and to aid in locating trouble areas.

c. Put settings on transfer switch, verify proper voltage magnitudes, current magnitudes, phasing, and correct operation during energizing

d. Check all interlocks and verify the correct operation of keyed interlocks (Kirk® key). (If required)

e. Equipment ground verification.

f. All measurements and tests shall be recorded.

g. Load centers

- Verify correct labeling and fusing of load center circuits
- Check or verify that construction has functionally checked the labeling of the load center loads

15.5.24.4.9. Miscellaneous equipment

a. Control & instrument switches

b. Verify operation and design function of and proper operation sequence of all devices.

c. Check control house temp alarm (check to annunciator and EMS)

d. Check control heater and vent fan controls and proper labeling

e. Verify time stamp and time reference systems.

f. Doble® surge arresters, bus work, free standing CT's, coupling capacitors (CCs), VTs, CVTs, and CCVTs, and air core reactors.

g. Verify functionality of HVAC systems.

h. Verify functionality of security intrusion alarm systems.

i. Verify functionality of fire alarm systems.

j. Verify functionality of substation lighting control system.

15.5.24.4.10. Motors

a. Verify that the correct voltage taps are in use.

b. Verify that the proper direction of rotation is present on the three-phase motors.

c. Verify that the motor is properly lubricated.

15.5.24.4.11. Phasing and Synchronizing

a. Maintain the correct phasing on all circuits and buses. The substation buses and connections shall have the phasing as shown in the Design Documents. All bus work shall be physically checked for phasing and verified to be correct and as shown on the station general arrangement drawings, the bus plans, the three line drawings, and the relaying schematics.

b. Perform phasing tests on all circuits that can be energized from two or more sources. All voltage and current phase angles shall be referenced to the same reference quantity for all readings on a specific scheme. The phasing shall be checked with phasing voltage probes where practical.

15.5.24.4.12. Corona Testing

a. For substations operating at or above 230 kV and for any substation that is operating with reduced phase-to-ground or reduced phase-to-phase clearances, that substation shall be tested for corona by use of "night vision" equipment.

b. Other means such as ultra-sonic equipment and time exposure photography shall also be used as needed to locate the sources of excess corona. The tester shall inspect all high voltage equipment, buses, leads, etc. for corona.

15.5.24.4.13. Substation Bus Protection

a. Perform current transformer (CT) Tests
b. Wire check AC circuit
c. Check bus VT's
d. Perform relay setting/calibrate relaying
e. Verify metering calibration
f. Check digital meter with analog mA output
g. Multifunction digital transducer/meter with MODBUS® plus output
h. Test function of control circuits
i. Perform bus differential upset test (if required)
j. Test alarms to annunciator and to RTU/PLC inputs
k. Test and document EMS analog, control, alarms and status

15.5.24.4.14. Current Transformers

a. Control Tests
b. Check that high voltage connections of transformers and breakers match the scheme
c. Verify high voltage phasing is correct
d. Verify phasing is correct
e. Verify that all documentation including, CT nameplates, M&R, relay test sheets, and schematics match (polarity marks and ratios).
f. All CT's used for revenue metering or interchange metering must have ratio correction test curves and phase angle correction test curves. All CT's in this service, which do not have these test curves available from the manufacturer or CT supplier, shall be tested and curves produced as outlined in the EEI "Handbook for Electricity Metering". Normally the ratio correction and phase angle correction curves are specified as part of the purchase specification and will be provided from the supplier.
g. Make sure CT connections are proper to give the desired protection.
h. Verify that actual tap connected will give the ratio on the scheme
i. Verify ratios and connections are correct for transformer differential relaying systems.
j. Fill out CT documentation
    - Polarity check – relative to polarity marks (physical), the bridging direction (electrical) and the drawings
    - Ratio/Taps check – all taps
    - Secondary injection (excitation)
    - Test and record CT voltage saturation
k. Wire checking – See Wire Checking below
l. Perform Meg Ohm test (500V scale) to ground

m. Make sure bushings are labeled with phase and bushing number

15.5.24.4.15. Voltage Transformers & Coupling Capacitor Voltage Transformers

a. VT and CCVT Physical Testing
b. Perform power factor tests
c. VT and CCVT Control Testing
d. Verify that actual tap connected will give the ratio on the scheme
e. Make sure VT nameplate, relay test sheets, and schematics match (polarity and ratios).
f. Perform wiring checks on CCVT
g. Perform ratio and polarity checks on wound VTs and distribution transformers used for metering or relaying
h. Wire checking – See Wire Checking below

15.5.24.4.16. Wire Checking

a. (CT and VT circuits only)
    - Perform continuity check of all current shorting switches
    - Perform continuity check of all CT wiring
    - Inject currents at the source of each current transformer string and check the string at each device with a clamp-on ammeter or current probe to verify that all current transformer strings are connected in accordance with schematics
    - Simulate the actual load current and fault current operation of the substation electrical systems by injecting appropriate currents into the CT strings to check the protective relay operation, the CT circuits, the meters, and the instruments.
    - Perform continuity check of all VT wiring (if required):
    - Pull the fuses from CVT. CCVT, PD, or VT junction boxes and apply the proper phase- to-phase and phase-to-ground voltages to the load side of the fuse blocks. Check for the proper voltages at all relays, instruments, switches, etc. to verify that the voltage circuit is connected in accordance with the schematics.
    - Verify tagging/labeling to standards
    - Verify proper fuse sizing of voltage circuits
    - Visually and mechanically (pull on wire) inspect terminations
    - Verify that all VT and CT circuits have one and only one ground (exception is for power/metering VT which are grounded at both transformer and at the first panel).

15.5.24.4.17. AC Circuits

a. Verify proper voltage rating of equipment before fusing up
b. Verify correct labeling and breaker size
c. Verify correct circuit feeds the equipment and that the scheme circuit number is correct
d. Verify that "wild leg" is not used on 120 V circuits.

15.5.24.4.18. DC Circuits

a. Verify proper voltage rating of equipment before fusing up
b. Verify correct labeling and fuse sizes as per the Design Documents
c. Verify that the scheme reflects the correct circuit number
d. Check for proper polarity at device
e. If possible, remove or turn off equipment power supplies before initial Energization then check polarity before turning on
f. Test for shorts, grounds and back-fed DC (cross-coupled voltage test) before initially installing DC fuses for the first time.
g. After each new circuit is fused up, check the battery for grounds
h. Make sure all unused fuse blocks have wooden dowels inserted

15.5.24.4.19. Metering

a. Check calibration of all metering including analog transducers, analog meters, and digital meters.
b. Apply standard configuration to programmable meters
c. Using a calibration standard, check the accuracy of the watt-hour meters and the pulse initiators (KYZ) according to ANSI C12 and as directed by the manufacturer.
d. Check and record the output at 0 percent and one non-zero point.

15.5.24.4.20. Relay Setting/Testing

a. Verify proper labeling of relay to match Design Documents. (Do not place labels on the removable covers of relays but rather on the panel or the relay itself)
b. Make sure that removable relays are tagged as well as the panel.
c. Relay testing
    - Perform acceptance tests in accordance with the manufacturer's instruction books.
    - Verify operation of all light emitting diode indicators on relays containing such features.
    - Set the contrast for liquid crystal display read-outs.
    - Check the electrical and mechanical continuity of all taps, jumpers, etc.
    - Verify that the electro-mechanical relay devices function at all tap settings (i.e., operable, not calibrated). Verify that the electro-mechanical relay devices are calibrated within the manufacturer's tolerance specifications at the relay settings provided by the Engineer.
    - Install settings on relays
    - Test all relays to the values provided.
    - Electro-mechanical relays shall be tested in a case. Cases shall not be pulled from the relay switchboards or unwired for this purpose. Relays can be tested in the case while mounted on the relay panel or in spare cases used for bench testing.

- Solid state types of relays that are in a draw-out style case shall be tested as outlined above.
- Microprocessor and solid state types of relays that cannot be removed from a case shall be tested, prior to being mounted or wired on the switchboard, by the use of test stabs or plugs into their access points.
- If testing is required after the relay is wired, the relay may be unwired and tested using the relay's access termination points. However, if a relay is unwired, all circuits disrupted shall be retested to verify correct termination and operation.
- All protective relay operating tolerances shall be set, at a maximum, to manufacturer's specification or +/- 5%, whichever is less.
- Verify all of the inputs and outputs of the relay device for the correct internal functioning. Verify that the correct targets drop/show for each output.
- Relays with no field settings, such as lockout and auxiliary tripping relays, shall be randomly tested for pickup and dropout voltages and times. Measure the coil impedance if required. Document and sign working copy of relay test sheets after calibration and logic testing are complete.

d. Label instruction book with date installed and equipment covered and write “substation copy” on the instruction book

e. Put label on back of relay with installed date and list communication parameters (cable, special interface software, passwords, etc.) if required

f. Provide as-left setting files for all devices including Relays, Meters, RTU’s, etc.

15.5.24.4.21. Demonstration Testing

a. Simulate real world tests with relaying systems by using AC quantities to operate the protective relays and then using the trip output to turn off the test set.

b. Trip and verify reclosing of breakers

c. Check MOD sectionalizing.

d. Trip lockouts from relays

e. Place all equipment in the condition it was found in at the beginning of the outage and place new equipment in service

15.5.24.4.22. Post-Energization Testing and Review

a. Review Design Documents to make sure all testing is documented or punch listed and that loose ends have been addressed.

b. Check all relaying is on and in service.

c. Make sure all equipment and control switches are in the position that they were switched out as.

d. Close all blocking bar switches/lockout switches if required

e. Check all panel grounds are landed.

f. Verify all unused CT’s are shorted and grounded.

g. Verify all alarms and EMS points are in service.

h. Check for battery grounds.

i. Verify that switching request allows for parallel sources during load check of differential relaying before feeding radially.

j. Load check & in service checks.

- Load check all new/modified CT circuits
- Differential Relays: Compare restraint to operating quantities to ensure correct configuration. It is especially important on differential relays to verify correct operation under load when all inputs are energized.
- Distance Relays: Measure the line power flow as seen by the relay inputs, and compare to line metered values to verify proper polarity and tap settings.
- Overcurrent Relays: Compare input currents with other metered values, and verify polarity where applicable.
- Phase check new/modified voltage circuits, verify all fuses are good.
- Verify metering locally and at EMS.
- Check rotation of transformer pumps and fans.
- Check load on transformer pumps/fans with clamp on meter.
- Check for proper operation of transformer/regulator LTC and paralleling operation.
- Check for proper operation of transformer differential relaying.
- Verify all relays have the proper voltages and current quantities present.

15.5.24.4.23. Cable Raceway Systems

a. Contractor shall accommodate inspection and testing activities by Owner. Before backfilling Contractor and Owner shall jointly inspect all trenches, conduit, cable placement, risers, and other construction not accessible after backfilling. If corrections are required, subsequent inspections will be made until all corrections are made and accepted by Owner.

b. The excavated trenches shall be maintained to be free of accumulated water and be maintained to the depths specified. Construction shall be arranged and marked so that trenches will be left open for the shortest practical time to trench collapse due to other construction activity, rain, or accumulation of water in the trench. Safety and traffic barriers shall be installed in accordance with local, State and Federal requirements.

c. All changes in routing of underground raceway systems shall be located exactly in the Design Documents.

15.5.24.4.24. Surface Coating Repair

a. Contractor shall accommodate inspection and testing activities by Owner. Contractor shall perform all surface coating repairs as required by this Section and as requested by Owner. All surface coating repairs to damaged equipment or structures occurring while in the possession of Contractor shall be made to the satisfaction of Owner and all costs to repair such surface coatings shall be borne by Contractor.

16. Attachment 5: Startup, Testing & Commissioning

16.1. The Contractor shall be responsible for startup, testing, and commissioning of the solar facility.

16.2. The electrical equipment and its installation shall be tested according to the current International Electrical Testing Association (NETA) Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

16.3. Contractor shall submit a startup, testing, and commissioning plan for review and approval by Owner. Documentation of testing performed shall be submitted for review and approval by Owner.

16.4. The output of the solar field shall be corrected to the base conditions listed in the performance guarantees.

17. Attachment 6: Packing, Shipping & Storage

17.1. The following are the minimum requirements for post-fabrication packaging, shipping and storage at the site prior to installation.

17.1.1. Shipments shall be by truck, FOB jobsite. The Contractor shall be responsible for receiving and unloading material.

17.1.2. Storage shall be outdoors. The Contractor shall provide weather resistant covers and adequate blocking for equipment and materials per the manufacturer's requirements.

18. Attachment 7: Site Plan

[Contractor shall provide site plan for specific site chosen for the project.]

19. Attachment 8: Interconnection Agreement with One-line Diagram

[Contractor shall provide interconnection agreements and one-line diagram for the specific site chosen for the project.]

20. Attachment 9: PV Solar Equipment Suppliers

20.1. Modules- Crystalline

20.1.1. JA Solar

20.1.2. Canadian Solar

20.1.3. Hanwha / Q-cell

20.1.4. Trina

20.1.5. Risen Energy

20.1.6. LONGi Solar

20.2. Modules- Thin Film

20.2.1. First Solar

20.3. PV Racking - Single Axis Tracker Mounting System

20.3.1. GameChange Solar

20.3.2. NEXTracker

20.3.3. Array Technologies, Inc. (ATI)

20.3.4. Soltec

20.3.5. PV Hardware

20.4. DC Combiner Boxes

20.4.1. Sunlink

20.4.2. SolarBOS

20.4.3. Shoals

20.4.4. Amphenol

20.4.5. Bentek Solar

20.5. Recombiner Boxes **(If Required)**

20.5.1. Sunlink

20.5.2. SolarBOS

20.5.3. Shoals

20.5.4. Amphenol

20.5.5. Bentek Solar

20.6. Central Inverters

20.6.1. SMA

20.6.2. TMEIC

20.6.3. Sungrow

20.6.4. Power Electronics

21. Attachment 10: Project Milestone Schedule

[Contractor shall provide a project specific schedule.]

22. Attachment 11: Geotechnical Investigation Report

[Contractor shall provide a Geotech report for the specific site chosen]

23. Attachment 12: Production Test - Facility Performance Ratio Test Specification

23.1. Purpose

23.1.1. The Performance Ratio of a solar photovoltaic (PV) power generating facility (The Facility) is defined as its energy production [kWh] divided by the product of its DC capacity [$\boldsymbol{MWp}$] and the normalized irradiance and a temperature correction factor over the Test Period.

23.1.2. The Performance Ratio Test in this specification is an application of the methodology[1] recommended by the US National Renewable Energy Laboratory (NREL) and UL 617240-3.

23.2. Requirements before the Test:

23.2.1. Before the test can commence, the following need to be completed:

23.2.1.1. The PV facility is electrically and mechanically completed, except for minor items approved by all parties that do not affect facility safety, operability or reliability.

23.2.1.2. The PV facility is connected and synchronized to the grid.

23.2.1.3. All inverters are operating in accordance with the manufacturer specifications and are calibrated and communicating properly with the PV facility monitoring system.

23.2.1.4. All commissioning tests are successfully achieved in accordance with the EPC contract.

23.2.1.5. The control and monitoring system are completed, and the facility can be monitored from the main control room.

23.2.1.6. All mandatory measurement instruments (energy meters and meteorological sensors) are installed, calibrated, operating properly. These signals shall be synchronized to the control and monitoring system.

23.2.1.7. All pyranometers have been cleaned in accordance with manufacturer's specifications.

23.2.1.8. Inverters will operate at unit Power Factor [$\boldsymbol{PF = 1}$] if they must operate at other power factors due to Utility requirements, the Guaranteed Performance Ratio shall be adjusted to this new power factor.

23.3. Measurement Requirements

23.3.1. Measurement Instrumentation Requirements

[1] Kurtz, S. et al, "Weather-Corrected Performance Ratio", NREL/TP-5200-57991, April 2013

23.3.1.1. The Plane of Array Solar Irradiance $[\frac{W}{m^2}]$ measurement instrumentation shall be used during the Test Period:

23.3.1.1.1. The Plane of Array (POA) shall mean the plane defined by the (array of) PV modules

23.3.1.1.2. POA irradiance shall be measured using ISO 9060 secondary standard rated pyranometers installed so that they are co-planar with the POA of the PV modules

23.3.1.1.3. A minimum of two of secondary standard grade pyranometers shall be installed for this facility capacity

23.3.1.1.4. Each pair (or more) of pyranometers shall be installed proximate to the PV array that they are monitoring

23.3.1.2. PV Module Backsheet Temperature [°C]

23.3.1.2.1. PV module backsheet temperature shall be measured using platinum resistance temperature detectors (RTDs) that are adhered to the back of operational PV modules using a thermally conductive compound consistent with the PV module manufacturer's recommendations

23.3.1.2.2. The tolerance of the RTDs shall meet or exceed IEC 751-95 Class A

23.3.1.2.3. A minimum of three RTDs shall be installed for this facility capacity

23.3.1.2.4. The RTDs shall be attached to PV modules that are located near the center of the PV array (up to 25 MW) that they are monitoring

23.3.1.3. Inverter Output Power [Wac]

23.3.1.3.1. Each inverter under test shall report its output power

23.3.1.4. AC Energy Production [kWh]

23.3.1.4.1. The energy production of the facility shall be measured at the Point of Metering in accordance with the EPC contract using an AC watthour meter that meets or exceeds the accuracy standards set forth in ANSI C12.1.

23.3.1.5. Copies of current calibration certificates for all required instruments shall be submitted to Owner for review and acceptance

23.3.1.6. All required instruments shall be installed and maintained in accordance with their respective manufacturer's specifications and recommendations

23.3.1.7. All pyranometers shall be cleaned monthly in accordance with the manufacturer's recommendations

23.3.1.8. All required instruments shall be synchronized and connected to a Data Acquisition System (DAS) that supports the requirements of this Specification, in accordance with the manufacturer's specifications, and that complies with the instrumentation manufacturers' specifications and recommendations

23.3.2. Measurement Data Record Requirements

23.3.2.1. All required measurement data shall be synchronized, collected and recorded at one-minute intervals and averaged into 15-minute intervals for the Test on Completion and averaged into 1-hour data during the Warranty Period.

23.3.2.2. Each measurement data record shall include the date and time, with one-minute resolution, when it was recorded

23.3.2.3. Required Measurement Data Fields

23.3.2.3.1. Each data record shall include the following data fields:

a. Date-Time Stamp: Date (Month, Day, Year) and Time (Hour, Minute)

b. Each required pyranometer

c. Each required RTD

d. The output power of each inverter

e. The watthour meter

23.3.2.4. Required Channel-Averaged Measured Data Fields

23.3.2.5. Each measurement data record shall include the following channel-averaged measured data fields:

23.3.2.5.1. The channel-averaged measured POA irradiance, shall be calculated as the average over all of the individual POA irradiance readings

23.3.2.5.2. The channel-averaged measured RTD temperature, shall be calculated as the average over all of the individual RTD temperature readings

23.4. Test Period

23.4.1. The test period is the period of time during which the required data for the Performance Ratio Test is collected for the purposes of analysis. The duration of the test period shall be sufficient to include a minimum number of Eligible Measurement Averaging Intervals (EMAIs).

23.4.2. The test period at the Test on Completion shall be seven (7) days, subject to EMAIs.

23.4.2.1. The test period during the Warranty Period shall be 2 years. The collected data for a complete year shall be used for Performance Ratio calculation.

23.4.3. Minimum Number of Eligible Measurement Averaging Intervals

23.4.3.1. The minimum number of EMAIs for the Performance Ratio Test at the Test on Completion shall be 150.

23.4.4. Eligible Measurement Averaging Intervals

23.4.4.1. An Eligible Measurement Averaging Interval (EMAI) shall:

23.4.4.1.1. Be a contiguous five-minute interval

23.4.4.1.2. Not overlap any other EMAI

23.4.4.1.3. Meet or exceed the Minimum Irradiance Requirement (Test on Completion only)

23.4.4.1.4. Only include measurements when the PV arrays do not experience any significant Shading Loss

23.4.4.1.5. Only include measurements when the output of each inverter is below its Clipping Limit

23.4.4.1.6. Exclude times when snow, ice or any other obstructions cover a portion of the array

23.4.4.1.7. Exclude time periods when force majeure events beyond the control of the Contractor impact the energy production of the facility

23.4.4.1.8. Exclude time periods during the grid unavailability when the facility is available to generate the output.

23.4.4.1.9. Not have any missing or flawed required measurement data

23.4.4.1.10. System downtime for reasons beyond Contractor control such as grid instability, scheduled preventive maintenance shall be excluded from Performance Ratio calculations

23.4.4.2. Minimum Irradiance Requirement

23.4.4.3. The Minimum Irradiance Requirement for an EMAI is an average POA irradiance of 500 W/m^2 in the Plane of Array over the interval

23.4.4.4. Shading Loss: Shading Loss is significant if it is greater than one percent

23.4.4.5. Inverter Clipping Limit: The clipping limit of an inverter is defined as 98 percent of its nameplate output rating

23.4.5. Interval-Averaged Measured Data

23.4.5.1. The following measured one-minute data entries within each EMAI shall be averaged over the interval to produce an EMAI data record of interval-averaged value for that EMAI

23.4.5.1.1. Channel-averaged measured POA irradiance

23.4.5.1.2. Channel-averaged measured RTD temperature

23.4.5.1.3. The watthour meter

23.4.5.2. Date-Time Stamps for EMAI Data Records

23.4.5.2.1. Each EMAI data record shall be stamped with the date and time to at least one-minute resolution of the earliest-occurring data record included in that EMAI

23.5. Calculation of Expected Performance Ratio

23.5.1. The Performance Ratio Test compares the Measured Performance Ratio, PR_m of a solar PV facility to its Expected Performance Ratio, PR_e.

23.5.2. Performance Model, Expected Solar Resource and Energy Production Estimate

23.5.2.1. Calculation of the Expected Performance Ratio, $\mathbf{PR_e}$ utilizes the following items, which shall have been mutually agreed to by The Parties prior to the commencement of the Performance Ratio Test:

23.5.2.1.1. A representative Performance Model for the facility

23.5.2.1.2. A complete Typical Year of hourly-resolution (8,760 hours/year) solar resource and weather dataset for the facility location

23.5.2.1.3. A complete-year of hourly-resolution (8,760 hours/year) Expected Energy Production Estimate using the above

23.5.2.2. Furthermore, the Performance Model for the facility must also report for each hour of the Typical Year (8,760 hours/year):

23.5.2.2.1. Expected POA irradiance

23.5.2.2.2. Expected PV module backsheet temperature

23.5.2.2.3. Note: The Pvsyst variable T_{array} (Average Module Temperature during running) is actual T_{cell}. To translate this value to Expected PV module temperature, $T_{(e,j)}$ [℃], use the following equation:

$$T_{(e,j)} = T_{array} + (3*G_{(e,j)}/1000)$$

(Ref: D.L. King, W.E. Boyson, J.A. Kratochvill, ” Photovoltaic Array Performance Model”, SANDIA REPORT, SAND2004-3535, Printed December 2004)

23.5.2.3. Losses Excluded from the Energy Production Estimate (EPE)

23.5.2.3.1. The following losses shall be excluded from the EPE used in the Performance Ratio Test at the test on completion when the facility is in new and clean condition:

a. Long-term degradation in PV module performance

b. Long-term soiling loss

c. System availability loss (Availability shall be 100%)

23.5.2.3.2. For the guaranteed PR of each year during the Warranty Period, soiling, long-term module degradation, and system availability loss shall be included in the guaranteed PR values.

23.5.2.4. Use of the Results from the Energy Production Estimate

23.5.2.4.1. The Expected Average Irradiance-weighted PV Module Temperature, $\overline{\boldsymbol{T_{e,k}}}$ and the Expected Performance Ratio, $\boldsymbol{PR_{e,k}}$ for each month, $\boldsymbol{k}$ are calculated using the hourly results, $\boldsymbol{j}$ from the PE, specifically:

23.5.2.4.2. Expected POA irradiance, $\mathbf{G_{e,j}}\left[\frac{\mathbf{W}}{\mathbf{m^2}}\right]$

23.5.2.4.3. Expected PV module temperature, $\boldsymbol{T_{e,j}}$[℃]

23.5.2.4.4. Energy production at the point of metering, $\boldsymbol{E_{e,j}}[\boldsymbol{kWh}]$

23.5.2.4.5. Hours in the EPE where one or more inverters operating at or above their Clipping Limit shall be excluded

23.5.2.4.6. The remaining hourly results in the EPE shall be grouped by month, $\boldsymbol{k}$

23.5.3. Monthly Expected PV Module Temperatures and Performance Ratios

23.5.3.1. Expected irradiance-weighted average PV module backsheet temperature for the $\boldsymbol{k^{th}}$ month, $\overline{\boldsymbol{T_{e,k}}}$ shall be calculated as:

$$\overline{T_{e,k}} = \frac{\sum_{i=1}^{M_k} T_{e,i} \cdot G_{e,i}}{\sum_{j=1}^{M} G_{e,j}}$$

23.5.3.2. The Expected Performance Ratio for the $\mathbf{K^{th}}$ month, $\mathbf{PR_{e,k}}$ shall be calculated as:

$$PR_{e,k} = \frac{\sum \frac{M_k}{j=1} E_{e,j}}{\frac{[P_0 \cdot Llr_e}{G_0} \cdot \sum_{j=1}^{M_k} G_{e,j}}$$

Where any hours excluded, $E_{e,j}$ and $G_{e,j}$ are set equal to zero:

$$E_{e,j} = G_{e,j} = 0$$

For any excluded hours and where:

Variable	Units	Description
$\overline{T_{e,k}}$	[°C]	Expected irradiance-weighted average PV module backsheet temperature for the k^{th} month (see **Table 23.1**)
$T_{e,j}$	[°C]	Expected PV module backsheet temperature for the j^{th} hour in a given month
$PR_{e,k}$	[%]	Expected Performance Ratio for the k^{th} month (Furthermore, the Performance Model for the facility must also report for each hour of the Typical Year (8,760 hours/year):)
$E_{e,j}$	[kWh]	Expected Energy Production in the j^{th} hour of the PE
P_0	[kWp]	Contracted DC Capacity of the Facility at STC[A]
$\Delta r_e = 1.0$	[hours]	Hourly time step in the PE
G_0	$\left[\frac{W}{m^2}\right]$	Irradiance at STC[A]
$G_{e,j}$	$\left[\frac{W}{m^2}\right]$	Expected POA irradiance in the j^{th} hour of the PE
k		Index running over all months, $k = \{1 \dots 12\}$
M_k		Total number of hours in the k^{th} month
j		Index running over all hours within a given month, $j = \{1 \dots M_k\}$

[A] Standard Test Conditions (STC): $1000 \left[\frac{W}{m^2}\right]$ POA irradiance, 25 [℃] cell temperature

23.5.3.3. Table of Expected Monthly and Yearly Values

23.5.3.3.1. Table 23.1 Monthly Expected Performance Ratios & Expected Average Irradiance-Weighted PV Module Temperatures provides places for the monthly Expected Performance Ratios, $PR_{e,k}$ and monthly Expected Average Irradiance-weighted PV Module Temperatures, $\overline{T_{e,k}}$ for each month, k to be entered.

23.5.3.3.2. The values shall be entered in prior to the start of the Test Period in accordance with this specification, as part of the terms of agreement between the Owner of the facility and the party that is responsible for its performance

Table 23.1 Monthly Expected Performance Ratios & Expected Average Irradiance-Weighted PV Module Temperatures

k	Month	$PR_{e,k}[\%]$	$T_{e,k}[℃]$
1	January	XX.X%	X.XX
2	February	XX.X%	X.XX
3	March	XX.X%	X.XX
4	April	XX.X%	X.XX
5	May	XX.X%	X.XX
6	June	XX.X%	X.XX
7	July	XX.X%	X.XX
8	August	XX.X%	X.XX
9	September	XX.X%	X.XX
10	October	XX.X%	X.XX
11	November	XX.X%	X.XX
12	December	XX.X%	X.XX

Expected Average Irradiance-weighted PV Module Temperatures for a complete year is xx℃.

23.5.4. Expected Values for the Performance Ratio Test

23.5.4.1. If the test occurs partially in two months, a weighted average shall be used to calculate the $\boldsymbol{PR_e}$. If $\boldsymbol{n}$ EMAIs occur in month $\boldsymbol{k}$, and $\boldsymbol{m}$ EMAIs occur in month $(\boldsymbol{k}+\mathbf{1})$, where $\boldsymbol{N}=(\boldsymbol{n}+\boldsymbol{m})$ then $\boldsymbol{PR_e}$ and $\boldsymbol{T_{\bar{e}}}$ shall be calculated from Table 23.1 Monthly Expected Performance Ratios & Expected Average Irradiance-Weighted PV Module Temperatures as:

$$T_{\bar{e}} = \frac{1}{N}\left[n \cdot T_{e,k} + m \cdot T_{e,k+1}\right]$$

$$PR_e = \frac{1}{N}\left[n \cdot PR_{e,k} + m \cdot PR_{e,k+1}\right]$$

23.6. Calculation of Measured Performance Ratio

23.6.1. The Measured Performance Ratio, $\boldsymbol{PR_m}$ shall be calculated as:

$$PR_m = \frac{\sum_{i=1}^{N} E_{m,i}}{\frac{P_0 \cdot Llr_m}{G_0} \cdot \sum_{i=1}^{N} G_{m,i} \cdot a_{T,m,i}}$$

$$a_{T,m,i} = \frac{\left|1 +, B_T \cdot \left[T_{m,i} - 25\right]\right|}{\left[1 +, B_T \cdot (T_{\bar{e}} - 25)\right]}$$

Where:

Variable	Units	Description
PR_m	$[\%]$	Measured Performance Ratio
$E_{m,i}$	$[kWh]$	Measured Energy Production over the j^{th} EMAI
P_0	$[kWp]$	Contracted DC Capacity of the Facility at STC[A]
Δr_m	$[hours]$	Time duration of the EMAIs (held constant over the Test Period)
G_0	$\left[\frac{W}{m^2}\right]$	Irradiance at STC[A]
$G_{m,i}$	$\left[\frac{W}{m^2}\right]$	Measured POA irradiance over the j^{th} EMAI
$a_{T,m,i}$		PV Module temperature correction factor for the j^{th} EMAI
$, B_T$	$\left[\frac{\%}{°C}\right]$	Temperature coefficient of Power (negative) for the PV modules
$T_{m,i}$	$[°C]$	Measured PV module backsheet temperature over the j^{th} EMAI
$T_{\bar{e}}$	$[°C]$	Expected irradiance-weighted average PV module backsheet temperature for the Test Period (see
N		Total number of EMAIs Index running over all EMAIs, $= \{1 \ldots N\}$

[A] Standard Test Conditions (STC): $1000 \left[\frac{W}{m^2}\right]$ POA irradiance, 25 $[°C]$ cell temperature

23.7. Performance Ratio Test

23.7.1. The Performance Ratio Test compares the Measured Performance Ratio, $\boldsymbol{PR_m}$ of the facility to its Expected Performance Ratio, $\boldsymbol{PR_e}$ reduced by the Measurement Uncertainty Allowance (MUA).

23.7.2. Measurement Uncertainty Allowance

23.7.2.1. The Measurement Uncertainty Allowance (MUA) allows for the inherent uncertainty in the measurement equipment.

23.7.2.2. The MUA shall be three percent (3%)

23.7.3. Acceptance Threshold of the Performance Ratio Test

23.7.3.1. The result from a Performance Ratio Test is acceptable if:

$$PR_m \geq PR_e \cdot (1 - MUA)$$

23.8. Reporting Requirements

23.8.1. The following data and calculations shall be provided to Owner in the Performance Ratio Test Report and associated documents.

23.8.2. General Requirements

23.8.2.1. The Performance Ratio Test Report shall include:

23.8.2.1.1. Dates of the Test Period, test conditions and Contractor's personnel responsible for The Performance Ratio Test

23.8.2.1.2. A statement of whether the Performance Ratio Test either passed or failed

23.8.2.1.3. If the Performance Ratio Test failed, a detailed explanation shall be submitted to Owner for review

23.8.2.1.4. A signed statement from Contractor that the project complies with all of the requirements set forth in this Specification

23.8.3. Requirements for Reporting Measured Data

23.8.3.1. A copy of all required measurement data collected throughout the entire Test Period shall be submitted to Owner for review and acceptance

23.8.4. Requirements for Reporting Test Results

23.8.4.1. The result from the calculation shall be submitted to Owner for review and acceptance

24. Attachment 13: Substation Scope of Work

24.1. Project Description

This scope of work is for engineering, procurement, and construction (EPC) for a high voltage substation and gen-tie (transmission line) for a Utility scale solar facility.

24.1.1. High Voltage-kV/Medium Voltage-kV, XXX-MWAC Collector Substation

24.1.2. High Voltage-kV overhead Gen-Tie (transmission line) to the local power Utility POI. The scope of this work includes the design, procurement, and installation of the proposed XXX-kV gen-tie of the solar facility Substation to the local power Utility POI.

24.1.3. The work shall be by Contractor and its suppliers, subcontractors, and subsidiaries for the Owner. The work shall comply with, and be performed in accordance with, the following:

24.1.4. Current one-line diagrams, substation plan view, and substation details, (as applicable).

24.1.5. Codes, including national, regional, and local (as applicable)

24.1.6. Industry standards (as applicable)

24.1.7. The detailed scope for each of the three portions is outlined below. Unless otherwise noted, the work outlined for each item includes all engineering design and detailing, procurement and supply, and construction including installation, testing and commissioning.

24.2. High-Voltage-kV/Medium-Voltage--kV Collector Substation

24.3. Complete substation engineering design documents including:

24.3.1. Complete construction drawings, including civil, physical and electrical engineering design.

24.3.2. System analytical studies including protection and coordination studies as follows:

24.3.2.1. Grounding Study with the objective of:

24.3.2.2. To meet touch and step voltage tolerable limits and conductor ampacity limits in accordance with IEEE during worst case fault conditions. Touch and Step voltage limits are to be met both inside the substation and around its periphery. A valid and previously approved soil testing procedure (e.g. Wenner 4-pin method) shall be used to measure soil resistivity values. A full report indicating final grounding design based on the grounding study results shall be presented.

24.3.2.3. Short Circuit and protection coordination Study:

24.3.2.4. Contractor is responsible to obtain fault contribution information at the POI (Point of Interconnection) from the Utility.

24.3.2.5. Owner will provide all PV Field related information as for medium voltage (e.g. 34.5kV), cable feeders looping all inverter stations, ISUs Transformer Electrical Parameters, Solar Inverter Electrical Parameters including their P-Q curve for reactive power capability.

24.3.2.6. Harmonic and Resonance Study with the following objectives:

24.3.2.7. To calculate the resonant/natural frequencies of the system

24.3.2.8. To evaluate harmonic levels in order to compare with the IEEE 519 standards for THD and IHD for both current and voltage.

24.3.2.9. Load Flow Analysis including:

24.3.2.10. Reactive capability for the generating facility.

24.3.2.11. Power Factor Assessment.

24.3.2.12. Capacitor bank sizing.

24.3.2.13. Transient and switching studies

24.3.2.14. Ferroresonance Study with the objective:

a. To check for ferroresonance situations likely to occur within the solar collector and HV substation system and to model these situations in an EMTP software to verify their impact on the system.

24.3.2.15. Lightning Protection Analysis

24.3.2.16. Arc Flash assessment and generation of arc flash labels for substation equipment.

24.3.3. Three weeks field measurements during energization in order to monitor harmonic, resonance and transient data up to the maximum MW exported from the PV facility. These measurements shall use THREE (3) Dranetz equipment meters or equivalent to ensure the capturing of high-speed switching events. One of the Dranetz meters shall be installed at one of the inverters AC output, the second Dranetz at the medium voltage busbar, and the third meter at the high voltage side of the GSU.

24.3.4. Engineering calculations. Including but not limited to:

a. Station Service AC loads.

b. Battery sizing for all DC loads such as Protection Relays, SCADA Relays, TELECOM Equipment, and other Emergency loads.

c. Overhead Bus bars.

d. Concrete Foundation calculations.

24.3.5. Equipment specifications and Data sheets for purchasing major equipment.

24.3.6. Design submittals made to Owner will include preliminary design documents for Owner review and final design documents intended to be issued for construction (“IFC”).

24.3.7. Site grading for the fenced substation area and the area immediately outside of the fence (within approximately 7 feet). This includes final crushed stone surface.

24.3.8. Foundations for all substation equipment and structures. Depending on individual structure loads, equipment types, and geotechnical considerations, foundations will be slab-on-grade, spread footing, or drilled piers. This includes all excavation and back fills.

24.3.9. Secondary oil containment system for main transformer. This will consist of concrete foundation and concrete containment with oil flow to a low spot with a padlockable valve used to drain water that has accumulated in the containment area.

24.3.10. Conduits, cable trenches, and terminations.

24.3.11. Substation grounding grid system

24.3.12. Fencing around the perimeter of the substation.

24.3.13. Main power transformer (GSU) with the following characteristics: XXX/XXX/XXX MVA, high- voltage-kV/medium-voltage-kV, Vector Group according to Utility requirements, including a tertiary Wye grounded winding for purposes of mitigating harmonics. Standard Impedance Z or as suggested by engineering studies, 3 phase, 60 Hz, oil filled transformer with De-Energized Tap Changer (DETC) on HV side with a regulation of +/- 5% in 2.5% steps. “No load” losses will not exceed 600 kW and load losses will not exceed 2500 kW at MVA base. Number of CTs as indicated on single line diagram. If requested by the owner, the main power transformer shall include an OLTC. Specifications for this device will be provided on later stage.

24.3.14. Steel support structures for equipment.

24.3.15. High voltage equipment including:

24.3.15.1. High Voltage Circuit breaker(s) XXX- kV, XXXX-A with current transformers ratio, accuracy, and class, as indicated on single line diagram for protective and metering purposes.

24.3.15.2. Motor operated disconnect switch(es) XXX-kV, XXXX-A, XXXX-kV BIL, XX-kAIC with ground connection.

24.3.15.3. CPT units for protective relaying purposes, ratio, accuracy, class, power rating and BIL, as indicated on single line diagrams.

24.3.15.4. High Voltage Surge Arresters, MCOV and BIL as shown in single line diagram

24.3.16. Medium Voltage equipment including:

24.3.16.1. Medium Voltage Vacuum Circuit Breakers and their respective CTs as indicated on single line diagram.

24.3.16.2. Hookstick operated switches, two sets per medium voltage vacuum circuit breakers, one set at the primary side and one set on the secondary side.

24.3.16.3. If required by Owner, a Snubber cabinet per medium voltage vacuum circuit breaker having the following configuration:

24.3.16.4. Fuse/switch disconnector – Resistor – Capacitor.

24.3.16.5. Capacitor sized as indicated on single line diagrams.

24.3.16.6. Resistor sized as indicated on single diagrams.

24.3.16.7. Capacitor and Resistor values shall be confirmed during switching/transient studies.

24.3.16.8. 1-φ Voltage Transformer for protective relaying. See quantity, voltages, and VA rating in single line diagram.

24.3.16.9. Station service transformer(s). See quantity, capacity rating and voltages in single line diagram.

24.3.16.10. MCOV surge arresters for MV feeders. See quantities, MCOV rating, and BIL class in single line diagram.

24.3.17. High voltage bus work including insulators, fittings, and conductors.

24.3.18. Backup propane generator with Automatic Transfer Switch. For generator's KW rating, transfer switch ampacity rating and voltage refer to single line diagram.

24.3.19. Equipment enclosure (i.e., "control building") consisting of a prefabricated enclosure, up to 16' x 32', for all protection and control equipment including AC and DC station service system. Space must be provided in the equipment enclosure for an RTU panel. The control building shall include at least one (1) DC and one (1) AC supply panelboards, connections between the relay panels and the Substation SCADA panel, connections between the RTU panel and fiber patch panel shall also be provided. The patch panel will serve as demarcation with others for PV facility communications.

24.3.20. Control cables

24.3.21. Supply of serial and/or Ethernet communication from all substation relays via the Substation Data Concentrator

24.3.22. Connection of all high voltage leads and wiring once commissioning is complete.

24.3.23. Relay settings for equipment in relay panels.

24.3.24. Testing and final connections of the main power transformer.

24.3.25. Active management of all engineering, procurement and construction activities to ensure a smooth and efficient workflow from timely material delivery to final commissioning.

24.3.26. Review of shop drawings, wiring diagrams, construction drawings, spare parts lists, Contractor submittals, instruction manuals, production schedules and related items for compliance with each material supply contract for our scope of the project.

24.3.27. Attendance at planning and design coordination meetings with local Utility for Contractor's scope of the project

24.3.28. Local engineering and construction support during construction for Contractor's scope of the project.

24.3.29. Record drawings based on construction redlines for Contractor's scope of the project work in CAD format.

24.3.30. Complete assembly of manufacturer supplied equipment manuals.

24.4. Project Execution Plan

24.4.1. Project Management

24.4.1.1. Contractor will work with Owner to develop a critical path project schedule that has major project milestones and defined tasks with predecessors and successors. The project schedule will have a separate line item for each main section of work, showing the start dates and finish, days of float and duration. After agreement on the schedule for delivery of major equipment, Contractor will baseline the schedule and provides formal updates on a regular basis. Contractor will assign a Project Manager that will have the overall project responsibility and will be the single point of contact to provide regular updates to Owner and address ongoing questions and discussions during the project. The lead project engineer will be responsible for providing and tracking the appropriate document revisions. All necessary documents will be uploaded to a shared site for access by the Owner and other applicable parties (e.g., major equipment suppliers and subcontractors).

24.4.2. Project Review Meetings

24.4.2.1. Weekly project meetings will commence after receipt of contract at a time mutually agreed to by Contractor and Owner. Project deliverables, schedule and review of pending action items will be reviewed and updated. As needed, additional impromptu meetings will be scheduled with relevant parties for technical or other non-typical discussions. With less frequency, more detailed face to face meetings will be scheduled with a focus on project design reviews. Typical milestones for design review meetings are 30%, 60%, 90% and Issued for Construction, but will be customized to the project requirements.

24.5. Allowances / Alternates:

24.5.1. Var Compensation (Cap banks) and including breaker on the medium voltage bus.

24.5.1.1. If power factor study already included on base price determines the need for cap banks.

24.5.1.2. If cap banks are required, a transient switching study for cap bank switching shall be included as part of this allowance.

24.5.2. Communication Infrastructure:

24.5.2.1. Allowance for Communication infrastructure on site.

24.5.3. Adding an On-Load Tap Changer (OLTC) to the Main Power Transformer and its respective programming/configuration in case load flow/reactive power flow study (already included on the base price) determines the need for an OLTC.

25. Attachment 14 - Substation Specifications

25.1. Design

All work and materials shall be in accordance with the Project Schedule, Design Documents, all the Transmission Owner requirements and all the Transmission Provider requirements. The Collector Substation shall include, but not be limited to: foundations, breakers, protective relays, RTU, ground grid, surge protectors, Electrical Equipment Enclosure (EEE), buss bar and communications circuits to meet all host utility requirements, including any requirements imposed by the Transmission Owner, Transmission Provider and applicable NERC and FERC standards.

25.1.1. Civil/Structural Design

25.1.1.1. The substation civil/structural design shall be in accordance with **XEL-STD-CRITERIA FOR ENG & DESIGN OF CIVIL & STRUCTURAL PERFORMANCE**.

25.1.1.2. Drilled pier foundations shall include details to resist frost heave such as installing sonotube around the pier perimeter throughout the frost zone depth.

25.1.1.3. Any engineer wishing to deviate from this standard must submit exception to Owner for approval.

25.1.2. Step-Up Transformer

25.1.2.1. Refer to SOLAR FACILITY ONE LINE METERING AND RELAYING for design requirements.

25.1.2.2. Shall have an in-tank, on-load tap changer.

25.1.3. Site Layout Criteria

25.1.3.1. All substations designs shall be in accordance with this specification and accepted industry standards and practices. The National Electric Safety Code (ANSI C2) shall be followed in all cases. The National Electric Code (NFPA 70) shall be followed to the extent that is possible and practical. In certain jurisdictions, the National Electric Code is part of the law and must be followed.

25.1.3.2. Number of feeders shall be determined by the collection system. For feeder and switch designation naming see Table

25.1.3.3. A cold storage unit shall be installed as a separate unit. The unit shall provide approximately 200 square feet of storage.

Table 25.1: Feeder and switch designation naming.

34.5 KV Feeders:
Bus 1: 311 to 319
Bus 2: 321 to 329

25.1.3.4. A disconnect switch between the collector substation and the utility interconnection facilities is required.

25.1.3.5. High side breaker and associated switches or bus position with multiple breakers and associated switches for each transformer

25.1.3.6. Low side bus and equipment shall be installed in accordance with acceptable industry standards and practices. Main breakers, a bus-tie breaker and associated switches shall be installed where applicable or required by Owner.

25.1.3.7. One grounding transformer per two circuits shall be incorporated into the design of the collector substation. Breakers that incorporate ground switching shall not be utilized.

25.1.3.8. The substation shall be constructed with steel structures. Use of wood poles is not allowed.

25.1.3.9. Bus spans shall be limited by switch pad loading.

25.1.3.10. Switches shall be group-operated.

25.1.3.11. Circuit breaker ratings shall be standard.

25.1.4. Fire Protection

25.1.4.1. Substation fire protection designs shall be in accordance with accepted industry standards and practices. IEEE 979 Guide for Substation Fire Protection shall be consulted for new facilities.

25.1.4.2. Protective firewalls or barriers should be considered whenever clearances from IEEE 979 cannot be achieved.

25.1.4.3. Electrical Equipment Enclosures shall have two exits on opposite sides or corners and the doors equipped with panic hardware. Fire extinguishers are to be provided at each exit of any enclosures within the substation.

25.1.5. Fault Duty Requirements

Design shall consider future fault values obtained from interconnecting utility for the worst-case value over a 30 year lifespan of the substation.

25.1.6. Environmental Requirements

25.1.6.1. Substation designs must be compatible with the environmental characteristics of the facility location. Table 25.2 gives typical design parameters for various regions. Particular sites within a given region may have different environmental conditions than that given in Table 25.2, the more stringent would apply. Additional environmental conditions for calculating bus conductor ampacity are in Table 15.3.

25.1.6.2. The existence of any unusual environmental conditions should be considered at each substation site. These conditions may include corrosive fumes or vapors, explosive mixtures of dust or gases, steam, magnesium chloride spray, and salt spray.

Table 25.2: Environmental design criteria.

	CO	MN/WI (South)(1)	MN/WI (North)(1)	NM	TX
Design Temperature Range (°C)	-40 to 40	-40 to 40	-50 to 40	-30 to 40	-30 to 40
Design Ice Loading(2) (inches, radial loading)	1 in	1 in	1 in	1 in	1 in
Elevation above mean sea level (feet/meters)	Min. design criteria is 5,900 ft (1800 m) Use 11,000 ft (3353 m) elev. at sites >8,500 ft (2591 m)	<3300 ft (1006 m)	<3300 ft (1006 m)	>=3700 ft (1128 m)	>=3700 ft (1128 m)

(1)The division between MN/WI north and south is roughly defined as the east-west line running between St. Cloud, MN and Eau Claire, WI.

(2)For issues related to structural design, including regional seismic zones, refer to the Civil/Structural Design Criteria.

Table 15.3: Design criteria for substation bus conductor and ampacity ratings.

	NSP	PSC	PSC ≥8500 ft	SPS
Summer Ambient Temp. (Deg. C)	40	40	35	40
Day of the Year	June 21 (172nd day)	June 21 (172nd day)	June 21 (172nd day)	June 21 (172nd day)
Temp. Rise (Deg. C)	45	45	50	45
Bus Temp. (Deg. C)	85	85	85	85
Emissivity Outdoors (*e*)	0.5	0.5	0.5	0.5
Emissivity Indoors (e)	0.35	0.35	0.35	0.35
Absorptivity (*a*)	0.5	0.5	0.5	0.5
Degrees N. Latitude	43	40	40	35
Time of Day	Noon	Noon	Noon	Noon
Atmospheric Conditions	Clear	Clear	Clear	Clear
Elevation	1,100 ft (336 m)	5,900 ft (1800m)	11,500 ft (3506 m)	>=3,700 ft (1128 m)
Wind Speed (ft/sec)	2	2	2	2
Wind Direction	90	90	90	90
Line Orientation	E/W (90˚)	E/W (90˚)	E/W (90˚)	E/W (90˚)

Note 1: For indoor calculations, solar heat gain should not be applied.
Note 2: When wind speeds are zero, forced convection heat loss rate should not be applied.

25.1.7. Bus layout criteria, clearances, etc.

25.1.7.1. A bus arrangement in substation should have "B" phase in the center. The phase sequence required for the transformers may fix the location of "A" and "C" phases. Coordination with the interconnecting utility is preferred. Tubular bus criteria — All tubular bus designs shall be in accordance with accepted industry standards and practices. The IEEE 605 - IEEE Guide for Bus Design in Air Insulated shall be followed in all cases.

25.1.7.2. Clearances – NESC C2 and ANSI C37.32 with any additional site specific requirements shall be considered and either meet or exceed the minimum requirements for design clearances. All substation arrangements will be designed to allow safe maintenance and repair of adjacent equipment.

25.1.7.3. Ampacity Ratings

25.1.7.3.1. Substation bus conductors are to be sized based on the ampacity requirements of the substation and any future expansions noted upon commencement of design. All conductor ratings shall follow the applicable Environmental design requirements. Once the bus conductor sizes are determined, switches and breakers are sized to meet or exceed the bus conductor ampacity ratings. In some cases, the determining factor in sizing the bus conductors will be structural and mechanical requirements.

25.1.7.3.2. The minimum standard continuous current rating that will be used for transmission switches and breakers is 1,200A. A load flow study should be performed to confirm ratings impacts on detailed high side facilities (ring bus, breaker and a half) that have influence other current sources.

25.1.7.4. Aluminum bus conductor applications

25.1.7.4.1. All Aluminum Conductor (AAC) is used for substation strain bus and connections where flexibility is required or rigid bus is not feasible. ACSR conductor can also be used where practical to gain rigidity in some special cable connections.

25.1.7.4.2. Aluminum tubing is used primarily to obtain structural rigidity in long unsupported spans of bus, usually in high voltage structures, and over designed in current carrying requirements is disregarded.

25.1.7.5. Bus Connections

25.1.7.5.1. All current carrying aluminum connections shall be thoroughly cleaned, coated and sealed with an oxide inhibiting agent. Aluminum oxide, which is a poor electrical conductor, forms rapidly on the surface of drawn or rolled aluminum. It must be removed and prevented from reforming after the connection is completed. This applies to all connections, whether bolted, clamp or compression type. Caution - Aluminum expands 30% (1.33 times) more than copper. Every connection involving a combination of aluminum and copper must be planned to avoid gradual loosening caused by large temperature changes. Unequal expansion of aluminum, copper and steel can cause extremely high pressure during hot conditions which stretches one or more of the metals leaving a loose connection when cold conditions occur

25.1.7.5.2. Bolted electrical connections shall be made on flat contact surfaces, completely cleaned with an oxidation inhibitor. This must be done by thoroughly scratch-brushing the contact surfaces through the inhibitor, leaving enough of it on the surface to control reformation of oxides. After the connection is completed, additional compound shall be applied and forced into every irregularity and opening in order to completely seal the joint against moisture and corrosion.

Aluminum to Aluminum connections shall be fastened with aluminum bolts, 2024-T4alloy with No. 205 alumalite finish and preferably NO-OX-ID coated. Nuts shall be of the same alloy and finish. Heavy series bolts and nuts (7/8" across flats) are preferred.

Aluminum to Copper connections shall be made only with flat contact surfaces. Dressing and sealing the connection with inhibitor is especially important where unlike metals are in contact. Care must be taken to place the aluminum above copper when in a horizontal plane so that corrosive copper salts do not flow onto the aluminum. The type of bolt used is also important because extreme temperature changes can cause a loose joint due to the expansion differential between copper and aluminum. Aluminum or bronze bolts will be used as specified below: (a) Use aluminum bolts if thickness of the aluminum conductor is the same or greater than the copper conductor. (b) Use bronze bolts (Everdur) if the copper conductor is thicker than the aluminum.

25.1.7.5.3. Cable terminations can be made with clamp, compression and welded type fittings; preferably welded or compression types. Welded fittings should be used only when there is enough other bus welding on the project to make it economical.

25.1.8. Ground Grid Criteria

25.1.8.1. The short-circuit design rating for a particular substation is selected based on the calculated maximum available fault current available at that location, and takes into account the future growth of the substation and power system. Step and touch potential calculations may be based on the estimated future maximum fault current level. Substation grounding design is based on the IEEE 80 standard.

25.1.8.2. Ground Potential Rise (GPR) calculations may be required to support the local telephone company provider design needs.

25.1.8.3. The substation grounding system is a grid buried 18” below rough grade and made of 4/0 - 19 strand soft drawn copper conductor, ¾” threaded ground rods, and appropriate connector fittings. The conductor is run as a continuous loop when attaching to ground rods, fence, structures, and most equipment (transformers are the exception).

25.1.8.4. The fence and the fence counterpoise (a conductor buried 3' beyond the substation fence) are both connected to the ground grid.

25.1.8.5. All equipment must have provisions for grounding in accordance with OSHA codes. The ground grid shall be attached to equipment at two different points such as opposite corners of a transformer or each leg of a switch stand. The grid shall be bolted or welded to all steel structures and fence posts.

25.1.8.6. Electrical Equipment Enclosure grounding shall be tied to the substation grounding system in two places, at opposite sides of the enclosure.

25.1.8.7. Cable Trench Conductor grounding shall conform to the following:

25.1.8.7.1. One #4/0 bare copper conductor is to be laid in all precast or direct burial cable trench. The ground conductor is required to protect control cables from stray ground currents or signals usually present in high voltage installations by equalizing the potential along the length of the cables.

25.1.8.7.2. The trench ground conductor must be connected to the station grounding system at every intersection and at the ends of each trench. In the case of direct buried trenches, the ground conductor shall be incorporated into the system grounding design.

25.1.8.8. Switch Handle grounding on steel structures shall have the operating pipe be bonded to the steel using a flexible grounding jumper.

25.1.8.9. Ground wells and other enhancements are utilized when required.

25.1.9. Conduit and Cable Trench Criteria

25.1.9.1. Direct buried cables shall not be used. If conduit size is greater than 4 inches then use multiple conduits instead. Does not apply to feeder risers.

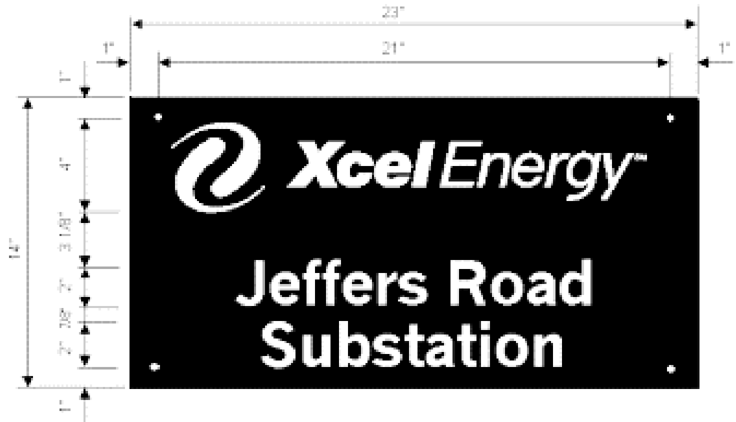
25.1.9.2. Cables within the substation shall be routed through a cable trench system extending from the Electrical Equipment Enclosure (EEE) to equipment located within the substation. The final route from the cable trench to the device shall be in schedule 40 PVC conduit for below grade portions of the conduit, and RGS conduit for bends / sweeps and above grade locations.

25.1.9.3. Cables shall be suitable for direct burial.

25.1.10. Outdoor Nameplate/Safety Sign Requirements

25.1.10.1. Each substation has a facility identification sign posted near the main entrance that gives the company name, substation name, and physical address. If there is a separate security gate installed at the entrance off of the public road, there will be a facility identification sign at this gate as well as at the main entrance. Additionally, warning signs are posted on each entrance gate and at intervals around the outside of the substation fence (typically every 50'). Within the substation, all power equipment and switches are labeled. Warnings signs are also posted for battery systems, buried cable, and areas of limited clearance. Substation signs must meet or exceed the requirements of the National Electric Safety Code.

25.1.10.2. Substation Identification Sign



14" x 23" sign

25.1.10.2.1. The sign should be placed on all substations unless this conflicts with local laws and ordinances.

25.1.10.2.2. The signs should be 6'-0" from grade to top of sign, placed adjacent to substation walk or drive gate and above the address sign.

25.1.10.2.3. Mount using a copper or aluminum wire tie in each hole.

25.1.10.2.4. Sign specifications:

Size: 14" x 23"

Material: 0.080 aluminum plate with 3M High Intensity Silver Scotchlite code #3870. Background to be silk-screened with 3M #845 black paint.

Text shall be 2" Helvetica Medium Upper and Lower Case. (example: Jeffers Road Substation).

Owner logo must be per company guidelines.

25.1.10.3. Substation Address Sign

25.1.10.3.1. The signs should be placed adjacent to substation walk or drive gate and under the Substation Identification Sign.

25.1.10.3.2. Mount using a copper or aluminum wire tie in each hole.

25.1.10.3.3. Sign specifications:

Size: 36" x 7" (vendor can make sign longer for longer addresses).

Material: 0.080 aluminum plate with 3M High Intensity Silver Scotchlite code #3870.

Background to be silk-screened with 3M #845 black paint.

Text shall be 3 ½" Helvetica Medium Upper and Lower Case.

25.1.10.4. Substation Safety Sign

25.1.10.4.1. The signs should be placed 2 to 3 times the readability distance of the message text (Table 1, ANSI Z535.2 "Minimum Letter Height Calculations"). In this case, 30 to 45 feet apart and no more than 15 feet from the corners of the enclosure.

25.1.10.4.2. Two signs should be placed on each drive gate, one on the inside and one on the outside (back to back). This is done so you can read the inside sign if the gate is open.

25.1.10.4.3. One sign should be placed on the outside of each walk gate.

25.1.10.4.4. The signs should be placed approximately 5'-0" form grade to top of sign.

25.1.10.4.5. Mount using a copper or aluminum wire tie in each hole.

25.1.10.5. Substation Battery Warning Sign

10" x 14"

25.1.10.5.1. Signs should be placed on the outside of all substation control house doors.

25.1.10.5.2. Sign is to be mounted to the door using sheet metal screws.

25.1.10.5.3. The signs should be placed approximately 5’-0” from the bottom of door to the top of the sign and centered on the door.

25.1.10.5.4. These signs are now required per the National Electrical Safety Code, Section 14, Part 146B.

25.1.10.6. Substation Buried Cable Sign

10” x 7” Sign

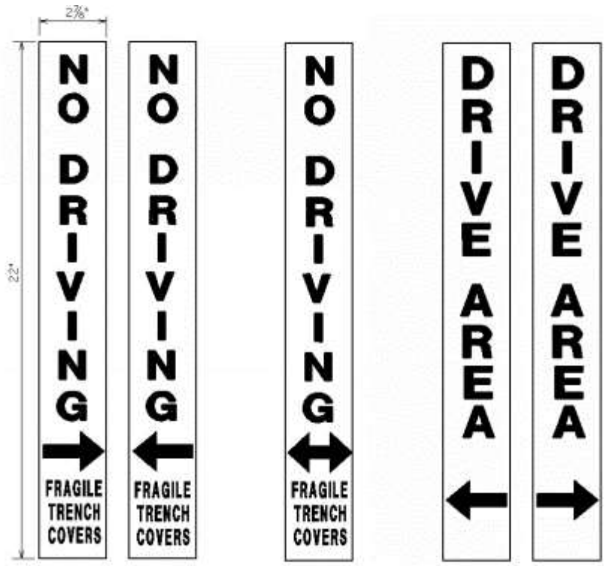
25.1.10.6.1. The sign should be placed at substations where cables are in the area and need to be marked to prevent accidental digging.

25.1.10.6.2. The signs should be mounted on each side of the substation fence fabric, back to back, at the location where cables pass under the fence.

25.1.10.6.3. Mount to fence using a copper or aluminum wire tie in each hole.

25.1.10.6.4. Outside of the substation fence this sign can be mounted to a steel channel post.

25.1.10.7. Substation Precast Cable Trench Signs



Sign #1 Decals Mounted Back-to-Back

Sign #2 Decals Mounted Back-to-Back

Sign #3 Decals Mounted Back-to-Back

25.1.10.7.1. Vehicles cannot drive over precast cable trench without breaking covers. The warning signs shown above will be driven into the ground at strategic locations where vehicles could mistakenly drive over the precast cable trench.

25.1.11. Indoor Equipment and Panel Labels

25.1.11.1. All indoor equipment and devices shall be labeled.

25.1.11.2. Blocking bar switch handles shall be labeled with a white background, black lettered label describing where the other end of the wire is landed.

25.1.11.3. Every test switch shall have a trip switch index hung in a C-Line 46058 document protector on the relay panel where the test switch is located.

25.1.11.4. Labels shall be laminated phenolic plastic tags with the following color coding.

25.1.11.4.1. White with black lettering: all devices or items not specifically called out.

25.1.11.4.2. Yellow with red lettering: Operator switches; 43, 97, other control switches.

25.1.11.4.3. Red with white lettering: Test switches

25.1.11.4.4. Orange with black lettering: Lockout switches (86).

25.1.11.5. The font sizes and types show in

25.1.11.6.

25.1.11.7.

25.1.11.8. Table shall be used.

Table 25.4: Indoor equipment and panel labels labeling machine font size and type requirements.

Font Size	Application
36 pt Bold	Panel names (Front and Rear) ACT, APT Phase Designations
30 pt Medium*	97, 43, SS, 243, 283, Switches
24 pt Medium* (16 pt (8x2) where space is limited)	FT Boxes Individual Indicating Lights Metering Relays Annunciator Box Number Trip Switches In Rear
16Pt (8x2) Medium	Annunciator Point Numbers
12 pt.	Annunciator Labels Plug in and Draw Out Relays AC & DC Panel Circuit Descriptions Chrysler 8000 RTU: CKT Descriptions (On Panel)
16/8 pt. (Double Line)	Indicating Fuses DC Circuit Numbers In Fuse Cabinet

*If medium cartridge is not available use the "bold" function on the machine.

25.1.12. Site Lighting Criteria

25.1.12.1. Outdoor substation lighting shall be controlled from the interior of the Electrical Equipment Enclosure with a switch, or switches. Lighting contactors may be used with switching to turn the outdoor lights on and off.

25.1.12.2. Outdoor yard lighting for substation equipment shall provide an average of 2 foot-candles for safe operation/maintenance of equipment and for security. Remote areas of the substation yard shall have an average of 0.2 foot-candles.

25.1.13. Lightning Protection Requirements

25.1.13.1. All substation electric equipment, electric bus, and support structures shall be shielded from direct lightning strikes. Shield masts and shield wires are the preferred methods of lightning shielding within substations. When economical, it is preferred to not have shield wires directly over bus.

25.1.13.2. Two widely used methods for designing substation lightning shielding are i) “fixed angle zone of protection” or “traditional cone” and ii) “electro-geometric model” or “rolling sphere”. Although the traditional cone method is more commonly used, either method is acceptable. IEEE 998 standard shall be applied in the evaluation.

25.1.14. Wildlife Protection of Bushings

25.1.14.1. Outdoor bushings operating at 35KV and below shall have protection installed on them to reduce the potential for phase to ground or phase to phase faults caused by wildlife getting near the area of the bushings. The protection shall be applied on equipment such as transformer bushings, surge arrestors, circuit breakers, circuit switchers, auxiliary transformers, potential transformers, etc. The bushing protection shall be “Therm-A-Guard” or equal, and shall also include covers for conductors extending from the bushings.

25.1.14.2. Each bushing protector shall have two cable ties around it to ensure it stays in place.

25.1.15. Cable Raceway System

25.1.15.1. This Section describes the requirements for a complete and proper cable raceway installation for the substation, as shown in the Design Documents. Cable raceway systems shall include any system designed expressly for holding or routing wires and cables including excavated trenches.

25.1.15.2. Contractor shall install all direct buried conduit or duct, concrete encased conduit or duct, indoor and outdoor conduit, cable tray, cable trench and accessories required for embedded and exposed raceway systems. Conduit accessories shall include but not be limited to the following items: conduit fittings, conduit connectors, outlet boxes, outlet bodies, pull boxes, junction boxes, locknuts, bondnuts, bushings, materials for sealing joints and ends of conduits, panelboards, cabinets, tray hanger supports, bracket supports and clamps, excavation warning tape and all other material and devices required for a complete and proper electrical cable raceway system.

25.1.15.3. Referenced Codes and Standards

25.1.15.3.1. The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard or code conflict with these Specifications Owner shall be notified at once and a remedy shall be determined.

25.1.15.3.2. National Fire Protection Association:

Most recent version of the National Electrical Code (NEC)

25.1.15.3.3. National Electrical Manufacturers Association:

NEMA Publication 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

25.1.15.4. Materials

25.1.15.4.1. Conduit

Above grade conduit and conduit extending from above grade to below grade including below grade sweeps shall be rigid galvanized steel (RGS). Below grade conduit extending from RGS sweeps shall be schedule 40 -polyvinyl chloride (PVC) conduit.

Electrical Metallic Tubing (EMT) thin wall conduit may be used in indoor, non-hazardous or in embedded locations. EMT connectors and couplings shall be gland compression type. Set-screw type connectors shall not be used.

All flexible conduit shall be steel reinforced and liquid tight.

25.1.15.4.2. Raceway Accessories

Breaker panels, junction boxes and outlet boxes, together with associated items for attaching and making connections, shall be installed in conformance with the Design Documents and this Section.

All outdoor, surface-mounted outlet boxes shall be cast aluminum or cast iron, with gasketed steel or aluminum cover plates. Crouse-Hinds, Russel & Stoll or Owner approved equal shall be used. Formed metallic outlet boxes shall not be used in outdoor locations.

Junction boxes used in outdoor locations for splicing and terminating wires shall be NEMA Type 3R, 16 or 14 gauge galvanized steel or Owner approved equal, supplied without knockouts. The size of all enclosures shall be in accordance with all applicable codes. Connections to the top and sides shall be made with waterproof hubs. Connections to the bottom shall be made with a bushing and two (2) locknuts.

Formed metallic outlet boxes may be used in indoor, non-hazardous locations in accordance with the NEC. Cover plates shall be steel or aluminum.

25.1.15.5. Raceway Installation

25.1.15.5.1. All raceway shall be installed in accordance with the Design Documents and this Section.

25.1.15.5.2. Above-Grade Conduit

All above-grade exposed conduit shall be RGS unless otherwise stipulated. Where it is connected to buried conduit, the RGS conduit coupler shall extend to one (1) inch above finished grade, making the required bend radius into the horizontal run.

Where possible, conduit runs shall be parallel to the centerlines of structures or parallel to each other in the case of multiple runs. A run of conduit, embedded or exposed, shall not contain more than the equivalent of four (4) quarter-bends (360* total) between outlet boxes, outlet bodies, junction boxes and pull boxes., including bends located immediately at the outlet box, or junction box. All exposed conduit and conduit inside the control house shall be one-half (1/2) inch minimum.

Factory bends or bends made with a hydraulic power bender shall be used for conduit two (2) inch and smaller. The minimum bending radius of conduit shall be seven (7) times the nominal diameter of the conduit. All bends for conduit sizes above two (2) inches shall be factory bends.

All conduit runs shall be supported at least every five (5) feet. Fittings and outlets that are for conductor feed-through shall have the attached conduit supported within three (3) feet of the outlet. Place conduit supports within eighteen (18) inches of outlets that contain devices such as receptacles or boxes that support fixtures.

Where conduit enters a box, vault, cable trench or any other fitting or termination, a bushing shall be provided to protect the cable from abrasions. At all points where the conduit terminates, the bushing shall be grounding type to provide an effective connection to ground. The ends of conduit shall be protected to prevent the entrance of any foreign material.

All material and equipment shall be stored so as to be protected from deteriorating effects of the elements. All exposed ends of conduit shall be protected during construction to prevent the entrance of any foreign material or moisture. Touch-up paint shall be provided by Owner as required.

Burrs or sharp projections which might injure the cable shall be removed.

Round, flexible, nylon-covered tapes or nylon ropes shall be used for fishing and wire-pulling in conduit.

Pre-drilled holes (if furnished) shall be used for mounting boxes. Drilling through the top, sides or back of a junction box is not acceptable for NEMA Type 3 ratings or above. Drilling through the top or sides of junction boxes rated below NEMA Type 3 is not acceptable. Formed channels shall be used for mounting boxes unless otherwise indicated in the Design Documents.

25.1.15.5.3. Direct Buried Conduit or Duct

Horizontal runs of buried conduit shall be PVC conduit unless otherwise specified. Locate underground runs in accordance with the Design Documents. Pull boxes shall be installed to limit any run of conduit to (4) quarter bends (360° total). All conduit runs shall contain a cable pulling tape or rope.

Underground conduit runs shall be installed as shown in the Design Documents and as follows:

Excavated trench bottom shall be smooth or filled with clean sand as required to make it such.

Conduit shall be used for runs under roadways as shown in the Design Documents.

All bends, including those within or at the ends of PVC conduit sections, shall be made with RGS conduit. Adapter connectors shall be provided between PVC conduit and all RGS conduit sections.

Backfill around the conduit shall be in accordance with the Design Documents.

Conduits which enter manholes pull boxes or building foundations shall use end bells and be grouted in place. End bells shall be flush with the surface.

As soon as practical after conduit runs are completed and concrete forms are stripped, all conduit runs shall be swabbed free of foreign material. Plugs or caps shall be installed with greased threads and left in place until the wire is installed.

RGS conduit shall be used to make entrance connections into buildings or equipment foundations and vaults. The RGS conduit is to be extended a minimum of eighteen (18) inches beyond exterior walls for buried cables, or as shown in the Design Documents. All conduit entrances into the control building or into any outdoor enclosure or vault shall be sealed with Duxseal or other Owner approved material.

The 34.5kV collection feeder conduit shall be protected with concrete bollards. Contractor shall submit plans for protection to Owner for approval.

25.1.15.5.4. Concrete-Encased Conduit or Duct

Conduit, conduit fittings and conduit boxes to be embedded in concrete shall be held securely in position while the concrete is being placed.

The conduit shall rest on spacers to ensure that the spacing between conduit runs does not change during the placement of the concrete. The spacers shall be placed at regular intervals as specified in the Design Documents or as recommended by the manufacturer, whichever is less. Conduit shall be secured to the trench bottom to prevent flotation.

Concrete used for encased conduit or duct shall have a twenty-eight (28)-day compressive strength of at least 2000 psi. The aggregate shall be less than three-fourths (3/4) inch in diameter. Red Dye shall be incorporated into top of ductbank concrete or Caution Buried

Electrical Line Below tape shall be placed 12” above top of ductbank. When the backfill above the concrete must be compacted, the concrete shall cure for seven (7) days before backfilling. When compaction of the backfill is not required, backfill can be placed twenty-four (24) hours after pouring.

After the forms are removed Contractor shall clean all concrete from the inside of conduit boxes and threads for attaching devices and covers.

25.1.15.5.5. Precast Concrete Trench

An assembled-component-type reinforced precast concrete cable trench system shall be installed in accordance with the Design Documents, this Section and the manufacturer’s recommendations.

Contractor shall excavate all substances encountered to a depth necessary to properly install the concrete trench system. All previously installed buried conduits, buried cables, copper ground grid wire and site drainage systems shall be located, by digging or other methods, prior to excavating in concrete trench locations. Ground grid wires interfering with the trench installation shall be spliced exothermically and buried six inches below the trench. The site drainage system shall not be modified in any way to facilitate the concrete trench installation and drain pipe back fill shall be restored to original condition if disturbed. Any damage to existing installations shall be repaired to the satisfaction of Owner.

Precast trench members shall be set only on firm, compacted earth, sand or gravel mix, such that the top of the sidewall will be at the elevation indicated in the Design Documents.

Excavations shall be kept free from water during the placement of concrete trench system components and during inspection.

Conduits entering the concrete trench system shall be laid beneath the sides of the trench and terminated with an angle deflection and bushing or acceptable conduit fitting to enter the trench.

Following the concrete trench installation, all excavation shall be backfilled and mechanically compacted to grade. Backfill along the trench system shall be performed according to the manufacturer’s recommendations and shall not deflect the trench sidewalls.

Covers shall be placed on the concrete trench after installation of cables is completed.

The concrete trench system shall be protected against entrance of construction debris, rock and earth during the construction and after placement of the sand bedding. Contractor shall clean the concrete trench system of any such foreign material immediately prior to placing cables and just before final placement of covers.

25.1.15.5.6. Overhead Cable Tray System

An assembled, overhead, indoor cable tray system shall be installed in the control building in accordance with the Design Documents, this Section and the Manufacturer’s recommendations.

Cable entrances to equipment enclosures and panelboards from a cable tray shall be made with conduit runs or via openings in the tray bottom. All cable entrance cutouts in the cable tray bottom, or equipment enclosure shall have grommets to protect the cable jacket from cuts or abrasions. Conduits entering the cable tray shall be securely fastened to the tray sidewall with hardware specifically used for that purpose.

The overhead cable tray shall be supported as shown in the Design Documents. The preferred method of support utilizes roll-formed uniform channel framing members attached to the floor and wall. An alternate method uses a trapeze-type support made of roll-formed channel with threaded rods fastened to the ceiling. All tray supports connected to the ceiling of a metal building shall be directly attached to roof purlins or to formed channel fastened to the nearest roof purlin. Tray supports in the ceiling of a masonry building shall utilize properly-sized drilled expansion anchors.

Cable tray located above wall-mounted equipment shall be supported with brackets fastened directly to wall columns and specifically designed for that purpose.

25.1.15.6. See Cable Raceway System testing requirements.

25.1.16. Shielded Cable

25.1.16.1. Shielded control cable shall only be required if there is 230 kV or greater present in the substation.

25.2. Civil/Grading

25.2.1. All civil and earthwork shall meet the construction requirements and the testing and inspection requirements..

25.2.2. Fill Material Applications

25.2.2.1. Fill material shall meet the requirements

25.2.2.1.1. Common Fill

Used as backfill below frost line or in berms in the graded area.

25.2.2.1.2. Select Fill

Used as fill in the graded areas and as subbase for the access roads or subcuts required for shallow foundations.

25.2.2.1.3. Granular Fill

Shall meet the project requirements

Used as a top course of the fill placement as shown in the Design Documents and as bedding and backfill for drainage piping or culverts.

A type of granular material used as a separation layer in substations is four (4) inches of 3/4" diameter clean crushed rock.

Granular Fill applications are as follows:

GRADATION TYPE "A"

a) wet-caving condition - all soils

b) suitable for pole excavation below water table where casing of hole is necessary to prevent soil caving.

GRADATION TYPE "B"

a) wet and caving condition with saturated granular or cohesive soils

b) dry and caving condition with sandy soils

c) dry condition with dense moist granular soils or stiff hard cohesive materials

GRADATION TYPE "C"

a) Dry condition with dense moist granular soils or stiff hard cohesive materials

25.2.2.1.4. Base Material

Base material is used primarily for improving roadway stability and shall be used as a top course on all access roads and over the substation graded area. Adequate compaction as specified in the Design Documents is essential in providing adequate material stability and long term durability. This material shall meet the Road Base and Cap Aggregate specification in Section **Error! Reference source not found.**.

25.2.2.1.5. Lean Concrete Backfill

Lean Concrete Backfill may be placed around buried conduit in conjunction with underground substation construction where compaction of granular material around conduit or piping is difficult and/or impractical. This material is recommended where existing slabs or foundations are in danger of being undermined. This material shall meet the Lean Concrete Backfill specification.

25.2.3. Security Fence

25.2.3.1. The security fence shall adhere to the requirements provided.

25.2.4. Bollards

25.2.4.1. Bollards shall be placed around no drive areas and areas such as in front of feeder risers to protect them from damage.

25.2.5. Substation Access Road

25.2.5.1. Driveways should be designed with a minimum 50 foot inside radius and enough space to straighten a truck out before going through the gate. Driveway paths within the fenced substation should avoid crossing precast cable trenches if possible.

25.2.6. Finish Conditions

25.2.6.1. The substation shall be covered with 4” of clean crushed stone. The crushed stone shall extend ~~5~~ 3 feet outside of the substation fence and provide an electrical resistivity value of greater than or equal to 3,000 ohm-meters.

The conductor in each cable shall be sized to withstand 100% of the available phase fault current for a minimum of 9 cycles. The substation feeder breaker will be set for an instantaneous fault (with 5 cycle delay) and will clear a fault in 9 cycles for normal system clearing.

Normal Fault Clearing Time:

- 5 Cycle Delay on Relay Tripping
- 1 Cycle Relay Margin
- 3 Cycle Breaker Interrupting Time
- 9 Cycle Total Clearing Time

The concentric shield wires in each of the three cables (A, B, & C Phase) shall be sized to withstand 70% of available ground fault current for a minimum of 6 cycles. The substation feeder breaker will be set for an instantaneous ground fault and will clear a fault in 6 cycles or less for normal system clearing.

Normal Fault Clearing Time:

- 0 Cycle Delay on Relay Tripping
- 3 Cycle Relay Margin
- 3 Cycle Breaker Interrupting Time
- 6 Cycle Total Clearing Time

The system trench ground, routed with the collection system feeder cables, shall be sized to withstand 100% of available ground fault current for a minimum of 6 cycles. The substation feeder breaker will be set for an instantaneous ground fault and will clear a fault in 6 cycles or less for normal system clearing.

Normal Fault Clearing Time:

- 0 Cycle Delay on Relay Tripping
- 1-3 Cycle Relay Margin
- 3 Cycle Breaker Interrupting Time
- 6 Cycle Total Clearing Time

25.2.6.2.

25.3. Structural

25.3.1. Structural Steel Erection

25.3.1.1. This section describes the requirements for the complete and proper erection of structural steel as shown in the Design Documents.

25.3.1.2. Structural steel consists of steel elements essential to support the design loads and includes but is not limited to the items listed below:

25.3.1.2.1. Anchor bolts.

25.3.1.2.2. Base plates.

25.3.1.2.3. Beams, girders, columns and posts.

25.3.1.2.4. Bracing.

25.3.1.2.5. Structural material for connecting structural element to structural element.

25.3.1.2.6. Fasteners.

25.3.1.2.7. Leveling plates and associated materials.

25.3.1.3. Referenced Codes and Standards

The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard or code conflict with these Specifications Owner shall be notified at once and a remedy shall be determined.

25.3.1.4. American Institute of Steel Construction:

25.3.1.4.1. AISC Steel Construction Manual

25.3.1.4.2. AISC Specification for Structural Steel Buildings.

25.3.1.4.3. AISC Code of Standard Practice for Steel Buildings and Bridges.

25.3.1.5. American Society for Testing and Materials

25.3.1.5.1. ASTM A36 Specification for Structural Steel.

25.3.1.5.2. ASTM A992 Standard Specification for Structural Steel Shapes

25.3.1.5.3. ASTM A780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.

25.3.1.5.4. ASTM A325 Specification for High-Strength Bolts for Structural Steel Joints.

25.3.1.5.5. ASTM A307 Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength.

25.3.1.5.6. ASTM F959 Specification for Compressible-Washer-Type Direct Tension Indicators for use With Structural Fasteners.

25.3.1.5.7. ASTM E94 Guide for Radiographic Testing.

25.3.1.5.8. ASTM E142 Methods for Controlling Quality of Radiographic Testing.

25.3.1.5.9. ASTM E164 Practice for Ultrasonic Contact Examination of Weldments.

25.3.1.5.10. ASTM E165 Practice for Liquid Penetrant Inspection Method.

25.3.1.5.11. ASTM E709 Practice for Magnetic Particle Examination.

25.3.1.6. American Welding Society:

25.3.1.6.1. AWS D1.1 Structural Welding Code – Steel

25.3.1.7. Research Council on Structural Connections:

25.3.1.7.1. Specification for Structural Joints Using ASTM A325 or A490 Bolts

25.3.1.8. Welder Certification

25.3.1.8.1. Contractor shall submit AWS qualifications of welders performing welding on structural steel.

25.3.1.9. Structure Erection

25.3.1.9.1. Contractor shall perform the following tasks to properly and completely erect each steel structure:

25.3.1.9.2. Set structural steel accurately to lines and elevations indicated.

25.3.1.9.3. Align and adjust various members forming part of a complete frame or structure before permanently fastening.

25.3.1.9.4. Clean bearing surfaces and other surfaces which will be in permanent contact before assembly.

25.3.1.9.5. Perform necessary adjustments to compensate for discrepancies in elevations and alignment.

25.3.1.9.6. Level and plumb individual members of each structure.

25.3.1.9.7. Splice members only where indicated in the Design Documents.

25.3.1.9.8. Complete all structural connections with proper installation and torque requirements of fasteners.

25.3.1.9.9. Foundation Loading

Steel structures shall not be erected on concrete foundations until the concrete has achieved 75% of design strength. Steel structures shall not be loaded until foundation concrete has achieved 100% of design strength.

25.3.1.9.10. Surveys

Contractor shall check elevations of concrete bearing surfaces and locations of anchor bolts and similar devices before erection work proceeds and report discrepancies to Owner. Contractor shall not proceed with erection until corrections have been made or until compensating adjustments to structural steel work have been approved by Owner.

25.3.1.9.11. Temporary Shoring and Bracing

Contractor shall provide temporary shoring and bracing members with connections of sufficient strength to bear loads imposed during construction. All temporary members and connections shall be removed when permanent members are in place and final connections are made. Temporary guy lines may be used to achieve proper alignment of structures as erection proceeds.

25.3.1.9.12. Setting Base and Bearing Plates

Contractor shall set loose and attached base plates and bearing plates for structural members on wedges or other Owner approved adjusting devices. Anchor bolts shall be tightened after supported members have been positioned and plumbed.

25.3.1.9.13. Bolted Connections

Wrenches which may deform the nuts or cut or flake the galvanizing will not be permitted.

Multiple-Bolt, Moment Connections

The bolts shall be tightened in accordance with Manufacturer's guidelines.

Single-Bolt, Pinned Connections

The bolts shall be tightened until the bolt head and nut are snug against the outer plates and the nut locking device is fully engaged. The inner plate surfaces do not necessarily need to be in full contact with each other to obtain an acceptable connection.

Enlarging Bolt Holes

Holes in members shall not be enlarged without Owner approval. Holes which must be enlarged shall be reamed, under the direction of Owner, to accommodate the next larger size bolt. Holes shall not be enlarged by burning or by using drift pins.

Substitution of Bolts

Substitution of the bolt sizes and materials specified in the Design Documents must be approved by Owner.

25.3.1.9.14. Field Correction of Fabrication Errors

Contractor shall not use gas cutting torches to correct fabrication errors in primary structural framing members. Gas cutting will be permitted only on secondary members that are not under stress.

Field Welding

Field welds shall not be permitted without review by Owner. All approved field welding shall be performed in accordance with AWS requirements for weld material and prequalified joints and shall be performed by certified welders.

Contractor shall submit AWS qualifications of welders performing field welding on structural steel.

Field Drilling

Missing holes shall be added by drilling or punching. Flame cutting of holes shall not be used.

Field Repair of Galvanizing

All metal exposed as a result of field repair activities shall be re-coated.

25.3.2. Surface Coating Repair

25.3.2.1. Reference Codes and Standards

The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard, or code conflict with these Specifications, Owner shall be notified at once and a remedy shall be determined.

25.3.2.1.1. Steel Structures Painting Council:

SSPC-PA1 Shop, Field, and Maintenance Painting.

SSPC-SP3 Power Tool Cleaning.

25.3.2.1.2. American Society for Testing and Materials:

ASTM A780 Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

25.3.2.2. Equipment

25.3.2.2.1. Surfaces of most electrical equipment (such as panels, switchgear, transformers, circuit breakers, cabinets, junction boxes, etc.) are finished at the factory. Contractor shall exercise great care to prevent damage to this original finish during installation of the equipment and during construction work. If the factory finish is damaged during shipment, installation or the course of construction, the damaged surface area of the component shall be refinished. The refinished surface shall be equivalent in every respect to the original surface, including color, texture, gloss, and smoothness. Refinishing paint if furnished with the equipment may be used; otherwise, the paint shall be obtained from the equipment manufacturer.

25.3.2.3. Structural Steel

25.3.2.3.1. Contractor shall be responsible for repairing galvanized surfaces of structural steel damaged during shipment, erection, field modifications or during the course of construction and for applying an approved surface coating over any bare metal areas which were not galvanized during fabrication. All bare metal areas and bolted connections which are subject to corrosion and requiring galvanizing repair shall be cleaned and repaired in conformance with SSPC-PA1, ASTM A780 and the manufacturer’s instructions.

25.3.2.3.2. Immediately after structure erection has been completed, all field welds shall be ground smooth and the adjacent uncoated areas and any areas where the coating has been damaged shall be cleaned in conformance with SSPC-SP3.

25.3.2.3.3. All steel requiring galvanizing repairs shall be coated with an inorganic, zinc-rich coating in accordance with the following conditions:

a. The galvanizing repair paint shall be SSPC-Paint 20 or DOD-P-21035, with a dry film containing a minimum of 94 percent zinc dust by weight.

b. Surfaces to be coated shall be free of abrasives, oils, dirt or other contaminants.

c. Handling of coating equipment and the steel surfaces to be repaired shall be performed in a manner to avoid contamination prior to, during and following the application of the protective coat.

d. The surface temperature of the steel to be coated shall be 50°F minimum and at least 5°F above the wet-bulb air temperature reading.

e. The coating shall be allowed to cure prior to application of a second (or top) coating for at least the minimum time recommended by the coating manufacturer.

f. The coating thickness shall be 3.0 mils dry film thickness. The thickness shall be monitored by wet-film thickness measurements.

g. Areas with dry-film thickness of less than 1.7 mils or greater than 5.0 mils shall be corrected by additional surface coating or by wire brushing and recoating.

25.4. Electrical

25.4.1. Equipment Installation

25.4.1.1. Power Circuit Breakers and Circuit Interrupters

25.4.1.1.1. Contractor's external inspection, receiving and installation activities shall include but not be limited to the following:

a. Receive the breaker at the shipping point.
b. Examine the shipment and note any obvious signs of damage or rough handling.
c. Inventory the shipment and check it against the shipping list.
d. Report any shortages to the Manufacturer and Owner.
e. Place the power circuit breaker on the foundation.
f. Orient the breaker mechanism cabinet as shown in the Design Documents.
g. Install SF6 gas if required.
h. Fill to proper pressure per name plate requirements.
i. Perform a gas system moisture check. (The gas should be processed and the breaker tank evacuated as need is indicated in the Manufacturer's instructions.)
j. Check for gas leaks.
k. Install bushings.
l. Install ground assemblies.
m. Install bus system connections
n. Install conduit runs into the equipment cabinet.
o. Make all secondary electrical power connections.
p. Terminate all control cables.

25.4.1.2. Power Transformers

25.4.1.2.1. Power transformer purchaser's activities shall include:

a. Delivery of transformer to site.
b. Offloading of transformer at site.
c. Assembly of transformer, including installation of all accessories that are shipped separately, filling of transformer with oil, oil processing, etc.

25.4.1.2.2. Contractor's installation activities shall include, but not be limited to:

a. Testing of transformer.
b. Install ground assemblies.
c. Install bus system connections.
d. Install conduit runs into the equipment cabinet.
e. Make all secondary electrical power connections.
f. Terminate all control cables.

25.4.1.3. Disconnect Switch and Fuse Installation

25.4.1.3.1. Contractor's installation activities shall include but not be limited to the following:

Install manual or motor operating mechanisms such that they affect a smooth and thoroughly controlled movement throughout the entire opening and closing cycles of the group operated switch. All rods, shafts, pipe linkages, connectors, operating levers, supports and fittings shall show no noticeable deflection when operating the switch.

Install group operated switches and operating mechanism such that the switch blades open and close simultaneously. All switches will be manually operated until approved by Owner. Adjust all cam, spare contacts and limit switches in accordance with the Manufacturer's installation and maintenance instructions.

Ground the switch handle as shown in the Design Documents. Arrange and align switch handles to ensure the proper switching of the unit from the operator's standing area. The switch operating mechanisms shall not be pierced until the installation has been inspected by Owner.

Install mechanical interlocks, electrical interlocks, or key interlocks in accordance with the Manufacturer's installation and maintenance instructions. Contractor shall be responsible for the final adjustment of the interlock schemes.

25.4.1.3.2. No drilling of any tubular member in the supporting structure to secure the switch-operating mechanism is allowed. All mounting assemblies shall require the approval of Owner.

25.4.1.3.3. Spare power fuse elements shall be stored by Contractor in the control building or other Owner approved shelter.

25.4.1.4. Lighting and Station Auxiliary Power

25.4.1.4.1. Contractor shall install the battery rack, install and test the battery cells, install intercell connectors and ready the battery terminals for Contractor connections.

25.4.1.4.2. Contractor's station auxiliary power installation activities shall include but not be limited to the following:

Locate . fixtures and outlet receptacles as shown in the Design Documents and coordinate with other work in the same area to prevent interference between fixtures and piping or other equipment. Contractor shall relocate any fixture or outlet if, after installation, it is found to interfere with other equipment or is so located to prevent its practical and intended use.

Install all lighting and receptacle load centers, AC control power panel boards and DC control power fuse cabinets as shown in the Design Documents.

Each cabinet shall be installed, conduits connected and wires pulled before the panel board interior is installed. Each panel board interior shall be carefully inspected, all connection and mounting screws tightened and mounted in the cabinet using all of the mounting provisions furnished. The panel board interior shall then be connected, with wires tightly secured in the terminals provided and with unnecessary lengths of wire eliminated. Wiring shall be neatly arranged in the gutters.

The circuit directory shall be accurately and neatly completed to permit ready location of the protective devices controlling circuit loads.

Install station service transformer(s), main disconnect safety switch(s) and automatic or manual transfer switch as shown in the Design Documents.

Install the battery charger as shown in the Design Documents.

25.4.1.5. Wall Mounted Equipment

25.4.1.5.1. All equipment located against the wall of the control building shall be secured by the following methods:

Equipment weighing less than 150 pounds shall be fastened to formed channel members that are secured directly to wall purlins or columns. The formed channel shall be configured in a neat arrangement utilizing the minimum number of members to mount all present and future equipment in the locations shown in the Design Documents.

Equipment weighing more than 150 pounds shall not be supported by the wall. Support stands, fabricated from formed channel and fastened to the floor, shall be used to transfer equipment load to the floor.

25.4.1.5.2. All field-fabricated equipment mounting arrangements shall be subject to Owner approval.

25.4.1.6. Reactive Compensation Equipment

25.4.1.6.1. The contractor shall evaluate the need for reactive compensation equipment as follows:

The facility shall be designed and constructed in accordance with FERC Order 827 as well as any Regional Transmission Organization (RTO) requirements. In the case of conflicting direction the more stringent requirement shall govern.

The capabilities of the proposed turbines as outlined in the provided turbine supply agreement (TSA) document, as well as transmission line lengths and/or joint use assets (multiple facilities sharing an element) shall be factored in.

Any applicable requirements of an interconnect agreement (IA) and/or system impact study (SIS) shall also be upheld.

25.4.1.6.2. Based on the above factors, any necessary capacitor banks, reactor banks, dynamic VAR equipment, etc. shall be included in the substation design, including all necessary related equipment such as circuit breakers, circuit switchers, bus, foundations, protective relaying, and any other necessary items for the full operation of the VAR equipment.

25.4.1.6.3. Coordination, design, and checkout with the turbine manufacturer based on the TSA documentation shall also be included.

25.4.1.6.4. An interlock system shall be provided to prevent the opening of energized ground switches.

25.4.2. Grounding System

Contractor shall install a complete buried ground grid system and a grounding system for all equipment and devices including, but not limited to, switch operating mechanisms, overhead shield wires, surge arresters, circuit breakers, regulators, meter cabinets, cable termination cabinets, potential and current transformers, power transformers, auxiliary power transformers, structures, fence, control building, relay and control panels, cable trays, AC distribution panels, conduit bushings, shielded cables and cable trench.

25.4.2.1. Referenced Codes and Standards

25.4.2.1.1. The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard, or code conflict with these Specifications, Owner shall be notified at once and a remedy shall be determined.

25.4.2.1.2. ANSI/IEEE Standards:

a) IEEE Std. 80Guide for Safety in AC Substation Grounding.
b) American Society for Testing and Materials:
c) ASTM B3 Soft or Annealed Copper Wire.
d) ASTM B-8 Concentric-Lay Stranded Copper Conductor.

25.4.2.1.3. National Fire Protection Association:

Most recent version of the National Electrical Code (NEC)

25.4.2.2. Installation

25.4.2.2.1. Grounding conductors shall be straight and free from kinks, breaks and other damage after installation. Connections shall be made in conformance with the manufacturer's instructions. Conductors shall be thoroughly cleaned prior to making connections. All junctions and splices of buried ground grid conductors shall be made at a ground rod location, wherever reasonably possible. Likewise, ground rods shall be installed at intersecting points of the ground grid conductors and at all equipment locations as shown in the Design Documents. Driving studs shall be utilized.

25.4.2.2.2. All bolted installations shall use lock washers. Paint, rust or other non-conducting material shall be completely removed from the contact surfaces until the bonding surfaces are clean and bright and these surfaces coated with an oxide-inhibitor compound such as Burndy "Penetrox A", Alcoa “No-Ox-Id”, Alcoa No. 2 or other Owner approved equal before making ground connections. Galvanized steel surfaces shall be cleaned with emery paper prior to the application of oxide-inhibitor compound. After the connection has been made any exposed metal subject to corrosion shall be coated.

25.4.2.2.3. Equipment and Structure Grounding

a) All equipment and all steel or aluminum structures shall be solidly connected to the buried ground grid system as shown in the Design Documents. Grounding conductor to loop up to the steel to be CAD welded rather than a pigtail coming up.
b) All neutral conductors, ground electrodes and groundable parts of equipment shall be interconnected as shown in the Design Documents

25.4.2.2.4. Fence Grounding

The fence system, that includes but is not limited to the fence gates, line posts, corner posts, top rail, fence fabric and barbed security wire, shall be solidly connected to the buried ground grid as shown in the Design Documents.

25.4.2.2.5. Electrical Equipment Enclosure Grounding

All ground bus bars in panels and on the interior walls and equipment within the control building shall be connected solidly to the ground grid as shown in the Design Documents.

25.4.2.2.6. Underground Power Circuits

All metallic conduits, metallic cable shielding and sheath and concentric neutral wires shall be effectively grounded at terminations only as shown in the Design Documents.

25.4.2.2.7. Ground Wells

Ground wells shall be located and installed as shown in the Design Documents. The Ground wells shall be installed after all other ground systems have been installed.

25.4.2.3. Grounding inspection and testing requirements.

25.4.2.3.1. All below-grade taps, junctions and splices shall be left uncovered until inspected by the Owner or owner's representative. All unsatisfactory ground connections shall be replaced at the Contractor's expense.

25.4.2.3.2. All exothermic welded connections shall not appear porous or deformed. All bolted ground connections shall be securely tightened.

25.4.2.4. Grid Resistance Test

25.4.2.4.1. The results of the ground grid resistance tests shall include a plan view diagram of the measurement area and a graph for each individual measurement. Appropriate dimensions shall be included on the plan view diagrams. A copy of each test result shall be forwarded immediately to the Owner.

25.4.3. Bus Systems

This Section describes the complete and proper installation of a substation bus system. All work described in this Section and shown in the Design Documents shall be thorough and performed in a neat and workmanlike manner. Bus systems shall include but are not limited to rigid buses, conductors, flexible strain and equipment jumper buses, cable jumpers, overhead shield wires, suspension insulators, station post insulators, fittings, and all hardware required to form a complete system of current-carrying paths connecting the equipment as shown in the Design Documents. Connectors shall include but are not limited to bolted devices, welded devices, clamps, strain clamps, dead-end fittings, terminal devices, and couplings as shown in the Design Documents.

25.4.3.1. Referenced Codes and Standards

The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard or code conflict with these Specifications, Owner shall be notified at once and a remedy shall be determined.

25.4.3.1.1. American Welding Society

c) Welding Handbook RP69
d) AWS D-1.2Structural Welding Code-Aluminum

25.4.3.1.2. American Society for Testing and Materials

ASTM B-8 Standard Specification for Concentric-Lay Stranded Copper Conductors, Hard, Medium-Hard, or Soft.

ASTM B-230 Standard Specification for Aluminum 1350-H19 Wire for Electrical Purposes.

ASTM B-231 Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors.

ASTM B-232 Standard Specification for Concentric-Lay-Stranded Aluminum Conductors, Coated Steel-Reinforced (ACSR).

ASTM B 345 Standard Specification for Seamless Aluminum Pipe, 6063-T6 alloy.

ASTM B 49 Standard Specification for Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel-Reinforced (ACSR).

25.4.3.1.3. The Institute of Electrical and Electronic Engineers

IEEE 524; IEEE Guide to the Installation of Overhead Transmission Line Conductors.

25.4.3.2. Rigid Bus Installation

All tubular bus connectors shall be welded type unless otherwise noted in the Design Documents. Welding of buses and connectors shall conform to the Manufacturer's recommendations and these Specifications. Welded bus couplers shall be located and installed as shown in the Design Documents. End plugs or caps shall be installed at all open ends of bus tubing including bus ends within an expansion fitting.

25.4.3.3. Tubular Bus

25.4.3.3.1. Tubular bus conductor bends shall be formed using a hydraulic conduit bending tool. The inside radii of bends shall be no less than seven (7) times the nominal diameter of the bus. The bus shall be free of kinks, indentations and flattened surfaces.

25.4.3.3.2. One-fourth (1/4)-inch weep holes shall be drilled in all bus risers, bends, A-frames and horizontal runs at the lowest practical point to drain moisture accumulation. All holes shall be reamed to remove sharp edges.

25.4.3.4. Bolted Connections

25.4.3.4.1. Utmost care shall be exercised when installing clamps, connectors, and other bolted devices. The contact surface of the flat surface, clamp or connectors and the bonding surface of the wire or tubing shall be clean and bright and an oxide-inhibitor compound such as Burndy "Penetrox A", Alcoa “No-Ox-Id”, Alcoa No. 2 or other Owner approved equal shall be applied. Use a stainless steel brush to clean mating surfaces by thoroughly scratch-brushing the contact surfaces through the inhibitor, leaving enough inhibitor on the surface to prevent reformation of oxides. Plated surfaces shall not be brushed. After the connection is completed, additional compound shall be applied and forced into every irregularity and opening to completely seal the joint.

25.4.3.4.2. Aluminum to Copper connections shall be made only with flat contact surfaces prepared as indicated above. The aluminum connector shall be located above the copper connector when placed in a horizontal plane. Bolts for aluminum to copper connections shall be used as specified below:

Aluminum bolts shall be used if the copper conductor is less than 1.5 times the thickness of the aluminum conductor.

Bronze (Everdur) bolts shall be used if the copper conductor is more than 1.5 times the thickness of the aluminum conductor.

25.4.3.4.3. Aluminum conductor shall not be used with bronze clamp-type equipment terminal lugs.

25.4.3.4.4. All bolted electrical connections shall be made with anodized aluminum hardware as shown in the Design Documents. Bolts shall be tightened firmly, but threads must not be over-stressed. Bolts in clamps over stranded conductor shall be tightened sufficiently to flatten the lock washers. Do not deform or damage the conductor. Bolts shall extend beyond the nut a minimum of one-half (1/2) bolt diameter. Aluminum bolts shall not be cut off and shall be tightened with a torque wrench per the following recommendations:

25.4.3.4.5. Required tightening torque for anodized aluminum 2024-T4 National Course thread bolts and nuts tightened against aluminum 2024-T4 washers and all parts being pre-coated with oxide inhibitor compound are as shown in

25.4.3.4.6.

25.4.3.4.7.

25.4.3.4.8. Table .

Table 25.5: Required tightening torque for anodized aluminum 2024-T4 National Course thread bolts and nuts tightened against aluminum 2024-T4 washers.

Bolt Size (in.)	Torque (ft.-lb.)
3/8	15
7/16	20
1/2	25
5/8	40
¾	60

25.4.3.5. Welded Connections

25.4.3.5.1. Welder Qualifications

All aluminum bus welds shall be performed and welded-type connectors shall be installed by a welder qualified per AWS D-1.2. The welder must be qualified for the following categories:

- Materials: No.23, aluminum base alloys.
- Weld: groove.
- Position: 6G.

A current welding certificate for each on-site welder must be submitted to Owner prior to task mobilization.

25.4.3.5.2. Preparation and Materials

All aluminum welding shall be done in strict conformance with the latest recommendations of the American Welding Society and the Aluminum Association in addition to the requirements stated herein. All surfaces to be welded shall be thoroughly cleaned to remove all moisture, grease, oil, grit and other foreign material prior to welding. Cleaning shall be performed as close to actual welding time as possible while still allowing sufficient time for complete drying of cleaning solvent. Surfaces shall then be wiped just prior to welding with a clean, dry cloth to remove solvent scum and any moisture that may be present. Surfaces shall be wire brushed immediately prior to welding.

The edges of the materials to be butt-welded together shall be prepared in conformance with the data tables and joint design drawings of Table 69.14, Table 69.16, and Figure 69.22 of Chapter 69, Welding Handbook RP69 of the American Welding Society. Where other than butt-weld joints are to be made, if joint details are not shown in the Design Documents, Contractor shall submit proposed joint designs for approval to Owner.

When the ambient temperature is below 40°F, the base metal shall be preheated for both tack welding and finish welding in such manner that the surface temperature of the parts to be welded are at or above 72°F for at least three (3) inches both laterally and in advance of the welding. Preheat temperature shall not exceed 400°F. Suitable enclosures shall be constructed as needed to protect the inert-gas envelope from interference by air currents or wind.

25.4.3.6. Bus Damping

25.4.3.6.1. External bolted-type tubular bus vibration dampers shall be installed on all horizontal bus spans in the locations shown in the Design Documents.

25.4.3.7. Strain and Jumper Bus Installation

25.4.3.7.1. Strain and jumper buses shall be installed in conformance with the Design Documents and manufacturer's recommendations. Cable for the strain and jumper buses shall conform to ASTM B-232. Each individual aluminum wire entering into the construction of the completed conductors shall conform to ASTM B-230.

25.4.3.7.2. Contractor shall install conductors, shield wire and accessories in accordance with the Manufacturer's recommendations and IEEE Std. 524-1992. This IEEE standard, covering conductor handling, grounding, stringing, sagging, dead-ending, splicing, equipment, installation of accessories and special conductors shall be followed in all respects with the exception of items defined in this Section.

25.4.3.7.3. Handling, stringing, sagging and clipping in of the conductor and shield wire shall be by methods which will prevent damage to the conductor, shield wire or line structures. Contact with the ground or other abrasive surfaces shall be prevented. Any remedial action regarding handling of the conductor will be at Owners direction, including replacing rejected material at no cost to Owner.

25.4.3.7.4. Jumper buses shall be smoothly formed and adjacent runs shall be similarly and symmetrically shaped to provide a uniform and pleasing appearance throughout. Stranded conductor shall be installed without twists “bird caging” or kinks and shall be handled to avoid abrasions or other damage. Splices shall not be allowed in overhead strain buses. Strain buses shall be sagged in conformance to sag tables supplied by Owner.

25.4.3.7.5. Contractor shall furnish Owner, at least two (2) weeks prior to intended use, the information detailed below. Failure to provide this information and receive approval shall be cause for the suspension of stringing operations.

A list showing the type, size, brand name and catalog number of all grips (including stocking type and come along) and/or other tools and equipment used for attachment to the conductor, shield wire and guys for the purpose of pulling and sagging conductors and shield wires and installing guys.

A list of the manufacturer and catalog numbers for all compressive type (hydraulic compression or implosive) dead-ends, splices, sleeving presses and dies.

25.4.3.7.6. Compression Connections

Cable connectors shall be compression or welded type as shown in the Design Documents.

All conductors at joints and fittings shall be clean and free of foreign matter. An oxide-inhibiting compound such as Burndy "Penetrox A", Alcoa “No-Ox-Id”, Alcoa No.2 or Owner approved equal shall be used on all aluminum conductor connections.

Compression type terminal lugs shall be made using a compression tool provided with a ratchet or toggle mechanism that ensures complete crimping before the tool can be removed.

Enough inhibitor must be in the barrel of each terminal lug such that it squeezes out around the conductor when inserted and compressed.

25.4.3.8. Insulator Installation

25.4.3.8.1. Station post insulators shall be installed in accordance with the Manufacturer's recommended procedures and the Design Documents.

25.4.3.8.2. All insulators shall be cleaned of oil, dirt, paper, tape or other foreign materials. Any insulator having the surface glaze damaged in any way shall not be installed.

25.4.3.8.3. Contractor shall be responsible for furnishing and installing all missing miscellaneous hardware necessary for a complete insulation system. Miscellaneous hardware can include but is not limited to bolts, nuts, lock washers, eye-bolts, shackles, clevis-pieces, etc.

25.4.3.9. Clearances

25.4.3.9.1. Clearances and spacing of bus work and conductors shall be equal to or greater than those shown in the Design Documents.

25.4.4. Panels and Instrumentation

25.4.4.1. Contractor shall install all mounting and attachment hardware for the panels and instrument racks. Instrument racks shall be securely attached to the floor with anchor bolts in accordance with the Design Documents.

25.4.4.2. Contractor shall install all components not installed by the panel fabricator and shall complete all internal panel wiring to these components.

25.4.4.3. Field Installation of Instruments

25.4.4.3.1. The installation of all field-added instruments, meters, terminal blocks, relays, switches, fuse blocks, terminal blocks, strip heaters and control devices shall conform to the Design Documents. In addition to the panel-front labels, device identification labels shall be placed on the back of the panels adjacent to, or on each device by the method described in the Design Documents.

25.4.4.3.2. All field cutting for the instrument mounting panel or enclosure shall be punched, drilled, or sawed. Contractor shall use the utmost care to avoid damaging the panel or enclosure finish. Thermal cutting shall not be used.

25.4.4.3.3. A minimum of a three (3) inch vertical space shall be maintained between all rear mounted test switches, blocking bar switches and fuse blocks. All rear mounted test switches, fuse blocks and devices shall be located on the wing pan near the relays or meters they are connected to.

25.4.4.4. Field Wiring

25.4.4.4.1. All wire installed in the field shall conform to the Design Documents

25.4.4.4.2. Internal panel wiring installed in the field shall be bundled, routed and secured adjacent to the side wing panels and back of the front panel using cable ties in a neat and workmanship like manner. The use of Panduit or other raceways will be accepted only on the side wing panels adjacent to terminal blocks as shown in the Design Documents or directed by Owner. The conductors shall not cross the width of the panel unsupported. The conductors shall be routed or secured in a manner that will not obstruct subsequent additional wiring, to the terminals of any installed component. Looping of excess wire in Panduit wireways is to be limited. Splicing of internal panel wiring will not be accepted.

25.4.5. Wiring Systems (600V and below)

25.4.5.1. Contractor shall install all indoor and outdoor lighting fixtures, panelboards, switches, indoor and outdoor outlets, wiring accessories and devices and all other electrical materials to complete the indoor and outdoor secondary electrical system. Contractor shall be responsible for all attachment materials to complete the installations. All materials and equipment to be used during installation of the wire and cable shall be stored so as to protect them from deterioration or damage. All control and power cables shall be unshielded, unless specifically stated otherwise in the Design Documents or this Specification.

25.4.5.2. Referenced Codes and Standards

25.4.5.2.1. The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard, or code conflict with these Specifications, Owner shall be notified at once and a remedy shall be determined.

25.4.5.2.2. National Electrical Manufacturers Association:

NEMA WC-3 Also known as ICEA S-19-81.

NEMA WC-7 Also known as ICEA S-66-524.

NEMA WC-8 Also known as ICEA S-68-516.

25.4.5.2.3. The Institute of Electrical and Electronic Engineers:

IEEE 383; Type Test of Class 1E Electric Cables, Field Splices and Connections

25.4.5.2.4. National Fire Protection Association:

Most recent version of the National Electrical Code (NEC)

25.4.5.3. Installation

25.4.5.3.1. Wire and cable shall be installed in such a manner that the cable jacket is not damaged. Any wire or cable that is damaged during installation shall be removed and replaced at Contractor's expense.

25.4.5.3.2. Labeling

All wire terminations shall be labeled.

The labeling method chosen shall not cover the barrel of the terminal lug or otherwise interfere in any way with access to the barrel of the lug.

The wire identification number used with the labeling system shall match the identification number on the terminal block marking strip that it originated from.

Instrumentation and control cables and wires in the same circuit or grouping shall be identified by circuit numbers as indicated in the Design Documents. The circuit number shall be fastened to each cable or wire grouping at each terminal, cable trench, pull box, manhole, hand hole and junction point. Ty-Rap cable markers, type TY551M or TY-546, manufactured by the Thomas & Betts Co., or other Owner approved equal are required.

Contractor shall use accepted NEC code practices for providing the required colors at the wire ends of AC power circuits.

25.4.5.3.3. Splices

Cables or wires, except for lighting and receptacle cable, shall not be spliced.

Wire for lighting circuits shall be continuous from outlet to outlet. Splices shall be made in outlet or junction boxes. At least six (6) inches of free conductor shall be left at each outlet to make splices of joints, except where it is intended to loop through sockets, receptacles and other fixtures without splices or joints.

25.4.5.3.4. Terminations

Solderless-type terminal lugs and connectors shall be used for connecting #9 AWG wire and smaller stranded cable to studs.

Terminations shall be made with pressure-type terminal lugs using a compression tool provided with a ratchet or toggle mechanism that ensures a complete and positive crimp before the tool can be removed.

Terminations for wire sizes larger than #8 AWG shall have at least two (2) indentations.

Cables and wires used for all instrumentation and control connections shall be terminated with seamless, non-insulated, ring-type Burndy YAV hylug-type compression connectors. Substitute connectors must be submitted for Owner approval at the time of bid with the following documentation:

Type of connector proposed.

Sample of proposed connector for Owner inspection.

Documentation of the process used for making the terminations and quality control measures.

Wire strands shall not be removed from the end of a cable in order to reduce the conductor diameter. Appropriately sized terminal lugs must be used to maintain the same ampacity rating as the cable.

Sufficient length shall be left at all ends of wires and cables to conveniently make connections to equipment and devices. Spare conductors at the end of a multiconductor cable shall be coiled neatly and retained in a length equal to that of the longest single conductor at each end of the multiple-conductor cable. All cables entering a terminal cabinet, switchgear compartment, distribution board, or other such device from a conduit, cable slot, or cable trench shall be clamped securely at the opening. All exposed cable or wire runs shall be bunched and tied so as to prevent movement.

Cable connections to pad-mounted equipment shall have enough slack left in the cable to allow for thermal expansion and contraction. When pad-mounted equipment has a wiring compartment underneath, a full coil of cable shall be installed before the cable is terminated.

Cables and wires shall not be bundled in a cable tray or floor trench, but shall be bundled and laced immediately after passing through an opening in the tray or trench cover at each instrument panel rack.

Spare conductors in a cable shall be neatly coiled with taped ends or terminated as shown in the Design Documents.

A threaded stud shall be used if more than two wires are landed on the same point on a terminal block.

25.4.5.3.5. Cable Pulling

A careful determination of the length of all wire and cable runs shall be made by Contractor prior to any cable installation in order to minimize pulling stresses. Cable pulling tensions shall not exceed those recommended by the cable vendor or supplier. Wire and cable shall be handled with care to avoid damage. Contractor shall carefully inspect all wire or cable for visible defects. Instances of damaged wire or cable shall be promptly brought to the attention of Owner or its representative, who shall determine the action to be taken to correct such defects.

A clean, dry, tight-fitting rag shall be drawn through the conduit immediately before installing the wire or cable. No wire or cable shall be installed in conduit unless it is free of all foreign material.

An Owner approved water-based lubricating material non-injurious to the insulation or jacket shall be used when necessary to prevent mechanical damage.

No cable shall be installed prior to the completion of the raceway system in which the cable is routed in.

25.4.5.3.6. Grounding of Shielded Wire and Cable

Shielded wire and cable shall have the shield grounded strictly in accordance with the Design Documents.

25.4.6. Fiber Optic Cable System

25.4.6.1. Contractor shall be responsible for supplying all attachment materials to complete the installation. All materials, equipment and accessories to be used during installation of the fiber optic cable shall be stored so as to protect them from deterioration or damage.

25.4.6.2. Referenced Codes and Standards:

25.4.6.2.1. The following codes and standards, amended to date, shall govern this work and are considered a part of these Specifications. If requirements in a referenced specification, standard, or code conflict with these Specifications, Owner shall be notified at once and a remedy shall be determined.

25.4.6.2.2. National Fire Protection Association:

Most recent version of the National Electrical Code (NEC)

25.4.6.2.3. Electronics Industry Association:

EIA-455 Series Standard Test Procedures for Fiber Optic Fibers, Cables, Transducers, Connecting and Terminating Devices

25.4.6.3. Installation

25.4.6.3.1. All fiber optic cable must be handled with care. The fiber optic cable must not be trampled upon, run over by vehicles or pulled over fences or metal fittings. Contractor shall not place any fiber optic cable without notifying Owner at least one working day prior to placement.

25.4.6.3.2. Fiber optic cable shall not be bent in a radius less than 16 times the outside diameter of the cable during the placing operations.

25.4.6.3.3. All open cable ends, either placed or remaining on a cable reel, shall have a cable cap placed on them. Cable caps shall be molded neoprene with adjustable stainless steel band for tightening cap to cable.

25.4.6.3.4. Contractor shall install all fiber optic cable in direct buried non-conducting conduit.

25.4.6.3.5. Temporary bonds to ground the splice cases shall be established during the construction and subsequent splice maintenance work to mitigate any possible electrical shock.

25.4.6.3.6. Care must be exercised to ensure that a solid bond is established between the Optical Phase Ground Wire (OPGW) and ground clamps without crushing the optical fiber unit.

25.4.6.3.7. Fiber patch panel schedules shall be updated when fibers are spliced in the panel.

25.4.6.4. Splices

25.4.6.4.1. Splicing of fiber optic cables shall be performed using the fusion splicing method utilizing an electric arc. Chemical bonding or mechanical splicing methods shall not be used. Fusion splicing equipment shall have the following features:

a) Optical viewing to simplify pre-alignment.
b) A pre-fusion process to round the fiber ends to avoid bubble formations.
c) Controllable inward movement of the fibers to prevent necking at the joint.

25.4.6.4.2. Contractor shall provide all tools, and labor to connect, via fusion splicing, the optical fibers of the direct buried fiber optic cable to the optical fibers of the OPGW.

25.4.6.4.3. The splices are to be housed in an outdoor weatherproof housing supplied with the OPGW. Owner reserves the right to reject any splices with losses in excess of 1 dB.

25.4.6.4.4. All splicing of fiber optic cable shall be performed at ground level in accordance with the Manufacturer's recommendations.

25.4.6.4.5. All fusion splices shall be housed in splice trays.

25.5. Submittals

25.5.1. Control Drawings

25.5.1.1. Owner utilizes template drawings for most control schematics, panel elevations, and other protection and control related drawings which are called **CONTROL MASTER**. Contractor shall reference these master drawings in the development of the substation control drawings along with this specification, and drawings provided with this specification.

25.5.2. The following drawings to be submitted:

25.5.2.1. Topography Layout

25.5.2.2. Contour and Grading Layout

25.5.2.3. Foundation Layout

25.5.2.4. Electrical Equipment Enclosure Architectural Layout

25.5.2.5. Steel Details

25.5.2.6. Circuit Diagram

25.5.2.7. Substation Operating One Line

25.5.2.8. General Arrangement

25.5.2.9. Electrical Layout

25.5.2.10. Minor Material List

25.5.2.11. Grounding Layout

25.5.2.12. Control and Lighting Layout

25.5.2.13. Electrical Equipment Enclosure

25.5.2.14. Metering and Relaying Diagram

25.5.2.15. Panel Elevation

25.5.2.16. Schematic Diagram

25.5.2.17. Data Retrieval Schematic Diagram

25.5.2.18. External Connections

25.5.2.19. Major Material Vendor Drawings

25.5.3. Other Substation Studies and Information

25.5.3.1. AC Service Sizing calculations to include transformer and fuse sizing, fault levels, and voltage drop.

25.5.3.2. DC Service Sizing calculations to include battery and fuse sizing, fault levels, and voltage drop.

25.5.3.3. AC and DC Voltage Drop calculations

25.5.3.4. CT burden and fault current saturation calculations

25.5.3.5. Ground Grid calculations

25.5.3.6. Lightning Shielding Design

25.5.3.7. RTU Points List

25.5.3.8. Relay Settings

25.5.3.9. RTU Settings

26. Attachment 15: Electrical Equipment Enclosure

26.1. Design

26.1.1. The electrical equipment enclosure (EEE) shall be pre-manufactured and pre-wired prior to delivery.

26.1.2. The location and orientation of the (EEE) including accurate dimensions shall be indicated on the overall substation location plan. The EEE shall be located near the entrance gate.

26.1.3. Construction of the EEE shall be suited for its intended application. All material shall be new, of recent manufacture, and free from defects. The EEE shall be fully assembled and suitable for use upon completion of installation.

26.1.4. The EEE shall be designed to be installed in the environmental conditions typical for the substation location. Submittals shall indicate these design considerations, including but not limited to: insulation, snow loading, and HVAC capability.

26.1.5. The EEE furnished under this specification shall be designed in compliance with the latest published standards of the International Building Code (IBC), ANSI, IEEE, NEMA, NEC, NESC, MBMA, ASME, ASTM, and ASCE-7 unless otherwise noted. Any applicable local building codes for the location where the substation is being constructed shall be taken into account. If any of the requirements of this specification are in conflict with these standards, Contractor shall notify Owner immediately.

26.1.6. The EEE shall be at a minimum 14 feet x 40 feet (nominal). The EEE shall have space allocated for Owner supplied equipment such as floor standing server cabinets. The size of the EEE shall be appropriate to house all indoor equipment for the substation, including but not limited to:

26.1.6.1. Relay and control panels. Optimize the panel space to keep the EEE size to a minimum, up to three relays on a panel.

26.1.6.2. Fiber patch panels & other communication equipment

26.1.6.3. Wind turbine generator management equipment

26.1.6.4. Field termination cabinets

26.1.6.5. Station service equipment, including AC panel boards and automatic transfer switches

26.1.6.6. DC panel boards, batteries, and battery chargers

26.1.6.7. Eye wash station

26.1.6.8. Lighting contactor for control of substation lighting

26.1.6.9. HVAC equipment

26.1.6.10. Interior and exterior lights and receptacles, including exterior receptacles for servicing HVAC units.

26.1.6.11. Small desk for operators

26.1.6.12. Hot-stick

26.1.6.13. Additional space for equipment not provided by Contractor

26.1.7. Stairs leading up to the entry/exit doors of the EEE. A three foot landing as wide as the door shall be provided.

26.1.8. A ground bus shall be provided in the EEE to provide grounding for all control, SCADA, and AC and DC panels. Ground location shall be indicated on submitted drawings.

26.1.9. Building alarms such as fire alarms, intrusion alarms, and temperature alarms shall be submitted for review. Note that the standard Owner termination cabinet includes temperature alarms for the EEE.

26.1.10. The eye wash station shall be located immediately adjacent to the area designated for the substation battery.

26.1.11. Cellular phone booster shall be included.

26.1.12. The following minimum requirements shall be met:

26.1.12.1. Steel Framing Members

26.1.12.1.1. Structural steel framing members 1/4 inch and thicker shall be of ASTM A36 or A572 steel. Hot rolled steel shall conform to ASTM A36, A500, A529, A570, A992 or A572, as required by design.

26.1.12.1.2. Structural steel framing members less than 1/4 inch thick shall be steel conforming to ASTM A446 Grade B (37,000 psi minimum yield strength) zinc-coated per ASTM A525 coating designation G90.

26.1.12.2. Fasteners

26.1.12.2.1. Structural framing shall utilize high strength bolts. Bolts shall conform to ASTM A325, Type 1 and shall be galvanized per ASTM A153, Class C or ASTM B695, Class 50.

26.1.12.2.2. Other bolts, nuts, and tap bolts shall conform to ASTM A307, Grade B, and shall be galvanized according to ASTM A153, Class C.

26.1.12.2.3. Sheet metal screws and/or self-tapping screws shall be zinc or cadmium-plated steel conforming to ANSI B-18.6.4, or equal.

26.1.12.2.4. Exposed wall and fascia panel fasteners shall have color-coated hearts to match the panel and washers for weather tightness.

26.1.12.3. Roof System

26.1.12.3.1. The Roof system shall include a 20-year warranty on material and weather tightness, and shall carry an Underwriters Laboratory (UL) Class 90 listing in accordance with UL 580.

26.1.12.3.2. The roof covering shall include exposed metal roof panels of 12 gauge (minimum) commercially pure aluminum coated steel, “Galvalume”, or coated steel (Galvanneal) with a color finish. As a minimum, base metal panels shall conform to the physical requirements of ASTM A446, Grade B. Panels shall be of such configuration to provide the load carrying capability and meet the deflection requirements specified herein. The coating shall have a 20 year warranty against rust perforation, a 20 year warranty against fading and chalking, and a 25 year warranty against flaking and peeling. Exterior color finish of roof, walls, doors shall be tan in color. Paint samples to be submitted for Owner approval.

26.1.12.3.3. Roof panels shall be “standing-seam interlocking” design and shall be secured to the roof purlins with a concealed structural fastening system. The concealed system shall provide minimal through penetration of the roof surface and allow the roof covering to move independently of any differential thermal movement by the structural framing system. Except at the concealed fastener, there shall be no thermal contact between the roof panels and supporting purlin. The standing seams shall have a factory-applied, non-hardening sealant.

26.1.12.3.4. Roof covering shall be properly designed with a sealing system provided at all roof and wall seams to provide a watertight building. The ridge, eaves, and openings together with necessary fascia and trim shall be caulked and sealed to provide a weather tight system.

26.1.12.3.5. Properly sized attic space ventilation shall be provided. All attic openings shall be screened to prevent entrance of bees, large insects, or birds.

26.1.12.4. Exterior Wall System

26.1.12.4.1. The exterior walls shall be comprised of galvanized steel panels with a PVDF resin-based finish. Exterior siding panels shall be overlapped and installed with appropriate self-tapping fasteners with integral gaskets and shall be removable without any disturbance to internal panels. The wall covering shall include a minimum 15-year warranty on paint. As a minimum, the panels shall be galvanized according to ASTM A525, coating designation G90.

26.1.12.4.2. Manufacturer's standard exterior base flashing shall be provided with the building. Material shall be zinc-coated steel conforming to ASTM A446, Grade B and ASTM A525, coating designation G90. Flashing shall be manufacturer's standard white in color, and have a baked silicon polyester (or equivalent) enamel coating.

26.1.12.4.3. Butted seams are not permissible.

26.1.12.4.4. All openings in the walls are to be structurally framed, sleeved, trimmed, and provided with external drip caps.

26.1.12.4.5. Repair or replacement of external panels must be able to be done entirely from the exterior of the EEE structure.

26.1.12.5. Interior Liner Panels

26.1.12.5.1. The EEE interior walls shall be lined with flush-fit with a minimum of 16 gauge, roll-formed liner panels. Liners shall be zinc-coated steel conforming to ASTM A446, Grade B and ASTM A525, coating designation G90. Liners shall be provided with base and ceiling trim. Panels shall be manufacturer's standard white in color, and have a baked silicon polyester (or equivalent) enamel coating.

26.1.12.5.2. Liner panels shall be fully reinforced with concealed fasteners.

26.1.12.5.3. The EEE interior shall feature a complete trim system, including base, jamb, header, and ceiling trim.

26.1.12.6. Floor System

26.1.12.6.1. The EEE floor shall have a hot-rolled welded steel framework, comprised of hot-rolled steel or steel tube supports with a maximum deflection of L/240 under required loads. Cold formed joists shall be sized and spaced to meet design loads. The steel framework shall be supported on concrete piers, spacing, anchorage requirements, and layout to be indicated by the building designer. Steel floor members shall be hot-rolled steel that meets a minimum standard ASTM-A36. All galvanized steel shall meet ASTM-A653.

26.1.12.6.2. Steel floor shall be a welded steel top surface of at least ¼" thickness to handle floor design loads with a maximum deflection of L/240. The floor shall have a painted, slip-resistant finish. The bottom of the floor shall have a rodent and moisture barrier of recessed 26 gauge sheet galvanized steel. Floor welding standards shall meet all AWS recommended practices.

26.1.12.6.3. The floor framework and floor deck plates shall be fully cleaned, primed, and painted with a self-priming coating system designed to provide a durable finish, suitable for heavy resistance to fading. Paint is to have a minimum Dry Film Thickness per coat of 3-5 mils. Color is to be ANSI 61. A non-slip texture shall be added to the paint.

26.1.12.7. Insulation

26.1.12.7.1. Floor shall be insulated with fiberglass batt insulation between the joists and rigid polystyrene insulation between joists and fully hot-dipped steel rodent and insect barrier. The insulation shall be at least R-13 for the floors and walls and R-19 for the roof, or a higher specific insulation value called out in applicable state and local codes. The entire Electrical Equipment Enclosure shall be insulated to thermal transmittance value of no more than 0.05 for walls and 0.03 for roofs when tested in accordance with ASTM C236.

26.1.12.8. Exterior Doors

26.1.12.8.1. There shall be two doors in the EEE, at least one of which is a 72-inch wide double door to facilitate the installation of equipment. Both doors shall have the same access key. Enclosure doors shall comply with Steel Door Institute directive SDI-100 and SDI-107. Doors shall have an insulated core and be constructed of no less than 18-gage steel-faced leafs with stiffeners and 16 gauge door frames. Doors and frames are to be hot-dipped galvanized to ASTM-A294 and ASTM-A653, then factory primed and painted with epoxy enamel to match the enclosure or trim.

26.1.12.8.2. There shall be three stainless steel ball bearing hinges per door.

26.1.12.8.3. A drip cap shall be provided on the exterior top and bottom of each door.

26.1.12.8.4. Each door shall have Sergeant 2828F low-profile rim device type panic interior openers, with cylinder lock keyed entry and thumb latch exterior.

26.1.12.8.5. A door closer with hold open arm shall be installed on each door.

26.1.12.8.6. Shock absorbing restraints shall be provided on the doors to prevent damage from high wind conditions.

26.1.12.9. HVAC

26.1.12.9.1. Heating, ventilating, and air conditioning (HVAC) equipment shall be sized and provided. HVAC equipment size shall be based on maintaining an interior temperature range of 60-80 degrees F, taking into consideration the heat load of present and future equipment and the site conditions. HVAC equipment shall consist of self-contained wall mount units, complete with supply and return grilles, lockable circuit breaker or disconnect switch, manual thermostat, barometric fresh air damper, and a disposable air filter. The following controls shall be supplied: high-pressure controls, low pressure controls, low ambient control, compressor anti-cycle relay, and alarm relay.

26.2. Civil/Grading

26.2.1. Erection Requirements

26.2.1.1. Defective material, such as bent, buckled, or scarred panels, shall not be erected. If such panels are erected, they shall be removed and replaced. The siding, roofing, corners, closures, and flashings shall be without wrinkles, buckles, or dimples.

26.2.1.2. Any and all marks, scrapes, scratches, etc. on each building component shall be repaired, at Contractor's expense prior to building acceptance, with the manufacturer's recommended coating matching the component's original color.

26.2.1.3. After the work has been completed, the surface of the sheeting shall be inspected for integrity of the coating. Where the coating is scratched or scraped off, Contractor shall touch-up such places with a coating of identical color compatible with the shop finish. Sheeting scratched, dented, or otherwise damaged which, after repair and touch-up, does not present a uniform appearance from the closest ground or public approach shall be replaced.

26.2.2. The Electrical Equipment Enclosure structure shall be designed for a minimum of 30-year life. The structure shall be designed and detailed in a manner which produces a weather tight, draft proof, and aesthetically pleasing building. The interior shall be fully lined with no exposed columns. All ceiling and wall surfaces shall be detailed and furnished flat, to allow for attachment of additional materials such as cabinets and equipment support.

26.2.3. The Electrical Equipment Enclosure structure shall be the design of a manufacturer regularly engaged in the fabrication of pre-engineered structures conforming to the recommendations of the MBMA Manual.

26.2.4. Contractor shall provide all static and dynamic loading calculations and analysis for the EEE as well as all mounting information.

26.2.5. The EEE manufacturer shall supply plans and calculations stamped by a Registered Professional Engineer for the state where the EEE is to be installed and is responsible for obtaining all State Industrial Building Commission Approvals and Third Party Inspections that are required by the state in which the EEE is to be installed.

26.2.6. Heavy duty lifting plates or similar hardware shall be supplied and mounted to the EEE as needed for lifting the enclosure.

26.2.7. The EEE shall have a minimum internal ceiling height of 10'-0" to allow for adequate equipment clearance below the cable tray.

26.2.8. The enclosure shall be able to be shipped via a semi-trailer method. The enclosure may be separated into two or more sections for shipment as required. If shipping splits are necessary, they shall be documented on all drawings and any wiring that is split shall be tagged and marked for easy field assembly. Any field installed wiring across shipping splits shall be done in ceiling mounted J-boxes.

26.2.9. The EEE roof shall be pitched to 2 inch in 12 inches or greater and shall be comprised of mechanically-seamed standing-seam roofing with a minimum seam height of 2".

26.2.10. Cable Tray shall be installed to facilitate external and internal connections.

26.2.10.1. The cable tray shall contain a 4/0 copper ground conductor as a ground bus for the cable tray and equipment to which it connects. Conductor shall be bonded to each cable tray section and all panels and cabinets per NEC requirements.

26.2.10.2. Cable tray shall be sized for all anticipated cables plus 50% margin.

26.2.10.3. Cable tray shall contain a 4" x 4" fiber tray for fiber optic cables. Fiber tray shall be installed in such a manner that the radius in corners shall not reduce the cable trays' capacity for copper cables.

26.2.10.4. The fiber tray shall utilize a trumpet spillout device above each panel to provide an appropriate radius vertical transition into each panel.

26.2.10.5. Cable tray shall be designed for an ultimate load of 100 pounds per foot.

26.3. Structural

26.3.1. Structural steel shall be designed according to the AISC Specification. Cold formed members shall be designed according to the AISI Specification.

26.3.2. The EEE shall have an internal, self-supporting structural steel frame that meets all structural loads without relying on exterior, interior, or roof panels for structural strength.

26.3.3. The EEE shall be designed to support roof live and dead loads that account for ice, snow, and wind loading, ceiling live and dead loads, wall loads, floor loads, and seismic requirements.

26.3.3.1. Dead loads - weight of permanent construction

26.3.3.2. Snow load - Design in accordance with ASCE 7.

26.3.3.3. Roof Live Load – minimum 20 lbs/sf.

26.3.3.4. Wind load - Design for basic wind speed per ASCE 7 in a terrain Exposure C (unless otherwise noted) in accordance with International Building Code Section 1609 or ASCE 7-10.

26.3.3.5. Suspended Systems from interior roof members - 10 psf.

26.3.3.6. Construction Maintenance load - concentrated weight of 250 lbs placed at any point on the roof.

26.3.3.7. The building shall be designed to withstand lifting loads during delivery, unloading, storing or erection of the building.

26.3.3.8. Floors – Equipment Area – Loading shall be rated at least 200 lbs/sf while on the foundation.

26.3.3.9. Floors – Battery Area – The area of the floor designated as the battery area on the control house layout shall be reinforced to 400 lbs./sf minimum while on the foundation.

26.3.3.10. The above loads or combination of loads shall be applied in conformance with the recommendations of the MBMA Manual.

26.3.3.11. Deflection Criteria - Deflection of primary structural framing members shall not exceed L/240. Deflection of secondary framing members and exterior wall and roof panels shall not exceed L/180.

26.3.3.12. Lateral deflection criteria – not exceed L/120 of eave height

26.4. Electrical

26.4.1. Wiring

26.4.1.1. All grounding, workmanship and materials shall conform as a minimum to the latest version of the National Electrical Code (NEC).

26.4.1.2. All wiring shall run tight to and parallel with walls and ceiling. All required wiring between equipment located within the Electrical Equipment Enclosure shall be installed at the factory.

26.4.1.3. Interior conduit shall be electrical thin wall EMT, all interior junction boxes NEMA 1, with flexible metallic conduit used for motor and fixture connections. Do not run conduit horizontally along walls, use cable tray or run along ceiling.

26.4.1.4. All conductors installed from the EEE field termination cabinets to the substation cable trench system shall be installed in RGS conduit. Ends of conduits shall be sealed following installation of conductors to block rodents from entering the conduits.

26.4.1.5. Duplex receptacles with weatherproof covers, and GFI protection shall be provided on the exterior of the enclosure near each entrance, and for service use at each HVAC unit.

26.4.1.6. Power wiring for 120V lighting and receptacles shall be single conductor THHN/THWN 600V insulation in EMT conduit with a minimum size of #12 AWG.

26.4.2. Electrical equipment enclosure lighting shall be in accordance with accepted industry standards and practices. The National Electric Safety Code (ANSI C2) shall be followed in all cases. Sufficient lighting is required for safe operation and testing in front and back of all control panels.

26.4.2.1. Exterior Lighting shall be provided above each personnel door. Exterior lights shall be wall mounted LED suitable for use in wet locations and have automatic dusk to dawn photo control.

26.4.2.2. Emergency lighting shall be a self-contained battery powered unit with two directionally adjustable illuminating heads. The units shall switch on automatically upon loss of AC power and provide 1.5 hours of continuous illumination, and then turn off automatically and recharge when AC power is restored.

26.4.3. AC and DC Station Service Criteria

26.4.3.1. AC Auxiliary Service:

Every substation shall include an AC auxiliary supply system for lighting, heating, maintenance, and other electrical loads. Additionally, each substation that has primary and secondary protective relays and a battery system should have two AC auxiliary sources. An automatic transfer switch will be included to switch between the two sources (preferred and emergency).

The sources for auxiliary power are usually transformer tertiary windings or medium voltage busses. If these sources are not available or are not economically feasible, auxiliary power may be obtained from the local distribution company, an emergency generator, or a voltage transformer connected to a transmission bus. No distribution load from the tertiary windings shall be outside of the substation yard.

The standard AC auxiliary system rating is 120/240V single-phase, and this is used with auxiliary equipment rated up to 400Amp. However, for substations that would require auxiliary equipment rated higher than 400Amp with a 120/240 single-phase system, a three-phase auxiliary system should be considered.

The AC Auxiliary System shall be in accordance with accepted industry standards and practices. The National Electric Safety Code shall be followed in all cases.

26.4.3.2. Primary Fusing and Switching

26.4.3.2.1. Fused Disconnects

Substation auxiliary power transformers shall be fused on the high side using S&C SM5 fused disconnects and fuses. The fuse sizes are selected by choosing the smallest rating, which is at least 150% of the high-side full load ampere current. In order to promote standardization of fuses 5E and 10E, standard time-rated fuses are used in the system, sizes 3E and 7E are not typically used.

Current-limiting Back-up Fuses

Some substations may have available fault currents greater than the interrupt rating of the fused disconnect. In these cases, current-limiting back-up fuses should be used in series with the fused disconnect. The current-limiting back-up fuse will limit the fault current and also provide for clearing of faults up to its interrupt rating. Note that the interrupt rating of the current-limiting back-up fuse must be greater than the available fault current. If it is not, then this approach is not sufficient and further engineering will be necessary (possibility of needing current-limiting reactors)

The back-up fuse should be placed downstream of the fused disconnect; in this way, the back-up fuse can be replaced by opening the fused disconnect, and without de-energizing the source. The design should make sure, to the greatest extent possible, that there is adequate clearance to replace the back-up fuse without de-energizing the source.

With this configuration, there is an accepted risk of a fault occurring in the lead between the two fuses which could not be cleared by the fused disconnect. This would be a bus fault, and would have to be cleared by the station relaying.

26.4.3.3. Secondary Fusing and Switching

26.4.3.3.1. AC Load calculations shall be provided. The station service and associated equipment will be sized in accordance with these calculations.

26.4.3.3.2. Automatic Transfer Switch

The Preferred and Emergency supplies to the electrical equipment enclosure shall brought into an Automatic Transfer Switch (ATS) before going to a Main Breaker Panelboard.

26.4.3.4. DC Auxiliary Service

26.4.3.4.1. The DC system supplies power for the circuit breakers, motor operated switches, instrumentation, emergency lighting, communications, fire protection system, annunciators, protective relaying and fault recorders at substations and includes a 125VDC battery bank and battery charger.

26.4.3.4.2. The DC Auxiliary System shall be accordance with accepted industry standards and practices. The National Electric Safety Code shall be followed in all cases.

26.4.3.4.3. Consideration of any applicable regulations regarding redundant battery systems shall be given. NERC and RTO regulations may be applicable. A redundant battery shall not be used except where required.

26.4.3.4.4. The Battery system and charger shall be sized to recharge the battery to 95% of full capacity within 12 hours. The battery sizing criteria is summarized below:

Summary of Battery Sizing

Beginning event	Loss of battery charger occurs, but no tripping event
Time which battery must carry continuous load (without battery charger)	8 hours
Final event, which battery must be able to supply	Worst case tripping event occurs, including one breaker failure event.

Notes:

- The tripping event that causes the most current to be drawn from the battery is considered the “worst case” event.
- Continuous loads are loads that the battery would have to carry throughout the duty cycle once the battery charger quits operating (Examples: indicating lights, relays).

26.4.3.4.5. DC Continuous Load Calculations shall be provided. The battery system and charger will be sized in accordance with these calculations.

26.4.3.4.6. Main Battery Fusing

The battery main fuses protect the battery against faults in the cable between the battery and the DC fuse cabinet or against faults on the bus in the DC fuse cabinet. These fuses shall not be considered as backup protection for the branch fuses. The main fuses are sized to allow all but a solidly bolted fault to cause them to operate. This is to avoid the nuisance of blown fuses and keep DC power operating the control systems as long as possible. The fuse is also used as a disconnect point to isolate the battery when necessary.

26.4.4. Relaying and Protection Criteria

26.4.4.1. See WIND FARM EEE AND PANEL ELEVATIONS and WIND FARM ONE LINE METERING AND RELAYING.

26.4.5. SCADA / RTU / Communication requirements.

26.4.5.1. See WIND FARM EEE AND PANEL ELEVATIONS and WIND FARM ONE LINE METERING AND RELAYING.

26.5. Submittals

26.5.1. Design documents shall be stamped by a professional engineer registered in the state where the building will be installed. Calculations shall be submitted for review with the approval drawings.

26.5.2. Submittals for the EEE shall include an overhead layout and elevations which clearly identify all equipment by bubble numbering. Drawings shall be accompanied by a spreadsheet which details each item number.

26.5.3. The building manufacturer shall prepare design and shop drawings and shall include the following:

26.5.3.1. Physical outlines as required to show the overall size and space requirements including doors, clear heights and floor area.

26.5.3.2. Cross sections and details as required demonstrating framing details and that components conform with specification requirements. It shall also include design and physical arrangements such as horizontal and vertical clearance.

26.5.3.3. Erection drawings and anchor bolt plans including foundation loads.

26.5.3.4. Cross sections and details as necessary to provide a complete and finished structure.

26.5.3.5. Item identification marks shall be included. Equipment identified by such marks shall be detailed in tabular format.

26.5.3.6. Manufacturer’s submittals for fans, louvers, door frames, hardware and doors shall be provided with the Design Documents.

26.5.3.7. One reproducible set of “record” drawings, incorporating any approval comments and certified by a registered engineer, shall be submitted to Owner prior to shipment of the building.

27. Attachment 16 Availability Test

27.1. Purpose

27.1.1. The Availability Test will verify the inverters are fully commissioned and ready for commercial operation by demonstrating all inverters are able to operate for at least 3 consecutive days. The Availability Test may run in parallel to other performance related tests, provided the other tests do not negatively impact the inverter or plant operation.

27.2. Definitions

27.2.1. Availability Test – A short term, plant wide test meeting the requirements of this Exhibit [ ] and a condition to Substantial Completion used to verify all inverters are fully commissioned and ready for commercial operation.

27.2.2. Availability Test Calculator– An Excel file provided by the Owner to be used to calculate the Measured Availability during the Availability Test Measurement Period.

27.2.3. Availability Test Measurement Period – A three (3) day period during which the Availability Test is conducted to verify inverter operation, as such period may be extended as permitted in paragraph 5 of the Procedures set forth in this Exhibit.

27.2.4. Availability Test Procedures – A detailed plan for administering the Availability Test to be provide by Contractor 45 Business Days prior to Availability Test, which plan shall meet all of the requirements therefor set forth in Appendix 1 to this Exhibit [ ] and include, at a minimum, all points to be monitored and identification of key personnel and parties.

27.2.5. Availability Test Report – A summary report of the Availability Test results, conditions during the test, the Inverter Availability Test Procedures, and calibration certificates of equipment used in the test, which report shall meet all of the requirements therefor set forth in this Attachment.

27.2.6. Eligible Time Intervals – Total number of time intervals during Availability Test Measurement Period where the plane of array irradiance is greater than 400 W/m2. The selected time interval shall be 5 minutes.

27.2.7. Guaranteed Availability –99.0%

27.2.8. Inverter Operational Time Intervals – For each inverter, the total number of Eligible Time Intervals during Availability Test Measurement Period when the inverter is producing power at all possible inverter stages, taking into account the incident irradiance.

27.2.9. Measured Availability – A percentage (rounded up or down to the nearest 0.1%), calculated as the quantity of Inverter Operational Time Intervals divided by the quantity of Eligible Time Intervals, multiplied by the number of inverters.

27.2.10. Multiple Measurements – Any measurement device or sensor where multiple devices or sensors measure the same parameter.

27.3. Procedure

27.3.1. No less than 45 Business Days prior to the first day of the scheduled Availability Test Measurement Period, the Availability Test Procedures shall be submitted to the Owner by the Contractor for Owner's review and comment. Contractor shall incorporate all of Owner's reasonable comments into the final Availability Test Procedures and resubmit the same for Owner's review and approval (such approval not to be unreasonably withheld or delayed).

27.3.2. The Contractor shall give written notice to the Owner 5 Business Days prior to the start of the Availability Test (including any re-performance thereof).

27.3.3. Contractor shall perform the Availability Test in accordance with the final approved Availability Test Procedures.

27.3.4. During the Availability Test Measurement Period the Contractor shall record all inverter power, revenue meter, and plane of array irradiance data in accordance with the Data Quality and Instrumentation Requirements set forth in this Attachment. Such date shall be made available during and after the test as requested by Owner.

27.3.5. During the Availability Test, the Contractor shall document all inverter or plant-related interruption events, including the identification of the event, the reason for the interruption, the time and duration of the event and any corrective actions undertaken. In the event that inverter or plant-related interruptions do occur, the Contractor has the option to restart the Availability Test, provided that Contractor shall notify Owner thereof and provide detailed documentation of identified issues and proposed resolution to rectify such issues prior to re-performing the Availability Test.

27.3.6. During the test, the Contractor shall document all interruption events caused by grid operations, including the identification of the event, the reason for the interruption, and the time and duration of the event, and any corrective actions undertaken. To the extent that such interruption event was not caused by the Project, such events are excusable, and the test shall be extended by the amount of excluded time on a minute-by-minute basis in order to achieve 5 complete days of data.

27.3.7. The result of the Measured Availability shall be calculated as follows:

$$\frac{The\ Sum\ of\ All\ Inverter\ Operational\ Time\ Intervals}{Eligible\ Time\ Intervals * Total\ Number\ of\ Inverters}$$

27.3.8. The Project must be capable of continued operation, without intermittency or downtime during the Availability Test Measurement Period except for excused events described in paragraph 6 above. If the Measured Availability of the Project does not meet or exceed the Guaranteed Availability, the Contractor shall identify and promptly resolve the source of the problem and promptly perform the Availability Test again in accordance with these procedures (other than Paragraph 1 hereof) until the Measured Availability of the Project achieves the Guaranteed Availability.

27.4. Availability Test Report

27.4.1. No later than five (5) Business Days following the end of the Availability Test Measurement Period in respect of a Successfully Completed Availability Test, a draft Availability Test Report will be submitted to the Owner by the Contractor. Owner shall have five (5) Business Days to accept or reject the results of the draft Availability Test Report, and provide in writing any comments of Owner on such draft Availability Test Report. In the event that Owner rejects all or any part of the draft Availability Test Report, Contractor shall, within five (5) Business Days thereafter address any comments of Owner and re-submit the draft Availability Test Report to Owner. This procedure shall continue until Owner accepts the draft Availability Test Report. Any dispute regarding the results of the Availability Test or the Availability Test Report shall constitute a Dispute as described in the Agreement.

27.4.2. The Availability Test Calculator, along with all raw data and QC disposition for each input data record, shall be provided electronically to the Owner with the Availability Test Report.

27.5. Appendix 1: Additional Requirements

27.5.1. Test Plan

27.5.1.1. The Availability Test Procedures shall include (at a minimum) the following information:

27.5.1.1.1. The test procedure set forth herein.

27.5.1.1.2. Identification of key personnel and parties to be involved in the test

27.5.1.1.3. Identification of the Project under test (at a minimum)

- Number and make/model of PV modules
- Array orientation
- Location (latitude, longitude, street address)
- Racking type and tilt
- Tracker range of motion (if applicable)
- Number and make/model of Inverters
- Row to row spacing (ground coverage ratio)

27.5.1.1.4. Identification of all data points to be monitored during the test

27.5.1.1.5. The scheduled starting and ending dates of the Availability Test Measurement Period.

27.5.1.1.6. Table of all sensors and transducers to be used, including cut sheets, calibration records, map of sensor locations with sufficient detail to allow observers to locate the sensors and transducers. This includes sensors required for all applicable input parameters (MET station sensors, inverters, and Revenue Meter).

27.5.1.1.7. MET station and pyranometer quality assurance and/or commissioning documentation (as an appendix).

27.5.1.1.8. Identification of SCADA nomenclature for data channels, and any SCADA calibration parameters (default or custom) for those data channels

27.5.1.1.9. Identification of SCADA data channels intended for use as auxiliary measurements

27.5.1.1.10. Identification of known data quality concerns, such as time intervals when inter-row shading may be expected to occur

27.5.1.1.11. Time-stamp convention and data logger averaging technique/interval to be used in reporting data

27.5.1.2. Measured data are to be made available to the Owner upon request during the Availability Test Measurement Period, for use in evaluating the progress of the Availability Test.

27.5.2. Availability Test Report

27.5.2.1. The Availability Test Report shall contain:

27.5.2.1.1. The Availability Test Procedures, including all requirements as outlined herein.

27.5.2.1.2. The actual start and end date/times of the Availability Test Measurement Period

27.5.2.1.3. Comments on environmental conditions during the Availability Test Measurement Period that affect the results of the test

27.5.2.1.4. Summary of data quality control results for all data records

27.5.2.1.5. Summary of test results

27.5.2.1.6. All calibration certificates for pyranometers, temperature sensors, and revenue meters used in the test

27.5.2.2. Raw data used as input to the Availability Test, along with QC disposition for each input data record, shall be provided electronically (via CSV, XLS, or XLSX formats) to the Owner with the Availability Test Report.

27.5.3. Data Quality and Instrumentation Requirements

27.5.3.1. Data quality shall be identified as one item from a set of quality categories for each data record analyzed. Only data from records where all input parameters are valid and within specified limits shall be used in computing capacity estimates.

27.5.4. Sensor Requirements

27.5.4.1. Irradiance sensors shall be at a minimum "High Quality" classified pyranometer(s) as defined in ASTM2848-A1.2 (Secondary Standard per ISO 9060). Pyranometers shall include device-specific characterization data that shall, at minimum, include cosine and temperature response. Alternative pyranometers may only be used if approved by the Owner.

27.5.4.2. Pyranometers shall be used only within their valid calibration period and shall be cleaned at the start of the Availability Test Measurement Period and cleaned daily during the test if the Availability Test Measurement Period extends beyond one (1) week.

27.5.4.3. All measurement devices and sensors shall meet the minimum accuracy requirements and range requirements set forth in the table below:

Sensor Requirements

Table 2 Sensor Requirements

Measurement	Instrument Type	Test Function	Range	Accuracy
Irradiance	Pyranometer (Global Horizontal Irradiance (GHI))	Primary for Energy Performance Test	0 to 1600 W/m^2 285 to 2800 nm	±2.0% daily
	Pyranometer (Plane of Array (POA))	Primary for Capacity Test and Availability Test		
Ambient Air Temperature	Temperature Probe	Primary for both Capacity Test and Energy Performance Test	-40°C to +60°C	±1°C
Wind Speed	Sonic Wind Sensor	Primary for Capacity Test and Energy Performance Test	0 – 60 m/s	±5%
PV Plant Power	PV Power Revenue Meter	Primary for both Capacity Test and Energy Performance Test primary for Capacity Test	0 to PV Power Plant size +20%	ANSI C-12.20
Inverter Power	Inverter Meter	Primary for Availability Test and Capacity Test	determined from inverter data sheet	determined from inverter data sheet
Soiling	Soiling Monitoring	Primary for Energy Performance Test	0 to 100%	±0.2%

	System (SMS)			

27.5.5. Multiple Measurements

27.5.5.1. Multiple Measurements shall be recorded for all environmental data throughout the Site in order to capture the operating conditions for all regions of the array. There is a high probability that there will be periods of time in which portions of the Project are exposed to significantly different irradiance conditions than other portions, e.g. due to isolated clouds.

27.5.6. Below are the main measurement devices and sensors to be used in the Availability Test:

27.5.6.1. Plane of Array Irradiance (POA): A minimum of one sensor shall be installed for each orientation (within ±2°). Multiple orientations or large arrays shall require Multiple Measurements. For projects or unique project Blocks within a project with potentially different irradiance conditions (like change in azimuth, tilt, or tracking range of motion) greater than 5 MW, at least 3 POA sensors shall be installed.

27.5.6.2. Inverter Meter: The power reading for each inverter.

27.6. Appendix 2: Availability Test Calculator

27.6.1. The table below provides the file names for all files needed for the Availability Test Calculator. Contractor shall provide the Availability Interval Data file once the test is complete.

Table 3 Availability Test Calculator Files

File Name	File Type	Comments
Availability Test Calculator	.xlxs	Used to log all raw measured data, Inverter Interval Data, and calculate the availability
Availability Interval Data	.csv	Interval values of measured Inverter Power Output, plane of array irradiance (POA), and Revenue Meter.

28. Attachment 17: Capacity Test

28.1. Purpose

28.1.1. The Capacity Test will verify the plant is fully operational and ready for commercial operation by achieving the Guaranteed Capacity.

28.2. Definitions

28.2.1. Capacity Test – A short term, plant wide test meeting the requirements of this Attachment and a condition to Substantial Completion used to verify the plant is fully commissioned and ready for commercial operation.

28.2.2. Capacity Test Calculator – An Excel tool provided by the Owner to be used to calculate the Target Capacity and Measured Capacity during the Capacity Test Measurement Period.

28.2.3. Capacity Test Measurement Period – The period when the Capacity Test is performed, which period shall be at least 2 days, and shall continue until for consecutive additional days until the Minimum Irradiance has been met, which may be up to a total of 15 days depending on weather conditions during the test.

28.2.4. Capacity Test Procedures –A detailed plan for administering the Capacity Test to be provide by Contractor 30 Calendar Days prior to the first date of the scheduled Capacity Test Measurement Period, which plan shall meet all of the requirements therefor set forth herein and include, at a minimum, all points to monitored and identification of key personnel and parties.

28.2.5. Capacity Test Report – A summary report of the Capacity Test results, conditions during the test, the Capacity Test Procedures, Data Quality and Instrumentation Plan and applicable calibration certificates for equipment used in the test, which report shall meet all of the requirements therefor set forth herein.

28.2.6. Capacity Test Bifacial Gain (CTBG) – The bifacial gain as calculated using the CTBG procedures outlined herein.

28.2.7. Guaranteed Capacity – A Measured Capacity Ratio of at least 98.0% or greater.

28.2.8. Minimum Guaranteed Capacity – A Measured Capacity Ratio of at least 95.0% or greater.

28.2.9. Minimum Datapoints – Occurs when at least 150 allowable data points meeting the requirements set forth in this Exhibit [ ] are recorded after all data filtering has occurred as outlined herein. If the Minimum Irradiance criteria set forth is causing a delay in the test and pushing it beyond the Guaranteed Project Substantial Completion Date, the test procedure may, subject to prior agreement by both parties, be modified to allow fewer data points.

28.2.10. Minimum Irradiance. 400 W/m2.

28.2.11. Measured Capacity – The measured capacity as calculated using the procedures outlined herein.

28.2.12. Measured Capacity Ratio – The Measured Capacity divided by the Target Capacity, calculated to the nearest 0.1%.

28.2.13. Monthly Reporting Conditions – The plane of array irradiance (POA), ambient temperature, and wind speed calculated for each month using the Project Model and P50 weather file as agreed to by the Parties and recorded in Table 4 of Appendix 2 attached herein.

28.2.14. Project Model – The Contractor PVSYST generation model for the Project, including post-processing that occurs outside of the program.

28.2.15. Project Capacity Model –The Project Model as adjusted to remove assumptions for snow, availability, and module degradation losses.

28.2.16. Revenue Meter – The revenue meter for the Project as agreed by the Parties.

28.2.17. Capacity Test Bifacial Gain (CTBG) – The bifacial gain as calculated using the CTBG procedures outlined herein.

28.2.18. Target Capacity – The target capacity as calculated using the procedures outlined herein.

28.3. Procedure

28.3.1. No less than 45 Business Days prior to the first day of the scheduled Capacity Test Measurement Period, a draft Capacity Test Procedures shall be submitted to the Owner by the Contractor for Owner's review and comment. Contractor shall incorporate all of Owner's reasonable comments into the final Capacity Test Procedures and resubmit the same for Owner's review and approval (such approval not to be unreasonably withheld or delayed).

28.3.2. The Contractor shall give written notice to the Owner 12 Business Days prior to the start of the Capacity Test (including any re-performance thereof).

28.3.3. Contractor shall perform the Capacity Test in accordance with the final approved Capacity Test Procedures.

28.3.4. Capacity Test Procedures shall identify the final Monthly Reporting Conditions and Target Capacities using the Project Capacity Model, and data filters described below.

28.3.5. The Capacity Test Measurement Period shall last no less than two (2) consecutive days. If the Minimum Irradiance requirement is not met during such 2-day period, the Capacity Test Measurement Period shall be extended for consecutive days until the Minimum Irradiance requirement is met.

28.3.6. The following input parameters shall be measured during the Capacity Test (collectively, the "Input Parameters"):

28.3.6.1. Plane-of-Array Irradiance (POA): An estimate of the average irradiance incident upon the PV array in the Project. No provision is allowed for shading, so any significant shading during any aggregation interval is causing to exclude that data record from the regression.

28.3.6.2. Ambient Temperature: As recorded by the Project meteorological stations as defined in Appendix 1 to this Exhibit H.

28.3.6.3. Wind Speed: As recorded as recorded by the Project meteorological stations as defined in Appendix 1 to this Exhibit H.

28.3.6.4. CTBG Parameter: Power measurement from the bifacial reference modules and monofacial reference modules

28.3.6.5. Revenue Meter Energy Generation: Energy as recorded by the Revenue Meter during the Capacity Test Measurement Period.

28.3.6.6. Inverter-Level Energy Generation: AC output data for each inverter shall be provided for the purposes of identifying periods of inverter clipping.

28.3.7. During the Capacity Test Measurement Period, irradiance data shall be sampled at no greater than five (5) second intervals. Irradiance data shall be reported at no greater than five (5) minute intervals, consisting of averaged five (5) second sampled data. Power generation data shall either be sampled and reported at the intervals required for irradiance, as noted above. Other data shall be sampled at no greater than one (1) minute intervals and shall be reported at no greater than five (5) minute intervals, consisting of averaged one (1) minute sampled data. All data shall be reported in time-synchronized intervals.

28.3.8. Data shall be averaged and filtered in accordance with the procedures below:

28.3.8.1. Missing Data: Missing records shall be marked as missing with a non-numeric identifier. Missing records shall not have a value included in the analysis, but shall be documented.

28.3.8.2. DAS Equipment Malfunction: Data records with invalid Input Parameters (e.g. all sensor readings reported as out of range by the DAS) shall also be marked as invalid.

28.3.8.3. Below Minimum Irradiance: To avoid large uncertainty in results due to increased impact of variable losses at low irradiance, all records with a minimum plane-of-array irradiance input parameter of 400 W/m^2 or less shall be marked as irradiance too low.

28.3.8.4. Unstable irradiance: Irradiance measurements shall be deemed stable if i) all individual sensor readings are within 25 Watts per meter squared of the average of all the sensor readings and ii) the average of all sensor readings is not more than 10% greater or less than the previous interval reading. If both conditions above are not met, the irradiance will be deemed unstable, flagged and the data will not be used in the test.

28.3.8.5. Inverter clipping: Any intervals where the power output of one (or more) inverters is greater than 98.0% of the rated or programmed power limit.

28.3.8.6. Power Factor: Any intervals where the inverter power factor is less than ±0.98 will be excluded from the test data.

28.3.8.7. Array shading by internal (array self-shading) or external (nearby objects). A schedule of expected shade times shall be defined in the Capacity Test Procedures. This schedule may be altered during the Capacity Test. Records occurring during these shade intervals identified during testing shall be marked as shaded and excluded from the test. Photographic evidence of array conditions shall be provided.

28.3.8.8. Array shading by environmental conditions (e.g. frost, snow or debris). Onsite observers shall record time intervals when such conditions exist as the Capacity Test progresses. Photographic evidence of array conditions shall be provided.

28.3.8.9. Wind Speed: Any intervals where average wind speed is greater than 15 meter per sec will be excluded from the test data.

28.3.9. Data will be collected for a minimum of 3 days until at least 150 allowable data points are collected.

28.3.10. Using the Capacity Test Calculator and the data filtering described herein, calculate the linear regression coefficients and Measured Capacity.

28.3.11. Calculate the Measured Capacity Ratio using the calculated Measured Capacity and appropriate monthly Target Capacity identified in the Table 4 of Appendix 2 attached herein.

28.3.12. If the Measured Capacity Ratio of the Project does not meet or exceed the Minimum Guaranteed Capacity, the Contractor shall identify and promptly resolve the source of the problem and promptly perform the Capacity Test again in accordance with these procedures (other than Paragraph 1 hereof) until the Measured Capacity of the Project achieves the Minimum Guaranteed Capacity. If the Measured Capacity Ratio is more than the Minimum Guaranteed Capacity but is less than the Guaranteed Capacity, then Contractor shall be responsible for the liquidated damages as set forth in the Agreement.

28.4. Capacity Test Bifacial Gain Calculation Procedure

28.4.1. This will be calculated by directly comparing the irradiance measured from the mono-facial reference modules to that of the bifacial reference modules. The calibrated reference modules shall be used in this test and their serial numbers shall be recorded to correlate to flash test data.

28.4.2. The power will be measured in 5-minute intervals from these reference modules at each MET station. The data shall be filtered as follows:

28.4.2.1. Dataset shall be limited to allowable data points of the Capacity Test.

28.4.2.2. Bifacial gain shall be calculated for each MET station and instances where the gain differs more than 5% from the average gain shall be excluded

28.4.2.3. Missing, unavailable, or NaN (Not a Number) data points will be excluded.

28.4.3. The CTBG for each module type shall be calculated as follows:

$$CTBG_i = \frac{\sum_{i=1}^{n} \frac{Power_{bi}/Power_{bi,STC}}{Power_{mono}/Power_{mono,STC}}}{n}$$

Where:
$CTBG_i$ = Capacity Test Bifacial Gain of module type i (%)
n = total number of filtered 5-minute data points (unitless)
$Power_{bi}$ = Power measured by the bifacial reference module (Watts)
$Power_{bi,STC}$ = STC Power of the bifacial reference module (Watts)
$Power_{mono}$= Power measured by the monofacial reference module (Watts)
$Power_{mono,STC}$= STC Power of the monofacial reference module (Watts)

28.4.4. Both the mono-facial and bifacial modules shall be cleaned prior to the Capacity Test. The CTBG shall be calculated specifically for the duration of the Capacity Test. For example, if the Capacity Test takes place from April 10 to April 20, the CTBG shall be calculated for all the filtered 5-minute data points in that time period.

28.5. Capacity Test Report

28.5.1. No later than three (3) Business Days following the end of the Capacity Test Measurement Period of a Successfully Run Capacity Test, a draft Capacity Test Report will be submitted to the Owner by the Contractor. Owner shall have five (5) Business Days to accept or reject the results of the draft Capacity Test Report, and provide in writing any comments of Owner on such draft Capacity Test Report. In the event that Owner rejects all or any part of the draft Capacity Test Report, Contractor shall, within five (5) Business Days thereafter address any comments of Owner and re-submit the draft Capacity Test Report to Owner. This procedure shall continue until Owner accepts the draft Capacity Test Report. Any dispute regarding the results of the Capacity Test or the Capacity Test Report shall constitute a Dispute as described in the Agreement.

28.6. Appendix 1: Additional Requirements

28.6.1. Test Plan

28.6.1.1. The Capacity Test Procedures shall include (at a minimum) the following information:

28.6.1.1.1. Identification of key personnel and parties to be involved in the test

28.6.1.1.2. The Project Model

- For the purposes of the Capacity Test, the Project Model shall exclude array soiling loss, module/system degradation and assume 100% availability
- Meteorological data used for calculation of the Monthly Reporting Conditions

28.6.1.1.3. Identification of the Project under test (at a minimum)

- Number and make/model of PV modules
- Array orientation
- Location (latitude, longitude, street address)
- Racking type and tilt
- Tracker range of motion (if applicable)
- Number and make/model of Inverters
- Row to row spacing (ground coverage ratio)

28.6.1.1.4. Identification of all data points to be monitored during the test

28.6.1.1.5. The Monthly Reporting Conditions and Target Capacity values

28.6.1.1.6. The starting and ending dates of the scheduled Capacity Test Measurement Period.

28.6.1.1.7. Table of all sensors and transducers to be used, including cut sheets, calibration records, map of sensor locations with sufficient detail to allow observers to locate the sensors and transducers. This includes sensors required for all applicable Input Parameters (MET station sensors, inverters, and Revenue Meter).

28.6.1.1.8. MET station and pyranometer quality assurance and/or commissioning documentation (as an appendix).

28.6.1.1.9. Identification of SCADA nomenclature for data channels, and any SCADA calibration parameters (default or custom) for those data channels

28.6.1.1.10. Identification of SCADA data channels intended for use as auxiliary measurements

28.6.1.1.11. Identification of known data quality concerns, such as time intervals when inter-row shading may be expected to occur

28.6.1.1.12. Time-stamp convention and data logger averaging technique/interval to be used in reporting data

28.6.1.1.13.

28.6.1.2. Measured data are to be made available to the Owner upon request during the Capacity Test Measurement Period, for use in evaluating the progress of the Capacity Test.

28.6.2. Capacity Test Report

28.6.2.1. The Capacity Test Report shall contain:

28.6.2.1.1. The Capacity Test Procedures, including all requirements as outlined herein.

28.6.2.1.2. The actual start and end date/times of the Capacity Test Measurement Period

28.6.2.1.3. Comments on environmental conditions during the Capacity Test Measurement Period that affect the results of the test

28.6.2.1.4. Summary of data quality control results for all data records

28.6.2.1.5. Summary of test results

28.6.2.1.6. Regression coefficients used to calculate Target Capacity and Measured Capacity

28.6.2.1.7. Comparison of test results with Minimum Guaranteed Capacity and Guaranteed Capacity

28.6.2.1.8. All calibration certificates for pyranometers, temperature sensors, and revenue meters used in the test

28.6.2.2. Raw data used as input to the Capacity Test, along with QC disposition for each input data record, shall be provided electronically (via CSV, XLS, or XLSX formats) to the Owner with the Capacity Test Report.

28.6.3. Data Quality and Instrumentation Requirements

28.6.3.1. Data quality shall be identified as one item from a set of quality categories for each data record analyzed. Only data from records where all input parameters are valid and within specified limits shall be used in computing capacity estimates.

28.6.4. Sensor Requirements

28.6.4.1. Irradiance sensors shall be at a minimum "High Quality" classified pyranometer(s) as defined in ASTM2848-A1.2 (Secondary Standard per ISO 9060). Pyranometers shall include device-specific characterization data that shall, at minimum, include cosine and temperature response. Alternative pyranometers may only be used if approved by the Owner.

28.6.4.2. Pyranometers shall be used only within their valid calibration period and shall be cleaned at the start of the Capacity Test Measurement Period and cleaned daily during the test if the Capacity Test Measurement Period extends beyond one (1) week. Bifacial reference modules (same batch from the field) shall be installed to measure bifacial plane of array and monofacial reference module to measure plane of array irradiance.

28.6.4.3. All measurement devices and sensors shall meet the minimum accuracy requirements and range requirements set forth in the table below:

Table 4 Sensor Requirements

Measurement	Instrument Type	Test Function	Range	Accuracy
Plane of Array Irradiance	**Front Pyranometer** **Rear Pyranometer** **Bifacial reference module** **Monofacial reference module**	Primary for Capacity Test	0 to 1600 W/m^2 285 to 2800 nm	**±2.0% daily**

Global Horizontal Irradiance	**Pyranometer**	Secondary for Capacity Test	0 to 1600 W/m^2 285 to 2800 nm	**±2.0% daily**
Ambient Air Temperature	Temperature Probe	Primary for Capacity Test	**-40°C to +60°C**	**±1°C**
Wind Speed	Sonic Wind Sensor	Primary for Capacity Test	0 – 60 m/s	±5%
PV Plant Power	PV Power Revenue Meter	Primary for Capacity Test	**0 to PV Power Plant size +20%**	ANSI C-12.20
Inverter Power	Inverter Meter	Primary for Capacity Test	**determined from inverter data sheet**	determined from inverter data sheet

28.6.5. Multiple Measurements

28.6.5.1. Multiple Measurements shall be recorded for all environmental data throughout the Site in order to capture the operating conditions for all regions of the array. There is a high probability that there will be periods of time in which portions of the Project are exposed to significantly different irradiance conditions than other portions, e.g. due to isolated clouds.

28.6.5.2. Below are the main sensors to be used in the Capacity Test:

28.6.5.2.1. Plane of Array Irradiance (POA): Plane of Array readings shall be averaged from sensors installed as outlined in SOW (MET Spec). To be clear, MET station will include front pyranometer, back pyranometer, bifacial reference module and monofacial reference module.

28.6.5.2.2. Ambient Air Temperature: Ambient temperature readings shall be averaged from sensors installed as outlined in SOW (MET Spec).

28.6.5.2.3. Wind Speed: wind speed sensors shall be averaged from sensors installed as outlined in SOW (MET Spec).

28.6.5.2.4. Inverter Meter: The power reading for each inverter.

28.6.5.2.5. PV Plant Meter: The power reading of the Revenue Meter.

28.7. Appendix 2: Project Capacity Model and Reporting Conditions Definition

28.7.1. Project Capacity Model

28.7.1.1. The requirements for the Project Capacity Model to be used for evaluating the Measured Capacity is detailed in this Exhibit. This section outlines all input parameters required to create the PVSYST simulation, in the event that PVSYST electronic project files are no longer available. This section shall be populated and submitted with the Capacity Test Procedures.

28.7.2. PVSYST Model Files

28.7.2.1. The table below provides the file names for all model files necessary to run the PVSYST simulation in the PVSYST version specified in the subsequent section. Contractor shall provide all Project Capacity Model files to the Owner.

Table 1: PVSYST File Names

Table 5 PVSYST File Names

PVSYST File Type	File Name
Project file [PRJ, VC0] Including all variants	
Meteorological file [MET]	
Site file [SIT]	
Module file [PAN]	
Inverter file [OND]	
Shade file [SHD]	
Horizon file [HOR]	

28.7.3. PVSYST Input Parameters

28.7.3.1. In the event that data files are lost or corrupted, all PVSYST inputs and assumptions have been documented in this section. The table below provides many of the PVSYST inputs required in the simulation.

Table 2: PVSYST Input Parameters

Input Parameter	Value	Comment
PVSYST Software Version		
Transposition Model		
Meteorological File		It is critical that the time stamp and other parameters are accurately accounted for when

Input Parameter	Value	Comment
		importing meteorological data. Data import files and techniques shall be documented and provided with the Performance Test Report.
Latitude / Longitude		
Altitude [m]		
Ground Albedo		
Array Orientation (PVSYST Field Type)		
Tilt		
Azimuth		0° is due South
Tracker Backtracking		
Min / Max Rotation Angle		
Number of sheds		
Ground Cover Ratio (GCR)		
Pitch [m]		
Collector width [m]		
Inactive band, Left (m)		
Inactive band, Right (m)		
Near Shading Type		
Electrical Effect		
Number of strings in row width		
Horizon		
Module Type		
Qty. of modules		
Qty. of modules per string		
Qty. of parallel strings		
Inverter Type		
Qty. of inverters		
Heat Transfer: Constant loss factor		
Heat Transfer: Wind loss factor		
DC circuit ohmic loss at STC		
Module Bifaciality factor	Off	Gain from bifacial module as per manufacturer specsheet
Module Quality	MQ - CTBG	CTBG is calculated during the capacity test and MQ is typical module quality factor that is used in the modeling

Input Parameter	Value	Comment
Mismatch [%]		
LID – Light Induced Degradation [%]		
Soiling Loss [%]	1%	1% soiling to be assumed for test unless a soiling station is installed. Then the soiling station soiling will be used.
Incidence Angle Modifier Factors or ASHRAE b0 value		User defined profile
AC circuit ohmic loss at STC		If modeled in PVSYST
External Transformer No Load Loss [%]		If modeled in PVSYST
External Transformer Full Load Loss [%]		If modeled in PVSYST
External Transformer Nighttime disconnect		If modeled in PVSYST

28.7.3.2. There are many additional settings required to recreate PVSYST files such as meteorological data import techniques, module file [PAN], inverter file [OND], etc. PVSYST version and model files will be placed in escrow to perform simulation. The files to be included in escrow include (a) all files listed in Table 2 of this Appendix 2 of Exhibit [ ], and (b) a copy of PVSYST version X.

28.7.4. Additional Losses (Post-Processed Loss)

28.7.4.1. There are multiple losses associated with an operating Project that may not be accounted for in PVSYST. Such losses include night-time demand of inverters, as well as auxiliary loads including but not limited to HVAC, lighting, security, SCADA, etc.

28.7.4.2. These losses have been included in the modeled power generation, the details of which are defined in the table below.

Table 3: Model Additional Loss

Parameter	Value	Comment
AC circuit ohmic loss [%]		
External Transformer Iron loss [%]		
External Transformer Resistive loss [%]		
External Transformer Nighttime disconnect		
Availability loss [%]		Not Included in Project Capacity Model

Parameter	Value	Comment
Curtailment loss [%]		Not included in Project Capacity Model
Auxiliary Loads [%]		
Nighttime Loads [%]		

28.7.5. Reporting Conditions and Target Capacities Identification

28.7.5.1. The Monthly Reporting Conditions and Target Capacities are to be specified below. Table 4 will be completed by Contractor and approved by Owner once the Project Capacity Model is complete. The following algorithm is recommended for identifying Reporting Conditions.

28.7.5.1.1. The Reporting Conditions shall be determined based on measured data set. Data records shall include the measured POA irradiance, ambient temperature and wind speed input parameters, as well as any simulated auxiliary parameters necessary for marking data records according to the primary data exclusion criteria.

28.7.5.1.2. Apply the primary data exclusion criteria identified in Section 8 of this procedure to the measured data records. (The secondary data exclusion is not applied.)

28.7.5.1.3. Grouping the remaining data records by month, compute the median values of incident plane-of- array irradiance, ambient air temperature, and wind speed. The reporting condition for plane-of-array (POA) irradiance shall not be less than 500 W/m².

28.7.5.1.4. Round median irradiance to the nearest integer W/m², median temperature to the nearest °C, and corrected median wind speed to the nearest 0.1 m/s. Use values as reporting conditions in Table 4.

28.7.5.1.5. Procure PVSyst hourly output from the Project Capacity Model. Project Capacity Model shall include following parameters:

- Soiling, Availability and Curtailment Losses shall be assumed 0%
- Module Quality Factor shall be adjusted with Capacity Test Bifacial Gain (CTBG) for bifacial modules
- Bifaciality factor in PVSyst simulation shall be turned off

28.7.5.1.6. The PVSyst hourly output, after post-processing, must contain at a minimum the plane of array irradiance, the ambient temperature, wind speed, inverter energy output, modeled power generation, shade loss, and clipping loss (GlobInc, TAmb, WindVel, EOutInv, POI Limited, ShdBLss, and IL Pmax) respectively.

28.7.5.1.7. Apply the data exclusion criteria identified in Section 8 to the simulation data records.

28.7.5.1.8. Compute regression coefficients and Target Capacity for the month(s) of the test. If the Capacity Test overlaps two months a weighted average based on the proportion of Qualifying Data points for each month will be used to calculate the Target Capacity.

Table 4: Example Monthly Reporting Conditions and Target Capacities Table

Month	Reference POA Irradiance (W/m^2)	Reference Ambient Temperature (°C)	Reference Wind Speed (m/s)	Target Capacity (kW)

28.8. Appendix 3: Capacity Test Calculator

28.8.1. The table below provides the file names for all files needed for the Capacity Test Calculator. Contractor shall provide the Project Capacity Model Hourly Data file once the Project Capacity Model is complete. If the Project design changes significantly, the Project Capacity Model Hourly Data shall be updated by the Contractor to reflect the As Built design and such updated Project Capacity Model Hourly Data shall be submitted to the Owner for review and approval. All Changes to Project Capacity Model shall be documented and approved by the Owner.

Table 1: Capacity Test Calculator Files

File Name	File Type	Comments
Capacity Test Calculator	.xlxs	Used to calculate reporting conditions, regression coefficients, Measured Capacity, and Target Capacity values
Project Capacity Model Hourly Data	.csv	Hourly Plane of Array (Global Incident in PVSYST), Ambient Temperature, Wind Speed, and Energy (after post processing, as necessary)

Revision History

Date	Revision Number	Change
12-16-08	1.0	New
7-10-09	1.1	Updated Logo
7-15-10	1.2	Review for 2010 Audit, Minor formatting changes made
10-11-11	1.3	Modified for capital project requirements
3-27-14	1.4	- Revised for 2014 Audit. Minor formatting changes made. - Revised Section 1.2 – Added O&M Manual Deliverable information.
8-18-15	1.5	Consolidated Regional Drawing Deliverable Standard WI's into one applicable for all Operating Regions.
6.15-18	1.6	Triannual Review complete, removed names replaced with titles, cleaned up regional references, linked TitleBlock standards,

1.0 REQUIREMENTS

1.1 GENERAL

The Engineering and Construction (E&C) division of Xcel Energy's Energy Supply unit provides multi-discipline Engineering (ENG), Design (DS), Construction, and Document services (EDS) for Xcel Energy Power Generation facilities throughout Xcel's Operating regions as defined below:

1.1.1 **Public Service Company of Colorado (PSCo) Operating region**: PSCo Power Plants located within the state of Colorado.

1.1.2 **Northern States Power (NSP) Operating region:** NSP Power Plants located within the states of Minnesota, Wisconsin, South Dakota, and North Dakota.

1.1.3 **Southwestern Public Service Company (SPS) Operating region:** SPS Power Plants located in the states of Texas and New Mexico.

Engineering and Construction includes the following departments:

EDDS – Engineering, Design, & Document Services
ENG – Engineering
DS – Design Services
EDS – Engineering Document Services

1.2 Existing Drawing Checkout: - The Architectural/Engineering (A/E) firm or Vendor shall request from Engineering & Construction's (E&C) EDDS department drawings needed for revision or changes using the EDS Media Request form or via e-mail to the respective EDS e-mail address (reference EEC 7.955 Engineering Document Management). The A/E firm or Vendor shall clearly request the drawings needed and any CAD files required. EDDS will perform a verification of the information on the Media Request form including status of the requested drawing (CAD or Manual) and check out the electronic drawing file(s) to the A/E firm or Vendor per request. If the drawing is manual, E&C Design Services (DS) will convert the drawing to electronic format (CAD/Tif Hybrid) for modification. Once E&C DShas completed checkout, a copy of the requested CAD files shall be placed on the project SharePoint Site and released for work to the A/E firm or Vendor. It is the A/E firm's or Vendor's responsibility to maintain the integrity and availability of the original electronic drawing file(s).

A redraw of an existing drawing shall only be done if it is faster to recreate the drawing versus making the revisions. If a drawing is redrawn, ALL information including existing revisions shall be carried over to the new file. This shall include, at minimum, all revision triangles as shown on the existing drawing as well as revision descriptions in the revision block. Both the existing original drawing and the new redrawn original drawing shall be sent to EDDS.

1.3 New Drawing Request/Checkout: - The Architectural/Engineering (A/E) firm or Vendor shall contact Engineering & Construction's (E&C) EDDS department for all new drawing requests. EDDS shall provide the following to the A/E firm or Vendor for all new drawings, per the Operating Region requirements:

- A unique drawing
- Standard Borders

Please contact the DS Supervisor for the Standard Border requirements.

In order to provide the new drawing number, EDDS will need the A/E firm or Vendor to provide the following information:

- Plant
- Unit Number
- Plant System and Sub-system Code
- Discipline Category
- Drawing Type

Once the above information is received, E&C DS will coordinate with E&C EDS to assign all new drawing numbers and properly reserve the drawing numbers in ProjectWise. Once reserved, EDDS shall communicate all new drawing numbers to the A/E firm or vendor via e-mail to the respective EDS e-mail address. All new drawings shall be identified as new.

1.4 DRAWING ISSUE PACKAGE:

When outside A/E firms or Vendors issue drawings, the following items shall constitute an issued package and shall not be considered complete unless all the deliverables are included, without exception. At time of issue, EDS shall be included on all transmittals and shall receive all items included in a drawing issue package. All drawing issue packages shall consist of the following items:

PDF of each Manual – One (1) unsecured pdf copy of all equipment manuals such as original equipment manufacturer (OEM), operation & maintenance, instruction and/or installation manuals. All final manuals must conform to, and include, all construction

As-Built information.

Hard Copy of each Manual – Company's plant or project manager will identify quantity of required equipment manuals such as OEM operation & maintenance, instruction and/or installation manuals. All final manuals must conform to, and include all construction As-Built information.

Hard Copy Original Record Drawings: (See Requirements per Operating Region below)

- **PSCo Operating Region**: – No hard copy record drawing required.

- **NSP Operating Region**: The hard copy original record drawing with all initials/signatures of approval included. These initials/signatures shall be in BLUE ink so identification of the original can be done quickly. These drawings shall match exactly with the image file provided. If required, the Hard Copy Original Drawing shall have a wet stamp by a registered professional engineer (PE) for the statein which work is being designed.

- **SPS Operating Region: -** Professional Surveyor (PS) (New Mexico) or Registered Professional Land Surveyor (RPLS) (Texas) Stamped Drawing – If required, one (1) hard copy original of each drawing shall be provided wet stamped by a Professional Surveyor (PS) or a Registered Professional Land Surveyor (RPLS) licensed within the state where the subject of the Work has been constructed or is being constructed. Where allowed by the appropriate State Licensing organization CAD seals are acceptable.

Image File of Drawing Being Issued – An unsecured image file of the official record drawing shall be provided. This image shall be created electronically from the native file, if possible. This image shall bethe correct drawing size, clear, legible, and shall not be rotated and match the Hard Copy Original Record Drawing exactly. If this image file is not of the utmost quality, the drawing issue package will be rejected and the A/E firm or Vendor will be asked to provide quality images with no additional charge to Xcel Energy. This shall also include record drawings submitted as As-Built and record drawings stamped by a P.E. See 1.5 DRAWING FILE FORMATS for acceptable image file format.

CAD File – A CAD file, shall be provided on all initial drawing issues as well as final "As-Built" issues. Each CAD drawing file shall have its own separate CAP Drawing file and not combined into one CAD drawing File. Each CAD file(s) shall correspond to the current revision of the official record drawing being issued. If the drawing requires further revisions, a copy of the current CAD file shall be made and provided. See **"FORMATS"** for acceptable CAD file formats. Below are the requirements that must be included in the CAD file:

- ✓ Initials/Signatures typed in the titleblock of all originators, checkers, approvals, etc. This includes the titleblock as well as the revision block.
- ✓ Detailed descriptive reason of the revision in the revision block.
- ✓ All CAD drawings shall be drawn in such a manner that quantities may be correctly derived from the CAD file or an identified referenced 3D Model file.
- ✓ Clouds shall be placed around all the areas where the drawing was changed.
- ✓ Provided CAD files shall include all associated CAD references and 3D models used in the design. All Cad files and 3D models shall be in native format used to create the drawing files. Acceptable formats are Microstation (.dgn) and AutoCAD (.dwg).
- ✓ All seed files associated with 3D model and CAD files.
- ✓ All CAD drawings shall include any customized fonts used on the provided drawings.

If drawings, 3D models, seed files, or borders are referenced in the working drawing, then they should be submitted with all associated CAD files used in the design and shall be included as part of the Drawing Issue Package. Drawings should not be bound prior to submitting to Xcel Energy.

<u>Transmittal</u> – One (1) transmittal shall be provided for every drawing issue. The transmittal shall include the following:

- ✓ If applicable, the name of the Project Manager for the project which the drawings are being issued.
- ✓ The A/E firm or Vendor's Project Manager
- ✓ The A/E firm or Vendor's Administrative person who created the transmittal
- ✓ EDDS personnel
- ✓ The recipients of the drawings being issued
- ✓ Clear and concise description of what the drawings are being issued for (Preliminary, Bid Issue, Construction, Not to be Used for Construction, Demolition Sketch, As-Built), any specific instructions, or information pertinent to the drawings
- ✓ All drawings shall be collated to match the transmittal, if issued hard copy.

<u>Design Services Review of Vendor Submitted Drawings:</u> – Upon transmittal of a

drawing package by an A/E firm or Vendor, Design Services (DS) shall review the package for compliance with E&C Design/Drafting standards. This review shall be performed in parallel to any Engineering review of the drawing package. All comments shall be forwarded to the Project Manager or Project Lead to be incorporated along with any Engineering comments and returned to the A/E firm or Vendor for correction and revision.

When all the drawings are agreed upon as complete, and are in As-Built or final status, the “DDI Import Form” (reference Attachment A) for the Xcel specific operating Region shall be completed by the A/E firm or Vendor. This shall be completed at the end of the project or may be deemed necessary by the Project Manager at any time during the project. This information is required so Xcel E&C can easily import drawing information into Xcel Energy’s drawing management system. Drawing information entered on the DDI Import Form shall be as descriptive as possible. The A/E firm or Vendor is responsible for adding this information relating to all columns and rows within the spreadsheet (examples can be provided if requested).

1.5 DRAWING FILE FORMATS:

During the project, PDF image files and/or CAD files may be requested. The following are acceptable electronic files to be delivered to E&C. The A/E firm or Vendor shall inquire of the DS and EDS departments as to current versions being used by E&C. All other formats shall be approved by E&C prior to being used and/or As-Built submitted.

Acceptable CAD File Formats:

DWG – AutoCad 2013 or newer - all files in Native Format
DGN – Bentley Microstation V8i - all files in Native Format

Acceptable Image File Formats:

PDF – Adobe Acrobat Format version 9.0 (Unsecured, electronically searchable, not a hard copy scanned document)

1.6 FILE NAMING

1.6.1 PSCo File Naming: All new engineering drawings shall be drawn in CAD and shall have a unique PSCo drawing number assigned. EDDS will provide this unique number to the A/E firm or Vendor. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDDS. No two (2) drawings will be assigned the same PSCo drawing number. The A/E firm or Vendor shall formally request from EDDS these assigned numbers.

1.6.2 **NSP File Naming:** All new engineering drawings shall be drawn in CAD and shall have a unique NSP drawing number assigned. EDS will provide this unique series number. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDS. No two (2) drawings will be assigned the same NSP drawing series number. The A/E firm or Vendor shall formally request from EDS these assigned series numbers.

1.6.3 **SPS File Naming:** All new engineering drawings shall be drawn in CAD and shall have a unique SPS drawing number assigned. EDDS will provide this unique number. All file names shall be identical to the assigned drawing number. The A/E firm or Vendor shall not change or alter any part of the drawing number/file names received from EDDS. No two (2) drawings will be assigned the same SPS drawing number, even if the drawing prefixes (referring to dwg size) differ. The A/E firm or Vendor shall formally request from EDDS these assigned numbers.

1.7 DRAFTING STANDARDS

1.7.1 Standard Drawing Templates: Drawings created will use standard templates/seed files to setup the drawing. A/E firms or Vendors shall contact the appropriate Regional Supervisors for the standard templates/seed files.

1.7.2 TitleBlock and Revision Attributes: All checked and approved names/initials with complete dates shall be typed on all revisions and titleblocks on the electronic CAD files. A/E firms or Vendors shall contact the appropriate Regional Supervisors for the TitleBlock standards.

NSP TitleBlock
PSCO TitleBlock
SPS TitleBlock

1.7.3 Drawing Scale: All drawings shall be drawn full scale in Model space and plotted in Paperspace with the titleblock inserted at a scale of 1:1.

1.7.4 Standard Text Fonts: Only standard AutoCad and Microstation text font styles shall be used.

1.7.4.1 AutoCAD standard text shall be text style "ARIAL" except for electrical drawings. Electrical Drawings shall use text Style "TIMES NEW ROMAN".

1.7.4.2 Microstation standard text shall be text style "ARIAL" except for electrical drawings. Electrical Drawings shall use text Style "TIMES NEW ROMAN".

1.7.5 Standard Text Height:

1.7.5.1 PSCo Drawings:

- 3/32" (.100") shall be the Standard Text Height for PSCo C,D, or E-Size drawings.
- 1/8" (.125") shall be used for all sub-titles that require Medium-Height Bold Text such as Equipment Specifications or Designations, Titles for Notes and Highlighted Text.
- 5/32" (.150") – shall be used for all Prominent Titles that require Large-Height Bold Text such as Equipment Titles, Detail Titles, Section Titles, Plan or Elevation View Titles, etc.
- 5/64" (.08") - shall be used when space limitations on the drawing require deviation from the Standard Text Height. In this case the Standard Text Height for the entire drawing will be .08 consistent throughout the drawing ; subtitles and equipment designations will be .100" and Bold text, Prominent Titles will be .125 and Bold text.
- 5/64" (.08") shall be the Standard Text Height for PSCo A or B-Size drawings.

1.7.5.2 NSP Drawings:

- 3/32" (.100") shall be the Standard Text Height for NSP A, B, or C-Size drawings. Lineweight = 1

- 1/8" (.125") shall be the Standard Text Height for NSP D or E-Size drawings. Lineweight = 1
- 5/32" (.150") – shall be used for all Prominent Titles that require Large-Height Bold Text such as Equipment Titles, Detail Titles, Section Titles, Plan or Elevation View Titles, etc. Lineweight = 2

1.7.5.3 SPS Drawings:

- 3/32" (.100") shall be the Standard Text Height for all SPS A, B, C, or D-size drawings.

1.7.6 Drawing Units:

1.7.6.1 AutoCAD drawing units shall be Decimal, Engineering, Architectural, and Fractional. Use the appropriate drawing units for the type of drawing that is being created.

1.7.6.2 All Microstation CAD files shall have the following working units:
Master Unit = FT, Label = '; Sub-units = IN, Label = ".
Coordinate Readout: Master Units, Accuracy: 0.12
Angles – Format: DD.DDDD, Mode: Conventional, Accuracy: 0.123

1.7.6.3 Land Surveys & Topographic drawings shall have the following Drawing Units:
Master Unit = FT, Label = '; Sub-units = IN, Label = ".
Coordinate Readout: Master Units, Accuracy: 0.12
Angles – Format: DD MM SS, Mode: Bearing, Accuracy: 0

1.7.7 Dimensions:

1.7.7.1 All drawings shall have dimension units shown in feet, inches, and fractions of inches with the exception of civil engineering drawings. Civil engineering drawings shall be dimensioned in feet and hundredths of a foot.

1.7.7.2 Dimensions on drawings shall be associative and shall not be exploded or dropped. Never override the default measurement on a dimension unless it is a hybrid drawing with an image file.

1.7.7.3 Dimension Precision shall be set to 0'-0 1/128" or 0'-0 1/256".

1.7.7.4 Dimension text shall be the same size as all other text on the drawing and shall be configured to plot the same width as all other Standard text on the drawing. (See section 1.7.5 – Standard Text Height).

1.7.7.5 Dimension text shall be placed above the dimension line and centered between the extension lines except when the text will not fit. Then move text to the right or left.

1.7.7.6 Dimension, extension, and leader lines shall not cross each other unless absolutely necessary. A dimension line shall not be broken. Extension lines or leader lines shall not run through a dimension nor shall they be broken except where they pass through or are adjacent to arrowheads.

1.7.7.7 Sufficient dimensions shall be shown in the view that clearly define the size, shape, and position of the component. Dimensions shall be given as to minimize the need to calculate, scale, or assume any dimension during the construction or fabrication process.

1.7.7.8 Place dimension lines across the top of an object and along the left side. If additional dimensions are required to clearly dimension an object, they can be placed along the bottom and right side of an object.

1.7.8 Sections & Details:

1.7.8.1 PSCo Drawings: Sections and Elevations shall be labeled with Alpha characters. Details shall be labeled with Numeric characters.

1.7.8.2 NSP Drawings: Sections and Elevations shall be labeled with Alpha characters. Details shall be labeled with Numeric characters.

1.7.8.3 SPS Drawings: Sections and Elevations shall be labeled with Numeric characters. Details shall be labeled with Alpha characters.

1.7.9 Drawing Notes:

1.7.9.1 General notes affecting all the sheets per that drawing number shall be placed on the first sheet and always be placed in the upper right hand corner of the drawing. They may serve any of several purposes; it may be a note that would become repetitive if placed at each point of application, a note that applies to the drawing in general, or a lengthy note that would occupy excessive space on the drawing.

1.7.9.2 All notes shall be equally spaced with a space equivalent to the one line of text between each note. Note text shall be indented from the note number.

1.7.9.3 General notes shall be presented in a sequence that corresponds to the construction process.

1.7.9.4 Local notes are placed on the drawing, normally outside the outline of the affected object and as near as practicable to the affected region of the object. Information presented in these notes normally applies to a particular portion of the overall drawing.

1.7.10 North Arrow:

1.7.10.1 North arrows shall always be located in the upper left hand corner of all plan views.

1.7.10.2 The north arrow should never be positioned pointing down.

1.7.11 Symbology:

1.7.11.1 Symbols and nomenclature used to create the drawings shall conform to the existing nomenclature sheets established for that particular plant, or with Xcel Energy's standard symbology sheets.

- Mechanical – Reference Mechanical Symbology & Nomenclature sheets.
- Instrumentation - Reference Instrumentation Symbology & Nomenclature sheets.
- Electrical – Reference Electrical Symbology & Nomenclature sheets.

1.7.12 Drawing Revisions:

1.7.12.1 When revising existing drawings, use existing layers/levels and colors.

1.7.12.2 Revisions shall be made by modifying the latest electronic version of that particular drawing.

1.7.12.3 Drawing revisions shall be clouded, being careful not to cross any text, dimensions, or notes. Clouds will be erased with the next revision, and the new changes will be clouded.

1.7.12.4 All revisions formally transmitted shall be routed and reviewed by appropriate E&C personnel. All drawings formally transmitted "Issued for Comments" shall have an alpha character as a revision. Once all comments have been reviewed, addressed, and incorporated by the proper personnel, the drawings are ready to be transmitted for "Issued for Construction" and shall have numeric revisions starting with revision 0.

1.7.12.5 When drawings are being "Issued for Construction," all previous preliminary revisions are removed from the revision block and shall only show Revision 0. All approvals shall be hand initialed in blue ink with the exception of the date and the drafter/designer which is typed on the original. After having the approvals hand written, these signatures/initials shall be typed in the electronic CAD file so they may be kept electronically.

1.7.12.6 Drawing revisions will be made by adding, deleting, crossing out the information, or by redrawing the drawing. The revision status is identified by a numeric revision number beginning with the number 0 (zero), and used in sequential order. Revisions to drawings shall be consistent with the original workmanship.

1.7.12.7 Once all drawing changes are As-Built and the drawing status is "Issue For Record," the revision block shall have "Issue For Record" typed into the description along with the Project Name, and Project Number. When issuing drawings as "Issue For Record," there shall be no clouds on the drawings; only a revision triangle shall be used to identify the As-Built changes unless clouds are specifically requested. All signatures/initials shall be typed in the electronic CAD file so they may be kept electronically.

ATTACHMENT A

DDI FORM

Xcel Energy

Energy Supply - Engineering & Construction Dept.

Drawing and Instruction Manual Submittal Form

Plant / Substation / Transmission-Line:

Plant Name Here

City State

Todays Date:

Consultant / Vendor Name & Address:

Consultant / Vendor Project Transmittal #

Xcel Project #

Maximo Work Order #

Submitted Date:

USE CURRENT VERSION

Submitted B[y]: Phone #: Mobile #:

Xcel Energy TS Coordnator: Phone #: Mobile #:

Project Title \ Description:

Comments \ Instructions:

Attached Files Created On: Delivery Method:

Total Drawings: 0

Total Manuals: 0

FORM NUMBER: TS 12 07 Rev. A PSCO - DDI Form.xls

Plant ID	MICROFILM #	MFR. Name	MFR. Dwg #	Sht.	Rev.	Rev. Date	Contract/PO #	Unit	System Code	Sub-System Code	(Top Line) SYSTEM DESCRIPTION	(Middle Line) COMPONENT DESCRIPTION	(Bottom Line) DRAWING TYPE	DWG. Size	Discipline

1.7.2.2 TITLEBLOCKS

Standard title blocks are created and shall be used on all Xcel drawings and shall not be altered. The Design Services Manager shall approve any changes required prior to being used.

Drawing Sizes

NSP, Architectural Engineering firm, or Consultants drawings are considered domestic, and are prefixed by an "N", and an identifier corresponding to the physical size of the end product. This identifier has a direct relationship to better known international standard sizes.
Vendor or Manufactured originated drawings and manuals
are prefixed with "**NX**"

(Example) "NX-12345-1-1. Vendor prefixes have no relationship to the drawing size.

PREFIX		SIZE(Height x Width)	NSP FILE SIZE CODE
NL	=	11 X 8.5	A
ND	=	11 X 17	B
NQ	=	17 X 22	C
NH	=	22 X 34	D (preferred size for P&ID's and Schematics)
NF	=	34 X 44	E (preferred size for GA, Site, UG Utilities)
NX	=	Vendor Only Various	A thru E

* **Obsolete** Industry Standard, do not use with new drawings, except to add to an existing series of that size.

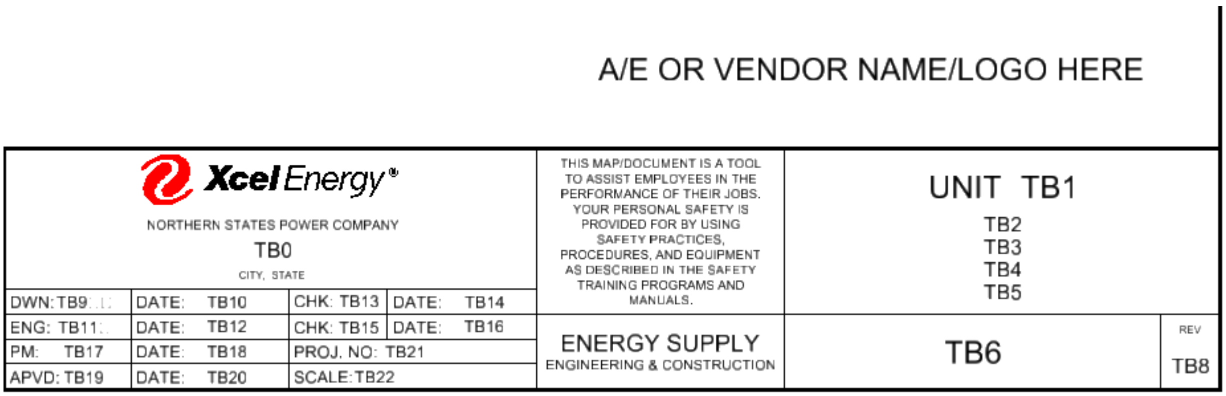
***NE/DE**	=	11 X 34	D
***B**	=	18 X 27	C
***A**	=	24 X 36	E
***E**	=	34 X 48	E
***AA**	=	30 X 42	E

Borders: Shall be scaled to 1:1 only.

Do Not Re-name Borders block name or tag set .
Do Not Reference Borders into drawings into drawings.

The **lower left** corner of all drawing borders will reside at **XY**="**0,0**", unless a UTM or USDS coordinate system is used.

Key Elements of Drawing Titleblock Information



The following information shall be input into all NSP plant project title blocks. It is the responsibility of the A/E firm's or Vendor's drafter/designer to include the correct information on the title block.

TB0 – PLANT NAME

This is the plant name for which the drawing content is to be located.

TB1 – UNIT#

This is the unit number for which the drawing content is to be located. If the drawing(s) relate to more than one unit, then the number (UNIT 0) zero is entered representing all units.

TB2 – SYSTEM

The system the drawing pertains to shall be input on this line. For example, if the project is for dust suppression, then DUST SUPPRESSION is entered. For a new instrument air compressor, INSTRUMENT AIR is entered.

TB3 – EQUIPMENT DESCRIPTION

The equipment the drawing pertains to shall be input on this line. For example above, for a new instrument air compressor, INSTRUMENT AIR COMPRESSOR would be entered.

TB4 – FURTHER DESCRIPTION

This is used if further equipment description is needed. If this is not needed, then this line is blank.

TB5 – DRAWING TYPE

This is the type of drawing. For example, if it is a wiring or connection diagram, then WIRING DIAGRAM is entered. If it is plan and sections, PLAN & SECTIONS is entered.

TB6 – DRAWING NUMBER

This is the NSP Drawing number. Xcel Energy's EDS Dept. assigns ALL drawing numbers. Architectural Engineers (AE's) to follow **example** "NH-200000-1-1" (First NH-is the prefix for "D" size followed by a 6 digit series number, then followed by dash and or sheet number if needed).

TB8 – CURRENT REVISION NUMBER

This is the current revision of the drawing. All revisions shall be numeric.

TB9 – DRAWN BY

This is the initial of the person who created the drawing. Two (2) or three (3) initials are required.

TB10 – DATE DRAWN

This is the date the drawing was created. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB11 – ENGINEERED BY

This is the engineer or designer who designed the system or worked on the drawing. Two (2) or three (3) initials are required.

TB12 – DATE ENGINEERED

This is the date the drawing was engineered or designed. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB13 – DRAFTING CHECKED BY

This is the initials of the person who checked the drafting of the drawing. Two (2) or three (3) initials are required.

TB14 – DATE DRAFTING CHECKED

This is the date the drafting was checked. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB15 – ENGINEERING CHECKED BY

This is the initials of the person who checked the engineering. Two (2) or three (3) initials are required.

TB16 – DATE ENGINEERING CHECKED

This is the date the engineering was checked. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB17 – PROJECT MANAGER (If Applicable)

This is the initials of the person who was the Project Manager. Two (2) or three (3) initials are required.

TB18 – DATE PROJECT MANAGER (If Applicable)

This is the date the Project Manager approved the drawing. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB19 – DRAWING APPROVED BY

This is the initials of the person who approved the drawing. Two (2) or three (3) initials are required.

TB20 – DATE APPROVED

This is the date of the person who approved the drawing. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

TB21 – XCEL PROJECT NUMBER

This is the Xcel Energy project number assigned to the NSP project. This field will not change with revisions of the drawing.

TB22 – DRAWING SCALE

This is the scale of the drawing. Drawings that are drawn to scale will indicate the scale, (for example, 3" = 1'-0"). Drawings that are not drawn to scale will indicate the scale as NONE.

TB23 – OPERATING COMPANY

This relates to the Minnesota/Wisconsin/South or North Dakota operating regional company, used is Northern States Power.

TB24 – OPERATING STATE

This relates to the City and State location of which the work is being performed at.

PROFESSIONAL ENGINEERS SEAL SECTION
This section is reserved for the Professional Engineer's Seal or Professional Architect's Seal if required by the Projects. This section may be turned off by layer or level if using a seal in lieu of the Minnesota engineering verbiage This section may be turned off by layer or level if using a seal in lieu of the Minnesota engineering verbiage.

Key Elements of Drawing (Revision) Block Information

NO.
This is the current revision of the drawing. All revisions shall be numeric.

REVISION
This is a short, clear, and concise description of the revision. Abbreviations can be used however they need to be clear and easily understood. Multiple lines can be used if required. Occasionally, a drawing revision will have new project number for which the revision was created. The new project number will be incorporated in the revision description. If the drawing was redrawn on CAD then this shall be the first item noted in the revision description.

ZONE
D-size and E-Size drawings are subdivided into zones. The zones are indicated by alphabetical and numerical entries along the border. The alphabetical entries are found along the top edge of the border and the numerical entries are found along the left edge of the border. The revision zone shall be entered with the alphabetical designation first, followed by a “dash”, followed by the numerical designation corresponding with the area of the drawing that was revised.

DATE
This is the date the drawing was revised. The date should be designated with separation by a dash and not a slash, for example, 00-00-00.

BY
This is the initials of who made the revision to the drawing. Two (2) or three (3) initials are required.

CHK
This is the initials of the person who checked the revision to the drawing. Two (2) or three (3) initials are required.

ENG
This is the engineer or designer who designed the system or worked on the drawing revision. This can also be the person who approves the revision. Two (2) or three (3) initials are required.

Key Elements of Drawing (Reference) Block Information

DRAWING NUMBER.
This is the drawing number of the drawing being referenced.

MANUFACTURER
This is the manufacturer, vendor, or Company name of the drawing being referenced.

DRAWING TITLE
This is the title of the drawing being referenced.

Preface

P.1. Scope and Purpose

This document describes the fundamental design criteria for substation facilities within Xcel Energy. It covers the construction of new facilities, modification, or extension of existing facilities, and to some extent, the rehabilitation of existing facilities.

P.2. Applicability

This document is a standard and shall be followed by all employees with XCEL Company for new substation installations. Any exceptions to following this standard need to be requested in writing and approved by the manager or director of engineering.

P.3. Responsibilities

P.3.1 Substation Engineering and Design

This document is to be used as reference for Substation Engineering and Design Engineers when constructing or modifying an Xcel Energy Substation.

P.4. Work Flow

P.4.1 Approval

The Xcel Energy Standards Council has approved this document.

Date	Name
2015/04/06	Jensen, Mike C
2015/04/02	Watkins, Diane
2015/04/03	Gragg, Jim
2015/04/06	Gutzmann, Mark G
2015/03/30	Bellinghausen, Alan L
2015/04/24	King, Mike
2015/04/02	Lorentz, Brian R
2015/04/03	Munsell, Kenny
2015/03/30	Hui, Ming-Wa

P.4.2 Creation

The following committee wrote this document.

Name	Title
Barry Gustafson	Principal Engineer, System Sustainability
David Miller	Principal Engineer (Ret), Substation Engineering Design
David Stamm	Consultant, High Energy Incorporated
Don Simpson	Principal Engineer, Substation Engineering Design
Jim Gragg	Manager, Substation Engineering Design
Mike Ibold	Manager, Substation Engineering Design
Sue McNelley	Consulting Engineer, Substation Engineering Design
Dick Bush	Principal Engineer, Substation Engineering Design
Joe Gravelle	Principal Engineer, Substation Engineering Design
Timothy Lougheed	Staff Engineer, Substation Engineering Design
Mike Jensen	Supervisor, Substation Engineering Design
Heather Malson	Staff Engineer, Transmission & Substation Standards

P.4.3 Version History

The personnel listed above have approved the following changes.

NOTE: The most recent changes to this document are highlighted in yellow throughout the document.

Date	Version Number	Change
6/17/2003	1	Initial Version
12/1/2011	2	Initial Revision for Review
6/8/2012	2.1	Updated Format of Document
8/28/2012	2.2	Updated document based on review comments
9/11/2012	2.3	Document reviewed by Substation Standards Council
9/28/2012	2.4	Changes made to document based on Council review
11/14/2012	2.5	Document updated and sent to Engineering for review
1/24/2013	2.6	Document sent to Substation Standards Council for review
3/25/2013	3.0	Document approved by Standards Council and set to “Released”
4/1/2013	3.1	Draft to make changes based on additional comments submitted during previous reviews
5/22/14 – 3/30/15	3.2-3.82	Team Revisions, open review and send to council for approval
5/11/15	4.0	Council approval
5/11/15-7/15/15	4.1	Update links and minor modification with team and council approval – set to release

Table of Contents

1 General

1.1. Introduction

This document describes the fundamental design criteria for transmission and distribution substation facilities within Xcel Energy. It covers the construction of new facilities, modification or extension of existing facilities, and to some extent, the rehabilitation of existing facilities. Civil and structural design criteria are provided in XEL-STD-Criteria for Eng & Design of Civil & Structural Performance.

This document is located in ProjectWise here: XEL-STD-Criteria for Eng & Design of Substations - Physical

When substantial additions to existing facilities are planned, they shall be in accordance with current criteria. The interface between the new and the old will be designed to satisfy existing and economically practical future technical requirements but not necessarily to satisfy current standards. It is the design engineer's responsibility to build a consensus on the balancing of trade-offs between economics, practical solutions, and standards when faced with upgrade decisions.

When deficiencies are discovered, the merits of correcting the deficiencies should be decided based on safety, budget, timing, and technical merit. A project in one area of a substation does not necessarily require bringing the entire facility up to current criteria. Rehabilitation projects often are limited in their ability to match current standards.

It is recognized that each substation project will have unique requirements and constraints and that these criteria cannot or should not be followed in all situations. In all cases, current criteria shall be used as a guide to a practical design with a goal to achieve as much standardization as possible.

1.2. Industry Standards

All substations designs shall be in accordance with IEEE standards and accepted industry standards and practices. IEEE C2-The National Electric Safety Code ("NESC") and the National Electrical Code (NFPA 70) should be followed to the extent that is possible and practical.

1.3. Glossary

General Arrangement – drawing showing the major electrical and physical components of a substation, including but not limited to breakers, transformers, bus, and lines

Ultimate Build Out/Ultimate Design – fully envisioned future size and arrangement of a substation

Buchholz relays – For transformers with a conservator type oil preservation system, a Buchholz relay is specified. This relay serves as a protective device and provides two functions. It acts as a sudden pressure relay (SPR) or rapid pressure rise relay (RPRR) and also provides a gas detection function for slower development of gases. These are alarmed separately, with the sudden pressure function wired to controls to trip the transformer. Buchholz relays were named after their inventor, Mr. Max Buchholz (1875-1956) in 1921.

Bulk Electric System (BES)* – Unless modified by the lists shown below, all Transmission Elements operated at 100 kV or higher and Real Power and Reactive Power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy.

Inclusions:

- I1 - Transformers with the primary terminal and at least one secondary terminal operated at 100 kV or higher unless excluded by application of Exclusion E1 or E3.
- I2 – Generating resource(s) including the generator terminals through the high-side of the step-up transformer(s) connected at a voltage of 100 kV or above with:

a) Gross individual nameplate rating greater than 20 MVA. Or,

b) Gross plant/facility aggregate nameplate rating greater than 75 MVA.

- I3 - Blackstart Resources identified in the Transmission Operator's restoration plan.
- I4 - Dispersed power producing resources that aggregate to a total capacity greater than 75 MVA (gross nameplate rating), and that are connected through a system designed primarily for delivering such capacity to a common point of connection at a voltage of 100 kV or above.

Thus, the facilities designated as BES are:

a) The individual resources, and

b) The system designed primarily for delivering capacity from the point where those resources aggregate to greater than 75 MVA to a common point of connection at a voltage of 100 kV or above.

- I5 –Static or dynamic devices (excluding generators) dedicated to supplying or absorbing Reactive Power that are connected at 100 kV or higher, or through a dedicated transformer with a high-side voltage of 100 kV or higher, or through a transformer that is designated in Inclusion I1 unless excluded by application of Exclusion E4.

Exclusions:

- E1 - Radial systems: A group of contiguous transmission Elements that emanates from a single point of connection of 100 kV or higher and:

a) Only serves Load. Or,

b) Only includes generation resources, not identified in Inclusions I2, I3, or I4, with an aggregate capacity less than or equal to 75 MVA (gross nameplate rating). Or,

c) Where the radial system serves Load and includes generation resources, not identified in Inclusions I2, I3 or I4, with an aggregate capacity of non-retail generation less than or equal to 75 MVA (gross nameplate rating).

Note 1 – A normally open switching device between radial systems, as depicted on prints or one-line diagrams for example, does not affect this exclusion.

Note 2 – The presence of a contiguous loop, operated at a voltage level of 50 kV or less, between configurations being considered as radial systems, does not affect this exclusion.

- E2 - A generating unit or multiple generating units on the customer's side of the retail meter that serve all or part of the retail Load with electric energy if: (i) the net capacity provided to the BES does not exceed 75 MVA, and (ii) standby, back-up, and maintenance power services are provided to the generating unit or multiple generating units or to the retail Load by a Balancing Authority, or provided pursuant to a binding obligation with a Generator Owner or Generator Operator, or under terms approved by the applicable regulatory authority.

- E3 - Local networks (LN): A group of contiguous transmission Elements operated at less than 300 kV that distribute power to Load rather than transfer bulk power across the interconnected system. LN's emanate from multiple points of connection at 100 kV or higher to improve the level of service to retail customers and not to accommodate bulk power transfer across the interconnected system. The LN is characterized by all of the following:

a) Limits on connected generation: The LN and its underlying Elements do not include generation resources identified in Inclusions I2, I3, or I4 and do not have an aggregate capacity of non-retail generation greater than 75 MVA (gross nameplate rating);

b) Real Power flows only into the LN and the LN does not transfer energy originating outside the LN for delivery through the LN; and

c) Not part of a Flowgate or transfer path: The LN does not contain any part of a permanent Flowgate in the Eastern Interconnection, a major transfer path within the Western Interconnection, or a comparable monitored Facility in the ERCOT or Quebec Interconnections, and is not a monitored Facility included in an Interconnection Reliability Operating Limit (IROL).

- E4 – Reactive Power devices installed for the sole benefit of a retail customer(s).

Note - Elements may be included or excluded on a case-by-case basis through the Rules of Procedure exception process.

*Source: http://www.nerc.com/files/glossary_of_terms.pdf

NOTE: Additional information may be found for topics in this standard by using resources at the following: https://www.ieee.org/index.html, http://pes-psrc.org/, http://www.ieee-pes.org/, or search tools like https://www.google.com/

2 Facility Planning

2.1. Site Selection and Preparation

Selecting a location for a new substation or a substation expansion generally requires input from the following groups: siting and land rights (for permitting and site acquisition), local customer service (for permitting and public relations), substation and transmission engineering (for site requirements, site selection, and permitting), operations, environmental, trouble service, and others as appropriate (e.g. law.). Refer to IEEE 1127 for community acceptance and environmental compatibility guidelines. New facilities require a name, a GPS location, an address or 911 address (if applicable), and other region-specific identifiers (e.g. substation mnemonic, functional unit number, or four-character identification). Project engineers should submit a suggested mnemonic when submitting a Capital Asset Accounting form for all new substations.

When purchasing land for a new substation, a site shall be chosen and acquired which can accommodate the ultimate substation requirements. Ultimate General Arrangement and One-Line drawings shall be created with Engineering's and Planning's input. If economically justified, the ultimate site may be graded and fenced during the initial development. For a first approximation, a 100-foot buffer from the outside of the fence is allowed for grading, drainage and landscaping. Drainage and landscaping requirements vary greatly with local ordinances and these need to be reviewed during the siting and land acquisition process.

Typical items that should be considered when selecting a site are:

- Physical requirements of the ultimate facility including a preliminary location plan, major structures, electrical equipment enclosure, driveways, road curve radius (if necessary), and drainage criteria such as storm water detention or retention ponds
- Transmission and distribution line route
- Topography of site and grade, including cost of necessary earthwork and grading
- Regulatory requirements such as planned unit development, archaeological surveys and considerations, special use permit, rezoning, watershed district, building codes, and building permits
- Special environmental conditions or concerns like unusual climate, flood plains, wetlands, endangered species, atmospheric conditions such as salt or corrosive conditions, environmental risks relative to oil spill potential, noise, and unusual adjacent land uses

- Aesthetic requirements such as landscaping, special wall or building requirements, and lighting
- Encumbrances such as easements, existing utilities, setbacks, sidewalk, driveway, and landscaping constraints
- Underground facilities such as duct lines, pipelines, manholes, telephone, gas, sewer, and water
- Enclosures required - chain link fence, wall, or unusual screening features
- Additional fencing around the perimeter of owned land may be necessary to protect land property. Land Rights and jurisdictional laws should be consulted when designing additional fence layouts
- Soil investigations to determine suitability of soil for substation structures, equipment foundations, and grounding
- Presence of hazardous materials in soil or existing structures (e.g. petrochemicals, PCBs, asbestos) and cleanup costs
- Accessibility to railroad/highways for large equipment moves under all weather conditions

General site preparation includes:

- Sites will be cleared and graded according to the civil design, including provisions for a stabilized surface and site drainage
- The substation will be fenced or otherwise enclosed
- The surface will be covered with four inches of crushed rock aggregate surfacing as part of the grounding design and as a finished surface to control dust and storm water run-off
- Storm Water Pollution Prevention Plan (SWPPP) is prepared and in place before constructions begins as needed by local jurisdictions

2.2. Jointly Owned Substations

Special care needs to be taken when Engineering and Designing a new or adding to a Jointly Owned Substation. The Engineer should obtain and fully understand any agreements that are currently in place with other utility (ies) involved in the substation.

Due to the FERC Compliance requirements for BES facilities, there could be compliance issues with Xcel owned BES facilities in a jointly owned substation where Xcel does not control access or may not own some of the equipment such as batteries, AC station service, EEE and the land. Xcel Energy could be held responsible and fined due to improper or lack of maintenance on the shared equipment owned by the other utility.

In a jointly owned substation, consideration should be given to Xcel Energy providing all of the necessary equipment for operation of the BES and having a physical boundary between the other utility's equipment. This may require Xcel Energy to provide a separate EEE which would include the AC and DC station service, all necessary protection and communications equipment and a fence to physically separate the Xcel owned BES equipment from the other utility's equipment. Separate access points should be considered. Minimal Xcel Energy equipment would be housed in the other utility's substation yard and EEE. The other utility would be able to house only minimal equipment in Xcel Energy's substation yard or EEE if separation exists.

2.3. Substation Yard Layout

2.3.1. Basic Layout

The electrical equipment enclosure (EEE) will normally be located near the substation fence to avoid drive paths near bus and equipment. The EEE should not obstruct access to transformers or other major equipment, or be located under a power line or substation conductor. The length of control and power cable to substation equipment should also be considered. EEE location should be selected so the EEE at least 50 feet from a transformer and if possible uphill of an anticipated oil spill to avoid installation of firewalls where possible.

Substation designs include drivable areas. Drivable access is provided to the electrical equipment enclosure, to large equipment, and around the inside perimeter of the fence. Drivable areas should avoid crossing concrete cable trench. When drive areas cross cable trench, traffic-rated trench covers will be provided. Non-drivable areas should be clearly identified with marker posts and chain barriers.

Drive lanes should be designed such that backing maneuvers can be avoided and equipment can be easily accessed. In some cases, this may require more than one gate. Drive areas should have adequate width and space for turning at corners. The standard practice is to provide a minimum of 30 feet, but an absolute minimum of 15 feet, from the perimeter fence to any structure inside the fence to allow for equipment access, maintenance, and snow removal requirements. In existing substations, or in special cases where this standard cannot be met, the fence clearance must meet the requirements of the NESC. The NESC requires fence clearances greater than 15 feet from fence to live parts at higher system voltages, and these requirements must be followed (refer to IEEE C2 for specific requirements).

2.3.2. Access to Equipment

Substation designs should provide for access to all equipment so that operation, maintenance, and removal of the equipment can be accomplished without significant extra work, additional outages, or relocations. Transformers, circuit breakers, reclosers, regulators, and other major equipment should have planned drive-alleys for removal and maintenance vehicle access.

Consideration should be given to operators needs for work space including room for an operator to move while switching (consider lengths of switching equipment/handles and hot sticks), an emergency escape path from any space requiring manual switching, room for maintenance trucks to drive next to equipment that requires regular maintenance, and access to lighting fixtures. In some cases, this may exceed regular phase spacing.

Drive aisles for access to equipment should be a minimum of 14ft wide, and 20ft is recommended. In addition, the drive aisles shall be provided with adequate vertical clearance to any overhead bus or conductors for a vehicle height of 12.5ft. Additional drive space may be required for removal of large station equipment, such as transformers or oil filled reactors, and should be considered during the design. Drive lanes near large power equipment normally require a minimum turning radius of 50 feet for tractor-trailer access and preferably a full path back to the site entrance without having to back out.

2.3.3. Driveways, Gates, and Locations

A minimum of one drive gate will be provided in each substation. Walk-in gates will not normally be provided, but this should be reviewed depending on specific area requirements. Larger substations or substations with special circumstances may require more gates. However, it is preferred to have only one gate for smaller substations as additional access points to roads or highways increase costs or may be limited.

Especially important considerations are the drive gate and driveway placement for moving transformers or other large equipment. Transformers require room for staging and for large truck and trailer access. All access roads require a minimum turning radius (specified XEL-STD-Criteria for Eng & Design of Civil & Structural Performance) to allow for delivery of large substation equipment.

2.3.4. Mobile Transformer Allowances

2.3.4.1 Transmission Substations

Xcel Energy has mobile transmission transformers with ratings of 115-69kV and 161-69kV. Mobiles are not available for other transmission transformer ratings.

Substation designs should include allowance for mobile transformers in those cases where a suitable mobile is available. This allowance must include adequate room to get the mobile in and out, and to make both the high and low side connections. The mobile installation may require the installation of temporary poles and bus work. Consideration should be given in the design to make the mobile installation as fast and as simple as possible. The installed location of the mobile should not hinder installation of a new transformer or removal of a failed one.

Xcel Energy does not provide mobile transformers for higher system voltages because of their large size, weight, and cost. For cases where mobiles are not available, transformer failures will be repaired or replaced as quickly as practical or an in-service transformer may be brought in from a less critical facility.

2.3.4.2 Distribution Substations

Xcel Energy has mobile distribution transformers/substations available for various distribution applications. Provisions for the connection of a mobile transformer are required in all standard distribution substation designs. This, includes grounding and land/space provisions and may include high and low-side switches. Consideration should also be given in the design to make the mobile installation as fast and simple as possible. Driveways and gates must allow for access of the mobile equipment as well as adequate room to get the mobile in and out. The installed location of the mobile should not hinder installation of a new transformer or removal of a failed one.

2.3.5. Transmission and Distribution Interface

The transmission and distribution parts of a substation may be designed and constructed by different groups. In these cases, the interface between the transmission and distribution parts of the substation must be carefully coordinated. A physical point may be required to define the boundary between the transmission substation and the distribution substation.

The boundary point between transmission and distribution equipment is often an air disconnect switch for the distribution equipment. Distribution equipment shall include medium voltage equipment, the power transformer, and the transformer high-side protector. For breaker-and-a-half and ring-bus configurations, it is preferred that distribution transformers be provided with a dedicated position. A dedicated position means that a distribution transformer will not be tied to a main bus that must remain in service (ring bus, single string breaker and a half, radially fed lines, etc.) or a shared position. This configuration is undesirable because of outage constraints, unnecessary outages to the load on the transformer, and protection concerns. Shared positions of elements need approval from the Director of Engineering.

A substation will be classified as a transmission substation if it has three or more transmission sources unless the number of distribution elements (transformer banks) exceeds the number of transmission sources. In addition, if the substation does not have Xcel Energy owned distribution, the substation will be classified as transmission.

A substation will be classified as a distribution substation if it has less than three transmission sources or the number of distribution elements (transformer banks) exceeds the number of transmission sources.

If the substation is radial and terminates on a distribution element, the substation will be assigned to that element. For further information, refer to the Capital Asset Accounting – Procedure Guidelines, Asset Separation – Funtionalization of Substations.

2.4. Substation Switching Configuration

Substation switching configuration is one of the most fundamental elements of substation design. It is the primary factor in determining the substation's construction cost, maintenance cost, and reliability. Operations, Planning, and Asset Management will specify or provide guidance as to which configuration to use based on the substation requirements and budgetary constraints. Transmission line structures that support multiple circuits outside of the substation require consideration of the configuration for the single contingency of a structure failure.

2.5. Transmission Substation Configuration

The transmission system should be designed, where practical, to allow for any one element to be out of service without loss of load (single contingency or "n-1" planning). Some areas will need to be designed to operate with even more contingencies because of greater reliability requirements. The choice of substation configuration should be made with consideration for single contingency planning requirements and operational flexibility.

The substation configuration is the choice of how many interrupting devices (such as circuit breakers) and isolating devices (such as switches) will be used, and how they will be laid out with respect to one another and the elements to be connected.

Increased reliability can be achieved by separating elements by circuit breakers, so that a problem with one element does not cause an outage to other elements in the substation. Increased operational flexibility can be achieved by connecting elements to the substation through more than one path (circuit breaker), so that an outage of one circuit breaker does not require taking an outage to the connected element. The location of line and transformer terminations in the configuration also affects reliability and operations. For instance, transformer terminations should be separated by two circuit breakers where possible, so that the failure of one circuit breaker does not lead to the simultaneous outage of both transformers. Similarly, two-breaker separation should be provided between sources and between loads as much as possible so that a circuit breaker failure does not cause a simultaneous outage for two sources, for loads, or for parallel lines.

In general, greater reliability and flexibility requires more circuit breakers and switches. Configurations with more circuit breakers and switches typically require more bus work, more instrument transformers, more equipment foundations, and more control and relay equipment. Ultimately, increased reliability and flexibility comes with increased cost.

The switching configuration must also take into account the present and future requirements of the substation. Consideration should be given for both the electrical configuration and the physical layout of the substation. Expandability of the substation should be planned in the initial layout so it can be performed in a simple manner without extended outages.

Xcel Energy has established standard transmission substation configurations and these are to be used except in special circumstances. This standardization provides numerous advantages in design, construction, and operation. Xcel Energy's standard transmission substation configurations are Single Bus, Double Breaker/Double Bus, Ring Bus, and Breaker-and-a-Half Bus.

Transmission substations are substations with a primary function for the transmission system (see Capital Asset Accounting – Procedure Guidelines, Asset Separation – Funtionalization of

Substations). The Xcel Energy standard transmission substation configurations are shown in the figures below. Each configuration is shown with three lines and one transformer to make comparison easier.

The breaker-and-a-half scheme is the ultimate standard layout for substations at voltages 115kV and above. The single bus (straight bus, SB) and the ring bus (RB) configuration should both be considered as a preliminary version of an ultimate breaker-and-a-half bus scheme (BHB). Whenever a ring-bus configuration is used, it should be designed to allow for the easiest possible upgrade to BHB. Whenever a single bus configuration is used, it should be designed to allow for the easiest possible upgrade to a ring-bus and ultimately BHB. A substation might initially be constructed as a straight bus with two or three elements, later developed into a ring bus with four or five elements, and finally upgraded into the ultimate BHB configuration with six or more elements. The conversion would be relatively easy if the basic BHB layout was used during all stages of substation development.

Xcel Energy standard configurations are described in the sections below. They are listed in order of increasing cost and (what is generally agreed to be) increasing reliability and operational flexibility. Table 1 gives standard substation switching configurations for each voltage level. Each substation project must be considered on an individual basis to confirm that the standard configuration is the best. In all cases other than double breaker-double bus (DBDB), the substation should be configured and laid out to allow for expansion to an ultimate BHB.

Standard Transmission Substation Configurations

Number of ultimate elements/positions	69kV	115kV	230kV	345kV
2	SB	SB	SB	SB
3	SB	SB or RB*	RB or BHB	RB or BHB
4	SB Variation	RB or BHB	RB or BHB	RB or BHB
5	SB Variation	RB or BHB	RB or BHB	RB or BHB
6	SB Variation	RB or BHB	RB or BHB	RB or BHB
7+	SB Variation	BHB	BHB	BHB

Table 1

*Note1: SPP requires all TO's in the SPP footprint to use a RB configuration for voltages of 100kV and above with 3 or more elements. SPS must comply with this requirement.
Note 2: 138kV and 161kV voltages follow the 115kV column configurations

2.5.1. Single Bus (SB)

In the single or straight bus configuration, all of the lines and transformers are connected to a single bus. There is one circuit breaker or less per line or transformer. The single bus configuration is the simplest and least expensive configuration, as it has the fewest number of circuit breakers and switches and the smallest footprint. It is also the least reliable and least flexible configuration. For instance, a fault on the bus will lead to an outage of the bus and the disconnecting of all of the elements connected to it. Bus maintenance work also requires a multi-terminal outage.

The SB scheme is used for almost all 69kV substations. The reason for this is due to the added complexity associated with the relay scheme with the other configurations. There are many variations on the single bus scheme. One type of single bus substation is the tap configuration in which a transmission line is connected to the substation through a radial tap. In this scheme, the line does not go through the substation. The substations at each end of the line provide the protective relays and circuit breakers for the transmission line. The tap configuration is typically used in single transformer or capacitor bank situations. An SB scheme variation is abbreviated as “SB Variation” in Table 1.

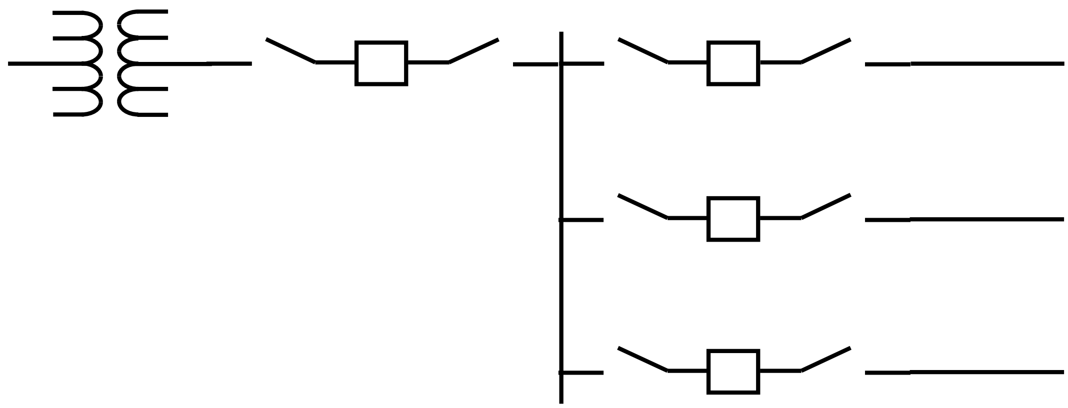


Figure 1: Single Bus

2.5.2. Main and Transfer Bus (MTB)

The main and transfer bus configuration is similar to the SB design, in that all of the lines and transformers are connected to the main bus. The MTB is considered a SB variation, as noted in Table 1. However, the MTB layout also features a transfer bus and transfer breaker, which provides much greater operational flexibility. For instance, a line breaker can be taken out of service without a line outage, because the line may be connected to the transfer bus and fault clearing can be provided by the transfer breaker. The main and transfer bus configuration is higher in cost than the single bus configuration, as it generally requires an additional circuit breaker, additional bus, and more disconnect switches. The reliability of the MTB is similar to that of the SB scheme, since a bus fault will still cause a complete bus outage and the disconnection of all the elements connected to the bus. Care must be exercised in operating the disconnecting switches in the proper sequence when transferring loads between the main and transfer buses. For added security, they may be interlocked to prevent opening under load. The MTB configuration is not commonly used for new transmission substations. An existing sub that is expanded may result in a MTB design.

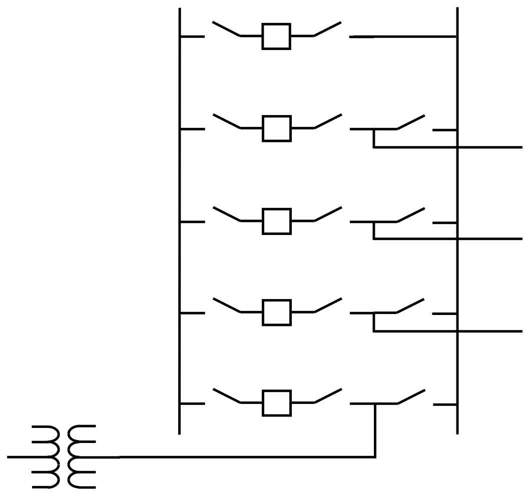


Figure 2: Main and Transfer Bus

2.5.3. Ring Bus (RB)

The ring bus is a common configuration for transmission substations. It is used when there are not enough lines or transformers to justify a BHB. Substations with up to six circuit breakers may be laid out in a RB configuration.

The ring bus configuration has considerable advantages in reliability and flexibility compared to the SB and MTB schemes. It is more flexible, as it allows opening of one circuit breaker at a time without de-energizing a line or other element, and with no loss of protection. It is more reliable, as a fault on one section of the bus can be isolated and cleared at just that section, and does not require de-energizing the entire bus. However, once one circuit breaker has been opened, the flexibility and reliability of the configuration is significantly reduced.

A line disconnect switch is required on all transmission line terminal positions connected to a ring bus configuration at voltages of 115kV, 138kV, and 161 kV. For voltages at 230 kV and higher, a case-by-case approval from the Director of Engineering is required based on the cost and reliability benefit of installing the switches at the prospective site. Once the ring bus has been converted to a breaker and a half configuration, no other line disconnect switches need to be added. The existing line disconnect switches do not need to be removed. The purpose of the line disconnect switch is to allow the adjacent circuit breakers to be closed in order to complete the ring after the faulted line has been disconnected. When line disconnect switches are installed, MOD's with SCADA controls will be installed.

The number of circuit breakers in a RB configuration equals the number of positions and each position shares two circuit breakers. Each position normally consists of one element. Compared to SB, the RB configuration has more bus work, potential transformers, and control and relay requirements. The RB is presently used for transmission substations 115kV and above.

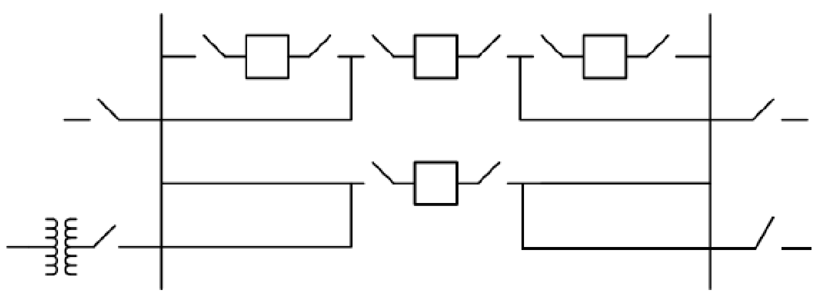


Figure 3: Ring Bus

2.5.4. Breaker-and-a-Half Bus (BHB)

The breaker-and-a-half bus configuration is the standard design for large yards at 115kV and above. A new substation configuration with six or more circuit breakers is built as a BHB. A BHB row provides for two line or transformer positions using three circuit breakers (1½ per element or position) located between two main buses. The two-main buses of the BHB design can be expanded as needed to serve more elements than the standard RB configuration.

The BHB scheme is a more expensive standard configuration than the RB since it requires 1½ circuit breakers and three switches per element (the RB only requires one circuit breaker and two switches per element).

Although more expensive, the BHB has significant advantages in flexibility and reliability. With a circuit breaker out for maintenance, each circuit still has breaker protection (same as in the RB scheme). However, in the BHB scheme with a circuit breaker out, a fault on a line can be cleared without affecting any adjacent elements. In the RB scheme, depending on which circuit is faulted, this may not be the case. Additionally, the BHB allows for multiple circuit breakers to be taken out of service simultaneously, with almost no loss in reliability, as long as they are not located in the same row.

For BHB substations, special attention needs to be given to the layout to ensure that equipment can be accessed for maintenance purposes. This may require additional drive aisles within the substation. When the ultimate layout requires only a six-position configuration, a fourth row shall be added for maintenance purposes.

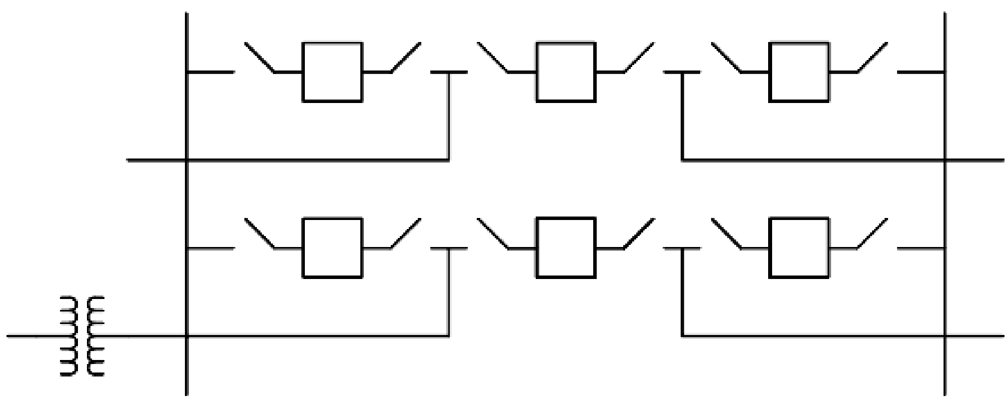


Figure 4: Breaker-and-a-Half Bus

2.5.5. Double Breaker – Double Bus (DBDB)

The double breaker–double bus configuration is the most expensive of all the standard configurations since it requires two circuit breakers and four switches per circuit element. However, in return for this high cost, it provides the best service reliability, continuity, and flexibility. A circuit breaker or bus may be taken out of service at any time without loss of circuit protection, and the remaining circuit breakers do not carry the load of more than one circuit. Thus, no circuit breaker operation can affect more than one circuit. This configuration is used only in the most critical locations, such as generating plant switchyards.

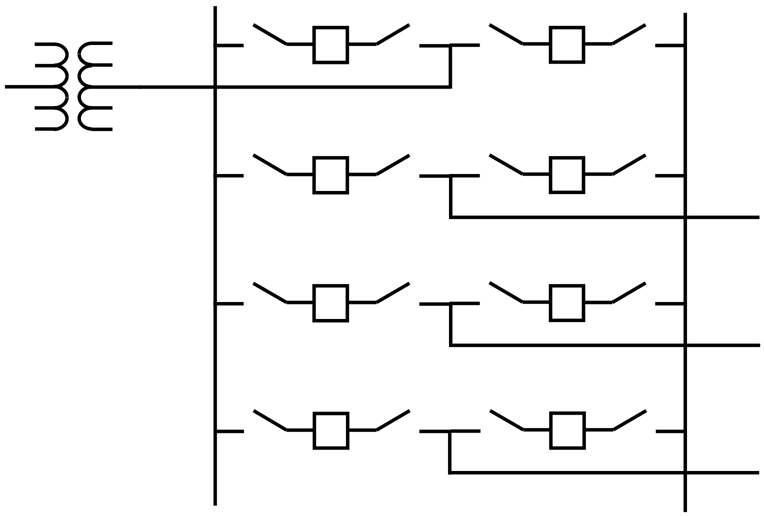


Figure 5: Double Breaker-Double Bus

2.5.6. Element Positions

When choosing a substation configuration, the number of elements to be connected (e.g. transformers, lines, VAR support) should be defined for the initial build and what is known or reasonably expected for future expansion. These elements may include autotransformers, distribution transformers, transmission lines, capacitor banks, or shunt reactors. Each element should be provided with a dedicated position in the substation configuration. However, Transmission Planning may dictate when an element can be installed on the bus, provided the element can be configured into a row position and removed from the bus during future expansion. The following sections elaborate on which elements shall be installed in a dedicated position versus allowing for installation on a bus position.

2.5.6.1 Auto-Transformer Positions

Auto-transformers shall be installed between breaker-positions in ring-bus and breaker-and-a-half configurations.

2.5.6.2 Shunt Capacitors and Reactors Positions

Shunt capacitors and shunt reactors should also be installed between breaker-positions in ring-bus and breaker-and-a-half configurations. However, these elements may be installed on a bus position, with an accompanying circuit breaker or interrupter, if Transmission Planning dictates. Primary consideration for not allowing installations on a bus is due to the inability to take an outage on the bus in order to maintain the associated interrupting device.

Multiple capacitor banks may also be installed from a single element position. This determination should be made by Transmission Planning's understanding of what the system can tolerate with a loss of the position.

2.5.6.3 Distribution Transformers Positions

Distribution transformers, along with a high-side manual or motor-operated disconnect switch, shall be installed between breaker-positions in the ring-bus and breaker-and-a-half configurations. In addition, a transformer high-side interrupting device shall be installed so that the distribution equipment can be removed from service without causing interruption to the transmission system (see next section for exceptions). A high-side interrupting device shall always be installed when a distribution transformer shares a position with a line termination.

2.5.6.4 Exception Process for Installation of a High-Side Transformer Interrupting Device

It is generally accepted, from a non-discriminatory access standpoint, that any transmission connected to end use loads will adhere to Xcel Energy Company's Interconnection Guidelines for Transmission Interconnected Customer Loads whether they be for 3rd party interconnections or for internally generated interconnections.

Therefore, as an interim process, prior to exceptions on projects being made from the Interconnection Guidelines document, guidelines are established and shall be adhered to for new capital substation projects.

For capital substation projects where a new power distribution transformer equal to or greater than 14MVA is to be installed, the following guidelines should be adhered to unless an acceptable documented exception to the guideline is provided. The documented exception should be provided upon creation of the Scoping Estimate or soon thereafter, but well before the Appropriation Estimate package is developed.

1. If installing a new distribution power transformer, then a new interrupting device is to be installed on the high-side of the new transformer.
2. If upgrading an existing distribution power transformer to a larger (increased MVA) transformer, then a new interrupting device is to be installed on the high-side of the new transformer.
3. If replacing an existing distribution power transformer with a similar size (same MVA) transformer, then a new interrupting device does not need to be installed on the high-side of the new transformer.

4. If there is no associated transformer installation or replacement, then it is not necessary to address the installation of a new interrupting device for any existing transformer.

For each of the exceptions listed above, an associated high side, motor-operated disconnect switch is also to be installed.

This policy provides internal consistency with Xcel Energy's Transmission-to-Load Interconnection Guidelines which require an interrupting device on the high voltage side of the transformer. The latest interconnection guidelines would not apply to existing installations which would be grandfathered into a blanket agreement. However from a FERC perspective, transformers upgraded to a higher capacity would necessitate a new interconnection agreement with Xcel Energy and would also need to adhere to the Transmission-to-Load Interconnection Guidelines.

2.6. Outages

All substation designs should take into consideration the required outages to build and maintain the facility. Construction of temporary facilities or staged construction planning may be required to minimize outages. Outage planning should be carried out well in advance with System Operations. All outages need to be reviewed by system protection in advance to maintain the integrity of protection for all lines and devices that remain in service during an outage.

If it is known or expected that new equipment will be added in the near future, switches may be added on the initial installation to avoid future bus outages. This is applicable in ring bus or breaker-and-a-half designs as well as for distribution system transformer switches and bus-tie switches.

2.7. Environmental Conditions

There may be significant differences in environmental conditions between various sites. Substation designs must be compatible with the environmental characteristics of the facility location. Table 2 gives typical design parameters for various regions. Particular sites within a given region may have different environmental conditions than that given in Table 2. Additional environmental conditions for calculating bus conductor ampacity are located in Table 7.

Environmental Design Criteria

	CO	MN/WI (South)[(1)]	MN/WI (North)[(1)]	NM	TX
Design Temperature Range (°C)	-40 to 40	-40 to 40	-50 to 40	-30 to 40	-30 to 40
Design Ice Loading[(2)] (inches, radial loading)	1 in	1 in	1 in	1 in	1 in
Elevation above mean sea level (feet/meters)	Min. design criteria is 5,900 ft (1800 m) Use 11,000 ft (3353 m) elev. at sites >8,500 ft (2591 m)	<3300 ft (1006 m)	<3300 ft (1006 m)	>=3700 ft (1128 m)	>=3700 ft (1128 m)

[(1)]The division between MN/WI north and south is roughly defined as the east-west line running between St. Cloud, MN and Eau Claire, WI.

[(2)]For issues related to structural design, including regional seismic zones, refer to the Civil/Structural Design Criteria.

Table 2

The existence of any unusual environmental conditions should be considered at each substation site. These conditions may include corrosive fumes or vapors, explosive mixtures of dust or gases, steam, magnesium chloride spray, and salt spray.

2.7.1. Snow Accumulation

For substation installations in regions where very high snow depths and severe wind drifting of snow may inhibit substation entry/exit or equipment access, a determination must be made, based on factors such as frequency of deep-snow events, critical maintenance areas, and work practices whether extra design considerations are required. Consulting local operations and maintenance personnel to provide guidance on local snow accumulations is recommended. Typical industry practices include elevating bus heights, junction boxes, and switch operators, as well as installing a Dutch pedestrian gate adjacent to the main gate. Additional warning signs may also be installed.

2.8. Governmental/Regulatory Requirements

2.8.1. SF6

Sulfur Hexafluoride (SF6) is an effective gaseous dielectric widely used in electric transmission equipment. SF6 is used in gas-insulated switchgear and bus and is the industry-preferred dielectric and interrupting medium for transmission circuit breakers. SF6 is also a potent and long-lived greenhouse gas.

Xcel Energy policy is to minimize SF6 emissions through recycling and avoidance of leakage. SF6 pressure in equipment is normally monitored via a pressure switch. Equipment to be purchased should be evaluated for its track record with respect to SF6 leaks and for the quantity of SF6 it requires. Besides its environmental effects, circuit breakers with SF6 leaks have higher maintenance costs, and, if undetected, could cause system contingencies.

The use of SF6 insulated equipment should be avoided if good non-SF6 alternatives, such as vacuum insulated equipment, are available.

2.8.2. PCBs

Polychlorinated Biphenyls (PCBs) are man-made chemical compounds with excellent flame retardant and insulating properties. PCBs also pose numerous health risks for humans and wildlife and are not biodegradable. Although PCBs were banned in the U.S. in 1977, they were often added to the oil used in electric equipment from the 1920s until the 1970s. New equipment and mineral oil does not contain PCBs, but equipment containing PCB fluid is still in operation in many substations.

Xcel Energy guidelines and EPA regulations define how oil-filled equipment is to be labeled, handled, documented, and disposed. According to Xcel Energy guidelines, equipment containing oil with PCB concentrations less than 45 ppm is classified as non-contaminated. Equipment containing oil with PCB concentrations between 45 and 450 ppm is defined as "PCB Contaminated." Equipment containing oil with PCB concentrations of 450 ppm or greater is defined as "PCB Equipment" and stringent regulations govern its use. These Xcel Energy-defined thresholds are more stringent than the EPA figures of 50 and 500 ppm to allow for inaccuracies in the test. For projects involving PCB equipment, current information on policies for handling PCBs should be obtained from the Environmental Services department.

2.8.3. Oil Containment

EPA regulations address requirements for oil Spill Prevention Control and Countermeasure Plans (SPCC Plans) and Facility Response Plans (FRPs). The goal of the SPCC rule is to prevent oil discharges from reaching navigable waters and to ensure effective responses to oil discharges. The rule also requires that proactive measures be used in response to oil discharges.

For projects at new or existing substations, a site-evaluation should be conducted to determine the potential environmental consequences of oil discharges and to evaluate the need for oil containment. Current information on Xcel Energy SPCC policies should be obtained from the Environmental Services department. Criteria for oil spill containment are given in the civil/structural design criteria XEL-STD-Criteria for Eng & Design of Civil & Structural Performance

NOTE: Care should be taken when designing oil containment for equipment that is located adjacent to other equipment needing a containment system for fire safety concerns and common system designs.

Containment facilities can include oil-containment berms, pits, curbs, or similar facilities. Containment can be designed for specific individual equipment or as a whole-site oil control. Engineering should work with Environmental Services department to determine the level of oil containment that will be required for each site. Civil and Electrical Engineering should also work together to determine the best type of oil containment for the site as what may be obvious to one group, may not be feasible or ideal for the other. IEEE 979 and IEEE 980 may also be useful references.

2.8.4. Asbestos

"Asbestos" is a term used to describe six naturally occurring fibrous minerals: chrysotile, amosite, crocidolite, tremolite, anthophylitte, and actinolite. Of these, the forms that were most commonly used are chrysotile (white asbestos), amosite (brown asbestos), and crocidolite (blue asbestos). Asbestos is strong, insulates well, and resists fire and corrosion and for these reasons, it has been used in hundreds of products. Asbestos is used in many forms, including raw form, yarn, cloth, felt, tape, wick packing, paper, millboard, and cement.

Asbestos became popular in the United States in the early 1900s. Its period of greatest use was from the 1940s to the 1970s. In the 1960s, evidence began to emerge of lung cancer, asbestosis, and other health risks associated with the inhalation of asbestos. The use of asbestos is not banned, but it is seldom used by American industry because of health and liability concerns. There is an international market for asbestos, however, and imported materials may still contain asbestos. Laboratory tests are the only way to conclusively identify asbestos.

Asbestos products are not being used with any new installation work, but it may exist in existing substations. Some of the common uses of asbestos are thermal pipe and boiler insulation, fireproofing, soundproofing, floor coverings, ceiling tiles, roofing materials, and transite pipe, transite conduit, and sheeting. For substation projects, some places to look for asbestos include: fireproofing and insulation for buildings, cables and pipes, electrical cloth and tape (e.g. tape wrapped around feeder cables), electrical equipment enclosure panels and partitions, and floor tiles.

Regulations govern asbestos removal and demolition for renovation projects that involve asbestos. Asbestos abatement must be performed in existing facilities if the asbestos will be disturbed as part of the project.

2.8.5. Mercury

Mercury is used in thermometers, barometers, diffusion pumps, and many other devices. It is used as a liquid contact for mercury switches, and it is used in mercury cell batteries and other electrical apparatus. Gaseous mercury is used in mercury-vapor lamps and advertising signs. Mercury is also used in some industrial processes. Exposure to mercury or its compounds can cause severe health problems. Mercury is an environmental pollutant in areas where industrial or agricultural waste can reach waterways. Numerous federal and state regulations govern mercury and its release into the environment. The use of equipment containing mercury in substations is to be avoided. Examples of where mercury may be found in substations include mercury switches and some Buchholz relays from European manufacturers. Mercury will be removed from substations where practical.

2.8.6. Noise

Normal substation operation produces continuous audible noise, impulse audible noise, and radio frequency noise. Of these, continuous audible noise is the most noticeable and is the most likely to be subject to government regulation. All new and expanded substations will be designed to comply with the sound level requirements for the jurisdictions in which the facility is located. Colorado Title 25, Article 12, is an example of local noise ordinances. This may be accomplished via specifications for the operating equipment (primarily transformers), additional setback distances, enclosures, barriers, or a combination thereof. Complaints raised about existing substations should be handled on a case-by-case basis. When a local permitting authority calls for more extensive treatment than required by state authority, reimbursement will be sought from the permitting authority for the added costs. Refer to IEEE 1127 for additional information with regard to design of substations for acceptance by the community.

2.8.7. Aesthetics

A permitting authority may place aesthetic constraints on new or expanded substation development. In these cases, these requirements will be followed within reason (as determined by Substation Engineering, Siting and Land Rights, and the Community Relations departments). When a permitting authority requires more extensive treatment than considered reasonable, reimbursement will be sought from the permitting authority for the costs to install the extra aesthetic treatment.

2.8.8. Electric and Magnetic Fields

Electric and magnetic fields decrease rapidly with distance, and are typically minimal at the fence lines of a substation. Although there are regulations regarding the strength of electric fields in public areas, these typically do not present design constraints on transmission substations. There are currently no design constraints on substations due to electric and magnetic fields.

Strong magnetic fields can occur with air-core reactors. This must be taken into consideration in the design for the installation of this type of equipment, such as with the spacing, structures, internal fencing, grounding, and foundations. The strength of the magnetic field around a reactor should be coordinated with the manufacturer to ensure that the magnetic fields do not cause problems for adjacent equipment or impose a danger to personnel in the vicinity of the reactors.

2.9. System Modeling and Analysis

The standard tool for calculating fault currents is CAPE (Computer Aided Protection Engineering).

The standard tool for carrying out transient analysis studies is Alternative Transients Program / Electromagnetic Transients Program (ATP/EMTP). It is recommended that transient analysis studies be performed when large capacitor banks or shunt reactors are to be installed. In addition, transient analysis studies may also be appropriate when major expansions are planned to the system or when interconnections to another utility are required.

3 Project Criteria

Multiple voltages listed in the tables below, indicated by asterisks, are legacy systems existing today. Those are generally not considered standard voltages for future installations.

3.1. Transmission System Voltages

Standard Transmission System Voltages

Nominal Voltage (kV)	NSP Region Standard	PSCo Region Standard	SPS Region Standard
34.5	Yes	No	No*
46	No	No*	No
69	Yes	Yes	Yes
88	No*	No	No
115	Yes	Yes	Yes
138	No	Yes	No
161	Yes	No	No
230	Yes	Yes	Yes
345	Yes	Yes	Yes
500	Yes	No	No

Table 3

3.2. Distribution System Voltages

Standard Distribution System Voltages

Nominal Voltage (kV)	NSP Region Standard	PSCo Region Standard	SPS Region Standard
2.4	No*	No	Yes
4.16	No*	Yes	Yes
7.2	No	No	Yes
12.0	No	No	Yes
12.5	Yes	Yes	Yes
13.2	No	Yes	Yes
13.8	Yes	Yes	Yes
22.9	No	No	Yes
23.9	Yes	No	No
24.9	No*	Yes	No*
34.5	Yes	No	Yes

Table 4

3.2.1. Regional Variations

In the PSC region, the distribution system uses a 13.2kV standard voltage instead of 13.8kV. One reason for this is insulation coordination. As noted elsewhere in this document, BIL must be derated at higher altitudes. When the insulation of 14.4kV-rated electrical equipment is derated for the elevations in the PSC region, it is not adequate for use on a 13.8kV operating voltage.

3.3. Electric Phase Rotation and Phase-Angle Relationships

All transmission voltages in the system are in phase electrically within an interconnected grid. In the United States, there are three main power grids or interconnections (Eastern, Western, and Texas/ERCOT), and these grids are not currently synchronous. Xcel Energy has transmission facilities in both the Eastern and Western Interconnects. PSCo is in the Western Interconnect. SPS, NSPM, and NSPW are in the Eastern Interconnect.

The phase-angle relationship between transmission and distribution voltages varies throughout the system, and must be verified for each location. In the Denver and northern front range portions of the PSC region, the distribution voltage typically leads the transmission voltage by 30°. Standard transformers (i.e. primary leads the secondary by 30°) are used, but they are connected in the substation such that the secondary leads the primary.

Care must be taken to make sure that the phase-angle relationship between all facilities affected by a project is known and is accounted for in the project design.

4 Outdoor Electrical

4.1. Transmission Substation Physical Arrangement

4.1.1. Outdoor Open-Type Air-Insulated Bus-and-Switch Arrangement

The Xcel Energy standard transmission substation structure is the conventional outdoor open-type air-insulated bus-and-switch arrangement. Standard structure design is low profile. Box structure designs exist in many substations and this type of design may be continued when modifying these substations or when required by space limitations or other constraints.

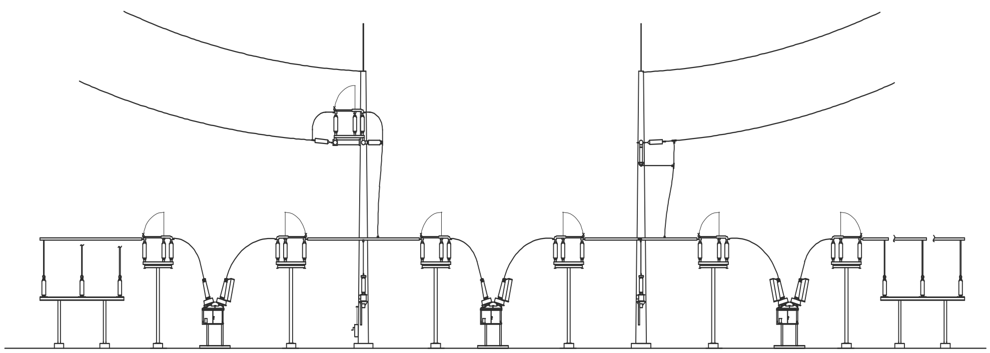


Figure 6: Example of Low Profile Substation

Steel is the standard material for all substation structures. Wood pole designs are discouraged for new installations because wood is less reliable, has a shorter life, requires more maintenance than steel, and may be less rigid causing switches to come out of adjustment. Wood structures typically have a lower installed cost than steel, however, and should be considered for temporary facilities. Refer to XEL-STD-Criteria for Eng & Design of Civil & Structural Performance and XEL-STD-EMS-J.08-001-OUTDOOR HIGH-VOLTAGE AIR

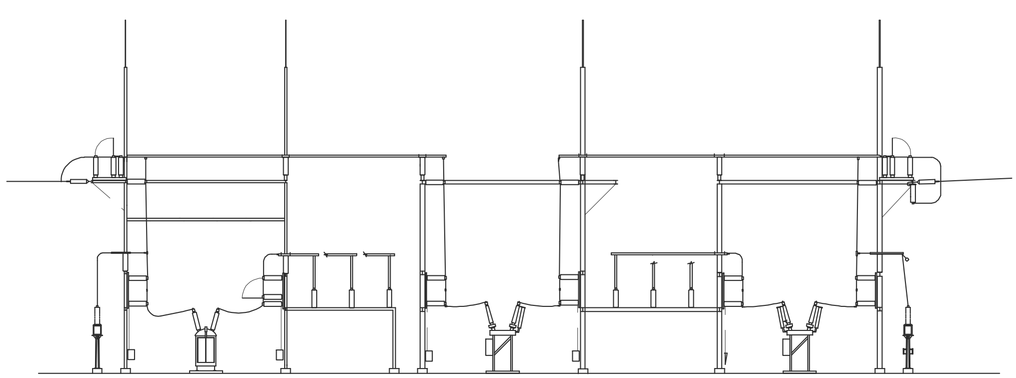


Figure 7: Example of a Box Structure Substation

SWITCHES AND OPERATING MECHANISMS for more details.

4.1.2. Gas-Insulated Substation

The SF6 gas-insulated substation is an alternative that may be considered in special cases. In the gas-insulated substation, all of the components and bus work are enclosed in SF6-filled compartments. The use of gas, instead of air, as the insulating medium allows the spacing and clearances to be significantly reduced, so that the substation requires a much smaller footprint. Additionally, the substation can be housed inside a building, which is generally considered an aesthetic improvement over visible bus work and equipment. The gas-insulated substation also provides protection from environmental factors such as pollution, salt, and snow.

The SF6 gas-insulated substation is not an Xcel Energy standard, and should only be considered where required by technical or permitting limitations.

4.2. Distribution Substation Physical Arrangement

The two Xcel Energy standard physical arrangements for distribution substations are metalclad switchgear and outdoor open-type air-insulated bus-and-switch arrangements. Xcel Energy typical configurations are described in the sections below. The type of structure to be used in a given substation is defined in the distribution planning philosophy document (XEL-STD-B.01-001-PHASE I DESIGN.pdf and XEL-STD-B.01-002-PHASE II DESIGN design documents). The selection will be based on factors including initial and ultimate substation loading, system voltage, switching configuration and requirements, and substation location. Refer to the distribution planning criteria for more information on distribution substation configurations.

4.2.1. Outdoor Open-Type Air-Insulated Bus-and-Switch Arrangement

Xcel Energy standard distribution substation arrangements include the conventional, outdoor, open-type, air-insulated, bus-and-switch arrangement. The standard structure design is box structure. In open-air type designs, the switches, circuit breakers, and bus connections are open and visible, making them easier to monitor and repair than switchgear configurations. Open-air designs can be configured for overhead or underground terminations. Adding additional feeder bays to a box structure lineup is a straightforward process. Therefore, it is standard practice to construct the feeder bays as they are needed.

Steel is the standard material for substation structures. Wood pole designs are discouraged for new installations because wood is less reliable, has a shorter life, and requires more maintenance than steel. Wood structures typically have a lower installed cost than steel, however, and should only be considered for temporary facilities. Refer to the sections below, as well as the civil/structural design criteria for more details.

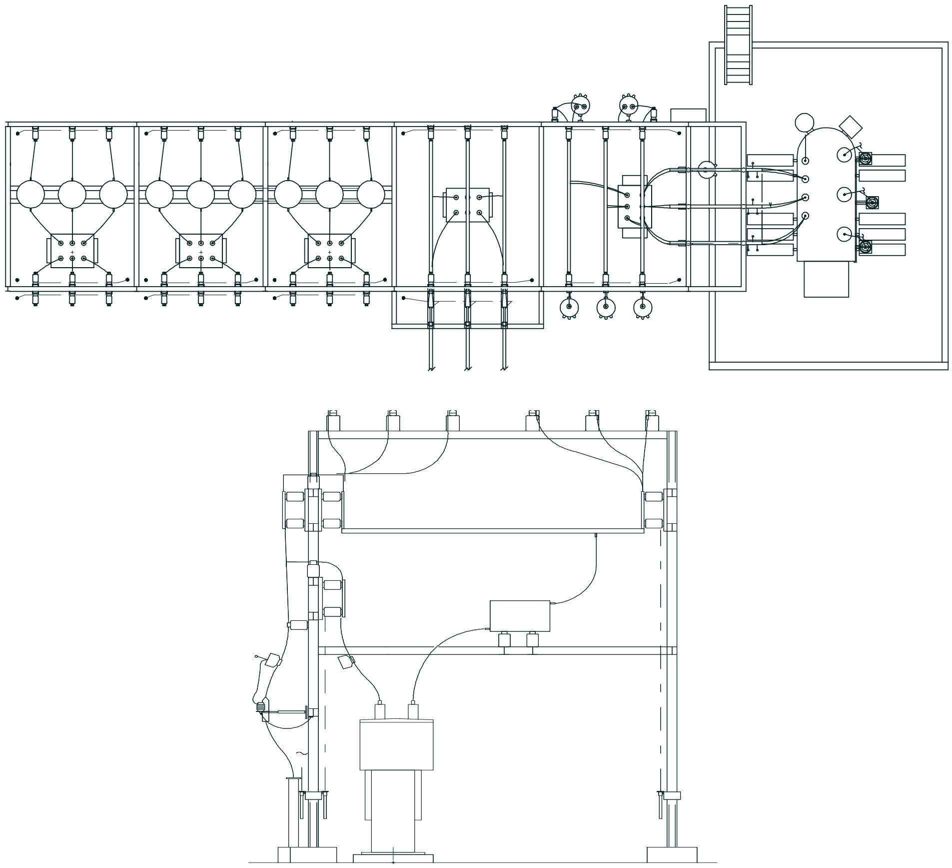


**Figure 8: Example of an NSP, Standard, Open-Type Air-Insulated Bus-and-Switch Arrangement.
Top picture is Plan View of Transformer and Distribution Bus Section
Bottom picture is Section View of Feeder Bay.**

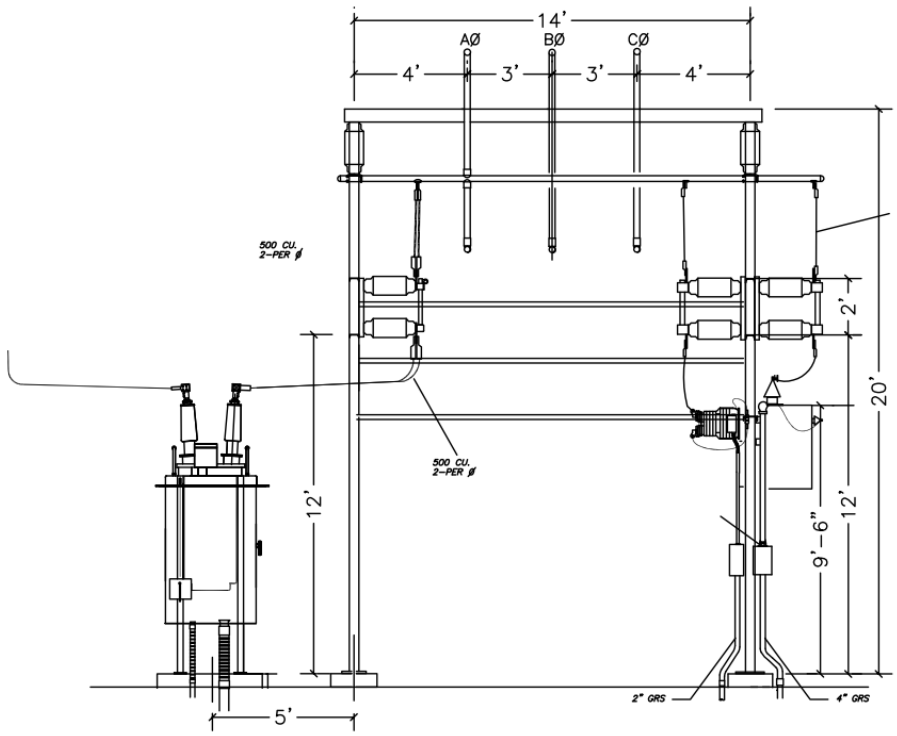


Figure 9: Example of an PSCo, Standard, Open-Type Air-Insulated Bus-and-Switch Arrangement.

4.2.2. Main and Transfer Bus

The main bus/transfer bus (MTB) design is used mainly for open-air distribution substations with a maximum firm capacity of 45 MVA and an ultimate installation of two 28 MVA transformers, bus regulators, (or individual feeder regulators) and transformer load-break switches. Regulators are not needed when the transformers are provided with a Load Tap Changer, and transformer circuit breakers can then be installed in the space provided for bus regulators. The MTB substation configuration has been used in the past for 69kV transmission substations in the NSP regions, and for 230kV and below in the PSC and SPS regions. The standard MTB configuration includes two sections but can include up to three. Each section has provisions for a main bus, transfer bus, and three feeders. Each feeder is complete with circuit breakers and switches. A load interrupter switch or circuit breaker can be installed between main bus sections. Feeder exits can be either underground or overhead and can be bifurcated if required. When feeder reactors are required, they should be located between the main bus and the circuit breaker to limit the fault current the breaker will see, as well as the downstream feeder equipment. Feeder regulators are normally installed outside the bay for easier access. For underground distribution, an additional structure may be needed to support the overhead to underground transition points (pot heads) for some designs.

If the substation is in its first stage of development and only one feeder is installed, the transfer bus may be left out and a fused by-pass installed. The Xcel Energy standard MTB configuration is shown in Figure 10 and Figure 11, and Figure 12.

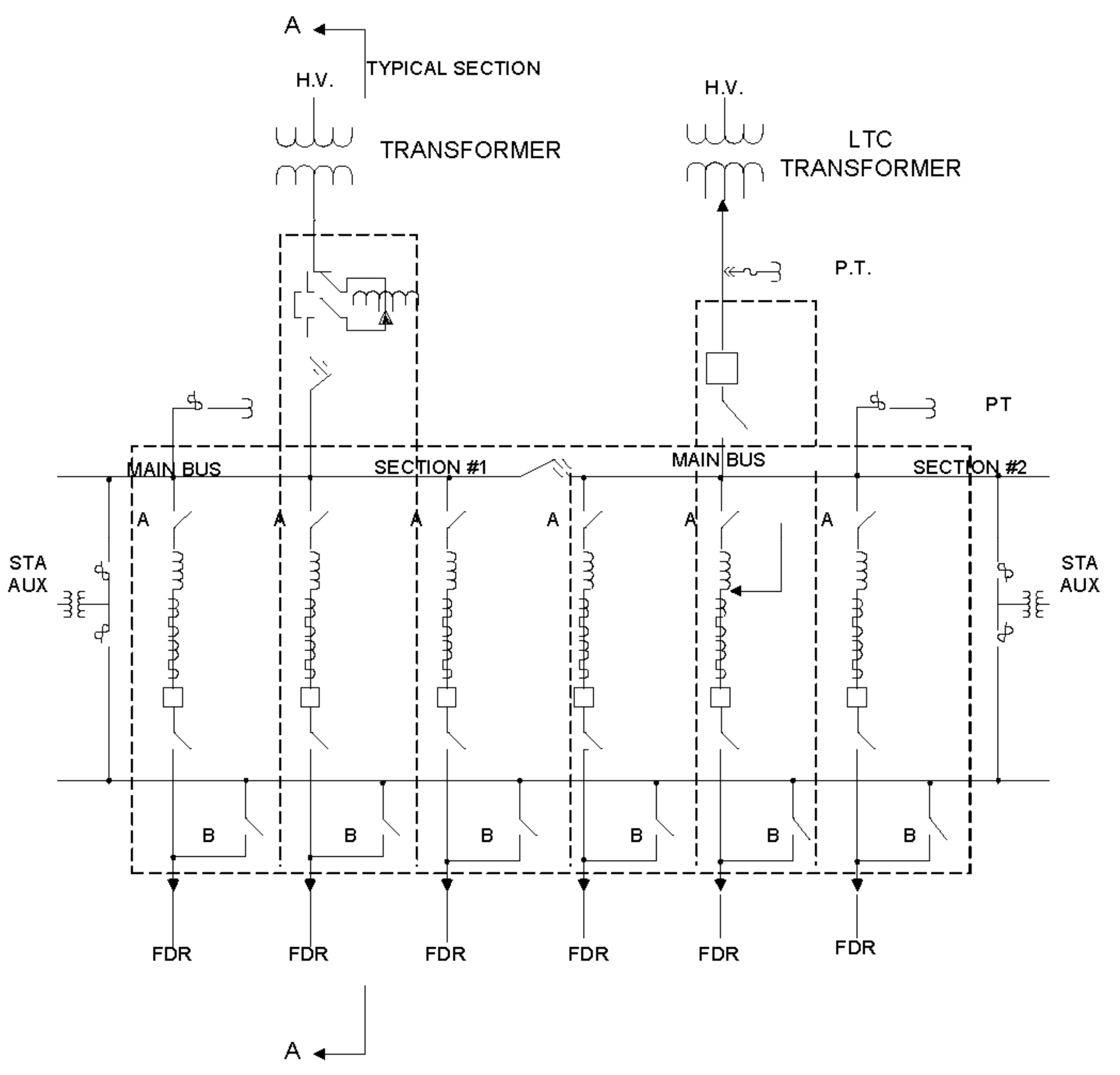


Figure 10: Standard NSP MTB Scheme

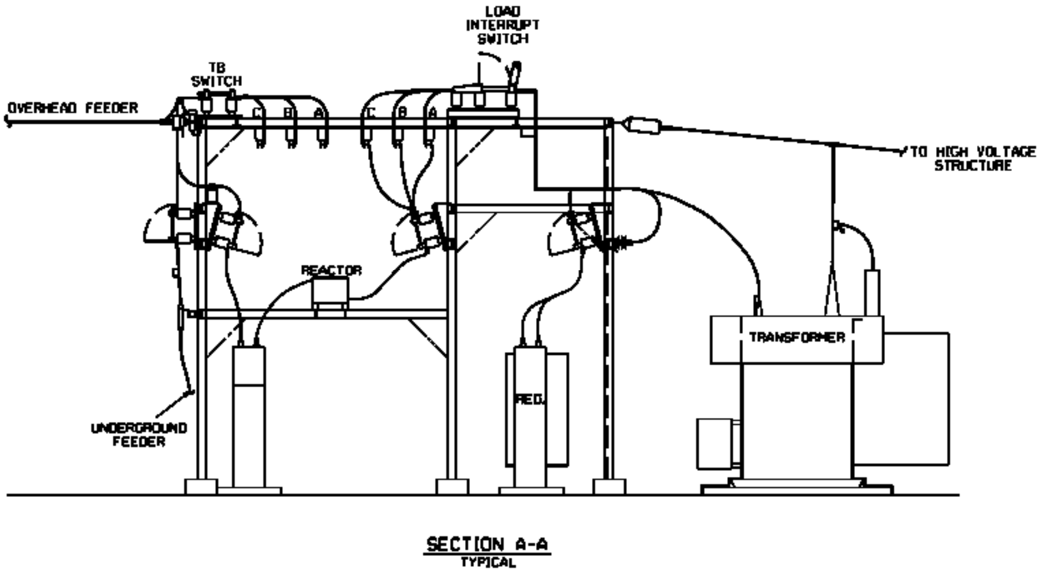


Figure 11: Example of an NSP MTB Scheme

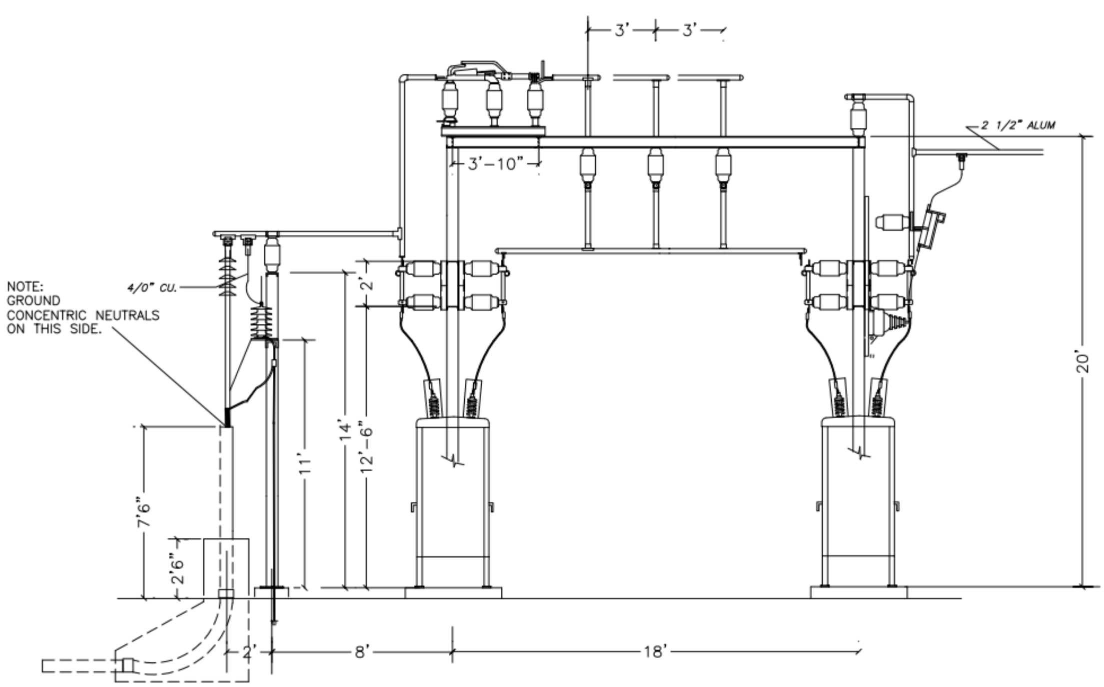


Figure 12: Example of a PSCo MTB Scheme

4.2.3. Tandem Bus Scheme (TB)

The tandem bus scheme design consists of two buses, Main and Tandem, with the same capacity. The main bus can be taken out of service and the entire load switched to the tandem bus. A transfer bus could be used instead of the tandem bus, therefore eliminating the TA switches, but is normally limited to the capacity of the feeder breaker that is serving the bus.

The TB configuration is used for distribution substations 50 MVA and larger with a maximum capacity of 200 MVA. The ultimate installation would include three 70 MVA transformers, transformer circuit breakers, and two bus tie breakers. The use of a TB configuration may also be applied to distribution substations with less than 50 MVA transformers when future capacity increases may be planned or reasonably expected.

There can be up to three bus sections with this design. Each section has provisions for a main bus, tandem bus, and up to 9 feeders. Each feeder may include a circuit breaker, reactors, and switches. Bus-tie breakers and associated switches are arranged to provide maximum flexibility of bus connections. The Xcel Energy standard TB configuration is shown in Figure 13 and Figure 14.

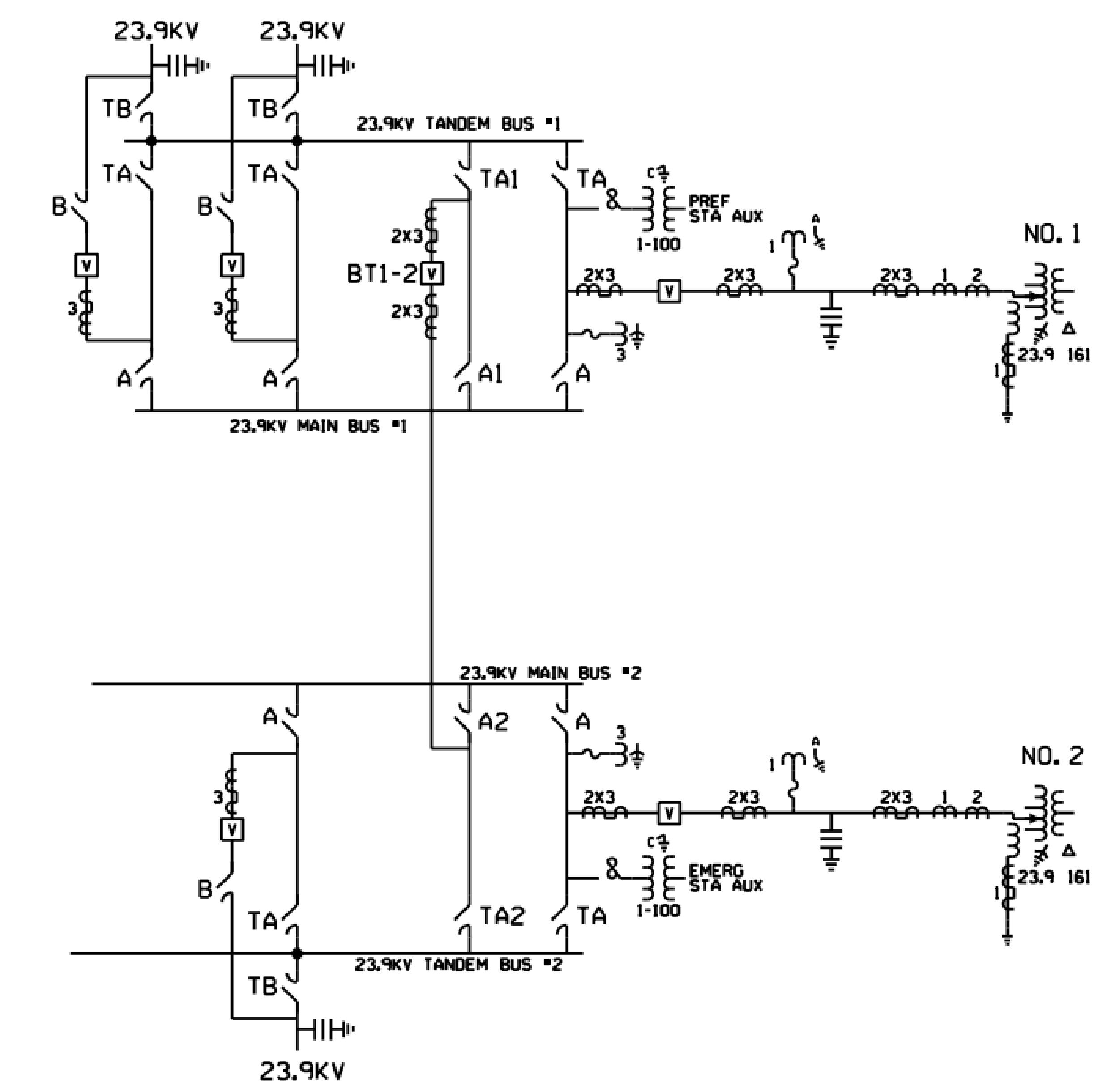


Figure 13: TB Scheme

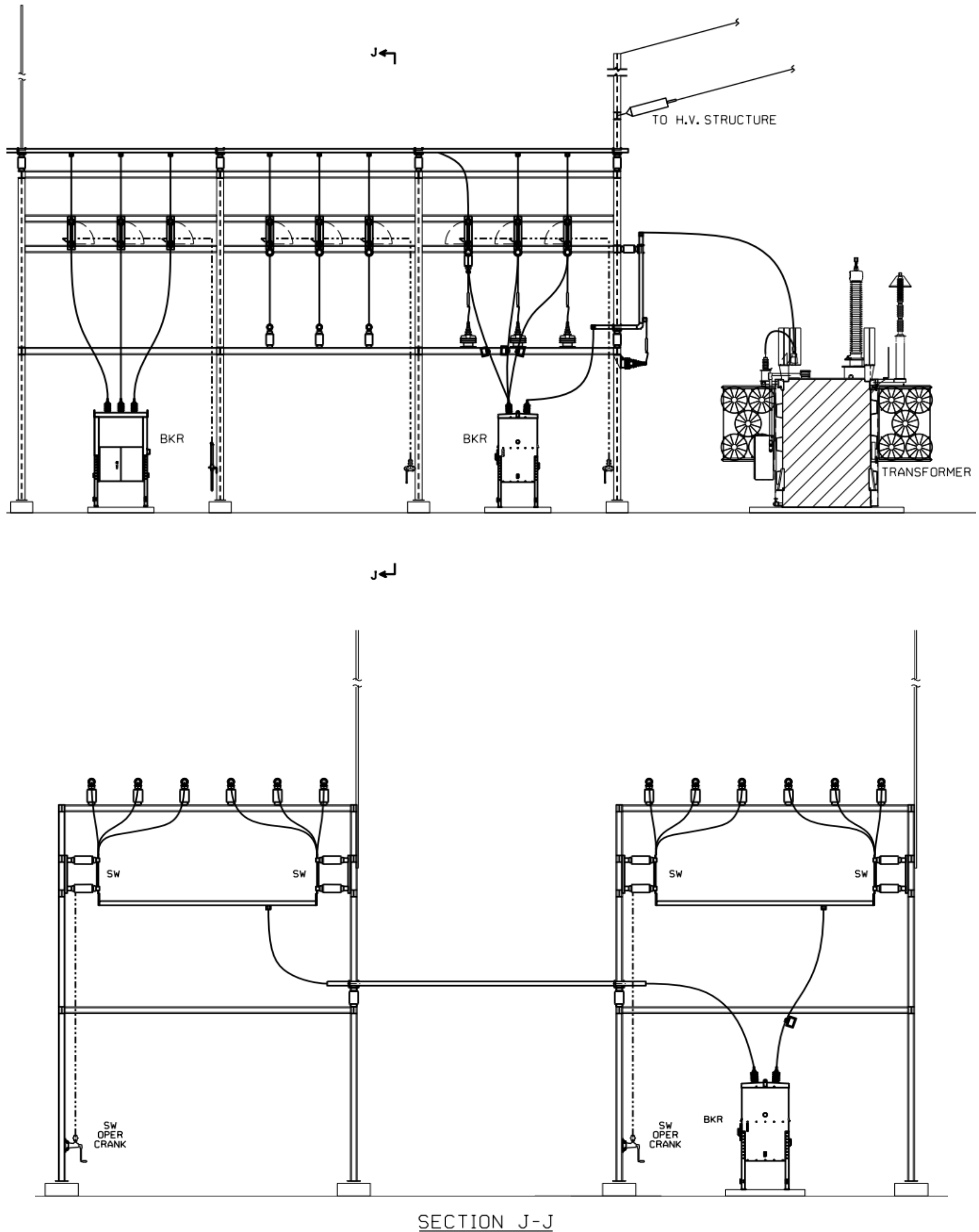


Figure 14: TB Scheme

4.2.4. Metal Clad Switchgear

Metal clad switchgear is one of Xcel Energy's standard physical configurations for distribution substations. Metal clad switchgear is housed in an equipment enclosure, complete with circuit breakers, disconnects, and control and relaying. Switchgear designs have a lower profile than open-type bus and switch arrangements, and have some advantages in the areas of space requirements and aesthetics. Being enclosed, switchgear should experience less outages caused by animals. Switchgear can be used with underground feeder entrances only. Adding additional cubicles to existing switchgear lineups may present difficulties. Therefore, when installing switchgear, it is standard practice to install the ultimate switchgear lineup at the initial construction.

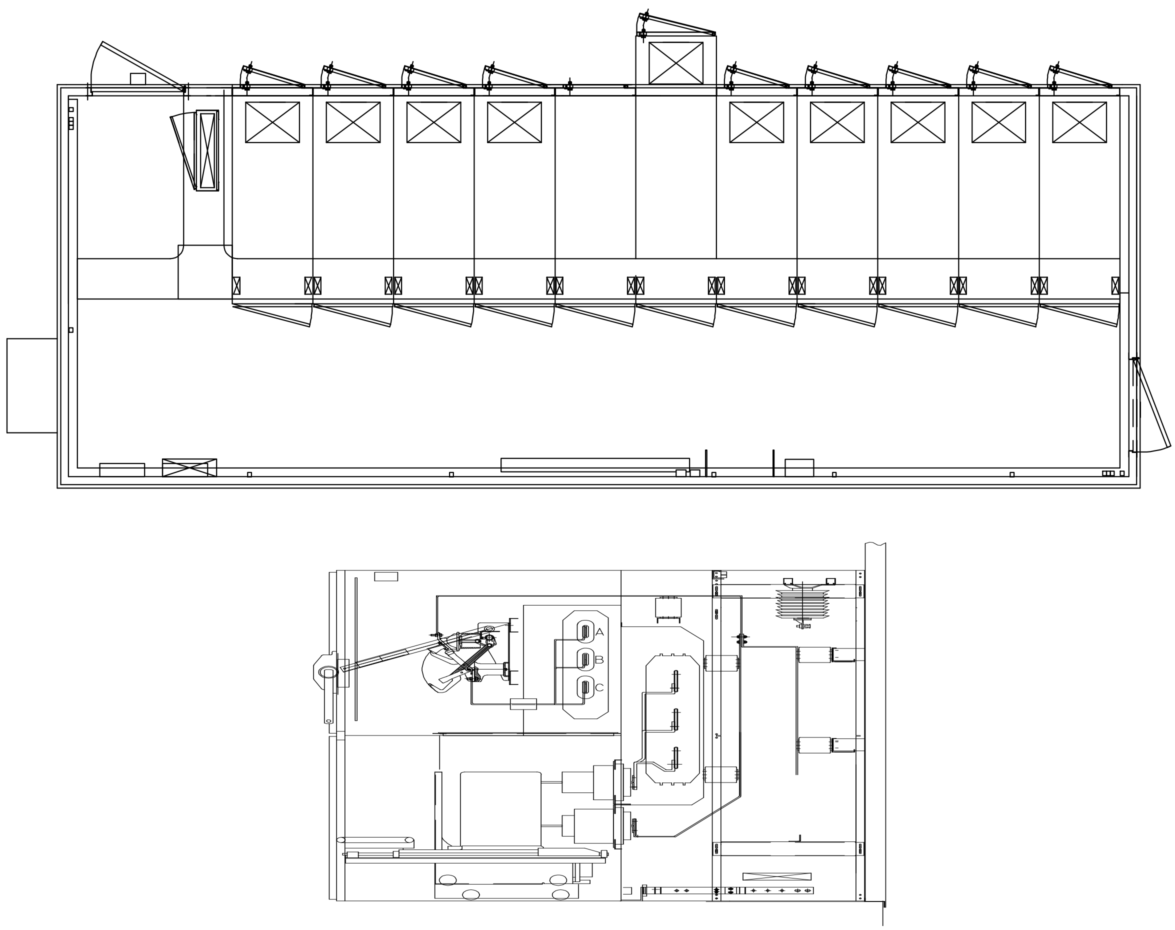


Figure 15: Example of a Metal Clad Switchgear
Top picture is Plan View of Equipment Enclosure and Switchgear Lineup
Bottom picture is Section View of Feeder Cubicle

4.3. Phase Sequence, Bus Arrangement, and Marking

At PSCo and NSP, the standard bus arrangement in substations has “B” phase in the center. The phase sequence required for the transformers may fix the location of “A” and “C” phases. When the transformers or other constraints do not determine the bus arrangement, the preferred bus layout is A-B-C from south to north, west to east, and top to bottom. These standards do not apply to SPS, which uses a “1-2-3” phase designation system.

Variation of the bus arrangement within a substation should be avoided. Variation may be necessary, however, in certain cases, such as substations with three different voltages or where similar three-phase transformers are located with their high voltage sides in opposite directions. Phase markings on equipment and structures consists of capital letters A-B-C, and should be clearly shown on the substation plan drawings.

4.4. Electric Clearances and Spacing

Electric clearance and spacing standards have been established by Xcel Energy for use in substation designs. These clearances meet or exceed NESC minimum requirements. For more information, refer to electrical clearance standards: NSP-STD-ED 4.02.02.01 for NSP, and PSC-STD-Substation Clearance for SPS and PSCo. All substation arrangements will be designed to allow safe maintenance and repair of adjacent equipment.

4.5. Insulation Coordination and Protection

Substation designs must provide for insulation coordination and protection. The first step in insulation coordination is to determine voltage stresses. System transient analysis studies can be performed to determine the amplitude, wave shape, and duration of system voltage stresses. The results will include temporary overvoltages, switching surges, lightning strikes, and longitudinal overvoltages. The results will vary from one substation to the next. Voltage stresses can be reduced by surge arresters and other protective devices, lightning protection (shielding) for substations and lines, grounding designs, air gaps, and other means.

The second step in insulation coordination is to select equipment insulation strength and design protective device/surge arrester applications to protect against expected failure conditions. Transient analysis studies will also aid in determining where surge arresters should be located.

NOTE: All line terminations and transformers (high and low side) should have surge arrestors, regardless of voltage or breaker type. If there are spark gaps on an existing site, they should be replaced at the next project opportunity.

Each OpCo of Xcel Energy has established Standard Basic Lightning Impulse Insulation Level (BIL) ratings and surge arrester ratings. These ratings may not be appropriate for all substations, however, and substation engineering must verify the correct insulation coordination for each substation project.

At elevations above 3000 ft., BIL ratings should not need to be increased, except at 34.5kV, when lightning arresters are also installed. This assumes that the arrester lead length has minimal affect on the protective voltages. Methods for calculating the effect of the arrester lead lengths are available and may be considered for individual projects. At locations where BIL ratings have already been increased due to altitude, future ratings should match.

In the Denver area, there are some “compact” 230kV substations that use 650kV BIL insulation. These are former 115kV substations that have been upgraded to 230kV. There was not sufficient space to build them to the 900kV BIL standard. This “compact” design is not a standard Xcel Energy practice, and should not be repeated except under special circumstances.

4.5.1. Transmission Insulation Coordination

Transmission Substation Standard BILs and Surge Arrester Ratings

Voltage (kV)	BIL (kV)[1]	MCOV(kV)[2]	Duty-Cycle (kV)
13.2	150	8.4	10
13.8[3][4]	150	8.4	10
34.5[3][4][5]	200	22	27
46	250		
69	350	48	60
88	450	57	72
115	550	76	96
138	650	84	108
161	750	106	132
230	900	152	192
345	1300	230	288
500	1550	335	420

[1]The standard BIL refers to external equipment and bus work BIL ratings. Transformers and other equipment sometimes use lower or higher internal BIL levels.

[2]This is the Maximum Continuous Operating Voltage for Metal Oxide Surge Arrester Applications. The standard surge arrester rating may not be correct for all locations. Engineering must verify the rating to use for each substation.

[3]Where surge arresters are installed for transformer delta tertiary windings rated for 13.8kV or 13.2kV, the surge arresters shall be rated for 15.3kV MCOV and 18kV duty-cycle. Where surge arresters are installed for transformer delta tertiary windings rated for 34.5kV, the surge arresters shall be rated for 39kV MCOV and 48kV duty-cycle.

[4] Due to overvoltage during $3I_0$ faults, arresters used on network feeders must have a nominal voltage rating of greater than phase-to-phase voltage (13.8kV)

[5]At elevations of 10,000 ft. and above, a 250kV BIL rating should be assumed.

Table 5

4.5.2. Distribution Insulation Coordination

Distribution Substation Standard BILs and Surge Arrester Ratings

Voltage (kV)	BIL (kV) [1]	MCOV (kV) [2]	Duty-Cycle
2.4	60	2.55	3
4.16	75	2.55	3
7.2	95	8.4	10
12.5	110	8.4	10
13.2[3][4]	110	8.4	10
13.8[3]	110	8.4	10
22.9	150	15.3	18
23.9	150	15.3	18
34.5[3]	200	22	27
46	250		

[1]The standard BIL refers to external equipment and bus work BIL ratings. Transformers and other equipment sometimes used reduced internal BIL levels.

[2]This is the Maximum Continuous Operating Voltage for Metal Oxide Surge Arrester Applications. The standard surge arrester rating may not be correct for all locations. Engineering must verify the rating to use for each substation.

[3]Where surge arresters are installed for transformer delta tertiary windings rated for 13.8kV or 13.2kV, the surge arresters shall be rated for 15.3kV MCOV and 18kV duty-cycle. Where surge arresters are installed for transformer delta tertiary windings rated for 34.5kV, the surge arresters shall be rated for 39kV MCOV and 48kV duty-cycle.

[4] Due to overvoltage during $3I_0$ faults, arresters used on network feeders must have a nominal voltage rating of greater than phase-to-phase voltage (13.8kV)

Table 6

4.5.3. Regional or Other Variations

By industry standard, insulation ratings are valid for elevations up to 3300 ft (1000 m). At altitudes higher than 3300 ft (1000 m), the rated dielectric strength of equipment and materials is decreased. This is because, at higher elevations, the density and pressure of air is lower and the insulating properties of air are decreased. Altitude correction factors can be found in various industry equipment standards. (One reference is IEEE Std C37.30 IEEE Standard Requirements for High-Voltage Air Switches.) In the SPS region, designs are typically based on >= 3700 ft elevation. In the PSC region, designs are typically based on a 5900 ft elevation.

The standard surge arrester rating may not be applicable to all locations. System parameters such as grounding, line lengths, and normal operating voltage range may require that surge arresters with different ratings be used. Special consideration should be given, or transient analysis studies performed, for surge arrester ratings and applications for EHV systems.

There may be existing substations that deviate from the table above. Such deviations from the table are not necessarily a basis for future designs except as noted. Deviations from standard designs, layouts, or equipment insulation specifications or large additions to the system (e.g. EHV lines, new generation, large capacitor banks) may require transient analysis studies. The output of these studies will aid in the selection of appropriate BIL ratings for a given application.

4.6. Ampacity of Equipment

4.6.1. Standard Ampere Ratings

An important part of the substation design is deciding the ampere ratings of the bus work and equipment. As with the rest of the design, future substation upgrades should be taken into account. System Planning should provide information regarding power flows into the substation for various system transmission line configurations and contingencies and for various future scenarios.

The substation bus conductors should, at a minimum, be sized based on the ampacity requirements of the substation (as provided by Planning). Once the ampacity requirements are determined, switches and circuit breakers will be sized to meet or exceed these ratings when required. In some cases, the determining factor in sizing the bus conductors will be structural and mechanical requirements. For any case, the substation bus conductor and equipment should not limit the capacity of connected transmission line facilities. Exceptions can be approved by Transmission Planning and Operations based on transmission and distribution line load levels.

Table 7 shows the design criteria variables to be used for determining the maximum ampacity ratings of the substation rigid and stranded bus conductors for new designs. Standard ampacity ratings for new rigid bus conductors shall be determined based on the calculation methods provided in IEEE 605-2008, and ampacity ratings for stranded conductors shall be determined using the calculation methods provided IEEE 738-2006.

Design Criteria for Substation Bus Conductor Ampacity Ratings

	NSP	PSC	PSC ≥8500 ft	SPS
Summer Ambient Temp. (Deg. C)	40	40	35	40
Day of the Year	June 21 (172nd day)	June 21 (172nd day)	June 21 (172nd day)	June 21 (172nd day)
Temp. Rise (Deg. C)	45	45	50	45
Bus Temp. (Deg. C)	85	85	85	85
Emissivity Outdoors (*e*)	0.5	0.5	0.5	0.5
Emissivity Indoors (e)	0.35	0.35	0.35	0.35
Absorptivity (*a*)	0.5	0.5	0.5	0.5
Degrees N. Latitude	43	40	40	35
Time of Day	Noon	Noon	Noon	Noon
Atmospheric Conditions	Clear	Clear	Clear	Clear
Elevation	1,100 ft (336 m)	5,900 ft (1800m)	11,500 ft (3506 m)	>=3,700 ft (1128 m)
Wind Speed (ft/sec)	2	2	2	2
Wind Direction	90	90	90	90
Line Orientation	E/W (90˚)	E/W (90˚)	E/W (90˚)	E/W (90˚)

Note 1: For indoor calculations, solar heat gain should not be applied.
Note 2: When wind speeds are zero, forced convection heat loss rate should not be applied.

Table 7

The ratings and criteria provided in the XEL-EXT-Facility Ratings Methodology, Bus Conductor Ampacity Facility Ratings Analysis are not to be used for determining conductor ampacities in new, upgraded or expanded substation designs. The criteria below shall be followed for design purposes.

4.6.2. Regional or Other Variations

At altitudes higher than 3300 ft, the rated continuous current of equipment and materials is decreased. Altitude correction factors can be found in various industry equipment standards. (One reference is IEEE Std C37.30 IEEE Standard Requirements for High-Voltage Air Switches.)

4.7. Transmission Bus Conductor Standard Ampere Ratings

Table 8 gives guideline minimum bus conductor ampacities for transmission substations. It is strongly recommended to use “Heavily Loaded Substations” ratings, except when designing taps to radial loads. Bus conductor ratings should not be rated below incoming transmission line loads. Exceptions to these minimums can be justified in certain cases, such as for small tapped substations. Higher ampacities will often be required, depending on the project requirements.

Transmission Substation Bus Conductor Guideline Minimum Ampacity Ratings

Nominal Voltage (kV)	Application	Lightly Loaded Substations (A)	Heavily Loaded Substations (A)
69	Transm. Transformer Termination	1200	2000
69	Line Termination	1200	2000
69	Main Bus	1200	2000
115 and above	Transm. Transformer Termination	1200	2500
115 and above	Line Termination	2000	2500
115 and above	BHB (Row and Bus) or RB	2000	2500

Table 8

4.8. Distribution Bus Conductor Standard Ampere Ratings

The distribution substation standard ampacity ratings for bus and feeders are given by the distribution planning philosophy documents (see XEL-STD-B.01-001-PHASE I DESIGN.pdf).

4.9. Short-Circuit Considerations

Short circuit calculations are conservative to account for future system additions such as nearby generation or an increase in system transmission lines. These changes can have a significant impact on available fault currents. Initially designing for higher fault currents will minimize the impact of higher fault currents in future designs.

Both phase and ground fault current values will be obtained for calculations. When selecting the design short-circuit value, the designer should take into consideration future surrounding system growth, if possible. All substations should be designed using the future five-year short-circuit value plus 20% or the In Service Date value plus 20%, whichever is higher. In areas with very low expected ground fault values, (less than 10kA) use 200% of the expected value for ground grid design, as shown in the table below. Generally, phase values are used for equipment and structure designs. Information for certain transmission and distribution equipment is described in Sections 4.9.1 and 4.9.2. Design values for Substation Grounding, Sec 4.11, will always be based on ground faults. In all cases, the maximum design value will not exceed 63kA due to breaker sizing.

Phase or Ground Fault Value (from Planning or CAPE)	Design Value	Minimum Value
<=10kA	200%	5kA
>10 kA	120%	20kA

NOTE: Fault current values should be checked against the design value every time an element is added to the substation which could increase the fault value such as a line or transformer. Also, the design fault values shall be listed on all substation one-line or circuit diagrams.

The phase and ground short-circuit design ratings, once selected, will be applied to all aspects of the substation design, including equipment ratings and bus design. While the available short-circuit current varies from station to station, some Xcel Energy standard equipment ratings have been defined.

4.9.1. Short-Circuit Considerations for Transmission Substations

For transmission substations, Xcel Energy standard circuit breakers' short-circuit ratings are: 40kA for 69kV, 115kV, and 230kV, and 63kA for 345kV. Xcel Energy standard circuit-switcher short-circuit ratings are: 40kA at 115kV and 20kA at 230kV. These values are based on Xcel-wide approved equipment selections and interruption capability requirements.

4.9.2. Short-Circuit Considerations for Distribution Substations

The distribution substation standard short-circuit ratings are listed in the distribution planning philosophy document (see XEL-STD-B.01-001-PHASE I DESIGN.pdf).

4.10. Rigid Bus Dampening

Bus vibration is caused by low steady winds, less than 15 mph, blowing across a bus span at approximately right angles. Under certain low velocity wind conditions, eddies will break off alternately from the top and bottom surfaces of the bus causing the bus to vibrate in a vertical plane. The bus will vibrate at its natural frequency, provided that this frequency is within the range that can be triggered by the wind. In general, longer bus spans will vibrate.

In the past, scrap cable was installed inside tubular bus to prevent vibration. Today, external dampers are preferred because they are more economical and easier to install than scrap cable. For additional information, see NSP-STD-ED 6.01.05-Bus Vibration Dampers For Rigid Bus.pdf and PSC-STD-7170-Substation Rigid BUS.pdf.

4.11. Substation Grounding

All substations shall include a grounding system designed in accordance with IEEE 80 guidelines to protect people inside and outside the facility by limiting step and touch potentials during faults and switching. The grounding system also: limits ground potential rise, protects system components, allows relays to identify faults, and provides a safe return path for neutral currents. Future fault currents in high growth areas may exceed existing system levels, and designs need to accommodate for higher fault levels than calculated during design. Procedures for modeling and calculating expected fault current values are described in Section 4.9. Once selected, the design value used for ground grid design shall be noted on the grounding drawing.

Soil resistivity affects the ability of a grounding system to dissipate fault current into the soil. Both ground grid resistance and voltage gradients within the substation increase with soil resistivity. Soil resistivity tests should be performed for new substations and during major expansions.

The standard substation grounding system is a partial grid with a driven rod bed. All substation ground grid and equipment grounding conductors shall be a minimum 4/0 copper cable. The ground grid shall extend 3ft outside the substation fence and beyond the swing of any gates. The fence shall be connected to the ground grid at regular intervals not to exceed 50ft. A surface layer of crushed rock will be used as a high resistivity surface to reduce step and touch potentials. Ground wells may be utilized when required. Refer to standard "XEL-STD-EDS-G.08-001-SUBSTATION GROUNDING for more information.

4.12. Lightning Shielding

All substation electric equipment, electric bus, and support structures should be shielded from direct lightning strikes. Shield masts and shield wires are the preferred methods of lightning shielding within substations. In some cases, it may not be economical to completely protect every piece of equipment. Any equipment left out of the protection areas shall be noted and reviewed by subject matter experts.

Two widely used methods for designing substation lightning shielding are i) "fixed angle zone of protection" or "traditional cone" and ii) "electro-geometric model" or "rolling sphere method" (RSM). The rolling sphere method is based on detailed scientific and mathematical analysis, is generally more conservative, and can lead to more costly shielding designs than the empirically based cone system. Xcel has chosen fixed angle and RSM as the preferred methods for design. The fixed angle method is to be utilized for substation applications with insulation levels less than 550 kV BIL, which corresponds to voltage under 115 kV and the RSM for 550 kV BIL (115 kV) and above. Refer to IEEE 998 for substation applications, IEEE 1243 for transmission line applications and IEEE 1410 for distribution applications.

In order to prevent significant outages for fallen shield wires or for modification to shield wires during construction, care should be taken to avoid crossing shield wires above multiple sections of bus or above multiple pieces of equipment.

4.13. Corona

Measures to limit corona on conductors and other energized parts shall be included in the designs for substations that operate at 345kV and above. In some cases, for example at higher altitudes or when there is excessive noise, corona mitigation may also be necessary at 230kV. Corona is limited primarily through use of larger diameter or bundled conductors and connectors or by devices that approximate smooth, spherical surfaces. Special hardware (e.g. bolt shields, corona rings, spherical balls) is used on switches, buses, and attachments, while conductors are polished smooth and free of any scratches or burrs. For additional information, see IEEE 605.

4.14. Outdoor Cabling and Raceway Systems

The design of cable and raceway systems varies from station to station. Below-grade (underground) cable in substation yards will be installed in conduits, in duct banks, in concrete cable trench, or direct buried. Above-grade cable in substation yards is installed in conduit, wire way, or cable tray.

High-voltage power and control/instrument cables (1000V, 600V respectively) should be installed in duct banks, other protective cableways, or conduits within the substation yard, unless it is not practical due to other design constraints. High-voltage power cables shall be segregated from all other cables. Refer to IEEE 525 for additional information.

5 Safety and Security

5.1. Personal Protective Grounds

All substation equipment and busses must have provisions for attaching personal protective grounding cables. Each device (transformers, circuit breakers, CCVTs, etc.) requiring regular access by maintenance personnel must have specific grounding points on each of the high-voltage leads attached to the device or have space to install clamps directly onto conductors. Only approved ground attachment devices are to be used. The ground attachment points must be adequate for the maximum available fault current (see Sec 4.11) in the substation. Any deficiencies should be corrected as they are discovered.

Testing of personal grounding cables and connection points has shown that there are no approved personal grounding provisions that are capable of safely grounding equipment at fault levels exceeding 50kA. At locations where the fault level may exceed 50kA, steps must be taken to reduce the available fault to a maximum of 50kA before the work site may be safely grounded. In locations where the fault levels are known to be at or above 47.5kA, the project engineer shall consult System Protection Engineering for fault studies to determine the fault levels at the substation, and whether switching to lower the available fault current is required.

The fault current used for design shall also be listed on all substation one-line or circuit diagrams (see Sec. 4.9) and should be updated on a yearly basis. Special provisions for grounding must also be included in metalclad switchgear. Refer to IEEE 1246 for additional information.

5.2. Wildlife Protection

5.2.1. Transmission Substations

Due to the relatively large clearance distances involved, transmission substations rarely experience flashovers due to animals and do not require the use of wildlife protection devices on energized equipment and bus structures. Transformer tertiary bushings may require wildlife protection. Animals may cause other types of damage and safety concerns in substations and basic measures to prevent or deter animal entry are to be taken. The standard substation fence design includes barriers to animals entering the substation (e.g. closely-spaced chain link, metal strip near the top).

5.2.2. Distribution Substations

Distribution substations have many design features intended to provide protection from wildlife.

Refer to the XEL-STD-Guideline for Wildlife Protection and XEL-STD-Guideline for Application of Wildlife Protection.pdf for additional information regarding wildlife protection considerations. IEEE 1264 may also be a useful reference.

5.3. Fencing

Substations are completely enclosed to provide a protective barrier for public safety and security for facilities. The standard enclosure is a galvanized, chain link fence, although a wall or the exterior wall of a building may be used to provide the barrier in some cases. A decorative wall or building may be installed in some locations if required by codes, regulations, or permits.

The fence or other type of barrier shall meet or exceed NESC requirements. The fence should also be in accordance with Xcel Energy Security guidelines (XEL-STD-Guideline for Substation Physical and Cyber Security). The standard fence is galvanized chain-link consisting of seven feet of fabric topped with one-foot of barbed wire. According to Xcel Energy security guidelines, a ten-foot minimum exterior clear zone free from trees, shrubs, structures, and equipment is recommended when property lines permit.

If there is no line-of-sight visibility between the main substation gate and the entrance off the public roadway, then a security gate will be installed at the driveway entrance off the public road. A security gate provides increased security at substation that may have an unusually long driveway, foliage, or other features that could provide cover to trespassers.

The substation fence will generally not be placed directly on the property line. The substation ground grid normally extends three feet outside the fence as part of the ground grid design. The ground grid should be within the property line and covered with the yard surface aggregate. It is recommended that the fence be located twenty (20) feet inside the property line, but where it is not possible, a minimum of five (5) feet inside the property line is required to accommodate typical grounding practices. All external fences adjacent to the substation security fence will be electrically isolated from the substation fence and ground grid. See standard XEL-STD-EDS-G.08-001-SUBSTATION GROUNDING for additional detail.

5.4. Substation Access Control

All exterior gates and doors shall be locked for security. Within the substation, equipment enclosure entrances shall also be locked. Gates may have a dual-padlock system if workers from other utilities or companies require access.

5.5. Substation Lighting

Substation yards and electrical equipment enclosures shall be illuminated in accordance with the National Electric Safety Code. Outdoor yard lighting for substation equipment shall provide an average of 2 foot-candles for safe operation/maintenance of equipment and for security. Remote areas of the substation yard shall have an average of 0.2 foot-candles.

The Xcel Energy standard is that unoccupied substations not be illuminated at night. Only a small percentage of substations are illuminated at night for various reasons specific to the substation. For instance, local codes or regulations may require lighting, or lighting may be necessary to improve security at a particular site.

5.6. Fire Protection

Special attention should be given to the location of large transformers in substations. Transformer fires can result in large amounts of flaming oil spread through the substation. This can lead to damage of nearby equipment. It is important that adequate equipment separation be provided so that damage to other substation equipment is kept to a minimum in the event of a transformer fire.

The substation grading should be prepared so that spilled oil flows away from buildings or other large transformers and cannot easily access underground cable trenches. Substations with remote oil containment may also offer a form of fire protection.

The edge of the oil containment or anticipated spill area of large transformers should be separated from the surface of other transformers or control buildings by the distances shown in Table 9 below. Table 9 distances are from IEEE 979-2012.

Separation Distances

Mineral Oil Volume (gal.)	Distance (ft.)
500 to 5000	25
>5000	50

Table 9

Protective firewalls or barriers should be considered whenever these clearances cannot be achieved. In rare cases, fire hydrants or sprinkler systems may also be beneficial as part of the fire protection system. IEEE 979-2012 mentions additional methods of fire suppression when a firewall is not feasible. These methods are not addressed in this document. However, a study of these methods will be conducted for possible inclusion in future revisions.

In general, electrical equipment enclosures have two exits on opposite sides or corners and the doors have panic hardware. Panic (emergency egress) hardware will be included on all new enclosures and as the opportunity occurs, will be added to existing enclosures that do not presently have panic hardware. Fire extinguishers are provided at each exit of the equipment enclosure. Some GIS equipment enclosures may require fire suppression systems. If a fire extinguisher is missing, contact an O&M manager. Refer to XEL-STD-Specification for Procurement of Fire Extinguishers, and IEEE 979-2012 for additional information related to fire protection.

5.7. Signs and Nameplates

A sign listing the substation name, 911 address, and GPS coordinates, should be posted in 3 ½-inch lettering on the substation fence. The sign should be located such that, during an emergency, a passerby or exiting employee can easily read it. “NO TRESSPASSING” and “HAZARD WARNING” signs shall also be posted at 50 to 100-foot intervals on each side of the substation fence. Xcel’s Public Safety Awareness Programs publish in Spanish any time more than 10% of the population speak Spanish as a primary language according to census data. In Colorado, Texas, and New Mexico, over 10% of the population speak Spanish as a primary language. With this data, the requirement is such that all external substation HAZARD signage will be in both English and Spanish at all installations so there is only one material requirement and not two different sign types in the catalog.

Within the substation, all power equipment and switches will be labeled. Warnings signs will also be posted for battery systems, buried cable, and areas of limited clearance. Examples of these signs are located in Appendix A. Substation signs shall meet or exceed the requirements of the National Electric Safety Code. See standard “XEL-STD-Guideline for Substation Physical and Cyber Security” for additional information.

6 Major Equipment

6.1. Transmission Transformers

6.1.1. Number and Size of Transformers

System Planning and Asset Management determine the number and size of transformers required for a substation. Transformers are manufactured to specification and there are no industry-preferred or standard MVA ratings. However, Xcel Energy does use several standard transformer size ratings for specifying and purchasing transformers. Having a limited number of standard sizes in the system simplifies transformer replacements and relocations. See XEL-STD-Criteria for Power Transformer Loading for more information.

Standard Transmission Transformer Ratings

Operating Region	Top MVA Rating[(1)]
NSP	47, 70, 112, 120, 187, 336, 448, 672
PSC	100, 150, 280, 560
SPS	84, 250, 448, 560

[(1)]based on operation at 65°C winding temperature rise

Table 10

6.1.2. Transformer Connections

The standard winding configuration for transmission transformers is a grounded-wye-connected autotransformer. A delta-connected tertiary winding is typically included as it provides a path for circulating third harmonic currents. The delta tertiary also allows the transformer to be a zero sequence source. The tertiary will be specified at a distribution voltage level (unless it is a buried tertiary) and will often be used to supply station auxiliary power or VAR control devices.

6.2. Distribution Transformers

6.2.1. Number and Size of Transformers

System Planning and Asset Management determine the number and size of transformers required for a substation. Transformers are manufactured to specification and there are no industry-preferred or standard MVA ratings. However, Xcel Energy does use several standard transformer size ratings for specifying and purchasing transformers. Having a limited number of standard sizes in the system simplifies transformer replacements and relocations.

A discussion of transformers to be used in distribution substations is provided in the distribution planning philosophy document (XEL-STD-B.01-001-PHASE I DESIGN.pdf and XEL-STD-B.01-002-PHASE II DESIGN). The standard sizes are given in the table below.

Standard Distribution Transformer Ratings

Distribution System Voltage	Top MVA Rating[1]
2.4	Undefined
4.16	Undefined
7.2	Undefined
12.5	7, 14, 28, 50
13.2	7, 14, 28, 50
13.8	7, 14, 28, 50, 70
22.9	7, 14, 28
23.9	7, 14, 28, 50, 90.5
34.5	12, 28, 50, 70
46	Undefined

[1]based on 65°C winding temperature rise

Table 11

6.2.2. Transformer Connections

The standard distribution transformer connection for new substations is delta-connected primary, grounded-wye-connected secondary. The high side leads the low side by 30°.

Other transformer connections have been, and still are, used in the different Xcel Energy operating regions.

6.3. Distribution Voltage Regulation

Voltage regulation on the distribution system will be provided by Voltage Regulators or by Load Tap Changer-equipped (LTC) transformers. These devices operate in a similar fashion. The distribution voltage is compared to a desired set point, and the regulator or LTC adjusts the voltage in discrete steps based upon the taps in the winding. LTC transformers regulate the voltage on the distribution bus. Regulators or capacitor banks can be applied to regulate the voltage on just one feeder or to regulate an entire bus.

6.4. Circuit Breakers

The proper selection and application of circuit breakers is critical in substation design. The Xcel Energy standard transmission circuit breaker design for 72.5kV to 362kV is dead-tank, SF6, with bushing CTs. Live-tank circuit breakers are also available and may be used in certain cases. (The dead-tank circuit breaker design has a grounded tank, whereas the live-tank circuit breaker design has interrupters that are at line voltage and are on insulated columns.) Synchronous-closing circuit breakers may be used on larger capacitor bank and reactor installations – the application is determined on a case-by-case basis. The Xcel Energy minimum continuous current rating for 72.5kV circuit breakers is 2000A. The Xcel Energy minimum continuous current rating for circuit breakers rated 121kV and higher is 3000A. See XEL-STD-EMS-J.04-007-OUTDOOR HIGH-VOLTAGE AC CIRCUIT BREAKERS.

6.5. Reclosers

Reclosers are specialized circuit breakers for use at distribution voltages. Reclosers have limited ratings designed specifically for distribution duty. They contain a complete three-phase and ground-overcurrent protection package. The protection for reclosers can be either relayed or series-trip. Relayed reclosers can be used where there is DC control voltage available.

Series-trip reclosers do not require a separate DC or AC control voltage to operate. These types of reclosers have been typically installed in rural substations or locations where there is no DC control voltage.

6.6. Metal Clad Switchgear

Metal clad switchgear (MCSG) consists of an outdoor metal enclosure which houses medium voltage bus and several physically separated areas known as cubicles or units. The MCSG also contains an aisle for personnel to access the cubicles. Within each cubicle resides a circuit breaker and connections for medium voltage cable or bus to exit the structure for connection with feeders, transformers, capacitor banks, and other switchgear. Relays for the control and communication of the MCSG reside on the door of each cubicle. Switchgear also typically will include an I/O Remote Terminal Unit (RTU), which will communicate to the substation master RTU. Metal clad switchgear is generally built by a manufacturer and installed as a single unit. See Section 4.2.4 above and XEL-STD-EMS-J.06-001 Metalclad Switchgear Assembly for more detail on switchgear components and ratings.

6.7. Disconnect Switches

Disconnect switches are used primarily for isolation of equipment. Care must be taken to properly apply disconnect switches, especially where the switch may be called on to interrupt current, such as loop or line charging currents. Typically, the switchblade is arranged to open towards the equipment it is protecting, and away from the energized bus. This allows the switch to be fully isolated and de-energized while in the open position.

The standard substation disconnect switch is a three-pole, outdoor, high-voltage, non-enclosed, group-operated air switch. The minimum continuous current rating of a switch will not limit the transmission power flow path. Hook-stick type switches are not used for transmission substations above 69kV. Grounding switches may be used for underground transmission lines or when required for maintenance at other locations. Manual operators are standard, unless motor-operators are needed for automatic or remote operation. Swing-handle operators are standard for smaller manually operated switches, while worm-gear operators are used for larger switches that require more force to open. Specifically, worm-gear operators are standard for manually-operated switches rated 115kV and above or 2000A or greater. See XEL-STD-EMS-J.08-001-OUTDOOR HIGH-VOLTAGE AIR SWITCHES AND OPERATING MECHANISMS for more information.

6.8. Capacitors

For detailed engineering and design information including vertical clearances for all voltage levels, see XEL-STD-Eng & Design of Capacitor Banks.

6.8.1. Shunt Capacitors

Shunt capacitor banks are often used for VAR support, voltage control, and to increase system capacity. The standard configuration for shunt capacitor banks is fuseless, grounded-wye. The number and size of capacitor banks will be determined by System Planning and Asset Management.

6.8.2. Shunt Capacitors for Transmission Substations

Stack construction with factory-assembled capacitor racks is used at all transmission voltages. An ultimate MVAR rating is normally specified such that additional capacitor cans may be added in the future to increase the MVAR rating without replacing the entire bank.

For new installations where there is not a station battery and the capacitor bank breaker/switching device has a capacitive trip device, the breaker is not used primarily for capacitor bank fault protection. In these installations, the capacitor bank will be protected with fuses. The breaker will then act as a capacitor bank switch for voltage control and during unbalanced conditions.

For additional information about capacitor bank design and controls see: XEL-STD-Eng & Design of Capacitor Banks

Current-limiting reactors may be required to limit inrush and outrush currents of the capacitor banks. If not reduced to an acceptable level, these currents may damage the capacitor bank switching devices or nearby circuit breakers.

6.8.3. Shunt Capacitors for Distribution Substations

Capacitor banks for distribution systems are sometimes installed in substations on either the bus or on feeders. This is discussed further in the distribution planning philosophy document (XEL-STD-B.01-001-PHASE I DESIGN.pdf and XEL-STD-B.01-002-PHASE II DESIGN).

6.8.4. Series Capacitors

Series capacitor banks are used on long transmission lines to increase line loadability. They have been applied in a few cases on long 345kV and 500kV lines.

6.9. Reactors

The Xcel Energy standard design for reactors is dry-type, air-core. Calculations should be performed to determine the reactor size. A transients study may also be required to confirm the necessity and size.

6.9.1. Shunt Reactors

Shunt reactors are used to provide VAR control and to limit voltage rise during light loading conditions. One standard application is to connect shunt reactors to transmission transformer tertiaries. This is due to the possibility of high tertiary fault currents from higher-capacity transformers. Tertiary reactors may be used in place of line reactors when allowed by the characteristics of the line. A study is required to determine the necessity and applicability of a shunt reactor on a line. A circuit breaker will be used for reactor switching and the preferred location is between the transformer and the reactor. The breaker must be sized for the available fault current. No switching will take place on the neutral side of tertiary reactors. See XEL-STD-Eng & Design of Capacitor Banks for more information.

6.9.2. Series Reactors

Series reactors may be used where current limiting is required or to limit transients caused from capacitor bank switching. One common application is in the circuits of shunt capacitor banks. When two or more shunt capacitor banks are installed in a substation, reactors will usually be required. Series reactors are also frequently used to limit fault current levels on distribution feeders.

6.10. Wave Trap Installations

For new installations, wave traps are to be supported by a pedestal or similar support and are not to be suspended. For special cases such as replacing an existing suspended wave trap, the engineer shall prepare an estimate of the cost to replace the suspended design. The Director of Engineering must approve all decisions to continue with a suspended design for a wave trap. If a suspended option for a wave trap is approved by the Director of Engineering, the Substation Design Manager shall approve the design in writing. The design shall also be sealed by a PE when the prints are issued due to the inherent risk of suspending wave traps. (Each of these is a custom design and only a current PE approval is valid.) See XEL-STD-Specification for Procurement of Line Traps for more information.

6.11. System Restoration

6.11.1. Black Start Emergency Generators

Several key transmission substations include a diesel generator designed to automatically start-up and carry the required station auxiliary load for up to 36 hours in the event of a system blackout. This should provide sufficient time to restart major generation and piece the grid back together under worst-case scenarios. Distribution substations do not typically have emergency generators.

7 Electric Equipment Enclosures

7.1. AC Auxiliary System

Every substation includes an AC auxiliary supply system for lighting, heating, maintenance, and other electrical loads. Additionally, each substation that has primary and secondary protective relays and a battery system should have two AC auxiliary sources. An automatic transfer switch will be included to switch between the two sources (preferred and emergency).

The sources for auxiliary power are usually transformer tertiary windings or distribution busses. If these sources are not available or are not economically feasible, auxiliary power may be obtained from the local distribution company, an emergency generator, or a voltage transformer connected to a transmission bus. No distribution load from the tertiary windings shall be outside of the substation yard.

The Xcel Energy standard AC auxiliary system rating is 120/240V single-phase, and this is used with auxiliary equipment rated up to 100kVA. However, for substations that would require auxiliary equipment rated higher than 100kVA with a 120/240 single-phase system, a three-phase auxiliary system is used. Three-phase auxiliary systems have been rated 120/240V in all three regions and 120/208V in the PSC region. See PSC-STD-E40.1–Alternating Current Station Service Design and NSP-STD-ED 4.04.01-AC System Requirements for more information.

7.2. DC Auxiliary System

Each substation that has protective relaying includes at least one DC system (including storage battery and charger). DC is the primary power source for relay and control power. Nearly all new substations utilize a 125VDC battery system. Other voltages, such as 12VDC or 48VDC, may be used when it is economically practical to do so. Today’s equipment includes sufficiently

DC System A	DC System B
Protection System 1	Protection System 2
Pilot Comm System 1	Pilot Comm System 2
DTT System 1	DTT System 2
Breaker Trip Coil 1	Breaker Trip Coil 2
Motor Operator 1 (Switch)	Motor Operator 2 (Switch)
	Breaker Failure
Metering & Transducers	
Local Alarm System (Annunciator/HMI/LCU)	RTU
	Telephone Protection

Table 12
Note: Motor operated switches will be placed on the same DC source as the initiating device

hardened power supplies so that electronics and trip coils can share the same DC supply without adverse effects. However, for all new installations above 100 kV, the DC circuits to the trip coils shall be separate circuits, in separate cables and routed in separate conduits, or separate cables if cables are direct buried, and with different circuit breakers on the panel as shown in Table 12. The DC panels should be configured to accommodate separate batteries in the future. Consideration should be given to adding a second DC source to existing stations based on criticality and reliability. Use Table 12

Note: Motor operated switches will be placed on the same DC source as the initiating device as the design for segregation in the event of a redundant battery design unless the existing configuration/wiring prevents the standard configuration from being implemented. For considerations regarding battery-monitoring systems, see the XEL-STD-Guideline for Engineering & Design of AC-DC Systems – Battery Monitoring Systems.

Refer to XEL-STD-DC-M.05-001 Design Criteria for Substation DC Auxiliary System for battery and charger sizing criteria.

Appendix A Warning Sign Examples

Figure 16 - Example of a 12" x 14" 'Hazardous Voltage' Bilingual Sign

Figure 17 - Example of a 10" x 14" 'No Smoking' Sign

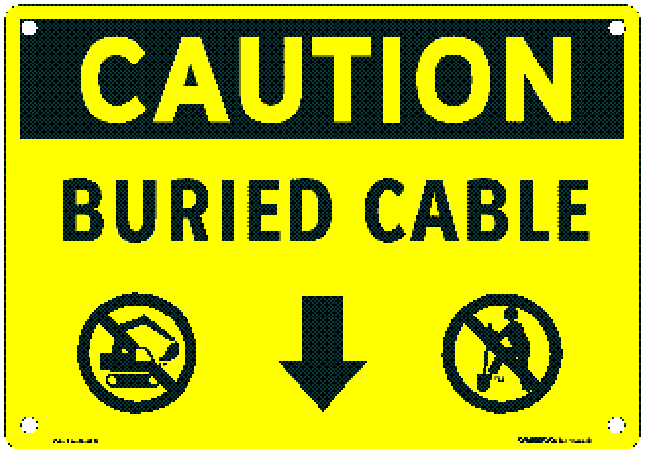


Figure 18 - Example of a 10" x 7" 'Buried Cable' Sign

Figure 19 - Example of a 10" x 12" 'Limited Clearances' Sign

Appendix B Reference Documents

B.1. Capital Asset Accounting – Procedure Guidelines, Asset Separation – Funtionalization of Substations

B.2. Colorado Title 25, Article 12, Noise Abatement

B.3. EDS-G.02-001, Substation Clearances – 345kV and Below

B.4. XEL-STD-Guideline for Wildlife Protection

B.5. IEEE 1127-1998, Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility

B.6. IEEE 1243-1997, Guide for Improving the Lightning Performance of Transmission Lines

B.7. IEEE 1246-2002, Guide for Temporary Protective Grounding Systems Used in Substations

B.8. IEEE 1264-2014, Guide for Animal Deterrents for Electric Power Supply Substations

B.9. IEEE 1410-2004, Guide for Improving Lightning Performance of Electric Power Overhead Distribution Lines

B.10. IEEE 525-2007, Guide for the Design and Installation of Cable Systems in Substations

B.11. IEEE 605-2008, Guide for Bus Design in Air Insulated Substations

B.12. IEEE 738-2006, Standard for Calculating the Current-Temperature of Bare Overhead Conductors

B.13. IEEE 80-2000, Guide for Safety in AC Substation Grounding

B.14. IEEE 979-2012, Guide for Substation Fire Protection

B.15. IEEE 980-2013, Guide for Containment and Control of Oil Spills in Substations

B.16. IEEE 998-2012 – Guide for Direct Lightning Stroke Shielding of Substations

B.17. IEEE C2-2012 - The National Electric Safety Code

B.18. IEEE Std C37.30 IEEE Standard Requirements for High-Voltage Air Switches

B.19. NFPA 70 – 2014 - National Electrical Code

B.20. NSP-STD-ED 4.02.02.01, Outdoor Electrical and Working Clearances

B.21. NSP-STD-ED 4.04.01-AC System Requirements

B.22. NSP-STD-ED 6.01.05, Bus Vibration Dampers for Rigid Bus

B.23. PSC-STD-7170, Substation Rigid Bus

B.24. PSC-STD-E40.1, Alternating Current Station Service Design

B.25. XEL-EXT-Facility Ratings Methodology Comparison for Rigid Bus Ampacity.pdf

B.26. XEL-STD-B.01-002, Substation Integration Design Phase 2

B.27. XEL-STD-Criteria for Eng & Design of Civil & Structural Performance

B.28. XEL-STD-Criteria for Power Transformer Loading

B.29. XEL-STD-Criteria for Eng & Design of Civil & Structural Performance

B.30. XEL-STD-DC-M.05-001, Design Criteria for Substation DC Auxiliary System

B.31. XEL-STD-EDS-G.08-001, Substation Grounding

B.32. XEL-STD-EMS-J.04-007-OUTDOOR HIGH-VOLTAGE AC CIRCUIT BREAKERS

B.33. XEL-STD-EMS-J.06-001, Metalclad Switchgear Assembly

B.34. XEL-STD-EMS-J.08-001-OUTDOOR HIGH-VOLTAGE AIR SWITCHES AND OPERATING MECHANISMS

B.35. XEL-STD-Eng & Design of Capacitor Banks

B.36. XEL-STD-Guideline for Application of Wildlife Protection

B.37. XEL-STD-Guideline for Engineering & Design of AC-DC Systems – Battery Monitoring Systems

B.38. XEL-STD-Guideline for Substation Physical and Cyber Security

B.39. XEL-STD-Guideline for Wildlife Protection

B.40. XEL-STD-Specification for Procurement of Line Traps

B.41. XEL-STD-Specification for Procurement of Fire Extinguishers

B.42. XEL-STD-B.01-001-PHASE I DESIGN.pdf

Outdoor Substation Direct Stroke Lightning Protection

Review of various lightning protection design practices - <u>ROLLING SPHERE</u>

1.0 Several techniques of protecting substations from direct lightning strokes have been used in the past. They can be classified basically into the following three categories.

1.01 The technique described in references [1], [2] and [7] is based on scale model tests developed in the 1940's to investigate the protective value of ground wires and vertical masts for transmission lines and substations. This is independent of the voltage level of the energized equipment and depends on the geometric relationship between the shield, the equipment, and the earth. Insulation level, surge impedance, stroke current "Magnitude, and probability of lightning occurrence in the area are not considered directly. These model tests were based on the following assumptions:

i) All lightning strokes propagate vertically downward.
ii) The station is in flat terrain.
iii) Thunderstorm cloud base is at 1000 ft. above ground.
iv) Earth resistivity is relatively low.

1.02 The second method, referred to as "Fixed Angle Zone of Protection" described in reference (8), is also based on the geometric relationship between "the shield, the equipment, and the ground. This method, in effect, is an extension of the previous technique. All equipment within a zone described by a fixed angle from the shield is said to be protected. The angle used for an independent shield is typically 45 degree from the vertical. The angle used for the area between two shields is typically 45 degree or 60 degree from vertical. Again, the normal operating voltage level, insulation level, surge impedance, stroke current magnitude, and probability of lightning occurrence in the area are not directly considered.

1.03 With the advent of high voltage and extra high voltage substations and switching stations, a new method called the "Electro-Geometric Model" has been developed to design shielding. This method is an extension of methods in use for transmission line protection. This model, used in this standard, takes into account the negative polarity impulse critical flashover voltage of insulation (ICFO) and surge impedance (Z) to determine the "Critical Striking Distance" (R_{sc}) which is to be used in the shielding design. This method does not directly consider isokeraunic level.

This method of protection is based on the following premises:

i) The length of the final jump of a lightning flash, called the "Critical Striking Distance", is related to the magnitude of current produced by the stroke.
ii) An impending stroke can begin its final jump from any point above the earth, and will strike the closer of two effectively grounded points within its striking distance.
iii The magnitude of current, which can be driven into an electrical system without causing a flashover of insulation, is dependent upon the surge impedance and the

insulation level. Therefore, for a given insulation level and-surge impedance, lightning strokes below a given current level (and therefore with less than a given striking distance) can be allowed to strike energized equipment.

Physical understanding of the Electro-Geometric Model may be aided by Visualizing a "Rolling Sphere" with radius equal to the critical striking distance (R_{sc}). If the sphere cannot be made to touch any energized equipment .due to interference of shields, then all strokes of magnitudes greater than that 'Corresponding to R_{sc} will always have a shorter path to the earth or a shield than to the energized equipment, and adequate shielding has been achieved. If 'the sphere can be made to contact any energized equipment, a stroke of great enough magnitude, with its final jump originating at the center of the sphere, will have a shorter path to the energized equipment than to the earth or a shield, and adequate shielding has not been achieved.

Therefore, it remains only to ensure that shield masts, wires, or structures etc., are placed such that all strokes with striking distance above the critical value will have a shorter path to the shielding feature than to equipment which is to be protected.

It is very important, however, to remember that the radius of the rolling sphere changes with the voltage level and it is very small at distribution voltage levels. At distribution voltage levels (e.g., 13.8kV), shielding base strictly upon R_{sc} may be extensive and costly, due to small values of R_{sc}. A fixed minimum useful radius is recommended for these voltage levels.

All that remains for a specific application is to determine the critical striking distance and to create a shield network and evaluate its adequacy.

2.0 Step-By-Step-Procedures And Design Flow-Chart

1) Study the general arrangement drawings and locate the take-off structures, high structures for bus supports, main equipment and other important points of interest.

2) Divide the total substation into areas by voltage level.

3) For large substations or switching stations, subdivide the voltage level areas into smaller areas of interest (e.g., 345 kV capacitor areas; 345/230 kV transformers, etc.).

4) Consider alternate positions of movable equipment (i.e., vertical-break disconnecting switches).

5) List the assumptions, (i.e., height of the shielding masts; typical sag for the shield wires, etc.).

6) Determine the critical striking distance for each voltage level in the station using Figs. 7 & 8.

7) Evaluate shielding provided by the existing substation structures. Find the unprotected areas.

8) Make several preliminary designs in order to provide adequate protection at minimum cost. Methods available to correct for inadequate shielding include

   i) Addition of masts on the top of existing steel structures.

   ii) Stringing shield wires between existing steel structures.

   iii) Addition of freestanding shield masts, possibly with shield wires attached.

   iv) Relocation of smaller equipment to an area which is already shielded.

   Methods (i) and (ii) are less costly than method (iii). In general, methods (i) and (ii) will achieve adequate shielding in most stations with standard layouts. Use of freestanding masts may be required for stations of low-profile design or where some equipment is rather remote from the main portion of the station.

9) At lower voltages (below 115kV), shielding based on Rsc may not be practical, since Rsc is small and excessive cost may be involved. minimum useful value of 60 ft. is recommended for Rsc.

10) Once the shielding design for each sub-area has been performed and evaluated for adequacy, check that the entire substation has been adequately shielded.

11) The flow chart (Figure 6) summarizes the step-by-step procedure.

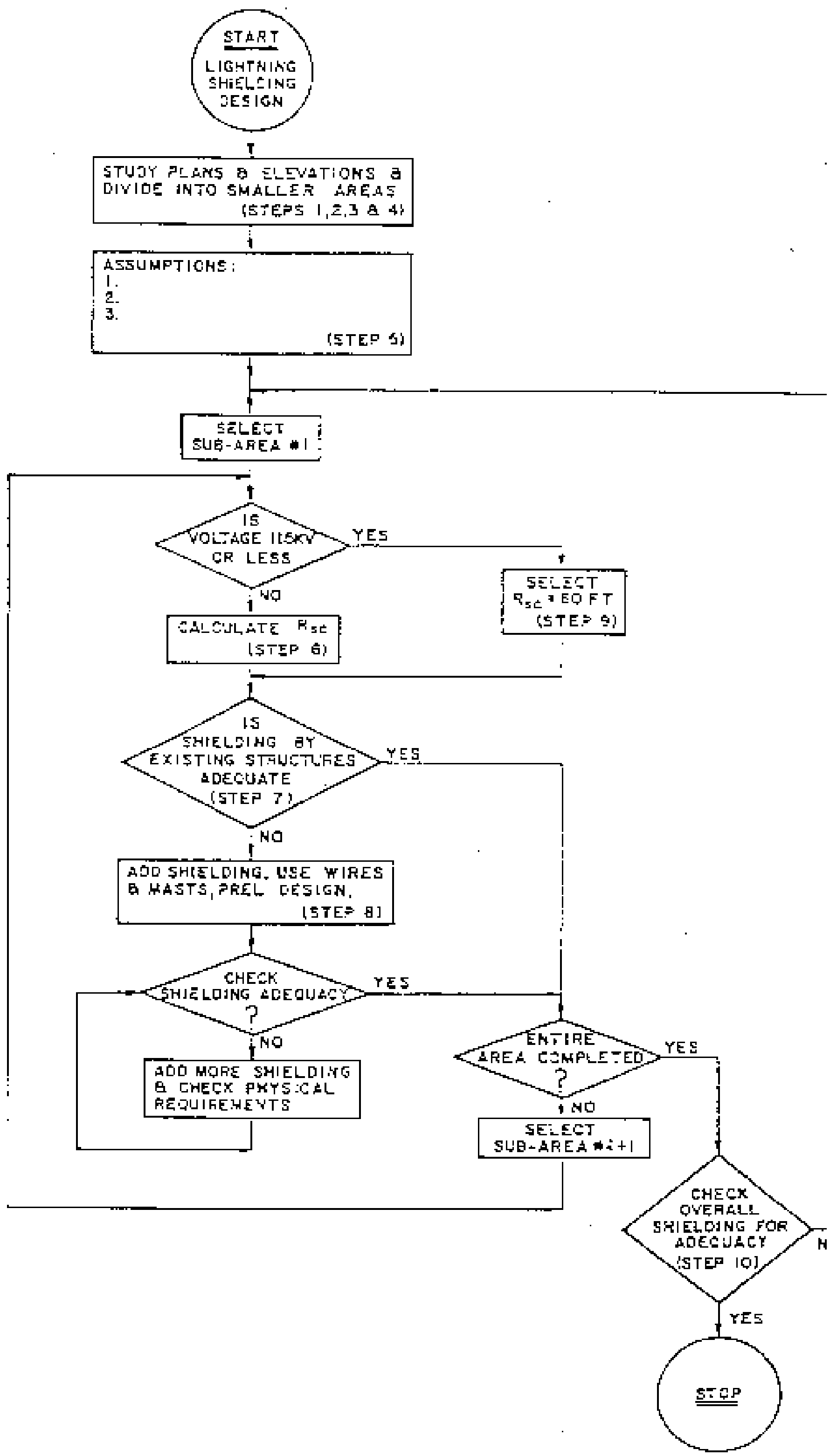


FIG 6 FLOW CHART

3.0 Definitions

R_{sc} - Critical-striking distance based on insulation level & surge impedance, in ft. (Radius of the Rolling Sphere.)

I_c - Critical lightning current in kA.

Z - Surge impedance of bus work in Ohms.

ICFO - Negative polarity impulse critical flashover level of insulation in kV.

H_{av} - Average height of bus phase conductor above ground in ft. For string bus, use attachment height minus 2/3 of the maximum sag.

r - Outside radius of bus phase conductor in ft. for single conductor. Use the geometric mean radius for bundled conductor.

BIL - Basic impulse level in kV

$_{Ioc}$ - Critical prospective lightning current to zero resistance earth in kA. = 1.1 x I_c

a - Distance between two shield wires in ft.

b - Super-elevation in ft.

h - Equipment height in ft.

hs - Height of the mast or the shield wire in ft.

x' - Distance from a mast to a protected object in ft.

x - Distance between masts in ft.

q' - Horizontal distance between the mast & the center of the Rolling Sphere in ft. (for R_{sc} greater than h_s)

4.0 Selected References

[1] McCann, G.D., "Lightning Protection of Hazardous Structures", Electrical Engineering, December, 1942, pp. 591-597.

[2] "Transmission and Distribution Reference Book", Westinghouse Electric Corporation, East Pittsburgh, 1964, pp. 630-632.

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[4] "Bibliography of Publications Pertaining to Lightning Protection", IEEE Transmission Substation Subcommittee of the IEEE Substations Committee, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-94, No. 4, July/August 1975, pp. 1241-1247.

[5] Linck, E., "Shielding of Modern Substations Against Direct Lightning Strokes", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-94, No. 5, September/October 1975, pp. 1674-1679.

[6] Mousa, A.M., "Shielding of High-Voltage Substations", IEEE Transactions on Power Apparatus and Systems,- Vol. PAS-95, No. 4, July/August 1976, pp. 1303-1310.

[7] "Surge Protection in Power Systems", Chapter 6, IEEE Tutorial Course Text 79EHO144-6-PVR, 1978, pp. /6-83.

[8] "Design Guide for Rural Substation", Chapter VI, Rural Electrification Administration, U.S. Dept. of Agriculture, June, 1978, pp. 35-37.

[9] Lee, R.H., "Lightning Protection of Buildings", IEEE Transactions on Industry Applications, Vol. IA-15, No. 3, May/June-1979, pp. 236-240.

[10] Changery, H.J., "National Thunderstorm Frequencies for the Contiguous United States", Report No. NUREG/CR-22.t2, National Oceanic and Atmospheric Administration, Ashville, North Carolina, November 1981.

[11] MacGorman, D.R., et al, "Lightning Strike Density for the-Contiguous United States from Thunderstorm Duration Record", Report No. NUREG/CR-3/89, National Oceanic and Atmospheric Administration, Norman, Oklahoma, May 1984.

APPENDIX 1: Critical Striking Distance (R_{sc}) For Transmission Voltage Levels

Critical Striking distance (the radius of the rolling sphere) can be calculated from the following equation derived from reference [6], equation number from the reference is shown in parenthesis following the equation.

$$R_{sc} = 47.2 \times \left(\frac{ICFO}{Z} \right)^{2/3} \text{ ft.}$$

$$\text{where, } Z = 60 \ln\left(\frac{2H_{av}}{r} \right) \text{ ohms} \qquad (2)$$

The critical lightning current (I_c) or the maximum stroke current that would not cause flashover to the phase conductor neglecting reflections from the substation equipment and bus structures is given by

$$I_c = \frac{ICFO}{\frac{Z}{2}} \qquad (1)$$

Critical prospective lightning current (I_{oc}) to zero resistance to earth is

$$I_{oc} = 1.1\, I_c \qquad (3)$$

where 1.1 is an uncertainty factor.

The effective striking distance, R_{sc}, in meters (or ft.) is related to I_{oc}, in kA, by the equation

$$R_{sc} = 8.5\,(I_{oc})^{2/3} \text{ meters} \qquad (4)$$

$$R_{sc} = 8.5\left(1.1 \times 2 \times \frac{ICFO}{Z}\right)^{2/3} \text{ meters}$$

$$R_{sc} = 14.38\left(\frac{ICFO}{Z}\right)^{2/3} \text{ meters}$$

$$\text{or} \quad R_{sc} = 47.2\left(\frac{ICFO}{Z}\right)^{2/3} \text{ ft}$$

The constant 8.5 and the exponent $^2/_3$ used in the above equation were calculated and refined from the empirical relations and statistical data [6].

Based on equations (2) and (4), two sets of curves have been drawn. Figure 7 shows the calculation of Surge Impedance (Z) as a function of radius (r) and average height of bus phase conductor (H_{av}). The range of Z is between 250 ohms and 400 ohms for most practical cases. Figure 8 shows the calculation of Critical Striking Distance (R_{sc}) versus Surge Impedance and ICFO.

The value of the negative polarity impulse critical flashover level of insulation (ICFO) is always greater than the basic impulse level (BIL). If the value of ICFO is not known, the BIL value may be used instead. This will produce a conservative design.

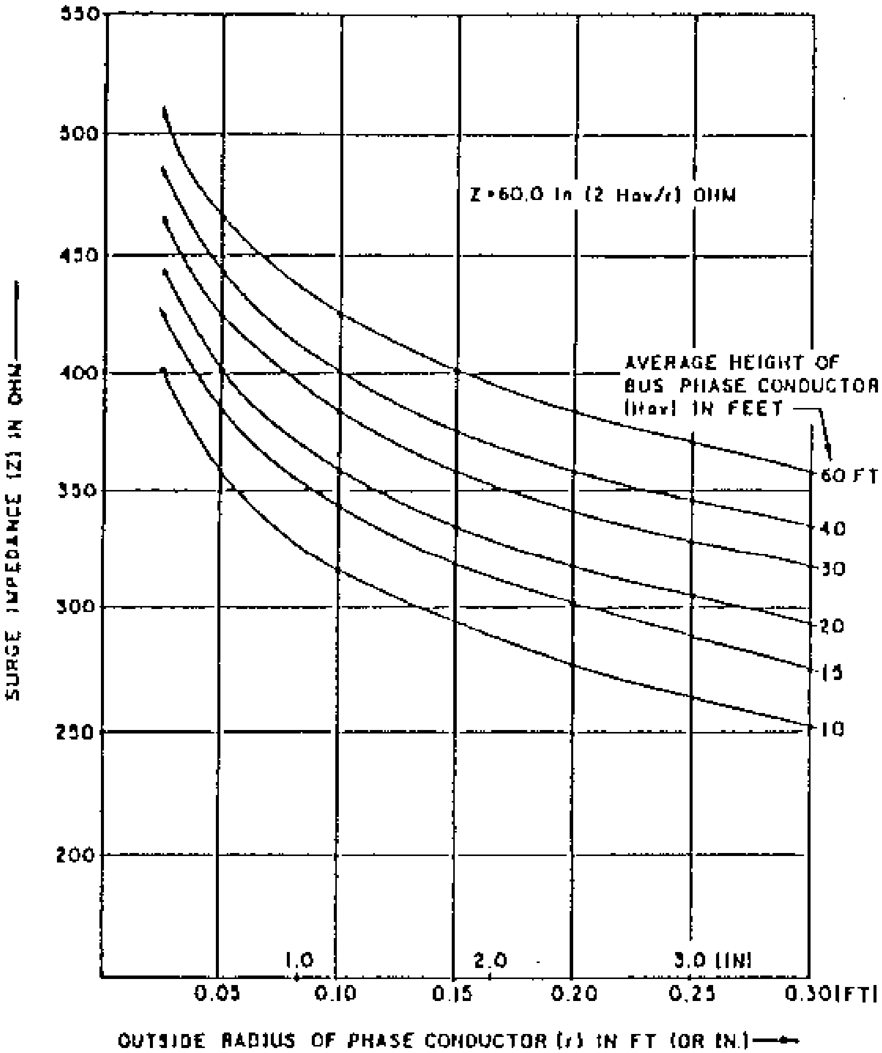


FIG 7 CALCULATION OF SURGE IMPEDANCE

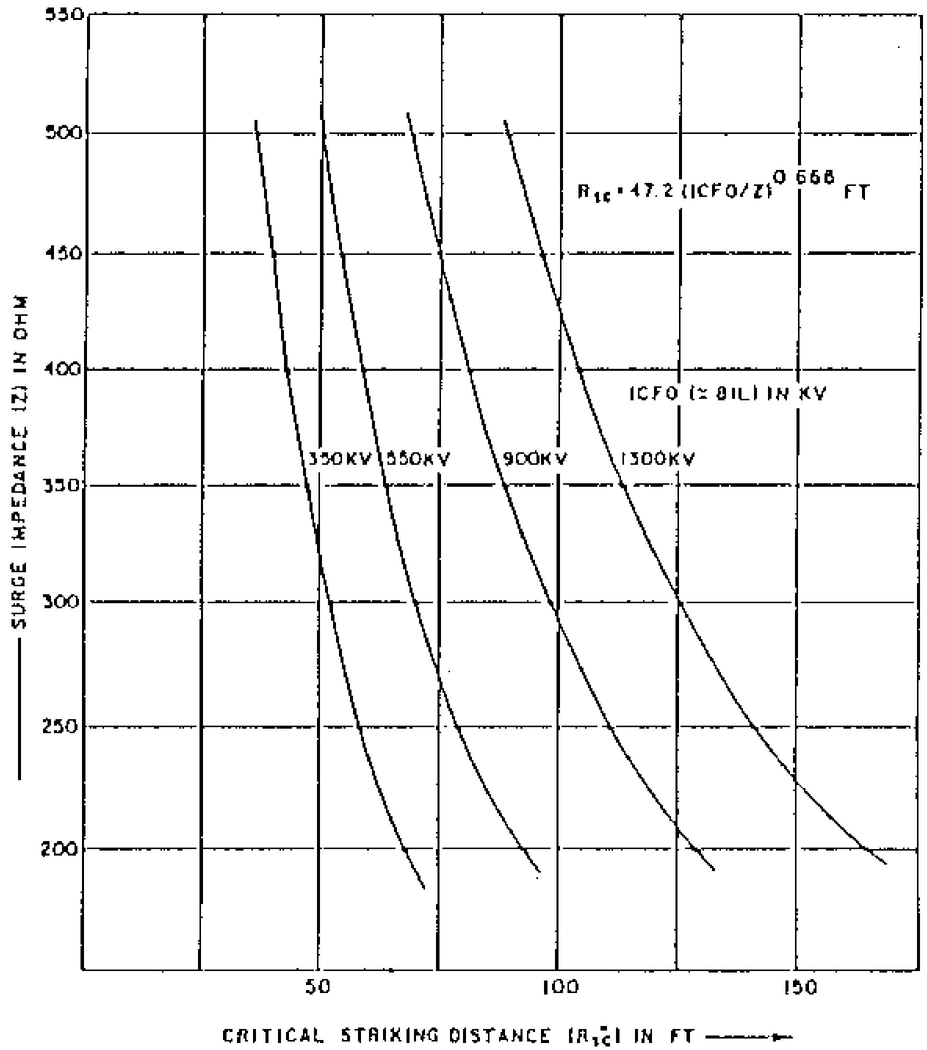


FIG 8 CALCULATION OF CRITICAL STRIKING DISTANCE

OUTDOOR SUBSTATION DIRECT STROKE LIGHTNING PROTECTION

APPENDIX 2: Critical Striking Distance for Subtransmission and Distribution-;Voltage Levels

Special attention must be given while designing direct stroke shielding for subtransmission and distribution voltage levels (below 115 kV). Shielding based on R_{sc} calculated from the insulation level (ICFO) may not be practical, since R_{sc} is small and excessive cost may be involved. This is evident from the following calculations.

69 kV system	H_{av}	=	17.5 ft.
	r	=	0.75 in. (1.5 in. tube)
	ICFO	=	350 kV (BIL)
	Z	=	379.7 ohms
	I_{oc}	=	2.03 k-A
	R_{sc}	=	44.7 ft.
15 kV system	H_{av}	=	15.0 ft.
	r	=	0.75 in. (1.5 in. tube)
	ICFO	=	110 kV (BIL)
	Z	=	370.4 ohms
	I_{oc}	=	0.653 kA
	R_{sc}	=	21.0 ft.

The critical current magnitudes involved based on BIL and Z are small for these voltages. All the statistical information available indicates that less than 1% of all lightning strokes have a current magnitude of 5 kA or less, and less than 0.1% of all strokes have current magnitudes of less than 2 kA.

A fixed minimum useful critical striking distance (R_{sc}) of 60 ft. is recommended for 115 kV and below in light of the following considerations. This will provide shielding from direct strokes with current magnitudes above 3.2 kA.

i) The total area of the substation occupied by lower voltage equipment is usually small. This, combined with the statistics showing that less than 1% of all lightning strokes has current magnitudes less than 5 kA, indicates that the probability of the lower voltage equipment actually being struck by lightning which penetrates the shielding is small.

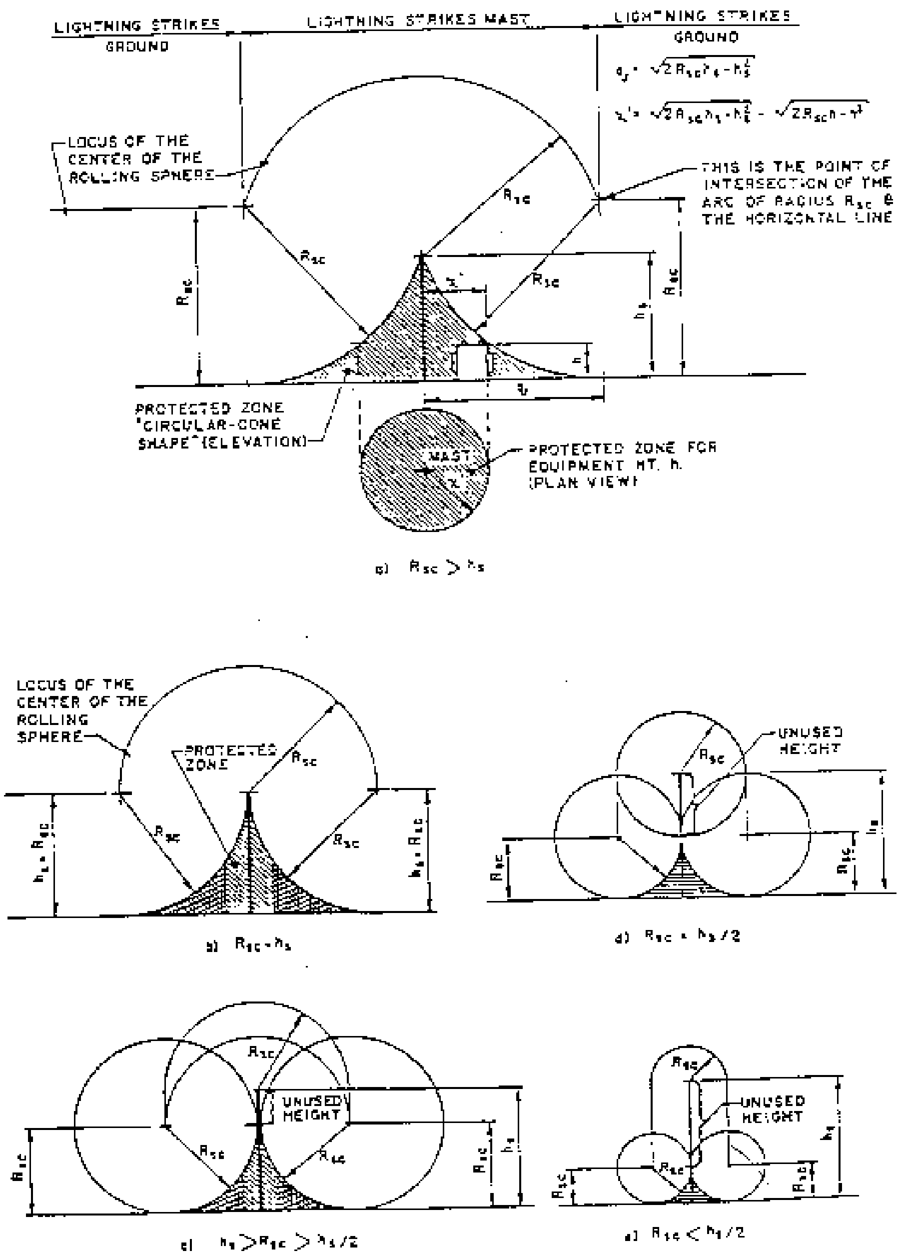
ii) The lower voltage equipment is usually not very tall.

iii) The lower voltage equipment is usually connected to a transformer which will normally have arresters connected to it. The arrester will provide protection against flashover for the area in most cases.

iv) The consequences (equipment damage, system stability, etc.) of a flashover in a lower voltage section of the station are normally not as severe as those for a flashover of transmission level equipment.

APPENDIX 3: Protected Zone for A Single Mast of Height(h_s)

The following sketches (Figure 9) illustrate graphically the zone of protection provided by a single mast of height h_s for various values of the radius of the rolling sphere. The single mast provides a "Circular Cone-Like" shaped protected zone.

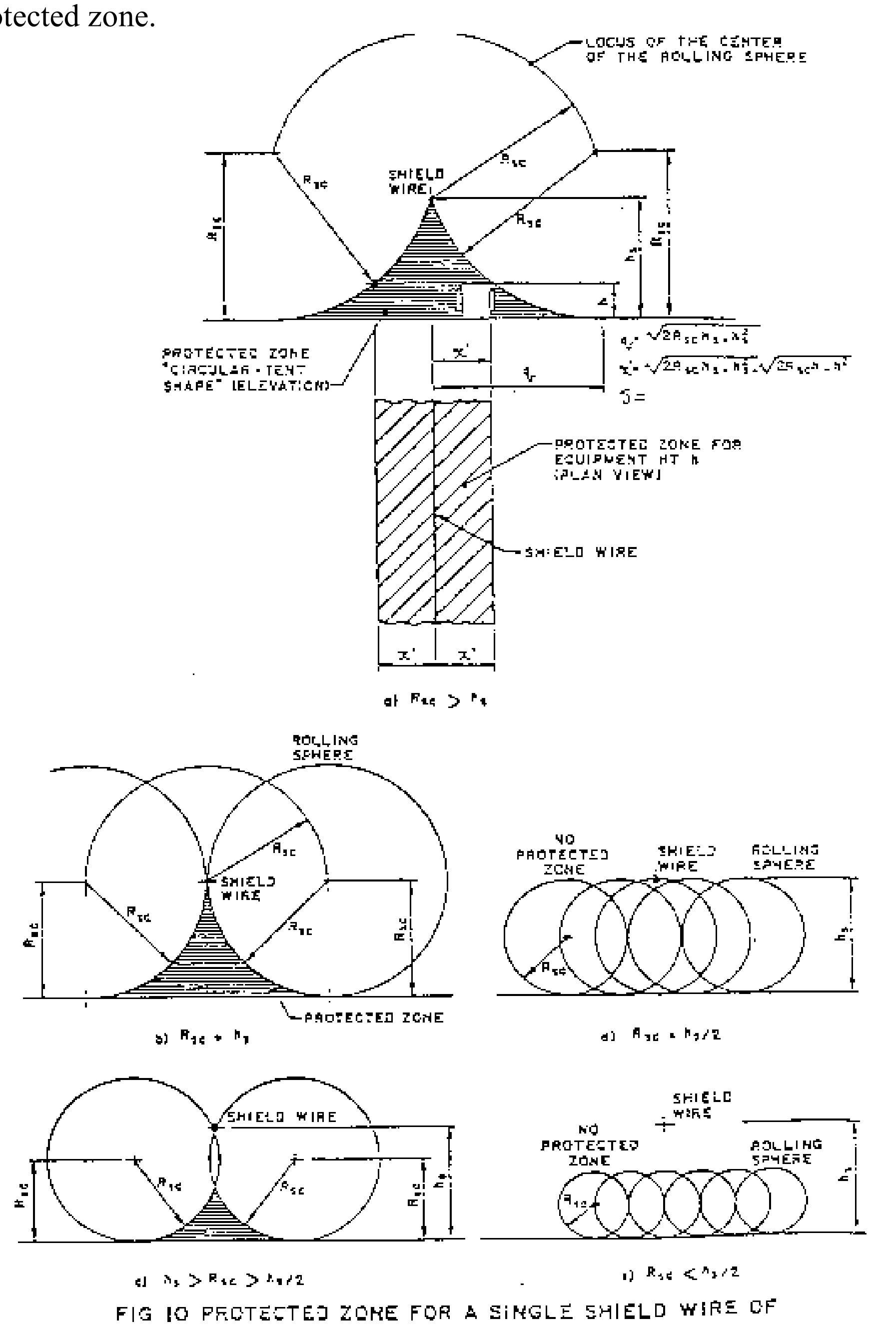


PROTECTED ZONE FOR A SINGLE MAST OF HEIGHT

Figure 9

APPENDIX 4: Protected Zone for A Single Wire of Height (h_s)

The following sketches (Figure 10) illustrate graphically the zone of protection provided by a single wire of height h_s for various values of the radius of the rolling sphere (R_{sc}). The single wire provides a "Circular Tent like" shaped protected zone.



PROTECTED ZONE FOR A SINGLE SHIELD WIRE OF HEIGHT (h_s) FOR A GIVEN R_{sc}

Figure 10

APPENDIX 5: Protected Zone for A Pair of Parallel Shield Lines

Parallel shield wires will provide a protected zone as shown in Figure 11. If it is desired to provide shielding such that equipment of height “h” is shielded anywhere between the two wires, the low point of the protected zone is set equal to “h”.

Since the Rolling Sphere "rests" on the wires, the distance between the shield height and the low point of the protected zone depends only on R_{sc} and “s”, the spacing between the shield wires. This distance between the shield height and the low point of the protected zone is defined as the “super-elevation”, “b”, of the shield wires over the low point of the protected zone.

To set the low point of the protected zone equal to “h”, the super-elevation “b” is set equal to the height of the shield wires minus the height of the protected equipment:

$$b = h_s - h$$

Then the proper spacing of the shield wires, “I_s” must be determined for that value of “b”, either graphically or from the equation:

$$s = 2\sqrt{(2 \times b \times R_{sc}) - b \times b)}$$

This equation is valid for “s” less than $2R_{sc}$.

If the diameter of the Rolling Sphere is less than the spacing of wires, the two wires no longer interact and should be checked individually. It is recommended that “s” be less than $1.33R_{sc}$. This will typically be achieved if the spacing is made to be approximate the bay width at 230 kV and above.

If the spacing “s” is already fixed, the required super-elevation “b” can .be determined graphically or from the equation:

$$b = R_{sc}\left(1 - \left(1 - \sqrt{\frac{0.5s}{R_{sc}}}\right)\right)$$

This equation is valid for “s” less than $2R_{sc}$.

The above discussion applies only to the area between the shield wires. For the areas outside the last shield wire, refer to the method for a single shield wire.

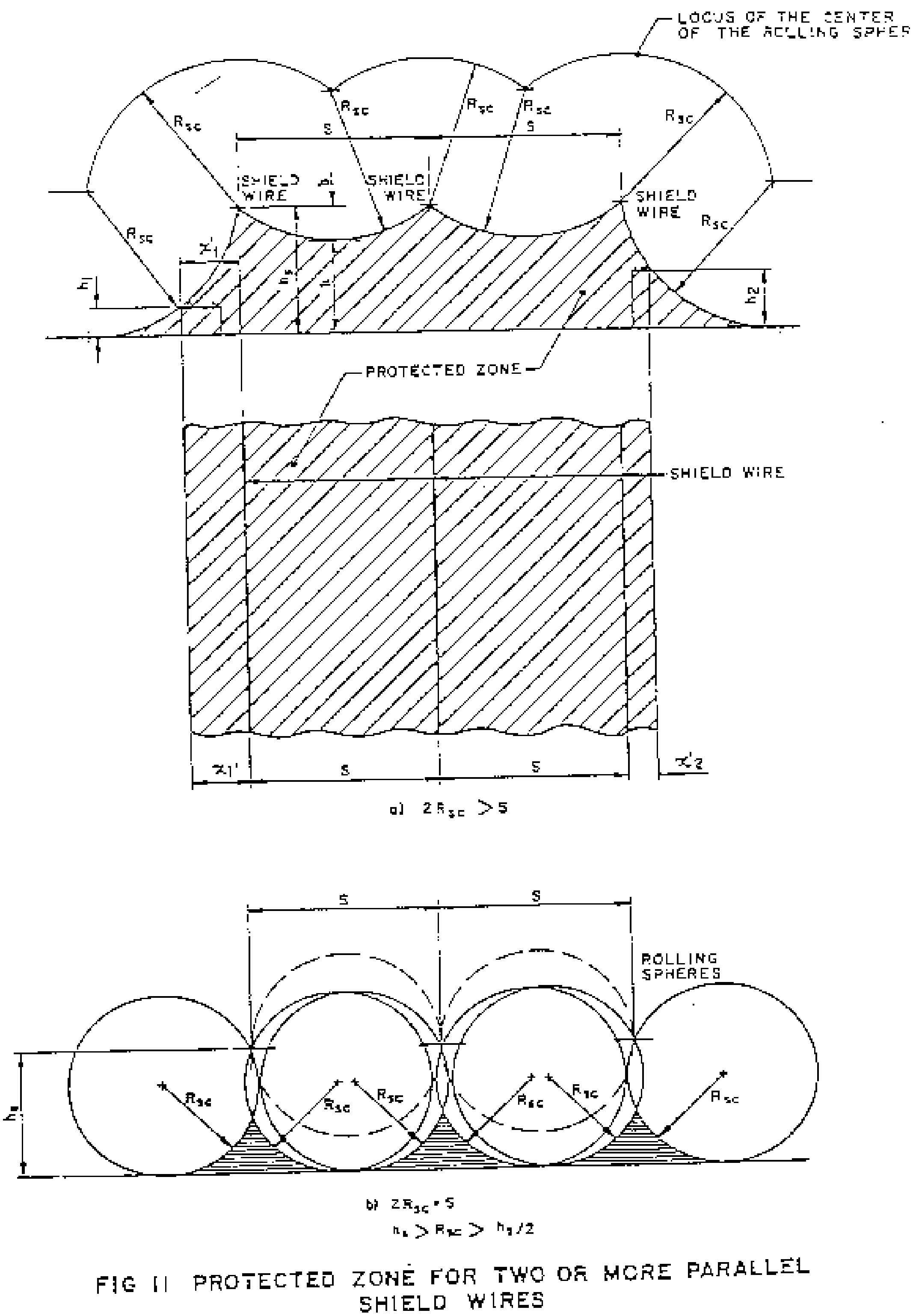


FIG 11 PROTECTED ZONE FOR TWO OR MORE PARALLEL SHIELD WIRES

OUTDOOR SUBSTATION DIRECT STROKE LIGHTNING PROTECTION

Rolling Sphere Example:

$$R_{sc} = 47.2\left(\frac{ICFO}{Z}\right)^{2/3} \text{ ft}$$

$$\text{where } Z = 60\ln\left(\frac{2H_{av}}{r}\right) \ \Omega$$

Using *ICFO* = 550 BIL, 5" BUS and 27' avg. bus height in area concerned,

$$Z = 60\ln\left(\frac{2\times 27'}{0.208'}\right)$$

$$Z = 333 \ \Omega$$

$$R_{sc} = 47.2\left(\frac{550}{333}\right)^{2/3} \text{ ft}$$

$$R_{sc} = 47.2\times 1.40 = 66' \text{ for } 115 \text{ kV}$$

R_{sc} of 60' should be used for the distribution area.

For the static wire,

$$S = 2\sqrt{\left(2(50'-27')\times 66'\right)-(50'-27')^2} = 100\text{ft spacing}$$

where, h_s = 50' (height of shield wires, and
h = 27' (height of protected equipment).

For the shield poles,

$$S = 2\sqrt{\left(2(60'-27')\times 66'\right)-(60'-27')^2} = 114.3 \text{ ft spacing}$$

where, hs = 60' (height of shield pole, and
h = 27' (height of protected equipment).

1. Phase Marking

1.1. The preferred arrangement and phase sequence marking of buses in three phase assembled switchgear shall be A - B - C from front to back, top to bottom, or left to right, as viewed from the circuit breaker operating mechanism side. This is in accordance with NEMA standard publication no. SG2-3-1950 standards for power switchgear assemblies.

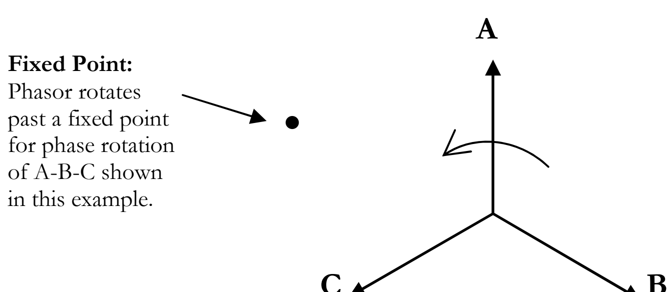
1.2. The arrangement of other buses, such as those in outdoor substations, shall always have the "B" phase in the center. When a transformer(s) is present or planned, it will determine the location of "A" and "C" phases. H1 and X1 will be connected to A-phase. If this is not easily done, then further discussion with the project engineer will be required. When the phase sequence of a transformer(s) does not determine the arrangement, the buses shall be A - B - C from south to north, west to east, and top to bottom.

It is also preferred that the phase sequencing in the N-S and E-W directions match from one voltage area of the substation to another. To do so, may require an exception to the phase match preference indicated in the paragraph above An exception to the phase match preference could be caused due to multiple voltages within the substation. See Figure 2 for two examples of these types of situations.

Caution should be taken when three-phase transformers are located with the high voltage sides in opposite directions. This may require difficult phase swapping to keep the A-phase on the H1 and X1 bushings. If all options for phase-swapping have been exhausted, further discussion will be required before proceeding.

1.3. Circuit breakers should normally be oriented so that bushings 1 and 2 are on A-phase. There may be occasions where this in not practical.

1.4. Except for the transformer phase sequence, section 1.2 above does not apply to EHV installations (345 kV and above). Bus phasing shall be arranged to match the line phasing.



Phase Rotation
FIGURE 1

2. Interconnected Companies – Phase Rotations

Phasing information for interconnected companies should always be verified with the specific company for each specific line or location.

3. Marking Phases in Stations

3.1. Phase markings will consist of a capital letter A - B - C.

3.2. Method of marking

Phase designations will usually be marked with stencils. Plastic, engraved symbols and stamped, metallic symbols may also be used.

3.3. Frequency of phase markings

Phases should be marked in a sufficient number of places so the phase relation of all equipment can be readily identified. However, a phase marking should not be applied to each piece of equipment.

3.4. Location of phase markings

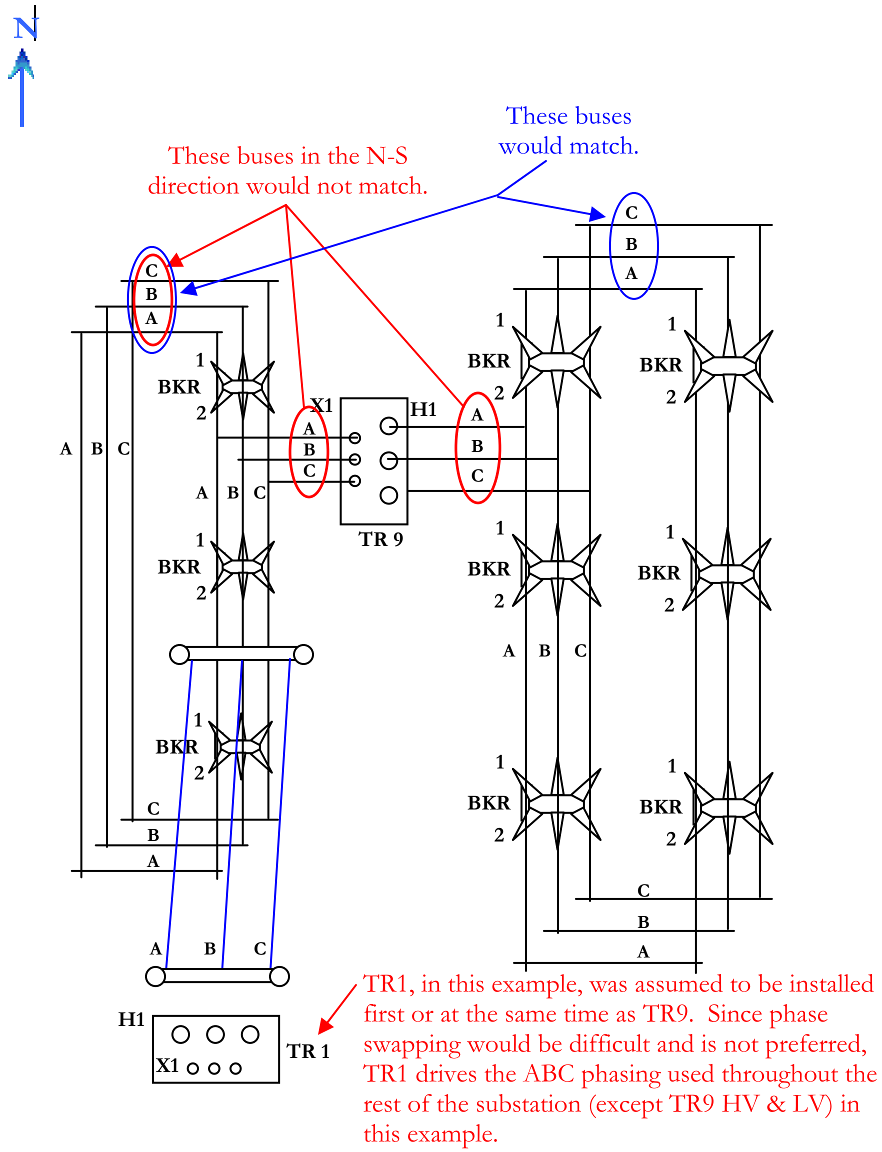
3.4.1. On the larger outdoor substations, the phases should normally be marked on circuit breakers, near all bushings of a three-phase transformer, and wherever else it appears desirable. On the smaller substations, the phases should normally be marked on a steel or wood structure - in preference to marking single-phase transformers or other equipment which may be replaced at relatively frequent intervals.

3.4.2. On indoor stations, the buses should be identified, but if practicable, the markings should be on a de-energized part of the installation. The phases should also -be marked near outgoing line terminations and wherever else it appears desirable.

3.4.3. Where relays, protective devices, or meters are associated with a particular phase, they should be identified with phase markings. The nameplates used for relays will include device number and phase identification when appropriate.

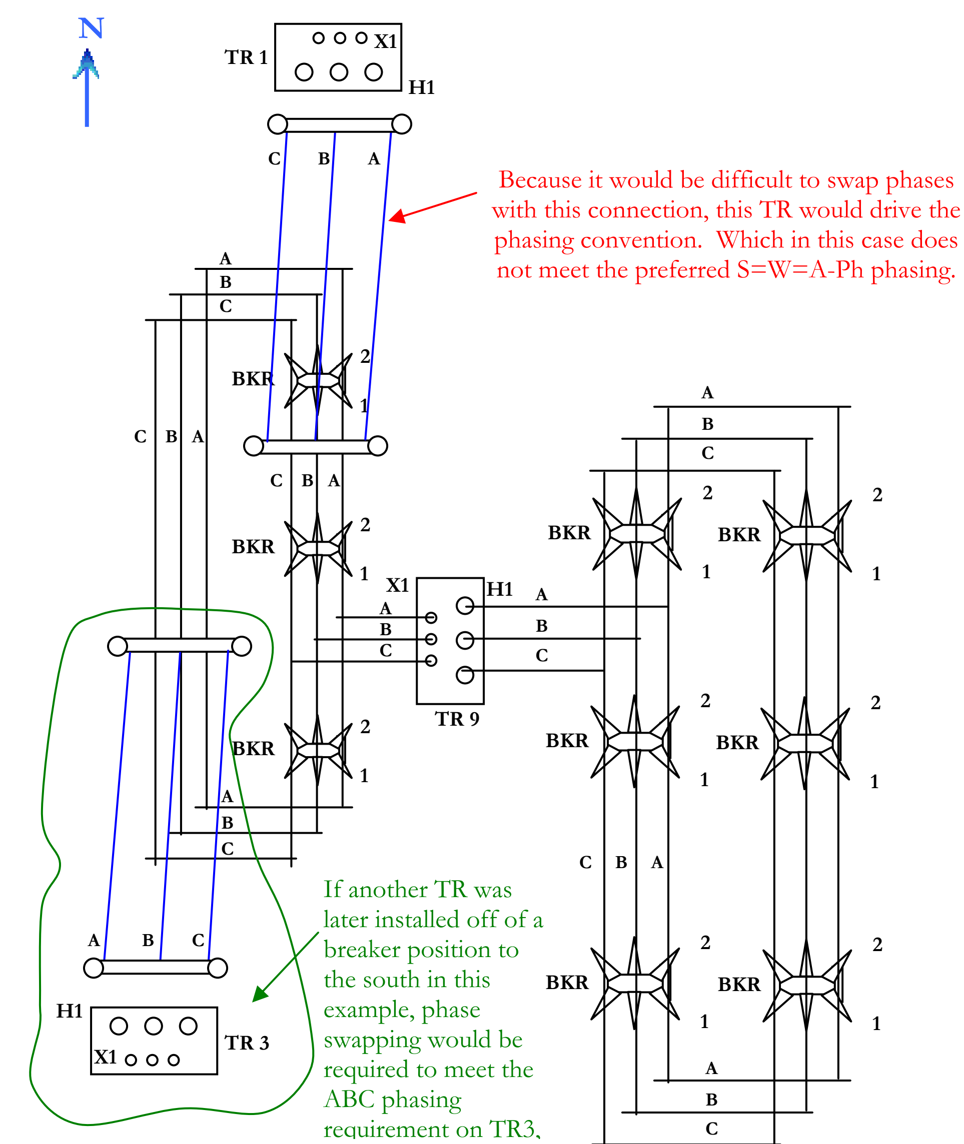
3.4.4. Phase markings should never be located on removable doors, circuit breaker oil tanks, etc. where the phase markings may be interchanged.

3.4.5. Whenever practical, phase markings should not be located on or near the energized parts of equipment.



Example 1

Situation where for the most part S = W = A-Ph for all but the buses connecting TR 9.



Example 2

Situation where all TR Phasing and buses match, but it is not the preferred S = W = A-Ph phasing

FIGURE 2

Instruction for Marking Phases in Stations

Xcel Energy - North	Date: 11/11/2011	Approved: SJM/JMT	Rev. 2	Substation Engineering & Design Standards	
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SUBSTATION TUBULAR BUS CRITERIA

TABLE OF CONTENTS

1. Introduction

This standard provides allowable tubular bus spans for typical Xcel Energy substation configurations and analyzes these typical bus layouts. Results from this analysis are in the form of tables that can be used to layout a substation. If the desired layout does not meet all aspects of the criteria, detailed analysis of the electrical and structural requirements will be necessary.

In the process of developing the standard, it was apparent that too many tables would be produced due to the number of variables. The tables provided at the end of this document are not meant to satisfy all anticipated Xcel Energy substation layouts, but will meet the needs of a majority of typical layouts.

2. Scope

This standard covers outdoor distribution and transmission substations which meet all criteria as defined in this standard. If a substation does not meet **all** criteria, calculations must be performed to determine an acceptable bus span length.

The following tables can be found at the end of this standard.

The criteria that are set forth in this document are agreed upon by civil and electrical entities and are to be strictly followed. Therefore, if a bus span is to be used or analyzed and the criteria fall outside the scope of this document, engineers shall determine the electrical and structural requirements of the configuration.

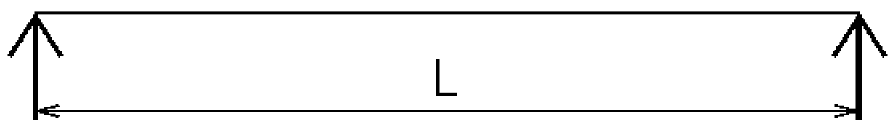
3. Definition of Terms

3.1. Span

Span is the allowable length of bus that can be supported by either a switch, a bus support or an A-frame tap. In the case of the bus supports and A-frame taps, the span is measured to the center-line of the supporting member. When switches are involved the span is measured from the middle of the switch pad.

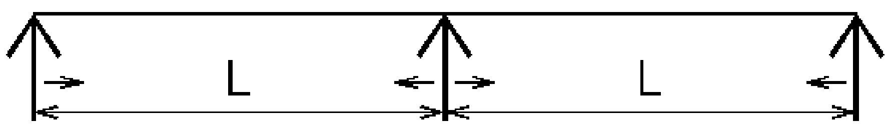
3.1.1. Single Span

A single span is a length of bus with two supports, one at each end.



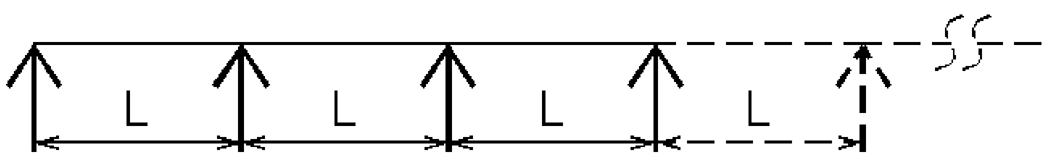
3.1.2. Double Span

A double span is a continuous length of bus with three supports. The spans can either be equal or unequal. If unequal spans are considered, the center support may be moved up to 20% of L along the bus in either direction and an end support may freely move towards the center support.



3.1.3. Multiple Span

A multiple span is a continuous length of bus with four or more supports. There is one support at each end and intermediate supports that divide the bus into three or more equal spans. If unequal spans are considered, the center and end supports may be moved as long as no single span is more than the allowable maximum span L.



4. Support Conditions

The support conditions of a bus span are either pinned or fixed connections to a supporting element.

4.1.1. Pinned Connection

In a pinned connection, moment is not transferred to the supporting member. In the case of a bus fitting over a bus support, the span is continuous and is considered a pinned connection even though it may be tack welded.

Examples: bus fittings over bus supports, expansion fittings on switches, A-frames

4.1.2. Fixed Connection

In a fixed connection, moment is transferred to the supporting member. In this standard, a fixed connection at the switch pad only transfers moment from vertical loads only.

Example: bus bolted directly to switch pad

4.2. Overbus and Underbus

Overbus and underbus loads are tap points from bus spanning perpendicular to a particular bus span. The placement of this point-load in the span varies with each configuration. The values in the tables represent overbus placed at mid-span.

Note: The placement of overbus in a span which has a fixed switch fitting should not be used; this **wi**ll always result in over-stressing the switch pad.

4.3. Bus Support

A bus support is assumed as a station post insulator for the purpose of this standard.

5. Design Criteria

5.1. Electrical Criteria

5.1.1. Voltage Classes

The following voltage classes (kV) were considered for this standard:

12.5/13.8
23
34.5
69
115
161
230
345

5.1.2. Fault Current

A maximum fault current value was determined for each voltage class considered in this standard. The maximum fault current selected for distribution voltages is based on typical transformer impedances and sizes utilized in most Xcel Energy distribution substations. The maximum fault current selected for transmission voltages (69 kV and above) is based on reasonably expected fault currents in Xcel Energy's system. Listed below are the selected fault currents for each voltage class:

Voltage Class (kV)	Basis for Selection	Selected Maximum Fault Current (kA)
12.5/13.8	3 - 28 MVA @ 7.5% 3 - 47 MVA @ 10.5% 2 - 70 MVA @ 10.5%	30
23	2 - 70 MVA @ 10.5%	20
34.5	2 - 70 MVA @ 7.5%	20
69	2 - 115/69 kV - 70 MVA @ 4%	20
115	Metro Area Loop Metro Area Loop Non-Metro Loop	63 40 23
161	Non-Metro Loop Eau Claire Substation (plus growth)	30 23
230	Metro Area Loop Non-Metro Loop Non-Metro Loop	40 30 23
345	Metro Area Loop Non-Metro Loop Non-Metro Loop	40 30 23

5.1.3. Phase Spacing

Phase spacing was taken from Xcel Energy standards ED 4.02.02.02 and ED 4.02.02.03 based upon current Xcel Energy standard substation design. The following table lists the minimum phase spacing used in this standard. Larger phase spacing may be used.

Voltage Class (kV)	Phase Spacing (feet)	
	w/o switches	w/ switches
12.5/13.8	3'-0"	4'-0"
23	3'-6"	5'-0"
34.5	3'-6"	6'-0"
69	5'-0"	8'-0"
115	8'-0"	10'-0"
161	9'-0"	14'-0"
230	16’-0”	16’-0”
345	16’-0”	16’-0”

5.2. Bus Type & Material

All tubular bus is formed using 6063-T6 aluminum alloy that has an allowable stress limit of 25,000 psi for bending. This standard is valid for the following aluminum tubular bus types at the selected voltage classes:

Voltage Class (kV)	Bus Type
12.5/13.8	3 1/2" & 5" Sch. 40
23	3 1/2" & 5" Sch. 40
34.5	3 1/2" & 5" Sch. 40
69	3 1/2" & 5" Sch. 40
115	3 1/2", 5", & 6" Sch. 40
161	3 1/2", 5", & 6" Sch. 40
230	3 1/2", 5", & 6" Sch. 40
345	3 1/2", 5", & 6" Sch. 40

5.3. Loading Conditions

All bus calculations were done with three loading conditions:

Load Case #1: 40 mph wind, short circuit load and 1/2" radial ice (influences load on fixed connection at switches)

Load Case #2: 90 mph wind, short circuit load and no ice (influences horizontal load on switches and bus supports)

Load Case #3: Self weight of the bus (used for normal deflections)

5.4. Equations

5.4.1. Wind Equations: The horizontal force on the bus due to wind (Ref. 3 and 5)

Load Case 1:

$$Wind_{40mph} := (4psf)\cdot\frac{Bus_{OD} + 2\cdot I}{12}$$

Load Case 2:

$$Wind_{90mph} := 0.00256k_z\cdot G_{RF}\cdot V^2\cdot\frac{Bus_{OD}}{12}$$

Where:

$Wind_{mph}$ = Wind load, lb/ft
V = Wind velocity, 90 mph
Bus_{OD} = Outer diameter of bus, inches
I = Radial ice thickness, ½ inches
k_z = Velocity pressure exposure coefficient, 0.92 for bus under 33 ft in elevation.
GRF = Gust response factor, 1.0

5.4.2. **Short Circuit Equation:** The horizontal force on the bus due to short circuitforce (IEEE Std 605-1998, Ref. 2):

$$F_{sc} := \frac{5.4\,\Gamma\cdot\left(D_f\cdot\sqrt{2}\cdot I_{sc}\right)^2}{10^7\cdot D}$$

Where:

F_{sc} = Short circuit load on bus, lb/ft
I_{sc} = Fault current, amps
D = Bus phase spacing, inches
D_f = Decrement factor, 1.6
 = constant based on fault type, 1.0

5.4.3. **Ice Load Equation:** The vertical load on the bus due to ice load (Ref. 1):

$$W_{ice} := \left(\gamma_{ice}\right)\cdot\left(\frac{\pi}{4}\right)\cdot\left[\left(\frac{Bus_{OD} + 1\cdot in}{12}\right)^2 - \left(\frac{Bus_{OD}}{12}\right)^2\right]$$

Where:

W_{ice} = Weight of ice on bus, lb/ft
γ_{ice} = Weight of ice, 57 lb/ft^3
Bus_{OD} = Outer diameter of bus, inches

5.5. Switch Pad Moment Capacity

The allowable switch pad moment capacity for all types of switches at all voltage classes being considered in this standard is assumed to be a minimum of 4000 in-lb due to vertical loads only. This capacity affects bus span when there is a fixed connection to a switch pad. A value of 4000 in-lb was decided to be the minimum acceptable pad moment strength and the maximum design moment capacity by Xcel Energy and switch manufacturers.

5.6. Horizontal Load Capacities of Switches

The following table lists the allowable horizontal loads at the switch pad allowed in this standard:

Voltage Class (kV)	Allowable Horizontal Switch Load (lbs.)
12.5/13.8	1,039
23	805
34.5	657
69	423
115	1,050
161	939
230	672
345	477

The controlling horizontal load capacities of the switches listed in the table were provided by USCO Power Equipment Corporation switches and are a function of the weakest component of the switch (insulator, bearing, etc.). These are not operational loads and are higher than ANSI C37.32 allowable terminal pad loads.

5.7. Horizontal Load Capacities of Insulators (Cantilever Strength)

The following table lists the ultimate horizontal loads applied at the top of the insulator allowed in this standard:

Voltage Class (kV)	Ultimate Horizontal Standard Strength Insulator Load (lbs.)	Ultimate Horizontal High Strength Insulator Load (lbs.)	Ultimate Horizontal Extra High Strength Insulator Load (lbs.)
12.5/13.8	2,000	Not Used	Not Used
23	2,000	Not Used	Not Used
34.5	2,000	Not Used	Not Used
69	1,500	Not Used	Not Used
115	1,700	2,600	4,500
161	1,200	1,850	Not Used
230	950	1,450	Not Used
345	1,000	1,450	2,000

Notes:

Overload factors for ultimate design are as follows: 2.5 for wind, 1.0 for short circuit.

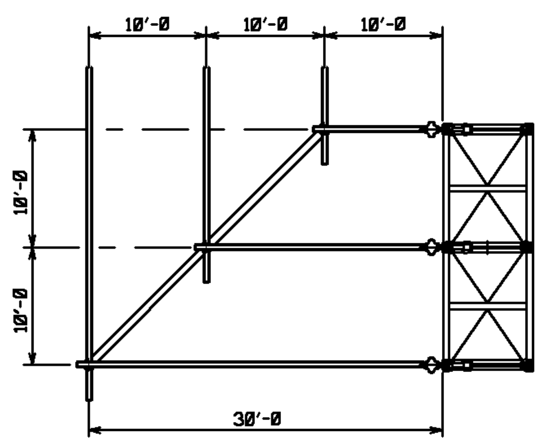
The bolt hole size and pattern changes for 115kV extra high strength insulators and for 345kV high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.

5.8. Overbus/Underbus Loads

The loads applied at an overbus/underbus tap point are treated as vertical point-loads on the span. It is assumed that the combined effects of short circuit loads acting simultaneously on the overbus and underbus are a less critical case for bus design and are not considered in this standard. The loads that were used for design are summarized in the following table:

Voltage Class (kV)	Bus Size	Overbus Span (ft.)	Overbus/Underbus Point-Load w/ No-Ice (lbs.)
12.5/13.8, 23, 34.5, 69, 115	3 1/2"	30	85
12.5/13.8, 23, 34.5, 69, 115	5"	30	125
115	6"	30	140
161	3 1/2"	40	105
161	5"	40	145
161	6"	40	175
230, 345	3 1/2"	40	160
230, 345	5"	40	200
230, 345	6"	40	230

The amount of weight that the vertical point-load induces is dependent on the voltage class and span arrangements. The overbus arrangement is an A-frame tapping up to a bus spanning perpendicular to the main bus. This perpendicular bus is assumed to span to either a switch or a bus support. Half of the overbus span plus the weight of the A-frame makes up the vertical point-load on the main bus span. For example*, in the case of 115kV with standard ten foot phase spacing, the overbus span would be 30 feet of bus: two ten foot phase spacing plus one more phase spacing to the next support. Also, for the 115kV class, there would be approximately 18 feet of two and a half inch bus in the A-frame. This brings the total vertical point-load to roughly 125 lb. For load cases with ice, the vertical point-load is doubled. The loads at 161kV, 230kV, and 345kV are greater because of larger phase spacing.



*115 kV Example

5.9. Bus Deflection

The vertical deflection of the bus was defined to be an aesthetic issue in bus span design. Deflection criteria for rigid bus shall be L/200, where L is the length of span between supports, with the exception of bus in a simple span with overbus where the deflection will be limited to L/150. Deflections should be considered on bus without ice. Ice loads are considered temporary and should not be included.

6. Calculations

6.1. Single Span Calculations

Calculations must be performed if the substation bus configuration does not meet all of the criteria in this standard. The following equations should be used (All equations are general structural equations, Ref. 4):

6.1.1. Single Span without Overbus

6.1.1.1. Fixed-Pinned End Conditions

a) Moment at Switch with Fixed Fitting:

$$M := \frac{3 \cdot W_{ice} \cdot L^2}{2}$$

Where:

M	=	Moment at switch with fixed fitting, in-lb.
W_{ice}	=	Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
L	=	Span, ft.

b) Maximum Horizontal Load:

$$H := \frac{1}{2} \cdot \left(Wind_{90} + F_{sc}\right) \cdot L$$

Where:

H	=	Horizontal reaction at the switch, lb
$Wind_{90}$	=	90 mph wind load on the bus, lb/ft
F_{sc}	=	Fault current load on the bus, lb/ft
L	=	Span, ft.

c) Maximum Vertical Load (at Fixed End):

$$V := \frac{5 \cdot W_{ice} \cdot L}{8}$$

Where:

- V = Vertical reaction at the switch, lb
- W_{ice} = Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
- L = Span, ft.

d) Normal Deflection:

$$\Delta := 9.34 \cdot \frac{W_{no\_ice} \cdot L^4}{E \cdot I}$$

Where:

- Δ = Deflection of bus, inches
- W_{no_ice} = Self weight of bus, lb/ft
- L = Span, ft.
- E = Modulus of elasticity of bus, 10,000,000 psi
- I = Moment of inertia of bus, in^4

e) Fiber Stress Moment: Use the greater of the following two equations:

Load Case 1:

$$M := 12\sqrt{\left(W_{ice} \cdot \frac{L^2}{8}\right)^2 + \left[\frac{\left(Wind_{40mph} + F_{sc}\right) \cdot L^2}{8}\right]^2}$$

Load Case 2:

$$M := 12\sqrt{\left(W_{no\_ice} \cdot \frac{L^2}{8}\right)^2 + \left[\frac{\left(Wind_{90mph} + F_{sc}\right) \cdot L^2}{8}\right]^2}$$

The maximum moment can then be used to determine the stress in the bus:

$$\sigma := \frac{M}{S}$$

Where:

- M = Maximum moment in bus, in-lb
- W_{ice} = Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
- W_{no_ice} = Self weight of bus, lb/ft
- L = Span, ft.
- $Wind_{mph}$ = Wind load, lb/ft
- F_{sc} = Fault current load on the bus, lb/ft
- σ = Stress in the bus, lb/in^2
- S = Section modulus of the bus, in^3

6.1.1.2. Pinned-Pinned End Conditions

a) Maximum Horizontal Load Either End:

$$H := \frac{1}{2} \cdot \left(Wind_{90} + F_{sc}\right) \cdot L$$

Where:

- H = Horizontal reaction at either end, lb
- $Wind_{90}$ = 90 mph wind load on the bus, lb/ft
- F_{sc} = Fault current load on the bus, lb/ft
- L = Span, ft.

b) Maximum Vertical Load:

$$V := \frac{W_{ice} \cdot L}{2}$$

Where:

- V = Vertical reaction at either end, lb
- W_{ice} = Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
- L = Span, ft.

c) Normal Deflection:

$$\Delta := 22.5 \cdot \left(\frac{W_{no\_ice} \cdot L^4}{E \cdot I} \right)$$

Where:

Δ	=	Deflection of bus, inches
W_{no_ice}	=	Self weight of bus, lb/ft
L	=	Span, ft.
E	=	Modulus of elasticity of bus, 10,000,000 psi
I	=	Moment of inertia of bus, in^4

d) Fiber Stress Moment: Use the greater of the following two equations:

Load Case 1:

$$M := 12 \sqrt{\left(W_{ice} \cdot \frac{L^2}{8} \right)^2 + \left[\frac{\left(Wind_{40mph} + F_{sc} \right) \cdot L^2}{8} \right]^2}$$

Load Case 2:

$$M := 12 \sqrt{\left(W_{no\_ice} \cdot \frac{L^2}{8} \right)^2 + \left[\frac{\left(Wind_{90mph} + F_{sc} \right) \cdot L^2}{8} \right]^2}$$

The maximum moment can then be used to determine the stress in the bus:

$$\sigma := \frac{M}{S}$$

Where:

M	=	Maximum moment in bus, in-lb
W_{ice}	=	Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
W_{no_ice}	=	Self weight of bus, lb/ft
L	=	Span, ft.
$Wind_{mph}$	=	Wind load, lb/ft
F_{sc}	=	Fault current load on the bus, lb/ft
σ	=	Stress in the bus, lb/in^2
S	=	Section modulus of the bus, in^3

6.1.2. Single Span with Overbus

6.1.2.1. Pinned-Fixed End Conditions

This calculation always results in the moment at the switch exceeding the 4000 in-lb switch pad capacity. Therefore, an expansion fitting must be used at the switch.

6.1.2.2. Pinned-Pinned End Conditions

a) Maximum Horizontal Load Either End:

$$H := \frac{1}{2} \cdot \left(Wind_{90} + F_{sc}\right) \cdot L$$

Where:

H	=	Horizontal reaction at either end, lb
$Wind_{90}$	=	90 mph wind load on the bus, lb/ft
F_{sc}	=	Fault current load on the bus, lb/ft
L	=	Span, ft.

b) Maximum Vertical Load:

$$V := \frac{W_{ice} \cdot L}{2} + \frac{P_{ice}}{2}$$

Where:

V	=	Vertical reaction at either end, lb
W_{ice}	=	Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
P_{ice}	=	Overbus load with ice, lb.
L	=	Span, ft.

c) Normal Deflection:

$$\Delta := 22.5 \cdot \left(\frac{W_{no\_ice} \cdot L^4}{E \cdot I}\right) + \frac{P_{no\_ice} \cdot L^3}{48 \cdot E \cdot I}$$

Where:

Δ	=	Deflection of bus, inches
W_{no_ice}	=	Self weight of bus, lb/ft
L	=	Span, ft.
P_{no_ice}	=	Overbus load without ice, lb.
E	=	Modulus of elasticity of bus, 10,000,000 psi
I	=	Moment of inertia of bus, in^4

d) Fiber Stress Moment: Use the greater of the following two equations:

Load Case 1:

$$M := 12\sqrt{\left(W_{ice}\cdot\frac{L^2}{8} + P_{ice}\cdot\frac{L}{4}\right)^2 + \left[\frac{\left(Wind_{40mph} + F_{sc}\right)\cdot L^2}{8}\right]^2}$$

Load Case 2:

$$M := 12\sqrt{\left(W_{no\_ice}\cdot\frac{L^2}{8} + P_{no\_ice}\cdot\frac{L}{4}\right)^2 + \left[\frac{\left(Wind_{90mph} + F_{sc}\right)\cdot L^2}{8}\right]^2}$$

Where:

M	=	Maximum moment in bus, in-lb
W_{ice}	=	Uniform vertical load on bus including 1/2" ice and self weight, lb/ft
W_{no_ice}	=	Self weight of bus, lb/ft
P_{ice}	=	Overbus load with ice, lb.
P_{no_ice}	=	Overbus load without ice, lb.
L	=	Span, ft.
$Wind_{mph}$	=	Wind load, lb/ft
F_{sc}	=	Fault current load on the bus, lb/ft

6.2. Double or Multiple Span Calculations

The equations for double and multiple spans are not easily written. The procedure for determining span reactions, deflections and moments should be done using a structural analysis program.

7. Explanation of Bus Span Tables

The tables present maximum spans that meet allowable design considerations that have been presented in this document. The spans were analyzed by modeling the supports, end conditions and members. Loads were applied to a model to determine the structural capacity. Normal deflections, stress and support reactions were checked against allowable values.

8. Assumptions and Recommended Practices

The lessons learned in the process of establishing this standard are numerous and complex. The following are some lessons that played roles in the forming of this standard.

1) <u>Switch as a Structural Component</u>

A switch is made up of several independent structural components including the pad, the insulators, the base, and the blade and jaw. It is not possible to accurately model the switch as a single structural component.

2) Switch Pad Capacity

This can be simply stated as " the stronger the pad the longer the span". Different switch manufactures have structurally stronger pads than others. A value of 4000 in-lb was decided to be the minimum acceptable pad moment strength and the maximum design moment capacity.

3) Expansion Fittings

The typical expansion fitting will relieve the switch pad of moment. The expansion fitting can be structurally installed with the fins orientated vertically or horizontally. However, for clearance purposes, Xcel Energy practice is to install the fins horizontal. Pullout of the bus from the expansion fitting was determined not to be an issue provided it is installed properly. On single span switch to switch configurations (both switches having expansion fittings), there should be a 1.25" gap between the casting face and the bus end. Other configurations should follow the manufacturer recommendations for installation.

4) Bus Deflection

The vertical deflection of the bus was determined not to be of paramount importance. The aesthetics of the bus deflection does not have to limit the span of the bus. However, for this standard, the deflection criteria for rigid bus shall be L/200, where L is the length of span between supports, with the exception of bus in a simple span with overbus where the deflection will be limited to L/150.

5) Breaker and Transformer Bushing Connections

When connecting directly to a breaker or transformer bushing, it is recommended to use a flexible jumper rather than a rigid bus connection. This standard does not include rigid bus connections to breaker or transformer bushings.

9. References

(1) Beer, F.P. and Johnston, E.R., "Mechanics of Materials", 2nd Edition, 1991.

(2) "IEEE Guide for Design of Substation Rigid-Bus Structures", ANSI / IEEE Standard 605-1998.

(3) "Civil/Structural Performance Criteria" Xcel Energy DC-F, 02/21/03.

(4) West, H.H., "Analysis of Structures", 2nd Edition, 1989.

(5) "National Electric Safety Code" IEEE C2-2002.

10. Maximum Rigid Bus Span Length Tables

The tables that follow are the applications that were analyzed for this standard.

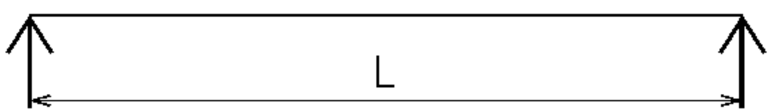
Note: The existence of IEEE 605-2008 is acknowledged. IEEE 605-2008 is a more recent standard than what is utilized in this standard. The incorporation of IEEE 605-2008 for this standard is presently in review; it may be incorporated into future versions of this standard.

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
12.5/13.8	30	3'-0	3.5”	Standard	21'-0	0.12	LF1	23'-0	0.41	LF3	23'-0	0.41	LF3
12.5/13.8	30	3'-0	5”	Standard	17'-0	0.03	LF1	26’-6	0.37	LF2	34’-0	0.99	LF3
12.5/13.8	30	4'-0	3.5”	Standard	21'-0	0.12	LF1	26'-0	0.67	LF3	26'-0	0.67	LF3
12.5/13.8	30	4'-0	5”	Standard	17'-0	0.03	LF1	34’-0	0.99	LF2	38’-6	1.63	LF3
23	20	4'-0	3.5”	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
23	20	4'-0	5”	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
23	20	5'-0	3.5”	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
23	20	5'-0	5”	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
34.5	20	4'-0	3.5”	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
34.5	20	4'-0	5”	Standard	17'-0	0.03	LF1	41'-0	2.10	LF2	43'-0	2.54	LF4
34.5	20	6'-0	3.5”	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
34.5	20	6'-0	5”	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
69	20	5'-0	3.5”	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
69	20	5'-0	5”	Standard	17'-0	0.03	LF1	31’-0	0.69	LF2	43'-0	2.54	LF4
69	20	8'-0	3.5”	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
69	20	8'-0	5”	Standard	17'-0	0.03	LF1	41'-0	2.10	LF2	43'-0	2.54	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	23	8'-0	3.5"	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
115	23	8'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
115	23	8'-0	6"	Standard	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4
115	23	10'-0	3.5"	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
115	23	10'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
115	23	10'-0	6"	Standard	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4
115	40	8'-0	3.5"	Standard	21'-0	0.12	LF1	27'-6	0.84	LF3	27'-6	0.84	LF3
115	40	8'-0	5"	Standard	17'-0	0.03	LF1	38'-0	1.55	LF2	40’-6	2.00	LF3
115	40	8'-0	6"	Standard	15'-6	0.01	LF1	37'-0	0.97	LF2	47’-0	2.53	LF5
115	40	10'-0	3.5"	Standard	21'-0	0.12	LF1	30'-0	1.19	LF3	30'-0	1.19	LF3
115	40	10'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
115	40	10'-0	6"	Standard	15'-6	0.01	LF1	44’-0	1.95	LF2	48’-6	2.87	LF4
115	40	8'-0	3.5"	High	21'-0	0.12	LF1	27'-6	0.84	LF3	27'-6	0.84	LF3
115	40	8'-0	5"	High	17'-0	0.03	LF1	38’-0	1.55	LF2	40’-6	2.00	LF3
115	40	8'-0	6"	High	15'-6	0.01	LF1	37’-0	0.97	LF2	48’-6	2.87	LF4
115	40	10'-0	3.5"	High	21'-0	0.12	LF1	30'-0	1.19	LF3	30'-0	1.19	LF3
115	40	10'-0	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
115	40	10'-0	6"	High	15'-6	0.01	LF1	44’-0	1.95	LF2	48’-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

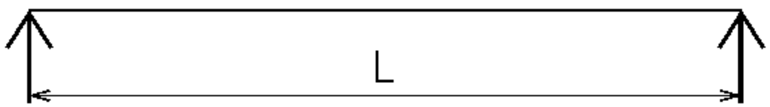
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	63	10	5"	Standard	17'-0	0.03	LF1	21'-0 *	0.14	LF2	30'-0	0.60	LF3
115	63	10	6"	Standard	15'-6	0.01	LF1	20'-6	0.09	LF2	29'-0	0.37	LF5
115	63	10	5"	Extra High	17'-0	0.01	LF1	21'-0 *	0.14	LF2	30'-0	0.60	LF3
115	63	10	6"	Extra High	15'-6	0.01	LF1	20'-6	0.09	LF2	37'-0	0.97	LF3

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

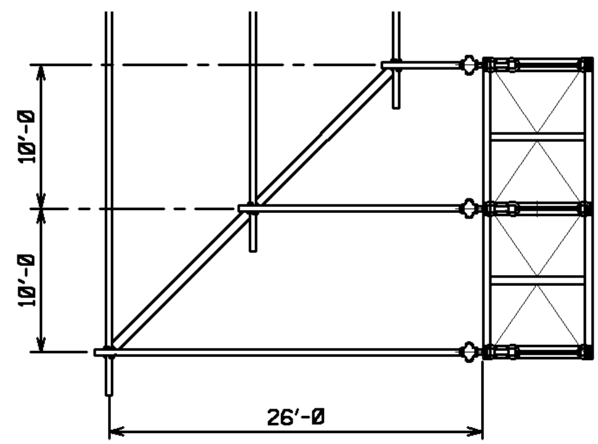
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support

* In the case where the standard 115kV ring-bus layout is used, a 26'-0 span is acceptable from the switch pad to the 45 degree bus support for the longest of the three spans. This is possible due to the shorter adjacent spans contributing less short circuit load.

<u>**Note:**</u> The bolt hole size and pattern changes for 115kV extra high strength insulators.
To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.



* 115 kV Ring-Bus Layout

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
161	23	9'-0	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
161	23	9'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	23	9'-0	6"	Standard	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
161	23	14'-0	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
161	23	14'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	23	14'-0	6"	Standard	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
161	23	9'-0	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
161	23	9'-0	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	23	9'-0	6"	High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
161	23	14'-0	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
161	23	14'-0	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	23	14'-0	6"	High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
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Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

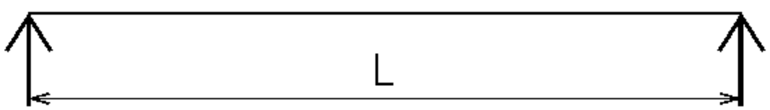
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
161	30	9'-0	3.5"	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
161	30	9'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	30	9'-0	6"	Standard	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4
161	30	14'-0	3.5"	Standard	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
161	30	14'-0	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	30	14'-0	6"	Standard	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4
161	30	9'-0	3.5"	High	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
161	30	9'-0	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	30	9'-0	6"	High	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4
161	30	14'-0	3.5"	High	21'-0	0.12	LF1	34’-0	1.96	LF4	34’-0	1.96	LF4
161	30	14'-0	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
161	30	14'-0	6"	High	15'-6	0.01	LF1	48’-6	2.87	LF4	48’-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

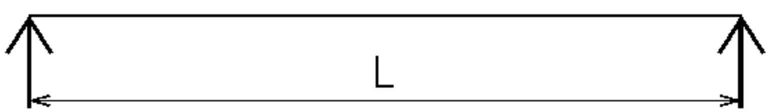
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
230	23	16	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	23	16	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
230	23	16	6"	Standard	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
230	30	16	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	30	16	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
230	30	16	6"	Standard	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
230	40	16	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	40	16	5"	Standard	17'-0	0.03	LF1	42'-0	2.31	LF2	42'-0	2.31	LF5
230	40	16	6"	Standard	15'-6	0.01	LF1	38'-0	1.08	LF5	38'-0	1.08	LF5
230	23	16	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	23	16	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
230	23	16	6"	High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
230	30	16	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	30	16	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
230	30	16	6"	High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
230	40	16	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
230	40	16	5"	High	17'-0	0.03	LF1	42'-0	2.31	LF2	43'-0	2.54	LF4
230	40	16	6"	High	15'-6	0.01	LF1	40'-0	1.33	LF2	48'-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

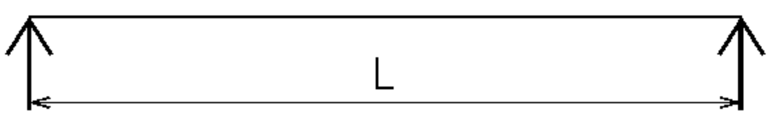
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
345	23	16	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	23	16	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	23	16	6"	Standard	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
345	30	16	3.5"	Standard	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	30	16	5"	Standard	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	30	16	6"	Standard	15'-6	0.01	LF1	40'-6	1.40	LF2	48'-6	2.87	LF4
345	40	16	3.5"	Standard	21'-0	0.12	LF1	32'-0	1.54	LF2	34'-0	1.96	LF4
345	40	16	5"	Standard	17'-0	0.03	LF1	30'-0	0.60	LF2	43'-0	2.54	LF4
345	40	16	6"	Standard	15'-6	0.01	LF1	28'-0	0.32	LF2	40'-6	1.40	LF5
345	23	16	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	23	16	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	23	16	6"	High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
345	30	16	3.5"	High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	30	16	5"	High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	30	16	6"	High	15'-6	0.01	LF1	40'-6	1.40	LF2	48'-6	2.87	LF4
345	40	16	3.5"	High	21'-0	0.12	LF1	32'-0	1.54	LF2	34'-0	1.96	LF4
345	40	16	5"	High	17'-0	0.03	LF1	30'-0	0.60	LF2	43'-0	2.54	LF4
345	40	16	6"	High	15'-6	0.01	LF1	28'-0	0.32	LF2	48'-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE I (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Extra High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	23	16	5"	Extra High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	23	16	6"	Extra High	15'-6	0.01	LF1	48'-6	2.87	LF4	48'-6	2.87	LF4
345	30	16	3.5"	Extra High	21'-0	0.12	LF1	34'-0	1.96	LF4	34'-0	1.96	LF4
345	30	16	5"	Extra High	17'-0	0.03	LF1	43'-0	2.54	LF4	43'-0	2.54	LF4
345	30	16	6"	Extra High	15'-6	0.01	LF1	40'-6	1.40	LF2	48'-6	2.87	LF4
345	40	16	3.5"	Extra High	21'-0	0.12	LF1	32'-0	1.54	LF2	34'-0	1.96	LF4
345	40	16	5"	Extra High	17'-0	0.03	LF1	30'-0	0.60	LF2	43'-0	2.54	LF4
345	40	16	6"	Extra High	15'-6	0.01	LF1	28'-0	0.32	LF2	48'-6	2.87	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

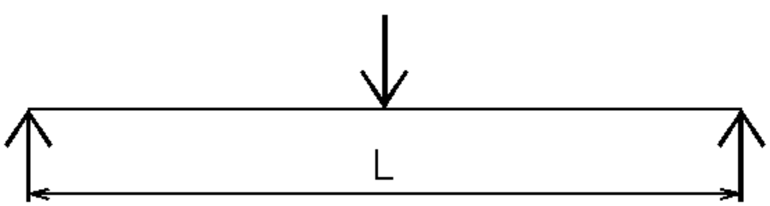
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
12.5/13.8	30	3'-0	3.5"	Standard	Do Not Use App #1		LF1	22’-6	1.11	LF3	22’-6	1.11	LF3
12.5/13.8	30	3'-0	5"	Standard	Do Not Use App #1		LF1	26'-6	0.92	LF2	33’-6	2.04	LF3
12.5/13.8	30	4'-0	3.5"	Standard	Do Not Use App #1		LF1	26'-0	1.80	LF3	26'-0	1.80	LF3
12.5/13.8	30	4'-0	5"	Standard	Do Not Use App #1		LF1	34'-0	2.17	LF2	37’-0	2.90	LF4
23	20	4'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
23	20	4'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
23	20	5'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
23	20	5'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
34.5	20	4'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
34.5	20	4'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
34.5	20	6'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
34.5	20	6'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
69	20	5'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
69	20	5'-0	5"	Standard	Do Not Use App #1		LF1	31'-0	1.57	LF2	37’-0	2.90	LF4
69	20	8'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
69	20	8'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

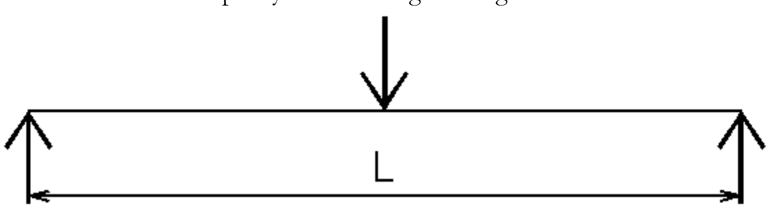
Application #3:
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	23	8'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
115	23	8'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	23	8'-0	6"	Standard	Do Not Use App #1		LF1	44'-0	3.50	LF4	44'-0	3.50	LF4
115	23	10'-0	3.5"	Standard	Do Not Use App #1		LF1	27'-6	2.18	LF4	27'-6	2.18	LF4
115	23	10'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	23	10'-0	6"	Standard	Do Not Use App #1		LF1	44'-0	3.50	LF4	44'-0	3.50	LF4
115	40	8'-0	3.5"	Standard	Do Not Use App #1		LF1	27’-0	2.04	LF3	27’-0	2.04	LF3
115	40	8'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	40	8'-0	6"	Standard	Do Not Use App #1		LF1	37'-0	1.89	LF2	44'-0	3.50	LF4
115	40	10'-0	3.5"	Standard	Do Not Use App #1		LF1	27’-6	2.18	LF4	27’-6	2.18	LF4
115	40	10'-0	5"	Standard	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	40	10'-0	6"	Standard	Do Not Use App #1		LF1	44'-0	3.50	LF4	44'-0	3.50	LF4
115	40	8'-0	3.5"	High	Do Not Use App #1		LF1	27’-0	2.04	LF3	27’-0	2.04	LF3
115	40	8'-0	5"	High	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	40	8'-0	6"	High	Do Not Use App #1		LF1	37'-0	1.89	LF2	44'-0	3.50	LF4
115	40	10'-0	3.5"	High	Do Not Use App #1		LF1	27’-6	2.18	LF4	27’-6	2.18	LF4
115	40	10'-0	5"	High	Do Not Use App #1		LF1	37'-0	2.90	LF4	37'-0	2.90	LF4
115	40	10'-0	6"	High	Do Not Use App #1		LF1	44'-0	3.50	LF4	44'-0	3.50	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

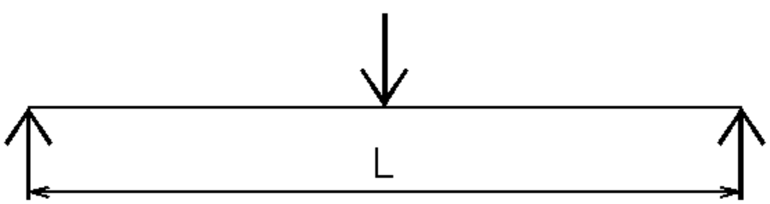
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	63	10	5"	Standard	Do Not Use App #1		LF1	21'-0	0.42	LF2	30'-0	1.41	LF3
115	63	10	6"	Standard	Do Not Use App #1		LF1	20'-6	0.25	LF2	29'-0	0.81	LF5
115	63	10	5"	Extra High	Do Not Use App #1		LF1	21'-0	0.42	LF2	30'-0	1.41	LF3
115	63	10	6"	Extra High	Do Not Use App #1		LF1	20'-6	0.25	LF2	37'-0	1.89	LF3
161	23	9'-0	3.5"	Standard	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	23	9'-0	5"	Standard	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	23	9'-0	6"	Standard	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	23	14'-0	3.5"	Standard	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	23	14'-0	5"	Standard	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	23	14'-0	6"	Standard	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	23	9'-0	3.5"	High	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	23	9'-0	5"	High	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	23	9'-0	6"	High	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	23	14'-0	3.5"	High	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	23	14'-0	5"	High	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	23	14'-0	6"	High	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support

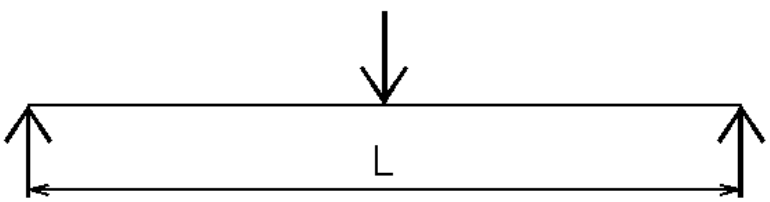
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
161	30	9'-0	3.5"	Standard	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	30	9'-0	5"	Standard	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	30	9'-0	6"	Standard	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	30	14'-0	3.5"	Standard	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	30	14'-0	5"	Standard	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	30	14'-0	6"	Standard	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	30	9'-0	3.5"	High	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	30	9'-0	5"	High	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	30	9'-0	6"	High	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4
161	30	14'-0	3.5"	High	Do Not Use App #1		LF1	26'-0	2.06	LF4	26'-0	2.06	LF4
161	30	14'-0	5"	High	Do Not Use App #1		LF1	36'-0	2.86	LF4	36'-0	2.86	LF4
161	30	14'-0	6"	High	Do Not Use App #1		LF1	42'-0	3.30	LF4	42'-0	3.30	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

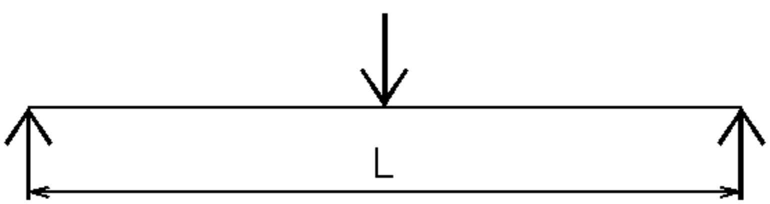
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
230	23	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	23	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	23	16	6"	Standard	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
230	30	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	30	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	30	16	6"	Standard	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
230	40	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	40	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	40	16	6"	Standard	Do Not Use App #1		LF1	38'-0	2.71	LF2	38'-8	2.80	LF5
230	23	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	23	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	23	16	6"	High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
230	30	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	30	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	30	16	6"	High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
230	40	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
230	40	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
230	40	16	6"	High	Do Not Use App #1		LF1	38'-0	2.71	LF2	40'-0	3.23	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:

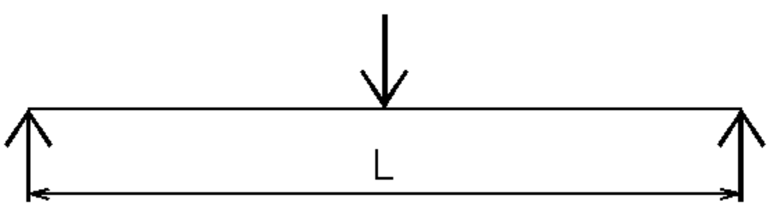
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
345	23	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	23	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	23	16	6"	Standard	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	30	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	30	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	30	16	6"	Standard	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	40	16	3.5"	Standard	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	40	16	5"	Standard	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	40	16	6"	Standard	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	23	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	23	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	23	16	6"	High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	30	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	30	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	30	16	6"	High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	40	16	3.5"	High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	40	16	5"	High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	40	16	6"	High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

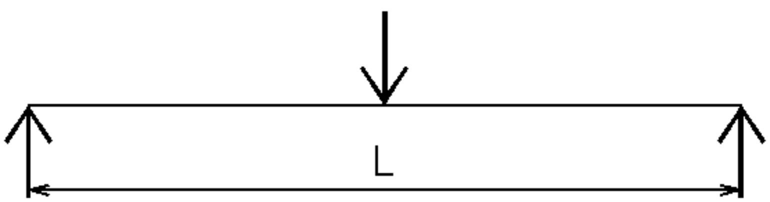
Application #3:
Bus Support to Bus Support

SINGLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE II (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
345	23	16	3.5"	Extra High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	23	16	5"	Extra High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	23	16	6"	Extra High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	30	16	3.5"	Extra High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	30	16	5"	Extra High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	30	16	6"	Extra High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4
345	40	16	3.5"	Extra High	Do Not Use App #1		LF1	22'-0	1.63	LF4	22'-0	1.63	LF4
345	40	16	5"	Extra High	Do Not Use App #1		LF1	33'-0	2.59	LF4	33'-0	2.59	LF4
345	40	16	6"	Extra High	Do Not Use App #1		LF1	40'-0	3.23	LF4	40'-0	3.23	LF4

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/150
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Switch Pad (expansion fitting at one end)
Switch Pad to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Switch Pad (expansion fitting at both ends)
Switch Pad to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
12.5/13.8	30	3'-0	3.5"	Standard	18'-6	0.09	LF5	18'-6	0.07	LF5	18'-6	0.07	LF5
12.5/13.8	30	3'-0	5"	Standard	17'-6	0.04	LF5	17'-6	0.03	LF5	17'-6	0.03	LF5
12.5/13.8	30	4'-0	3.5"	Standard	23'-6	0.22	LF5	23'-6	0.19	LF5	23'-6	0.19	LF5
12.5/13.8	30	4'-0	5"	Standard	21'-6	0.08	LF5	21'-6	0.07	LF5	21'-6	0.07	LF5
23	20	4'-0	3.5"	Standard	28'-0	0.45	LF1	36'-6	1.09	LF3	36'-6	1.09	LF3
23	20	4'-0	5"	Standard	23'-0	0.10	LF1	35'-6	0.50	LF5	35'-6	0.50	LF5
23	20	5'-0	3.5"	Standard	28'-0	0.45	LF1	40'-0	1.58	LF3	40'-0	1.58	LF3
23	20	5'-0	5"	Standard	23'-0	0.10	LF1	39'-6	0.76	LF5	39'-6	0.76	LF5
34.5	20	4'-0	3.5"	Standard	28'-0	0.45	LF1	36'-6	1.09	LF3	36'-6	1.09	LF3
34.5	20	4'-0	5"	Standard	23'-0	0.10	LF1	35'-6	0.50	LF5	35'-6	0.50	LF5
34.5	20	6'-0	3.5"	Standard	28'-0	0.45	LF1	42'-6	2.01	LF3	42'-6	2.01	LF3
34.5	20	6'-0	5"	Standard	23'-0	0.10	LF1	42'-6	1.02	LF5	42'-6	1.02	LF5
69	20	5'-0	3.5"	Standard	28'-0	0.45	LF1	35'-0	0.92	LF5	35'-0	0.92	LF5
69	20	5'-0	5"	Standard	23'-0	0.10	LF1	29'-6	0.24	LF5	29'-6	0.24	LF5
69	20	8'-0	3.5"	Standard	28'-0	0.45	LF1	44'-0	2.31	LF5	44'-0	2.31	LF5
69	20	8'-0	5"	Standard	23'-0	0.10	LF1	35'-0	0.47	LF5	35'-0	0.47	LF5

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	23	8'-0	3.5"	Standard	28'-0	0.45	LF1	42'-6	2.01	LF3	42'-6	2.01	LF3
115	23	8'-0	5"	Standard	23'-0	0.10	LF1	36’-0	0.52	LF5	36’-0	0.52	LF5
115	23	8'-0	6"	Standard	20'-6	0.05	LF1	32’-6	0.24	LF5	32’-6	0.24	LF5
115	23	10'-0	3.5"	Standard	28'-0	0.45	LF1	46'-0	2.76	LF4	46'-0	2.76	LF4
115	23	10'-0	5"	Standard	23'-0	0.10	LF1	39’-6	0.76	LF5	39’-6	0.76	LF5
115	23	10'-0	6"	Standard	20'-6	0.05	LF1	35'-0	0.33	LF5	35'-0	0.33	LF5
115	40	8'-0	3.5"	Standard	22'-0	0.17	LF5	22'-0	0.14	LF5	22'-0	0.14	LF5
115	40	8'-0	5"	Standard	20'-0	0.06	LF5	20'-0	0.05	LF5	20'-0	0.05	LF5
115	40	8'-0	6"	Standard	18’-6	0.03	LF5	18’-6	0.03	LF5	18’-6	0.03	LF5
115	40	10'-0	3.5"	Standard	25’-6	0.31	LF5	25’-6	0.26	LF5	25’-6	0.26	LF5
115	40	10'-0	5"	Standard	23'-0	0.10	LF1	23'-0	0.09	LF5	23'-0	0.09	LF5
115	40	10'-0	6"	Standard	20'-6	0.05	LF1	21’-6	0.05	LF5	21’-6	0.05	LF5
115	40	8'-0	3.5"	High	28'-0	0.45	LF1	27’-6	0.35	LF3	27’-6	0.35	LF3
115	40	8'-0	5"	High	23'-0	0.10	LF1	30’-6	0.27	LF6	30’-6	0.27	LF6
115	40	8'-0	6"	High	20’-6	0.05	LF1	28’-6	0.14	LF6	28’-6	0.14	LF6
115	40	10'-0	3.5"	High	28'-0	0.45	LF1	30’-0	0.50	LF3	30’-0	0.50	LF3
115	40	10'-0	5"	High	23'-0	0.10	LF1	35’-0	0.47	LF6	35’-0	0.47	LF6
115	40	10'-0	6"	High	20'-6	0.05	LF1	33’-0	0.26	LF6	33’-0	0.26	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

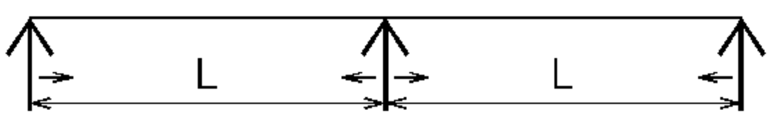
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	63	10	5"	Standard	12’-0	0.01	LF5	12’-0	0.01	LF5	12’-0	0.01	LF5
115	63	10	6"	Standard	11’-6	0.00	LF5	11’-6	0.00	LF5	11’-6	0.00	LF5
115	63	10	5"	Extra High	23’-0	0.10	LF1	28’-0	0.19	LF2	30’-0	0.25	LF3
115	63	10	6"	Extra High	20’-6	0.05	LF1	27’-6	0.13	LF2	30’-6	0.19	LF7
161	23	9'-0	3.5"	Standard	28'-0	0.45	LF1	32’-6	0.69	LF5	32’-6	0.69	LF5
161	23	9'-0	5"	Standard	23'-0	0.10	LF1	27'-0	0.17	LF5	27'-0	0.17	LF5
161	23	9'-0	6"	Standard	20'-6	0.05	LF1	24'-0	0.07	LF5	24'-0	0.07	LF5
161	23	14'-0	3.5"	Standard	28'-0	0.45	LF1	39'-0	1.42	LF5	39'-0	1.42	LF5
161	23	14'-0	5"	Standard	23'-0	0.10	LF1	31'-0	0.29	LF5	31'-0	0.29	LF5
161	23	14'-0	6"	Standard	20'-6	0.05	LF1	27'-0	0.12	LF5	27'-0	0.12	LF5
161	23	9'-0	3.5"	High	28'-0	0.45	LF1	44’-6	2.41	LF3	44’-6	2.41	LF3
161	23	9'-0	5"	High	23'-0	0.10	LF1	41’-6	0.92	LF6	41’-6	0.92	LF6
161	23	9'-0	6"	High	20'-6	0.05	LF1	37’-0	0.41	LF6	37’-0	0.41	LF6
161	23	14'-0	3.5"	High	28'-0	0.45	LF1	45’-6	2.64	LF4	45’-6	2.64	LF4
161	23	14'-0	5"	High	23'-0	0.10	LF1	48’-0	1.65	LF6	48’-0	1.65	LF6
161	23	14'-0	6"	High	20'-6	0.05	LF1	42’-0	0.68	LF6	42’-0	0.68	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support to Bus Support

Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
161	30	9'-0	3.5"	Standard	24’-6	0.26	LF5	24’-6	0.22	LF5	24’-6	0.22	LF5
161	30	9'-0	5"	Standard	21’-0	0.07	LF5	21’-0	0.06	LF5	21’-0	0.06	LF5
161	30	9'-0	6"	Standard	19’-0	0.03	LF5	19’-0	0.03	LF5	19’-0	0.03	LF5
161	30	14'-0	3.5"	Standard	28'-0	0.45	LF1	31’-0	0.56	LF5	31’-0	0.56	LF5
161	30	14'-0	5"	Standard	23'-0	0.10	LF1	26’-0	0.14	LF5	26’-0	0.14	LF5
161	30	14'-0	6"	Standard	20'-6	0.05	LF1	23’-0	0.06	LF5	23’-0	0.06	LF5
161	30	9'-0	3.5"	High	28'-0	0.45	LF1	36’-6	1.08	LF3	36’-6	1.08	LF3
161	30	9'-0	5"	High	23'-0	0.10	LF1	32’-6	0.34	LF6	32’-6	0.34	LF6
161	30	9'-0	6"	High	20'-6	0.05	LF1	30’-0	0.17	LF6	30’-0	0.17	LF6
161	30	14'-0	3.5"	High	28'-0	0.45	LF1	43’-0	2.08	LF3	43’-0	2.08	LF3
161	30	14'-0	5"	High	23'-0	0.10	LF1	40’-0	0.79	LF6	40’-0	0.79	LF6
161	30	14'-0	6"	High	20'-6	0.05	LF1	36’-0	0.36	LF6	36’-0	0.36	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:
Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support to Bus Support

Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
230	23	16	3.5"	Standard	28'-0	0.45	LF1	32'-0	0.65	LF5	32'-0	0.65	LF5
230	23	16	5"	Standard	23'-0	0.10	LF1	25'-0	0.12	LF5	25'-0	0.12	LF5
230	23	16	6"	Standard	20'-6	0.05	LF1	22'-0	0.05	LF5	22'-0	0.05	LF5
230	30	16	3.5"	Standard	26'-0	0.34	LF5	26'-0	0.28	LF5	26'-0	0.28	LF5
230	30	16	5"	Standard	21'-6	0.08	LF5	21'-6	0.07	LF5	21'-6	0.07	LF5
230	30	16	6"	Standard	19'-0	0.03	LF5	19'-0	0.03	LF5	19'-0	0.03	LF5
230	40	16	3.5"	Standard	19'-6	0.11	LF5	19'-6	0.09	LF5	19'-6	0.09	LF5
230	40	16	5"	Standard	16'-6	0.03	LF5	16'-6	0.02	LF5	16'-6	0.02	LF5
230	40	16	6"	Standard	15'-0	0.01	LF5	15'-0	0.01	LF5	15'-0	0.01	LF5
230	23	16	3.5"	High	28'-0	0.45	LF1	46'-0	2.76	LF4	46'-0	2.76	LF4
230	23	16	5"	High	23'-0	0.10	LF1	39'-0	0.72	LF6	39'-0	0.72	LF6
230	23	16	6"	High	20'-6	0.05	LF1	34'-0	0.29	LF6	34'-0	0.29	LF6
230	30	16	3.5"	High	28'-0	0.45	LF1	40'-0	1.56	LF6	40'-0	1.56	LF6
230	30	16	5"	High	23'-0	0.10	LF1	33'-0	0.37	LF6	33'-0	0.37	LF6
230	30	16	6"	High	20'-6	0.05	LF1	29'-6	0.16	LF6	29'-6	0.16	LF6
230	40	16	3.5"	High	28'-0	0.45	LF1	30'-0	0.50	LF6	30'-0	0.50	LF6
230	40	16	5"	High	23'-0	0.10	LF1	25'-6	0.13	LF6	25'-6	0.13	LF6
230	40	16	6"	High	20'-6	0.05	LF1	23'-6	0.07	LF6	23'-6	0.07	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

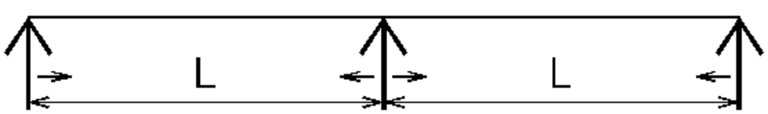
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Standard	28'-0	0.45	LF1	34'-0	0.82	LF5	34'-0	0.82	LF5
345	23	16	5"	Standard	23'-0	0.10	LF1	27'-0	0.17	LF5	27'-0	0.17	LF5
345	23	16	6"	Standard	20'-6	0.05	LF1	23'-6	0.07	LF5	23'-6	0.07	LF5
345	30	16	3.5"	Standard	27'-6	0.42	LF5	27'-6	0.35	LF5	27'-6	0.35	LF5
345	30	16	5"	Standard	22'-6	0.10	LF5	22'-6	0.08	LF5	22'-6	0.08	LF5
345	30	16	6"	Standard	20'-0	0.04	LF5	20'-0	0.03	LF5	20'-0	0.03	LF5
345	40	16	3.5"	Standard	20'-6	0.13	LF5	20'-6	0.11	LF5	20'-6	0.11	LF5
345	40	16	5"	Standard	17'-6	0.04	LF5	17'-6	0.03	LF5	17'-6	0.03	LF5
345	40	16	6"	Standard	16'-0	0.02	LF5	16'-0	0.01	LF5	16'-0	0.01	LF5
345	23	16	3.5"	High	28'-0	0.45	LF1	46'-0	2.76	LF4	46'-0	2.76	LF4
345	23	16	5"	High	23'-0	0.10	LF1	39'-0	0.72	LF6	39'-0	0.72	LF6
345	23	16	6"	High	20'-6	0.05	LF1	34'-0	0.29	LF6	34'-0	0.29	LF6
345	30	16	3.5"	High	28'-0	0.45	LF1	40'-0	1.56	LF6	40'-0	1.56	LF6
345	30	16	5"	High	23'-0	0.10	LF1	33'-0	0.37	LF6	33'-0	0.37	LF6
345	30	16	6"	High	20'-6	0.05	LF1	29'-6	0.16	LF6	29'-6	0.16	LF6
345	40	16	3.5"	High	28'-0	0.45	LF1	30'-0	0.50	LF6	30'-0	0.50	LF6
345	40	16	5"	High	23'-0	0.10	LF1	25'-6	0.13	LF6	25'-6	0.13	LF6
345	40	16	6"	High	20'-6	0.05	LF1	23'-6	0.07	LF6	23'-6	0.07	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE III (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Extra High	28'-0	0.45	LF1	46'-0	2.76	LF4	46'-0	2.76	LF4
345	23	16	5"	Extra High	23'-0	0.10	LF1	53'-6	2.53	LF7	53'-6	2.53	LF7
345	23	16	6"	Extra High	20'-6	0.05	LF1	47'-0	1.05	LF7	47'-0	1.05	LF7
345	30	16	3.5"	Extra High	28'-0	0.45	LF1	45'-0	2.50	LF3	45'-0	2.50	LF3
345	30	16	5"	Extra High	23'-0	0.10	LF1	45'-6	1.32	LF7	45'-6	1.32	LF7
345	30	16	6"	Extra High	20'-6	0.05	LF1	40'-6	0.58	LF7	40'-6	0.58	LF7
345	40	16	3.5"	Extra High	28'-0	0.45	LF1	36'-6	1.08	LF3	36'-6	1.08	LF3
345	40	16	5"	Extra High	23'-0	0.10	LF1	35'-0	0.46	LF7	35'-0	0.46	LF7
345	40	16	6"	Extra High	20'-6	0.05	LF1	32'-0	0.23	LF7	32'-0	0.23	LF7

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

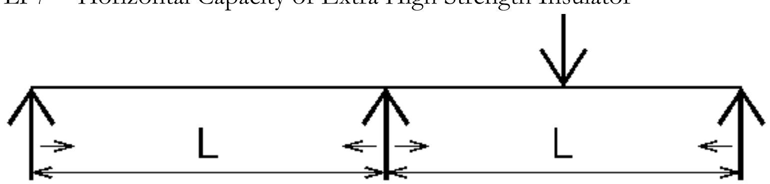
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
12.5/13.8	30	3'-0	3.5"	Standard	18’-6	0.36	LF5	18’-6	0.36	LF5	18’-6	0.36	LF5
12.5/13.8	30	3'-0	5"	Standard	17’-6	0.14	LF5	17’-6	0.14	LF5	17’-6	0.14	LF5
12.5/13.8	30	4'-0	3.5"	Standard	23’-6	0.77	LF5	23’-6	0.78	LF5	23’-6	0.78	LF5
12.5/13.8	30	4'-0	5"	Standard	21’-6	0.28	LF5	21’-6	0.28	LF5	21’-6	0.28	LF5
23	20	4'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
23	20	4'-0	5"	Standard	23’-0	0.35	LF1	35'-6	1.43	LF5	35'-6	1.43	LF5
23	20	5'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
23	20	5'-0	5"	Standard	23’-0	0.35	LF1	39’-6	2.04	LF5	39’-6	2.04	LF5
34.5	20	4'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
34.5	20	4'-0	5"	Standard	23’-0	0.35	LF1	35'-6	1.43	LF5	35'-6	1.43	LF5
34.5	20	6'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
34.5	20	6'-0	5"	Standard	23’-0	0.35	LF1	42'-0	2.51	LF4	42'-0	2.51	LF4
69	20	5'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
69	20	5'-0	5"	Standard	23’-0	0.35	LF1	29'-6	0.77	LF5	29'-6	0.77	LF5
69	20	8'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
69	20	8'-0	5"	Standard	23’-0	0.35	LF1	35'-0	1.36	LF5	35'-0	1.36	LF5

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	23	8'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
115	23	8'-0	5"	Standard	23’-0	0.35	LF1	36'-0	1.50	LF5	36'-0	1.50	LF5
115	23	8'-0	6"	Standard	20’-6	0.15	LF1	32'-6	0.68	LF5	32'-6	0.68	LF5
115	23	10'-0	3.5"	Standard	28’-0	1.39	LF1	30'-0	1.72	LF4	30'-0	1.72	LF4
115	23	10'-0	5"	Standard	23’-0	0.35	LF1	39'-6	2.04	LF5	39'-6	2.04	LF5
115	23	10'-0	6"	Standard	20’-6	0.15	LF1	35'-0	0.87	LF5	35'-0	0.87	LF5
115	40	8'-0	3.5"	Standard	22'-0	0.63	LF5	22'-0	0.63	LF5	22'-0	0.63	LF5
115	40	8'-0	5"	Standard	20'-0	0.22	LF5	20'-0	0.22	LF5	20'-0	0.22	LF5
115	40	8'-0	6"	Standard	18’-6	0.11	LF5	18’-6	0.11	LF5	18’-6	0.11	LF5
115	40	10'-0	3.5"	Standard	25’-6	1.02	LF5	25’-6	1.01	LF5	25’-6	1.01	LF5
115	40	10'-0	5"	Standard	23’-0	0.35	LF1	23'-0	0.34	LF5	23'-0	0.34	LF5
115	40	10'-0	6"	Standard	20’-6	0.15	LF1	21’-6	0.17	LF5	21’-6	0.17	LF5
115	40	8'-0	3.5"	High	27’-6	1.31	LF3	27’-6	1.29	LF3	27’-6	1.29	LF3
115	40	8'-0	5"	High	23’-0	0.35	LF1	30’-6	0.86	LF6	30’-6	0.86	LF6
115	40	8'-0	6"	High	20’-6	0.15	LF1	28’-6	0.44	LF6	28’-6	0.44	LF6
115	40	10'-0	3.5"	High	28’-0	1.39	LF1	30’-0	1.72	LF3	30’-0	1.72	LF3
115	40	10'-0	5"	High	23’-0	0.35	LF1	35’-0	1.36	LF6	35’-0	1.36	LF6
115	40	10'-0	6"	High	20’-6	0.15	LF1	33’-0	0.71	LF6	33’-0	0.71	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
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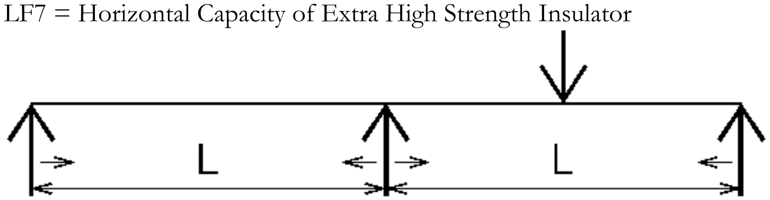


Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

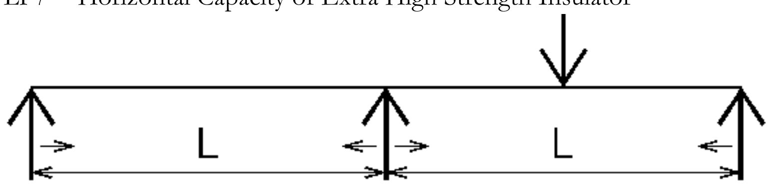
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
115	63	10	5"	Standard	12’-0	0.04	LF5	12’-0	0.04	LF5	12’-0	0.04	LF5
115	63	10	6"	Standard	11’-6	0.02	LF5	11’-6	0.02	LF5	11’-6	0.02	LF5
115	63	10	5"	Extra High	23’-0	0.35	LF1	28’-0	0.65	LF2	30’-0	0.82	LF3
115	63	10	6"	Extra High	20’-6	0.15	LF1	27’-6	0.39	LF2	30’-6	0.55	LF7
161	23	9'-0	3.5"	Standard	28’-0	1.62	LF4	28'-0	1.61	LF4	28'-0	1.61	LF4
161	23	9'-0	5"	Standard	23’-0	0.39	LF1	27'-0	0.65	LF5	27'-0	0.65	LF5
161	23	9'-0	6"	Standard	20’-6	0.18	LF1	24'-0	0.29	LF5	24'-0	0.29	LF5
161	23	14'-0	3.5"	Standard	28’-0	1.62	LF4	28'-0	1.61	LF4	28'-0	1.61	LF4
161	23	14'-0	5"	Standard	23’-0	0.39	LF1	31'-0	0.91	LF5	31'-0	0.91	LF5
161	23	14'-0	6"	Standard	20’-6	0.18	LF1	27'-0	0.43	LF5	27'-0	0.43	LF5
161	23	9'-0	3.5"	High	28’-0	1.62	LF4	28’-0	1.61	LF4	28’-0	1.61	LF4
161	23	9'-0	5"	High	23’-0	0.39	LF1	40’-0	2.35	LF4	40’-0	2.35	LF4
161	23	9'-0	6"	High	20’-6	0.18	LF1	37’-0	1.21	LF6	37’-0	1.21	LF6
161	23	14'-0	3.5"	High	28’-0	1.62	LF4	28’-0	1.61	LF4	28’-0	1.61	LF4
161	23	14'-0	5"	High	23’-0	0.39	LF1	40’-0	2.35	LF4	40’-0	2.35	LF4
161	23	14'-0	6"	High	20’-6	0.18	LF1	42’-0	1.85	LF6	42’-0	1.85	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to Bus Support to Bus Support

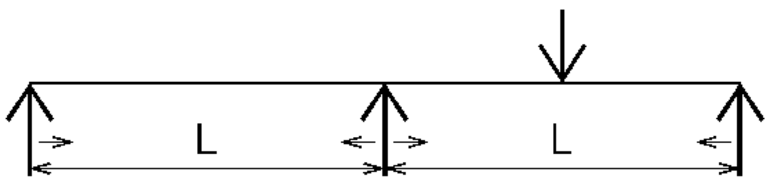
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
161	30	9'-0	3.5"	Standard	24’-6	1.05	LF5	24’-6	1.05	LF5	24’-6	1.05	LF5
161	30	9'-0	5"	Standard	21’-0	0.29	LF5	21’-0	0.29	LF5	21’-0	0.29	LF5
161	30	9'-0	6"	Standard	19’-0	0.14	LF5	19’-0	0.14	LF5	19’-0	0.14	LF5
161	30	14'-0	3.5"	Standard	28’-0	1.62	LF4	28'-0	1.61	LF4	28'-0	1.61	LF4
161	30	14'-0	5"	Standard	23’-0	0.39	LF1	26’-0	0.57	LF5	26’-0	0.57	LF5
161	30	14'-0	6"	Standard	20’-6	0.18	LF1	23’-0	0.26	LF5	23’-0	0.26	LF5
161	30	9'-0	3.5"	High	28’-0	1.62	LF4	28’-0	1.61	LF4	28’-0	1.61	LF4
161	30	9'-0	5"	High	23’-0	0.39	LF1	32’-6	1.19	LF6	32’-6	1.19	LF6
161	30	9'-0	6"	High	20’-6	0.18	LF1	30’-0	0.61	LF6	30’-0	0.61	LF6
161	30	14'-0	3.5"	High	28’-0	1.62	LF4	28’-0	1.61	LF4	28’-0	1.61	LF4
161	30	14'-0	5"	High	23’-0	0.39	LF1	40’-0	2.35	LF6	40’-0	2.35	LF6
161	30	14'-0	6"	High	20’-6	0.18	LF1	36’-0	1.11	LF6	36’-0	1.11	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

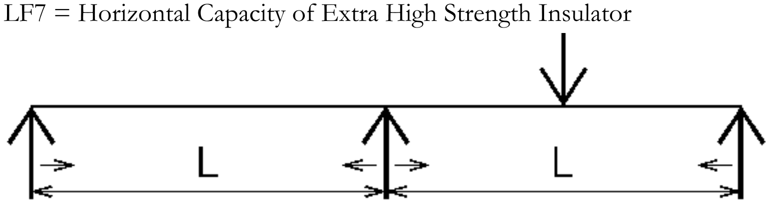
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
230	23	16	3.5"	Standard	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
230	23	16	5"	Standard	23'-0	0.49	LF1	25'-0	0.65	LF5	25'-0	0.65	LF5
230	23	16	6"	Standard	20'-6	0.22	LF1	22'-0	0.28	LF5	22'-0	0.28	LF5
230	30	16	3.5"	Standard	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
230	30	16	5"	Standard	21'-6	0.40	LF5	21'-6	0.40	LF5	21'-6	0.40	LF5
230	30	16	6"	Standard	19'-0	0.17	LF5	19'-0	0.17	LF5	19'-0	0.17	LF5
230	40	16	3.5"	Standard	19'-0	0.65	LF5	19'-0	0.67	LF5	19'-0	0.67	LF5
230	40	16	5"	Standard	16'-6	0.17	LF5	16'-6	0.18	LF5	16'-6	0.18	LF5
230	40	16	6"	Standard	15'-0	0.08	LF5	15'-0	0.08	LF5	15'-0	0.08	LF5
230	23	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
230	23	16	5"	High	23'-0	0.49	LF1	36'-0	2.09	LF4	36'-0	2.09	LF4
230	23	16	6"	High	20'-6	0.22	LF1	34'-0	1.11	LF6	34'-0	1.11	LF6
230	30	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
230	30	16	5"	High	23'-0	0.49	LF1	33'-0	1.58	LF6	33'-0	1.58	LF6
230	30	16	6"	High	20'-6	0.22	LF1	29'-6	0.70	LF6	29'-6	0.70	LF6
230	40	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
230	40	16	5"	High	23'-0	0.49	LF1	25'-0	0.65	LF6	25'-0	0.65	LF6
230	40	16	6"	High	20'-6	0.22	LF1	23'-0	0.32	LF6	23'-0	0.32	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

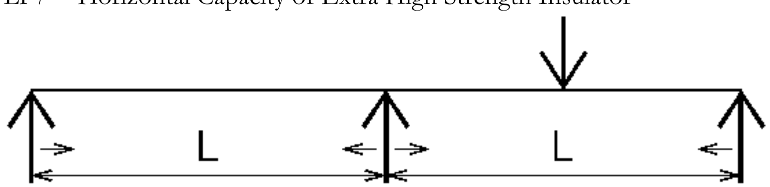
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Standard	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	23	16	5"	Standard	23'-0	0.49	LF1	27'-0	0.83	LF5	27'-0	0.83	LF5
345	23	16	6"	Standard	20'-6	0.22	LF1	23'-6	0.34	LF5	23'-6	0.34	LF5
345	30	16	3.5"	Standard	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	30	16	5"	Standard	22'-6	0.46	LF5	22'-6	0.47	LF5	22'-6	0.47	LF5
345	30	16	6"	Standard	20'-0	0.20	LF5	20'-0	0.20	LF5	20'-0	0.20	LF5
345	40	16	3.5"	Standard	20'-0	0.77	LF5	20'-0	0.79	LF5	20'-0	0.79	LF5
345	40	16	5"	Standard	17'-6	0.21	LF5	17'-6	0.21	LF5	17'-6	0.21	LF5
345	40	16	6"	Standard	16'-0	0.10	LF5	16'-0	0.10	LF5	16'-0	0.10	LF5
345	23	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	23	16	5"	High	23'-0	0.49	LF1	36'-0	2.09	LF4	36'-0	2.09	LF4
345	23	16	6"	High	20'-6	0.22	LF1	34'-0	1.11	LF6	34'-0	1.11	LF6
345	30	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	30	16	5"	High	23'-0	0.49	LF1	33'-0	1.58	LF6	33'-0	1.58	LF6
345	30	16	6"	High	20'-6	0.22	LF1	29'-6	0.70	LF6	29'-6	0.70	LF6
345	40	16	3.5"	High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	40	16	5"	High	23'-0	0.49	LF1	25'-0	0.65	LF6	25'-0	0.65	LF6
345	40	16	6"	High	20'-6	0.22	LF1	23'-0	0.32	LF6	23'-0	0.32	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

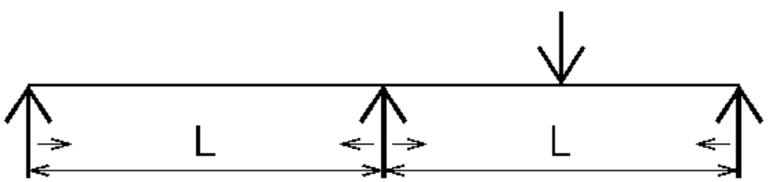
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

DOUBLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE IV (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
345	23	16	3.5"	Extra High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	23	16	5"	Extra High	23'-0	0.49	LF1	36'-0	2.09	LF4	36'-0	2.09	LF4
345	23	16	6"	Extra High	20'-6	0.22	LF1	44'-0	2.59	LF4	44'-0	2.59	LF4
345	30	16	3.5"	Extra High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	30	16	5"	Extra High	23'-0	0.49	LF1	36'-0	2.09	LF4	36'-0	2.09	LF4
345	30	16	6"	Extra High	20'-6	0.22	LF1	40'-6	1.98	LF7	40'-6	1.98	LF7
345	40	16	3.5"	Extra High	24'-0	1.38	LF4	24'-0	1.39	LF4	24'-0	1.39	LF4
345	40	16	5"	Extra High	23'-0	0.49	LF1	35'-0	1.91	LF7	35'-0	1.91	LF7
345	40	16	6"	Extra High	20'-6	0.22	LF1	32'-0	0.92	LF7	32'-0	0.92	LF7

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to Bus Support to Switch Pad (expansion fitting at one end)
Switch Pad to Bus Support to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to Bus Support to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to Bus Support to Switch Pad (expansion fitting at both ends)
Switch Pad to Bus Support to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to Bus Support to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to Bus Support to Bus Support

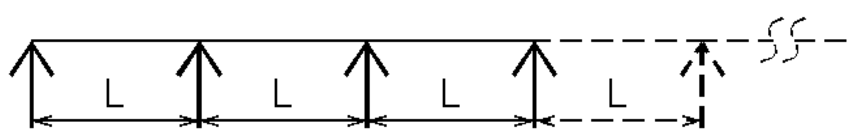
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center support may be moved up to 20% of L along the bus in either direction. An end support may freely move towards the center support.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
12.5/13.8	30	3'-0	3.5"	Standard	21'-0	0.14	LF5	21'-0	0.15	LF5	21'-0	0.15	LF5
12.5/13.8	30	3'-0	5"	Standard	20'-0	0.06	LF5	20'-0	0.06	LF5	20'-0	0.06	LF5
12.5/13.8	30	4'-0	3.5"	Standard	25'-0	0.29	LF1	26’-6	0.38	LF5	26’-6	0.38	LF5
12.5/13.8	30	4'-0	5"	Standard	20'-0	0.06	LF1	24’-6	0.14	LF5	24’-6	0.14	LF5
23	20	4'-0	3.5"	Standard	25'-0	0.29	LF1	41'-0	2.20	LF3	41'-0	2.20	LF3
23	20	4'-0	5"	Standard	20'-0	0.06	LF1	40'-0	1.01	LF5	40'-0	1.01	LF5
23	20	5'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
23	20	5'-0	5"	Standard	20'-0	0.06	LF1	45'-0	1.61	LF5	45'-0	1.61	LF5
34.5	20	4'-0	3.5"	Standard	25'-0	0.29	LF1	41'-0	2.20	LF3	41'-0	2.20	LF3
34.5	20	4'-0	5"	Standard	20'-0	0.06	LF1	40'-0	1.01	LF5	40'-0	1.01	LF5
34.5	20	6'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
34.5	20	6'-0	5"	Standard	20'-0	0.06	LF1	48'-0	2.09	LF5	48'-0	2.09	LF5
69	20	5'-0	3.5"	Standard	25'-0	0.29	LF1	39’-6	1.89	LF5	39’-6	1.89	LF5
69	20	5'-0	5"	Standard	20'-0	0.06	LF1	33’-6	0.50	LF5	33’-6	0.50	LF5
69	20	8'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
69	20	8'-0	5"	Standard	20'-0	0.06	LF1	40'-0	1.01	LF5	40'-0	1.01	LF5

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

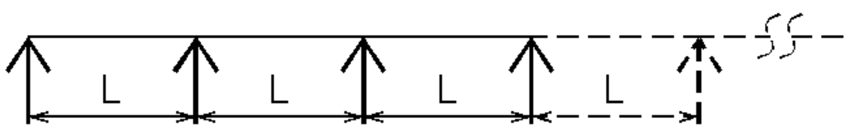
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
115	23	8'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
115	23	8'-0	5"	Standard	20'-0	0.06	LF1	41'-0	1.11	LF5	41'-0	1.11	LF5
115	23	8'-0	6"	Standard	18'-0	0.03	LF1	37'-0	0.52	LF5	37'-0	0.52	LF5
115	23	10'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
115	23	10'-0	5"	Standard	20'-0	0.06	LF1	45'-0	1.61	LF5	45'-0	1.61	LF5
115	23	10'-0	6"	Standard	18'-0	0.03	LF1	40'-0	0.70	LF5	40'-0	0.70	LF5
115	40	8'-0	3.5"	Standard	25'-0	0.29	LF5	25'-0	0.30	LF5	25'-0	0.30	LF5
115	40	8'-0	5"	Standard	20'-0	0.06	LF1	22’-6	0.10	LF5	22’-6	0.10	LF5
115	40	8'-0	6"	Standard	18'-0	0.03	LF1	21'-0	0.05	LF5	21'-0	0.05	LF5
115	40	10'-0	3.5"	Standard	25'-0	0.29	LF1	29'-0	0.55	LF5	29'-0	0.55	LF5
115	40	10'-0	5"	Standard	20'-0	0.06	LF1	26'-0	0.18	LF5	26'-0	0.18	LF5
115	40	10'-0	6"	Standard	18'-0	0.03	LF1	24’-6	0.10	LF5	24’-6	0.10	LF5
115	40	8'-0	3.5"	High	25’-0	0.29	LF1	30’-6	0.67	LF3	30’-6	0.67	LF3
115	40	8'-0	5"	High	20'-0	0.06	LF1	34’-6	0.56	LF6	34’-6	0.56	LF6
115	40	8'-0	6"	High	18'-0	0.03	LF1	32’-6	0.31	LF6	32’-6	0.31	LF6
115	40	10'-0	3.5"	High	25'-0	0.29	LF1	33’-6	0.91	LF3	33’-6	0.91	LF3
115	40	10'-0	5"	High	20'-0	0.06	LF1	40’-0	1.01	LF6	40’-0	1.01	LF6
115	40	10'-0	6"	High	18'-0	0.03	LF1	37’-6	0.54	LF6	37’-6	0.54	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

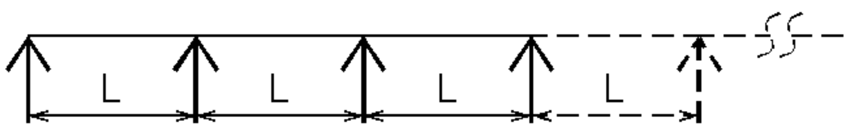
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
115	63	10	5"	Standard	13'-6	0.01	LF5	13'-6	0.01	LF5	13'-6	0.01	LF5
115	63	10	6"	Standard	13'-0	0.01	LF5	13'-0	0.01	LF5	13'-0	0.01	LF5
115	63	10	5"	Extra High	20'-6	0.07	LF1	26'-0	0.18	LF2	33'-6	0.50	LF3
115	63	10	6"	Extra High	18'-6	0.03	LF1	25'-6	0.12	LF2	34'-6	0.39	LF7
161	23	9'-0	3.5"	Standard	25'-0	0.29	LF1	37'-0	1.46	LF5	37'-0	1.46	LF5
161	23	9'-0	5"	Standard	20'-0	0.06	LF1	30'-0	0.32	LF5	30'-0	0.32	LF5
161	23	9'-0	6"	Standard	18'-0	0.03	LF1	27'-0	0.15	LF5	27'-0	0.15	LF5
161	23	14'-0	3.5"	Standard	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
161	23	14'-0	5"	Standard	20'-0	0.06	LF1	35'-0	0.59	LF5	35'-0	0.59	LF5
161	23	14'-0	6"	Standard	18'-0	0.03	LF1	31'-0	0.25	LF5	31'-0	0.25	LF5
161	23	9'-0	3.5"	High	25'-0	0.29	LF1	42'-6	2.53	LF4	42'-6	2.53	LF4
161	23	9'-0	5"	High	20'-0	0.06	LF1	47'-0	1.92	LF6	47'-0	1.92	LF6
161	23	9'-0	6"	High	18'-0	0.03	LF1	42'-0	0.86	LF6	42'-0	0.86	LF6
161	23	14'-0	3.5"	High	25'-0	0.29	LF1	42'-6	2.53	LF4	42'-6	2.53	LF4
161	23	14'-0	5"	High	20'-0	0.06	LF1	53'-0	3.11	LF4	53'-0	3.11	LF4
161	23	14'-0	6"	High	18'-0	0.03	LF1	48'-0	1.46	LF6	48'-0	1.46	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

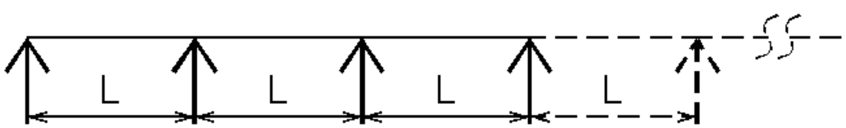
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

					Application #1			Application #2			Application #3		
Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
161	30	9'-0	3.5"	Standard	25'-0	0.29	LF1	28’-0	0.48	LF5	28’-0	0.48	LF5
161	30	9'-0	5"	Standard	20'-0	0.06	LF1	24’-0	0.13	LF5	24’-0	0.13	LF5
161	30	9'-0	6"	Standard	18'-0	0.03	LF1	22’-0	0.06	LF5	22’-0	0.06	LF5
161	30	14'-0	3.5"	Standard	25'-0	0.29	LF1	35’-6	1.23	LF5	35’-6	1.23	LF5
161	30	14'-0	5"	Standard	20'-0	0.06	LF1	29’-6	0.30	LF5	29’-6	0.30	LF5
161	30	14'-0	6"	Standard	18'-0	0.03	LF1	26’-6	0.14	LF5	26’-6	0.14	LF5
161	30	9'-0	3.5"	High	25'-0	0.29	LF1	41’-0	2.20	LF3	41’-0	2.20	LF3
161	30	9'-0	5"	High	20'-0	0.06	LF1	37’-0	0.74	LF6	37’-0	0.74	LF6
161	30	9'-0	6"	High	18'-0	0.03	LF1	34’-0	0.37	LF6	34’-0	0.37	LF6
161	30	14'-0	3.5"	High	25'-0	0.29	LF1	42’-6	2.53	LF4	42’-6	2.53	LF4
161	30	14'-0	5"	High	20'-0	0.06	LF1	45’-6	1.69	LF6	45’-6	1.69	LF6
161	30	14'-0	6"	High	18'-0	0.03	LF1	40’-6	0.74	LF6	40’-6	0.74	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to X# of Bus Supports

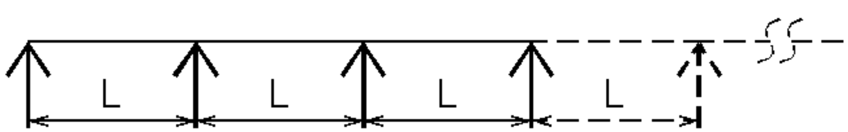
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
230	23	16	3.5"	Standard	25'-0	0.29	LF1	36'-6	1.38	LF5	36'-6	1.38	LF5
230	23	16	5"	Standard	20'-0	0.06	LF1	29'-0	0.28	LF5	29'-0	0.28	LF5
230	23	16	6"	Standard	18'-0	0.03	LF1	25'-0	0.11	LF5	25'-0	0.11	LF5
230	30	16	3.5"	Standard	25'-0	0.29	LF1	29'-6	0.59	LF5	29'-6	0.59	LF5
230	30	16	5"	Standard	20'-0	0.06	LF1	24'-6	0.14	LF5	24'-6	0.14	LF5
230	30	16	6"	Standard	18'-0	0.03	LF1	22'-0	0.06	LF5	22'-0	0.06	LF5
230	40	16	3.5"	Standard	22'-0	0.17	LF5	22'-0	0.18	LF5	22'-0	0.18	LF5
230	40	16	5"	Standard	19'-0	0.05	LF5	19'-0	0.05	LF5	19'-0	0.05	LF5
230	40	16	6"	Standard	17'-6	0.03	LF5	17'-6	0.03	LF5	17'-6	0.03	LF5
230	23	16	3.5"	High	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
230	23	16	5"	High	20'-0	0.06	LF1	44'-0	1.48	LF6	44'-0	1.48	LF6
230	23	16	6"	High	18'-0	0.03	LF1	39'-0	0.64	LF6	39'-0	0.64	LF6
230	30	16	3.5"	High	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
230	30	16	5"	High	20'-0	0.06	LF1	37'-6	0.78	LF6	37'-6	0.78	LF6
230	30	16	6"	High	18'-0	0.03	LF1	33'-6	0.35	LF6	33'-6	0.35	LF6
230	40	16	3.5"	High	25'-0	0.29	LF1	34'-0	1.04	LF6	34'-0	1.04	LF6
230	40	16	5"	High	20'-0	0.06	LF1	29'-0	0.28	LF6	29'-0	0.28	LF6
230	40	16	6"	High	18'-0	0.03	LF1	26'-0	0.13	LF6	26'-0	0.13	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

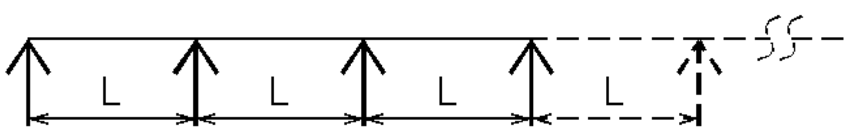
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Standard	25’-0	0.29	LF1	38’-6	1.71	LF5	38’-6	1.71	LF5
345	23	16	5"	Standard	20’-0	0.06	LF1	30’-6	0.34	LF5	30’-6	0.34	LF5
345	23	16	6"	Standard	18’-0	0.03	LF1	26’-6	0.14	LF5	26’-6	0.14	LF5
345	30	16	3.5"	Standard	25’-0	0.29	LF1	31’-6	0.76	LF5	31’-6	0.76	LF5
345	30	16	5"	Standard	20’-0	0.06	LF1	25’-6	0.17	LF5	25’-6	0.17	LF5
345	30	16	6"	Standard	18’-0	0.03	LF1	23’-0	0.08	LF5	23’-0	0.08	LF5
345	40	16	3.5"	Standard	23’-0	0.21	LF5	23’-0	0.22	LF5	23’-0	0.22	LF5
345	40	16	5"	Standard	20’-0	0.06	LF5	20’-0	0.06	LF5	20’-0	0.06	LF5
345	40	16	6"	Standard	18’-0	0.03	LF5	18’-0	0.03	LF5	18’-0	0.03	LF5
345	23	16	3.5"	High	25’-0	0.29	LF1	42’-0	2.42	LF4	42’-0	2.42	LF4
345	23	16	5"	High	20’-0	0.06	LF1	44’-0	1.48	LF6	44’-0	1.48	LF6
345	23	16	6"	High	18’-0	0.03	LF1	39’-0	0.64	LF6	39’-0	0.64	LF6
345	30	16	3.5"	High	25’-0	0.29	LF1	42’-0	2.42	LF4	42’-0	2.42	LF4
345	30	16	5"	High	20’-0	0.06	LF1	37’-6	0.78	LF6	37’-6	0.78	LF6
345	30	16	6"	High	18’-0	0.03	LF1	33’-6	0.35	LF6	33’-6	0.35	LF6
345	40	16	3.5"	High	25’-0	0.29	LF1	34’-0	1.04	LF6	34’-0	1.04	LF6
345	40	16	5"	High	20’-0	0.06	LF1	29’-0	0.28	LF6	29’-0	0.28	LF6
345	40	16	6"	High	18’-0	0.03	LF1	26’-0	0.13	LF6	26’-0	0.13	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITHOUT OVERBUS

TABLE V (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Extra High	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
345	23	16	5"	Extra High	20'-0	0.06	LF1	53'-0	3.11	LF4	53'-0	3.11	LF4
345	23	16	6"	Extra High	18'-0	0.03	LF1	53'-0	2.17	LF7	53'-0	2.17	LF7
345	30	16	3.5"	Extra High	25'-0	0.29	LF1	42'-0	2.42	LF4	42'-0	2.42	LF4
345	30	16	5"	Extra High	20'-0	0.06	LF1	51'-6	2.77	LF7	51'-6	2.77	LF7
345	30	16	6"	Extra High	18'-0	0.03	LF1	46'-0	1.23	LF7	46'-0	1.23	LF7
345	40	16	3.5"	Extra High	25'-0	0.29	LF1	40'-0	1.99	LF2	41'-0	2.20	LF3
345	40	16	5"	Extra High	20'-0	0.06	LF1	37'-0	0.74	LF2	40'-0	1.01	LF7
345	40	16	6"	Extra High	18'-0	0.03	LF1	35'-0	0.41	LF2	36'-6	0.49	LF7

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator

Application #1:

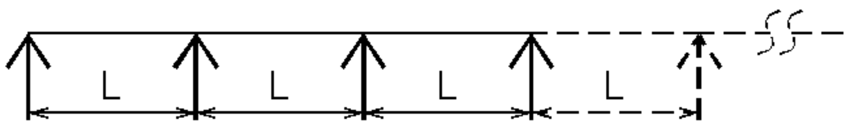
Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports



Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
12.5/13.8	30	3'-0	3.5"	Standard	21'-0	0.43	LF5	21'-0	0.44	LF5	21'-0	0.44	LF5
12.5/13.8	30	3'-0	5"	Standard	20'-0	0.18	LF5	20'-0	0.18	LF5	20'-0	0.18	LF5
12.5/13.8	30	4'-0	3.5"	Standard	25'-0	0.77	LF1	26'-6	0.95	LF5	26'-6	0.95	LF5
12.5/13.8	30	4'-0	5"	Standard	20'-0	0.18	LF1	24'-6	0.35	LF5	24'-6	0.35	LF5
23	20	4'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
23	20	4'-0	5"	Standard	20'-0	0.18	LF1	40'-0	1.92	LF5	40'-0	1.92	LF5
23	20	5'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
23	20	5'-0	5"	Standard	20'-0	0.18	LF1	44'-0	2.68	LF4	44'-0	2.68	LF4
34.5	20	4'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
34.5	20	4'-0	5"	Standard	20'-0	0.18	LF1	40'-0	1.92	LF5	40'-0	1.92	LF5
34.5	20	6'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
34.5	20	6'-0	5"	Standard	20'-0	0.18	LF1	43'-0	2.47	LF4	43'-0	2.47	LF4
69	20	5'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
69	20	5'-0	5"	Standard	20'-0	0.18	LF1	33'-6	1.03	LF5	33'-6	1.03	LF5
69	20	8'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
69	20	8'-0	5"	Standard	20'-0	0.18	LF1	40'-0	1.92	LF5	40'-0	1.92	LF5

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
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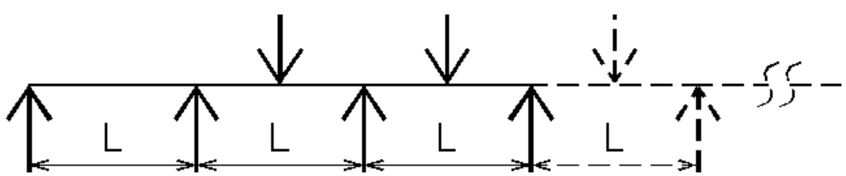
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

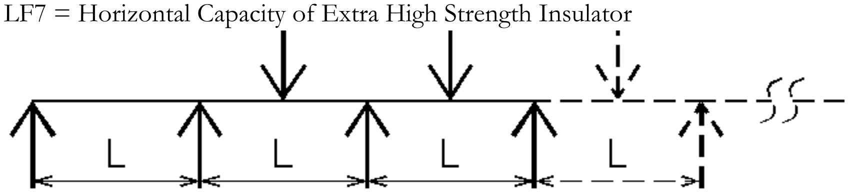
Bus Support to X# of Bus Supports

Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflectio (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
115	23	8'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
115	23	8'-0	5"	Standard	20'-0	0.18	LF1	41'-0	2.09	LF5	41'-0	2.09	LF5
115	23	8'-0	6"	Standard	18'-0	0.08	LF1	37'-0	0.95	LF5	37'-0	0.95	LF5
115	23	10'-0	3.5"	Standard	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
115	23	10'-0	5"	Standard	20'-0	0.18	LF1	42'-0	2.28	LF4	42'-0	2.28	LF4
115	23	10'-0	6"	Standard	18'-0	0.08	LF1	40'-0	1.26	LF5	40'-0	1.26	LF5
115	40	8'-0	3.5"	Standard	25'-0	0.77	LF5	25'-0	0.78	LF5	25'-0	0.78	LF5
115	40	8'-0	5"	Standard	20'-0	0.18	LF1	22'-6	0.26	LF5	22'-6	0.26	LF5
115	40	8'-0	6"	Standard	18'-0	0.08	LF1	21'-0	0.13	LF5	21'-0	0.13	LF5
115	40	10'-0	3.5"	Standard	25'-0	0.77	LF1	29'-0	1.30	LF5	29'-0	1.30	LF5
115	40	10'-0	5"	Standard	20'-0	0.18	LF1	26'-0	0.43	LF5	26'-0	0.43	LF5
115	40	10'-0	6"	Standard	18'-0	0.08	LF1	24'-6	0.23	LF5	24'-6	0.23	LF5
115	40	8'-0	3.5"	High	25'-0	0.77	LF1	30'-6	1.54	LF3	30'-6	1.54	LF3
115	40	8'-0	5"	High	20'-0	0.18	LF1	34'-6	1.14	LF6	34'-6	1.14	LF6
115	40	8'-0	6"	High	18'-0	0.08	LF1	32'-6	0.60	LF6	32'-6	0.60	LF6
115	40	10'-0	3.5"	High	25'-0	0.77	LF1	32'-0	1.82	LF4	32'-0	1.82	LF4
115	40	10'-0	5"	High	20'-0	0.18	LF1	40'-0	1.92	LF6	40'-0	1.92	LF6
115	40	10'-0	6"	High	18'-0	0.08	LF1	37'-6	1.00	LF6	37'-6	1.00	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:
Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:
Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:
Bus Support to X# of Bus Supports

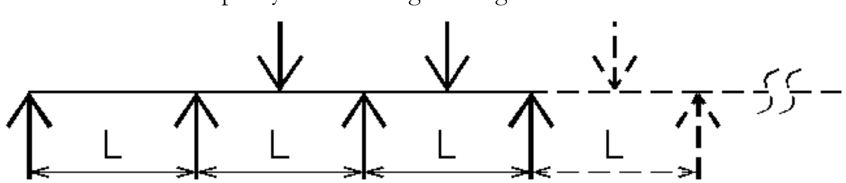
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
115	63	10	5"	Standard	13’-6	0.05	LF5	13’-6	0.05	LF5	13’-6	0.05	LF5
115	63	10	6"	Standard	13’-0	0.03	LF5	13’-0	0.03	LF5	13’-0	0.03	LF5
115	63	10	5"	Extra High	20’-0	0.18	LF1	26’-0	0.43	LF2	33’-0	0.98	LF3
115	63	10	6"	Extra High	18’-0	0.08	LF1	25’-6	0.26	LF2	34’-6	0.74	LF7
161	23	9'-0	3.5"	Standard	25’-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	23	9'-0	5"	Standard	20’-0	0.19	LF1	30'-0	0.76	LF5	30'-0	0.76	LF5
161	23	9'-0	6"	Standard	18’-0	0.09	LF1	27'-0	0.36	LF5	27'-0	0.36	LF5
161	23	14'-0	3.5"	Standard	25’-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	23	14'-0	5"	Standard	20’-0	0.19	LF1	35'-0	1.30	LF5	35'-0	1.30	LF5
161	23	14'-0	6"	Standard	18’-0	0.09	LF1	31'-0	0.58	LF5	31'-0	0.58	LF5
161	23	9'-0	3.5"	High	25’-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	23	9'-0	5"	High	20’-0	0.19	LF1	42’-0	2.44	LF4	42’-0	2.44	LF4
161	23	9'-0	6"	High	18’-0	0.09	LF1	42’-0	1.66	LF6	42’-0	1.66	LF6
161	23	14'-0	3.5"	High	25’-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	23	14'-0	5"	High	20’-0	0.19	LF1	42’-0	2.44	LF4	42’-0	2.44	LF4
161	23	14'-0	6"	High	18’-0	0.09	LF1	48’-0	2.65	LF6	48’-0	2.65	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

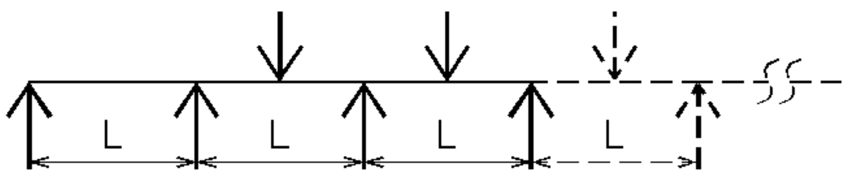
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The bolt hole size and pattern changes for 115kV extra high strength insulators. To maintain standard insulator height with the 115kV extra high strength insulator, a Locke Insulator or equal should be used.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
161	30	9'-0	3.5"	Standard	25'-0	0.89	LF1	28'-0	1.31	LF5	28'-0	1.31	LF5
161	30	9'-0	5"	Standard	20'-0	0.19	LF1	24'-0	0.36	LF5	24'-0	0.36	LF5
161	30	9'-0	6"	Standard	18'-0	0.09	LF1	22'-0	0.18	LF5	22'-0	0.18	LF5
161	30	14'-0	3.5"	Standard	25'-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	30	14'-0	5"	Standard	20'-0	0.19	LF1	29'-6	0.72	LF5	29'-6	0.72	LF5
161	30	14'-0	6"	Standard	18'-0	0.09	LF1	26'-6	0.34	LF5	26'-6	0.34	LF5
161	30	9'-0	3.5"	High	25'-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	30	9'-0	5"	High	20'-0	0.19	LF1	37'-0	1.58	LF6	37'-0	1.58	LF6
161	30	9'-0	6"	High	18'-0	0.09	LF1	34'-0	0.71	LF6	34'-0	0.71	LF6
161	30	14'-0	3.5"	High	25'-0	0.89	LF1	31'-0	1.84	LF4	31'-0	1.84	LF4
161	30	14'-0	5"	High	20'-0	0.19	LF1	42'-0	2.44	LF4	42'-0	2.44	LF4
161	30	14'-0	6"	High	18'-0	0.09	LF1	40'-6	1.46	LF6	40'-6	1.46	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

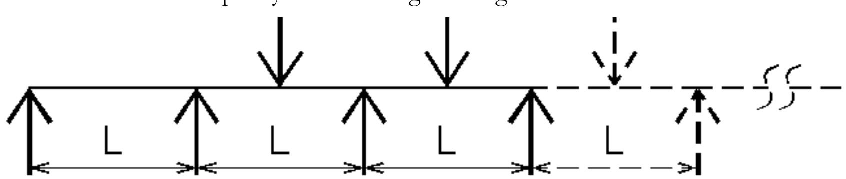
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1 Maximum Span (L) (ft)	Application #1 Expected Deflection (in)	Application #1 Limiting Factor	Application #2 Maximum Span (L) (ft)	Application #2 Expected Deflection (in)	Application #2 Limiting Factor	Application #3 Maximum Span (L) (ft)	Application #3 Expected Deflection (in)	Application #3 Limiting Factor
230	23	16	3.5"	Standard	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
230	23	16	5"	Standard	20’-0	0.24	LF1	29’-0	0.83	LF5	29’-0	0.83	LF5
230	23	16	6"	Standard	18’-0	0.11	LF1	25’-0	0.33	LF5	25’-0	0.33	LF5
230	30	16	3.5"	Standard	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
230	30	16	5"	Standard	20’-0	0.24	LF1	24’-6	0.48	LF5	24’-6	0.48	LF5
230	30	16	6"	Standard	18’-0	0.11	LF1	22’-0	0.22	LF5	22’-0	0.22	LF5
230	40	16	3.5"	Standard	22’-0	0.79	LF5	22’-0	0.80	LF5	22’-0	0.80	LF5
230	40	16	5"	Standard	19’-0	0.21	LF5	19’-0	0.21	LF5	19’-0	0.21	LF5
230	40	16	6"	Standard	17’-6	0.10	LF5	17’-6	0.10	LF5	17’-6	0.10	LF5
230	23	16	3.5"	High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
230	23	16	5"	High	20’-0	0.24	LF1	40’-0	2.46	LF4	40’-0	2.46	LF4
230	23	16	6"	High	18’-0	0.11	LF1	39’-0	1.48	LF6	39’-0	1.48	LF6
230	30	16	3.5"	High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
230	30	16	5"	High	20’-0	0.24	LF1	37’-6	1.98	LF6	37’-6	1.98	LF6
230	30	16	6"	High	18’-0	0.11	LF1	33’-6	0.88	LF6	33’-6	0.88	LF6
230	40	16	3.5"	High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
230	40	16	5"	High	20’-0	0.24	LF1	29’-0	0.83	LF6	29’-0	0.83	LF6
230	40	16	6"	High	18’-0	0.11	LF1	26’-0	0.37	LF6	26’-0	0.37	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

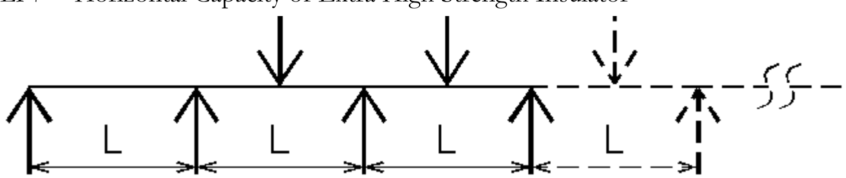
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Standard	25'-0	1.20	LF1	28'-0	1.74	LF4	28'-0	1.74	LF4
345	23	16	5"	Standard	20'-0	0.24	LF1	30'-0	0.93	LF5	30'-0	0.93	LF5
345	23	16	6"	Standard	18'-0	0.11	LF1	26'-6	0.40	LF5	26'-6	0.40	LF5
345	30	16	3.5"	Standard	25'-0	1.20	LF1	28'-0	1.74	LF4	28'-0	1.74	LF4
345	30	16	5"	Standard	20'-0	0.24	LF1	25'-6	0.54	LF5	25'-6	0.54	LF5
345	30	16	6"	Standard	18'-0	0.11	LF1	23'-0	0.25	LF5	23'-0	0.25	LF5
345	40	16	3.5"	Standard	23'-0	0.92	LF5	23'-0	0.92	LF5	23'-0	0.92	LF5
345	40	16	5"	Standard	20'-0	0.24	LF5	20'-0	0.25	LF5	20'-0	0.25	LF5
345	40	16	6"	Standard	18'-0	0.11	LF5	18'-0	0.11	LF5	18'-0	0.11	LF5
345	23	16	3.5"	High	25'-0	1.20	LF1	28'-0	1.74	LF4	28'-0	1.74	LF4
345	23	16	5"	High	20'-0	0.24	LF1	40'-0	2.46	LF4	40'-0	2.46	LF4
345	23	16	6"	High	18'-0	0.11	LF1	39'-0	1.48	LF6	39'-0	1.48	LF6
345	30	16	3.5"	High	25'-0	1.20	LF1	28'-0	1.74	LF4	28'-0	1.74	LF4
345	30	16	5"	High	20'-0	0.24	LF1	37'-6	1.98	LF6	37'-6	1.98	LF6
345	30	16	6"	High	18'-0	0.11	LF1	33'-6	0.88	LF6	33'-6	0.88	LF6
345	40	16	3.5"	High	25'-0	1.20	LF1	28'-0	1.74	LF4	28'-0	1.74	LF4
345	40	16	5"	High	20'-0	0.24	LF1	29'-0	0.83	LF6	29'-0	0.83	LF6
345	40	16	6"	High	18'-0	0.11	LF1	26'-0	0.37	LF6	26'-0	0.37	LF6

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



Application #1:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

Application #2:

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

Application #3:

Bus Support to X# of Bus Supports

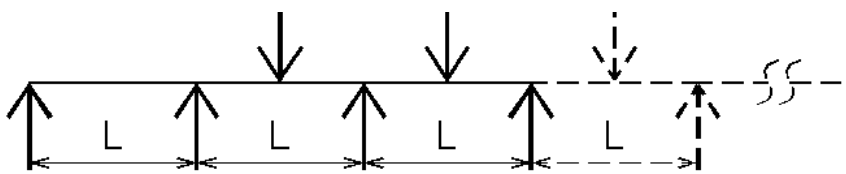
Note: Use an expansion fitting at the switch if overbus is in the same span as the switch.
Note: The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

MULTIPLE SPAN BUS CONFIGURATIONS WITH OVERBUS

TABLE VI (Contd.)

Nominal Voltage (kV)	Fault Current (kA)	Phase Spacing (ft)	Bus Type (in)	Insulator Strength	Application #1			Application #2			Application #3		
					Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor	Maximum Span (L) (ft)	Expected Deflection (in)	Limiting Factor
345	23	16	3.5"	Extra High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
345	23	16	5"	Extra High	20’-0	0.24	LF1	40’-0	2.46	LF4	40’-0	2.46	LF4
345	23	16	6"	Extra High	18’-0	0.11	LF1	47’-0	2.81	LF7	47’-0	2.81	LF7
345	30	16	3.5"	Extra High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
345	30	16	5"	Extra High	20’-0	0.24	LF1	40’-0	2.46	LF4	40’-0	2.46	LF4
345	30	16	6"	Extra High	18’-0	0.11	LF1	46’-0	2.61	LF7	46’-0	2.61	LF7
345	40	16	3.5"	Extra High	25’-0	1.20	LF1	28’-0	1.74	LF4	28’-0	1.74	LF4
345	40	16	5"	Extra High	20’-0	0.24	LF1	37’-0	1.89	LF2	40’-0	2.46	LF4
345	40	16	6"	Extra High	18’-0	0.11	LF1	35’-0	1.02	LF2	36’-6	1.18	LF7

LF1 = Switch Pad Moment Capacity Limited to 4,000 in-lb
LF2 = Horizontal Capacity of Switch
LF3 = Fiber Stress of the Bus Limited to 25,000 psi
LF4 = Maximum Deflection Limited to L/200
LF5 = Horizontal Capacity of Standard Strength Insulator
LF6 = Horizontal Capacity of High Strength Insulator
LF7 = Horizontal Capacity of Extra High Strength Insulator



__Application #1:__

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at one end)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (fixed fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (fixed fitting at switch)

__Application #2:__

Switch Pad to X# of Bus Supports to Switch Pad (expansion fitting at both ends)
Switch Pad to X# of Bus Supports to A-Frame Bus Tap (expansion fitting at switch)
Switch Pad to X# of Bus Supports to Bus Support (expansion fitting at switch)

__Application #3:__

Bus Support to X# of Bus Supports

__Note:__ Use an expansion fitting at the switch if overbus is in the same span as the switch.
__Note:__ The center and end supports may be moved as long as no single span is greater than the allowable maximum span L.

System Voltages **(1)**			Electrical Clearances and Spacings of Live Parts **(2) (3) (4) (5)**						Working Clearances to Live Parts							
Nominal	Maximum	Impulse Withstand	**Minimum**			**NSP Recommended ⁋**			Guard Zone Radius "R" **(7)**		Clearances to Live Parts From Any Permanent Supporting Surface for Personnel **(8)**				Clearances between Bare Overhead Conductor and Roadways	
			Phase-to-Phase **(6)**		Ph-to-Gnd	Phase-to-Phase **(6)**		Ph-to-Gnd			Vertical **(9) (10)**		Horizontal			
(Ph-Ph)	(Ph-Ph)	(BIL)	C-to-C	S-to-S	S-to-S	C-to-C	S-to-S	S-to-S								
(kV)	(kV)	(kV)	Spacings (ft-in)††	Clearances (ft-in)†	Clearances (ft-in)†	Spacings (ft-in)	Clearances (ft-in)	Clearances (ft-in)	Minimum ‡ (ft-in)	NSP ⁋ (ft-in)	Minimum ‡ (ft-in) **(11)**	NSP ⁋ (ft-in)	Minimum ‡ (ft-in)	NSP ⁋ (ft-in)	Minimum ‡‡ (ft-in) **(12)**	NSP ⁋ (ft-in)
2.4	2.54	95	1-3	0-7	0-6	1-6	**0-10**	**0-9**	0-3	0-3	8-9	10-9	3-4	3-4	18-6	20-0
4.16	4.4	95	1-3	0-7	0-6	1-6	**0-10**	**0-9**	0-3	0-3	8-9	10-9	3-4	3-4	18-6	20-0
12.5	13.2	110	£	£	£	3-0	**1-0**	**0-10**	£	0-6	£	11-0	£	3-6	18-6	20-0
13.8	14.52	110	2-0	1-0	0-7	3-0	**1-0**	**0-10**	0-6	0-6	9-0	11-0	3-6	3-6	18-6	20-0
23	24.34	150	2-6	1-3	0-10	3-0	**1-6**	1-3	0-9	0-9	9-3	11-3	3-9	3-9	18-7	20-0
34.5	36.51	200	3-0	1-6	1-1	3-6	1-6	**1-4**	1-0	1-0	9-6	11-6	4-0	4-0	19-0	22-0
69	72.5	350	5-0	2-7	2-1	5-0	**2-10**	**2-4**	1-11	1-11	10-5	12-5	4-11	4-11	20-2	23-0
115	121	550	7-0	4-5	3-6	8-0	**5-0**	**4-0**	3-1	3-1	11-7	13-7	6-1	6-1	21-10	25-0
161	169	750	9-0	6-0	4-2	9-0	**6-3**	**5-0**	4-4	4-10	12-10	14-10	7-4	7-10	23-5	26-0
230*	242	900	11-0	7-5	5-11	11-0	**8-6**	7-0	6-4	6-4	14-10	16-10	9-4	8-6	25-10	27-0
345*	362	1300	§	§	§	16-0	**11-0**	10-0	8-8	8-8	17-2	19-2	11-8	11-8	29-10	§
500*	550	1800	§	§	§	§	§	15-0	12-0	12-0	20-6	22-6	15-0	19-0	36-1	§

( ) Indicates an application note listed on the next sheet.

* EHV clearances are shown for reference only and should be verified with engineering before using.

⁋ NSP Recommended Clearances are NSP Company adopted values that are always greater than or equal to Minimum values taken from accepted national code publications. NSP recommended values shown in **BOLD** text were revised 12/03/96 to follow industry accepted criteria concerning phase-to-phase and phase-to-ground clearance comparisons discussed in section 4 of ED4.02.02. Care should be taken when applying these clearances that an appropriate ratio of phase-to-phase, surface-to-surface and phase-to-ground, surface-to-surface clearances is maintained.

† Minimum values taken from NEC Table 710-33 "Minimum Clearance of Live Parts."

‡ Minimum values taken from NESC Table 124-1 "Clearance From Live Parts."

†† Minimum values taken from NEMA Standards Publication No. SG6-1974 (R1979), Appendix A, Table 1 "Outdoor Substations -Basic Parameters," under column heading "Recommended Phase Spacing Center to Center for Bus Supports..."

‡‡ Minimum values taken from NESC Table 232-1, Cases 1 and 2, for Open Supply Conductors, see application note (12).

§ Indicates that the value is not available.

£ NESC Minimum clearance and spacing values for the 12.5kV system voltage level are not available. Minimum 12.5kV values shall be identical to those used at the 13.8kV system voltage level

S-to-S and C-to-C stand for Surface-to-Surface and Center-to-Center respectively.

OUTDOOR ELECTRICAL AND WORKING CLEARANCES

(1) System voltage designations are taken from ANSI Standard C84.1-1989, "Voltage Ratings (60 Hertz) for Electric Power Systems and Equipment", and NSP Engineering and Design Standard ED 4.01.02.01 "Basic Impulse Insulation Levels".

(2) The Electrical Clearances and Spacings shown in this table shall not apply to interior portions or exterior terminals of equipment designed, manufactured, and tested in accordance with accepted national standards. For NSP Recommended Clearances between external live parts of power transformers, see Standard ED 4.02.02.02 "Outdoor Equipment Phase Spacings".

(3) For clearance measurements, live metallic hardware electrically connected to line conductors shall be considered to be a part of the line conductors. Metallic bases of potheads, surge arresters, and similar devices shall be considered a part of the grounded supporting structure *(NESC rule 230B).*

(4) The Minimum Electrical Clearances and Spacings shown in this table are for rigid parts and bare conductors under favorable conditions. These clearances should be increased, to NSP recommended values or greater, if excess conductor movement or unfavorable service conditions exist.

(5) The Electrical Clearances and Spacings shown in this table apply to both rigid bus and short-span strain bus conductors. The conductor type, short circuit magnetic forces, and wind and ice loading conditions, should be considered in the design.

(6) The adopted NSP phase-to-phase clearance between live parts of different voltages shall be determined by the sum of the phase-to-ground clearances of each voltage level (i.e. assume a ground plane exists between the live parts).

(7) The clearance values for the Guard Zone Radius "R" are for guidance when installing a physical shield where the live part is not adequately guarded by location, isolation, or insulation *(NESC table 124-1, note 1).*

(8) Parts of indeterminate potential, such as ungrounded neutral connections, ungrounded frames, ungrounded parts of insulators or surge arresters, or ungrounded instrument cases connected directly to a high voltage circuit, shall be guarded in accordance with NESC Rule 124A1 on the basis that the maximum voltage may be present on the surface of that part. The vertical clearance above grade[1] to the bottom of such a part shall be not less than 8 ft.-6 in. (unless it is enclosed or guarded in accordance with Rule 124C) *(NESC rule 124A3).*

(9) The Minimum Vertical Working Clearances shown in this table may be reduced (provided surge-protective devices are applied to protect live parts) to a height not less than 8'-6" plus the electrical clearance between energized parts and ground as limited by the surge protective device *(NESC Table 124-1, note 1).*

---

[1] For NSP Substations, top-of-concrete elevations, not grade, will always be used as the general design basis for establishing the required vertical clearances to live parts.

(10) The NSP Recommended Vertical Clearances to Live Parts include two (2) feet of additional height over Minimum values for compacted snow depths. Vertical Working Clearance requirements for pedestal-mounted equipment do not include additional height for snow accumulation under the assumption that snow can be safely removed from the access area around this type of equipment.

(11) The Minimum Vertical Working Clearance dimension is calculated by adding the Guard Zone Radius "R" to the 8'-6" minimum dimension from grade to the bottom parts of indeterminent potential (see application note (8) above).

(12) The Minimum values for Clearances between Bare Overhead Conductors and Roadways is equal to the vertical clearance requirements in NESC Table 232-1, Cases 1 and 2, for "Open Supply Conductors 22kV and below". The vertical clearance dimensions for voltages above 22kV are specified by NESC Rule 232C1a, which increases this dimension at a rate of 0.4 inches per kilovolt above 22kV based on the maximum system operating voltage. e.g.: For 34.5kV, $H = [(36.5kV - 22kV) \times (0.4) \div 12] + 18.5 = 18.98$ feet (rounded up to 19'-0").

System Voltages		Switch Spacings Measured Center-to-Center						Clearances	
Nominal	Impulse Withstand	Vertical Break Disconnect Switches and Non-Vented Fuse Units		Side Break Disconnect Switches (Center, Single-End and Double-End)		Vertical and Side Break Horn-Gap Switches and Vented Fuse Units [g]		External Live Parts of Power Transformers **(3)**	
(Ph-Ph)	(BIL)	Minimum [a]	NSP [b]	Minimum [a]	NSP [b]	Minimum [c]	NSP [b]	(Ph-Grd)	(Ph-Ph)
(kV)	(kV)	(ft-in) **(1)**	(ft-in)	(ft-in) **(1)**	(ft-in)	(ft-in)	(ft-in)	(ft-in)	(ft-in)
2.4-7.2	95	1-6	3-0	2-6	3-0	3-0	4-0	0-4½	0-5
13.8	110	2-0	3-0	2-6	3-0	3-0	4-0	0-6	0-6½
23	150	2-6	3-0	3-0	4-0	4-0	5-0	0-8	0-9
34.5	200	3-0	3-0	4-0	4-0	4-3 [f]	6-0	1-0	1-1
69	330	5-0	7-0	6-0	7-0	7-0	8-0	1-11	2-1
115	550	7-0	9-0	9-0	9-0	9-0	10-0	3-1	3-5
161	750	9-0	9-0	13-0	13-0	13-0	14-0	4-4	4-9
230 [d]	900	11-0	11-0	16-0	16-0	16-0	16-0	6-4	7-0
345 [d]	1300	14-6	14-6	[e]	16-0 (2)	16-0	16-0 (2)	[e]	[e]

( ) Indicates an application note below.

[a] Minimum values taken from NEMA Standards Publication No. SG6-1974 (R1979), Appendix A, Table 1 "Outdoor Substations -Basic Parameters," under column heading "Recommended Phase Spacing Center to Center for ...Vertical Break Disconnect Switches and Non-Expulsion Type Power Fuses... "

[b] NSP Recommended Switch Spacings are NSP Company adopted values that are always greater than or equal to Minimum values taken from accepted national code publications.

[c] Minimum values taken from NEMA Standards Publication No. SG6-1974 (R1979), Appendix A, Table 1 "Outdoor Substations -Basic Parameters," under column heading "Recommended Phase Spacing Center to Center for Horn Gap Switches and Expulsion Type Fuses."

[d] EHV spacings are shown for reference only.

[e] Indicates that the value is not available.

[f] Value increased from Minimum NEMA Standard value to obtain required switch clearances with some suppliers.

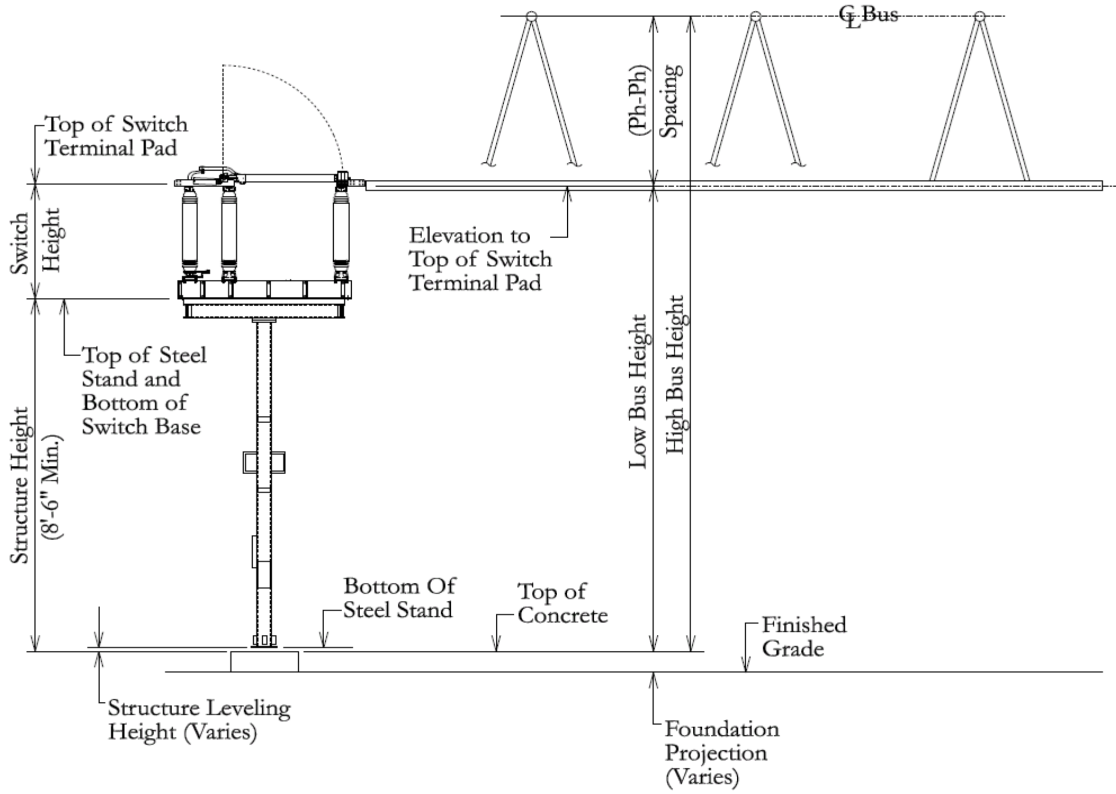
[g] The standard arcing contacts specified in the Xcel Energy Standard EMS-J.08-001 "Outdoor High-Voltage Air Switches and Operating Mechanisms" are arcing horns that do not affect phase separation. Vertical break switches with these standard arcing horns can be mounted with the spacings listed in column 4, "Vertical Break Disconnect Switches and Non-Vented Fuse Units". Solid material fuses normally used in substations (such as S&C SM and SMD fuses) are considered non-venting and can also be mounted with these column 4 spacings. Switches with optional arcing whips will need to be reviewed for proper phase separation.

(1) The Minimum values for vertical and side break switches may be reduced dependent upon the switch manufacturer. However, in no case should the surface-to-surface distance between energized parts be less than that shown in Standard ED 4.02.02.01.

(2) The NSP values for 345kV side break and horn-gap switches are based on a double break disconnect switch.

(3) The surface-to-surface clearance values used for external live parts of power transformers are based on NEMA Standards Publication TR1-0.15.

Low-Profile Bus Height Measurements



Nominal Voltage System (Ph-Ph) (kV)	Maximum System Voltage (Ph-Ph) (kV)	Impulse Withstand Voltage (BIL) (kV)	Xcel Energy Standard Switch Height (ft-in) (1)	Low-Profile Bus Heights (2) (3) (4) (5): Low Bus Height — Minimum † (ft-in) (6) (7)	Low Bus Height — Xcel Energy ☞ (ft-in) (8)	High Bus Height — Minimum (ft-in) (10)	High Bus Height — Xcel Energy ☞ (ft-in) (11)
15	15.5	110	2-3	9-0	14-3 (9)	11-0	17-3
34.5	36.51	200	2-6	9-6	14-3 (9)	12-6	17-9
69	72.5	350	3-8	10-5	12-6	15-5	17-6
69	72.5	350	3-4 (V-Style)	£	£	£	£
115	121	550	5-4	11-7	14-0	18-7	22-0
161	169	750	6-8	12-10	15-2	21-10	24-2
230*	242	900	8-6	14-10	17-0	25-10	28-0
345*	362	1300	11-0	§	21-2	§	37-2
500*	550	1800	16-2	§	31-2	§	53-2

( ) Indicates an application note on the next sheet.

* EHV bus heights are based on past Xcel Energy practice and have not been updated.

☞ Xcel Energy-North Recommended Low-Profile Bus Heights are Company adopted values that are always greater than or equal to Minimum values taken from accepted national code publications.

† Minimum values taken from NESC Table 124-1 "Clearance From Live Parts".

£ V-style switches are for package substations only.

§ Indicates that the value is variable.

(1) Xcel Energy-North Standard Switch Heights are measured from the bottom of the switch base to the top of the switch terminal pad. These dimensions are required for all Xcel Energy-North specified switches.

(2) The Structure Height is measured from the top of concrete to the bottom of the switch base and is calculated by subtracting the Switch Height from the Xcel Energy-North Low-Bus Height dimension. The variable Structure Leveling Height is included in this structure height dimension. In no case shall the Structure Height be less than 8 feet-6 inches.

(3) All low profile bus heights listed in this Standard are measured from the top of concrete to the top of the switch pad. This bus height dimension does not include projection heights of foundations above finished grade. Dimensions shown on project drawings should be shown accordingly.

(4) These low profile bus heights do not include special conditions such as buses over driveways or connections to power transformers or circuit breakers. Additional clearance requirements should be anticipated in these cases.

(5) The Phase-to-Phase dimension between the low bus and the high bus is measured centerline-to-centerline.

(6) The Minimum Low Bus Height is equal to the Minimum Vertical Working Clearance requirement shown in Standard ED 4.02.02.01.

(7) The Minimum Low Bus Height may be reduced (provided surge-protective devices are applied to protect live parts) to a height not less than 8 feet-6 inches plus the electrical clearance between energized parts and ground as limited by the surge protective device *(NESC Table 124-1, note 1)*.

(8) The Xcel Energy-North Recommended Low Bus Height shall always be equal to or greater than the Minimum Vertical Working Clearance (see Standard ED 4.02.02.01) plus 2 feet of additional height for average compressed snow conditions. The Xcel Energy-North Recommended Low Bus Height shall not be less than the Xcel Energy-North Standard Switch Height plus 8 feet-6 inches.

(9) The Xcel Energy-North Recommended Low-Bus heights at 15kV and 34.5kV are designed to meet switchgear bus requirements and exceed Minimum Low Bus Height requirements.

(10) The Minimum High-Bus Height is calculated by adding the Minimum Low Bus Height to the Minimum Center-to-Center Electrical Spacing dimension (see Standard ED 4.02.02.01).

(11) The Xcel Energy-North Recommended High Bus Height of all system voltage levels, except 500kV, are calculated by adding the Xcel Energy-North Recommended Low-Bus Height to the Xcel Energy-North Recommended Center-to-Center Electrical Spacing dimension (see Standard ED 4.02.02.01).

Nominal System Voltage (Ph-Ph) (kV)	Maximum System Voltage (Ph-Ph) (kV)	Impulse Withstand Voltage **(1)** (BIL) (kV)	Indoor Electrical Clearance Between Live Parts Measured Surface-to-Surface **(2) (3) (4) (5)**			
			Phase-Phase		Phase-to-Ground	
			Minimum † (inches)	NSP • (inches)	Minimum † (inches)	NSP • (inches)
2.4	2.54	45	4.5	4.5	3.0	3.0
4.16	4.4	60	4.5	4.5	3.0	3.0
12.5	13.2	95	§	7.5	§	5.0
13.8	14.52	95	7.5	7.5	5.0	5.0
23	24.34	125	10.5	13.0	7.5	7.5
34.5	36.51	200	18.0	18.0	13.0	13.0

( ) Indicates an application note below.

• NSP Recommended Clearances are NSP Company adopted values that are always greater than or equal to Minimum values taken from accepted national code publications.

† Minimum values taken from NEC Table 710-33 “Minimum Clearance of Live Parts.”

§ Indicates that the value is not available

(1) The BIL voltages listed in this table are for indoor applications.

(2) These values are the required clearances for rigid parts and bare conductors under favorable service conditions (no dust or moisture). The values should be increased to allow for conductor movement, when operating under unfavorable service conditions or whenever space limitations permit *(NEC Article 710-33).*

(3) The minimum phase-to-phase centerline spacing of indoor switches and fuses, without the use of barriers, shall be equal to the maximum width of live parts plus the minimum surface-to-surface clearances in this table.

(4) These values do not apply to interior portions or exterior terminals of equipment designed, manufactured, and tested in accordance with accepted national standards *(NEC Article 710-33).*

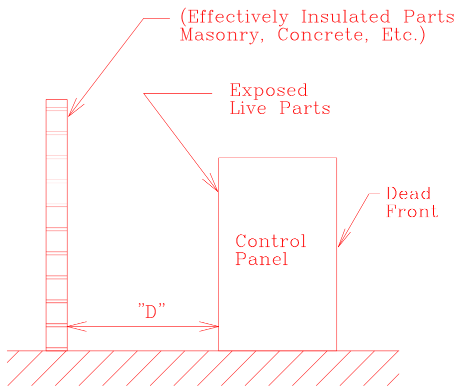
(5) The proper installation of adequate insulating barriers between phases or between phase and ground may permit the reduction of these clearance values.

INDOOR ELECTRICAL CLEARANCES (ABOVE 600 VOLTS)

Nominal System Voltage Phase-Ground	"D" Minimum Indoor Working Clearance in Front of Electric Equipment **(1) (2) (3) (4)**		
	Case 1*	Case 2*	Case 3*
(Volts)	(ft-in)	(ft-in)	(ft-in)
0-150	3-0	3-0	3-0
151-600	3-0	3-6	4-0

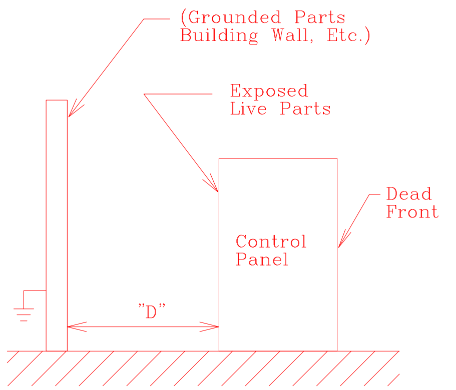
( ) Indicates an application note listed on the next sheet.

* See the case descriptions and sketches below.



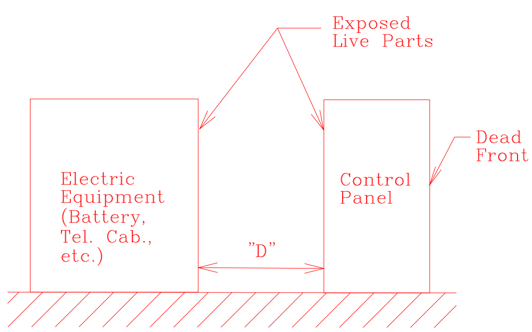
Case 1

Case 1: Exposed live parts on one side and no live or grounded part on the other side of the working space, or exposed live parts effectively guarded by suitable insulating materials. Insulated wire or insulated busbars operating at not over 300 volts shall not be considered live parts. *(NESC Table 125-1, note 1).*



Case 2

Case 2: Exposed live parts on one side and grounded parts on the other side. *(NESC table 125-1, note 2).*



Case 3

Case 3: Exposed live parts on both sides of the work space with the operator between. *NESC Table 125-1, note 3).* Where there is an enclosure on opposite sides of the work space, the clearance is required for only one work space. *(NESC Handbook, Figure 110-12).*

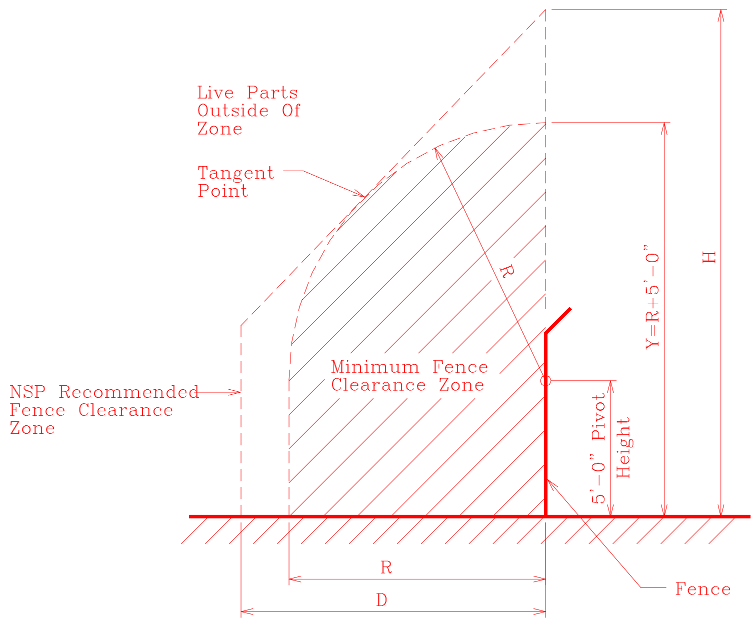
INDOOR WORKING CLEARANCES (600 VOLTS AND BELOW)

(1) Working space is not required in back of equipment such as dead-front switchboards or controls assemblies if there are no renewable or adjustable parts such as fuses or switches on the back, and if all connections are accessible from locations other than the back. Where it is necessary to work on de-energized parts in the back of enclosed equipment, a minimum horizontal working space of 30 inches is required. *(NESC Table 125-1)*.

(2) Working areas about equipment shall be clear, unobstructed space and shall not be used for storage. *(NESC Rule 125A1).*

(3) Distances shall be measured either from the live parts, if such are exposed, or from the enclosure front or rear if the live parts are enclosed. *(NESC Rule 125A3).*

(4) Equipment must not be installed so close to walls that the equipment door or hinged panel cannot open at least 90 degrees. Where doors or hinged panels are wider than 3 feet, work space, greater than 3 feet, must be provided to meet the 90 degree requirement. *(NEC Article 110-16a).*



Clearance Zone for Substation Perimeter Fences

Nominal System Voltage (Ph-Ph) (kV)	Maximum System Voltage (Ph-Ph) (kV)	Impulse Withstand Voltage (BIL) (kV)	Fence Clearance Zone **(1)** Minimum Zone Dimension "R" (ft-in) **(2)**	Fence Clearance Zone **(1)** Minimum Zone Dimension "Y" (ft-in) **(3)**	Fence Clearance Zone **(1)** NSP Recommended Zone Dimension "D" (ft-in) **(4)**	Fence Clearance Zone **(1)** NSP Recommended Zone Dimension "H" (ft-in) **(5)**
up to 7.2	——	——	10-0	15-0	15-0	20-0
13.8	14.52	110	10-2	15-2	15-0	20-0
23	24.34	150	10-4	15-4	15-0	20-0
34.5	36.51	200	10-7	15-7	15-0	22-0
69	72.5	350	11-7	16-7	15-0	23-0
115	121	550	13-0	18-0	15-0	25-0
161	169	650	14-4	19-4	15-0	26-0
230	242	900	15-5	20-5	20-0	27-0
345	362	1300	16-5	21-5	20-0	§
500	550	1800	17-4	22-4	20-0	§

( ) Indicates an application note shown on the next sheet.

§ Indicates that the value is not available.

PERIMETER FENCE CLEARANCES

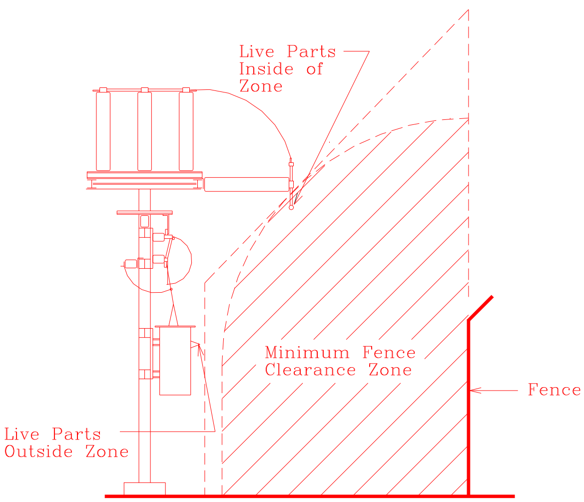
(1) For nominal phase-to-phase voltages of 115kV and above, the dimensions should be increased 3% for each 1000 ft. in excess of 3300 ft. above mean sea level[1]

(2) The values for dimension "R" are taken from NESC Rule 110A2, CP 1828, Fence Safety Clearance Zone.

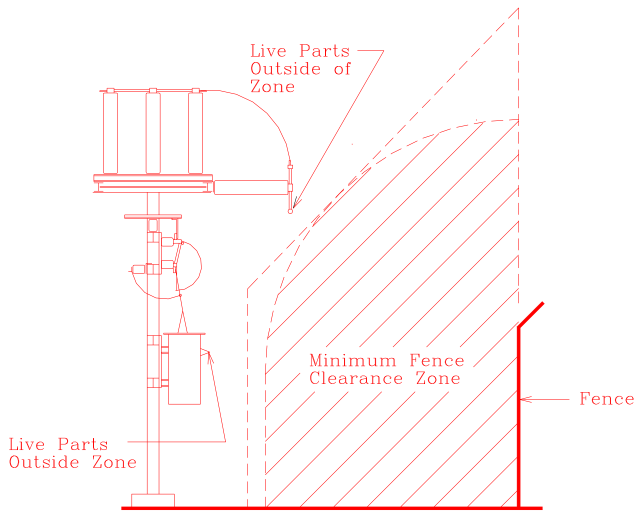
(3) The Minimum values for dimension "Y" are equal to the Minimum value of "R" plus a pivot height of five (5) feet (see note 2 above).

(4) The NSP Recommended values for dimension "D" are the adopted values for equipment access, maintenance and snow removal. This dimension should be increased to provide additional equipment access and drive space when required.

(5) The NSP Recommended value for dimension "H" is equal to the NSP Recommended Vertical Clearance between Bare Overhead Conductors and Roadways as shown in Standard ED 4.02.02.01 "Outdoor Electrical and Working Clearances".



Example 1
Illustration Showing <u>Inadequate</u> Fence Clearance



Example 2
Illustration Showing <u>Adequate</u> Fence Clearance

Example 1: As shown in the illustration above, the proposed fence location allows the live parts, located on the structure column, to meet the NSP Recommended Fence Clearance requirement. However, in the same example, the live parts located overhead extend into the clearance zone making this arrangement unacceptable.

Example 2: As shown in the illustration above, the proposed fence location allows both the live parts located on the structure column and the live parts located overhead to meet the NSP Recommended Fence Clearance requirement.

Refer to ANSI C2-1993, National Electric Safety Code (NESC), 1993 Edition, Part 2, "Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communication Lines", Rule 232C1b.

PERIMETER FENCE CLEARANCES

Electrical and Working Clearance Standard Subcommittee Approval

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Table of Contents

1. INTRODUCTION

1.1. Purpose

This standard provides electrical clearance guidelines and design application information for outdoor, open-bus type electrical substation installations. Requirements for accessibility about electric equipment inside substation control buildings and aisle-type, medium voltage, switchgear units are also discussed. These clearances will aid in the design of safe and reliable substations under normal and anticipated abnormal operating conditions with a minimum of system disruptions.

While proper application of these standards is necessary to achieve the above mentioned goals, ultimately, it is the user's level of understanding of this document, familiarity with national and local code requirements, knowledge of the unique project requirements, and good engineering judgment that will lead to safe substation construction, maintenance and operation.

1.2. Scope

This standard addresses outdoor electrical and working clearance requirements within effectively grounded electric supply substations that are accessible only to qualified or authorized personnel. System voltages from 2.4kV through 161kV, with corresponding BIL voltages currently used in NSP transmission and distribution substations, are accepted as a basis for this clearance standard. Clearances for EHV levels (230kV through 500kV) are included in some tables but are for reference purposes only. Design procedures for establishing EHV clearances and spacings, based on BIL or switching surge factors, are not within the scope of this standard. All clearances in this standard assume non-contaminated air or insulation surfaces.

1.2.1. Engineering and Design Standards

The following NSP Electric Delivery Standards for Substation Engineering and Design supplement this Design Criteria:

- ED 4.02.02.01: Included in this standard is a listing of minimum and NSP Recommended Electrical and Working Clearances. This table includes specific design application notes to explain and clarify the use of the values in the table. This table of values is a key element of this standard and should be referred to when establishing clearance requirements.
- ED 4.02.02.02: Phase spacings of air-break switches, power fuses, and external live parts of power transformers are tabulated in this standard.
- ED 4.02.02.03: Standard bus heights and switch heights for low-profile substations are presented in this table.
- ED 4.02.02.04: A table of Minimum and NSP Recommended Indoor Electrical Clearances is included in this standard. These values provide guidance in verifying electrical clearances for switchgear and pad-mounted distribution equipment.

- ED 4.02.02.05: Working space requirements for qualified/authorized personnel are covered in this standard for the area around electrical equipment, switchgear breaker cubicles and panelboards within control buildings and metal-enclosed switchgear.
- ED 4.02.02.06: Guidelines for enclosing outdoor electrical equipment with fences are discussed in this standard which includes supplemental sketches and design application notes.

1.2.2. New and Existing Installations

The NSP Recommended Electrical and Working Clearances and Spacings specified within this Standard shall be applied to all new substation installations and additions to existing substations. It is recognized, however, that structural dimensions, equipment locations, vehicle access requirements, and limited land area may not permit the application of the NSP Recommended values. In these cases, clearances and spacings shall meet or exceed the Minimum values shown in Standard ED 4.02.02.01.

1.2.2.1. Uprating and Compacting

In no case should clearances and spacings be used that are less than the Minimum values shown in Standard ED 4.02.02.01 unless insulation coordination studies, and system transient analysis data on switching surges indicate that reduced minimum phase-to-phase clearances and spacings may be applied.

Methods of utilizing calculated magnitudes of over-voltage stresses or the protective action of surge arresters to determine reduced minimum phase-to-phase clearances for the uprating or compacting of high voltage substations are not addressed in this standard[1, 2].

1.2.3. Exclusions

This standard does not include guidelines for the following applications and installations:

- Overhead electric supply and communications lines, and pole-top mounted equipment [3].
- Working clearances around energized lines and equipment[4].

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1 Refer to IEEE Working Group 59.1, IEEE Transactions, Vol. 91, 1972 "Minimum Line-to-Ground Electrical Clearances for EHV Substations Based on Switching Surge Requirements".

2 Refer to IEEE Transactions, Vol. PAS-98, No. 3, May/June 1979, Sebo, S., Caldecott, R., "Scale Model Studies of AC Substation Electric Fields,"

3 Refer to ANSI C2-1993, National Electric Safety Code (NESC), 1993 Edition, Part 2, "Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communication Lines."

4 Refer to ANSI C2-1993, National Electric Safety Code (NESC), 1993 Edition, Part 4, "Rules for the Operation of Electric Supply and Communications Lines and Equipment."

2. REFERENCES

The following standards and publications are referred to in the text of this document. Material taken from a specific reference is indicated by the use of brackets [ ], with a number corresponding to the following list:

2.1. Industry Standards

[1] ANSI C2-1993, National Electric Safety Code (NESC),1993 Edition Part 1, "Rules for the Maintenance of Electric Supply Stations and Equipment."

[2] National Electric Safety Code Handbook, Third Edition, "A Discussion of the Grounding Rules, General Rules, and Parts 1, 2, 3, and 4 of the 3rd (1920) through 1993 Editions of the National Electric Safety Code, ANSI C2."

[3] National Electric Code Handbook, Seventh Edition, based on the 1996 Edition of the National Electric Code (NEC), NFPA 70-1996. Note: Although the scope of the NEC does not include Electric Supply Stations, some clearance and workspace requirements are applicable to this type of installation..

[4] ANSI/IEEE 1119-1988, "Guide for Fence Safety Clearances in Electric-Supply Stations." This standard is referenced in lieu of its incorporation into the NESC under Rule 110A2.

[5] ANSI C84.1-1989, "Voltage Ratings (60 Hertz) for Electric Power Systems and Equipment."

[6] NEMA SG6, "Power Switching Equipment."

[7] ANSI/IEEE Standard 100-1988, "IEEE Standard Dictionary of Electrical and Electronics Terms."

2.2. Industry Approved Research Publications

[8] Panek, J., Elahi, H., Sublich, M., "Criteria for Phase-to-Phase Clearances of HV Substations," IEEE Paper No. 89 SM 619-8 PWRD, IEEE/PES 1989 Summer Meeting.

[9] Udo, T., "Minimum Phase-to-Phase Electrical Clearances for Substations Based on Switching Surges and Lightning Surges," IEEE Transactions, Vol. PAS-85, No. 8, August 1966.

2.3. NSP Standards for Substation Engineering and Design

[10] ED 4.09.03, "Fencing System."

[11] ED 7.02.01, "Location Drawing - Title Function and Reference."

3. DEFINITIONS OF TERMS

The following definitions are used in this Standard and are taken from the references indicated. Definitions without a reference are adopted by NSP for this Standard. For a listing of terms used in this document, but not shown below, see Reference [7].

Apparatus Bushing: See "Insulator."

Basic Impulse Insulation Level (BIL): An insulation strength expressed in terms of the crest value of a standard 1.2x50μs impulse wave having a rise time (1.2μs) and duration (50μs) similar to a lightning surge for which the insulation of electrical equipment experiences a very low probability of failure when subjected to a specific number of tests under specific conditions [7].

Clearance: The unobstructed distance between two objects measured surface-to-surface [1].

Effectively Grounded: A ground connection or connections intentionally connected to earth through a sufficiently low impedance such that for all system conditions the ratio of zero-sequence reactance to positive-sequence reactance (X_0/X_1) is positive and less than 3, and the ratio of zero-sequence resistance to positive-sequence reactance (R_0/X_1) is positive and less than 1. The ground connection or connections shall also have sufficient current-carrying capacity to prevent the buildup of voltages that may result in undue hazard to connected equipment or to persons [1].

Electric Supply Station: Any building, room, or separate space within which electric supply equipment is located and the interior of which is accessible only to qualified persons. This includes generating stations, substations, and does not include facilities such as pad-mounted equipment and installations in manholes and vaults [1].

Energized Parts: See "Live Parts."

Finished Grade: The elevation of the compacted crushed-rock surfacing of a substation site that is typically four inches above the rough grade.

Guarded: Covered, fenced, enclosed, or otherwise protected by means of suitable covers or casings, barrier rails or screens, mats or platforms designed to minimize the possibility, under normal conditions, of dangerous approach or accidental contact by persons or objects [1].

Guard Zone: A well-defined space, established by the NESC surrounding a live part within which a person shall not enter nor extend a conductive object while the part is energized.

Handhole: An access opening, provided in equipment or in a below-the-surface enclosure in connection with underground lines, into which personnel reach but do not enter for the purpose of installing, operating, or maintaining equipment or cable or both [1].

Insulated: Separated from other conducting surfaces by a dielectric (including air space) offering a high resistance to the passage of current [1].

Insulator: Insulating material such as porcelain, polymer, or epoxy compound, designed to support or isolate an energized conductor physically and electrically from another conductor or object. An indeterminate voltage exists along the outer surface of the insulator, therefore, "live parts" includes the insulator body itself [1]. See Figure 1.

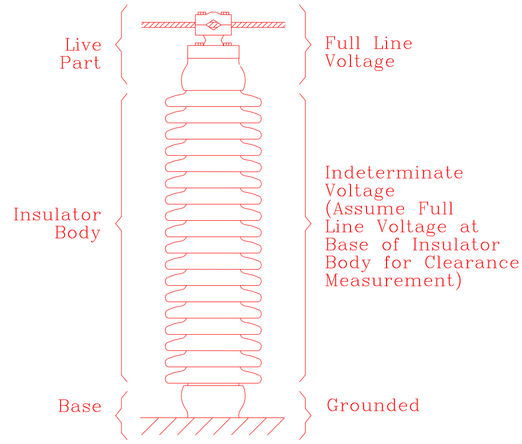


Figure 1
Voltage Classification of Insulator Parts

Live Parts: Those parts that are designed to operate at a voltage different from that of the earth [1].

Maximum System Voltage: The highest rms phase-to-phase voltage that occurs under normal operating conditions, and the highest rms voltage at which electrical apparatus and equipment is designed for satisfactory continuous operation without derating of any kind [5].

Minimum Clearances: The minimum values taken from accepted national code publications.

Nominal System Voltage: The rms phase-to-phase voltage by which a portion of the system is designated, and to which certain operating characteristics of the system are related [5].

NSP Recommended Clearances: NSP Company adopted values that are always greater than or equal to Minimum Clearances.

Pad Mounted Equipment: A general term describing enclosed equipment, the exterior of which enclosure is at ground potential, positioned on a surface-mounted pad [1].

Qualified: Having adequate knowledge of the installation, construction, or operation of the apparatus and the hazards involved [3].

Spacing: The unobstructed distance between two objects measured centerline to centerline [1].

Switching Surge Factor: An expression of the maximum switching-surge crest voltage in terms of the maximum operating line-to-neutral crest voltage of the power system [1].

4. OUTDOOR ELECTRICAL CLEARANCES

As defined above, *clearances* in this Standard shall be measured from surface-to-surface and all *spacings* shall be measured center-to-center [1], see Figure 2. The industry accepted criteria used in determining phase-to-phase electrical clearances for voltages up to 230kV comes from the comparison of phase-to-ground clearances with phase-to-phase clearances such that a flashover, due to a standard 1.2x50μs lightning impulse wave, will occur phase-to-ground rather than phase-to-phase or across an open switch [8].

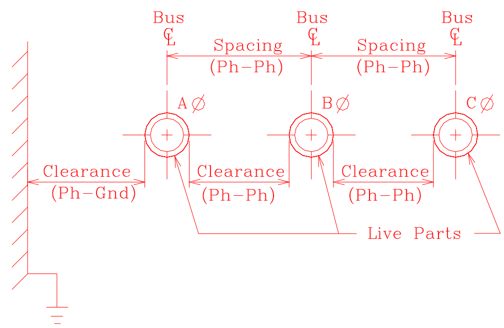


Figure 2
Clearance and Spacing Measurements

As a result of this criteria, the NSP recommended phase-to-ground and surface-to-surface clearances for some voltage classes were revised to be in compliance.

An example of when this criteria should be applied is when factory-installed switch insulators are proposed to be replaced with longer insulators (and a corresponding increase in BIL rating) to increase the height of the live parts. This action may compromise the BIL coordination of the switch insulators with the flash-over distance of the open-switch air gap and is not a recommended NSP practice.

4.1. Rigid Bus

Bus height, clearance, and spacing requirements given in Standard ED 4.02.02.01 can be used for general rigid bus design applications. This standard has been established primarily because of the effort, within NSP, to standardize both the structural support heights and the dimensions of the disconnect switches from the bottom of the switch base to the top of the switch terminal pad. Refer to Standard ED 4.02.02.03 for a table of bus heights for low-profile substations.

Electrical clearances between rigid and short-span strain bus conductors that cross over each other, within the substation fence, are not strictly governed by code requirements. Therefore, this standard applies the same criteria for crossover clearances as those used for horizontal bus clearances. See Standard ED 4.02.02.01. This interpretation of the code is based on the fact that conductor and bus movement is controlled more carefully in the restricted area of a substation than in typical overhead conductor environments [2].

4.2. Strain Bus

When non-rigid (strain) conductors are used for overhead bus installations in a substation, the movement of the conductors, caused by wind and ice loads, extreme temperature changes, and short-circuit forces must be considered when determining strain bus clearances and spacings.

Short strain-bus spans (less than 40 feet), typically used for box structures, may follow the same electrical clearances and spacings that are applied to rigid bus conductors because the typical dead-ending configurations and mid-span bus taps help limit conductor movement.

The electrical clearances and spacings of long strain-bus spans (greater than 40 feet) within a substation should be greater than those used for rigid bus because wind and short-circuit magnetic forces can cause a temporary, though significant, reduction in conductor spacing. The practice of increasing the minimum rigid bus spacings and clearances by fifty (50) percent for long span strain-bus applications is an accepted method. The spacing of slack spans dead-ending at the substation should be at least the same spacing as the transmission line structure. Spans that have a vertical-to-horizontal transposition or do not terminate perpendicular to the substation dead-end structure require special clearance and spacing consideration. If sag and tension data of the span is known, more precise clearances and spacings can be determined for vertical clearances.

4.3. Electrical Apparatus

The following electrical apparatus are designed, manufactured, and tested in accordance with accepted national standards and are not designed for a particular installation:

- Power Transformers
- Power Circuit Breakers
- Power Circuit Reclosers
- Instrument Transformers (CT, VT, CCVT)
- Surge Arresters (including grading rings)
- Cable Terminators

The manufacturer of these items is assumed to provide the necessary electrical clearances within, or on the apparatus [2][3]. NSP does, however, require that certain minimum clearances between external live parts of power transformers comply with NEMA Standards Publication No. TR1-0.15. See Standard ED 4.02.02.02 for these required dimensions.

4.4. Switches and Fuses

In determining Electrical Clearances, live metallic hardware, electrically connected to line conductors shall be considered to be a part of the line conductors [1]. Standard ED 4.02.02.02 includes a table of NSP Recommended switch spacings which should be applied to all installations, if possible. Adequate clearances must be maintained for switches in the open or closed positions and anywhere between the open and closed positions. Vertical-break, side-break, center-side-break, and double-end-break type switches each have clearance issues specific to the style of switch and manufacturer; clearances that are acceptable for one type of switch may not apply to a different type of switch. All spacings of switches and power fuse holders shall be verified against specific manufacturer recommendations and the clearance requirements shown in Standard ED 4.02.02.01.

Minimum Electrical Clearances must be maintained between live metallic hardware on the switch poles including, but not limited to, such devices as arcing horns, vacuum interrupter attachments, grounding switch attachments, corona hardware and bus expansion terminals. High velocity, whip-type interrupter attachments require additional overhead clearances and the installation of these devices shall follow manufacturer recommendations. Hookstick-operated disconnect switches frequently include switch blade stops that limit the travel of the blade to avoid interference with equipment cable connections and to maintain phase-to-ground clearances. It should be noted that items such as grounding stirrups and surge arrester attachments may also reduce clearances. Clearance measurements must take these design issues into consideration to ensure an acceptable final installation.

5. INDOOR ELECTRICAL CLEARANCES

Although the primary purpose of this clearance standard is to provide clearance guidelines for open-bus (outdoor) type substations, Standard ED 4.02.02.04 is included to provide guidance in verifying electrical clearances for switchgear and pad-mounted distribution equipment.

6. OUTDOOR WORKING CLEARANCES

Every effort must be made at NSP substation installations to maintain adequate working clearances. It is important to note that, because of the competing requirements for inspection, repair or adjustment, and quick access to equipment, guarding live parts will always be less than foolproof or perfect [2]. See Standard ED 3.04.03 for equipment access and removal requirements.

In the effort to safeguard authorized personnel within an NSP substation installation, all live parts must be guarded either by *location, physical isolation,* or *insulation*.

6.1. Guarding by Location

Live parts installed according to Standard ED 4.02.02.01 are guarded by *location*, meaning that no physical shield exists but that the energized part is located safely out of reach. See Figure 3. The NESC has established a "Guard Zone" distance to ensure that live parts of indeterminate potential (e.g. insulators and bushings) are guarded on the basis that the maximum line potential may be present at the base of the insulator body. By subtracting this Guard Zone distance from the Minimum Vertical Working Clearance dimension, a height of 8 feet 6 inches results as the closest allowable approach distance to a live part guarded by location [2]. This 8 foot 6 inch dimension shall be maintained to the base of

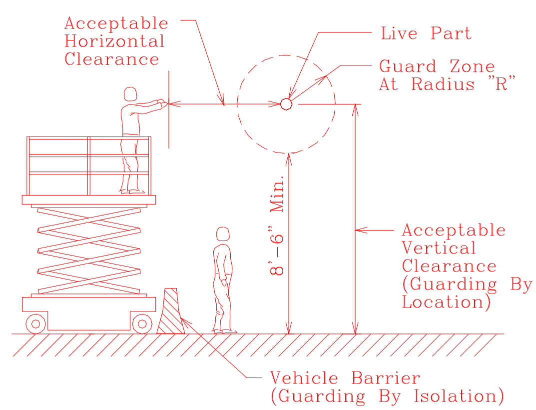


Figure 3
Guarding Live Parts by Location and Isolation

all insulators and apparatus bushings for any voltage class, regardless of their height, unless appropriate enclosures or physical guards are used.

6.1.1. Measuring to Live Parts

The NESC states that "...if a raised concrete foundation extends out far enough for a worker to stand on it without conscious effort, the required clearance is to be measured from the top of the foundation. Otherwise, the height of the foundation above ground contributes to meeting the vertical clearances" [2].

For NSP substations, however, top-of-concrete elevations shall always be used as the general design basis for establishing the required vertical clearances to live parts *even when a worker cannot stand on the top surface of the supporting foundation*. This practice provides a consistent basis for establishing vertical working clearances since site grading requirements and non-uniform rock surfacing depths hamper efforts to determine the exact finished grade elevations.

6.1.2. Electrical Apparatus

Working Clearances for safe personnel movement must be provided around all electrical apparatus in its final installation. The Vertical and Horizontal Clearances, given in Standard ED 4.02.02.01, are required between any permanent supporting surface (defined by NSP as the top of concrete) and live parts of all electrical apparatus [2]. The required working clearance to live, unguarded parts of electrical apparatus can be achieved by meeting either of the following criteria:

- The Horizontal Working Clearance via permanent guards or rails (see "Guarding by Isolation in this Design Criteria).
- The Vertical Working Clearance dimension.
- The "Taut String Distance" equal to the required Vertical Clearance See Figure 4.

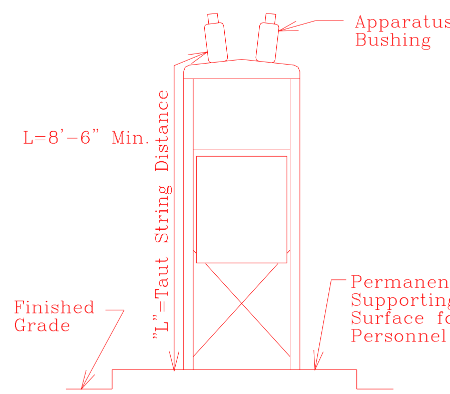


Figure 4
"Taut String" Measurement

6.1.3. Pedestal Mounted Equipment

For the purpose of establishing Vertical Clearance requirements, grounded metallic bases of potheads, surge arresters, current and potential transformers, capacitive voltage transformers, and similar devices shall be considered to be a part of the supporting structure [1]. An example of this application is the installation of an outdoor potential transformer with a grounded metallic base, bolted to the structure, and a porcelain bushing attached to the top of the base. See Figure 5.

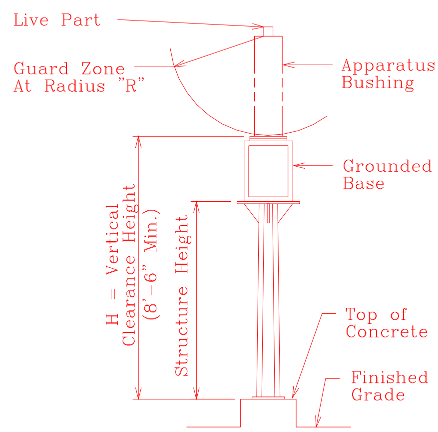


Figure 5
NSP Vertical Clearance Measurement

In this example, the Minimum Vertical Working Clearance measurement required by the NESC (resulting in the shortest structure) is taken from the finished grade to the top of the grounded equipment base (bottom of the bushing).

However, as in the case of electrical apparatus installations in an NSP substation, Vertical Working Clearances should always be measured from the supporting concrete surface to the bottom of the bushing and not measured from the finished grade elevation. If the exact outline dimensions of the equipment are not known at the design stage of the project, a minimum structure height of 8 feet 6 inches shall be used to ensure adequate Vertical Working Clearances.

6.1.4. Mobile and Portable Equipment

Clearances for portable electrical equipment such as mobile transformers are based on maintenance procedure requirements and personnel safety. For voltages below 230kV, an accepted vertical clearance is obtained by considering the maximum height of the mobile or maintenance equipment, and providing a normal line-to-ground clearance plus a margin of 10-15%. Clearances given in Standard ED 4.02.02.01 can be used for the general applications of conductors over roadways. However, applications involving mobile equipment should be verified with specific equipment dimensions.

Clearance must be provided beneath energized buses where a roadway for such equipment is to be placed. Roadways within the substation fence should be carefully planned, using vehicle turning radius templates for the expected equipment, to prevent difficult and/or unsafe entry and exit paths. Signs, mounted on all vehicle entrance gates of substation installations, shall warn of limited overhead clearances [11].

6.2. Guarding by Isolation

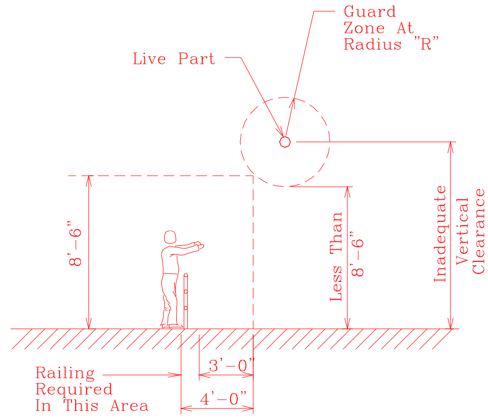


Figure 6
Guarding by Isolation Using Railings

Live parts are guarded by *isolation* if all access paths are locked, barricaded, or roped off, and warning signs are posted at all entrances (Live parts within a substation fence are not, according to the NESC, inherently guarded by isolation) [1]. The NESC requires that "... spaces in which electric supply conductors or equipment are installed shall be so arranged with fences, screens, partitions or walls to form an enclosure as to minimize the possibility of entrance of unauthorized persons or interference by them with equipment inside" [1]. See Figure 6.

6.2.1. Permanent Guards

Permanent electrical guards, if carefully planned and installed, may allow safe repairs near energized parts without requiring temporary protective devices or outages of adjacent circuits. Permanent guards also tend to prevent accidental short circuits and the inadvertent spread of outages beyond the place of origin [2]. Apparatus bushing guards are an example of such a device.

6.2.2. Removable or Temporary Barriers

Operations involving repairs, maintenance, construction, reconstruction and extensions to existing equipment may expose unqualified personnel to unfamiliar hazards. The use of temporary barriers, guards, warning signs or other special care is necessary under these circumstances. Electrical and working clearances that apply to a substation in its normal state of operations (Standard ED 4.02.02.01) also apply to the substation undergoing construction changes or additions [1], see Figures 3 and 6.

6.2.3. Railings

Railings, while not a substitute for complete and permanent guards, can be used to limit the opportunity for persons within the substation to inadvertently contact energized parts located below the Minimum Vertical Clearances required in Standard ED 4.02.02.01. If the required vertical clearance cannot be realized, and railings are used, they shall be located at a horizontal distance of at least three (3) feet, and not more than four (4) feet from the nearest point of the guard zone that is 8'-6" above the floor [1], see Figure 6. The location requirements for the railing are given so that an authorized person may be aware of which live part the railing is guarding. No portion of a perimeter fence may be used for such a railing. This NESC rule is intended to clearly limit access to a dangerous area and to require a conscious effort for persons to climb up-to or into an area where live parts are located.

6.2.4. Fence Clearances

The intent of fence clearance requirements is to provide a reasonable clearance zone so that "someone inserting an object through a substation fence, partition, or wall, installed to minimize the possibility of entrance of unauthorized persons, should not contact live parts or come close enough to the live parts to violate the required live-part-to-ground clearance requirements" [4].

As illustrated in Figure 7 and defined in Standard ED 4.02.02.06, the Fence Clearance Zone inside the substation perimeter fence is defined by certain boundaries. All live metallic hardware of equipment, throughout the range of motion of the energized part, shall be located outside the clearance zone [4].

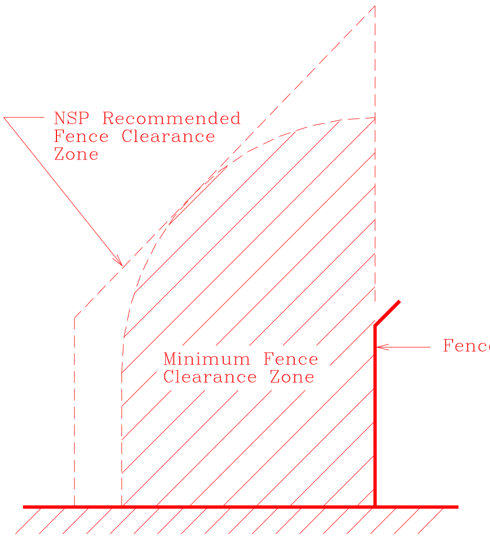


Figure 7
Fence Clearance Zone

Adopted NSP practice is to provide a minimum of fifteen (15) feet from the perimeter fence to any structure for equipment access, maintenance, and snow removal requirements. All new NSP substation installations shall be designed using the NSP Recommended Fence Clearance Zone. All existing substation installations shall maintain at least a Minimum Fence Clearance Zone.

The fence clearance zones are not applicable to fences within the perimeter fence of a substation. This would include, but not be limited to, fences around capacitor banks and reactors [4].

When an impenetrable fence or wall is used, with no openings through which sticks or other objects can be inserted, live parts may be located within the Fence Clearance Zone provided the live parts are below a horizontal line projected from the top of the impenetrable fence or wall [4].

6.2.5. Fence Height and Construction

Refer to NSP Standard ED 4.09.03 [10], and the NESC Handbook, Rule 110A [2], for detailed information on fencing materials and applications.

6.2.6. Warning Signs

Warning signs on the fence and at entrances to enclosed areas enhance the effectiveness of the fence. "Such warning signs should be conspicuously located on or near the door, gate, removable barriers, or other entrance area" [2].

Openings not intended as entrances, such as windows or ventilation grills, are not subject to the warning sign requirements. "Unauthorized entry through such openings is usually considered 'breaking and entering' and subject to the penalties thereof" [2]. Unattended entrances to buildings and substations must be kept locked.

Warning signs shall be installed on all NSP substation fences, gates and building doors. For application and for mounting instructions and descriptions of the signs, refer to Standard ED 7.02.04.

Substation installations that are partially or totally bounded on one or more sides by a building meet the requirements of the NESC for adequate equipment enclosure with the following conditions [2]:

- Access to the building is permitted only to qualified or authorized personnel.

- Access to the enclosed substation yard via the building is physically blocked to unqualified and unauthorized persons.

6.2.7. Fencing Adjoining Areas

The fence requirements of the NESC, that apply to areas containing energized electrical parts, do not apply to adjoining areas of substations such as coal storage and handling areas, ash and sludge disposal areas, and intake and discharge water ponds of remotely located generating stations. Stranded barbed-wire fencing is a practical alternative for perimeter fences around the nearby areas of these installations [2]. All perimeter fencing of this type shall be electrically isolated from the substation fence or from any structure connected to the substation grounding system to avoid transferred potentials during a fault condition. See Standard ED 4.03.00 "Grounding System" for more on this topic.

6.3. Guarding by Insulation

Conductors and live parts are guarded by *insulation* under the following conditions:

- The conductors have an insulation covering of a type and thickness suitable for the voltage and conditions under which they are expected to be operated and have an effectively grounded metallic insulation shield or semi-conducting shield [1]. This insulation may be used in lieu of a guard even if the clearances of Standard ED 4.02.02.01 are not met, see Figure 8.

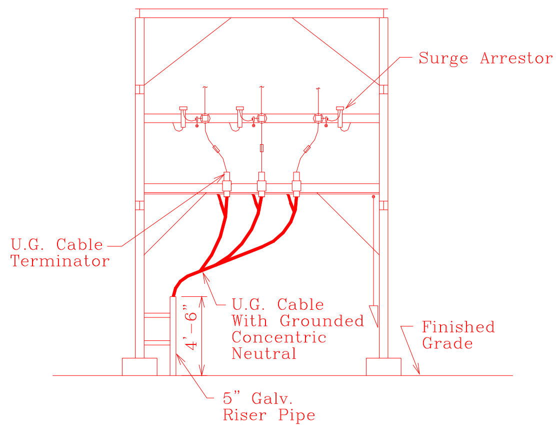


Figure 8
Guarding by Insulation

- The conductors or live parts have barriers or enclosures that are electrically and mechanically suitable for the conditions under which they are expected to be operated [1] (e.g. bus duct, padmounted distribution equipment, dead-tank circuit breakers and power transformers).

6.4. Environmental Conditions

Environmental conditions such as air contamination, lightning, and snow depths may affect the clearances requirements of a substation installation. Air contamination effects, as mentioned previously, is not within the scope of this Standard. For engineering considerations regarding lightning protection, see Standard ED 4.01.03.01 "Outdoor Substation Direct Stroke Lightning Protection."

6.4.1. Snow Accumulation

All NSP Recommended Vertical Working Clearances in Standard ED 4.02.02.01 and Standard Bus Heights in ED 4.02.02.03, include a minimum of two (2) feet of additional clearance for average compressed snow conditions. Vertical Working Clearance requirements for pedestal-mounted equipment do not include additional height for snow accumulation under the assumption that snow can be safely removed from the access area around this type of equipment.

For substation installations in regions where very high snow depths and severe wind drifting of snow is common, a determination must be made, based on factors such as frequency of deep-snow events, critical maintenance areas and cost, whether extra bus heights should be considered or if only additional warning signs are needed.

7. INDOOR WORKING CLEARANCES

This section covers all switchboards, panelboards and distribution boards installed for the control of lighting and power circuits. Although relaying and control panel installations in a control house or isle-type switchgear are not bound by the clearance requirements of the NEC, it is recommended that these clearance requirements be incorporated into the design.

As with Outdoor Working Clearances, indoor live parts, 600 volts or less, shall be guarded against accidental contact by *location*, *isolation* or *insulation*. Because of the relatively low voltage levels, the main methods used to guard live parts 600 volts or less are as follows:

Guarding by Location:

- Provide proper working space around equipment.
- Elevate the live parts a minimum of 8 feet above the floor.

Guarding by Isolation:

- Locate the live part inside a room, vault or similar enclosure that is accessible only to qualified persons.
- Install physical shields such as cabinets or box enclosures.

7.1. Front Working Space

In all cases, where there are live parts normally exposed on the front of switchboards or motor control centers, the working space in front of such equipment shall not be less than three feet [3]. The electrical equipment is not required to be directly centered in the front working space if it can be shown that the space is sufficient for the safe operation and maintenance of such equipment [3]. No equipment, electrical or otherwise is allowed in the defined workspace. See Standard ED 4.02.02.05 for examples of Front Working Space requirements. See Figure 9.

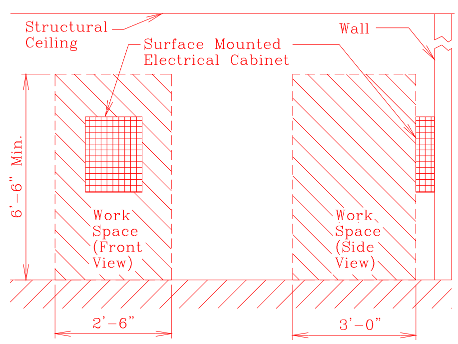


Figure 9
Front and Headroom Working Space

7.2. Headroom Working Space

The minimum headroom for working spaces around electric equipment such as service equipment, switchboards, panelboards or motor control centers shall be 6 feet-6 inches [1]. An exception to this rule is for service equipment or panelboards in existing buildings that do not exceed 200 amperes.

To provide for cable and conduit access, an exclusively dedicated space with a width and depth equal to the equipment and extending to a maximum height of 25 feet (or the height to the structural ceiling) is required over an electrical cabinet mounted to a wall. Dropped or suspended ceilings, not intended to add strength to the building structure, are not considered to be structural ceilings [3].

7.3. Entrance and Access to Work Space

The working space requirements for access to live parts requiring examination, adjustment, servicing, or maintenance while energized shall not be less than that shown in Standard ED 4.02.02.05. If the equipment is de-energized before inspection or maintenance, this standard does not apply [3].

At least one entrance shall be provided to give access to the working space about electric equipment inside substation control buildings and aisle-type switchgear.

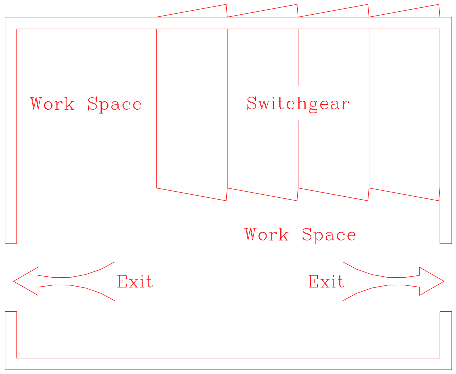


Figure 10
Access to Equipment in Switchgear Building

For equipment, such as switchgear, rated 1200 amperes or more and over 6 feet wide, an entrance is required at each end of the equipment lineup (see Figure 10), unless the following conditions are met:

- Equipment location permits a continuous and unobstructed way of exit travel.
- The minimum required workspace is doubled and the edge of the entrance nearest the equipment is the minimum clear distance away from the equipment [2].

1. General Description

A substation grounding system provides for protection of employees inside the sub, the public outside the substation, and equipment. The ground system is designed to dissipate fault currents through equipment into the earth without causing injury to people. The ground system also provides a low resistance path such that when a fault occurs the protective relay system can sense the fault and "trip" breakers before damaging equipment or adversely affecting service to customers.

For the purposes of this document, the substation grounding system is divided into two main portions; below grade equipment and above grade equipment. Below grade, the ground rods and mat must provide adequate means to dissipate electric current into the earth without exceeding operating or equipment limits and assures that personnel are not subjected to the danger of electric shocks. Above grade, equipment design must provide low resistance connections between the grid and all equipment. In addition, attachment locations must be provided for personal grounding assemblies. Personal grounding assemblies are not included in this grounding standard (they are included in the *Personal Grounding Practices & Procedures* manual).

2. Function/Application

The ground system is designed for an ultimate fault current of 50,000 amperes and to provide a reliable ground grid for the life of the substation. Presently fault current on the system is less than the 50,000 ampere capacity of the grid. When fault current exceeds this level larger conductor may be required between the equipment or steel and the grid. Because the current divides at each connection, the main grid will carry the current without modification. All conductor sizes are based on a 125o C temperature rise.

Reliability is affected by grid to earth resistance, which is dependent on soil moisture content. Moisture content is more variable at the surface therefore the grid is buried at 18 inches below rough grade with ground rods driven to 20 feet or more. Corrosion limits the life span of the grid and its ability to carry fault current. Soil tests (see ED 4.03.01) should be performed to determine if corrosive conditions exist. If so, then cathodic protection of the grid may be required. Normally, use of 4/0 19-strand soft drawn copper and ¾" ground rods provides the desired life expectancy and exothermic (welded) type connectors prevent corrosion within the connectors.

3. Protective Relaying/Control/Metering

Protective relaying monitors current and voltage levels in the substation and on transmission and distribution lines. A low resistance ground path must be provided to insure adequate ground currents for the relaying to operate correctly. Calibration of the relaying is based on the transformer to earth impedance. Because this impedance varies with soil moisture content, the relaying should be adjusted for "worst case" impedance which is winter conditions.

4. Operating and Maintenance Characteristics

Provisions must be made for attachment of personal grounds. All steel shall have a minimum of one grounding bracket per structure capable of holding 6 beam clamps. Transformers shall have a 5" X 18" grounding bracket mounted 5' up from the bottom, on the side of the tank. These brackets shall be pre drilled to accept two NEMA 4-hole pads.

Connection of conductor to transformer bushings should be installed to provide a ground attachment point which is parallel to grade. If transformer connections can't be made to provide an easy ground attachment point an approved stirrup, such as the multi angle stirrup, should be installed. Stirrups shall be installed on conductor 2' or more outside the bushings/surge arresters to provide an easily accessible grounding point.

Although the ground system is a static system, there are operating concerns (corona may be caused by the grounding stirrups and studs), but no maintenance concerns. Periodic inspection for corrosion of the grid connections is highly recommended, details of this inspection process are provided in the supporting documentation for this standard.

5. Electrical Testing Requirements

After installation of the ground system it is important to measure the grid resistance for verification against design values. Grid resistance design values will vary from site to site; therefore, no general grid resistance value will be specified. The grid resistance design value should be included on the ground layout drawings so the foreman can compare with actual installed values. Normally testing is performed by construction and the results recorded on the grounding drawing, details of this test are provided in the supporting documentation for this standard.

6. Ground Grid Design Considerations

The ground grid must be designed to assure safety from step and touch potentials within and directly outside the substation fence. There are several critical parameters, which are site-dependent, that have significant impact on grid design. These are maximum grid current (I_G), fault duration (t_f), shock duration (t_s), soil resistivity (p), high resistance surface material (p_s), and grid geometry. To minimize the variability this standard will use I_G = 50,000 ampere, $t_f = t_s$ = 30 cycles (this is the time required for secondary relaying to clear a fault), and p_s = 5000 ohm/meter. Grid geometry will vary based on soil resistance and substation layout. Design guidelines are discussed in the supporting documentation.

7. Major Components

7.1. Ground Grid

The ground grid is a system of conductors and rods imbedded in the earth, which is used to dissipate fault current into the earth. The grid is made of 4/0 19-strand soft drawn copper conductor, ¾" threaded ground rods at least 20' long, and appropriate welded fittings. The conductor is run as a continuous loop when attaching to ground rods, fence, structures, and most equipment (transformers are the exception). The double 4/0 provides greater capacity than 350 MCM and is much more flexible and easier to work with.

The grid extends to 3' outside the substation fence. The grid is buried 18" below rough grade. The ground grid is attached to equipment at two different points such as opposite corners of a transformer or each leg of a switch stand. The grid is welded to all steel structures and fence posts.

The grid is bolted to aluminum structures, transformers, breakers, or other equipment, which may be removed. A NEMA 2-hole or 4-hole pad is welded to the grid and bolted to the equipment. When equipment such as a CCPD is installed on a stand, weld the grid to the base of the stand and weld a 4/0 jumper near the top of the stand. This jumper is then bolted to the grounding pad on the equipment (see master drawings NF-160158-1 and -2, NH-43213, NH-44306, NH-72802).

7.2. Surface Material

Crushed rock, ¾-inch diameter, is applied to the surface of the substation site to provide a high resistance between the grid and an operator. Rock is installed after all other work on the ground system is complete. Because it is very difficult to provide the same size, type, and depth of rock at each site, a minimum depth of 4 inches is specified. If the rock is deeper than 8 inches vehicles become stuck. The rock should extend 2 feet past outside the grid, this means 5 feet past the fence.

7.3. Foundation Reinforcing Cages

Foundation reinforcing cages are not connected to the grid through the side of the foundations as was previously done. Reinforcing cages are grounded through the equipment anchor bolts only.

7.4. Steel Structure Connections

All steel structures shall have the ground grid welded directly to the steel. The 4/0 grid conductor shall be run as a continuous loop up the foundation to the steel, then welded as indicated on the grounding drawing.

7.5. Aluminum Structure Connections

All aluminum structures shall have the ground grid bolted to the structure. Anti-corrosion compound shall be applied to the bolted connection.

7.6. Fence Connections

All substation fences shall be connected to the ground grid. Fence posts will have welded connections. Fence fabric will no longer be connected to the ground grid. A grounding jumper will be installed between the gateposts and gate to insure adequate connection. A #4 soft drawn copper bonding wire shall be welded to the top fence support and connected to the barb wire by split bolt connectors (see Master Drawing NF-160158-1 and -2).

7.7. Transformer Connections

Transformers will be bolted to the ground grid via NEMA 2-hole or 4-hole pads. These connections shall be at opposite corners of the tank. Surge arresters shall be grounded by installing a 4/0 copper wire or a ¼" X 3" copper bar between the mounting bracket or NEMA 2-hole pads when available on the tank, and the arrester base. A spacer must be installed under the other "feet" of the arrester too. The neutral bushings will be terminated at a NEMA 4-hole pad on the top of the transformer, using ¼" X 3" copper bar, or to the steel using flexible conductor rated for 1/3 the capacity of the phase conductors. The transformer tank and steel structures are adequate to carry the neutral current therefore a copper bus bar does not need to be installed down the tank to ground.

7.8. Circuit Breaker Connections

The ground grid shall be bolted to breakers. If the breaker is mounted on a steel stand the ground grid shall be bolted at the base of the stand. Bolted joints, such as legs of the stand or stand to breaker, provide an adequate ground path.

7.9. Capacitor Bank Connections

Most capacitor banks are installed on aluminum structures, use bolted connections. Capacitor banks require single-point or peninsular connection to the ground grid. Single-point connections prevent high frequency currents from back-to-back switching from flowing in the ground grid. Peninsular connections allow the neutral potential to rise during switching but provides a low impedance path between capacitor banks. See the Capacitor Bank Standard ED 5.02.01 or ANSI/IEEE 37.99.

7.10. Switchgear Building Connections

Switchgear buildings shall have exterior ground connections welded at each of the corners. The ground bus inside the building shall be ¼" X 2" aluminum bus bar, this shall be bolted to the ground grid (see master drawings NH44306, NH72802).

7.11. Disconnect Switch Connections

All disconnect switches shall be grounded by bolting a flexible grounding jumper to the steel structure and the vertical operating pipe (see master drawing NF-160158-1 and -2). If a flexible grounding jumper is not provided with the switch, an exothermic connection shall be used. If the switch is mounted on a wood structure then the flexible grounding jumper should be bolted to the vertical operating pipe and to the ground wire, which is attached to the structure.

7.12. PT/CT Connections

Metering PTs/CTs which have their neutral bolted to the steel will continue to be bolted to the steel. PTs/CTs, which are mounted on steel structures, are adequately grounded through the mounting bolts, no additional grounding is necessary. Steel structures are welded directly to the grid. If PT/CT is mounted on a wood structure it should be attached to the ground grid with 1/0 copper as indicated in the Wood Structures section.

7.13. Wood Structures

Substations with wood structures are normally in locations with little fault current. These substations will have a 4/0 ground grid to insure long life. The ground wire, which is attached to the structure, shall remain 1/0 copper. All connections to the 1/0 shall be bolted with the existing clamps. The ground grid shall be Cadwelded to the 1/0.

8. Personal Grounding

Personal grounds are required when working on equipment. It is necessary to provide grounding attachment locations on equipment for the beam clamps, C-clamps, or socket clamps, which are used on personal ground assemblies. See Standard ED 4.09.05 for application of grounding attachment point devices. Bus work and conductors must also include either attachments such as stirrups or studs or have clamps available on site for grounding directly to the bus (ED 4.09.05). Studs or stirrups, when used, must be easily accessible from grade, bucket truck, or lift devices. Stirrups, when necessary, shall be attached to the lead 2' or more outside any surge arresters.

9. References

ANSI/IEEE STD80-1986 IEEE Guide For Safety In AC Substation Grounding

ANSI/IEEE 81-1983 Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System, Guide for Measuring

IEEE Transactions on Power Delivery, Vol. PWRD-2 No. 3, July 1987

Xcel Energy Equipment Specifications/Standards

Steel Design Standard
Circuit Breaker Specification
Transformer Specification
Capacitor Bank Standard

Soil Testing

Since the grid design is dependent on soil conditions, tests must be performed to determine moisture content, soil resistance, and acidity. Guide lines for performing these test can be found in ANSI/IEEE 81-1983.

The Four-Point or Wenner method of testing is best suited to NSP's needs. This test involves driving four rods into the soil, injecting a known current through the outer two and measuring the potential across the inner two. Use Ohms Law to calculate the resistance. Tests should be performed to obtain readings at 10, 20, and 30 foot depths. These readings should be taken at the locations shown on the Soil Resistivity Test Result Form. If it is not possible to get soil resistivity tests, use the resistivity from ANSI/IEEE 80-1986 table 1 which is shown below.

Average Resistivity Of The Ground

Type Of Ground	Resistivity ρ, Ohm-Meters
Wet organic soil	10
Moist soil	100 (normal NSP conditions)
Dry soil	1,000
Bed rock	10,000

Soil resistivity impacts the ability to dissipate fault current into the soil. Therefore grid resistance and voltage gradients within the substation increase with soil resistivity. Soil resistivity is primarily dependent on moisture content which is affected by soil type, compaction, and grain size.

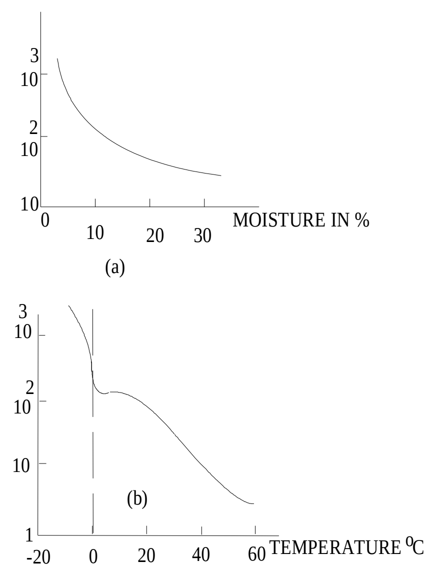


FIG 1. from IEEE Std 81-1983

The resistivity of most soils rises abruptly when the moisture content is less than 15% of the soil weight. The rate of change slows until about 22% when further saturation has little impact on soil resistivity.

Temperature also affects soil resistivity. When water freezes the resistivity increases, by almost a factor of ten. Surprisingly, grid resistance during the winter is nearly as good as during the summer. This is because the soil freezes from the top down and the high resistance surface layer, normally just rock, now includes the frozen soil. Spring condition are actually the worst for grid performance. The lower layers remain frozen while the surface layer thaws providing a low resistance layer over a high resistance layer. Not a desirable condition! When performing grid calculations be sure to check the spring conditions.

It is also important to test the acidity level of the soil. Acidity does not affect soil resistivity but will eat away the grid if the soil is too acidic. If this is the case, cathodic protection may be needed.

Design Procedure

This procedure is a general guide to designing a ground grid for a new substation. Design calculations (see IEEE Std 80-1986) may be verified using the Substation Grounding Workstation, an EPRI program, or Excel spreadsheet \\Black\Team\DSC\Forms\Sub\Calcs\Grndg.xlt.

All design data and assumptions should be recorded in the Ground Grid Design Data section of the grounding drawing.

1. Estimate size of area to be grounded (can be estimated from substation location plan).

2. Determine soil resistivity profile and soil model (soil testing is recommended or use the approximation from ED 4.03.00).

3. Verify minimum conductor size (is conductor >4/0 required) based on 125^{O}C rise at the expected fault current level.

4. Determine maximum step and touch potential. Based on the design criteria these values should be less than:

   $E_{step70} = (R_B + R_{2Fs})I_B = 1{,}775\ V$

   $E_{touch70} = (R_B + R_{2Fp})I_B = 606\ V$

   assumptions based on 4" rock

   $I_B = 0.216$ *amps* (*Eq 5, 70kg body weight*)

   $R_B = 1{,}000$ *ohms* (*Eq 7*)

   $R_{2Fs} = 7{,}200$ *ohms* (*Eq 16, p=2000 ohm-meter*)

   $R_{2Fp} = 1{,}800$ *ohms* (*Eq 17, p=2000 ohm-meter*)

5. Develop preliminary design. A counter poise should be run around the exterior of the sub. Grid density is dependent on proximity to the bus work. Conductor spacing should be 20' apart near the bus. Further from the bus grid spacing may be increased. At the interior corners of the fence you may need to decrease grid spacing because step potential may be too high. Ground Rods should be at least 20' long and placed at 50' - 70' intervals along the counterpoise. Place ground rods underneath the outer phases at all line entrance locations. Other ground rods should be placed at lightning arresters, control panels on transformers and breakers, all corners of the control house, and near the entrance gate.

6. Estimate the grid resistance.

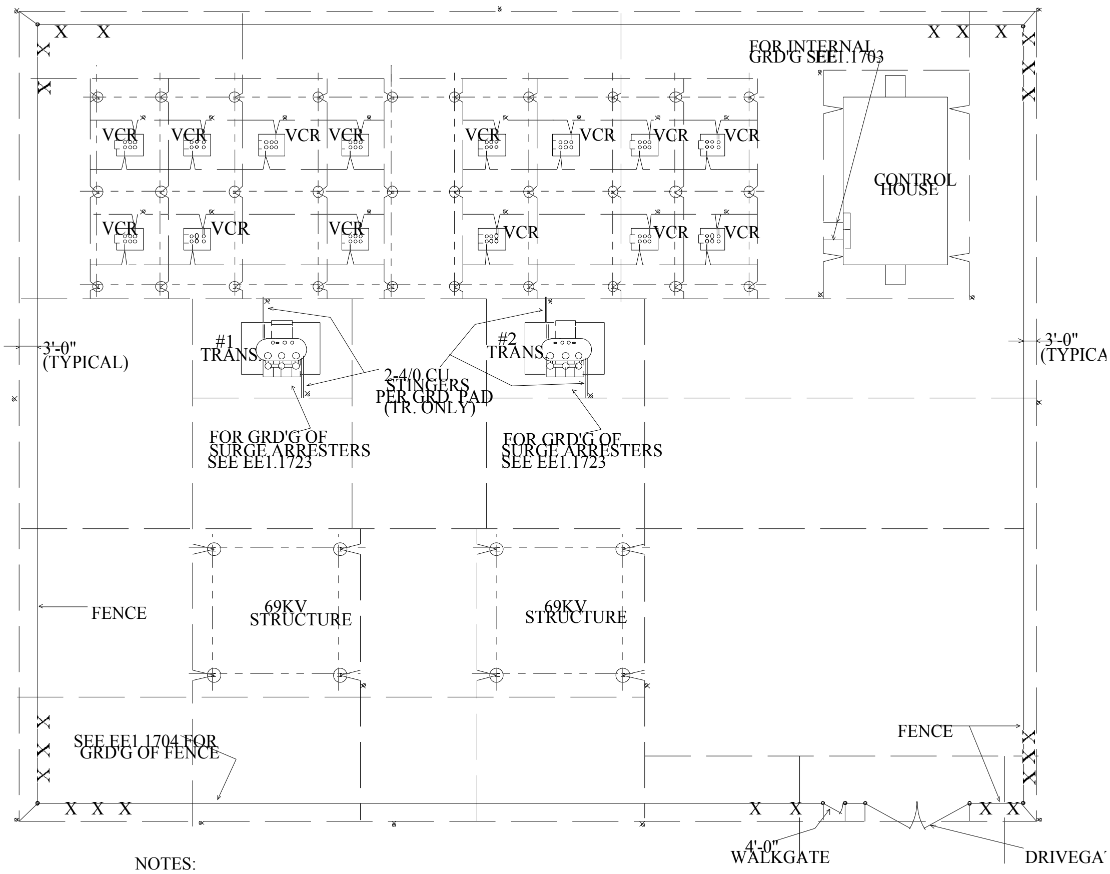
   R_g = *(earth resistivity/4)(pi/grid area in* $m^2)^{0.5}$

7. Determine the grid current (*Ig*). The grid current can be as high as the fault current which is the zero sequence current, $3I_0$. Normally it has been assumed that all fault current flows through the grid. This may not be correct, when the transmission lines and feeders are connected there is a current division which occurs (see "Determination of Maximum Substation Grounding System Fault Current Using Graphical Analysis") and drastically reduces the apparent grid current.

8. Calculate the ground potential rise**,** *GPR*. It should be less than the tolerable touch potential, $E_{touch70}$. If not, then preliminary design must be refined, possibly by reducing grid spacing, adding more rods, increasing grid area, installing a well, etc.

   $GPR = I_g * R_g$

The desired resistance reading for a large substation is **less than 1 ohm** and for a small substation it is **less than 3 ohms**, (max. 6 feeders or 15 MVA capacity).



NOTES:

1. GRID SYSTEM INSTALLED WHERE ROCK OR CONDITIONS PROVIDE POOR GROUNDING POTENTIAL. PROVIDE CONNECTIONS TO REMOTE GROUND IF NECESSARY.

2. GROUND GRID SPACING BETWEEN CONDUCTORS DETERMINED BY SOIL CONDITIONS AND SUBSTATION FAULT CURRENT.

3. GRID CONDUCTOR SHALL BE RUN AS A CONTINUOUS LOOP UP THE FOUNDATION TO THE STEEL.

4. FOUNDATION REINFORCING CAGES ARE GROUNDED THROUGH ANCHOR BOLTS ONLY.

LEGEND

GROUND ROD-TWO OR MORE 3/4 " X 10'-0" COUPLED COPPER CLAD RODS DRIVEN TO A DEPTH REQUIRED TO OBTAIN AN INITIAL GROUND RESISTANCE NOT GREATER THAN 30 OHMS PER ROD-MIN. DEPTH 20'-0" FENCE RODS AVERAGE DEPTH OF STATION RODS.

BURIED WIRE-4/0 BARE SOFT DRAWN CU. WIRE 18" BELOW ROUGH GRADE.

EXPOSED CONDUCTOR-4/0 CU. WIRE

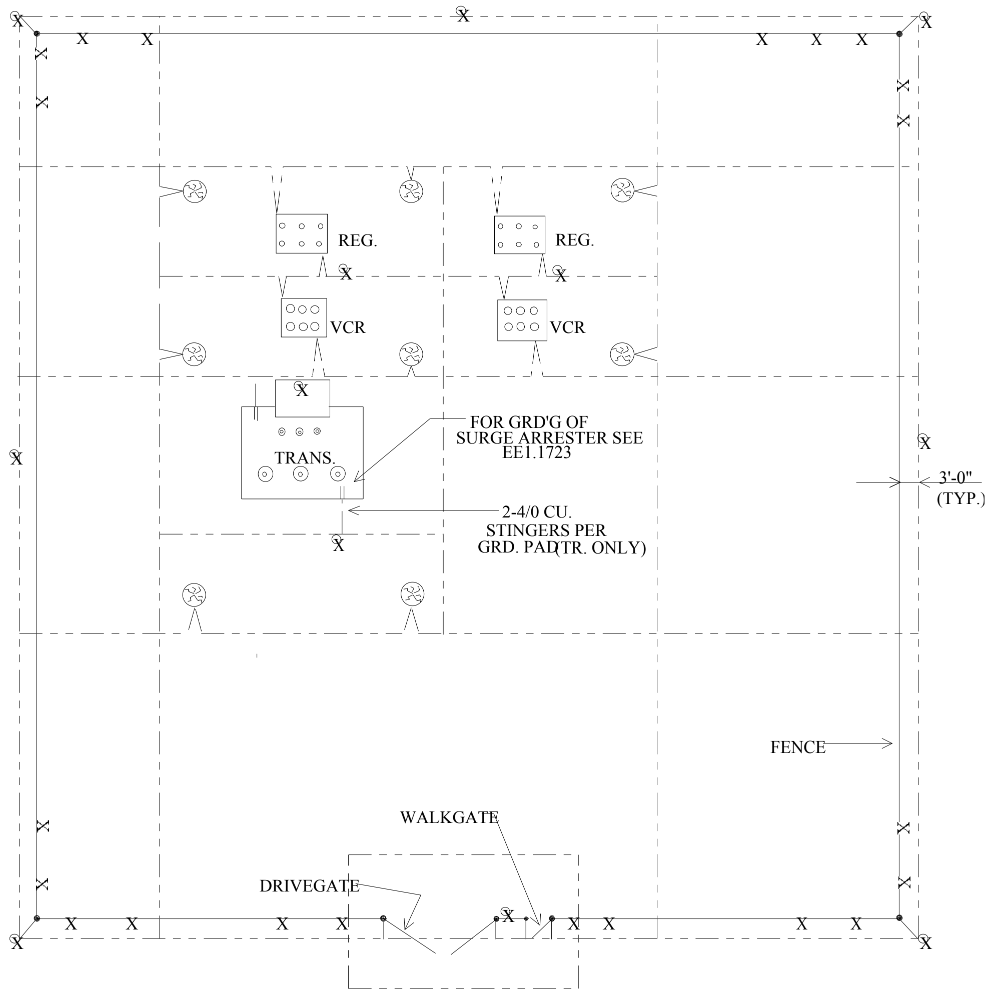
EXPOSED CONDUCTOR-BAR

FENCE

FENCE CORNER AND GATE POST

SUBSTATION GROUNDING

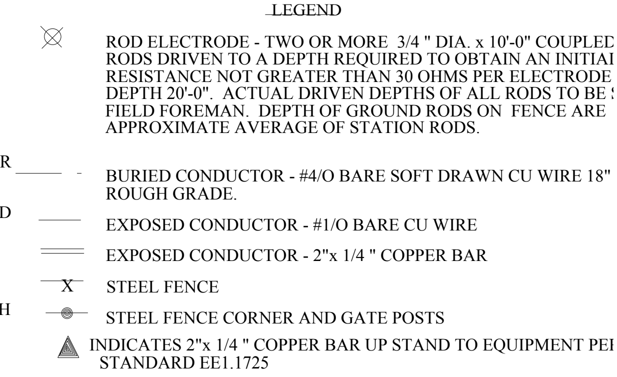
Substation Grounding - Design Guide



NOTES:

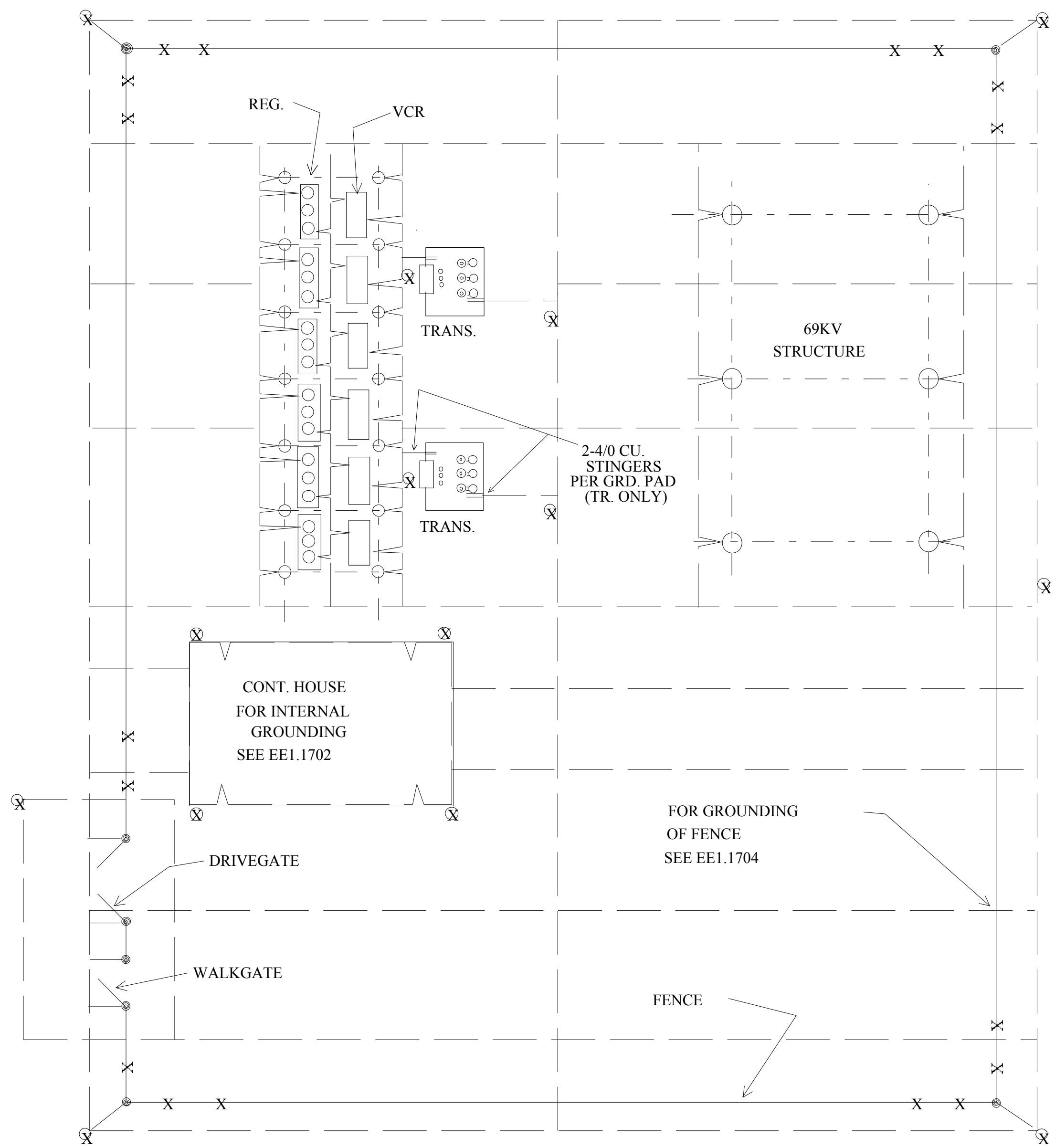
1. 1/0 COPPER CONDUCTOR RUN UP ALL POLES TO STATION NEUTRAL BUSES, SURGE ARRESTERS, INSTRUMENT AND AUXILIARY TRANSFORMERS, SWITCH AND FUSE BASES, BUS SUPPORTS 23KV AND ABOVE AND STRAIN INSULATOR ANCHOR BOLTS.
2. GROUND GRID SPACING BETWEEN CONDUCTORS DETERMINED BY SOIL CONDITIONS AND SUBSTATION FAULT CURRENT.
3. GRID CONDUCTOR SHALL BE RUN AS A CONTINUOUS LOOP UP THE FOUNDATION TO THE STEEL.
4. FOUNDATION REINFORCING CAGES ARE GROUNDED THROUGH ACHOR BOLTS ONLY.

LEGEND



WOOD STRUCTURE GROUNDING SYSTEM

Substation Grounding - Design Guide



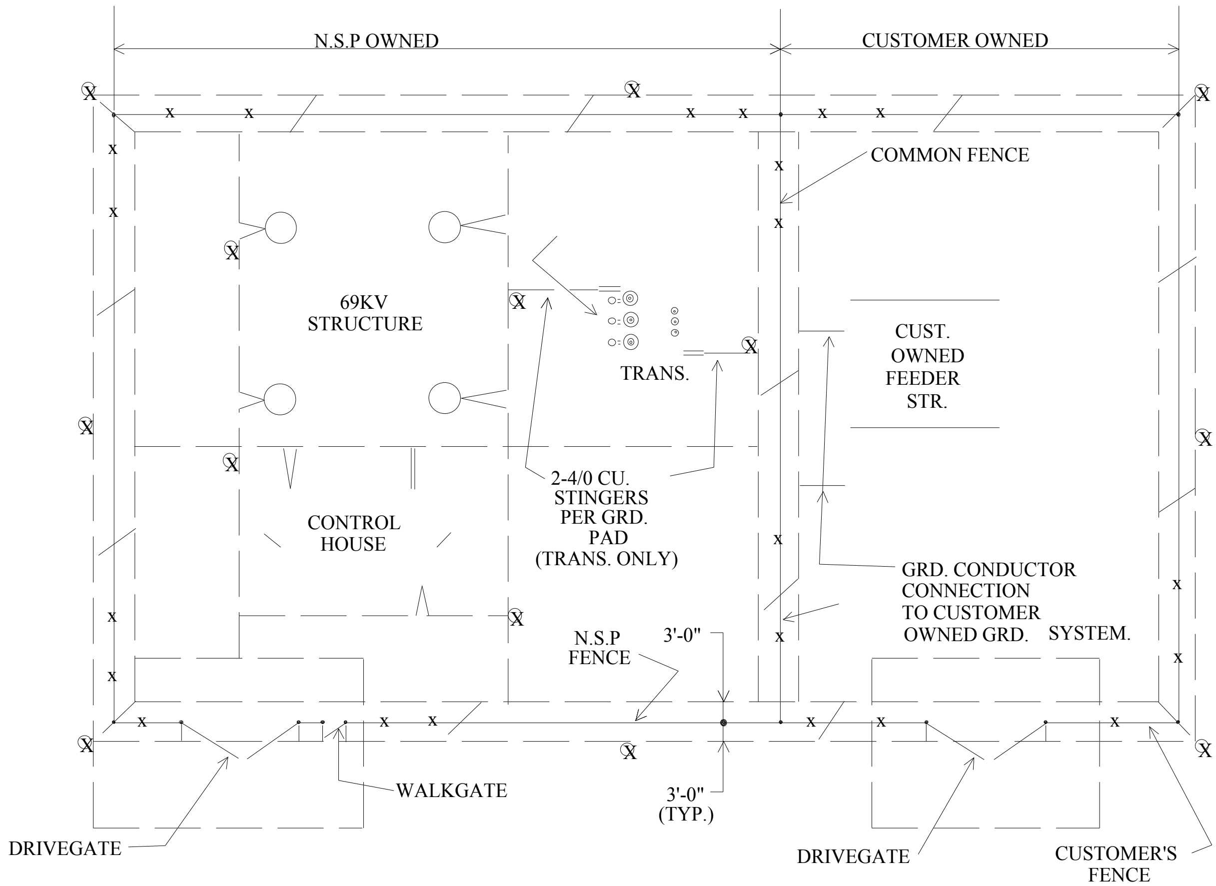
NOTES:

1. GRID SYSTEM INSTALLED WHERE ROCK OR CONDITIONS PROVIDE POOR GROUNDING POTENTIAL. PROVIDE CONNECTIONS TO REMOTE GROUND IF NECESSARY.
2. GROUND GRID SPACING BETWEEN CONDUCTORS DETERMINED BY SOIL CONDITIONS AND SUBSTATION FAULT CURRENT.
3. GRID CONDUCTOR SHALL BE RUN AS A CONTINUOUS LOOP UP THE FOUNDATION TO THE STEEL.
4. FOUNDATION REINFORCING CAGES ARE GROUNDED THROUGH ANCHOR BOLTS ONLY.

LEGEND

- ROD ELECTRODE- TWO OR MORE 3/4 " DIA. X 10'-0" COUPLED COPPER RODS DRIVEN TO A DEPTH REQUIRED TO OBTAIN AN INITIAL GROUND RESISTANCE NOT GREATER THAN 30 OHMS PER ELECTRODE- MINIMUM DEPTH OF 20'-0". ACTUAL DRIVEN DEPTHS OF ALL RODS TO BE SHOWN BY FIELD FOREMAN. DEPTH OF GROUND RODS ON FENCE ARE APPROXIMATE AVERAGE OF STATION RODS .
- BURIED CONDUCTOR-4/0 BARE SOFT DRAWN CU. WIRE 18" BELOW ROUGH GRADE.
- EXPOSED CONDUCTOR - 2" X 1/4 " COPPER BAR
- STEEL FENCE
- STEEL FENCE CORNER AND GATE POSTS
- INDICATES COPPER BAR UP STAND TO EQUIPMENT PER N.S.P COMPANY STANDARD EE1.1725

GRID SYSTEM



NOTES:

1. WHEN A COMMON FENCE IS INSTALLED BETWEEN AN N.S.P AND CUSTOMER'S SUBSTATION, BOTH GROUNDING SYSTEMS MUST BE INTERCONNECTED AND TIED INTO THE FENCES WITH A COUNTERPOISE 3'-0" EACH SIDE OF THE FENCE. ADEQUATE GROUND CONNECTIONS SHALL BE MADE TO ALL ELECTRICAL EQUIPMENT, STRUCTURES AND FENCE SO THAT, UNDER FAULT CONDITIONS, ALL COMPONENTS OF THE SUBSTATION ARE AT THE SAME POTENTIAL.

2. IF THE N.S.P AND CUSTOMERS FENCES ARE SEPERATED BY A MINIMUM OF 10'-0" BOTH FENCES AND STATION GROUNDING SYSTEMS WILL BE ISOLATED IN ACCORDANCE WITH OUR USUAL PRACTICE. THERE WILL BE NO COMMON TIE BETWEEN THE TWO GROUNDING SYSTEMS EXCEPT FOR THE NEUTRAL CONDUCTOR, WHICH MUST BE HEAVY ENOUGH TO CARRY THE FAULT CURRENT WITHOUT DAMAGE. IF THERE IS NO NEUTRAL, BEING A DELTA CONNECTED LOW VOLTAGE SYSTEM, PROVIDE AN OVERHEAD TIE BETWEEN THE TWO GROUNDING SYSTEMS OF ADEQUATE SIZE TO CARRY FUTURE FAULT CURRENTS IF CONVERTED TO A WYE SYSTEM.

3. IN ALL CASES WE WILL RECOMMEND TO THE CUSTOMER THAT HE DESIGN HIS GROUNDING SYSTEM SIMILAR TO OURS.

LEGEND

Ⓧ GROUND ROD-TWO OR MORE 3/4 " X 10'-0" COUPLED COPPER CLAD RODS DRIVEN TO A DEPTH REQUIRED TO OBTAIN AN INITIAL GROUND RESISTANCE NOT GREATER THAN 30 OHMS PER ELECTRODE - MINIMUM DEPTH 20'-0" .

— — BURIED CONDUCTOR-#4/0 BARE SOFT DRAWN COPPER WIRE 18" BELOW GRADE.

—— EXPOSED CONDUCTOR-#1/0 CU. WIRE

—— EXPOSED CONDUCTOR-2"X 1/4 " COPPER BAR OR OTHER.

—x— STEEL FENCE

◎ STEEL FENCE CORNER AND GATE POSTS.

▲ INDICATES 2" X 1/4 " COPPER BAR UP STAND T EQUIPMENT PER N.S.P CO. STANDARD EE1.1725

SUBSTATION GROUNDING

Substation Grounding - Design Guide

Control House Grounding

Control house grounding is covered in this section. The following Master Drawings should be referenced for details:

NH-44306	Control House with Access Floor - Miscellaneous Equipment Details
NH-72802	Control House without Access Floor - Miscellaneous Equipment Details
NH-160332-1,2 & 3	Control House Equipment Layout

Use the following rules as design guides:

1. The substation grounding system conductor must encircle each control house.

2. The building ground bus shall be tied to the substation grounding system in two places, at opposite sides of the control house. In most cases, this will consist of bringing a ground in through a cable entrance on one side and through the control house wall on the other as indicated below and detailed on the appropriate Master Drawing for grounding methods in buildings with and without access floors.

   Two #4/0 copper ground conductors shall enter the building through cable openings in the floor and connect to the building ground bus system via two 2" x 1/4" aluminum bars inside the terminal cabinet.

   One #4/0 copper ground conductor shall enter the building through a 3/4” diameter x 12” long copper rod which is tied to the building ground bus via a 2" x 1/4" aluminum bar up the building wall.

3. The building ground bus shall be 2" x 1/4" aluminum bar mounted approximately 7’-6” high on the side walls only and shall be long enough to accommodate connections to equipment. The side wall mounted building ground buses shall be interconnected across the ceiling at each end with 2” x 1/4" aluminum bar supported by the unistrut light fixture hangers.

4. A #4 bare copper wire must be run from the building ground bus directly to the internal neutral or ground bus of all A.C. distribution, auxiliary transformer and telephone equipment cabinets and also shall connect to the housing of all other cabinets and electrical equipment.

5. In buildings without access floor the ground bus of each panel row must be connected to the building ground bus with 2" x 1/4" aluminum bar mounted on a panel brace. The ultimate installation should provide a connection near each end of each panel row and once in the middle.

6. Take special care in masonry buildings to see that any conduit, box or equipment not effectively grounded through raceway or trough is bonded to the building ground bus.

7. If toilet facilities are to be provided, the water pipe shall be connected to the control house ground bus as shown in ED 4.03.08.

Grounding of Cable Trench Conductor

One #4/0 bare copper conductor is to be laid in all precast or direct burial cable trench as detailed on Master Drawing NH-43213. The ground conductor is required to protect control cables from stray ground currents or signals usually present in high voltage installations by equalizing the potential along the length of the cables.

The trench ground conductor must be connected to the station grounding system at every intersection and at the ends of each trench. The cable trench ground conductor connections will be shown on the Grounding Layout drawing and, in the case of direct buried trenches, the ground conductor shall be incorporated into the system grounding design.

In precast trenches, the ground conductor may be located below all the cables, mixed in with the control cables, placed on top of the control cables or attached to the side of the precast trench depending on when it is installed and construction preferences. In any case, future installations of additional control cables should be of primary consideration.

Branches from the main cable trench, that are lighting circuits or are less than 25 feet in length, do not *require* the trench ground conductor to be extended to the equipment, however, consideration should be given in extending the ground conductor in the branches to the equipment, especially in new installations.

In existing non-grounded precast or direct buried trenches, where the trench is opened to replace or install new control cables, one #4/0 bare copper conductor shall be installed.

Switch Handle Grounding

Introduction

The problem is that of protecting employees operating manually operated air-break switches from the accidental energization of the operating mechanism, which may occur during the operation of the switch. This energization may result from mechanical failure dropping an energized part on the operating mechanism, base or frame of the switch, or from a flashover resulting from transient overvoltage during switching.

Rules

1. No appreciable hazard exists at 2.4 kV and 4.16 kV due to the type of system and switching equipment used.

2. The present practice of using rubber gloves and hard hats when operating any type of air-break switch at any voltage shall be continued.

3. Persons not operating the switch should stay at least 10 ft. away from the operator and also stay out from under any portion of the switch itself.

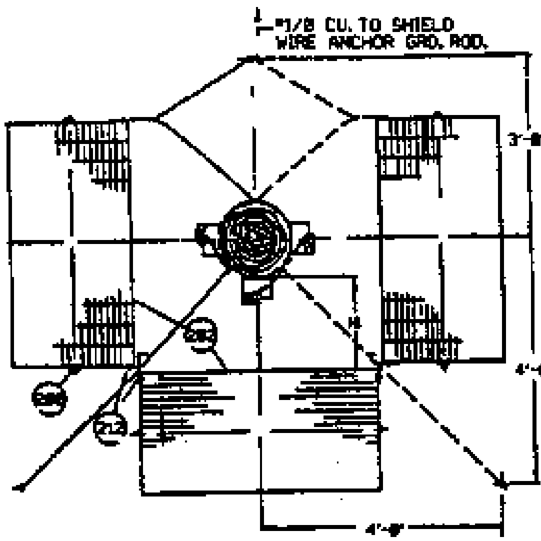
4. The grounding system in stations, if provided as detailed in Standard ED 4.03.00, makes unnecessary any additional grounding or stands for the operators.

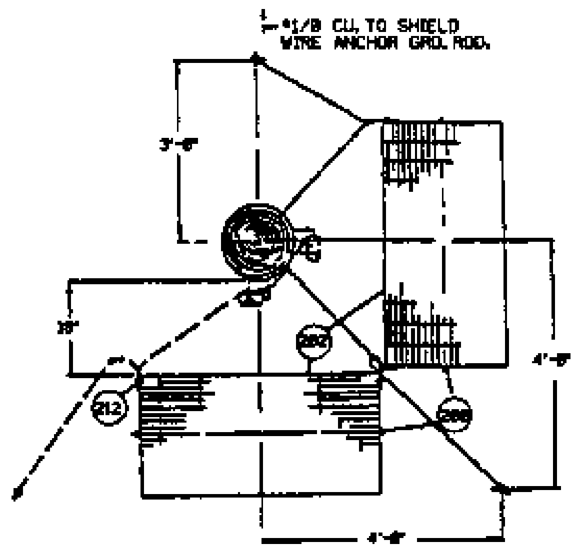
5. On line switches at 12.5 kV or above (including 13.8, 23, 34.5, 69 and 115 kV) the operating mechanism, to which the handle is electrically connected, should be tied solidly to the line neutral or static wire, if there is one available. This connection should be made below any porcelain or wood members, which may be in the operating rod. If the switch frame is grounded, connecting the frame itself to the neutral or static wire will meet this requirement.

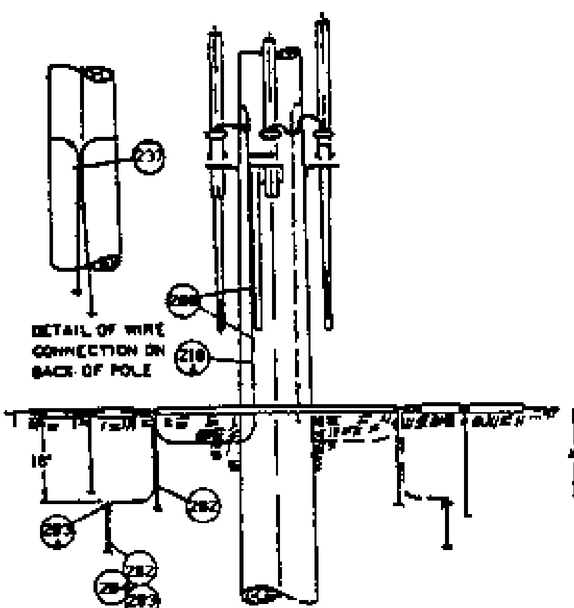
6. The connection to the neutral or static wire should be duplicated so that the tie wire will exist even if one connection becomes broken, burned off, or dislodged.

7. For switches 23 kV and above, outside of station grounding areas, a metallic grating or grid shall be provided on which the operator can stand when operating the switch. This grating or grid should be tied solidly to the switch handle or operating mechanism with at least two-connections, to provide for breakage of one connection. The handle or mechanism should also be tied to two or more ground rods driven in the vicinity of the pole. A steel grating mounted approximately flush with the surface of the ground is the most desirable and safe. Details are shown on sheet 2.

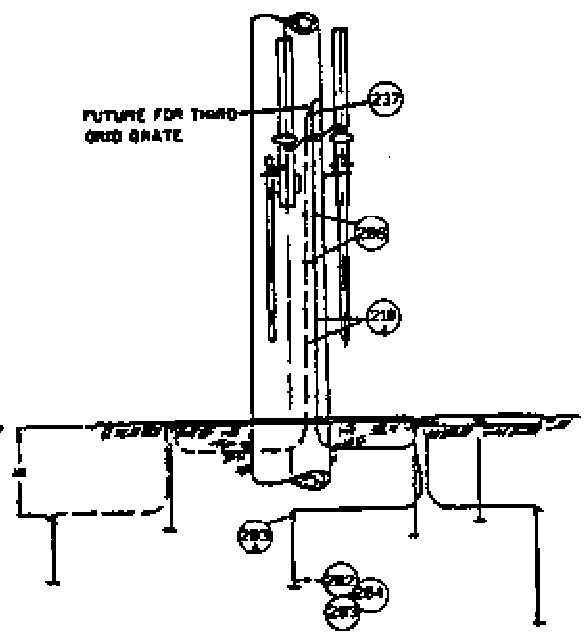
8. For switches mounted on steel structures, the operating pipe shall be bonded to the steel using a flexible grounding jumper. If a flexible grounding jumper is not provided with the switch, an exothermic connection shall be used.





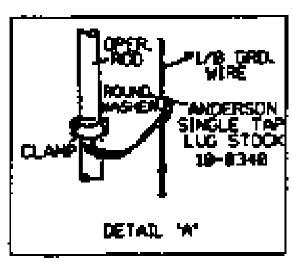


GS-15
3-WAY GOAB SWITCH



GS-16
3-WAY GOAB SWITCH
ONE SIDE BUSSED

NOTE:
WIRES SHOWN BY SOLID OR DOTTED LINES TO BE INSTALLED IN CONTIN-UOUS SEGMENTS OF WIRE.
GROUND RODS ATTACHED TO GRID GATE ARE 5 FT SECTIONS. (10 FT ROD CUT IN HALF.

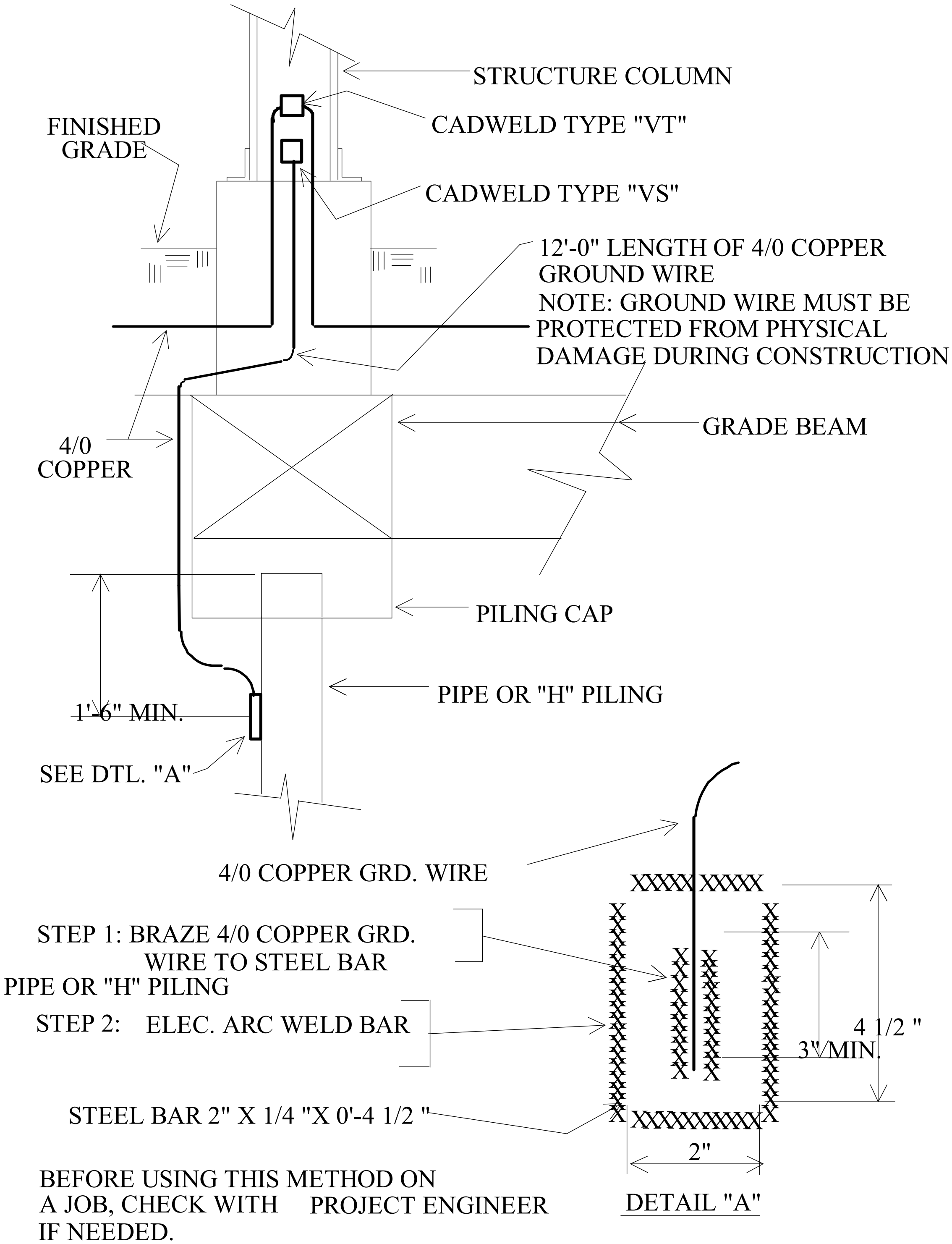


DETAIL "A"

ITEM	QUAN GS-15	QUAN GS-16	DESCRIPTION	NSP CO STOCK #
202	0	0	5/8" X 10' STAR SECTIONAL GROUND ROD	07-2912
203	3	3	5/8" STAR COUPLING	07-2918
204	3	3	5/8" STAR HALF TWIST BIT	07-2938
205A	4	4	5/8" GROUND ROD CLAMP	07-2942
208	30	30	2" CEMENT COATED FENCE STAPLES	07-2948
209	6	4	GROUND ROD CLAMP (BURNDY GJ11)	
210A	50'	50'	#1/0 STRANDED BARE COPPER WIRE	03-1855
212	6	5	GROUND WIRE CLAMP (BURNDY GC-26-26-T4)	07-2952
213	2	1	ANDERSON TAP LUG	10-8540
237	1	1	SOLDERLESS CONNECTIONS (#1/0 COPPER WIRE	03-6252
262	3	2	GRID GRATE, NSP CO. DWG. ND-24767	

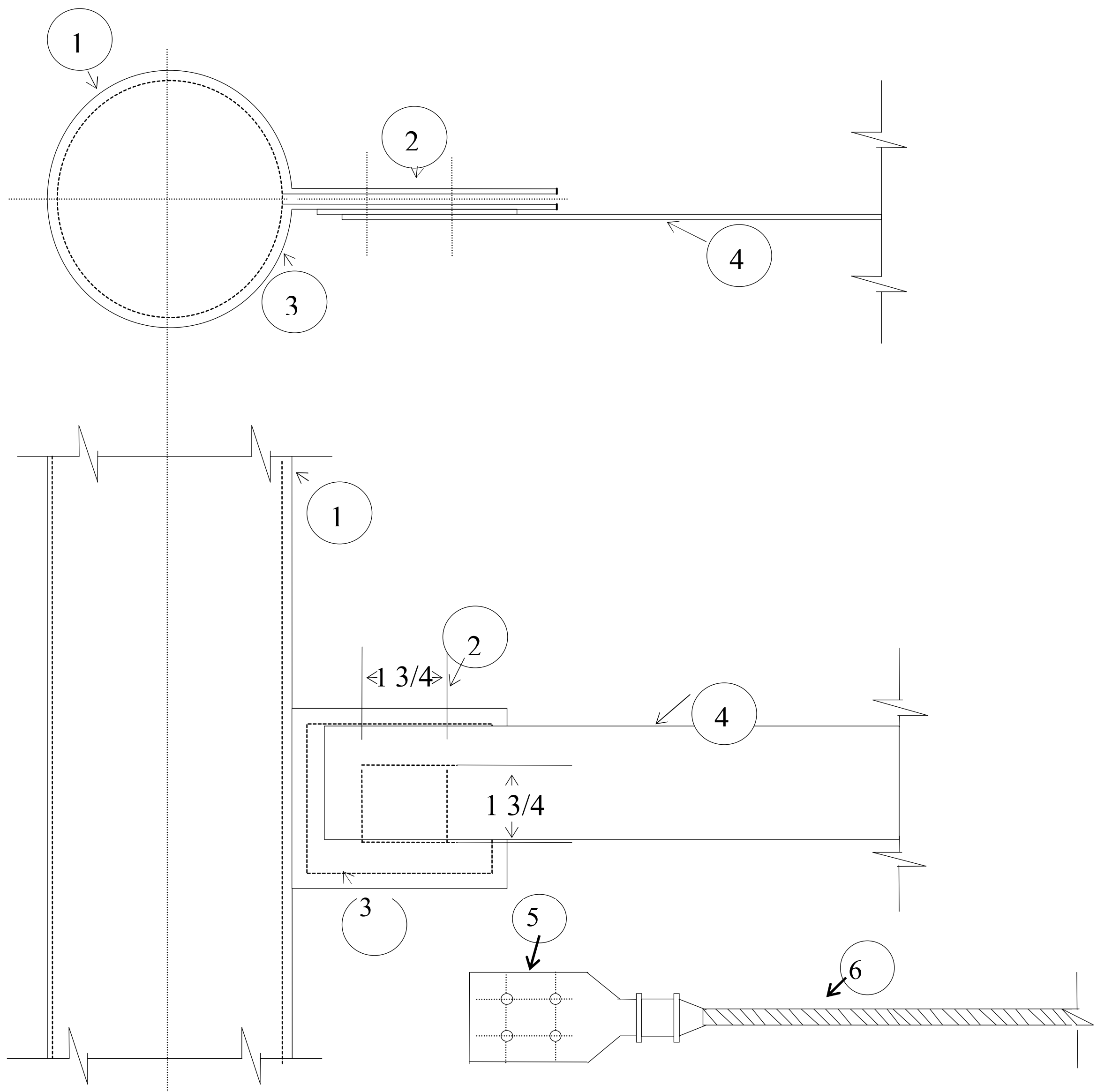
Switch Handle Grounding System

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE 11/4/98		1	SHEET 2 of 2	ED 4.03.05



Method Of Grounding Pipe Or "H" Piling

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **9/1/94**		**1**	**SHEET 1**	**ED 4.03.0.7**



NO.	DESCRIPTION
1.	Steel casings, conduit or pipe
2.	Steel plates welded to copper conduit or pipe
3	Copper bar or plate to steel plate
4	Copper bar bolted to cooper plate
5	Copper clamp (conductor to flat pad)
6	Copper stranded conductor

Method Of Connecting Copper Ground Bar Or Conductor To A Steel Casing, Conduit Or Pipe

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **9/1/94**		**1**	**SHEET 1**	**ED 4.03.0.8**

Ground System Design Data Block

A ground grid “Design Data Block” will be added to Grounding Layout drawing near the drawings General Notes. This block of information records the data used to design the grounding system shown on this drawing and the completed system tested results. The blocks design data is filled out by the Engineer and Designer before project drawings are transmitted and the systems test results by the field on “as built” markups. Field should inform Project Teams Physical Engineer of test results before considering the projects grounding installation complete. Poor readings may require grid system additions.

Ground grid design data

DESIGN IS BASED ON IEEE STD. 80-1986 USING THE FOLLOWING DATA:

1. TOP LAYER SOIL MODEL
   TOP LAYER RESISTIVITY __________OHM-METER
   TOP LAYER DEPTH __________FEET
   BOTTOM LAYER RESISTIVITY __________OHM-METER
   MOISTURE CONTENT __________SOIL TEMPERATURE

2. SURFACE ROCK RESISTIVITY __________OHM-METER
3. SURFACE ROCK DEPTH __________INCHES
4. MAXIMUM SYSTEM FAULT __________CURRENT AMPS.
5. FAULT DURATION __________CYCLES
6. GRID CURRENT __________OF MAXIMUM FAULT CURRENT
   BASED ON PARALLEL GROUND PATH WITH: TRANSMISSION LINE CONNECTED Y N
   FEEDERS CONNECTED Y N

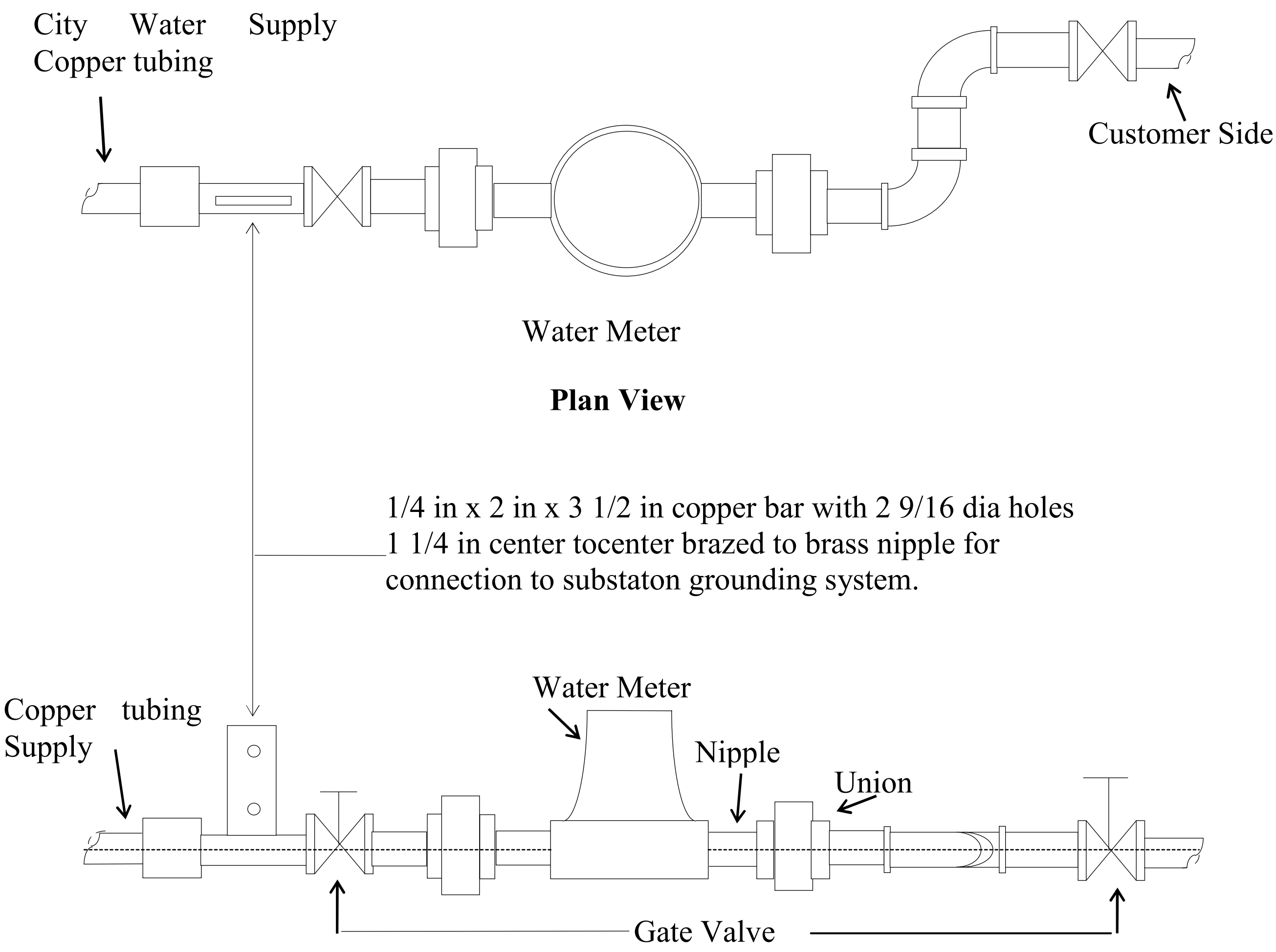
<u>STEP POTENTIAL</u>
CALCULATED: ________VOLTS ALLOWABLE: __________VOLTS

<u>TOUCH POTENTIAL</u>
CALCULATED: ________VOLTS ALLOWABLE: __________VOLTS

<u>GRID RESISTANCE</u>
CALCULATED: ________OHMS # OF TRANSMISSION LINES CONNECTED__________
OF FEEDERS CONNECTED _________

BY FIELD
MEASURED: __________OHMS # OF TRANSMISSION LINES CONNECTED
OF FEEDERS CONNECTED__________
DATE OF TEST__________

Ground System Design Data Block



Plan View

Side View

Connection Of Substation Grounding System To Water Supply

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **9/1/94**		**0**	**SHEET 1**	**ED 4.03.10**

Substation AC Auxiliary Systems

This document describes Xcel Energy's practices with respect to alternating current (AC) auxiliary systems in substations.

Recommended references for AC auxiliary systems are:

- National Fire Protection Association 70, National Electric Code (NEC)
- IEEE Std 141, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (Red Book).
- IEEE Std 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book).

It is the philosophy and intent of this standard to comply with the National Electric Code (NEC). There are a few practices which do not follow the NEC; in these cases, this standard will describe the situation and explain the reasons for the deviation from the NEC.

1. General

Typically, substation AC systems are used to supply power to loads such as transformer cooling, oil pumps and load tap changers (LTCs); circuit breaker auxiliaries and control circuits; outdoor equipment heaters, lighting and receptacles; and control house lighting, receptacles, heating, ventilating, air conditioning and battery chargers. The AC auxiliary system can consist of the following components:

a. High-side fused disconnect(s)
b. Auxiliary transformer
c. Secondary fused disconnects
d. Automatic transfer switch (ATS)
e. Main circuit breaker panelboard
f. AC power and lighting cabinets

Most Xcel Energy North substations utilize a single-phase, 120/240 VAC, three-wire auxiliary supply system for lighting, heating, maintenance, and other site-specific electrical needs. In some substations, a three-phase system is used because it is the more economical choice or because it is required to supply three-phase loads such as breaker heat, compressors, or transformer pumps. (The general rule which has been used is that if using a single-phase system would require equipment with ratings greater than 400A, then a three-phase system should be used.)

Substations are usually provided with both a preferred and an emergency station auxiliary source. Any relayed substation that has station batteries always requires two sources. Distribution substations using series-trip reclosers and having no batteries generally do not require an emergency auxiliary source. Site-specific requirements must be considered in determining whether an emergency auxiliary source is required.

For standard schematic drawings of auxiliary systems, refer to the CE Master Drawings NH-110-11-1, NH-110-11-2, and NH-110-11-5.

2. Station Auxiliary Sources

In distribution substations, it is common for the auxiliary supplies to be taken from the distribution bus, with the preferred source on one bus and the emergency source on another bus. In transmission substations, auxiliary supplies are frequently supplied from transformer tertiaries. For single power transformer substations requiring an emergency auxiliary source, the emergency source is normally supplied from a distribution source outside the station. It is important to verify that this external source comes from a feeder from a different substation.

In some cases, where distribution voltage is not available in the substation, it may be more cost effective to utilize a station-service voltage transformer connected to the transmission voltage than to bring in local distribution. This may be used to provide an emergency source in instances where there is only one power transformer, or to provide the preferred source in cases where there is no transformer (such as a switching station or a capacitor bank station).

When a second source is not available, a single source has sometimes been used until either a second transformer is installed or an external source becomes available.

In substations with a preferred and an emergency source, an ATS is normally used so that the substation loads can be supplied from either of the auxiliary sources. However, in order to limit the size of the ATS and other downstream equipment, power transformer cooling loads are connected ahead of the ATS. Each transformer should provide the auxiliary power source for its own cooling loads, so that each transformer can operate independently. This means that for substations with more than two power transformers, an additional auxiliary transformer (beyond those used for the preferred and emergency source) is required for each additional power transformer to service its auxiliary power requirements. It is important, however, that each LTC should be connected downstream of the ATS, to allow operation of the LTC (for maintenance purposes) when the transformer is out of service.

3. Auxiliary Transformer Connections

This section provides general guidelines on how to choose the transformer high-side connections for substation auxiliary systems. Careful consideration should be given to the specific requirements of each substation.

3.1. Single-Phase Auxiliary Systems

The auxiliary transformers in single-phase auxiliary systems are typically connected line-ground on the primary side. However, there are cases where this connection should not be used. For instance, for connection to any ungrounded or potentially ungrounded system (such as a delta tertiary or a delta-connected system that uses grounding banks) a line-ground connection should not be used, because the auxiliary transformer will become a ground point for the system.

The secondary connection for a single-phase auxiliary shall be 120/240V, three-wire with the center-tap grounded.

3.2. Three-phase Auxiliary Systems

When connecting a three-phase auxiliary system to a distribution bus (voltages ranging from 12.5kV to 34.5kV), the preferred transformer connection is two-legged-grounded, open-wye primary to open-delta secondary. The reasons for using a wye connection on the primary, rather than a delta connection, is that it is preferable to have a grounded auxiliary system when possible, and that, in our experience, a wye connection has less ferroresonance problems than a delta connection.

When connecting to a transformer tertiary, the preferred transformer connection is two-legged, open-delta primary to open-delta secondary. The reason for this is that tertiaries are typically delta-connected, and a grounded-wye primary connection on the auxiliary transformers would cause the auxiliary system to become a ground point for the system.

There are concerns associated with a closed-delta secondary connection and, as a rule, this connection should be avoided. For a closed-delta to closed-delta system, if one phase of the secondary cables fails, ferroresonance and high voltages on the primary can result. For a grounded-wye to closed-delta system, the auxiliary transformer bank provides an additional ground source which desensitizes protective relays. If a wye-to-closed-delta system is desired, it may be done if the primary side is not grounded (two-bushing transformers would be required).

If the kVA rating of a two-legged, open-delta secondary auxiliary system needs to be increased, it is usually preferable to replace the two transformers with two larger transformers, rather than add the third transformer to the bank.

The secondary connection for three-phase auxiliary systems shall be delta (normally two-legged, open-delta). The center-tap point of one transformer shall be grounded. This point shall be chosen so that B-phase is the system high-leg. That is, the voltage B-to-ground will be 208V. The voltages A-to-ground and C-to-ground will each be 120V. The A-B, B-C, and C-A voltage will each be 240V.

In the past, Xcel Energy North's standard was to make C-phase the high leg. However, the current standard is to follow NEC requirements. Therefore, for three-phase systems, B-phase shall be the high leg. In all panels, the center phase shall be the high leg, and this shall correspond to B-phase. That is, left to right, the bars in the panel will be A-B-C phase, and correspondingly, X-Y-Z. Single phase, 120V loads will be connected X-to-Gnd or Z-to Gnd. The 240V single-phase loads can be connected across A-B, B-C, or C-A. This should be done so as to balance the loading on the panels.

4. Auxiliary Transformer Ratings

4.1. kVA Rating

To determine the correct sizing of the auxiliary transformers, the substation AC loads need to be calculated. The loads should be calculated at winter peak loading to see the worst case heating loading requirements. When calculating the winter peak loading, the transformer cooling load would normally not be included, but this should be verified. Some substations may have transformer cooling loads in the winter. Summer loading requirements should include all transformer auxiliary requirements, as well as any air conditioning loads at the substation. Special needs, such as maintenance and construction requirements, also need to be taken into account. Future expansion/growth needs should also be addressed.

Welders and other equipment used by construction forces require up to 50 kVA, single-phase of load capacity. Since this equipment can be used at any time of the year, calculation of normal winter peak substation load requirements should be made to ensure that the transformer sizing is adequate for both the substation loading and construction and maintenance equipment.

Note that the large oil processing units (OPU) use either large portable generators or a portable transformer to supply the required 200A of 480V three-phase power. (The transformer is temporarily connected to a feeder when the noise level of the generators is a concern.) Thus, the OPUs always have their own power source and are not powered from the substation auxiliary source.

The minimum auxiliary transformer rating to be used is 25kVA. This is large enough to handle most construction and maintenance loads, and the cost is only slightly more than for a lower rated transformer.

The standard auxiliary transformer rating for typical two-transformer distribution substations (in which the power transformers are protected by relays, not fuses) is 75 kVA, single-phase. This rating is usually sufficient for maintenance and construction requirements, as well as, normal station loading. This must be verified as adequate for each particular situation before proceeding with the design.

For small, rural substations, a minimum size of 25kVA is standard. Again, this rating must be verified as adequate for the specific application.

For substations having a preferred and an emergency station auxiliary, the loads to be connected downstream of the ATS need to be determined so the ATS can be properly sized. Such critical loads include: battery chargers; heat for breakers and other equipment, AC to power circuit breakers and controls; LTC controls; station and security lighting and receptacles; and control house heaters.

For substations with large loading requirements, the use of a three-phase auxiliary system should be considered. The normal configuration for three-phase auxiliary systems is two-legged, open-delta secondary. When using this connection, the auxiliary cannot be loaded to the sum of the nameplate ratings of the two transformers. For example, two 75kVA transformers connected with a two-legged, open-delta secondary connection generally cannot supply 150kVA of auxiliary load without being overloaded. A reference for information on the loading of two-legged, open-delta connected transformers is the "ABB Distribution Transformer Guide", ABB publication 3A49299H01, Revised October, 1991.

4.2. Voltage Ratings

The primary voltage rating of the transformer is selected based on the voltage of the source bus. The secondary voltage rating shall be 120/240V. The following table defines the various transformer voltage designations:

Designation of Voltage Ratings of Single-Phase Windings

Nomenclature	Nameplate Marking	Condensed Usage Guide
E/E_1Y	2400/4160Y	E/E_1Y shall indicate a winding of E volts that is suitable for Δ connection on an E volt system or for Y connection on an E_1 volt system.
E/E_1GrdY	2400/4160GrdY	E/E_1GrdY shall indicate a winding of E volts having reduced insulation which is suitable for Δ connection on an E volt system or Y connection on an E_1 volt system, transformer neutral effectively grounded.
E_1GrdY/E	12470GrdY/7200	E_1GrdY/E shall indicate a winding of E volts with reduced insulation at the neutral end. The neutral end may be connected directly to the tank for Y or for single-phase operation on an E_1 volt system, provided the neutral end of the winding is effectively grounded.
E/2E	120/240	E/2E shall indicate a winding, the sections of which can be connected in parallel for operation at E volts, or which can be connected in series for operation at 2E volts, or connected in series with a center terminal for three wire operation at 2E volts between the extreme terminals and E volts between the center terminal and each of the extreme terminals.
2E/E	240/120	2E/E shall indicate a winding for 2E volts, two-wire full kVA between extreme terminals, or 2E/E volts three-wire service with ½ kVA available only, from midpoint to each extreme terminal.

$Key : E_1 = \sqrt{3}E$ Source: IEEE Std C57.12.01-1989.

Care must be taken to select a transformer with proper voltage ratings for the application. For a line-ground or wye primary connection, either a single-bushing transformer or a two-bushing transformer may be used. For a line-line or delta primary connection, a two-bushing transformer must be used. For all applications, the voltage rating of the transformer winding must be matched to the voltage being applied to the winding, i.e. between the two bushings (two-bushing transformers) or between the bushing and ground (single-bushing transformers).

Example 1: A transformer rated "13800/23900Y" has a winding rated for 13,800V. It is suitable for line-line or delta connection on a 13.8kV system. It is also suitable for line-ground or wye connection on a 23.9kV system. Since it can be used on a delta connection, it must have two bushings. However, it must not be line-line or delta connected on a 23.9kV system, since that would apply 23,900V to a winding only rated for 13,800V.

Example 2: A transformer rated "13800GrdY/7970" has a winding rated for 7,970V, with reduced insulation at the neutral end. It is suitable for line-ground or wye connection on a 13.8kV system. It is not suitable for any line-line or wye connections, as it only has one bushing. The neutral end must be grounded.

5. Primary Fusing and Switching

5.1. Fused Disconnects

Substation auxiliary power transformers shall be fused on the high side using fused disconnects as shown in the following tables. The fuse sizes were selected by choosing the smallest rating, which is at least 150% of the high-side full load ampere current (FLA). In order to promote standardization of fuse sizes used in the system, sizes 3E and 7E are not used.

High-Side Fusing for
Single-Phase Systems Connected Line-Ground
and
Three-Phase Systems with Two-Legged, Open-Wye to Open-Delta, Closed-Wye to Delta or Closed-Delta to Delta Connection*

	34.5/19.9 kV		23.90/13.80kV		13.8/7.97 kV		12.5/7.2 kV	
TR kVA	Line FLA	Fuse Rating	Line FLA	Fuse Rating	Line FLA	Fuse Rating	Line FLA	Fuse Rating
10	0.50	5E	0.72	5E	1.26	5E	1.39	5E
15	0.75	5E	1.09	5E	1.88	5E	2.08	5E
25	1.26	5E	1.81	5E	3.14	5E	3.46	10E
37.5	1.88	5E	2.72	5E	4.71	10E	5.20	10E
50	2.51	5E	3.62	10E	6.28	10E	6.93	15E
75	3.77	10E	5.44	10E	9.41	15E	10.39	20E
100	5.02	10E	7.25	15E	12.55	20E	13.86	25E

* For 3-Phase systems, TR kVA in the tables refers to the size of one of the single-phase transformers in a matched bank of two or three transformers. For example, a bank of two 75kVA, 34.5/19.9kV transformers connected two-legged, open-wye to open-delta would be fused with two 10E rated fuses.

High-Side Fusing for
Single-Phase Systems Connected Line-Line
and
Three-Phase Auxiliary Systems with Two-Legged-Open-Delta to Open-Delta Connection*

TR kVA	34.5/19.9 kV		23.90/13.80kV		13.8/7.97 kV		12.5/7.2 kV	
	Line FLA	Fuse Rating	Line FLA	Fuse Rating	Line FLA	Fuse Rating	Line FLA	Fuse Rating
10	0.29	5E	0.42	5E	0.72	5E	0.80	5E
15	0.43	5E	0.63	5E	1.09	5E	1.20	5E
25	0.72	5E	1.05	5E	1.81	5E	2.00	5E
37.5	1.09	5E	1.57	5E	2.72	5E	3.00	5E
50	1.45	5E	2.09	5E	3.62	10E	4.00	10E
75	2.17	5E	3.14	5E	5.43	10E	6.00	10E
100	2.90	5E	4.18	10E	7.25	15E	8.00	15E

* For 3-Phase systems, TR kVA in the tables refers to the size of one of the single-phase transformers in a matched bank of two or three transformers. See previous Table note for an example.

The fuse sizes shown in the tables above are based on the use of S&C SM5 fuses. The S&C SM5 is the standard fuse to be used in the system. In the past, both SM4 and SM5 type fuses were used. However, to promote standardization of fuse types, the SM4 type should not be used for new applications. The SM5 fused disconnects have a significantly higher fault interrupting rating and a slightly higher cost than the SM4 type.

When purchasing fused disconnects, one replacement element should be purchased for each element to be installed. These spares should be kept in the substation as replacement parts.

The standard time-rated fuse should be used (rather than the slow or very-slow rating).

5.2. Current-limiting Back-up Fuses

Some substations may have available fault currents greater than the interrupt rating of the fused disconnect. In these cases, current-limiting back-up fuses should be used in series with the fused disconnect. The current-limiting back-up fuse will limit the fault current and also provide for clearing of faults up to its interrupt rating.

Note that the interrupt rating of the current-limiting back-up fuse must be greater than the available fault current. If it is not, then this approach is not sufficient and further engineering will be necessary. For instance, current-limiting reactors could be used to reduce the fault current, or a high-rated current-limiting fuse could be employed.

The back-up fuse should be placed downstream of the fused disconnect; in this way, the back-up fuse can be replaced by opening the fused disconnect, and without deenergizing the source. The design should make sure, to the greatest extent possible, that there is adequate clearance to replace the back-up fuse without deenergizing the source.

With this configuration, there is an accepted risk of a fault occurring in the lead between the two fuses which could not be cleared by the fused-disconnect. This would be a bus fault, and would have to be cleared by the station relaying.

The back-up fuse is meant to be used in series with another fuse. For low current level faults, the primary fuse will clear the fault. For high current level faults, the current-limiting back-up fuse will clear the fault. The time-current characteristics of the two fuses do not coordinate; therefore, if the element of either fuse blows, both elements should be replaced at the same time.

When installing back-up fuses in a substation, spare fuses should also be ordered and kept in the substation as replacement parts.

Xcel stocks the following current-limiting back-up fuse: Cooper NX Companion II, 25A, 23kV fuse (Stock #09-2663). This fuse can be applied on systems up to 36.5kV. (See Cooper bulletin 240-64, which is available at www.cooperpower.com, for product information and ratings). The interrupting rating of this fuse at various system voltages is shown in the following table:

Interrupt Rating of 23kV Cooper NX Companion II Fuse
(Xcel Energy Stock #09-2663)*

Applied System Voltage (Line-Line)	Interrupting Rating
System Voltage ≤ 15.2kV	50kA
15.2kV < System Voltage ≤ 26.4kV	43kA
26.4kV < System Voltage ≤ 36.5kV	31kA

*Note: The application of the 23kV NX fuse at lower system voltages was discussed with Cooper. The 23kV NX fuse has the same element as the 8.3kV and the 15.5/17.2kV NX fuses, the ratings of which are shown in the table below. Therefore, it was established that the interrupt rating of the 23kV fuse, when applied at lower voltages, would be as shown in the table above.

Interrupt Rating of Cooper NX Companion II Fuses

Fuse Voltage Rating	For Application at	Interrupting Rating
8.3kV	System Voltage ≤ 15.2kV	50kA
15.5/17.2kV	15.2kV < System Voltage ≤ 26.4kV	43kA
23kV	26.4kV < System Voltage ≤ 36.5kV	31kA

6. Secondary Fusing and Switching

For new installations (and retrofits when appropriate), a 120/240V, 600 Ampere outdoor main panelboard is to be installed at the station auxiliary transformer(s) (1000A panels are generally used because that is what is available at the best price). For single-phase systems, the panelboard shall be 600A single-phase three-wire. For three–phase systems, the panelboard shall be rated 600A, three-phase, four-wire. One panelboard shall be installed at the preferred auxiliary source and another shall be installed at the emergency auxiliary source. If the emergency source is supplied from outside of the substation, then the installation of an outdoor fused disconnect panelboard may not be reasonable.

The panelboard shall contain three sets of current-limiting, fused disconnects and space for at least one additional set of fused disconnects (See table below). One set of fused disconnects will be for protection of the AC panels in the control house, one set will be for the transformer cooling requirements, and a third set will be for maintenance/construction connections. The fused disconnects protecting the circuit to the control house will also protect the automatic transfer switch when applicable. To comply with the NEC, the panelboard shall not have more than six disconnects.

For single-phase systems, three standard, outdoor, fused disconnect panelboards have been set up as follows:

Standard Outdoor Fused Disconnect Panelboards
for Single-Phase Auxiliary Systems

Description:	Stock No.
Single-phase, three-wire, 60 Hz, 120/240V, 100kAIC minimum, 600A main lug, copper bus in a NEMA 3R enclosure, 44" minimum width, top feed, rejection type fuses and with:	
• two 200A/2P fused disconnects (normally for ATS and maintenance source) • one 60A/2P fused disconnect (normally for transformer cooling loads) • two 200A/2P spaces only • two 100A/2P spaces only • one 60A/2P space only	S5-1012
• one 400A/2P fused disconnect w/ 2 #2-600 MCM Lugs (normally for ATS) • one 200A/2P fused disconnect (normally for maintenance source) • one 60A/2P fused disconnect (normally for transformer cooling loads) • one 200A/2P space only • one 60A/2P space only	S5-1013
• one 400A/2P fused disconnect w/ 2 #2-600 MCM Lugs (normally for ATS) • one 200A/2P fused disconnect (normally for maintenance source) • one 100A/2P fused disconnect (normally for transformer cooling loads) • one 200A/2P space only • one 100A/2P space only	S5-1014

Sizing of the individual fuse elements for the fused disconnect modules needs to be determined for each specific application. The individual fuses *are not* included in the above stock numbers.

For stations with auxiliary transformers of 25kVA or less, the standard 600A panel is not required. For these sites, a 100A, single-phase, three-wire panelboard with a 100A main breaker shall be installed in the substation yard. It is not necessary to use a separate fused safety switch upstream from the panelboard. If there is a panelboard mounted in the control house and an outdoor panelboard is not required for any other outdoor branch circuits, then a 100A fused safety switch mounted at the auxiliary transformer will suffice.

Conduits with weatherheads are to be used to route the secondary conductors to the outdoor main panelboard.

Xcel Energy stock transformers come equipped with eyebolt-type secondary bushing terminals. In some cases, the size or number of the secondary conductors may be larger than the bushing terminals can accommodate. In these cases, transformer adapter connectors should be used, rather than purchasing a non-stock transformer with a different type of terminal. One terminal adapter, which may be used, is the Burndy FCB64-4N, which consists of a stud connected to a NEMA standard 4-hole flat pad. Stock transformers are to be used whenever possible, as it makes replacements easier.

7. Grounding and Neutral Connections

The grounded neutral conductor shall be sized in accordance with the NEC-1999, Article 250-24.

The station auxiliary neutral is to be grounded in three places:

1. At the neutral bushing of the auxiliary transformer.
2. In the fused panel located in the yard.
3. In the transfer switch in the control house. (Note: This is a deviation from the NEC. See explanation below for details.)

<u>**Explanation of Deviation from the NEC**</u>

Re-grounding the neutral at the transfer switch in the control house, when there is also continuous metallic ground path between the panel in the yard and control house, is a deviation from the NEC-1999 Article 250-32(b)(2). The NEC is written to cover typical electrical installations outside of utility substations and does not consider the unique situation where the primary system is in close proximity to the secondary system. In a substation, it is possible for disturbances on the primary system to have a greater effect on the secondary system than what is experienced on systems outside of the substation. Therefore, exceptions are taken to the NEC because of these special conditions.

When a line to ground fault occurs on the primary system within a substation, the ground grid in the area of the fault can rise to a much higher potential than a part of the grid located some distance away from the fault. If this primary fault was to occur near the fused panel in the yard and the neutral were not regrounded in the control house there could be a significant difference in potential between the neutral and the ground grid in the control house. This voltage difference could present a hazard to anyone that happened to be in the control house when the fault occurred. It could also subject the equipment to line-to-ground potentials outside of their ratings. When the auxiliary system neutral is bonded to ground in the control house, any potential difference between the ground grid and neutral in the control house is kept to a minimum and below levels that would put people or equipment at risk.

The NEC prohibits this connection in order to prevent normal load current from using the metallic ground as a return path. Whenever current flows through a conductor, the resistance of the conductor generates a voltage drop. In the case of current through a ground conductor, this voltage drop causes a voltage difference between the conductor and what is considered “true earth”. This voltage difference could put a person at risk should they come in contact with the grounded system and “true earth”. Since our substations have a ground grid with all equipment and structures bonded together, the risk of coming in contact with the substation ground system and “true earth” is considered insignificant. Therefore, this deviation is made to the NEC to protect substation personnel and equipment from what we consider to be the more significant risk.

8. ATS and Indoor Panels

For new installations (and retrofits when appropriate), the preferred and emergency supplies to the control house will be brought into the automatic transfer switch and then into a control house main breaker panelboard. This standard does not require service disconnects to be installed inside the control house on the supply side of the ATS. Instead, the service disconnects are located at the fused panelboard in the yard. This is allowed by the NEC as there is a hold-card system in place to ensure that the service is not inadvertently energized.

The main panel in the control house shall be 120/240V, 600 Ampere main lug only. For single-phase systems, the main panelboard shall be 600A, single-phase, three-wire. For three–phase systems, the panelboard shall be 600A, three-phase, four-wire.

For new installations, 200 Ampere, single-phase, AC power and lighting panels should be installed, which would each require 200 Ampere feeder breakers on the main panelboard. For existing substations, the feeder breakers need to be matched to the AC panels.

For three-phase systems, a 225A, three-phase, AC power panel may be installed in addition to the single-phase power and lighting panels. This panel would be used to power 240V loads such as heaters, as well as, any three-phase loads. It is recommended that no 120V loads be supplied from this panel.

The standard indoor main breaker panelboards are listed below:

Standard Indoor Main Breaker Panelboards for Single-Phase Auxiliary Systems

Description:	Stock No.
Single-phase, three-wire, 60 Hz, 120/240V, 22kAIC minimum, 600A main lug, copper bus in a NEMA 1 enclosure, 36" minimum width, top feed and with: • four 200A/2P breakers • two 200A/2P breaker spaces • two 125A/2P breaker spaces	S5-1010
• two 200A/2P breakers • two 200A/2P breaker spaces • two 125A/2P breaker spaces	S5-1011

9. Secondary Available Fault Currents

The available fault currents and ratings of equipment must be taken into consideration when designing the auxiliary system. A reference for further information on this subject is:

IEEE Std 242, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book).

The available fault current at the secondary terminals of the auxiliary transformers according to auxiliary transformer kVA sizing is as follows:

Available Fault Current
Single-Phase Auxiliary Systems
With 120/240V secondary

TR kVA	Approx. Fault Duty (kA) *	Assumed $Z_{\%}$ Impedance (%)
25	4.5	2.3
37.5	7.4	2.1
50	9.5	2.2
75	19.5	1.6
75	17.4	1.8
75	15.6	2.0
100	14.4	2.9

* Assumes infinite source

$$Z_B = \frac{V^2}{VA} \qquad Z_{act} = Z_B \times \frac{Z_\%}{100} \qquad I_F = \frac{V}{Z_{act}}$$

V = Line-to-Line Voltage (i.e. 240V)
Z_B = Transformer Base Impedance
Z_{act} = Transformer Actual Impedance
I_F = Fault Current

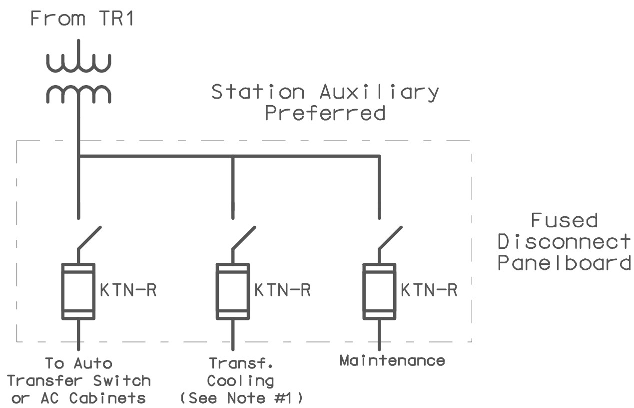
Available (3-Phase) Fault Current
for Closed-Delta or Two-Legged, Open-Delta Secondary
Three-Phase Auxiliary Systems with 120/240V secondary

Single TR kVA	3-Phase Total kVA**	Approx. Fault Duty (kA) *	Assumed $Z_\%$ Impedance of each transformer (%)
25	75	7.8	2.3
37.5	112.5	12.9	2.1
50	150	16.4	2.2
75	225	33.8	1.6
75	225	30.1	1.8
75	225	27.1	2.0
100	300	24.9	2.9

* Assumes infinite source
** Choose the row of the table based on the kVA of the individual transformers used. Using the value in this column for both two-legged-open-delta and closed-delta systems will provide the correct worst-case three-phase fault current.

$$Z_B = \frac{V^2}{VA_{3-Phase}} \qquad Z_{act} = Z_B \times \frac{Z_\%}{100} \qquad I_F = \frac{V}{\sqrt{3} \times Z_{act}}$$

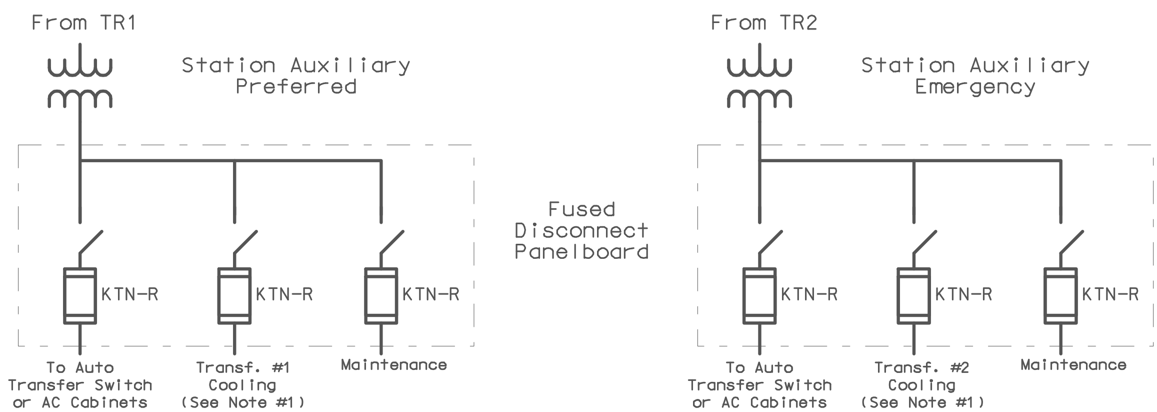
V = Line-to-Line Voltage (i.e. 240V)
Z_B = Transformer Base Impedance
Z_{act} = Transformer Actual Impedance
I_F = Fault Current



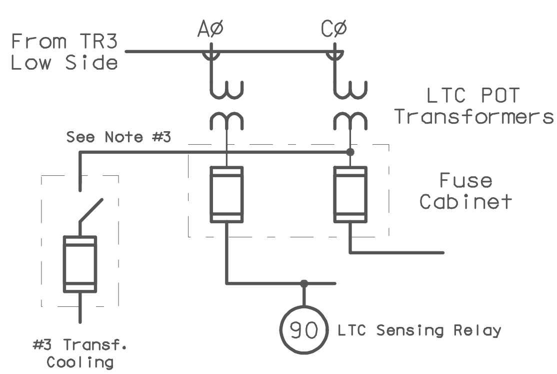
Notes:

1. Fuse size to be determined when transformer manufacturer's drawings are received.
2. For Transformer #1 & #2 supplies, see Two Transformer scheme.
3. The 3rd transformer cooling is not to be taken from the LTC POT used for LTC sensing. Where only one POT exists, the transformer cooling should be taken from the AC cabinet.

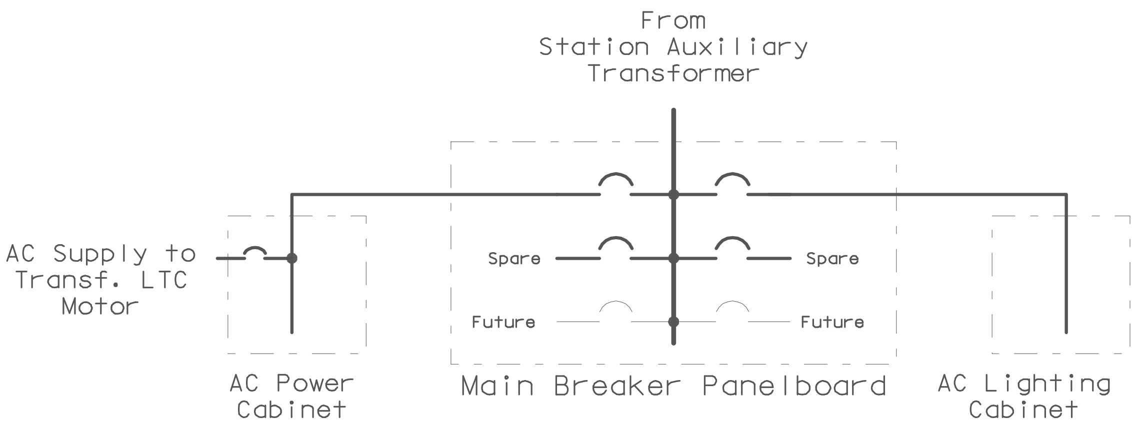
One Transformer



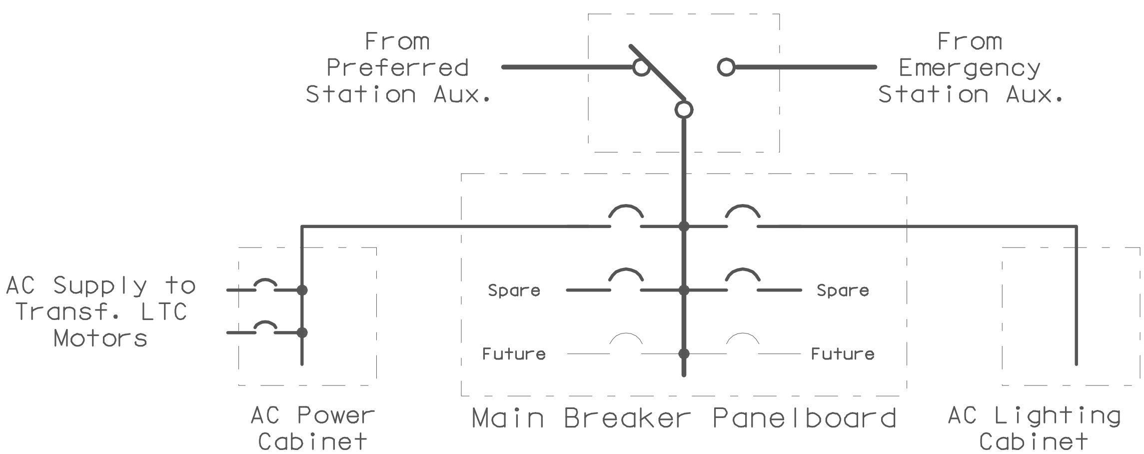
Two Transformer



Third Transformer
(See Note #2)



Control House Load Center - No Emergency Source



Control House Load Center
With Preferred & Emergency Sources

Nameplates for Substation Equipment and Cabinets

1. General

All outdoor equipment and cabinets shall be identified with 1” x 2”, 1 ½” x 6”, 1 ½” x 7”, 5” x 8”, 6” x 10” or 6” x 14” on 0.080 aluminum plate covered with 3M high intensity yellow Scotchlite, code 3871, and one inch high letters (except CCVT grd, carrier, potential, and norm which shall have 1/2” letters). The letters shall be silk screened with 3M #845 black paint.

1.01. Outdoor nameplates shall be mounted either by the use of pop-rivet or 3M Adhesive No. 847 when drilling is not feasible.

1.02. Three-line equipment identification shall be on a 5” x 8” plate. Four-line equipment identification shall be on a 6” x 10” or 6” x 14” plate. All power transformers shall be identified with a 6” x 10” plate. The word “Transformer” shall not be abbreviated on the power transformer nameplate. Transformer may be abbreviated on other equipment nameplates. Use “TR” as the identification for a transformer. The identification “bank” shall not be used for the identification of a transformer.

1.03. Transformers, breakers, reclosers and motor-operated disconnect switches shall have the nameplate located on the equipment cabinet at approximately 5 to 6 feet above grade, when possible, and near the center of the cabinet. Transformers, also require 1 UTC # nameplate (1½”x7” adhesive nameplate). Reclosers require 2 nameplates located on each side of the control cabinet. See examples in Sections 4.01, 4.01, 4.04, and 4.04.

1.04. Manual group operated disconnect switches shall have the nameplate located in such a way that it is clearly visible when operating the disconnect switch. See the examples in Section 4.05.

1.05. When multiple manual disconnect switches are mounted on one column, install nameplates as shown in Section 4.06.

1.06. Hook-stick disconnect switches shall be identified as shown in examples in Sections 4.07, 4.08, and 4.09. When identifying the phasing, the information shall appear on the third line of the nameplate. As you face the switch, the right phase shall be on the right side, the center phase shall be in the center, and the left phase shall be on the left side of the nameplate.

1.07. Coupling capacitor voltage transformers (CCVT), potential transformers (PT), and metering units shall be identified as shown in the example in Section 4.10.

1.08. Coupling capacitor voltage transformers (CCVT) with/without carrier shall be identified as shown in the example in Section 4.11.

1.09. Secondary fuse cabinets shall be identified as shown in the example in Section 4.12.

1.10. Capacitor banks shall have (1) nameplate on each phase and shall be identified as shown in the example in Section 4.13.

1.11. Station auxiliary transformers shall be identified as shown in the example in Section 4.14.

1.12. Control test receptacles shall have a 6" x 10" nameplate and shall identify both receptacles. The nameplate shall be identified as shown in the example in Section 4.15.

1.13. Foreign utility substation equipment maintained and operated by Xcel Energy shall have equipment nameplates. All other foreign substations maintained and operated by Xcel Energy shall have equipment nameplates when approved by the foreign company.

1.14. Feeder reactors, wave traps, and current transformers do not require nameplates.

1.15. Nameplates should label <u>operating</u> voltage, <u>not</u> designed voltage.

2. N/A

3. Nameplate Layout

The following tables contain a list of examples of the different variations of equipment nameplates that are required.

3.01. 345 KV Substation

8N4 345KV BKR	8N4A 345KV DISC	8N4A1 345KV DISC	BUS 1 PT 345KV DISC
BUS 1 345KV PT A PHASE	BUS 1 345KV PT SEC FUSES	BUS 2 345KV CCVT SEC FUSES	BLL LINE 345KV CCVT SEC FUSES
BLL LINE 345KV CCVT A PHASE	BLL LINE TUNING UNIT	TRANSFORMER 8 GENERATOR 345-20KV	TRANSFORMER 8 345-115-13.8KV
TR8 345KV MOD	FRA LINE 345KV METERING UNIT A PHASE	FRA LINE 345KV METERING UNIT SEC FUSES	MTC LINE 345KV REACTOR A PHASE

3.02. 230 KV Substation

TR7 230KV MOD	7N2 230KV MOD	7N2A 230KV DISC	FRA LINE 230KV METERING UNIT SEC FUSES
BEN LINE 230KV CCVT B PHASE	BEN LINE 230KV CCVT SEC FUSES	TRANSFORMER 7 230-69KV	FRA LINE 230KV METERING UNIT A PHASE

3.03. 161 KV Substation

WBG LINE 161KV CCVT A PHASE	WBG LINE 161KV CCVT SEC FUSES	WBG LINE TUNING UNIT	FRA LINE 161KV METERING UNIT A PHASE
FRA LINE 161KV METERING UNIT SEC FUSES	TR6 161KV DISC	TRANSFORMER 6 161-69KV	

3.04. 115 KV Substation

TR5 115KV DISC	5M193A 115KV DISC	5N6 115KV BKR	CAP1 115KV A PHASE BANK
5N6A 115KV DISC	FRA LINE 115KV CCVT A PHASE	FRA LINE 115KV CCVT SEC FUSES	FRA LINE TUNING UNIT
FRA LINE 115KV METERING UNIT A PHASE	FRA LINE 115KV METERING UNIT SEC FUSES	BUS 1 115KV PT SEC FUSES	BUS 1 115KV PT A PHASE
TRANSFORMER 5 115-69KV	TR5 115KV MOD	TR5 115KV CKT SW	

3.05. 69 KV Substation

TR3 69KV PT A PHASE	TR3 69KV PT SEC FUSES	TR3 69KV BKR	TRANSFORMER 3 69-13.8KV
BUS 1 69KV PT A PHASE	BUS 1 69KV PT SEC FUSES	BUS 1 69KV CCVT A PHASE	BUS 1 69KV CCVT SEC FUSES
4E61A 69KV DISC A B C	4X40A1 69KV DISC	4X40 69KV BKR	FRA LINE 69KV METERING UNIT A PHASE
FRA LINE 69KV METERING UNIT SEC FUSES	4E256B 69KV PT A PHASE	KLS LINE 69KV PT A PHASE	
	This PT is located between the breaker and the "B" disc.	This PT is located on the transmission line	

3.06. 34.5 KV Substation (23 KV Similar)

3P1 34.5KV BKR	3P1A 34.5KV DISC	HUG311-HUG321 34.5KV MOD	HUG311-HUG321 34.5KV DISC
FRA LINE 34.5KV METERING UNIT A-PHASE	FRA LINE 34.5KV METERING UNIT SEC FUSES	YNK311 34.5KV DISC	
TR9 GRD DET TR A PHASE	TR9 GRD DET TR 34.5KV DISC	TR9 GRD DET TR 34.5KV SEC FUSES	TR9 GRD DET TR 34.5KV RES CAB
REACTOR 9 34.5KV A PHASE	REACTOR 9 34.5KV PT A PHASE	REACTOR 9 34.5KV PT SEC FUSES	

3.07. 13.8 KV Substation

TR9 13.8KV-240V AUX TR	BLM61 13.8KV BKR (2 REQUIRED)	BLM61A 13.8KV DISC	WLM62TB 13.8KV DISC
STA AUX TR 13.8KV FUSED DISC A B C	GRD TR 13.8KV A PHASE	WLM62B 13.8KV DISC A B C	RRK62A 13.8KV DISC
STM21C 12.5KV FUSED DISC C B A	BUS 1 13.8KV CAPACITOR GRD SW	BUS 1 13.8KV PT A B C	BUS 1 13.8KV PT SEC FUSES
DBL43 13.8KV DISC GRD SW C B A	BUS 1 13.8KV FUSED DISC A B C	BUS 1 13.8KV METERING UNIT A B C	BUS 1 13.8KV METERING UNIT SEC FUSES
TRANSFORMER 1 115-13.8KV	TR1 13.8KV BKR	TR1 13.8KV MOD	WAT81 13.8KV REGULATOR A PHASE
BT1-2A1 13.8KV DISC	BT1-2TA1 13.8KV DISC		

3.08. Pad Mounted Cap Bank

WIL66 13.8KV CAP BANK (2 REQUIRED)	FUSES	RADIO NO

3.09. By-Pass Switch

BUS 1 13.8KV REG BY-PASS SW A B C	L *(LOAD)* *(TO BE MOUNTED ON SW BLADES)*	S *(SOURCE)* *(TO BE MOUNTED ON SW BLADES)*	BP *(BY-PASS)* *(TO BE MOUNTED ON SW BLADES)*

3.10. Switch Fuse Combination

WLM62B 13.8KV DISC A B C	WLM62C 13.8KV FUSED DISC A B C

3.11. CCVT with Carrier

NOTE: CCVTs <u>without</u> carrier require only 1 nameplate each for POTENTIAL, NORM AND GRD. No CARRIER nameplate is required. These are all ordered using assigned Cat. ID's, see Physical Material List items: 723A, 723B, 723C & 723D.

CARRIER	POTENTIAL	NORM	GRD
		(2 required)	(2 required)

3.12. Switchgear

BLC61 13.8KV CUBICLE	SWGR CHASKA BLC 81,82,83	SWGR BLC 81,82,83 BUS 2-SEC 1
(2 required)	(2 required)	(Xcel Energy SWGR doors only) (2 required)

3.13. Outdoor Substation Power & Light

345KV AC LTG CAB M	115KV YARD AC LOAD CENTER	AUTO TRANSFER SWITCH 1	1 DIST. TR 480-120/240V
DISTR PANEL A	LTG CAB L 120/240V FUSED DISC	LTG TERM CAB C3	AC PWR CAB M
1 STA AUX 120/240V JUNCTION BOX	345KV SUB PWR CAB L	EMERGENCY STA AUX 120/240V FUSED DISC	PREFERRED STA AUX 120/240V FUSED DISC
PREFERRED STA AUX TR 13.8KV-120/240V B & C PHASE	EMERGENCY STA AUX TR 13.8KV-120/240V B & C PHASE	PREFERRED STA AUX TR 120/240V FUSED SAF SW	EMERGENCY STA AUX TR 120/240V FUSED SAF SW
345KV SUB LOAD CTR 3 AUTO TRANSFER SW	345KV SUB LOAD CTR 3 FUSED SAF SW PREFERRED	PREFERRED STA AUX TR 120/240V PANELBOARD	MAINTENANCE AC SUPPLY 120/240V

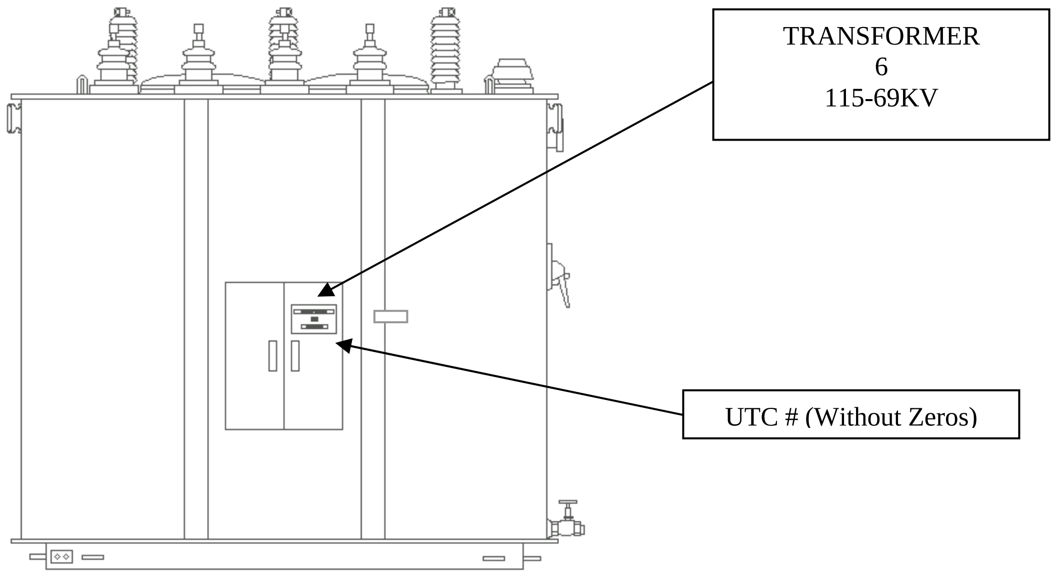
3.14. Miscellaneous

TR1 8400V SPOT TRW B PHASE	MOBILE TR CONTROL CABLE CONNECTION CABINET	EBL64-EBL65 VCR RECEPTICAL	UTC #1686665
TR1 CABLE TERM CAB			

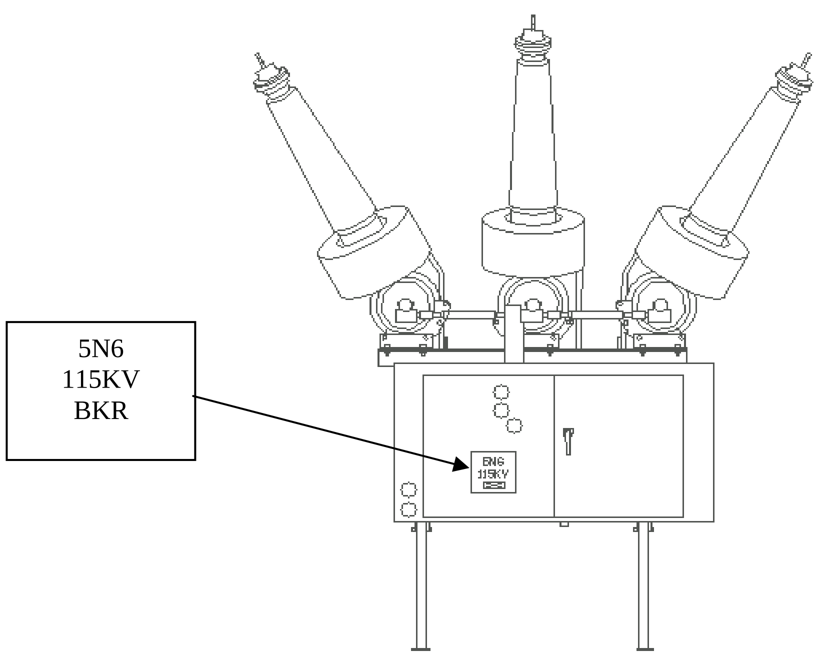
4. Location of Nameplates

The following is a list of examples indicating the location of nameplates.

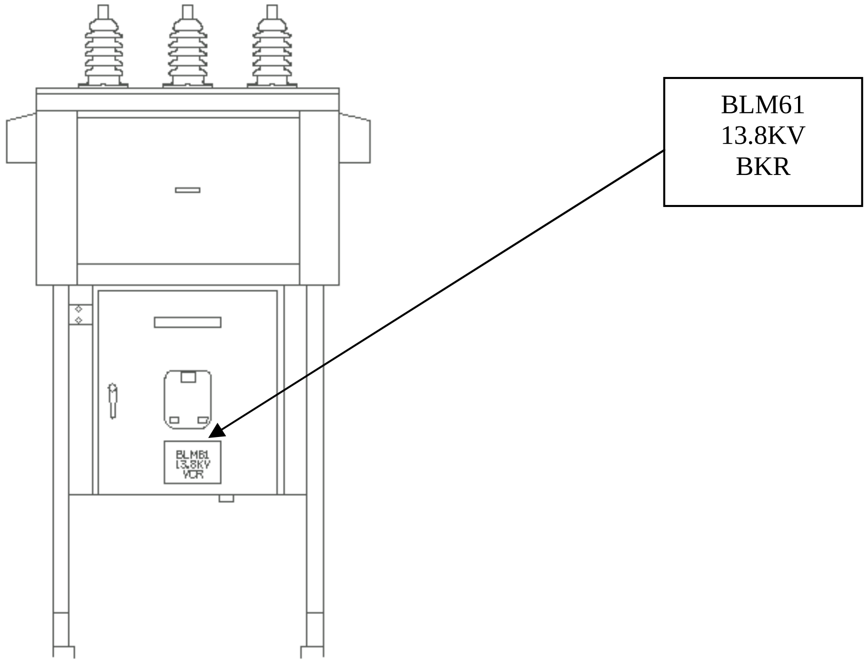
4.01. Power Transformers (UTC # Nameplate)



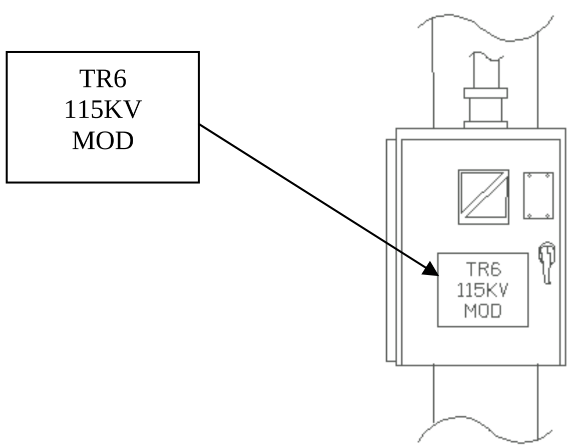
4.02. Breakers



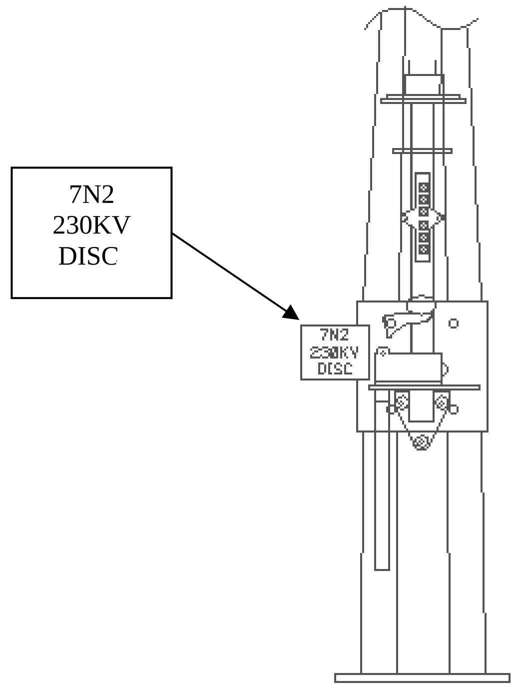
4.03. Reclosers (2 Nameplates Required – one on each side of the control cabinet)



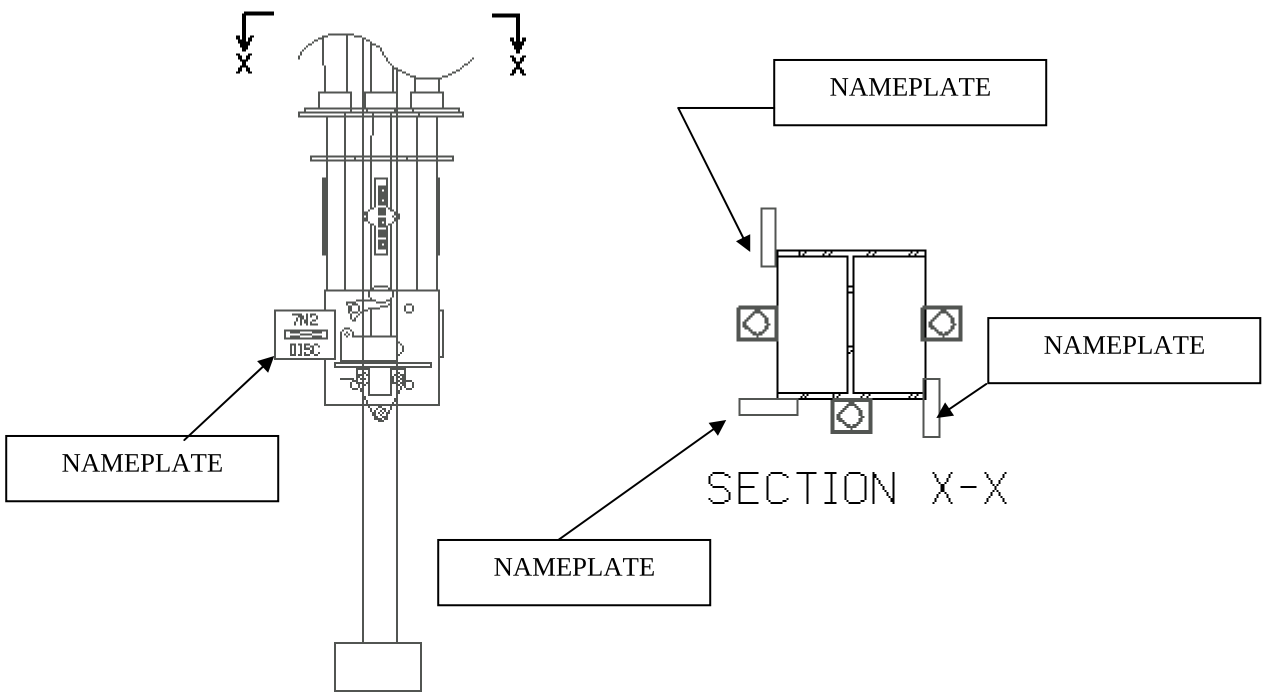
4.04. Motor Operated Disconnect Switch



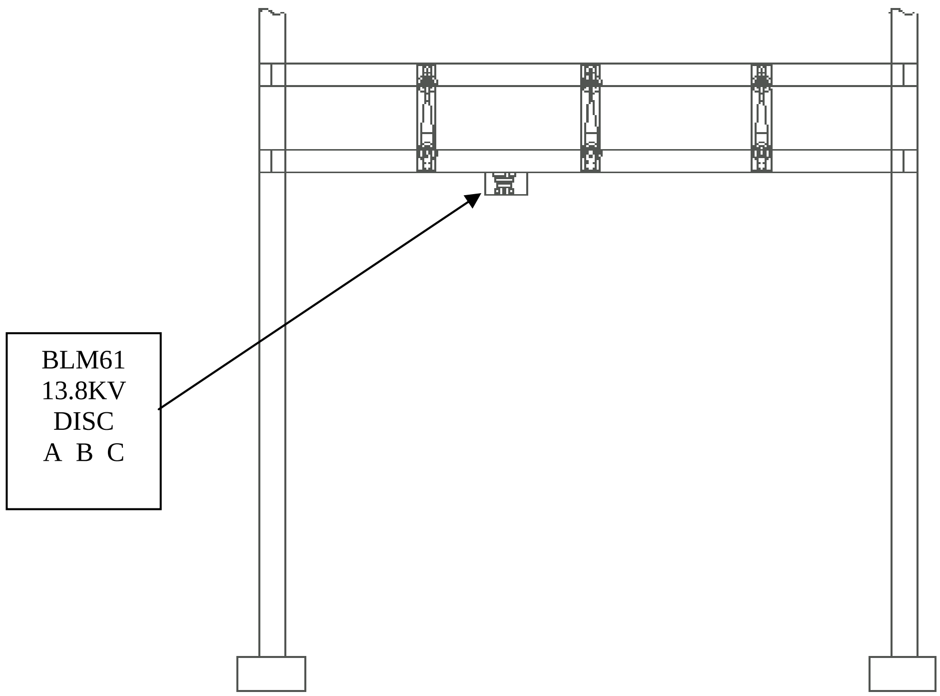
4.05. Disconnect Switch – Crank Operated



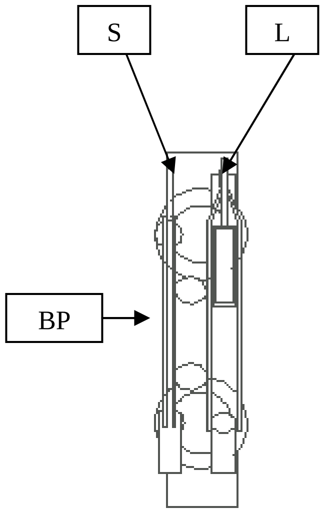
4.06. Multiple Manual Disconnect Switches



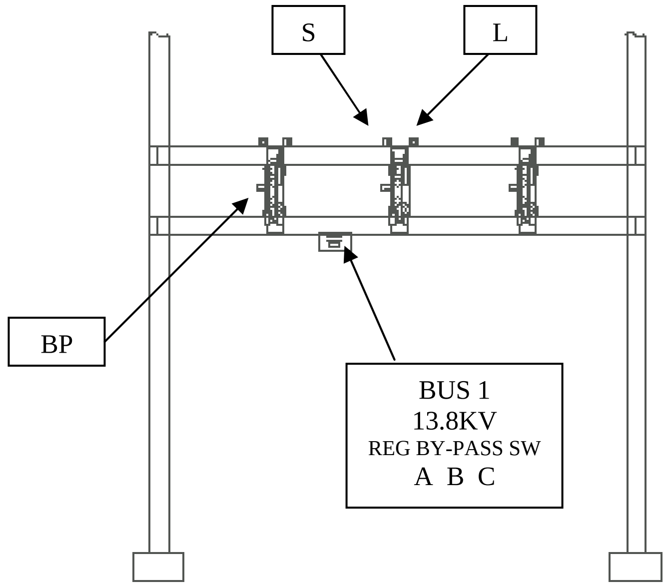
4.07. Hook-Stick Disconnect Switches

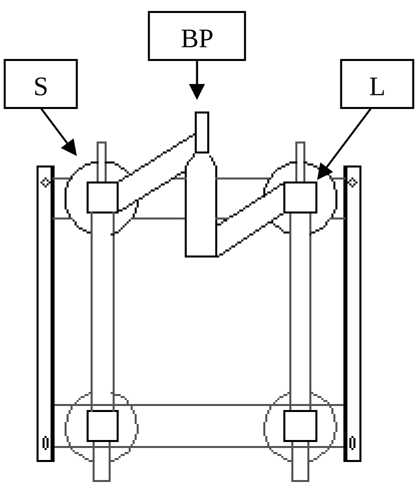


4.08. By-Pass Switches

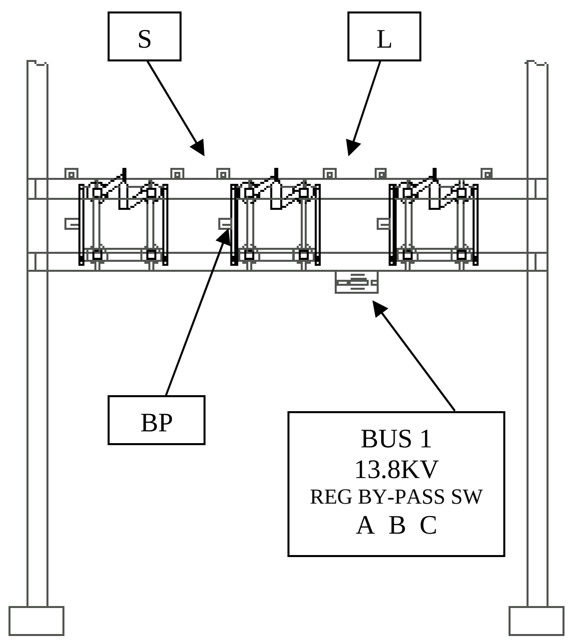


FOR 600AMPS AND BELOW

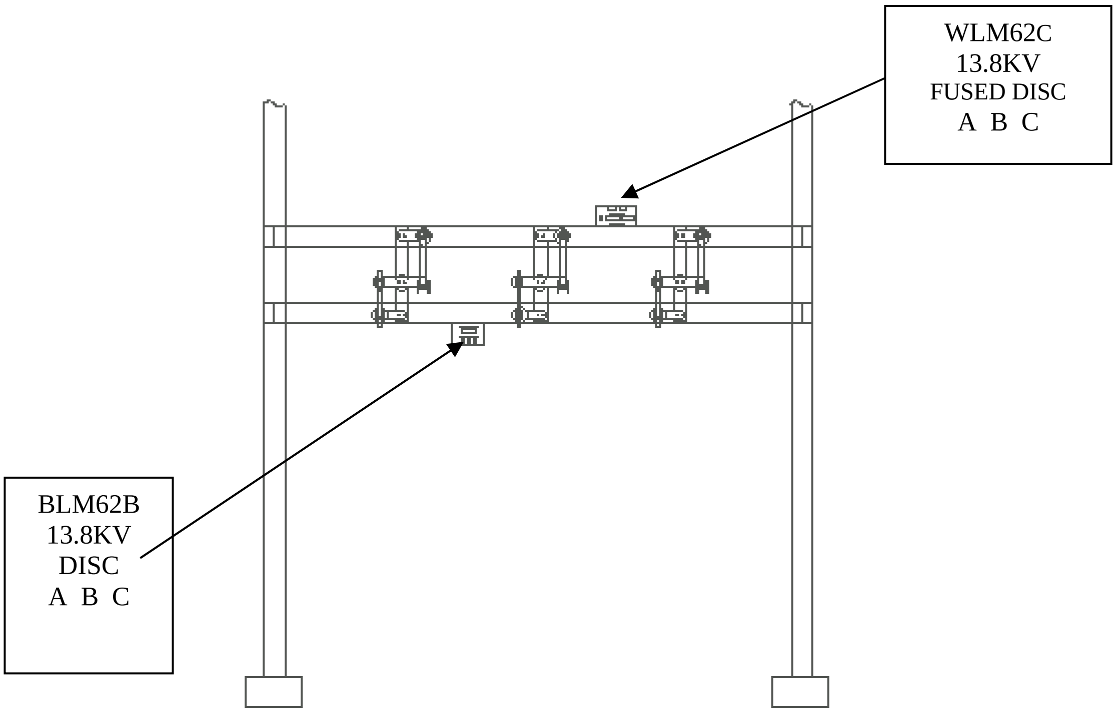




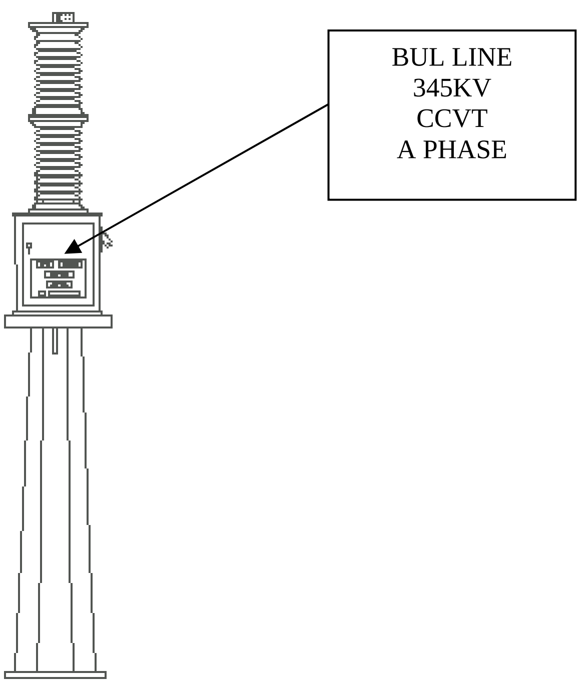
OVER 600 AMPS

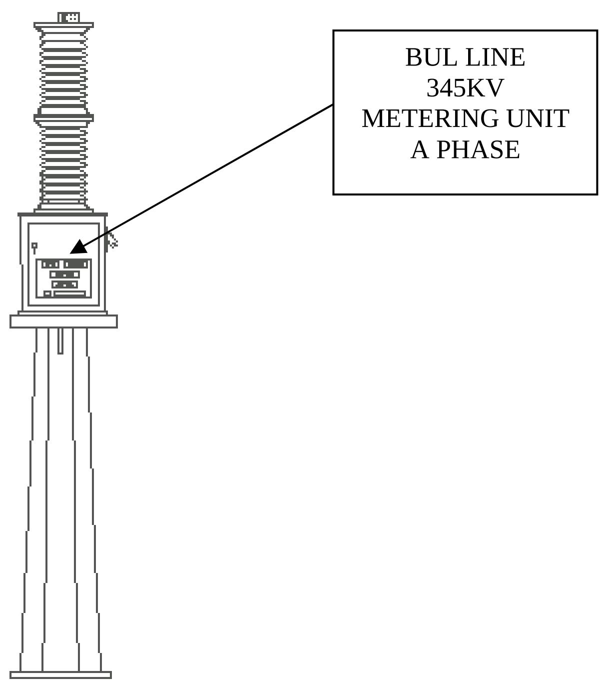


4.09. Switch Fuse Combination



4.10. Coupling Capacitor Voltage Transformer (CCVT), Potential Transformer (PT), and Metering Unit. Mount using 3M adhesive #847



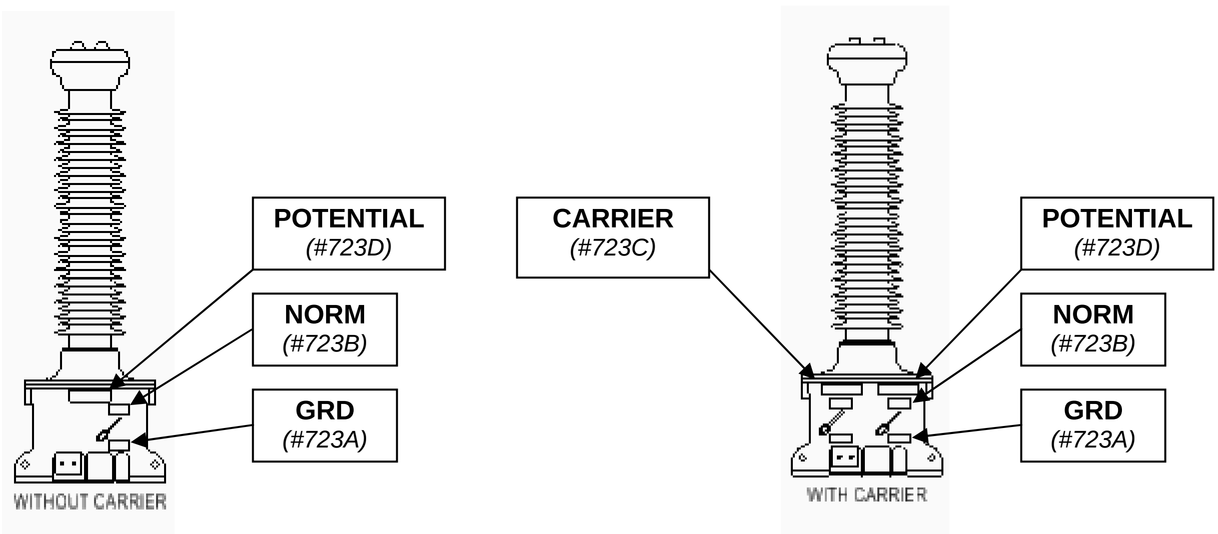


4.11. Coupling Capacitor Voltage Transformer (CCVT)

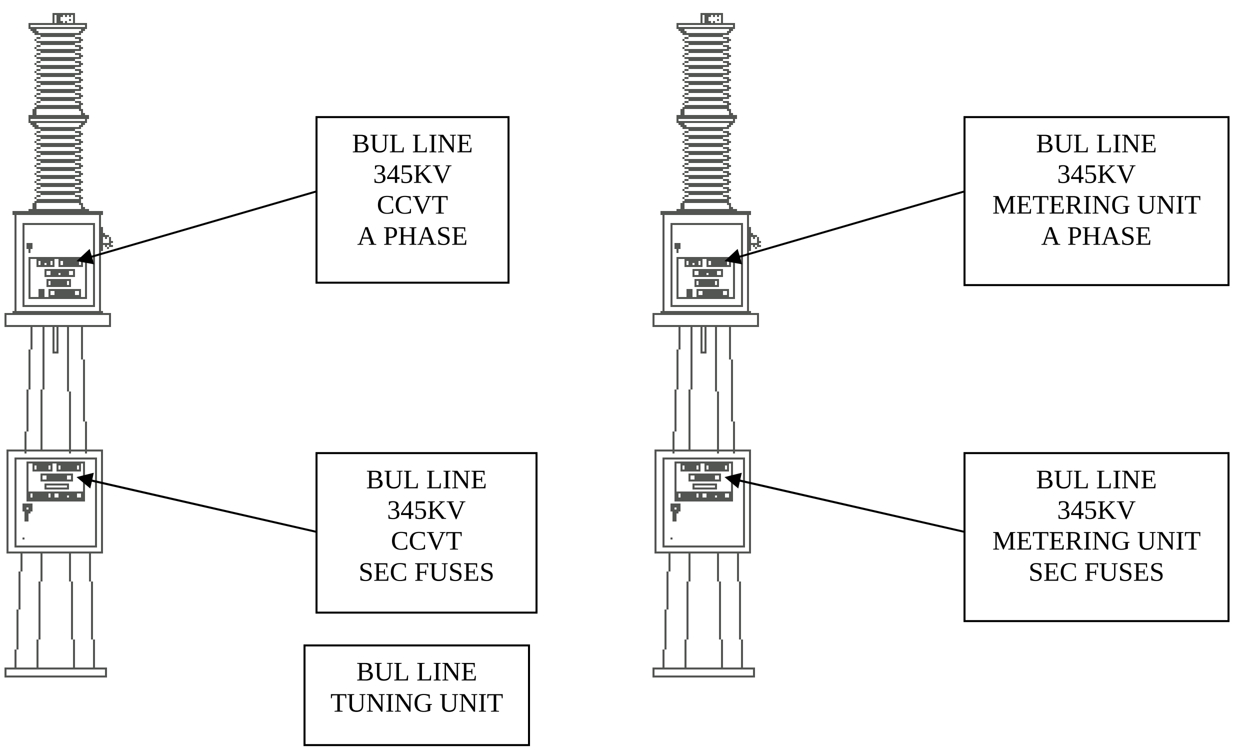
NOTE: CCVT's <u>without</u> carrier require only 1 nameplate each for POTENTIAL, NORM and GRD. No CARRIER nameplate is required. These are all assigned using assigned Cat. ID's, see Physical Material List items: 723A, 723B, 723C & 723D.

Potential Transformers with grounding switch require NORM and GRD nameplates.

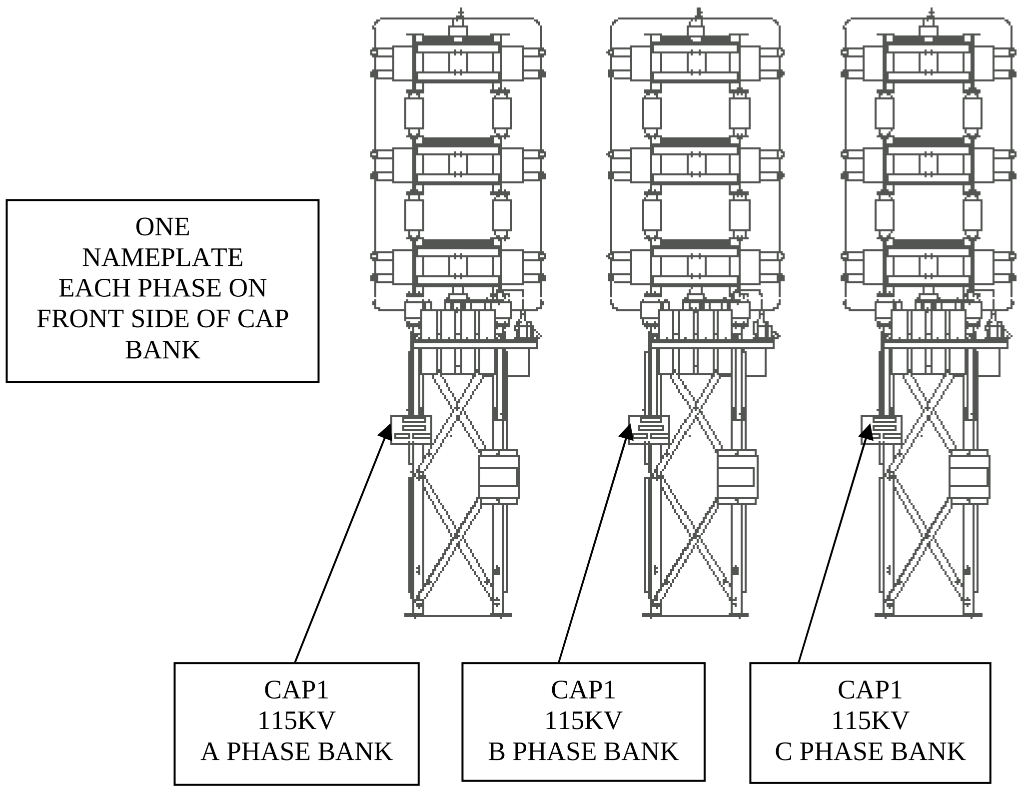
Mount using 3M adhesive #847



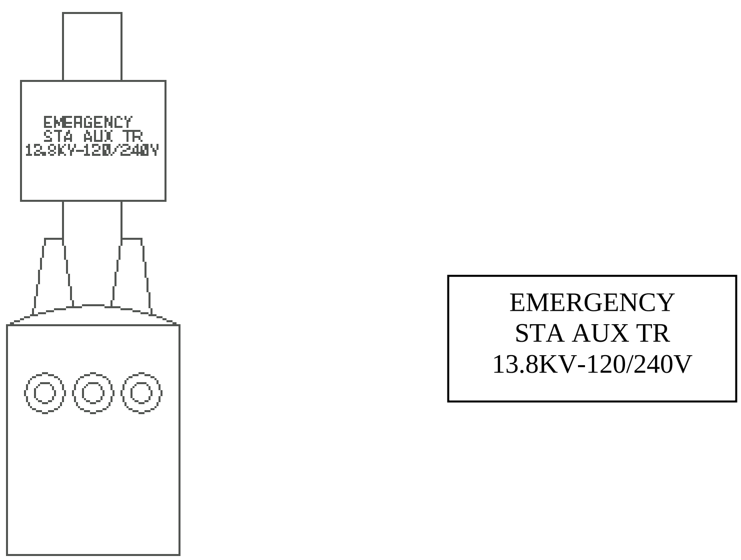
4.12. Secondary Fuse Cabinets. Mount using 3M adhesive #847



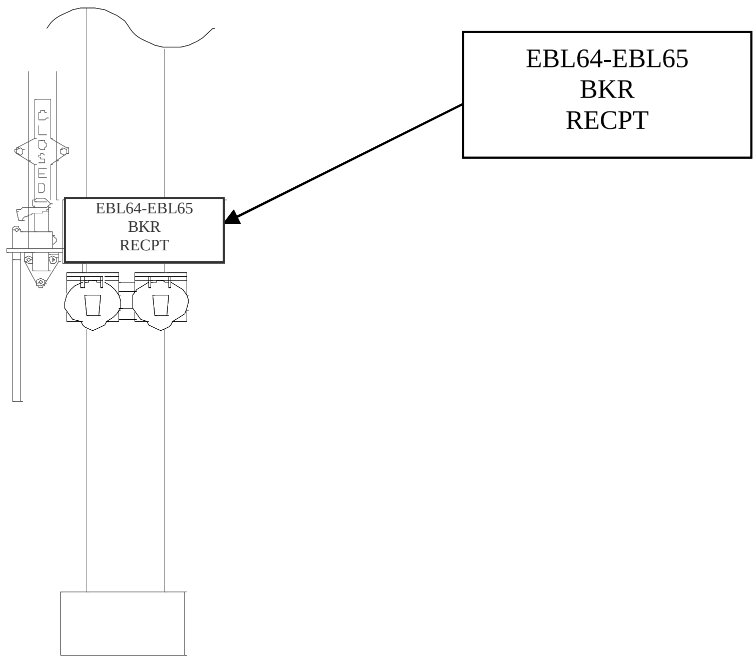
4.13. Capacitor Bank



4.14. Station Auxiliary Transformers

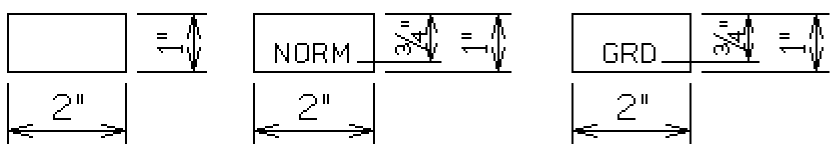


4.15. Receptacles (These receptacles are no longer installed)

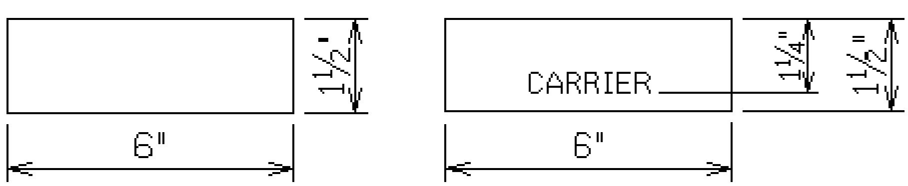


5. Nameplate Size and Use

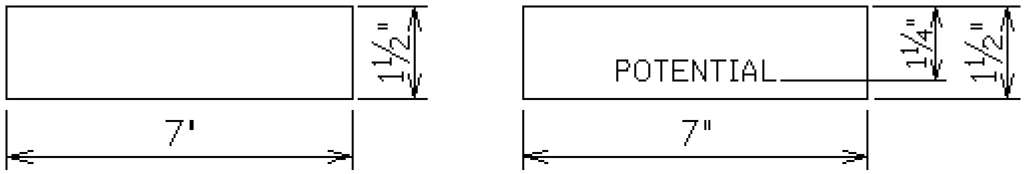
5.01. Size 1” x 2” – Used for regulator by-pass switch letters ”L”, “S” and “BP” or other signs with a maximum of four ½” tall characters.



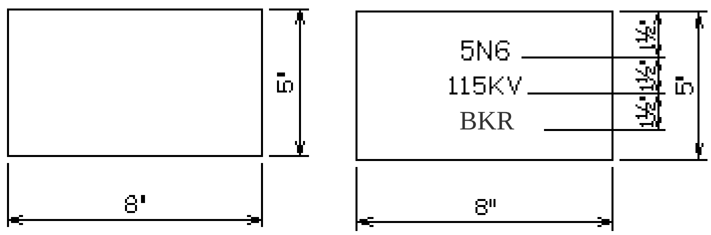
5.02. Size 1½” x 6” – Used for signs with from five to nine ½” tall characters.



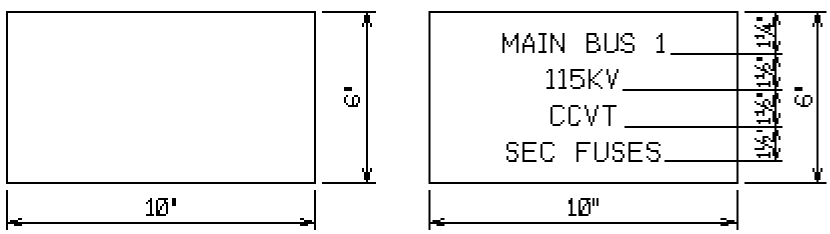
5.03. Size 1 ½" x 7" – Used for signs with from ten to thirteen ½" tall characters.



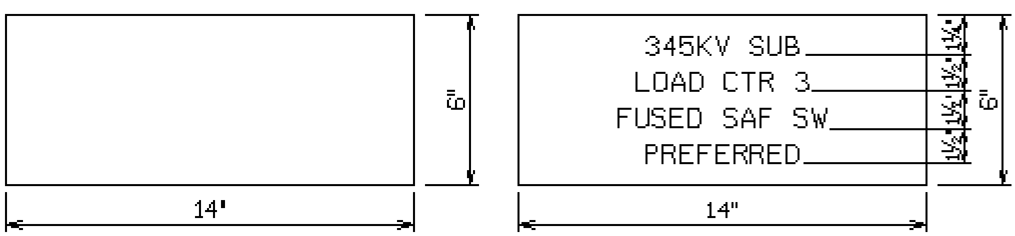
5.04. Size 5" x 8" – Used for three text lines; maximum of twelve 1" tall characters per line.

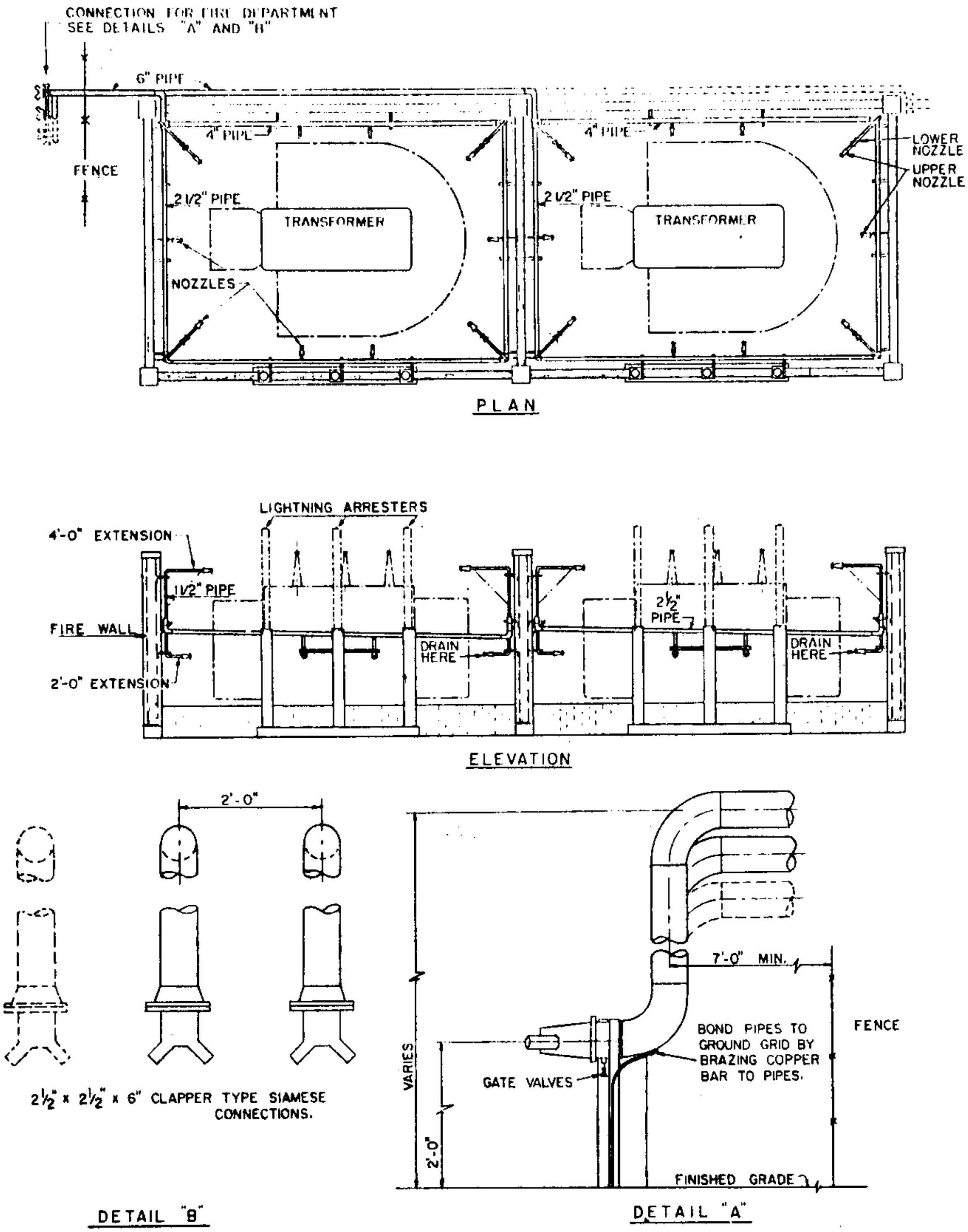


5.05. Size 6" x 10" – Used for TRANSFORMER and signs with four text lines; maximum of fifteen 1" tall characters per line.



5.06. Size 6" x 14" – Used for long identification signs with a maximum of twenty 1" tall characters per line.

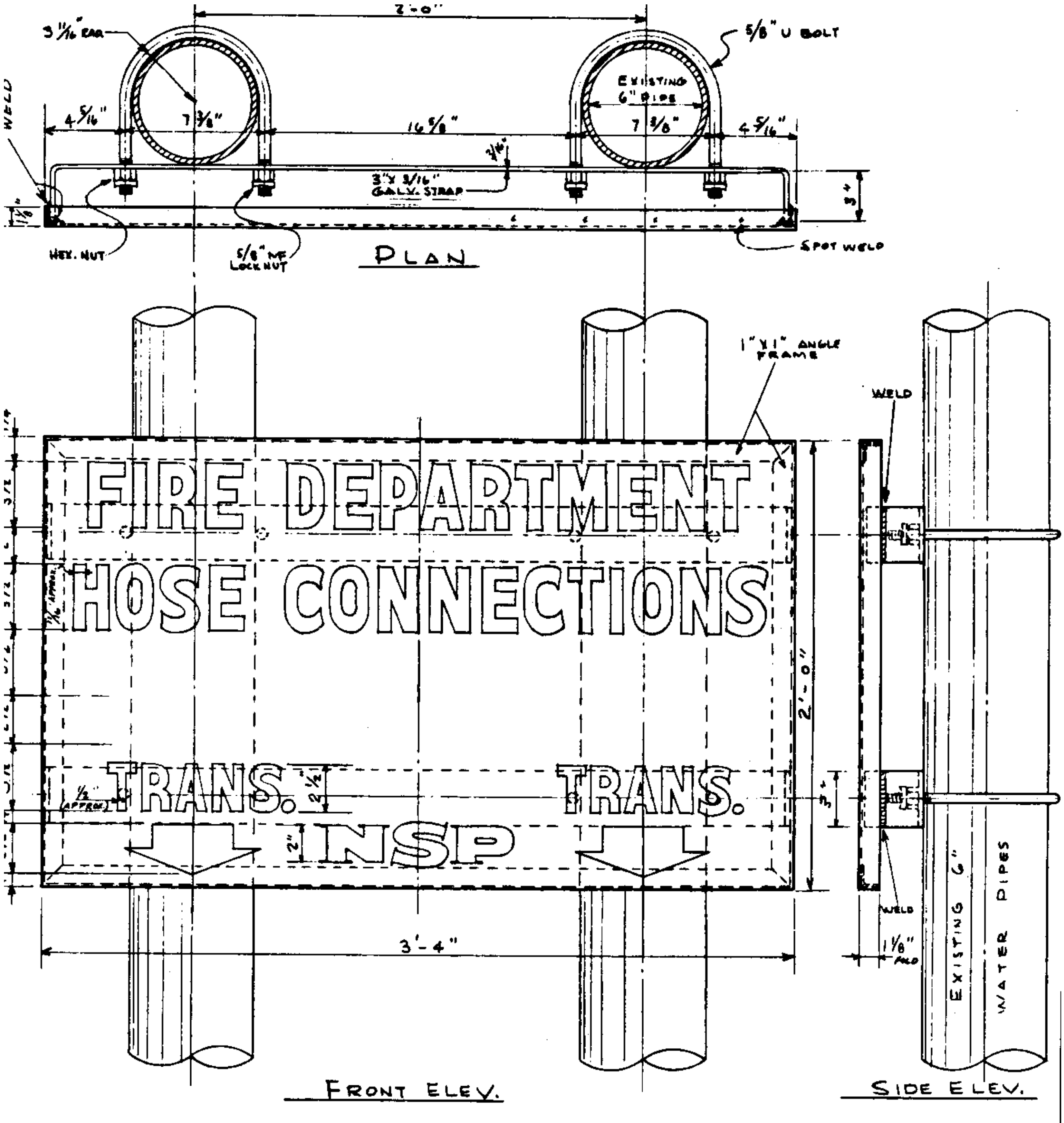




NOTES
1 1/2" MARINE TYPE FOG NOZZLES WITH I.P.T. THREADS

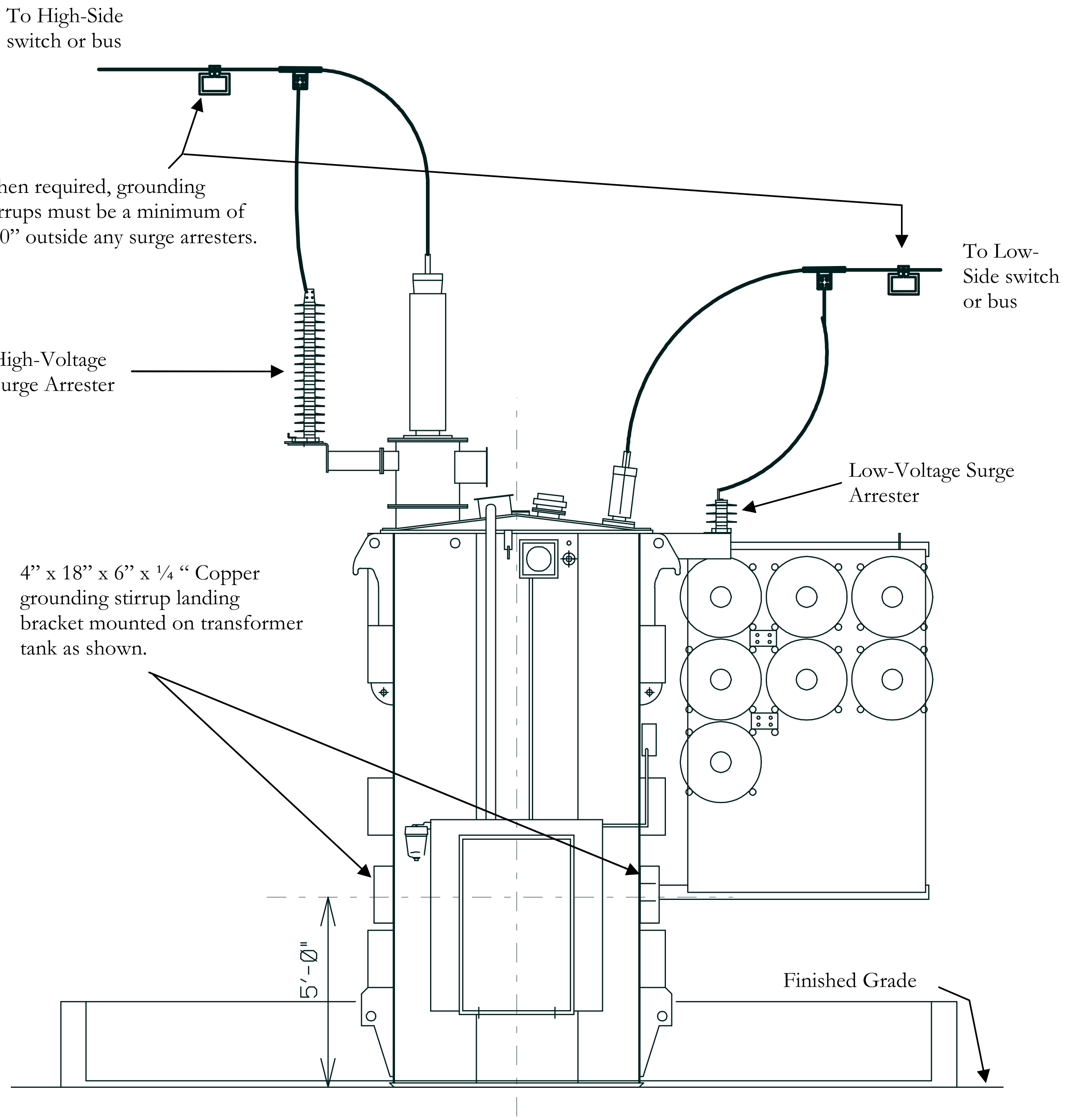
Typical Fire Protection System For Major Bulk Power Stations

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **12/7/56**		**0**	**SHEET 1**	**ED 4.09.04**



SIGN FOR FIRE PROTECTION SYSTEM FOR MAJOR BULK POWER STATIONS

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **8/20/2013**		**0**	**SHEET 2**	**ED 4.09.04**



1. Provisions must be made for attachment of personal grounds. Transformers shall have a 4" x 18" x 6" x ¼" copper, galvanized, or stainless steel bracket mounted 5'-0" from the bottom side of the tank to the centerline of the bracket.

2. Connections to transformer bushings should be installed to provide a ground attachment point which is parallel to grade. If transformer connections can't be made to provide an easy ground attachment point due to vertical bus or bundled conductor, an approved stirrup should be installed. The stirrup should be installed on the conductor 2'-0" or more outside the bushing/surge arresters to provide an easily accessible grounding point.

1.0 Purpose

The purpose of this standard is to provide direction for application of new personal protective grounding attachment point devices on the Xcel Energy system. This standard will also address the handling and limitations of the previously used ground stirrups and studs. Background information regarding some of the history of these devices is provided in a power point presentation complete with notes, located in **DSC\LIBRARY\REFERENC\Presentations\Grounding.ppt**. There is also a supporting paper written for the 2000 Minnesota Power Systems Conference located in **DSC\ Library\ Referenc\ Presentations\Papers\Substation Ground Testing.doc**.

2.0 Retired or Superseded Devices

The devices listed in Table 1 and shown in Figure 1 were tested and found to no longer be acceptable for new installation in Substations on the Xcel Energy system (see note "a" below Table 1 and Figure 1). These devices are still safe for use at fault currents of 24 kA or less. However, even though the devices have been tested and are safe at this limited fault level, projects in substations where these devices already exist, should request funding to remove and/or replace the devices with those listed in Section 3.0 of this standard.

In substations where the fault is below the 24 kA level, these devices shall be removed/replaced on any bus section or portion of the substation that will be outaged during a construction or maintenance project. In substations where the fault levels already exceed the 24 kA level and a project has been identified at that location, the project funding authority should be consulted to determine whether all ground attachment devices at the substation not presently approved are to be removed and/or replaced.

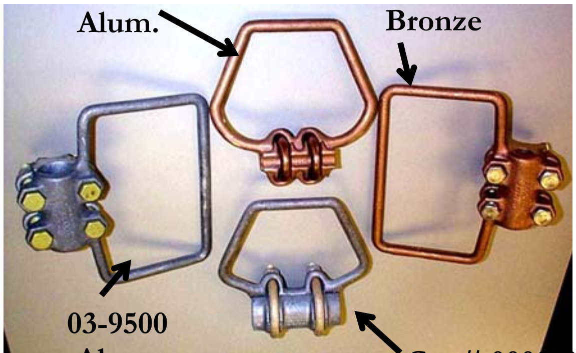
In no circumstance where the fault level exceeds 24 kA are the devices listed in Table 1 to be used for personal protective ground attachment points. Safety grounds will be attached directly to the bus conductor. If this is not possible due to bus configurations, additional outages will be required to obtain a point that can be safely grounded.

Table 1
Superseded Ground Attachment Devices (Studs and Stirrups)

Stock #	PassPort Catalog #	Description	Cat. #
03-9500		Aluminum rectangular ground stirrup (Anderson)	C14995
03-9530		Aluminum ground stirrup (Anderson)	ACT-13A
03-9510		Bronze rectangular ground stirrup (Anderson)	C14995-1
03-9540 [a]	0000106079	Bronze ground stirrup (Anderson)	BCT-6
03-9550		Aluminum stud, 2-hole (Anderson)	CC5806
11-2004 11-2006 S1-0002		Aluminum stud, welded (Anderson)	WTESR-10-24 WTESR-30-60

[a] Stock # 03-9540 **will be retained** for use in low fault (less than 24kA) areas where copper conductor is in use.

Under **no** circumstances at **any** fault level are devices **not** listed in Table 1 or Table 2 to be used for personal grounding attachment points. Any such devices shown on drawings or found in the field shall be removed on maintenance or construction projects done for that substation.



Cat # 0000106079
NSP Stock #03-9540
Bronze [a]

Stirrups

Two Hole Bolted Stud
NSP Stock # 03-9550

Welded Stud
NSP Stock # 11-2004, 11-2006, & S1-0002

[a] PassPort Cat # 0000106079 (Old NSP Stock # 03-9540) will be retained for use in low fault (less than 24kA) areas where copper conductor is in use.

Figure 1 - Superseded Ground Attachment Devices

3.0 Installation of Approved Attachment Devices

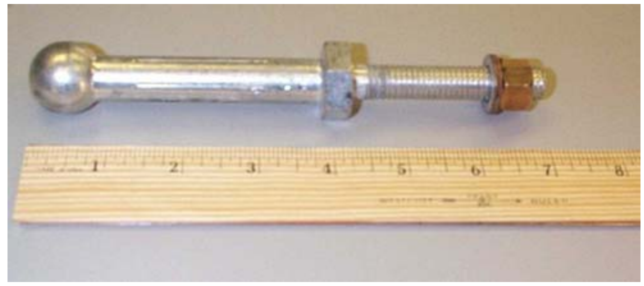
The devices listed in Table 2 and shown in Figure 2 have been approved by the Xcel Energy North Grounding Committee for use on the Xcel Energy System. These devices are safe and acceptable for use when the available fault current is less than or equal to 50kA. At locations where the fault level may exceed 50 kA, steps must be taken to reduce the available fault to a maximum of 50 kA before the work site may be safely grounded. In locations where the fault levels are known to be close to or exceeding the maximum 50 kA fault level, the project engineer shall perform fault studies to determine the fault levels at the substation and whether additional outages to lower the fault are required.

The grounding attachment devices will also be used as a connection point for devices that are connected to the bus with hot line clamps, i.e. mobile transformers. The **hot line clamp, NSP Stock # 03-6441** (Passport Cat. # 0000106010), has been chosen because it will fit over the larger stirrup and welded stud. Installation of any new equipment requiring a hot line clamp shall utilize this clamp along with the stirrup or stud for connection to the bus.

Table 2
Approved Ground Attachment Devices (Studs and Stirrups)

Old NSP Stock #	Passport Catalog #	Description	Approved Manf. Cat. #
03-9555	0000106081	Aluminum rectangular 1” ground stirrup (Anderson)	C16125
03-9595	0000106082	Aluminum stud, bolted (AB Chance)	T600-2364
03-9597	0000106083	Aluminum stud, welded (Electrical Builders)	EBIGS6-W

1" Aluminum Stirrup
PassPort Cat # 0000106081



Bolted Stud
PassPort Cat # 0000106082

Welded Stud
PassPort Cat # 0000106083

Figure 2 - Approved Ground Attachment Devices

4.0 Design Application Guidelines

The following sections provide guidelines for the consistent installation of ground attachment devices. The spacing of the devices is based on spacing used during tests of the devices and the adequacy of the devices cannot be assured if they are applied differently in the field.

4.1 Stirrups

Ground stirrups are to be applied only as necessary. Ground stirrups should be considered necessary when bus sections that need to be grounded are vertical and/or bundled conductor. When bus conductor is a single conductor with an adequate horizontal expanse for attachment of ground clamps, no grounding attachment devices are required. In those instances, grounding should be done directly to the conductor.

Horizontal bundled conductors - One stirrup shall be installed for every *two* ground cables required for the station fault level. If more than one stirrup per phase is required, they shall be installed on different conductors of the bundled set. The stirrup spacing shall be such that from the outside edge of one stirrup to the next is approximately **six (6) inches**. See Figure 3 for an example of a horizontal bundled conductor application.

Vertical conductors (bundled or single) - One stirrup shall be installed for *every* ground cable required for the station fault level. If more than one stirrup is required per phase, they shall be installed on different conductors of bundled sets as much as possible considering the number of stirrups and the number of conductors in a bundle. The stirrup spacing shall be such that from the outside edge of one stirrup to the next is approximately **six (6) inches**. The stirrups may be turned so that they are not in the same plane so that multiple ground cables do not interfere with each other (See Figure 4a). See Figure 4a and Figure 4b for examples of a vertical bundled and unbundled conductor applications.

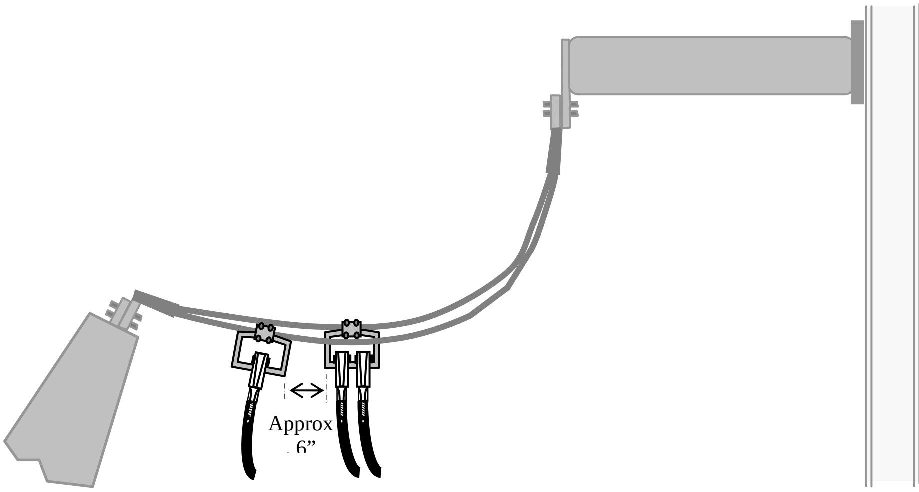


Figure 3 – Horizontal Bundled Conductor - Example

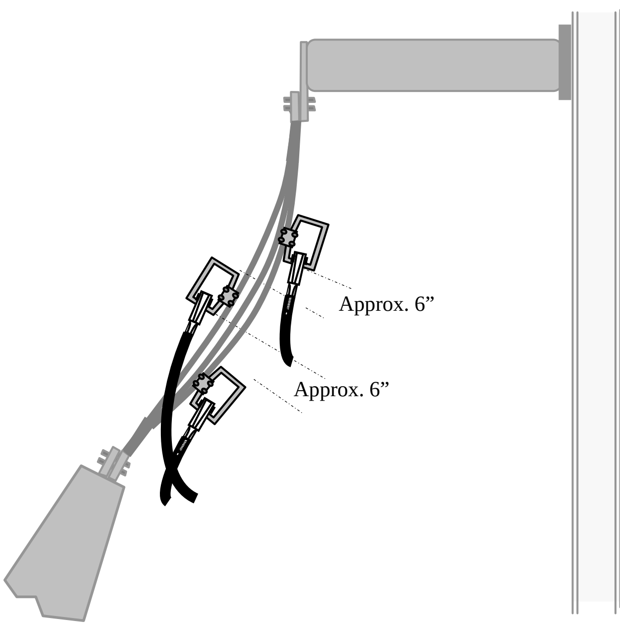


Figure 4a – Vertical Bundled Conductor – Example

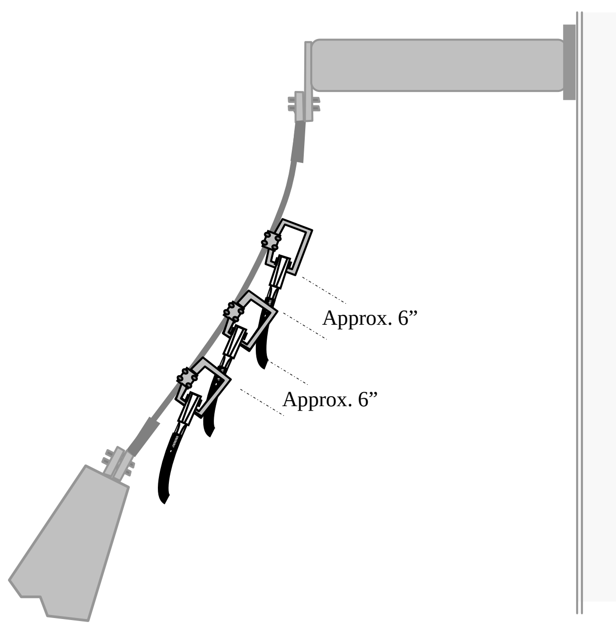


Figure 4b – Vertical Single Conductor - Example

4.2 Studs

Ground studs are to be applied only as necessary. Ground studs should be considered necessary when bus sections that need to be grounded are tubular bus larger than 2.5” in diameter or integral web channel bus (IWCB) which the standard ground clamps cannot fit around.

Welded Stud - One welded stud shall be installed for every *two* ground cables required for the station fault level. If more than one stud is required per phase, they shall be installed such that they are directly opposite from each other or spaced **one (1) foot** apart on the same side of the bus conductor. See Figure 5 for examples.

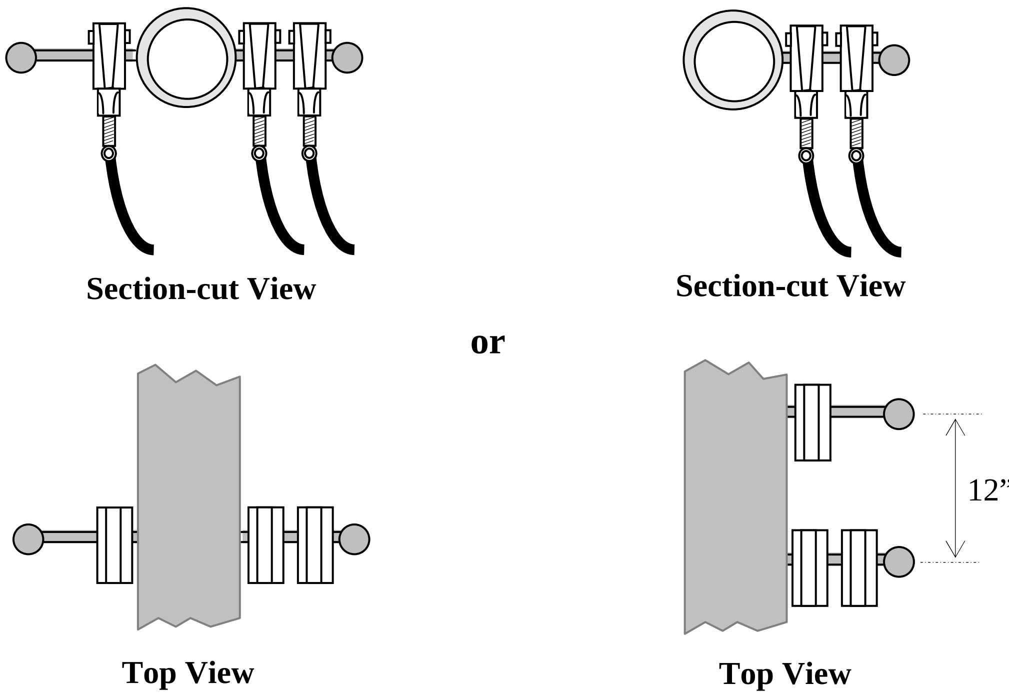


Figure 5 – Welded Stud - Example

Bolted Stud - One bolted stud shall be installed for *every* ground cable required for the station fault level. If more than one stud is required per phase, they shall be installed such that they are opposite from each other (spaced slightly apart to avoid installation problems with bolts) or spaced **one (1) foot** apart on the same side of the bus conductor. See Figure 6 for examples.

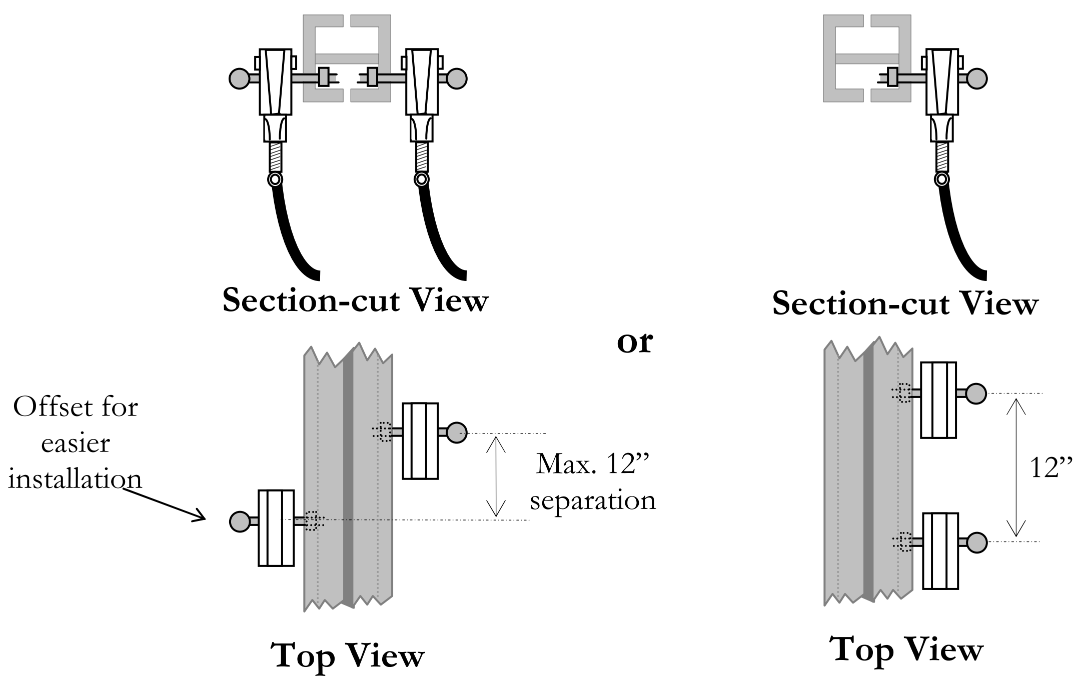


Figure 6 – Bolted Stud - Example

5.0 Retrofit Guidelines

Devices listed in Table 1 and shown in Figure 1 should be replaced or removed whenever possible on projects. The installation guidelines in Section 3.0 should be followed when retrofitting a substation. There are three situations that will be present in existing substations:

1. **Substations with fault levels exceeding 24 kA.**
   At these locations, replacement/removal of all unacceptable devices should be done when practical on the next capital project at that location. Superseded stirrups or studs used for attachment of hot-line clamp connections for PTs, arresters, etc. should be left in place **only** if they are not in a position where they could be used as a personal grounding point or when it is not practical to remove them. When it is not practical to replace or remove unacceptable devices, the Project Engineer should verify that suitable ground clamps, when necessary, for large tubular or integral web channel bus are available at the site.

2. **Substations with fault levels at or slightly less than 24 kA.**
   At these locations, replacement/removal of unacceptable devices shall be done in areas directly affected by, or within equipment outage areas, on the next capital project at that site. Superseded stirrups or studs, in these areas, used for attachment of hot-line clamp connections for PTs, arresters, etc. may be left in place **only** if they are not in a position where they could be used as a personal grounding point.

3. **Substations with significantly less than 24 kA (12 kA or less).**
   At these locations, devices that are safe up to 24 kA may be replaced or left in place at the discretion of the Project Engineer. At a minimum, devices in locations where grounding could be easily connected directly to bus conductor should be removed when the opportunity arises.

6.0 Ground Clamps

When grounding to devices listed in **either** Table 1 or Table 2, it is also important to use an appropriately sized ground clamp. For these devices, the clamp should be designed for no larger than 2 inch IPS conductor. If only larger clamps are available in the substation, a set of appropriately sized ground sets should be ordered.

Substation Safety Sign

12" x 14" sign

1. General

1.1. Signs should be placed on all substation enclosure types unless this conflicts with local laws and ordinances.

1.2. The signs should be placed 2 to 3 times the readability distance of the message text (Table 1, ANSI Z535.2-1998 section B3.3.14 "Minimum Letter Height Calculations"). In this case, 30 to 45 feet apart and no more than 15 feet from the corners of the enclosure.

1.3. Two signs should be placed on each drive gate, one on the inside and one on the outside (back to back). This is done so you can read the inside sign if the gate is open.

1.4. One sign should be placed on the outside of each walk gate.

1.5. The signs should be placed approximately 5'-0" form grade to top of sign.

1.6. Mount using a copper or aluminum wire tie in each hole.

1.7. The Xcel Energy stock number is 16-0092, manufactured by Electromark # XCE999-W-FG-Z32. The material is embedded fiberglass.

2. Sign specifications:

2.1. Wherever possible use ANSI Z535.1, 2, 3 (1998) for safety signs placed on the outside of facility enclosures. Specific laws and ordinances pertaining to facility safety signs supersede the ANSI standards in those locations specified only.

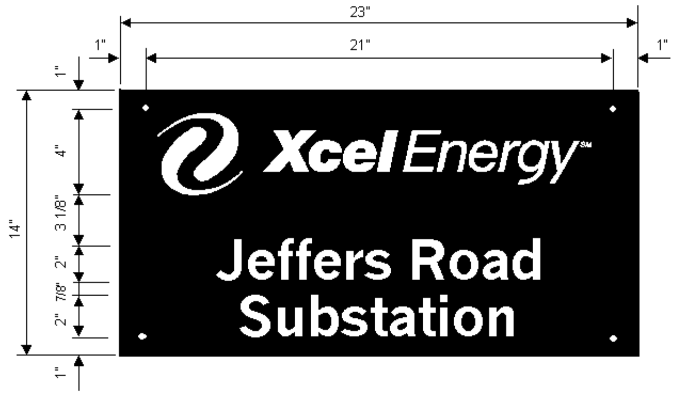
2.2. The word “WARNING” should be placed at the top most portion of the sign. Black text with safety orange background as specified in Table 1 of ANSI Z535.1-1998. The word should be all caps and a height of 1.2 inches. There should be a “safety alert symbol” included to the left of the word “WARNING” (arrangement ANSI Z535.2 section B2). It should be a safety orange exclamation mark inside a black equilateral triangle within the safety orange background which includes the word “WARNING”.

2.3. The symbol portion should be designed with the proportions shown in Figure 2 of ANSI Z535.3-1998 following section A9. The example symbol in section 8.1 of ANSI Z535.3 of the falling body with electrical wire near arm is the preferred symbol. No height is specified in the standard, so a reasonable height that does not completely dominate the sign should be used. The symbol should be black with white background.

2.4. The message text portion should consist of the words “Keep Out!,” “Hazardous voltage inside,.” “Will shock, burn or cause death.”. Each phrase should have its own line for easier readability. The first phrase (“Keep Out!”) should be a text height of 0.8 inches. The rest of the message text should be 0.6 inches. Text should be black with a white background. It should be of a sans serif font with 120% leading between lines of text (ANSI Z535.2-1998 section B3.3.11 “Choice of type spacing”). The text should all be left justified. The text should be mixed capitals and lower case letters as typed above.

2.5. Section 4.7 “Panel” of ANSI Z535.2 dictates that there should be a “clearly delineated” line between sections of the panel that do not have “distinctive background color”. There should be a line bordering the symbol.

Substation Identification Sign



14" x 23" sign

1. General

1.1. The sign should be placed on all substations unless this conflicts with local laws and ordinances.

1.2. The signs should be 6'-0" from grade to top of sign, placed adjacent to substation walk or drive gate and above the address sign.

1.3. Mount using a copper or aluminum wire tie in each hole.

1.4. To order the sign use file located at \\BLACK\TEAM\DSC\FORMS\GEN\NAMEPLATE & SIGNS.XLS.

2. Sign specifications:

2.1. Size: 14" x 23"

2.2. Material: 0.080 aluminum plate with 3M High Intensity Silver Scotchlite code #3870. Background to be silk-screened with 3M #845 black paint.

2.3. Text shall be 2" Helvetica Medium Upper and Lower Case. (example: Jeffers Road Substation)

2.4. Xcel Energy logo must be per company guidelines as approved by Betsy Brown, Brand/Advertising Director, on 2-14-2001.

Substation Address Sign

1. General

1.1. The sign should be placed on all substations unless this conflicts with local laws and ordinances.

1.2. The signs should be placed adjacent to substation walk or drive gate and under the Substation Identification Sign.

1.3. Mount using a copper or aluminum wire tie in each hole.

2. Sign specifications:

2.1. Size: 36" x 7" (vendor can make sign longer for longer addresses).

2.2. Material: 0.080 aluminum plate with 3M High Intensity Silver Scotchlite code #3870. Background to be silk-screened with 3M #845 black paint.

2.3. Text shall be 3 ½" Helvetica Medium Upper and Lower Case.

Battery Warning Sign

10" x 14"

General

1. Signs should be placed on the outside of all substation control house doors.

2. Sign is to be mounted to the door using sheet metal screws.

3. The signs should be placed approximately 5'-0" from the bottom of door to the top of the sign and centered on the door.

4. These signs are now required per the National Electrical Safety Code, Section 14, Part 146B.

5. The Xcel Energy stock number is S7-5454, manufactured by Electromark # IPCO14-W-FQ-AM3. The material is rigid fiberglass.

Substation Buried Cable Sign

10" x 7" Sign

General

1. The sign should be placed at substations where cables are in the area and need to be marked to prevent accidental digging.

2. The signs should be mounted on each side of the substation fence fabric, back to back, at the location where cables pass under the fence.

3. Mount to fence using a copper or aluminum wire tie in each hole.

4. Outside of the substation fence this sign can be mounted to a steel channel post (stock number 16-0095)

5. The Xcel Energy stock number is 16-0088, manufactured by Electromark # XCE170-G-FG-A71. The material is embedded fiberglass.

Substation Danger Sign

10" x 12" Sign

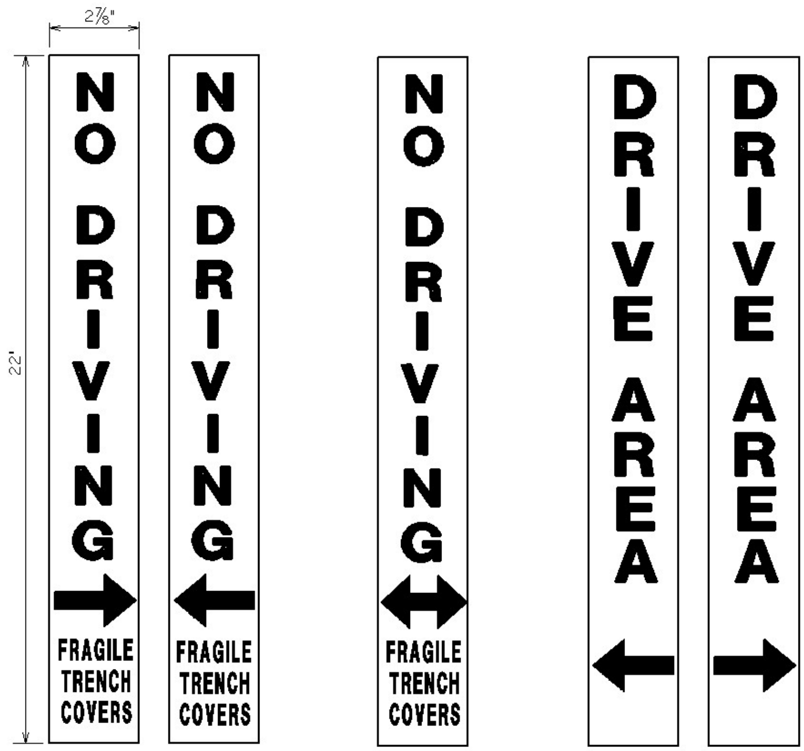
General

1. This sign is used to remind field people of a danger they may need to be aware of. (example: Low profile bus)

2. This sign is intended to be used **only** inside the substation fence.

3. The Xcel Energy stock number is 16-0056, manufactured by Electromark # XCE167-W-FG-BC2. The material is embedded fiberglass.

Substation Precast Cable Trench Signs



Sign #1 Decals Mounted Back-to-Back | **Sign #2 Decals Mounted Back-to-Back** | **Sign #3 Decals Mounted Back-to-Back**

1. **General**

   1.1. Vehicles cannot drive over precast cable trench without breaking covers. The warning signs shown above will be driven into the ground at strategic locations where vehicles could mistakenly drive over the precast cable trench.

   1.2. Drive post into ground using an installation tool made for this post.

   1.3. The Xcel Energy Catalog ID for the signs are:

   Sign #1 – 211428   Sign #2 - 211429   Sign #3 - 211430

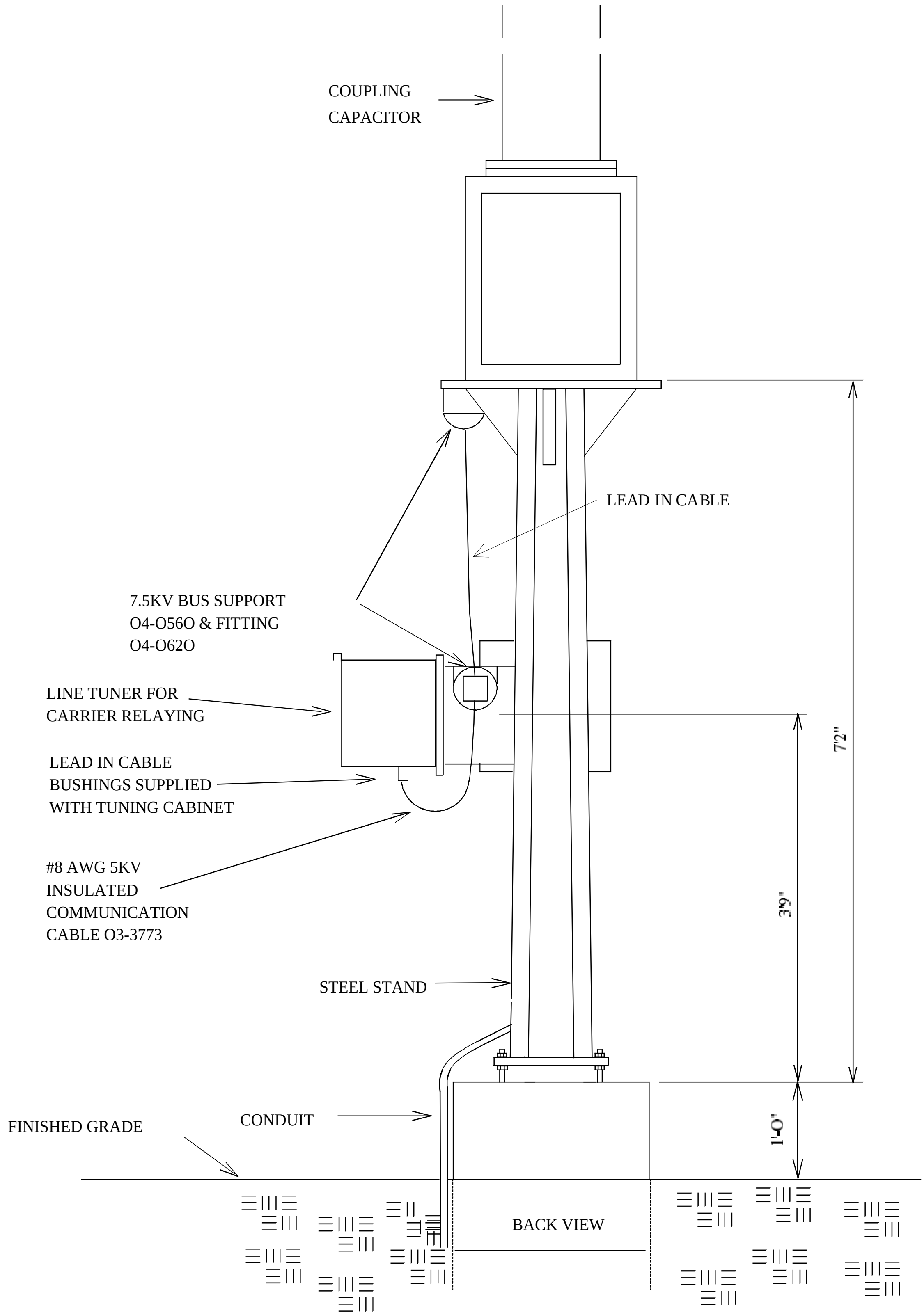
2. **Sign specifications:**

   2.1. Post: 3.8" x 78" yellow fiberglass reinforced composite.

   2.2. Decal: 2 7/8" x 22" with solid black letters and yellow background.

   2.3. The "NO DRIVING" and " DRIVE AREA" text is 1" or larger if space allows.

   2.4. The "FRAGILE TRENCH COVERS" text is 5/8" or larger if space allows.



COUPLING CAPACITOR INSTALLATION
WITH LEAD IN CABLE BUSHING ON BOTTOM OF TUNER

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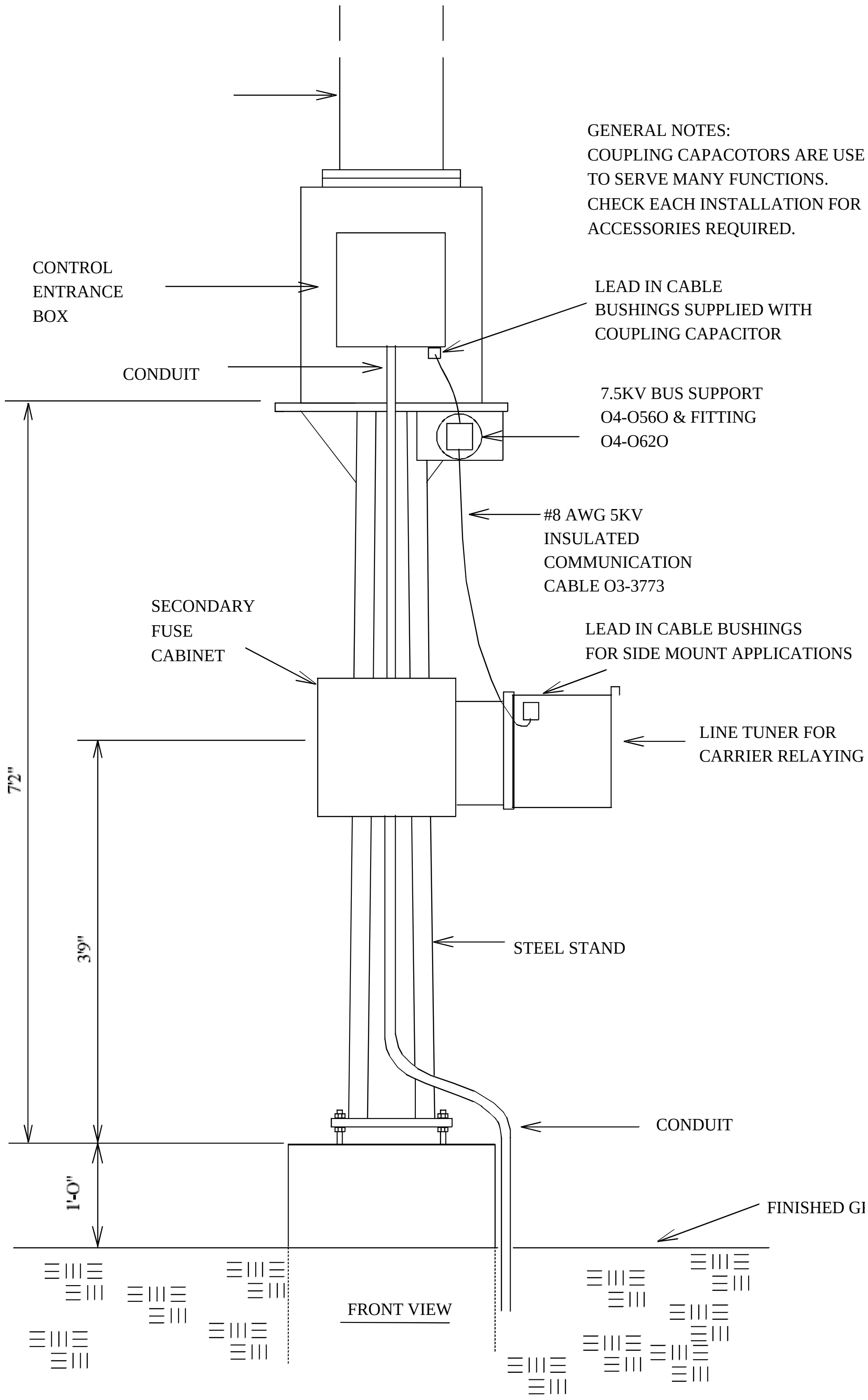
NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE 9/15/95		1	SHEET 1	ED 5.05.04.01



COUPLING CAPACITOR INSTALLATION

WITH LEAD IN CABLE BUSHING ON SIDE OF TUNER

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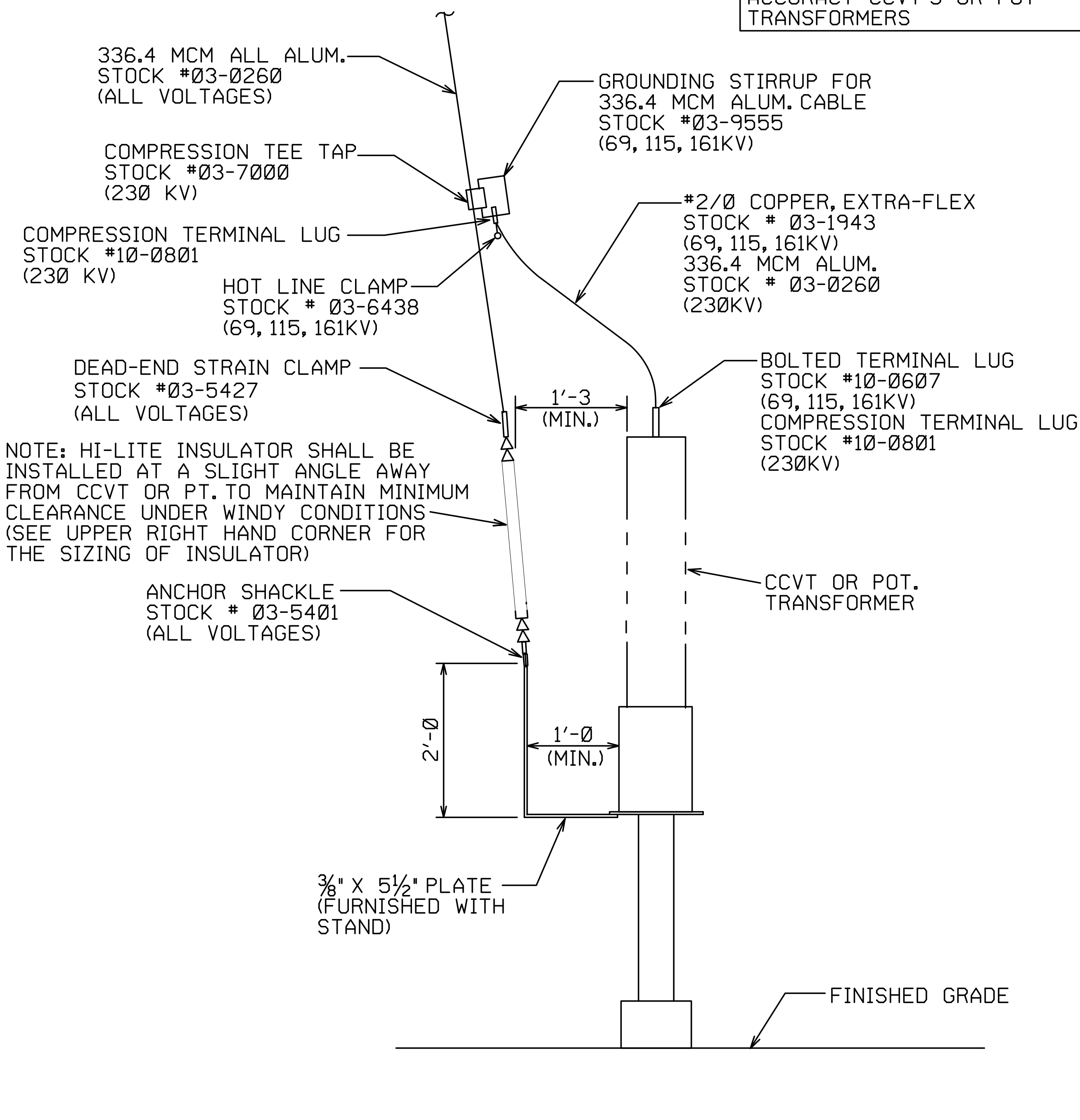
NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE 9/15/95		1	**SHEET 1**	**ED 5.05.04.02**

OHIO BRASS CO. HI-LITE INSULATOR	
69KV	CAT. #511005-1000
115KV	CAT. #511207-1000
161KV	CAT. #511011-1000
230KV	CAT. #511212-1000
CHECK WITH PROJECT ENGINEER FOR SPECIFIC LENGTH OF HI-LITE INSULATORS WHEN USING METERING ACCURACY CCVT'S OR POT TRANSFORMERS	



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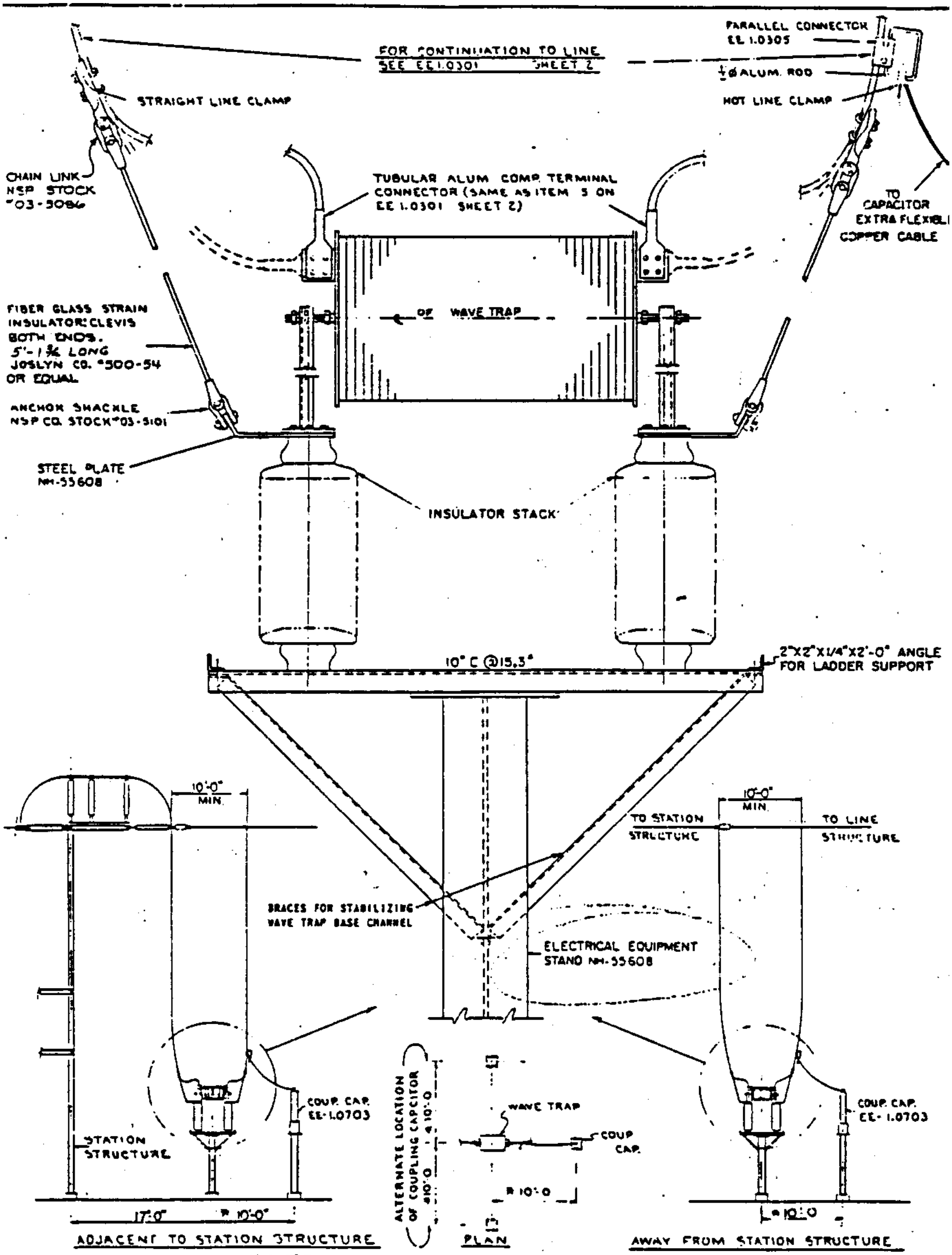
Single-Phase CCVT or Pot Transformer Connection to Overhead Line

	Date:	Approved:	Rev.	Substation Engineering & Design Standards	
Xcel Energy - North	09/18/2001		5	Sheet 1 of 1	ED 5.05.04



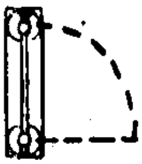
Wave Trap Installation - Pedestal Mounted

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **1/3/74**		**4**	SHEET 1	**ED 5.07.04**

Switches - Switch Type - Definitions

A. Hookstick - 7.2 - 69kV 600-.4000 Amp.

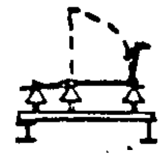
B. Side Break - 7.2 - 115kV 600-1200 Amp. - Normally not used at 115kV



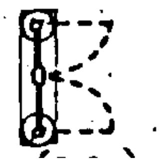
1. Horn Gap, Quick Break Quick Whip - Normally used for line dropping - to break line charging current

2. Load Break - Separate attachments-Normally used for parallel

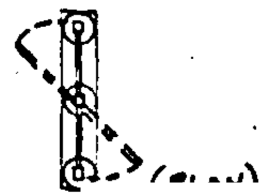
C. Vertical Break - 7.2 - 345kV 600-4000 Amp. Not used at 345kV by NSP
B 1 and B 2 above also apply



D. Center Break - 7.2 - 345kV. 600-2000 Amp.
B I and B 2 above also apply

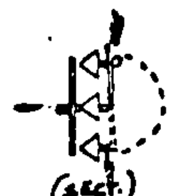


E. Double Bids Break - 7.2 - 345kV 600-200 Amp



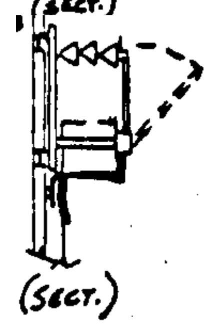
F. Circuit switches - used to interrupt higher magnitude" line charging currents.

G. Vacuum Switches - load currents or for capacitor switching 7.2 - 115kV

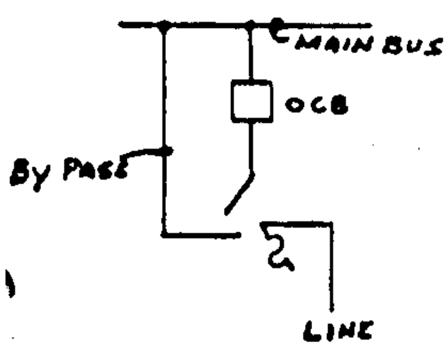


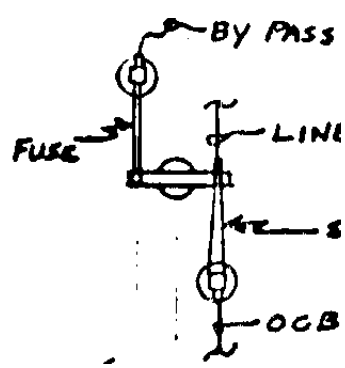
H. Indoor switches - Can be hookstick or group operating'- Switches are available SP ST, SP, DT, front or back connected or combination front or back on same switch to simply connections in cramped space.

I Ground Switches - Up to 115kV - High speed ground apply to line to open remote breakers quicker to remove fault - usually applied where system Z is high and fault current is low. Normal used for clearing of remote breakers which could allow fault to hang on longer.



J. Switch/Fuse Combination - Used on 4 thru 13.8kV installations and only when there to no transfer



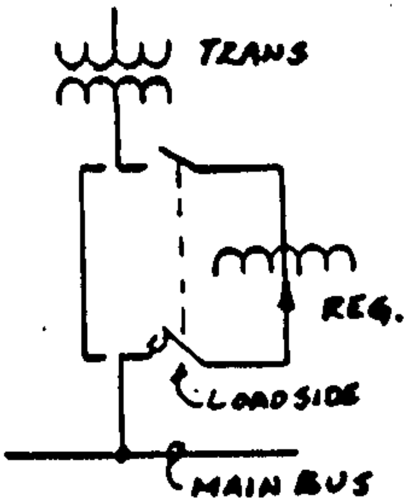


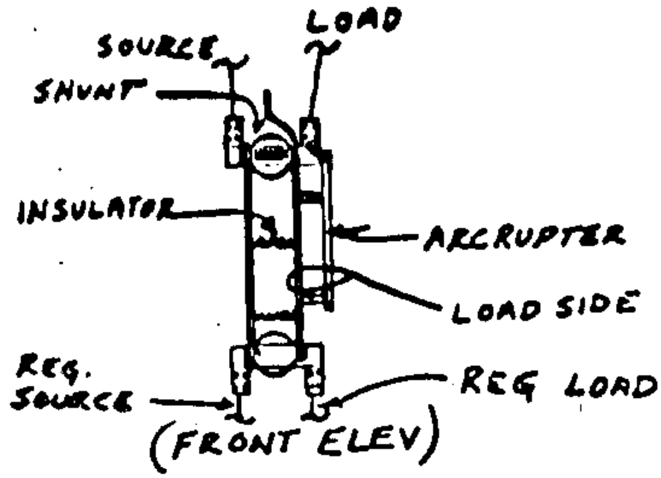
Front Elevation

SWITCHES - SWITCH TYPE - DEFINITIONS

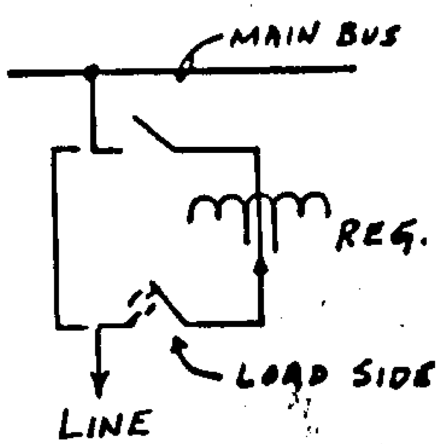
Regulator By pass Switch 4 - 7.2 - 23kV

Hookstick - Normally used with bus regulator





Feeder Position - When used in feeder position normally no breaker in feeder



L. Fuse

M. Motor Mechs Electric operated AC or DC - one MM Switch Hydraulic - one hydraulic system can operate up to 5 - 6 switches

Manual operated swing handle - thru 69KV or 2000 Amp. switch
Crank Gear box - all 115KV or
- a. Worm gear -lower voltage
- b. Reduction gear high amps

Switching Equipment Capabilities

The following switching device capabilities are intended only as a general guide and may be affected by system conditions and other factors, such as weather, conductor spacing, number of circuits, conductor size, etc. In addition, these switching devices should be operated remotely, whenever possible to provide additional protection for the operator. Exceeding the limitations of these switching devices could result in damage to the equipment and/or inadvertent tripping with possible service interruption.

I. Air Break (with horn gap)

1. De-energize a maximum of approximately 3 amps of line charging current on a single circuit line.
   a. 161 kV Approximately 5 miles
   b. 115 kV Approximately 8 miles
   c. 69 kV Approximately 20 miles
2. Energize and de-energize all -transformers except 500 kV.
3. Open and close most parallel circuits of 115 kV and below. The actual capabilities will depend on the length of the parallel circuits and the megawatt and megavar load.
4. Re-energize a maximum of 50 miles of 161 KV line and 50 miles of 115 KV line and 40 miles of 69 KV line.

II. Air Break Switch With Quick Break Device QB

1. De-energize a maximum of approximately 15 amps of line charging current on a single circuit line.
   a. 161 KV Approximately 20 miles
   b. 115 KV Approximately 50 miles
   c. 69 kV Approximately 100 miles
2. Energize and de-energize all transformers except 500 KV.
3. This device should not be used to open parallel circuits because the full load current will flow through the quick break attachment for several seconds. The quick break attachment has minimum current carrying capability.
4. Close most parallel circuits on 115 KV and below. The actual capability will depend on the length of the parallel circuit and the megawatt and megavar load.
5. Re-energize a maximum of 50 miles of 161 KV line and 50 miles of 115 KV line and 40 mils of 69 KV line.

III. Circuit Switcher

Note: This device will appear as an MOD on the CRT.

1. De-energize charging current for any length line of 345 KV and below.
2. De-energize any transformer.
3. Open and close any parallel circuit of 345 KV and below.

4. De-energize load up to steady state amperage rating of switch.
5. Energize and de-energize Capacitor banks and reactors.
6. Re -energize any line of 345 KV or below or any transformer except 500 KV..

Examples: Panther #7Nl6
S & C
MFG
Type - Mark IV

IV. Transrupter

This device is similar to a circuit switcher except the associated disconnect switch is external to the interrupting device and may or' may not be motor operated. This device will appear as a breaker on the CRT.

1. De-energize charging current for any length line of 345 KV and below.
2. De-energize any transformer.
3. Open and close any parallel circuit of 345 KV and below.
4. De-energize load up to steady state amperage rating of switch.
5. Energize and de-energize Capacitor banks and reactors.
6. Re-energize any line of 345 KV or below on any transformer, except 500 KV.

Examples: Westgate #3 and #4 TR
MFG Joslyn Mfg. Co.
Type VBU 4 Transrupter

V. Loop Break Switch

1. De-energize a maximum of approximately 3 amps of line charging current on a single circuit line.
   a. 161 KV Approximately 5 miles
   b. 115 KV Approximately 8 miles
   c. 69 kV Approximately 20 miles
2. De-energize all transformers except 500 KV.
3. Open or close any parallel circuit of 115 KV or below.
4. Re-energize a maximum of 50 miles of 161 KV line and 50 miles of 115 KV line and 40 miles of 69 KV line.

Examples: Avon #4N65 & #4N64 MFG - Joslyn Mfg. Co. Type - Vac-Rupter Interrupter

VI. Loop Break with Quick Break Attachment

1. De-energize a maximum of approximately 15 amps of line charging current on a single circuit line.
   a. 161 KV Approximately 20 miles
   b. 115 KV Approximately 50 miles
   c. 69 kV Approximately 100 miles
2. De-energize any transformer.
3. Open & close any parallel circuit of 115 KV or below.
4. Re-energize a maximum of 50 miles of 161 KV line and 50 miles of 115 KV line and 40 miles of 69 KV line..

   Example: Crossroads 5N44 & SN46
   MFG Joslyn Mfg. Co
   Type Load Sectionalized Interrupter

VII. Load Interrupter

1. De-energize charging current for any length line of 115 KV or below.
2. De-energize any transformer except 500 KV.
3. Open or close any parallel circuit of 115 KV or below.
4. De-energize load up to amperage rating of switch.
5. Re-energize a maximum of 50 miles of 161 KV line and 50 miles of 115kV line and 40 miles of 69 KV line..'

Manual Operation Mechs for Switches

Crank 115kV and above regardless of amps
Crank 69kV 2000 amps and above
Crank below 69kV 2000 amps and above

All others are switch handles.

There are exceptions to this but for doing sketches this guide should be close.

ALUMINUM CONDUCTOR STANDARDS - BUS AND CONNECTIONS

1.0 INTRODUCTION

The use of aluminum conductor has become standard practice in all NSP Company substations. When adding to existing installations having copper conductors, consideration should be given to the feasibility of converting to aluminum in the new portion. Aluminum conductors in the forms of cable, tubing, bar, angle, integral web channel bus (IWCB) and solid rod are carried in NSP Company stock for this purpose. All respective conductor sizes, shapes and specifications are tabulated in Engineering and Design Standards. The following information describes aluminum conductors most commonly used in NSP substations.

2.0 CONDUCTOR APPLICATION

Standard conductor sizes should be used wherever possible. The selection of aluminum conductor for a particular purpose depends upon the following electrical and physical (mechanical) requirements:

2.1 CABLE

All aluminum cable is used for substation strain bus and connections where flexibility is required or rigid bus is not feasible. ACSR conductor can also be used where practical to gain rigidity in some special cable connections. The following cables are commonly used in substations:

CABLE - ALL ALUMINUM E.C. ALLOY

Size	Strands	Dia.	Weight 1000 FT	Ampere Capacity				Stock No.
				30/40°C	40/40°C	50/40°C	60/40°C	
*3/0	19	.470	157.5	270	310	340	375	03-0280
336,400cm	19	.666	315.8	430	490	545	590	03-0260
556,500cm	19	.856	522.4	595	680	755	810	03-0236
954,000cm	37	1.124	895.5	845	965	1075	1160	03-0221
1,590,000cm	61	1.454	1493.0	1200	1320	1460	1590	03-0217

Used for substation grounding conductor above ground.

2.2 TUBING

Tubing is used primarily to obtain structural rigidity in long unsupported spans of bus, usually in high voltage structures, and over design in current carrying requirements is disregarded. Welding is used to form tubing joints and electrical connections.

The following tubing sizes are commonly used in substations:

SEAMLESS TUBING SCHEDULE 40 (20 and 40 ft Lengths) 6063-T6 ALLOY

IPS Size	Weight lbs/ft	Ampere Capacity			Stock No.
		30/40°C	40/40°C	50/40°C	
1”	.58	650	767	878	03-2901
1 1/2”	.94	925	1092	1249	03-2902
2”	1.26	1150	1357	1553	03-2903
2 1/2”	2.00	1550	1829	2093	03-2904
3”	2.62	1890	2230	2552	03-2905
3 1/2"	3.15	2170	2561	2930	03-2906
4”	3.73	2460	2903	3321	03-2907
5”	5.06	3080	3634	4158	03-2909

2.3 ANGLE

Universal angle provides the convenience of bolted connections. It is used in small installations where ultimate bus capacity will not exceed that of a single angle. The installation of double angle bus has been discontinued in favor of integral web channel bus (see 2.5) for higher capacities. Extensions to existing double angle bus shall be made with IWCB where practical.

The following angle bus conductor is used in substations:

UNIVERSAL ANGLE BUS CONDUCTOR (UABC) 2EC-T6 ALLOY

3 1/4" x 31/2" x 1/4" Angle Stock No. 03-2964 (25 ft. Lengths)	Weight Lbs/Ft	Ampere Capacity		
		30/40°C	40/40°C	50/40°C
Single Angle-ALCOA No. 88286	1.85	1800	2124	2430
Two Angles-Back to Back No Spacing	3.70	2400	2800	3200
Two Angles-Back to Back 1/4" Spacing	3.70	2900	3422	3915

2.4 BAR

Bar is used for making joints and electrical connections. The radius of bends shall be no less than two times the bar thickness.

The following sizes are commonly used in substations:

BAR - #2EC-T61 (Slightly rounded edges) 20 Ft. LENGTHS

Sizes	Weight lbs/ft.	Ampere Capacity (flat) 30/40°C	40/40°C	Stock No.
1/4” x 1”	0.29	300		03-2945
1/4” x 2”	0.58	530	640	03-2944
1/4” x 3”	0.80	735	890	03-2943
1/4” x 4”	1.17	900	1120	03-2942
1/4” x 5”	1.47	1120	1360	03-2941
1/4” x 6”	1.76	1270		03-2940
1/2” x 5”	2.94	1520		03-2948

2.5 INTEGRAL WEB CHANNEL BUS (IWCB)

Integral web channel bus is installed where high current carrying capacity is required and to provide rigidity in long unsupported spans. It is used extensively in both low voltage and high voltage buswork. The following sizes are used in substations:

Integral Web Channel Conductor 2EC-T61 Alloy	Weight Lbs/Ft	Ampere Capacity 30/40°C	40/40°C	50/40°C	Stock No.
4" x 4" ALCOA No. 88960	5.36	3400	4000	4600	03-2970
4" x 6" ALCOA No. 250011	8.27	4400	5200	5900	
6" x 6" ALCOA No. 86498	13.47	5800	6800	7800	

2.6 RODS

Solid rod is most commonly used to form low current carrying connections, such as those made with hot line clamps. They are most frequently used for surge arrester and coupling capacitor connections. The rod is 1/2" diameter solid aluminum 6061-T6 alloy, NSP Stock Number 03-2984. (12 foot lengths)

3.0 CONNECTIONS

3.1 GENERAL

All current carrying aluminum connections shall be thoroughly cleaned, coated and sealed with an oxide inhibiting agent. Aluminum oxide, which is a poor electrical conductor, forms rapidly on the surface of drawn or rolled aluminum. It must be removed and prevented from reforming after the connection is completed. This applies to all connections, whether bolted, clamp or compression type. Three approved inhibitors are NO-OX-ID A, PENETROX A and ALCOA NO. 2.

Caution - Aluminum expands 30% (1.33 times) more than copper. Every connection involving a combination of aluminum and copper must be planned to avoid gradual loosening caused by large temperature changes. Unequal expansion of aluminum, copper and steel can cause extremely high pressure during hot conditions which stretches one or more of the metals leaving a loose connection when cold conditions occur.

3.2 FLAT SURFACE BOLTED CONNECTIONS

Bolted electrical connections shall be made on flat contact surfaces, completely cleaned with an oxidation inhibitor. This must be done by thoroughly scratch-brushing the contact surfaces through the inhibitor, leaving enough of it on the surface to control reformation of oxides. After the connection is completed, additional compound shall be applied and forced into every irregularity and opening in order to completely seal the joint against moisture and corrosion.

3.21 **Aluminum to Aluminum** connections shall be fastened with aluminum bolts, 2024-T4 alloy with No. 205 alumalite finish and preferably NO-OX-ID coated. Nuts shall be of the same alloy and finish. Heavy series bolts and nuts (7/8" across flats) are preferred.

3.22 **Aluminum to Copper** connections shall be made only with flat contact surfaces. Dressing and sealing the connection with inhibitor is especially important where unlike metals are in contact. Care must be taken to place the aluminum above copper when in a horizontal plane so that corrosive copper salts do not flow onto the aluminum.

The type of bolt used is also important because extreme temperature changes can cause a loose joint due to the expansion differential between copper and aluminum. Aluminum or bronze bolts will be used as specified below:

(a) Use aluminum bolts if thickness of the aluminum conductor is the same or greater than the copper conductor.

(b) Use bronze bolts (Everdur) if the copper conductor is thicker than the aluminum.

3.3 CABLE CONNECTIONS

Cable terminations can be made with clamp, compression and welded type fittings; preferably welded or compression types. Welded fittings should be used only when there is enough other bus welding on the project to make it economical.

3.31 **Compression Type Terminal Lugs** shall be used for 336.4, 556.5, 954 and 1590 MCM all aluminum and ACSR conductors. There must be enough inhibitor in the barrel of each terminal lug so that it squeezes out around the wire when inserted and compressed. The various lugs are stocked by NSP Co.

3.32 **Compression Type Tee Connectors** with a flat pad tap terminal shall be used for full current carrying tee connections on 336.4, 556,5, 954.0 and 1590 MCM all aluminum cable bus.

3.33 **Conductors for Non Current Carrying Connections**, such as for potential transformers, surge arresters, coupling capacitors, etc., may be joined with special wide range parallel groove clamps of approved design. This type of connection frequently involves a solid rod conductor looped through one side of the parallel clamp, to which a hot line clamp is attached. Seal the grooves as completely as possible with inhibitor.

3.34 **Equipment Terminals** should provide a flat pad for attaching terminal lugs or direct bolting of rigid bus. Where bronze clamp type or aerial lugs are furnished, do not place aluminum conductor in bronze terminals. Expansion differential and chemical reaction between the two metals can cause faulty connections. Install copper conductor to the first point at which a conversion to aluminum can be made on a flat surface or equipment terminal such as a switch.

3.35 **Clamp Type Terminal Lugs** should be avoided for use on aluminum cable whenever possible. Due to the open design of the clamps, it is difficult to completely seal the cable contact area.

3.4 WELDED CONNECTIONS

The inert gas shielded arc electric welder is preferred in making welded bus connections. This method shall be employed for aluminum tubing and integral web channel bus (IWCB), including welded type cable terminal lugs where practical. See ED 6.01.04 for tubing and cable welding details and for IWCB details.

4.0 MASTER DRAWINGS

The following Master Drawings of bus connection details described in these Standards are reproduced for project construction drawings:

NH-25532	Angle Bus Connections
NH-48651	Misc. Elect. Connections
NH-48652	IWCB Connections
NH-48850	Tubing Connections
NH-51505	Misc. 345 kV Connections

Bus & Connections -Safety Identification Markings Specifications And Application

INTRODUCTION

Aluminum bus conductor consisting of bar, angle, integral web channel and tubing are being used In Northern States Power Company Substations.

The similarity In appearance of aluminum shapes and galvanized structural steel has created a need for identifying aluminum bus; also energized structural members.

Aluminum tubing bus normally need not be marked unless It can be mistaken for nearby galvanized pipe or conduit.

METHOD OF IDENTIFICATION

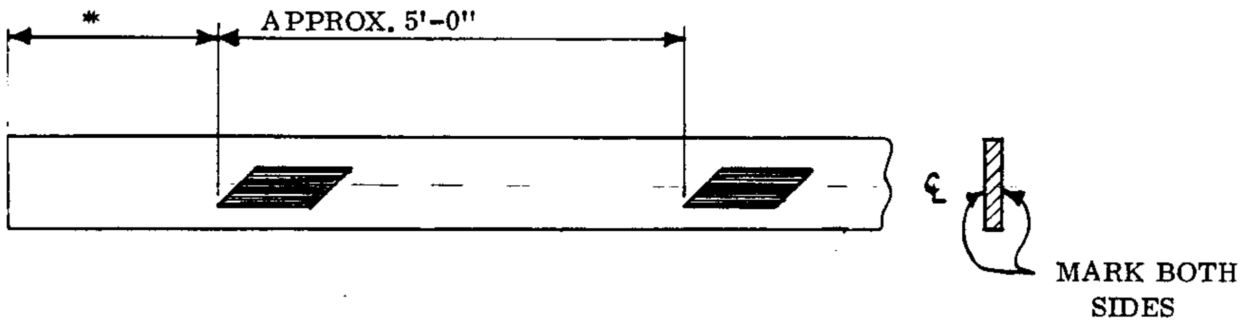
The use of a red colored reflecting tape with an adhesive back is the preferred method of Identification. A 45°parallelogram 2” wide by 4” long shall be placed' at approximately 60” Intervals along the most visible side(s) of the bus conductor or structural member. See sheet 2 for details of marking aluminum and sheet 3 for energized steel.

MATERIAL

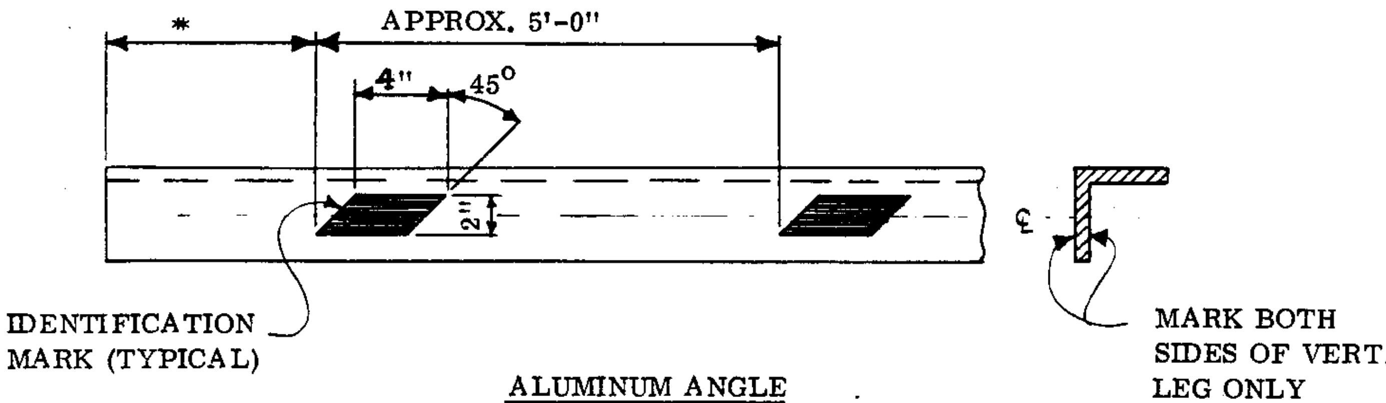
Minnesota Mining and Manufacturing Company adhesive tape, 2 inch x 50 yards of No. 3272 Scotchlite Reflective Sheeting. shall be used. (NSP Co. Stock No 14-3457)

APPLICATION

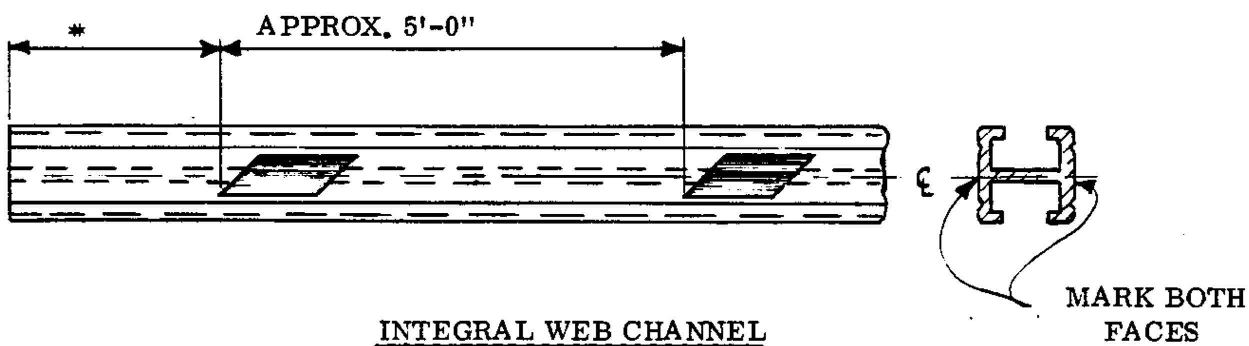
Clean the surface of the conductor with a rag and attach the adhesive backed tape directly to the metal. If the tape is applied at temperatures of 50°F or below, Scotchlite A-3 adhesive activator, for use on Scotchlite reflective sheeting type 3 adhesive coated 3270 series only, should be first applied sparingly to the adhesive on the back of the tape.



ALUMINUM BAR



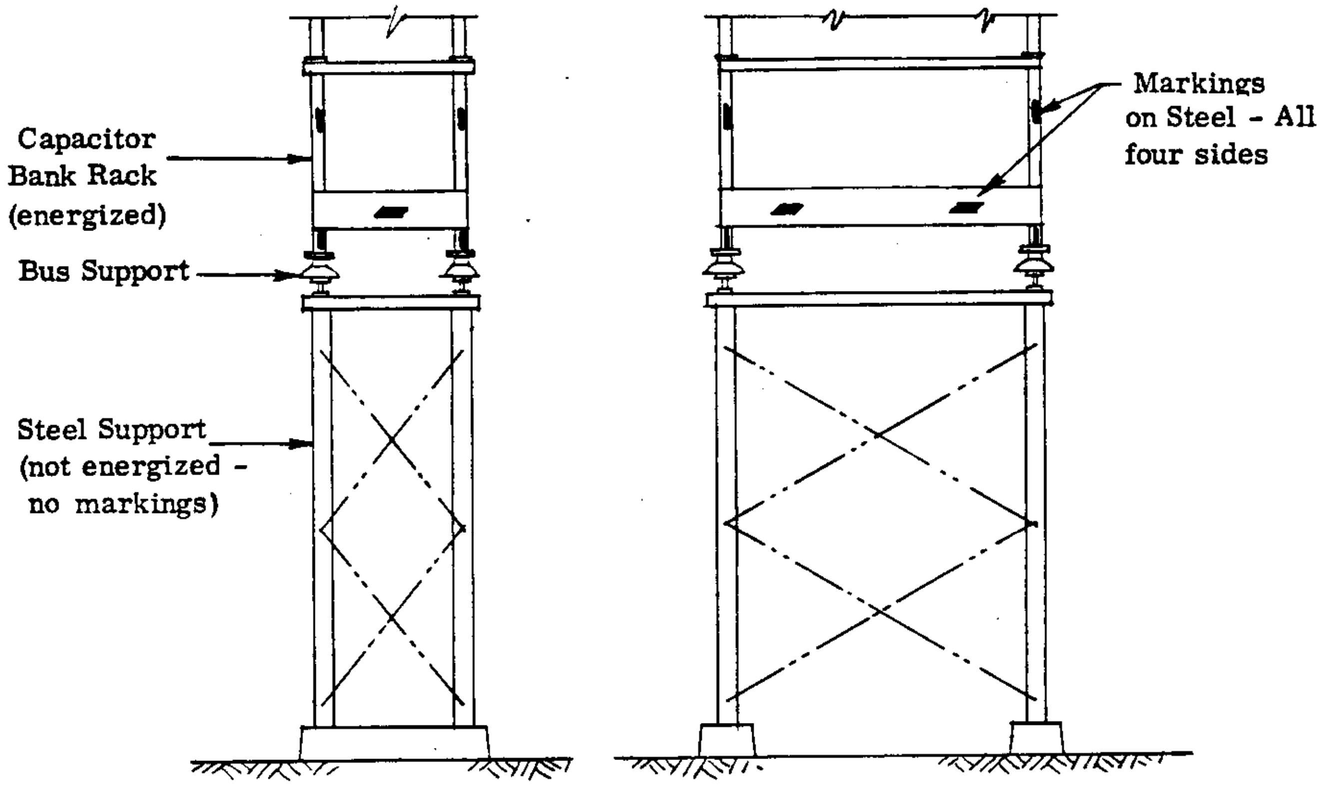
ALUMINUM ANGLE



INTEGRAL WEB CHANNEL

BUS & CONNECTIONS -SAFETY IDENTIFICATION MARKINGS

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **1/14/77**		**2**	SHEET 2	**ED 6.01.03**



CAPACITOR BANK

Energized structural members shall be marked similar to the aluminum busses shown on Sheet 2.

BUS CONNECTIONS STANDARD

1. Introduction

This document describes standard connection methods for bus conductors in Xcel Energy substations. All connections shall be made in accordance with this standard. If an existing connection is taken apart and put back together, it shall be treated as a new connection and shall be made in accordance with this standard.

It is recognized that there may be situations where this standard cannot or should not be followed. In these cases, substation engineering and/or the worker's supervisor should be consulted.

This document is intended for use in the portion of Xcel Energy formerly known as NSP. It has not yet been considered for company-wide application.

2. Detail Drawings of Bus Connections

For detail drawings of bus connections, refer to Master Drawings NH-25532 (Aluminum Angle Bus Connections), NH-48652 (Aluminum IWCB Bus Connections), NH-48850 (Aluminum Tubing Bus Connections), NH-48651 (Miscellaneous Electrical Connections). Current copies of these drawings may be obtained from substation engineering. Note that equipment vendors may provide their own connection details and these should be used as specified by the vendor.

3. Bus Materials

3.1. Aluminum

Aluminum is the standard bus conductor material used in Xcel Energy substations.

Aluminum oxide, which is a poor electrical conductor, forms rapidly on the surface of drawn or rolled aluminum. The aluminum oxide must be removed before a connection is made and prevented from reforming after the connection is completed. Therefore, all current carrying aluminum connections must be thoroughly cleaned, coated, and sealed with an oxide-inhibiting agent (see section 5.1). This applies to all aluminum connections, whether bolted, clamped, or compression type.

3.2. Copper

Although aluminum is the standard material for bus conductors, copper bus conductors are often found in existing substations. Additionally, copper bus is frequently used in enclosed switchgear.

Copper is the standard material used for grounding conductors in Xcel Energy substations. Cadweld connections are standard for both above and below grade grounding connections. Many existing ground connections in substations are bolted. If cadweld material is not available for a reworked connection, a bolted connection may be used. See section 6.1.2 for details.

Connections between aluminum and copper require that special care be taken. For changes in temperature, aluminum expands 36% more than copper does. Therefore, aluminum-to-copper connections must be carried out so as to avoid gradual loosening caused by temperature changes. The unequal expansion of aluminum and copper can cause extremely high pressure during high temperatures, which deforms one or more of the metals, leaving a loose connection when low temperatures occur. Additionally, because of the electrochemical relationship between the two metals, aluminum is anodic to copper. Therefore, the aluminum will be susceptible to galvanic corrosion. The accumulation of films or corrosion products on the contact surfaces will increase the electrical resistance of the joint. See section 6.1.3 for details on making the connection.

3.3. Bronze

Bronze is not to be used as a bus material in Xcel Energy substations.

Where bronze clamp type or aerial lugs (as on cable potheads) are furnished, do not place aluminum conductor in bronze terminals. Expansion differential and chemical reaction between the two metals can cause faulty connections. Install copper conductor to the first point at which a conversion to aluminum can be made on a flat surface or equipment terminal such as a switch.

4. Bolting Hardware Materials

4.1. Aluminum

Aluminum bolting hardware is to be used for aluminum-to-aluminum connections.

Aluminum bolting hardware is also used in certain cases for aluminum-to-copper connections. See the bolted connections section below for further information on aluminum-to-copper connections.

Aluminum bolts and nuts must not be reused. The stresses of the previous bolted connection, age, and exposure can all change the mechanical properties of the hardware and prevent a good connection from being made. Therefore, new bolting hardware must be used for each bolted connection.

Aluminum bolts should be 2024-T4 alloy with No. 205 Alumalite finish, with a no-oxide coating. Nuts shall be of the same alloy and finish. Aluminum washers should be 3003 series alloy.

Standard aluminum hardware and stock numbers are shown in the following tables. Note that aluminum washers are not stock items.

Standard Aluminum Bolts
Hex Head – Anodized - No-Ox-Id Coated

Diameter	Length	Length of Thread	Stock No.
3/8	1	FULL THREAD	01-5978
3/8	1 ½	FULL THREAD	01-5980
½	1 ½	FULL THREAD	01-5990
½	1 ¾	1 ½	01-5991
½	2 ¼	1 ½	01-5992
½	3	1 ½	01-5995
½	4	1 ½	01-5996
½	4 ½	1 ½	01-5997
½	5	1 ½	01-5998

Standard Aluminum Nuts - Hexagon	
Diameter	**Stock No.**
3/8 – 16 Thread	01-8258
½ - 7/8 Across Flats	01-8260

4.2. Bronze

Bronze is commonly known by the trade names Duron and Everdur. It is also referred to as silicon bronze.

Bronze bolting hardware is to be used for copper-to-copper connections.

Bronze bolting hardware is also used in certain cases for aluminum-to-copper connections. See the bolted connections section below for further information on aluminum to copper connections.

In general, bronze bolting hardware is not to be reused. Bronze bolting hardware may be reused with discretion, but only if it is in good condition and the situation warrants it.

Standard bronze hardware and stock numbers are shown in the following tables:

Standard Bronze Bolts Hex Head – Everdur – Bronze			
Diameter	**Length**	**Length of Thread**	**Stock No.**
3/8	1 ¼	FULL THREAD	01-5900
3/8	1 ½	FULL THREAD	01-5901
3/8	1 ¾	FULL THREAD	01-5902
3/8	2	FULL THREAD	01-5903
3/8	2 ½	2	01-5905
3/8	4	2	01-5907
½	1	FULL THREAD	01-5917
½	1 ¼	FULL THREAD	01-5919
½	1 ½	FULL THREAD	01-5920
½	1 ¾	FULL THREAD	01-5921
½	2	1 ¾	01-5922
½	2 ½	2	01-5923
½	3	2	01-5924
½	3 ½	2	01-5925
½	2 ¼		01-5926

Standard Bronze Nuts – Hexagon	
Diameter	**Stock No.**
3/8	01-8341
½	01-8342

Standard Bronze Flat Washers	
Diameter	**Stock No.**
3/8	01-8781
½	01-8782

Standard Bronze Lock Washers	
Diameter	**Stock No.**
3/8	01-8783
½	01-8784

4.3. Stainless Steel

Stainless steel bolting hardware is NOT for standard use in Xcel Energy substations (See exception below). This material was removed from the Xcel Energy warehouse stock and the bolting standard in 1994. After almost four years of trying to establish stainless steel as a universal bolting material that could replace all the other alloys being used, this effort was abandoned for the following reasons:

- Material quality and sizing problems continued to occur too frequently even with intensified specification and warehouse receipting efforts.
- Equipment and material specifications did not include detailed controls on all tapped holes a manufacturer includes with their equipment (such as on station auxiliaries or bus supports) which would have to interact with the stainless steel bolting hardware.
- The predominant industry use of stainless steel bolting hardware was primarily where corrosiveness was a problem such as in the marine or aircraft industry and this was not Xcel's main reason for using this material.
- The cost of the stainless steel material was two and a half to three times that of the other alloys.

Exception:

Although stainless steel bolting hardware is not for standard use, there are a few cases where it may make sense to use it. For instance, stainless steel hardware is sometimes provided by an equipment vendor. Stainless steel bolts, nuts, flat, and Belleville washers can be considered an acceptable material for electrical and mechanical bolting needs when the material meets all the following requirements: AISI 300 series and 302 or 304 as applicable; Bolts, nuts, and flat washers are typically grade 18-8; Belleville washers are required to be 302 stainless steel (cold roll); Bolt threads rolled to class 2A fit and furnished uncoated; Nut threads to be class 2B fit and furnished uncoated. Specific torquing requirements should be followed for each size of bolt. Check for consistent alloy and sizing of all material received.

In general, stainless steel bolting hardware is not to be reused. Stainless steel bolting hardware may be reused with discretion, but only if it is in good condition and the situation warrants it.

5. Connection Accessories

5.1. Oxide Inhibitors

Oxide inhibitors serve several functions in electrical connections. The inhibitor prevents moisture from coming in contact with the connecting surfaces. The inhibitor provides active resistance to oxidation and corrosion. Finally, when applied to stranded conductors, the inhibitor promotes uniform interstrand current distribution, thereby reducing current concentrations and the resulting effect of localized heating.

Note that oxide inhibitors should not be applied to connections which will be submersed in oil (i.e. inside a transformer or oil breaker).

The approved oxide inhibitors are shown in the following table:

Approved Oxide Inhibitors			
Inhibitor	**Stock Number**	**Common Packaging**	**Application**
Alcoa No. 2 EJC	10-1808	Blue Tube	**Preferred for Bolted Connections**
Alcoa Alnox	10-1809	Red Tube (contains nickel grit)	**Preferred for Compression-Type Connections**
Alnox-UG	10-1807	Green Tube	Bolted Connections, Underground Applications
NO-OX-ID "A"	S980A5	Pint Can	Bolted Connections, Battery Applications, Welded Joints
Penetrox A	Not a stock item	--	Bolted Connections (Not Preferred)
Alcoa Filler Compound	10-1806	Caulking Tube	Compression Lugs and Tees (where not factory-filled)

Alcoa No. 2 EJC is the preferred compound for all flat-to-flat surface connections.

Alcoa Alnox is the preferred oxide inhibitor for compression-type connections.

Alnox-UG is preferred where compatibility with rubber products is required, and is particularly suited for underground usage.

NO-OX-ID "A" is often heated and liquefied when used in the substation. It is useful for battery cable connections. It may also be poured into completed welded connections to prevent water penetration; for instance, it may be used to prevent water seeping into voids around a stranded conductor.

Alcoa Filler Compound AFC may be used for lugs and tees that are not factory prefilled. For instance, size 1590 and 2312 lugs are typically not factory-prefilled.

5.2. Wire Brushes

Contact surfaces must be hand brushed with the proper brush so the machined surface is not damaged. There are 2 types of hand wire brushes approved for cleaning aluminum conductors and pads. They may also be used for copper conductors. These brushes can be ordered from the tool warehouse. The approved wire brushes are:

Stock number NS-4804 stainless steel brush.

Stock number NS-4808 2-pronged v-shaped wire brush.

An electric grinder with a wire wheel or abrasive pad should never be used on the face of a lug or on aluminum wire.

6. Making Connections

6.1. Bolted connections

The preferred oxide inhibitor for bolted connections is ALCO EJC No. 2.

6.1.1 Aluminum-to-Aluminum

Aluminum-to-aluminum bolted electrical connections shall only be made on flat contact surfaces.

Connection shall be made as follows:

1) Verify that the materials to be bolted are clean and free of debris. Pay special attention to the area around the backside of the bolt-holes and to the connecting surfaces.
2) Apply oxide inhibitor to the surfaces of the connection.
3) Use a wire brush to thoroughly scratch the contact surface through the inhibitor, leaving enough of it on the surface to control reformation of oxides.
4) Bolt the surfaces together with aluminum bolting hardware. Follow the torquing guidelines below.
5) Wipe off excess oxide inhibitor.

6.1.2 Copper-to-Copper

Copper-to-copper bolted electrical connections shall be made as follows:

1) Verify that the materials to be bolted are clean and free of debris. Pay special attention to the area around the backside of the bolt-holes and to the connecting surfaces.
2) Use a wire brush or other fine abrasive material to thoroughly clean the contact surface.
3) Apply inhibitor to the surfaces of the connection.
4) Bolt the surfaces together with bronze bolting hardware. Follow the torquing guidelines below.
5) Wipe off excess oxide inhibitor.

Note that a wire brush should not be used when making bolted connections of silver or tin-plated copper bus. A fine abrasive material should be used instead.

6.1.3 Aluminum-to-Copper

Aluminum-to-copper connections shall be made only with flat contact surfaces. Dressing and sealing the connection with inhibitor is especially important when dissimilar metals are in contact. Care must be taken to place the aluminum above the copper when in a horizontal or inclined plane so that corrosive copper salts do not flow onto the aluminum. When making a connection in a vertical plane, it is acceptable to place the two materials side-by-side.

The type of bolts used is also important because temperature changes can cause a loose joint due to the expansion differential between copper and aluminum. For instance, if a copper bolt is used, when the temperature increases the aluminum bar will expand more than will the bolt. The bolt will undergo stretching forces. Then, when the temperature is reduced, a loose connection will result. In order to minimize this problem, the following guidelines are to be used:

- Use aluminum bolts if the aluminum bar is as thick as or is thicker than the copper bar.

- Use bronze bolts if the copper bar is thicker than the aluminum bar.

The connection shall be made as follows:

1) Verify that the materials to be bolted are clean and free of debris. Pay special attention to the area around the backside of the bolt-holes and to the connecting surfaces.
2) Prepare the aluminum contact surface as follows:
   a) Apply inhibitor to the surface of the connection.
   b) Use a wire brush to thoroughly scratch the contact surface through the inhibitor, leaving enough of it on the surface to control reformation of oxides.
3) Prepare the copper contact surface as follows:
   a) Use a wire brush or other fine abrasive material to thoroughly clean the contact surface.
   b) Apply inhibitor to the surface of the connection.
4) Bolt the surfaces together. Place the aluminum above the copper when in a horizontal or inclined plane. Follow the torquing guidelines below.
5) Wipe off excess oxide inhibitor.

6.1.4 Tightening Requirements

A torque wrench shall be used on all bolted connections. The torque wrench should be used on the nut, not the bolt.

After the nut is tightened, at least one complete thread of the bolt must extend beyond the end of the nut.

In order to maintain a consistent appearance, the preferred bolt orientation shall be with the bolt-head above the bolted material and the nut below.

Bolts shall be tightened in accordance with the torquing table below:

Tightening Torque for Bolts (Ft-Lbs.)			
	Bolting Hardware Material		
Bolt Dia. (In.)	**Aluminum**	**Bronze**	**Stainless Steel (18-8) ***
5/16	10	12	12
3/8	15	20	20
7/16	20	30	35
½	25	40	45
5/8	40	80	95
¾	60	100	130

(Applies to aluminum bolts with Alumilite 205 finish and lubricant coating.)
Sources: ALCOA Conductor Accessories, Section ACP904, 88-03-15;
Dossert Corporation Internet Site; P.A. Sturtevant Co. Torque Manual.
*** Note**: Stainless steel bolting hardware is NOT for standard use in Xcel Energy substations.

6.1.5 Washer Requirements

The need for flat-washers and split lock-washers is dependent on the type of bolting hardware being used. (Note that washers are always necessary in certain applications; for instance, expansion fittings of angle bus typically require washers.)

For aluminum bolting hardware:

Lock-washers shall NOT be used when using aluminum bolting hardware.

Whether flat-washers are necessary for use with aluminum bolting hardware depends on the diameter of the bolt, the diameter of the bolt-head, and the diameter of the nut. For a given bolt diameter, washers are not needed if the diameter of the bolt-head and nut are great enough. Generally, flat-washers do not need to be used with the aluminum bolts and nuts stocked by Xcel. See the following table:

Flat-Washer Requirements for Aluminum Bolting Hardware			
Bolt Shaft Dia. (In.)	**Hole Dia. (In.)**	**Hex Head Wrench Size (In.)**	**Washer Required?**
3/8	7/16	9/16	Yes
3/8	7/16	11/16	No
½	9/16	¾	Yes
½	9/16	7/8	No

For bronze and stainless steel bolting hardware:

Both flat-washers and split lock-washers should ALWAYS be used when using bronze or stainless steel bolting hardware.

Washer application

Washers must be of the same material as the bolting hardware being used.

The order of washer installation shall be: bolt, flat-washer, material being connected, flat-washer, lock-washer (when used), nut.

6.1.6 Ampacity of Bolted Joints

This section gives a general guideline which can be used to determine the ampacity of bolted joints if no other guidance is given. Note that equipment vendors may provide their own connection details and these should be used as specified by the vendor.

Due to the nature of a bolted joint, it is appropriate to consider amperes per clamping bolt rather than a flat figure based on amperes per square inch. The current rating per bolt will also depend upon the method of preparation of the contact surfaces between the conductors, the size of the bolt and its tightening torque, and proper distribution of the clamping forces. Capacity figures in the following table are suggested current ratings for each fastener in a lapped joint of two rectangular bars where a contact aid such as NO-OX-ID compound is used.

Bolt Diameter	**Amperes per Bolt**
Less than ½ "	225
½ "	300
5/8"	375
¾ "	450

(Source of information: Penn-Union Electric Corporation, Letter dated 10-18-57)

The number of bolts used in a lapped joint will depend upon the current rating of the individual bar. Knowing the current rating, the number of fasteners can easily be determined.

For example, a rectangular bar rated at 1000 amperes will require the following number of 1/2 diameter bolts: 1000/300 = 3.3 or 4 Bolts (1/2" Diameter). Proper design will also make provision for adequate distribution of the applied pressure over the surface on the flats.

The above table may be used for aluminum or bronze bolts.

Detailed engineering may be required for high-current-carrying connections requiring a large number of bolts.

6.2. Welded Connections

A properly welded joint is the most reliable joint from the electrical standpoint because there is no contact resistance. Welded fittings are generally used when there is enough bus welding on the project to make it economical.

The preferred welding method is gas tungsten arc welding (GTAW). The preferred shielding gas is 100% pure argon. The preferred filler metal for welding aluminum is 4043 aluminum alloy.

Care should be taken while welding to prevent sparks from landing on and damaging insulators and bushings. Although metal inert gas welding is generally faster than tungsten inert gas welding, this method is more prone to producing sparks and damaging equipment. Therefore, metal inert gas welding is not recommended.

No inhibitor or sealant is to be applied prior to weld. In cold weather, the surfaces to be welded should be preheated to 200°F or until it is too hot to touch to draw all moisture out of the connection.

Welded connections shall be made as follows:

1) Verify that the materials to be welded are clean and free of debris.
2) In cold weather, preheat the materials to be welded to 200°F.
3) Clean the surfaces to be welded with a stainless steel wire brush to remove oxidation.
4) Tack weld as needed.
5) Wire brush the area around the tack weld.
6) Make final weld. Two welding passes are recommended for 5” bus. One pass is usually sufficient for bus smaller than 5”.

6.3. Compression Fittings for Tubular Bus

Compression fittings for tubular bus are not approved for use in Xcel Energy substations.

6.4. Cable Bus (Stranded Conductor) Connections

6.4.1 Compression-Type Connections

Terminations for aluminum cable bus can be made with compression-type fittings. For compression-type connections, the preferred oxide inhibitor is Alcoa EJC.

Compression-type connections for aluminum cable bus shall be made as follows:

1. Verify that the materials to be used are clean and free of debris.
2. Apply oxide inhibitor to the aluminum cable bus.
3. Use a wire brush to thoroughly scratch the surface of the wire through the inhibitor.
4. Verify that the fitting is factory pre-filled with inhibitor. If not pre-filled, apply inhibitor. Do NOT remove inhibitor as a means to make insertion of conductor easier. Check for foreign particles, and remove if necessary.
5. Insert the conductor into the lug body and crimp.

Compression-type terminal lugs may be used for 336.41, 556.5, 954, and 1590 MCM all-aluminum and 2312 MCM ACSR conductors. There must be enough inhibitor in the barrel of each terminal lug so that it squeezes out around the wire when inserted and compressed. The various lugs stocked by Xcel Energy are listed in this standard (See Section 9).

Compression-type tee connectors with a flat pad tap terminal shall be used for full current carrying tee connections for 336.41, 556.5, 954, and 1590 MCM all-aluminum and 2312 MCM ACSR conductors.

6.4.2 Clamp-Type Connections

Clamp-type terminal lugs should NOT be used on aluminum cable bus. Due to the open design of the clamps, it is difficult to completely seal the cable contact area. An exception to this rule is in the use of clamp-type stirrups for personal grounds or low-current carrying connections.

Clamp-type terminal lugs may be used on copper cable.

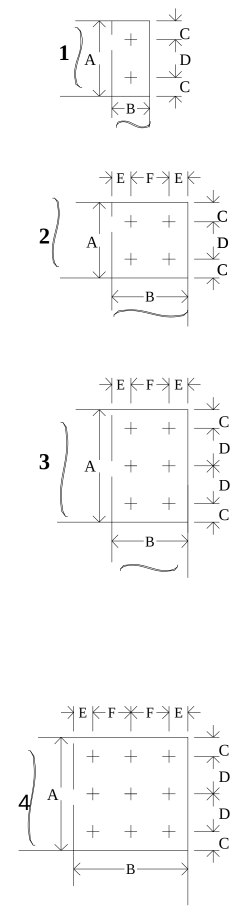
Low-current-carrying connections (such as for potential transformers, surge arresters, coupling capacitors, etc.) may be made by installing a clamp-type stirrup on the bus, and then connecting a conductor from the equipment to the stirrup with a hot-line clamp. In the past, conductors for low-current-carrying connections were joined with special wide range parallel groove clamps. This type of connection frequently involved a solid rod conductor looped through one side of the parallel clamp, to which a hot line clamp was attached. However, these connections are subject to excessive corrosion and are no longer recommended.

7. Bolting Schedule for Aluminum Bus

Table 1

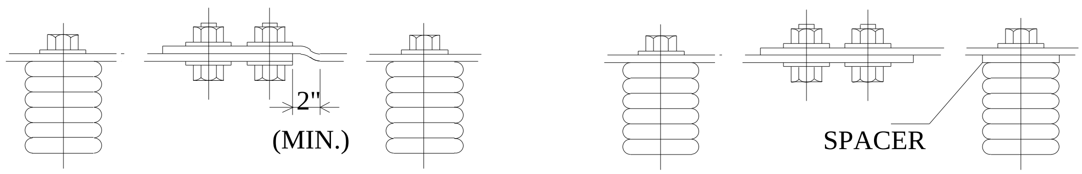
Bar Width (In.) A	B	Arrangement	Bolt Spacing (In.) C	D	E	F	No. of Bolts	Bolt Size Alum	Steel
2	1	1	1/2	1			2	3/8	5/16
2	1 1/2	1	1/2	1			2	3/8	5/16
2	2	1	1/2	1			2	3/8	5/16
3	1	1	3/4	1 1/2			2	3/8	5/16
3	1 1/2	1	3/4	1 1/2			2	3/8	5/16
3	2	1	3/4	1 1/2			2	3/8	5/16
3	3	2	3/4	1 1/2	3/4	1 1/2	4	3/8	5/16
4	2	1	1	2			2	1/2	1/2
4	3	2	1	2	3/4	1 1/2	4	3/8	3/8
4	4	2	1	2	1	2	4	1/2	1/2
5	2	1	1 1/4	2 1/2			2	1/2	1/2
5	3	2	1 1/4	2 1/2	3/4	1 1/2	4	3/8	3/8
5	4	2	1 1/4	2 1/2	1	2	4	1/2	1/2
5	5	2	1 1/4	2 1/2	1 1/4	2 1/2	4	1/2	1/2
6	2	1	1 1/2	3				1/2	
6	3	2	1 1/2	3	3/4	1 1/2	4	1/2	3/8
6	4	2	1 1/2	3	1	2	4	1/2	1/2
6	5	2	1 1/2	3	1 1/4	2 1/2	4	5/8	1/2
6	6	2	1 1/2	3	1 1/2	3	4	5/8	5/8
8	4	3	1 1/4	2 3/4	1	2	6	1/2	3/8
8	5	3	1 1/4	2 3/4	1 1/4	2 1/2	6	1/2	1/2
8	6	3	1 1/4	2 3/4	1 1/4	3	6	5/8	1/2
8	8	4	1 1/4	2 3/4	1 1/4	2 3/4	9	5/8	5/8

Tangent or Right Angle Joint

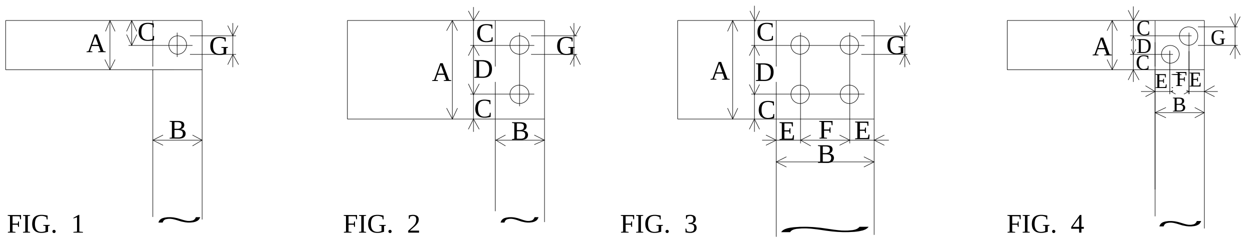


Bus Connections Standard

8. Bolting Schedule for Copper Bus



TYPICAL BUSBAR JOINTS AND MOUNTINGS



STANDARD BOLTING FOR BUS AND CONNECTION BARS

Table 2

Bars (In.)		Fig. No.	Bolt Spacing and Hole Dia. (In.)				
A	**B**		**C**	**D**	**E**	**F**	**G**
1	1	1	½	--	--	--	17/32
1 ½	1	1	¾	--	--	--	17/32
1 ½	1 ½	4	7/16	5/8	7/16	5/8	9/16
2	1	1	1	--	--	--	17/32
2	1 ½	4	9/16	7/8	7/16	5/8	9/16
2	2	4	½	1	1/2	1	9/16
2 ½	1	2	½	1 ½	--	--	9/16
2 ½	1 ½	2	½	1 ½	--	--	9/16
2 ½	2	2	½	1 ½	--	--	9/16
2 ½	2 ½	3	½	1 ½	½	½	9/16
3	1	2	5/8	1 ¾	--	--	9/16
3	1 ½	2	5/8	1 ¾	--	--	9/16
3	2	2	5/8	1 ¾	--	--	9/16
3	2 ½	3	5/8	1 ¾	½	1 ½	9/16
3	3	3	5/8	1 ¾	5/8	1 ¾	9/16
4	1	2	1 1/8	1 ¾	--	--	17/32
4	1 ½	2	1 1/8	1 ¾	--	--	9/16
4	2	2	1 1/8	1 ¾	--	--	9/16
4	2 ½	3	1 1/8	1 ¾	½	1 ½	9/16
4	3	3	1 1/8	1 ¾	5/8	1 ¾	9/16
4	4	3	1 1/8	1 ¾	1 1/8	1 ¾	9/16

9. Aluminum Compression Lug Details

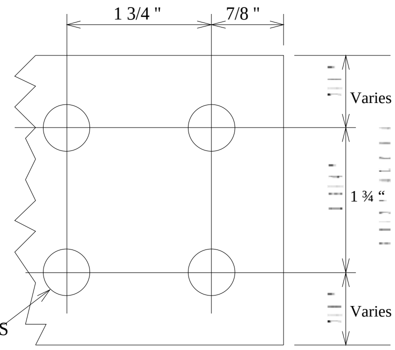
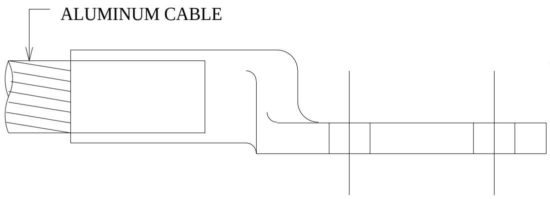


FIG. 4
1590 MCM



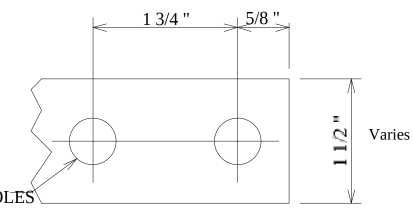


FIG. 1
336.4 MCM 8 #3/0

A ONLY

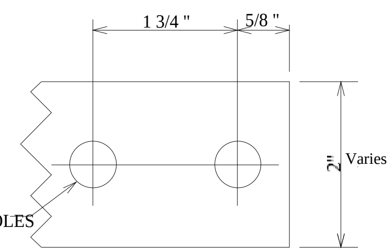


FIG. 2
556.5 MCM

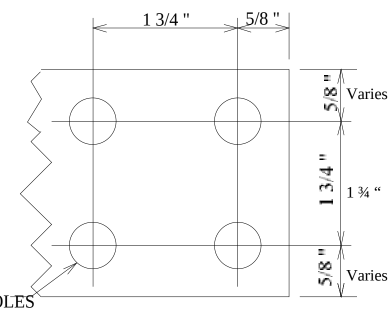


FIG. 3
954 MCM

CONDUCTOR SIZE	NUMBER OF STRANDS	COMPRESSOR MODEL	DIE	NSP STOCK NUMBER
3/0	19	12	74AH	10-0800
336.4 MCM	19	* 12A	* B76AH	10-0801
556.5 MCM	37	60A	6024AH	10-0803
954 MCM	37	60A	6030AH	10-0805
1590 MCM	61	60A	6038AH	10-0808
2312 MCM (ACSR)		* *	* *	

* ALTERNATE COMPRESSOR 60A WITH DIE 6076AH COMPRESSION LUGS COME WITH INHIBITOR

* * USE TRANSMISSION COMPRESSOR AND DIE

ALUMINUM COMPRESSION LUGS
ALUMINUM TERMINAL DETAILS

Bus Vibration

Bus vibration is caused by low steady winds, less than 15 mph., blowing across a bus span at approximately right angles. Under certain low velocity wind conditions, eddies will break off alternately from the top and bottom surfaces of the bus causing the bus to vibrate in a vertical plane. The bus will vibrate at its natural frequency provided that this frequency is within the range that can be excited by the wind.

Winds over 15 mph are generally too gusty to induce vibration. A span that is "sheltered" from the wind will not be as prone to vibrate as an-exposed span. Shelters may be created by trees planted around the substation, equipment in the substation, or by the surrounding topography of the substation.

Long spans are more prone to vibration than short spans. A long span can have one, two or three (in-the case of extremely long spans) loops of vibration. A loop of vibration is the portion of a vibrating body between two node points. A “node” is the point of a vibrating body that is free of vibration (any point of support would be a node point). The diameter of the bus tube will increase the vibration free span; however, whether a bus tube is Schedule 40 or Schedule 80 has little effect on whether a span will vibrate or not. For maximum vibration free rigid bus lengths, see table for maximum vibration free span.

Support losses are an indeterminable factor, such as support type, insulator type, structure flexibility, and other related factors. In some substations, the support losses are high enough to provide adequate damping but in other substations the support losses are less and the bus will vibrate more.

In general, bus spans greater than a minimum length will vibrate. (See tables for maximum vibration free spans.

In the past, “scrap cable” was installed inside the tubular bus to prevent vibration. Today, external type manufactured dampers are preferred because they are much cheaper and easier to install than scrap cable. The following tables are supplied as bus vibration references:

1. Maximum Vibration Free Span for- Tubular Bus
2. Maximum Vibration Free Span for Universal Angle Bus Conductor (UABC)
3. Maximum Vibration Free Span for Integral Web Channel Bus (IWCB)
4. Damper Spacing for Rigid Bus
5. Recommended Sizes of Cable to be Inserted in Tubular Bus to Prevent Vibration

Table 1
Maximum Vibration Free Span for- Tubular Bus

Nominal Pipe Size	Maximum Safe Span Length
1	5’- 0”
1-1/4	6’- 3”
1-1/2	7’- 0”
2	9’- 0”
2-1/2	10’- 9”
3	13’- 3”
3-1/2	15’- 3”
4	17’- 0”
4-1/2	19’- 0”-
5	21’- 3”
6	25’- 3’

Table 2
Maximum Vibration Free Span for Universal Angle Bus Conductor (UABC)

UABC Size	Maximum Safe Span Length [a, b, c]
3-1/4 x 3-1/4 x 1/4	12’-0
4 x 4 x 1/4	15'-0
4 x 4 x 3/8	14’-9
4-1/2 x 4-1/2 x 3/8	16’-9
5 x 5 x 3/8	18’-6

[a] Lengths based on one span with support at each end
[b] Lengths apply to both Schedule 40 and Schedule 80 tubular bus
[c] Lengths can be increased approximately 20% with reasonable assurance there will be no vibration.

Table 3
Maximum Vibration Free Span for Integral Web Channel Bus (IWCB)

IWCB Size (Inches)	Maximum Safe Span Length [a, b]
4 x 4	14’-6
6 x 4	20’-9
6 x 5	21’-3
6 x 6	21’-9
7 x 7	26’-3
8 x 5	29’-0

a. Spans based on one span with support at each end
b. Lengths can be increased approximately 20% with reasonable assurance there will be no vibration.

Table 4
Damper Spacing for Rigid Bus [a, b]

SPAN	SPACING	SPAN	SPACING	SPAN	SPACING	SPAN	SPACING
15’-0	7’-0	26’-6	10’-10	38’-0	14’-8	49’-6	18’-6
15’-6	7’-2	27’-0	11’-0	38’-6	14’-10	50’-0	18’-8
16’-0	7’-4	27’-6	11’-2	39’-0	15’-0	50’-6	18’-10
16’-6	7’-6	28’-0	11’-4	39’-6	15’-2	51’-0	19’-0
17’-0	7’-8	28’-6	11’-6	40’-0	15’-4	51’-6	19’-2
17’-6	7’-10	29’-0	11’-8	40’-6	15’-6	52’-0	19’-4
18’-0	8’-0	29’-6	11’-10	41’-0	15’-8	52’-6	19’-6
18’-6	8’-2	30’-0	12’-0	41’-6	15’-10	53’-0	19’-8
19’-0	8’-4	30’-6	12’-2	42’-0	16’-0	53’-6	19’-10
19’-6	8’-6	31’-0	12’-4	42’-6	16’-2	54’-0	20’-0
20’-0	8’-8	31’-6	12’-6	43’-0	16’-4	54’-6	20’-2
20’-6	8’-10	32’-0	12’-8	43’-6	16’-6	55’-0	20’-4
21’-0	9’-0	32’-6	12’-10	44’-0	16’-8	55’-6	20’-6
21’-6	9’-2	33’-0	13’-0	44’-6	16’-10	56’-0	20’-8
22’-0	9’-4	33’-6	13’-2	45’-0	17’-0	56’-6	20’-10
22’-6	9’-6	34’-0	13’-4	45’-6	17’-2	57’-0	21’-0
23’-0	9’-8	34’-6	13’-6	46’-0	17’-4	57’-6	21’-2
23’-6	9’-10	35’-0	13’-8	46’-6	17’-6	58’-0	21’-4
24’-0-	10’-0	35’-6	13’-10	47’-0	17’-8	58’-6	21’-6
24’-6	10’-2	36’-0	14’-0	47’-6	17’-10	59’-0	21’-8
25’-0	10’-4	36’-6	14’-2	48’-0	18’-0	59’-6	21’-10
25’-6	10’-6	37’-0	14’-4	48’-6	18’-2	60’-0	22’-0
26’-0	10’-8	37’-6	14’-6	49’-0	18’-4		

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a Spacing based on 1/3 span length plus two feet
b Damper may be installed from either end of the span

Table 5
Recommended Sizes of Cable to be Inserted in Tubular Bus to Prevent Vibration [a, b, c]

Nominal Bus Size (Inches)	Recommended Min. Size (Circular Mills – CM)
2	266,800
2-1/2	266,800
3	266,800
3-1/2	397,500
4	795,000
5	1,431,000
6	1,590,000

[a] Cable should have a multi-strand core
[b] Based on no energy absorption by supports
[c] Scrap cable is an alternate method of dampening to be used only when manufactured dampers are not available.

Outdoor Bus Supports For Substations Standardization Of Insulation Levels

In 1942 the Electrical Industry adopted as standard, certain Basic Insulation Levels (BIL) for all standard operating voltages. These insulation levels were arrived at only after many years of exhaustive study by various interested groups in the Industry and were approved by the National Electrical Manufacturer's Association (NEMA), later by the American Standards Association (ASA) and presently by the American National Standards Institute, Inc. (ANSI).

By use of these standards it is possible to coordinate the insulation strength of all equipment in a station or substation so surges entering the station will be conducted to ground by protective devices before flashing over or puncturing the insulation of any component part.

Prior to 1942 Delta Star type ZO insulators were used. These insulators were below the present basic insulation levels. Some may yet be in use, particularly at 69kV. The line protective gap for 69kV ZO-7 insulators is 18 3/4 inches. All ZO insulators should be replaced when possible and bring the installation up to standard BIL. This decision will be made by the Sponsor Engineer.

STATION POST INSULATORS

Station post insulators are the insulator of choice for Northern States Power. NSP stocks insulators through 161kV and places all orders for new insulators through the Maple Grove Stores Facility.

Governing Standards

ANSI Standard C 29.9.
NSP Material Standard 4SC6.

Station Post Insulators - Dimension Information

Rating (KV)	BIL (KV)	(5) ANSI TRN	Units Per Stack	Stack Height (In)	† Stack Wt. (Lbs)	(5) Bolt Circle Dia.	Max Dia. (In)	Stock Number
7.5	95	202	1	7.5	15	3(1)	7.5	04-0560
15	110	44 *	1	10	32	5(2)	8.75	04-0561 §
15	110	205	1	10	21	3(1)	7	04-0562
15	110	225 *	1	12	44	5(2)	8.5	04-0563
23	150	208	1	14	30	3(1)	7.25	04-0564
34.5	200	210	1	18	41	3(1)	7.5	04-0566
34.5	200	231 *	1	20	95	5(2)	9.75	None
46 (4)	250	214	1	22	67	3(1)	8	04-0567
69	350	216	1	30	97	3(1)	9.5	04-0568
69	350	278 *	1	30	141	5(2)	10.5	None
115	550	286	1 or 2	45	206	5(2)	11	04-0570
115	550	287 *	1 or 2	45	213	5(2)	10.5	None
161	750	291	2	62	307	5(2)	11	04-0572
230	900	308 *	2 or 3	80	490	5(2)	14	04-0574
345	1300	324	2 or 4	106	654	5(2)	14	04-0576
345	1300	367 *	2 or 4	106	594	Top 5(2) Bot 7(3)	14	None
500	1800	391	3 or 5	152	1007	Top 5(2) Bot 7(3)	14	04-0578
500	1800	**ND** **	3	152	1031	Top 5(2) Bot 14(3)	12	None

Legend:

(1) For 1/2" - 13 Thread Bolts
(2) For 5/8" - 11 Thread Bolts
(3) For 3/4" - 10 Thread Bolts
(4) Used for spacers between capacitor bank series groups
(5) ANSI Standards Publication C-29.9

* High Strength
** Extra High Strength
ND No TRN designation listed
§ For cap and pin replacement.
† Worst Case of approved vendors

High leakage and extra-high leakage insulators are available and have been used to reduce the chance of insulator flashover in substations adjacent to freeways such as at Parkers Lake Substation.

Insulators - Outdoor, Station Post Bus Support

An Excel spreadsheet based on IEEE Standard 605 is available in the Engineering Calcs directory on the Black Server with the file name BUSLOAD.XLS. This spreadsheet can be used to determine when higher strength insulators are required if the criteria for a specific location does not fall within what was used in the Substation Tubular Bus Criteria Standard ED 4.02.01. The IEEE Standard 605 should be reviewed prior to use of this spreadsheet.

Station Post Insulators - Approved Purchasing Supplement

The products of the following manufacturers meet the specifications set forth in the Approved Material Standard #4SC6. These products shall be purchased and stocked under the following NSP Stock Numbers:

NSP Stock #	Rating (kV)	ANSI TRN	Lapp		Victor		NGK-Locke		Newell	
			Cat #	U/S	Cat #	U/S	Cat #	U/S	Cat #	U/S
04-0560	7.5	202	315202-70	1	1750	1	PS00910	1	231001	1
04-0561 §	15	44	315044-70	1	-	-	-	-	-	-
04-0562	15	205	315205-70	1	1751	1	PS01110	1	231002	1
04-0563	15	225 *	315225-70	1	1767	1	PH01110	1	41512	1
04-0564	23	208	315208-70	1	1752	1	PS01510	1	231003	1
04-0566	34.5	210	315210-70	1	1753	1	PS02010	1	231004	1
None	34.5	231 *	315231-70	1	1763	1	PH02010	1	41520	1
04-0567	46	214	315214-70	1	1754	1	PS02510	1	231005	1
04-0568	69	216	315216-70	1	1755	1	PS03510	1	231006	1
None	69	278 *	315278-70	1	1765	1	PH03510	1	41530	1
04-0570	115	286	315286-70	1	1720	2	PS05510	1	47801	2
None	115	287 *	315287-70	1	1725	2	PH05510	1	47821	2
04-0572	161	291	None †	-	1722	2	None †	-	47803	2
04-0574	230	308 *	315308-70	2	1728	3	PH090201	2	47825	3
04-0576	345	324	315324-70	2	16PA00	2	PH130201	2	47831	4
None ‡	345	367 *	315367-70	2	16PA01	2	PH130202	2	47761	4
04-0578	500	391	315391-70	3	1630	5	PE18030	3	47854	5
None	500	**ND** **	314934-70	3	None	-	None	-	None	-

Legend:

- * High Strength
- ** Extra High Strength
- **ND** No TRN designation listed
- **U/S** Units per stack
- § For cap and pin replacement.
- † Only single piece insulator available at this rating which is not acceptable.
- ‡ May be less than or equal in cost to the standard strength unit (TRN 324). When requisitioning new switches or just the station post insulator, the requester may wish to have both standard and high strength units quoted for comparison.

Care should be taken when obtaining units from stock that like units from the same manufacturer are obtained as the manufacturers do not all supply the same number of units per stack and sections from different manufacturers are not interchangeable, nor are units from the same manufacturer but of different vintages necessarally interchangeable. Bolt circle dimensions between standard, high strength and extra high strength units differ.

CAP AND PIN INSULATORS

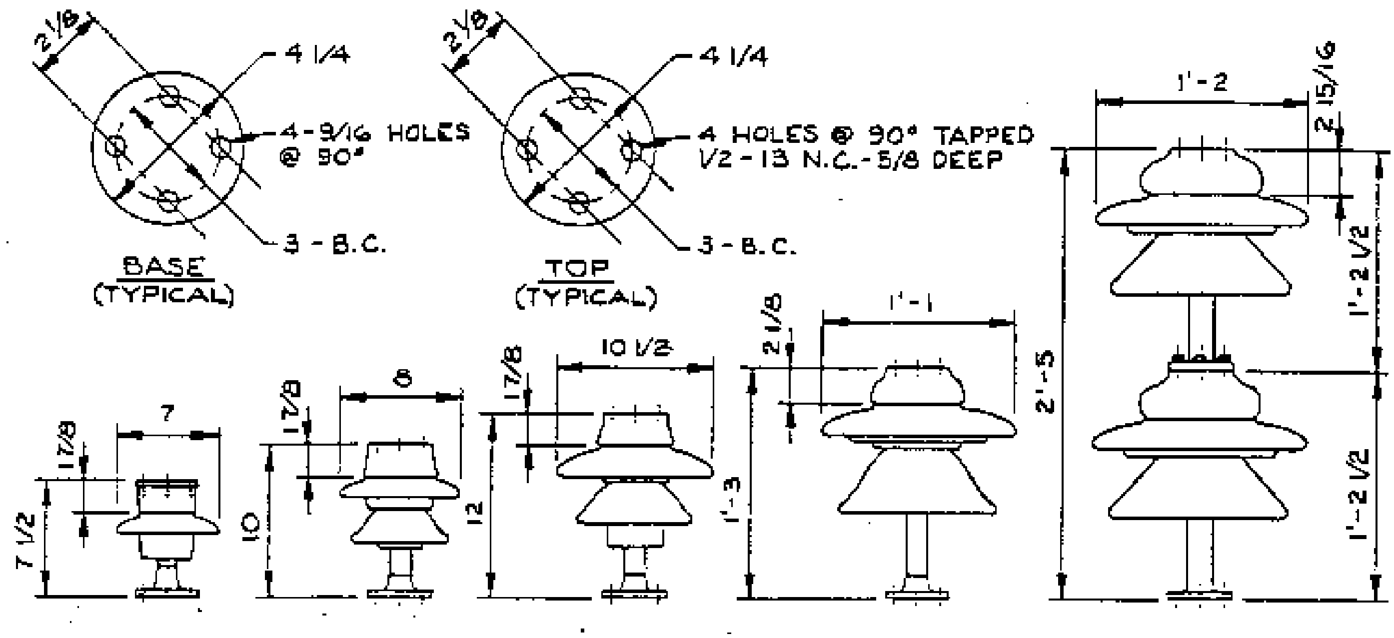
Cap and Pin Substation Insulators are covered by ANSI Standard C 29.8. These insulators are emergency stock items. Cap and Pin Insulators will not be used for new construction. Emergency stock is limited, and the design of these insulators has caused failure problems. Station Post Insulators should be used whenever possible.

When replacing broken Cap and Pin Insulators, always try to use Station Post Insulators. There may be height differences between Station Posts and the similarly rated Cap and Pins.

Rating (kV)	BIL (kV)	(1)Tech Ref No.	Units per Stack	(1)Tech. Ref. No of Sgl Units	Hgt. of Stack (in)	(5)Bolt Circle Diam.	Max Dia (in)	Stock Number
7.5	95	1	1	1	7 1/2	3	7	04-0521
15	110	4	1	4	10	3	8	04-0527
15(4)	110	44	1	44	10	5	10	
23	150	7	1	7	12	3	10 1/2	04-0534
23(4)	150	46	1	46	12	5	12	
34.5	200	10	1	10	15	3	13	
69	350	16	2	147	29	3	14	04-0548
115	550	19	3	140	431/2	5	17	04-0556
					47(2)			
161(3)	750	26	4	4-140	58	5	17	04-0556
				1-141(4)	61 1/2(2)		18	

Legend:

(1) ANSI Standards Publication C-29.8
(2) Total Height of Bus Support with 3 1/2" Spacer (Required) - Stock No. 04-0942
(3) Station Post Insulators Preferred 161kV and Above - See Sheet 3
(4) High Strength Ins., at Insulator Supporting End, When More Than 1 Unit is Used
(5) 3" Diameter B.C. for 1/2" - 13 Thread Bolts, 5" B.C. for 5/8" - 11 Thread Bolts

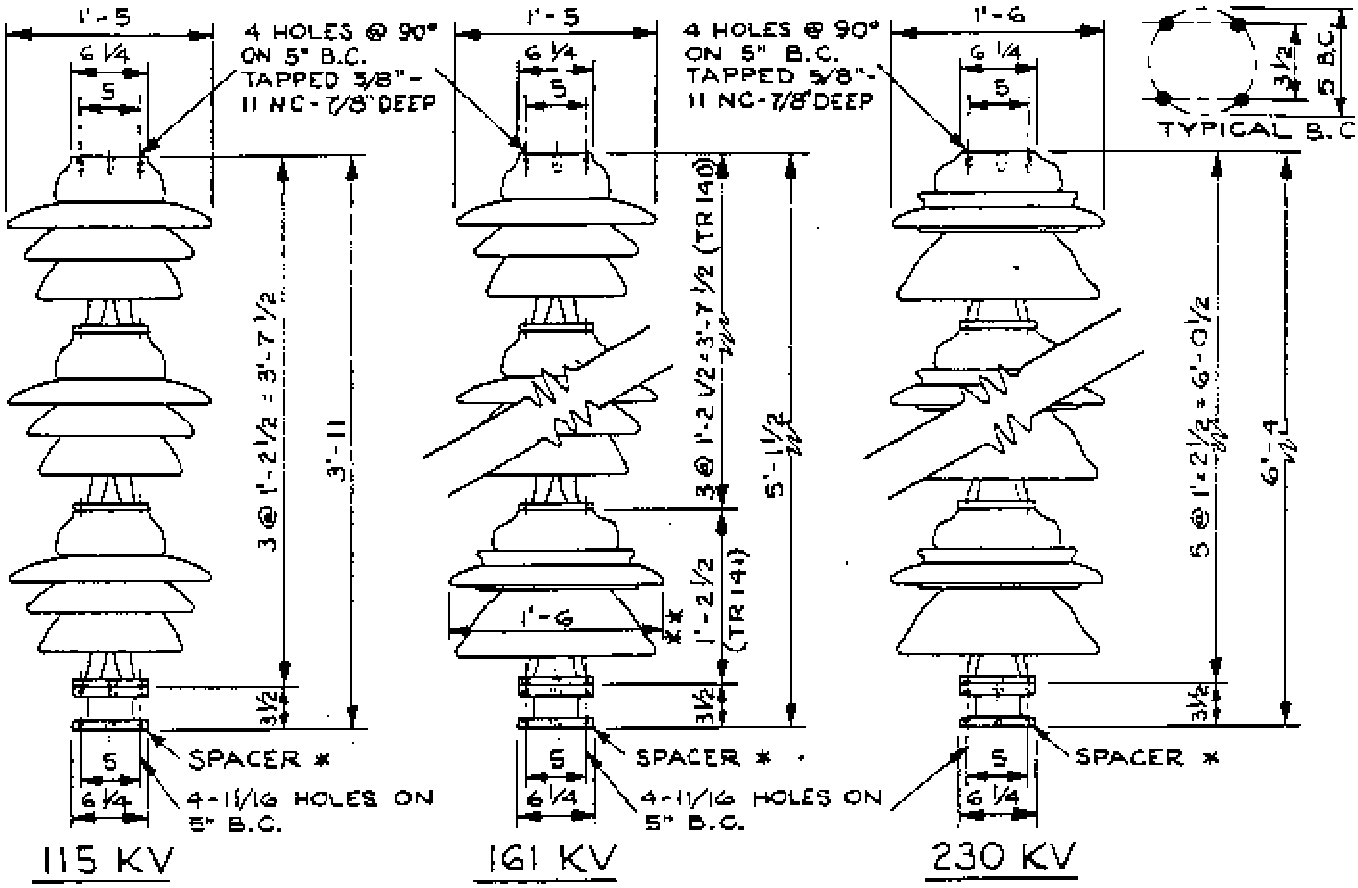


NOMINAL VOLTAGE	7.5 kV	15 kV	23 kV	34.5 kV	69 kV
BIL	95 kV	110 kV	150 kV	200 kV	350 KV
TECH. REF.	1	4	7	10	16 (STACK) 147 (UNIT)
WEIGHT	12 LBS.	16 LBS.	24 LBS.	38 LBS.	100 LBS.(TOTAL

REFERENCE ONLY
Not for design purposes

Insulators - Outdoor, Cap & Pin - 7.5 kV To 69 kV

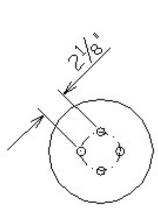
NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE 12/18/96		2	SHEET 2	ED 6.02.01.03



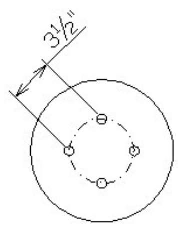
NOMINAL VOLTAGE	115 kV	161 kV	230 kV
BIL	550 kV	750 kV	900 kV
STACK TECH. REF.	19	26	27
UNIT TECH. REF	140 STANDARD STRENGTH	1-END UNIT 141 3- END UNITS140	141 HIGH STRENGTH
STACK WEIGHT	250 LBS.	364 LBS.	580 LBS.

REFERENCE ONLY
Not for design purposes

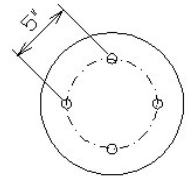
Insulators - Outdoor, Cap & Pin - 115 kV To 230 kV



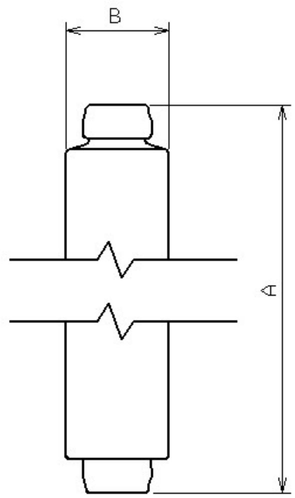
4 HOLES @ 90° ON 3" B.C.
TAPPED ⅝"-11



4 HOLES @ 90° ON 5" B.C.
TAPPED ½"-13



4 HOLES @ 90° ON 7" B.C.
TAPPED ¾"-10



Nominal Voltage kV	Strength	BIL kV	Dimensions		B.C. DIA.	WT. LBS	Tech. Ref. Single Unit	PassPort Cat #
			A	B				
7.5	STANDARD	95	7 ½”	6 ¾”	3”	13.5	202	106104
15	STANDARD	110	10”	7”	3”	20	205	86859
15	HIGH	110	1’- 0”	8”	5”	44	225	86861
23	STANDARD	150	1’- 2”	7”	3”	30	208	51517
34.5	STANDARD	200	1’- 6”	7 ½”	3”	41	210	86867
69	STANDARD	350	2’- 6”	8”	3”	85	216	51523
115	STANDARD	550	3’- 9”	11”	5”	206	286	51524
115	EXTRA HIGH	550	3’- 9”	10 ½”	TOP-7” BOT-7”	257	None	
161	STANDARD	750	5’- 2”	11”	5”	331	291	106109
230	HIGH	900	6’- 8”	10”	5”	371	308	86875
345	STANDARD	1300	8’- 10”	9”	5”	388	324	106110
345	EXTRA HIGH	1300	8’- 10”	10 ½”	TOP-5” BOT-7”	675	369	
500	STANDARD	1800	12’- 8”	9 $^{5}/_{8}$”	TOP-5” BOT-7”	705	391	196318

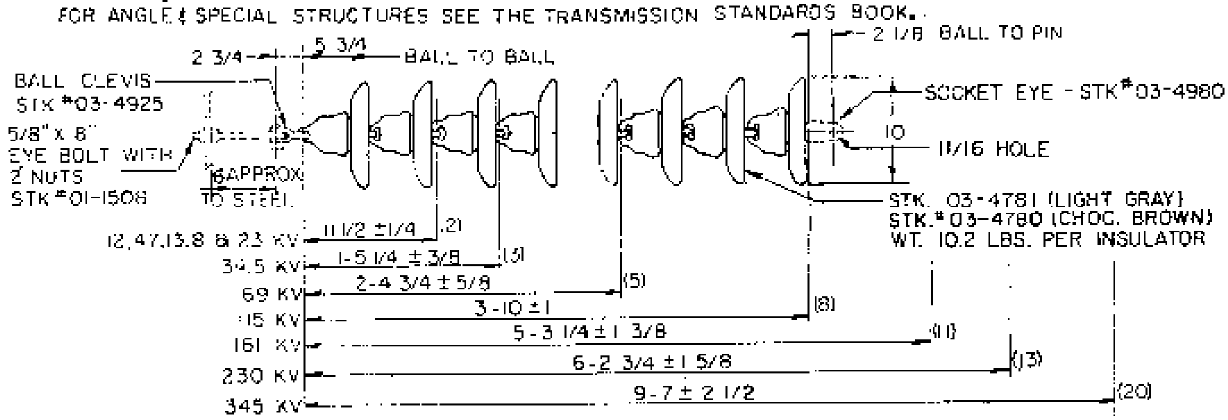
NOTE:

1. All bus supports to be requisitioned as ‘light gray’ unless otherwise notified. (Stock no's are for light gray)
2. The number of stacks determined by manufacturer.
3. Diameter and weight may very by manufacturer.

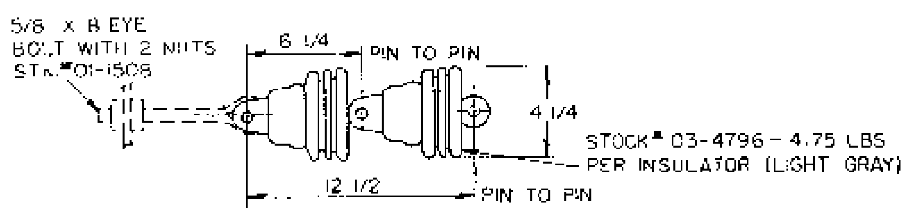
Insulators Station Post Outdoor Bus Support

SUSPENSION INSULATORS					
	SUBSTATION	TRANSMISSION TANGENT		TRANSMISSION DEAD END	
VOLTAGE	INSULATORS	WOOD	STEEL	WOOD	STEEL
2.4 /4.16 & 11.9 KV	2 - 4 1/4"				
12.47 3 13.8 KV	2 - 10"				
23 KV	2 - 10"	2	3	3	4
34.5 KV	3 - 10"	3	4	4	
69 KV	5 - 10"	4	5	5	6
115 KV	8 - 10"	7	8	8	9
161 K V	11 - 10"	9	10	10	11
230KV	13 - 10"	12	14	14	15
345 KV	20 -10"	18	16	20	20

* SOME EXISTING INSTALLATIONS HAVE 3 INSULATORS. IT IS DESIRABLE TO MAINTAIN THIS INSULATOR LEVEL.
** THIS TABLE COVERS THE GENERALLY ACCEPTED N.S.P. STANDARD FOR TANGENT & DEAD END STRUCTURES. FOR ANGLE & SPECIAL STRUCTURES SEE THE TRANSMISSION STANDARDS BOOK.



10 INCH INSULATOR STRINGS FOR SUBSTATIONS



4 1/4 INCH INSULATOR STRING

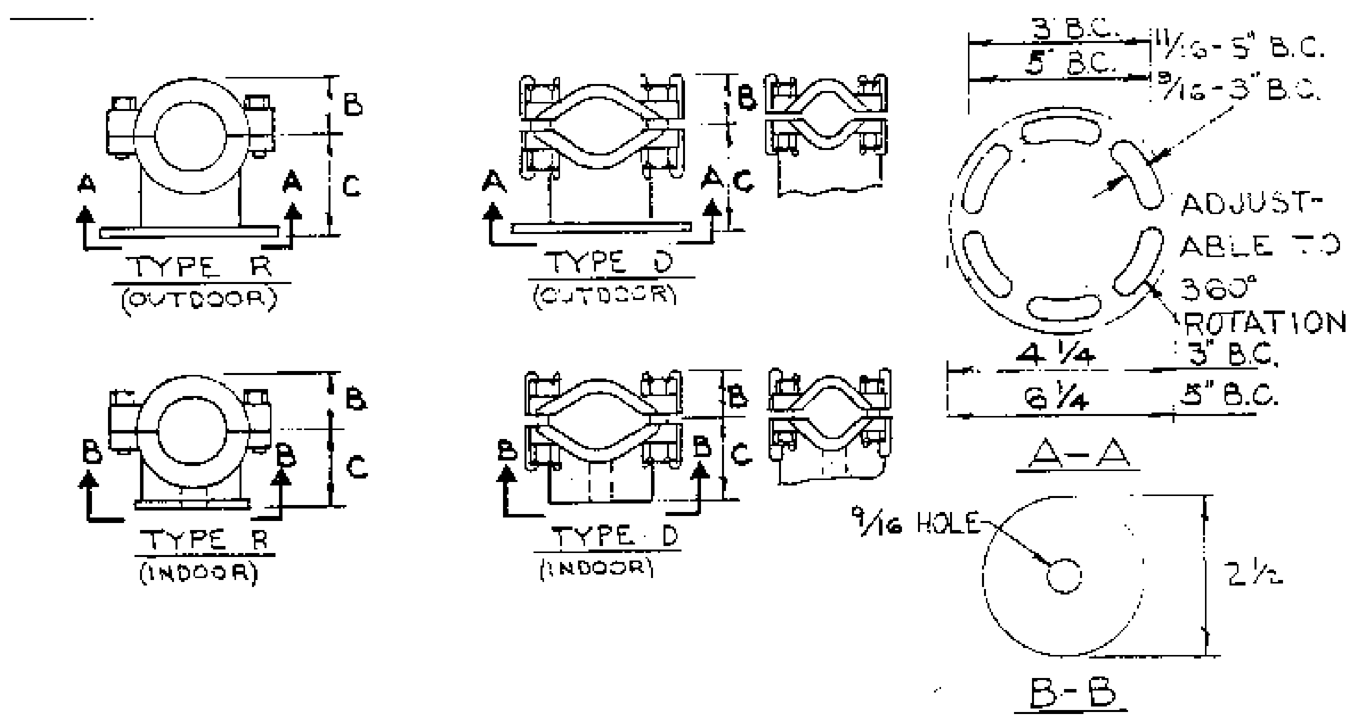
NOTES:

1. ALL SUSPENSION INSULATORS FOR SUBSTATION ARE TO BE REQUISITIONED AS "LIGHT GRAY" UNLESS OTHERWISE SPECIFIED.

2. USA STANDARD SPECS. ALLOW A TOLERANCE OF PLUS OR MINUS 1/8" ON THE LENGTH OF EACH 10" SUSPENSION INSULATOR.

Suspension Insulators

NORTHERN STATES POWER COMPANY SUBSTATION/TRANSMISSION SERVICES	DRAWN	FILMED	REV	SUBSTATION ENGINEERING & DESIGN STANDARDS	
	CHECKED	APPROVED			
	DATE **6/5/73**		**0**	**SHEET 1**	**ED 6.02.01.05**



MALLEABLE & BRONZE FOR COPPER CONDUCTOR

Range-MCM	Range-Inches	Tubing IPS	D.S. Co. Cat. No.	Bolt Circle	NSP Stock No.	B	C	Type
Up to 500	3/16 to 13/16	1/2	630013	3"	04-0620	15/16	1 9/16	D
4/0 to 1250	1/2 to 1 5/16	3/4 & 1	630023	3"	04-0634	1 5/16	2 1/8	D
Up to 500	3 16 to 13/16	1/2	630015	5"	04-0638	15/16	1 9/16	D
4/0 to 1250	1/2 to 1 5/16	3/4 & 1	630025	5"	04-0645	1 5/16	2 1/8	D
Up to 500	3/16 to 13/16	1/2	630011	bolt center	04-0626	15/16	15/16	D
4/0 to 1250	1/2 to 1 5/16	3/4 & 1	630021	bolt center	04-0632	1 5/16	1 5/8	D
	1.315	1	630333	3"	04-0814	1 1/8	2	R
	1.900	1 1/2	630353	3"	04-0822	1 5/8	2 1/2	R
FOR STRANDED ALUM CONDUCTOR (SAC)								
4/0 to 1272	1/2 to 1 5/16	3/4 & 1	630023AL	3"	04-0714	1 5/16	2 1/8	D
795 to 1590	1 to 1 7/8	1 1/4 & 1 1/2	630033AL	3"	04-0722	1 3/8	2 5/8	D
4/0 to 1272	1/2 to 1 5/16	3/4 & 1	630025AL	5"	04-0720	1 5/16	2 1/8	D
795 to 1590	1 to 1 7/8	1 1/4 & 1 1/2	630035AL	5"	04-0724	1 3/8	2 5/8	D

NOTE - Bus support fittings for special shapes, except 4"x4" IWCB items. Each project must be checked for the latest approved fittings are not stock.

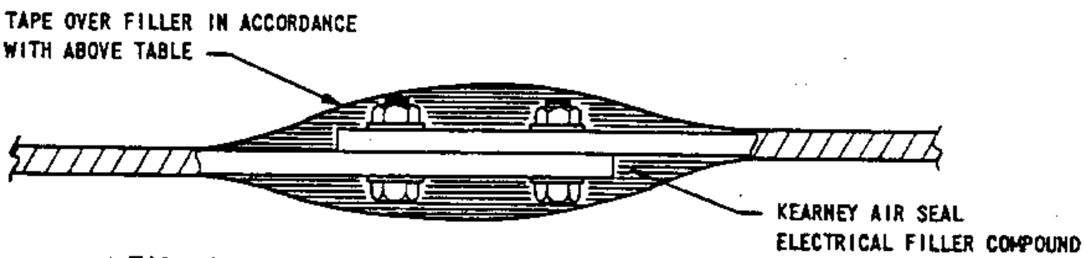
Bus Support Fittings

Taping Bus Bars Connections With Polyvinyl Chloride (Pvc) Tape

Thickness and number of layers of 20 mil (.02") polyvinyl chloride tape for taping bus bars

	FULL VOLTAGE TAPING		FLASH VOLTAGE TAPING	
VOLTAGE	MILS	ONE HALF LAPPED	MILS	ONE HALF LAPPED
0 TO 600	120	3 LAYERS (6 THICKNESSES)	40	1 LAYERS (2 THICKNESSES)
601 TO 2000	160	4 LAYERS (8 THICKNESSES)	40	1 LAYERS (2 THICKNESSES)
2001 TO 3000	160	4 LAYERS (8 THICKNESSES)	40	1 LAYERS (2 THICKNESSES)
3001 TO 4000	200	5 LAYERS (10 THICKNESSES)	40	1 LAYERS (2 THICKNESSES)
4001 TO 6000	200	5 LAYERS (10 THICKNESSES)	40	1 LAYERS (2 THICKNESSES)

THE ABOVE TAPING IS BASED ON THE FOLLOWING
Full voltage taping is I.P.C.E.A. recommended thickness for one conductor cable 1000 MCM and larger. Flash voltage taping is based on the dielectric strength of PVC Tape which is equal to V.C. Tape (20% of 900 volts. - The acceptance test voltage for V.C. Tape under 6% elongation)



General Notes On Taping Bus Bars

1. PVC Tape shall not be used on bus bar voltages exceeding 6,000 volts.
2. Do not wrap bus below temperatures of 32°F unless arrangements are made to warm tape or bus before applying.
3. Tape to meet NSP Company tests on PVC Tape of Sept. and Oct. 1955
4. In the application of the tape apply just sufficient tension to the tape so that it is firm on the bus bar. Never over stress the tape.
5.. At the joints and tee connections, use Kearney Air Seal filler compound to make a uniform surface over which to tape.
6. Use narrower widths and thicknesses of tape at the joints and irregular surfaces because of its greater flexibility.

General Notes On Fireproofing Bus Bars

1. All bus bars should be fireproofed on voltage above 600 volts with a covering of 1 layer 1/2 lapped of asbestos tape.

Reference drawings

1. For terminating bus bars see other drawings.

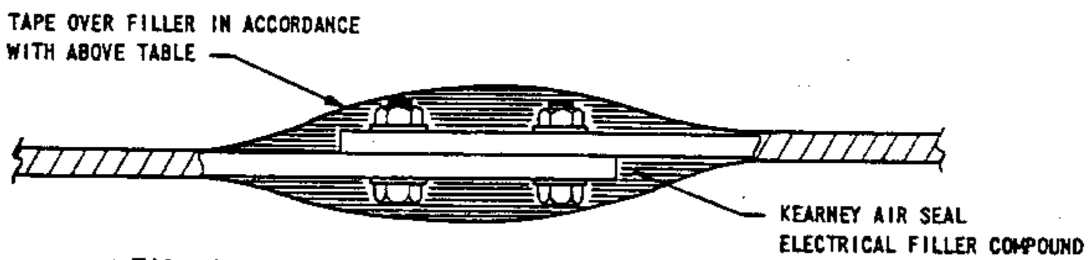
Width and Thickness Of PVC Tape
3/4" - 7 mil (Scotch electrical #88)
1" - 20 mil (Scotch electrical #21)
1/2" - 20 mil (Scotch electrical #21)

Bus & Connections - taping bus bars with polyvinyl chloride (PVC) Tape

Thickness and number of layers of 10 mill (.01") varnished cambric tape for taping bus bars

	FULL VOLTAGE TAPING		FLASH VOLTAGE TAPING	
VOLTAGE	MILS	ONE HALF LAPPED	MILS	ONE HALF LAPPED
0 to 600	140	7 layers (14 thicknesses)	20	1 layers (2 thicknesses)
601 to 4000	140	7 layers (14 thicknesses)	40	2 layers (4 thicknesses)
4001 to 7000	160	8 layers (16 thicknesses)	40	2 layers (4 thicknesses)
7001 to 8000	180	9 layers (18 thicknesses)	60	3 layers (6 thicknesses)
8001 to 11000	200	10 layers (20 thicknesses)	60	3 layers (6 thicknesses)
11001 to 12000220	10 layers (22 thicknesses)	80	4 layers (6 thicknesses)	
12001 to 14000240	12 layers (24 thicknesses)	80	4 layers (8 thicknesses)	
14001 to 15000260	13 layers (26 thicknesses)	100	5 layers (10 thicknesses)	
15001 to 25000420	21 layers (42 thicknesses)	140	7 layers (14 thicknesses)	

THE ABOVE TAPING IS BASED ON THE FOLLOWING:
Full voltage taping is I.P.C.E.A. recommended thickness of V.C Tape for one conductor cable 1000 MCM and larger. Flash voltage taping is 20% of acceptance test voltage when tape is under tension (Acceptance test voltage is 900 volts per mil when tape is under 6% elongation)



GENERAL NOTES ON TAPING BUS BARS

1. Varnished cambric tape used on bus bar voltages up to 25,000 volts.
2. Use high quality insulating varnish between each layer of varnished cambric tape on voltages above 4160 volts.
3. Varnished cambric tape to meet NSP Co. Material standard No. 51
4. At joints and tee connections use Kearney Air Seal-to make a uniform surface over which to tape.
5. Use narrower widths of tape at joints and irregular surfaces because of its greater flexibility.

General notes on fireproofing bus bars

1. All bus bars insulated with varnished cambric tape should be fireproofed with a covering of 1 layer 1/2 lapped of asbestos tape. Fireproof all voltage bus bars with full voltage taping or flash voltage taping.

Reference drawings

1. For terminating bus bars see other drawings
   Varnished cambric tape
   2 inch
   4 inch
   6 inch

Taping bus bars with Varnish Cambric tape

Equipment Installation of Test Link

1.0 Scope

This document serves as an application guide for the installation of test links on substation power transformers.

2.0 General

Substation power transformers are equipped with test links to facilitate isolation of transformers for Doble tests. Transformers are Doble tested both on a routine basis (except in Wisconsin) and under emergency conditions. Tests are performed to determine insulation power factor and dielectric loss characteristics. Maintenance tests are done at two year intervals with the results recorded. Historic data can then be used to detect and/or foresee insulation deterioration before a catastrophic failure occurs.

The justification for installing test links is based on the following criteria:

2.01 Labor man-hours required to disconnect and remake terminations to the transformer bushing is significantly reduced. This savings in man-hours is associated with high ampacity connections (multiple conductors) and/or rigid bus connections. These connections are generally difficult to work with and can also require a considerable amount of joint surface preparation. Test links, however, can be operated with minimal effort and preparation.

2.02 Test links can be effectively used to eliminate the need for a bucket truck. Normally, a bucket truck would be required when the height of the connection is such that the terminations cannot be easily reached by hand while standing on top of the transformer tank. Since test links can be opened and closed with minimal effort it is acceptable practice to stand on the lower portion of the transformer bushing skirts to reach the test links. It is also possible to have a local troubleman operate the test links since very little time is required. Neither practice, however, is acceptable when disconnecting and remaking bolted connections.

2.03 Test links also provide a safe and reliable method of disconnecting the transformer leads. Again, this is true mainly for high ampacity connections. The rigidness and inherent strains associated with tubular bus can cause it to ‘snap’ apart when disconnected. This can result in equipment damage as well as being a personnel safety hazard. Flexible leads consisting of multiple large conductors are heavy enough to crack or chip a bushing skirt if dropped while working on termination. The probability of a bad connection also increases if the terminations have to be redone every time Doble tests are made. All of these problems are virtually eliminated with the use of test links.

3.0 Physical considerations

Some of the physical design factors influencing the use of test links are the number, size and type of connecting lead conductors, the height of the transformer bushings, and the location of disconnect switches and connections to surge arresters. Each of these factors are discussed in detail below.

3.01 **Rigid bus conductors:** In general, all transformer bushing connections utilizing rigid leads at 115 kV and above should have test links unless transformer -disconnect switches can be used for isolation as covered in section 3.04. The height of the bushing coupled with the bus rigidity make these connections difficult to work with. Installation at 69 kV and below should be considered individually. If the bus is flexible enough to allow an insulating block to be wedged between the bus and bushing terminal pads, then test links would not be required. Approximate lengths of unsupported bus required to provide this flexibility are as follows:

ASA Schd. 40 Pipe Size	Minimum Unsupported Span Length-Feet
1”	5
½”	7
2”	9
2 ½”	12
3”	15
3 ½”	17
4”	20
5”	25

This rule applies only to those connections expected to carry load currents of less than 2000 amperes. In other words, it is intended that this rule be applied to installations where rigid conductors are used due to physical conditions and not for ampacity requirements. The rigidity of the conductor would make it difficult to effectively prepare the joint for reconnection. Poor joint preparation can lead to hot spots and eventual failure. This is of particular concern with high ampacity connections since they are commonly designed for 40°C temperature rise conductors and as such are subject to more severe cycling.

3.02 **Multiple conductor leads:** Test links should be installed on all multiple conductor leads rated 2000 amperes and above unless disconnect switches can be used for isolation in accordance with section 3. This is partly justified based on the reduction of labor man-hours associated with joint preparation. These connections require twice as much surface area (generally two 4-hole lugs rather than one 4-hole or two 2-hole lug) as lower ampacity circuits. Additional care must also be taken when making a high ampacity connection to prevent hot spots from developing. Approximately 4 man-hours on each three-phase connection can be saved with the use of test links for this type of installation. This results in a decrease in maintenance expenditures over the life of the transformer (35 years) equivalent to approximately half of the installed cost of the test links.

This reduction in expenditures coupled with a lower probability of joint failure and/or equipment damage provides sufficient justification for installing test links on high ampacity multiple conductor terminations.

3.03 **Height of bushing:** For low ampacity (below 2000 ampere), non-rigid lead conductors, the height of the bushing is a determining factor in whether or not test links should be installed. Bushings for use on 161 kV system and below are short enough (less than six feet from mounting flange) for a person to effectively work with a connection while standing on the transformer tank. Test links are not normally required on such installations. Bushings rated 230 kV and above, however, would require a bucket truck if full joint preparation is necessary. Test links should therefore be used on these installations unless disconnect switches can be used for isolation in accordance with section 3.04 below.

3.04 **Disconnect switches:** The location or use of transformer disconnect switches at 34.5 kV and below has no impact on whether or not test .links should be installed. Even though the disconnect switch (or switches) can be opened to isolate the transformer from the rest of the system, it does not provide sufficient isolation for testing purposes. The switch insulators are too short (creepage distance) to provide the necessary insulation from ground for the Doble tests. Therefore, even with the switch open, the bushings connections would have to be removed for accurate test results.

At 69 kV and above, however. The switch insulators are sufficient height so that they would have only a negligible affect on the tests. Therefore, if a disconnect switch is located close enough to the transformer (25 feet or less to limit electrostatic interference and there are no intermediate bus supports, then test links would not be required.

Those installations where the leads to the transformer surge arresters can be readily disconnected without the use of a bucket truck. This would cover all installations at 161 kV and below when the surge arrester connections are made with hot-line clamps. This would not generally be true for installations above 161 kV or for those installations utilizing rigid lead with fixed connections to the surge arresters.

4.0 Location of test links

Test links should normally be installed on the transformer bushings. This makes them accessible from the top of the transformer.

If the design of the substation is such that a bucket truck will normally be required for Doble tests, the test links can be cantilevered off the rigid bus rather than on the bushings. This is acceptable at 500 kV installations since a bucket truck is required because of the bushing height. This practice may also be acceptable at lower voltages because of unique physical designs.

5.0 Application chart

The application chart shown in Figure 1 is based on criteria Outlined in the previous sections. It is expected that this chart can be applied for most installations. Unique equipment or substation designs may preclude the use of this chart. Such cases shall be reviewed with the physical design engineer to determine if test links are required.

SUBSTATION DC SYSTEMS

This document describes NSP's present practices with respect to direct current (DC) systems, in substations. Generally, a DC system consists of a substation battery, a charger, and a delivery system for equipment requiring DC power in substations. This document is not intended to be fully comprehensive or limiting in regard to the application and protection of the DC systems.

1.0 GENERAL

The DC system supplies power for the circuit breakers, motor operated switches, instrumentation, emergency lighting, communications, fire protection system, annunciators, protective relaying and fault recorders at substations.

A standard DC system consists of three major components: a battery, a charger, and a distribution system. Normally, the battery is float charged by the battery charger. That is, the battery charger supplies all the continuous DC load connected to the bus and powers the battery in order to maintain it in a full state of charge. Under normal conditions, the battery does not supply any load but is held in the fully charged condition, ready to supply the DC loads for continuous operation or simultaneous tripping events if all AC sources to the battery charger are lost.

2.0 BATTERY SELECTION CRITERIA

When selecting a battery based on capacity and/or performance, it is of great importance that all applicable criterion is reviewed to insure that the most reliable, cost affective battery has been selected for the life of the installation. All batteries exhibit different operating characteristics.

Factors to consider:

- Load on the DC system when the maximum output of the battery charger is exceeded.
- Demand on the battery when the output of the charger is interrupted.
- Duration of the battery carry over, when auxiliary AC power is lost.
- Battery Life - What is the projected minimum life of the installation?
- Cost/Reliability - What was the cost and quality of the battery initially selected?
- Operating Temperatures - Will the battery be subjected to temperature extremes?
- Maintenance Intervals - The overall reliability of the battery depends on proper maintenance.
- Location - Will the battery be located where required maintenance can be completed? Is the battery properly ventilated? Will any associated equipment be susceptible to damage from corrosive lead acid fumes?
- Cycle life - Will the battery be required to perform numerous charge/discharge operation throughout its life. Certain batteries are not conducive to repeated discharge/charge cycles.
- Vibration/Shock - Will the battery be located near rotating equipment? Lead-acid batteries easily shed their active materials from the surface of the plates, affecting battery life.
- Weight/size - Physical size and weight can play a significant role in determining the type of battery to be selected. Is there enough room for the battery and rack in the proposed location?

3.0 LEAD ACID BATTERY

Lead-acid batteries in various forms are currently in use at NSP, including: Wet cells (Lead-Selenium, Lead-Calcium, Lead-Antimony) and Valve-Regulated Sealed Batteries.

Lead-acid, "wet cell" batteries, use lead plates immersed in a water diluted solution of sulfuric acid, to produce electricity. Lead-peroxide, which is the active material on the positive plate when charged, reacts with the pure lead in the negative plate, through the electrolyte, to create the electric discharge. The chemical reaction results in the conversion of the active material to lead sulfate on each plate.

Present design of the plates, both positive and negative, use grids made from lead alloys. The grids contain small amounts of either selenium, antimony or calcium to provide strength. The amounts of these materials in the lead are small enough to preserve the good electrolytic properties of the lead. When the grids are filled with lead compounds in a paste form, they are called pasted plates. If the positive grids use pure lead with the surface area increased by mechanical means, they are called Plante' plates, after the inventor, Plante'.

The valve-regulated, sealed lead-acid batteries in use by NSP, are of the absorbed glass mat design. These batteries have the positive and negative plates separated by a highly porous fiberglass mat that contains the required electrolyte to deliver the desired capacity. The other valve-regulated, sealed lead acid battery available is a gel cell. These batteries have the lead plates surrounded by a gelled acid solution that provides the electrolyte to deliver the desired capacity. This type of battery is commonly referred to as "sealed" or "maintenance free". Both of these terms are incorrect because they are valve-regulated (not sealed) and they require, at minimum, annual routine inspections.

The valve-regulated batteries that are currently in limited use on NSP's system are being evaluated by the Electric Maintenance and Protection Department. At this point the valve-regulated batteries are only being purchased in special circumstances. The Electric Maintenance and Protection Department should be consulted before any new valve-regulated, sealed lead-acid battery systems are purchased. It is expected that at some point in the future, if the evaluation of the original valve-regulated batteries is positive, that additional valve-regulated systems will be purchased.

4.0 BATTERY SIZING

Three basic factors determine the size of the battery: 1) Minimum System Voltage, 2) Maximum System Voltage and 3) The Load Profile. Since substation batteries are composed of a number of cells connected in series, the voltage of the battery, is the voltage of a cell times the number of cells in series. The capacity of a battery, is the same as the capacity of a single cell, which depends upon the size and number of plates.

4.1 Maximum and Minimum DC System Voltage

The normal DC operating voltages at NSP are: 27 volts, for 24 volt nominal systems, 52 volts, for 48 volt nominal systems and 130 volts, for 125 volt nominal systems. The float voltages (voltage in the nominal charged condition) for an individual cell will vary from approximately 2.17 volts per cell to 2.25 volts per cell depending on the type of battery. In most cases, these batteries are equalize charged (continuation of the regular charge at a higher voltage to bring the battery back to a fully recharged condition) at approximately 2.33 volts per cell.

The number of cells connected in series is based on the required minimum and maximum voltages of the battery load. Currently, NSP is purchasing lead calcium and lead selenium battery systems whose individual nominal cell voltage is approximately 2.25 volts per cell. These batteries require 12 cells for the 24 volt system, 23 cells for the 48 volt system and 58 cells for a 125 volt system. Some older installations, where lead-antimony batteries (2.17 volts per cell nominal) were used have 24 cells for 48 volt DC systems and 60 cells for 125 volt systems.

The maximum acceptable cell voltage is approximately 2.40 volts per cell. At this point excessive battery gassing (evolution of hydrogen and oxygen) occurs and the maximum voltage limits of the connected equipment is approached. The minimum voltage for these battery cells is typically 1.75 volts per cell, which is normally considered fully discharged. As the voltage falls to this level the ability of connected equipment to operate may become questionable. Typically, breaker trip coils will operate at half their rated voltage but other DC operated equipment may not function properly at or around 1.75 volts per cell. Make sure to check connected equipment ratings if there are any questions.

The voltage of the battery is calculated by using the following formula:

$$(Voltage\ of\ the\ Cell) * (\#\ of\ Cells\ in\ Series) = Battery\ System\ Voltage$$

The number of cells and the end voltage of a battery system can be calculated using the following formulas:

$$Number\ of\ Cells = \frac{Max.\ Allowable\ Battery\ Voltage}{Max.\ Cell\ Voltage\ Required\ for\ Charging} = 58 Cells = \frac{140V}{2.40Vpc}$$

$$End\ of\ Voltage = \frac{Min.\ Allowable\ Battery\ Voltage}{Number\ of\ Cells} = \frac{1.75 Volts}{Cells} = \frac{101.5V}{58}$$

4.2 LOAD PROFILE - Sizing Criteria

At NSP, substation batteries are usually sized to operate during a "Worst Case" tripping event after a 12 hour blackout. The "Worst Case" event consists of a fault occurring somewhere in the substation and while attempting to clear, a single breaker fails to open (single contingency), causing additional breakers to operate. The scenario that causes the most current to be drawn from the battery is considered the "Worst Case" event. The engineer must randomly place faults at different locations in the substation and add up the DC loads, until the "Worst Case" is found. Often this "Worst Case" scenario occurs during a transformer fault.

The load profile typically associated with NSP substations consists of a continuous load (Ic) that starts on loss of ac (black-out), and lasts **11 hours and 59 minutes**. At that point, a momentary load (Im) occurs from the tripping of equipment and lasts for one minute.

The operation of DC equipment in any substation may consist of a different load profile than that assumed here. It is the responsibility of the individual sizing the battery to investigate the DC loads connected to the battery and develop a new "Worst Case" load profile.

TYPICAL NSP SUBSTATION D.C. LOAD PROFILE

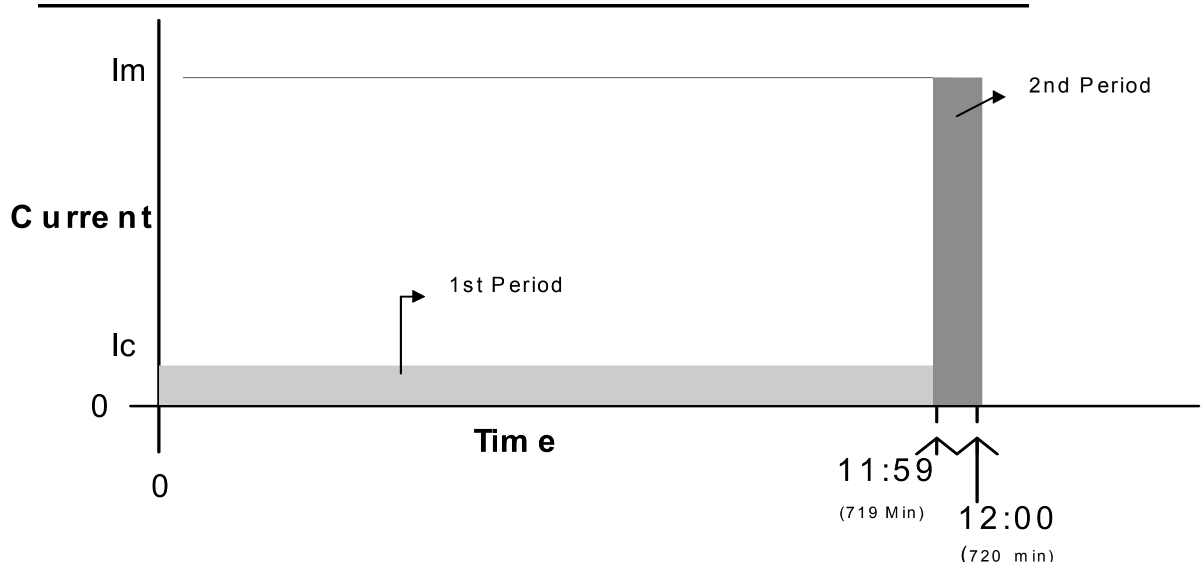


Figure 1

The following is the basic formula used by Substation/Transmission Services to size substation batteries with the load profile in Figure 1: This formula is consistent with IEEE 485-1983 for sizing a battery with two load periods.

$$C = \left[\left(\frac{Ic}{TCF}\right) * K_T + \left(\frac{Im}{TCF}\right) * * K_T \right] * [\,AF\,] * [\,DFEM\,]$$

Where : C = Ampere our capacity (at the 8 hour rate)

K_T = "K_T" value, (Constant from manufacturers data)

Im = Momentary current (less than 1 minute)

Ic = Continuous current

TCF = Temperature Correction Factor to 55°F

AF = Aging Factor

$DFEM$ = Design and future equipment margin

"K_T" is the ratio of rated ampere hour capacity at a standard time rate, at 25°C (77°F), to a standard end of discharge voltage of a cell, to the amperes that can be supplied by that cell for "T" minutes at 25°C.

4.2.1 Continuous loads (Ic) - Loads that the substation battery would have to carry throughout the duty cycle once the battery charger quits operating. This is the load typically carried by the battery charger when it is operational. (Example: indicating lights, continuously energized coils, relays, carrier equipment, etc.) When replacing an existing battery, the continuous load used for sizing can be taken from the ampere meter on the existing charger. If the continuous load is being calculated, then all loads connected to the DC cabinet must be included.

Typical Continuous DC loads (engineer to verify for each specific device)

- Line relay = 3 amps
- Annunciator = 2 amps
- Telephone = 0.5 amps
- Data retrieval = 3 amps

4.2.2 Non Continuous Loads - Loads that are energized only during a portion of the duty cycle and may come and go for any length of time. (Example: generator pump motors, emergency lighting). This type of load is not typically seen in NSP substations. There may be some cases (plant batteries) when a "non-continuous" load needs to be incorporated into a DC load profile.

4.2.3 Momentary loads (Im) - Loads lasting for short time periods, usually less than 60 seconds. Loads lasting less than 60 seconds, are considered to last a full minute, even if the duration is for only a few seconds. This is because the voltage drop of the battery for a given momentary load of only a few seconds, is essentially the same as the voltage drop for that same load, after one minute. For NSP substations a worst case tripping scenario must be found and the amount of current that each trip coil and motor will draw during this event must be calculated.

4.2.3.1 Breakers - Use trip coil ratings. Typically, breakers with two trip coils will have them both energized during a worst case event (primary and secondary relaying). Thus, when adding the number of breakers that will operate and the amount of current that will be drawn, make sure you assume both trip coils being energized. Trip Coil ratings range from 3-100 amperes.

4.2.3.2 MOD's - Use the locked rotor current when defining the momentary current drawn for MOD's. This value is used because the worst case scenario is when the switch is asked to open and hesitates because it's covered with ice. Typical values for locked rotor current will run from 10 - 60 amperes.

4.2.3.3 Base Load - An additional 20 amperes of "base load" should be added to the trip coil and motor currents to allow for the current used by control systems when clearing a worst case fault.

4.2.4 Aging Factor - ANSI/IEEE Std 485-1983 recommends that a battery be replaced when its actual capacity drops to 80% of its rated capacity. Therefore, the battery's rated capacity should be at least 125% of the load expected at the end of its service life. Currently, NSP does not use an aging factor when determining the size of its battery system. The reason is most of NSP's batteries are failing, for reasons other than age, after 12 to 14 years of service. It is felt, that at the present time it is not economically feasible to purchase additional battery capacity for a time frame, in the life of a battery, that the battery will probably never reach, due to other failures.

4.2.5 Design and Future Equipment Margin A design margin should be used based on the confidence of the load profile that was developed. It should also account for **less-than-optimum** operating conditions of the battery due to improper maintenance or recent discharge. A future equipment design margin should also be added based on the probability of additional DC load being introduced during the expected life of the battery. A typical design margin used in a substation where there is very little future DC load growth expected and a relative high confidence in the load profile exists would be 10%-20%.

4.2.6 Temperature Correction Factor When sizing a battery, the minimum and maximum temperatures that might be seen must be considered. Typically, the batteries that are bought for NSP substations are rated at 77°F at the eight-hour rate. As temperatures increase from 77°F, the available capacity increases and as temperature decreases the capacity decreases. Besides the change in capacity, there are side effects that occur as the temperature changes.

If temperatures in the area around the battery are expected to deviate from 77°F, then a temperature correction factor must be used. A temperature correction factor is required to select a cell large enough to have the required capacity available at the lowest expected temperature. Currently, NSP sizes the battery based on the assumption, that the minimum battery cell temperature will not drop below **55°F** during the "worst case" 12 hour black out in a substation. This is a difficult temperature to verify because cell temperatures have not been monitored for extended periods of time, in extremely cold weather when AC power is lost in the substation. Manufactures have gone as far as to saying that the cell temperature will lag ambient temperature changes by several hours. This is an item that needs to be addressed in the future, especially in NSP's northern substations.

The following temperature correction factor (TCF) table is used by NSP is sizing batteries.

Electrolyte Temperature °F	Electrolyte Temperature °C	Temperature Correction Factor	Electrolyte Temperature °F	Electrolyte Temperature °C	Temperature Correction Factor
25	-3.9	0.658	76.0	24.4	0.994
30	-1.1	0.699	77.0	25.0	1.000
35	1.7	0.741	78.0	25.6	1.006
40	4.4	0.769	79.0	26.1	1.013
45	7.2	0.800	80.0	26.7	1.020
50	10.0	0.840	81.0	27.2	1.025
55	12.8	0.870	82.0	27.7	1.029
60	15.6	0.909	83.0	28.3	1.033
65	18.3	0.926	84.0	28.9	1.037
66	21.1	1.040	85.0	29.4	1.042
67	19.4	0.940	85.5	29.7	1.046
68	20.0	0.947	86.0	30.0	1.050
69	20.6	0.954	87.0	30.5	1.055
70	21.1	0.962	88.0	31.1	1.059
71	21.7	0.967	89.0	31.7	1.064
72	22.2	0.972	90.0	32.2	1.075
73	22.8	0.977	95.0	35.0	1.090
74	23.3	0.983	100.0	37.8	1.136
75	23.9	0.989	120.0	48.9	1.163

TABLE 1

Note: A more detailed procedure for sizing substation batteries is described in the IEEE standard 485-1983. The method shown above is a simplified version of one of the two methods of sizing batteries that are outlined in IEEE 485-1983. NSP has preferred to use this simplified method for sizing substation batteries because of the simplistic load profile that is assumed for most substation application.

Application spreadsheets have been created and exist on the LAN to assist in calculating the size of the battery.

M:\ENG\BATTERY\BATPROF.XLS	Calculates the size of battery and battery charger required based on load profile.

5.0 BATTERY RACKS AND CELL PLACEMENT

5.1 Battery Racks

The main concern with battery racks should be to reduce height variations between upper and lower racks. Height variations will cause differences in cell temperatures within the same battery system. Since temperature can have such a drastic effect on battery characteristics, interconnecting cells at different temperatures can lead to an early failure of the battery system. As a general rule, temperature gradients in excess of 5 degrees Fahrenheit should be avoided.

When selecting a battery rack, there are several things including temperature differences, weight of the battery, available space and maintenance requirements that must be considered. A battery rack should be selected in the following order based on the constraints listed above.

1. **Single tier**
2. **Two step**
3. **Two tier**
4. **Three step**
5. **Three tier**
6. **Two step/tier**

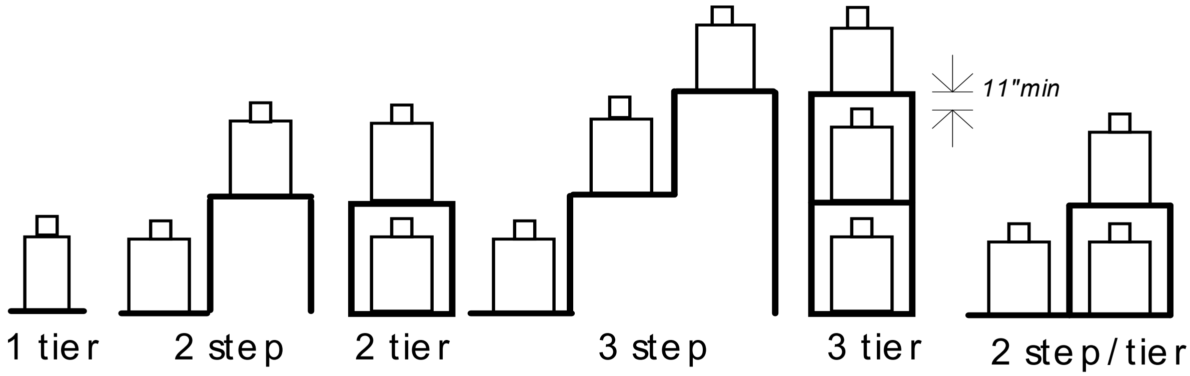


FIGURE 2

Single tier racks are preferred, because the battery is easily accessible for maintenance and installation. A single tier rack also ensures that the cells are held at a closer temperature. Maintenance prefers the use of step racks, instead of tiered racks. Often this is impossible because of the space limitations. When selecting a step rack make sure there is sufficient width available in the control house or battery room. Two and three tier racks are probably the most widely used at NSP because of space limitations in the control houses.

5.2 Battery Cell Placement

In general, the battery jars should be located 1 inch from the side supports of the battery rack and should be spaced approximately 1/2 inch from adjacent jars. When using two or three tier racks, maintenance requires at least 11 inches between the top of the battery and the bottom of the rack above the cell. The 11 inches, is the room required to place a hydrometer in the top of a battery when taking specific gravity readings.

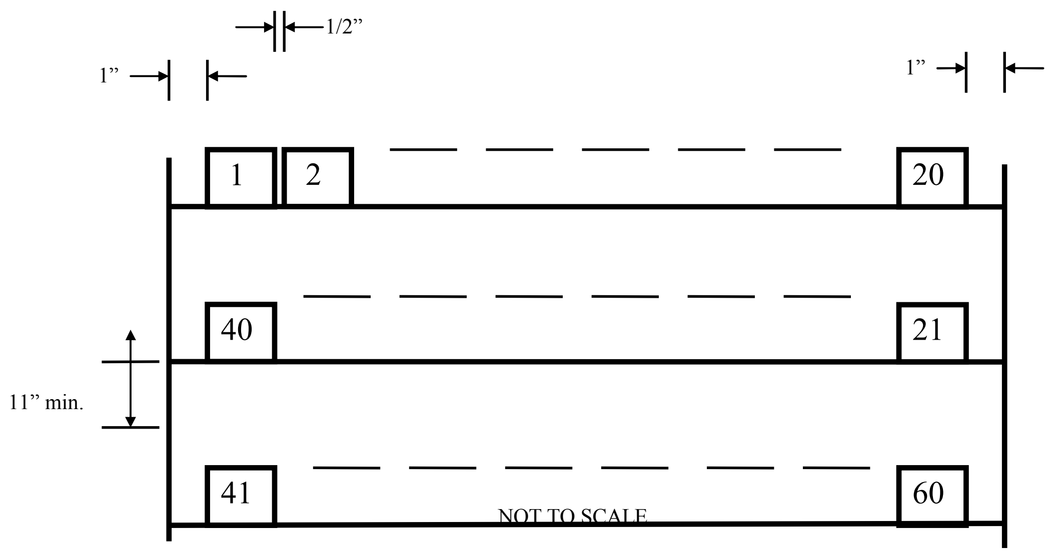


FIGURE 3

Once on the rack, the battery cells should be labeled such that the #1 cell is located in the upper left hand corner of the rack and should follow the convention in figure 3. The positive lead to the battery should also connected to the upper left hand (#1) cell and the negative lead should be connected to the lower right hand cell (see figure 6).

For many years, NSP fabricated its own battery racks. In recent times many of these racks have shown evidence of bowing in the middle, causing pressure on the post seals of the battery. Because of cost, ease of installation and stronger racks, NSP has been purchasing new battery racks directly from the battery manufacturer. See EE 1.2903 for information regarding the details and sizing criteria that were used in the past for these NSP fabricated battery racks.

6.0 GROUNDED VS UNGROUNDED SYSTEMS

NSP has two types of DC systems, **grounded** and **ungrounded**. Nominal voltage ratings for ungrounded DC systems in substations are 24 volt, 48 volt, and 125 volt DC. Grounded systems are typically seen only on older 48 volt batteries at NSP.

6.1 Ungrounded Systems

Most of NSP DC systems are of the ungrounded type. This means that positive and negative terminals are connected across all loads without using a station ground. Ungrounded systems are safer to use. Unintentional grounds can be easily detected by checking the voltage to ground from the positive and negative terminals. The location of battery main fuses should be installed as shown below.

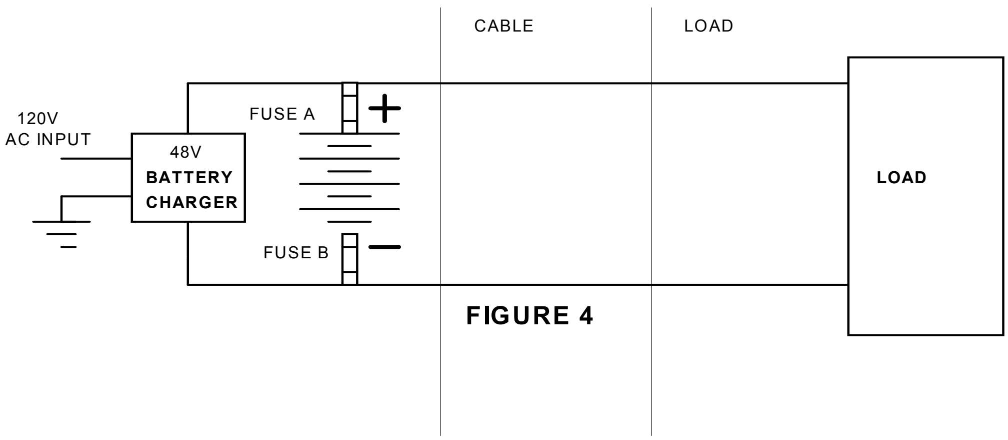


FIGURE 4

6.2 Grounded Systems

Some DC systems require a positive ground and some a negative ground. The ground is used to protect semiconductor devices from transients and noise. Radio noise is very high when an ungrounded chassis is used. This reduces the "signal to noise ratio" potentially causing the device to misoperate. A grounded system also makes it more difficult to locate unintentional grounds with de-energizing the load equipment. Wherever it is technically and economically possible, grounded DC systems should be avoided. Grounded DC systems should never be allowed where the load includes power circuit breaker trip coils.

Whenever a grounded DC system is unavoidable for electronic equipment the following procedures are recommended. The battery main fuses should be installed in both the positive and the negative main battery cables, at the battery end, as close as possible to the battery. The permanent ground should be installed at the equipment or load end, not at the battery end. Ground detectors need not be installed. A sign should be mounted on the battery charger, warning personnel that a grounded system is present. Battery leads must stay within the control house. (See CE 1.1100)

The location of battery main fuses and permanent ground should be installed as shown below.

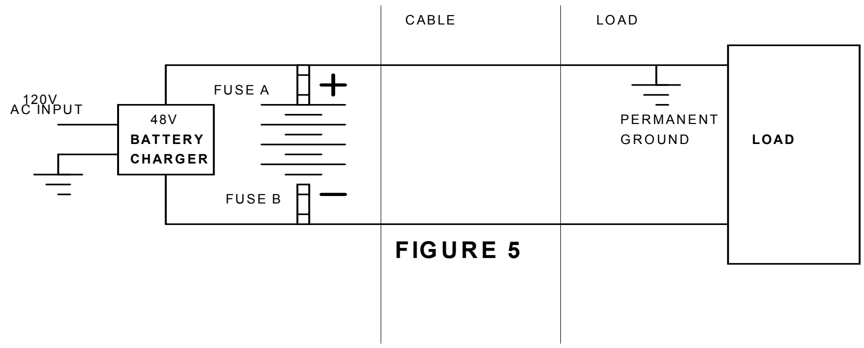


FIGURE 5

7.0 MAIN BATTERY FUSING

The battery main fuses protect the battery against faults in the cable between the battery and the DC fuse cabinet or against faults on the bus in the DC fuse cabinet. These fuses shall not be considered as backup protection for the branch fuses. The main fuses are sized to allow all but a solidly bolted fault to cause them to operate. This is to avoid the nuisance of blown fuses and keep DC power operating the control systems as long as possible. The fuse is also used as a disconnect point to isolate the battery when necessary. This is true for both grounded and ungrounded battery systems.

The main fuses should be placed in an individual cabinet and positioned on either both sides of the battery rack or next to each other on one side of the battery rack. The cabinet placement should be made by looking at the type of rack (two tier vs. three tier) and the physical constraints surrounding the battery (See examples in Figure 6).

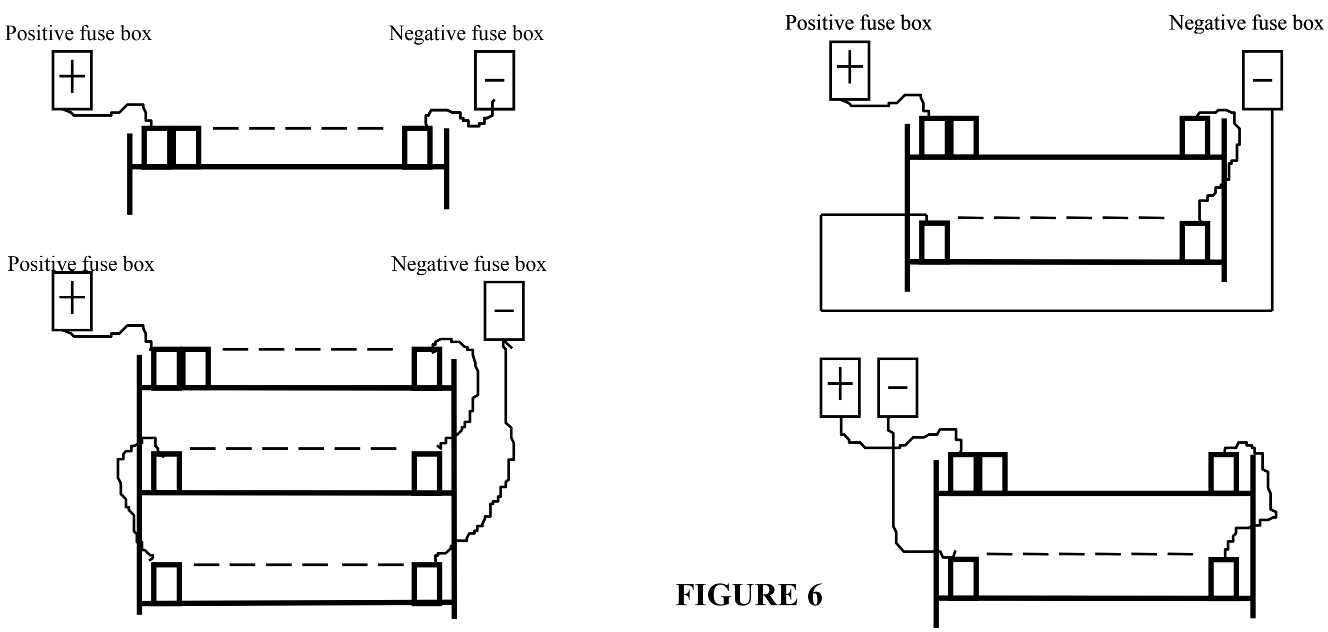


FIGURE 6

The fuse cabinets, based on one fuse per cabinet, shall be sized in accordance with the Table 2.

Fuse Block Size	Cabinet Size
31 - 60 Amp.	1'- 8" H x 8" W x 6" D
61 - 100 Amp.	1'- 8" H x 8" W x 6" D
101 - 200 Amp.	1'- 8" H x 8" W x 6" D
201 - 400 Amp.	2'- 0" H x 10" W x 6" D
401 - 600 Amp.	2'- 6" H x 12" W x 6" D

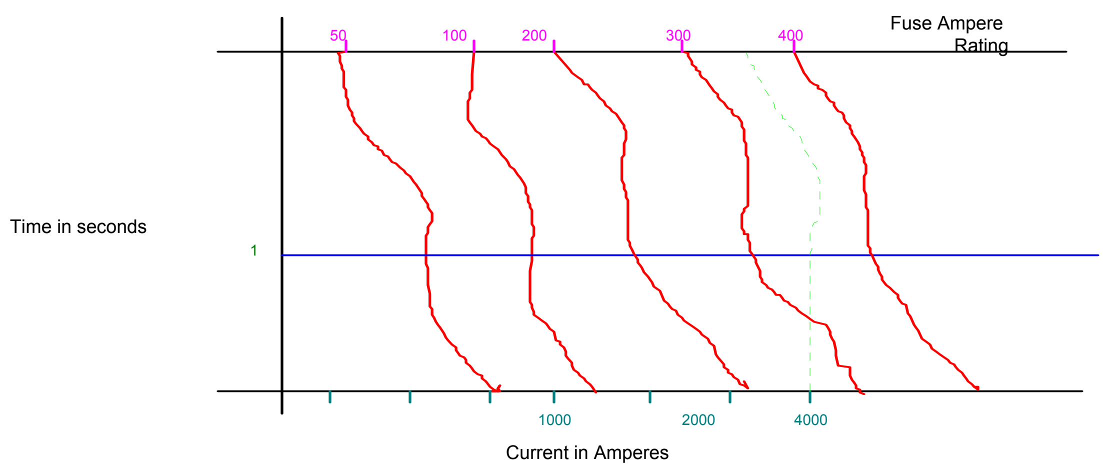
TABLE 2

The lead acid batteries that NSP purchases can produce fault currents from 7 to 12 times the 1 minute discharge rating of the battery. The battery can withstand the full fault current for more than a second without damage to the battery. NSP selects battery main fuses to operate in **one second for a fault 10 times the one minute discharge rating of the battery**. The main fuse should be selected from the time current characteristic curves for Bussman type FRN-R, 250 volt AC fuses. These fuses are fully UL listed for 125 volt DC.

EXAMPLE

BATTERY MANUFACTURER	TYPE	BATTERY SIZE	1-MIN. RATING	BOLTED FAULT	SELECTED FUSE TYPE
C&D	KCR-9	330 A.H.	404A	4040 A	FRN-R 250V/400A

Find the one minute current rating (to 1.75 v/c) of the battery (404A). Multiply the 1 minute rating by 10 (4040A) and locate this value on the time current characteristic curves for the FRN-R fuse. Find the intersection of the current value and the one second point on the graph. Follow the nearest curve to the top of the graph to locate the proper fuse size (400A fuse). If the curve ends between two fuse sizes use the larger of the two sizes. (See graph below)



SAMPLE TIME CURRENT CHARACTERISTIC CURVE

8.0 OVER & UNDER VOLTAGE ALARMS

Over and Under voltage alarms are set to give operating personnel a warning signal that something is not operating properly with the DC system. It is important that low and high battery alarms be set at voltages, which will indicate a battery warning and not give erroneous alarms. These alarms are typically sent to the annunciator panel and the RTU. See CE 1.0111 for current alarm requirements.

8.1 Low Voltage Alarm:

The low voltage alarm should be set at a voltage that indicates to the annunciator that the battery is beginning to discharge into the load. This is of concern since the battery voltage may drop quickly in the first hour after AC is lost. A battery starts to lose capacity quickly after it reaches 2V/cell. Little capacity is lost until the battery discharges to 2V/cell, that usually takes about an hour after the charger loses power.

8.2 High Voltage alarms:

The high battery alarm, when received, indicates an unstable voltage condition caused by the charging source. The high alarm should be set at a point where excessive battery gassing occurs or hydrogen over voltage begins. It is also set at a point to protect connected equipment from higher than recommended bus voltages.

The following high/low voltage ranges have been established for lead acid stationary batteries, intended for general substation use. It should be noted that the values are initial settings and can be varied if battery configurations or connected load requires another setting. The settings are intended to give an early indication of trouble but not unwarranted over-protection.

LEAD ACID BATTERY ALARMS

No of Cells Lead Acid	Low Voltage Alarm	High Voltage Alarm	Acceptable Range Low Voltage Alarm	Acceptable Range High Voltage Alarm
120	240	288	240 - 242	288 - 289
60	120	144	120 - 121	144 - 145
58	116	139	116 - 117	139 - 140
24	48	58	48 - 49	48 - 59
23	46	55	46 - 47	55 - 56
12	24	29	24 - 24.5	29 - 29.5
11	22	26	22 - 22.5	26.5 - 27

* Low battery alarm set at 2.00 volts per cell
* High battery alarm set at 2.40-2.41 volts per cell

9.0 DC CABLE SIZING - (From Battery to DC Cabinet)

The cable size for the DC distribution system depends on the acceptable voltage drop, continuous current rating and burn off characteristics (fault current).

9.1 Voltage Drop

Voltage drop is not normally a problem because the battery, charger and DC cabinet are usually in close proximity. If this is not the case, then the cable size should be investigated. See standard EE 1.3511 for further cable sizing information.

9.2 Continuous Current Rating

Since the continuous current delivered through the main battery cables, in almost all cases, is relatively small (≤ 20 amps) there is little concern with sizing the cable for continuous current. **This does not relieve the engineer from making sure the main battery cable is properly sized.**

9.3 Burn-off Characteristics

The available fault current from the lead-acid batteries that NSP buys is somewhere between 7 and 12 times the one minute rating of the battery. NSP uses 10 times the one minute rating to select the cable size and coordinate fusing.

The size of the cable from the battery to the main fuses and from the main fuses to the DC cabinet should be large enough to withstand the full fault current for a period of time long enough for the main fuse to blow. The main fuse is coordinated to blow for a bolted fault at approximately one second. The cable should be designed to carry the full fault current for a longer period of time, (approximately two to three seconds). Currently, NSP uses extra flex welding cable. This cable has excellent high current characteristics and is very flexible allowing tight bends and easy installation. The following are guidelines NSP uses for sizing this cable.

a) #1/0 rubber insulated extra flex copper welding cable for batteries 0 to approximately 350 A.H. (The 1 minute rating must be < 400 amperes)

b) #4/0 rubber insulated, extra flex, copper welding cable for batteries 350 to approximately 1000 A.H., (the one minute rating must be < 1200 amperes).

c) The conductor size for a battery over 1000 A.H., one minute ratings over 1200 amperes or with continuous current in the system over 40 Amps. should be reviewed with engineering.

10.0 DC CABINETS AND CONTENTS

10.1 DC Distribution Cabinets

All fuse cabinets must have doors hinged on the longest side of the cabinet. Cabinet dimensions depend upon the fuse and wire sizes. Those over 2'- 0" wide must have double doors similar to the Telephone Equipment Cabinets shown on master drawing NH-59197. Conductors normally enter from the top and/or bottom. Master drawings NH-57687 (for steel cabinets) and NH-59208 (for aluminum cabinets) are used for design and ordering information.

The following is a list of standard size dc distribution cabinet drawings:

50 Position (Alum) - NH-94258
50 Position (Steel) - NH-94259
34 Position (Alum) - NH-94260
34 Position (Steel) - NH-94261

10.2 Fusing

Branch type circuits with motors shall use time-lag type FRN fuses. All other circuits should use one-time, type NON fuses which are sized according to the load. Normally, the wire size shall be based on the fuse size and voltage drop. (See Engineering Design Std. EE 1.3511 and Control Engineering & Design Std CE 1.0803).

All fuses 60 amps and below, including those for outdoor boxes, are supplied and installed by the field according to the Schematic Diagram. However, so that they are not overlooked, they should be included in the material list as one item, to be ordered "By Field" and described as "Fuses per Schematic Diagram". No quantities are required.

10.3 Cables Originating from the DC Cabinets

The main supply cables should be sized for the load that they carry. In some cases, DC must be provided across very long distances (Example: to a MOD in a remote corner of a very large substation). In these cases, the voltage drop should be calculated so the correct size cable can be selected to provide proper voltage to the equipment being served.

The nominal voltage and the permissible ranges for the DC distribution system for switching and interrupting devices are as shown. (ANSI C37.16-1980). Check each individual piece equipment for its specific electrical ratings.

Rated Voltage	Voltage Range
24 VDC	14 - 28 Volts
48 VDC	38 - 56 Volts
125 VDC	105 - 130 Volts

11.0 BATTERY CHARGER

Battery chargers convert AC into a regulated DC output, which is used to charge the battery and to supply all continuous loads connected to the bus. The standard nominal AC input, is single-phase, 240 volts. Some older installations have a single-phase, 120 or 108 volt AC input. There are a few chargers that operate from 480 volts, three-phase sources. These are typically chargers with DC outputs of 50 amperes or greater.

The battery charger can tolerate AC input voltage variations of $\pm$ 10%. Nominal DC output voltages are: 27 volts, 52 volts, and 130 volts DC and are normally regulated to within $\pm$ 1%. The DC output of battery chargers normally contains a ripple voltage superimposed on the average output voltage.

In nearly all substation installations the battery chargers are required to supply "float" and "equalizing" voltage for the battery. The "float voltage" is the voltage required to maintain the battery in a fully charged condition, compensating for the internal losses in the battery. The equalizing or high charging voltage is required to **recharge the battery to 95% of full charge within 12 hours after a discharge**. The charging voltage is normally set at 2.33 v/cell (for lead calcium batteries).

The equalizing charge voltage is used to equalize the cell voltage of the battery. Because not all cells charge at the same rate, the voltages of the individual cells can be higher or lower then the average voltage, even though the battery terminal voltage is normal. A longer charging period, at elevated voltage, helps to correct low capacity cells and even out their voltages. Equalizing of lead selenium, lead calcium, or the valve-regulated type battery system is normally not required. Each battery manufacturer has specific instructions regarding equalizing voltage and time to satisfy their design.

11.1 BATTERY CHARGER SIZING

The battery charger is sized to recharge the battery to **95% of full capacity within 12 hours.** The charger is sized with the following formula:

$$\left(\frac{A}{t}\right)g + Ic = I$$

I	=	Calculated charge (amps) of the battery charger
A	=	Size of the battery to be charged (Amp-hours at 8 hour rate)
t	=	Time (typically 12 hours for substations)
Ic	=	Continuous current. This is the same as Ic used to size the battery
g	**=**	Growth factor (typically 1.15)

The following are some items that should be obtained to properly size a battery using the IEEE Method:

- Sequence of the load on a battery during a worst case tripping event
- Number of circuit breakers & MOD's that will operated
- Individual breaker trip and close currents
- Individual MOD motor currents and run time
- Individual breaker trip and close times
- Individual breaker spring recharge current (if the breaker uses DC motor)
- What is the continuous load current (from the battery charger)?
- Is there emergency lighting? What are the load and time duration?
- What is the minimum and maximum system DC voltage?
- What is the design margin?
- What is the aging factor?
- What are the minimum and maximum temperature ranges?

12.0 MAINTENANCE

This section will be added to in future revisions.

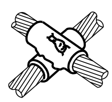
13.0 TOPICS TO BE DISCUSSED IN FUTURE REVISIONS OF THIS DOCUMENT

- NESC Rules
- Remote monitoring and testing of battery systems.
- Specification for sealed batteries
- Vendor partnering
- Sizing batteries and chargers in “Black Start” substations.

LIST OF MATERIAL FOR THESE DETAILS (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43		4/0 CU. CABLE, 19 STRAND	265		CADWELD SHOT 65, COLOR DARK GREEN
261		GROUND ROD, ¾" × 10′ LONG	266		CADWELD SHOT 115, COLOR ORANGE
262		GROUND ROD COUPLING, ¾" DIAMETER	267		CADWELD SHOT 150, COLOR DARK BLUE
263		CADWELD LUG TYPE GL	268		CADWELD SHOT 200, COLOR YELLOW
264		CADWELD SHOT 45, COLOR LIGHT BLUE	269		CADWELD SHOT 250, COLOR PURPLE

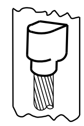
269 4/0 TO 4/0
268 1/0 TO 4/0



DETAIL "A"

TYPE "XB" MOLD
HORIZONTAL X-CONNECTION,
LAPPED

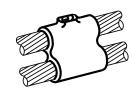
267 4/0
266 #4



DETAIL "B"

TYPE "VB" MOLD
CABLE DOWN TO STEEL
NOTE: DIFFERENT DIES REQUIRED
FOR ROUND & FLAT SURFACES.

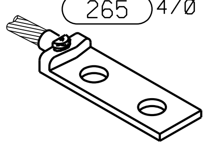
267 4/0 TO 1/0
268 4/0 TO 4/0



DETAIL "C"

TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

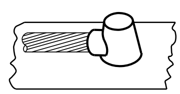
263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"

TYPE "GL" MOLD
CABLE TO LUG

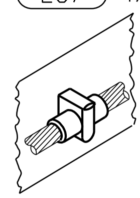
266 4/0 (TYPE "HS")
264 #4 (TYPE "HA")



DETAIL "E"

TYPE "HA" AND "HS"
CABLE TO STEEL
NOTE: DIFFERENT DIES REQUIRED
FOR ROUND & FLAT SURFACES.

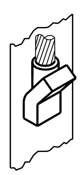
267 4/0



DETAIL "F"

TYPE "VT" MOLD (VTC-2Q-001)
CABLE TO STEEL OR CU.
(THRU CONNECTION)
USE BACKING PLATE ON CU BAR

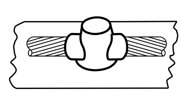
268 4/0
265 #4



DETAIL "G"

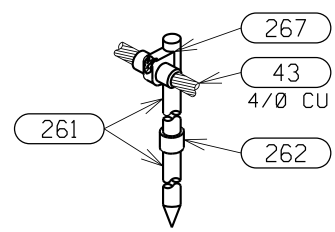
TYPE "VF" MOLD
CABLE UP TO STEEL
NOTE: DIFFERENT DIES REQUIRED
FOR ROUND & FLAT SURFACES.

264 #4



DETAIL "H"

TYPE "HC" MOLD
CABLE TO PIPE THRU CONNECTION
(ERICO CAT #XLHCA-1L-(PIPE SIZE)
ADD PIPE SIZE AT END OF CAT
NUMBER. EXAMPLE: XLHCA-1L-2)



DETAIL "J"

TYPE "GY" MOLD
HORIZONTAL THRU CABLE
TO ¾" GROUND ROD

FIELD NOTE:

- FIELD TO ORDER ALL CADWELD MOLDS, IGNITORS, BRUSHES ETC.
- DESIGNER TO ORDER CADWELD SHOTS ONLY.
- FOR COMMONLY USED MOLDS AND ACCESSORIES SEE XCEL ENERGY STD ED 4.03.02.01.

LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-1

SUBSTATION GROUNDING DETAIL

CADWELD MOLD TYPES AND SHOT REQUIRED FOR EACH MOLD

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy®

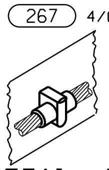
SCALE	DRAWING NO.	REV
NONE	NL-200902-1-1	F

200902-1-1.DGN

9/19/2013 7:47:34 AM

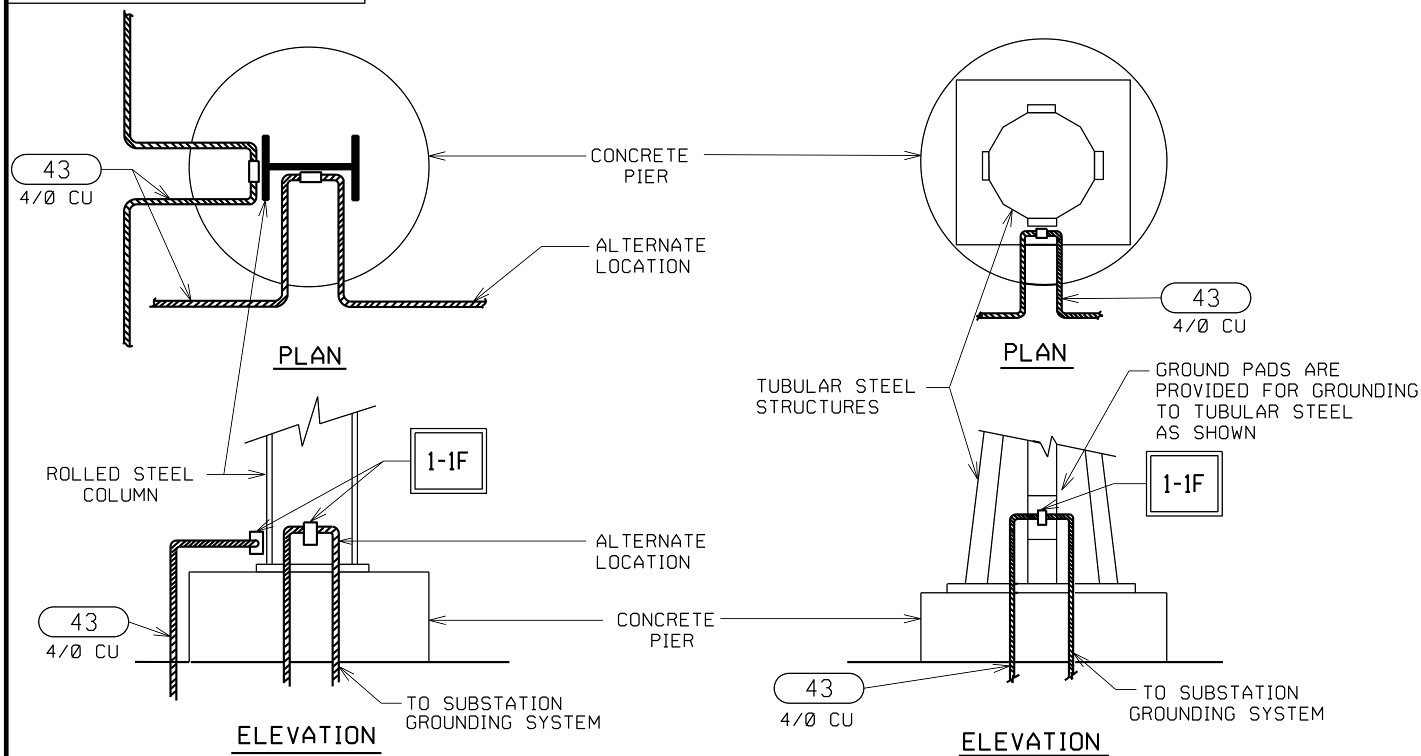
MATERIAL REQUIRED FOR CONNECTION TO ONE STRUCTURE					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43		4/0 CU CABLE, 19 STRAND			
267	1 EA	CADWELD SHOT 150, COLOR DARK BLUE			

267 4/0



DETAIL "F"

TYPE "VT" MOLD (VTC-2Q-001)
CABLE TO STEEL OR CU.
(THRU CONNECTION)
USE BACKING PLATE ON CU BAR



ROLLED STEEL GROUNDING

TUBULAR STEEL GROUNDING

FEILD NOTE:
- STEEL COLUMN MAY HAVE TO BE TOUCHED UP WITH GALVANIZED PAINT AFTER CONNECTION IS MADE.
- LOCATION OF WELD DETERMINED BY CONSTRUCTION.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-2
SUBSTATION GROUNDING DETAIL
GROUNDING FOR SUBSTATION STEEL STRUCTURES

Xcel Energy®

SCALE: NONE

NL-200902-1-2

REV: D

200902-1-2.DGN

9/19/2013 7:52:10 AM

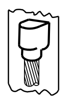
MATERIAL REQUIRED FOR SWING GATE

ITEM NO.	QTY	DESCRIPTION
43	4 FT	4/0 CU CABLE, 19 STRAND
267	3 EA	CADWELD SHOT 150, COLOR DARK BLUE
268	1 EA	CADWELD SHOT 200, COLOR YELLOW
C174	4 FT	4/0 CU INSULATED WELDING CABLE

MATERIAL REQUIRED FOR BARBED WIRE

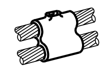
ITEM NO.	QTY	DESCRIPTION
43	4 FT	4/0 CU CABLE, 19 STRAND
53	3 FT	#4 SOLID CU. WIRE
111	3 EA	SPLIT-BOLT CONN. FOR #4 CU.
264	2 EA	CADWELD SHOT 45, COLOR LIGHT BLUE
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN
266	1 EA	CADWELD SHOT 115, COLOR ORANGE
267	1 EA	CADWELD SHOT 150, COLOR DARK BLUE
268	1 EA	CADWELD SHOT 200, COLOR YELLOW

267 4/0
266 #4



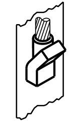
DETAIL "B"
TYPE "VB" MOLD
CABLE DOWN TO STEEL
NOTE: DIFFERENT DIES REQUIRED FOR ROUND & FLAT SURFACES.

267 4/0 TO 1/0
268 4/0 TO 4/0



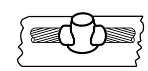
DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

268 4/0
265 #4

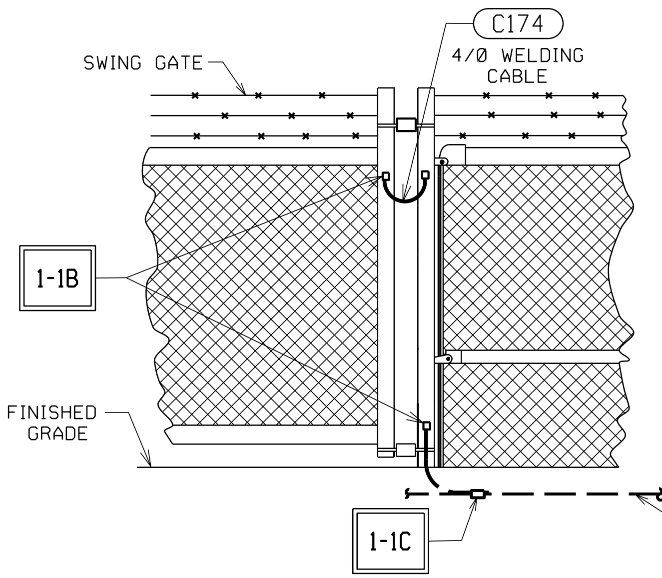


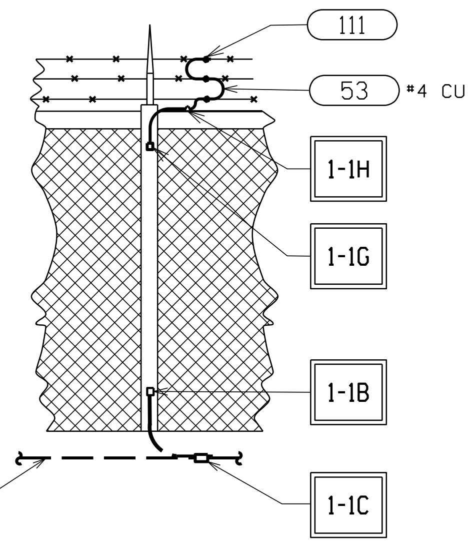
DETAIL "G"
TYPE "VF" MOLD
CABLE UP TO STEEL
NOTE: DIFFERENT DIES REQUIRED FOR ROUND & FLAT SURFACES.

264 #4



DETAIL "H"
TYPE "HC" MOLD
CABLE TO PIPE THRU CONNECTION
(ERICO CAT #XLHCA-1L-(PIPE SIZE)
ADD PIPE SIZE AT END OF CAT NUMBER. EXAMPLE: XLHCA-1L-2)





43
4/0 CU

SWING GATE

GROUND WIRE JUMPER ATTACHED TO FENCE FRAME INSIDE SUBSTATION. PROVIDE ENOUGH SLACK TO OPEN GATE (APPROXIMATELY 36")

BARBED WIRE GROUNDING DETAIL

SPACED EVERY 50'-0" AND POST MUST BE CONNECTED TO GROUNDING SYSTEM.

FIELD NOTE:
- A TEST WELD SHOULD BE MADE TO CHECK THE POSSIBILITY OF BURN-THROUGH ON THIN-WALL PIPE. A TYPE "GL" LUG MAY ALSO BE USED.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-3
SUBSTATION GROUNDING DETAIL
GROUNDING FOR FENCE AND GATE

Xcel Energy®

SCALE: NONE

NL-200902-1-3

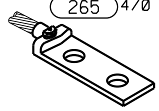
REV: C

200902-1-3.DGN

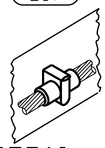
9/19/2013 11:14:38 AM

MATERIAL REQUIRED FOR CONNECTION TO ONE TRANSFORMER

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	40 FT	4/0 CU CABLE, 19 STRAND	267	2 EA	CADWELD SHOT 150, COLOR DARK BLUE
72	*	1/4" x 3" x 12" LONG RECT. CU. BAR			
263	4 EA	CADWELD LUG TYPE GL			
265	4 EA	CADWELD SHOT 65, COLOR DARK GREEN			* VARIES

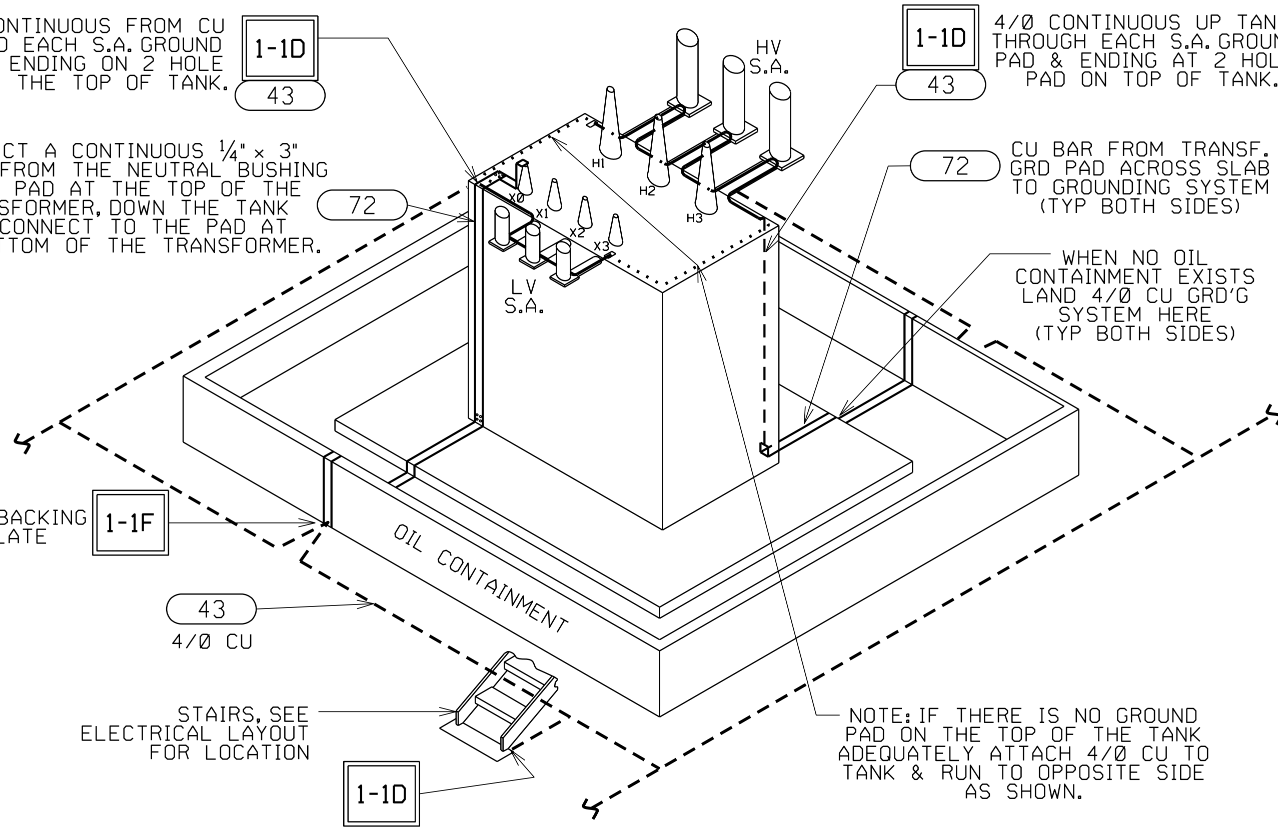


DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



DETAIL "F"
TYPE "VT" MOLD (VTC-2Q-001)
CABLE TO STEEL OR CU.
(THRU CONNECTION)
USE BACKING PLATE ON CU BAR

** NOTE: IF TERTIARY BUSHINGS ARE PROVIDED, GROUND THE SURGE ARRESTERS IN A LOOP SIMILAR TO LOW VOLTAGE ARRESTERS.



FIELD NOTE:
- THE GROUNDING SHOWN IS TO BE INSTALLED, UNLESS SUPPLIED BY MANUFACTURER.

LEGEND:
(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-4
SUBSTATION GROUNDING DETAIL
GROUNDING FOR TRANSFORMER

Xcel Energy®

SCALE: NONE

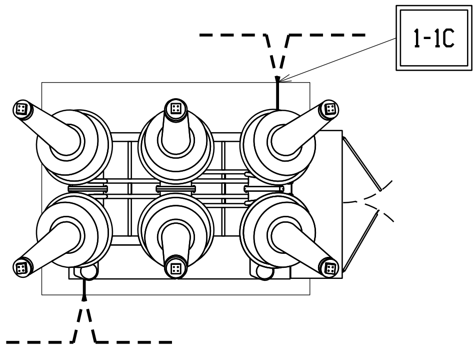
NL-200902-1-4

REV: E

200902-1-4.DGN
9/19/2013 7:54:28 AM

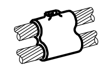
MATERIAL REQUIRED FOR CONNECTION TO ONE BREAKER

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	20 FT	4/0 CU, 19 STRAND			
263	3 EA	CADWELD LUG TYPE GL			
265	3 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	3 EA	CADWELD SHOT 200, COLOR YELLOW			
234A	4 EA	SINGLE GROOVE, SINGLE TAPPED CONN.			



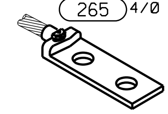
TOP VIEW

267 4/0 TO 1/0
268 4/0 TO 4/0

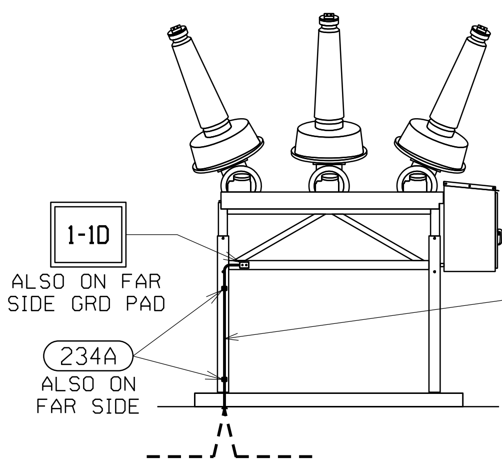


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



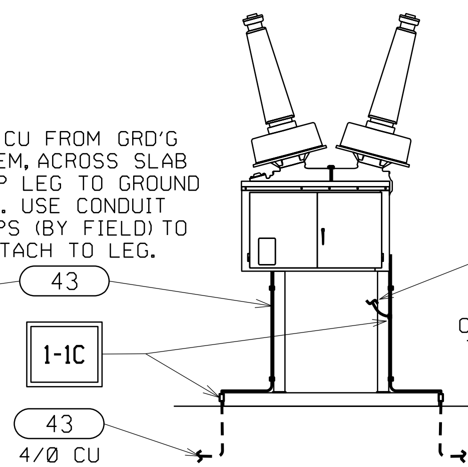
DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



ELEVATION

4/0 CU FROM GRD'G SYSTEM, ACROSS SLAB AND UP LEG TO GROUND PAD. USE CONDUIT STRAPS (BY FIELD) TO ATTACH TO LEG.

43



NOTE:
SOME BREAKERS HAVE ADDITIONAL GROUND PADS ON TANK AND CABINETS. IF THERE IS MORE THAN ONE PAD, BRANCH OFF 4/0 CU WITH "PT" CONNECTION AND RUN TO EACH PAD.

SIDE VIEW

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-5
SUBSTATION GROUNDING DETAIL
GROUNDING FOR BREAKERS

Xcel Energy®

SCALE	DRAWING	REV
NONE	NL-200902-1-5	E

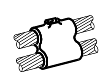
200902-1-5.DGN

5/20/2011 12:23:46 PM

MATERIAL REQUIRED FOR CONNECTION TO ONE NOVA RECLOSER

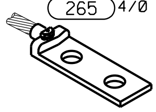
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	10 FT	4/0 CU, 19 STRAND	263	2 EA	CADWELD LUG TYPE GL
53	2 FT	#4 SOLID CU. WIRE	265	2 EA	CADWELD SHOT 45, COLOR LIGHT BLUE
234A	3 EA	SINGLE GROOVE, SINGLE TAPPED CONN.	268	2 EA	CADWELD SHOT 200, COLOR YELLOW
244	1 EA	TEE CONNECTOR FOR #4 TO 250 MCM CU			

267 4/0 TO 1/0
268 4/0 TO 4/0

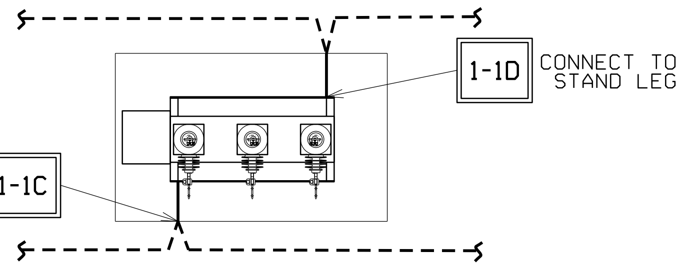


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

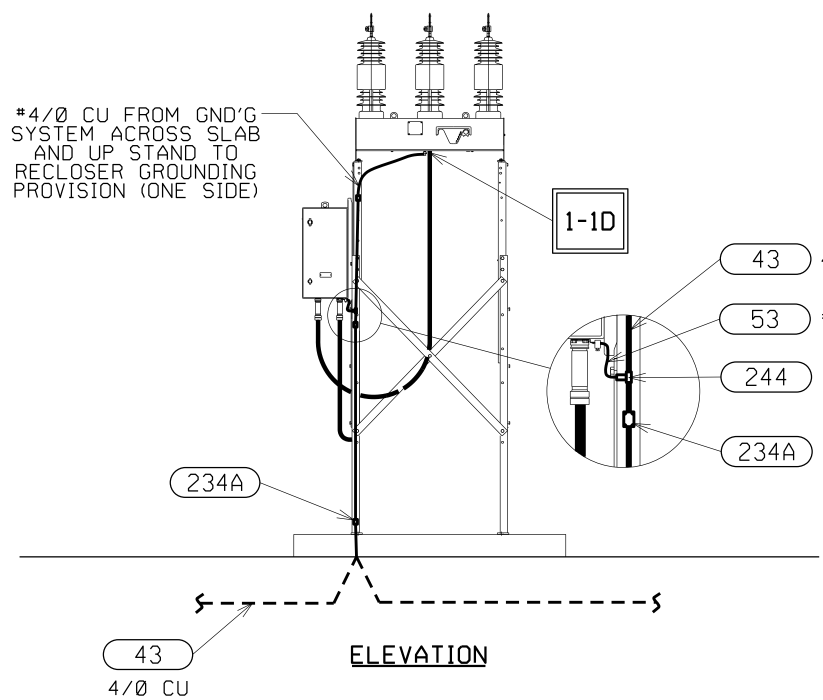
263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



TOP VIEW



ELEVATION

LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

1-1F INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-6
SUBSTATION GROUNDING DETAIL
GROUNDING FOR NOVA RECLOSER

Xcel Energy®

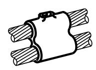
SCALE NONE | NL-200902-1-6 | REV C

5/20/2011 12:24:23 PM

MATERIAL REQUIRED FOR CONNECTION TO ONE BREAKER					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	20 FT	4/0 CU, 19 STRAND			
234A	2 EA	SINGLE GROOVE, SINGLE TAPPED CONN.			
263	6 EA	CADWELD LUG TYPE GL			
265	6 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	2 EA	CADWELD SHOT 200, COLOR YELLOW			

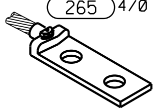
200902-1-7.DGN

267 4/0 TO 1/0
268 4/0 TO 4/0

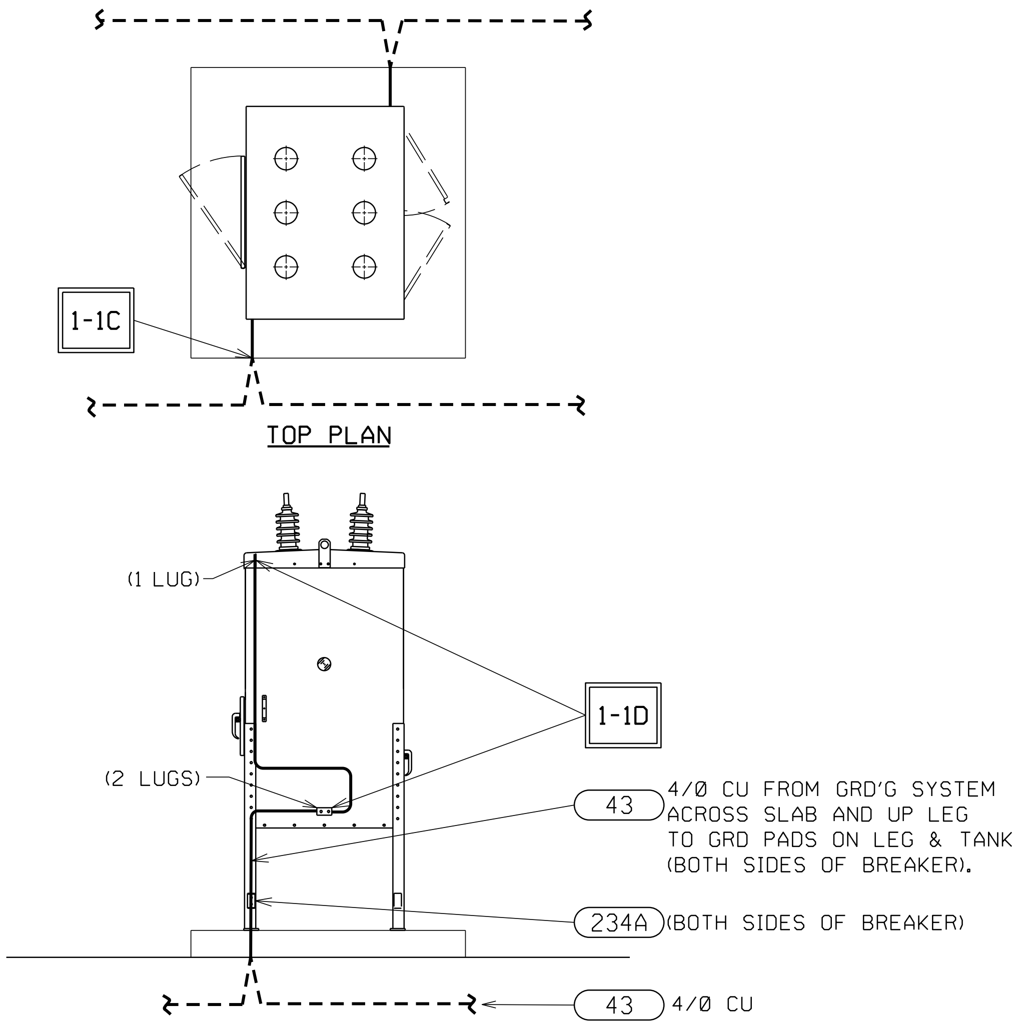


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



FEILD NOTE:
- ALL GROUND PADS ON BREAKER NEED TO BE CONNECTED TO GROUND GRID.

LEGEND:
(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)
[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-7
SUBSTATION GROUNDING DETAIL
GROUNDING FOR DIST BREAKER

Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-1-7	E

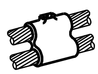
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

10/26/2012 10:30:24 AM

MATERIAL REQUIRED FOR CONNECTION TO ONE SET OF 3 REGULATORS

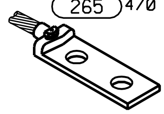
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	50 FT	4/0 CU CABLE, 19 STRAND			
234A	6 EA	SINGLE GROOVE, SINGLE TAPPED CONN.			
263	12 EA	CADWELD LUG TYPE GL			
265	12 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	10 EA	CADWELD SHOT 200, COLOR YELLOW			

267 4/0 TO 1/0
268 4/0 TO 4/0

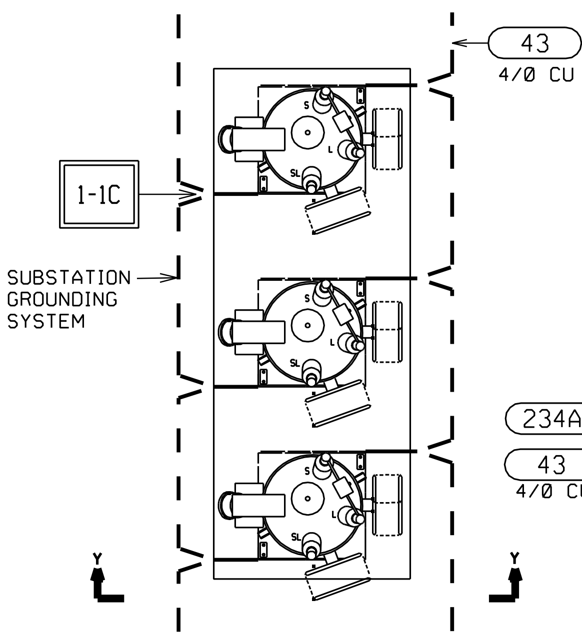


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

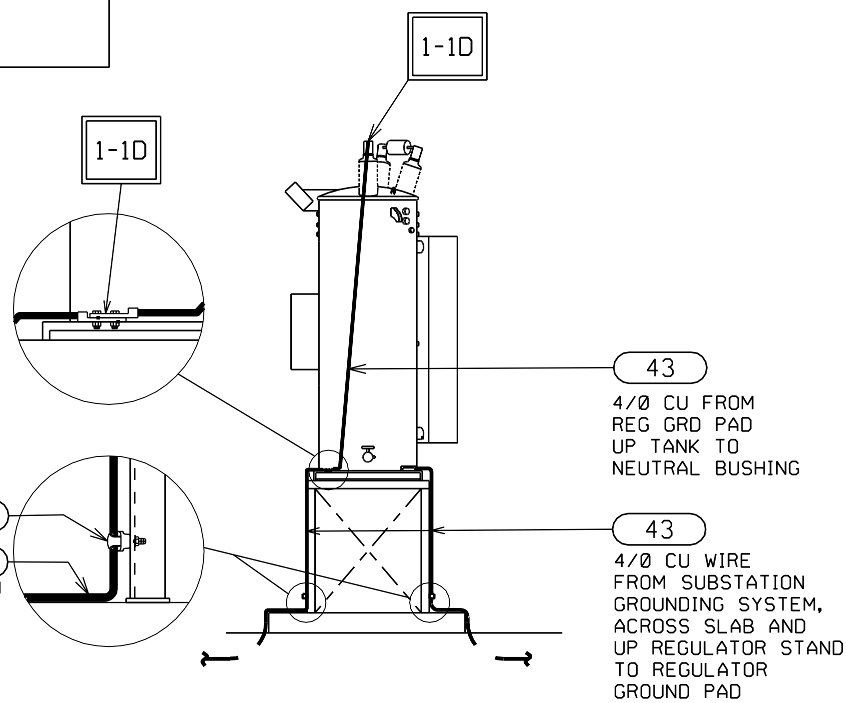
263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



TOP VIEW



ELEVATION Y-Y

FIELD NOTE:
- DO NOT CADWELD TO REGULATOR STAND

LEGEND:
(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-8
SUBSTATION GROUNDING DETAIL
GROUNDING FOR REGULATOR

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy®

SCALE: NONE

NL-200902-1-8

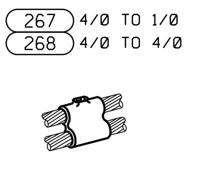
REV: B

200902-1-8.DGN

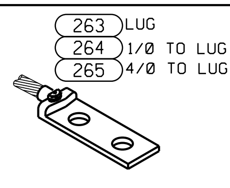
$TIME$ 02/20/2008

MATERIAL FOR DEAD-END TOWER		
ITEM NO.	QTY	DESCRIPTION
43	90 FT	4/0 CU, 19 STRAND
263	3 EA	CADWELD LUG TYPE GL
265	3 EA	CADWELD SHOT 65, COLOR DARK GREEN
267	2 EA	CADWELD SHOT 150, COLOR DARK BLUE
268	6 EA	CADWELD SHOT 200, COLOR YELLOW
275	1 EA	TERM LUG, 1 HOLE

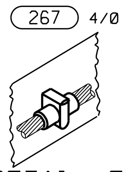
MATERIAL FOR SINGLE OR DOUBLE COLUMN STAND		
ITEM NO.	QTY	DESCRIPTION
43	20 FT	4/0 CU CABLE, 19 STRAND
263	3 EA	CADWELD LUG TYPE GL
265	3 EA	CADWELD SHOT 65, COLOR DARK GREEN
267	1 EA	CADWELD SHOT 150, COLOR DARK BLUE
268	3 EA	CADWELD SHOT 200, COLOR YELLOW



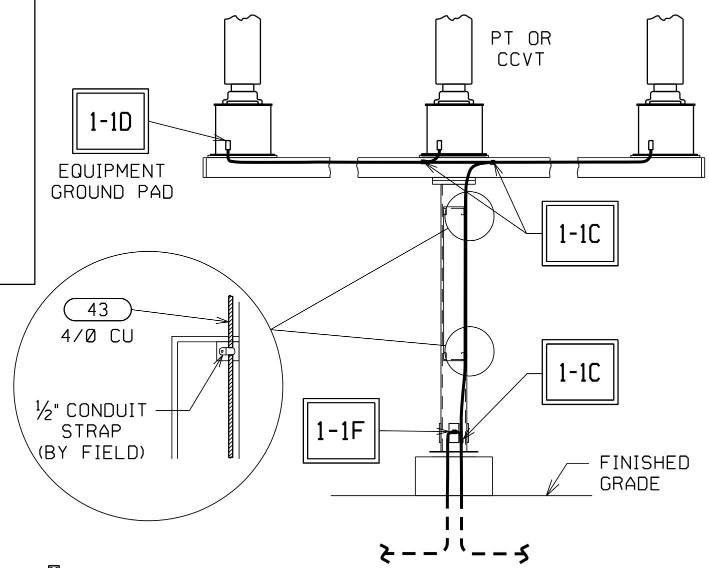
DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE



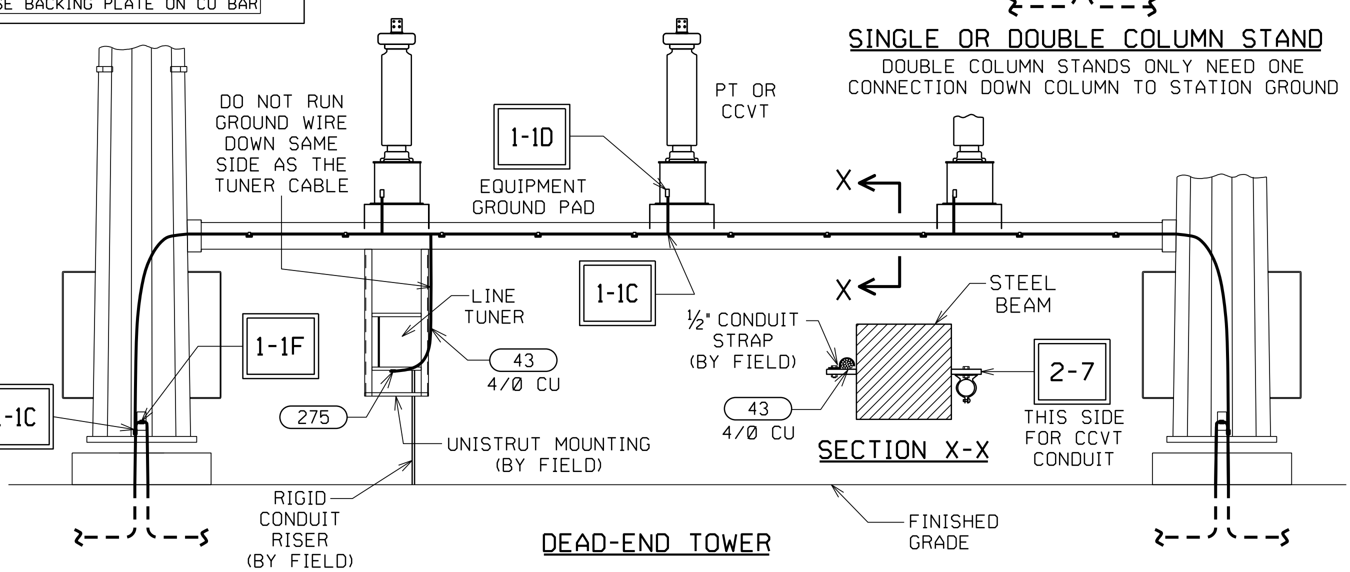
DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



DETAIL "F"
TYPE "VT" MOLD (VTC-2Q-001)
CABLE TO STEEL OR CU.
(THRU CONNECTION)
USE BACKING PLATE ON CU BAR



SINGLE OR DOUBLE COLUMN STAND
DOUBLE COLUMN STANDS ONLY NEED ONE CONNECTION DOWN COLUMN TO STATION GROUND



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-9
SUBSTATION GROUNDING DETAIL
GROUNDING FOR P.T. AND C.C.V.T.

Xcel Energy

SCALE	DRAWING	REV
NONE	NL-200902-1-9	E

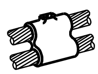
200902-1-9.DGN

9/19/2013 7:54:58 AM

MATERIAL REQUIRED FOR CONNECTION TO ONE CAPACITOR BANK

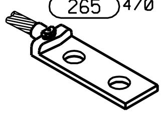
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	20 EA	4/0 CU CABLE, 19 STRAND			
263	2 EA	CADWELD LUG TPYE GL			
265	2 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	2 EA	CADWELD SHOT 200, COLOR YELLOW			

267 4/0 TO 1/0
268 4/0 TO 4/0

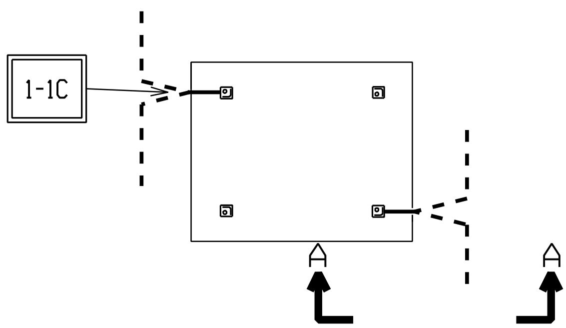


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

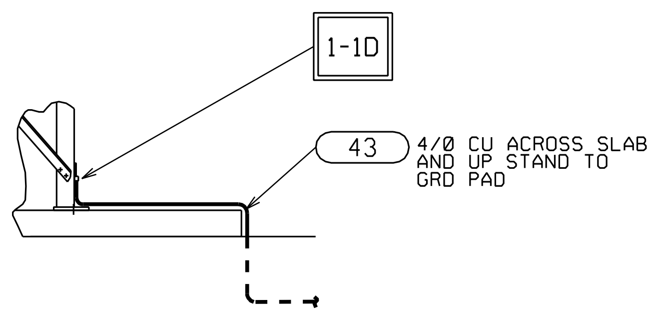
263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



VIEW OF CAP BANK LEGS



SECTION A-A

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-10
SUBSTATION GROUNDING DETAIL
GROUNDING FOR CAPACITOR BANK STAND

Xcel Energy

SCALE NONE

NL-200902-1-10

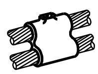
REV B

200902-1-10.DGN $TIME$ 02/20/2008

MATERIAL REQUIRED FOR CONNECTION TO ONE CAPACITOR BANK

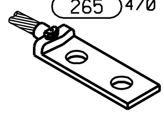
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	20 FT	4/0 CU CABLE, 19 STRAND			
234A	4 EA	SINGLE GROOVE, SINGLE TAPPED CONN.			
263	1 EA	CADWELD LUG TYPE GL			
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	1 EA	CADWELD SHOT 200, COLOR YELLOW			

267 4/0 TO 1/0
268 4/0 TO 4/0

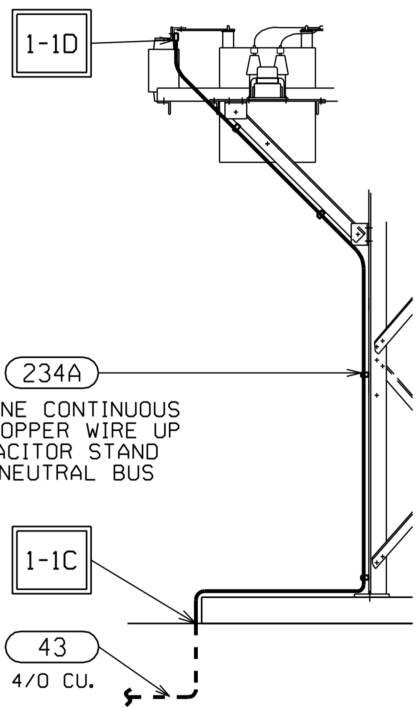


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

1-1F INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-11
SUBSTATION GROUNDING DETAIL
GROUNDING FOR SINGLE CAPACITOR BANK

Xcel Energy

SCALE: NONE

NL-200902-1-11

REV: B

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-1-11.DGN

$TIME$

02/20/2008

MATERIAL REQUIRED FOR CONNECTION TO ONE CAPACITOR BANK CONNECTION

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
704	2 EA	WARNING SIGN	C402	*	SPLICE CONNECTOR
C26	*	15KV DIRECT BURIAL 4/0 CU CABLE	C403	1	CABLE TERMINATOR
C400	1 EA	TERMINAL LUG FOR 4/0 CU	C404	2	CABLE MOUNTING BRACKET
C401	*	COLD SHRINK SPLICE JACKET, 15KV CABLE			* DETERMINED BY DESIGNER

200902-1-12A.DGN

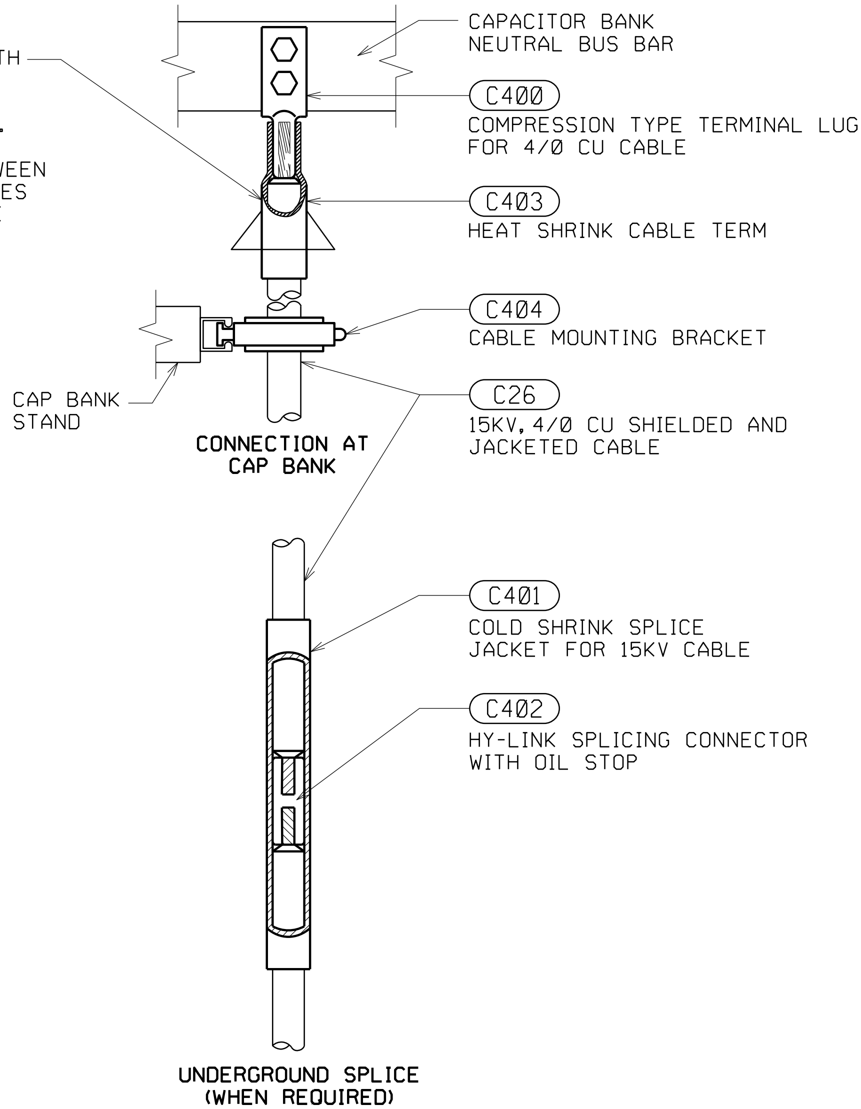
CONSTRUCTION NOTES:

CUT OFF CONCENTRIC NEUTRAL ON BOTH ENDS OF 15KV SINGLE POINT GROUND CABLE. DO NOT CONNECT SHIELD TO LUG AND DO NOT CONNECT TO GROUND.

MAINTAIN AT LEAST 6" OF EARTH BETWEEN WHERE THE POWER AND CONTROL CABLES CROSS AND 3'-0" WHERE THE RUNS ARE PARALLEL.

704

TWO SIGNS SHOULD BE PLACED ON EACH CAP BANK WITH AN INSULATED GROUNDED NEUTRAL. ONE SIGN MOUNTED ON THE FRONT SIDE OF THE CENTER PHASE RACK AND ONE ON THE BACK WHERE THE CABLE IS TERMINATED.



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-12A
SUBSTATION GROUNDING DETAIL
GROUNDING FOR CAPACITOR BANK SINGLE POINT CONNECTION

Xcel Energy®

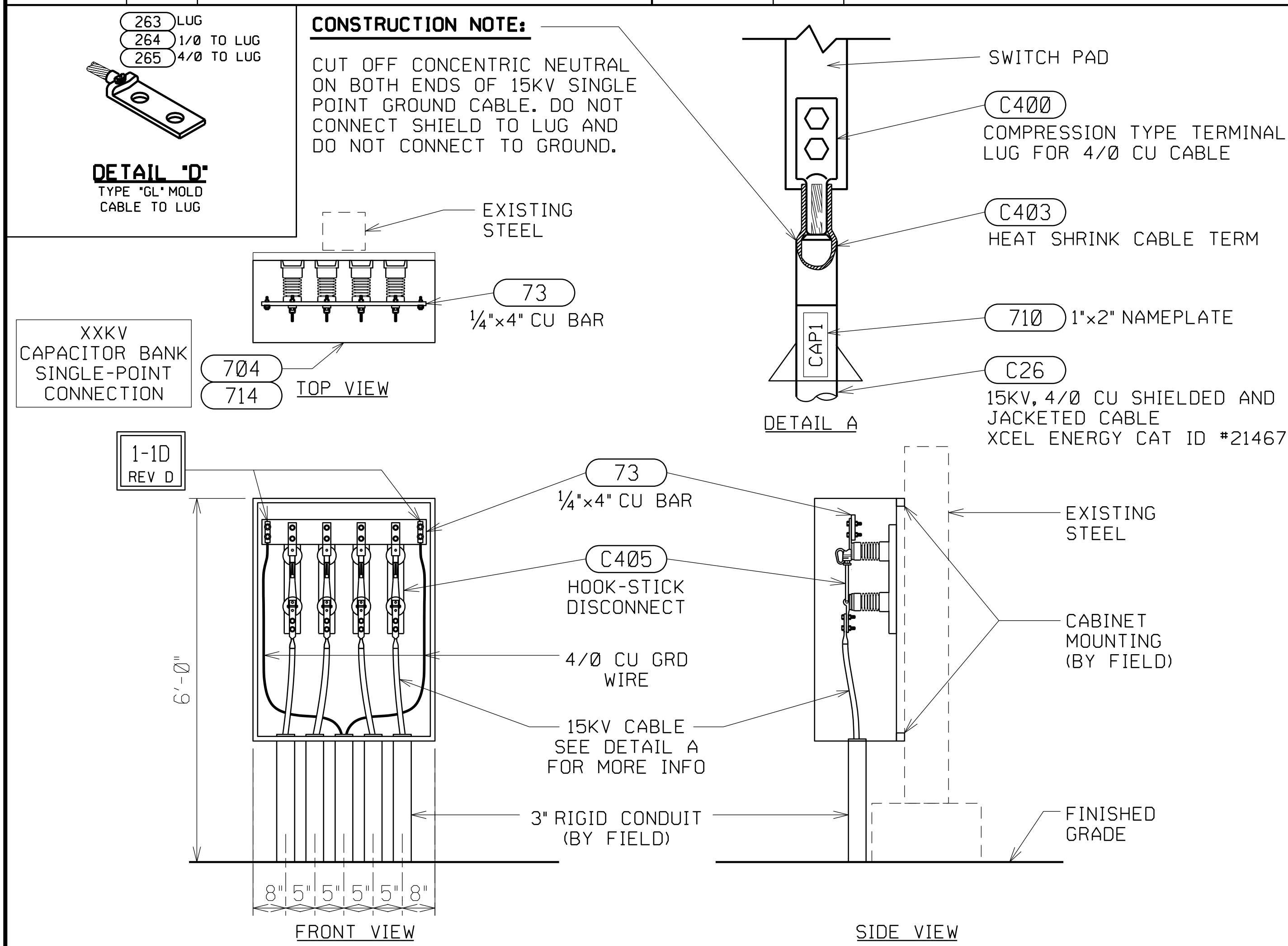
SCALE		REV
NONE	NL-200902-1-12A	D

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

5/20/2011 12:18:50 PM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	20 FT	4/0 COPPER	C257A	1	CABINET 48" x 36" x 16" WITH BACK PNL
73	3 FT	1/4"x4" CU BAR	C257C	1	HANDLE FOR ITEM C257A
263	2	CADWELD LUG	C257D	1	MOUNTING KIT FOR ITEM C257A
265	2	CADWELD SHOT	C257E	1	DOOR STOP FOR ITEM C257A
704	1	WARNING SIGN	C400	*	TERMINAL LUG FOR 4/0 CU (ONE PER CBL)
710	*	1"x2" NAMEPLATE (ONE FOR EA CAP BANK)	C403	*	CABLE TERMINATION (ONE PER CBL)
714	1	6"x10" NAMEPLATE (FOR CABINET)	C405	*	HOOK STICK DISCONNECT (ONE PER CBL)
C26	*	15KV DIRECT BURIAL 4/0 CU CABLE			* DETERMINED BY DESIGNER



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-12B
SUBSTATION GROUNDING DETAIL
CAPACITOR BANK SINGLE POINT CONNECTION CABINET

Xcel Energy

SCALE NONE

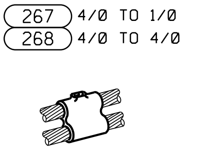
NL-200902-1-12B

REV D

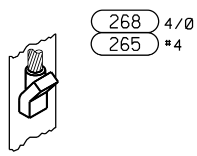
200902-1-12B.DGN
5/20/2011 12:21:09 PM

MATERIAL REQUIRED FOR CONNECTION TO ONE GROUND WELL

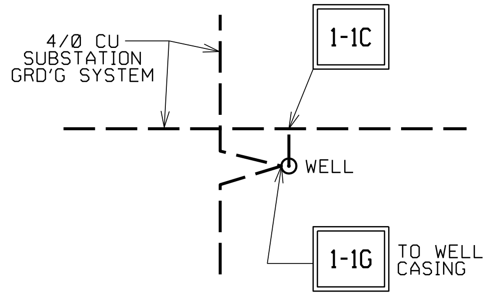
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43		4/0 CU. CABLE, 19 STRAND			
268	3 EA	CADWELD SHOT 200, COLOR YELLOW			



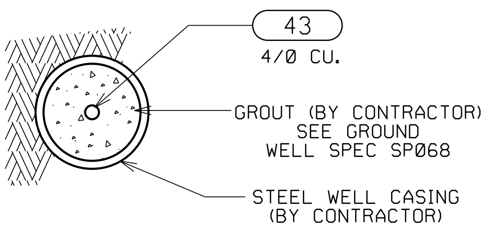
DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE



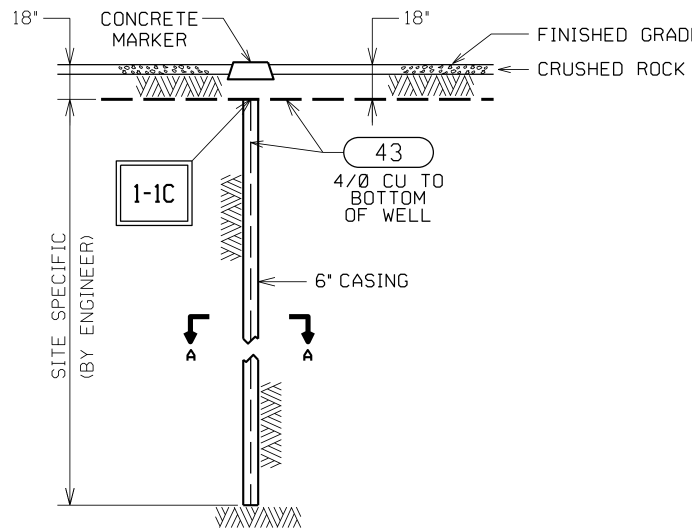
DETAIL "G"
TYPE "VF" MOLD
CABLE UP TO STEEL
NOTE: DIFFERENT DIES REQUIRED
FOR ROUND & FLAT SURFACES.



TOP VIEW



SECTION A-A



ELEVATION

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-13
SUBSTATION GROUNDING DETAIL
GROUND WELL

Xcel Energy

SCALE NONE

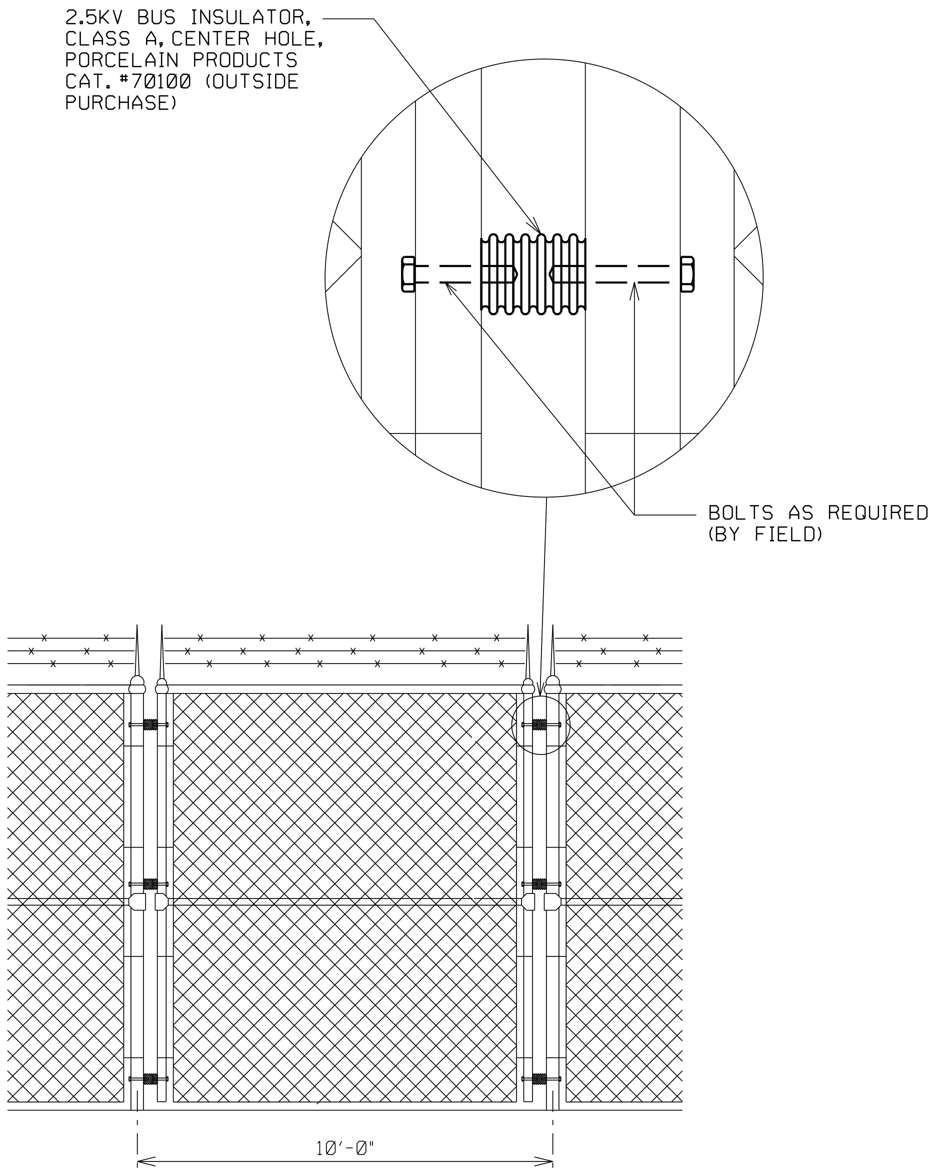
NL-200902-1-13

REV D

200902-1-13.DGN
7:49:21 AM
9/19/2013

MATERIAL REQUIRED FOR CONNECTION TO ONE ISOLATION POINT

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-14
SUBSTATION GROUNDING DETAIL
FENCE GROUND ISOLATION

Xcel Energy

SCALE		REV
NONE	NL-200902-1-14	A

200902-1-14.DGN

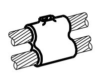
8/13/2013 2:55:08 PM

MATERIAL REQUIRED FOR CONNECTION TO ONE POLE

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
13	2 #	5/8 THREADED ROD 26" LONG	43	80 FT	4/0 CU. CABLE, 19 STRAND
24	4 #	M.F. LOCK NUT, FOR 5/8" DIA BOLT	263	1 EA	CADWELD LUG, TYPE GL
27	2 #	WASHER, 3" SQ. CUT, FOR 5/8" DIA BOLT	265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN
			268	1 EA	CADWELD SHOT 200, COLOR YELLOW

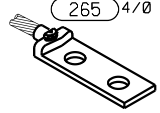
ORDERED WITH STEEL
* VARIES

267 4/0 TO 1/0
268 4/0 TO 4/0

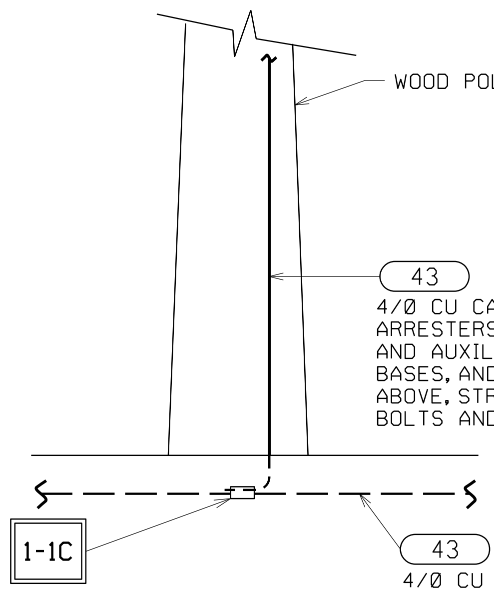


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

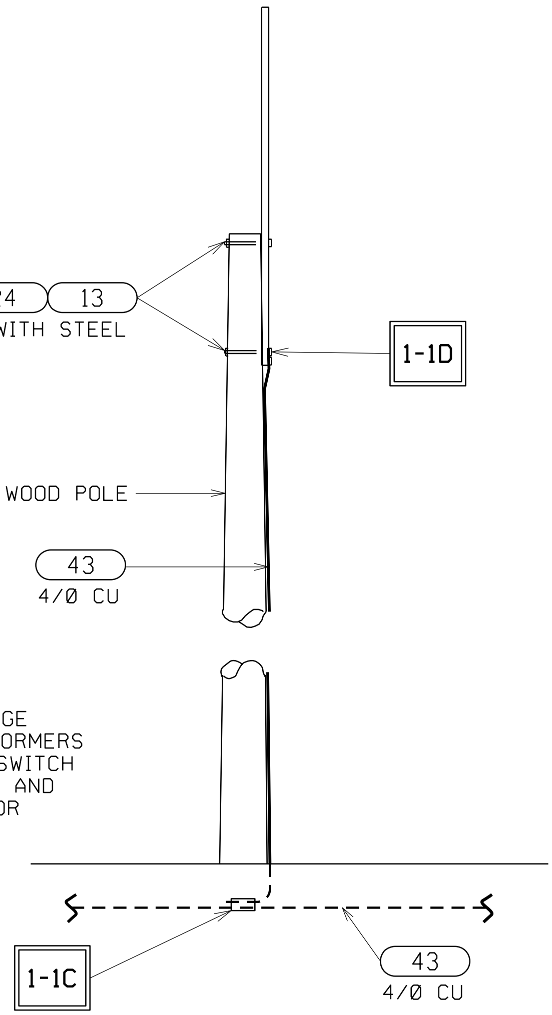
263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



WOOD STRUCTURE EQUIPMENT GROUNDING



SHIELD SPIKE GROUNDING

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1F] INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-16
SUBSTATION GROUNDING DETAIL
GROUNDING FOR SHIELD SPIKE ON WOOD POLE

Xcel Energy®

SCALE NONE

NL-200902-1-16

REV C

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

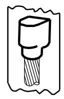
200902-1-16.DGN

5/20/2011 12:23:00 PM

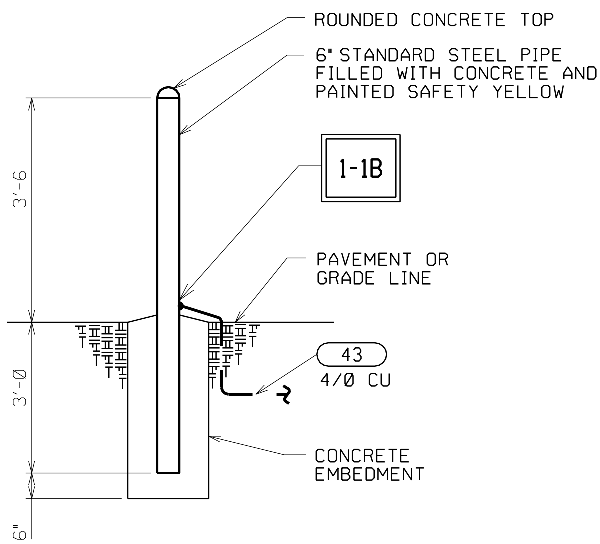
MATERIAL REQUIRED FOR CONNECTION TO ONE POST

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43		4/0 CU. CABLE, 19 STRAND			
267	1/4 PKG	CADWELD SHOT, CAT #XL150 (PKG 4)			

267 4/0
265 #4



DETAIL "B"
TYPE "VB" MOLD
CABLE DOWN TO STEEL
NOTE: DIFFERENT DIES REQUIRED FOR ROUND & FLAT SURFACES.



LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

1-1F INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 1-17
SUBSTATION GROUNDING DETAIL
GROUNDING FOR GUARD POST

Xcel Energy

SCALE: NONE

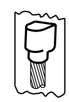
NL-200902-1-17

REV: A

MATERIAL REQUIRED FOR FOR ONE FEEDER

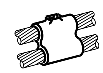
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	*	4/0 CU. CABLE, 19 STRAND	267	1 EA	CADWELD SHOT 150, COLOR DARK BLUE
64	*	1/4" x 2" ALUMINUM BAR	268	2 EA	CADWELD SHOT 200, COLOR YELLOW
263	1 EA	CADWELD LUG TYPE GL			
		* VARIES			

267 4/0
266 #4



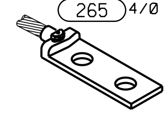
DETAIL "B"
TYPE "VB" MOLD
CABLE DOWN TO STEEL
NOTE: DIFFERENT DIES REQUIRED FOR ROUND & FLAT SURFACES.

267 4/0 TO 1/0
268 4/0 TO 4/0

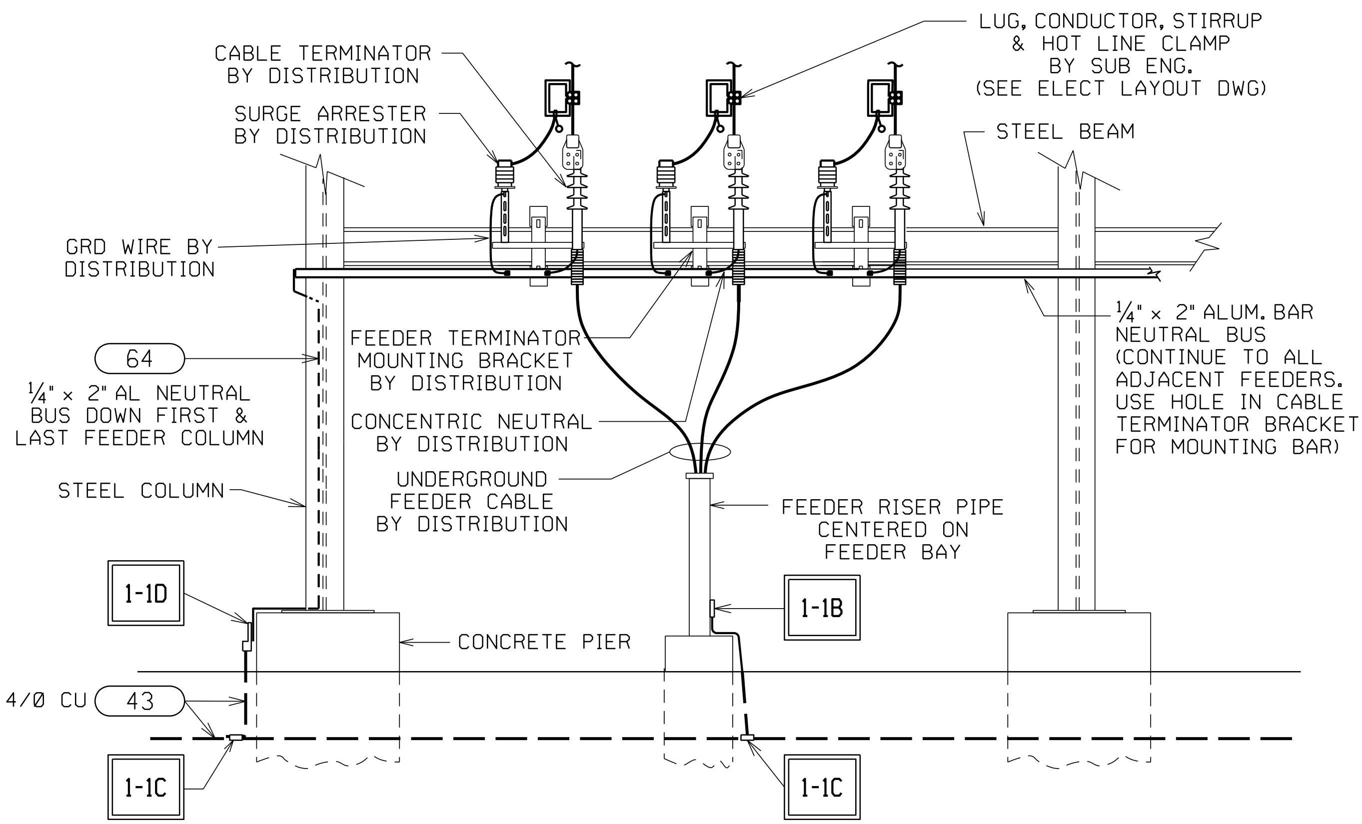


DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL THRU CABLE

263 LUG
264 1/0 TO LUG
265 4/0 TO LUG



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

1-1F INDICATES DETAIL "F" SHOWN ABOVE & ON SHEET 1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-18
SUBSTATION GROUNDING DETAIL
GROUNDING FOR OUTDOOR UNDERGROUND FEEDER NEUTRAL

Xcel Energy

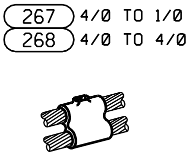
SCALE: NONE

NL-200902-1-18

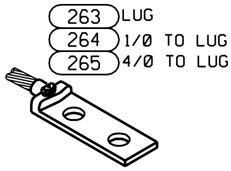
REV: C

200902-1-18.DGN
9/19/2013 7:51:03 AM

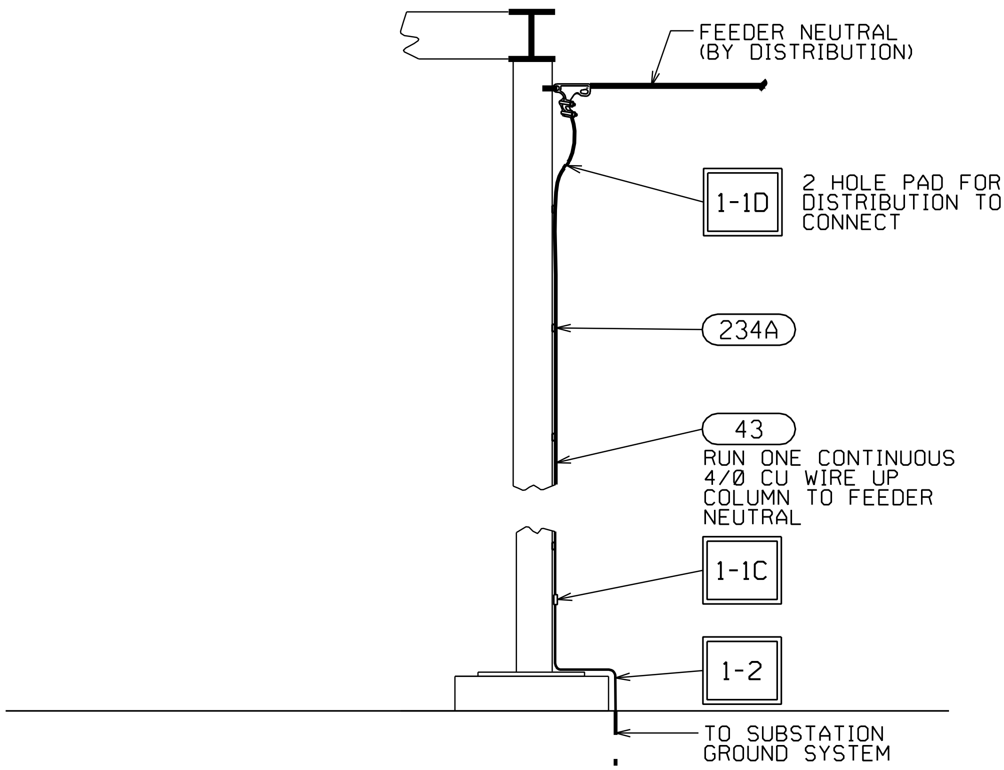
BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	30 EA	4/0 CU. CABLE, 19 STRAND			
234A	6 EA	SINGLE GROOVE, SINGLE TAPPED CONN.			
263	1 EA	CADWELD LUG, TYPE GL			
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN			
268	1 EA	CADWELD SHOT 200, COLOR YELLOW			



DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE



DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-19
SUBSTATION GROUNDING DETAIL
OVERHEAD FEEDER NEUTRAL CONNECTION TO GROUND GRID

Xcel Energy®

SCALE NONE | NL-200902-1-19 | REV B

$TIME$ 02/20/2008

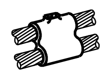
MATERIAL FOR CABINET MOUNTED ON COLUMN

ITEM NO.	QTY	DESCRIPTION
43	2 FT	4/0 COPPER WIRE
263	1 EA	CADWELD LUG TYPE GL
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN
268	1 EA	CADWELD SHOT 200, COLOR YELLOW

MATERIAL FOR CABINET NOT MOUNTED ON COLUMN

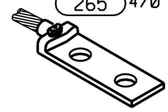
ITEM NO.	QTY	DESCRIPTION
43	5 FT	4/0 CU. CABLE, 19 STRAND
263	1 EA	CADWELD LUG TYPE GL
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN
268	1 EA	CADWELD SHOT 200, COLOR YELLOW

267 4/0 TO 1/0
268 4/0 TO 4/0



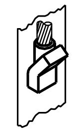
DETAIL "C"
TYPE "PT" MOLD
HORIZONTAL PARALLEL
THRU CABLE

263 LUG
264 1/0 TO LUG
265 4/0 TO LUG

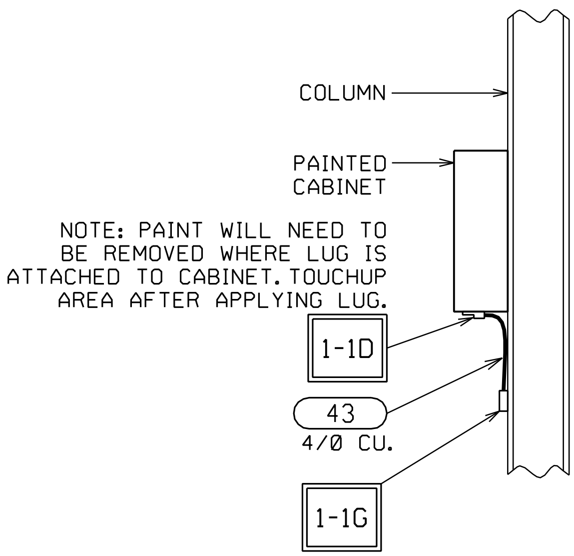


DETAIL "D"
TYPE "GL" MOLD
CABLE TO LUG

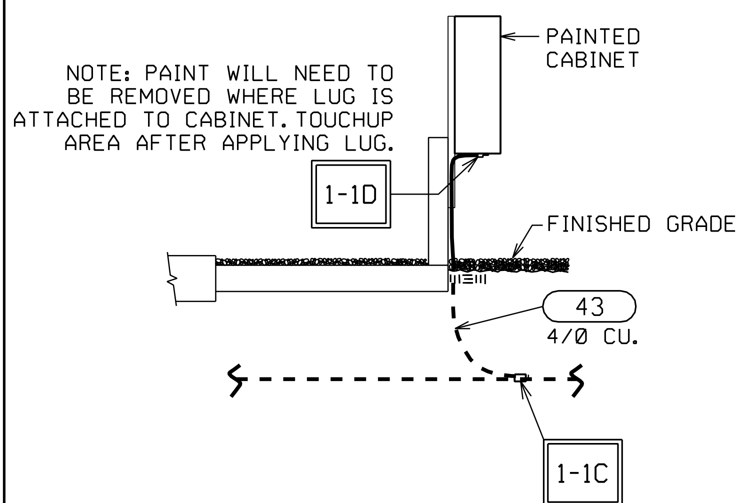
268 4/0
265 #4



DETAIL "G"
TYPE "VF" MOLD
CABLE UP TO STEEL
NOTE: DIFFERENT DIES REQUIRED FOR ROUND & FLAT SURFACES.



CABINET MOUNTED ON COLUMN



CABINET NOT MOUNTED ON COLUMN

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

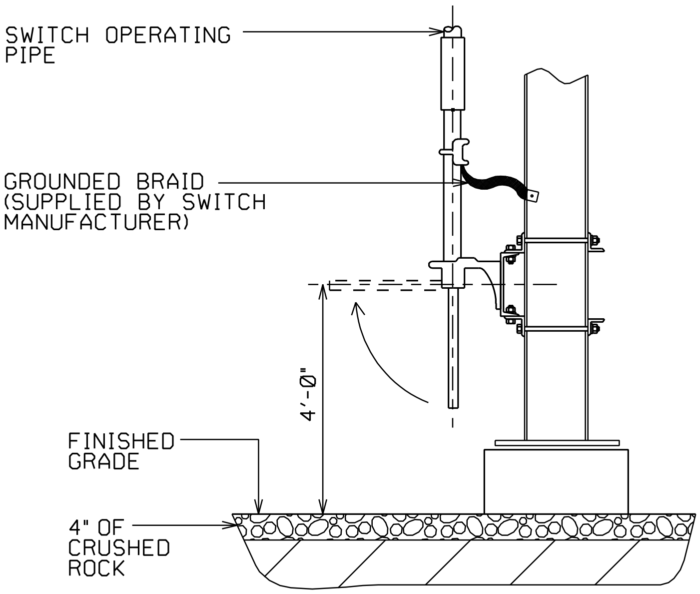
NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-20
SUBSTATION GROUNDING DETAIL
GROUNDING FOR PAINTED CABINETS

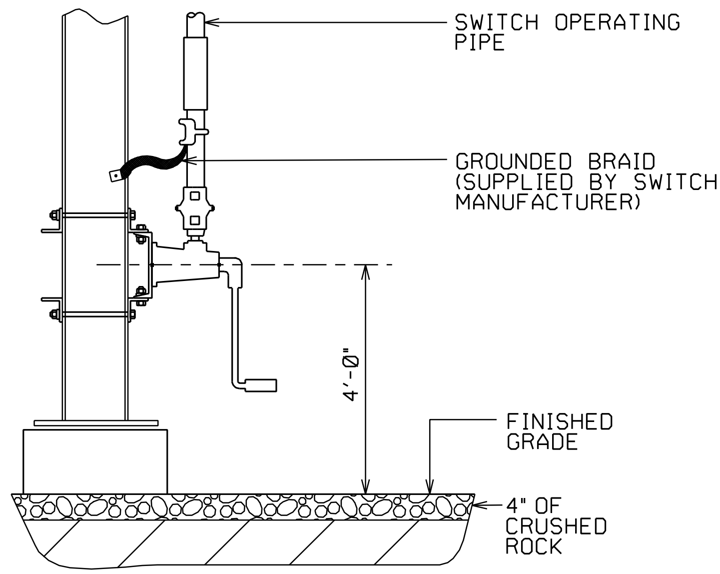
Xcel Energy®

SCALE NONE | NL-200902-1-20 | REV B

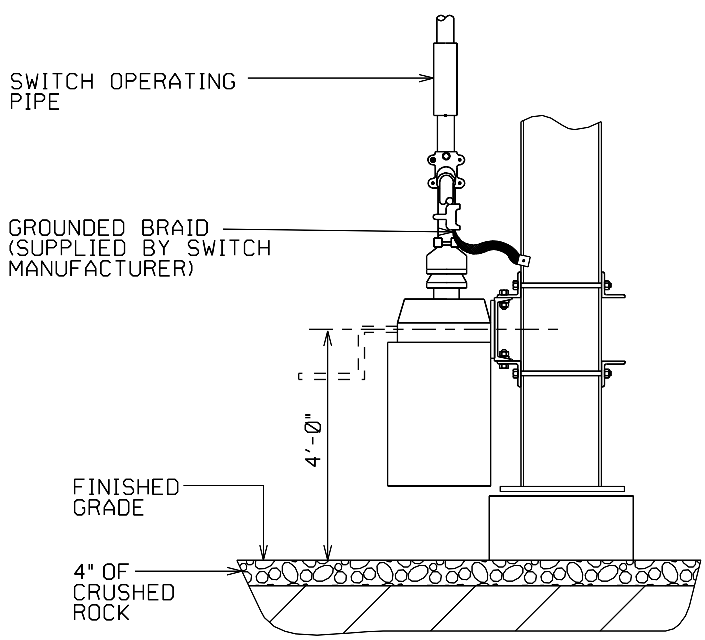
200902-1-20.DGN $TIME$ 02/20/2008



OPERATING PIPE



OPERATING CRANK



MOTOR MECHANISM

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-21
SUBSTATION GROUNDING DETAIL
SWITCH OPERATING PIPE GRD'G & OPERATING CRANK MOUNTING HEIGHT

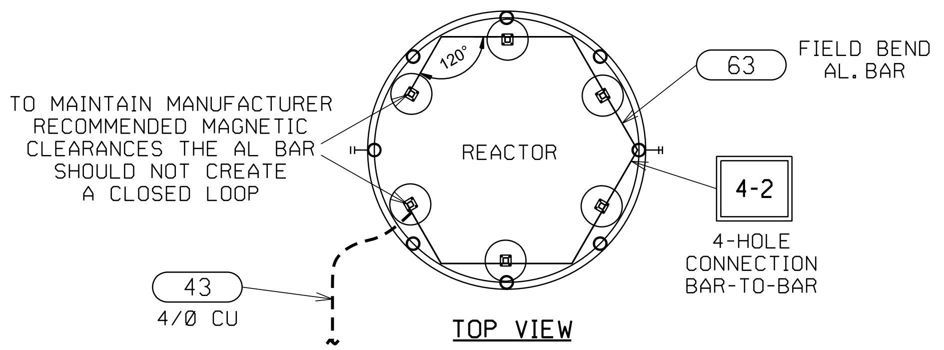
Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-1-21	A

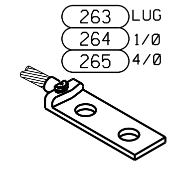
200902-1-21.DGN
$TIME$
06/04/2007

MATERIAL REQUIRED FOR CONNECTION TO ONE REACTOR

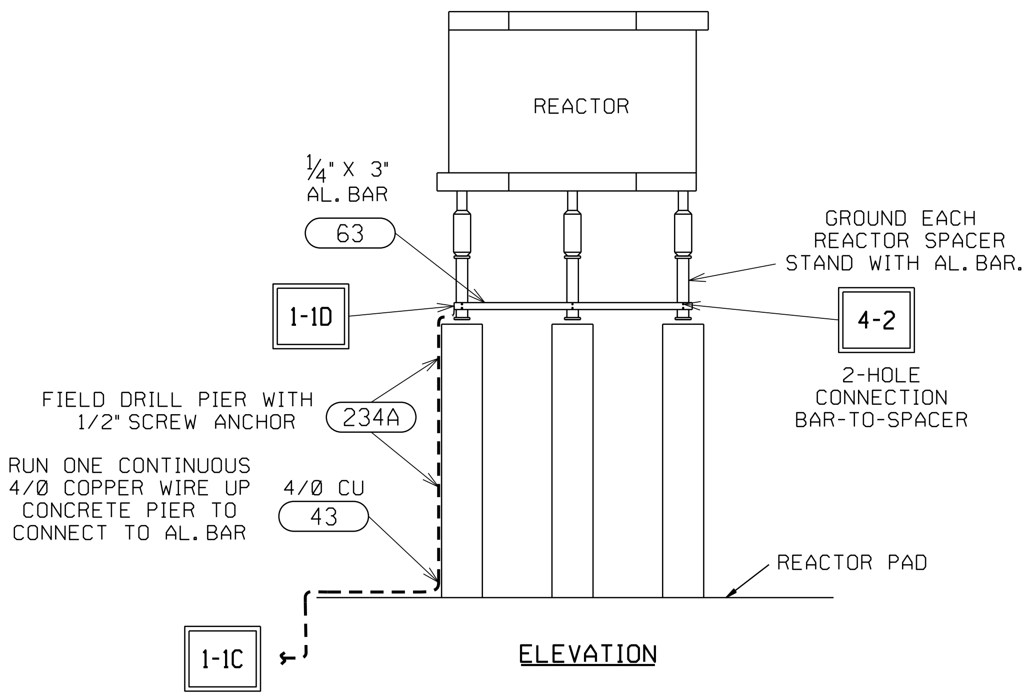
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
43	40 FT	4/0 CU, 19 STRAND	265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN
63	24 FT	1/4" x 3" ALUMINUM BAR	268	1 EA	CADWELD SHOT 200, COLOR YELLOW
234A	3 EA	SINGLE GROOVE, SINGLE TAPPED CONN.	263	1 EA	CADWELD LUG TYPE GL



TOP VIEW



DETAIL "D"
TYPE "GL" MOLD CABLE TO LUG



ELEVATION

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[1-1D] INDICATES DETAIL "D" SHOWN ABOVE & ON SHEET 1-1

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 1-22
SUBSTATION GROUNDING DETAIL
GROUNDING FOR COLUMN MOUNTED REACTORS

Xcel Energy

SCALE: NONE

NL-200902-1-22

REV: A

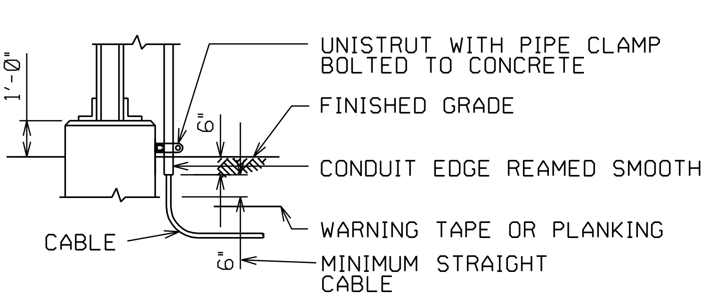
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	0001
6	
CL	

200902-1-22.DGN

7/31/2012 8:58:28 AM

ALL ITEMS SHOWN ARE ORDERED BY CONSTRUCTION

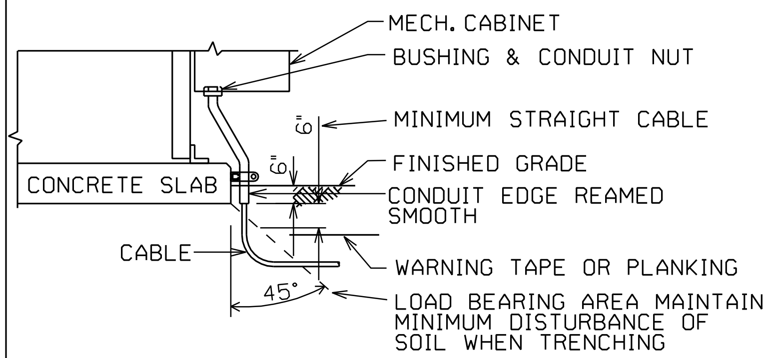
NOTE: GALVANIZED CONDUIT IS USED FOR ALL ABOVE GROUND CONDUITS.



DETAIL "A"

TYPICAL CONDUIT RISER FOR UNDERGROUND CABLE ADJACENT TO DEEP FOOTING

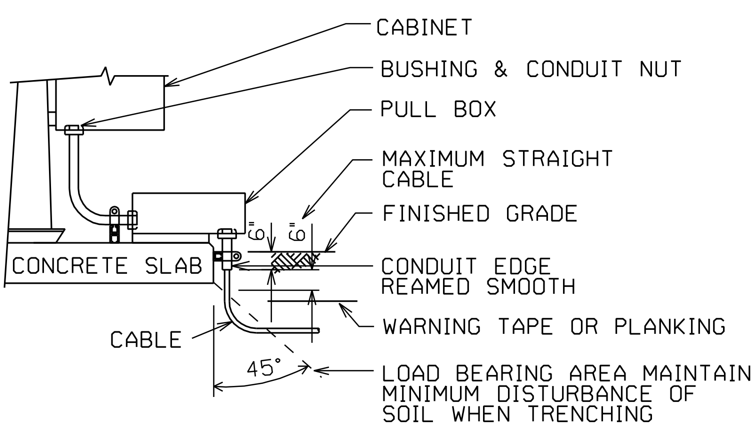
NOTE: GALVANIZED CONDUIT IS USED FOR ALL ABOVE GROUND CONDUITS.



DETAIL "B"

TYPICAL CONDUIT RISER FOR SLAB MOUNTED EQUIPMENT

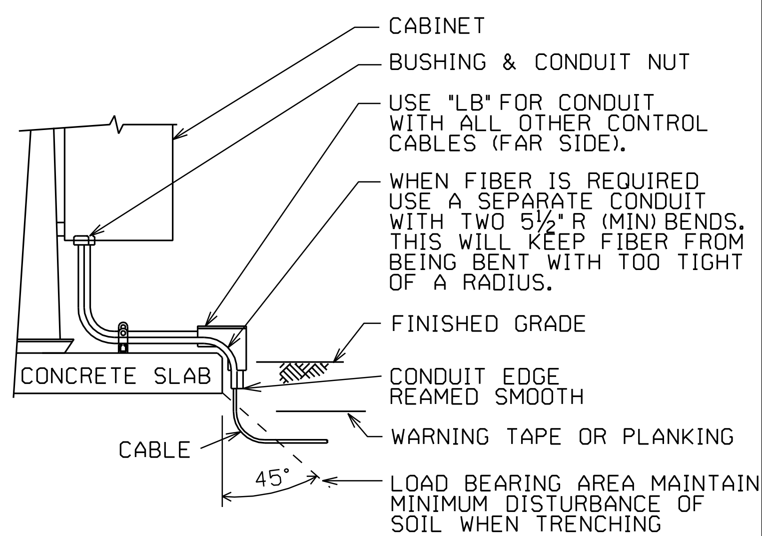
NOTE: GALVANIZED CONDUIT IS USED FOR ALL ABOVE GROUND CONDUITS.



DETAIL "C"

ALTERNATE CONDUIT RISER FOR SLAB MOUNTED EQUIPMENT

NOTE: GALVANIZED CONDUIT IS USED FOR ALL ABOVE GROUND CONDUITS.



DETAIL "D"

CONDUIT RISER FOR SLAB MOUNTED EQUIPMENT WITH OR WITHOUT FIBER OPTIC CABLE

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-1

SUBSTATION CONTROL AND LIGHTING DETAIL

CONDUIT RISER DETAIL "A", DETAIL "B", DETAIL "C" & DETAIL "D"

Xcel Energy

SCALE: NONE

NL-200902-2-1

REV: C

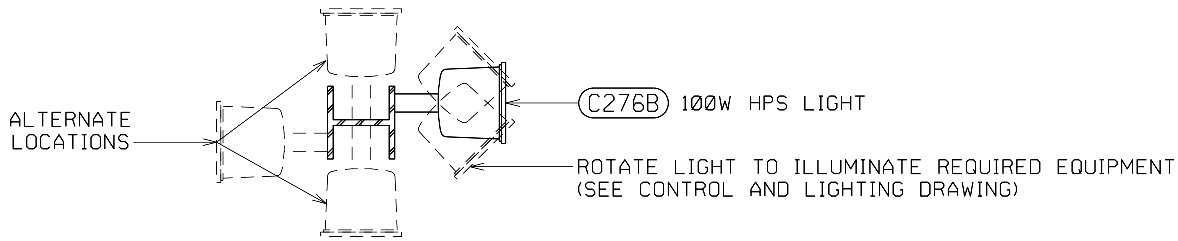
200902-2-1.DGN

$TIME$

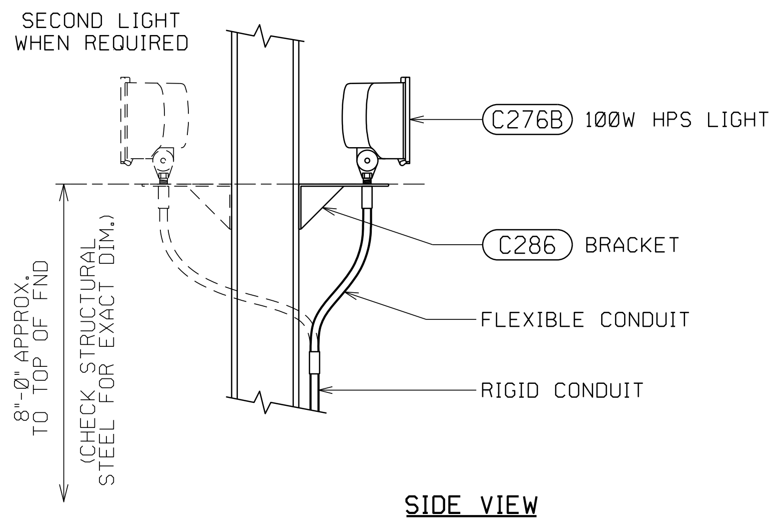
09/20/2007

BILL OF MATERIAL FOR FLOOD LAMPS

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C276B	*	100 WATT HPS LIGHT			
C286	*	BRACKET, ANGLE, 12½"			
		* VARIES			



TOP VIEW



SIDE VIEW

FIELD NOTE:

- LIGHT AIMING QUADRANT OPTIONAL FOR EACH LAMP. EQUIPMENT OR AREA TO ILLUMINATE IS DESIGNATED ON LAYOUT DRAWING.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-2
SUBSTATION CONTROL AND LIGHTING DETAIL
FLOODLAMP LIGHTING FIXTURE MOUNTING

Xcel Energy

SCALE		REV
NONE	NL-200902-2-2	B

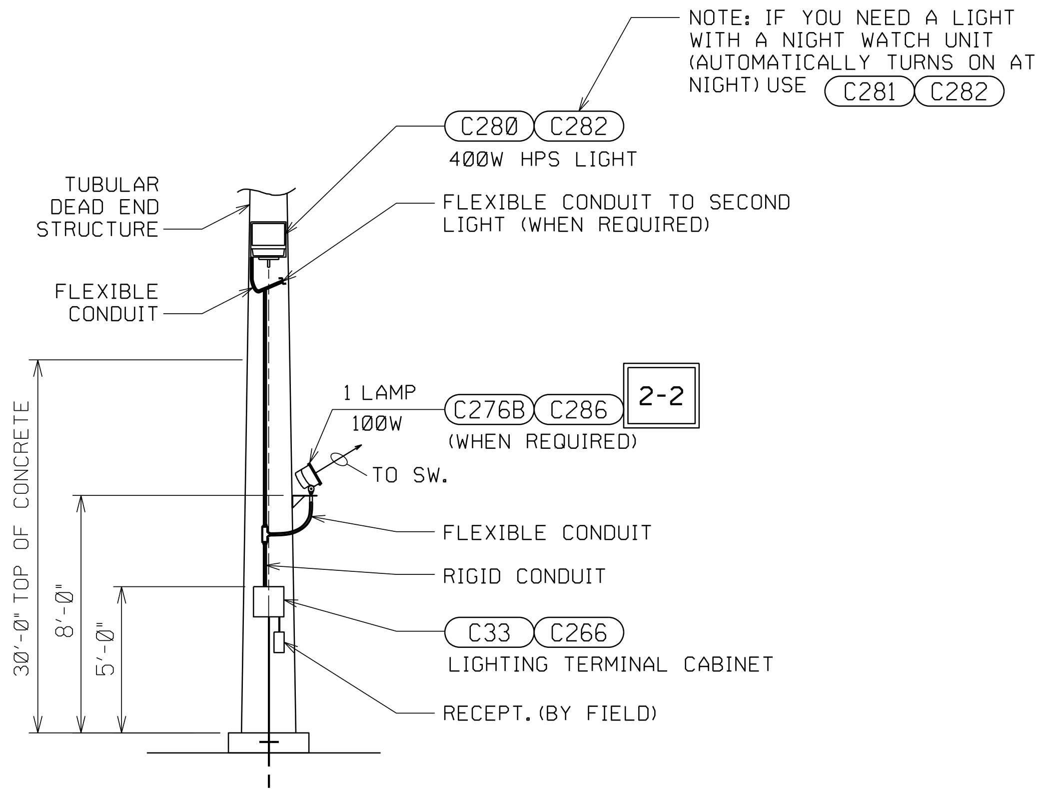
200902-2-2.DGN

11/20/2013 11:06:57 AM

BILL OF MATERIAL FOR 400W HIGH PRESSURE SODIUM LIGHT

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C33	1	4 POINT TERMINAL BLOCK	C280	*	400 WATT HPS LIGHT (NO BULB)
C266	1	TERMINAL CABINET, 12" x 12" x 6"	C281	*	400 WATT HPS LIGHT NIGHT - WATCH UNIT
C276B	*	100 WATT HPS LIGHT	C282	*	400 WATT BULB (FOR ITEM C280 & C281)
C286	*	BRACKET, ANGLE, 12½"			

* QUANTITY VARIES & SOME ITEMS MAY NOT BE NEEDED



NOTE: DO NOT MOUNT LIGHTS NEAR OR ABOVE ENERGIZED BUS. CONSIDER MOUNTING LOCATIONS THAT ALLOW ACCESSIBILITY WHEN BULBS NEED REPLACING.

FIELD NOTE:
- LIGHT AIMING QUADRANT IS 2½ TIMES MOUNTING HEIGHT.
- FIELD TO FABRICATE MOUNTING AS REQUIRED FOR EACH LIGHT.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[2-1A] INDICATES DETAIL "A" SHOWN ON SHEET 2-1

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-3
SUBSTATION CONTROL AND LIGHTING DETAIL
400W HIGH PRESSURE SODIUM LIGHT FIXTURE MOUNTING

Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-2-3	E

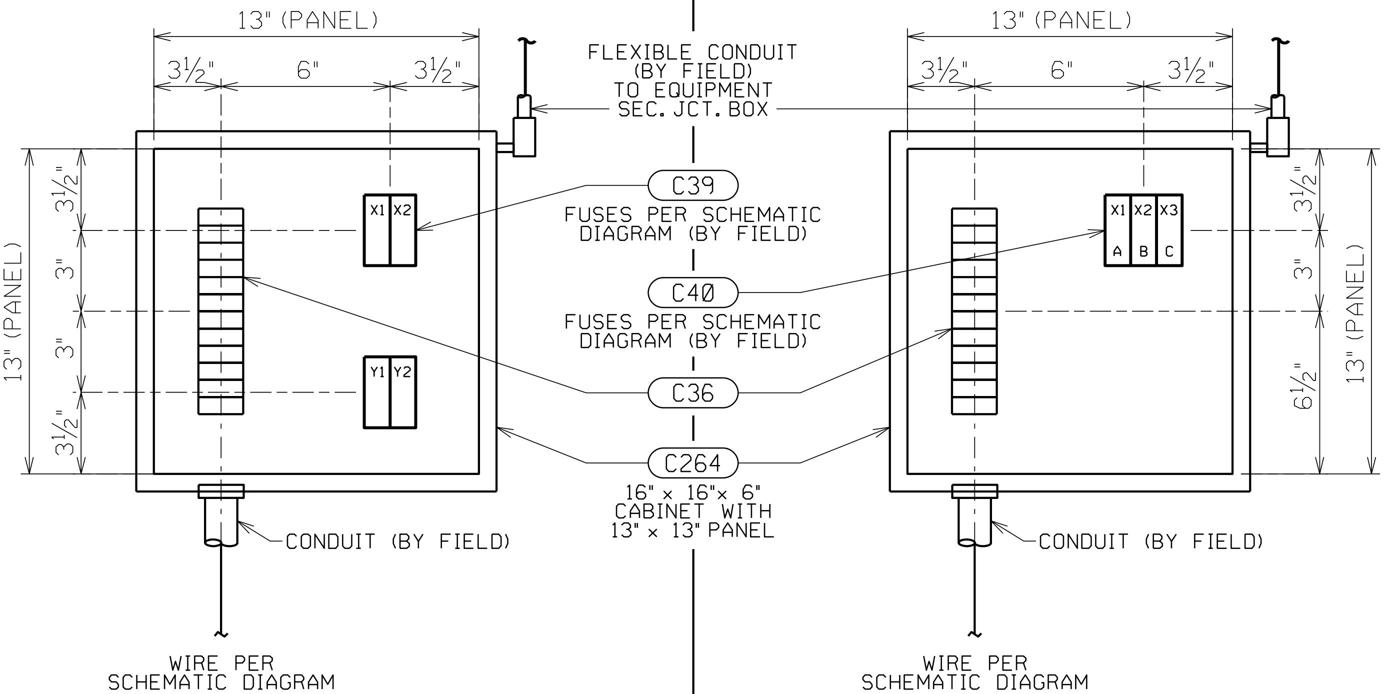
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-2-3.DGN 11:08:50 AM 11/20/2013

BILL OF MATERIAL FOR DETAIL "A"		
ITEM NO.	QTY	DESCRIPTION
C36	1	12 POINT TERMINAL BLOCK
C39	2	FUSE BLOCK, 30 AMP, 250V, DOUBLE POLE
C264	1	SEC. FUSE CAB., OUTDOOR, 16" x 16" x 6"

BILL OF MATERIAL FOR DETAIL "B"		
ITEM NO.	QTY	DESCRIPTION
C36	1	12 POINT TERMINAL BLOCK
C40	1	FUSE BLOCK, 30 AMP, 250V, TRIPLE POLE
C264	1	SEC. FUSE CAB., OUTDOOR, 16" x 16" x 6"

200902-2-4.DGN



DETAIL "A"

FOR USE IN SINGLE PHASE PT'S OR CCVT'S

DETAIL "B"

FOR USE IN DIST. BUS PT'S (OR 3 SINGLE PH PT'S)

FIELD NOTE:
- WIRE CABINET PER SCHEMATIC DIAGRAM.
- PLACE A WOOD DOWEL IN ALL SPARE FUSE POSITIONS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-4
SUBSTATION CONTROL AND LIGHTING DETAIL
FUSE CABINET FOR SINGLE PHASE P.T. OR CCVT AND DIST. BUS PT'S

Xcel Energy

SCALE	DRAWING	REV
NONE	NL-200902-2-4	D

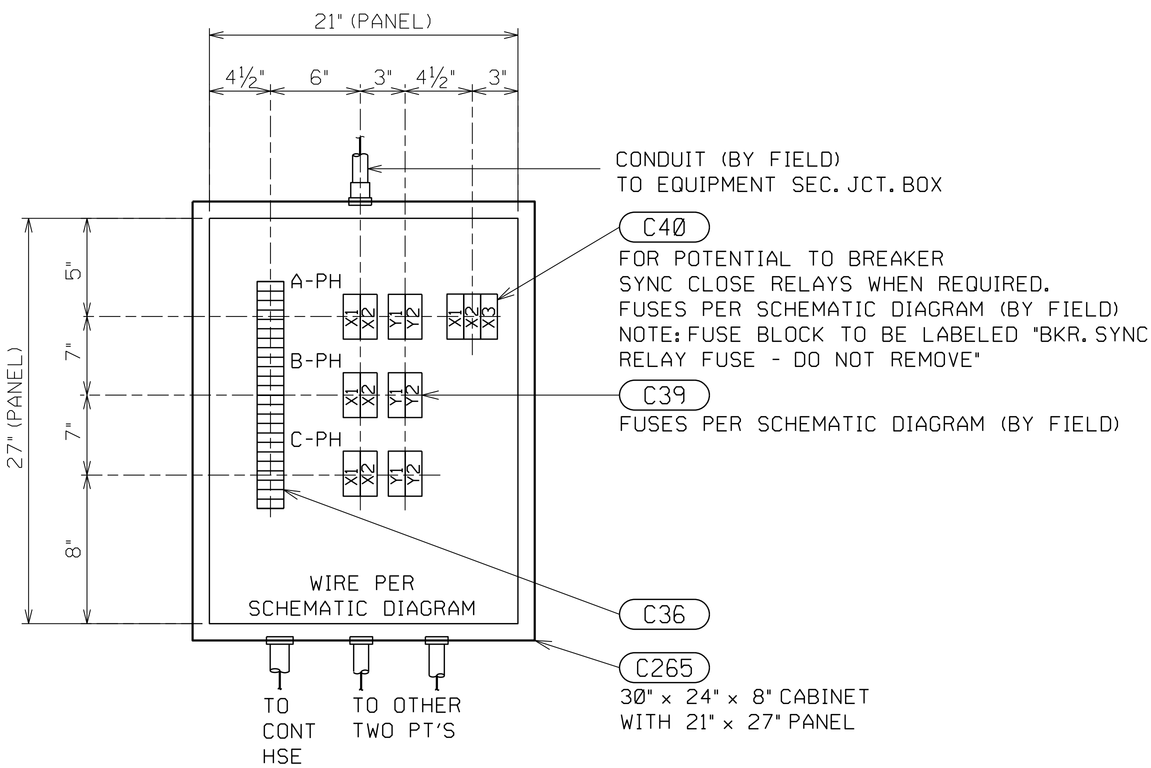
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

9/19/2013 7:56:31 AM

200902-2-5.DGN

MATERIAL REQUIRED FOR THIS DETAIL

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C36	2	12 POINT TERMINAL BLOCK			
C39	6	FUSE BLOCK, 30 AMP, 250V, 2 POLE			
C40	1*	FUSE BLOCK, 30 AMP, 250V, 3 POLE			
C265	1	SEC. FUSE CAB. 30" x 24" x 8"			
		* ONLY WHEN REQUIRED			



FIELD NOTE:

- PLACE A WOOD DOWEL IN ALL SPARE FUSE POSITIONS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

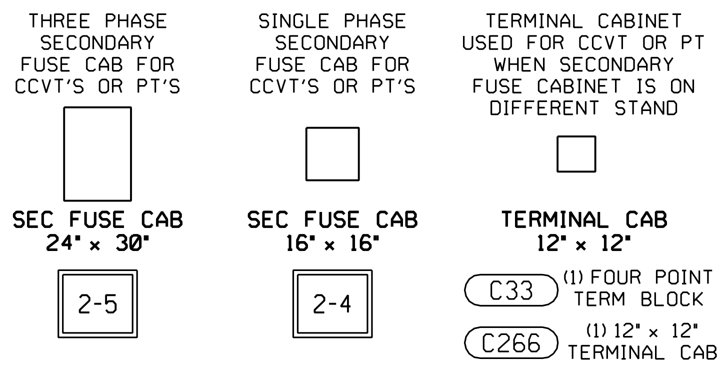
SUBSTATION PHYSICAL DETAIL 2-5
SUBSTATION CONTROL AND LIGHTING DETAIL
FUSE CABINET FOR THREE SINGLE PHASE PT'S OR CCVT'S

Xcel Energy®

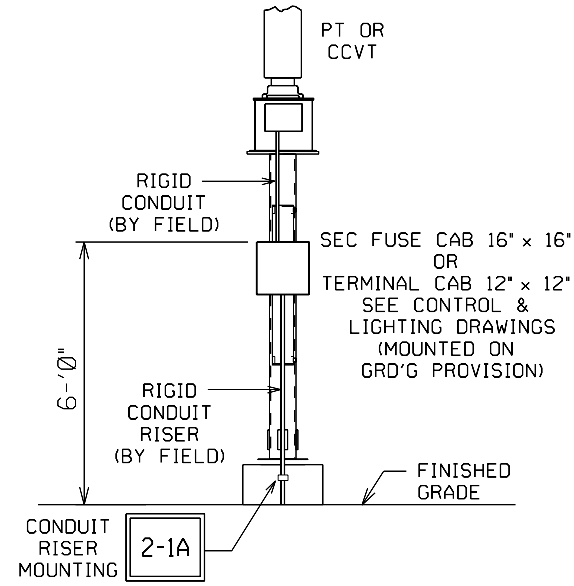
SCALE		REV
NONE	NL-200902-2-5	C

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

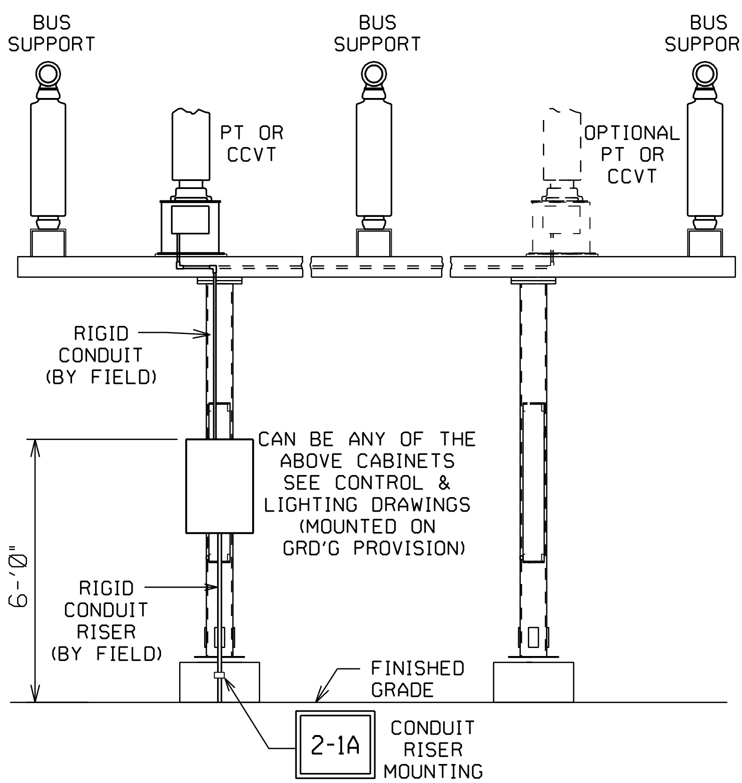
5/3/2013 9:56:55 AM



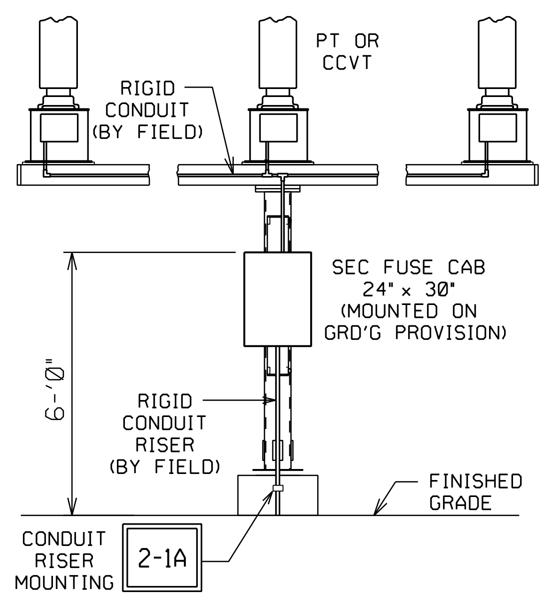
CABINET OPTIONS



SINGLE PHASE



ONE OR TWO PHASE - MOUNTED ON BUS SUPPORT STAND



THREE PHASE

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[2-1A] INDICATES DETAIL "A" SHOWN ON SHEET 2-1 [2-5] INDICATES DETAIL ON SHEET 2-5

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-6
SUBSTATION CONTROL AND LIGHTING DETAIL
CONTROL CABLE CONNECTION FOR PT'S OR CCVT'S

Xcel Energy

SCALE		REV
NONE	NL-200902-2-6	B

GRP	SIGNIFICANT NUMBER
LOC ID	
GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-2-6.DGN

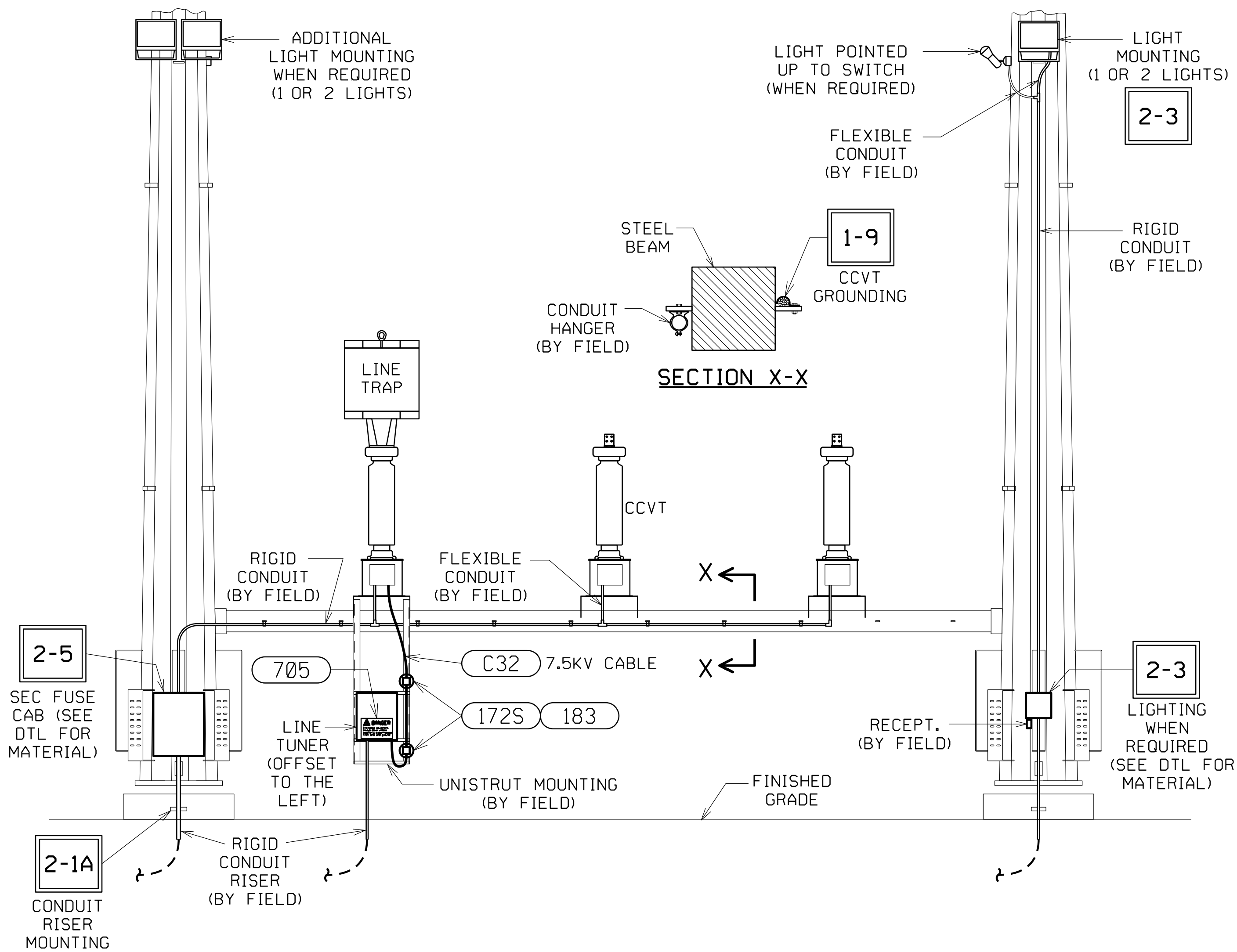
$TIME$

11/05/2008

BILL OF MATERIAL FOR LINE TRAP

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
172S	2	7.5KV BUS SUPPORT, 7½" HIGH	705	1	SIGN, "DANGER ENERGIZED EQUIPMENT..."
183	2	BUS SUPPORT CONDUCTOR FITTING	C32	15 FT	COMMUNICATION CABLE, 7.5KV

NOTE: SEE INDIVIDUAL DETAILS FOR MATERIAL OF OTHER ITEMS SHOWN ON THIS DRAWING.



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

[2-1A] INDICATES DETAIL "A" SHOWN ON SHEET 2-1 [2-3] INDICATES DETAIL ON SHEET 2-3

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

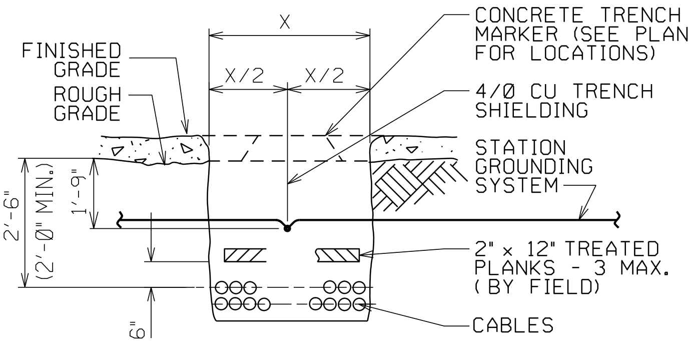
NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-7
SUBSTATION CONTROL AND LIGHTING DETAIL
CONTROL CABLE CONNECTION FOR THREE SINGLE PHASE CCVT'S

Xcel Energy® | SCALE NONE | NL-200902-2-7 | REV C

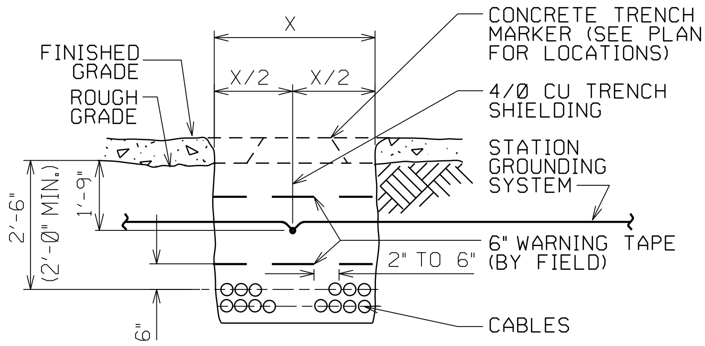
200902-2-7.DGN

12:28:31 PM 5/20/2011



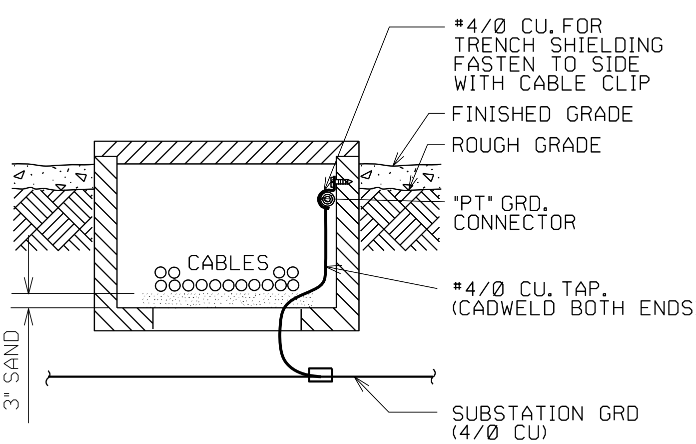
DETAIL "A"

DIRECT BURIAL TRENCH
WITH SHIELDING & PLANK



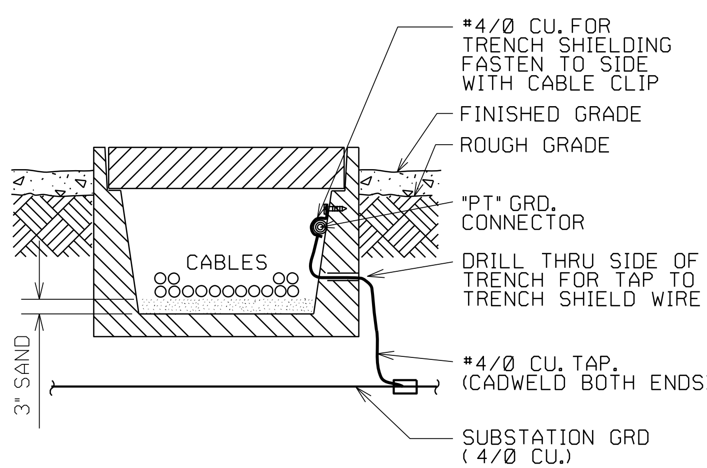
DETAIL "B"

DIRECT BURIAL TRENCH
WITH SHIELDING



DETAIL "C"

PRECAST CONCRETE LIGHT-WEIGHT
OPEN BOTTOM TRENCH
WITH SHIELDING



DETAIL "D"

PRECAST CONCRETE HEAVY
ROAD CROSSING TRENCH
SOLID BOTTOM
WITH SHIELDING

FIELD NOTE:

- TRENCH DEPTH DETERMINED BY THE NUMBER OF CABLE LAYERS REQUIRED.
- FOR BACKFILL USE EXCAVATED EARTH IF IT IS FREE OF SHARP OR ABRASIVE MATERIAL AND IS ADEQUATE FOR EASY REDIGGING.
- REMOVE SHARP OR ABRASIVE MATERIAL FROM TRENCH BOTTOM.
- SUBSTATION 4/Ø CU GROUND CONDUCTOR AND 4/Ø CU TRENCH SHIELDING MUST BE CONNECTED AT EACH INTERSECTION AND AT THE END OF EACH RUN.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-8

SUBSTATION CONTROL AND LIGHTING DETAIL

CABLE TRENCH DETAIL "A", DETAIL "B", DETAIL "C" & DETAIL "D"

Xcel Energy

SCALE: NONE

NL-200902-2-8

REV: C

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-2-8.DGN

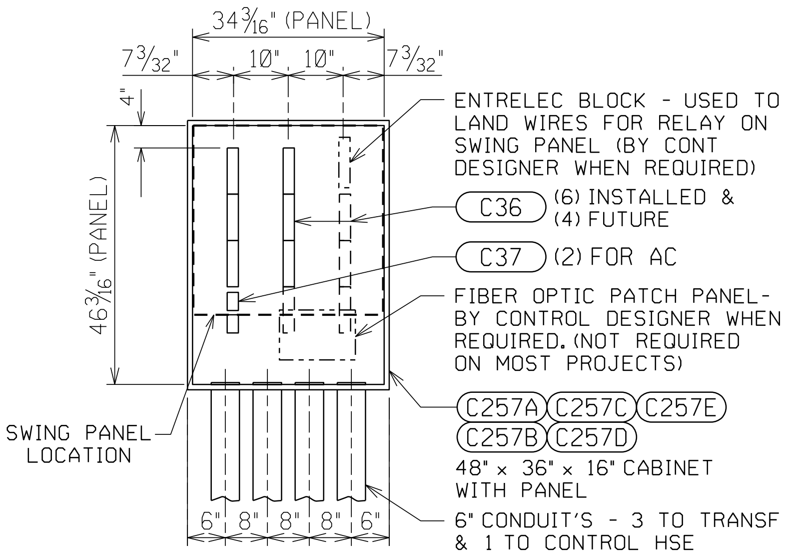
5/3/2013 12:05:48 PM

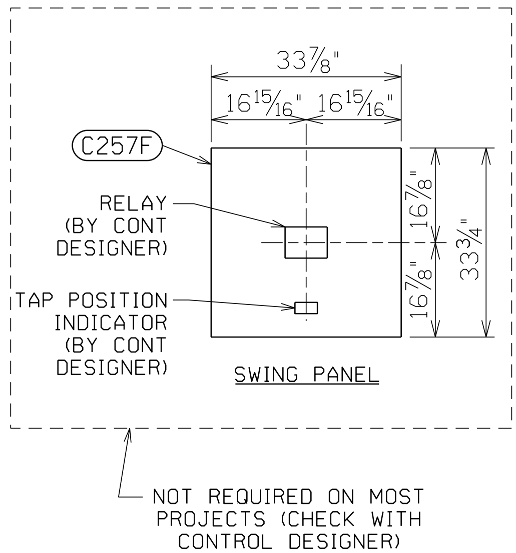
BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

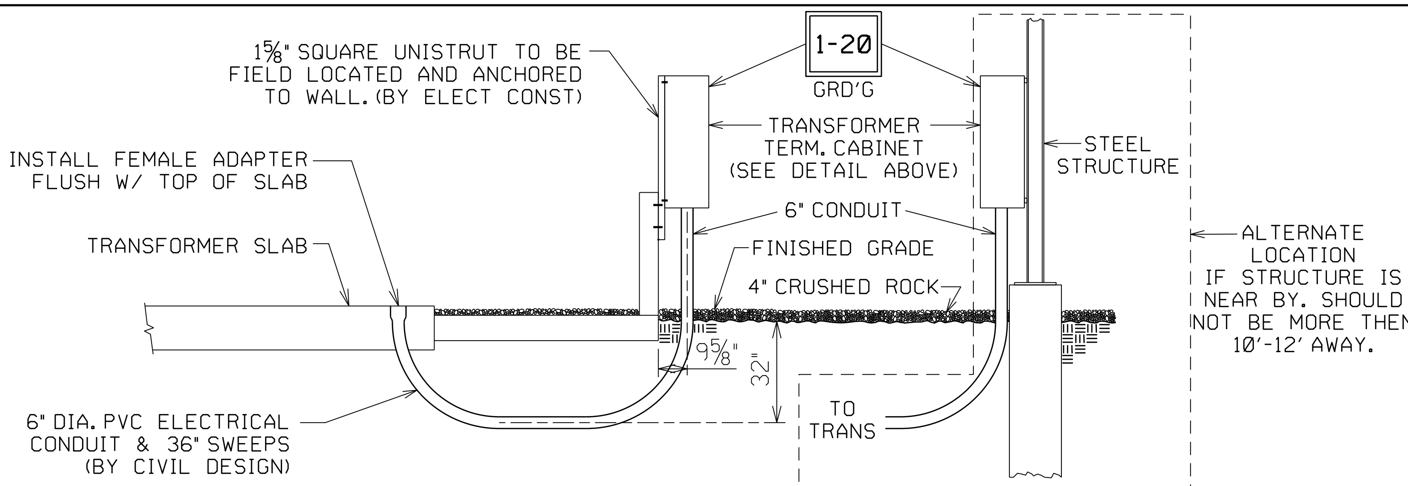
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C36	6	12 POINT TERMINAL BLOCK	C257C	1	HANDLE FOR ITEM C257A
C37	2	2 POINT TERMINAL BLOCK EB-1	C257D	1	MOUNTING KIT FOR ITEM C257A
C257A	1	CABINET 48" x 36" x 16" WITH BACK PNL	C257E	1	DOOR STOP FOR ITEM C257A
C257B	1	INTERIOR PANEL FOR ITEM C257A	C257F	*	SWING PANEL FOR ITEM C257A

NOTE: ON MOST PROJECTS THIS CABINET WILL BE USED AS A PULL BOX ON THE INITIAL INSTALLATION (ONLY ORDER ITEMS C257A THRU C257E). CONSTRUCTION TO PROVIDE ENOUGH SLACK TO LAND CABLES IN THE FUTURE.

*1 REQUIRED ONLY IF NEEDED BY CONTROL DESIGNER.







LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-9
SUBSTATION CONTROL AND LIGHTING DETAIL
TRANSFORMER CABLE TERMINATION CABINET

Xcel Energy

SCALE: NONE

NL-200902-2-9

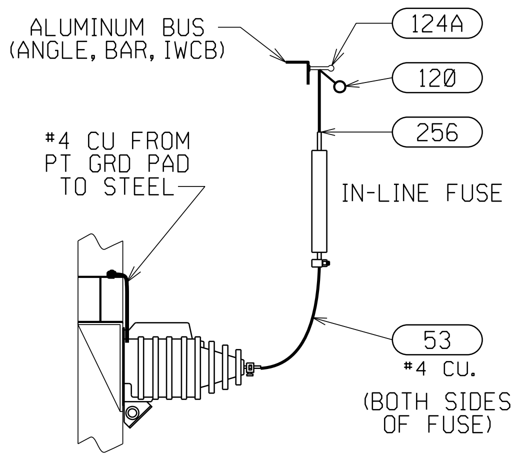
REV: C

200902-2-9.DGN 9:57:31 AM 5/3/2013

MATERIAL FOR FUSE HANGING FROM RIGID BUS (PER PHASE)		
ITEM NO.	QTY	DESCRIPTION
53	*	4 AWG SOLID CU. WIRE
120	1	HOT LINE CLAMP
124A	1	GROUNDING STUD, ½" DIA x 7" LONG
256	1	SPLICE/REDUCER, BURNDY AMS-250

MATERIAL FOR FUSE HANGING FROM FLEXIBLE CONDUCTOR (PER PHASE)		
ITEM NO.	QTY	DESCRIPTION
53	*	4 AWG SOLID CU. WIRE
123	1	HOT LINE CLAMP (USE W/ 124)
124	1	GROUNDING STIRRUP
256	1	SPLICE/REDUCER, BURNDY AMS-250

* = VARIES



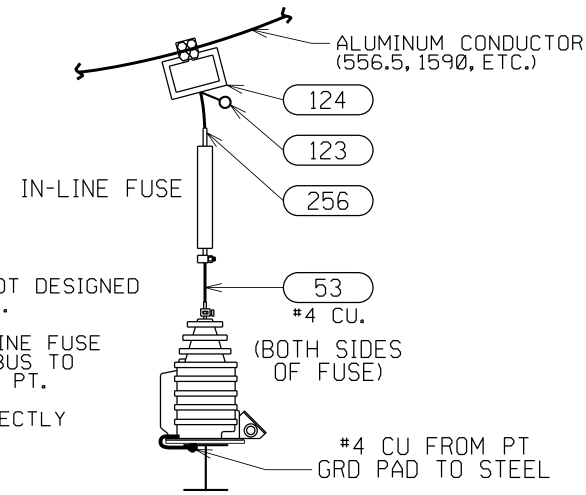
HORIZONTALLY MOUNTED PT

NOTES:

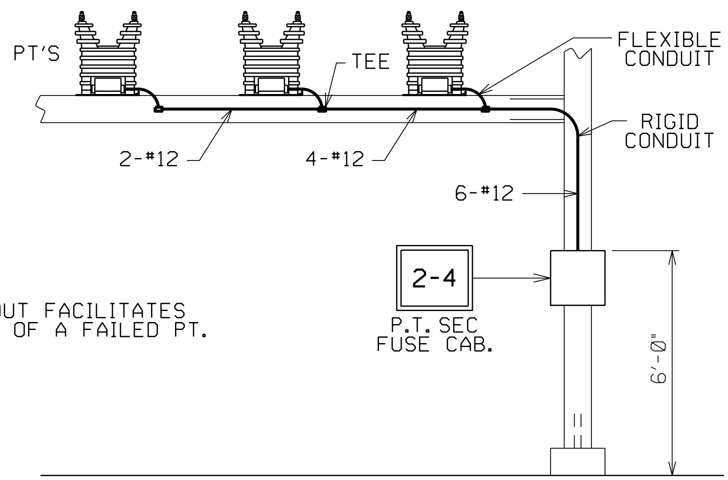
THE PT BUSHING IS NOT DESIGNED TO SUPPORT THE FUSE.

ALWAYS SUPPORT IN-LINE FUSE FROM THE OVERHEAD BUS TO AVOID DAMAGE TO THE PT.

DO NOT PUT FUSE DIRECTLY IN PT BUSHING.



VERTICAL MOUNTED PT



NOTE:

THIS CONDUIT LAYOUT FACILITATES EASY REPLACEMENT OF A FAILED PT.

EXAMPLE PT LAYOUT

SEE ELECTRICAL LAYOUT DRAWINGS FOR EXACT LAYOUT OF P.T.'S

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID	
GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-10

SUBSTATION CONTROL AND LIGHTING DETAIL

POTENTIAL TRANSFORMER MOUNTING AND CONDUIT LAYOUT

Xcel Energy®

SCALE	DRAWING	REV
NONE	NL-200902-2-10	C

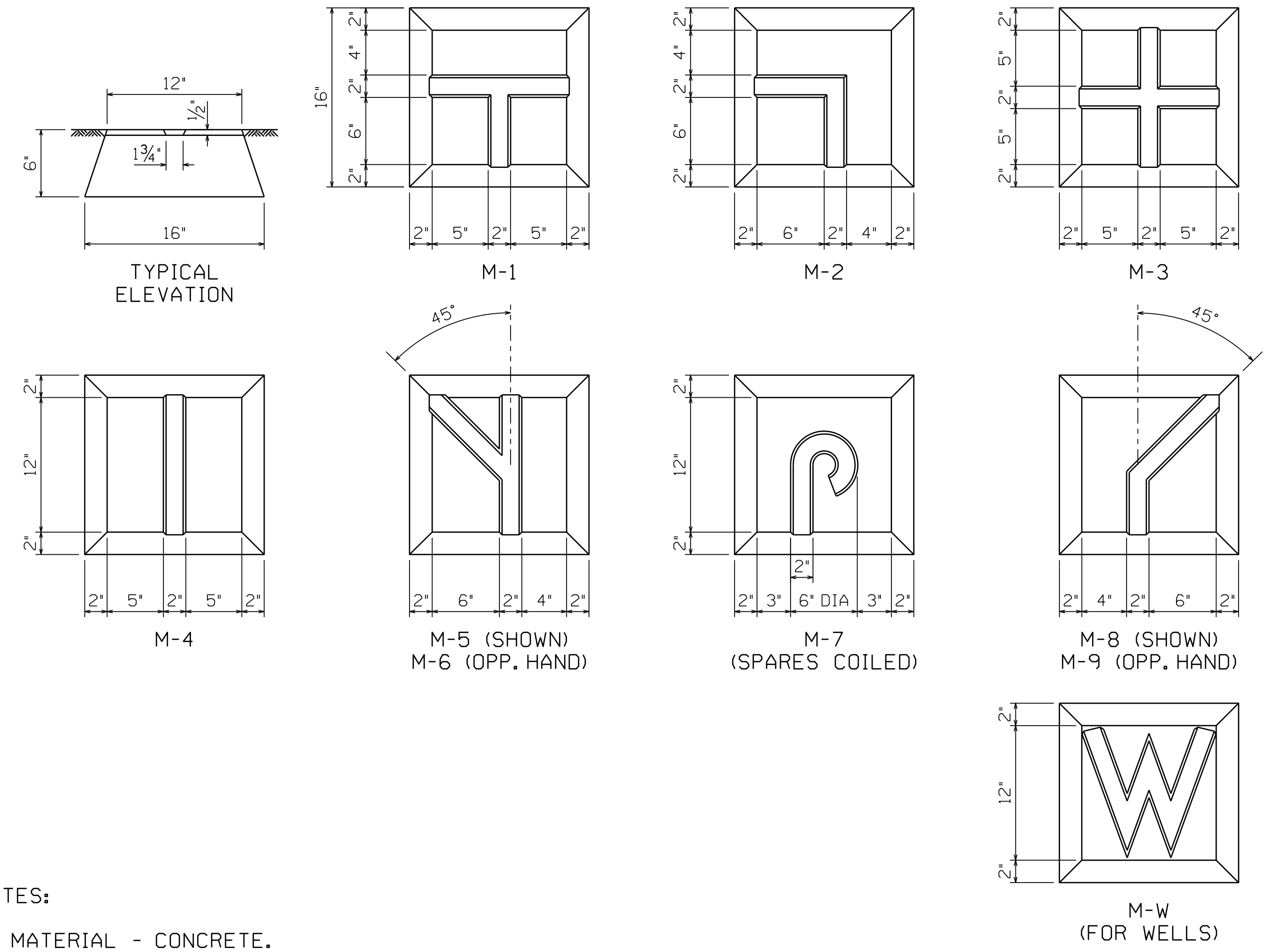
200902-2-10.DGN

12:19:41 PM

5/3/2013

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION



NOTES:

1. MATERIAL - CONCRETE.
2. SLOTS UNPAINTED FOR POWER CABLES 600V AND BELOW AND FOR CONTROL
3. SLOTS PAINTED RED FOR POWER CABLES OVER 600V. (CALLED OUT ON DWG AS MR-1, MR-2...)
4. SLOTS PAINTED BLUE FOR WATER OR SEWER LINES. (CALLED OUT ON DWG AS MB-1, MB-2...)
5. SLOTS PAINTED ORANGE FOR PHONE CABLES. (CALLED OUT ON DWG AS MO-1, MO-2...)
6. MARKERS TO BE PLACED 5'-0" MAX. FROM EACH SIDE OF THE FENCE AND APPROXIMATELY 20FT INTERVALS ALONG CABLE ROUTE TO PROPERTY LINE. USE DISCRETION IN SPACING ON LONG RUNS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 2-11
SUBSTATION CONTROL AND LIGHTING DETAIL
CONCRETE MARKERS FOR UNDERGROUND CABLE RUNS

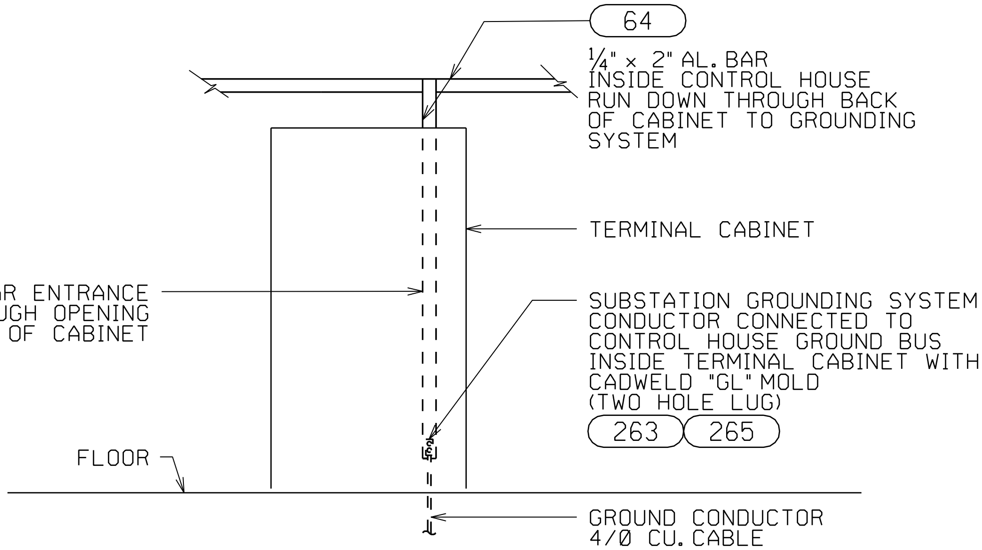
Xcel Energy

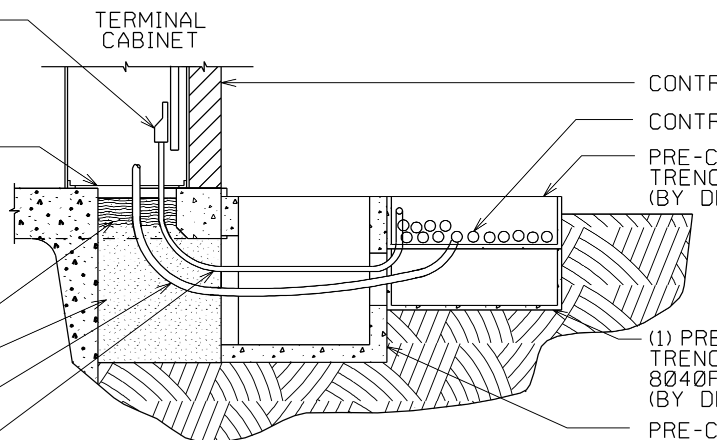
SCALE	DRAWING	REV
NONE	NL-200902-2-11	B

200902-2-11.DGN
9/19/2013 11:05:10 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
64		1/4" x 2" x 20' LONG RECT. AL. BAR			
263	1	CADWELD LUG, TYPE GL			
265	1/4PKG	CADWELD SHOT, CAT #XL65 (PKG 4)			





LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-1

CONTROL HOUSE DETAIL

CABLE ENTRANCE TO CONTROL HOUSE (PRE-CAST PULL BOX)

Xcel Energy

SCALE: NONE

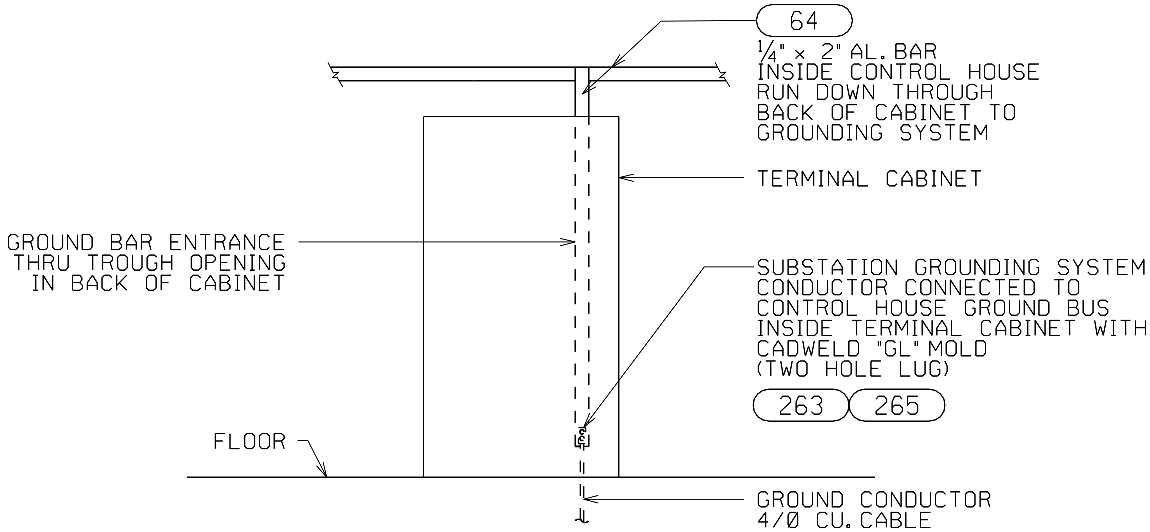
NL-200902-3-1

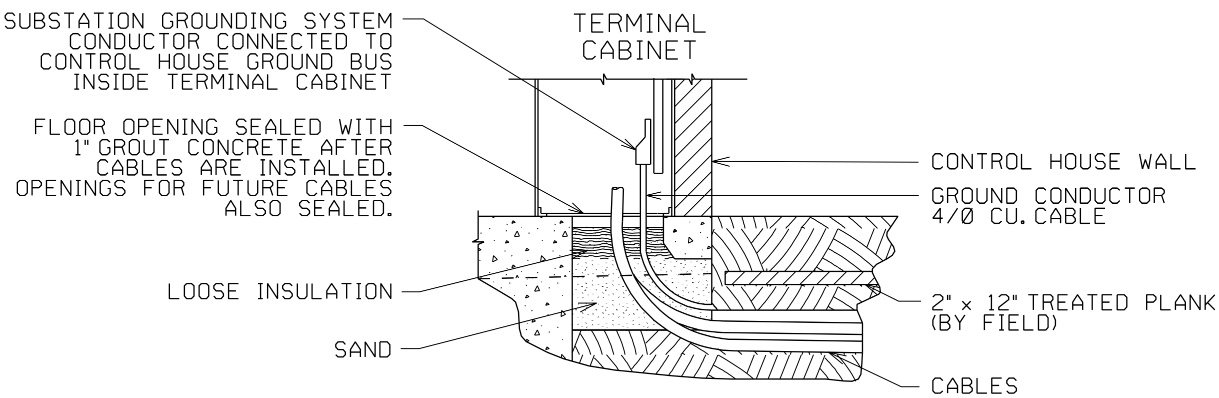
REV: B

08/16/2006 200902-3-1.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
64		1/4" x 2" x 20' LONG RECT. AL. BAR			
263	1	CADWELD LUG, TYPE GL			
265	1/4PKG	CADWELD SHOT, CAT #XL65 (PKG 4)			





LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-2
CONTROL HOUSE DETAIL
CABLE ENTRANCE TO CONTROL HOUSE (BURIED CABLE)

Xcel Energy

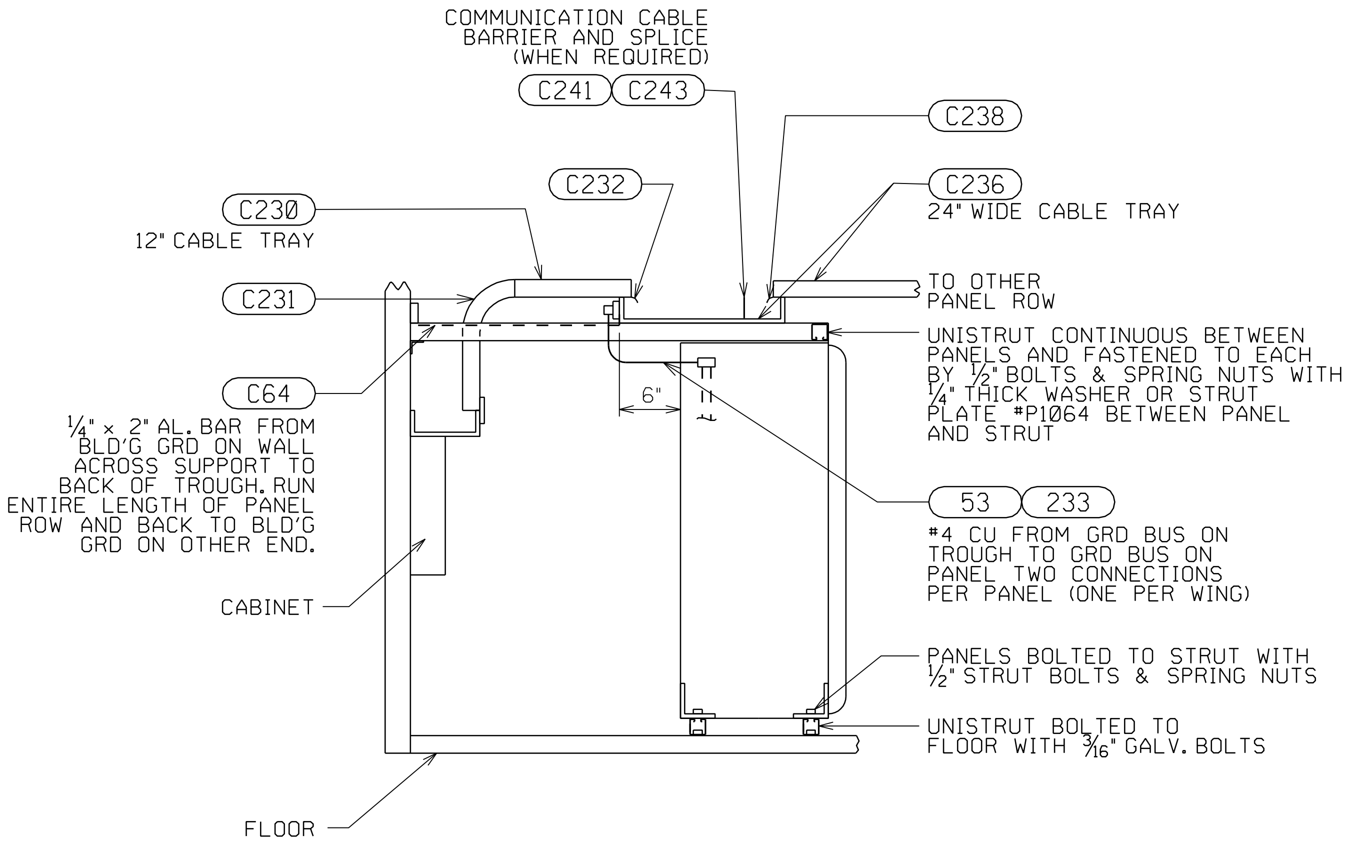
SCALE: NONE

NL-200902-3-2

REV: B

08/16/2006 200902-3-2.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
53		4 AWG SOLID COPPER WIRE	C236		24" AL. LADDER CABLE TRAY
64		1/4" x 2" x 20' LONG RECT. AL. BAR	C238		END DROP OUT FOR 24" WIDE CABLE TRAY
233		TERMINAL LUG, 14 AWG - 4 AWG CU.	C241		STRAIGHT SECTION BARRIER
C230		12" AL. LADDER CABLE TRAY	C243		BARRIER STRIP SPLICE
C231		90 DEG ELBOW, FOR 12" WIDE CABLE TRAY			
C232		END DROP OUT FOR 12" WIDE CABLE TRAY			



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

THIS MAP/DOCUMENT IS A TOOL TO ASSIST EMPLOYEES IN THE PERFORMANCE OF THEIR JOBS. YOUR PERSONAL SAFETY IS PROVIDED FOR BY USING SAFETY PRACTICES, PROCEDURES AND EQUIPMENT AS DESCRIBED IN THE SAFETY TRAINING PROGRAMS, MANUALS AND SPARS.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-3

CONTROL HOUSE DETAIL

TYPICAL PANEL AND CABLE TRAY MOUNTING

Xcel Energy

SCALE: NONE

NL-200902-3-3

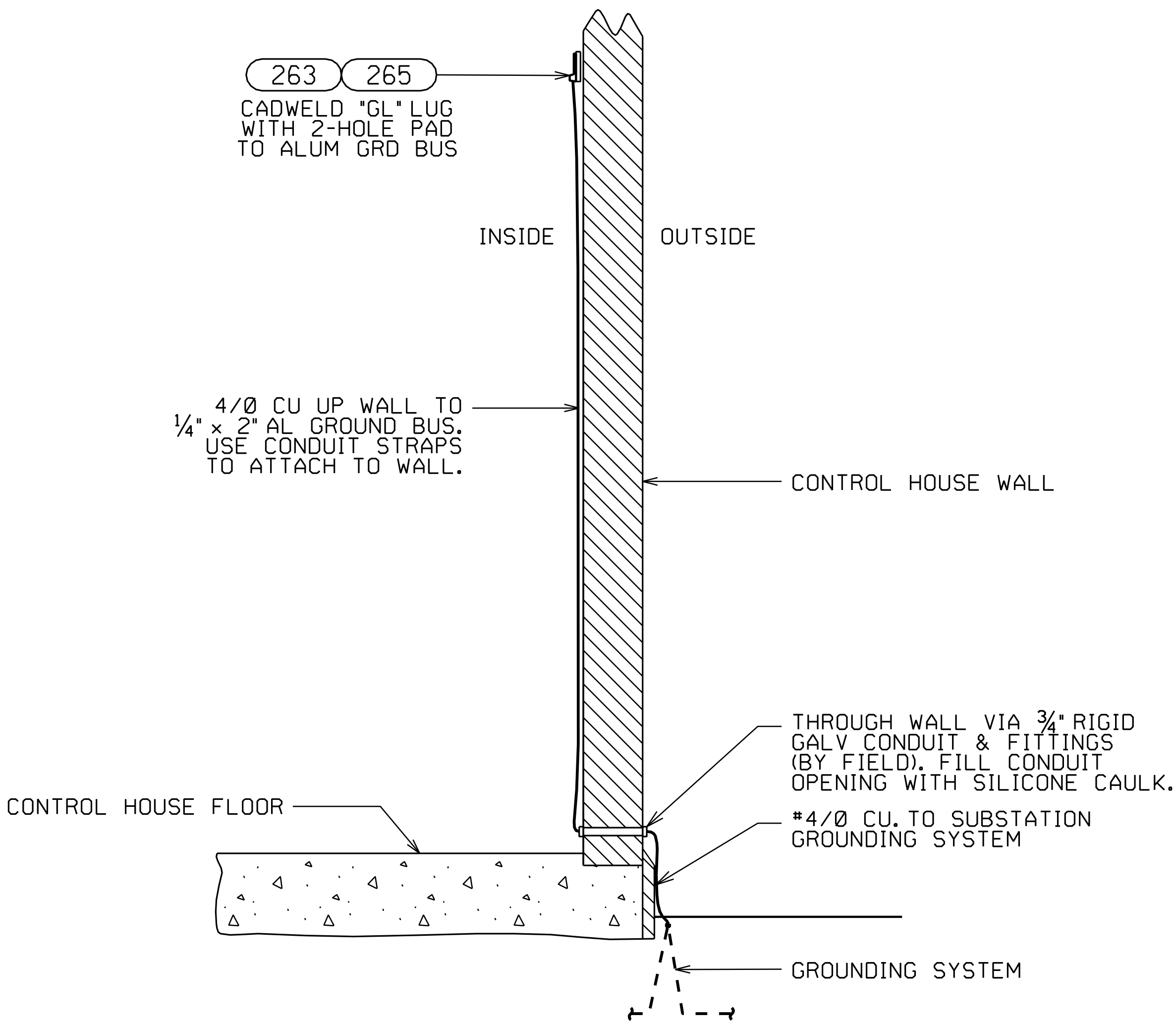
REV: A

05/25/2006 200902-3-3.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
263	1 EA	CADWELD LUG, TYPE GL			
265	1 EA	CADWELD SHOT 65, COLOR DARK GREEN			

200902-3-4.DGN



LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP I	
3	
4	
5A	
5B	DETAIL
6	
CL	

$TIME$

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-4

CONTROL HOUSE DETAIL

GROUND BUS ENTRANCE

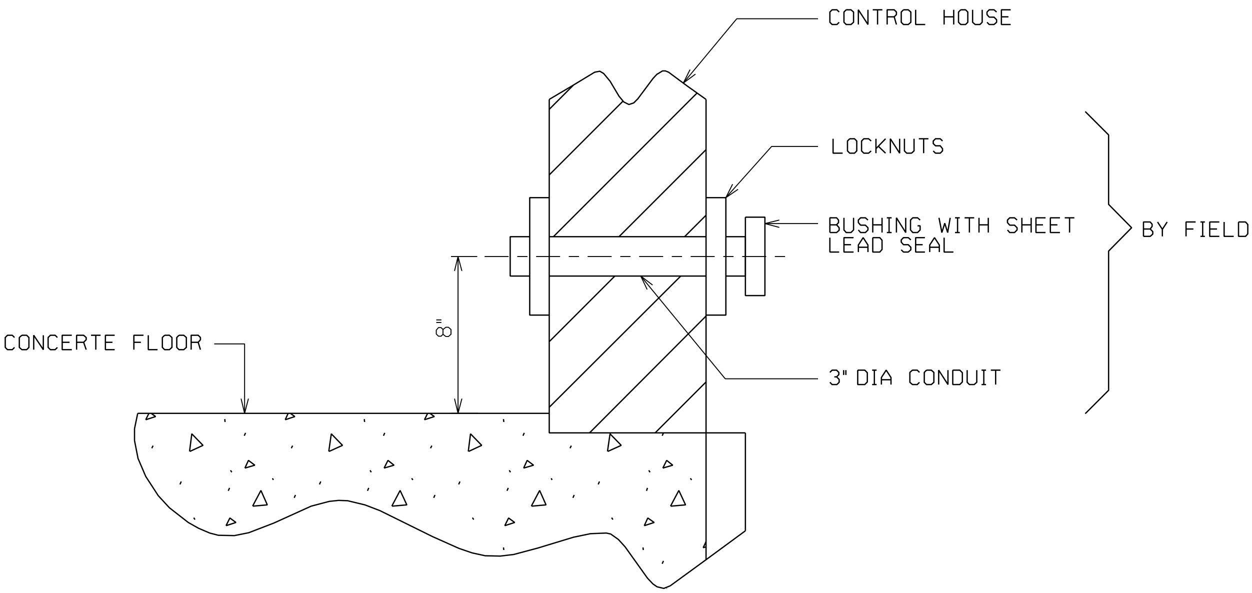
Xcel Energy

SCALE: NONE

NL-200902-3-4

REV: B

09/20/2007



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-5

CONTROL HOUSE DETAIL

MOBILE TRANSFORMER CONTROL CABLE ENTRANCE

Xcel Energy™

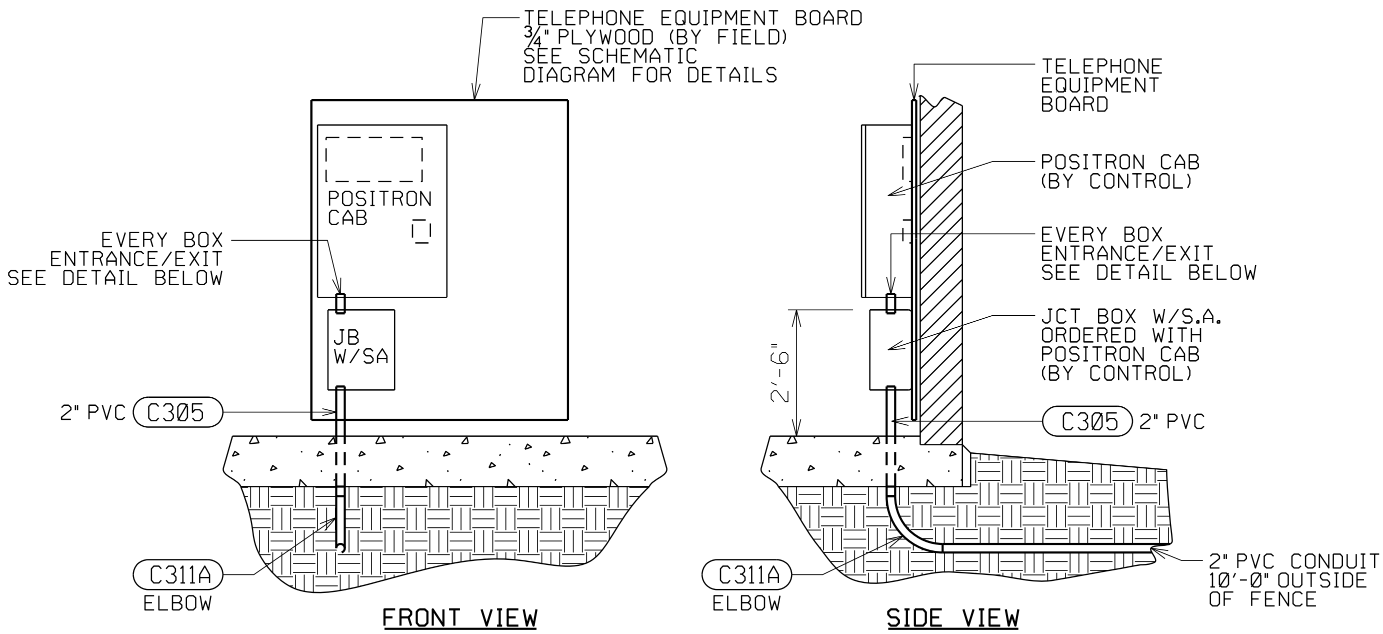
SCALE	DRAWING	REV
NONE	NL-200902-3-5	A

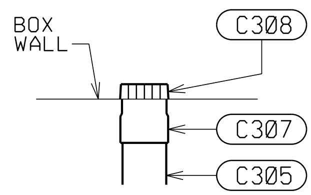
GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

05/25/2006 200902-3-5.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
703	1 EA	CAUTION SIGN	C308	3 EA	INSULATED CONDUIT BUSHING FOR 2" PVC
C305	* FT	2" PVC CONDUIT, SCHEDULE 40	C310	1 EA	CLEAR PVC CEMENT
C307	3 EA	TERMINAL ADAPTERS FOR 2" PVC	C311A	1 EA	ELBOW, 24" RADIUS FOR 2" PVC SCHED 40
					* DETERMINED BY DESIGNER





DETAIL

PVC TERMINATION TO BOX

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-6

ELECTRICAL EQUIPMENT ENCLOSURE DETAIL

TELEPHONE CABLE ENTRANCE

Xcel Energy®

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

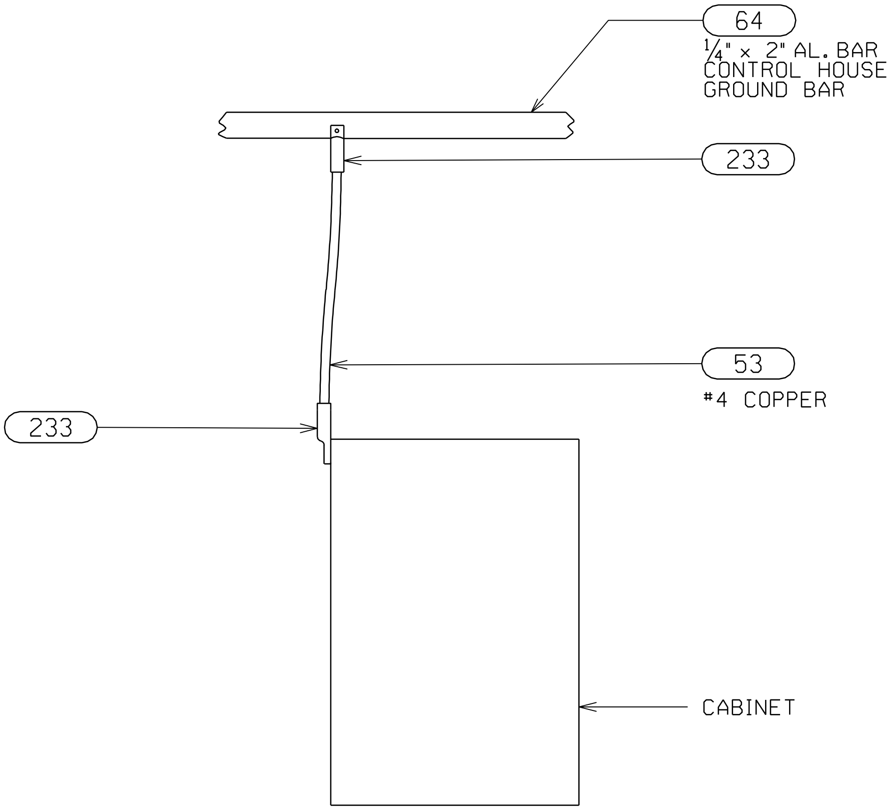
SCALE: NONE | NL-200902-3-6 | REV: D

11/17/2011 11:41:16 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
53	3 FT	#4 AWG SOLID COPPER WIRE			
64	*	1/4" x 2" AL. BAR			
233	2	TERMINAL LUG, 14 AWG - 4 AWG			

* VARIES



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

THIS MAP/DOCUMENT IS A TOOL TO ASSIST EMPLOYEES IN THE PERFORMANCE OF THEIR JOBS. YOUR PERSONAL SAFETY IS PROVIDED FOR BY USING SAFETY PRACTICES, PROCEDURES AND EQUIPMENT AS DESCRIBED IN THE SAFETY TRAINING PROGRAMS, MANUALS AND SPARS.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-7

CONTROL HOUSE DETAIL

TYP GRD'G FOR ALL CAB., BOXES, SAF. SW., BATT. RACK & CHARGER

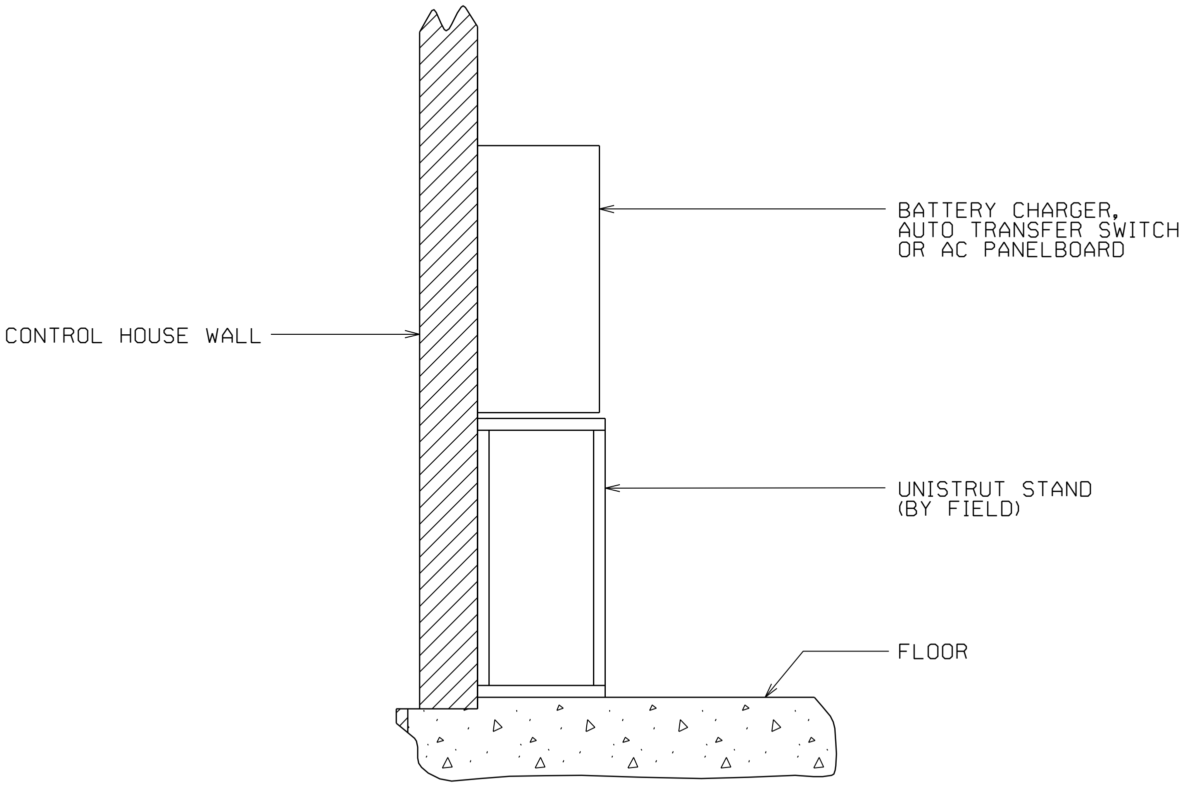
Xcel Energy

SCALE NONE

NL-200902-3-7

REV A

05/25/2006 200902-3-7.DGN



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-8

CONTROL HOUSE DETAIL

MOUNTING FOR HEAVY EQUIPMENT

Xcel Energy™

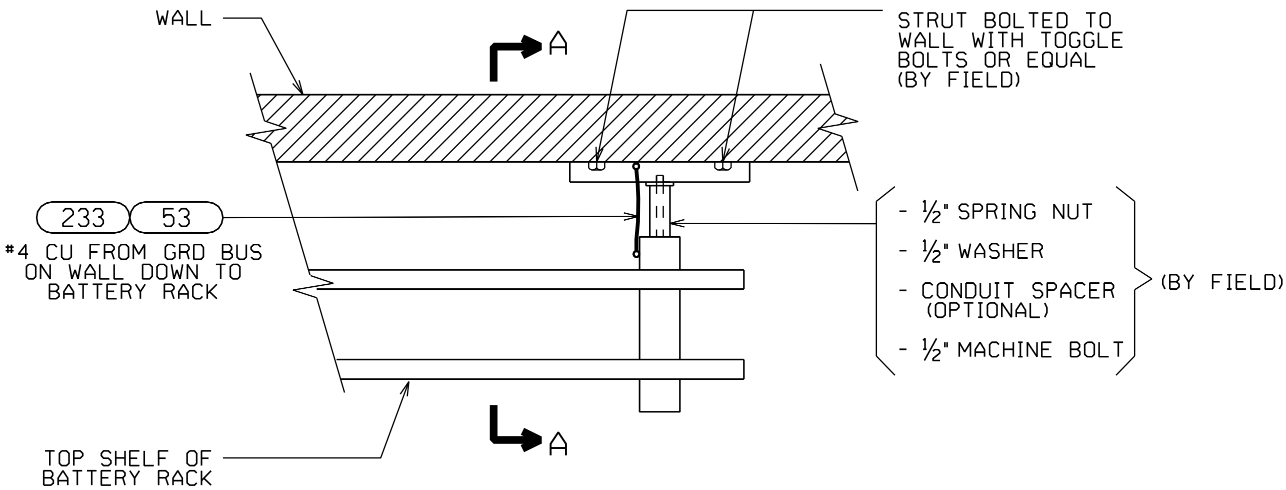
SCALE	DRAWING	REV
NONE	NL-200902-3-8	A

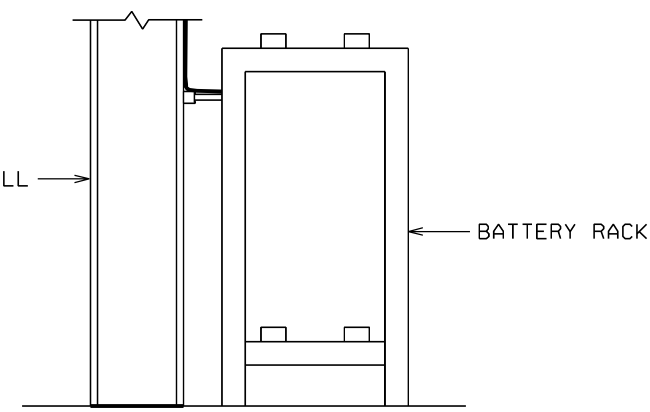
GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

05/25/2006 200902-3-8.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
53	10 FT	4 AWG SOLID COPPER WIRE			
233	2	TERMINAL LUG, 14 AWG - 4 AWG			





SECTION A-A

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-9

ELECTRICAL EQUIPMENT ENCLOSURE DETAIL

TYPICAL MOUNTING OF BATTERY RACK TO WALL

Xcel Energy®

SCALE		REV
NONE	NL-200902-3-9	B

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

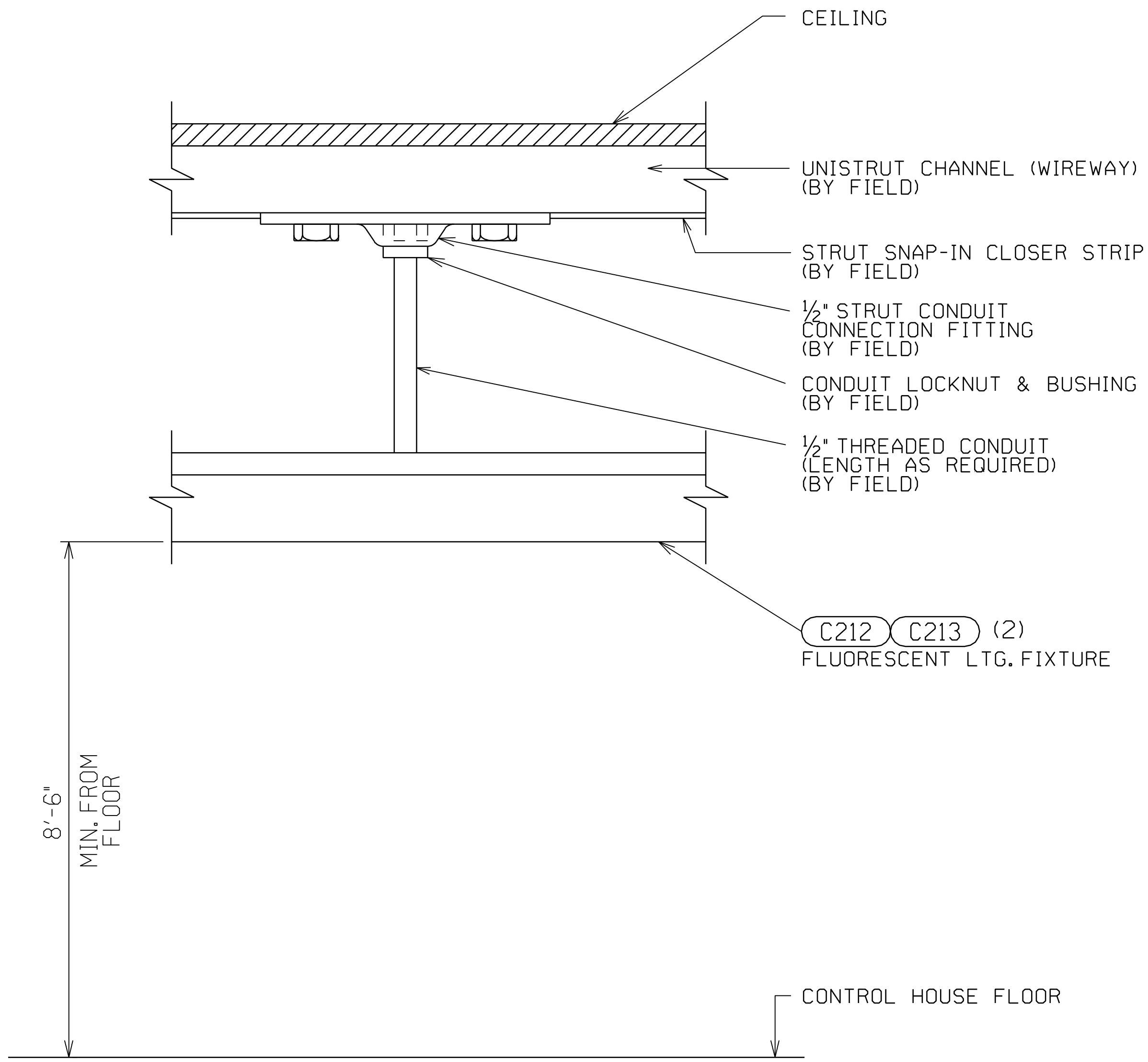
200902-3-9.DGN

$TIME$

02/20/2008

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C212		FLUORESCENT LIGHTING FIXTURE 4'-0" UNIT			
C213		FLUORESCENT LAMP, 35W, 48"			



FIELD NOTE:
- AN OPTION WOULD BE TO MOUNT THE LIGHTS FLUSH WITH STRUT.

LEGEND:
(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-10
CONTROL HOUSE DETAIL
FLUORESCENT LIGHT FIXTURE HANGER

Xcel Energy

SCALE: NONE

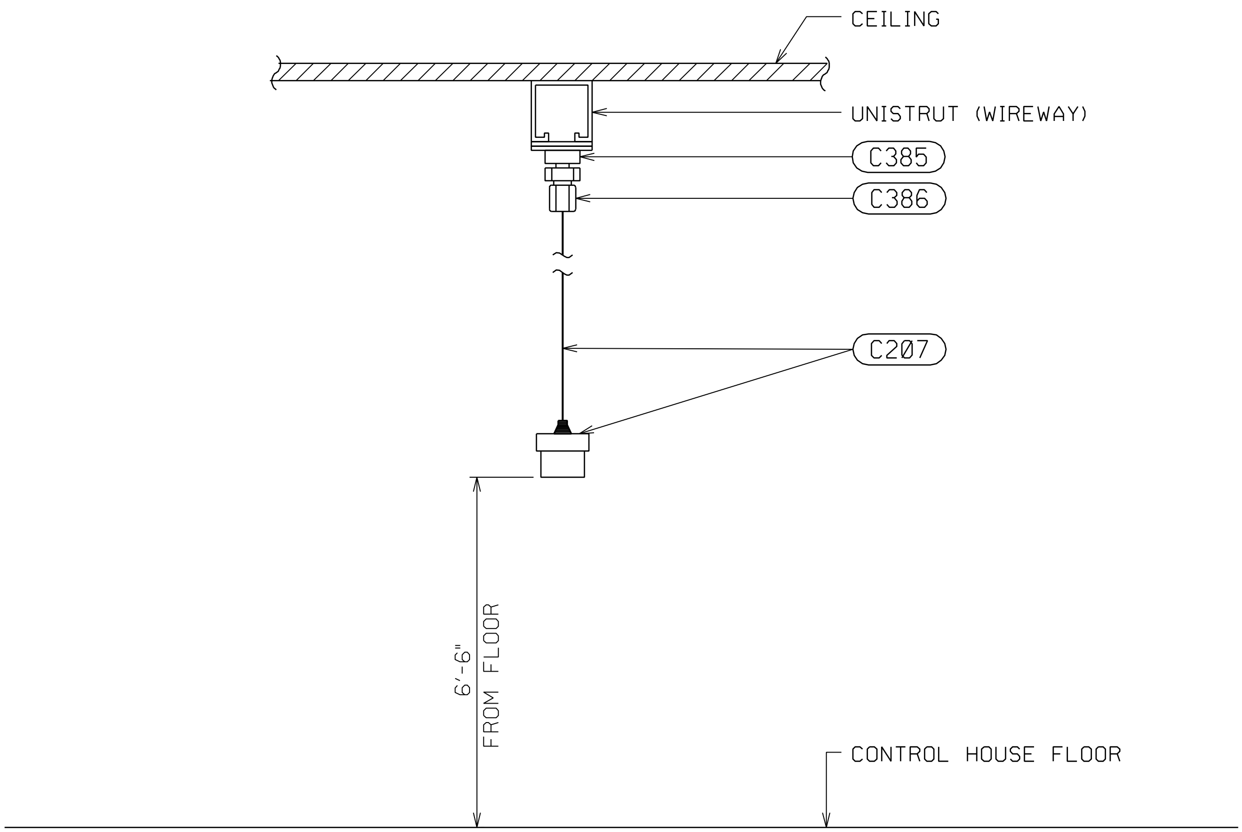
NL-200902-3-10

REV: A

05/25/2006 200902-3-10.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C207	1	GROUND RECEPTACLES ON DROP CORD.			
C385	1	CONDUIT CONN. PLATE FOR ¾" CONDUIT			
C386	1	STRAIGHT CORD. CONNECTOR			



FIELD NOTE:

- RECEPTACLES LOCATED IN BACK OF PANEL ROWS AT APPROXIMATELY 10'-0" INTERVALS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-11

CONTROL HOUSE DETAIL

MOUNTING DETAIL FOR PANEL DROP CORD RECEPTACLES

Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-3-11	A

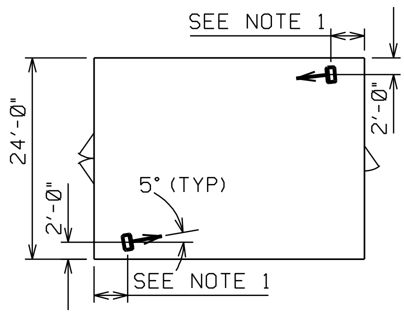
GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

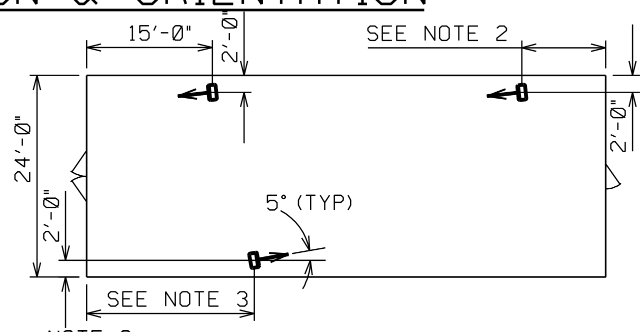
05/25/2006 200902-3-11.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C195		5KW HEATER, 240 VOLT, SINGLE PHASE			
C198		HEATER THERMOSTAT			

HEATER LOCATION & ORIENTATION

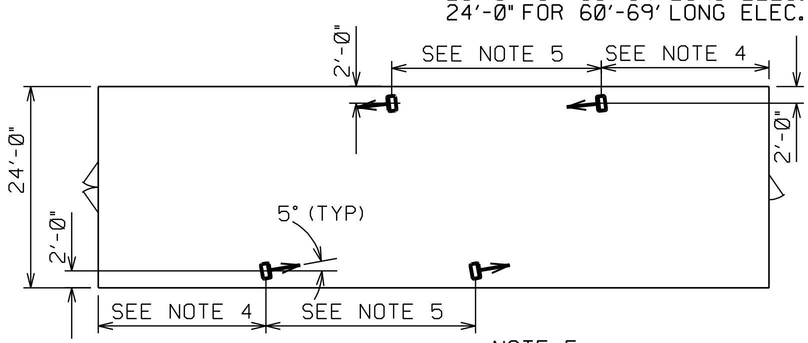




NOTE 1:
4'-0" FOR 20'-29' LONG ELEC. EQUIP. ENCLOSURE
5'-0" FOR 30'-39' LONG ELEC. EQUIP. ENCLOSURE
8'-0" FOR 40'-49' LONG ELEC. EQUIP. ENCLOSURE

NOTE 2:
10'-0" FOR 50'-59' LONG ELEC. EQUIP. ENCLOSURE
12'-0" FOR 60'-79' LONG ELEC. EQUIP. ENCLOSURE

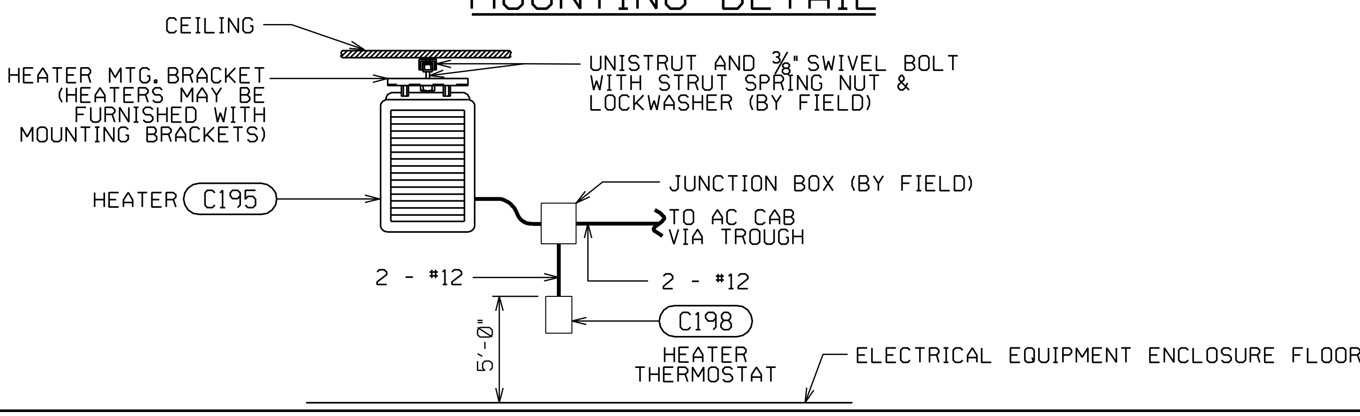
NOTE 3:
20'-0" FOR 50'-59' LONG ELEC. EQUIP. ENCLOSURE
24'-0" FOR 60'-69' LONG ELEC. EQUIP. ENCLOSURE



NOTE 4:
20'-0" FOR 80'-99' LONG ELEC. EQUIP. ENCLOSURE
24'-0" FOR 100'-110' LONG ELEC. EQUIP. ENCLOSURE

NOTE 5:
25'-0" FOR 80'-99' LONG ELEC. EQUIP. ENCLOSURE
35'-0" FOR 100'-110' LONG ELEC. EQUIP. ENCLOSURE

MOUNTING DETAIL



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-12
ELECTRICAL EQUIPMENT ENCLOSURE DETAIL
HEATER INSTALLATION

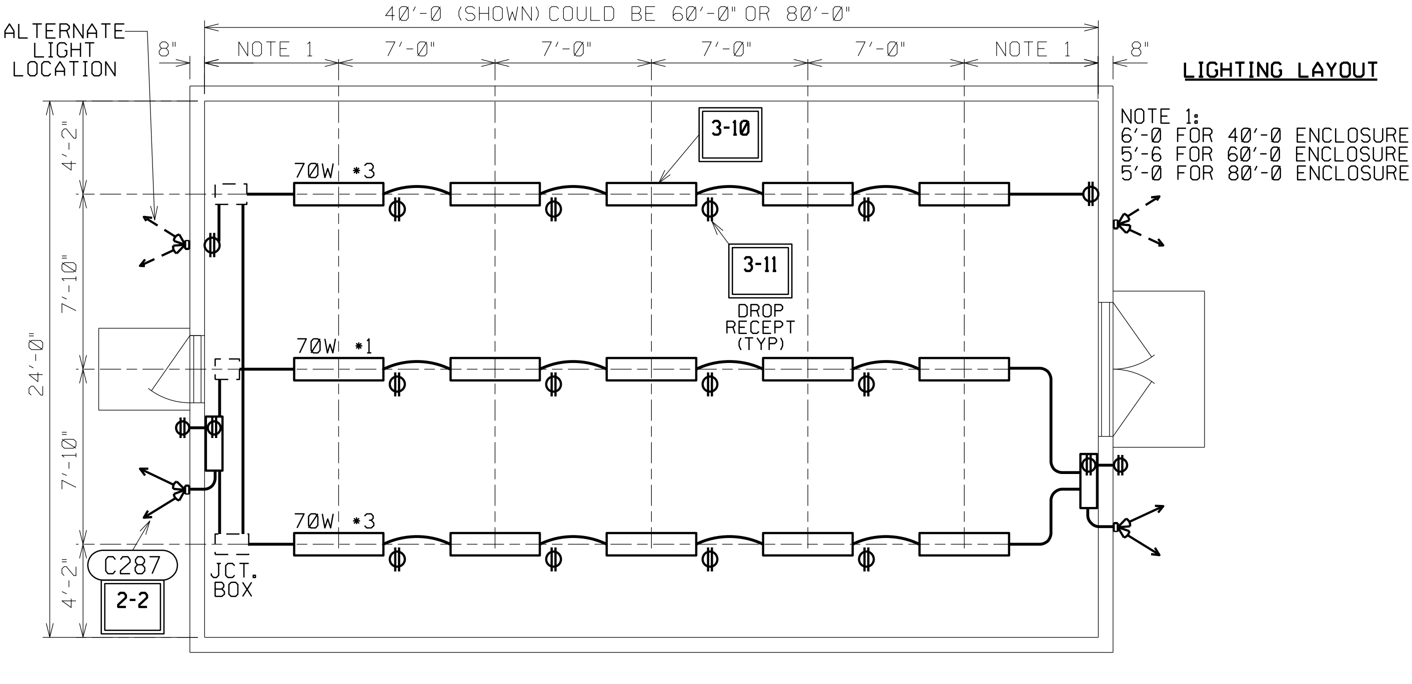
Xcel Energy

SCALE	DRAWING	REV
NONE	NL-200902-3-12	B

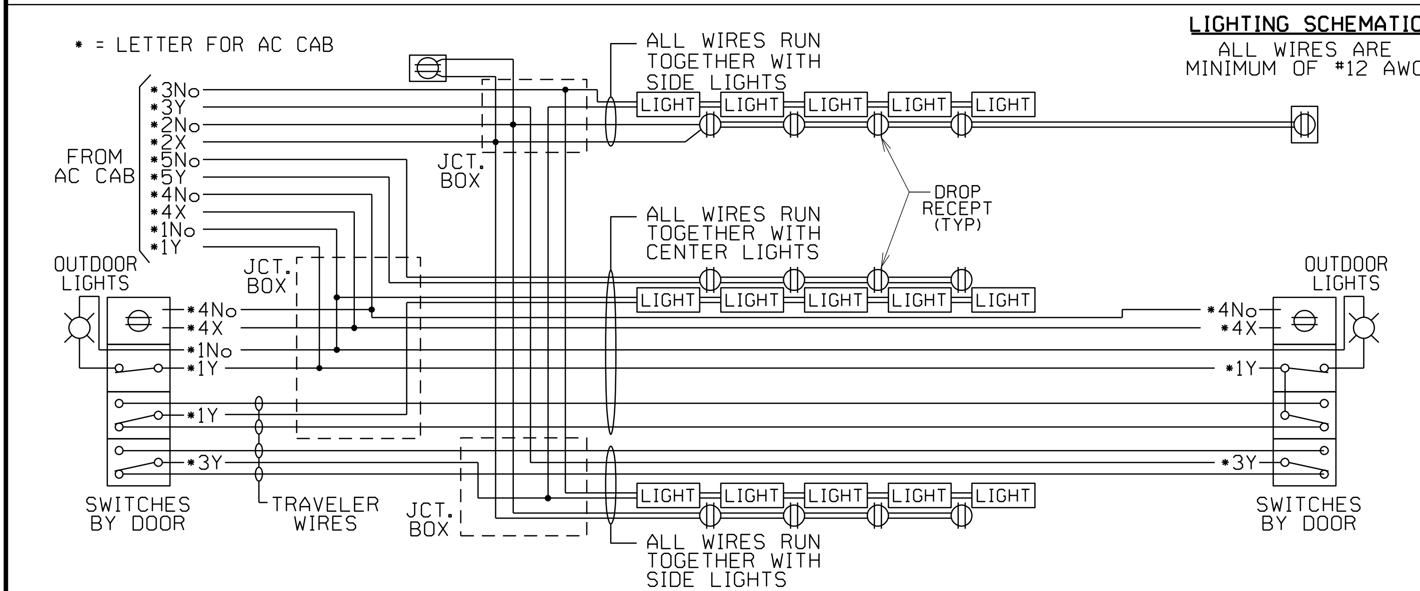
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-3-12.DGN
$TIME$
02/20/2008

LIGHTING LAYOUT



LIGHTING SCHEMATIC



FIELD NOTE:

- ENCLOSURE SHOWN IS 40'-0", 60'-0" AND 80'-0" ENCLOSURE WIRED THE SAME EXCEPT THERE ARE MORE LIGHTS.
- NUMBER OF LIGHTS REQUIRED: 40'-0 REQUIRES 15, 60'-0" REQUIRES 24 AND 80'-0 REQUIRES 33.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-13

ELECTRICAL EQUIPMENT ENCLOSURE DETAIL

LIGHTING LAYOUT AND WIRING

Xcel Energy®

SCALE NONE

NL-200902-3-13

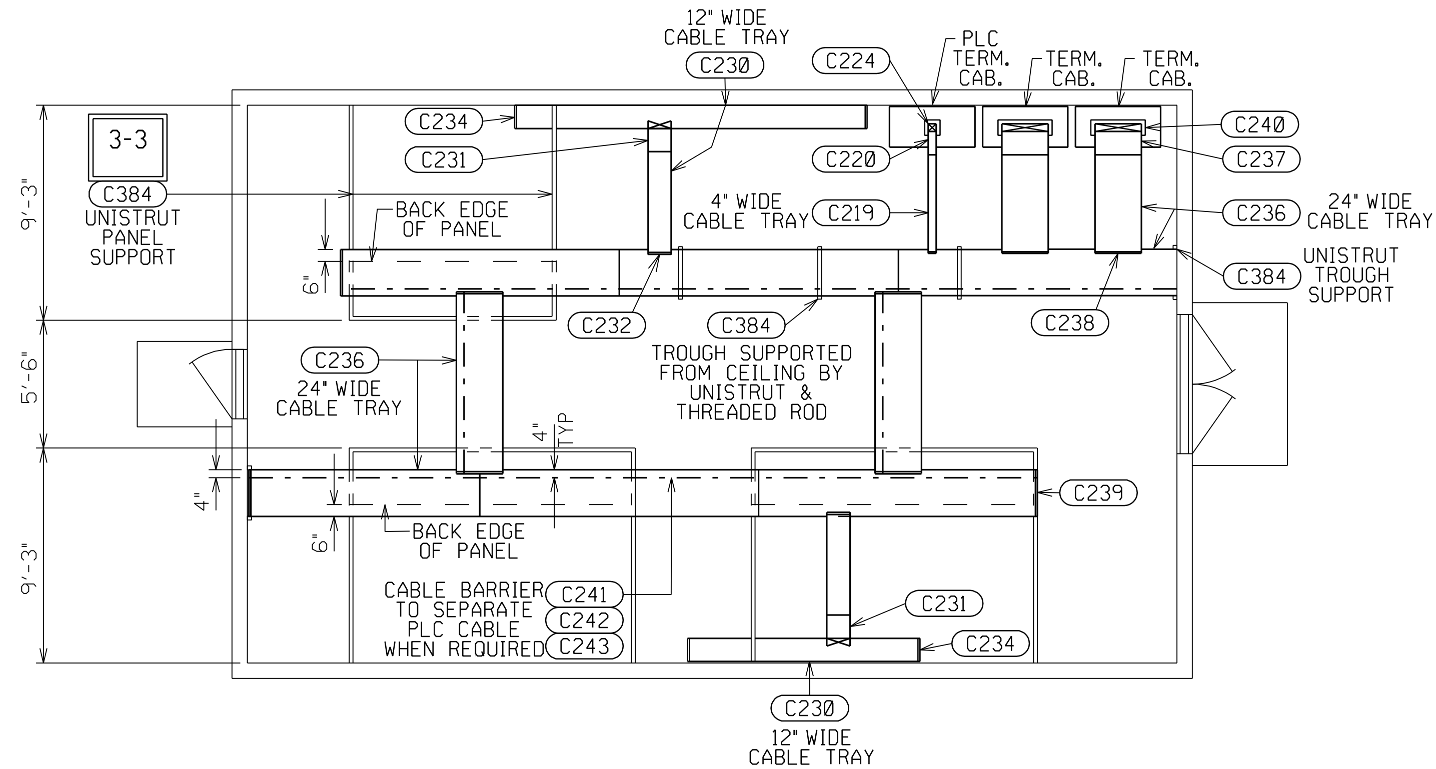
REV C

200902-3-13.DGN

5/20/2011 12:48:52 PM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C230		12" AL. LADDER CABLE TRAY	C239		BLIND END PLATE FOR 24" CABLE TRAY
C231		90 DEG. ELBOW, FOR 12" WIDE CABLE TRAY	C240		FRAME BOX CONN., FOR 24" CABLE TRAY
C232		END DROP OUT FOR 12" WIDE CABLE TRAY	C241		STRAIGHT SECTION BARRIER
C234		BLIND END PLATE FOR 12" CABLE TRAY	C242		VERTICAL BEND BARRIERS
C236		24" AL. LADDER CABLE TRAY	C243		BARRIER STRIP SPLICE
C237		90 DEG. ELBOW, FOR 24" WIDE CABLE TRAY	C384		GALVANIZED UNISTRUT CHANNEL P-1000
C238		END DROP OUT FOR 24" WIDE CABLE TRAY			



FIELD NOTE:

- MAXIMUM UNSUPPORTED SPAN OF TROUGH SHOULD NOT BE MORE THEN 10'-0"

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 3-14
CONTROL HOUSE DETAIL
CONTROL HOUSE EXAMPLE TROUGH LAYOUT

Xcel Energy

SCALE: NONE

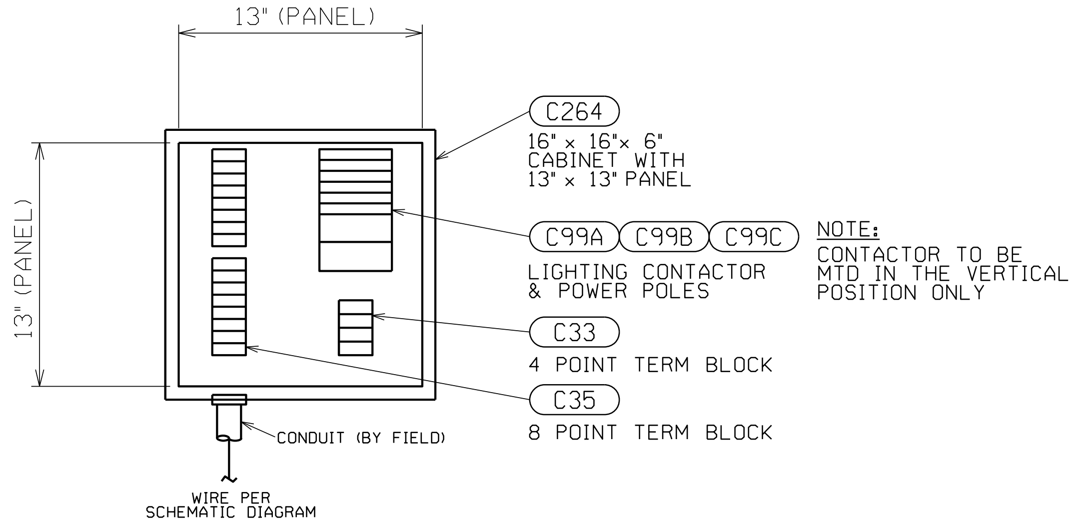
NL-200902-3-14

REV: A

05/30/2006 200902-3-14.DGN

BILL OF MATERIAL FOR THIS DETAIL

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C33	1	4 POINT TERMINAL BLOCK	C99B	4	SINGLE CIRCUIT POWER POLES
C35	2	8 POINT TERMINAL BLOCK	C99C	2	DOUBLE CIRCUIT POWER POLES
C99A	1	LIGHTING CONTACTOR	C264	1	16" x 16" x 6" CAB. WITH BACK PANEL



THIS EXAMPLE IS TYPICAL FOR EACH LIGHTING CONTACTOR REQUIRED.

Design Notes:

Circuit breakers in the AC lighting cabinet in the Electrical Equipment Enclosure are not to be used for switching yard lights on and off.

A toggle switch(es) shall be installed in the Electrical Equipment Enclosure to operate the substation yard lighting. The switches shall be mounted near the main door helping to provide the operators with immediate access to yard lighting during a system emergency. (Switches will be labeled to indicate which area of the yard they operate).

Receptacles will be provided at each outdoor light location and are to be connected to separate circuits in the AC lighting cabinet.

The standard cable configuration used for yard lighting and receptacles is 4/C #10.

The maximum length of a lighting circuit is the distance from the AC cabinet to the last light on the circuit. The maximum voltage drop allowed is 5% or 6 volts on a 120 volt circuit.

The following table gives the maximum length that #10 AWG conductor can be run, when loaded as noted, withhout exceeding the allowed voltage drop:

# of lights	Watts	Amps	Maximum Length of Circuit
Four	1600	13	188 feet
Three	1200	10	250 feet
Two	800	7	375 feet
One	400	3	750 feet

For yard lighting installations falling outside these parameters, work with the project engineer for a site specific design.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-15

ELECTRICAL EQUIPMENT ENCLOSURE DETAIL

WIRING OF OUTDOOR LIGHTING

Xcel Energy

SCALE NONE

NL-200902-3-15

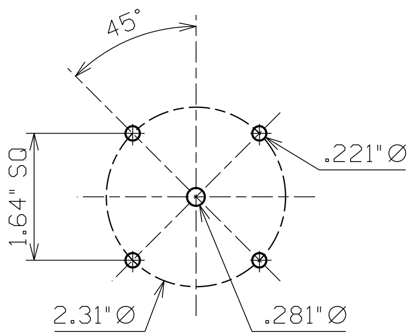
REV C

200902-3-15.DGN
7/27/2012 2:08:49 PM

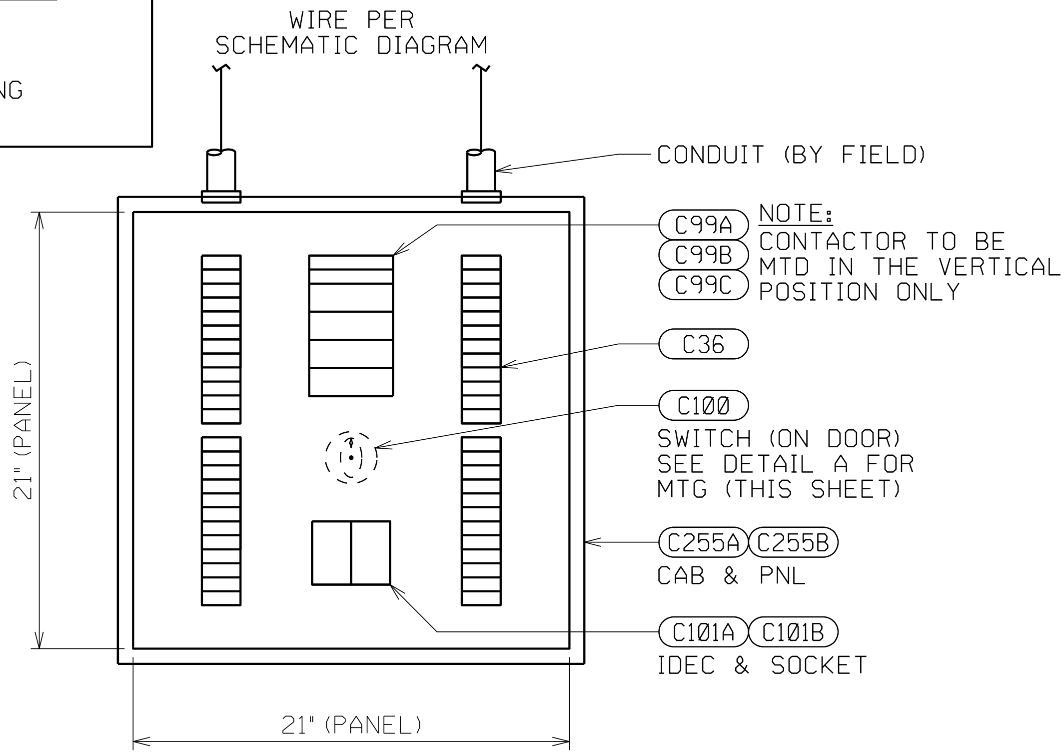
200902-3-16.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C36	4	12 POINT TERMINAL BLOCK	C101A	2	IDEC RELAY, 120VAC SELF RESET
C99A	1	LIGHTING CONTACTOR	C101B	2	11 BLADE SQUARE SOCKET
C99B	2	SINGLE CIRCUIT POWER POLES	C255A	1	24" x 24" x 8" CAB.
C99C	4	DOUBLE CIRCUIT POWER POLES	C255B	1	BACK PANEL, 21" x 21" (FOR ITEM C255A)
C100	1	SWITCH, SELECTOR, MANUAL-OFF AUTO			



DETAIL A
SWITCH DRILLING DIMENSIONS



LEGEND:

153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

1-5 INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & 1-1E INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 3-16
ELECTRICAL EQUIPMENT ENCLOSURE DETAIL
VENT FAN CONTROL CABINET

Xcel Energy

SCALE NONE

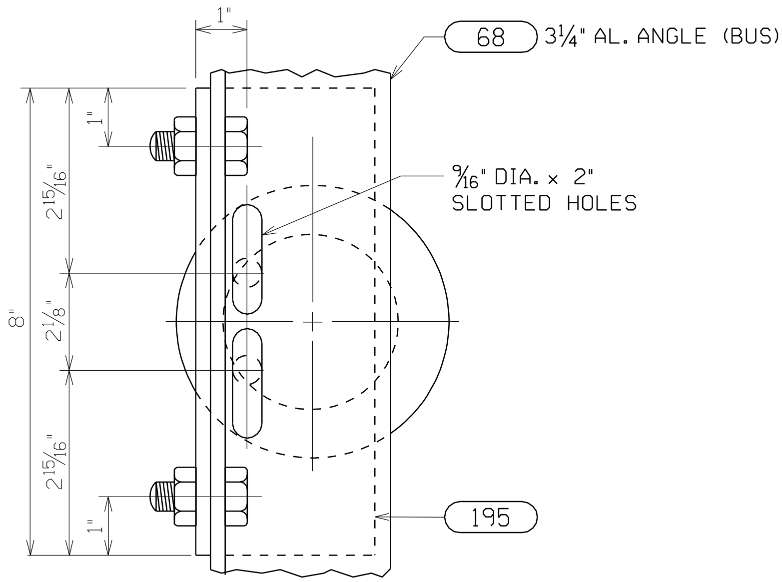
NL-200902-3-16

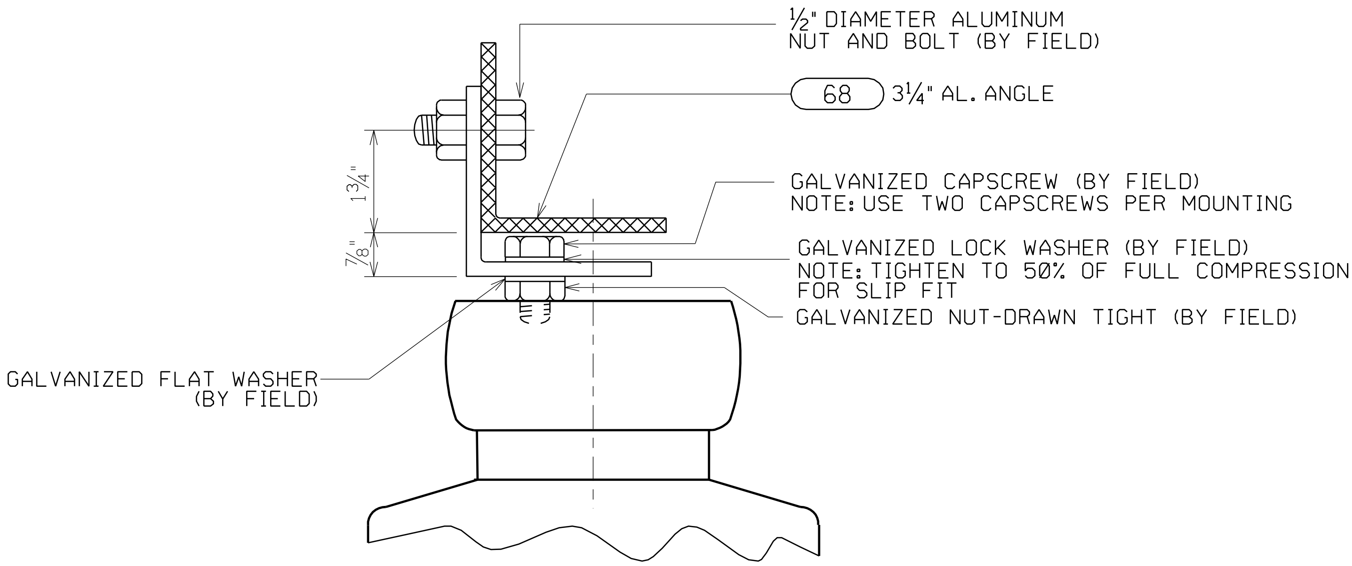
REV B

9:59:10 AM 5/3/2013

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68		3¼" × 3¼" × ¼" × 25′ LONG AL. ANGLE			
195	1	MOUNTING CLIP FOR 3¼" AL ANGLE			





LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-1
ELECTRICAL CONNECTION DETAIL
BUS MOUNTING FOR ALUMINUM ANGLE

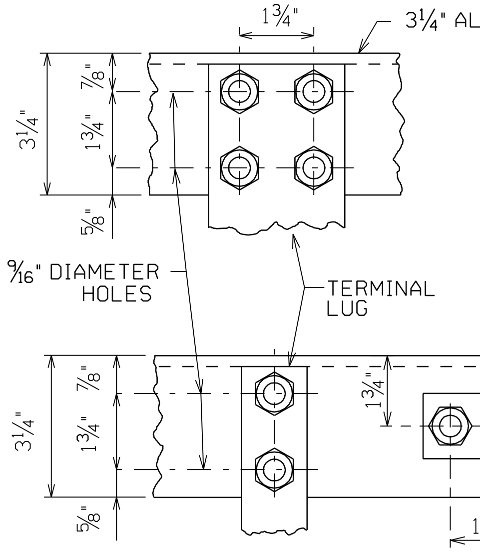
Xcel Energy

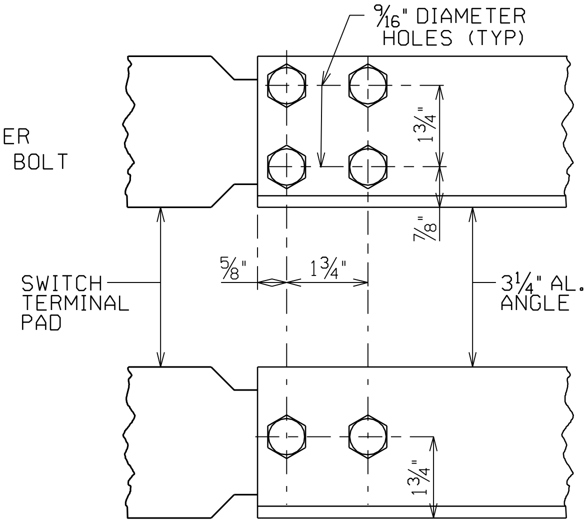
SCALE NONE

NL-200902-4-1

REV A

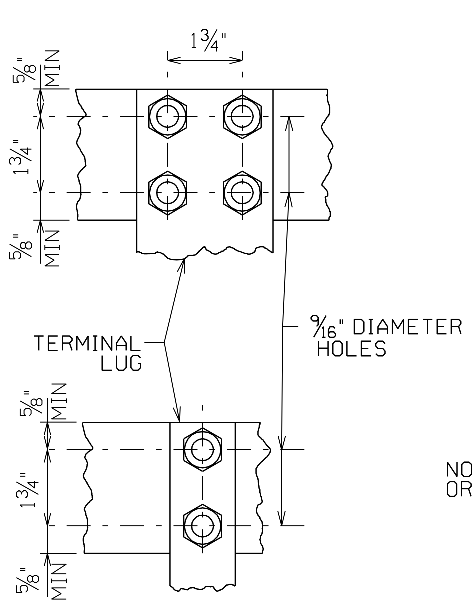
10/19/2005 200902-4-1.DGN

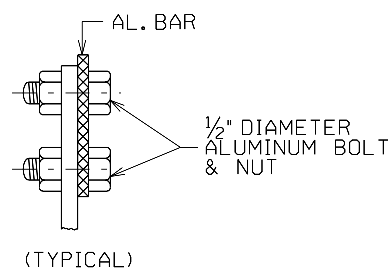




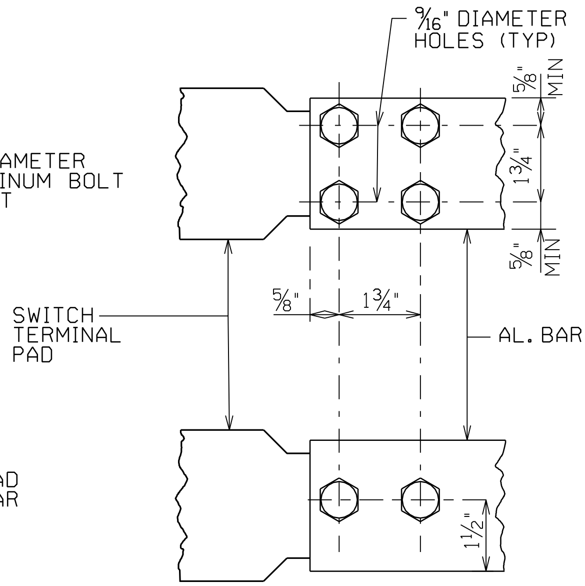
AL. ANGLE TERMINAL LUG DRILLING

AL. ANGLE SWITCH DRILLING





NOTE: CENTER SWITCH PAD OR TERMINAL LUG ON BAR WHEN POSSIBLE.



AL. BAR TERM LUG DRILLING

AL. BAR SWITCH DRILLING

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-2

ELECTRICAL CONNECTION DETAIL

TERMINAL LUG & SWITCH DRILLING FOR ALUMINUM ANGLE AND BAR

Xcel Energy

SCALE: NONE

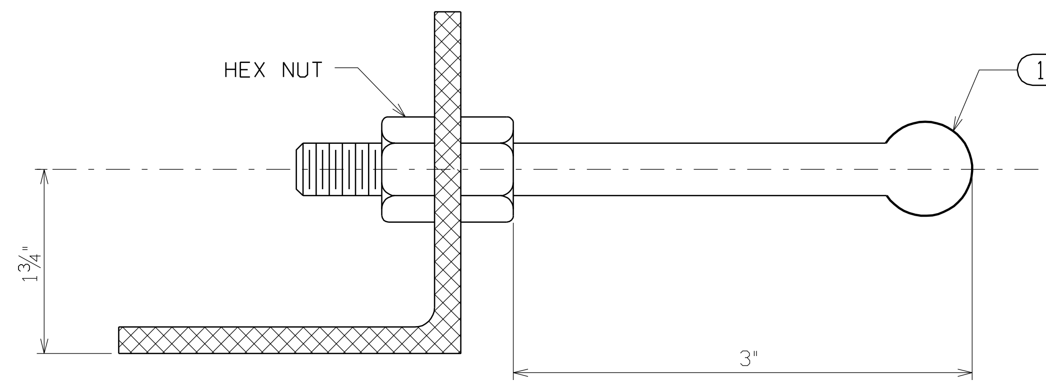
NL-200902-4-2

REV: B

04/05/2006 200902-4-2.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
124A	1	GROUNDING STUD, $\frac{1}{2}$" DIA x 7" LONG			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-3

ELECTRICAL CONNECTION DETAIL

PROVISION FOR HOT LINE CLAMP

Xcel Energy

SCALE NONE

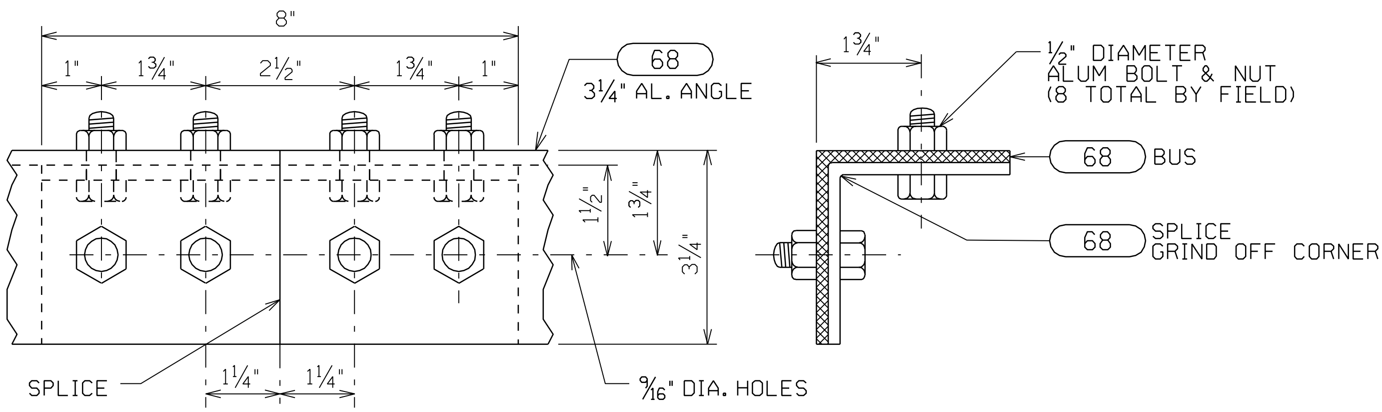
NL-200902-4-3

REV A

10/19/2005 200902-4-3.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68	8"	3¼" × 3¼" ×¼" × 25' LONG AL. ANGLE			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-4

ELECTRICAL CONNECTION DETAIL

ALUMINUM ANGLE SPLICE

Xcel Energy

SCALE: NONE

NL-200902-4-4

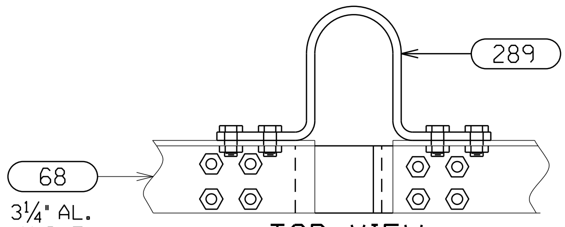
REV: B

11/29/2006 200902-4-4.DGN

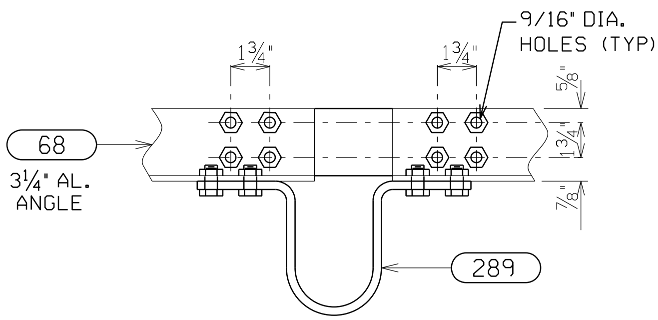
BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68		3¼" x 3¼" x ¼" x 25' AL. ANGLE	289	*	ALUM. FLEX CONNECTOR

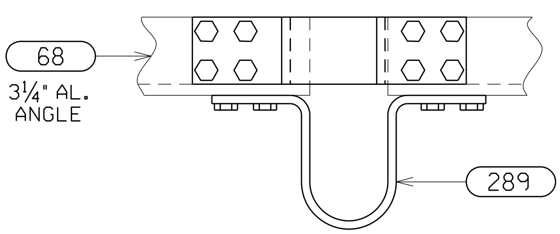
* 1 CONNECTOR REQUIRED FOR 1200 AMPS AND 2 CONNECTORS REQUIRED FOR FULL AMP OF ANGLE



TOP VIEW

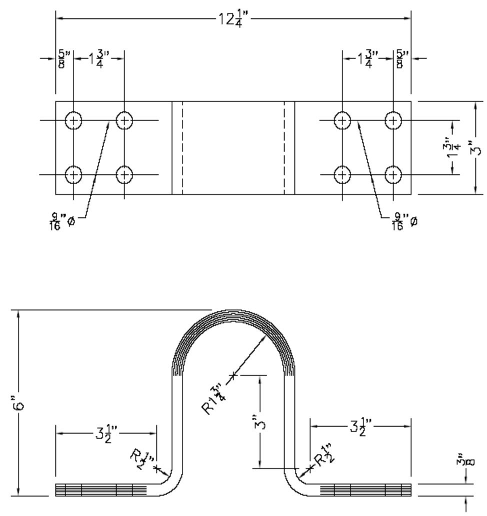


SIDE VIEW



BOTTOM VIEW

Catalog No. AFX-4A-3-SP | CONDUCTOR: 1200A



MATERIAL: (6) PCS 1/16" x 3" x 25" LONG (3003-0 ALUMINUM)

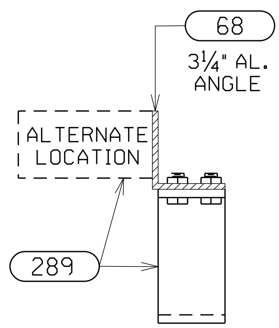
NOTE: FACTORY TO WIRE BRUSH EACH LAMINATION 3½" EACH END AND APPLY A THIN COAT OF NO-OX-ID TO BOTH SIDES.

Job no. ________
Item(s) no. ________
Qty. req'd ________

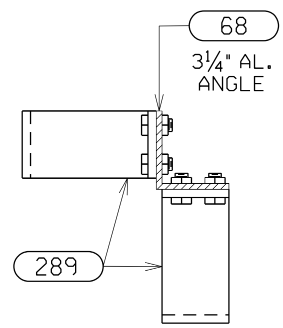
Ass'y Wt. 2.75 #

1200 AMP APPLICATION

No.	By	Date	Revision	SEFCOR INC. GRIFFIN, GEORGIA	DWS 3/9/06 AFX-4A-3-SP



END VIEW
SINGLE CONNECTION



END VIEW
DOUBLE CONNECTION

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-5
ELECTRICAL CONNECTION DETAIL
ANGLE BUS EXPANSION JOINT

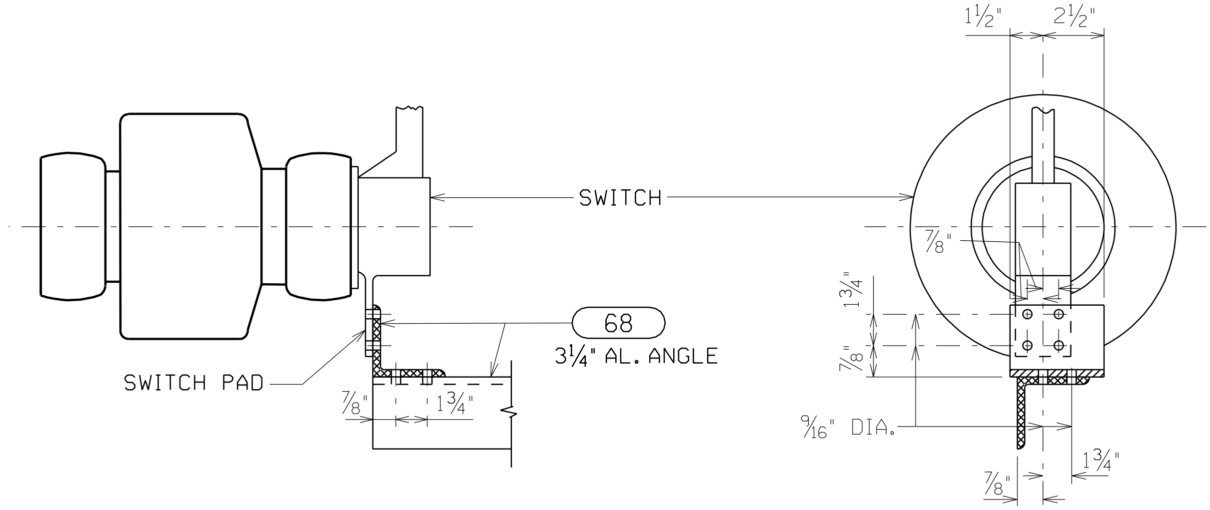
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy | SCALE NONE | NL-200902-4-5 | REV C

200902-4-5.DGN
5/20/2011 12:43:52 PM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68		3¼" x 3¼" x ¼" x 25' LONG AL. ANGLE			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-6

ELECTRICAL CONNECTION DETAIL

ALUMINUM ANGLE TO SWITCH 90 DEGREE CONNECTION - 900 AMPS MAX

Xcel Energy

SCALE: NONE

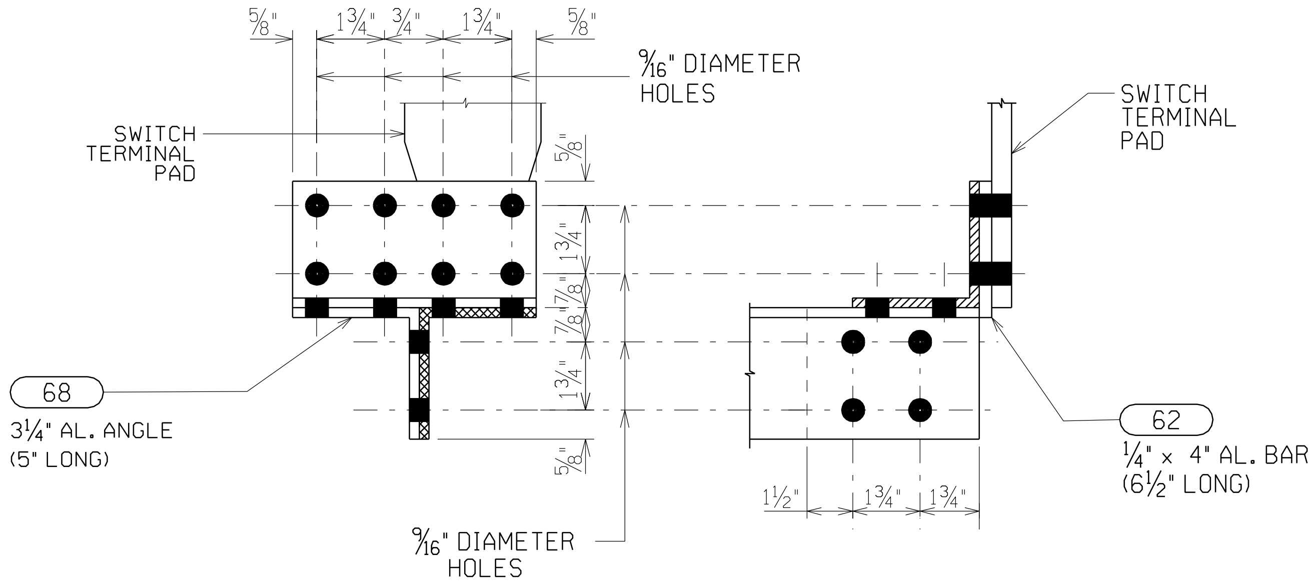
NL-200902-4-6

REV: A

10/19/2005 200902-4-6.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
62		1/4" x 4" x 20' LONG AL. BAR			
68		3 1/4" x 3 1/4" x 1/4" x 25' LONG AL. BAR			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-7
ELECTRICAL CONNECTION DETAIL
ALUMINUM ANGLE BUS TO SWITCH 90 DEGREE CONN. - 1800 AMPS MAX.

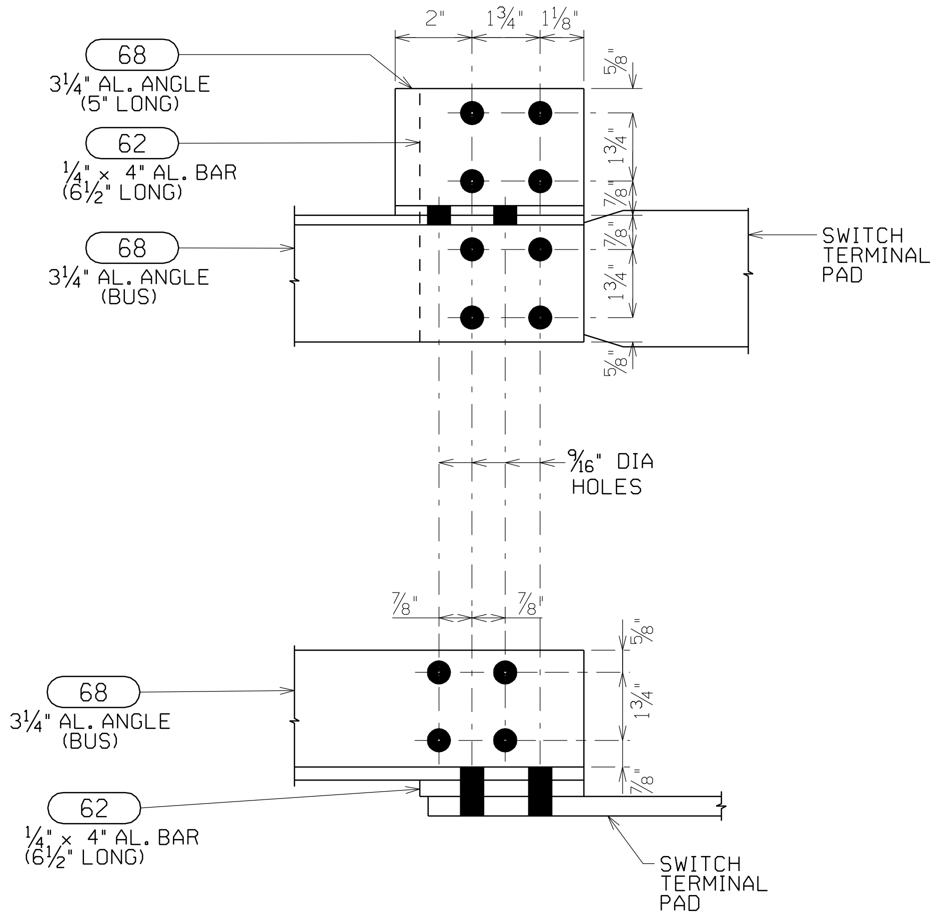
Xcel Energy

SCALE		REV
NONE	NL-200902-4-7	A

10/19/2005 200902-4-7.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
62		1/4" x 4" x 20' LONG AL. BAR			
68		3 1/4" x 3 1/4" x 1/4" x 25' LONG AL. BAR			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-8
ELECTRICAL CONNECTION DETAIL
ALUMINUM ANGLE TO SWITCH - 1800 AMPS MAX

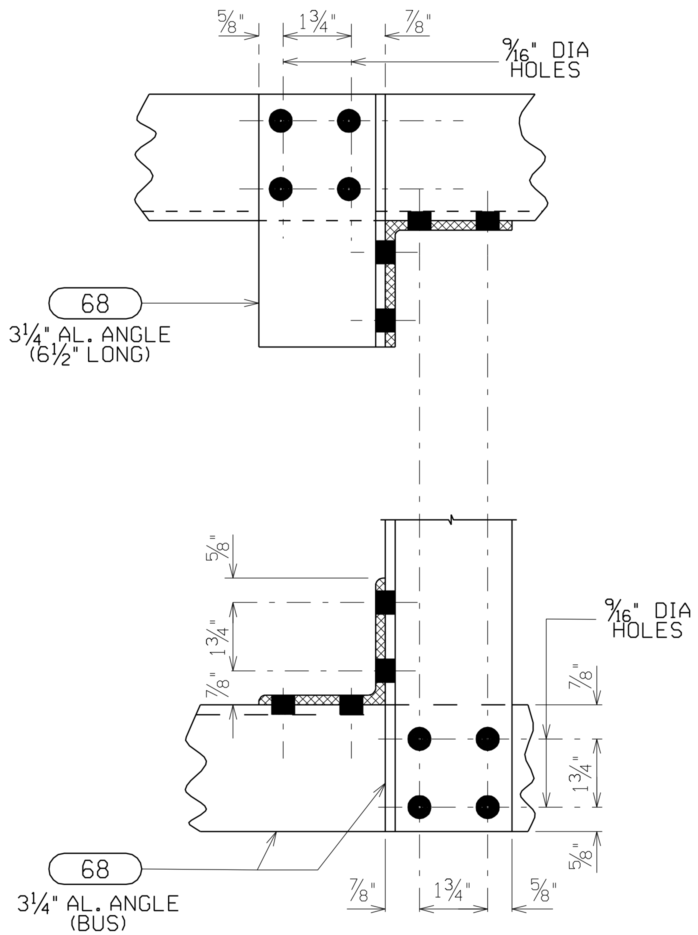
GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy

SCALE		REV
NONE	NL-200902-4-8	A

10/19/2005 200902-4-8.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68		3¼" × 3¼" × ¼" × 25' LONG AL. BAR			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-9
ELECTRICAL CONNECTION DETAIL
ALUMINUM ANGLE TO ALUMINUM ANGLE 90 DEGREE CONN. - 1800AMP MAX

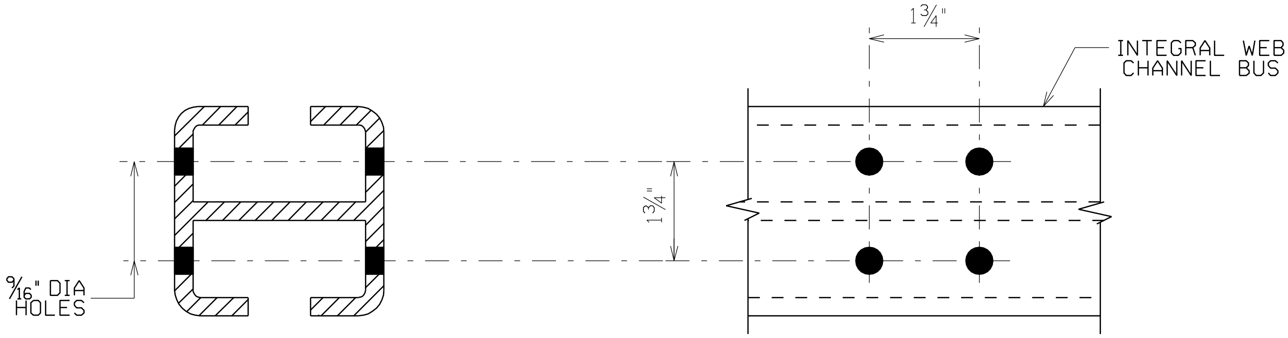
Xcel Energy™

SCALE: NONE

NL-200902-4-9

REV: A

10/19/2005 200902-4-9.DGN



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-10

ELECTRICAL CONNECTION DETAIL

DRILLING FOR TERMINAL LUG CONNECTION TO INTEGRAL WEB CHANNEL BUS

Xcel Energy

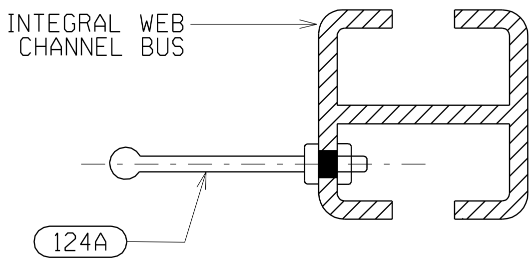
SCALE	DRAWING	REV
NONE	NL-200902-4-10	A

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

10/19/2005 200902-4-10.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
124A	1	GROUNDING STUD, ½" DIA × 7" LONG			



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-11

ELECTRICAL CONNECTION DETAIL

PROVISION FOR HOT LINE CLAMP CONN. TO INTEGRAL WEB CHANNEL BUS

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

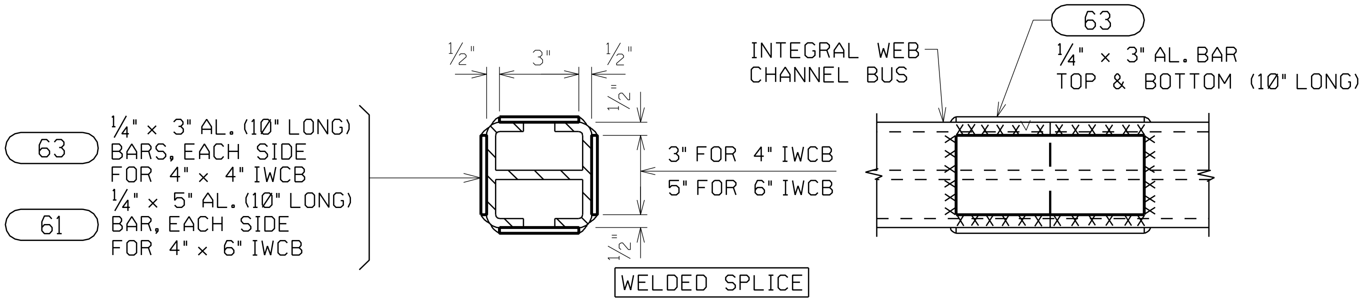
Xcel Energy

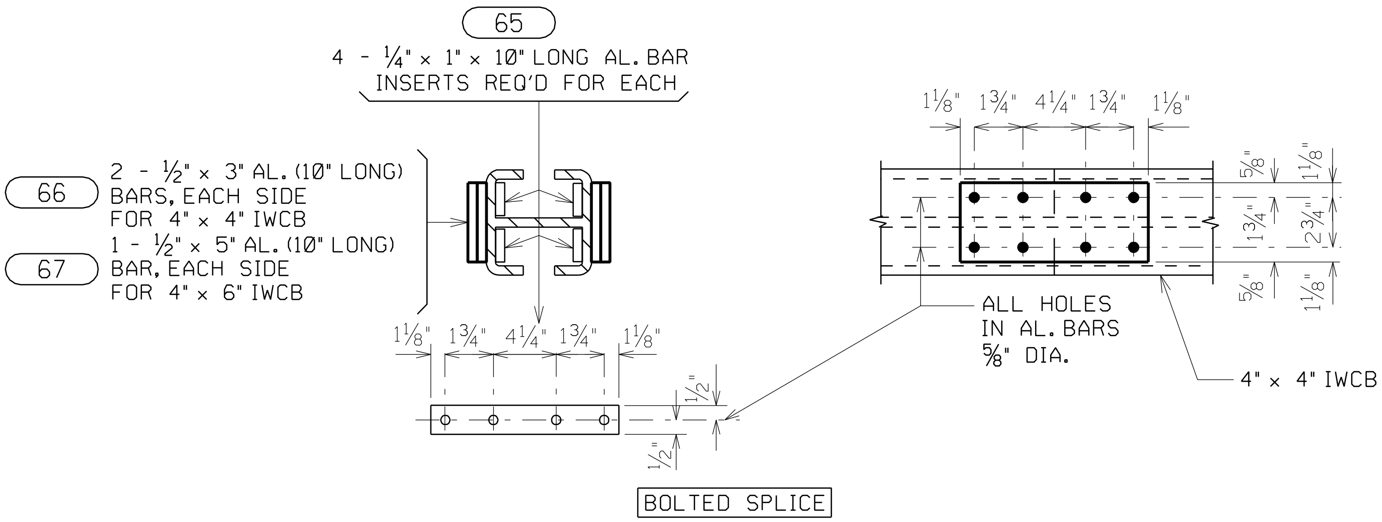
SCALE		REV
NONE	NL-200902-4-11	A

10/19/2005 200902-4-11.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
61		¼" × 5" × 12′ LONG RECT. AL. BAR			
63		¼" × 3" × 20′ LONG RECT. AL. BAR			
65		¼" × 1" × 12′ LONG RECT. AL. BAR			
66		½" × 3" × 12′ LONG RECT. AL. BAR			
67		½" × 5" × 12′ LONG RECT. AL. BAR			





FIELD NOTE:

- ALL HOLES DRILLED IN INTERGAL WEB CHANNEL, 9/16" DIAMETER

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-12
ELECTRICAL CONNECTION DETAIL
WELDED OR BOLTED SPLICE FOR INTEGRAL WEB CHANNEL BUS

Xcel Energy

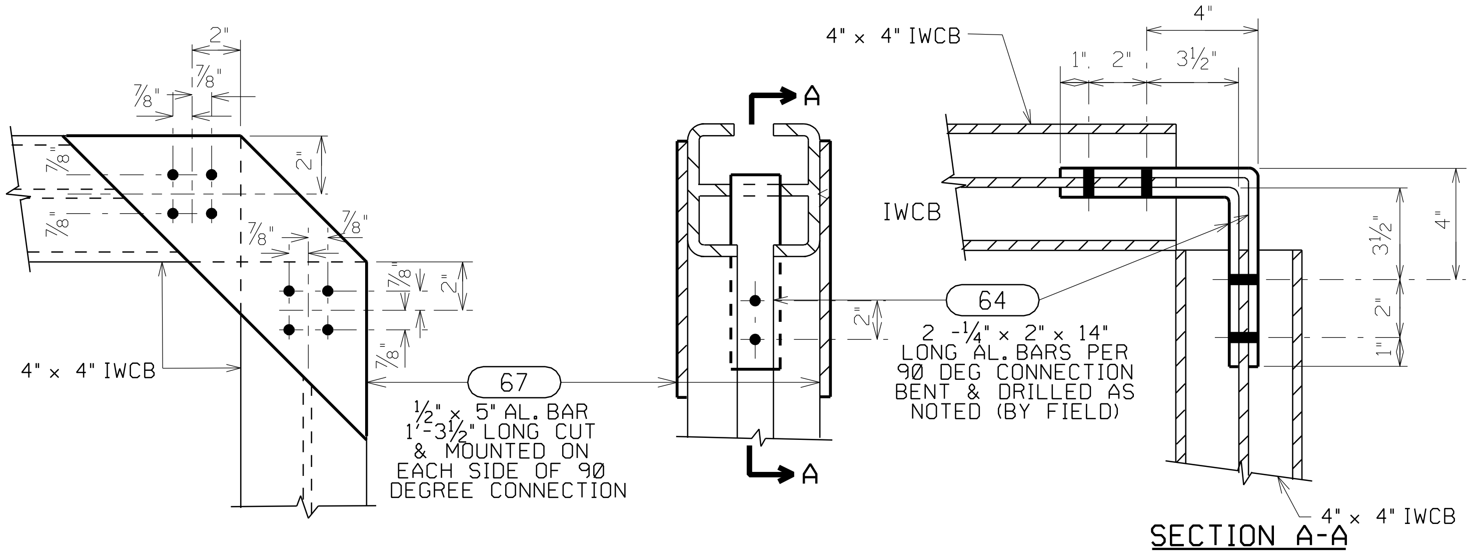
SCALE		REV
NONE	NL-200902-4-12	A

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

10/19/2005 200902-4-12.DGN

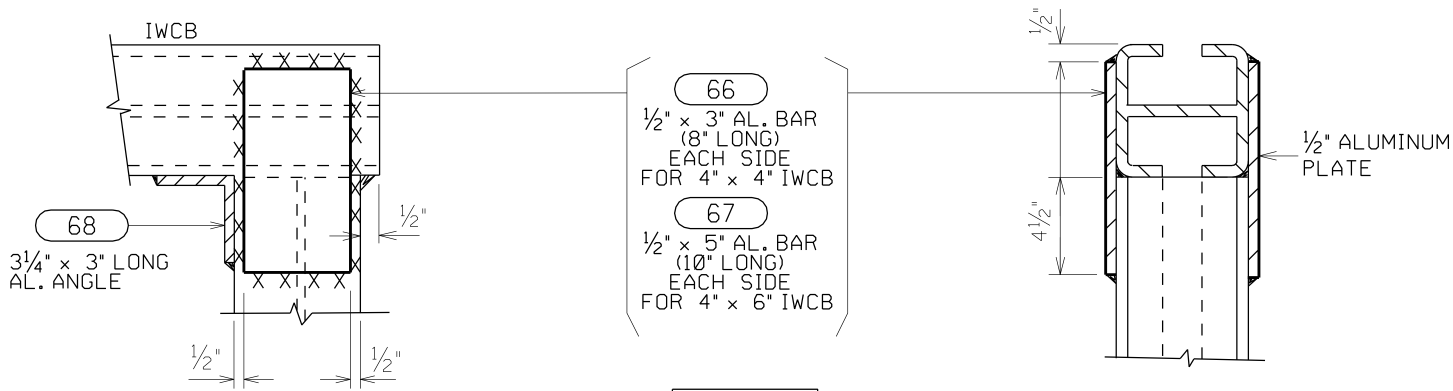
BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
64		¼" × 2" × 20' LONG RECT. AL. BAR			
66		½" × 3" × 12' LONG RECT. AL. BAR			
67		½" × 5" × 12' LONG RECT. AL. BAR			
68		3¼" × 3¼" × ¼" × 25' LONG AL. ANGLE			



BOLTED

(FOR 4×4 IWCB ONLY)



WELDED

FIELD NOTE:

- ALL HOLES DRILLED IN INTEGRAL WEB CHANNEL 9/16" DIAMETER

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-13

ELECTRICAL CONNECTION DETAIL

WELDED-BOLTED 90 DEGREE ANGLE CONN. FOR INTEGRAL WEB CHANNEL BUS

Xcel Energy

SCALE: NONE

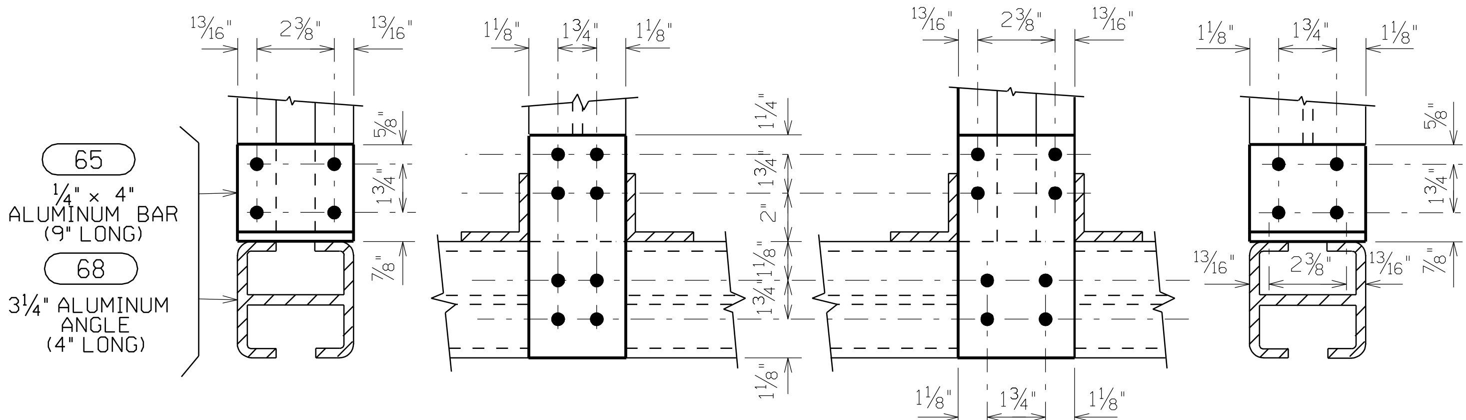
NL-200902-4-13

REV: A

10/19/2005 200902-4-13.DGN

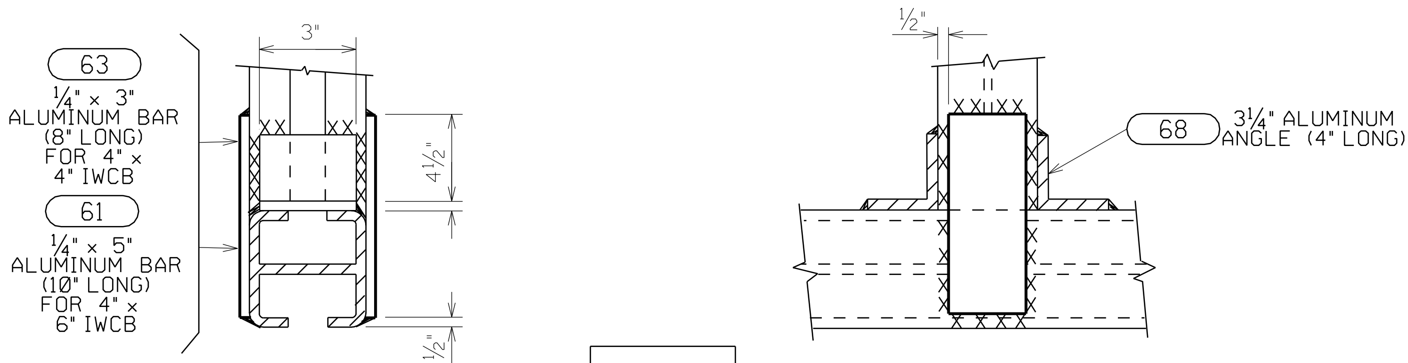
BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
61		1/4" x 5" x 12' LONG RECT. AL. BAR			
63		1/4" x 3" x 20' LONG RECT. AL. BAR			
65		1/4" x 1" x 12' LONG RECT. AL. BAR			
68		3 1/4" x 3 1/4" x 1/4" x 25' LONG RECT. AL BAR.			



BOLTED

(FOR 4" x 4" IWCB TURNED EITHER DIRECTION)



WELDED

FIELD NOTE:

- ALL HOLES DILLED IN INTEGRAL WEB CHANNEL 9/16" DIAMETER

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-14

ELECTRICAL CONNECTION DETAIL

WELDED OR BOLTED TEE TAP FOR INTEGRAL WEB CHANNEL BUS

Xcel Energy

SCALE NONE

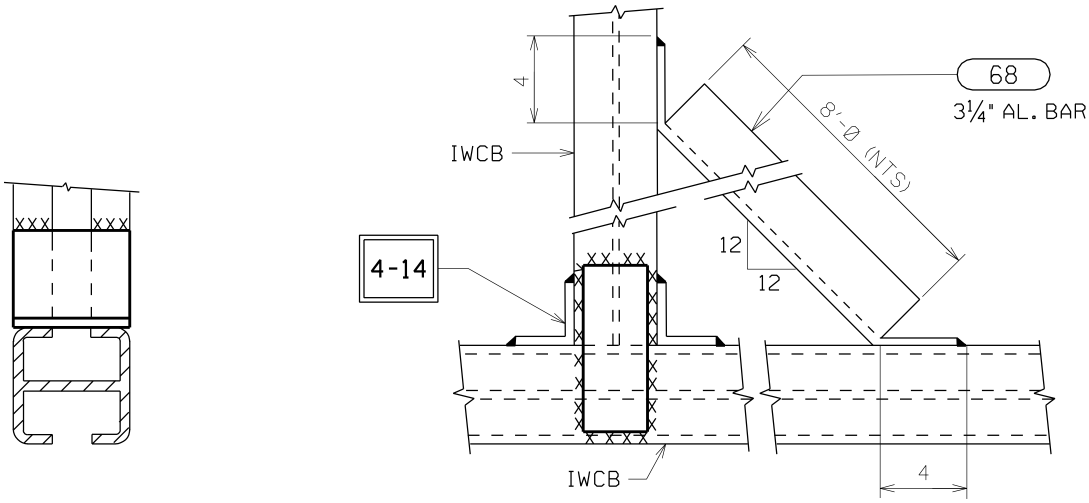
NL-200902-4-14

REV A

10/19/2005 200902-4-14.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
68		3¼" × 3¼" × ¼" × 25′ LONG RECT. AL. BAR			



LEGEND:

(   ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[4-14] INDICATES DETAIL SHOWN ON DWG NL-200902-4-14

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-15
ELECTRICAL CONNECTION DETAIL
WELDED ANGLE BRACE FOR INTEGRAL WEB CHANNEL BUS

Xcel Energy

SCALE NONE

NL-200902-4-15

REV A

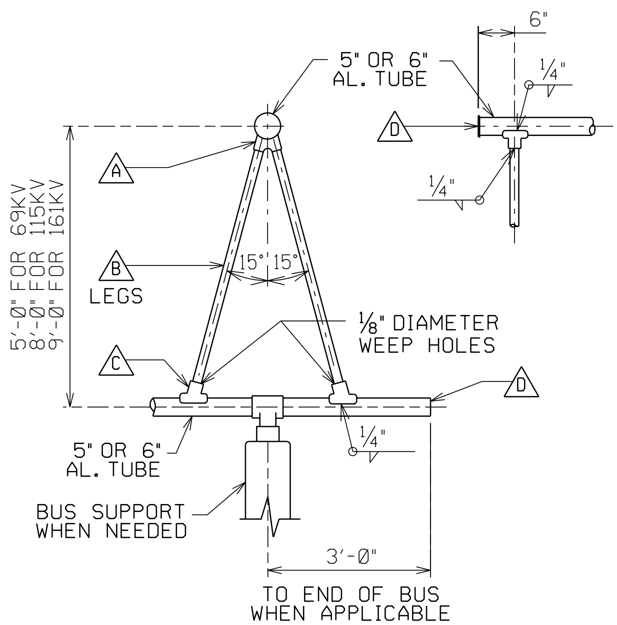
10/19/2005 200902-4-15.DGN

MATERIAL REQUIRED FOR DETAIL "A"

	ITEM NO.	QTY	DESCRIPTION
A	564	1	VEE CONN., 5" IPS TUBE TO 2½" TUBE
A	568		VEE CONN., 6" IPS TUBE TO 4" TUBE
B	55	20 FT	2½" IPS ALUMINUM TUBE
B	58		4" IPS ALUMINUM TUBE
C	516	2	TEE CONN., 5" IPS TUBE TO 2½" TUBE
C	518		TEE CONN., 6" IPS TUBE TO 2½" TUBE
C	513		TEE CONN., 5" IPS TUBE TO 4" TUBE
D	640	1	END CAP, DRIVE FIT, 5" IPS AL. TUBE
D	641		END CAP, WELDED, 6" IPS AL. TUBE

NOTES: 1. ONLY ORDER ONE OF THE ITEM NUMBERS FROM EACH SECTION. QUANTITY LISTED IS PER PHASE.

2. IF TOP BUS IS: 5" USE 2½" LEGS
6" USE 4" LEGS



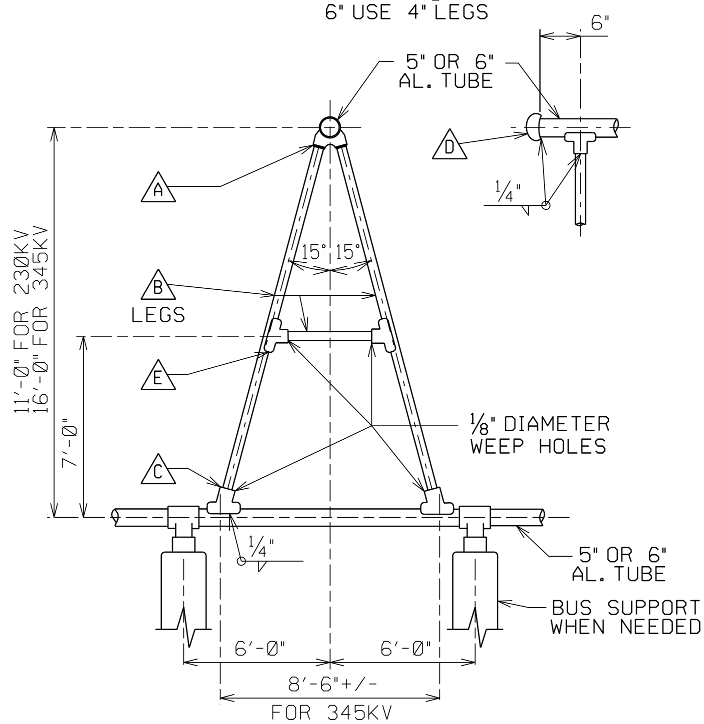
DETAIL "A"
69, 115 AND 161KV

MATERIAL REQUIRED FOR DETAIL "B"

	ITEM NO.	QTY	DESCRIPTION
A	564	1	VEE CONN., 5" IPS TUBE TO 2½" TUBE
A	568		VEE CONN., 6" IPS TUBE TO 4" TUBE
B	55	40 FT	2½" IPS ALUMINUM TUBE
B	58		4" IPS ALUMINUM TUBE
C	516	2	TEE CONN., 5" IPS TUBE TO 2½" TUBE
C	518		TEE CONN., 6" IPS TUBE TO 2½" TUBE
C	513		TEE CONN., 5" IPS TUBE TO 4" TUBE
D	826	1	END BELL, WELDED FOR 5" AL. TUBE
D	827		END BELL, WELDED FOR 6" AL. TUBE
E	503	2	TEE CONN., 2½" IPS TUBE TO 2½" TUBE
E	512A		TEE CONN., 4" IPS TUBE TO 4" TUBE

NOTES: 1. ONLY ORDER ONE OF THE ITEM NUMBERS FROM EACH SECTION. QUANTITY LISTED IS PER PHASE.

2. IF TOP BUS IS: 5" USE 2½" LEGS
6" USE 4" LEGS



DETAIL "B"
230 & 345KV

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-16
ELECTRICAL CONNECTION DETAIL
TUBING BUS "A" FRAME TAP

Xcel Energy

SCALE NONE

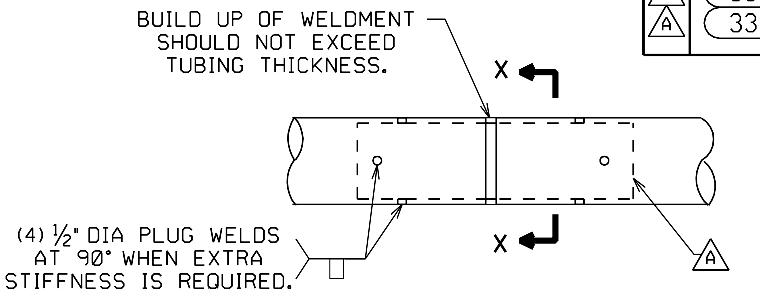
NL-200902-4-16

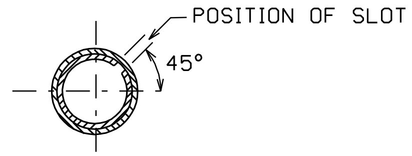
REV G

200902-4-16.DGN
9:32:06 AM
10/29/2013

MATERIAL FOR PREFABRICATED SPLICE

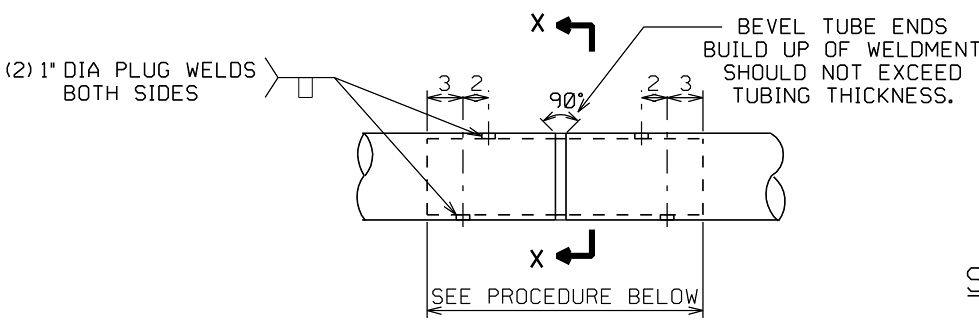
	ITEM NO.	QTY	DESCRIPTION
A	326	1 EA PER PHASE	COUPLER SPLICE, SCHED 40 2" AL TUBE
A	327		COUPLER SPLICE, SCHED 40 2½" AL TUBE
A	328		COUPLER SPLICE, SCHED 40 3" AL TUBE
A	329		COUPLER SPLICE, SCHED 40 3½" AL TUBE
A	330		COUPLER SPLICE, SCHED 40 4" AL TUBE
A	331		COUPLER SPLICE, SCHED 40 5" AL TUBE
A	332		COUPLER SPLICE, SCHED 80 6" AL TUBE
A	333		COUPLER SPLICE, SCHED 40 6" AL TUBE

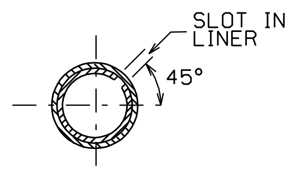




SECTION X-X

PREFABRICATED WELDED SPLICE





SECTION X-X

CONSTRUCTION PROCEDURE

1. PLACE LINER IN ONE TUBE, CENTER IT AND MAKE ONE PLUG WELD.

   A LINER WILL BE MADE FROM ALUMINUM TUBE THE NEXT SIZE SMALLER OR THE SAME SIZE AND CUT TO PROVIDE A SNUG FIT WHEN INSERTED.

   LENGTH OF LINER APPROXIMATELY 6 TIMES NOMINAL PIPE SIZE (MINIMUM LENGTH 15").

2. MAKE BUTT WELD.
3. MAKE REMAINING PLUG WELDS.

WELDED SPLICE FOR TUBE WHEN PREFABRICATED SPLICE IS NOT AVAILABLE

LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-17

ELECTRICAL CONNECTION DETAIL

WELDED SPLICE FOR TUBE

Xcel Energy

SCALE: NONE

NL-200902-4-17

REV: B

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
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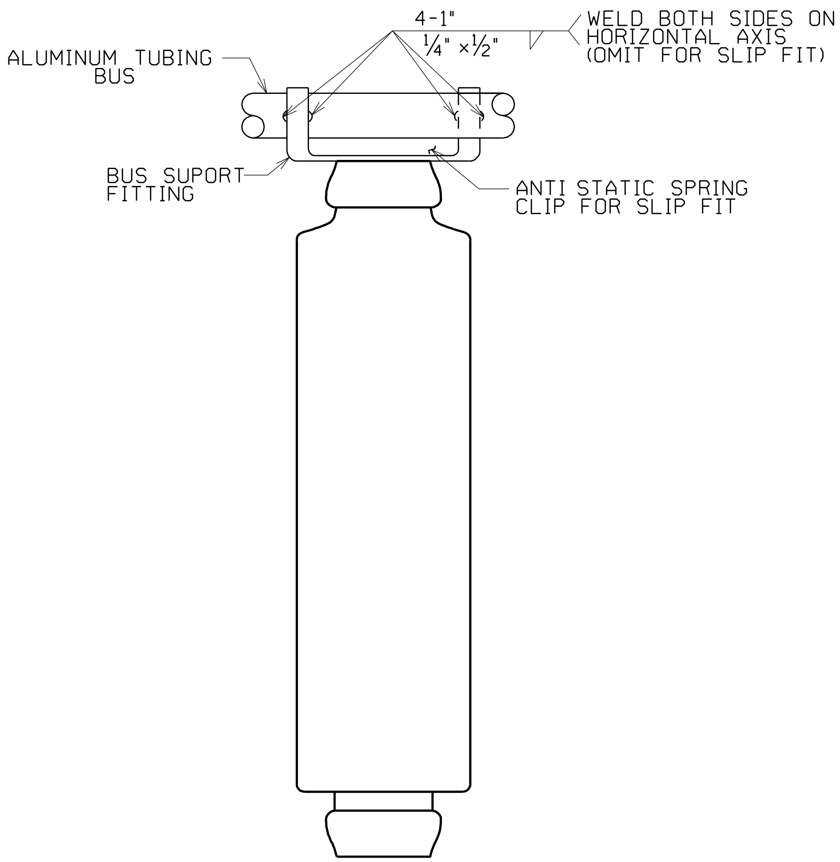
200902-4-17.DGN

$TIME$

02/21/2008



LEGEND:

( ) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-18

ELECTRICAL CONNECTION DETAIL

BUS SUPPORT FIXED & SLIP FITTING FOR ALUMINUM TUBE

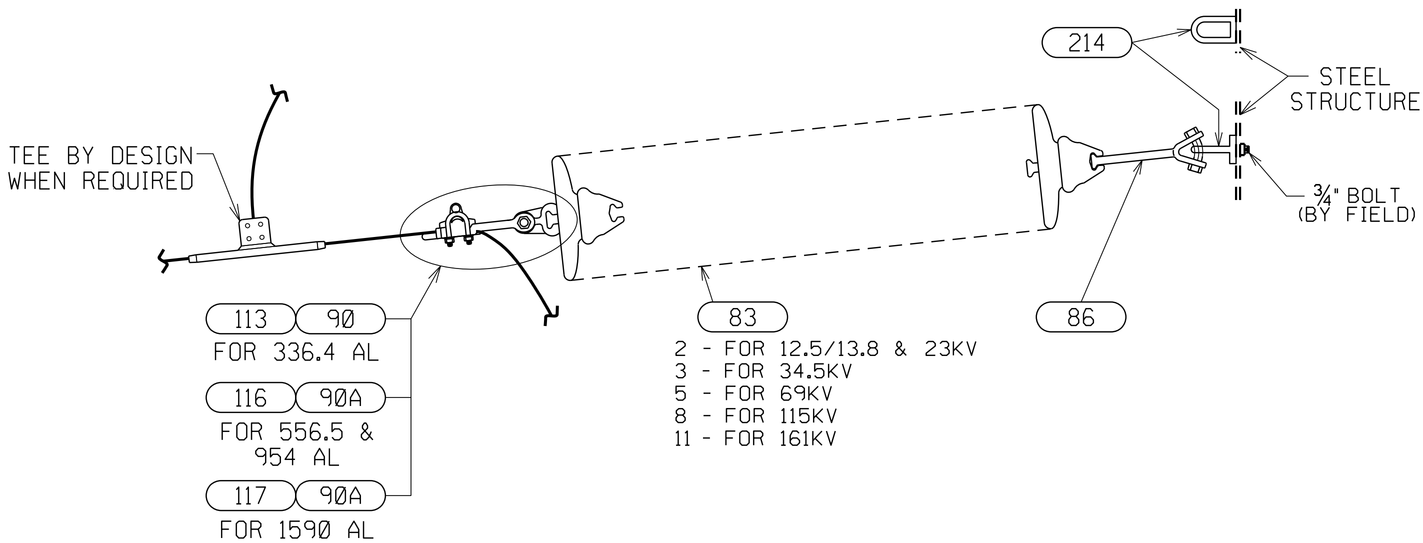
Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-4-18	A

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

10/19/2005 200902-4-18.DGN

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
83		10" SUSPENSION INSULATOR	214		BOLT EYE FOR ¾" BOLT
86		Y-CLEVIS BALL (30,000 LB)			
90		SOCKET EYE, ½" NECK (10,000 LB)			
90A		SOCKET EYE, ¾" NECK (25,000 LB)			
113		DEAD-END STRAIN CLAMP (1,000 LB)			
116		DEAD-END STRAIN CLAMP (12,000 LB)			
117		DEAD-END STRAIN CLAMP (12,000 LB)			



NOTES:

1. LINE IS HORIZONTAL OR RUNS DOWN HILL
2. CONNECTION TO STRUCTURE CAN BE STEEL CLIP OR ITEM 214 WITH ¾" BOLT (STEEL CLIP IS PREFERRED).

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-19A

ELECTRICAL CONNECTION DETAIL

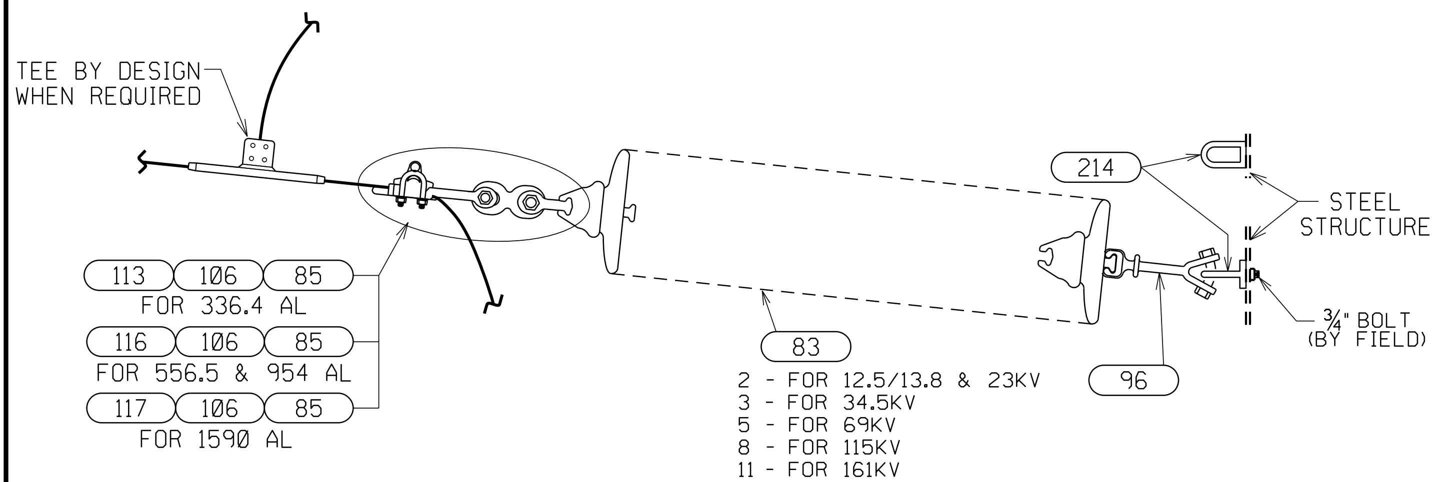
STRAIN BUS SUSPENSION INSULATOR ASSEMBLY

Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-4-19A	G

200902-4-19A.DGN
5/3/2013 9:59:55 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
83		10" SUSPENSION INSULATOR	214		BOLT EYE FOR ¾" BOLT
85		Y-CLEVIS BALL (30,000 LB)			
96		SOCKET Y-CLEVIS (30,000 LB)			
106		FIGURE 8 STRAIGHT LINK (30,000 LB)			
113		DEAD-END STRAIN CLAMP (1,000 LB)			
116		DEAD-END STRAIN CLAMP (12,000 LB)			
117		DEAD-END STRAIN CLAMP (12,000 LB)			



NOTES:

1. LINE RUNS UP HILL
2. CONNECTION TO STRUCTURE CAN BE STEEL CLIP OR ITEM 214 WITH ¾" BOLT (STEEL CLIP IS PREFERRED).

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-19B

ELECTRICAL CONNECTION DETAIL

STRAIN BUS SUSPENSION INSULATOR ASSEMBLY

Xcel Energy®

SCALE: NONE

NL-200902-4-19B

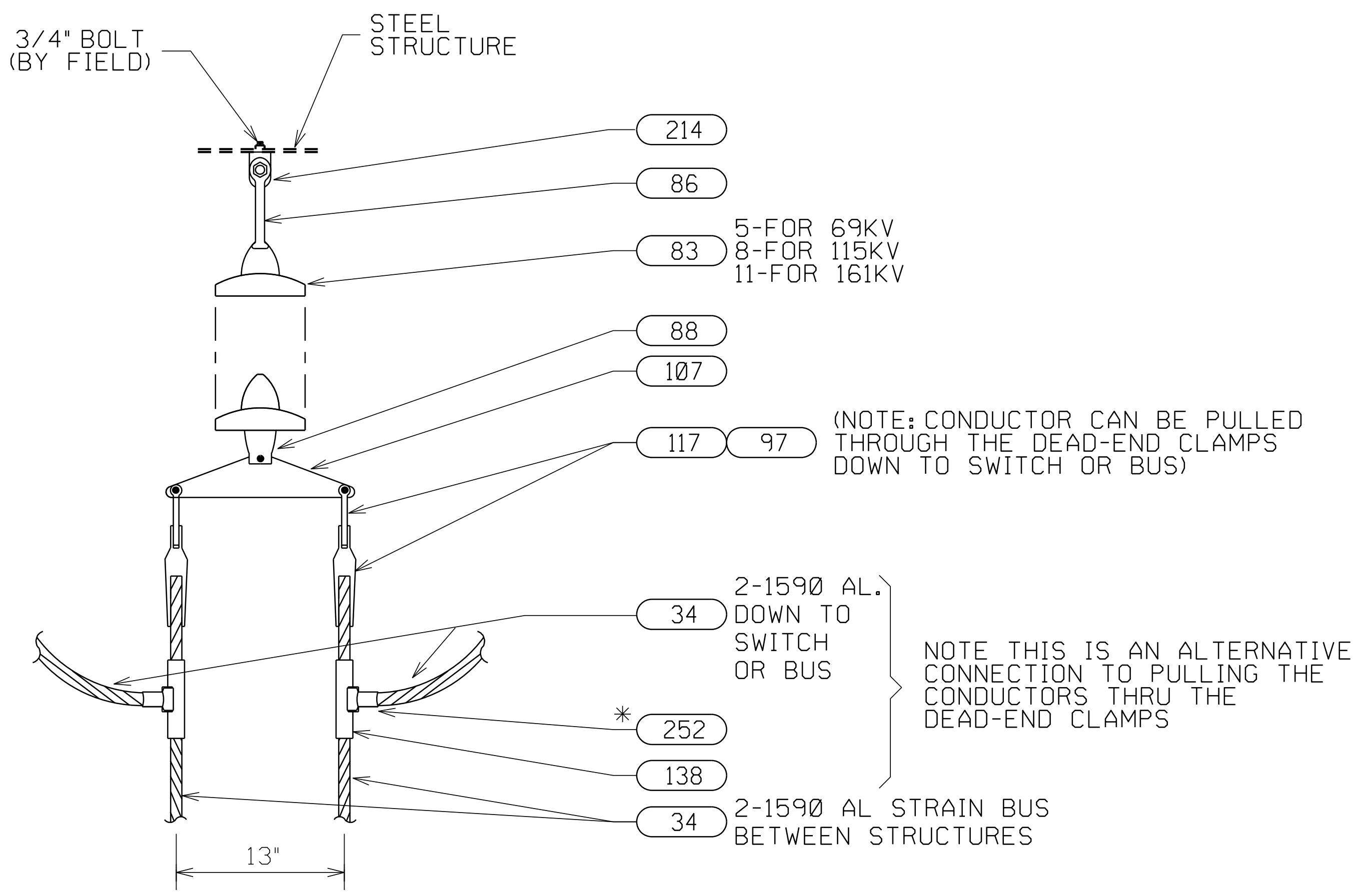
REV: G

200902-4-19B.DGN

5/3/2013 10:00:14 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
83		10" SUSPENSION INSULATOR	214	1	BOLT EYE FOR ¾" BOLT
86	1	BALL Y-CLEVIS (30,000 LB)	138	2	COMPRESION TEE TAP FOR 1590 AL.
88	1	SOCKET CLEVIS (30,000 LB)	* 252	2	COMPRESION TERM. LUG FOR 1590 AL.
97	2	Y-CLEVIS EYE (30,000 LB)			
107	1	YOKE PLATE -13" SEPERATION (40,000 LB)			
117	2	DEAD-END STRAIN CLAMP (12,000 LB)			* TYPE OF TERMINAL LUG (WELD OR COMP.) TO BE DETERMINED BY FIELD.



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-19C

ELECTRICAL CONNECTION DETAIL

BUNDLED STRAIN BUS SUSPENSION INSULATOR ASSEMBLY

Xcel Energy®

SCALE: NONE

NL-200902-4-19C

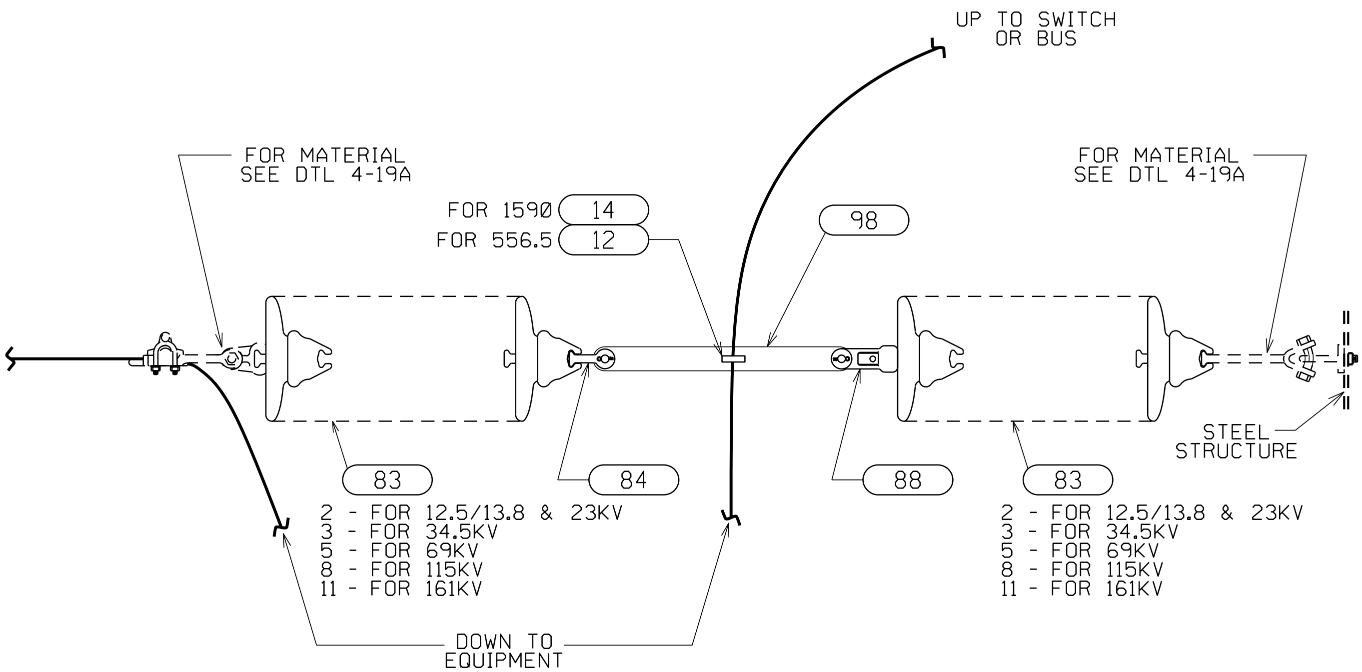
REV: H

200902-4-19C.DGN

5/3/2013 10:00:57 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
12		U-BOLT FOR 556.5 AL			
14		U-BOLT FOR 1590 AL			
83		10" SUSPENSION INSULATOR, GRAY			
84		BALL CLEVIS (30,000 LB)			
88		SOCKET CLEVIS (30,000 LB)			
98		EXTENSION LINK 1½" W x 18" L (10,000 LB)			



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-19D

ELECTRICAL CONNECTION DETAIL

DOUBLE STRAIN BUS SUSPENSION INSULATOR ASSEMBLY

Xcel Energy®

SCALE		REV
NONE	NL-200902-4-19D	G

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-4-19D.DGN

10/26/2012 10:31:54 AM

BILL OF MATERIAL FOR 161KV AND BELOW
(ORDERED BY DESIGNER)

2-1590 AL (1-ON EACH SIDE)

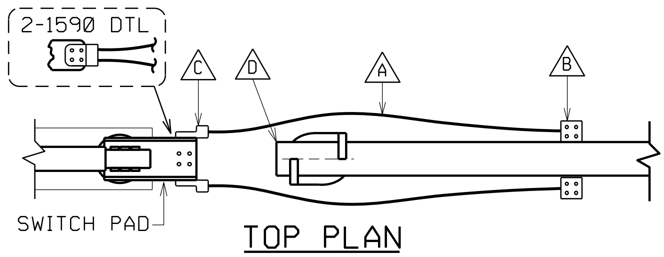
REV	ITEM NO.	QTY	DESCRIPTION
A	34	15 FT	2-1590 AL CABLE (1-ON EACH SIDE)
B	427	2	TEE CONNECTOR FOR 3"-6" TUBE
B	654	2	TERM LUG, WELDMENT FOR 1-1590 AL
C	674A	1	TERM LUG, WELDMENT FOR 2-1590 AL
D	640	1*	END CAP, DRIVE FIT FOR 5" TUBE
D	641	1*	END CAP, DRIVE FIT FOR 6" TUBE

4-1590 AL (2-ON EACH SIDE)

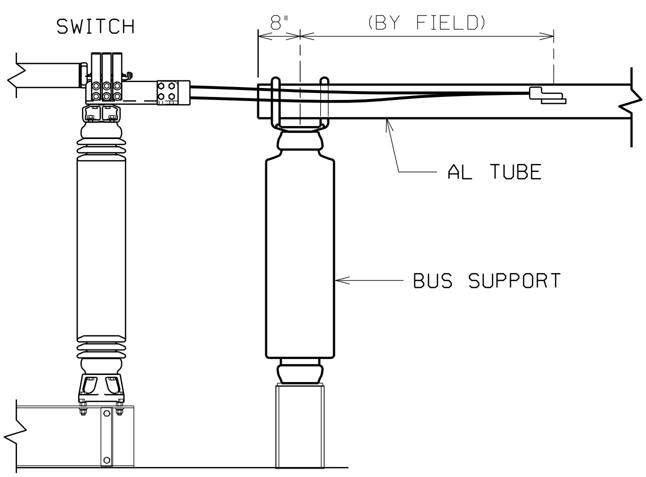
REV	ITEM NO.	QTY	DESCRIPTION
A	34	30 FT	4-1590 AL CABLE (2 ON EACH SIDE)
B	427	2	TEE CONNECTOR FOR 3"-6" TUBE
B C	674	4	TERM LUG, WELDMENT FOR 2-1590 AL
D	640	1*	END CAP, DRIVE FIT FOR 5" TUBE
D	641	1*	END CAP, DRIVE FIT FOR 6" TUBE

NOTE: MATERIAL LISTED IS PER PHASE

* THIS IS THE QUANTITY REQUIRED FOR ONE OF THE ITEMS. DO YOU HAVE 5" OR 6" TUBE?



TOP PLAN



SIDE VIEW

BILL OF MATERIAL FOR 230KV AND ABOVE
(ORDERED BY DESIGNER)

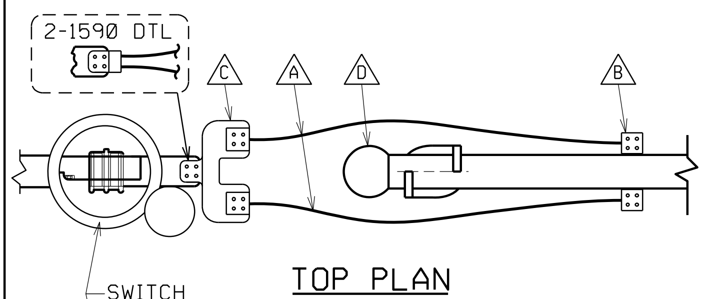
2-1590 AL (1-ON EACH SIDE)

REV	ITEM NO.	QTY	DESCRIPTION
A	34	15 FT	2-1590 AL CABLE (1-ON EACH SIDE)
B	427	2	TEE CONNECTOR FOR 3"-6" TUBE
B	654	2	TERM LUG, WELDMENT FOR 1-1590 AL
B C	894	5	EHV SHIELD FOR 4 HOLE FLAT PAD
C	674A	1	TERM LUG, WELDMENT FOR 2-1590 AL
D	826	1	EHV END BELL FOR 5" AL TUBE

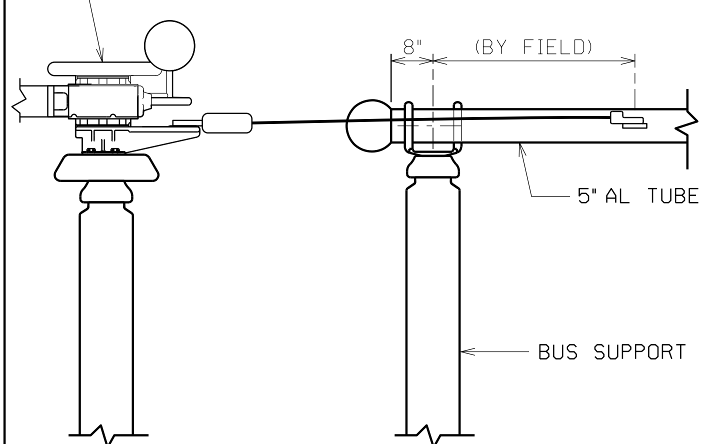
4-1590 AL (2-ON EACH SIDE)

REV	ITEM NO.	QTY	DESCRIPTION
A	34	30 FT	4-1590 AL CABLE (2 ON EACH SIDE)
A	286	2	CABLE SPACER
B	427	2	TEE CONNECTOR FOR 3"-6" TUBE
B C	674A	4	TERM LUG, WELDMENT FOR 2-1590 AL
B C	894	6	EHV SHIELD FOR 4 HOLE FLAT PAD
C	986	1	EHV BIFURCATING TERMINAL
D	826	1	EHV END BELL FOR 5" AL TUBE

NOTE: MATERIAL LISTED IS PER PHASE



TOP PLAN



SIDE VIEW

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-20
ELECTRICAL CONNECTION DETAIL
SWITCH TO BUS CONNECTION - BUS SUPPORT IS PART OF SWITCH STAND

Xcel Energy®

SCALE NONE

NL-200902-4-20

REV B

200902-4-20.DGN

5/20/2011 12:40:00 PM

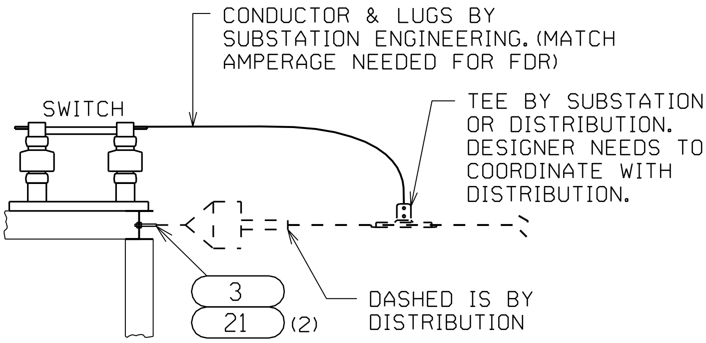
MATERIAL FOR DETAIL "A" & "B"

ITEM NO.	QTY	DESCRIPTION
3	1	EYE BOLT, 5/8" DIA × 8" L
21	2	5/8" DIA. HEX. NUT

MATERIAL FOR DETAIL "C"

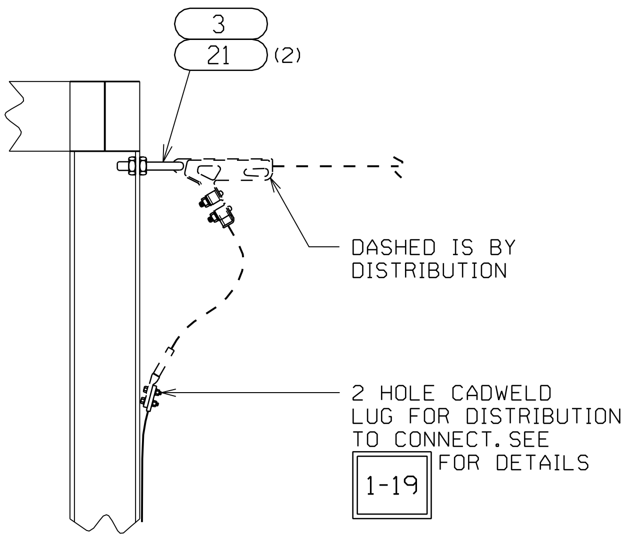
ITEM NO.	QTY	DESCRIPTION
11	1	THREADED ROD, 3/4" DIA × 26" LONG
18	1	NUT, SQUARE FOR 3/4" DIA BOLT
20	4	WASHER NUT, FOR 3/4" DIA BOLT
25	3	LOCKNUT, FOR 3/4" DIA BOLT
214	1	BOLT EYE FOR 3/4" DIA THREADED ROD

NOTE: MATERIAL LISTED IS PER PHASE



DETAIL "A"

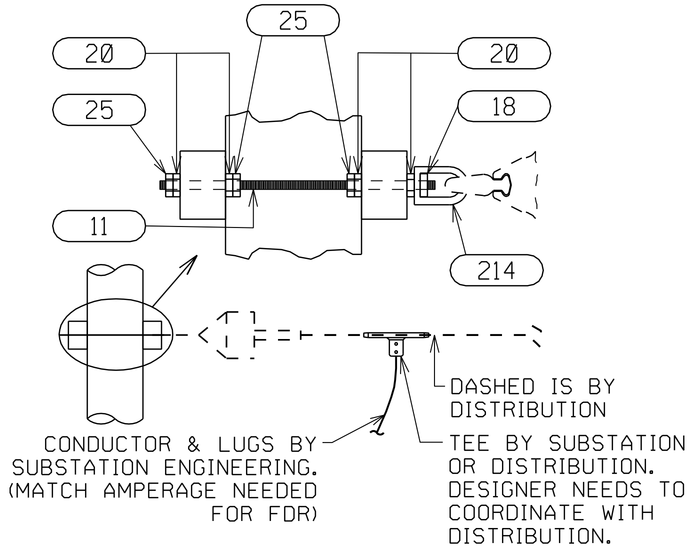
STEEL STRUCTURE
TERMINATION OF LINE



DETAIL "B"

STEEL STRUCTURE
TERMINATION OF NEUTRAL

NOTE: MATERIAL LISTED IS PER PHASE



DETAIL "C"

WOOD POLE STRUCTURE
TERMINATION OF LINE

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

[1-5] INDICATES DETAIL SHOWN ON DWG NL-200902-1-5 & [1-1E] INDICATES DETAIL "E" SHOWN ON DWG NL-200902-1-1

THIS MAP/DOCUMENT IS A TOOL TO ASSIST EMPLOYEES IN THE PERFORMANCE OF THEIR JOBS. YOUR PERSONAL SAFETY IS PROVIDED FOR BY USING SAFETY PRACTICES, PROCEDURES AND EQUIPMENT AS DESCRIBED IN THE SAFETY TRAINING PROGRAMS, MANUALS AND SPARS.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-21

ELECTRICAL CONNECTION DETAIL

DISTRIBUTION OVERHEAD TERMINATIONS AT SUBSTATION

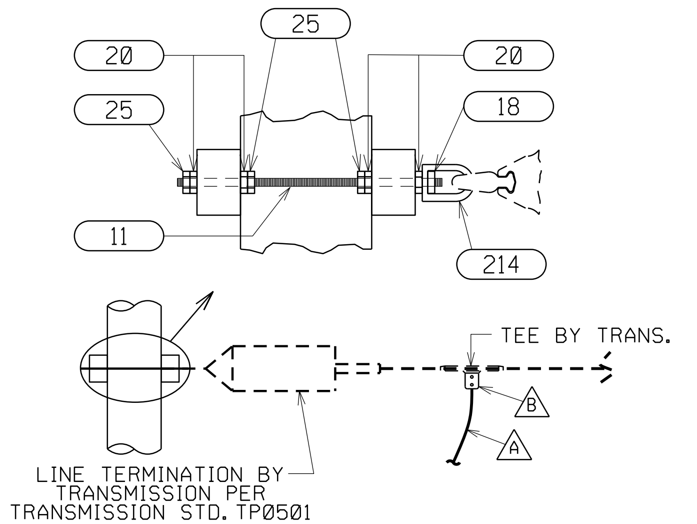
Xcel Energy

SCALE NONE

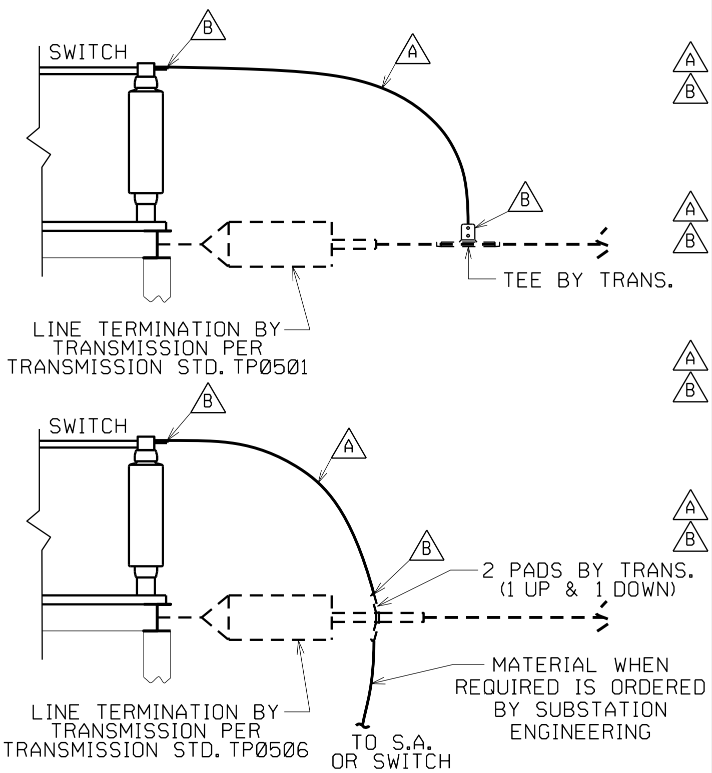
NL-200902-4-21

REV A

05/25/2006 200902-4-21.DGN



WOOD POLE TERMINATION



STEEL TERMINATIONS

WOOD POLE TERMINATION MATERIAL (ORDERED BY DESIGNER)

ITEM NO.	QTY	DESCRIPTION
11	1	THREADED ROD, ¾" DIA × 26" LONG
18	1	NUT, SQUARE, FOR ¾" DIA BOLT
20	4	WASHER NUT, FOR ¾" DIA BOLT
25	3	LOCKNUT, FOR ¾" DIA BOLT
214	1	BOLT EYE FOR ¾" DIA THREADED ROD

NOTE: MATERIAL LISTED IS PER PHASE

MATERIAL FOR TAP FROM LINE TO EQUIPMENT

556.5 AL

	ITEM NO.	QTY	DESCRIPTION
A	37	10 FT	556.5 AL. CABLE
B	250	2	TERM. LUG FOR 556.5 AL.

954 AL

	ITEM NO.	QTY	DESCRIPTION
A	35	10 FT	954 AL. CABLE
B	251	2	TERM. LUG FOR 954 AL.

1590 AL

	ITEM NO.	QTY	DESCRIPTION
A	34	10 FT	1590 AL. CABLE
B	252	2	TERM. LUG FOR 1590 AL.

2-1590 AL

	ITEM NO.	QTY	DESCRIPTION
A	34	20 FT	(2) - 1590 AL. CABLE
B	674	2	(2) - TERM. LUG FOR 1590 AL.

NOTE: MATERIAL LISTED IS PER PHASE

LEGEND:
153 INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-22
ELECTRICAL CONNECTION DETAIL
LINE TERMINATIONS FOR 34.5KV & 69KV

Xcel Energy®

SCALE: NONE

NL-200902-4-22

REV: B

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-4-22.DGN

5/20/2011 12:40:45 PM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

556.5 AL

	ITEM NO.	QTY	DESCRIPTION
A	37	10 FT	556.5 AL. CABLE
B	250	2	TERM. LUG FOR 556.5 AL.

954 AL

	ITEM NO.	QTY	DESCRIPTION
A	35	10 FT	954 AL. CABLE
B	251	2	TERM. LUG FOR 954 AL.

1590 AL

	ITEM NO.	QTY	DESCRIPTION
A	34	10 FT	1590 AL. CABLE
B	252	2	TERM. LUG FOR 1590 AL.

2-1590 AL

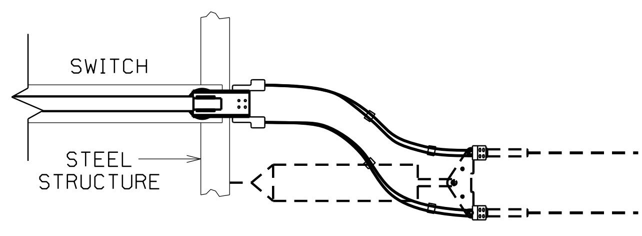
	ITEM NO.	QTY	DESCRIPTION
A	34	20 FT	(2) - 1590 AL. CABLE
B	674	2	TERM. LUG FOR 2-1590 AL.

NOTE: MATERIAL LISTED IS PER PHASE

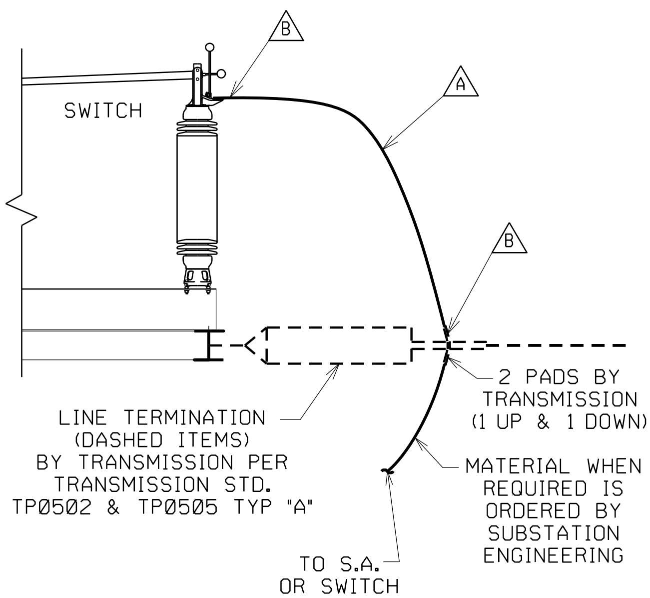
4-1590 AL

ITEM NO.	QTY	DESCRIPTION
34	40 FT	1590 AL. CABLE
286	4	CABLE SPACER FOR 2 OR 3-1590 AL
674	4	TERM. LUG FOR 2-1590 AL.

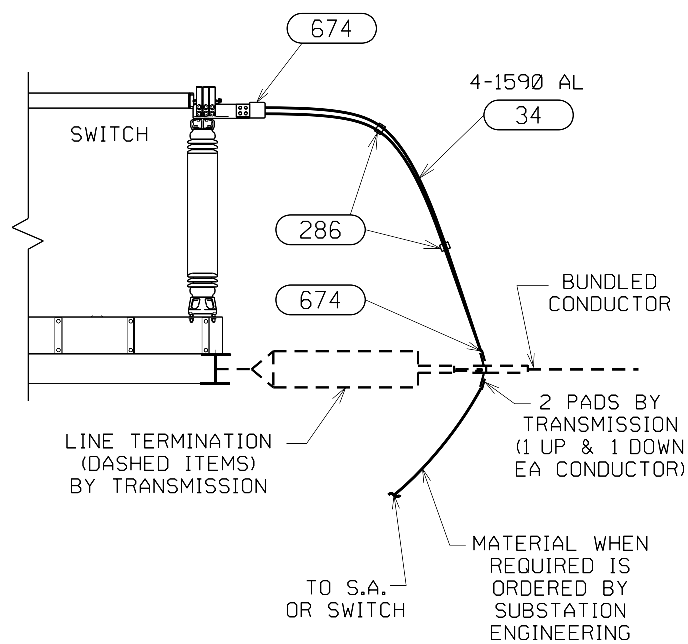
NOTE: MATERIAL LISTED IS PER PHASE



TOP VIEW



2000 AMPS AND BELOW



3000 AMPS

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-23

ELECTRICAL CONNECTION DETAIL

LINE TERMINATION FOR 115KV TO 230KV WITH NO LINE TRAP

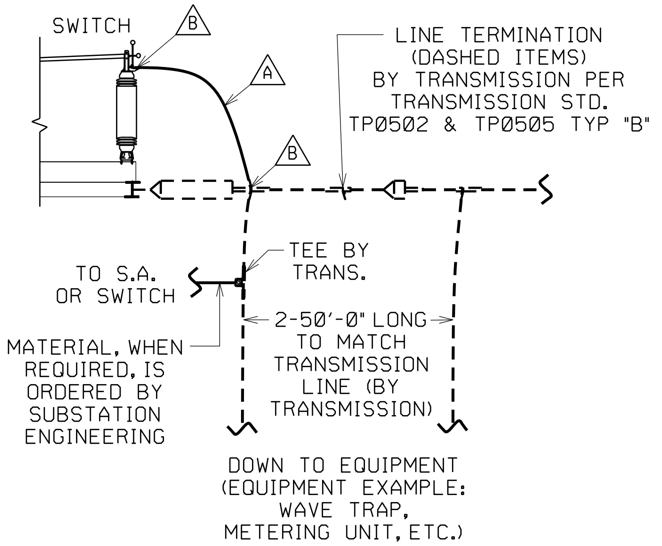
Xcel Energy

SCALE	DRAWING NO.	REV
NONE	NL-200902-4-23	C

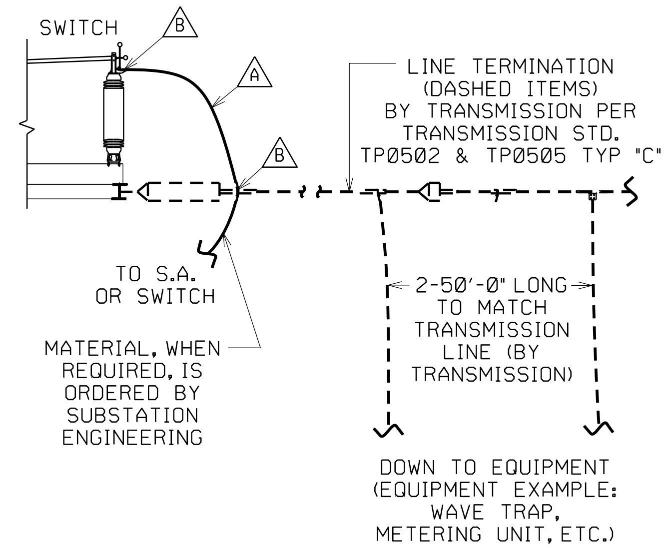
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-4-23.DGN

5/20/2011 12:41:23 PM



EQUIPMENT NEAR STRUCTURE



EQUIPMENT AWAY FROM STRUCTURE

BILL OF MATERIAL FOR THIS DETAIL
(ORDERED BY DESIGNER)

556.5 AL

	ITEM NO.	QTY	DESCRIPTION
(A)	37	10 FT	556.5 AL. CABLE
(B)	250	2	TERM. LUG FOR 556.5 AL.

954 AL

	ITEM NO.	QTY	DESCRIPTION
(A)	35	10 FT	954 AL. CABLE
(B)	251	2	TERM. LUG FOR 954 AL.

1590 AL

	ITEM NO.	QTY	DESCRIPTION
(A)	34	10 FT	1590 AL. CABLE
(B)	252	2	TERM. LUG FOR 1590 AL.

2-1590 AL

	ITEM NO.	QTY	DESCRIPTION
(A)	34	20 FT	(2) - 1590 AL. CABLE
(B)	674	2	(2) - TERM. LUG FOR 1590 AL.

NOTE: MATERIAL LISTED IS PER PHASE

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-24

ELECTRICAL CONNECTION DETAIL

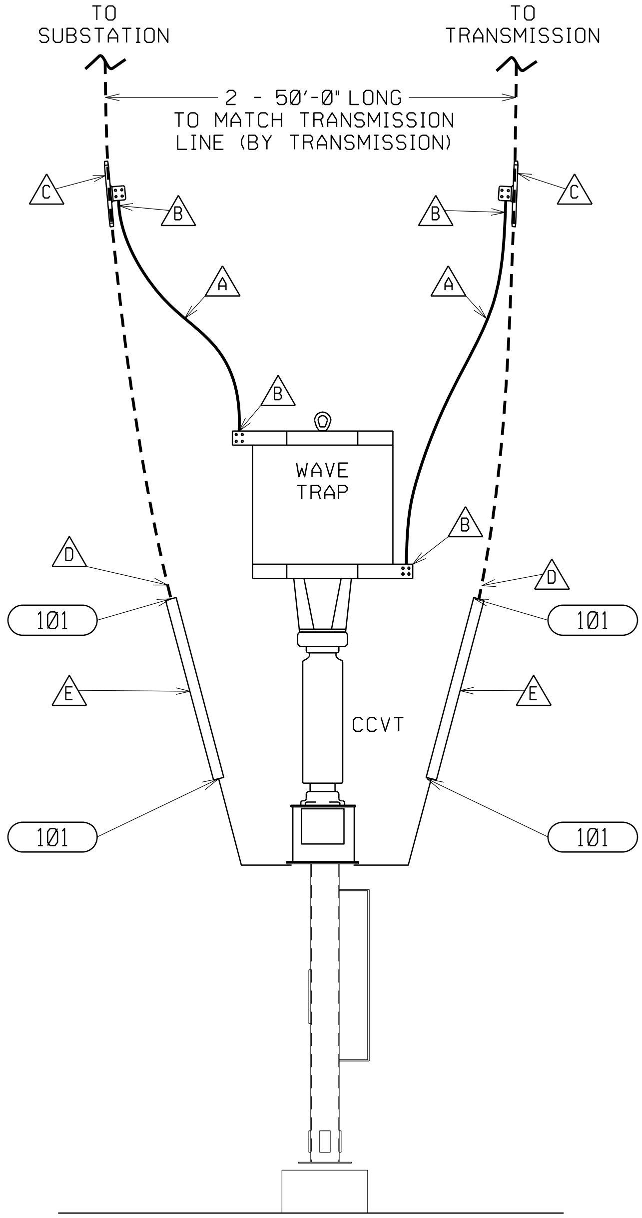
LINE TERMINATION FOR 115KV TO 230KV - DOWN TO EQUIPMENT

Xcel Energy®

SCALE	DRAWING NO.	REV
NONE	NL-200902-4-24	B

200902-4-24.DGN

5/20/2011 12:42:02 PM



NOTE: MATERIAL LISTED IS PER PHASE

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

556.5 AL

	ITEM NO.	QTY	DESCRIPTION
A	37	20 FT	556.5 AL. CABLE
B	250	4	TERM. LUG FOR 556.5 AL.

954 AL

	ITEM NO.	QTY	DESCRIPTION
A	35	20 FT	954 AL. CABLE
B	251	4	TERM. LUG FOR 954 AL.

1590 AL

	ITEM NO.	QTY	DESCRIPTION
A	34	20 FT	1590 AL. CABLE
B	252	4	TERM. LUG FOR 1590 AL.

2-1590 AL

	ITEM NO.	QTY	DESCRIPTION
A	34	40 FT	(2) - 1590 AL. CABLE
B	674	4	(2) - TERM. LUG FOR 1590 AL.

C TEE FOR ACSS & ACSR (2 REQUIRED)

ITEM NO.	QTY	DESCRIPTION
139A	2 EA OF 1 ITEM REQ.	TEE FOR 336.4 26/7
139B		TEE FOR 477 24/7, 26/7, 30/7 & 556.5 26/7
139C		TEE FOR 636 24/7
139D		TEE FOR 795 26/7 & 45/7 & 954 54/7
139E		TEE FOR 2500 KCMIL ALL AL

D DEAD END FOR ACSS & ACSR (2 REQUIRED)

ITEM NO.	QTY	DESCRIPTION
141A	2 EA OF 1 ITEM REQ.	COMP DEAD END FOR 336.4 26/7
141B		COMP DEAD END FOR 477 24/7
141C		COMP DEAD END FOR 477 26/7
141D		COMP DEAD END FOR 477 30/7
141E		COMP DEAD END FOR 556.5 26/7
141F		COMP DEAD END FOR 636 24/7
141G		COMP DEAD END FOR 795 26/7
141H		COMP DEAD END FOR 795 45/7
141J		COMP DEAD END FOR 954 54/7
141K		COMP DEAD END FOR 2500 KCMIL ALL AL

E POLYMER SUSPENSION INSULATOR (2 REQUIRED)

ITEM NO.	QTY	DESCRIPTION
147	2EA OF 1 ITEM REQ.	115KV POLY SUSPENSION INSULATOR
148		161KV POLY SUSPENSION INSULATOR

ITEM NO.	QTY	DESCRIPTION
101	4	ANCHOR SHACKLE

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-25

ELECTRICAL CONNECTION DETAIL

WAVE TRAP CONNECTION TO TRANSMISSION LINE

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy	SCALE NONE	NL-200902-4-25	REV C

200902-4-25.DGN

12:42:37 PM

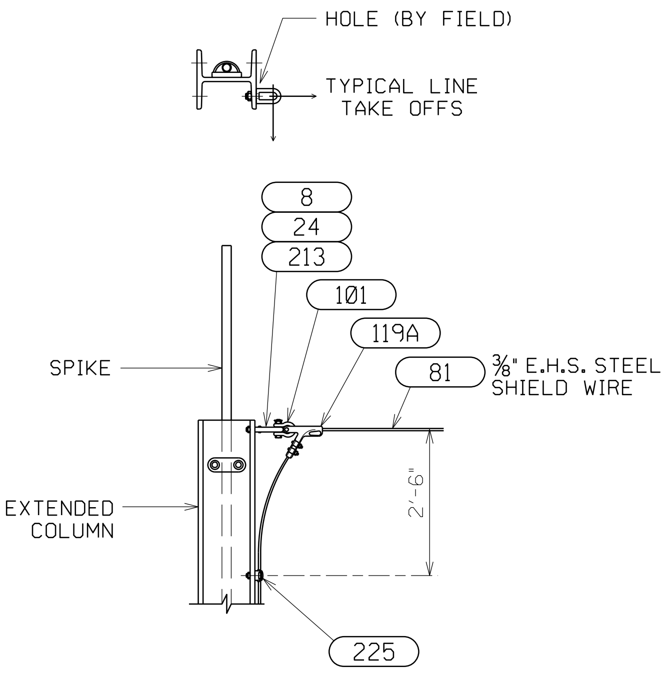
5/20/2011

MATERIAL FOR DETAIL BELOW		
ITEM NO.	QTY	DESCRIPTION
8	1	MACHINE BOLT, GALV., 5/8" DIA × 1½" L
24	1	LOCK NUT, GALV., FOR 5/8" DIA BOLT
81	*	3/8" GALV. E.H.S. SHIELD WIRE
101	1	ANCHOR SHACKLE, GALV., 30,000 LB
119A	1	DEAD-END STRAIN CLAMP
213	1	BOLT EYE FOR 5/8" DIA BOLT
225	1	AL. TOWER CLAMP, SINGLE GROOVE

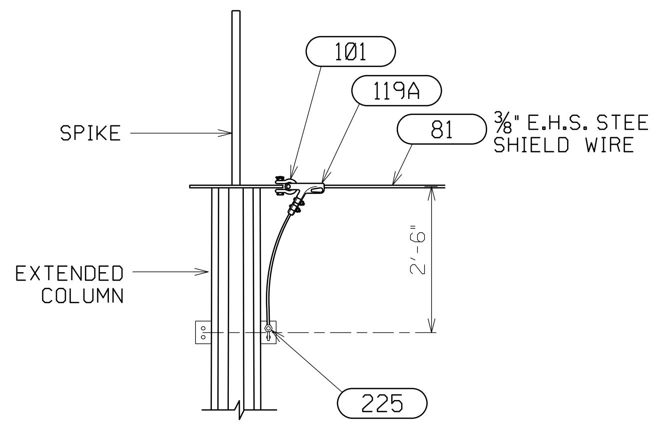
* VARIES

MATERIAL FOR DETAIL BELOW		
ITEM NO.	QTY	DESCRIPTION
81	*	3/8" GALV. E.H.S. SHIELD WIRE
101	1	ANCHOR SHACKLE, GALV., 30,000 LB
119A	1	DEAD-END STRAIN CLAMP
225	1	AL. TOWER CLAMP, SINGLE GROOVE

* VARIES



SHIELD WIRE TO ROLLED STEEL



SHIELD WIRE TO TUBULAR STEEL

NOTE:

THESE DETAILS ARE USED FOR SHIELD WIRES THAT STAY WITHIN A SUBSTATION. TRANSMISSION SHIELD WIRE DETAILS ARE SHOWN ON TRANSMISSION STANDARD TP0504.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-26
ELECTRICAL CONNECTION DETAIL
SHIELD WIRE ATTACHMENT

Xcel Energy®

SCALE: NONE

NL-200902-4-26

REV: B

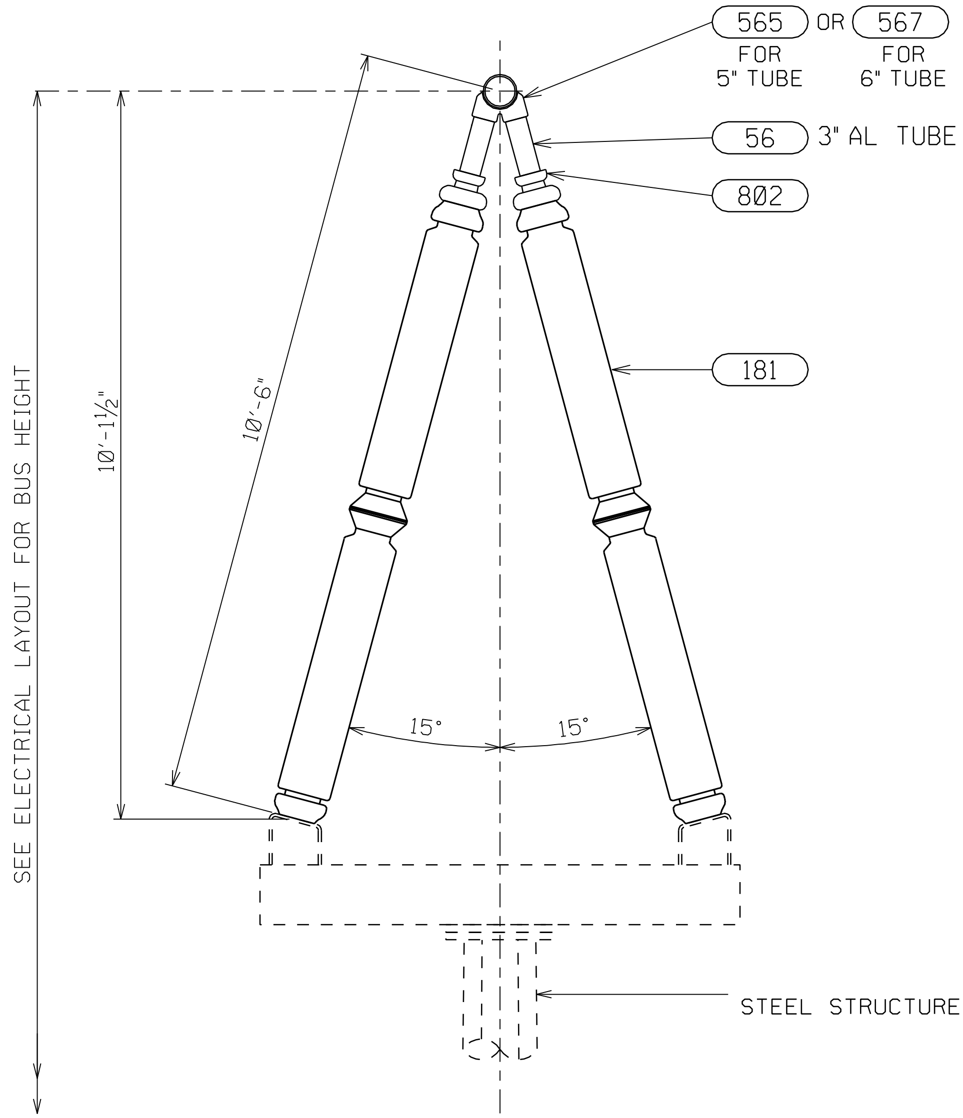
GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

200902-4-26.DGN

5/20/2011 12:43:12 PM

MATERIAL REQUIRED FOR ONE TRIANGULAR BUS SUPPORT					
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
56	2FT	3" IPS ALUMINUM TUBE			
181	2	345KV BUS SUPPORT 8'-10" HIGH			
565	1*	VEE CONN., 5" IPS TUBE TO 2-3" TUBE			
567		VEE CONN., 6" IPS TUBE TO 2-3" TUBE			
802	2	B.S. FTG, VERT TUBE SUPP FOR 3" TUBE			

* THIS IS THE QUANTITY REQUIRED FOR ONE OF THE ITEMS. DO YOU HAVE 5" OR 6" TUBE?



LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
1	
2	
3	
4	
5A	
5B	DETAIL
6	
CL	

ENGINEERING DEPARTMENT
MINNEAPOLIS, MN

SUBSTATION PHYSICAL DETAIL 4-27
ELECTRICAL CONNECTION DETAIL
345KV TRIANGULAR BUS SUPPORT

Xcel Energy

SCALE: NONE

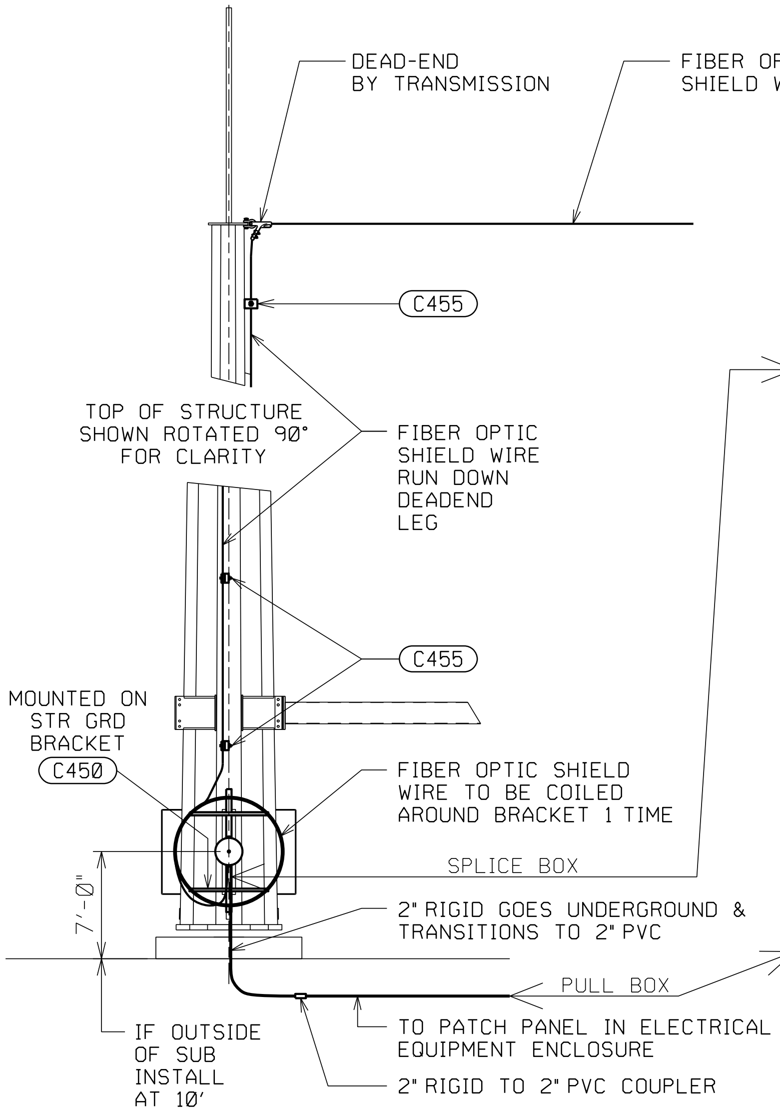
NL-200902-4-27

REV: A

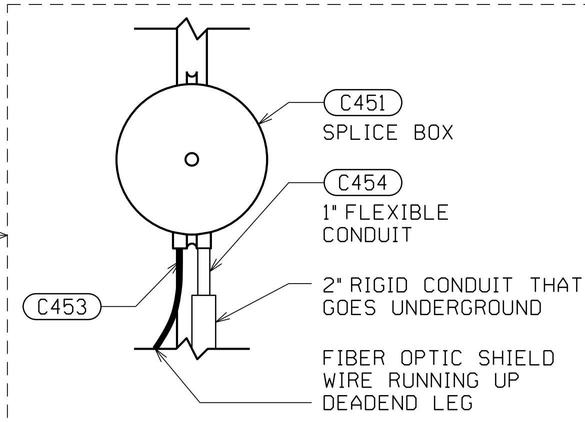
MATERIAL REQUIRED FOR ONE SPLICE

ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
C305	FIELD	2" RIGID PVC CONDUIT, 20' LENGTHS	C453	1 EA	FIBER OPTIC CONNECTOR KIT
C306	1 EA	CONDUIT JCT. BOX, W/COVER 1' x 1' x 6"	C454	1 EA	LOOSE TUBE CABLE CONNECTION KIT
C450	1 EA	EXTERNAL COIL BRACKET	C455	8 EA	FIBER OPTIC DOWN LEAD CLAMP
C451	1 EA	FIBER OPTIC SPLICE BOX ENCLOSURE	C459	5 PG*	FIBER OPTIC SPLICE PROTECTION SLEEVE

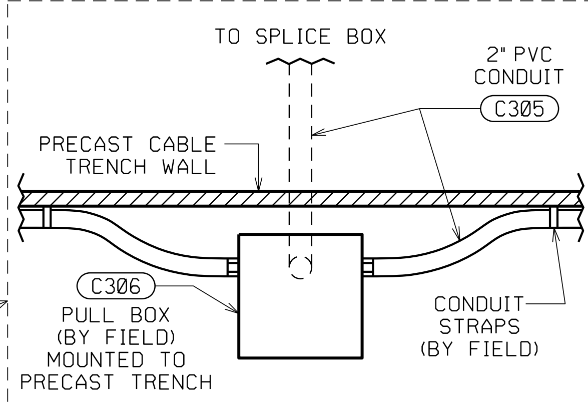
* DEPENDING ON AMOUNT OF FIBERS



ELEVATION



SPLICE BOX DETAIL



CABLE TRENCH
PULL BOX DETAIL

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST. (ORDERED BY DESIGNER)

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-28
ELECTRICAL CONNECTION DETAIL
FIBER OPTIC SHIELD WIRE, OVERHEAD TO UNDERGROUND SPLICE

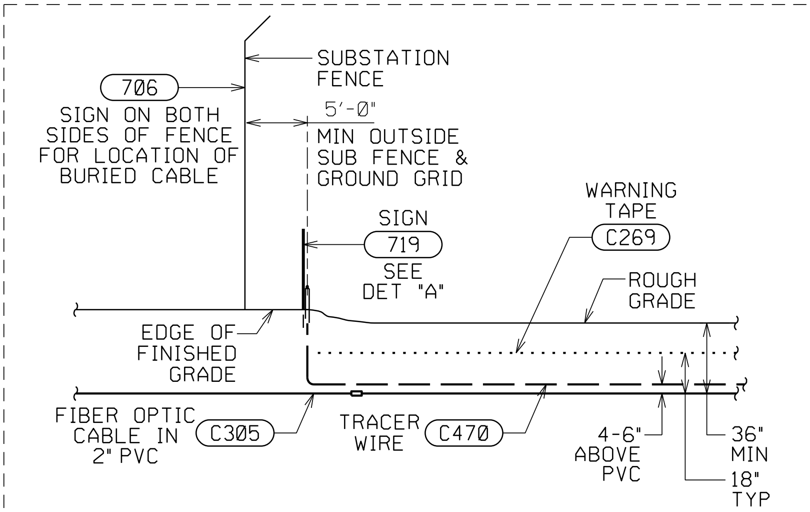
Xcel Energy®

SCALE	DRAWING NO.	REV
NONE	NL-200902-4-28	C

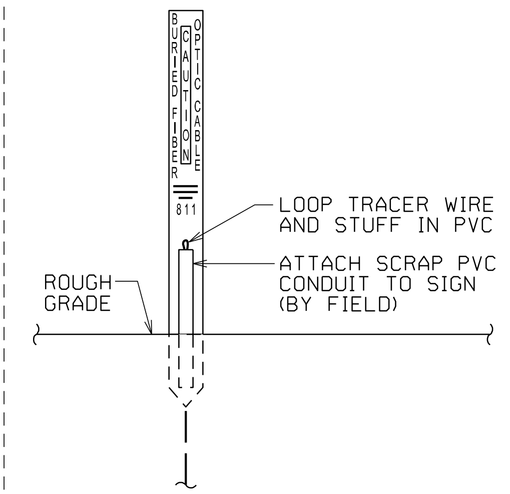
200902-4-28.DGN
10/26/2012 10:32:24 AM

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

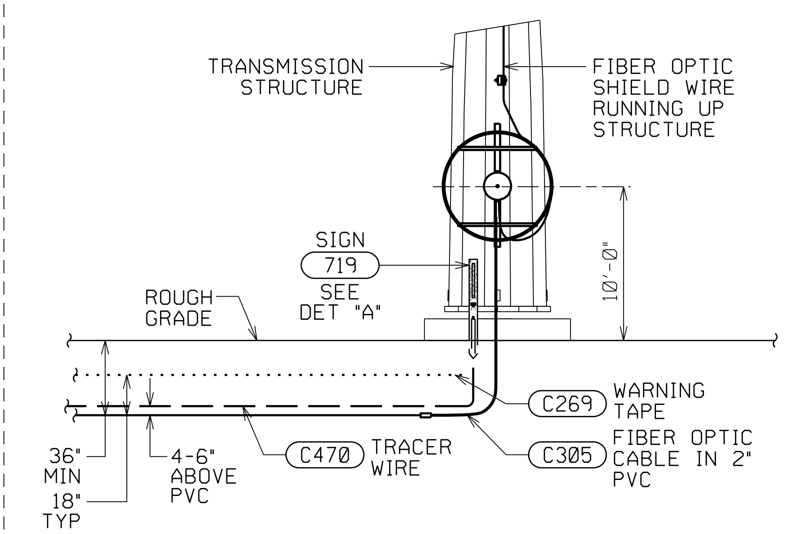
ITEM NO.	QTY	DESCRIPTION	ITEM NO.	QTY	DESCRIPTION
706	2	SIGN, "WARNING BURIED CABLE BELOW"	C305	FIELD	2" RIGID PVC CONDUIT, 20' LENGTHS
719	2 EA	SIGN, "BURIED FIBER OPTIC CABLE"	C470	*	TRACER WIRE, 12 GAUGE, BLACK
C269	*	6" WIDE WARNING TAPE			* DEPENDING ON RUN LENGTH



TRACER WIRE OUTSIDE SUB FENCE



SIGN DETAIL "A"



TRACER WIRE AT STRUCTURE

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA ENGINEERING Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 4-29

ELECTRICAL CONNECTION DETAIL

TRACER WIRE FOR FIBER OPTIC LOCATED OUTSIDE SUBSTATION

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

Xcel Energy

SCALE NONE

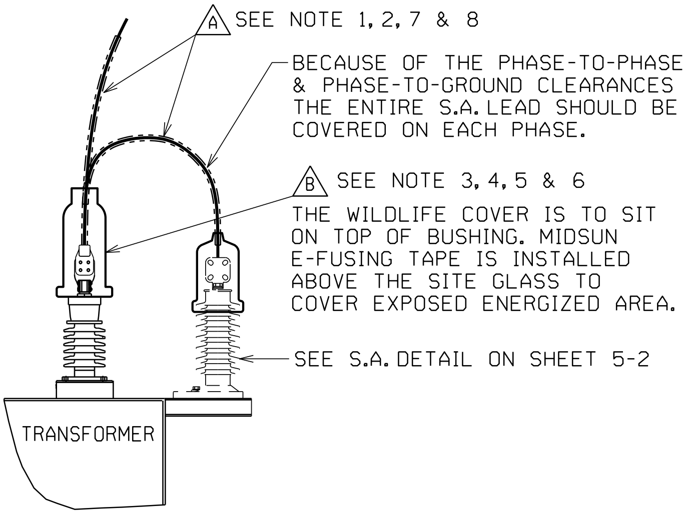
NL-200902-4-29

REV A

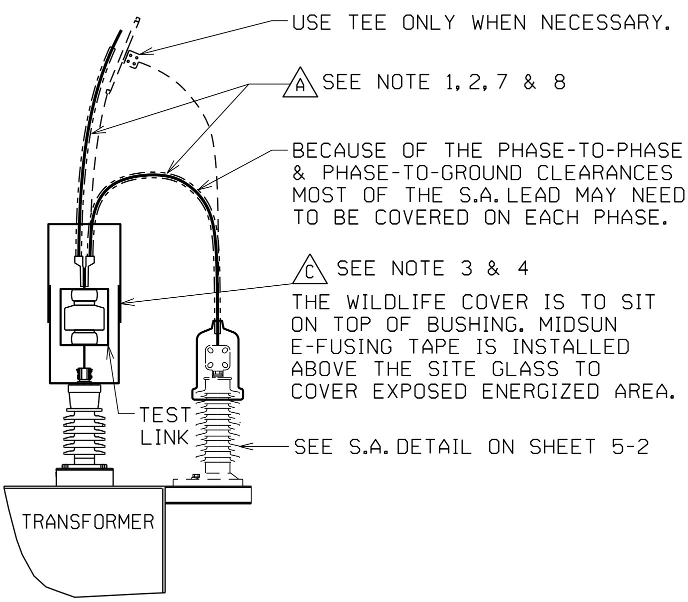
200902-4-29.DGN

9/19/2013 8:27:06 AM

200902-5-1.DGN



LOW SIDE TRANSFORMER BUSHING AND TERTIARY BUSHINGS 35KV AND BELOW



LOW SIDE TRANSFORMER BUSHING WITH TEST LINK 35KV AND BELOW

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

WILDLIFE CONDUCTOR COVER

	ITEM NO.	QTY	DESCRIPTION
A	W30	*	COND. COVER FOR #4-2/0
A	W31	*	COND. COVER FOR #3/0-336.4
A	W32	*	COND. COVER FOR 397.5-636
A	W33	*	COND. COVER FOR 666.6-954
A	W34	*	COND. COVER FOR 1033-2167
A	W60	*	TAPE, SILICONE, SELF-FUSING, 2½" WIDE NOTE: USE TAPE SPARINGLY SEE NOTE 8

* DESIGNER TO DETERMINE WHAT IS NEEDED

WILDLIFE COVERS

	ITEM NO.	QTY	DESCRIPTION
B	W1	1 EA	THERM-O-GUARD COVER, 19" H
C	W20	1 AY	TEST LINK COVER, RAYCHEM

NEED EITHER ITEM B OR C (NOT BOTH).

NOTE: MATERIAL LISTED IS PER PHASE

NOTES:

1. INSULATION SHOULD BE INSTALLED ON EACH PHASE FROM INSIDE THE COVER TO A POINT WHERE THE PHASE-TO-GROUND CLEARANCE IS 18" OR GREATER. INSULATION SHOULD ALSO BE INSTALLED ON THE CENTER PHASE TO A POINT WHERE A PHASE SPACING OF 36" IS REACHED.
2. INSULATION SHALL BE USED ON THE OUTSIDE PHASES WHEN 18" PHASE-TO-GROUND CLEARANCE CAN NOT BE ACHIEVED.
3. A BUSHING COVER SHOULD ALWAYS ALLOW FOR THE OIL INDICATORS TO BE VISIBLE FROM THE GROUND.
4. IF OIL INDICATORS DO NOT EXIST, THE BUSHING COVER IS INSTALLED BETWEEN THE FIRST AND SECOND SKIRT FROM THE TOP OF THE BUSHING. NEVER COVER MORE THAN THE FIRST SKIRT.
5. THERM-A-GUARD RECOMMENDS A MINIMUM OF 1" CLEARANCE FROM THE ENERGIZED CONNECTOR TO THE INSIDE SURFACE OF THE GUARD.
6. THERM-A-GUARD BUSHING COVERS CAN BE TRIMMED TO ACCOMMODATE CONDUCTOR EXITS OTHER THAN THE TOP. TRIM CAREFULLY SO THE OPENING DOES NOT GET OVERSIZED AND DO NOT REMOVE MORE THAN ONE HINGE.
7. FOR THE INSULATING HOSE TO COVER THE BARREL OF THE LUG, PURCHASE HOSE THAT IS ONE SIZE LARGER THAN THE HOSE SIZE RECOMMENDED FOR THE ACTUAL CONDUCTOR SIZE.
8. INSULATING TAPE CAN BE USED IN SMALL AREAS WHERE A BUSHING COVER OR OTHER INSULATING MATERIAL CANNOT BE USED. THE TAPE HAS A DESIGN LIFE OF ONLY 10 YEARS AND ALL OTHER ITEMS HAVE A DESIGN LIFE OF 20-40 YEARS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 5-1

WILDLIFE PROTECTION DETAIL

TRANSFORMER BUSHINGS - 35KV AND BELOW

Xcel Energy

SCALE: NONE

NL-200902-5-1

REV: C

11/20/2013 11:10:43 AM

BILL OF MATERIAL FOR THIS DETAIL
(ORDERED BY DESIGNER)

WILDLIFE CONDUCTOR COVER

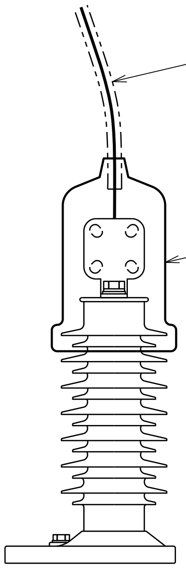
	ITEM NO.	QTY	DESCRIPTION
A	W30	*	COND. COVER FOR #4-2/0
A	W31	*	COND. COVER FOR #3/0-336.4
A	W32	*	COND. COVER FOR 397.5-636
A	W33	*	COND. COVER FOR 666.6-954
A	W34	*	COND. COVER FOR 1033-2167
A	W60	*	TAPE, SILICONE, SELF-FUSING, 2½" WIDE NOTE: USE TAPE SPARINGLY SEE NOTE 3

* DESIGNER TO DETERMINE WHAT IS NEEDED

WILDLIFE SURGE ARRESTER COVER

	ITEM NO.	QTY	DESCRIPTION
B	W2	1 EA	THERM-O-GUARD COVER, 14" H

NOTE: MATERIAL LISTED IS PER PHASE



A COVER CONDUCTOR AS NECESSARY. SEE NOTE 1, 2 & 7

B WILDLIFE COVER SITS ON TOP OF THE SURGE ARRESTER. TO PREVENT ANIMALS FROM LIFTING THE COVER A SMALL AMOUNT OF SILICONE CAULK CAN BE USED TO GLUE THE COVER TO THE TOP SKIRT. SEE NOTE 3, 4 & 5

SURGE ARRESTER - 35KV AND BELOW

NOTES:

1. INSULATION SHOULD BE INSTALLED ON EACH PHASE FROM INSIDE THE COVER TO A POINT WHERE THE PHASE-TO-GROUND CLEARANCE IS 18" OR GREATER. INSULATION SHOULD ALSO BE INSTALLED ON THE CENTER PHASE TO A POINT WHERE A PHASE SPACING OF 36" IS REACHED.
2. INSULATION SHALL BE USED ON THE OUTSIDE PHASES WHEN 18" PHASE-TO-GROUND CLEARANCE CAN NOT BE ACHIEVED.
3. THE BUSHING COVER IS INSTALLED BETWEEN THE FIRST AND SECOND SKIRT FROM THE TOP OF THE BUSHING. NEVER COVER MORE THAN THE FIRST SKIRT.
4. THERM-A-GUARD RECOMMENDS A MINIMUM OF 1" CLEARANCE FROM THE ENERGIZED CONNECTOR TO THE INSIDE SURFACE OF THE GUARD.
5. THERM-A-GUARD BUSHING COVERS CAN BE TRIMMED TO ACCOMMODATE CONDUCTOR EXITS OTHER THAN THE TOP. TRIM CAREFULLY SO THE OPENING DOES NOT GET OVERSIZED AND DO NOT REMOVE MORE THAN ONE HINGE.
6. FOR THE INSULATING HOSE TO COVER THE BARREL OF THE LUG, PURCHASE HOSE THAT IS ONE SIZE LARGER THAN THE HOSE SIZE RECOMMENDED FOR THE ACTUAL CONDUCTOR SIZE.
7. INSULATING TAPE CAN BE USED IN SMALL AREAS WHERE A BUSHING COVER OR OTHER INSULATING MATERIAL CANNOT BE USED. THE TAPE HAS A DESIGN LIFE OF ONLY 10 YEARS AND ALL OTHER ITEMS HAVE A DESIGN LIFE OF 20-40 YEARS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 5-2
WILDLIFE PROTECTION DETAIL
SURGE ARRESTERS - 35KV AND BELOW

Xcel Energy®

SCALE	DRAWING NO.	REV
NONE	NL-200902-5-2	C

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

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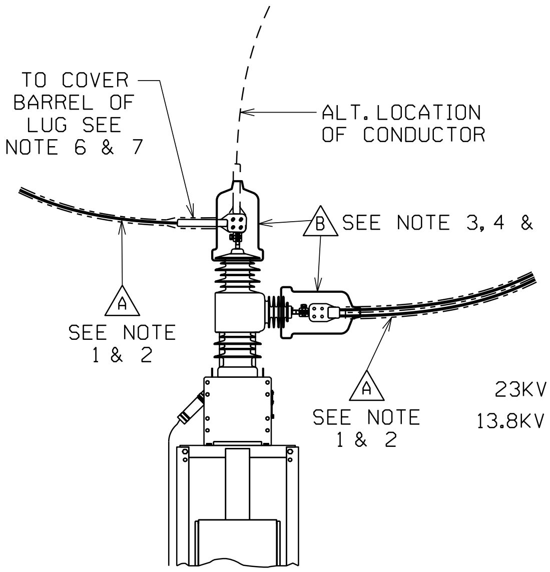
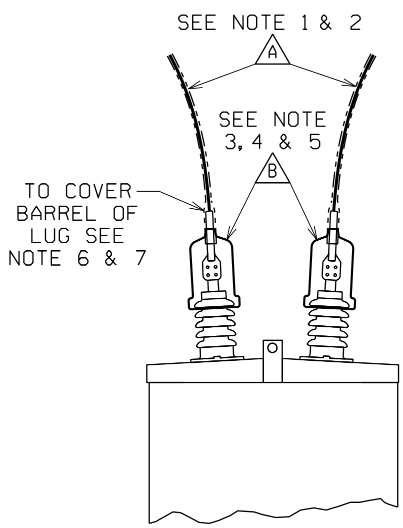


NOVA RECLOSER
35KV AND BELOW



TYPICAL CIRCUIT BREAKER
OR RECLOSER
35KV AND BELOW

BILL OF MATERIAL FOR THIS DETAIL (ORDERED BY DESIGNER)

WILDLIFE CONDUCTOR COVER

	ITEM NO.	QTY	DESCRIPTION
A	W30	*	COND. COVER FOR #4-2/0
A	W31	*	COND. COVER FOR #3/0-336.4
A	W32	*	COND. COVER FOR 397.5-636
A	W33	*	COND. COVER FOR 666.6-954
A	W34	*	COND. COVER FOR 1033-2167
A	W60	*	TAPE, SILICONE, SELF-FUSING, 2½" WIDE NOTE: USE TAPE SPARINGLY SEE NOTE 7

* DESIGNER TO DETERMINE WHAT IS NEEDED

WILDLIFE BUSHING COVER

	ITEM NO.	QTY	DESCRIPTION
23KV & ABOVE B	W1	6 EA OF 1 ITEM REQ.	THERM-O-GUARD COVER, 19" H
13.8KV & BELOW B	W2		THERM-O-GUARD COVER, 14" H

NOTE: MATERIAL LISTED IS PER BREAKER

NOTES:

1. INSULATION SHOULD BE INSTALLED ON EACH PHASE FROM INSIDE THE COVER TO A POINT WHERE THE PHASE-TO-GROUND CLEARANCE IS 18" OR GREATER. INSULATION SHOULD ALSO BE INSTALLED ON THE CENTER PHASE TO A POINT WHERE A PHASE SPACING OF 36" IS REACHED.

2. INSULATION SHALL BE USED ON THE OUTSIDE PHASES WHEN 18" PHASE-TO-GROUND CLEARANCE CAN NOT BE ACHIEVED.

3. THE BUSHING COVER IS INSTALLED BETWEEN THE FIRST AND SECOND SKIRT FROM THE TOP OF THE BUSHING. NEVER COVER MORE THAN THE FIRST SKIRT.

4. THERM-A-GUARD RECOMMENDS A MINIMUM OF 1" CLEARANCE FROM THE ENERGIZED CONNECTOR TO THE INSIDE SURFACE OF THE GUARD.

5. THERM-A-GUARD BUSHING COVERS CAN BE TRIMMED TO ACCOMMODATE CONDUCTOR EXITS OTHER THAN THE TOP. TRIM CAREFULLY SO THE OPENING DOES NOT GET OVERSIZED AND DO NOT REMOVE MORE THAN ONE HINGE.

6. FOR THE INSULATING HOSE TO COVER THE BARREL OF THE LUG, PURCHASE HOSE THAT IS ONE SIZE LARGER THAN THE HOSE SIZE RECOMMENDED FOR THE ACTUAL CONDUCTOR SIZE.

7. INSULATING TAPE CAN BE USED IN SMALL AREAS WHERE A BUSHING COVER OR OTHER INSULATING MATERIAL CANNOT BE USED. THE TAPE HAS A DESIGN LIFE OF ONLY 10 YEARS AND ALL OTHER ITEMS HAVE A DESIGN LIFE OF 20-40 YEARS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 5-3

WILDLIFE PROTECTION DETAIL

CIRCUIT BREAKERS OR RECLOSERS - 35KV AND BELOW

Xcel Energy®

SCALE	DRAWING NO.	REV
NONE	NL-200902-5-3	C

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
LOC GRP	
3	
4	
5A	
5B	DETAIL
6	
CL	

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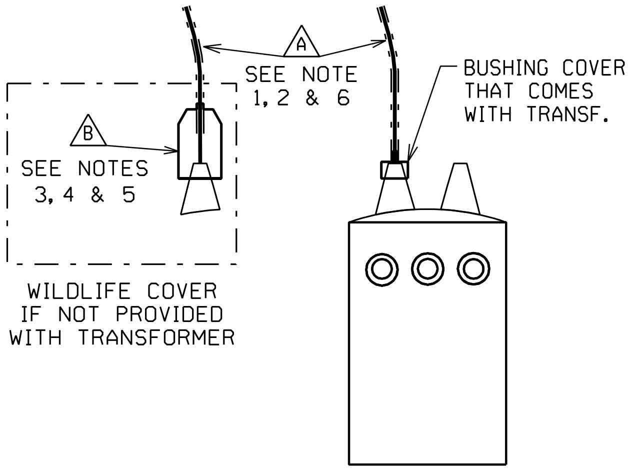
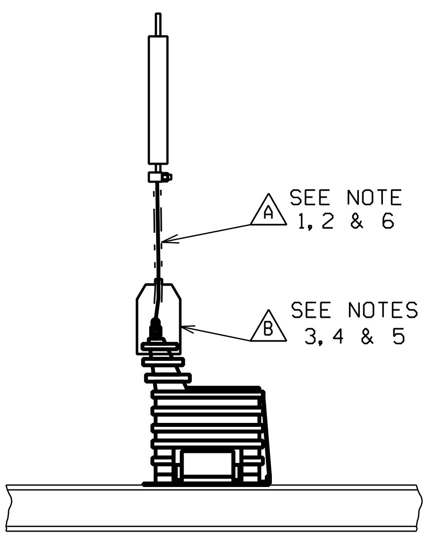


TYPICAL AUX TRANSFORMER
35KV AND BELOW



TYPICAL POT TRANSFORMER
35KV AND BELOW

BILL OF MATERIAL FOR THIS DETAIL
(ORDERED BY DESIGNER)

WILDLIFE CONDUCTOR COVER

	ITEM NO.	QTY	DESCRIPTION
A	W30	*	COND. COVER FOR #4-2/0
A	W31	*	COND. COVER FOR #3/0-336.4
A	W32	*	COND. COVER FOR 397.5-636
A	W33	*	COND. COVER FOR 666.6-954
A	W34	*	COND. COVER FOR 1033-2167
A	W60	*	TAPE, SILICONE, SELF-FUSING, 2½" WIDE NOTE: USE TAPE SPARINGLY SEE NOTE 6

* DESIGNER TO DETERMINE WHAT IS NEEDED

WILDLIFE BUSHING COVER

	ITEM NO.	QTY	DESCRIPTION
B	W4	1 EA	THERM-O-GUARD COVER, 8" H

NOTE: MATERIAL LISTED IS PER PHASE

NOTES:

1. INSULATION SHOULD BE INSTALLED FROM INSIDE THE COVER TO THE FUSE OR FUSE DISCONNECT.
2. WHEN MORE THAN ONE TRANSFORMER IS USED ALL LEADS BETWEEN THE FUSE DISCONNECTS AND THE TRANSFOMERS SHALL BE COVERED.
3. THE BUSHING COVER IS INSTALLED BETWEEN THE FIRST AND SECOND SKIRT FROM THE TOP OF THE BUSHING. NEVER COVER MORE THAN THE FIRST SKIRT.
4. THERM-A-GUARD RECOMMENDS A MINIMUM OF 1" CLEARANCE FROM THE ENERGIZED CONNECTOR TO THE INSIDE SURFACE OF THE GUARD.
5. THERM-A-GUARD BUSHING COVERS CAN BE TRIMMED TO ACCOMMODATE CONDUCTOR EXITS OTHER THAN THE TOP. TRIM CAREFULLY SO THE OPENING DOES NOT GET OVERSIZED.
6. INSULATING TAPE CAN BE USED IN SMALL AREAS WHERE A BUSHING COVER OR OTHER INSULATING MATERIAL CANNOT BE USED. THE TAPE HAS A DESIGN LIFE OF ONLY 10 YEARS AND ALL OTHER ITEMS HAVE A DESIGN LIFE OF 20-40 YEARS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 5-4
WILDLIFE PROTECTION DETAIL
STATION AUX AND POT TRANSFOMERS - 35KV AND BELOW

Xcel Energy

SCALE: NONE

NL-200902-5-4

REV: A

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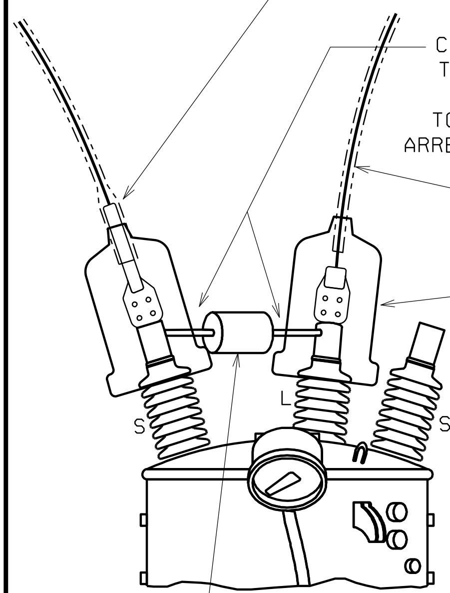

REGULATOR
35KV AND BELOW

BILL OF MATERIAL FOR THIS DETAIL
(ORDERED BY DESIGNER)

WILDLIFE CONDUCTOR COVER

	ITEM NO.	QTY	DESCRIPTION
A	W30	*	COND. COVER FOR #4-2/0
A	W31	*	COND. COVER FOR #3/0-336.4
A	W32	*	COND. COVER FOR 397.5-636
A	W33	*	COND. COVER FOR 666.6-954
A	W34	*	COND. COVER FOR 1033-2167
A	W60	*	TAPE, SILICONE, SELF-FUSING, 2½" WIDE NOTE: USE TAPE SPARINGLY SEE NOTE 6

* DESIGNER TO DETERMINE WHAT IS NEEDED

WILDLIFE BUSHING COVER

	ITEM NO.	QTY	DESCRIPTION
B	W2	2 EA	THERM-O-GUARD COVER, 14" H

NOTE: MATERIAL LISTED IS PER PHASE

NOTES:

1. INSULATION SHALL BE INSTALLED ON EACH PHASE FROM INSIDE THE COVER TO THE FIRST POINT OF ATTACHMENT. THIS WILL BE DONE FOR BOTH THE SOURCE AND LOAD BUSHINGS ON THE REGULATOR BECAUSE OF MINIMAL CLEARANCES.
2. THE BUSHING COVER IS INSTALLED BETWEEN THE FIRST AND SECOND SKIRT FROM THE TOP OF THE BUSHING. NEVER COVER MORE THAN THE FIRST SKIRT.
3. THERM-A-GUARD RECOMMENDS A MINIMUM OF 1" CLEARANCE FROM THE ENERGIZED CONNECTOR TO THE INSIDE SURFACE OF THE GUARD.
4. THERM-A-GUARD BUSHING COVERS CAN BE TRIMMED TO ACCOMMODATE CONDUCTOR EXITS OTHER THAN THE TOP. TRIM CAREFULLY SO THE OPENING DOES NOT GET OVERSIZED AND DO NOT REMOVE MORE THAN ONE HINGE.
5. FOR THE INSULATING HOSE TO COVER THE BARREL OF THE LUG, PURCHASE HOSE THAT IS ONE SIZE LARGER THAN THE HOSE SIZE RECOMMENDED FOR THE ACTUAL CONDUCTOR SIZE.
6. INSULATING TAPE CAN BE USED IN SMALL AREAS WHERE A BUSHING COVER OR OTHER INSULATING MATERIAL CANNOT BE USED. THE TAPE HAS A DESIGN LIFE OF ONLY 10 YEARS AND ALL OTHER ITEMS HAVE A DESIGN LIFE OF 20-40 YEARS.

LEGEND:

(153) INDICATES ITEM NUMBER SHOWN ABOVE AND ON PHYSICAL MATERIAL LIST.

GRP	SIGNIFICANT NUMBER
LOC ID GRP 1	
3	
4	
5A	
5B	DETAIL
6	
CL	

NSP OPERATING AREA
ENGINEERING
Minneapolis, MN

SUBSTATION PHYSICAL DETAIL 5-5
WILDLIFE PROTECTION DETAIL
REGULATORS - 35KV AND BELOW

Xcel Energy

SCALE	DRAWING	REV
NONE	NL-200902-5-5	B

200902-5-5.DGN

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PHYSICAL DETAIL INDEX AND REVISION LEGEND

NL-INDEX

REVISION "F"

This Map/Document is a tool to assist employees in the performance of their jobs. Your personal safety is provided for by using safety practices, procedures and equipment as described in safety training programs, manuals and SPAR's

Revised?	DRAWING NUMBER		REV	DESCRIPTION 1	DESCRIPTION 2	What Changed on the revision above?
	NL	200902-1-1	D	SUBSTATION GROUNDING DETAIL	CADWELD MOLD TYPES AND SHOT REQUIRED FOR EACH MOLD	
	NL	200902-1-10	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR CAPACITOR BANK STAND	
	NL	200902-1-11	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR SINGLE CAPACITOR BANK	
	NL	200902-1-12	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR CAPACITOR BANK SINGLE POINT CONNECTION	
	NL	200902-1-13	C	SUBSTATION GROUNDING DETAIL	GROUND WELL	
	NL	200902-1-14	A	SUBSTATION GROUNDING DETAIL	FENCE GROUND ISOLATION	
	NL	200902-1-15	A	SUBSTATION GROUNDING DETAIL	GROUNDING FOR SURGE ARRESTER	
	NL	200902-1-16	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR SHIELD SPIKE ON WOOD POLE	
	NL	200902-1-17	A	SUBSTATION GROUNDING DETAIL	GROUNDING FOR GUARD POST	
	NL	200902-1-18	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR OUTDOOR UNDERGROUND FEEDER NEUTRAL	
	NL	200902-1-19	B	SUBSTATION GROUNDING DETAIL	OVERHEAD FEEDER NEUTRAL CONNECTION TO GROUND GRID	
	NL	200902-1-2	C	SUBSTATION GROUNDING DETAIL	GROUNDING FOR SUBSTATION STEEL STRUCTURES	
	NL	200902-1-20	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR PAINTED CABINETS	
	NL	200902-1-21	A	SUBSTATION GROUNDING DETAIL	SWITCH OPERATING PIPE GRD'G & OPERATING CRANK MOUNTING HEIGHT	
	NL	200902-1-3	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR FENCE AND GATE	
	NL	200902-1-4	D	SUBSTATION GROUNDING DETAIL	GROUNDING FOR TRANSFORMER	
	NL	200902-1-5	D	SUBSTATION GROUNDING DETAIL	GROUNDING FOR BREAKERS	
	NL	200902-1-6	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR NOVA RECLOSER	
	NL	200902-1-7	C	SUBSTATION GROUNDING DETAIL	GROUNDING FOR RECLOSER	
	NL	200902-1-8	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR REGULATOR	
	NL	200902-1-9	B	SUBSTATION GROUNDING DETAIL	GROUNDING FOR P.T. AND C.C.V.T.	
	NL	200902-2-1	C	SUBSTATION CONTROL AND LIGHTING DETAIL	CONDUIT RISER DETAIL "A", DETAIL "B", DETAIL "C" & DETAIL "D"	
	NL	200902-2-10	A	SUBSTATION CONTROL AND LIGHTING DETAIL	POTENTIAL TRANSFORMER MOUNTING AND CONDUIT LAYOUT	
	NL	200902-2-2	A	SUBSTATION CONTROL AND LIGHTING DETAIL	FLOODLAMP LIGHTING FIXTURE MOUNTING	
	NL	200902-2-3	C	SUBSTATION CONTROL AND LIGHTING DETAIL	400W HIGH PRESSURE SOIDUM LIGHT FIXTURE MOUNTING	
	NL	200902-2-4	B	SUBSTATION CONTROL AND LIGHTING DETAIL	FUSE CABINET FOR SINGLE PHASE P.T. OR CCVT AND DIST. BUS PT'S	
	NL	200902-2-5	B	SUBSTATION CONTROL AND LIGHTING DETAIL	FUSE CABINET FOR THREE SINGLE PHASE PT'S OR CCVT'S	
	NL	200902-2-6	B	SUBSTATION CONTROL AND LIGHTING DETAIL	CONTROL CABLE CONNECTION FOR PT'S OR CCVT'S	
	NL	200902-2-7	B	SUBSTATION CONTROL AND LIGHTING DETAIL	CONTROL CABLE CONNECTION FOR THREE SINGLE PHASE CCVT'S	
	NL	200902-2-8	A	SUBSTATION CONTROL AND LIGHTING DETAIL	CABLE TRENCH DETAIL "A", DETAIL "B", DETAIL "C" & DETAIL "D"	
	NL	200902-2-9	B	SUBSTATION CONTROL AND LIGHTING DETAIL	TRANSFORMER CABLE TERMINATION CABINET	
	NL	200902-3-1	C	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	CABLE ENTRANCE FOR PRE-CAST PULL BOX	
	NL	200902-3-10	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	FLUORESCENT LIGHT FIXTURE HANGER	
	NL	200902-3-11	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	MOUNTING DETAIL FOR PANEL DROP CORD RECEPTACLES	
	NL	200902-3-12	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	HEATER INSTALLATION	
	NL	200902-3-13	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	LIGHTING LAYOUT AND WIRING	
	NL	200902-3-14	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	EXAMPLE TROUGH LAYOUT	
	NL	200902-3-15	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	WIRING OF OUTDOOR LIGHTING	
	NL	200902-3-2	C	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	CABLE ENTRANCE FOR BURIED CABLE	
	NL	200902-3-3	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	TYPICAL PANEL AND CABLE TRAY MOUNTING	
	NL	200902-3-4	C	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	GROUND BUS ENTRANCE	
	NL	200902-3-5	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	MOBILE TRANSFORMER CONTROL CABLE ENTRANCE	
	NL	200902-3-6	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	TELEPHONE CABLE ENTRANCE	
	NL	200902-3-7	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	TYP GRD'G FOR ALL CAB., BOXES, SAF. SW., BATT. RACK & CHARGER	
	NL	200902-3-8	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	MOUNTING FOR HEAVY EQUIPMENT	
	NL	200902-3-9	B	ELECTRICAL EQUIPMENT ENCLOSURE DETAIL	TYPICAL MOUNTING OF BATTERY RACK TO WALL	
	NL	200902-4-1	A	ELECTRICAL CONNECTION DETAIL	BUS MOUNTING FOR ALUMINUM ANGLE	
	NL	200902-4-10	A	ELECTRICAL CONNECTION DETAIL	DRILLING FOR TERMINAL LUG CONNECTION TO INTEGRAL WEB CHANNEL BUS	
	NL	200902-4-11	A	ELECTRICAL CONNECTION DETAIL	PROVISION FOR HOT LINE CLAMP CONN. TO INTEGRAL WEB CHANNEL BUS	
	NL	200902-4-12	A	ELECTRICAL CONNECTION DETAIL	WELDED OR BOLTED SPLICE FOR INTEGRAL WEB CHANNEL BUS	

PHYSICAL DETAIL INDEX AND REVISION LEGEND

Xcel Energy

This Map/Document is a tool to assist employees in the performance of their jobs. Your personal safety is provided for by using safety practices, procedures and equipment as described in safety training programs, manuals and SPAR's

REVISION "F"

Revised?	DRAWING NUMBER		REV	DESCRIPTION 1	DESCRIPTION 2	What Changed on the revision above?
	NL	200902-4-13	A	ELECTRICAL CONNECTION DETAIL	WELDED-BOLTED 90 DEGREE ANGLE CONN. FOR INTEGRAL WEB CHANNEL BUS	
	NL	200902-4-14	A	ELECTRICAL CONNECTION DETAIL	WELDED OR BOLTED TEE TAP FOR INTEGRAL WEB CHANNEL BUS	
	NL	200902-4-15	A	ELECTRICAL CONNECTION DETAIL	WELDED ANGLE BRACE FOR INTEGRAL WEB CHANNEL BUS	
	NL	200902-4-16	E	ELECTRICAL CONNECTION DETAIL	TUBING BUS "A" FRAME TAP	
	NL	200902-4-17	B	ELECTRICAL CONNECTION DETAIL	WELDED SPLICE FOR TUBE	
	NL	200902-4-18	A	ELECTRICAL CONNECTION DETAIL	BUS SUPPORT FIXED & SLIP FITTING FOR ALUMINUM TUBE	
Y	NL	200902-4-19A	F	ELECTRICAL CONNECTION DETAIL	STRAIN BUS SUSPENSION INSULATOR ASSEMBLY	Updated Material
Y	NL	200902-4-19B	F	ELECTRICAL CONNECTION DETAIL	STRAIN BUS SUSPENSION INSULATOR ASSEMBLY	Updated Material
Y	NL	200902-4-19C	F	ELECTRICAL CONNECTION DETAIL	BUNDLED STRAIN BUS SUSPENSION INSULATOR ASSEMBLY	Updated Material
Y	NL	200902-4-19D	F	ELECTRICAL CONNECTION DETAIL	DOUBLE STRAIN BUS SUSPENSION INSULATOR ASSEMBLY	New Detail
	NL	200902-4-2	B	ELECTRICAL CONNECTION DETAIL	TERMINAL LUG & SWITCH DRILLING FOR ALUMINUM ANGLE AND BAR	
	NL	200902-4-20	A	ELECTRICAL CONNECTION DETAIL	SWITCH TO BUS CONNECTION - BUS SUPPORT IS PART OF SWITCH STAND	
	NL	200902-4-21	A	ELECTRICAL CONNECTION DETAIL	DISTRIBUTION OVERHEAD TERMINATIONS AT SUBSTATION	
	NL	200902-4-22	A	ELECTRICAL CONNECTION DETAIL	LINE TERMINATIONS FOR 34.5KV & 69KV	
	NL	200902-4-23	B	ELECTRICAL CONNECTION DETAIL	LINE TERMINATION FOR 115KV TO 230KV WITH NO LINE TRAP	
	NL	200902-4-24	A	ELECTRICAL CONNECTION DETAIL	LINE TERMINATION FOR 115KV TO 230KV - DOWN TO EQUIPMENT	
	NL	200902-4-25	B	ELECTRICAL CONNECTION DETAIL	WAVE TRAP CONNECTION TO TRANSMISSION LINE	
	NL	200902-4-26	A	ELECTRICAL CONNECTION DETAIL	SHIELD WIRE ATTACHMENT	
	NL	200902-4-27	A	ELECTRICAL CONNECTION DETAIL	345KV TRIANGULAR BUS SUPPORT	
	NL	200902-4-3	A	ELECTRICAL CONNECTION DETAIL	PROVISION FOR HOT LINE CLAMP	
	NL	200902-4-4	B	ELECTRICAL CONNECTION DETAIL	ALUMINUM ANGLE SPLICE	
	NL	200902-4-5	B	ELECTRICAL CONNECTION DETAIL	ANGLE BUS EXPANSION JOINT	
	NL	200902-4-6	A	ELECTRICAL CONNECTION DETAIL	ALUMINUM ANGLE TO SWITCH 90 DEGREE CONNECTION - 900 AMPS MAX	
	NL	200902-4-7	A	ELECTRICAL CONNECTION DETAIL	ALUMINUM ANGLE BUS TO SWITCH 90 DEGREE CONN. - 1800 AMPS MAX.	
	NL	200902-4-8	A	ELECTRICAL CONNECTION DETAIL	ALUMINUM ANGLE TO SWITCH - 1800 AMPS MAX	
	NL	200902-4-9	A	ELECTRICAL CONNECTION DETAIL	ALUMINUM ANGLE TO ALUMINUM ANGLE 90 DEGREE CONN. - 1800AMP MAX	
	NL	200902-5-1	A	WILDLIFE PROTECTION DETAIL	TRANSFORMER BUSHINGS - 35KV AND BELOW	
	NL	200902-5-2	A	WILDLIFE PROTECTION DETAIL	SURGE ARRESTERS - 35KV AND BELOW	
	NL	200902-5-3	A	WILDLIFE PROTECTION DETAIL	CIRCUIT BREAKERS OR RECLOSERS - 35KV AND BELOW	
	NL	200902-5-4	A	WILDLIFE PROTECTION DETAIL	STATION AUX AND POT TRANSFORMERS - 35KV AND BELOW	
	NL	200902-5-5	A	WILDLIFE PROTECTION DETAIL	REGULATORS - 35KV AND BELOW	
	NL	200902-5-3	A	WILDLIFE PROTECTION DETAIL	CIRCUIT BREAKERS OR RECLOSERS - 35KV AND BELOW	
	NL	200902-5-4	A	WILDLIFE PROTECTION DETAIL	STATION AUX AND POT TRANSFORMERS - 35KV AND BELOW	
	NL	200902-5-5	A	WILDLIFE PROTECTION DETAIL	REGULATORS - 35KV AND BELOW	

Preface

P.1. Scope and Purpose

The purpose of the criteria is to provide a general instruction for the civil/structural design for Xcel Energy substations. The criteria apply to the structures that support electrical equipment and rigid bus and other conductors, foundations and all civil work within Xcel Energy substations.

P.2. Responsibilities

The Substation Engineering and Design department of Xcel Energy and all consulting firms involved in the substation civil/structural design shall follow these criteria for the design and analysis of new and expanded electrical substation facilities. Exceptions to the following criterion need to be requested in writing to the sponsoring engineer and approved by the director of engineering.

Users of the criteria shall notify the Xcel Energy Standards Department of errors and other opportunities for improvements.

P.3. Work Flow

P.3.1 Approval

The Xcel Energy Standards Council Sponsors has approved this document.

Date	Name
7/12/2017	Philpott, Lester W
7/14/2017	Harvey, Brian D
5/25/2017	Gragg, Jim
5/16/2017	Hui, Ming-Wa
5/12/2017	Jensen, Mike C
5/15/2017	Foster, Perry D
5/12/2017	Gutzmann, Mark G
5/26/2017	Munsell, Kenny
7/26/2017	Newton, Jeremy H

P.3.2 Creation

The following committee updated this document.

Name	Title
Troy Livgard	Engineer, NSP
Mark Lavanish	Engineer, PSCo
Don Simpson	Engineer, PSCo
Kyle Vriesman	Engineer, Standards

P.3.3 Version History

The personnel listed above have approved the following changes.

Date	Version Number	Change
02/21/2003	TSD-4	Initial Version
03/31/2014	1.0	Release
1/22/2015	3.0	Added Sections 4.3-4.6 to address grading
2/18/2015	4.0	Addressed comments from Open Review and finalized
8/18/2015	4.1	Section 2.2.5 redirected to new standard XEL-STD-Structural Design of Tubular Bus
8/18/2015	5.0	Released
1/18/2017	6.2	Updated Grading Design Criteria - Open Review
2/8/2017	6.3	Updated to current template
4/17/17	6.4	Updated Grading Design Criteria
5/12/2017	6.5	Out for Council Approval
7/26/2017	7.0	Published

Table of Contents

1 Overview

1.1. Philosophy

The purpose of the criteria is to provide a general instruction for the civil/structural design for Xcel Energy substations. The criteria apply to the structures that support electrical equipment and rigid bus and other conductors, foundations and all civil work within Xcel Energy substations.

This document addresses four main sections. Section 2 addresses structural performance criteria, including load cases, load factors and combinations, deflection criteria, structure materials, structure connections, and rigid bus design considerations. Section 3 presents requirements for foundations, including design load, factor of safety, bearing capacity, frost heave protection, settlement, shallow foundation, drilled pier foundations. Section 4 is civil performance criteria, including substation treatment, traffic, storm water drainage, oil spill containment, and fencing. Section 5 addresses the geotechnical performance criteria, including soil identification, sampling and testing, soil parameters and design values, water conditions, back fill material qualification, sub-grade treatment, and foundation recommendations. The fifth section presents the requirements for survey, boundary survey, layout standard and topographic survey. The last section presents the requirement for Electrical Equipment Enclosure (EEE)/Switchgear Enclosure performance criteria.

Any engineer wishing to deviate from this standard must fill out an exception request form and submit it for approval. The exception request form can be found in ProjectWise here XEL-FRM-Standards Exception Request

1.2. References

The following codes, standards and guides shall govern the civil and structural activities associated with substation design and are considered a part of this criteria document. All codes and standards shall be applied as amended to date unless otherwise indicated.

- AASHTO GDHS A Policy on Geometric Design of Highways and Streets
- AASHTO Guide for Design of Pavement Structures, 1993, Chapter 4, Aggregate-Surfaced Road provisions
- ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass concrete
- ACI 301 Specifications for Structural Concrete for Buildings
- ACI 305 Guide to Hot Weather Concreting
- ACI 306 Guide to Cold Weather Concreting
- ACI 318 Building Code Requirements for Structural Concrete and Commentary

- ACI 336.3R Design and Construction of Drilled Piers
- AISC 325 Steel Construction Manual
- AISC 341 Detailing for Steel Construction
- AISC 360 Specifications for Structural Steel for Buildings
- ANSI C2 National Electric Safety Code
- ASCE Manual of Engineering Practice No. 17 -Timber piles and Construction Timbers
- ASCE 113 Substation Structure Design Guide
- ASCE/SEI 7-05 Minimum Design Loads for Buildings and Other Structures
- ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
- ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- ASTM A36 Standard Specification for Carbon Structural Steel
- ASTM A500 Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
- ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
- ASTM A572 Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
- ASTM A588 Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
- ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- ASTM A775 Standard Specification for Epoxy-Coated Steel Reinforcing Bars
- ASTM A871 Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance
- ASTM A992 Standard Specification for Structural Steel Shapes
- ASTM D1586 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

- ASTM D1586 Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
- ASTM D2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
- ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
- ASTM D2488 Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
- ASTM D4546 Standard Test Methods for One-Dimensional Swell or Collapse of Cohesive Soils
- ASTM D698 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft3 (600 kN-m/m3))
- ASTM F1554 Standard Specification for Anchor Bolts
- ASTM F1852 Standard Specification for "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- ASTM F567 Standard Practice for Installation of Chain-Link Fence
- AWS D1.1 Structural Welding Code-Steel
- AWS D1.2 Structure Welding Code-Aluminum
- IEEE 605 IEEE Guide for Bus Design in Air Insulated Substations
- IEEE 693 IEEE Recommended Practices for Seismic Design of Substations
- IEEE 979 IEEE Guide for Substation Fire Protection
- IEEE 980 IEEE Guide for Containment and Control of Oil Spills In Substations
- WLG 2445 Wind Load Guide for the Selection of Line Post Spacing

2 Structural Design Criteria

2.1. Design Requirements

2.1.1. Overview

Structure applications include termination structures, switch stands, bus and equipment supports, rigid frame box structures and shield poles. Engineers shall design substation structures and their components with the strength and rigidity to adequately resist maximum stresses resulting from combination of loads. Specific performance criteria for structure types are described below.

Substation structure design shall be per ASCE 113, with specific requirements below.

2.1.2. Design Loads

In addition to dead and equipment loads, design loads must consider normal and extreme climatic conditions to assure the operational performance of the substation while in service. Design loads for substation structures shall include the following:

- NESC Heavy
  NESC Heavy loading providing for a 4 psf horizontal wind pressure with 0.5" radial thickness of ice at 0°F on wire-loaded structures, such as dead end structures and wire-loaded box structures. NESC HEAVY load does not apply to other substation structures. The wind load shall be determined using Equation 1. The loading conditions which must be considered in the design of substation structures and supports must require wind load applications longitudinal, perpendicular and at 45-degrees to the line or bus

Extreme Wind
Extreme wind loading of 3-second gust wind speed of 90 mph at 60°F shall be applied on structures, equipment, and conductors. The 90 mph basic wind speed is applicable to all Xcel Energy service areas (CO, MI, MN, NM, ND, SD, TX, WI, and OK) except where the local conditions are higher. A check with the local authority is required for special wind areas, which exist in the Front Range and mountains of Colorado and Southwest Minnesota. The wind load shall be determined using Equation 2.
The gust response factor, G_{SRF}, for equipment support structures is based on ASCE 113 for rigid structure. Rigid structures not supporting wire for wind response are defined as structures with a fundamental frequency of 1HZ or greater. For these structures, the gust response factor, G_{SRF} can be assumed as a constant value of 0.85.
The loading conditions which must be considered in the design of substation structures and

$$W_{NESC} = 4 \cdot C_f \cdot A$$

Where:
W_{NESC}: NESC Heavy wind load, lbs.
A: projected wind surface area normal to the direction of wind, ft^2.
C_f: Force Coefficient listed in Table 1.

Equation 1: Wind load for NESC Heavy load case.

Member Shape	Force Coefficient, C_f
Circular (including rigid and flexible bus)	1.0
Hexadecagonal	1.0
Dodecagonal	1.0
Octagonal	1.4
Hexagonal	1.4
W, C, and L Shapes	1.6
Rectangle and Square Shapes	2.0

Table 1: Force coefficient based on member shape

supports must require wind load applications longitudinal, perpendicular and at 45-degrees to the line or bus

The following are the URL links to wind maps in the front range and mountains of Colorado:

PSC-STD-WIND SPEED-FRONT RANGE-STATE

PSC-STD-WIND SPEED FRONT RANGE-METRO

- Combined Ice and Wind Load

  Combined ice and wind load shall be applied to structures, equipment, and conductors. Refer to ASCE 7-05 maps for ice thickness and wind speed. The loading conditions which must be considered in the design of substation structures and supports must require wind load applications longitudinal, perpendicular and at 45-degrees to the line or bus

- Line Loads

  Line loads, including conductor and shield wire, shall be based on standard or typical conductor sizes determined by the substation electrical criteria. Tensions and sags at various temperatures and conditions will be determined and selected jointly by the electrical and structural areas to assure cost effective choices of structures. Engineers shall consider tensions for wind and ice load combinations and broken conductor criteria in the design loads. For strain-bus loading, −30°F is recommended for extreme cold temperature.

$$W = Q \cdot k_z \cdot V^2 \cdot I_{FW} \cdot G_{RF} \cdot C_f \cdot A$$

Where
W: wind force in the direction of wind (lb)
Q: air density factor, default value=0.00256
k_z: terrain exposure coefficient, Exposure C, refer to ASCE 113
V: basic wind speed, 3-second gust wind speed (mile/hour), taking 90 mile/hour.
I_{FW}: importance factor for basic wind speed, taking 1.00
G_{RF}: gust response factor (for structure G_{SRF} and wire G_{WRF}), based on Exposure C.
C_f: Force Coefficient, from **Table 1**.

Equation 2: Wind load for Extreme Wind load case.

- Equipment Loads

  The dynamic load supplied by the manufacturer shall be applied for the supported equipment structure.

- Dead Loads

  Gravity loads from bus, insulators, equipment, and structures shall be applied.

- Short Circuit Loads

  The engineer shall consider short circuit forces from fault currents. The electrical substation engineer must provide the ultimate electrical current values for the determination of forces, which occur at the top of the insulator and must be accounted for in the design of the insulator support system. Short circuit forces shall be calculated using Equation 3.

- Seismic Loads

  Seismic loading is an environmental loading condition that – based on the specific site and substation structure characteristics – may govern design in certain regions of Colorado. Seismic design should be considered in areas where the 0.2 second spectral response acceleration is 30% g or higher, the loads shall be developed according to ASCE 113.

- Platform Loads

$$F_{SC} = \frac{5.4 \cdot \Gamma \cdot \left(D_f \cdot \sqrt{2} \cdot I_{SC}\right)^2}{10^7 \cdot D}$$

Where:
F_{sc}: Short circuit load on bus, lb/ft
I_{sc}: Fault current, amps
D: Bus phase spacing, inches
D_f: Decrement factor, 1.6
Γ: constant based on fault type, 1.0

Equation 3: Short Circuit Equation: The horizontal force on the bus due to short circuit force (IEEE Std 605-1998; the existence of IEEE 605-2008 is acknowledged but deprecated).

Load Cases		USD Load Factors and Combinations
Case 1	NESC Heavy	$1.5 \cdot D + 1.5 \cdot I_{NESC} + 1.65 \cdot T_{NESC} + 2.5 \cdot W_{NESC}$
Case 2	Extreme Wind (no ice)	$1.1 \cdot D + 1.2 \cdot W + 0.75 \cdot SC + 1.1 \cdot T_W$
Case 3	Combined Ice + Wind load	$1.1 \cdot D + 1.2 \cdot I_W + 1.2 \cdot W_I + 0.75 \cdot SC + 1.1 \cdot T_W$
Case 4	Short circuit	$1.1 \cdot D + 1.0 \cdot SC + 1.1 \cdot T_W$
Case 5	Earthquake	$1.1 \cdot D + 1.25 \cdot E$

Where
D: Dead load Use 1.0 for D if this causes higher stresses.
I_{NESC}: NESC 0.5" radial ice
T_{NESC}: NESC Line load
W_{NESC}: NESC wind load
I_W: Ice load in combination with wind
W: Wind load
W_I: Wind load in combination with ice.
SC: Short-circuit load
T_W: Wire tension for the appropriate wind and temperature condition
E: Earthquake load

Table 2: Load factors for USD. For allowable stress design, the load factor should equal 1.0.

Stairways and platforms provided as part of any substation structure shall be designed for a live load of 100 pounds per square foot.

2.1.3. Load Factors and Combinations

Allowable stress design (ASD) is a method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads do not exceed specified allowable stress. ASD is also called working stress design.

Ultimate strength design (USD) is a method of proportioning structural members such that the computed forces produced in the members by the factored loads do not exceed the member design strength. USD is also called load and resistance factor design or LRFD.

USD and ASD are both acceptable for design of substation structures.

2.2. Design Requirements

2.2.1. Deflection

Structures are classified for by the sensitivity of supported equipment. Table 3 summarizes the structure classes and associated deflection limits.

- Class A Structures

  Support equipment with mechanical mechanisms where structure deflection could impair or prevent proper operation. Examples are group-operated switches, vertical reach switches, ground switches, circuit-breaker supports, and circuit-interrupting devices.

Member Type	Deflection Direction	Class A	Class B	Class C
Horizontal	Vertical	1/300	1/200	1/200
Horizontal	Horizontal	1/200	1/100	1/100
Vertical	Horizontal	1/200	1/150	1/50

Table 3: Maximum Structure Deflection as a Ratio of Span Length

Switches mounted on dead end structures with no rigid bus connection are classified as Class B.

- Class B Structures
  Support equipment without mechanical mechanisms, but where excessive deflection could result in compromised phase-to-phase or phase-to-ground clearances or unpredicted stresses in equipment, fittings, or bus conductors. Examples are support structures for rigid bus conductors, surge arresters, metering devices (such as CTs, PTs, and CCVTs), station power transformers, hook-stick switches or fuses, and wave traps.
- Class C Structures
  Support equipment relatively insensitive to deflection or are stand-alone structures that do not support any equipment. Examples are structures for flexible (stranded conductor) buses, masts for lightning shielding, and dead end structures for incoming transmissions lines. Deflection limitations for these structures are intended to limit P-delta stress, wind-induced vibrations, and visual impact.

Table 4 lists load cases for deflection limitations. Deflection shall be determined for NESC heavy and extreme wind, combined ice & wind load with load factor 1.0. Loads resulting from bus short circuits and earthquakes should not be considered in deflection analysis.

2.2.2. Tall Lightly Loaded Structures

Wind induced motion and vibration on lightly loaded tall structures must be controlled to assure performance and prevent fatigue of members, bus or accessories.

Dampening devices must be provided on shield poles or other lightly loaded structures, which are typically subject to vibration. Suspended dampening chains shall be provided inside the tubular columns as a minimum.

Deflection Cases		Load Factor and Combinations
Case A	NESC Heavy	$D + I_{NESC} + T_{NESC} + W_{NESC}$
Case B	Extreme Wind (no ice)	$D + W + T_W$
Case C	Combined Ice + Wind load	$D + I_W + W_I + T_W$

Table 4: Load cases for Deflection. Parameter definitions same as Table 2.

	Shape/Section	ASTM Standard	F_y (ksi)
Rolled Steel	W	A992	50
	M, S, C, MC	A36	36
	L	A36	36
	Plate	A36	36
		A572 Grade 50	50
	HSS	A500 Grade B	46
	Pipe	A53 Grade B	35
Tubular Steel	Tapered Tubular	A36	36
		A500, Grade B	46
		A572, Grade 50	50
		A588	50

Table 5: Preferred material grades for rolled and tubular products.

2.2.3. Steel Frame

The box structure designs shall be designed with moment resisting connections to allow for the elimination of all bracing in order to provide flexibility for future additions.

2.2.4. Bolted Connections

Bolted connections shall be specified for field connections using A325 high strength bolts. Bolt patterns and bearing type will follow AISC design and details. Use of welded connections in the field is discouraged.

2.2.5. Rigid Bus

See XEL-STD-Structural Design of Tubular Bus.pdf

2.3. Materials

2.3.1. Steel

Structural steel shapes and plates used for steel frames, materials for tubular steel plates for shafts, base plates, and accessory plates shall conform to Table 5.

All high strength steel structures supporting high wire tension shall meet or exceed minimum Charpy Impact values of 15 ft lbs at -20°F. Documentation of representative Charpy Impact tests shall be received for all high strength steel plate, not for rolled steel.

The flatness of equipment mounting surfaces and flange plates of companion structural members must be maintained to assure correct fit-up and closure of joints and structural

Fastener Type	ASTM Standard
High-Strength Bolts	A325,
Nuts	A563 (Grade DH3) A194 2H
Washers	F436
Threaded Rods	A36
Anchor Bolts	A 307 Grade C F1554 Grade 36,55 and 105

Table 6: Preferred material for fasteners.

integrity throughout the service life of the structures and supports. Tolerance criteria for substation structures shall meet the minimum requirements of ASTM A6.

The preferred protective coating for substation structures is hot-dipped galvanizing per ASTM A123 and ASTM A153. Galvanizing has proven to be highly reliable and has eliminated the need for coating system maintenance in energized substations.

Review of new coating technologies that are also environmentally acceptable should be periodically performed to assure the use of the most reliable and economic choice of protective coating systems.

When paint or other finish is required for permitting, it shall be applied over galvanizing in accordance with an approved coating system intended for use over galvanized surfaces.

2.3.2. Fasteners

Fasteners shall conform to Table 6.

Documentation of representative Charpy Impact tests shall be received for all anchor bolts. All steel shall meet or exceed minimum Charpy Impact values of 15 ft lbs at -20°F.

2.3.3. Wood

Steel is the preferred material for the design of substation structures due to its dependability and performance. Wood structures, although cheaper to install, cannot guarantee the structural performance stated in this document. Wood structures can be used for emergency or temporary use of no more than one year or for retrofit of an existing wood structure substation. NESC criteria shall govern in the design of wood structures.

Wood structures and poles should be designed and constructed in accordance with recommendations in ASCE 113 using either ultimate strength or allowable stress design.

3 Foundations Design Criteria

3.1. Foundation Applications and Equipment Performance

3.1.1. Overview

Performance of foundations for substations, are driven by requirements of the electrical equipment being supported. The types of equipment having specific foundation needs are stated below.

3.1.2. Foundation Reveal

Reveal is defined as the amount of concrete that rises above the surfacing rock. Top of Concrete (TOC) must be coordinated with pad grading and bus height design. Steps in TOC should not be less than 6" and should be located at flexible bus connections whenever possible. If the step is more than 12" coordination with the electrical engineer is required to ensure minimum electrical clearances are met.

Reveal for bus support foundations (not including switches) should be a maximum of 2'-0" and a minimum of 4".

Reveal for equipment foundations (including switches) should be a maximum of 1'-6" and a minimum of 4".

3.1.3. Transformers

Transformer performance requires the oil in the transformer to be maintained in a level position. The slab foundation shall meet settlement criteria for long-term differential and total vertical settlement. Design for the eccentricity of the center of gravity, rolling and jacking conditions.

3.1.4. Breakers

Breakers may require dynamic loadings and wind to be considered depending on the type of breaker. Oil type breakers may require mass ratios of two or more to resist dynamic uplift forces. Equipment dynamic forces provided by manufacturer and wind/seismic condition specified here must be considered in foundation design.

3.1.5. Capacitors

Capacitor (large shunt capacitor) performance requires banks to be supported on insulators located at a number of points. Each point of support may not move differentially with respect to other points of support. The foundation must be configured to incorporate all points of support on a rigid foundation element. Capacitor banks typically have high profiles and can accumulate significant wind loads. The design shall consider wind loadings as defined in this document. Series capacitors should be addressed separately.

3.1.6. Reactors

Reactor performance requires insulating the foundation from the effects of magnetic fields. The support steel or reinforcing steel must be isolated from the reactor. This requires insulator supports of appropriate height to isolate the magnetic field with an arrangement of insulators supported by a rigid foundation.

The foundation must provide a rigid configuration to prevent any differential displacement between supports. Movement between points of reactor supports will cause breakage of the insulators supporting the reactor. Where the economics of using larger insulators are not feasible, reactors may require a non-magnetic frame, such as aluminum between the reactor and foundation to provide magnetic field isolation.

Design of the surrounding steel structure or other magnetic materials must provide adequate clearance from the reactor's magnetic field.

3.1.7. Switches

Switches in single or group operating configurations require a rigid mounting surface for the entire switch assembly to assure operating performance and minimize the long-term operating and maintenance problems of the device. This requires support steel and foundations to be designed to perform to strict limits of differential movement where rigid bus ties into switches. The performance of bus and switch accessories such as expansion joints is critical to the performance of the foundation with limits on horizontal and vertical displacements.

3.2. Load Requirements

3.2.1. Design Loads

- Live Loads
  Live loads for substation foundations must include the loading discussed in the structural criteria portion of this document and the additional loads below which are specific to equipment:
- Dead Loads
  Dead Loads shall be applied and must include weight of equipment, insulators, conductor accessories, oil (when applicable), and the weight of foundation and supporting steel.
- Construction Loads
  Construction loads such as jacking and rolling must be considered for the installation and removal of transformers on slab foundations, cable pulling and thermal loads for underground termination structures

3.2.2. Factor of Safety

Foundation bearing capacity and stability shall be checked with all load factors equal to 1.0 (working load). The minimum factors of safety (FS), the ratio of the resisting to applied forces, shall be as Table 7 or as recommended by geotechnical report.

	Factor of Safety
Shallow Foundations	
Bearing Capacity	3.0
Stability (Overturning and Sliding)	1.5
Drilled Pier Foundations	2.0
Slope Stability	1.5
Retaining Wall	
Bearing Capacity	2.0
Stability (Overturning and Sliding):	1.5

Table 7: Factor safety for foundation design.

3.2.3. Bearing Capacity

Minimum Bearing Capacity at the bottom elevation of any type of substation foundation shall be as specified by the geotechnical report. Sub-grades of a lower value must be improved to a value equal to or exceeding the report or a deep foundation type must be considered.

3.3. Design Requirements

3.3.1. Frost Depth/Heave/ Swell

Substation structure vertical loads vary from very light to moderate in magnitude and foundations may be susceptible to significant differential vertical movements where significant frost is present. Specific study of frost susceptible soils shall be provided when present in the frost zone. The minimum frost depth for design consideration shall be governed by the local code.

The presence of groundwater in the frost zone creates potential for excessive frost heave caused by ice lensing. Sub-drains may be provided where it is not economical to cut to the full frost depth and fill with imported and qualified fill.

Where swell is significant, sensitive structures such as masonry buildings, floor slabs etc. shall be designed in accordance with recommendations in the Geotechnical Report.

3.3.2. Settlement

The total settlement of any single foundation shall be limited to 1.0 inch. This limit is established to prevent tilting of slab foundations supporting transformers, switchgear, control houses or other equipment, which may affect operating performance. This limit applies to supports to prevent forces from being imposed on rigid bus and connections within the overall bus arrangement of substations.

Differential settlement across the diagonal of any shallow slab or mat foundation supporting substation equipment shall be limited to ½”. The structural engineer shall collaborate with the geotechnical engineer to insure the subsoil preparation, allowable bearing capacity and the required eccentricity of the equipment loads will not cause the foundation to exceed this criterion.

3.3.3. Durability

Durability of the slab must be assured to reduce the risk of slab deterioration, which could result in taking the transformer or the electrical equipment out of service during its intended service life. Surface flatness, distributed bearing pressure of equipment, and elimination of water on finished surfaces enhance durability of the concrete and enhance service life.

Strength and air content of concrete must be provided to assure adequate service life. Repair of concrete is difficult with equipment in service. Outages and removal of the equipment are usually not acceptable from an operating or cost perspective.

Structural design of concrete foundations must be in accordance with ACI code.

3.4. Foundation Types

3.4.1. Shallow Slab Foundations

Minimum edge distance of equipment base to edge of slab shall be 12 inches for heavy equipment and 9 inches for light equipment. These minimums are provided to minimize soil pressure and allow for future replacement of equipment, which may vary in size and loading.

Sub-grade preparation for slabs should be performed when needed to ensure uniformity and stability for the foundation. The site grading design for new substations should consider sub-grade preparation for slabs and other foundations to avoid duplication.

Sites with cohesive materials in the sub-grade and requiring sub-grade preparation will require cohesionless backfill, or granular material.

3.4.2. Drilled Pier Foundations

Drilled piers are used over a wide range of substation foundation applications and are considered the most flexible and an economical choice for support of light equipment stands or dead end structures. This is due to the minimal forming and absence of backfilling in drilled pier construction. Piers are the most efficient foundation for supporting lateral loads.

The design of drilled piers shall disregard the top layer of soil to account for freeze thaw, erosion, lack of compaction or disturbance. The depth of the ignored layer shall be as recommended in the geotechnical report, but shall in no case be less than 1’-0”.

Drilled pier foundation shall be designed to conform to the requirements of ACI 336.3R-Design and Construction of Drilled Piers.

	Vertical and Horizontal Deflection	Rotation
Switch support structure foundation	0.25 inch	0.5°
All other support structure foundations	0.50 inch	0.5°

Table 8: Deflection limits for drilled pier foundations.

In addition to satisfying strength and stability requirements, the deflection and rotation of the drilled pier foundations shall be limited to those listed in Table 8 under working loads (unfactored loads).

3.4.3. Formed Foundations / Walls

Spread footings, pile caps, grade beams, mat foundations, walls and other cast in place concrete construction may be used as foundation solutions in substations. Standards for minimum dimensions, concrete and reinforcement, finish and durability will be per ACI.

Shallow spread footing foundations are utilized where site specific needs do not allow for drilled piers as standard solutions. Conditions, which result in the consideration of cast-in-place footings, include outage restraints, shallow bedrock, difficult drilling conditions for deep piers, equipment access, existing foundation types at a site or special soil conditions.

ACI 318 shall govern the design and ACI 301 the construction of reinforced concrete foundations and walls.

Retaining or firewalls constructed of reinforced concrete may be required by space or permit requirements. The International Building Code shall govern the design of walls except where electrical equipment is involved, in which case the requirements for design loads and conditions stated in the structures portion of this document will apply. Cast in place concrete retaining walls should be compared with sheet pile retaining walls, masonry, precast walls, nailed earth, mechanically stabilized earth (MSE), concrete cribbing, etc, for determining the most economical solution.

3.4.4. Piling Foundations

Piling foundations may be necessary where poor soils require a deep foundation. This is necessary when shallow foundations are not suitable, or practical, or when the constructability of drilled piers are not favorable.

Piles are primarily used to control settlement on marginal soil sites. Pile sizes are selected based on required cross sectional area, depth of marginal soil and the embedment length into the good soil required to support the loads generated by the above ground structure and equipment. Piles must be designed for bearing, lateral and uplift loads as, determined by structure reactions and pile patterns.

Piling foundations must not exceed the minimum uplift and bearing capacities recommended by the geotechnical engineer. Negative skin friction (downdrag forces) may be significant and must be considered in pile designs.

Typical steel pile sections include pipe pile, H-pile and concrete filled pipe pile. Pipe piles are the standard for most applications in substations. H-piles with heavy compression and uplift loads are used in deep end-bearing applications where structural considerations control selection of the pile. Driving in clay soils where friction forces for displacement piles are excessive may require H-pile as a preferred pile type.

3.4.5. Timber Mat Foundations

Treated Timber foundations for transformers and other equipment may be used for temporary storage or operation. Performance requirements for the equipment or the foundation cannot be met or guaranteed for an extended period of time. Drawings shall note this performance limitation when treated timber foundations are specified.

4 Civil Design Criteria

For definitions of grading terminology, please refer to XEL-PRO-SUB-DESIGN-Contour & Grading Layout - Drawing Function & Instructions.doc

4.1. Geometric Design for Traffic

The substation access road/driveway and circulation areas inside the substation shall, at a minimum, meet the driveway turning templates shown in Figure 1 which are based on the AASHTO Intermediate Semi-Trailer WB-67 design vehicle. Vehicles larger than WB-67 are usually required for equipment such as transformers greater than 100MVA, mobile substations, pre-manfactured medium and large EEE's, or metal clad switchgear. In these cases the designer should obtain specficications from the equipment hauler fore the expected vehicle(s). Specialty software such as Auto Turn should be used to ensure adequate access to and from the large equipment position. Coordinate with the physical engineer to determine the need for oversize vehicles.

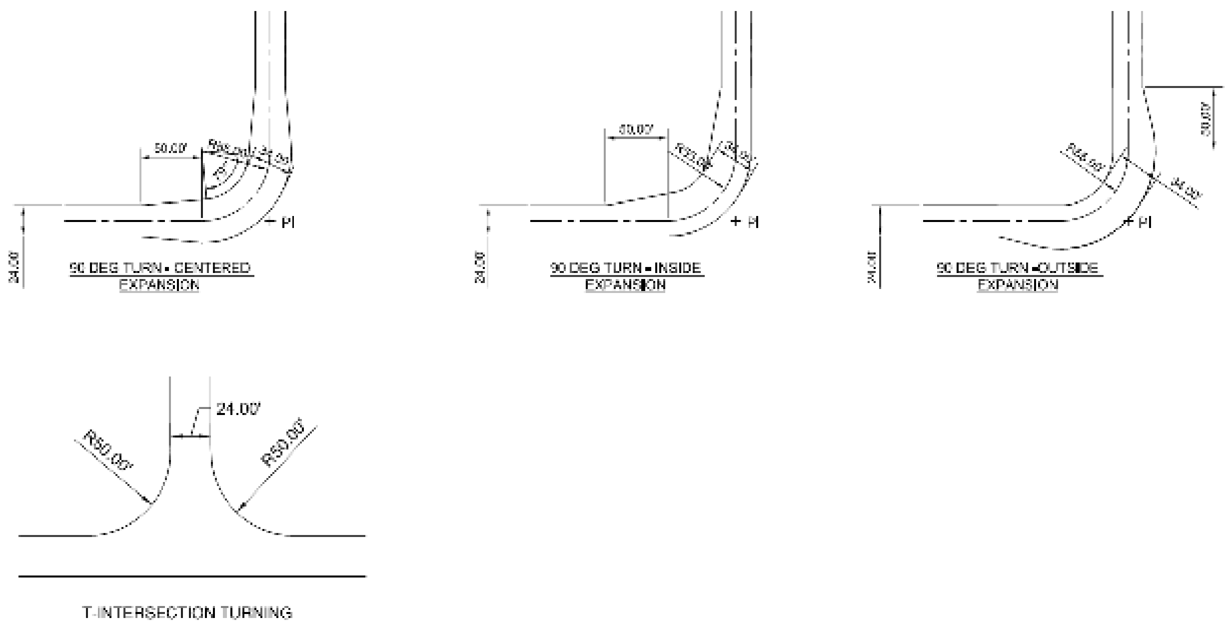


Figure 1

4.1.1. Access Road Geometric Design Criteria

Substation access roads shall conform to the following geometric design criteria.

Cross Section:

- 24' aggregate base width
- 3% cross slope for road base (standard design)
- 2% cross slope for asphalt/concrete (only if required by jurisdiction)
- Aggregate Road base thickness to match substation pad design

- Ditches – 1.5' minimum depth measured from edge of roadway
- Ditch side slope - 3:1 maximum – 4:1 (or flatter) preferred

Horizontal Alignment:

- Minimum centerline radius - 55'
- Roadway widening for small curve radius:
  - 55' Radius = 4'
  - 100' radius = 0'
  - Linear interpolate widening for curves between 55' and 100'

Vertical Alignment:

- Maximum grade = 6%. Up to 8% (with approval of an exception request) for straight alignments only
- Minimum grade = 0.5%
- Grade breaks are allowed up to a maximum algebraic difference of 4% without a vertical curve design
- For vertical curves: minimum K factor at crest = 20, minimum K factor at sag = 30

4.2. Pad Grading

The substation pad is the area inside and outside the fence that has, at a minimum, been improved with a layer of base material as designed per Section 4.3 of this document. Substation pad grading design is complex and based on numerous factors, including, but not limited to: geotechnical conditions, existing topography, earthwork balance, erosion prevention, site drainage, vehicle access and adjacent properties.

- Pad size - The pad should be constructed to a full depth 8' outside the fence when possible. This is the preferred size and allows for installation of the fence and ground grid as well as ease of access, once construction is complete, for repairs and vegetation management. For ground grid design and personnel safety in the event of an electrical fault, the pad shall not be less than 5' outside the fence unless approved by the standard exception request. There are existing sites with space constraints that necessitate less than 5' outside the fence. These situations need to be reviewed and coordinated with the engineer responsible for the substation grounding design and all options explored prior to making this deviation.

- Pad Slope - Coordination with the foundation and physical engineer is critical when designing the slope of the pad. Pads that are too flat may not drain properly and result in soft areas or standing water, pads that are too steep may cause erosion problems or require stepping of top of foundations. If this can be minimized or eliminated, it would be preferred. Additional guidance on foundation reveal can be found in section 3.1.2 of this document.

  - Preferred pad slope should be between 1.0% and 1.5%. Pad slope shall be no greater than 3.0% or less than 0.5% unless approved via the standard exception process.

- Special attention is required on pad side slopes and other drainage features to prevent erosion. When large pads are needed the grading engineer shall utilize all tools available to collect and direct stormwater in a way that long term maintenance is minimized due to water runoff. Some possible methods are reinforced swales/slopes, seed and mulch, fiber blankets, drain tile (underdrain), curb and gutter systems, drainage pipes, stepping of the pad and bus, etc. If possible, a slope of 6:1 or flatter is recommended to minimize erosion problems, slopes of up to 3:1 can be used if site conditions necessitate.

4.3. Pad Strength Design

Substation pads and associated parking and access roads shall be designed with an aggregate base course layer and, if required, a subbase or stabilized subgrade, to assure the surface will support traffic loads up to 18,000 ESAL without producing rutting under wet conditions.

Factors that need to be considered in designing the pad section to provide the desired surface performance include:

- Traffic Loading – Equivalent Single Axle Load (ESAL)
- Subgrade Strength – Soil Resilient Modulus (M_R) in PSI
- Climate – Region I – VI
- Drainage – Surface and subsurface
- Frost Susceptible Soils
- Swelling Soils

Required thickness of the aggregate base course shall be determined using the AASHTO Guide for Design of Pavement Structures, 1993, Chapter 4, Aggregate-Surfaced Road provisions. Either the Design Chart, Section 4.1.2, or the Design Catalog, Section 4.2.3, method may be used. Table 1 and Exhibit 11.4.2 B&C can be used for the Design Catalog method.

In using either method **all** of the following conditions shall apply:

1. Traffic Loading: Use the Medium Traffic Level. This is based on 30,000 to 60,000 ESAL. The reasons for requiring the Medium Traffic Levels are, when comparing to a typical low volume road design that the catalog is based on; a) design life of the substation pad should be much longer, b) very high axle loads are experienced while moving heavy equipment into substations, and c) substation pad surface drainage is much worse than a crowned roadway.
2. Subgrade Strength: Relative Quality of the Subgrade/Subbase Soil must be at least fair. For poor or very poor soils, imported subbase or improved subgrade by moisture and density treatment is required. See Exhibit 11.4.2.B&C for correlation of AASHTO/ASTM Soil Class to Relative Quality of Subgrade Soil for use in the Catalog method.
3. Climate: Use the appropriate U.S. Climatic Region. Xcel Energy operates in regions III, V and VI. See Exhibit 11.4.2-D
4. Drainage: Flatter slopes and long sheet flow distances will increase the moisture content of the base and subgrade decreasing the support strength. Consider increasing the aggregate base thickness for slopes < 1.0% and sheet flow lengths > 300 feet.
5. Frost Susceptible Soils: Aggregate base course and subbase materials meeting specification requirements may be placed in the frost zone. Common backfill determined to be frost susceptible may only be placed at depths below average frost penetration or on slopes outside the limits of the substation and access road.
6. Swelling Soils: If the average swell of the top 4.0 feet of the subgrade soils is greater than 4%, the Geotechnical Report shall provide a recommendation for subgrade moisture treatment and subgrade stabilization. Swell, % shall be determined at 200 psf surcharge on natural soil from liner samples. Ref.: Metropolitan Government Pavement Engineers Council (MGPEC)-Volume 1- Pavement Design Standards (4/15/11 draft)

TABLE 1 - AGGREGATE SURFACED SUBSTATION DESIGN CATALOG
RECOMMENDED MINUMUM AGGREGATE BASE THICKNESS IN INCHES

Relative Quality of Subgrade/Subbase Soil	Traffic Level	U.S. Climatic Region		
		III	V	VI
Very Good	Medium	11	7	11
Good	Medium	12	9	12
Fair	Medium	12	10	12
Poor	N/A	Not Allowed (See Condition #2 Above)		
Very Poor	N/A	Not Allowed (See Condition #2 Above)		

This table is based on Table 4.10 in AASHTO Guide for Design of Pavement Structures, 1993, Chapter 4, Aggregate-Surfaced Road provisions and may be used to determine the minimum required aggregate base course thickness. In no case shall the aggregate base course be less than 7 inches thick.

Manholes, trench covers, or other substructures shall be designed for a minimum of HS20 loads where subject to substation truck traffic.

Exhibit 11.4.2.B&C - CORRELATION OF AASHTO/ASTM SOIL CLASS TO RELATIVE

Exhibit 11.4.2.B
AASHTO and ASTM Soil Classification

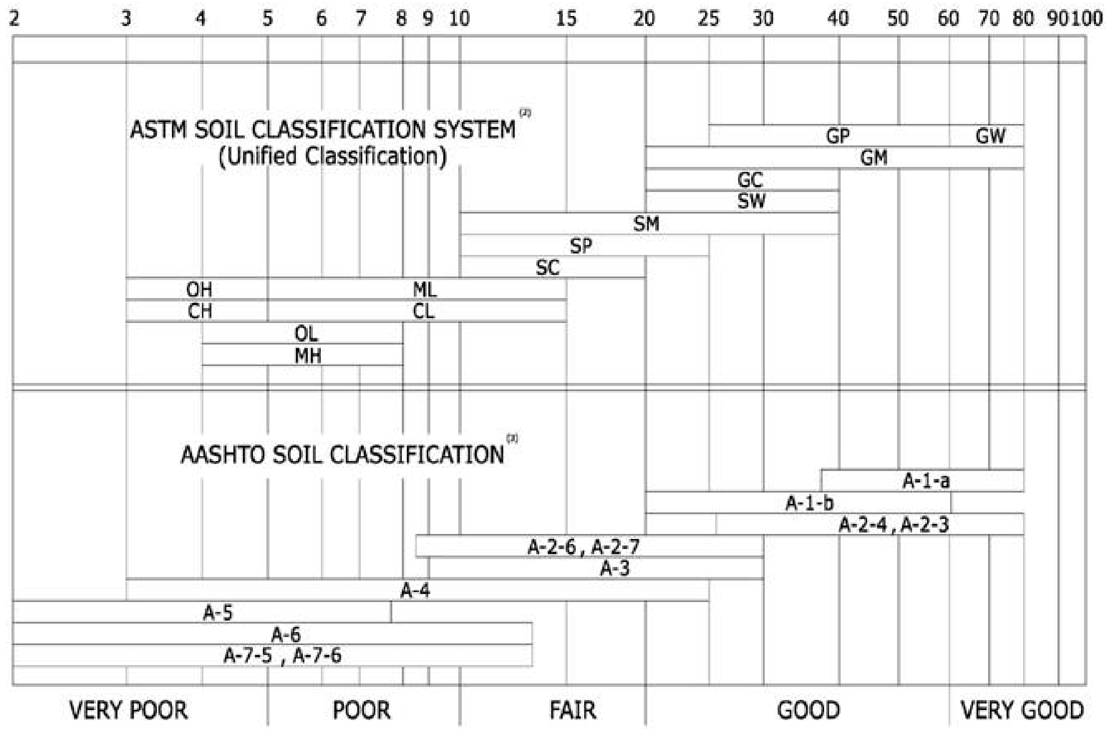


Exhibit 11.4.2.C
Roadbed Soil Strength

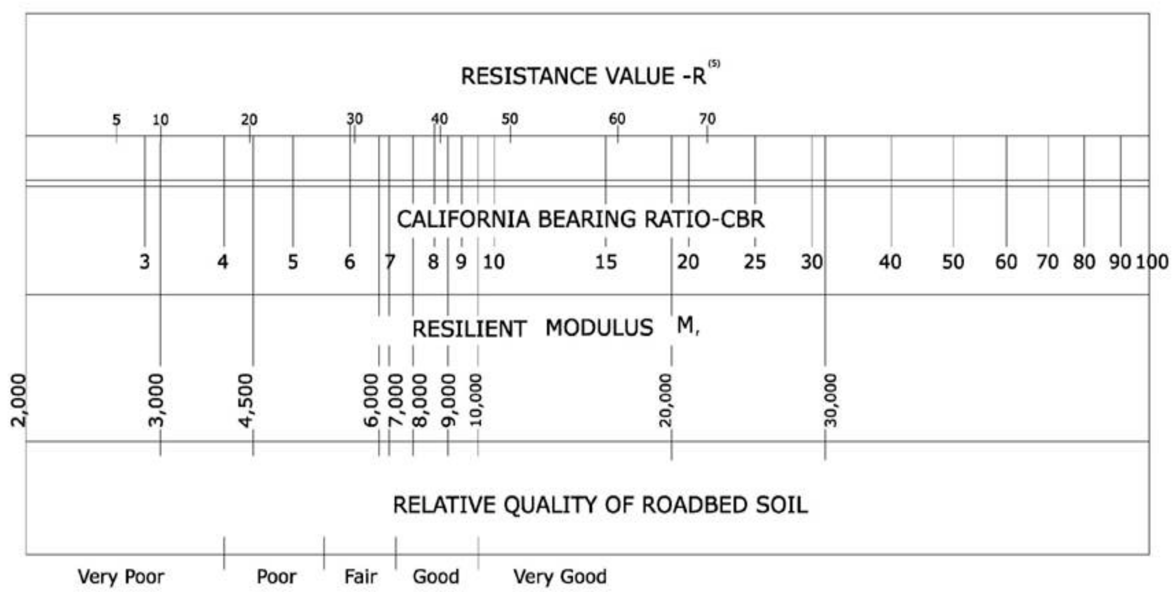
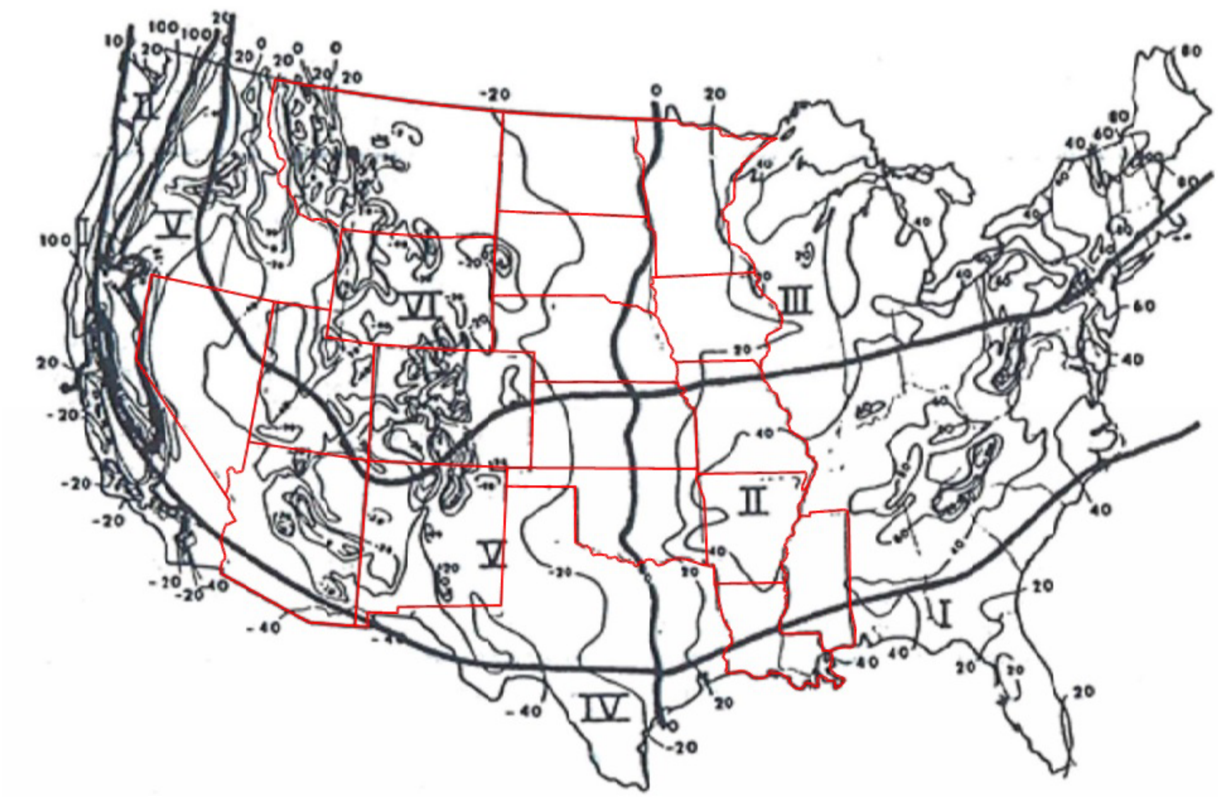


Exhibit 11.4.2-D – THE SIX CLIMATIC REGIONS IN THE UNITED STATES



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze – thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze – thaw cycling
VI	Dry, hard freeze, spring thaw

4.4. Stormwater Drainage

1) Permanent Stormwater Drainage Design

a. Engineer will adhere to local regulations and published criteria for drainage design and site development. These criteria may require detention/water quality ponds, infiltration basins, level spreaders, etc.

b. The minimum recurrence event for the design for storm water conveyances shall be a 100-year storm. Unless superseded by local regulation or criteria, the minimum recurrence design event for pad drainage/conveyances shall be a 100-year storm.

c. Off-site runoff shall not be allowed to flow through or onto the substation pad. This practice will prevent pad flooding and subgrade damage, as well as avoid possible transfer of oil spill material to an offsite area, watershed or wetland. Storm water drainage onto adjacent property must be designed in accordance with local regulations.

d. Should a pond or other treatment system be used on the substation site, the entire pad and access drive shall be a minimum of 1.0' above the calculated 100 year, 24 hour duration High Water Level (HWL) or 0.5' above the designed overflow spillway, or emergency overflow elevation, whichever is higher. This will ensure the pad and drive do not flood during the design rain event or should the outlet system fail.

e. Rainfall data can be referenced in the links below:

i. NOAA Atlas 14 Point Precipitation Data available here: http://dipper.nws.noaa.gov/hdsc/pfds/

ii. *Technical Paper No. 40-Rainfall Frequency Atlas of the United States* Texas only. Available here: http://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf

f. The finished slopes for substation grades shall provide for positive drainage of storm water to drainage ditches or inlets/pipes on or around the perimeter of the graded area. All concentrated flows shall be routed down the embankment in pipes, or armored rundowns. Erosion of pad edges requires careful consideration, such as:

i. Sheet flow length

ii. Embankment slope and height

iii. Erosive potential of in-situ soils

iv. Surface protection (grass, rock, geoweb, etc.)

g. Sheet flow for greater than 300’ is difficult to maintain. When designing larger pads, limit sheet flow to 300’ through the use of concentrated flow facilities.

h. Concentrated discharges through/under security fencing requires barriers to unauthorized entry.

i. Cable trenches, pull pits, and duct banks will intercept surface/subsurface drainage. Where possible, these facilities shall be located on drainage ridges or parallel to the direction of flow. Use of cable trenches is discouraged from a drainage standpoint however, if required, the civil engineer shall work with the electrical engineer to determine optimal placement.

j. Perched water tables, seasonal groundwater fluctuations, artesian weeps, and other complex subsurface drainage can cause frost heave and water infiltration issues in basements, pull pits, and trenches. Unfortunately, these conditions are difficult to predict and are often discovered during construction excavations. Subsurface dewatering/French drains should be used to minimize this condition. Additionally, where possible, pad placement should avoid the lowest areas of the substation properties.

2) Construction Storm Water Drainage Design

a. The Clean Water Act and resulting EPA regulation 40CFR Part 122 "National Pollutant Discharge Elimination System" (NPDES) governs storm water discharge during construction where the disturbed area is equal to or greater than one acre. These regulations require state permits for storm water runoff. Local regulations may be more restrictive.

b. Local and state construction storm water processes must be completed/approved prior to construction mobilization.

4.5. Floodplain Analysis

Sites located within, or adjacent to, mapped flood plains of rivers and tributaries shall be designed with top of grade for substation and its access a minimum of 1 foot above the FEMA defined 100-year Base Flood Elevation, or maximum flood of record (whichever is highest).

Flood information used for the design of substations shall be based on the more restrictive (highest) flood elevations as defined by FEMA or local jurisdictions. Coordination with local floodplain managers is often also required and may include floodplain development analysis/modeling and permitting. Please note: Elevation comparisons must account for any applicable datum differences. (There are two vertical datum typically used in the U.S. NGVD was established in 1929. NAVD was established in 1988. There is approximately a 3.0 foot difference between NAVD and NGVD, which varies slightly depending on the location horizontally on the earth.)

FEMA information: https://msc.fema.gov/portal/advanceSearch

4.6. Wetland and Waters of US Analysis

If a defined waterway or wetland is suspected to be located on, or potentially impacted by the substation project, an official evaluation must be conducted by a qualified individual. The evaluation will identify and delineate the Waters of the US and/or wetland extents, and will provide the basis for substation grading and drainage design. Any impact to a Waters of the US or wetland will required United States Army Corps of Engineers 404 permitting, such as a Nationwide or Individual Permit. PLEASE NOTE: 404 reviewing and permitting can be very time consuming and must be identified early in the siting and design process.

4.7. Oil Spill Containment

EPA 40CFR 112 Oil Spill Prevention Regulation establishes the requirement that Spill Containment and Countermeasure Plans (SPCC) be prepared for all applicable facilities. The size of the oil spill containment shall be determined by the oil volume plus 25-year, 24-hour rainfall. Engineers shall check with the OpCo they are working with for specific requirements.

4.8. Fencing

Fence design shall comply with XEL-STD-Guideline for Substation Physical and Cyber Security, Section 2.3. XEL-STD-Guideline for Substation Physical and Cyber Security.pdf

Fences shall be based on structural calculations for fence frame and foundation. Calculations shall be in accordance with “Chain Link Fence Wind Load Guide for the Selection of Line Post and Line Post Spacing (WLG 2445)” and “ASTM F567, Standard Practice for Installation of Chain-Link Fence”.

5 Geotechnical Design Criteria

5.1. Soil Parameters and Design Values

Minimum soil parameters and design values shall be determined on the basis of site-specific testing or representative testing selected on the basis of the geotechnical engineer's experience in the area. These minimum values must identify with correlated values indicative of the typical values judged to be inherent at the specific site.

A geotechnical investigation shall be required for new or existing sites where no previous investigations have been performed. Both site grading and foundation designs shall be established on the basis of known site conditions and engineering data, obtained from the investigation.

The classification of observed soils shall be made in accordance with ASTM D2487 and D2488 the "Unified Soil Classification System".

5.2. Sampling and Testing

5.2.1. Overview

Rock and Soil Sampling shall adhere to the requirements of ASTM D420. Soil sampling shall be performed in accordance with ASTM D-1586 for split spoon sampling, and D-1587 for thin wall Shelby tube sampling. Rock sampling shall be done in accordance with ASTM D2113.

5.2.2. Swell ASTM D4546

Specific design recommendations to minimize swell effects on foundations must be made to assure performance within the guidelines specified in the foundation and civil performance sections of these criteria.

5.2.3. Water Soluble Sulfates

Specific design recommendations as to type of cement to minimize sulfate effects on concrete must be made. The test for water soluble sulfate in soil shall be performed in accordance with ASTM C1580.

5.3. Design Recommendations

5.3.1. Frost Heave/swell

Specific design recommendations to minimize frost heave/swell effects on foundations must be made to assure performance within the guidelines specified in the foundation and civil performance sections of these criteria.

5.3.2. Settlement / Consolidation

The geotechnical engineer shall make recommendations for foundation sizing based on anticipated service loads provided by the engineer. Limits for settlement established in the foundation and civil sections of these criteria shall not be exceeded.

5.3.3. Water Conditions

When groundwater is present in the frost zone within the graded area of the substation or access, the geotechnical engineer shall make recommendations, which will minimize the heave potential caused by ice lensing in the soil.

Drain systems, engineered fills or other functional solutions shall be recommended with economic considerations of each alternative. Recommended choices should be made based on best performance and cost.

5.3.4. Backfill Material Qualification

Backfill for substation sub-grades shall be qualified to assure that material is sound and of sufficient strength to sustain specified equipment, traffic and maintenance loads without excessive deformation.

The geotechnical engineer shall qualify native sub-grade or imported materials used as backfill.

5.3.5. Sub-grade Treatment

Sub-grade treatment for slab foundations will be required in situations where soils with inadequate bearing capability or stability concerns that are not meeting performance criteria for foundations and equipment are present.

Sub-grades with excessive depths of soils with inadequate stability or deformation properties may require a geotextile material under the graded area or road access to provide the required stability under wet or saturated conditions.

Sub-grade preparation or geotextile treatment needs to be clearly stated and referenced on site grading or foundation drawings.

5.3.6. Foundation Recommendations

The civil/structural engineer is responsible for the design of foundations and sub-grade stability for substations. Structural aspects and the general understanding of the geotechnical issues are considered as a part of this role. The geotechnical engineer must determine and recommend specific design values that are geotechnical in nature and are appropriate for the intended use and application on each project.

The civil engineer must recommend design solutions to the geotechnical engineer and review with the geotechnical engineer design values and application of specific solutions. The civil engineer must negotiate and seek agreement with the geotechnical engineer, while maintaining focus on the technical and economic issues involved.

Typical conditions and standard foundation applications must be communicated to the geotechnical engineer. Recommendations for these conditions are more general in nature however, more specific design values such as bearing capacity must be determined and reported based on actual or closely correlated soil parameters.

Variable conditions where standard or special foundation application are a concern requiring more intensive technical study will require more in-depth communication with the Civil/structural Engineer on design solutions and soil recommendations.

The geotechnical engineer must perform qualification testing and prepare recommendations concerning the use of native materials as backfill.

Preface

P.1. Scope and Purpose

This document describes the parameters for conductor and other wire for use on overhead transmission lines. This applies to property unit 2920187209 for overhead conductor and shield wire, to property unit 2920188809 for OPGW, and to down guy-wires and span guy-wires.

P.2. Responsibilities

Effective design and use of conductor and wires requires the cooperation of multiple responsible parties internal and external to Xcel Energy. The System Planning department shall recommend the conductor to meet electrical requirements. The Transmission Engineering department will use this conductor recommendation to design the transmission line. It is the responsibility of each of these parties to understand the requirements and limitations described in this document and to apply them appropriately to each individual design.

Geographic location and special site conditions will at times cause deviation from these standard conditions. Exceptions to this standard require approval by the Director of Engineering.

P.3. Work Flow

P.3.1 Approval

The Xcel Energy Standards Council has approved this document.

Date	Name
2015/02/20	Cozad, Brad D
2014/11/17	Dunham, Michael P
2014/11/25	Long, Brian D
2014/11/17	Urban, Paul J
2015/02/20	Winter, Kent G
2014/11/25	Woodard, James C

P.3.2 Creation

The following committee wrote this document.

Name	Title
Benjamin Gallay	Senior Engineer
Jeff Gutzmann	Principal Engineer
Parker Wrozek	Senior Engineer
Terry Randall	Principal Engineer
Tim Wachholz	Engineering Manager

P.3.3 Version History

The personnel listed above have approved the following changes:

Date	Version Number	Change
2/20/15	1.0	Initial Version supersedes the following documents in whole or in part SPS-STD-TB001 Mechanical Deadend Use NSP-STD-TB003 Automatic Splice Use XEL-STD-Guideline for Eng & Design of Spiral Vibration Dampers NSP-STD-CONDUCTOR DESIGN CRITERIA PSC-STD-CONDUCTOR DESIGN CRITERIA SPS-STD-TRANSMISSION LINE DESIGN CRITERIA

Table of Contents

1 Overview

1.1. Philosophy

Select conductors, shield wires, and optical ground wires based on required capacity with consideration to both lowest initial installation cost and lowest life cycle cost.

- **Required Line Rating:** Xcel Energy System Planning or System Operations will determine a minimum line capacity. Transmission Line Engineering will select an appropriate phase conductor to meet or exceed this requirement. (See XEL-POL-Facility-Rating-Methodology.doc)
- **Tension Criteria – Mechanical Strength:** Design tensions may not exceed 60% of the rated breaking strength of the selected conductor, for the loads of Rule 250B, per the NESC and Xcel Energy Standards. Line designs must also consider the effect of Aeolian vibration and address it through tension reductions, use of vibration mitigation attachments, or a combination of both. These criteria must be met under all load cases. (See XEL-STD-Transmission Line Structural Loading Criteria)
- **Wire Hardware Criteria:** Wire attachments and support hardware should be consistent throughout an individual line design. Whenever possible, use the current standard stock hardware supported by Supply Chain.
- **Clearance Criteria - Environment:** Vertical and Horizontal clearance requirements, per the NESC and Xcel Energy Standards, must be met in all designs during the worst-case sag conditions for the line design. (See XEL-STD-Transmission Line Clearance Criteria)

1.2. Glossary

AAMT

Average temperature of the coldest month at geographic location of the line.

ACSR

Aluminum Conductor Steel Reinforced; is conductor that consists of a solid or stranded galvanized steel core surrounded by one or more layers of aluminum. The steel core provides the majority of the tensile strength of the conductor. The overall conductor strength derives from contributions of both the steel and aluminum.

ACSS

Aluminum Conductor Steel Supported; is conductor made of aluminum stranded around a steel core. ACSS is a high temperature conductor that allows for higher operation capacity. ACSS has annealed aluminum that does not provide significant tensile and bearing strength. Therefore, it is advisable to use clamps that apply the least bearing stress on the conductor.

Aeolian Vibration

Aeolian vibration is a high frequency motion that can occur when a smooth, steady crosswind blows on aerial cables.

Armor Rod

A set of preformed protective metal rods wound helically around a conductor at the suspension point, preformed and placed prior to the installation of the suspension clamp.

Armor Grip Suspension (AGS)

This is a Heliformed suspension clamp manufactured by PLP.

Catenary Constant

The constant in the catenary and parabolic equations, geometrically represented by the radius of curvature at the lowest point of the span. The catenary constant H/w is the quotient of the horizontal tension in the conductor H at a given temperature by its unit weight w, which must take into account the ice and wind loads, if applicable.

Conductor

A wire or combination of wires not insulated from one another, for carrying an electric current.

Cushion Grip Suspension (CGS)

This is a conductor clamp that has rubber bushings inserted into a metal body housing. CGS is a trademark of Preformed Line products.

Damper

A device attached to a conductor or an earth wire in order to suppress or minimize Aeolian vibrations due to wind

Departure Angle

The angle between the wire at the suspension point and the horizontal plane.

Fittings

Hardware equipment used to attach a suspension clamp to an insulator. Fittings include material like yoke-plates, corona rings, clevis eye, Y-clevis eye, socket eye, hold-down weight shackle, and socket clevis, shackle, link, turnbuckle, etc.

Galloping

Periodic motion of a conductor of the order of a fraction of one Hz and high amplitude, whose maximum value can be of the same order as the original sag.

Heliformed Suspension Clamp

This conductor clamp configuration uses a combination of armor rods, a rubber bushing, and a metal housing to suspend a conductor on a transmission line. There are two manufacturers of Heliformed suspension clamps: AGS by PLP, and HAWS by AFL.

Hinged Armor Wire Suspension (HAWS)

This is a Heliformed suspension clamp manufactured by AFL.

Hinged Bushing Clamp (HIBUS)

This conductor clamp has rubber bushings inserted into a hinged metal housing. HIBUS is an AFL trademark.

OHGW

Overhead Ground Wire, typically consisting of steel and/or aluminum strands and used to provide lightning protection to phase conductors; also called static wire or shield wire.

OPGW

Optical Ground Wire, typically consisting of fiber optic core strands surrounded by steel and/or aluminum outer support strands, provides for lightning protection as well as a communications path.

RTS

Rated Tensile Strength is the maximum load that a material can withstand while being stretched or pulled before failing a manufacturer's minimum rating requirements.

Ruling Section

A number of spans between two dead-ends.

Ruling Span

The span length in which the tension in the conductor, under changes in temperature and loading, will most nearly agree with the average tension in a series of spans of varying lengths between dead ends.

Sag

The maximum vertical distance in a span of an overhead line between a conductor and the straight line joining its points of support.

Shoe

This is industry jargon meaning standard suspension clamp.

Slip Load

The maximum load that a clamp can handle before losing grip on the conductor.

Span

The length of a line between two consecutive points of support of a conductor

Splice

a joint inserted between two lengths of a conductor to provide electrical and mechanical continuity of the conductor

Suspension Clamp

A device used to hold the conductor cable on a transmission line. Using fittings, it attaches to an insulator that is supported on the transmission structure. A standard suspension clamp consists of a saddle shaped metallic device and has a keeper held down using U-bolts.

Wire

Flexible strand or strands of metal used to bear mechanical load.

1.3. References

The following publications are useful to the proper understanding and implementation of this document. These references include internal Xcel Energy documents as well as external documents.

- XEL-STD-Specification for Procurement of Overhead Conductors
- CIGRE 273 Conductor Safe Design Tension with Respect to Aeolian Vibrations
- CIGRE 324 Sag-Tension Calculation Methods for Overhead Lines.pdf
- CIGRE-ELT-181-3-Modeling of Aeolian Vibration of Single Conductors
- CIGRE-ELT-223-2-Modeling of Aeolian Vibrations of Single Conductor plus Damper
- EPRI Orange Book (2005) Transmission Line Wind Induced Conductor Motion
- EPRI Red Book AC Transmission Line Reference Book-200kV and Above
- IEC 60050 - International Electrotechnical Vocabulary
- IEEE 524 Guide to the Installation of Overhead Transmission Line Conductors
- National Electrical Safety Code: 2012 Edition
- RUS Design Manual for High Voltage Transmission Lines 1724e-200
- XEL-POL-Facility-Rating-Methodology.doc
- XEL-STD-Guideline for Optical Ground Wire - OPGW
- XEL-STD-SHIELD WIRE SPECIFICATION
- XEL-STD-Specification for Procurement of Overhead Conductors

2 Electrical Criteria

2.1. Phase Conductors

The line capacity requirements given by Xcel Energy System Planning determine conductor selection for new lines. The design engineer should work closely with the planning to determine the appropriate conductor. The Xcel Energy Rating Methodology defines how transmission lines are to be rated: XEL-POL-Facility-Rating-Methodology.doc. These planning considerations set a lower limit on the aluminum content of the conductor (the value expressed in kcmil for ACSR and ACSS conductors).

The Siting and Land Rights department dictates secondary considerations. These include corona and other electromagnetic field effects that may dictate a minimum conductor diameter, or a conductor bundle. Also dictated by Siting and Land Rights is the choice of specular and non-specular conductor finish options. Non-specular finish is a postproduction process applied to the conductor as such it has a cost and production time increase versus a standard specular finish. This is a common permitting requirement to limit “visual pollution” on Federal ands.

Once these project requirements are understood, Transmission Line Engineering shall select an appropriate phase conductor, or bundle of conductors, to meet or exceed this requirement. (Mechanical constraints – see §3 – affect choice of conductor diameter and steel content. The engineer is at liberty to choose between ACSR and ACSS to minimize costs.) In the case of line maintenance, emergency repair, or line rebuild projects the conductor selection shall meet or exceed the capacity of existing conductor.

Whenever possible, the design engineer shall use Xcel Energy preferred conductors to maximize interchangeability of parts across the system. Listings of the preferred conductors can be found in XEL-STD-Specification for Procurement of Overhead Conductors. When design conditions dictate a non-standard conductor size be used, such as a long span crossing a restricted access area, the design engineer must develop emergency repair/replacement options and coordinate them with the Supply Chain, and construction groups. Both round wire and trapezoidal wire version of the standard conductor sizes are available. Diameter equivalent trapezoidal wire has several advantages to round wire from both an engineering and a construction perspective, and only a marginal cost increase over round wire due to the increased aluminum content. Trapezoidal wire should be considered as the primary design option by engineering, wherever an ultimate lowest INITIAL cost design is not required. System Planning may also require trapezoidal wire on a specific project due to long-term system considerations.

2.2. Overhead Ground Wire

2.2.1. Fault Current

The currents from phase-to-ground faults return through the ground and the ground wires. The fault can occur anywhere in the transmission line with short circuit current being higher near substations. These short circuit currents cause a temperature rise in the wire. This temperature rise can cause the aluminum to anneal, birdcage, or melt.

Equation 1 shows the design constraints on selecting shield wire (based on energy conservation during a fault). The left hand side consists of material constraints provided by the manufacturer. The right hand side consists of design requirements of interest to a utility, and is why OPGW is often listed in catalogs with the parameter $kA^2 \cdot s$. 3/8" EHS stranded steel cable has a fault withstand capability of $24 \cdot kA^2 \cdot s$. The maximum allowable temperature for steel is its softening point at about 600·°C, allowing for a compact shield wire. The maximum allowable temperature for OPGW is the softening point of the glass fiber coating at about 180·°C generally requiring a much larger diameter and higher aluminum content.

Xcel Energy's engineer shall obtain the exact values of the three-phase fault current from the System Protection engineering group. A clearing time of 6 cycles shall be assumed. The line design (i.e. use of multiple shield wires) may allow for the fault current to split, and therefore allow for use of correspondingly smaller shield wires. The design engineer should consult with System Protection Engineering to determine the fraction of the total fault current that will flow through each individual shield wire. The maximum energy value of I^2*t, shall determine the short circuit current capability. Preferred shield wire sizes are listed in XEL-STD-SHIELD WIRE SPECIFICATION and XEL-STD-Guideline for Optical Ground Wire - OPGW.

When lines parallel communication circuits, railroads, or pipelines, shield wire may also be constrained by induced current effects during line faults. Under these situations, the design engineer shall perform a study to determine whether a higher conductivity shield wire is necessary.

$$D^4 \cdot \left(\frac{T_H - T_L}{\alpha \cdot \rho^2} \right) \cdot C = i^2 \cdot t$$

Equation 1: Material constraints on shield wire

D: Shield wire diameter
T_H: Maximum allowable temperature
T_L: Ambient temperature
α: Thermal diffusivity of wire
ρ: Electrical conductivity of wire
C: proportionality constant
i: fault current
t: fault duration

2.2.2. Optical Ground Wire

The Transmission Line Engineer or Designer should consult with System Protection Engineering and Communications Engineering departments to determine if OPGW is required on a specific project. The Transmission Line Engineer or Designer should prepare estimates for OPGW for all lines operated at or above 115·kV. Even if it is not required at the time of the current project, the final design should consider the need for possible future addition of a fiber-optic communication path in some fashion. ("External" or "competitive bid" projects with specific estimate guidelines may waive this requirement with the approval of the Director of Engineering.)

OPGW weights and diameters are, in many configurations, larger than traditional shield wires and require greater tensions to maintain comparable sag characteristics. The larger OPGW wire diameters result in greater structure loading due to the increase in wind and ice loads. Where OPGW replaces shield wire(s) on existing transmission lines, Xcel Energy's engineer shall evaluate the resulting sags and tensions for proper application. XEL-STD-Guideline for Optical Ground Wire - OPGW outlines additional details and standard OPGW sizes and hardware.

The Xcel Energy standard overhead shield wire is a 3/8" Extra High Strength stranded steel cable. EHS steel and alumoweld cables have a higher strength to weight ratio and therefore sag less than phase conductors. This assures that the shielding angle determined by the structure geometry will not diminish anywhere in the span, and neither will clearances with respect to galloping.

2.2.3. Grounding Methods

Xcel Energy's design shall bond the mechanical support of the shield wire to the structure ground. The existence of a jumper across the mechanical support is not necessary for lightning or fault current dissipation unless the shield wire is in uplift. Any resistance in the mechanical support for the shield wire will be overcome when the first traveling wave intersects the connection. An arc will quickly form, and the arc will provide a relatively low resistance connection during a fault or lightning event.

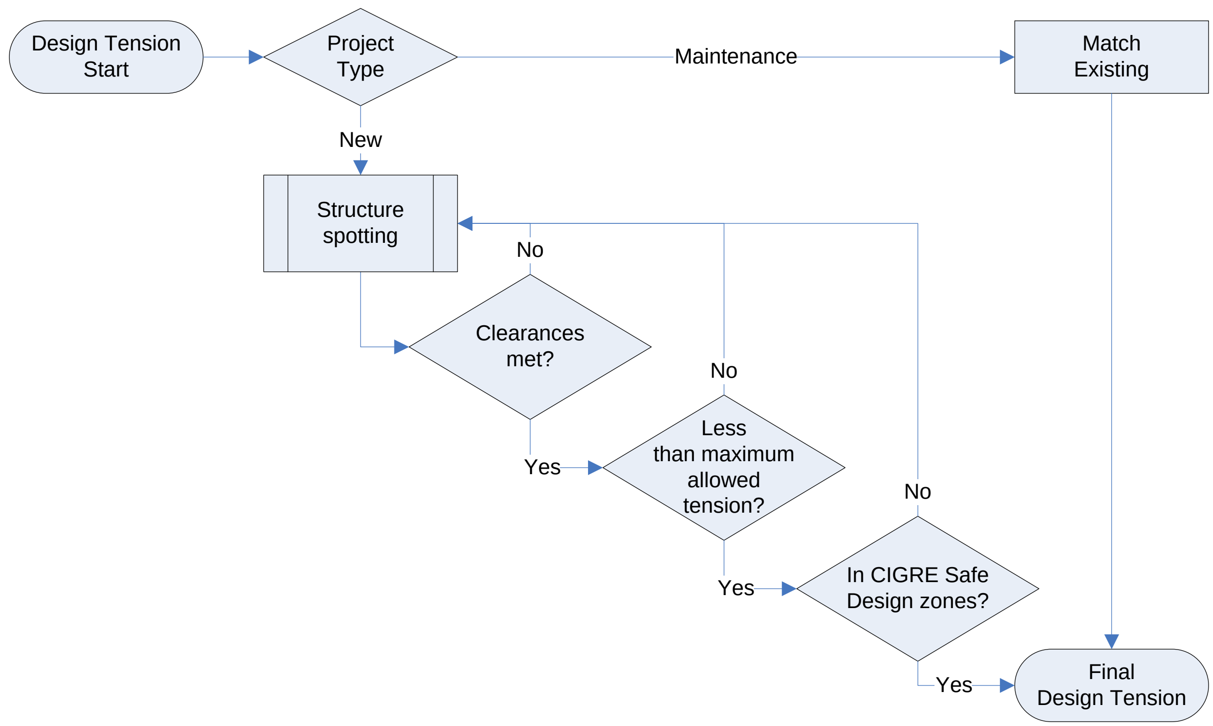


Figure 1: Flow chart showing iterative process for determining design tension for new line design, re-conductor, or maintenance projects.

3 Tension Criteria

3.1. Design Tension Process

Figure 1 shows the design tension process. Selecting design tension for a project is a tradeoff between several constraints: project constraints, clearance requirements, and the mechanical properties of the conductor. Limits on the mechanical properties of the conductor are the primary scope of this document, discussed below in § 3.2 and § 3.3. XEL-STD-Transmission Line Clearance Criteria discusses clearance requirements in detail. Project constraints include total budget, and available right-of-way. Appendix B provides guidelines for managing these constraints given clearance and mechanical limits.

3.2. Worst Case Mechanical Loading

Per the National Electrical Safety Code (NESC) phase conductor and overhead shield wire tensions shall not be more than: 60% of their rated breaking strength for the load of Rule 250B multiplied by a load factor of 1.0, or more than 80% of their rated breaking strength under loads of Rules 250C and 250D multiplied by a load factor of 1.0. They also shall not be more than (35% Initial) or (25% Final) of their rated breaking strength in an unloaded condition at the appropriate temperature for the loading zone used in the design.

Weather Parameters						Tension Limits (RBS)		
Case	Wire Temp (°F)	Wind (mph)	Wind (psf)	Ice (in)	Final / Initial	NESC Limit	XEL Limit ACSR	XEL Limit ACSS
NESC Rule 250B	See XEL-STD-Transmission Line Structural Loading Criteria				I	60%	40%	50%
NESC Rule 250C	60	90	20.7	0	I	80%	80%	80%
NESC Rule 250D	15	50	6.4	1	I	80%	80%	80%
NESC - Rule 261.H.1.b - Initial	NESC 250 B	0	0	0	I	35%	35%	35%
NESC - Rule 261.H.1.b - Final	NESC 250 B	0	0	0	F	25%	25%	25%

Table 1: Cable Tension Limits based on NESC Rule 261.H.1.

These tension limits will manage mechanical failure of the conductor or shield wire due to typical weather conditions across the United States. Table 1 lists these base conditions per the NESC as well as the Xcel Energy design standards chosen to exceed those requirements. Special loading areas exist throughout the United States and the Xcel Energy service area, examples such as the higher wind speed areas in south west Minnesota and along the Colorado foothills may require design limits in excess of those listed in the table.

Construction limitations must also be accounted for in determining the design tension such as; substation dead end loading limits, which typically require a “slack” span, limits due to available stringing equipment or available stringing locations in the field, mechanical damage to conductors due to the type of pulling grips available.

While the base cases shown in Table 1 account for the majority of these variables, it is the responsibility of the design engineer to intelligently apply and adjust these rules as required by the conditions specific to their project location.

These tension requirements apply equally to both phase conductors and shield wires, both OHGW and OPGW. (Shield wires will end up not having the same tension as phase conductors for two main reasons. First, OPGW and OHGW are made from different material so that weight per foot and RBS will be different; see XEL-STD-Guideline for Optical Ground Wire - OPGW for more details. Second, shield wire must always have less sag than phase conductors to provide adequate lightning protection; see XEL-STD-Transmission Line Clearance Criteria for more details.)

3.3. Conductor Fatigue

An important mechanical constraint on conductor tension is fatigue failure due to persistent Aeolian vibration. Since the 1960’s, an Every Day Stress (EDS) design evaluation has been used to evaluate Aeolian vibration and set upper limits to tension in terms of % RTS. (This is one of the reasons for the Xcel Energy standard design tension limits in Table 1 being more conservative than the limits imposed by the NESC: the NESC does not account for vibration fatigue.)

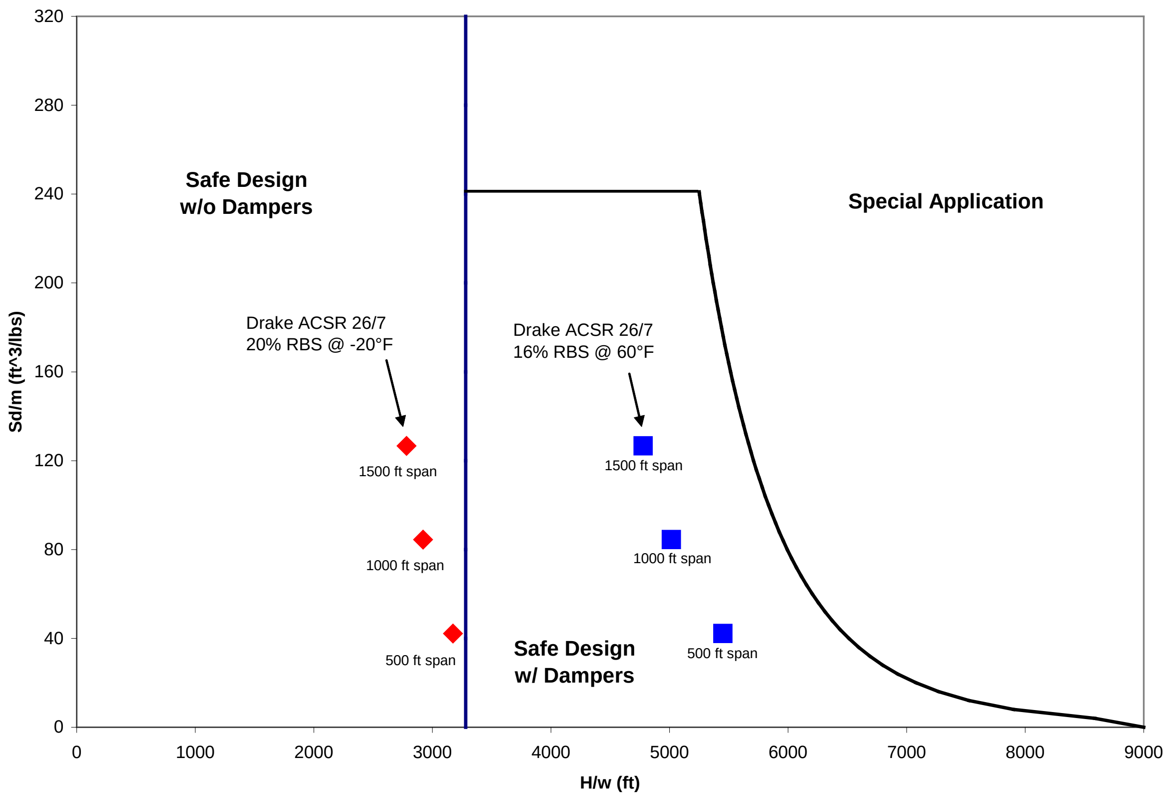


Figure 2: Recommended Safe Design Tensions for Single Conductor Lines. (Based on CIGRE TB 273, and Terrain Category 1.)

Modern studies have shown that while this method produces simple rule of thumb thresholds, it has proven to be inaccurate, as it does not account for all the variables that exist from span to span along a transmission line. For the purpose of fatigue endurance for ACSR conductor, it is the stresses in the outer aluminum strands that should be limited, rather than the average stress across all strands of the complete conductor as implied by EDS criteria. Because the final ratio of elastic moduli is approximately equal to the ratio of the densities of steel and aluminum, the tensile stress in the aluminum strands is a function of H/w, irrespective of the steel/aluminum ratio. The H/w ratio is the ratio between the initial horizontal tensile load (H), before any significant wind and ice loading and before creep at the average temperature of the coldest month at the location of the line, and conductor weight (w) per unit length. When using anti-vibration devices, such as Stockbridge dampers, an additional parameter is used to account for their effect on a given span, S·d/*m*: the span length S, times the conductor diameter d, divided by the conductor mass per unit length *m*.

CIGRE Technical Brochure 273 describes these parameters in detail, and design engineers should familiarize themselves with its contents, as it forms the basis for Aeolian vibration mitigation on all new construction at Xcel Energy. Figure 2 shows expected EDS and H/w values for Xcel Energy standard conductors applied to typical structure configurations and varying span lengths on the CIGRE design zone chart.

The intended design process is for the engineer to evaluate vibration effects as the last step in selecting design tension. Using the proposed design tension to this point, the engineer would plot H/w and S·d/*m* parameters for each differing design section of the overall line. Designs in the "No Damping" zone do not require dampers. Designs in the "End Damping" zone shall use dampers, with location and size determined per the manufacturer's recommendations (see § A.4 for details). Designs that fall in the "Special Application" zone shall be redesigned, because custom and expensive damping solutions would be necessary to protect these designs.

Appendix A Accessories

A.1. General

Wire accessories and fittings should be consistent throughout an individual line design. Whenever possible, use the current standard stock hardware supported by Supply Chain.

A.2. Full Tension Accessories

A.2.1 Dead End Accessories

Compression dead end fittings shall be used for all conductor sizes and types. Compression dead end fittings, properly installed provide both a better conductive path for electrical connections as well as significantly higher holding strengths than are possible with bolted fittings.

An exception for the use of bolted dead end fittings can be requested for special cases where a specific need is identified, such as for temporary bypass or jumper configurations which would require frequent dis-assembly and re-assembly, or for installing taps energized. When specifying bolted fittings, the engineer must ensure that the conductor tensions do not exceed the rated holding strength.

A.2.2 Splices

Compression splices shall be used for all wire sizes and types. "Automatic splices" are <u>not</u> compressed with dies to provide holding strength but rely on internal automatic mechanism to hold the wires after they are inserted into the splice. Water runs down the wire, collects in the automatic splices (even those with drainage holes), and corrodes the wire or inner splice parts, which has resulted in mechanical failure and dropped lines.

A.3. Suspension Accessories

Armor grip suspension (AGS) units, or Cushion Grip suspension (CGS) units, shall be used on all sizes of ACSS conductor, as well as ACSR conductor larger than 636 kcmil. Clamps with armor rods may be used on ACSR conductor up to 636 kcmil. Clamps without armor rod shall not be used on any new construction.

All suspension hardware has an upper limit on departure angle to limit the bend radius and stress in the conductor at the suspension hardware. This limit may be 22.5° or 30°; the design engineer should consult the vendor data sheets. This is mostly a concern at angle structures where the angle of the line compounds the departure angle. At locations with a large departure angle, two clamps or grips are often necessary to spread the force applied to the conductor over a larger area.

A.4. Vibration Dampers

A.4.1 General

Dampers are devices attached to conductors and shield wires to reduce the fatigue on line components due to wind-induced vibration. While many types of dampening devices exist on the market Xcel Energy uses the two most common. Stockbridge type dampers are used on conductors that are 0.75·in in diameter and larger. Spiral Vibration Dampers should be used on shield wires and conductors that are 0.75·in in diameter and smaller. The same recommendation applies to OPGW.

A.4.2 Stockbridge Dampers

The Stockbridge-type damper reduces the vibration amplitude of the conductor by dissipating mechanical energy as heat. An example is shown in Figure 3. The friction between wires strands of the messenger cable is the location of this energy conversion. The Stockbridge type dampers perform in a wide vibration frequency bandwidth and protect the conductor even at high tensions and long spans. One (1) or more dampers may be required to provide the necessary protection. Stockbridge type dampers are placement sensitive and need to be installed at the optimum position recommended by the manufacturer. The different damper designs require each manufacturer's damper recommendation software be used exclusively for their corresponding dampers. Although there are many vibration-damping systems on the market today, the Stockbridge style dampers is the most time tested and economical solution to reduce conductor fatigue on the transmission system with conductors larger than 0.75" diameter. The line designer should keep in mind that Stockbridge type dampers are span and tension dependent

The main concern in regards to the use of Stockbridge type dampers on small diameter

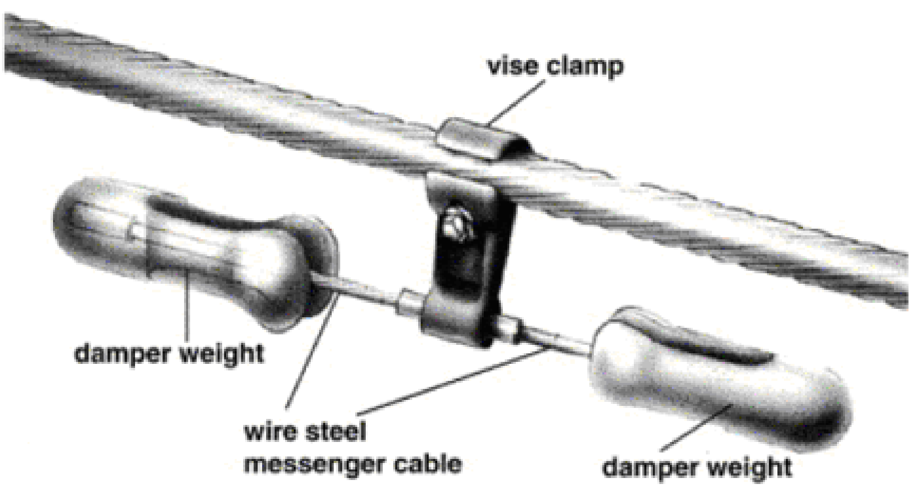


Figure 3: Example of Stockbridge vibration damper.

Conductor	AFL		Fargo 4-R	
	Cat ID	Part No.	Cat ID	Part No.
266..8	201548	1704-5BA	217818	607051011
336.4	197278	1704-6BA	217818	607051011
477	76375	1705-7	217818	607051011
636	51432	1706-9	217820	6071012
795	51433	1706-10	217820	6071012
954	51433	1706-10	217821	6071513
1033.5	51436	1707-11	217821	6071513
1272	51435	1707-13	217821	6071513

Table 2: Passport Cat ID's for Stockbridge Dampers.

conductors is the installation precision. Stockbridge type damper must move to dissipate energy. As the conductor diameter decreases, the loop lengths also decrease. The decrease in loop length causes the node and anti-node to converge, which places more emphasis on the installers precision. If a Stockbridge type damper is installed at a node, it becomes ineffective and may begin to create issues rather than suppress them.

Table 2 lists standard stockbridge dampers available through Passport. These must be sized using the applicable manufacturer's software. In addition to typical project data - such as span length – the software will also ask the user for the following three assumptions:

- Terrain Category: Use category should be Category 1 / open terrain.
- Direction of line: Use the direction between dead-ends for each ruling section.
- Average Annual Minimum Temperature: Use -20°F in the PSCo and NSP regions and 0°F in the SPS region.

A.4.3 Spiral Vibration Dampers

The Spiral Vibration Damper (SVD) is an impact style damper that interrupts and negates the Aeolian vibration motion so the conductor or wire does not lock into resonance and cause fatigue damage. Spiral dampers are most effective at high vibration frequencies (100 Hz to 300 Hz) associated with smaller wires. A decrease in diameter results in higher vortex frequencies and shorter loop lengths, so this makes spiral dampers an ideal candidate to

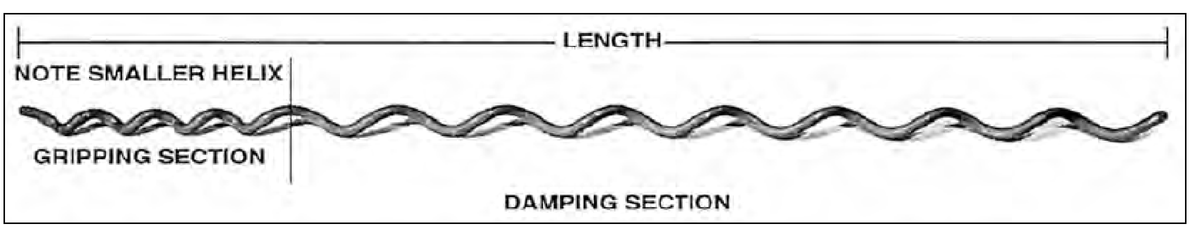


Figure 4: Example of spiral vibration damper.

Span Length	0-800’	801’-1600’	1601’-2400’
Standard	**2**	**4**	**6**
Hi-Mass	**1**	**2**	**3**

Table 3: Number of SVD’s per span.

Catalog ID	Manufacturer	Part Number	Type	Diameter Range
217928	PLP	5050200	Hi-mass	0.250" - 0.326"
212981	PLP	5050201	Hi-mass	0.327" - 0.461"
212982	PLP	5050202	Hi-mass	0.462" - 0.563"
217929	PLP	5050203	Hi-mass	0.564" - 0.760"

Table 4: Passport Cat ID’s for SVD’s.

suppress Aeolian vibration on conductor’s less than 0.75”, shield wire, and OPGW. SVDs are not available for wires larger than 0.75” diameter as they are not economically feasible to manufacture and use when compared to Stockbridge-type dampers.

All conductors, shield wire, and OPGW less than 0.75" in diameter shall use spiral vibration dampers. This decision was made based on the following.

- Spiral dampers are most effective at higher frequencies, which are associated with smaller diameter wires.
- As diameter decreases the nodes and anti-nodes converge, which places more emphasis on the precision of installation, when compared with Stockbridge dampers, spiral dampers are NOT placement sensitive.
- Spiral dampers are theoretically less susceptible to weather events
- PLP, a spiral damper manufacturer, has performed tests that show equivalent power dissipation between their Stockbridge-type dampers and their spiral dampers

The Hi-mass spiral design shall be specified whenever possible. The Hi-mass design allows for fewer components and installations when compared with standard designs.

The quantity of spiral dampers is dependent on the length of the span. If the manufacturer of the spiral damper is PLP, Table 3 provides the minimum quantity requirements.

The placement of spiral dampers does not require any software or calculations. The recommended installation point for spiral dampers is approximately one hand's length from the end of the armor rod or other hardware.

A.5. In-Span Accessories

A.5.1 Aerial Warning Markers

The FAA or Army Corp of Engineers may require spherical markers be attached to the top wire of a transmission line to increase visibility of the wire. Markers are installed in spans crossing navigable rivers and where aircraft operate close to the ground. One must take into account the added weight of the markers in the sag-tension calculations.

A.5.2 Bird-Diverters

The Department of Natural Resources (DNR) or the United States Fish and Wildlife Service, in areas of heavy bird traffic, sometimes request installations of bird-diverters to increase the visibility of the wires to the birds. Many varieties of bird-diverters exist; in the absence of a specific permitting requirement, Xcel Energy uses a spiral-type bird-diverter, similar to the spiral vibration dampers in design and installation. The additional weight of the bird-diverters shall be considered in the sag-tension calculations.

Appendix B Design Considerations

B.1. General

This Appendix provides guidelines for managing project constraints given clearance and mechanical limits. Picking a cost-effective, project specific design tension involves many tradeoffs. In addition, engineering judgment plays a determining factor. The material in this appendix is informative only and is not a mandatory part of the standard.

When the design engineer makes final decisions about tension – and correspondingly, sag – this must be documented carefully. See EDG-E.11-001 Sag Tables and Miscellaneous Attachments.DOC and EDG-E.11-002 Sag Tables and Miscellaneous Attachments - Check List.doc for details.

B.2. Worst Case Sag

Design tensions must provide for the NESC required code clearances during the worst-case sag conditions for the line design. These minimum clearance limits are specified in the NESC section 23. The Xcel Energy standard design clearances are selected to exceed these requirements and have been outlined in XEL-STD-Transmission Line Clearance Criteria. An optimum tension can be found where the change in sag becomes small compared to the tension change. This optimal tension point, when meeting the required maximum tension limits, should be used as the base case for cost comparisons between alternate line designs.

The maximum sag condition used for this evaluation is typically the maximum operating temperature condition for the conductor type. These temperature and weather conditions are established in the XEL-POL-Facility-Rating-Methodology.doc. However, there may be instances where a weather condition, such as extreme ice and wind loading, will exceed a maximum operating sag condition. It is the responsibility of the design staff to evaluate a range of possible sagging conditions and select the appropriate maximum sag condition for the line design.

B.3. Vertical Clearance - Sagging

B.3.1 Structure Height

Structure heights play an important role in determining the optimal conductor tension for a line design. The design engineer must pay attention to locations where structure height is determined by external factors, such as airport approach areas, highway and railway crossings, or sensitive areas with restricted access. Increasing or decreasing design tensions beyond what is typical on the Xcel Energy system may be required to optimize designs in these situations and is an acceptable practice.

B.3.2 Structure Type

Higher tensions will result in higher cost for dead end and angle structures due to increased loading; conversely, lower tensions will result in high tangent structure costs due to the increased height needed to maintain the minimum required ground clearances. The design engineer should consider the number of each type of structure in a ruling segment, and find an optimal tension that provides the most efficient overall design.

B.3.3 Under build

Under built services are common on transmission structures. Typical applications are distribution primary service lines, owned by Xcel Energy as well as other utilities, and third party communications circuits. The design engineer should consider the sag characteristics of these under built facilities and adjust the design tension to coordinate with them and maintain the required safe clearances.

B.4. Horizontal Clearance - Blowout

B.4.1 Span Length

The span or span length is the distance between two consecutive points of support. With longer spans, fewer structures are required but the structures required will be stronger i.e. taller, higher-class poles and heavier steel structures. The design engineer should perform a cost comparison using different span lengths and tensions to determine the most economical design.

Several factors may limit span length due to the amount of conductor blowout experienced at a give design tension. Limited available right of way width and NESC safe clearance requirements to buildings, bridges, trees or other objects may require increase design tensions where shorter spans are not an option.

While modern line modeling such as PLS-CAD has made it efficient to do span-by-span calculations, the Ruling Span method is still widely practiced and often referenced when describing the design tension for a line segment. Tests have shown that wood poles and cross arms supporting conductors attached by means of pin, or suspension, type insulators are quite flexible. Therefore, when temperature changes or changes in loading tend to cause different tensions to exist in spans of different lengths, the poles, and cross arms, are flexible enough to

$$S_R = \sqrt{\frac{\sum_n S_n^{\ 3}}{\sum_n S_n}}$$

Equation 2: Definition of Ruling Span

S_n: Length of span *n*
S_R: Ruling span

equalize these differences and the conductor tension will be substantially the same in all spans. Thus, it is possible to calculate the length of dead end span that will have the same changes in insulator swing or cross-arm deflection as will be found in a series of spans of varying lengths between dead ends. The ruling span is the length of an equivalent span with the average slack per span between dead-ends, using a parabolic approximation (see Equation 2).

B.4.2 Parallel Lines

Just as with under built facilities, the design engineer must coordinate clearances with parallel lines – both those owned by Xcel Energy as well as those owned by other utilities. Safe clearances to these adjacent facilities must be maintained during conductor blow out conditions, as well as the spacing needed for construction activities within the right of way, and may well set a lower limit on the design tension.

Appendix C Down and Span Guys

C.1. Material

C.1.1 Strength

Three different strengths of guy-wire are available for most guying applications. 7-No. 8 alumoweld wire with a strength rating of 15,000 pounds is most commonly used. For structures with heavier loads 25,000 pound, 25m alumoweld, or 35,000 pound, 5/8" steel is used. When loads exceed 35,000 pounds, doubling of the wires or a larger wire should be considered.

The factored load in the guy-wire must not exceed 90% of the rated breaking strength of the guy-wire.

C.1.2 Hardware

Two types of end fittings are used on the guy-wire. A preformed grip is less expensive and is used at the pole; a strand-vice is used at the anchor because the tension in the guy-wire is more easily adjusted with this type of fitting.

Splices are not allowed in overhead or down guy-wires. Broken or damaged guy-wires shall be completely replaced between attachment points.

When automatic splices are installed during line restoration, the field engineer should schedule a return trip to replace the automatic splices with compression splices as soon as practical. Order correct length (longer than normal) compression splice to allow for cutting out of automatic splice or splice in wire with two compression splices to replace the automatic splice.

For existing automatic splices in lines, note their location in the TAMS maintenance database as a critical replacement item. The automatic splices should be replaced in the next capital project on that line section or regularly scheduled maintenance project whichever occurs first.

C.1.3 Guy Markers

Per NESC Rule 264E, the ground end of an anchor-guy exposed to pedestrian traffic shall be provided with a substantial and conspicuous marker. Xcel Energy requires guy-markers installed on all guy-wires.

C.1.4 Grounding

To protect a person on the ground from contacting an energized guy-wire, all guy-assemblies shall be bonded to the ground wire of the pole.

C.2. Design

The purpose of structure guying is to keep a structure in a vertical position when loads due to line angle and wind are applied. The strength of the guy-assembly must be sufficient to support these loads. Typically, a guy-assembly consists of a length of cable with one end attached to the pole near the attachment point of the shield wire or conductor and the other end attached to an anchor embedded in the ground.

Guy wires that cycle through zero stress will fail – keep them under tension always. If positive tension cannot be maintained due to structure or anchor settlement then there will be trouble some day; vendors recommend a minimum tension of 10% RTS. On angle structures, the design engineer must perform a review of all conditions at which transverse wind blows into the guy-wire causing it to unload and subjecting the pole to material bending.

The analysis of single pole guyed structures is based either on bending stress just above the highest guy-attachment and/or Euler long column buckling theory. If the structure has more conductor attachments than guy-wires and the highest guy-attachment is below the lowest conductor attachment (see figure A), then bending is induced in the pole and it will need to be checked for both bending and buckling. If the structure has the same number of conductor attachments as guy-wires and the conductor attachments are at the same approximate elevations as the guy-wires (see figure B) then the pole just needs to be checked for buckling since no bending is induced. Guy-assemblies (per NESC Rule 261C) when used to meet the strength requirements, shall be considered as taking the entire load in the direction in which they act, when the structure is acting as a strut only. The bending moment capacity of the pole is disregarded in calculating the load in the guy-assembly.

Preface. Specification for Transmission and Distribution Wood Poles

P.1. Purpose

This Specification covers the manufacturing, preservative treatment, inspection and handling of Distribution and Transmission wood poles.

P.2. Applicability

This document is a standard and shall be followed by all employees with XEL Company. Any deviations must be approved by Standards Council.

P.3. Work Flow

P.3.1 Approval

The Xcel Energy Standards Council Sponsors {have / have not} approved this document. This document was set to release on {field}.

Approval	Date	Name	Title

P.3.2 Creation

The following committee wrote this document. The committee forwarded this document to the standards council on {field}.

Approval	Date	Name	Title
		Michael Garrels	Transmission & Substation Standards
		Dave Flaten	Senior Specialty Engineer, Distribution
		Rob Nelson	Project Director, EDM International

P.3.3 Version History

The personnel listed above have approved the following changes.

Date	Version Number	Supercedes	Change
8/31/09			Latest Version

1 Scope

This Specification covers the manufacturing, preservative treatment, inspection and handling of Distribution and Transmission wood poles.

2 General Requirements:

Poles supplied to Xcel Energy shall be in accordance with the American National Standards Institute (ANSI) O5.1, "Specifications and Dimensions of Wood Poles" and American Wood Protection Association (AWPA) standards as referenced herein. The latest version of the standards shall apply unless otherwise specified.

Xcel Energy only accepts full-length pressure treated wood poles.

Manufacturer shall maintain facilities, quality control processes and trained staff to assure compliance with all elements of this specification.

Final inspection will be performed by Xcel Energy or its designated agent either at the manufacturing facility and/or upon receipt to assure compliance of material to this specification.

3 Species Requirements:

Southern yellow pine, lodgepole pine, red pine, western redcedar and Coastal Douglas fir are acceptable species for poles 50 feet in length or shorter. For poles in excess of 50 feet in length, only western redcedar and Douglas fir are acceptable species.

4 Material Requirements:

Materials and methods of manufacturing shall comply with the ANSI O5.1, with the following exceptions:

Knots

Spike knots (sucker knots) are prohibited unless and except it is no wider than 2" and no longer than 4".

Spiral Grain

Spiral grain shall not exceed 1 twist in 20 ft for poles 45 ft and shorter.

Spiral grain shall not exceed 1 twist in 30 ft for poles 50 ft and longer.

SPLITS AND CHECKS

Splits and through checks (two or more checks intersecting at the pith) extending more that 6 ins. from the pole top are prohibited.

5 Manufacturing Requirements:

5.1. Framing:

5.1.1. Unless specified on the purchase order, all poles shall be undrilled.

5.1.2. All drilling specified on purchase order shall be done prior to preservative treatment.

5.1.3. The tops of all poles shall have a flat roof only.

5.1.4. To mitigate top splits, Pole Anti-splitting devices (ASDs), such as the Star Lock or equivalent, shall be placed in pole tops in all Douglas fir and western redcedar species poles in excess of 50 feet in length prior to treatment. ASDs may also be installed in pole tops in shorter poles prior to treatment at the discretion of the pole supplier. The device is not to be used to repair split tops.

5.2. Incising and Through-Boring:

5.2.1. Western redcedar poles shall be incised to a depth no less than 0.75 in. and the area shall be 3 ft above to 3 ft below the specified groundline.

5.2.2. Douglas fir poles 40 feet in length and longer shall be through-bored prior to treatment in accordance with Drawing 1. Through-bored poles shall use holes one-half (1/2) in. in diameter and spaced per Drawing 1 Through-Boring Specification. All poles shall be drilled two (2) ft above to four (4) ft below the ground line unless otherwise specified on the purchase order.

5.2.3. If sapwood thickness is less than 7/8 in. in thickness measured near the brand location, the pole shall be full-length incised above the through-bored zone.

5.3. Marking:

All poles shall have two, *non-corrosive* tags stamped with the following information: pole length, class, species code, treatment code, treatment date and supplier's name and plant location. All code lettering of the tag shall comply with the latest revision of AWPA Standard M6. One pole tag shall be placed on the butt of the pole and the other placed on the *face* (concave surface if present) of the pole at a point six (6) ft ± two (2) in. above the standard groundline, as defined by ANSI O5.1 or otherwise specified in the purchase order.

Tags shall be two (2) in. diameter and recessed ¼ in. below the surface of the pole and attached with two, 2-in. aluminum twist nails.

5.4. Seasoning:

5.4.1. The seasoning of all poles shall be as per ANSI O5.1.2008, except as noted below.

5.4.2. Air drying of poles is permitted provided:

a. To prevent the formation of blue stain and decay, the supplier shall, as appropriate, completely saturate the outer surface of poles with a chemical solution as soon as possible after debarking.

b. Poles are stacked so as to allow the free circulation of air around individual poles.

5.4.3. Southern yellow pine poles shall not be air seasoned for more than three (3) months and other pine species shall not be air seasoned for more than ten (10) months.

5.4.4. Southern yellow pine and red pine poles shall be tested randomly prior to treatment to ensure that the moisture content at the mid-point and at the three-inch depth does not exceed 35%.

5.4.5. A combination of Boulton drying, air seasoning, and kiln drying of Douglas fir is acceptable provided that the sterilization requirement of section 6.2 is met.

6 Preservative Treatment:

6.1. Process:

An empty-cell process shall be used to treat the material. Treatment shall be in accordance with the requirements of AWPA Standards U1 for Use Category 4B, and T1-07, except as modified or changed by this Specification.

6.2. Sterilization

Air seasoned poles must be subjected to a heating period sufficient to continuously raise the temperature at the pith center of the largest pole in the charge to a minimum 160°F for a minimum of 75 minutes.

7 Acceptable Preservatives:

7.1. Pentachlorophenol:

Pentachlorophenol (penta) shall meet the requirements of AWPA Standard P-8. It shall be dissolved in hydrocarbon solvent Type A complying with the requirements of AWPA P-9.

7.2. Creosote:

Creosote shall meet the requirements of AWPA Standards P1/P13.

8 Treatment Results:

8.1. Penetration:

8.1.1. Penetration and retention shall be determined from increment borer cores, taken approximately one (1) foot below the brand. Where penetration is difficult to detect, such as in material treated with a light-colored solvent, AWPA Standard A-3 Section 6 shall be used. Where dark-colored solvents are used, a visual examination should be sufficient. Poles that do not comply with the above requirements for penetration shall be rejected but may be retreated provided that the total treatment time does not exceed any heating limitations.

8.1.2. Douglas fir poles shall also have penetration and retention in the through-bored zone determined from increment borer cores taken approximately one (1) foot below the assumed groundline. Borings shall be taken on through-bored poles near the midline of the pole at the location shown in Drawing 2. The increment bore shall be directed parallel to the through borings toward the center of the pole. Penetration of preservative on through-bored poles shall be as specified in Table 1.

8.2. Net Retention:

The net retention of Pentachlorophenol shall be determined in the appropriate assay zone by the lime-ignition method of chemical analysis as indicated in AWPA Standard A5 Section 5, or by x-ray spectroscopy according to AWPA Standard A9. All treatment shall be in accordance with Use Category 4B in sections U1-07 and T1-07. See Table 1 for minimum requirements. Poles that do not conform to the above requirements for retention shall be rejected.

Table 1 - Penetration and Retention Requirements for Treatment of Poles

Category	Southern yellow pine	Lodgepole pine	Red pine	Western redcedar	A.1. Douglas fir
Penetration	3.0" or 90% of sapwood	0.75" or 85% of sapwood	2.5" or 85% of sapwood	0.5" or 100% of sapwood	.75" or 85% of sapwood. 100% in the Through-Bore zone* (see note)
Retention Assay Zone	0.5–2.0"	0.1–0.75"	0.1–1.6"	0.0–0.50"	Outer 0.25–1.0" Inner 3.0--3.5"
Retention (lbs/cubic ft of wood)					
Creosote	7.5	12.0	10.0	20.0	Outer zone - 9.0 Inner zone - 4.5
Pentachloro-phenol	0.38	0.60	0.50	1.0	Outer zone - 0.60 Inner zone - 0.30

*Douglas Fir Through Boring Note: In the through boring zone, there will 100 % penetration to pith center. Core may reveal only one annual ring skip in the 4" to pith center zone. Cores must be to the pith center or at least a minimum of 10 inches long for poles larger than 20 inches in diameter.

8.3. After Treatment Moisture Content:

The average moisture content after treatment for Douglas fir poles, using a moisture meter fitted with insulated probes inserted to a depth of 2 inches at the mid-point of the pole, shall not exceed 22%. Poles shall be tested randomly, after treatment, to ensure compliance.

8.4. Retreatment:

Rejected poles may be retreated one time provided the temperature and pressure limits applying to the original treatment apply to retreatment and do not exceed maximums allowed in AWPA. Retreated material shall be inspected the same as when material was originally treated.

8.5. Pole Appearance:

When creosote, creosote solutions, or oil borne preservatives are used, material should be supplied reasonably free of exudates and surface deposits. The surface appearance can be inspected using the BMP (Best Management Program) Quality Assurance Inspection Program. The exudates may evaporate, remain liquid and greasy, or harden into a semisolid or solid state.

The preservative solution and the process for Pentachlorophenol treatment shall be such that the surface of all poles shall be reasonably clean, dry, and free from blooming (crystallized penta on the pole surface). Poles exhibiting evidence of bleeding or otherwise out of compliance with the *appearance* requirements shall be rejected.

9 Cleaning:

At the supplier's option, the poles rejected for cleanliness may be offered for inspection after they have been cleaned. To be accepted, poles must comply with the *appearance* requirements, Section 8.5.

10 Inspection:

Plant inspection, by the supplier, of 100% of the poles in the white wood stage and after treatment to ensure compliance with the above requirements is mandatory. Evidence of these inspections should be maintained by the Supplier for review.

At Xcel Energy’s discretion poles may be inspected at the supplier’s yard by Xcel Energy or its designated representative. Inspection shall be performed in accordance with AWPA Standard M-2 except where modified or amended in this Specification. Inspectors shall stamp their mark on the top of the pole for material approval and on the butt for approval of treatment. Test borings in all respects shall be made in accordance with this Specification. Borings shall be furnished to Xcel Energy or its representative when requested.

11 Reports:

11.1. Supplier

Upon request, the supplier shall furnish (for mailing to Xcel Energy or its representative) one copy of the treating report. When a kiln drying is used, a copy of the kiln chart or schedule shall be supplied.

11.2. Inspector/Designated Representative:

Upon request, the following information shall be made available:

- One (1) complete inspection report for every accepted charge of poles treated for the purchaser.
- One (1) shipping report for every carload of poles shipped to the purchaser.
- One (1) complete inspection report for every charge of poles not accepted.
- One (1) copy of the chemical analysis work sheet or if an X-Ray analyzer is used for retention analysis, a printout (or legible copy) shall be supplied as a part of each inspection report.

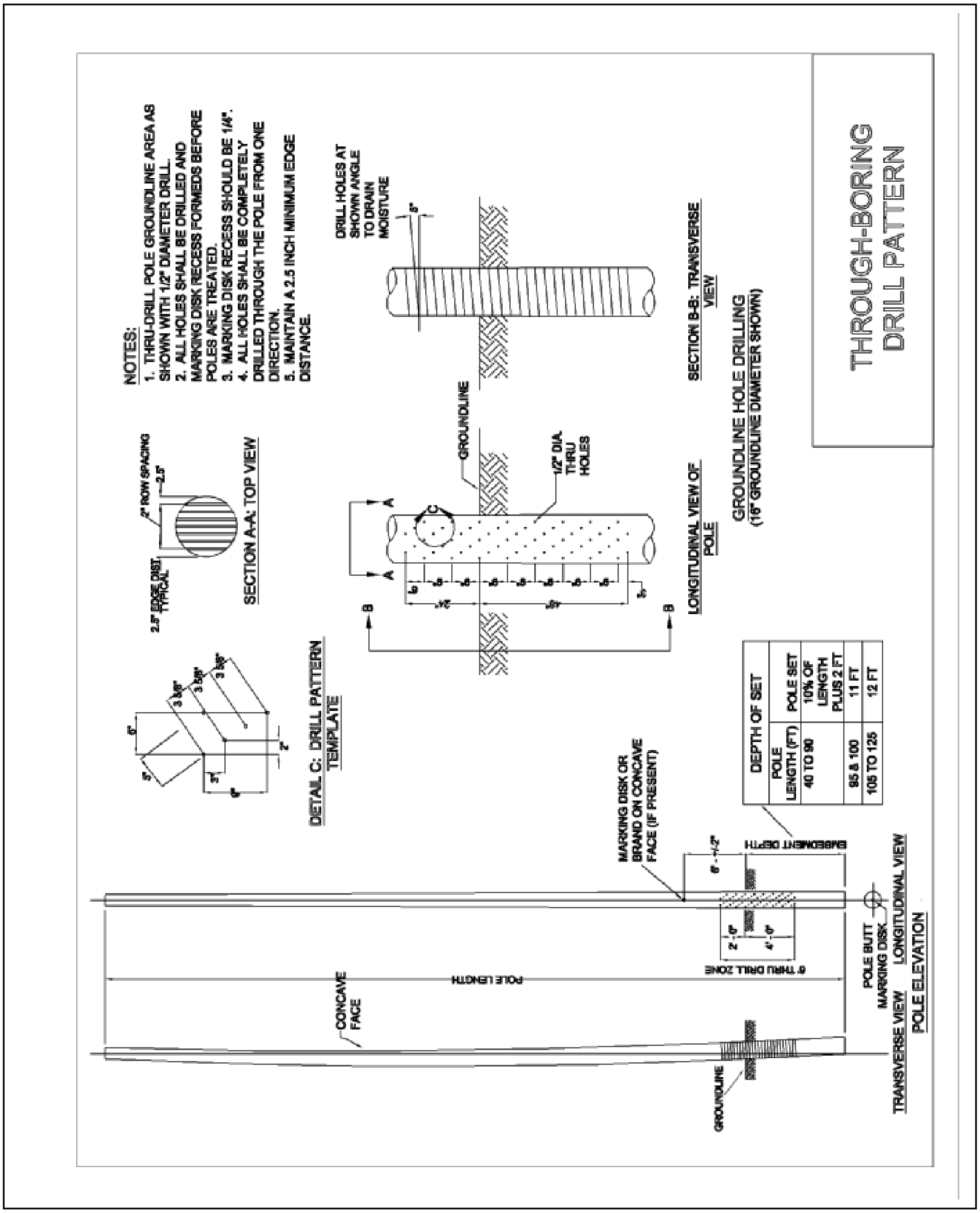
Included in the reports shall be sapwood and preservative penetration measurements, treatment retention by charge, and the number and cause for all rejected poles. Each shipping report and invoice shall show the material Purchase Order number and release number. The shipping report shall show the street address of the delivery point for the poles. All reports shall be mailed upon request to the appropriate party.

12 Shipping:

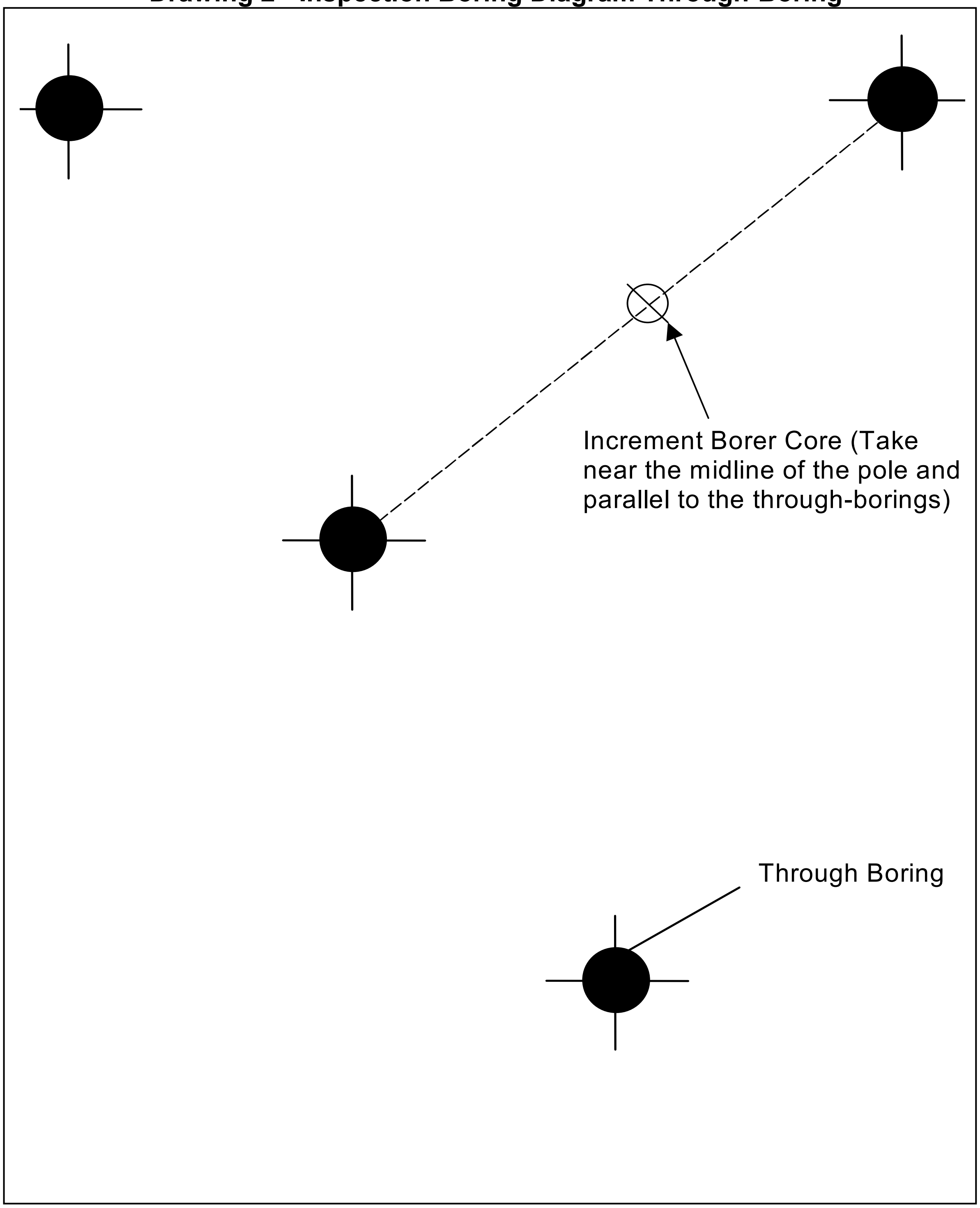
All poles shall be shipped by either rail or trucks. When poles are shipped via rail and Xcel Energy is responsible for the unloading, the poles shall be loaded on flat cars in accordance with the latest edition of the "Rules of the Mechanical Division of the Association of American Railroads Governing the Loading of Commodities on Open Top Cars". All rail cars shall have a card showing the street address of the delivery point attached to the poles at a point near the center of the load on the side of the rail car.

Attachments:

Drawing 1 Through-Boring Drill Pattern



Drawing 2 - Inspection Boring Diagram Through-Boring



Preface

P.1. Scope and Purpose

This specification covers the minimum requirements for furnishing all material, labor, and equipment necessary to design and fabricate tubular steel transmission pole structures for use by Xcel Energy. This includes poles for use under property unit 6460816409, arms under property unit 6460817409, and anchor bolt cages for use under property unit 3580274409.

This specification covers the technical aspects of design, materials, fabrication, welding, inspection, protective coatings, Vendor's drawings, and delivery of welded tubular steel pole structures for overhead electrical transmission and distribution lines. This specification does not include contract pricing (front-end) documents or specifications for construction.

P.2. Responsibilities

All Xcel Energy personnel and contractors shall use this document and the procedures herein when purchasing and designing tubular steel transmission pole structures. Xcel Energy is responsible for supplying configuration drawings and load requirements adequate for the design of steel transmission pole structures. Xcel Energy is responsible for reviewing Vendor design calculations, drawings, and test reports in a timely manner.

The Vendor shall use this document and the procedures herein to design and fabricate all tubular steel transmission pole structures for Xcel Energy. Xcel Energy will not allow exceptions to this document unless submitted in writing.

P.3. Work Flow

P.3.1 Approval

The Xcel Energy Standards Council has approved this document.

Approval	Name	Title
2014/11/03	Cozad, Brad D	Manager Transmission Engineering, PSC
2014/10/30	Dunham, Michael P	Manager Trans Line Const. & Maint, NSP
2014/11/04	Kunze, Robert H	Manager Strategic Sourcing
2014/10/30	Urban, Paul J	Manager Trans Line Const. & Maint, PSC
2014/11/06	Winter, Kent G	Manager Transmission Engineering, SPS
2014/10/31	Woodard, James C	Manager Trans Line Const. & Maint, SPS
2014/10/30	West, Julia A	Manager Safety & Training

P.3.2 Creation

The following committee wrote this document:

Name	Title
Brad Hill	Engineer, NSP
Mark Flashinski	Engineer, NSP
Eliot Fisher	Engineer, SPS
Tim Wachholz	Engineer, Xcel Energy
Cary Yuan	Engineer, PSCo
Mike Garrels	Engineer, Transmission Standards
Stacey Barajas	Strategic Sourcing

P.3.3 Version History

The personnel listed above have approved the following changes.

Date	Version Number	Change
25 July 2012	1.0	Initial Version
10 November 2014	2.0	Contract revision Supersedes the following: NSP-STD-STEEL POLE STRUCTURES PROCUREMENT PSC-STD-Specification of Tubular Steel Pole Structures SPS-STD-STEEL POLE STRUCTURES

Table of Contents

1 Overview

1.1. Philosophy

The design, fabrication, allowable stresses, processes, tolerances, and inspection shall conform to the American Society of Civil Engineers (ASCE) Standard 48, "Design of Steel Transmission Pole Structures," with the additions and/or exceptions as described herein. This document lists minimum design parameters to be used unless project specific submittals indicate otherwise.

The steps for design, fabrication, and shipping of the steel structure shall be as described in Figure 1. Proceeding to subsequent steps without review by Xcel Energy will be at the Vendor's risk.

	Xcel Energy Responsibilities	Vendor Responsibilities
Structure Design	Prepare and Submit Design Loads and Structure Configuration Drawings Review and File Design Calculations, provide extended Anchor Bolt length (if applicable)	Prepare and Submit Design Calculations
Detailing	Review and File Anchor Bolt & Structure Assembly Drawings	Prepare and Submit Anchor Bolt & Structure Assembly Drawings
Fabrication	Review and File Material Test Reports, Plant audit (if desired)	Fabricate Anchor Bolts & Structures, Prepare and Submit Material Test Reports
Shipping & Installation	Receive and Install Structure	Load and Ship Structure

Figure 1: Process for steel pole design and purchasing. Anchor bolt drawings, fabrication, and delivery may precede the structures for construction and sequencing.

1.2. Glossary

Anchor Bolt

High strength threaded deformed reinforcing steel bar used to transfer loads from the pole base-plate to the concrete foundation.

Arm

Tubular structural element in predominantly horizontal orientation that supports shield wires or phase wires. Arms attach to the face of pole shafts. Arms may be uniform and attached at each end to multiple pole shafts or tapered and attached at one end.

Base-Plate

Plate attached to the bottom of the pole shaft with a full penetration weld and attached to a concrete foundation with anchor bolts.

Camber

Pole curvature, induced in fabrication, used to counteract predetermined pole deflection, such that the pole will appear straight under a specified load condition.

D/t

Ratio of the diameter of a tubular pole, or flat to flat outside diameter for polygonal pole of more than 16 sides to wall thickness

Flange Plate

Connection plate element welded to the end of pole sections and used to connect adjacent pole sections. Connection includes an equally spaced series of bolts installed through both plate elements with a recommended bolt pre-tension load.

Ground-Line

A designated location on the pole where the surface of the ground will be after installation of a direct embedded pole.

Pole Shaft

Tubular structural element in a predominantly vertical orientation, which supports wire loads with davit arms, cross arms, swinging angle brackets, or vangs, and may be freestanding or guyed.

Slip Joint

Connection of two tapered, tubular pole shaft sections where sections telescope together.

Structure

A structure consists of one or multiple tubular steel pole and all attachments, including vangs, arms, braces, brackets, anchor bolt cages, etc., supporting one or more circuits of conductors and static wires.

Swinging Angle Bracket

Support for a conductor insulator to provide adequate air gap to arm above, found on pole shafts or at the end of a davit arm.

Twist

The as-constructed angle from centerline of the arm or vang appurtenance to the theoretical location of the design reference line of the arm/vang appurtenance on the base-plate before the arm or vang is loaded.

Vang

Attachment plate used to attach shield wire or conductor insulator located either on pole shaft or on arm.

Vendor

Party named on the Purchase Order who shall be responsible for designing, fabricating, and delivering the structures covered by this specification. Work done by a subcontractor of the Vendor is the responsibility of the Vendor.

WPS

Welding Procedure Specification: the detailed essential variables, methods and practices including all joint welding procedures involved in the production of a weldment.

w/t

Ratio of the flat width to the plate thickness of a flat side of a polygonal pole.

Xcel Energy

Party on purchase order that shall be responsible for requesting and receiving structures covered by this specification. This may refer to Xcel Energy, its wholly owned subsidiaries Northern States Power Company (NSP), Public Service Company of Colorado (PSCo), and Southwestern Public Service Company (SPS) or any agents on its behalf. Its agents include staff employees, outside consultants and their duly authorized assistants and representatives.

1.3. References

Codes, standards, or other documents referred to in this specification are part of this specification, as are documents referred to in those references, etc. Unless otherwise indicated in this specification, the current edition of these references as of the date of the contract documents shall govern.

In the event of conflict between this specification and referenced documents, the requirements of this specification shall take precedence. In the case of conflict between several referenced documents, the more stringent requirement shall control. If a conflict exists between this specification, the referenced documents, or the supplied drawings, the supplied drawings shall control.

The following codes and standards are part of this specification:

- ASCE 48 Design of Steel Transmission Pole Structures
- ASTM A6/A6M Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105·ksi Minimum Tensile Strength
- ASTM A350 Standard specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
- ASTM A354 Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs and Other Externally Threaded Fasteners
- ASTM A370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- ASTM A385/A385M Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)
- ASTM A388 Standard Practice for Ultrasonic Examination of Steel Forgings
- ASTM A500/A500M Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
- ASTM A563 REV A Standard Specification for Carbon and Alloy Steel Nuts
- ASTM A572/A572M Standard Specification for High-Strength Low-Alloy Columbium Vanadium Structural Steel
- ASTM A588/A588M Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50·ksi [345·MPa] Minimum Yield Point, with Atmospheric Corrosion Resistance
- ASTM A615/A615M Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
- ASTM A633/A633M Standard Specification for Normalized High-Strength Low-Alloy Structural Steel Plates
- ASTM A666 Standard Specification for Annealed or Cold-Worked Austenitic Stainless

Steel Sheet, Strip, Plate, and Flat Bar

- ASTM A673/A673M Standard Specification for Sampling Procedure for Impact Testing of Structural Steel
- ASTM A780/A780M Standard Practices for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
- ASTM A847/A847M Standard Specification for Cold-Formed Welded and Seamless High-Strength, Low-Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance
- ASTM A871/A871M Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance
- ASTM A1066/A1066M Standard Specification for High-Strength Low-Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)
- ASTM E165/E165M Standard Practice for Liquid Penetrant Examination for General Industry
- ASTM E709 Standard Guide for Magnetic Particle Testing
- ASTM F436 Standard Specification for Hardened Steel Washers
- ASTM F1554 Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
- AWS C2.16 Guide for Thermal Spray Operator Qualification
- AWS C2.18 Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites
- AWS D1.1/D1.1M Structural Welding Code - Steel
- AWS QC1 Standard for AWS Certification of Welding inspectors
- NEMA CC 1 Electric Power Connections for Substations
- SSPC SP 1 Solvent Cleaning
- SSPC SP 7 Brush-off Blast Cleaning - NACE No. 4
- SSPC SP 8 Pickling
- SSPC SP 10 Near-White Blast Cleaning

2 Design

2.1. Process

2.1.1. Xcel Energy Submittals

Xcel Energy will provide the Vendor with design loads and geometric configuration drawings per ASCE 48 Chapter 4. Any design parameters not listed in this specification, ASCE 48, or the Xcel Energy submittals shall be at the discretion of the Vendor.

Xcel Energy provides configuration drawings as conceptual and dimensional guides. Vendor shall maintain outline dimensions as shown on Xcel Energy's detail drawings. Material dimensions presented on drawings are for guide purposes and the Vendor may deviate from them as necessary.

Xcel Energy will review the Vendor submittals. Review by Xcel Energy does not relieve the Vendor of the responsibility for the adequacy of the design calculations.

2.1.2. Vendor Calculations

The structure shall be capable of withstanding all specified loading cases, including secondary stresses from foundation movements, deflections, or apparatus loads, but not considering the possible restraining effect of conductors or shield wires. The structure shall withstand the loads without failure, permanent distortion, or exceeding any specified deflection limitations.

The Vendor shall design poles to resist, in addition to all other loads and their appropriate overload factors, the effect of deflection on all vertical loads including the dead load of the pole. The flexibility of the structure shall not reduce the specified longitudinal loads.

The Vendor shall furnish to Xcel Energy a complete set of loading calculations used in the design of each individual structure or structure family. Calculations shall include applied loads and dimensions used in final design of pole shaft, base-plate, anchor bolts, and arms. The Vendor shall supply the following information:

- Geometry, material thickness, section properties, deflections, stresses, and forces in the X and Y directions, w/t for polygonal and D/t for round cross-sections at all splices, ends of members, and at arm attachment points (top and bottom), and at least every 10-ft along the pole.
- List of materials with weights of all sections, base-plate, and anchor bolts - with appropriate ASTM specifications for the materials used.
- Ground-line reactions due to all loads for all load combinations.
- Base-plate configurations and bolt spacing.
- Anchor bolt lengths, sizes, quantities, type of materials and safety factors.

The design calculations shall be the responsibility of the Vendor. Vendor shall indicate the source of the analysis and the design of the structure if the Vendor does not perform it in-house.

The Vendor shall submit one electronic portable document format (PDF) copy of design calculations for review by Xcel Energy for each structure design or family. Vendor shall provide a table of contents for submittals that contain calculations for more than one structure.

If the Vendor believes that it would be advantageous to deviate from the requirements specified, then the Vendor may submit such alternatives. The Vendor shall indicate such alternate calculation packages with an estimate of cost or lead-time savings.

2.2. Design Restrictions

2.2.1. Material

Computed unit stress under the full design load shall be less than the minimum specified material properties as stated in the applicable ASTM specifications. Allowed grades of steel for galvanized structures are limited to ASTM A350, ASTM A572, ASTM A633, and ASTM A871. Allowed grades of steel for weathering structures are limited to ASTM A871, ASTM A588, and ASTM A1066. The Vendor shall design pole shaft and arm components with a minimum wall thickness of 3/16·in.

2.2.2. Pole Shaft Joints

The Vendor shall design the pole shaft with as few pieces as practicable for shipping and field assembly. Pole shaft joints for Xcel Energy to assemble in the field shall be slip joints or bolted flange joints. All switch poles shall have flanged joints. All other pole shaft joints shall be slip joints unless otherwise indicated on Xcel Energy submittals.

2.2.3. Deflection

Deflection at the top of the structure shall not exceed 2% of the structure height under the deflection load case unless otherwise indicated on Xcel Energy submittal.

2.2.4. Camber

The Vendor shall camber the pole if deflection of the top of the pole shaft under the camber load case is greater than one-half of the pole top diameter. The camber shall be the calculated deflection plus the tolerances specified in section 3.2.1.

2.2.5. Tolerances

The phase-to-phase and phase-to-ground dimensions on the Xcel Energy submittals are minimums. The Vendor shall account for cumulative fabrication and installation tolerances from foundation, pole shaft, joint slip, connections, and arms to maintain these design dimensions. Tolerances on loads shall be as indicated in Xcel Energy submittals.

2.3. Foundation Restrictions

2.3.1. General

For all load cases, the Vendor shall include a foundation rotation from vertical of 1.5° unless otherwise stated on the Xcel Energy submittal.

2.3.2. Direct Embedment

Direct embedded structures shall have a solid bearing plate not more than 2·in greater than the pole base diameter. (Any holes for drainage shall be in shaft walls.)

2.3.3. Foundation Supported

For structures indicated as such the Vendor shall design a base-plate and anchor bolt arrangement to resist the ground-line loads induced by the pole. The Vendor shall design base plates such that the design moment load may be applied in any direction, regardless of the base plate orientation.

The Vendor shall design the anchor bolt cluster such that the required strength is satisfactory to withstand all design conditions and tolerances without requiring the use of grout or other similar material between the base-plate and top of concrete. The design shall assume a clear space between the top of the foundation and the bottom of the base-plate equal to 2·in plus the height of the leveling nut. The minimum anchor bolt projection out of the top of concrete shall be 12·in unless otherwise indicated in the Xcel Energy submittal. Concrete strength to be used for anchor bolt design shall be as noted on the Xcel Energy drawings.

The Vendor shall supply anchor bolt patterns as specified on the Xcel Energy drawings. The Vendor shall provide an optimum bolt pattern based on minimum structure cost, and when requested, the Vendor shall provide an optimum bolt pattern minus 6·in, or an optimum bolt pattern minus 12·in. Xcel Energy will select the structure design based upon the economics of the total combined installed cost of the structure and foundation.

For design requirements pertaining to poles installed on drilled piers, detailing, fabrication, and acceptance criteria for anchor bolt cages, see Appendix A.

3 Detailing

3.1. Process

3.1.1. Xcel Energy Review

Xcel Energy will provide the Vendor with detail requirements concurrently or separately from the geometric configuration drawings. Any detailing not listed in this specification, ASCE 48, or the Xcel Energy submittals shall be at the discretion of the Vendor.

Xcel Energy will review the Vendor assembly drawings. Review of the drawings by Xcel Energy does not relieve the Vendor of responsibility for the adequacy of the design, correctness of the dimensions, details on the drawings, and the proper fit of parts. Material ordering and fabrication prior to Xcel Energy review will be at Vendor's risk.

3.1.2. Vendor Assembly Drawings

The Vendor shall furnish to Xcel Energy a complete set of assembly drawings used in the design of individual structures or structure families. Assembly drawings shall include final drawings and calculations for pole shaft, base-plate, anchor bolts, arms, and other appurtenances – including their connections – for all structures. The Vendor shall submit one electronic portable document format (PDF) copy of assembly drawings for review by Xcel Energy for each structure design or family. Drawings shall utilize Xcel Energy title blocks and drawing numbering as noted in the Xcel Energy submittal. Vendor title blocks may be used in addition to the Xcel Energy title blocks and shall be suitable for including a table of revisions. Drawing numbers shall be suitable for indexing and cross-referencing.

Assembly drawings shall show, as a minimum, the following information:

- Structure type
- Structure geometry, including pole height, phase spacing, arm length, design line angle
- Maximum design reactions at base
- Tube section data (tube length, plate thickness, large and small end OD, taper)
- Materials of construction
- Pole camber
- Bill of materials required for erection
- Individual weights of all components and the total weight of the structure
- Size and number of bolts, nuts and washers required for each connection
- Entire assembled structure, including pole shafts, arms, vangs, etc., shall be shown on a

single sheet indicating their position

- All erection procedures including bolt tensioning and slip joint jacking procedures

The Vendor shall furnish PLS-Pole back-up models of each structure prior to commencing fabrication of individual structures.

3.2. Structures

3.2.1. General

When fully assembled, structures shall meet the following tolerances:

- Straightness or camber in 10·ft: +1/8·in, -1/8·in
- Total straightness or camber: +3·in, -0·in

3.2.2. Identification

Each structure shall be permanently marked with a structure identification plate on the pole shaft at 60·in above ground-line. The marking shall include the following information:

- Structure Identifying Number
- Structure Height
- Structure Type
- Date of Fabrication
- Vendor Name
- Vendor serial number
- Ground-line Moment in ft-kips

Xcel Energy uses the following as Structure Identifying Numbers:

- NSP OpCo = Xcel Energy's item number - from the Owner supplied drawings.
- PSCO OpCo = Structure number.
- SPS OpCo = Vendor's pole number - from the assembly drawings.

When indicated on Xcel Energy submittals, structures shall also have brackets for aerial markers or welded nuts for number signs.

Positioning of identification plates shall be to the following tolerances:

- Location of Identification plate or bracket: +24·in, -24·in

Characters shall be at least 3/8·in tall, and shall be clearly legible after finishing.

3.3. Members

3.3.1. General

All longitudinal welds on tubular members shall be at least 80% penetration welds. For at least 6·in from the end of each pole shaft section – and within 6·in of circumferential butt welds – longitudinal welds shall be 100% penetration welds. In the female slip joint area (up to maximum overlap), longitudinal welds shall be 100% penetration welds up to maximum overlap length. 100% penetration welds shall be provided at all butt joints of backup strips and at circumferential welds joining structural members.

The Vendor shall fabricate members to the following tolerances:

- Arm length per 10 ft of arm length: +1·in, -1·in
- Arm rise per 10·ft of arm length: +1·in, -1·in
- Length of individual section: +3·in, -3·in
- Dimension of major axis, minor axis or diameter: +1/2·in, -1/4·in
- Total twist of members (per 10·ft of length): +1°, -1°

3.3.2. Identification and Marking

Each separate part of the steel pole structure (arms, pole shafts, etc.) shall be permanently marked to identify the type, structure, and position of the piece on the structure. The vendor shall weld one (1) nameplate on the lower end of each member. Characters shall be at least 3/8·in tall, and shall be clearly legible after finishing. For multi-section poles, the vendor shall install all nameplates on the same flat from pole top to bottom. This nameplate shall include:

- Vendor unique identifier to match with inspection reports
- Type identifier to match with assembly drawing

Identifiers shall be temporarily marked on the bottom of each pole shaft's bearing, flange, or base-plates to aid in delivery and storage. Identifiers shall be temporarily marked on each end of all davit arms to aid in delivery and storage.

Center of gravity shall be temporarily marked on at least two sides of each member to aid in handling and assembly.

3.3.3. Arm Connections

Arm connections to the pole shaft may be pinned or bolted, at the discretion of the Vendor. Pin fasteners shall utilize through bolts at ends to prevent pin removal with ANCO® lock nuts (or equivalent ratcheting style). Cotter pins, cotter keys, and common keeper pins are not acceptable. Structural pins shall have tapered ends to aid in connection fit-up.

Arms connected to two or more pole shafts shall be detailed with slotted holes or multiple holes to allow for construction tolerances to aid in field erection

Detail design of arms and pole shafts by the Vendor shall minimize the effects of biological and environmental damage. At arm end openings and at channel or box arm connections to thru vangs, provisions are required for openings greater than 1·in in any dimension to eliminate access by birds and nesting insects, and to minimize moisture retention. The vendor shall submit these details in the fabrication drawings to Xcel Energy.

The Vendor shall fabricate arm connections to the following tolerances:

- Outer dimension of inside piece of fitting pieces: +0·in, -1/8·in
- Inner dimension of outside piece of fitting pieces: +3/16·in, -0·in
- Deviation from flat of mating flat pieces in 12·in: +1/8·in, -0·in
- Spacing between holes of same connection: +1/16·in, -1/16·in
- Hole size for connection bolts or pins: +1/16·in, -0·in
- Position of arm connection relative to pole shaft: +3/4·in, -3/4·in
- Twist of arm connection relative to pole shaft center line: +2°, -2°

3.3.4. Slip Joints

Slip joints shall be marked for ease of assembly in the field. The male end shall be marked with design, maximum, and minimum insertion depths.

- Minimum slip joint – 1.5 times the maximum diameter
- Design slip joint – Minimum * 1.1
- Maximum slip joint – Design slip +5·in

The Vendor shall weld nuts (lugs) as shown on Xcel Energy submittals to provide capability to jack structure sections together. The Vendor shall provide locking devices as necessary to counteract uplift and other motion.

3.3.5. Flange Plates and Base-Plates

Circumferential welds connecting flange plates or base-plates to pole shaft shall be complete penetration welds. The Vendor shall match mark base-plates to anchor bolt template, and flange-plates to flange plate connections.

Positioning of flange and base-plates shall be to the following tolerances:

- Plate diameter: +1·in, -1/4·in
- Base-plate perpendicular to pole 1/8·in for 5·ft as measured on a perpendicular axis.

- Deviation from flat of plates in 12·in : +1/8·in, -0·in
- Spacing between holes on plates (non-accumulative): +1/16·in, -1/16·in
- Hole sizes in flange plates: +1/8·in, -0·in
- Hole sizes in base-plates: +3/8·in, -0·in
- Height of assembled structure (with flanges): +12·in, -6·in
- Total twist of base plate from center line: +2°, -2°

3.3.6. Detailing for Maintainability

The Vendor shall design tubular members of galvanized poles to minimize environmental degradation. Galvanized poles shall have a drain hole at the bottom. Galvanized arms shall have drain holes where appropriate. Galvanized poles shall have a metal cap plate covering the entire pole shaft opening to minimize wind noise and rain entry. For members of galvanized structures with openings greater than 1·in wide, the Vendor shall cover the openings to eliminate bird or pest entry.

The Vendor shall design tubular members of weathering steel to minimize environmental degradation. The Vendor shall design weathering steel pole shafts so that they are sealed against moisture penetration once erected. The Vendor shall provide airtight seal on both ends of the bottom pole section and all arms. The Vendor shall seal the upper end of the top pole section. The intermediate pole ends do not need to be sealed. The Vendor shall seal all weathering steel arms. The Vendor shall sleeve all drilled holes in weathering steel members. The Vendor shall detail weathering steel structures to avoid uncoated pockets, crevices, and faying surface that can collect and retain water, damp debris, and moisture.

Poles for direct embedment shall have a corrosion collar (ground sleeve) welded at the ground-line. Corrosion collars shall have a minimum thickness of 3/16·in. Corrosion collars shall have a length of at least 4·ft, and have 2·ft above ground-line and 2·ft below ground-line, unless otherwise indicated on Xcel Energy submittals. The Vendor shall seal weld the corrosion collar to the pole shaft to prevent moisture intrusion.

3.4. Appurtenances

3.4.1. General

Hardware attachments such as vangs, equipment brackets, end plates, swinging angle brackets, insulator attachments, and other appurtenances shall be provided when listed on Xcel Energy submittals. Holes and cuts shall be true to size, smooth, and clean without excessive tear-out or depressions. Burrs that remain after machining shall be removed by grinding, reaming, etc. The Vendor shall not perform field fabrication without approval from Xcel Energy.

Fabrication of appurtenances shall be to the following tolerances:

- Size of Chamfer: +1/32·in, -1/32·in
- Drilled Hole Sizes for Bolts and Attachments: +1/16·in, -0·in
- Hardware attachment locations relative to pole top: +2·in, -2·in
- Length and Width of Plates: +1/2·in, -1/2·in
- Location of a Drilled Hole in a Piece: +1/16·in, -1/16·in

3.4.2. Fasteners

Minimum bolt diameter for use in attaching arms, flanges, and other appurtenances shall be 5/8·in. The Vendor shall furnish bolts of sufficient length to assure full thread engagement of the nut during field assembly.

All bolts shall conform to ASTM A354 or ASTM A325. All washers shall conform to ASTM F436. All nuts shall conform to ASTM A563. The supplier shall furnish ANCO® lock nuts (or equivalent ratcheting style) for all structural and keeper bolts. Surface finish of nuts, bolts, and washers shall conform to the finish of the structure.

3.4.3. Climbing Devices

Pole shafts shall have ladder attachment clips or step lugs where indicated on Xcel Energy submittals. Ladders shall be “McGregor” type ladders or equivalent. The Vendor shall space the ladder attachment clips to avoid interference with the jacking device at pole splices. The Vendor shall place clips for ladders on one face of the pole from the top of the pole to approximately the ground-line or base-plate. The Vendor shall place clips on three additional faces from the top of the pole to approximately 10·ft below the bottom conductor attachment unless otherwise indicated on Xcel Energy submittals. Clips shall be evenly spaced around the diameter of the pole.

Each ladder clip shall support a minimum 1000·lb. vertical load and a minimum 200·lb. horizontal working load. The Vendor shall weld ladder clips to the pole surface. Ladder clips shall be located to avoid interference between ladders and other attachments. Ladder clips shall provide maximum safety, minimal projection beyond the pole shaft surface, minimum opportunity for corrosion, and shall not permit air to enter the pole shaft.

Arms or other non-vertical members shall have climbing devices if detailed on Xcel Energy submittals.

Positioning of ladder clips shall be to the following tolerances:

- Spacing between independent ladders: +3·in, -0·in
- Spacing of ladder lugs or climbing loops: +1/8·in, -1/8·in

3.4.4. Grounding Devices

The Vendor shall provide NEMA terminal pads per the dimensions described in NEMA CC-1 Annex A for grounding of the structure at all structure ground-lines, shield wire attachment points, and bolted or pinned armed connections. The Vendor shall also provide NEMA pads at flanges and slip joints on weathering steel structures.

The pads shall be stainless steel plate welded to the structure with holes tapped to a depth of at least 1/2·in. The default size shall be two-hole pads unless Xcel Energy submittals indicate otherwise. The Vendor shall not paint or cover grounding devices with any coating, and shall remove galvanizing, to shiny surface, from terminal pads on galvanized structures. For poles with base-plates, the pad shall be located 18·in vertically above the base-plate. For poles with corrosion collars, the pad shall be located 6·in vertically above the corrosion collar.

The Vendor shall provide personnel grounding loops below each conductor attachment. Personnel ground loops shall be 3/4·in diameter, stainless-steel rod. Ground loop shall be 1·ft long and project from the pole 4·in. The Vendor shall remove galvanizing, to shiny surface, from personal grounds of galvanized structures.

3.4.5. Lifting Devices

The Vendor shall provide instructions for the handling and assembly of structures. The Vendor shall provide lifting lugs or rigging holes in appropriate locations on all pole shaft sections. On single piece pole shafts and the top section of multi-piece pole shafts, the Vendor shall provide two (2) vangs at the top end of the top pole section for lifting purposes. These vangs are to be located on opposite faces that are parallel to one side of the base-plate, if possible. The Vendor may design static wire vangs to support the total weight of the structure for use as lifting vangs. The Vendor shall provide two (2) holes 2-1/2·in diameter at the top end of the base and middle pole sections for lifting purposes. These holes are to be located on opposite faces parallel to one side of the base-plate.

4 Fabrication and Quality Control

4.1. Process

4.1.1. Xcel Energy Review

Quality assurance by Xcel Energy of steel structures will occur by any or all of the following:

- Qualification of individual Vendor plants by periodic or random audits, inspections, and witnessing by Xcel Energy or third party to ensure compliance with the requirements of the specification, codes, and procedures. Xcel Energy shall have access to all parts of the Vendor's plant, which concerns the fabrication of structures under purchase. Plant inspections may be planned or unplanned.
- Review of material test reports and quality control records or other information for all major components and anchor bolts cages. Vendor shall make available material test reports and quality control records upon request for 10 years from installation.
- Random or systematic field inspections of staged or installed structures by Xcel Energy or third party.

Failure of Xcel Energy to exercise the right to inspect, witness, or audit prior to shipment shall not relieve the Vendor of the obligation to comply with the terms and conditions of the purchase order.

4.1.2. Vendor Reports and Quality control records

The Vendor shall be responsible for all quality control. Upon request, the Vendor shall clearly define their quality control functions, and provide quality control manuals for review by Xcel Energy or third party. The Vendor shall maintain permanent records of all pertinent information on materials, welding procedures, welder identification, type of inspections, inspector's test result, all visual and nondestructive testing, and other items.

The Vendor shall give written notice to Xcel Energy upon significant process changes including change of primary manufacturing plant for Xcel Energy projects, change of material, and change of welding procedures. A change of manufacturing plant shall include any manufacturing plant not used for Xcel Energy projects in the past two years. For commonly used plants, the Vendor shall provide scheduling information upon request to allow for manufacturing plant audits. The Vendor shall provide notice sufficiently in advance of the start of fabrication to permit Xcel Energy to make arrangements for inspection of facilities, materials, and fabrication methods.

The Vendor shall furnish upon request to Xcel Energy a quality control record for each major component shipped indicating materials, welding procedures, welder's identification, type of inspection, inspectors test results, records of all visual inspection and nondestructive testing, inspectors' identification and other items agreed upon between Xcel Energy and the Vendor.

Test reports include mill test reports, and Charpy test reports as described in Section 4.2. Inspection reports include but are not limited to quality control records, weld inspection reports, and coating thickness reports as described in Section 4.4.3 and Section 4.4.4.

4.2. Material Testing

4.2.1. Chemistry

The Vendor shall provide test reports indicating compliance with the chemistry requirements of ASTM A572, ASTM A588, ASTM A633, ASTM A847, ASTM A871, or ASTM A1066 for all plate used in arms, pole shafts, flanges, vangs, and base-plates. Any deviations from these compositions – such as for “roll forged plate” – shall be approved for use in writing by Xcel energy.

The Vendor shall use these test reports to reject material under the following circumstances:

- The Vendor shall reject material with high carbon equivalent for weldability. The Vendor shall reject ASTM A572 and ASTM A633 material with a carbon equivalent greater than 0.50%. The Vendor shall reject ASTM A588, ASTM A871, and ASTM A1066 material with a carbon equivalent greater than 0.60%.
- The Vendor shall manage ASTM A572 and ASTM A633 material based on silicon content to ensure high quality zinc coatings. Recommended values for silicon content are discussed in ASTM A385.

4.2.2. Mechanical Strength

The Vendor shall provide test reports indicating compliance with mechanical requirements of ASTM A6 and their respective standards for all plate used in arms, pole shafts, flanges, vangs, and base-plates. Xcel Energy requires that the mechanical test coupons shall not be heat treated separately from the plate material used.

Xcel Energy requires the Vendor to reject material that does not comply with the following supplementary requirements of ASTM A6:

- S5. Charpy V-Notch Impact Test
  All plate shall have Charpy V-Notch Testing. The frequency of the testing shall be on a heat lot basis. Minimum average absorbed energy shall be 15·ft-lb on full size samples at -20·°F.
- S18. Maximum Tensile Strength
  All plate shall comply with the maximum tensile strength limits stated in ASTM A6 S18. Maximum tensile strength of steel having a specified minimum tensile strength of less than 70·ksi, shall not exceed the minimum specified tensile strength by more than 30·ksi. Maximum tensile strength of steel having a minimum specified tensile strength of 70·ksi or

higher shall not exceed the minimum tensile strength by more than 25 ksi.

The Vendor shall use only material specified in the Vendor calculations agreed upon in Section 2 of this document.

4.2.3. Geometry

The Vendor shall provide test reports as described in Section 4.1.2 indicating compliance with geometric requirements of ASTM A6 for all plate used in arms, pole shafts, flanges, vangs, and base-plates. Xcel Energy will allow machining to achieve surface roughness requirements.

The Vendor shall ensure that all structural material is straight and clean before being laid out or worked in any manner. If straightening is necessary, the Vendor shall do it by methods that will not compromise the metal. The Vendor shall do all forming or bending during fabrication by methods that will prevent embrittlement or loss of strength in the material being worked.

The Vendor shall document all dimensional errors and steps taken to correct them on the quality control record. The Vendor shall inspect all structural components for dimensional compliance with shop detail drawings, assembly drawings, procedures, established tolerances, as defined in Section 3 of this document. All parts of the structure shall be neatly finished and free from kinks or twists. Blocks, clips, and copes shall be clean and of good quality without torn, ragged, or sharp edges

The Vendor shall reject material that does not comply with all of the above requirements.

4.3. Welding

4.3.1. Welding Program

All welding shall be in accordance with AWS D1.1. The Vendor shall demonstrate the quality of their welding program by providing the following documents for all welds (structural, non-structural, repair, etc.):

- Welding Procedure Specification (WPS)
  The Vendor shall prepare a WPS for each weld type performed. The WPS shall include the essential variables used in production welding including material parameters, type of weld joint, welding process, welding position, preheat and interpass temperatures – including provision for interruption of welding – and electrical characteristics of the weld. Any deviation from the essential variables as outlined here and in AWS D1.1/D1.1M shall require re-qualification.

- Procedure Qualification Record (PQR)
  The Vendor shall prepare a PQR to qualify each weld type performed at each factory. Certain weld types may be pre-qualified under AWS D1.1; the Vendor shall indicate as such on the WPS. Complete Joint Penetration (CJP) welds for use on base plates or flange plates, and not pre-qualified under AWS D1.1, shall be qualified as described in Appendix B.

- Welder Performance Qualification Record (WPQR)
  Welders shall be qualified in accordance with AWS D1.1 Clause 4, Part C: Performance Qualification. WPQR shall be kept for six (6) years by the Vendor.

Welding consumables used to fabricate weathering steel structures shall conform to the requirements of AWS D1.1 Clause 3, subsection 3.7.3. Welding consumables used to fabricate structures that are to be galvanized shall conform to the same requirements as prescribed in this specification for the plate materials.

4.3.2. Weld Inspection Program

The Vendor shall demonstrate weld inspection capabilities as part of their quality control program. The Vendor shall provide a concise inspection procedure, referencing the use of mock-up blocks for inspector training, equipment calibration, and sensitivity standards. Personnel qualification for nondestructive weld testing shall be in accordance with AWS D1.1 Section 6.14.6.1. The Vendor's inspection department shall demonstrate they can locate discontinuities in the base-plate, in the weld joining the base to the pole shaft, and toe cracks that may result from hot dip galvanizing. This demonstration shall be done using mock ups, as defined in AWS D1.1, Annex S, UT Examination of Welds by Alternative Techniques. The toe crack mockup shall replicate the typical formed corner of the multi-sided pole shaft. Vendor shall have bare steel and galvanized steel ultrasonic calibration blocks made of the same pole shaft material(s) utilized in the pole shafts to be used for calibrating the ultrasonic equipment prior to testing the pole shafts. Transfer correction method is an acceptable calibration method in lieu of the calibration blocks.

The Vendor shall provide certified welding reports for each structure. Report shall include all welds of the structure. The Vendor shall clearly identify each weld and the report shall consist of the method of acceptance testing, if the weld is acceptable, structure identification, date and name and signature of inspector. The Vendor shall have inspectors qualified according to AWS QC1.

4.3.3. Weld Inspection Procedures

The Vendor shall inspect all welds – including backer welds and backer strips – for cracks and other defects. The Vendor shall visually examine work to determine if it meets the requirements of this Specification. The Vendor shall measure the size and contour of welds with calibrated gauges. Welds shall be free of any cracking, either surface or subsurface, rollover, and incomplete fusion. Weld quality shall comply with AWS D1.1 Clause 6, Part C, subsection 6.9, and Table 6.1. Magnifiers may be required for clear visibility. The Vendor shall supplement visual inspection with dye penetrant inspection per ASTM E165, magnetic particle testing per ASTM E709, and ultrasonic testing, as necessary.

Quality and acceptability of complete penetration welds shall be determined by ultrasonic testing per AWS D1.1. Backing bar splice joints shall be complete penetration welds and included in the final weld joint ultrasound testing to assure complete fusion and soundness. Areas of the backing splice that fall outside of the weld zone shall be visually inspected as required by the preceding paragraph. The vendor shall not perform testing until the weldment has cooled to ambient temperature allowing potential defects time to form. The Vendor shall use a 70° 5/8·in minimum size transducer per AWS D1.1 on the entire circumference of the shaft-to-base-plate and flange plate welds, with specific emphasis on the bend lines for evidence of toe-cracking. The Vendor shall perform 100% volumetric ultrasonic testing in the weld zone to assure against shadows, dead zones, or any defects which could lead to lamellar tearing. Galvanized surfaces shall be prepared to provide a smooth surface for ultrasonic inspection on the full circumference of the shaft. Acceptance-rejection criteria shall be as defined in AWS D1.1 table 6.2 for Statically Loaded Connections.. All rejectable indications greater than 50% screen height at scanning level and within 1/16·in of the weld surface shall be investigated further with MT examination."

Additionally – for complete penetration base plate and flange plate welds subject to the thermal shock of the hot dip galvanizing process – the Vendor shall perform post-galvanizing ultrasonic inspection as outlined in AWS D1.1 Annex S, or shall perform post-galvanizing magnetic particle testing per ASTM E709.

4.3.4. Weld Repair

Any positive indications found during these examinations, and considered unacceptable, shall be repaired and re-examined using the same methods.

- All rejectable indications shall be properly excavated and magnetic particle tested to verify their removal.
- A WPS shall be used for the repair weld.
- At completion of repairs, the vendor shall inspect the repair zone plus 12·in on either side.

4.4. Surface Finish

4.4.1. Inspection

The Vendor shall document all finishing discontinuities and steps taken to correct them on the quality control record. Fabrication shall be complete prior to finishing. The Vendor shall remove all flux from welds and all sharp edges and burrs prior to finishing. The inside surface of female slip joints shall be free of any material detrimental to the assembly of the slip joint.

4.4.2. Weathering Steel

After fabrication, the Vendor shall clean the outside surface of all weathering steel structures of oil, scale, etc., removing all visible deposits of oil, grease or other contaminants in accordance with SSPC SP 1. Surface preparation Standards SSPC SP 7 shall be followed to ensure uniformed cleaning of the steel to provide the promotion of its protective oxide layer.

4.4.3. Galvanizing

For poles to be galvanized, the Vendor shall remove all flux, surface (silicone) glaze or any other inert materials or contaminants from welds, and sharp edges and burrs prior to finishing. The Vendor shall do no punching, drilling, reaming, bending, or cutting after galvanizing. After fabrication is complete, the surface of all steel for galvanized structures shall be prepared in accordance with SSPC-SP8 before zinc is applied.

The Vendor shall hot dip galvanize in accordance with ASTM A123 subject to the quality constraints described in ASTM A385. The Vendor may repair defects sized less than 0.75·in by any method described in ASTM A780. The Vendor shall repair defects sized greater than 0.75·in by thermal spray coating, or zinc based solder ("hot patching"). The Vendor shall apply protective zinc coating as follows:

- Members requiring galvanizing and with base-plate diameter less than 84·in shall be welded then hot dip galvanized.
- Members requiring galvanizing and with base-plate diameter greater than 84·in shall be hot dip galvanized, then ground to bare metal in the weld area, then welded. After completion and inspection of the welds, they shall be thermal spray coated, or zinc based soldered ("hot patched").

For thermal spray repair work, the Vendor shall have an Operator Qualification for thermal spray zinc coating in accordance with AWS C 2.16. The Vendor shall thermal spray coat in accordance with AWS C2.18. Thermal spray coating shall have a minimum thickness of 0.005·in. Thermal spray coating of welds or repairs shall overlap galvanizing by a minimum length of 2·in.

The Vendor shall inspect thermal spray zinc and hot dip galvanized coatings for thickness by a magnetic thickness gauge. The poles shall be free of dirt, oil blisters, flux, black spots, dross, teardrop edges, or flaking zinc. In general, the structure shall be smooth, attractive, and unscarred.

Members requiring “dull galvanizing” shall be galvanized then chemically treated to provide a coloration of aged, naturally weathered, and dulled galvanized steel, except that it may be a gray or blackish gray. The treatment shall eliminate the gloss and reduce the reflectance of all surfaces, and shall provide a uniform appearance. The Vendor shall provide dulling upon request, and shall provide samples for confirmation of quality.

4.4.4. Direct Embed Coating

Poles for direct embedment shall have a coating applied that is resistant to abrasion and ultraviolet light. The coating shall extend from the butt of structure to the top of the corrosion collar. After fabrication and prior to coating, the Vendor shall clean the portion of the structure to of oil, scale, etc., in accordance with SSPC-SP10.

The Vendor shall use Chemline Chemthane 2260 or equivalent. The Vendor may change coating type, application method, and inspection procedure with prior approval by Xcel Energy. Coating shall have reliability proven by accelerated laboratory tests and outdoor exposure tests. Coatings shall have adhesion to substrate of at least 2000·psi per ASTM D4541. Further the Vendor shall ensure that the controlling state is inter-coating failure.

Direct embedment coatings showing sags, checks, teardrops, or fat edges are not acceptable. The Vendor shall check product preparation and coating thickness to ensure minimum dry film thickness requirements. The dry film thickness shall be a minimum of 15·mils. The Vendor shall perform visual inspection to detect pinholes, cracking, and other undesirable characteristics. The Vendor shall remove and recoat poles with defects of size larger than 0.75·in. Defects of size smaller than 0.75·in may be touched up.

5 Acceptance

5.1. Process

5.1.1. Xcel Energy

Acceptance is subject to Xcel Energy inspection and receipt of final calculations, drawings, and reports.

Xcel Energy will make payment of invoices for structures upon receipt and acceptance of the complete structure.

5.1.2. Vendor

The Vendor shall furnish to Xcel Energy a final set of documents used in the design and fabrication of the structures. Documents include Vendor calculations per Section 2.1.2, final assembly drawings per Section 3.1.2 and inspection reports per Section 4.1.2, The Vendor shall have a Professional Engineer seal all final drawings and calculations.

The Vendor shall notify Xcel Energy at least 48-hours (2-business days) prior to shipment that such shipment is to take place. During the 48-hour grace period following the Vendor's notification and prior to poles leaving the Vendor's plant, Xcel Energy reserves the right to delay shipment when crews, equipment, and lay-down yards are not available. Xcel Energy reserves the right to inspect the components prior to shipment. The notification shall include an electronic version of the Bill of Materials, as described in Section 5.2.2, as well as names of common carriers used, and expected time of arrival.

Any structure that is of unique and/or complex design should be shop assembled before shipment.

5.2. Shipping

5.2.1. Handling

Unless otherwise specified, the Vendor shall deliver the shipment to the address shown on the purchase order. The Vendor shall notify Xcel Energy when making each shipment. The notification shall give quantities, weight, and name of common carrier used, bill of lading number, expected time of arrival, and other pertinent information. The truck driver or railroad shall notify Xcel Energy three (3) business days prior to delivery or car spotting. Xcel Energy will furnish the name and telephone number of the representative for material receipts prior to shipping. Tubular steel structures shall be shipped in optimized truckloads, and in order of installation as stated on the Xcel Energy submittal.

All parts required for any one structure should be in one shipment, if possible. The Vendor should ship structure components or parts no more than five (5) days after the first of its component delivers. The Vendor shall box, crate, or bundle – and identify by structure – bolts, nuts, and other small hardware to prevent loss or damage, and identified by structure. The vendor shall furnish nuts and locking devices (excluding anchor bolts/nuts) in a quantity five percent over actual requirements, with a minimum of one extra per structure, unless otherwise indicated on the Xcel Energy submittals. The Vendor shall provide a field repair kit for the embedded pole coating with each shipment.

All sections shall be prepared for shipment to prevent damage during transit. The Vendor shall not use salt-treated wood blocking and urethane foams when shipping or storing weathering steel poles. The Vendor shall allow coatings to fully cure before structures are loaded for shipment. To prevent damage to the finish of the items, the Vendor shall not use chains to secure loads. The Vendor shall install plastic plugs or screws in nuts welded to the structure and to tapped holes. The Vendor shall properly block material on trucks to prevent damage to the finish or distortion of components during transit and to facilitate unloading. The Vendor shall ship all structures completely “knocked down” unless otherwise specified. The Vendor shall support pole shafts and arms with dunnage, and secure with straps as necessary. The Vendor shall properly secure the shipment to allow for safe unloading.

5.2.2. Bill of Materials

Each shipment shall be accompanied by a detailed Bill of Materials. The minimum information required on the Bill of Materials shall be: Xcel Energy project number, title, purchase order, work order number, and the Bill of Materials for each item shipped. The Bill of Material shall include description, dimension, and weight of each attachment item, section, and total assembled structure. Xcel Energy shall use this information for coding, receiving of materials, and payment for materials received.

The Vendor shall identify arms, bolts, and miscellaneous hardware by the list for match-up with the respective pole shaft. Each container or bundle of parts shall bear a waterproof tag containing the following information: Xcel Energy’s name, purchase order number and purchase order item number; Vendor’s name and shop order number.

5.3. Field Inspection

5.3.1. Receipt

Upon receipt, the structure will be subject to random field inspections for compliance with all of Section 3 and Section 4 of this document. The supplier is responsible for any cost associated with repair caused by fabrication error or shipment. The cost for rejected material and associated costs shall be at the expense of the Vendor.

5.3.2. Field Repairs

The quality and re-inspection requirements for field repairs shall be the same as for repairs done at the Vendor's facility. This limits the feasibility of field repairs in certain scenarios. Specifically:

- If the shipment fails to meet the requirements of Appendix A, the Vendor shall replace the material.
- If the shipment fails to meet the requirements of Section 3 or of Section 4.4 the Vendor may perform field repairs.
- If the shipment fails to meet the requirements of Section 4.2 or of Section 4.3 the Vendor shall perform shop repairs or replace the material.

Appendix A Anchor Bolt Cages

A.1. Detailing

A.1.1 Drawings

Anchor bolt drawings shall indicate:

- Bolt size
- Bolt length
- Thread length
- Bolt embedment
- Bolt projection
- Bolt arrangements
- Bolt circle
- Embedded bolt template dimensions

A.1.2 Anchor Bolts

The Vendor shall fabricate anchor bolts from steel bar conforming to ASTM A615 Grade 75. Fabrication of the threaded portion – including tolerances, galvanizing, and recommended nuts and washers – shall conform to ASTM F1554. The Vendor shall thread extended length anchor bolts at the top end to the projection length listed on Xcel Energy submittals. The Vendor shall thread partial length anchor bolts at the top end a minimum of 12·in, or as listed on the Xcel Energy submittal. Anchor bolts shall be galvanized at the top end a minimum of 24·in. Each anchor bolt shall include two hex nuts. After galvanizing, the Vendor shall thread a nut fully onto the anchor bolt and leave on for shipping.

The Vendor shall cut all anchor bolts to the length listed on the assembly drawings. The Vendor shall provide extended length anchor bolts when indicated on Xcel Energy supplied Drawings.

The Vendor shall fabricate anchor bolts to the following tolerances:

- Length of anchor bolts: +3·in, -0·in
- Length of galvanized portion on anchor bolts: +12·in, -0·in

A.1.3 Templates

The Vendor shall furnish one (1) bottom anchor bolt template (minimum thickness: 3/8·in) required that can be embedded with each foundation. The Vendor shall also furnish one (1) top anchor bolt template (minimum thickness: 3/8·in) for each foundation. Xcel Energy may request additional templates. The Vendor shall furnish intermediate anchor bolt template (minimum thickness: 3/8·in) as required that can be embedded with each foundation. The Vendor shall reinforce all templates or otherwise design them to maintain flatness and warping tolerance as specified below for optimum cage alignment after assembly.

The removable template at the top of the anchor bolt assembly shall be marked with two (2) v-notches to show the transverse direction for tangent structures and the angle bisector for angle structures. The Vendor shall drill two (2) 1/2·in diameter holes in the template at locations 90° to bisector.

The Vendor shall fabricate anchor bolt templates to the following tolerances:

- Deviation in bolt hole size in top template: +1/16·in, -0·in
- Deviation in spacing between Holes in base-plate and templates: +1/16·in, -1/16·in
- Deviation of flatness of top templates: +5/8·in, -0·in

A.1.4 Assembled Cages

The Vendor shall design anchor bolts for shipment as a rigid cage with top and bottom plates holding the anchor bolts in place. However, anchor bolt assemblies may be shipped assembled or un-assembled at the discretion of Xcel Energy.

The Vendor shall design anchor bolt assemblies to be rigid enough to withstand the normal jolts of shipping, handling, and installation with no displacement of bolts from the proper positions within the cluster, or twisting or racking of the assembly. The Vendor shall weld anchor bolts to the holding plate no more than 3·in from the bottom of the cage. The Vendor shall cut and weld cage-forming members in accordance with AWS D1.1 Section 8. The Vendor shall design the top template to be removable and to support the assembled cage during lifting and setting operations without detrimental deformations. The Vendor shall consider all miscellaneous steel used in the cage assembly for the anchor bolts as non-structural. For anchor bolts to be shipped loose, template bracing and spacers shall be provided and kitted together with the anchor bolts, templates, nuts, and miscellaneous parts for each foundation.

The Vendor shall fabricate anchor bolt cages to the following tolerances:

- Distance between anchor bolt in cluster (accumulative): +1/8·in, -1/8·in
- Distance between anchor bolts in cluster (non-accumulative): +1/16·in, -1/16·in

A.2. Fabrication

The Vendor shall provide upon request test reports with each anchor bolt assembly indicating compliance with the chemical, tensile, and bend requirements of ASTM A615 for all bar used in anchor bolts. The Vendor shall provide certification that the anchor bolts comply with the dimensional requirements of ASTM F1554. Galvanizing requirements shall be per ASTM A153. All anchor bolts shall be free of loose rust, scale, or coatings that reduce bond.

All rebar shall have Charpy V-Notch Testing. The frequency of the testing shall be on a heat lot basis (Frequency H) according to ASTM A673. Charpy impact requirements shall be 15 ft-lb minimum at -20·°F, and measured in accordance with ASTM A370.

A.3. Shipping and Handling

Anchor bolt cages shall be marked in accordance with the Vendor's drawings and shipped prior to the rest of the pole shipment, unless otherwise specified. The Vendor shall ship anchor bolts and templates together and identify each bundle by job number, customer PO, structure number. All anchor bolts after threading or galvanizing, shall be handled and stored in a manner not to damage threads. The Vendor shall handle anchor bolt assemblies and transport them to the delivery site in a manner that does not result in racking, bending or twisting of any part of the assembly. Xcel Energy considers damaged threads, or deformed, bent, or distorted anchor bolt assemblies at the delivery site reasonable cause for rejection of the material.

Xcel Energy will make payment of invoices for anchor bolts – assembled or loose – upon receipt and acceptance of the complete cage.

Appendix B CJP Weld Qualification

The Vendor shall prepare a PQR to qualify Complete Joint Penetration (CJP) welds for use on base plates or flange plates welded to shaft walls. A weld test assembly shall be prepared for through-thickness testing of the weld. A welding procedure qualification test shall be performed on the weld test assembly according to the requirements of AWS D1.1/D1.1M and additional requirements listed in this Appendix.

The weld test assembly is sketched in Figure 2. The weld test assembly shall consist of two (2) shaft plates welded perpendicular and on opposite sides of the base material. The shaft plates shall be aligned with each other and of sufficient height to obtain adequate length for through-thickness tensile specimens (suggested overall length of 20·in.). The base material shall be the maximum thickness intended for production welding, or 4·in, whichever is greater. The required test specimens shall have weld joint lengths of at least 20·in. Additional plates shall be welded to the two sides of the assembly to prevent warping. The welding of the test assembly shall be witnessed by an Xcel Energy approved independent third party.

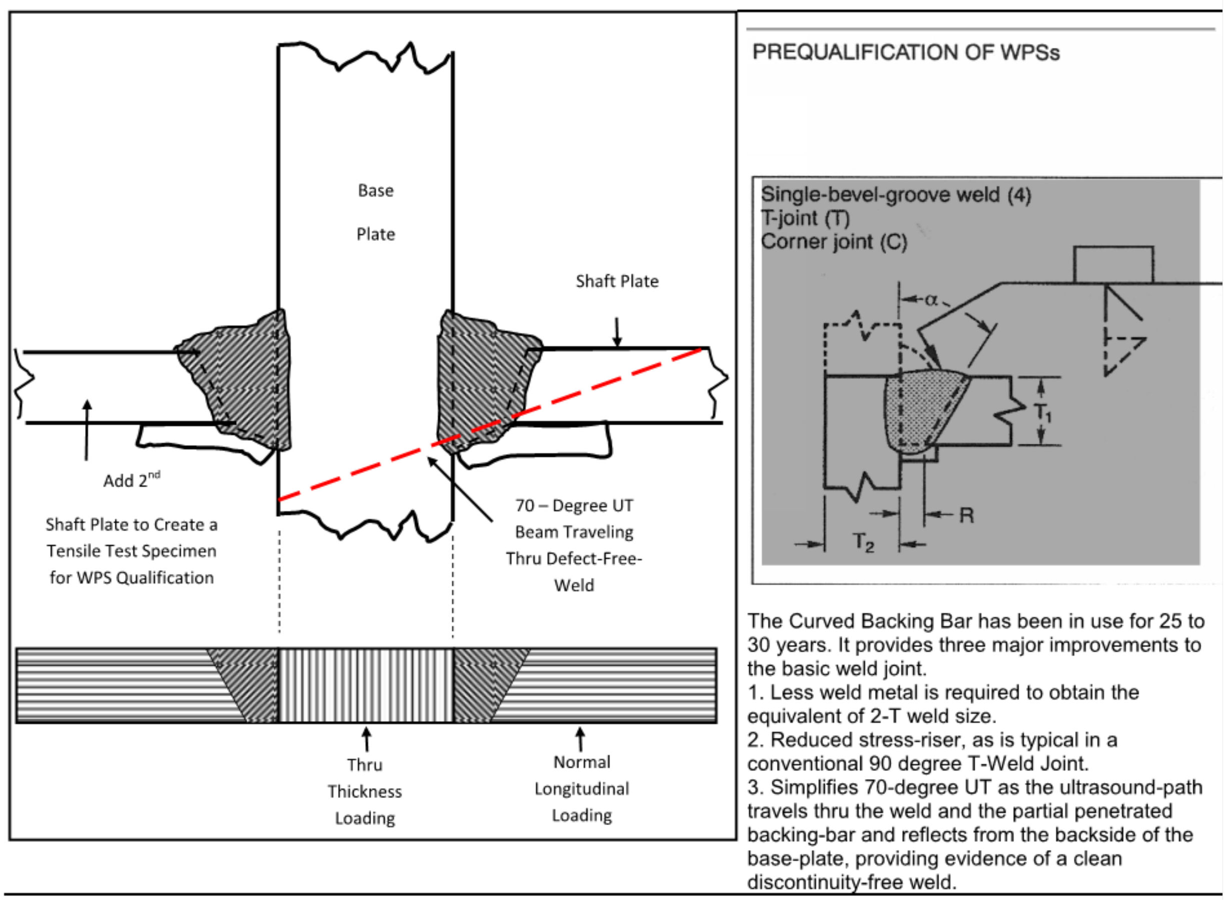


Figure 2: Weld test assembly for CJP weld qualification.

The tests conducted on the weld test assembly shall be according to the requirements of AWS D1.1/D1.1M plus additional requirements of Charpy V-notch impact specimens for both base metals (pole shaft and base-plates), both heat-affected zones, the weld deposit, and two macro-etch specimens that include the entire weld cross section (3/8·in. thick). The through-thickness tensile specimens shall include the weld joints on both sides of the base material. The Charpy specimens shall consist of one (1) set of three (3) specimens at each location. Charpy impact requirements shall be 15 ft-lb minimum at -20·°F, and measured in accordance with ASTM A370. Metallographic specimens cut from one of the macro-etch specimens shall be tested for micro-hardness across the heat-affected zone for the face of both the pole shaft and base material and at the root of the weld. Micro-hardness test results shall be 37 HRC max with an average no higher than 33 HRC in the heat-affected zone, starting at the weld interface extending for 0.060·in into the base-plate, and in accordance with ASTM A370.

The tests shall be conducted by an Xcel Energy-approved independent testing laboratory and shall be witnessed by an Xcel Energy-approved independent third party. The test results shall meet the requirements specified in AWS D1.1/D1.1M and shall be submitted to Xcel Energy for review. The Vendor shall provide and pay for program tests.

P.1. Scope and Purpose

This standard details the technical and quality assurance requirements for furnishing, testing, and delivering single- and three-phase power transformers and oil filled reactors. It supplements project specific Transformer or Reactor Detail Sheets. Provisions in this standard may be overruled by exceptions stated within the project specific Transformer or Reactor Detail Sheet. Use of this standard by the recipient is restricted to Xcel Energy, (hereafter referred to as "Purchaser,") business only. Distribution of this standard, in part or whole, to utilities or consultants outside of the Purchaser without written permission from the Purchaser is strictly prohibited.

P. 2. Responsibilities

The individuals listed below were on the Transformer Committee at the time the document was revised. The standard is a Material Standard for use with the applicable Transformer or Reactor Spec Detail Sheet.

Name	Title
Mike Ibold	Mgr –PSC Substation Engineering & Design
Susan McNelly	Lead – NSP Substation Engineering
Nate Steward	NSP Substation Engineering - Alternate
Josh Trimble	PSC Substation Engineering
Chad Schell	PSC Substation Engineering Alternate
Juan Nieto	SPS Substation Engineering
Mike Rebstock	SPS Substation Engineering - Alternate
Tom Matson	PSC Substation Maintenance Engineering

P.3. Work Flow

P.3.1 Approval

The Xcel Energy Standards Council Sponsors have not approved this document. This document was set to released on **/**/****.

Approval	Date	Name	Title

P.3.2 Version History

Extremely important to have a well documented history of major changes even when the document is being drafted. These changes may be documented when versioning through Projectwise.

The personnel listed under Section P2 above have approved the following changes.

Date	Version Number	Change
//****	2	Initial Version

Table of Contents

1. General

1.01. Scope

This standard details the technical and quality assurance requirements for furnishing, testing, and delivering single- and three-phase power transformers and oil filled reactors. It supplements project specific Transformer or Reactor Detail Sheets. Provisions in this standard may be overruled by exceptions stated within the project specific Transformer or Reactor Detail Sheet. Use of this standard by the recipient is restricted to Xcel Energy, (hereafter referred to as "Purchaser,") business only. Distribution of this standard, in part or whole, to utilities or consultants outside of the Purchaser without written permission from the Purchaser is strictly prohibited.

1.02. References

Power transformers and reactors shall meet the requirements of the following Standards listed and all other Standards as appropriate. Unless otherwise stated, the latest revisions of ANSI, ASME, ASTM, AWS, IEEE, NEMA, and OSHA Standards shall be met in the design, testing, and manufacture of the transformer~~(s)~~ or reactor, related equipment, and accessories. The ~~transformers(s)~~transformer or reactor shall be designed, manufactured, and tested in strict compliance with the latest revision of ANSI C57 series of transformer standards. Where the Transformer or Reactor Detail Sheet or this Material Standard differ from the ANSI C57 series of transformer/reactor standards, the transformer~~(s)~~ or reactor shall be supplied in compliance with the Transformer or Reactor Detail Sheet and/or Material Standard.

1.02.01. ANSI

C57.12.00	IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
C57.12.10	Transformers 230 kV and Below, 833/958 through 8333/10 417 kVA Single Phase, and 750/862 through 60 000/80 000/100 000 kVA Three Phase, Requirements for
C57.12.90	Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers and Guide for Short-Circuit Testing of Distribution and Power Transformers
C57.13	IEEE Standard Requirements for Instrument Transformers
C57.19.00	IEEE Standard General Requirements and Test Procedure for Outdoor Power Apparatus Bushings
C57.21	IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500 kVA
C57.91	IEEE Guide for Loading Mineral-Oil-Immersed Transformers
C57.98	IEEE Guide for Transformer Impulse Tests
C57.100	IEEE Standard Test Procedure for Thermal Evaluation of Liquid-Immersed Distribution and Power Transformers
C57.104	Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers
C57.106	Guide for Acceptance and Maintenance of Insulating Oil in Equipment
C62.11	Metal-Oxide Surge Arresters for Alternating Current Power Circuits

1.02.02. ASTM

D877	Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
D924	Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
D971	Standard Test Method for Interfacial Tension of Oil Against Water by the Ring Method
D974	Standard Test Method for Acid and Base Number by Color-Indicator Titration
D1298	Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D1500	Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D1524	Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field
D1533	Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration
D1816	Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes
D3283	Standard Specification for Air as an Electrical Insulating Material
D3612	Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
D5837	Standard Test Method for Furanic Compounds in Electrical Insulating Liquids by High- Performance Liquid Chromatography (HPLC)

1.02.03. IEEE

C57.13	IEEE Standard Requirements for Instrument Transformers
C57.93	IEEE Guide for Installation of Liquid-Immersed Power Transformers

1.02.04. NEMA

ICS1	Industrial Control and Systems: General Requirements
ICS2	Industrial Control and Systems: Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC
TR 1	Transformers, Regulators, and Reactors

1.02.05. OSHA

29CFR 1926	Safety And Health Regulations For Construction

2. Performance and Operation

2.01. Overload Capability and Ratings

2.01.01. The transformer shall be capable of performance at the ANSI Standard loading conditions and at the overload and normal load conditions provided in Table 1 below. All per unit overload multipliers in Table 1 shall be applied to the transformer's 65°C top nameplate rating. Bushings, tap changers, bushing current transformers (including any LDC or WTI current transformers), leads, and all other auxiliary equipment shall be provided so as not to limit the capabilities of the transformer. Lead hot spot rises shall not exceed the winding hot spot rises.

2.01.02. The transformer's overload capability shall be designed to perform at the per unit overloads identified in Table 1 for a 24-hour duration load cycle without exceeding the specified maximum temperatures (top oil temperature and hot spot temperature).

2.01.03. For Distribution Transformers, the overload rating shall be designed for sequential loading starting with a pre-load condition (90% of the transformer's top 65°C MVA rating for a minimum of 8 hours in duration), followed by the two-hour emergency rating, and finally the single cycle rating . The overload conditions above will be followed by a return to the 90% load condition for the remaining time of the 24-hour load cycle. The average ambient temperature is assumed to be 30°C with a peak ambient temperature of 40°C.

2.01.04. For Transmission Transformers the overload rating shall be designed for sequential loading starting with a pre-load condition (90% of the transformer's top 65°C MVA rating for a minimum of 8 hours in duration), followed by the one-half hour emergency rating, the two-hour emergency rating, and finally the multi-cycle rating. The overload conditions above will be followed by a return to the 90% load condition for the remaining time of the 24-hour load cycle. The average ambient temperature is assumed to be 30°C with a peak ambient temperature of 40°C. The overload rating applies to simultaneous loading with a full reactive, unity power factor and with the tertiary at full nameplate rating.

Table 1

Emergency Loading Criteria for Power Transformers

	Per unit overload at 30°C ambient [a,b]	Per unit overload at 0°C ambient [a,b]	Maximum Hot Spot (°C)	Maximum Top Oil (°C)
Distribution Transformers				
Emergency (2 hour) Loading	1.50 [c]	1.60	180	110
Single-Cycle (8 hour.) Loading	1.25 [d]	1.45	140	110
Multi-Cycle (8 hour) Loading	1.15 [d]	1.35	130	110
Normal (24 hour) Loading	1.05 [d]	1.20	~~120~~110	105
Transmission Transformers				
Emergency (1/2 hour) Loading	1.35 [c]	1.55	140	110
Emergency (2 hour) Loading	1.25 [c]	1.40	140	110
Multi-Cycle (8 hour) Loading	1.15 [d]	1.30	130	110
Normal (24 hour) Loading	1.00 [d]	1.00	~~120~~110	105

[a] **Distribution Transformers:** The temperatures and loading levels for Emergency and Single-Cycle loading are approximately equal to the "0.25% Loss of Life" per cycle rating in IEEE C57.92-1981 for the two step model for 90% pre-load, 30°C ambient, and an 8 hour peak.

[b] **Transmission Transformers:** The temperatures and loading levels for the 8 hour, 2 hour, and ½ hour loadings are approximately equal to the Normal Life rating in IEEE C57.92-1981 for the two step model for 90% pre-load, 30 °C ambient, and an 8 hour, 2 hour, or ½ hour peak

[c] The per unit overload assumes a peak ambient temperature of 40°C

[d] The per unit overload assumes a average ambient temperature of 30°C

2.02. Temperature and Altitude Conditions

2.02.01. The transformer or reactor shall be capable of operation for an ambient temperature range of -40°C to +40°C. All external auxiliary equipment and components shall be designed for an ambient temperature range of -50°C to +40°C, whether the ~~transformer~~equipment is in operation or in storage.

2.02.02. The transformer or reactor shall be designed for the elevation option identified in Table 2 below that correlates to the elevation identified on the Transformer or Reactor Detail Sheet. The specified impedance will be on the base ONAN MVA rating for the elevation designated as the full MVA elevation.

Table 2

Transformer Detail Sheet Elevation Requirement	Nameplate Rating Information	Minimum Elevation for Auxiliary Components and Bushings
Full MVA at 1000 m	MVA Ratings at 1000 m	1000 m
Full MVA at 1000 m, Derated at 2000 m	MVA Ratings at 1000 and 2000 m	2000 m
Full MVA at 2000 m, Derated at 3000 m	MVA Ratings at 1000, 2000, and 3000 m	3000 m
Full MVA at 3000 m	MVA Ratings at 1000, 2000, and 3000 m	3000 m

2.02.03. The ~~transformer~~ auxiliary equipment and other components (such as bushing external BIL levels and clearances) shall not limit operation of the transformer or reactor at the altitude indicated in the column labeled "Auxiliary Components and Bushings" in Table 2 above based on the elevation requirement specified on the Transformer or Reactor Detail Sheet.

2.03. Sound Levels

The transformer or reactor average load sound level shall be designed not to exceed the ~~following~~ maximum levels indicated in the Spec Detail Sheet, regardless of DETC or LTC tap position, at the transformer top 65°C MVA rating or at 115% voltage (maximum operating voltage) for reactors. Maximum levels specified are with transformer loaded to full nameplate and all fans, pumps, and equipment, such as oil filters, in operation:

~~Transformer Top Rating~~	~~Maximum Sound Level~~
~~≤ 70 MVA~~	~~10 dB below NEMA TR 1~~
~~> 70 MVA~~	~~NEMA TR 1~~

3. Design and Construction

3.01. Parallel Operation

When paralleling with LTC transformers for which a nameplate drawing and test report have been provided, the impedances must be matched at the neutral tap, as well as, within ±10% at the 16R and 16L LTC taps.

3.02. Windings and Leads

3.02.01. Windings and leads shall be made of copper material. Aluminum windings and leads are not acceptable. Rectangular windings are not acceptable for the main, tap, or regulating windings.

3.02.02. Transformer or reactor windings shall be designed to be free-buckling and shall not rely on winding tubes for their short circuit strength.

3.02.03. Winding transitions or crossovers spanning across a key spacer column **are not allowed**.

3.02.04. Insulation sleeves or flex tubes are not allowed on winding leads.

3.02.05. The Seller shall provide certification that all insulation materials used in the transformer or reactor meet the requirements of IEEE Standard C57.100 for thermally upgraded insulation.

3.02.06. For windings utilizing continuously transposed cable (CTC) type conductor, Dennison ~~calendared~~ calendered-crepe type, thermally upgraded tape shall be used. ~~An alternative~~, at a minimum, for the outside two layers of tape. Alternative paper may be provided ONLY if certified thermal upgrading test results based on IEEE Standard C57.100 aging tests are provided.

3.02.07. Angular displacement of high voltage and low voltage windings shall follow C57.12.00 unless otherwise specified. Tertiary windings, when required, shall lag the high voltage windings by 30 electrical degrees unless otherwise specified.

3.02.08. Plastic self-locking tie wraps are not an acceptable material for lead support.

3.02.09. All windings, components, and parts of the transformer or reactor shall be mechanically braced to withstand through faults. The source of the fault should be assumed to be from an infinite source at one per unit voltage.

3.02.10. The transformer or reactor windings shall be oil immersed.

3.02.11. Transformer or reactor designs **shall not** include internal or LTC surge arresters.

3.02.12. Cleats and leads structure members in contact with winding leads shall be pressboard material for BIL levels 450kV and above.

3.02.13. Tertiary/Stabilizer Winding

3.02.13.01. The tertiary bushings will be located on Segment 4 unless otherwise specified.

3.02.13.02. A tertiary winding, when required, will have three leads brought out for each three-phase transformer and two leads brought out for each single-phase transformer. When a buried tertiary is specified, no leads are required to be brought out. Labeling of the tertiary shall be Y1, Y2, Y3, from left to right when facing the transformer tank.

3.02.13.03. The tertiary impedance shall be sized such that the maximum symmetrical fault at the terminals is less than 32,000 amperes for 13.8kV or 16,000 amperes for 34.5kV tertiaries. The impedances to tertiary ($Z_{(H-T)}$ and $Z_{(L-T)}$) are desired to be as low as practical while still meeting these fault requirements. All values of negative sequence impedances ($Z_{2(H-L)}$, $Z_{2(H-T)}$, and $Z_{2(L-T)}$) shall be equal to the positive sequence values, on the same base MVA. All values of zero sequence impedances ($Z_{0(H-L)}$, $Z_{0(H-T)}$, and $Z_{0(L-T)}$) shall be equal to or less than the positive sequence impedance values. When calculating fault values, assume HV and LV both as infinite bus sources.

3.02.13.04. The transformer shall be designed such that the tertiary, when present, can be simultaneously loaded by either vectoral or arithmetic, whichever is the worst-case, with the HV fully loaded for Step-Down operation, the LV fully loaded for Step-

Up operation, or either the HV or LV fully loaded for respective Step-Down or Step-Up operation as identified on the Transformer Detail Sheet.

3.02.13.05. The Seller shall indicate on the transformer main nameplate the maximum MVA load that the tertiary can carry using either arithmetic or vector loading, whichever is the worst-case condition, for the operation specified on the Transformer Detail Sheet.

3.02.14. The neutral rating from the neutral point to the bushing shall be rated for line current.

3.02.15. An X_0/X_1 ratio of 2 shall be used for the short circuit fault current calculations.

3.03. Core

3.03.01. The transformer design shall limit the internal core temperature for overload ratings as identified in Section 2.01 including simultaneous loading of the tertiary when present, to **less than** ~~130~~90°C. rise over ambient air temperature. The reactor design shall limit the internal core temperature for specified maximum ratings to **less than** 90°C rise over ambient air temperature

3.03.02. Materials in contact with the core surface must be rated for operation at the maximum calculated core surface temperature for the overload operation requirements in Section 2, including simultaneous loading of the tertiary when present.

3.04. Drying and Processing

3.04.01. The core and coil assembly and all other internal components shall be dried by vapor-phase process to assure proper dryness of the insulation material. Transformers or reactors 450 kV BIL or below, may be dried by another method if pre-approved by the Purchaser.

3.04.02. Oil impregnated core and coil assemblies of any voltage class, which have been exposed to the atmosphere for longer than one week, shall be dried by vapor-phase process, or by another method approved by the Purchaser to assure proper dryness of all insulation material.

3.05. Transportation Strength

3.05.01. The transformer or reactor shall be designed to withstand transportation related mechanical loadings generated by impacts, swaying, yawing, fatigue, and vibration. The minimum design limits for impact loading for units shipped by rail or truck only with respect to the transformer shall be: 5 g longitudinal, 1 g vertical, and 3 g transverse directions. The minimum design limits for impact loading for units shipped by sea vessel with respect to the transformer or reactor shall be: 5 g longitudinal, 3 g vertical, and 3 g transverse directions. The transformer or reactor shall be designed to allow transportation by both rail and truck, as well as, by sea vessel when the unit will be shipped from outside North America.

3.05.02. The core legs shall have a solid support from the bottom to the top clamp to prevent sideways deformation and bulging of the outermost laminations. The core shall be adequately braced to the core clamping structure, so that it cannot move in any direction. The windings shall be tight to prevent sideways movements. The core and coil assembly and other internal components shall be supported by permanent bracing to the interior of the tank. No temporary shipping braces shall be allowed without special approval.

3.06. Load Tap Changer (LTC)

3.06.01. LTC Operation

3.06.01.01. The LTC shall provide for adjustment of the low voltage in 32 approximately equal steps in accordance with the percentage required in the Transformer Detail Sheet.

3.06.01.02. The tertiary voltage shall be constant for a constant high voltage level independent of the low voltage LTC position.

3.06.01.03. The transformer shall be suitable for full capacity operation at nominal X-terminal rated voltage and above, and reduced capacity (constant current) operation below nominal X-terminal rated voltage. The function of the LTC shall be to maintain constant voltage at the X terminals for fluctuating voltage applied at the H terminals, and to regulate the voltage at the X terminals for fluctuating load levels.

3.06.01.04. On all two winding transformers, the LTC shall be located in the low voltage winding.

3.06.02. LTC Mechanism

3.06.02.01. The LTC shall be reactance-compensated vacuum or spring-charged, resistance-bridging type.

3.06.02.02. On vacuum type LTCs, there shall be a monitoring system that supervises the integrity of the vacuum bottle. See Alarm Requirements Section 4.07.04.

3.06.02.03. The LTC shall have a 400,000 operation contact life at top nameplate rating of the transformer. The LTC shall be capable of withstanding a minimum of 200 operations over the life of the transformer at an overload of 150% of the transformers 65°C top nameplate rating.

3.06.02.04. The LTC switching compartment shall be separate from the main transformer tank. If the LTC is vented it shall pass through a desiccant to prevent the introduction of moisture to the compartment. The LTC switching compartment shall have a pressure relief device. See Section 3.15.02.01 for details.

3.06.02.05. The LTC is to be designed so that for a complete loss of control power it shall remain on position.

3.06.02.06. The LTC equipment shall be constructed so that a tap-change, once started, will be completed even if the supply or control voltage is interrupted. In the case of vacuum LTCs where this is not possible, the LTC shall be constructed so that no damage will result if the tap-changer remains in the intermediate position under full load.

3.06.02.07. A hand wheel or crank shall be provided for use during maintenance, interlocked with motor control.

3.06.02.08. An oil level indicator with high and low alarm contacts shall be installed on the side of the LTC compartment and any other isolated, oil filled compartment that may be required for the LTC. The indicator shall be readable from ground level.

3.06.02.09. The LTC switching compartment door shall have jack bolts with captive hinge pins, or similar devices, to assist in opening the door.

3.06.02.10. Any LTC equipment which requires de-energizing the transformer and draining the oil from the LTC compartment during maintenance of the drive motor and related mechanism will not be accepted.

3.06.02.11. The LTC motor drive must be designed to run off of an AC, preferably 120VAC, single-phase, source. If necessary, a three-phase 240 Volt Delta connected or 208 Volt Wye connected requirement will be allowed, but the Supplier shall verify with the Purchaser which voltage will be available. A DC voltage requirement will not be acceptable.

3.07. De-energized Tap Changer (DETC)

3.07.01. Welded, gasketed access ports on the side of the transformer must be provided if the DETC is not accessible from the top of the transformer.

3.07.02. The DETC mechanism shall be externally operated by a single operating handle extended through the wall of the tank. DETC linkage should be kept to a minimum and be such that the tap position is in a clearly defined position. The DETC handle shall have provisions for padlocking with a minimum 3/8” diameter hole for the padlock hasp, and shall provide visible indication of the tap position from the ground without unlocking. The DETC nameplate shall indicate "for de-energized operation only" or similar wording. No keyed locking device other than the provision for the padlock is allowed.

3.07.03. The DETC shall be capable of continuous operation on one tap position without rotation through the tap positions on a routine basis. Devices requiring periodic rotation through tap positions are not acceptable.

3.08. Insulating Oil

3.08.01. Insulating Oil shall conform to the requirements of ANSI C57.106. It shall be completely tested, in accordance with ASTM standards, including ASTM 1275 Method B for corrosive sulfur, and certified test reports shall be provided at the time of oil shipment.

3.08.02. Insulating oil will be Type II (inhibited) mineral oil with a target inhibitor level of 0.25% by weight and a minimum inhibitor level of 0.2% and a maximum inhibitor level of 0.3% by weight.

3.08.03. The insulating oil shall be identified on the transformer or reactor main nameplate as Type II inhibited mineral oil.

3.08.04. The Seller shall furnish a sufficient quantity of oil for the complete ~~transformer~~ installation.

3.08.05. All oil-filled compartments, including bushings, shall be certified to be less than one (1) part per million PCB. The certification shall be permanently attached to the individual compartments.

3.08.06. Transformers or reactors shipped without oil shall have oil delivered by tanker truck for Purchaser performed installations:

3.08.07. Installation of the transformer or reactor by the Seller:

3.08.07.01. The Seller shall furnish oil test reports which include all tests indicated in C57.106 and fall within guidelines indicated in C57.106.

3.08.07.02. If the transformer or reactor is shipped without oil, transfer of the oil from the truck or rail shipping container into the transformer **is not allowed** until receipt oil testing for each shipping container has been completed and reviewed by the Purchaser for acceptability.

3.09. Oil Preservation System

3.09.01. On transformers rated greater than 70 MVA top 65ºC rating, a conservator type oil preservation system is required for the main tank oil preservation system. For transformers less than or equal to 70 MVA top 65ºC rating, a gas blanketed or conservator type oil preservation system may be provided for the main tank oil preservation system. Proposals shall indicate which type of oil preservation system will be provided.

3.09.02. Spaces in which oil is in contact with air shall have a dehydrating breather provided.

3.09.03. Gas Blanketed System

3.09.03.01. Sealed tank with inert gas pressure system (nitrogen bottle make-up) with a pressure/vacuum gauge with a scale range of positive 10 psi to negative 10 psi shall be provided.

3.09.03.02. A bleed tube for gas blanket dew point measurement shall be provided from the gas space to an elevation of five feet above the base of the transformer or reactor.

3.09.03.03. The system shall include a gas control cabinet with the top mounted six feet above the base of the transformer or reactor. As per Exhibit E, typical nitrogen system.

3.09.03.04. The system shall include one standard gas storage ~~bottle~~cylinder (220 cu ft @ 21ºC, 2200 lb/sq inch).

3.09.03.05. ~~Storage bottle~~Gas cylinders shall be manufactured to US DOT type 3AA high-pressure cylinder specifications and the Supplier shall comply with the transportation requirements of the Federal Regulations, 49 CFR.

3.09.03.06. Cyliners shall be stamped or stenciled “Property of Xcel Energy” “Fill and Return”. The nitrogen ~~bottle~~cylinder shall be installed at a location on the transformer or reactor, near the base of the ~~transformer~~ main tank.

3.09.03.07. Provide a one and one-half (1½) inch upper filter valve located below the 25°C liquid level, and located diagonally opposite from the drain valve (See Section 3.09.06.01). The valve shall have a flanged and gasketed connection to the tank.

3.09.04. Conservator System

3.09.04.01. Air-sealed, bladder-type conservators shall include an oil level gauge on the conservator set to alarm before exposing active part (live parts inside the ~~vacuum/pressure bleeder operates~~equipment). The gauge shall be legible from the ground.

3.09.04.02. Complete dimensions, drawings, manufacturer, and part numbers for conservator bladders must be provided in the final record drawing package.

3.09.04.03. A dehydrating breather shall be provided for the air space between the conservator tank and the bladder.

3.09.04.04. The conservator tank shall have a one and one-half (1½) inch oil fill and a two (2) inch oil drain valve.

3.09.04.05. Provide one and one-half (1½) inch upper filter valve within six (6) inches of the top (above the core and coils) of the main tank. The upper filter valve shall be located diagonally opposite from the main tank drain valve (See Section 3.09.06.01). The valve shall have a flanged and gasketed connection to the tank.

3.09.04.06. A shut-off valve shall be provided on each end of the connection piping to the main tank.

3.09.04.07. The conservator tank shall be located on Segment 4, except in the case where a tertiary winding is brought out. In the case where a tertiary is brought out, the Seller will discuss conservator tank location options with the Purchaser before the design is finalized.

3.09.05. LTC Oil Preservation System

The LTC oil preservation system shall include the following devices:

3.09.05.01. Filtered dehydrating breather, responsive to pressure or vacuum changes.

3.09.05.02. Relief of sudden, excessive pressure changes shall be provided as required in Section 3.15.02.01 of this Material Standard.

3.09.05.03. Oil level indicator, as required in Section 3.09.06.02.

3.09.05.04. A one and one-half (1½) inch or two (2) inch drain valve shall be provided to drain the oil as completely as possible but to at least within one (1) inch of the bottom of the LTC compartment.

3.09.05.05. An oil filtering system shall be provided on transformers with non-vacuum type LTCs. The filtering system shall include pumps, filters, pressure controlled shut-off switches with alarms, and an adjustable timer (settable from daily, or every other day in 2, 3, 8, and 24 hour operation intervals).

3.09.06. Accessories

3.09.06.01. A combination drain and lower filter valve shall be provided to drain the oil as completely as possible but to at least within one (1) inch of the bottom of the main tank and for outlet to the filtering means. The drain valve shall be two (2) inches with a built-in 3/8-inch sampling device. The valve shall have a flanged and gasketed connection to the tank.

3.09.06.02. Liquid Level Indicators

a) Liquid level indicators (Main Tank and **all** other oil filled compartments) shall be provided with all alarm contacts wired to terminal blocks located in control cabinets.
b) The main tank shall either have a single, magnetic-type, level indicator with two low level and one high level alarm contacts or two separate, magnetic-type, level indicators. All contacts shall be Form "C" contacts.
    i) The first low level contact and the high level contact shall activate at a level considered safe for continued operation of the transformer.
    ii) The second low level oil level indication contact is for emergency tripping on rapid loss of oil due to physical damage to the transformer..
c) All other oil filled compartments shall have single indicators at the lowest level considered safe for continued operation of the transformer and wired to terminal blocks in the main control cabinet.

3.10. Cooling System

3.10.01. The cooling system shall be complete with power and control wiring, conduit, and automatic control of fans and pumps. Fans and pumps shall be individually connected and grounded to the power supply through a flexible, rubber-covered cord with weatherproof plugs and receptacles. Each stage of cooling shall be connected through separate circuit breakers or fuses to the power supply for protection. See Exhibit B1 for wiring details.

3.10.02. A switch shall be installed to select which bank of cooling will be designated as Stage 1 for those transformers specified with more than one stage of forced cooling. The transformer cooling must be designed (fan locations for Stage 1 and Stage 2 should be interspersed) such that the Stage 1 MVA rating is not reduced due to a rotation of the cooling stages.

3.10.03. Seller shall furnish for each cooling stage total watt and kVA requirements for the cooling power supply on the bid data sheet and on the certified test report.

3.10.04. Motors shall be totally enclosed and shall have sealed bearings. Non-metallic bearings for fan and pump motors are not acceptable.

3.10.05. When pumps are provided, a liquid flow gauge with alarm contacts shall be provided responsive to pump flow and flow direction. The flow gauge shall be located on the lower cooler piping.

3.10.06. All radiators shall be mounted separately and provided with valves so that any radiator can be removed while the rest remain in service. The radiators shall be provided with vent plugs. It is preferred that the radiators have two lifting eyes on the top of each radiator and one on the bottom. When a radiator header is provided, a shut off valve to the main tank and a drain valve shall be provided.

3.10.07. One set of additional ports, complete with valves, shall be provided to accommodate the addition of one future radiator or portable cooler for enhanced cooling.

3.10.08. Pumps, when provided, shall have valves on both sides and have bypass piping to allow removal or maintenance without having to remove or drain oil from the radiators or coolers. TecSonic bearing wear monitors shall be provided which are manufactured by Harley.

3.10.09. On two winding transformers, radiators shall not be mounted on Segment 1.

3.10.10. Fans should be mounted on the sides of the radiators, rather than on the bottom.

3.10.11. Components manufactured outside of the United States must be fully interchangeable with domestically available devices. For example, foreign manufactured fans must be interchangeable in all aspects with domestically supplied fans. This means that if the device such as a fan were replaced, that there would be no affect on the operation (in this case cooling capability) of the transformer or reactor.

3.11. Bushings

3.11.01. All bushings provided shall be sized per Exhibit A, A1.

3.11.02. All bushings shall be PD free and either porcelain, oil-filled, condenser-type, with a visible oil level gauge or sight glass at the top; or silicon weather shed type bushings.

3.11.03. Bushing external clearances shall at a minimum meet the minimum external clearances per IEEE C57.12.00. These clearances shall not be reduced due to the application of surge arresters on the transformer or reactor.

3.11.04. All bushings, including the core ground bushing, shall be cover mounted.

3.11.05. The bushing color shall be ANSI 70 light gray.

3.11.06. Draw lead bushing leads must be insulated.

3.11.07. On Distribution transformers, the neutral and LV bushings shall be identical in kV BIL and ampere ratings. On Small System and Large System transformers with graded insulation, the neutral and TV bushings (unless the TV is buried) shall be identical in kV BIL and ampere ratings.

3.11.08. The Transformer or Reactor Detail Sheet provides a minimum external bushing kV BIL rating based on a 1000m elevation. For elevation requirements above 1000m, it shall be the Seller's responsibility to ensure that external BIL and clearance requirements can be met for the increased elevation requirements. The Seller shall provide higher BIL bushings than the specified minimum rating when necessary to meet the elevation requirements as identified in the Transformer or Reactor Detail Sheet and Section 2.02.02 of this document.

3.11.09. A NEMA four–hole or larger pad for bushing terminal connectors, depending on overload ampacity requirements, shall be furnished by the Seller and shall be tinned for compatibility with either aluminum or copper connections. For 230 kV (900kV BIL) and above, corona free terminal connectors shall be provided. The bushing terminals shall be threaded type studs.

3.11.10. Draw lead or draw rod connections with silver plated threaded studs are preferred. The lead shall be tied inside the bushing cover for shipment.

3.11.11. All bottom connected bushings must be accessible through a cover mounted removable access plate.

3.11.12. Bushings rated 350 kV BIL and above shall have a bushing test tap.

3.11.13. The tertiary bushings shall be located on top of the transformer cover, common to Segment 4.

3.11.14. To facilitate neutral grounding of the high and/or low voltage neutral (H_o/X_o), the Seller shall furnish a permanently installed 1/4" x 3" rigid copper grounding bus. This bus shall be installed from a stainless steel, NEMA standard four (4) hole ground pad on the transformer or Reactor cover adjacent to the neutral bushing, down the side to the stainless steel, NEMA standard four (4) hole ground pad (referenced in section 3.15.02.05) located six (6) inches from bottom of transformer base. The copper ground bus shall be painted ANSI 70 gray except at the termination points to blend with the transformer tank.

3.11.15. The transformer or reactor design shall not utilize reduced clearance capabilities specific only to one bushing manufacturer. The transformer or reactor design shall allow for interchangeability of all approved manufacturer's bushings in accordance with ANSI C57.19.00. The Purchaser understands that adaptation of the bushing flange may be necessary for interchangeability.

3.11.16. Core Ground Bushing(s)

3.11.16.01. ~~The transformer core~~Core grounds (main, preventative autotransformer, and series transformer) shall be grounded on top of the main ~~transformer~~ tank.

3.11.16.02. The core ground bushing(s) shall be rated 5 kV minimum.

3.11.16.03. The core grounds shall be connected to the tank with a detachable connector so the cores can be meggered without opening the tank or lowering the transformer or reactor oil.

3.11.16.04. The core ground assembly shall be enclosed with a weatherproof, removable cover to prevent physical damage to the core ground bushing. and to the ground circuit. The ground point should be inside the protective cover.

3.11.16.05. The lead, connector, and bushing shall be accessible from a handhole or manhole in the transformer or reactor tank cover for core ground testing purposes.

3.11.16.06. A core ground nameplate shall be supplied adjacent to the bushing protective cover. When multiple ground bushings are brought out, they shall be clearly labeled as to their purpose.

3.12. Bushing Current Transformers (BCT)

3.12.01. Bushing and in winding current transformers shall meet IEEE C57.13 and be furnished as required in the Transformer Detail Sheet.

3.12.02. The continuous current Thermal Rating Factor (TRF) shall be as specified on the Transformer Detail Sheet and shall be identified on BCT performance curves, on the main nameplate with BCT information, and stamped on the CT nameplate (See Exhibit B~~2 and B3~~ for terminal block wiring details).

3.12.03. The bushing and in winding current transformers for Purchaser's use shall be ANSI standard multi-ratio type unless otherwise specified.

3.12.04. The set of relay class BCTs (not including WTI BCTs or in-winding CTs unless otherwise noted) closest to the windings on the HV and LV bushings should have the polarity towards the windings, all other BCT polarities should be on the side towards the bushings.

3.12.05. Metering BCTs, when required, shall be ANSI standard with an accuracy class as specified on the Transformer or Reactor Detail Sheet.

3.12.06. For autotransformers, the WTI CT shall be installed ~~on~~for the series, common (neutral end, not line end), and tertiary windings.

3.12.07. There shall be no internal splices or joints in BCT or CT wiring between the BCT or CT and the junction box.

3.13. Arresters

3.13.01. Approved Arrester suppliers are listed Exhibit A, Section A2.

3.13.02. Arresters shall be in accordance with the latest IEEE C62.11.

3.13.03. Surge arresters shall be gapless, metal-oxide, station-class arresters and shall have polymer housings.

3.13.04. Arrester ratings shall be supplied as specified on the Transformer or Reactor Detail, Sheet. The ~~transformer~~manufacturer shall provide arresters and self-supporting, tank-mounted, arrester brackets adjacent to their respective bushings on all winding phases brought out.

3.13.05. The arrester color shall be ANSI 70 light gray.

3.13.06. All required terminal connectors and hardware (including voltage grading rings as recommended by the arrester manufacturer) shall be included with the arresters. Arresters shall have a two-hole or four-hole NEMA terminal connector. Spacing of arresters and bushings must take into account grading rings and hardware.

3.13.07. Arrester line terminals shall be tin plated.

3.13.08. A copper ground bus loop, consisting of rigid copper bus bar or 4/0 AWG cable shall be provided by the Seller to provide an electrical ground connection between the arrester grounds and the ground pads (referenced in section 3.15.02.05) at the base of the transformer tank. The copper down lead shall be supported on the tank at intervals not to exceed 4.5 feet. The copper ground lead shall be painted ANSI 70 gray except at the termination points to blend with the ~~transformer~~ tank.

3.13.09. Arrester mounting brackets shall not be mounted directly on radiators or radiator headers.

3.14. Neutral Grounding Reactors (NGR)

3.14.01. When specified, the Seller shall furnish a tank-mounted, air-cooled, outdoor, neutral grounding reactor, complete with all mounting material and a nameplate, but without a surge arrester.

3.14.02. The tolerances for the neutral grounding reactor impedance shall be +7 to -3%.

3.14.03. The neutral grounding reactor color shall be ANSI 70 light gray.

3.14.04. The neutral grounding reactor nameplate shall be mounted near the transformer nameplate and shall show reactor impedance (in ohms), continuous current rating, voltage rating, and the 10 second current rating.

3.14.05. The neutral grounding reactor impedance in ohms shall also be clearly shown on the main transformer nameplate.

3.14.06. The neutral grounding reactor shall be mounted on the transformer tank near the X_o neutral bushing. The neutral grounding reactor shall be mounted to the left of the X_o bushing on segment 1 side of the cover, such that a minimum clearance of 24" shall be maintained from the reactor and a plane perpendicular to the tank wall. When "*mounting provisions only*" are specified in the Transformer Detail Sheet, the mounting bracket shall allow the above requirements for the specified neutral grounding reactor information.

3.14.07. A ¼" by 3" rigid copper bus shall be provided to connect the neutral grounding reactor to the X_o bushing and from the neutral grounding reactor to the ground pad (referenced in section 3.15.02.05) at the base of the transformer as required in Section 3.11.14.

3.15. Tank

3.15.01. General

3.15.01.01. The transformer or reactor shall be designed with the following facilities for moving and handling:

a) Welded cover with lifting eyes
b) Lifting facilities for the core and coil
c) The jacking point shall be not less than sixteen inches above the floor line and shall provide a minimum unobstructed jack clearance of six inches from the tank wall or other obstruction. The jack pad shall have a minimum area of 4" x 4".
d) The tank base shall be designed to be capable of moving the completely assembled transformer, with or without oil, on pipe rollers along either axis, and to prevent corrosive failure in the presence of water on a flat concrete slab. Flat base transformers are preferred and must be at least ¾ inch thick. This capability shall be indicated on the base and outline drawing.

3.15.01.02. Center lines of gravity (shipping and complete) of the transformer or reactor shall be identified and designated by punch marks or nameplates on each side and each end of the ~~transformer~~tank.

3.15.01.03. Oil filled compartments (main tank, LTC, piping, and auxiliary) shall be designed for full vacuum filling. If a compartment cannot be independently vacuum filled, an exception shall noted on the proposal. If a compartment cannot be independently vacuum filled this shall be clearly stated on the outline drawings and on the transformer or reactor nameplate. Valves capable of withstanding full vacuum shall be provided to isolate all of these compartments.

3.15.01.04. All interiors and exteriors of tanks (including the base), enclosures, cabinets and other metal parts which are not galvanized, stainless steel or of corrosion resistant material and are exposed to oil or weather shall be thoroughly cleaned and painted as required in Section 3.15.01.05 and 3.15.01.06. Galvanized materials shall not be used for any interior parts exposed to or in contact with oil, including all valves.

3.15.01.05. The interior color of the transformer or reactor tank and control cabinet(s) shall be white and shall be fully capable of withstanding transformer operating conditions as identified in Section 2.01 without degradation such as chipping, cracking, or peeling.

3.15.01.06. Exterior color of the transformer or reactor and transformer accessories shall match in color, and shall be ANSI 70 light gray. The Seller shall supply a minimum of two (2) 12oz. spray cans of touch up paint.

3.15.01.07. The top of the transformer or reactor tank shall be covered with a skid resistant paint, the same color as the exterior tank walls. A note indicating that this has been provided shall be included on the transformerequipment outline drawing.

3.15.01.08. Tank side seams and the connection point of the tank sides to the tank bottom shall be fully welded both inside and outside.

3.15.01.09. Tank corner seams shall be set back a minimum of 2 inches from the actual tank corner.

3.15.01.10. Leaks discovered during tank and component testing in the factory shall be repaired by welding only. Leaks shall not be repaired by use of epoxy or other similar substances.

3.15.01.11. Manholes

a) A minimum of two 24” diameter manholes shall be provided on top of the transformer or reactor tank.
b) One of the required manhole covers shall include a one (1) inch threaded nipple and a flanged vacuum fitting for connection of a four (4) inch diameter vacuum hose. The four (4) inch (nominal) vacuum fitting shall have eight (8) ¾-inch diameter bolt holes, equally spaced on a 7½-inch diameter bolt circle. The vacuum fitting flange shall be mounted sufficiently high off of the manhole cover to allow for easy access for removing and replacing bolts and nuts.

3.15.02. Accessories

3.15.02.01. Pressure Relief

An automatic, directed-flow, pressure relief device shall be provided on the cover of both the transformer main tank and the LTC compartment to relieve excessive internal pressure. The location of the pressure relief device shall be such that operation of the device will not result in physical damage to bushings.

PVC piping for directed flow is not allowed. Piping be shall be screened at the bottom to prevent access to birds and animals.

a) Pressure Relief Device (Main Tank): An automatic pressure relief device (63P-1(MT)) with form C alarm contacts wired out for Purchaser's use (see Exhibit B~~1~~) shall be provided on the cover of the ~~transformer~~ main tank to relieve excessive internal pressure. This device shall be of the mechanical, automatic resealing type, and shall include a manually resettable target.

b) Pressure Relief Device (LTC Compartment): A pressure relief device (63P-2(LTC)), with form C alarm contacts shall be provided wired out for Purchaser's use (see Exhibit B~~1~~). The device shall be of the automatic resealing type, and shall include a manually resettable target.

3.15.02.02. Fall Protection Devices

a) Brackets for mounting of 2 inch diameter pipes for use as safety rails shall be provided at the top of the transformer or reactor. Design and fabricate brackets to resist OSHA required lateral loads at the top of the safety rail. Brackets shall be spaced a maximum of 4 feet apart, with one on or near each corner of the transformer or reactor. See Exhibit C, Figure 1 for details.

b) A weld-on base as shown in Exhibit C, Figure 2 shall be provided near the center of the transformer or reactor top. It will be used for attaching a 4' Purchaser supplied tether pole to meet OSHA's 29CFR 1926.502(d). The base should be designed to support a horizontal force of 10,800 lbs at the top of a 4' tether pole. The area above the base should be clear of obstructions as to facilitate attachment of the Purchaser supplied tether pole.

c) ~~Unique Concepts Ltd.~~Capital Safety (DBI SALA) weld-on base(s), item #~~108168~~8517412 with a tie off anchor, shall be installed by the Seller for attachment of a portable fall arrest system provided by the Purchaser. The weld-on base shall be installed on the transformer or reactor cover within three (3) inches of each manhole. See Exhibit C, Figure 3 for placement details. A Seller fabricated version of this part is NOT acceptable.

3.15.02.03. All gauges or indicators shall be legible from the ground. Devices mounted at a height of greater than ~~6'~~10' from the base of the transformer or reactor shall be mounted at an angle of 30° from the vertical plane.

3.15.02.04. All accessories, including the LTC indicator, having drag pointers that need resetting, shall have the reset device located no higher than six (6) feet above the base of the transformer or reactor.

3.15.02.05. Four stainless steel, NEMA standard four (4) hole ground plates one on each corner of Segment 1 and 3, one stainless steel, NEMA standard four (4) hole ground plate located on the top of the transformer or reactor near the ~~H_0/X_0~~neutral bushing(s), and stainless steel, NEMA standard two (2) hole ground plates adjacent to each core ground bushing.

3.15.02.06. Two (2) grounding brackets, for portable grounds, shall be provided per high- and low-voltage side of the transformer or reactor, for a total of four grounding brackets. The brackets shall be made of copper or stainless steel and shall be brazed if copper, or welded if stainless steel to the tank near each corner on both the high- and low-voltage sides. A minimum of 6 inches of clear space to all sides of the bracket shall be provided. If brackets cannot be mounted due to obstructions such as radiator fins, the brackets should be mounted just around the corner. Appropriate procedures for brazing copper or welding stainless steel to the tank shall be used to ensure both good electrical conductivity and mechanical strength. The brackets shall not be painted. See Exhibit D for dimension details.

3.15.02.07. Gaskets and gasketed joints shall be designed so that the gasket shall not be exposed to the weather or standing water, and shall be provided with mechanical stops to prevent crushing. Dimension and material information shall be supplied for all gaskets with Approval and Final drawings.

3.15.02.08. The Seller shall furnish one (1) complete extra set of gaskets for all bolted gasketed manholes, handholes, and bushings to replace shipping gaskets for the initial installation.

3.15.02.09. The transformer or reactor shall be fitted with a suitable connection for the future addition of a gas-in-oil monitor. This connection shall include ~~a~~two 1½ inch ~~valve and~~valves, with a protective cover over ~~the~~each valve opening. The ~~valve~~valves shall have ~~a~~ flanged and gasketed ~~connection~~connections to the tank. See Exhibit A, Section A3 for information regarding the location and specification of mounting provisions.

3.16. Nameplates

3.16.01. All nameplates shall be inked and engraved stainless steel. Nameplates shall be attached by at least four bolts or rivets. Mounting holes shall be provided with rubber grommets or equivalent to decrease vibration noise.

3.16.02. The main ~~transformer~~ nameplate shall be in accordance with ANSI C57.12, and shall include the following additional information:

3.16.02.01. The ~~transformer~~ main nameplate shall include the Purchaser's transformer Uniquely Tracked Commodity (UTC) number, which is a unique number for tracking transformers. The UTC number will be provided to the Seller at the time Approval Drawings are reviewed.

3.16.02.02. The ~~transformer~~ main nameplate shall include the transformer MVA or reactor MVAR ratings at the altitudes identified in Section 2.02.02.

3.16.02.03. For transformers with a tertiary winding that is brought out, the nameplate shall indicate the maximum MVA load that the tertiary can carry per Section 3.02.13.05 and whether the loading is vectoral or arithmetic.

3.16.02.04. The nameplate shall indicate that the transformer or reactor was originally provided with Type II inhibited oil per Section 3.08.03.

3.16.02.05. The CT Thermal Rating Factors shall be identified on the main nameplate per Section 3.12.02.

3.16.02.06. The neutral grounding reactor impedance, when required, shall be provided on the main nameplate per Section 3.14.05.

3.16.02.07. Any oil filled compartment (including conservator bladders) that cannot be independently vacuum filled shall be identified on the main ~~transformer~~ nameplate per Section 3.15.01.03.

3.16.02.08. Ratios and ampacity of series or preventive auto transformers and/or the LTC, when present, shall be provided on the main nameplate.

3.16.03. A temperature relay nameplate shall be supplied and shall give the recommended temperatures at which the first set of cooling equipment shall be started, the second set of cooling equipment shall be started, and the temperature at which an alarm shall be actuated. All of these shall be calculated on the basis of operation at 65°C winding temperature rise. This information shall also be provided on the wiring diagram. The nameplate shall be mounted on or near to the temperature indicator(s) and shall be identified on the transformer outline drawing.

3.16.04. LTC and DETC nameplates shall be provided and shall include make and model information, the turns ratio of the LTC coupling transformer, if applicable, year of manufacture, model number, continuous current rating and the maximum overload rating.. These nameplates shall be mounted next to the main nameplate or the information may be incorporated into the main nameplate.

3.16.05. All gauges shall have a nameplate to identify their specific function, i.e. "Main Tank Oil Level." This includes, but is not limited to, oil levels, oil temperatures, and winding temperature gauges. The nameplates and their locations shall be identified on the transformer outline drawing.

4. Controls and Protection

Standardized control drawings (See Exhibit B) have been provided as a guide/example for the Supplier to follow in preparation of control drawings. These drawings are meant to depict a general uniform look and feel that Xcel Energy would like to see used for the control drawings. The drawings in Exhibit B are only examples. Some of the information shown is to provide an example of what type of information for devices should be provided. They are not an indication as to specific vendors, materials, or catalog numbers, **unless** those vendors, materials, or catalog numbers are specifically required to be used per this Power Transformer/Reactor Material Standard or any of the remaining Exhibits.

4.01. Main and LTC Control Cabinets

4.01.01. All equipment, alarms, controls, protection, and current transformer leads shall be brought to individually identified terminals on terminal blocks centralized in a NEMA type 3 control cabinet mounted on the equipment tank. The cabinet(s) shall be fabricated of steel plate of sufficient thickness to prevent warping or buckling and shall have drip-proof hoods.

4.01.02. The cabinet(s) shall include vertically hinged doors arranged to permit ready access to the cabinet from the ground level. A locking device shall be provided to hold the doors in the fully open position. If design of cabinets be such that door width is in excess of 30 inches, double doors shall be provided such that the door width does not exceed 30" and the doors shall be hinged for center opening. Hinge material shall be stainless steel. If it is not possible to limit the door size to 30", suitable cross bracing must be used strengthen the door and prevent twisting or flexing of the door.

4.01.03. Doors shall have three-point latches for the closed position and shall include provisions for attaching padlocks. Additional locking provisions using keys, screwdrivers, special tools, bolts, or screws to secure the door shall not be used. The control cabinet outline layout drawing shall indicate with a note that the three-point latch is provided.

4.01.04. The control cabinet preferred location is on Segment 1 of the transformer or reactor. The top of control cabinet(s) shall not be more than seven (7) feet above the bottom of the tank. The bottom of the control cabinet(s) shall be located a minimum of 2.5 feet above the bottom of the tank. If location of the control cabinet on Segment 1 will require it to be removed for shipment, alternate locations should be discussed with the Purchaser.

4.01.05. A removable, gasketed plate, minimum size 12" x 16", shall be provided in the bottom of control cabinet(s) to permit field drilling and installation of control system conduits. The Seller shall not place the plate directly under any device within the control cabinet that would encumber the pulling of control conductors into the cabinet.

4.01.06. A metal drawing pocket shall be installed inside the main control cabinet. The size of the pocket shall be a minimum of 12 inches wide by 8 inches high by 3 inches deep or larger if required. The transformer or reactor shall be shipped from the factory with a complete instruction manual, all drawing attachments, and a copy of the test report included within the drawing pocket.

4.01.07. All control devices, controllers, and control systems and assemblies shall be in accordance with NEMA ICS 1 and 2 and shall meet the requirements of this Standard.

4.01.08. The transformer or reactor control cabinets shall be equipped with both thermostatically and continuously energized heaters. The continuously energized heater shall be adequate for prevention of condensation buildup, without overheating any apparatus, for the ambient temperature range indicated in Section 2.02.01.

4.01.09. The control cabinet shall be equipped with a 120V duplex receptacle (3-wire) with ground fault interruption (GFI) served from the same air circuit breakers as the cabinet lighting. The air circuit breakers shall be sized to provide overcurrent protection. A work light shall be mounted in the control cabinet with a door activated switch.

4.01.10. Cable conduits entrances into the control cabinet shall have a protective grommet to protect cable from rubbing on the edge of the conduit.

4.02. Auxiliary Power

4.02.01. All auxiliary components requiring AC power shall be capable of operation at 120/240 Volt, three-wire, single-phase and 120/208 Volt, three-wire, single-phase.

4.02.02. The DC source voltage shall be as indicated in the Transformer or Reactor Detail Sheet.

4.02.03. All auxiliary power circuits shall be protected by air circuit breakers at the control cabinet. The supply voltages will be regulated to within plus and minus 10% of nominal.

4.02.04. All air circuit breakers required by this document shall be industrial class, molded case, UL listed for use on 125 volt DC, minimum 10,000 amp DC I.C. and 240 Volt AC, 22,000 amp I.C.

4.02.05. Provide separate circuits for cooling and LTC control AC power sources.

4.02.06. The total auxiliary load shall be noted in kVA on the control schematic diagram.

4.03. Rigid Conduit

4.03.01. ~~Rigid~~ Appropriate UV-rated, rigid (galvanized steel) conduit shall be used for all power, control, and alarm external wiring. When the wiring terminates at an externally tank-mounted power, control, or alarm device, rigid conduit shall be provided to a suitable location near the device. Wiring may be routed through tank support channels as an alternate to rigid conduit.

4.03.02. Liquid-tight, flexible, metal conduit may be provided from a point near the device to the device itself.

4.03.03. All conduit, cable, and fittings shall be weatherproof, and securely fastened to the transformer at regular intervals. Rubber covered cable is acceptable for fans and gauges, and external wiring runs of less than 4 feet, however, its use shall be limited. Cable lengths shall be appropriate to the location of the device. Excess cable that has to be coiled is not acceptable. Fan cables shall not be tied to radiator fins.

4.04. Wiring

4.04.01. All wire shall be stranded, tinned, copper conductor with 600V flame-retardant, cross-linked synthetic polymer insulation, type XHHW or equal.

4.04.01.01. The minimum size for control and alarm functions shall be stranded No. 14 AWG.

4.04.01.02. The minimum wire size for motor circuits, power circuits, and CT circuits shall be No. 12 AWG.

4.04.02. Wiring shall not be spliced or tapped. All interconnections shall be made and identified with wire markers at equipment terminals or terminal blocks.

4.04.03. Enclosed terminal boards with screw-type terminal blocks and marking strips shall be used to terminate all wiring. Screws shall be cinch-head type or shall include star or lock type washers. Screws provided shall have slotted-head, not universal-type head. Approved terminal blocks are listed in Exhibit A, A4. A minimum font size of 8pt shall be used on terminal block marking strips.

4.04.04. Associated terminal points shall be grouped together to facilitate the use of multi-conductor control cables for interconnecting equipment. A minimum of 10 percent spare terminals shall be provided and shall be grouped and reserved for Purchaser's use only (See Exhibit B~~1~~). All equipment shall be wired to the terminal blocks in the control cabinet.

4.04.05. All terminal blocks shall be mounted on side or back walls only, and shall be easily accessible with normal tools.

4.04.06. All CT secondary leads shall be brought to terminal blocks identified in Exhibit A, A4 mounted in a junction box outside the transformer tank.

4.04.07. All connectors used for terminating current transformer, control, and secondary wiring shall be full circle lugs with non-insulating, seamless barrels for visible crimping. Burndy type YAV Hylugs are preferred.

4.05. Fault Pressure Relay

4.05.01. On conservator type ~~transformers~~units, a gas-detector relay (71GD), Buchholz fault sensing relay, shall be provided, see Exhibit A, A5.01 for approved types. The relay shall be located in the piping between the main tank and the conservator. Form C contacts rated for a minimum of 10A (wired out to terminal blocks for Purchaser's use) shall be provided – see Exhibit B~~1)~~. The Seller is responsible for providing the Purchaser information on the Buchholz relay to be used. This relay shall be complete with piping, fittings and detailed instructions that describe the mounting of the relay to the piping in the assembly instructions of the transformer. Methods for directing evolved gases from the transformer or reactor other than external piping are preferred. If external piping is provided, it shall be of rigid steel with minimal joints. Piping, when necessary, shall not impede access to manholes, hand holes, fall protection mounting provisions, junction boxes, or other necessary access points. See Section 3.09.04.06 for valve requirements.

4.05.02. For gas-blanketed type transformers or reactor, an oil type, flange mount rapid pressure rise relay (RPRR, dev. 63-1 (MT)) shall be provided, see Exhibit A, A5.02 for approved devices.

4.05.02.01. A continuous wire assembly without splice shall be provided between the RPRR connector and the transformer or reactor control cabinet. The cable assembly shall terminate at the RPRR with a female Mil Spec pin and sleeve connector. See Exhibit A, A5.02 for approved devicesA straight connector is preferred. The cable from the RPRR to the control cabinet shall be protected from the elements by weatherproof conduit, a weatherproof armored flexible cable, or Sealtite conduit. The conductor shall not be exposed rubber insulated or jacketed.

4.05.02.02. A two (2) inch shut-off valve shall be provided between the tank and the relay on the transformer or reactor for purposes of isolation and testing. The valve and RPRR assembly should be mounted on the side of the main tank, accessible for testing from ground level. The mounting height of the RPRR shall be no more than 5 feet above the bottom of the ~~transformer~~main tank. The RPRR shall be mounted or protected in such a manner that it is protected from falling objects.

4.05.03. An oil type, flange mount rapid pressure rise relay (RPRR, dev. 63-1 (MT)) shall be provided on the LTC, see Exhibit A, A5.03 for approved devices.

4.05.03.01. A continuous wire assembly without splice shall be provided between the RPRR connector and the transformer or reactor control cabinet. The cable assembly shall terminate at the RPRR with a female Mil Spec pin and sleeve connector. See Exhibit A, A5.03 for approved devices. A straight connector is preferred. The cable from the RPRR to the control cabinet shall be protected from the elements by weatherproof conduit, a weatherproof armored flexible cable, or Sealtite conduit. The conductor shall not be exposed rubber insulated or jacketed.

4.05.03.02. A two (2) inch shut-off valve shall be provided between the tank and the relay on the LTC tank for purposes of isolation and testing. The valve and RPRR assembly should be mounted on the side of the LTC tank. The RPRR shall be mounted or protected in such a manner that it is protected from falling objects.

4.06. Temperature Monitors

4.06.01. The cooling system shall be controlled and monitored by a temperature monitor responsive to the winding hottest spot temperature and to the top oil temperature of the transformer or reactor.

4.06.02. Temperature monitors shall be mounted adjacent to, or within, the ~~transformer's~~ main control cabinet, at an approximate height of 5 ft. to the center of the device above the base of the transformer or reactor (for easy viewing from ground level). All Purchaser required outputs shall be wired out and terminated to terminal blocks located in the ~~transformer's~~ main control cabinet, as shown in the attached Exhibit B~~1~~.

4.06.03. Pick-up set points for the temperature monitors shall be set as indicated below. A temperature set point nameplate shall be provided adjacent to the temperature monitor.

	Pick up º C Setting
Stage 1 Cooling	55º C
Stage 2 Cooling	65º C
Alarm Hot Spot (49T)	130º C
Alarm Top Oil (26Q)	110º C

For transformers with pumps, the manufacturer may provide alternate recommended settings for consideration.

4.06.04. Electronic Temperature Monitor (ETM)

4.06.04.01. Electronic Temperature Monitors, when specified in the Transformer Detail Sheet, shall be provided. ETMs approved for use are indicated in Exhibit A, A6.01 .

4.06.04.02. Electronic Temperature Monitors shall have the following features:

a) Hot spot CT input for calculated winding temperature - The hot spot CT shall have a rated 5 amp output for input into the ETM. If the available current at 200% of the ~~transformer's~~transformer or reactor maximum nameplate rating exceeds the input rating of the ETM Manufacturer, auxiliary CTs may have to be used to prevent damage to the ETM.
b) Top oil input for top oil temperature - The input shall come from a removable temperature probe mounted on the side the tank in a closed, unheated, dry, thermowell. The dry well shall be located such that it is always at least one (1) inch below the oil level at minimum operating temperature. The dimensions for the thermowell used with the ETM should adhere to the requirements of IEEE Std. C57.12.00. Wet wells are not acceptable.
c) The source to the ETM shall be as specified for the DC control voltage on the Transformer or Reactor Detail Sheet. Set point relays shall be configured such that on loss of DC, all stages of fans (**not pumps** if applicable) shall be

triggered to come on. Set point relays shall also be configured to allow their response to sensor failures to be set by the user.

d) A minimum of six (6) form C dry contact outputs shall be provided to control cooling auxiliaries and alarm initiation. Four of the six output contacts shall be used for 1st and 2nd stage temperature alarm levels on each the top oil and hot spot winding temperatures, with the other contacts used for controlling the cooling system response to the simulated winding hottest spot temperature. The four -top oil and hot spot winding temperature outputs shall be 0 to 1mA DC (corresponding to 0 to 200°C) and shall be labeled as such on the control drawings. If the ETM does not have relays with a 125VDC contact make/break rating, interposing relays external to the ETM shall be provided as needed to achieve the higher rating.

e) A weather tight NEMA 3R, or better, enclosure with a digital display shall be provided when the device is installed external to the main ~~transformer~~ control cabinet. If the device is mounted in the main ~~transformer~~ control cabinet, a window shall be provided in the ~~transformer~~ control cabinet door for viewing the monitor screen without opening the control cabinet door. An operator accessible front panel for the temperature monitor shall be provide to allow for manual control of the system.

f) The Seller shall provide the transformer/ETM completely configured with the correct parameters as required by the ETM manufacturer.

g) Transformer ~~Parameters~~or reactor parameters grouped together on one page and identified as temperature monitor input data shall be supplied by the Seller along with Test Reports and other data. This data shall be provided from the actual temperature rise test information or from a thermal duplicate. The following information is required whether or not it is necessary for the particular model of temperature monitor provided:

    1) Average winding temperature rise over top oil (average winding temperature gradient) at the transformer or reactor base rating and at the top maximum rating.
    2) Average winding temperature rise over ambient at the transformer or reactor base and top maximum rating.
    3) Hottest spot winding temperature rise over top oil (Hot spot winding temperature gradient) at the transformer or reactor base and top maximum rating.
    4) Hottest spot winding temperature rise over ambient at the transformer base and top maximum rating.
    5) Thermal time constants for each winding.
    6) Winding exponent.
    7) Temperature differential between LTC (when present) and the main tank.

4.06.05. Mechanical Temperature Monitor (MTM)

4.06.05.01. Mechanical Temperature Monitors approved for use are indicated in Exhibit A, A6.02. Mechanical temperature monitors shall be provided when specified on the Transformer or Reactor Detail Sheet.

4.06.05.02. Mechanical Temperature Monitors shall have the following features:

a) Simulated hottest spot thermal input shall come from a removable temperature probe mounted on the **side** of the tank in a closed, heated thermowell. The thermowell heating element shall receive its energy from current drawn from a bushing or other instrumentation CT; proportional to load current. Means shall be provided to calibrate the thermowell such that the indicator will accurately simulate the true winding temperature up to 200% of the ~~transformer~~equipment nameplate rating. Since the dimensions of the probe are unique to its design, thermowells for this input are typically non-standard and are provided by the MTM manufacturer. The thermowell shall be located such that it is immersed in to a minimum depth of one (1) inch when the oil level and operating temperatures are at a minimum. Wet wells are not acceptable.
b) Top oil thermal input shall come from a removable temperature probe mounted on the side of the tank in a closed, unheated thermowell. Since the dimensions of the probe are unique to its design, thermowells for this input are typically nonstandard and are provided by the MTM manufacturer. The thermowell shall be located such that it is immersed in to a minimum depth of one (1) inch when the oil level and operating temperatures are at a minimum.
c) A minimum of four (4) contacts shall be provided to control cooling auxiliaries and alarm initiation. Two (2) of the contacts shall initiate alarms for stages 1 and 2 of the winding or top oil temperature. The remaining two (2) contacts shall control stages 1 and 2 of the cooling auxiliaries. When fans and pumps are used, the fans shall be operated by the stage 1 relay and the pumps shall be operated by the stage 2 relay. If the MTM does not provide contacts with a 125VDC contact make/break rating, interposing relays external to the MTM shall be provided as needed to achieve the higher rating.
d) A weather tight NEMA 3R or better enclosure with outdoor rated dial and controls shall be provided when the devices are installed external to the main ~~transformer~~ control cabinet. If the devices are mounted in the main transformer control cabinet, a window shall be provided in the ~~transformer~~ control cabinet door for viewing the gauges without opening the control cabinet door.
e) Basic temperature error (including probe) to be less than 5 degrees Celsius. Basic error for the temperature monitoring system shall be less than 2% of the full scale reading.
f) In order to properly calibrate the winding temperature MTM, certain data is required to be provided by the transformer or reactor manufacturer. The parameters shall be grouped together on one page and identified as

temperature indicator settings. This data shall be provided from the actual temperature rise test information or from a thermal duplicate.

1) The calibration curve for the heated thermo well which shows the winding temperature rise of the thermo well probe cavity with respect to current flowing in the heating coil.
2) Average winding temperature rise over top oil (average winding temperature gradient) at the transformer or reactor base and top maximum rating.
3) Average winding temperature rise over ambient at the transformer or reactor base and top maximum rating.
4) Hottest spot winding temperature rise over top oil (Hot Spot winding temperature gradient) at the transformer or reactor base and top maximum rating.
5) Hottest spot winding temperature rise over ambient at the transformer or reactor base and top maximum rating.
6) Thermal time constant for each winding.
7) Winding exponent.

4.07. Alarm and Auxiliary Contacts

4.07.01. Alarm and auxiliary contacts shall be Form C, non-grounded, and suitable for operation on ungrounded 125 VDC systems. These contacts shall be furnished on all gauges and relays. Alarm contacts shall be brought out to a terminal board located in the main control cabinet and shall not be wired together at a common side. One side of the Purchaser specified terminal blocks shall be reserved for Purchaser's external cable connections only (See Exhibit B~~1~~).

4.07.02. Mercury-wetted contacts are not allowed.

4.07.03. Downstream switches or breakers except for the "main" AC breaker should not affect alarm 27-1.

4.07.04. Alarm Requirements

The following alarm points shall be provided where applicable:

4.07.04.01. Top Oil Temperature – (26Q/A1 & 26Q/A2).
4.07.04.02. Winding Temperature – ~~Monitor One Winding~~ (49T/A1 & 49T/A2).
4.07.04.03. Liquid Level Indicator - Main Tank/Conservator - Normal High (71Q-1 (MT) High~~/HA~~)
4.07.04.04. Liquid Level Indicator - Main Tank/Conservator - Normal Low – (71Q-1 (MT) Low~~/LA)~~
4.07.04.05. Liquid Level Indicator - Main Tank/Conservator - Emergency Low – (71Q-~~3~~1 (MT) Trip)
4.07.04.06. Liquid Level Indicator - LTC Compartment – High and Low – (71Q-2(LTC)~~/HA~~ High & 71Q-2(LTC)~~/LA~~ Low)
4.07.04.07. ~~Fault~~ Rapid Pressure – Main Tank – (63SP-1 (MT) Trip)

4.07.04.08. ~~Fault~~ Rapid Pressure – LTC – (63SP-1 (LTC) Trip)
4.07.04.09. Transformer or reactor Gas Detection – Buchholz Relay – (71GD (MT))
4.07.04.10. Pressure Relief Device - Main Tank (63P-1(MT), – (63P-2 (MT), etc.)
4.07.04.11. Pressure Relief Device - LTC Compartment. – (63P-1 (LTC), 63P-2 (LTC), & 63P-3 (LTC))
4.07.04.12. Low Oil Flow - 1st Stage of Cooling – (80Q/P (MT)~~/P~~)
4.07.04.13. Low Oil Flow - 2nd Stage of Cooling – (80Q/S (MT)~~/S~~)
~~4.07.04.14.AC Supply – Loss of Main AC Supply, Time delayed (27-1)~~
~~4.07.04.15.~~4.07.04.14. Stage 1 Cooling - Loss of AC Supply, Time delayed – (27-~~2~~1)
~~4.07.04.16.~~4.07.04.15. Stage 2 Cooling - Loss of AC Supply, Time delayed – (27-~~3~~2)
~~4.07.04.17.~~4.07.04.16. Loss of Cooling Control Voltage Supply, Time delayed – AC (27-~~4~~3)
~~4.07.04.18.~~4.07.04.17. Loss of LTC Control, AC Voltage Supply, Time delayed (27-~~5~~4)
~~4.07.04.19.Loss of DC Control Voltage Supply, Time delayed (27-6)~~
~~4.07.04.20.LTC Automatic Controls Blocked Due to Out-of-Step – (78 LTC).~~
~~4.07.04.21.~~4.07.04.18. LTC Lockout Relay – (86/68 (LTC~~-VIPS~~))
~~4.07.04.22.~~4.07.04.19. Inert Gas Bottle Alarm – (74/63 ~~LV~~LC)
~~4.07.04.23.~~4.07.04.20. Inert Air Gas Tank Alarm – High – (74/63 HP)
~~4.07.04.24.~~4.07.04.21. Inert Air Gas Tank Alarm – Low – (74/63 LP)
~~4.07.04.25.~~4.07.04.22. LTC Vacuum Bottle Alarm
~~4.07.04.26.~~4.07.04.23. LTC Off-Position Alarm – (78-LTC)
~~4.07.04.27.~~4.07.04.24. LTC Oil Filter Pressure Alarm
~~4.07.04.28.~~4.07.04.25. Loss of Potential to LTC – (74-DB)
4.07.04.26. LTC First-Protect/Regulator Backup Alarm – (90BU)
4.07.04.27. LTC Regulating Relay (90 Self-Test, 90 User Programmable)
4.07.04.28. Auto-Recharging Dehydrating Breather, when provided, Failure Alarm – ARDB (MT)
4.07.04.29. Auto-Recharging Dehydrating Breather, when provided, Failure Alarm – ARDB (LTC)

4.08. LTC Control/Relaying System

4.08.01. The operator interface control panel in the LTC control cabinet shall be a dead front, hinged type, and shall be so hinged that it can be swung through a 90° arc (minimum) without detaching any wiring or devices mounted on the panel. The control cabinet shall conform to Section 4.01.

4.08.02. An external raise/lower input shall be provided through two non-latching auxiliary relays, denoted as 90/RX and 90/LX auxiliary relays. The Seller shall provide an interlock scheme, which will prevent simultaneous raise and lower control signals being applied to the tap changer mechanism. These relays may also serve as the interface to the automatic controller, if specified. The relay will be DC operated with a "low energy coil" for use on a SCADA system.

4.08.03. A "Auto-Manual" transfer switch and a "Raise-Lower" control switch (Electroswitch Series 24 type) are to be installed in the transformer control compartment. Purchaser indicating contacts shall be included to monitor status of the “Auto/Manual” switch.

4.08.04. A tap position indicator shall be located in such a position that the person operating the "Raise-Lower" switch will have full view of the tap position indicator. The indicator shall be equipped with drag-hands, that can be reset from ground level, to indicate max/min travel.

4.08.05. An LTC position transmitter capable of working with an LTC position display unit shall be provided for remote indication of the LTC position. The five control wires shall be brought to a terminal block for Purchaser connection. See Exhibit A, A7 for the approved LTC position transmitter and display devices.

4.08.06. Provide LTC “on-position” indication as part of the LTC operator. Provide an LTC “off-position” alarm.

4.08.07. Provide a six-digit operation counter.

4.08.08. Limit switches and mechanical stops to prevent travel beyond extreme tap positions with Purchaser use contacts to alarm upper and lower extreme tap positions shall be provided.

4.08.09. LTC Control

~~4.08.09.01.Two winding or Distribution transformers shall include an automatic LTC Controller (90-LTC). Space shall be left available in the control cabinet to allow future installation of a parallel balance module and an excessive circulating current relay. See Exhibit A, A8.01 for approved devices.~~

4.08.09.01. A~~utotransformers shall include a~~n automatic LTC Controller (90-LTC) shall be provided when required on the Transformer Spec Detail Sheet. In addition, a parallel balance module and an excessive circulating current relay shall be supplied when required. See Exhibit A, A8~~.02~~ for approved devices and details.

4.08.09.02. A voltage back-up relay shall be provided on all units.

4.08.09.03. Voltage test terminals shall be provided for the LTC controls.

4.08.09.04. LTC current transformers shall be provided by the Seller on the X1 and X2 bushings and shall be compatible for use with the LTC automatic control devices identified in Exhibit A, A8. The current transformers shall not restrict the overload capability of the power transformer.

~~4.08.09.06.~~4.08.09.05. A current “test switch” for Purchaser use shall be installed in series with the LTC CT circuit into the control.

5. Test Requirements

5.01. General Testing

5.01.01. The transformer or reactor shall be fully assembled prior to factory test.

5.01.02. Tests shall be performed in accordance with IEEE C57.12.00, C57.12.90, and/or C57.21 unless otherwise indicated below. Unless otherwise specified, all tests indicated below are considered routine and are required on all units. The purchaser shall be notified prior to the completion of testing of any test that does not meet minimum requirements identified in IEEE C57.12.00, C57.12.90, and/or C57.21 or this document.

5.01.03. The tank cover shall be welded prior to factory acceptance testing, unless preapproved with the purchaser, and no further production work inside the transformer tank, including retightening of the unit, shall be done after final testing.

5.01.04. Lightning Impulse Tests

a) Units which have one or more windings designed for 350 kV BIL or higher, shall have **all** windings subjected to standard impulse tests in accordance with ANSI C57.12.90, as supplemented by ANSI C57.98. The neutral current method of fault detection shall be employed and digital records (voltage and current waveforms including voltage, times, and current) of all impulse tests, comparison of RFW to FW shots, comparison of CW shots, and transfer function comparisons, if available, for each winding shall be furnished with the test report.
b) All windings shall be individually impulse tested.
c) The neutral shall be impulse tested regardless of the BIL level.

5.01.05. Internal Partial Discharge Test

a) An internal partial discharge test shall be made as part of the induced voltage test consisting of a measurement of radio noise influence at standard induced voltage test on each phase on transformers with a winding rated 350 kV BIL and above.
b) Calibration shall be performed for both pC and microvolt measurements at, or close to, the maximum allowed levels. Comparison of sample input and output readings shall be performed at three levels (maximum allowed level, and one value below and one value above the maximum allowed value).
c) Measurements shall be taken on **all** terminals rated 350 kV BIL or higher. Filters between the transformer and power supply may be necessary to eliminate the noise coming from the power supply and background RIV.
d) Discharge monitoring shall be continuous over the one hour test period to insure the transformer is free of damaging partial discharge in the insulation structure. A test frequency of 120 Hz to 300 Hz is acceptable.
e) Damaging partial discharge shall be defined as RIV exceeding 80 microvolts at test voltage.

f) The Seller shall also supply/perform corona measurements in units of pico coulombs (pC). Damaging partial discharge shall be defined as values exceeding 300pC, increases of more than 150pC over the one-hour duration of the test, and any steady increase in value in the last 20 minutes. If a steady increase in the last 20 minutes is measured, the test shall be extended until a leveling of values for a period of not less than 20 minutes is achieved.

g) The certified test report shall include a report showing all measurements recorded during the partial discharge test; including calibration and verification testing that was done.

5.01.06. Switching Impulse Test

A switching impulse test is required for units with high voltage windings operating at 345 kV and above

5.01.07. Insulation Power Factor Test

5.01.07.01. Insulation power factor testing shall be done on all winding-to-winding and winding-to-ground insulation. Measurements shall not exceed 0.5% corrected to 20°C.

5.01.07.02. Insulation power factor testing shall be done on all bushings. Measurements shall not exceed 0.5% corrected to 20°C. In addition, power factor measurements shall not vary more than 10% from the bushing nameplate value and the capacitance shall not vary more than 2% from the nameplate values.

5.01.07.03. For bushings, the capacitance of both C1 and C2 shall be measured and compared to their respective nameplate values. The measurements and their comparison shall be included in the certified test report.

5.01.08. Oil Tests

5.01.08.01. Dissolved Gas-in-Oil Test

a) Dissolved gas-in-oil tests are required as follows:
   i) before any testing is started
   ii) after **each** temperature rise test (Base and Top MVA)
   iii) after the overload temperature rise test
   iv) after dielectric testing

b) The maximum allowed change in gas-in-oil values from test to test is as follows:

Gas	Max. Change (ppm) before & after Dielectric Tests & after Temp. Rise Test	Max. Change (ppm) after Overload Temp. Test
Hydrogen (H_2)	15	20
Methane(CH_4)	2	2
Ethane (C_2H_6)	2	2
Ethylene (C_2H_4)	1	1
Acetylene (C_2H_2)	0	0
Carbon Monoxide (CO)	25	50
Carbon Dioxide (CO_2)	250	300

If the values listed above are exceeded, the Seller is to notify the Purchaser to jointly determine what action, if any, is required. The certified test report shall indicate if the transformer oil has been filtered or processed between tests. If the oil is filtered or processed, an oil test prior to and after filtering shall be provided for reference.

5.01.08.02. Oil Particle Count Test

A particle count shall be performed before start of temperature rise testing and at the completion of all temperature rise testing. Particle counts must be less than or equal to 15,000 particles per 100 ml using a 5 micron filter. Particle counts using a 5 micron filter must meet the following:

Particles per 100ml	**Voltage Class**
≤ 15,000	≤ 230 kV
≤ 10,000	> 230 kV

A copy of the particle count test results shall be provided with the final certified transformer test report. If the particle count value exceeds the 15,000/100ml value, results will be discussed.

5.01.08.03. Bulk Oil Test

A test of the bulk oil supply just prior to filling TR shall be performed. The testing shall include PF of oil, water content, breakdown voltage, and corrosive sulfur. The corrosive sulfur test shall be in compliance with ASTM 1275, Method B. A copy of the bulk oil test report shall be provided with the final certified transformer test report.

5.01.09. Audible Sound Level Test

5.01.09.01. The transformer sound level test shall be performed on the first unit of a design and shall be conducted according to the provisions of ANSI C57.12.90 or C57.21 and NEMA Standard TR 1.

5.01.09.02. Calculated sound power values shall be provided in the certified test report in addition to the actual sound test results.

5.01.09.03. The Purchaser reserves the right to request this test any time prior to final testing.

5.01.10. Impedance Tests

5.01.10.01. Impedance Test and Load Losses

DC Winding resistances in ohms corrected to 85°C (also indicate temperature at which the resistance was measured).

1) Binary short-circuit measurements

a) Positive Sequence Short-Circuit Tests:

1. Three-phase MVA base used for each test.
2. Short-circuit impedance in percent on test MVA base.
3. Load losses at test MVA.

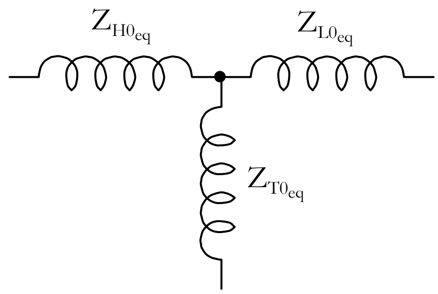
Impedance and load losses corrected to 85°C shall be measured for each set of windings for each no-load tap position at rated current on the rated voltage connection at the ONAN rating. The impedance shall also be provided for the 16R and 16L positions on LTC transformers at the rated no-load position. The positive sequence impedance, resistance, and reactance shall be furnished by Seller as part of the test report.

b) Zero Sequence Short-Circuit Tests:

1. Three-phase MVA base used for each test.
2. Short-circuit impedance in percent on test MVA base.
3. Load losses at test MVA.

Zero phase sequence impedance tests shall be made between all windings at rated taps. The zero sequence impedances, reactance, and resistances corrected to 85°C shall be furnished by the Seller as part of the test reports. The zero sequence impedance shall be measured without the neutral reactor (when supplied) connected and the test report shall explicitly indicate this. The Z_H equivalent impedance shall be a positive quantity under all conditions.

An equivalent zero sequence model shall be provided with the certified test report. Below is an example for an autotransformer.



5.01.10.02. EMTP Modeling

EMTP modeling information shall be submitted with certified test reports for EMTP modeling purposes.

1) Core Construction
   a) Three-legged, 5-legged, shell type, etc.
   b) Core material
      - Manufacturer
      - Catalog #
      - Lamination thickness
      - Stacking (lamination) factor
   c) Core Dimensions
      - Window dimensions
      - Leg and yoke dimensions
2) Coil Design
   a) Number of windings per leg
   b) Arrangement diagram including dimensions

3) Open Circuit Tests

a) Positive Sequence Data

1. Calculate the exciting current at voltage levels from 50% to 120% (and higher if possible, depending on the test source) of the rated voltage using 10% increments in voltage up to 90%, 5% increments thereafter.

Provide waveform plots of the phase voltages and phase currents (i.e. calculate the line current for Y-connected windings and, if possible, calculate the phase current for delta-connected windings). Provide plots of the RMS current as a function of the RMS voltage for each phase.

For transformers with delta windings, make note of whether the delta connections were open or closed during the measurements.

2. Excitation losses in kW at each excitation level.

b) Zero Sequence Data: Zero Sequence measurements are not required on transformers with a delta tertiary unless four leads are brought out. Calculated data shall be supplied when measurement due to a closed delta winding is not possible.

1. Calculate the exciting current at voltage levels from 50% to 120% (and higher if possible, depending on the test source) of the rated voltage using 10% increments in voltage up to 90%, 5% increments thereafter.

Provide waveform plots of the phase voltages and phase currents (i.e. calculate the line current for Y-connected windings and, if possible, calculate the phase current for delta-connected windings). Provide plots of the RMS current as a function of the RMS voltage for each phase.

2. Excitation losses in kW at each excitation level.

5.01.11. Complete function testing of controls shall be performed by the Supplier prior to shipment.

5.01.12. Ratio and polarity testing of all bushing current transformers shall performed by the Supplier prior to shipment.

5.01.13. The operation of the gas accumulation system for conservator type transformers shall be checked by injecting 1000cc of dry air into the transformer tank through a valve at the bottom and farthest away from the gas accumulation (Buchholz) relay. The gas accumulation relay must send an alarm signal within 10 minutes after injecting the dry air or the test will be considered as failed. It the test fails, subsequent tests may be performed, but only after all of the trapped air injected in the previous test has been bled off.

5.01.14. A plot of the voltage vs. time curve (V/Hz) shall be provided with the certified test report.

5.01.15. Sweep Frequency Response Analysis (SFRA) Test

5.01.15.01. The SFRA test shall be performed on the HV, LV, and TV windings as applicable using the "Sweep" Method. It is preferred that the manufacturer uses the Doble M5100 or M5200 test equipment. If the FRAMIT test equipment is used, the vendor shall be required, in the event that shipping damage is suspected, to perform the FRAMIT test on site for comparison purposes at no additional charge to the Purchaser.

5.01.15.02. The SFRA test shall be performed with the transformer in the condition in which the Purchaser will receive it. The test shall be done with the transformer set at the extreme raise position on the LTC (if present) and at the nominal position on the DETC (if present). Both an open-circuit and short-circuit test of each winding shall be performed. The purpose of the test in the "as-shipped" condition is to be able to perform an on site comparison test in the event shipping damage is suspected. If variations on bushing lead positions would adversely affect the comparison of test results, then the manufacturer should use test bushings in the factory and ship the unit with the test bushings in place.

5.01.15.03. If a Doble test set is used the SFRA test report shall be provided electronically in a CSV (comma separated values) or other Doble test equipment recognizable format for import into the Purchaser's Doble test equipment.

5.02. Power Transformer Testing

5.02.01. Losses and Excitation Current Tests

5.02.01.01. Results of no-load losses and excitation current tests shall be made at rated frequency at 90 percent, 100 percent and 110 percent of rated voltage referenced to 20°C.

5.02.01.02. For units containing either a preventive auto (PA) transformer or an LTC reactor, the no-load losses are to be measured on an odd numbered tap position. PA and or LTC reactor losses are to be added to the temperature rise losses. Guaranteed no-load losses shall include loss contributions from the PA or LTC reactor when present.

5.02.01.03. No load losses shall be measured before and after dielectric testing. The losses measured after dielectric testing shall be compared to the guaranteed value.

5.02.01.04. If load losses are not specifically guaranteed, they will be calculated by subtracting the guaranteed no-load losses from the guaranteed total losses. For load loss test requirements, see Section **Error! Reference source not found.**.

5.02.01.05. Auxiliary losses shall be verified by actual test measurements. Estimated auxiliary losses are not acceptable.

5.02.01.06. If the individual tested no-load, load, and auxiliary losses exceed the individual guaranteed loss values by **less** than 5%, the **sum** of the tested losses multiplied by their individual penalty factors minus the sum of the guaranteed values of the losses will be subtracted from the transformer purchase price. If the tested no-load, load, or auxiliary losses exceed the guaranteed loss values by **more** than 5%, the loss value that exceeds the 5% will be penalized at a rate of three (3) times the specified factor.

5.02.01.07. No credit will be given for tested losses that are less than guaranteed. There are no allowed tolerances from the quoted guarantee.

5.02.02. Core Insulation Resistance Test

The insulation between the core and the tank shall be checked using a 2500 volt megger between the tank of the transformer and the intentional core ground terminal. This test shall be done prior to Dielectric testing and at the conclusion of the induced potential test while the transformer is still filled with oil. The resistance shall be 1000 Mega ohms (corrected to 20°C) or greater after one minute of application of 2500 volts in order for the transformer to pass this test.

5.02.03. Temperature Rise Tests

5.02.03.01. The transformer temperature monitor shall be activated during the temperature rise test. The actual top oil temperature at the end of each temperature rise test for both the test probe and the temperature monitor shall be documented in the test report. The test probe and the WTI probe shall be in close enough proximity to each other such that the results are within 2°C.

5.02.03.02. The following information shall be included in the certified test report:

a) Ambient temp at end of total loss run (cutback)
b) Top Oil Temperature at end of total loss run
c) Top radiator temp at end of total loss run
d) Bottom radiator temp at end of total loss run
e) Ambient temp at shutdown
f) Top Oil Temperature at shutdown
g) Top radiator temp at shutdown
h) Bottom radiator temp at shutdown
i) Hot spot factors from engineering for HV and LV
j) Hot resistance value used for HV and LV

k) Hot resistance temperature
l) Shutdown hot resistance measurements and times
m) Hot resistance versus time curves
n) Cold resistance measurement and associated temperature
o) Calculated Gradient for each winding for each temperature rise test

5.02.03.03. The temperature rise tests shall be done in the configuration that would produce the highest temperature rise for the winding. For two winding transformers, this would be the lowest HV tap and the lowest LV tap position for full capacity taps below neutral, or the lowest HV tap and the rated LV tap for reduced capacity below neutral. If an LTC is present and includes a PA or an LTC reactor, then the next bridging position should be used. For autotransformers, the highest series and common winding currents occur in opposite HV tap positions; therefore the temperature rise must be corrected to actual winding currents if the shutdown is done in one tap position only.

5.02.03.04. An infrared scan of each Segment of the transformer shall be taken at the peak of the top MVA and the Overload Temperature Rise tests. The test scans shall be provided, in color, with the certified test report.

5.02.03.05. Standard Temperature Rise Test

a) The temperature rise test shall be performed on the first unit only of a design. Test reports from similar thermal duplicates are not acceptable. This test shall be made at the self-cooled rating and at the maximum forced cooled rating. The temperature rise test, when required, shall be performed prior to dielectric testing.
b) Temperature take-off readings for the self-cooled rating, when within 2 degrees of the maximum allowed values, shall be taken on all three windings.
c) Temperature take-off readings for the test at the maximum forced cooled rating shall be taken on all three phases with separate shutdowns for each phase.
d) The results (top oil temperature, winding temperatures, hottest spot temperature, and load losses) of the temperature rise test shall be documented in the certified test report. In addition, all readings taken for the duration of the test shall be provided in the certified test report.

5.02.03.06. Overload Temperature Rise Test

a) The overload temperature rise test shall be performed on the first unit only of a design. Test reports from similar thermal duplicates are not acceptable.
b) The overload temperature rise test take-off measurements shall be taken on the phase with the highest readings during the maximum forced cooled rating test.
c) This test shall be performed, at the conclusion of the standard temperature rise test while the transformer is still filled with oil. Prior to the start of the 8 hour overload test, the top oil temperature should be brought back up to the top oil temperature achieved during the standard ONAF temperature rise test.

d) All "Distribution and Small System Transformers" shall be tested for satisfactory performance at the "Single-Cycle" overload condition specified in Table 1.

e) All "Large System Transformers" shall be tested for satisfactory performance at the "Multi-Cycle" overload condition specified in Table 1.

f) The results (top oil temperature, winding temperatures, hottest spot temperature, and load losses) of the overload temperature rise test shall be documented in the certified test report. In addition, the winding temperatures, top oil temperature, hottest spot temperature, and load loss information for all of the overload cases identified in Table 1, shall be calculated with respect to the overload conditions of the table, and documented in the transformer's certified test report.

g) The calculated temperature performance numbers shall not exceed the maximum temperature performance numbers specified.

5.02.03.07. Temperature Rise Test for duplicate units

a) A temperature rise test shall be performed at the maximum forced cooled rating on all duplicate transformers as a quality control test in place of the standard temperature rise test.

b) The temperature rise test for duplicate units shall be performed prior to dielectric testing.

c) The temperature rise test for duplicate units shall be performed on all three phases.

d) The winding rises over mean oil from the temperature rise test for the duplicate unit shall be compared with the results from the transformer for which the standard temperature rise test was performed. The plot of both of these curves shall be provided along with the Factory Test results (including the reference Serial Number for the original unit). Any winding rise over mean oil exceeding the results of the transformer which had the full temperature rise test shall be reported immediately to the Purchaser and the discrepancy shall be resolved with the Purchaser.

5.02.04. Single-phase excitation tests on each phase shall be performed using Doble test equipment and procedures.

5.03. Shunt Reactor Testing

5.03.01. Temperature Rise testing shall be performed as a routine test on all units.

5.03.01.01. The temperature rise test shall be performed at 115% of the rated voltage.

5.03.01.02. The transformer temperature monitor shall be activated during the temperature rise test. The actual top oil temperature at the end of each temperature rise test for both the test probe and the temperature monitor shall be documented in the test report. The test probe and the WTI probe shall be in close enough proximity to each other such that the results are within 2°C.

5.03.01.03. The following information shall be included in the certified test report:

a) Ambient temp at end of total loss run (cutback)
b) Top Oil Temperature at end of total loss run
c) Top radiator temp at end of total loss run
d) Bottom radiator temp at end of total loss run
e) Ambient temp at shutdown
f) Top Oil Temperature at shutdown
g) Top radiator temp at shutdown
h) Bottom radiator temp at shutdown
i) Hot spot factor from engineering
j) Hot resistance value and temperature
k) Shutdown hot resistance measurements and times
l) Hot resistance versus time curves
m) Cold resistance measurement and temperature
n) Calculated Gradient

5.03.01.04. Temperature take-off readings shall be taken on all three phases on the first unit of a design. On duplicate units, the take-off reading shall be taken on the hottest phase identified from testing of the first designed unit. If the winding rise is within 2 degrees of the maximum allowed value, readings shall be taken on all three phases.

5.03.01.05. An infrared scan of each Segment of the reactor shall be taken at the peak of the Temperature Rise test. The test scans shall be provided, in color, with the certified test report.

5.03.02. Losses

5.03.02.01. If the tested load losses exceed the guaranteed loss values by **more than** 5%, the losses will be penalized at a rate of three (3) times the specified factor.

5.03.02.02. No credit will be given for tested losses that are less than guaranteed. There are no allowed tolerances from the quoted guarantee.

5.03.03. The Audible Sound Test shall be performed at the maximum specified operating voltage identified on the Spec Detail Sheet.

5.03.04. A Vibration Test is required on all units.

5.03.05. A Magnetic Characteristics (Linearity) Test is required on the first unit of a design.

5.04. Test Reports

5.04.01. Four (4) certified copies of all test reports shall be furnished to the Purchaser within 2 weeks after test completion.

5.04.02. Test reports shall be furnished by the Seller **on all tests requested**, and shall include but are not limited to:

- Impulse and Switching Surge test results, waveforms, and shot logs
- Partial Discharge test results including calibration testing verification
- No-Load losses
- Excitation current curves for the main core-coil assembly
- Impedance and Load loss measurements
- EMTP modeling
- Insulation Power Factor
- Oil tests including DGA, Corrosive Sulfur, Particle Count, and other standard oil tests
- Audible Sound Level test results including measurement logs and data
- Temperature Rise and Overload Temperature Rise test details including resistance take-off measurements, the data required in Section 5.02.03.02, Infra-Red scans, and the resistance measurement readings and curves
- Function Testing of controls
- CT Ratio and Polarity tests
- SFRA
- V/Hz curve
- Single-Phase Excitation Test
- Vibration Test (Power Reactors)
- Magnetic Characteristic (Linearity) Test (Power Reactors)
- Test reports for all components such as bushings and neutral grounding reactors. Test equipment shall be traceable to NIST (National Institute of Standards and Technology). Test data shall be referenced to 1000 meters altitude.

5.04.03. The Purchaser reserves the right to witness tests performed by the Seller. The Seller shall notify the Purchaser a minimum of two weeks prior to test.

5.04.04. Test Failures/Non Conformances

5.04.04.01. **Failure to meet any test or the Transformer or Reactor Detail Sheet requirements of the transformer during factory tests or test results that for any reason exceed acceptance criteria or standard tolerances shall be reported immediately by phone to the contact listed in the Drawing Coordinator Section of the Transformer or Reactor Detail Sheet**, unless an authorized Purchaser's representative is present during testing. A written report shall be prepared with color photographs, documenting any test floor failures, the reason for the failure, and the corrective action to be taken prior to retest. Photographs both before and after any repairs shall be provided.

5.04.04.02. The Purchaser shall have the option to inspect such damages and/or test failures.

5.04.04.03. The Purchaser reserves the right to witness retests performed by the Seller. If the Purchaser has opted to witness tests, it shall be the Seller's responsibility to pay full travel costs, expenses, and labor, associated with the Purchaser's *return* to rewitness testing if the delay to retest after a failure is greater than 24 hours from the time the transformer or reactor failed test.

5.04.04.04. For any internal failure or flashover during dielectric testing, at a minimum, all dielectric tests shall be performed again after necessary repairs or corrections are made, regardless of when in the sequence of dielectric tests the failure occurred.

5.04.04.05. For any failure during testing that requires complete more that untanking to repair, at a minimum a duplicate unit temperature rise test shall be performed to verify that the cooling system has not been compromised during reassembly.

5.05. Factory Assembly

Factory Assembly (complete assembly) of the transformer or reactor with all accessories and components supplied, (surge arresters, bushings, tap changers, conservator tanks, radiators, fans, coolers, reactors, etc.) shall be performed prior to shipment to ensure proper fit of all components, adequate electrical clearances are maintained, and parts are available for successful field assembly of the transformer. Color photographs of the completely assembled transformer or reactor at the factory shall be provided with the instruction manuals. See Section 7.07.06.02 for details.

6. Field Installation and Testing

The Purchaser will determine on a case-by-case basis whether field assembly, oil processing, and testing by the Seller will be required and will identify the requirement on the purchase order or contract. Xcel Energy reserves the right to cancel this requirement prior to it being scheduled without penalty.

6.01. Field Assembly

Field assembly, when required in the Purchase Requisition/Contract shall include: offloading of the transformer onto the foundation; an internal inspection; installation of the radiators, bushings, arresters, etc.; all auxiliary equipment furnished by the Seller; vacuum oil fill; and pre-energization testing in accordance with ANSI Standard C57.93, and with testing and checks identified in Section 6.02. If field installation is performed by a Subcontractor to the Seller, the Subcontractor must be approved by the Purchaser prior to installation. The field installer is responsible for providing all equipment and electrical power required for complete installation. The Seller shall at all times throughout the process of field installation, keep work areas neat and orderly. Waste materials from the installation work shall be removed and disposed of by the Seller.

6.02. Field Oil Processing

Oil processing procedures shall, at a minimum, follow the procedures in the Seller's instruction manual.

6.03. Field Testing/Checks

6.03.01. Field testing, when required in the Purchase Requisition/Contract to be performed by the Seller, shall include all the tests listed below unless otherwise agreed to by Seller and Purchaser. All field testing may be witnessed by the Purchaser's Field Representative.

6.03.02. An internal and external inspection shall be performed on the transformer or reactor, when possible, after assembly and prior to oil filling. See Exhibit F for the minimum internal inspection requirements. The Seller shall be responsible for ensuring that all applicable safety requirements for workers, including air monitoring measures, are met. Only tools necessary for the inspection shall be taken into the transformer or reactor and any tools taken into the ~~transformer~~equipment must be adequately tethered to allow retrieval if dropped. In the event that an inspection must be held in inclement weather, and temporary enclosure must be constructed to prevent the entrance of contaminants into the transformer and its associated compartments. The Seller shall provide a copy of the completed checklist with any comments with the final field test report documentation.

6.03.03. All testing shall be done on the specified equipment after it is fully assembled and installed at its permanent location, unless otherwise directed by the Purchaser. The Seller shall maintain a written record of all tests showing date, personnel performing test, results, and type of testing equipment used by manufacture, model type, and model serial number. The test sheets must show all equipment nameplate data (including all bushings and surge arresters). The testing shall be performed by using a Doble Model M4000 test set and a Doble M4110 leakage reactance interface. The field tester is responsible for providing all equipment and electrical power required to complete the electrical testing requirements.

6.03.04. A copy of the original written test report results shall be provided to the Purchaser's Field Representative after completion of the testing and before leaving the site. Two (2) additional bound field test reports and CD ROM with the information in a Doble M4000 format shall be provided to the Purchaser no later than (30) calendar days after completion of the field testing.

6.03.05. Questionable test results/readings shall be immediately reported to the Purchaser with recommendations for correction, as soon as practical. All revisions and changes found on field drawings should be shown on the Seller's drawings and copies provided to the Purchaser.

6.03.06. Photographs shall be taken of all issues/defects identified during the internal and external inspections. Copies of all photographs shall be included in the final bound test report as well as in the electronic CD ROM format.

6.03.07. The following field tests and checks shall be performed:

6.03.07.01. Initial Tests/Checks

a) Verify instruction manual in control cabinet.
b) Check impact recorder results (See Section 3.05**Error! Reference source not found.** for impact limits).
c) Perform an internal inspection before oil filling. The Seller is responsible for notifying the Purchaser's representative prior to performing the internal inspection so that he/she may be present. See Exhibit F for check list to be completed and included in the test report packet. When practical, color photographs of the bottom connection of the HV and LV bushing connections shall be taken. Provide color copies of photographs and internal inspection report with the written field-test report.
d) Verify positive pressure in the main tank.
e) Perform a dew point test.
f) Equipment ground verification/visualization.
g) Perform (2500V) core to ground megger test.

6.03.07.02. Insulating Oil Tests/Checks

a) Provide certified test report of oil delivered in the transformer or reactor or for each tanker of oil delivered. The following tests shall be included on the certified test report and resultant values shall comply with C57.106 guidelines where provided.
   i) Power factor 25°C & 100°C per ASTM D924
   ii) Dissolved gas-in-oil test per ASTM D3612
   iii) Moisture content per ASTM D1533B
   iv) Dielectric breakdown per ASTM D1816
   v) Interfacial tension per ASTM D971
   vi) Acidity per ASTM D974
   vii) Color per ASTM D1500
   viii) Furanic compound per ASTM D5837
   ix) Specific gravity per ASTM D1298.
   x) PCB test
   xi) Inhibitor content
   xii) Perform a visual and sediment examination per ASTM D1524 (look for contaminants).
   xiii) Corrosive Sulfur test per ASTM D1275 Method B.
b) Check all oil levels after filling.
c) Check valve positions.

d) Perform a dielectric test per ASTM D877 during installation and ASTM D1816 for final acceptance prior to energization. Values shall comply with C57.106 guidelines.
e) Perform Doble power factor test on insulating oil prior to and after filling transformer.
f) Perform a dissolved gas analysis test and a Karl Fischer test on the transformer or reactor and LTC compartment after all processing and testing is complete.

6.03.07.03. Equipment Tests per ANSI C57.12.90; Method II

a) Perform Doble power factor test of bushings, prior to installation if shipped separately.
b) Perform Doble capacitance test of bushings.
c) Perform Doble hot collar test of bushings.
d) Perform Doble test of surge arresters.

6.03.07.04. CT Tests (all tests shall be done from the CT terminal blocks in the control cabinet)

a) Polarity Test all CTs.
b) Megger Test to ground all CTs.
c) Perform CT ratio test – all taps.
d) Perform saturation (secondary excitation) tests on all CTs (check tests against curve test data).
e) All CT terminal block wiring shall be verified to match Seller's drawings.

6.03.07.05. Winding Tests (Per Doble transformer winding test sheet)

a) Perform Doble power factor test.
b) Perform single-phase, low-voltage excitation tests (i.e., 10 kV excitation current test) at all LTC taps at rated DETC tap.
c) Perform turns ratio test (TTR) on all DETC taps with LTC in Neutral and on all LTC taps (16R-1L), when applicable, with the DETC on the highest voltage tap.
d) Perform winding resistance test on each DETC tap with the LTC in neutral and on all LTC taps (16R-1L), when applicable, with the DETC on the highest voltage tap.
e) Set taps control as required by the Purchaser. After final tap is set, Seller shall perform a final TTR at that setting.

6.03.07.06. SFRA Tests

a) In the event that damage incurred during shipping is suspected, an SFRA test shall be done by the Seller with Doble M5100 or M5200 test equipment in the as received condition (prior to assembly or oil filling, if not shipped oil filled) with the transformer set to the same tap positions used for the factory test. This shall then be compared to the test done by the Seller at the factory. If Doble SFRA test equipment was not used by the Seller at the factory, the

Seller shall supply the same test equipment at the site in order to compare results.

b) An SFRA test shall be done with Doble M5100 or M5200 test equipment after the transformer has been fully assembled and oil filled. The test shall be done with the transformer set at the extreme raise position on the LTC (if present) and at the nominal position on the DETC (if present). Both an open-circuit and short-circuit test of each winding shall be performed.

6.03.07.07. Nitrogen Gas Equipment Checks

a) Check regulator operation.
b) Check valve positions.
c) Test moisture content of N_2 gas per ASTM D3283.

6.03.07.08. Control/Cooling Equipment Functional Test

All control and cooling equipment shall be functional tested. Functional testing means applying the appropriate inputs (voltage, current, pressure, temperature, etc.) to a device and verifying all required responses or outputs. The types of tests usually included, but not limited to, are the following:

a) Fault pressure relays (main tank, tap changer, fault flow). Full calibration test performed with enough points tested and plotted to compare with manufacture's curves.
b) Motor starting current on pumps
c) Fan and/or pump rotation checking air/oil flow.
d) Alarm checkout.
e) Alarm sensors tests (top oil temperature, winding temperature, low oil, etc.) (function and calibration tests).
f) 90 LTC voltage controller verification including all auxiliary contacts, remote control and indication.
g) All control and cooling terminal block wiring should be verified to match the Seller's drawings.

7. Drawings/Documentation

7.01. Required Documentation

Drawings, manuals, and other documentation shall be provided in accordance with the documentation schedule below. Documentation shall be sent to the Drawing Coordinator address identified in the Transformer or Reactor Detail Sheet or Purchase Order. Each document submittal must identify the Xcel Energy purchase order number, Supplier's work or shop order number, and the equipment serial number (if applicable).

7.02. Approval Drawing Review

The Seller shall allow the time specified in the documentation schedule below for Purchaser's review of the approval drawings without affecting the ship date. Upon review of the drawings by the Purchaser, one scanned copy of marked-up drawings will be returned to the Seller. Acceptance of the approval drawings by the Purchaser, with or without any changes noted, shall not relieve the Seller of its responsibility for meeting all requirements of the Purchase Order, Transformer or Reactor Detail Sheet and Material Standard or for the proper design and construction of the equipment. If the Approval Drawing changes are determined by the Purchaser to be significant enough to require further review cycles, the Seller shall revise and resubmit the Approval Drawings for approval. Seller shall provide the final full serial number as it will be engraved on the nameplate at the time of the approval drawing review.

7.03. Drawing Revisions

Each drawing shall have a specific revision number associated with each revision. All Seller-generated changes or modifications occurring after the return of the Approval Drawings shall be clouded on a separate set of non-reproducible drawings. These drawing revisions shall be provided with the Final drawing packages. Any revisions to the Final Drawings after submittal of the Final Drawings must be identified and approved by the Purchaser prior to proceeding with the drawing changes.

7.04. Format of Documentation

7.04.01. Paper drawings shall be blue-line or black-line prints provided in ANSI Standard sizes "A" (8.5" x 11"), "B" (11" x 17"), or "D" (24" x 36") only.

7.04.02. Electronic drawing data shall be provided for all paper drawings submitted in Microstation Integraph ISIF ASCII command format (.dgn) or AutoCad (.dwg or .dxf) format, as well as in Portable Document Format (PDF) format.

7.04.03. Electronic versions of all other paper documentation (including Manuals) and other textual documentation shall be provided in addition to the paper versions. These electronic documents shall be provided in PDF format. Whenever possible, if PDF format is provided, it shall be a searchable PDF file not a scanned document.

7.04.04. Electronic versions of all documents shall be submitted electronically for the Approval Drawing submittals and on a CD ROM disk for Final Drawing submittals. The Instruction Manual, photographs, test reports, and SFRA test data shall be included on the Final Drawing CD ROM. If multiple PDF files are submitted for the Instruction Manual, the documents must be non secured such that they can be combined with other PDF documents. It is highly preferred that the Instruction Manual be one electronic document with electronic bookmarks marking each section or equipment brochure. The Seller supplied drawings should not be included in the electronic version of the Instruction Manual. Separate CAD **and** PDF versions of **each** drawing are to be provided. A combined PDF of individual CAD generated drawings is not acceptable.

7.04.05. Information on all drawings or documentation supplied shall be fully legible when printed on 11” x 17” paper.

7.05. Manuals

7.05.01. Instruction manuals shall be bound ~~and have~~ or in binders with a durable cover and locking rings to prevent them from inadvertently opening up. Each manual shall include:

7.05.01.01. detailed equipment installation, operation, and maintenance instructions,

7.05.01.02. a complete set of full size drawings ~~contained in envelopes or bound in the manual~~. **If reduced size prints are provided in the manual**, then two separate folded copies of each full size print~~s~~ are ~~also required~~to be provided, and should **not** be inserted into plastic sleeves or envelopes.

7.05.01.03. certified test reports, **a warranty certificate with warranty duration and limitations clearly identified**, a list of required information from the Purchaser to the Seller in order to validate the Seller's warranty (if required), and a list of recommended special tools and spare parts (including type and manufacturer) required to assemble, operate, and maintain the equipment.

7.05.02. The instruction manuals shall be sent to the Purchaser no later than seven (7) calendar days after the transformer or reactor ship date. One~~, of the seven,~~ complete instruction manual~~s~~ and all attachments **shall be shipped with the transformer or reactor** in the control cabinet.

7.06. Document Reproduction

The Purchaser requests permission from the Seller to reproduce his drawings and other data as required. Acceptance of the Purchase Order/Contract by the Seller grants such permission. The Purchaser shall not use the Seller's drawings in any way detrimental to the Seller's interest.

7.07. Document Types and Content

7.07.01. The Purchaser's Location, Project WO Number, ~~Transformer ID~~UTC Number, ~~Project number,~~ Purchase Order/Contract Release Number, and the Seller's Serial Number shall appear on all drawings. The ~~Transformer ID Number and~~ Location and Project WO Number will be identified on the Purchaser's Purchase Order/Contract. The UTC number will be identified at the approval drawing stage.

7.07.02. When the Seller utilizes the same design~~/specification~~ as on previous~~for multiple transformer~~ orders, the Approval/Final drawings shall also list on all of the drawings, the Location, Project WO Number, Transformer ~~ID~~ UTC Number, and Serial Number for the original unit, which utilized~~apply to~~ that design, and for which the original temperature rise and sound testing was performed. ~~In addition, each transformers's Final drawing set, shall uniquiely identify the transformer's specific ID number.~~ On multiple transformer orders, ~~this requirement may be met by providing~~ a table showing the information requested in Section 7.07.01 shall be included on all of the drawingsall orders for this design on each drawing.

7.07.03. The Seller shall provide production schedules on a monthly basis after receipt of order (ARO) and on at a minimum of a bi-weekly basis once thea transformer unit has gone into actual production.

7.07.04. All drawing dimensions, weights, and volumes shall be first provided in U.S. standard units of measure. Metric (SI) units may be provided as **secondary** units of measurement in parenthesis or brackets.

7.07.05. Drawings furnished shall be unique to the transformer or reactor being furnished and shall clearly indicate the physical parameters, electrical characteristics, and auxiliary equipment. These drawings include but are not limited to the following:

7.07.05.01. Nameplate Drawings - The information supplied shall be in accordance with the ANSI Standard requirements.

a) Transformer or Reactor Nameplate
b) Bushing Nameplate
c) Reactor Nameplate
d) Arrester Nameplate
e) Current Transformer Nameplate
f) Tap Changer Nameplate
g) Temperature Alarm Set-Point Nameplate

7.07.05.02. Dimensioned Elevations and Outline Drawings including the following:

a) elevations of all four sides, the base and the top plan labeled as "HV-LV", "HV", "LV-HV", "LV", "Top Plan", and "Base"
b) dimensions (including untanking)
c) dimensioned location of all parts and accessories including the bushings, surge arresters, radiators, control cabinets (to top and to bottom) and centers of gravity (in three dimensions) of the completely assembled transformer with oil and for shipment without oil
d) weights (shipping and completely assembled) with gallons of oil and weights separately provided for the main tank, conservator, radiators, and LTC compartment.
e) volumes
f) identify all items to be removed for shipment and provide weight information
g) Shipping restrictions shall be noted on the transformer or reactor outline drawing. For example, "Transformer not designed for rail shipment." Parts and accessories shall be identified on a Bill of Material.
h) Item descriptions should include quantities, manufacturer, and part or catalog numbers, where appropriate. In addition to the above, bushing descriptions are to also include at BIL and ampere ratings, and whether the bushing is

draw-lead, draw-rod, or bottom connected. Items that are called out on both the outline drawing and control drawings shall have a common designation.

i) Fan stages shall be adequately identified such that each fan is identified as stage 1 or stage 2, as appropriate.

7.07.05.03. Internal Assembly Drawings (with final drawings) including the following:

a) bushing pockets (fully dimensioned sectional and top views of the bushing pockets with and without bushings installed.)
b) flanges
c) current transformer pockets
d) all minimum clearances
e) leads

7.07.05.04. A Shipping Outline shall be provided. The drawing shall include location and routing of all conduits, junction boxes, impact recorder type and mounting provisions, dry air canister and mounting, as well as all other devices, brackets, etc. not removed for shipment. A top view and all four segments shall be provided.

7.07.05.05. Bushing Outlines showing physical and electrical parameters.

7.07.05.06. Reactor Outlines showing physical and electrical parameters.

7.07.05.07. Surge Arrester Outlines showing physical and electrical parameters.

7.07.05.08. Gasket Information Drawings or information shall be provided showing gasket dimensions and materials to allow the Purchaser to purchase or field fabricate replacement gaskets.

7.07.05.09. Schematic and Wiring Diagrams - LTC control and elementary which shall be used by the Purchaser in preparing interconnection diagrams between the various items of equipment. The wiring diagrams shall use "point-to-point" method; i.e. terminal points on devices are labeled with the destination device and terminal point, and shall include auxiliary power requirements and fuse and breaker sizes. Wire diagrams that make use of wire lists, are not acceptable. The Seller shall use the terminal numbers indicated on the Purchaser's schematic diagram (see Exhibit B~~1~~), when furnished, on all terminal points leaving his equipment. Associated terminal points shall be grouped together to facilitate the use of multi-conductor control cables for interconnecting equipment. Terminal blocks shall be shown on the same sheet with internal devices to which they are connected.

7.07.05.10. CT Curves - secondary excitation, ratio correction factor, and TRF for all current transformers, including LDC and WTI current transformers shall be provided.

7.07.05.11. Conservator Tank Oil Fill Table – A drawing containing the conservator tank oil fill table data shall be provided to allow the Purchaser to determine the distance to the oil level below the top flange or opening in the top of the conservator at 25ºC. In addition, the table shall provide the oil temperature for nine step increases in 2" increments and for nine step decreases in 2" increments. A formula for calculating the distance from the top of the conservator tank to the top of the oil level for varying oil temperatures shall also be provided on this drawing so that the Purchaser may verify measurements or extend the table if necessary.

7.07.05.12. Items that are common to both physical drawings and control drawings should be identified with the same designation.

7.07.06. Color photos

7.07.06.01. Color photos (8" x 10") or color copies of all four sides (complete views) and top view of the transformer internal assembly immediately prior to tanking and before protective wraps, if possible, are applied shall be provided. The Seller's Serial Number shall be displayed in each photo **without** obstructing the view of the core and coils. Digital photographs must be a minimum of *3 megapixel resolution* **and** provide clear, quality pictures when printed at an 8" x 10" size. Digital files in JPEG or TIF file format shall be provided in addition to the 8" x 10" printed photos.

7.07.06.02. Color photos of each side of the completely assembled transformer or reactor shall be ~~provided~~taken **prior** to ~~shipping~~testing.

7.08. Documentation Schedule

The Purchaser will examine all approval drawings and return one copy of the drawings within 3 weeks (21 calendar days) after receipt.

Documentation Schedule and Requirements

Drawing / Document	Approval Drawings Quantity Format[a]/Schedule[b]	Final Drawings Qty Format[a]/Schedule
Production Schedule	Electronic - See Section 7.07.02	-
Drawing List	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Nameplate Drawing	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Dimensioned Elevations, Outline, and Base Drawings	1 E / 16 – 20 wks prior to ship	1 P, 1 E / 2 wk ASO
Shipping Outline	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Neutral Reactor Outline Drawing	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Bushing Outline Drawings	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Surge Arrester Outline Drawings	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Conservator Tank Oil Fill Table	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Internal Assembly Drawing	1-E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Control Cabinet layout Drawing	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Control Schematics & Connection Drawings	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
CT Excitation Curve & Ratio Correction ~~Factor~~Factor Drawings	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Detailed Factory Test Plan	1 E / 16–20 wks prior to ship	
All other drawings	1 E / 16–20 wks prior to ship	1 P, 1 E / 2 wk ASO
Gasket Dimensions and Materials		1 P, 1 E / 2 wk ASO
Test reports [c]		1 P, 1 E / 2 wk ASO
EMTP Modeling Information		1 P, 1 E / 2 wk ASO ~~See Section~~ See Section **Error! Reference source not found.**
Photographs of Core and Coils		1 E within 48 hrs of photographing & 1 P, 1 E (on CD)/2 wk ASO. See Section 7.07.06.01
Photographs of Assembled ~~Transf.~~Unit.		1 P, 1 E / 2 wk ASO See Section 7.07.06.02
Manuals (delivered to dwg coordinator)		4 B, 1 E / 2 wk ASO 5B for units delivered to WI & MI
Manuals (incl. with equip. in control cabinet)		1 B / with equipment delivery

[a] Format of drawing / document:
P) paper format – Full Size Print (separate from those included in the manuals if manuals contain reduced size prints)
E) electronic format
B) bound manuals including all drawings and test reports

Documentation Schedule and Requirements

[b] Certain drawings may be required earlier to support foundation or physical design needs.

[c] Seller to supply Test Report data to Purchaser for approval prior to transformer shipment. Purchaser contact information will be supplied on the purchase order. Data files for Factory SFRA testing shall be provided in electronic format (.sfra or .csv).

Definitions: ARO – After Receipt of Order/Contract
ASO – After Shipment of Order

Note: For multiple purchase orders, one set of all electronic documentation is acceptable as long as the equipment is identical and all orders are referenced

8. Warranty Period

8.01.The Seller shall warranty the transformer against defects in materials and workmanship for a minimum of three (3) years from the date the transformer is delivered.

8.02.The warranty shall cover, as a minimum, for the first year (in/out) costs for rigging; oil removal, filling, storage and processing (see Section 6.02); transformer removal, dismantling, assembly and re-assembly; and field testing (including any investigative testing and acceptance testing after reinstallation) per Section 6.03. Transportation costs to and from the factory during the first year shall be fully covered, but not included in any limitation or cap on first year in/out costs.

8.03.8.01. The warranty period shall start on energization of the transformer or reactor or 6 months after receipt, whichever is earlier.

8.04.8.02. The Seller shall provide a warranty certificate in the Instruction Manual identifying the warranty expiration date, and any special terms or conditions.

8.03. During the warranty period, gas generation levels above Condition 2, as defined in C57.104-2008, Clause 6.5.1 and Table 2, shall be an indication of transformer failure. and shall require immediate action by the Seller.

9. Shipment

9.01. General

9.01.01. Each transformer or reactor shall be filled with dry air under positive pressure or oil filled for shipment to the Purchaser's destination point. The transformer shall be clearly marked as shipped with dry air when shipped without oil. Dry air cylinders shall be manufactured to US DOT type 3AA high-pressure cylinder specifications and the Supplier shall comply with the transportation requirements of the Federal Regulations, 49 CFR.

9.01.02. The transformer or reactor and any components which are packaged separately shall be fastened so that they will not shift, tip, or drop during shipment. All railroad cars or trailers used in the shipment of the transformer or reactor and accessories shall be marked for careful handling.

9.01.03. Transformer or reactor equipment and accessory shipping containers and packing lists are to be clearly labeled identifying job title, destination, and Purchase Order/Contract number. The small accessories, assembling components and their shipping containers are to be packaged such that they are easily identified as to the specific transformer assembly for which they are part..

9.01.04. All parts and accessories shall arrive at the destination point within 24 hours of the transformer or reactor delivery. These items are to be shipped to the substation/project job site or to the Purchaser's storeroom specified by the Purchaser.

9.01.05. Radiators shall be shipped detached filled with dry air and with steel, gasket-sealed blind-flanges in place.

9.01.06. All parts removed for shipment shall be match marked and identified.

9.01.07. Control cabinets shall be shipped in place and as completely wired as possible.

9.01.08. Purchaser to be notified by telephone the day the transformer or reactor leaves the factory indicating railroad car or carrier numbers, routing, actual shipping height, and actual shipping weight of the transformer as listed on the freight bill. In addition, the Purchaser shall be notified forty-eight (48) hours prior to the transformer or reactor arrival at the final destination.

9.01.09. If the transformer or reactor is shipped without insulating oil, the oil shall be furnished by bulk shipment in truck-trailers, for arrival at the construction site at the time designated by the Purchaser. After oil arrives at the construction site, a testing period of up to 24 hours may be required before oil is transferred to the Purchaser's handling or storage equipment.

9.01.10. Units shipped to NSP or PSC operating companies, between November 1 and April 30, must be covered in some manner to prevent road dirt/salt from coating the transformer or reactor and parts.

9.02. Impact Recorders

9.02.01. Two three-way impact recorders providing continuous record of all impacts (all 3-axis) during the entire period of shipment shall be installed on the transformer or reactor tank for ocean or rail transportation. One impact recorder shall be placed within one foot of the transformer base and the other impact recorder shall be placed within one foot of the transformer cover or on the cover. At least one of the impact recorders shall be an electronic type recorder with GPS tracking capability.

9.02.02. One three-way, electronic, impact recorder providing continuous record of all impacts (all 3-axis) during the entire period of shipment shall be installed on the transformer or reactor tank for ~~transformers~~units shipped entirely by truck.

9.02.03. A report shall be provided to the Purchaser identifying all impacts or recorder failures within two weeks after delivery of the transformer or reactor.

9.02.03.01. In the event a transformer or reactor arrives at its destination with an inoperable impact recorder, dead battery, insufficient paper, or with indicated recordings of Zone 3 impacts or higher, the Seller shall determine at his expense and to the Purchaser's satisfaction, the true condition of the transformer by performing at a minimum, the following inspection and tests:

a) A complete comprehensive internal inspection with the Purchaser's representative before oil filling. Color photographs shall be taken documenting the existing condition, and a report documenting the inspection shall be prepared by the Seller.
b) Frequency Response Analysis (FRA) Tests shall be performed on each winding using the "Sweep" Method.

9.02.03.02. If the Purchaser is not satisfied with the results of the transformer or reactor condition assessment performed as a result of the ~~transformer~~equipment experiencing a Zone 3 impact or higher, the Purchaser has the right not to accept the ~~transformer~~equipment and to require additional field testing or the transformer or reactor to be shipped back to the factory for additional testing at the Seller's expense.

9.03. Rail Shipment

9.03.01. If the transformer or reactor and accessories are shipped by rail, the Purchaser requires that the freight cars carrying the transformer and the accessories be shipped together. In addition, the Purchaser requests that the Seller put the following on the Bill of Lading:

"The transformer (or reactor) car No. ________ and accessories car(s) No. _________ are to travel together".

9.04. Ocean or Barge Shipment

9.04.01. If the transformer or reactor and accessories are shipped by ocean vessel or barge, the Purchaser requires that the vessels carrying the transformer or reactor and the accessories be shipped together.

9.04.02. It is the Seller's responsibility to verify whether impact recorders, dry air cylinders, and any pressure sealed accessories are still in operable or sealed prior to transfer from the ship or barge to the next transportation stage. It may be necessary to replace dry air cylinders, batteries, or re-pressurize accessories before transportation can continue. If an impact recorder is found to be inoperable at this point, it must be repaired or replaced before the next segment of transportation can begin.

Exhibit A

Approved Suppliers

A1. Bushing Suppliers

ABB
Lapp/PCORE
Passoni and Villa
Trench

A2. Surge Arresters

ABB
Cooper
General Electric
Ohio Brass
Siemens

A3. Gas-in-Oil Monitor

The transformer shall be fitted with a suitable connection for the future addition of a Morgan Schaffer Calisto, General Electric Hydran or similar sensor for dissolved gas-in-oil monitoring.

A4. Terminal Blocks

A4.01. Control terminal blocks shall be 12-point, 600V, 30A class minimum, Marathon type 1512, GE type EB-25, or Buchanan type 2B112.

A4.02. Current transformer (CT) terminal blocks shall be 6 point, shorting type, 600V, 30A class minimum, Marathon type 1506, GE type EB-27, or Penn Union type 606.

A4.03. DC power blocks shall be 600 V class, GE type EB-1 or equivalent.

A5. Fault Pressure Relay Devices

A5.01. Conservator Type Transformers

Type	Manuf.	Model #
~~SPRR~~ RPRR Buchholz	VEM Buchholz	Type BF80-10, Twin-Float relay DR80, Model 09-236, with Form C contacts or approved equivalent
Seal-in relay	Qualitrol	Model No. 909-300-01 (Provide when required on the Transformer or Reactor Spec Detail Sheet)

A5.02. Gas-Blanketed Type Transformers

Type	Manuf.	Model #
SPRR RPRR - Oil Type, Flange Mounted	Qualitrol	Model No. 900-003-62 with a male Mil Spec pin and sleeve connector Cannon Cat. No. MS-3102E-16-10P
Seal-in relay	Qualitrol	Model No. 909-300-01 (Provide when required on the Transformer or Reactor Spec Detail Sheet)
Female Mil Spec pin and sleeve connector - Straight	Cannon	MS-3106F16-10S (straight)
Female Mil Spec pin and sleeve connector – 90 degree	Bendix	10-72817-10S (90 degree)

A5.03. LTC Compartments

Type	Manuf.	Model #
SPRR RPRR - Oil Type, Flange Mounted	Qualitrol	Model No. 900-003-62 with a male Mil Spec pin and sleeve connector Cannon Cat. No. MS-3102E-16-10P
Seal-in relay	Qualitrol	Model No. 909-300-01 (Provide when required on the Transformer or Reactor Spec Detail Sheet)
Female Mil Spec pin and sleeve connector - Straight	Cannon	MS-3106F16-10S (straight)
Female Mil Spec pin and sleeve connector – 90 degree	Bendix	10-72817-10S (90 degree)

A6. Temperature Monitor Devices:

A6.01. Electronic Temperature Monitor Devices

Manuf.	**Model**	**Part #**
Weschler Instruments	Transformer Advantage CT (Use this model when there is no LTC or for when three 1PH in-tank type LTCs are provided.)	**Two Winding TRs**: G4EF * * 50WR * XBXX or G4EF * * 50WR * XNXX **Auto or Three Winding TRs:** G4EF * * 50WR * PBXX or G4EF * * 50WR * PNXX
Weschler Instruments	Transformer Advantage CT/LTC (Use this type when 3PH LTC in a separate compartment is provided)	**Two Winding TRs:** G8EF * * 50WR * XBXX or G8EF * * 50WR * XNXX **Auto or Three Winding TRs:** G8EF * * 50WR * PBXX or G8EF * * 50WR * PNXX

Notes:

1. The CT input for the ETM provided must be capable of operation up to 10A with no degradation of ETM accuracy.
2. Seller to determine configuration for part number blanks above designated with an *,.

A6.02. Mechanical Temperature Monitor Devices:

Manuf.	Model #
Qualitrol	104-400 Series – Mechanical **with** analog outputs
Messko	Compact Series MT-ST160SK/TT and MT-ST160W/TT both w/signal converter

A7. LTC Position Transmitter and Display Devices

LTC Position Transmitter: Selsyn INCON 1292 (120 VAC)

LTC Position Display (provided by Purchaser): Selsyn INCON 1250B-1

A8. LTC Control Devices

~~A8.01. Two Winding or Distribution Transformers~~

Option	Description	Manuf.	Model #
1	Voltage Back-up Relay only, provide space only for additional items in Options 2 & 3	Beckwith	M-0329B
2	Automatic Voltage Control with Voltage Back-up Relay, provide space only for additional items in Option 3	Beckwith	▪ M-2001B or newer in a M-2067 panel ▪ M-2029 TapTalk communications sofware ▪ M-0329B
3	Automatic Voltage Control with Voltage Back-up Relay, Parallel Balance Module, and Excessive Circulating Current Relay.	Beckwith	▪ M-2001B or newer in a M-2067 panel ▪ M-2029 TapTalk communications sofware ▪ M-0329B ▪ M-0115A ▪ M-0127A

~~**A8.02. Autotransformers**~~

A9. Terminal Blocks

A9.01. Control terminal blocks shall be 12-point, 600V, 30A class minimum, Marathon type 1512, GE type EB-25, or Buchanan type 2B112.

A9.02. Current transformer (CT) terminal blocks shall be 6 point, shorting type, 600V, 30A class minimum, Marathon type 1506, GE type EB-27, or Penn Union type 606.

A9.03. DC power blocks shall be 600 V class, GE type EB-1 or equivalent.

MAIN LEGEND

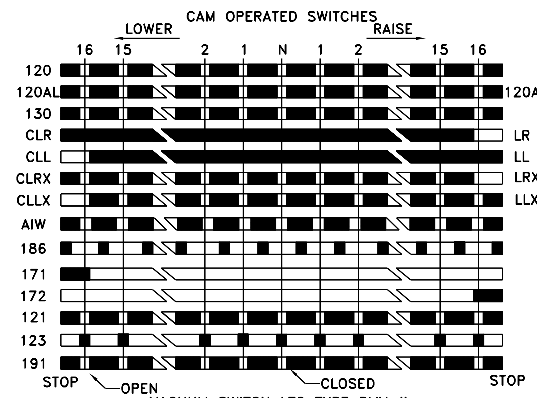
SYMBOL	DESCRIPTION	MANUFACTURER	CATALOG NUMBER
4-1	MOTOR CONTACTOR FOR FIRST STAGE FANS	SQUARE D	8910DPA-12V02
4-2	MOTOR CONTACTOR FOR SECOND STAGE FANS	SQUARE D	8910DPA-12V02
8-1	20 AMP BREAKER FOR FIRST STAGE FANS	SQUARE D	QOUR220VH
8-2	20 AMP BREAKER FOR SECOND STAGE FANS	SQUARE D	QOUR220VH
8-3	10 AMP BREAKER FOR FAN CONTROL RELAY,	SQUARE D	QOUR 110
27-1	240 VAC LOSS OF 1ST STAGE FAN SUPPLY POWER RELAY,	OMRON	H3CR-H8L 200-240AC M
27-2	240 VAC LOSS OF 2ND STAGE FAN SUPPLY POWER RELAY,	OMRON	H3CR-H8L 200-240AC M
27-3	120 VAC LOSS OF COOLING CONTROL	OMRON	H3CR-H8L 100-120AC M
33-1	AUTO-OFF-MANUAL SWITCH FOR FIRST STAGE FANS	ALLEN BRADLEY	800T-J2A
33-2	AUTO-OFF-MANUAL SWITCH FOR SECOND STAGE FANS	ALLEN BRADLEY	800T-J2A
43-1	FAN TRANSFER SWITCH	ALLEN BRADLEY	800T-H2B
88-1	FIRST STAGE FAN MOTOR, 208/240 VOLT, 850 RPM, 26 INCH DIA., 1 FLA, 192 WATTS	KRENZ	F26D-A9770-9
88-2	SECOND STAGE FAN MOTOR, 208/240 VOLT, 850 RPM, 26 INCH DIA., 1 FLA, 192 WATTS	KRENZ	F26D-A9770-9
8-4	20 AMP BREAKER FOR LIGHT AND CONVIENCE OUTLET	SQUARE D	QOUR120VH
8-9	10 AMP BREAKER FOR HEATERS IN MAIN CAB. AND INERT GAS	SQUARE D	QOUR 110
33-3	HEATER SWITCH	ALLEN BRADLEY	800T-H2A
33-5	HEATER SWITCH (INERT AIR)	ALLEN BRADLEY	800T-H2A
63P-1 (MT)	PRESSURE RELIEF DEVICE (MAIN TANK)	VIAT	3051004
63P-2 (LTC)	PRESSURE RELIEF DEVICE (LTC)	VIAT	3051004
63SP (MT)	SUDDEN PRESSURE RELAY (MAIN TANK)	QUALITROL	900-003-62
63SP (LTC)	SUDDEN PRESSURE RELAY (LTC)	QUALITROL	900-003-62
71Q-1(MT)	LIQUID LEVEL GAUGE (MAIN TANK)	MESKO	MTO-ST160RM/3U/AF
71Q-2(LTC)	LIQUID LEVEL GAUGE (LTC)	MESKO	MTO-ST160RM/1U/AF
74/63HP	PRESSURE SWITCH-TRANSFORMER TANK	BARKSDALE	96211-BB6-W24
74/63LP	VACUUM SWITCH-TRANSFORMER TANK	BARKSDALE	D2S-H18SS-W36
74/63LV	PRESSURE SWITCH FOR NITROGEN CYLINDER	McMASTER	46995K6
BCT	BUSHING CURRENT TRANSFORMER	MERIMEC	
BCT-A THRU X2WTI	6 PIN TERMINAL BLOCK (SHORTING TYPE)	GENERAL ELECTRIC	EB27B06S
CO1	20 AMP 120V GFCI RECEPTACLE	LEVITRON	6899-1
CTB1, CTB2, CTB3	CURRENT TRANSFORMER BLOCK	CENTRAL MALONEY	
ETM	ELECTRONIC TEMPERATURE MONITOR	WESCHLER	
GB1	GROUND BAR (CONTROL CABINET SEGMENT)	KUHLMAN	
GB2	GROUND BAR (POWER CABINET SEGMENT)	KUHLMAN	
PH1,2	HEATER, 120 VOLTS, 65 WATTS (MAIN)	HIGH VOLTAGE	PTC-B00
H3	HEATER, 120 VOLTS, 65 WATTS (INERT AIR)	HIGH VOLTAGE	PTC-B00
HT-2	HEATER THERMOSTAT (INERT AIR)	DAYTON	2E815
JB	JUNCTION BOX TERMINAL BLOCK		
LS	LIGHT SWITCH-DOOR ACTIVATED	NEWARK	BZ-2R01-A2
LT	CONTROL CABINET LIGHT, 130 VOLT, 75 WATTS	EPCO	15055
PB	4 PIN POWER TERMINAL BLOCK	GENERAL ELECTRIC	EB25B04
TB	12 PIN TERMINAL BLOCK	GENERAL ELECTRIC	EB-25B12C
TB-B	6 PIN TERMINAL BLOCK	PENN UNION	6006
TBG	TERMINAL BLOCK (INERT AIR)	PENN UNION	6012
TSW	TEST SWITCH (LDC)	STATES	20K02-G

LTC LEGEND

SYMBOL	DESCRIPTION	MANUFACTURER	CATALOG NUMBER
8-5	10 AMP BREAKER FOR 120V MONITORING AND CONTROL CIRCUIT	SQUARE D	QOUR 110
8-6	10 AMP BREAKER FOR HEATERS IN MOTOR DRIVE UNIT	SQUARE D	QOUR 110
8-7	6 AMP BREAKER FOR LTC MOTOR	SIEMENS	3RV1021-1HA10
8-8	10 AMP BREAKER FOR 120V POTENTIAL	SQUARE D	QOUR 110
23-1,23-2	THERMOSTAT-(CAM SWITCH COMPARTMENT)	REINHAUSEN	____
26Q	HOT OIL THERMOSTAT LTC LOW TEMP.	REINHAUSEN	____
26QB	LOCKOUT RELAY LTC	ALLEN BRADLEY	700-NX-123
26QBRL	LOCKOUT LOW TEMP. LIGHT (RED)	ALLEN BRADLEY	800T-Q11R
27-4	RELAY, 120 VAC LOSS OF LTC VOLTAGE POWER	OMRON	H3CR-H8L 100-120AC M
33-4	HEATER SWITCH (MAIN CONTROL CABINET)	ALLEN BRADLEY	800T-H2A
43LR	LOCAL-REMOTE SWITCH THERMAL RELAY	ALLEN BRADLEY	800T-H2BW/LP
49	LTC MOTOR THERMAL RELAY (LTC MOTOR OVERLOAD)	ALLEN BRADLEY	700-NX-123
49AL	LIGHT - AMBER	ALLEN BRADLEY	800T-Q11A
52a	LTC AUXILIARY BLOCK CONTACT	____	____
60	LTC PARALLEL BALANCE MODULE	BECKWITH	M-0115A
78LTC	OFF POSITION AUXILIARY RELAY (TIE DEVICE)	TYCO	CNS-35-92
74/62RL	OFF POSITION ALARM LIGHT (RED)	ALLEN BRADLEY	800T-Q11R
74AM	AUTO-MANUAL SWITCH (LTC)	BECKWITH	M2067
74DB	LOSS OF POTENTIAL RELAY	OMRON	H3CR-H8L 100-120AC M
84H-1	HANDCRANK INTERLOCK SWITCH	REINHAUSEN	____
84L	MOTOR CONTROL LOWER RELAY	ALLEN BRADLEY	700-NX-124
84M	MOTOR 240V SINGLE PHASE	REINHAUSEN	____
84R	MOTOR CONTROL RAISE RELAY	ALLEN BRADLEY	700-NX-124
86-68	LOCKOUT AUXILIARY RELAY	ALLEN BRADLEY	700-NX-123
86-L,C,R	SEQUENCE MONITOR RELAYS	REINHAUSEN	____
86GL	SUPERVISORY POWER CONTROL LIGHT (GREEN)	ALLEN BRADLEY	800T-Q11G
86RL	LOCKOUT LIGHT (RED)	ALLEN BRADLEY	800T-Q11R
86XL	LOCKOUT RUN BACK RELAY (LOWER)	ALLEN BRADLEY	700-NX-123
86XR	LOCKOUT RUN BACK RELAY (RAISE)	ALLEN BRADLEY	700-NX-123
88	BRAKE RELAY	REINHAUSEN	____
90	LTC REGULATING RELAY	BECKWITH	M-2067/M-2001C
90BU	LTC REGULATOR BACK-UP RELAY	BECKWITH	M-0329B
120	REMOTE OFF POSITION LIGHT CAM SWITCH	REINHAUSEN	____
121	OPERATION COUNTER CAM SWITCH	REINHAUSEN	____
120AL	MOTOR CONTROL RELAY CAM SWITCH	REINHAUSEN	____
120AR	MOTOR CONTROL RELAY CAM SWITCH	REINHAUSEN	____
123	ON POSITION CAM SWITCH	REINHAUSEN	____
123X	ON POSITION AUXILIARY RELAY	REINHAUSEN	____
123WL	ON POSITION LIGHT (WHITE)	ALLEN BRADLEY	800T-Q11W
130	LOSS OF POWER CAM SWITCH	REINHAUSEN	____
171	LOWER LIMIT CAM SWITCH	REINHAUSEN	____
172	RAISE LIMIT CAM SWITCH	REINHAUSEN	____
186	MONITORING CONTROL SWITCH	REINHAUSEN	____
191	OFF POSITION CAM	REINHAUSEN	____
ACT	AUXILIARY CURRENT TRANSFORMER	REINHAUSEN	____
AIW	LIGHT PIPE VERIFICATION SWITCH	REINHAUSEN	____
C-1,2,3	CAPACITOR COURSE LIMIT CAM SWITCH	REINHAUSEN	____
CLL	COURSE LIMIT CAM SWITCH	REINHAUSEN	____
CLLX	VERNIER LOWER LIMIT CAM SWITCH	REINHAUSEN	____
CLR	COURSE LIMIT CAM SWITCH	REINHAUSEN	____
CLRX	VERNIER RAISE LIMIT CAM SWITCH	REINHAUSEN	____
CS	LOWER-OFF-RAISE SWITCH (LTC MOTOR DRIVE COMPARTMENT)	REINHAUSEN	____
CS-1	LOWER-OFF-RAISE SWITCH (MAIN CONTROL CAB.)	BECKWITH	M2067
DPRS	RESET SWITCH	REINHAUSEN	____
EPI	ELECTRONIC POSITION INDICATOR	INCON	1250B-4
FU	FUSE 3AG, 0.25A	REINHAUSEN	____
HTR-1,2,3	HEATER-CAM SWITCH COMPARTMENT	REINHAUSEN	____
JT	JUNCTION PLATE TERMINAL	REINHAUSEN	____
LE-1,2,3	LIGHT EMITTER	REINHAUSEN	____
LL	COURSE LIMIT CAM SWITCH	REINHAUSEN	____
LLX	VERNIER LOWER LIMIT CAM SWITCH	REINHAUSEN	____
LP	LIGHT PIPE	REINHAUSEN	____
LR	COURSE LIMIT CAM SWITCH	REINHAUSEN	____
LR-1,2,3	LIGHT RECEIVER	REINHAUSEN	____
LRX	VERNIER RAISE LIMIT CAM SWITCH	REINHAUSEN	____
MPI	MECHANICAL POSITION INDICATOR	REINHAUSEN	____
OC	OPERATION COUNTER, MECHANICAL	REDINGTON	R2-4816, P2-4816
P	MONITORING SYSTEM POWER SUPPLY	REINHAUSEN	____
PC	PARALLEL BALANCER--M-0115 (FUTURE)	REINHAUSEN	____
PL	EIGHT-PIN PLUG	REINHAUSEN	____
PLC	EIGHT-PIN PLUG CONNECTION	REINHAUSEN	____
PTR	LTC TAP POSITION TRANSMITTER	REINHAUSEN	____
RC	ELEC. RESET COIL (MAX.-MIN. HANDS)	REINHAUSEN	____
RSM	MONITORING RESET SWITCH-PUSH BUTTON (RED)	REINHAUSEN	____
SP	SUPERVISION POWER	REINHAUSEN	____
t°	MOTOR THERMOSTAT	REINHAUSEN	____
T1-60	TERMINAL BOARD IN MOTOR DRIVE UNIT	REINHAUSEN	____
TSM	MONITORING TEST SWITCH-PUSH BUTTON (GREEN)	REINHAUSEN	____
TT	TEST TERMINAL	NEWARK	35N845
VIM	VACUUM INTERRUPTER MONITOR (CSC)	REINHAUSEN	____
VIM1-17	TERMINAL BOARD IN MONITORING CABINET (CSC)	REINHAUSEN	____

LTC SYMBOL LEGEND

- □ TERMINAL BLOCK POINT INSIDE CONTROL CABINET
- ○ DEVICE TERMINAL POINT
- ⊡ LTC MANUFACTURE FURNISHED TERMINAL BLOCK POINT
- ⊗ DEVICE TERMINAL POINT INSIDE LTC MOTOR DRIVE COMPARTMENT



VACUUM SWITCH LTC TYPE RMV-II
SEQUENCE CHART
(33 POS. 32 STEP)

SWITCH SETTINGS

TOP OIL THERMOMETER (26Q) (LTC)
SW1 CLOSES AT TEMPERATURES BETWEEN
-35°C & -40°C
SW2 & 3 ARE NOT USED. ADDITIONAL CONTACTS ARE FOR FUTURE HEATER APPLICATIONS (IF NEED)

PRESSURE RELIEF DEVICE (63P-1(MT), 63P-2(LTC)
SW OPERATES AT +10.0 P.S.I.G.

TANK PRESSURE SWITCH (74/63HP)
SW OPERATES AT +8.5 P.S.I.G.

TANK VACUUM SWITCH (74/63LP)
SW OPERATES AT -3.0 P.S.I.G.

NITROGEN CYLINDER PRESSURE SWITCH (74/63LV)
SW OPERATES AT 200 P.S.I.G.

SWITCH RATINGS

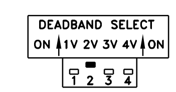
26/49 ELECTRONIC TEMPERATURE MONITOR
6.25 AMPS AT 48 VDC
1.00 AMPS AT 125 VDC

LIQUID LEVEL GAGE (71Q-1(MT), 71Q-2(LTC)
10.00 AMPS AT 125, 250 VAC
0.50 AMPS AT 110 VDC } NON-INDUCTIVE
0.25 AMPS AT 250 VDC }
1.30 AMPS AT 48 VDC

PRESSURE RELIEF DEVICE (63P-1(MT), 63P-2(LTC)
SUDDEN PRESSURE RELAY (63SP(MT), 63SP(LTC)
15.00 AMPS AT 125, 250 AND 480 VAC
0.50 AMPS AT 48 VDC } NON-INDUCTIVE
1.30 AMPS AT 48 VDC }

LTC BACK-UP RELAY (90BU)

DEADBAND SETTING IS FACTORY SET AT 2 VOLTS.



90BU--RIGHT END VIEW

NOTE: ALARM CONTACTS FOR 90BU RELAY ARE SHOWN ENERGIZED.

DEADBAND SETTING	1	2	3	4
1V	UP	DOWN	DOWN	DOWN
2V	DOWN	UP	DOWN	DOWN
3V	DOWN	DOWN	UP	DOWN
4V	DOWN	DOWN	DOWN	UP

CAUTION:
IF MORE THAN ONE SWITCH IS IN THE "UP" POSITION, THE CONTROL'S OPERATION AND DEAD BAND SETTING WILL BE UNPREDICTABLE.

FAN TRANSFER SWITCH (43-1)	LOCAL-REMOTE SWITCH (43LR)
MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART	MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART
FAN SWITCH (33-1, 33-2)	**LOWER-OFF-RAISE SWITCH (CS, CS-1)**
MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART	MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART
HEATER SWITCH (33-3, 33-4, 33-5)	**AUTO-MANUAL SWITCH ( )**
MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART	MANUFACTURER TO ADD SWITCH CONTACT CALLOUT CHART

INCLUDE ALL LEGEND AND MISC INFO ON THIS LEAD SHEET(S) AS SHOWN. THIS DWG IS AN EXAMPLE OF TYPICAL INFO TO BE INCLUDED.

EXHIBIT B

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.
XCEL ENERGY				

TRANSMISSION & SUBSTATION STANDARDS

Xcel Energy® — XCEL ENERGY COMPANY WIDE

POWER TRANSFORMER/REACTOR MATERIAL STANDARD — VERSION: 2

FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

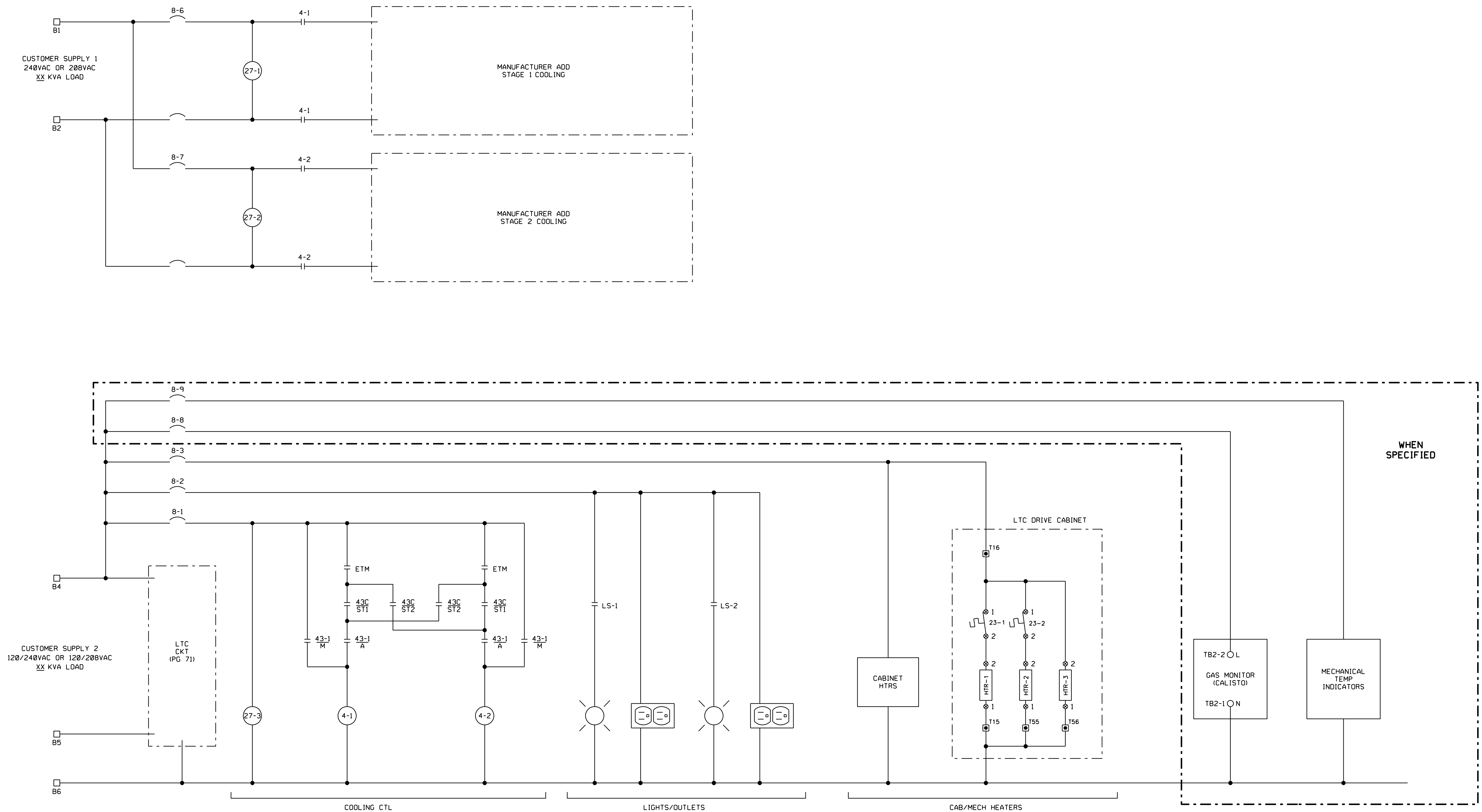


EXHIBIT B

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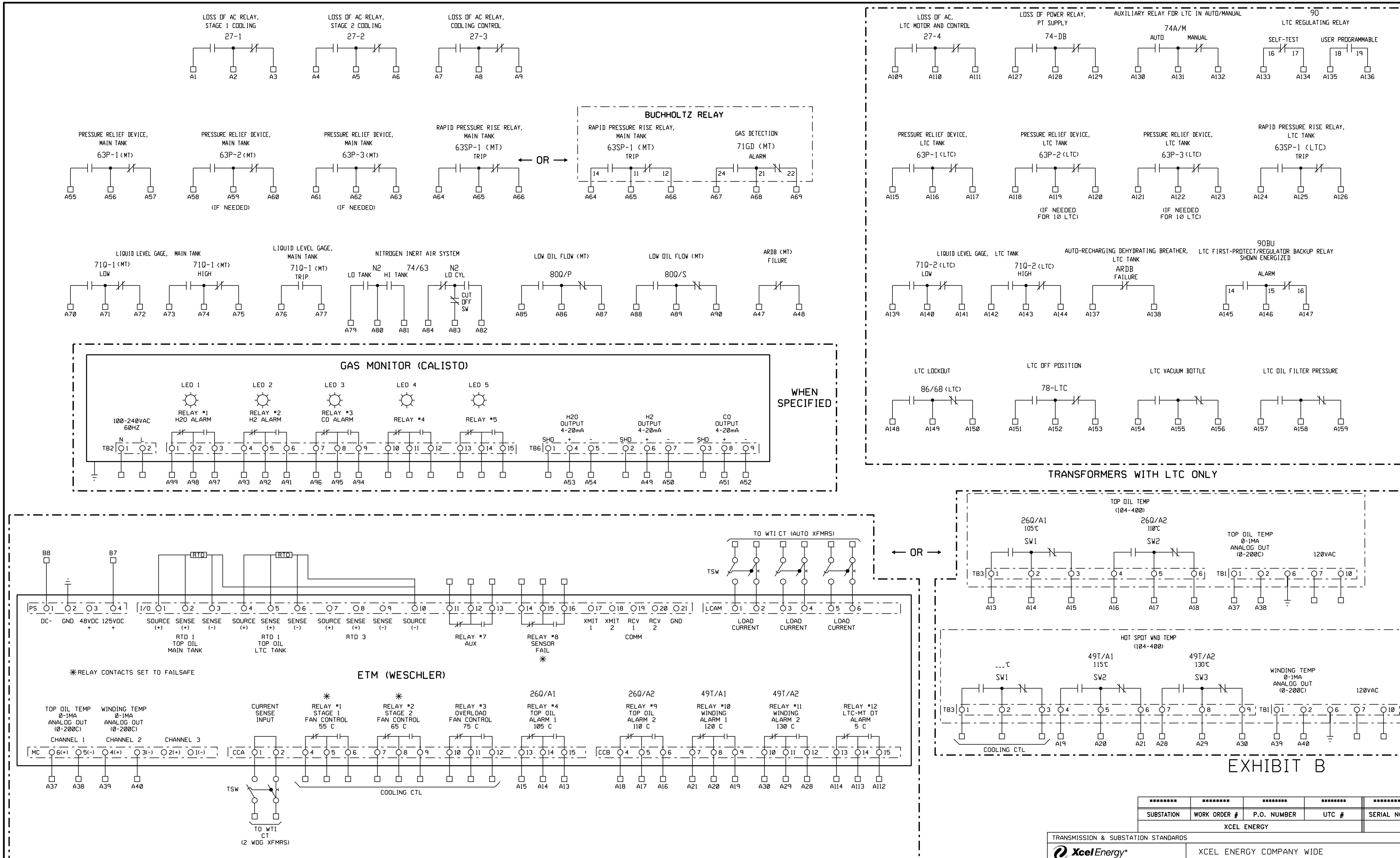

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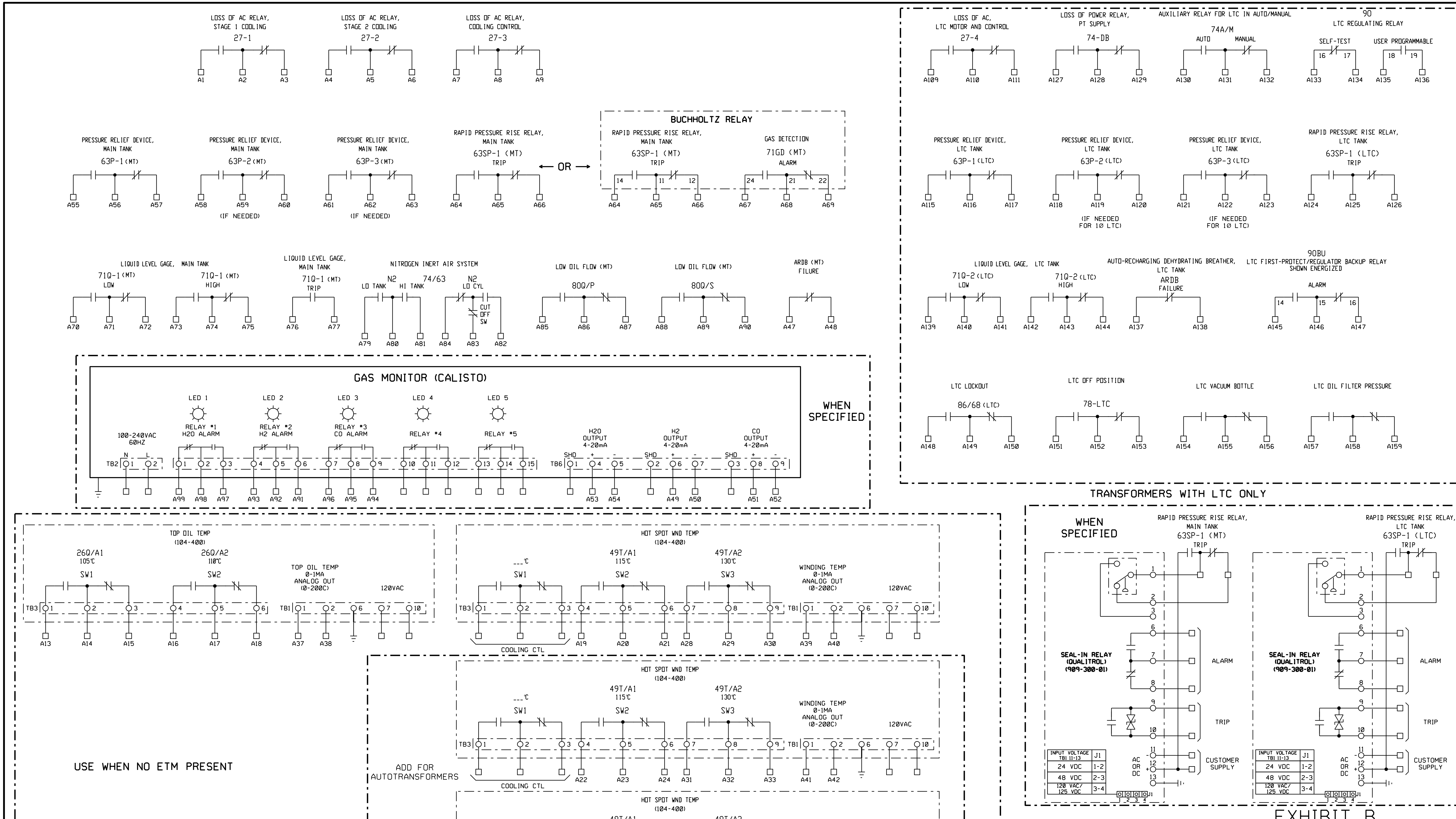

EXHIBIT B

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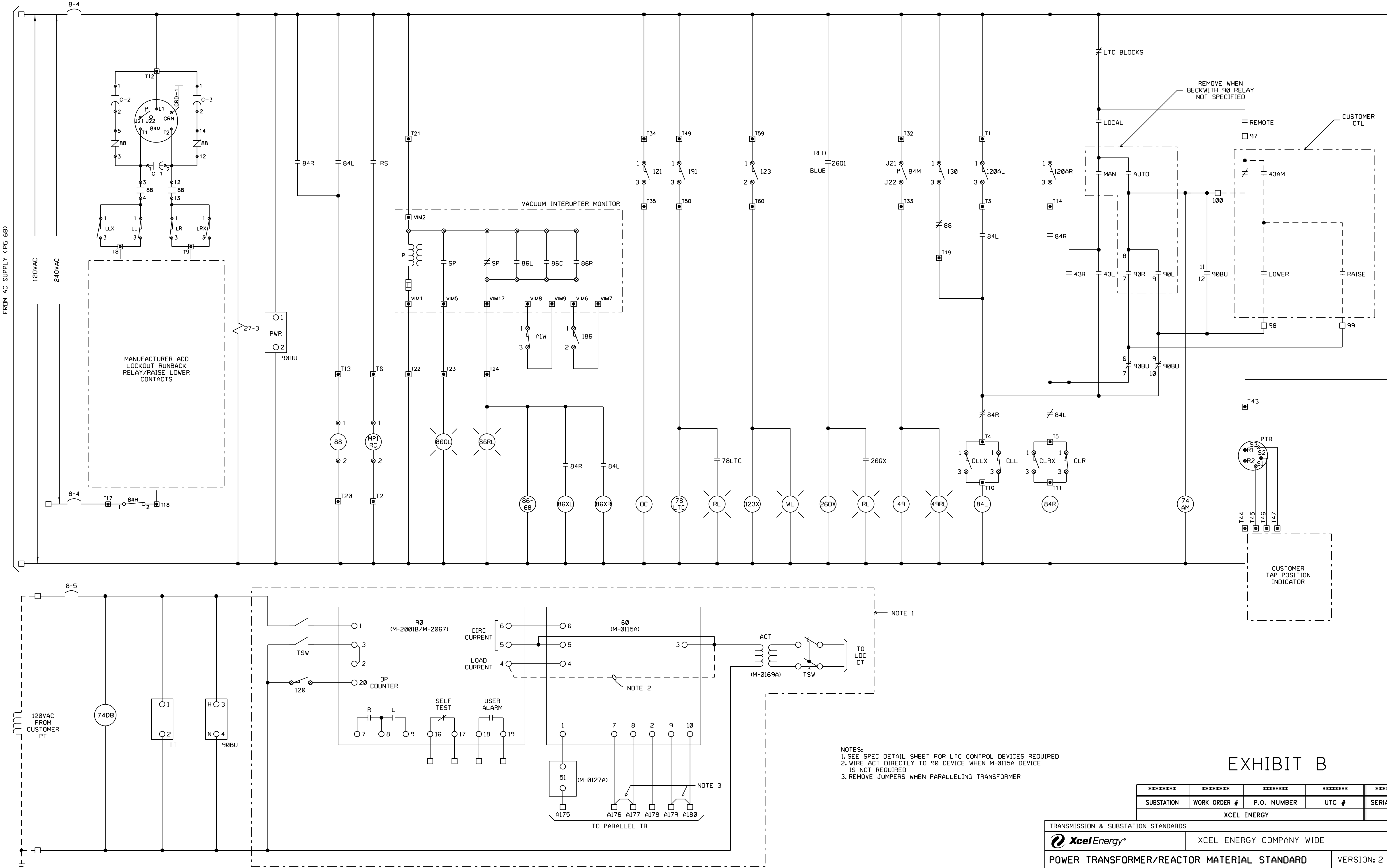

NOTES:
1. SEE SPEC DETAIL SHEET FOR LTC CONTROL DEVICES REQUIRED
2. WIRE ACT DIRECTLY TO 90 DEVICE WHEN M-0115A DEVICE IS NOT REQUIRED
3. REMOVE JUMPERS WHEN PARALLELING TRANSFORMER

EXHIBIT B

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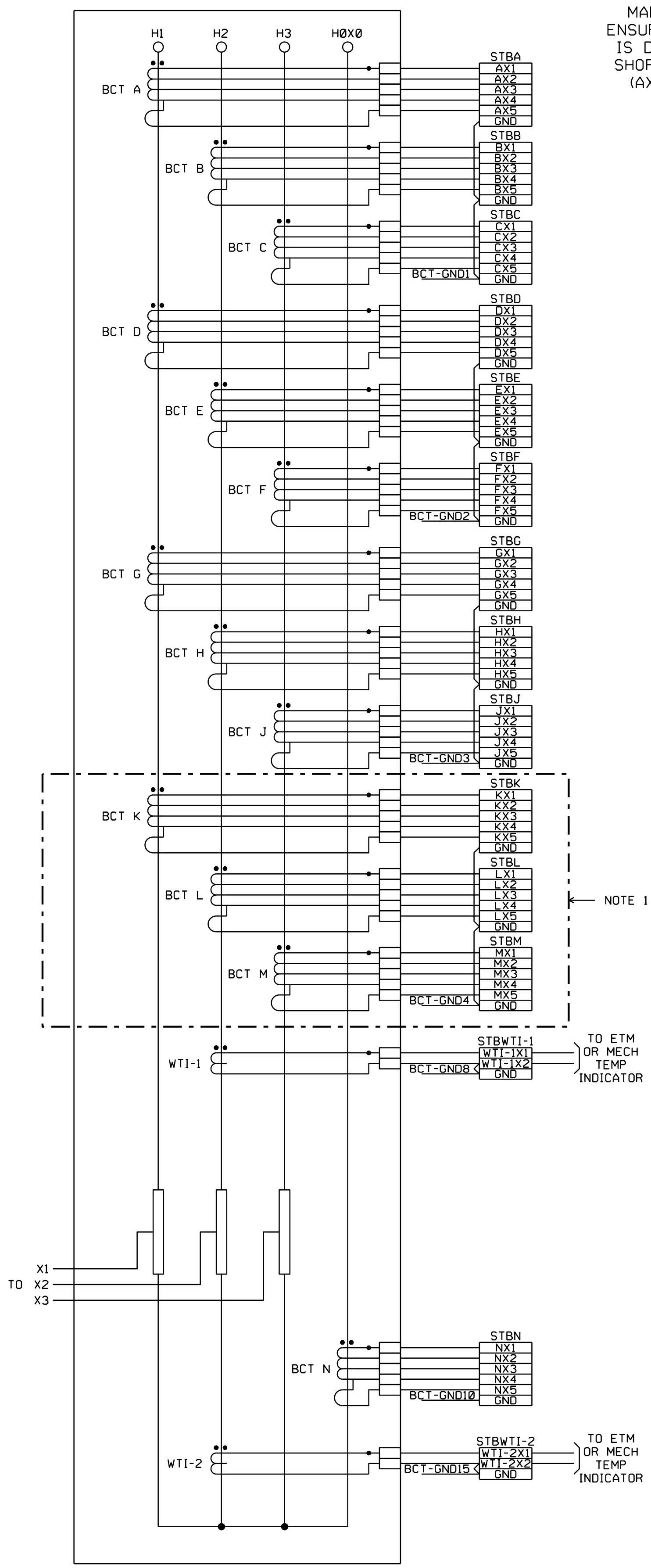
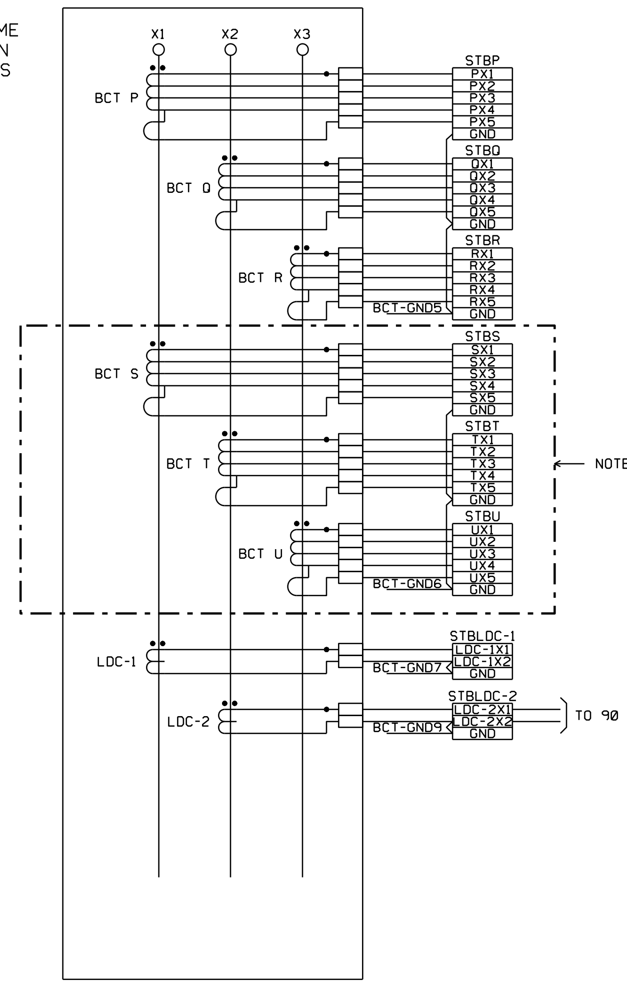
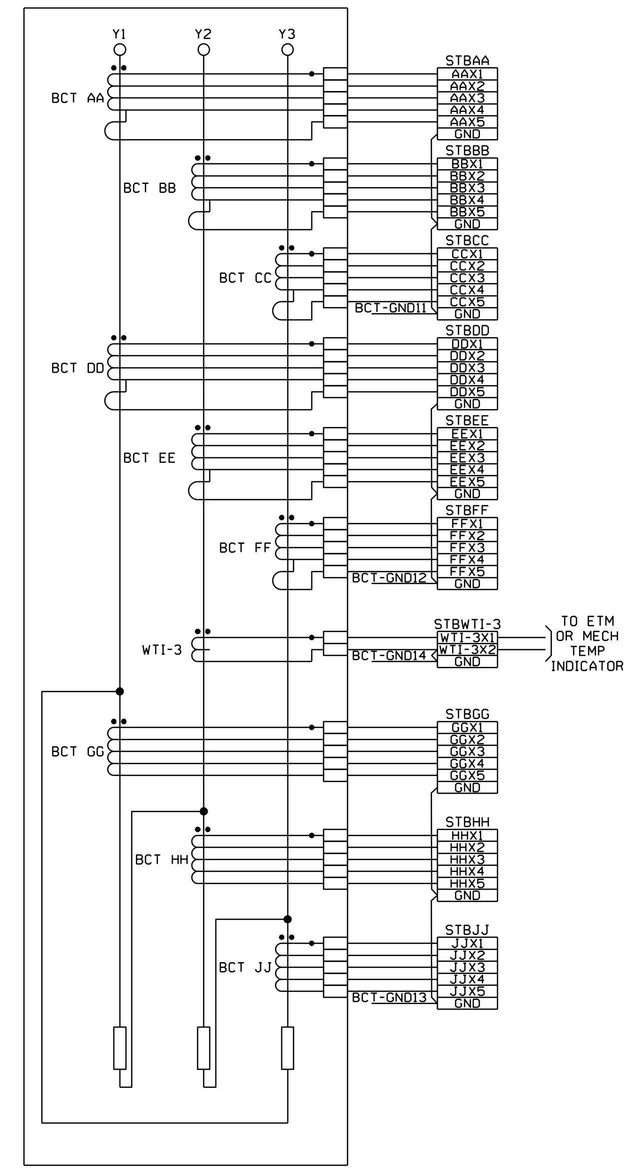
POWER TRANSFORMER/REACTOR MATERIAL STANDARD — VERSION: 2

FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

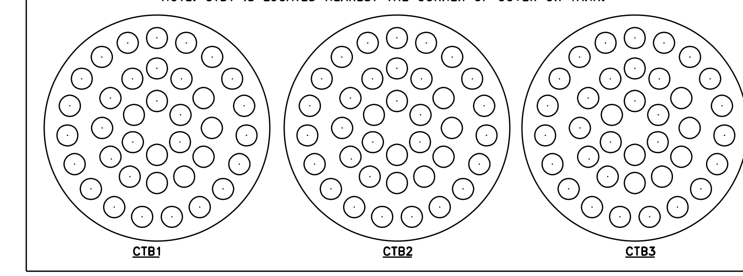
MANUFACTURER
ENSURE FULL NAME
IS DISPLAYED ON
SHORTING BLOCKS
(AX1, AX2, ETC)







NOTE: CTB1 IS LOCATED NEAREST THE CORNER OF COVER OR TANK.



CT JUNCTION BOX

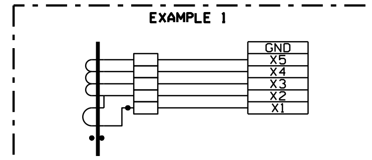
CTB1	BCT LEAD	TERMINAL BLOCK
1	AX1	BCT-A-1
2	AX2	BCT-A-2
3	AX3	BCT-A-3
4	AX4	BCT-A-4
5	AX5	BCT-A-5
6	BX1	BCT-B-1
7	BX2	BCT-B-2
8	BX3	BCT-B-3
9	BX4	BCT-B-4
10	BX5	BCT-B-5
11	CX1	BCT-C-1
12	CX2	BCT-C-2
13	CX3	BCT-C-3
14	CX4	BCT-C-4
15	CX5	BCT-C-5
16	DX1	BCT-D-1
17	DX2	BCT-D-2
18	DX3	BCT-D-3
19	DX4	BCT-D-4
20	DX5	BCT-D-5
21	EX1	BCT-E-1
22	EX2	BCT-E-2
23	EX3	BCT-E-3
24	EX4	BCT-E-4
25	EX5	BCT-E-5
26	FX1	BCT-F-1
27	FX2	BCT-F-2
28	FX3	BCT-F-3
29	FX4	BCT-F-4
30	FX5	BCT-F-5
31	GX1	BCT-G-1
32	GX2	BCT-G-2
33	GX3	BCT-G-3
34	GX4	BCT-G-4
35	GX5	BCT-G-5
36	BLANK	BLANK
37	BLANK	BLANK

CTB2	BCT LEAD	TERMINAL BLOCK
1	HX1	BCT-H-1
2	HX2	BCT-H-2
3	HX3	BCT-H-3
4	HX4	BCT-H-4
5	HX5	BCT-H-5
6	JX1	BCT-J-1
7	JX2	BCT-J-2
8	JX3	BCT-J-3
9	JX4	BCT-J-4
10	JX5	BCT-J-5
11	KX1	BCT-K-1
12	KX2	BCT-K-2
13	KX3	BCT-K-3
14	KX4	BCT-K-4
15	KX5	BCT-K-5
16	LX1	BCT-L-1
17	LX2	BCT-L-2
18	LX3	BCT-L-3
19	LX4	BCT-L-4
20	LX5	BCT-L-5
21	MX1	BCT-M-1
22	MX2	BCT-M-2
23	MX3	BCT-M-3
24	MX4	BCT-M-4
25	MX5	BCT-M-5
26	NX1	BCT-N-1
27	NX2	BCT-N-2
28	NX3	BCT-N-3
29	NX4	BCT-N-4
30	NX5	BCT-N-5
31	WTIX1	WTI-1
32	WTIX2	WTI-2
33	LDC-1X1	LDC-1-1
34	LDC-1X2	LDC-1-2
35	LDC-2X1	LDC-2-1
36	LDC-2X2	LDC-2-2
37	BLANK	BLANK

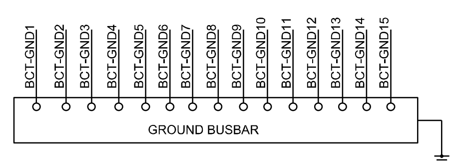
CTB3	BCT LEAD	TERMINAL BLOCK
1	PX1	BCT-P-1
2	PX2	BCT-P-2
3	PX3	BCT-P-3
4	PX4	BCT-P-4
5	PX5	BCT-P-5
6	QX1	BCT-Q-1
7	QX2	BCT-Q-2
8	QX3	BCT-Q-3
9	QX4	BCT-Q-4
10	QX5	BCT-Q-5
11	RX1	BCT-R-1
12	RX2	BCT-R-2
13	RX3	BCT-R-3
14	RX4	BCT-R-4
15	RX5	BCT-R-5
16	SX1	BCT-S-1
17	SX2	BCT-S-2
18	SX3	BCT-S-3
19	SX4	BCT-S-4
20	SX5	BCT-S-5
21	TX1	BCT-T-1
22	TX2	BCT-T-2
23	TX3	BCT-T-3
24	TX4	BCT-T-4
25	TX5	BCT-T-5
26	UX1	BCT-U-1
27	UX2	BCT-U-2
28	UX3	BCT-U-3
29	UX4	BCT-U-4
30	UX5	BCT-U-5
31	BLANK	BLANK
32	BLANK	BLANK
33	BLANK	BLANK
34	BLANK	BLANK
35	BLANK	BLANK
36	BLANK	BLANK
37	BLANK	BLANK

NOTES:
1. WHEN SPECIFIED REVERSE POLARITY OF BCT'S K,L,M & S,T,U (SEE EXAMPLE 1)

EXAMPLE 1



MANUFACTURER ADD
BCT TAP CHARTS



SPECIFICATION OF BUSHING CURRENT TRANSFOMER

BUSHING CURRENT TRANSFORMER				
TYPE	RATIO (A)	CLASS	TRF	REMARK

EXHIBIT B

********	********	********	********	********
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XCEL ENERGY				

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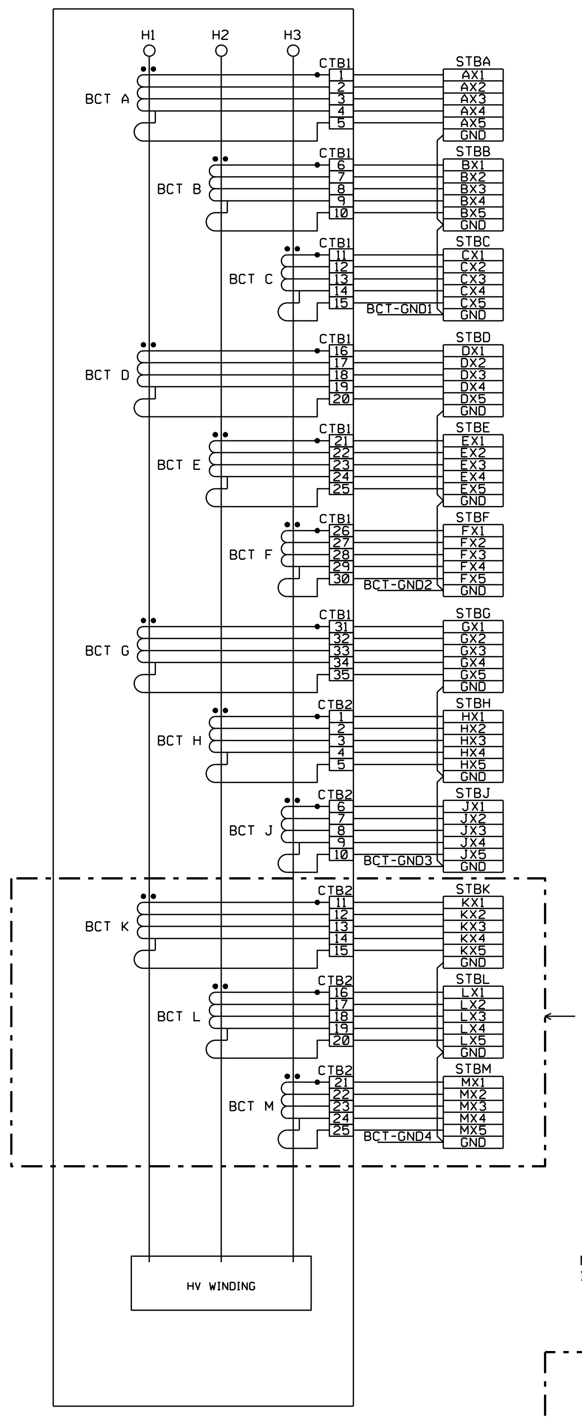
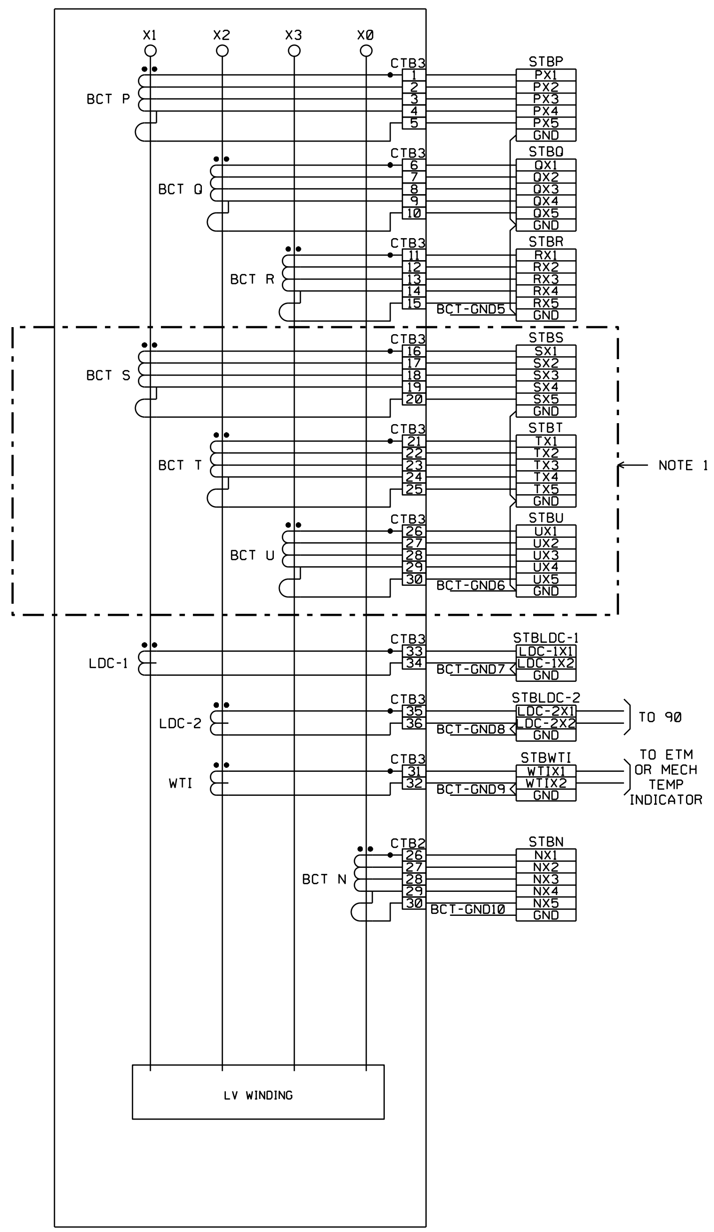
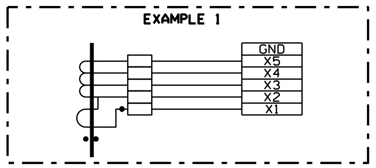
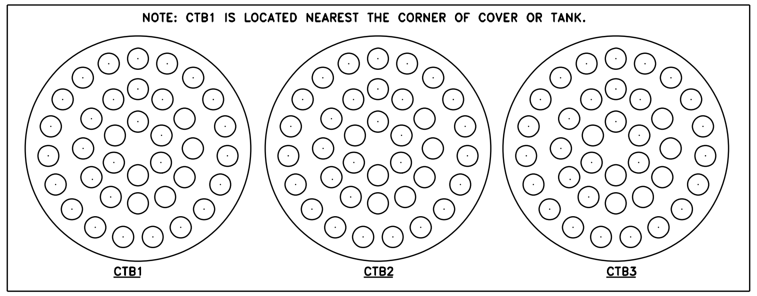


MANUFACTURER ENSURE FULL NAME IS DISPLAYED ON SHORTING BLOCKS (AX1, AX2, ETC)



NOTES:
1. WHEN SPECIFIED REVERSE POLARITY OF BCT'S K,L,M & S,T,U (SEE EXAMPLE 1)





CT JUNCTION BOX

CTB1	BCT LEAD	TERMINAL BLOCK
1	AX1	BCT-A-1
2	AX2	BCT-A-2
3	AX3	BCT-A-3
4	AX4	BCT-A-4
5	AX5	BCT-A-5
6	BX1	BCT-B-1
7	BX2	BCT-B-2
8	BX3	BCT-B-3
9	BX4	BCT-B-4
10	BX5	BCT-B-5
11	CX1	BCT-C-1
12	CX2	BCT-C-2
13	CX3	BCT-C-3
14	CX4	BCT-C-4
15	CX5	BCT-C-5
16	DX1	BCT-D-1
17	DX2	BCT-D-2
18	DX3	BCT-D-3
19	DX4	BCT-D-4
20	DX5	BCT-D-5
21	EX1	BCT-E-1
22	EX2	BCT-E-2
23	EX3	BCT-E-3
24	EX4	BCT-E-4
25	EX5	BCT-E-5
26	FX1	BCT-F-1
27	FX2	BCT-F-2
28	FX3	BCT-F-3
29	FX4	BCT-F-4
30	FX5	BCT-F-5
31	GX1	BCT-G-1
32	GX2	BCT-G-2
33	GX3	BCT-G-3
34	GX4	BCT-G-4
35	GX5	BCT-G-5
36	BLANK	BLANK
37	BLANK	BLANK

CTB2	BCT LEAD	TERMINAL BLOCK
1	HX1	BCT-H-1
2	HX2	BCT-H-2
3	HX3	BCT-H-3
4	HX4	BCT-H-4
5	HX5	BCT-H-5
6	JX1	BCT-J-1
7	JX2	BCT-J-2
8	JX3	BCT-J-3
9	JX4	BCT-J-4
10	JX5	BCT-J-5
11	KX1	BCT-K-1
12	KX2	BCT-K-2
13	KX3	BCT-K-3
14	KX4	BCT-K-4
15	KX5	BCT-K-5
16	LX1	BCT-L-1
17	LX2	BCT-L-2
18	LX3	BCT-L-3
19	LX4	BCT-L-4
20	LX5	BCT-L-5
21	MX1	BCT-M-1
22	MX2	BCT-M-2
23	MX3	BCT-M-3
24	MX4	BCT-M-4
25	MX5	BCT-M-5
26	NX1	BCT-N-1
27	NX2	BCT-N-2
28	NX3	BCT-N-3
29	NX4	BCT-N-4
30	NX5	BCT-N-5
31	WTIX1	WTI-1
32	WTIX2	WTI-2
33	LDC-1X1	LDC-1-1
34	LDC-1X2	LDC-1-2
35	LDC-2X1	LDC-2-1
36	LDC-2X2	LDC-2-2
37	BLANK	BLANK

CTB3	BCT LEAD	TERMINAL BLOCK
1	PX1	BCT-P-1
2	PX2	BCT-P-2
3	PX3	BCT-P-3
4	PX4	BCT-P-4
5	PX5	BCT-P-5
6	QX1	BCT-Q-1
7	QX2	BCT-Q-2
8	QX3	BCT-Q-3
9	QX4	BCT-Q-4
10	QX5	BCT-Q-5
11	RX1	BCT-R-1
12	RX2	BCT-R-2
13	RX3	BCT-R-3
14	RX4	BCT-R-4
15	RX5	BCT-R-5
16	SX1	BCT-S-1
17	SX2	BCT-S-2
18	SX3	BCT-S-3
19	SX4	BCT-S-4
20	SX5	BCT-S-5
21	TX1	BCT-T-1
22	TX2	BCT-T-2
23	TX3	BCT-T-3
24	TX4	BCT-T-4
25	TX5	BCT-T-5
26	UX1	BCT-U-1
27	UX2	BCT-U-2
28	UX3	BCT-U-3
29	UX4	BCT-U-4
30	UX5	BCT-U-5
31	BLANK	BLANK
32	BLANK	BLANK
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34	BLANK	BLANK
35	BLANK	BLANK
36	BLANK	BLANK
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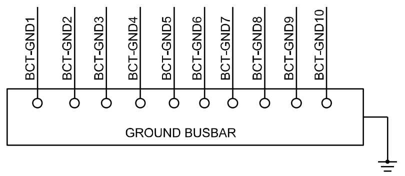

MANUFACTURER ADD BCT TAP CHARTS

SPECIFICATION OF BUSHING CURRENT TRANSFOMER

BUSHING CURRENT TRANSFORMER				
TYPE	RATIO (A)	CLASS	TRF	REMARK

EXHIBIT B

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.

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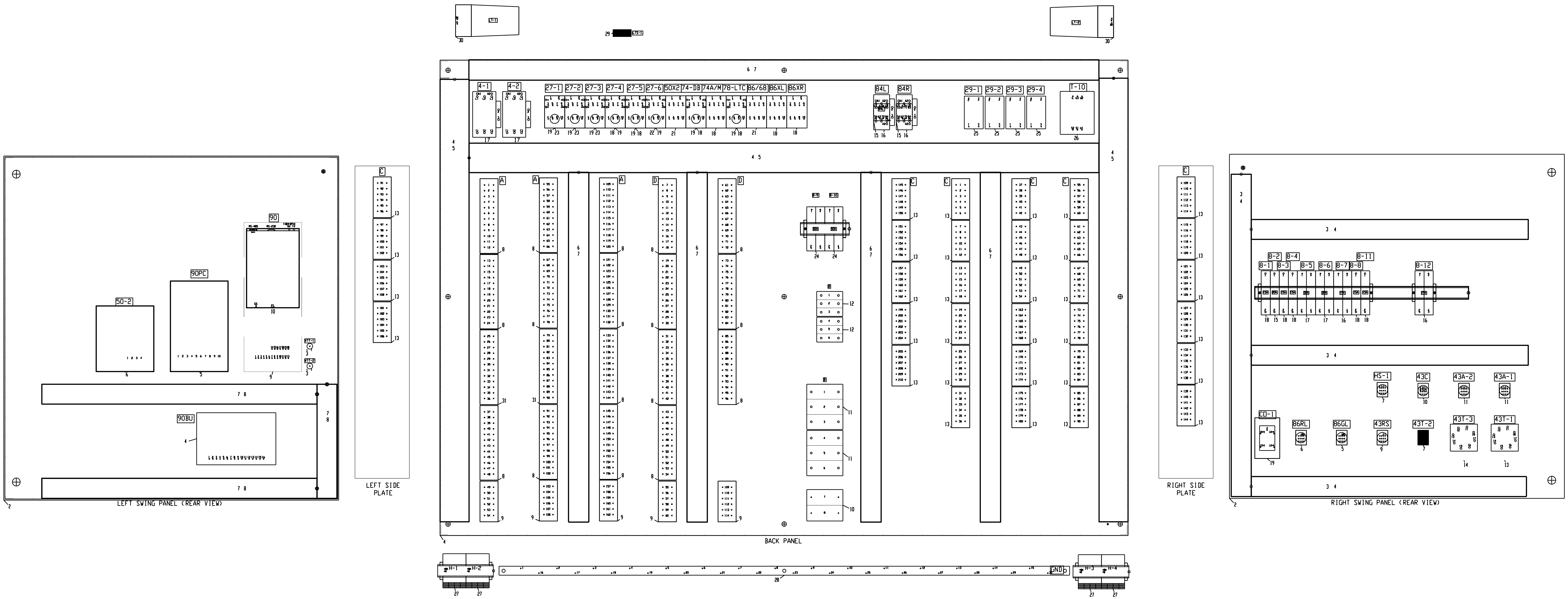
FILE NAME: XEL-STD-EMS-J.Ø1-ØØ1-POWER TRANSFORMER MATERIAL STANDARD



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TRANSMISSION & SUBSTATION STANDARDS

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BACK PANEL TERMINAL BLOCK ROW LAYOUT

EXHIBIT B

*** MANUFACTURER TO FILL IN CT RATIOS

A (terminals 1–108) ☆

1	NO	27-1 LOSS OF AC VOLTAGE COOLING GROUP #1 AL	63P-1 (MT) MECH PRD MAIN TANK AL1	55	NO
2	COM			56	COM
3	NC			57	NC
4	NO	27-2 LOSS OF AC VOLTAGE COOLING GROUP #2 AL	63P-2 (MT) MECH PRD MAIN TANK AL2 (IF NEEDED)	58	NO
5	COM			59	COM
6	NC			60	NC
7	NO	27-3 LOSS OF AC VOLTAGE COOLING CONTROL	63P-3 (MT) MECH PRD MAIN TANK AL3 (IF NEEDED)	61	NO
8	COM			62	COM
9	NC			63	NC
10	NO	27-5 LOSS OF DC VOLTAGE	63SP-1 (MT) RAPID PRES RELAY TRIP	64	NO
11	COM			65	COM
12	NC			66	NC
13	NO	26Q/A1 TOP OIL TEMP AL	71GD (MT) GAS DETECTION CONS-ALARM	67	NO
14	COM			68	COM
15	NC			69	NC
16	NO	26Q/A2 TOP OIL TEMP AL	71Q-1 (MT) LIQ LEV LOW AL	70	NO
17	COM			71	COM
18	NC			72	NC
19	NO	49T/A1 HS WND TEMP AL (ETM OR MECH 1)	71Q-1 (MT) LIQ LEV HIGH AL	73	NO
20	COM			74	COM
21	NC			75	NC
22	NO	49T/A1-LV HS WND TEMP AL (MECH 2)	71Q-1 (MT) LIQ LEV CRIT LOW-TRIP	76	NO
23	COM			77	
24	NC			78	
25	NO	49T/A1-TV HS WND TEMP AL (MECH 3)	N2 INERT AIR LOW/HIGH AL	79	NO
26	COM			80	COM
27	NC			81	NC
28	NO	49T/A2 HS WND TEMP AL (ETM OR MECH 1)	N2 INERT AIR LOW CYL AL	82	NO
29	COM			83	CO SW
30	NC			84	NC
31	NO	49T/A2-LV HS WND TEMP AL (MECH 2)	80Q/P PUMP LOW OIL FLOW-AL	85	NO
32	COM			86	COM
33	NC			87	NC
34	NO	49T/A2-TV HS WND TEMP AL (MECH 3)	80Q/S PUMP LOW OIL FLOW-AL	88	NO
35	COM			89	COM
36	NC			90	NC
37	RTX1(+)	TOP OIL TEMP ANALOG OUT	GAS MONITOR H2 ALARM	91	NO
38	RTX1(-)			92	COM
39	RTX2(+)	WND TEMP ANALOG OUT (ETM OR MECH 1)		93	NC
40	RTX2(-)		GAS MONITOR CO ALARM	94	NO
41	RTX3(+)	WND TEMP ANALOG OUT (MECH 2)		95	COM
42	RTX3(-)			96	NC
43	RTX4(+)	WND TEMP ANALOG OUT (MECH 3)	GAS MONITOR H2O ALARM	97	NO
44	RTX4(-)			98	COM
45	RTX5(+)	LOAD AMP 0-1 mA ANALOG		99	NC
46	RTX5(-)			100	
47	NC	AUTORECHARGING DEHYDR. BREATHER MT- FAILURE		101	
48				102	
49	+	GAS MONITOR H2 ANALOG OUT		103	
50	-			104	
51	+	GAS MONITOR CO ANALOG OUT		105	
52	-			106	
53	+	GAS MONITOR H2O ANALOG OUT		107	
54	-			108	

☆

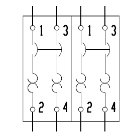
A (terminals 109–198) ☆

109	NO	27-4 LOSS OF AC LTC MTR & CTRL	LTC REMOTE CONTROL	163	REMOTE
110	COM			164	LOWER
111	NC			165	RAISE
112	NO	ETM LTC-MT TEMP DIF AL		166	AUTO
113	COM		SELSYN TRANSMITTER LTC TAP POSITION	167	T1
114	NC			168	T2
115	NO	63P-1 (LTC) MECH PRD LTC AL1		169	M1
116	COM			170	M2
117	NC			171	M3
118	NO	63P-2 (LTC) MECH PRD LTC AL2		172	
119	COM			173	
120	NC			174	
121	NO	63P-3 (LTC) MECH PRD LTC AL3	M-0115A IF SPECIFIED	175	1
122	COM			176	7
123	NC			177	8
124	NO	63SP-1 (LTC) RAPID PRES RELAY-TRIP		178	2
125	COM			179	9
126	NC			180	10
127	NO	74-DB LOSS OF POWER PT SUPPLY- AL		181	
128	COM			182	
129	NC			183	
130	NO	74A/M LTC AUTO/ MANUAL		184	
131	COM			185	
132	NC			186	
133	NO	90 LTC REG RLY SELF TEST		187	
134				188	
135	NO	90 LTC REG RLY USER PROGRAMABLE		189	
136				190	
137	NC	AUTORECHARGING DEHYDR. BREATHER LTC- FAILURE		191	
138				192	
139	NO	71Q-2 (LTC) LIQ LEV LOW		193	
140	COM			194	
141	NC			195	
142	NO	71Q-2 (LTC) LIQ LEV HIGH		196	
143	COM			197	
144	NC			198	
145	NO	90BU LTC FIRST PROT/ RE BACK UP RELAY			
146	COM				
147	NC				
148	NO	86/68 LTC LOCKOUT AL			
149	COM				
150	NC				
151	NO	78-LTC LTC OFF POSITION AL			
152	COM				
153	NC				
154	NO	LTC VACUUM BOTTLE AL			
155	COM				
156	NC				
157	NO	LTC OIL FILTER PRESSURE AL			
158	COM				
159	NC				
160					
161					
162					

↑ IF NO LTC, DO NOT NEED TO INSTALL THIS ROW

☆

☆



D

1
2
3
4
5
6

B

PURCHASER'S AC SUPPLY 1 FAN SUPPLY 208/240VAC, 1PH 9.2KVA MAX	1
	2
	3
PURCHASER'S AC SUPPLY 2 CONTROLS 120/240VAC OR 120/208VAC 1PH 6.4 KVA W/OUTLET	4
	5
	6
PURCHASER'S DC SUPPLY XXVDC 0.15 KW, MIN	7
	8

☆

C ☆ C

145	WTIX1 ◇	X2 WTI	***:5 CXXX HOT SPOT CT	H1 CTA	1	◇ AX1
146	WTIX2 ◇				2	AX2
147	WTIX3				3	AX3
148	WTIX4				4	AX4
149	WTIX5				5	◇ AX5
150	GND ◇		***:5 CXXX MRCT'S UPPER		6	◇ GND
151	LDC-1X1 ◇	X1 LDC-1	***:5 CXXX LDC CT	H2 CTB	7	◇ BX1
152	LDC-1X2 ◇				8	BX2
153	LDC-1X3				9	BX3
154	LDC-1X4				10	BX4
155	LDC-1X5				11	◇ BX5
156	GND ◇				12	◇ GND
157	LDC-2X1 ◇	X2 LDC-2	***:5 CXXX LDC CT	H3 CTC	13	◇ CX1
158	LDC-2X2 ◇				14	CX2
159	LDC-2X3				15	CX3
160	LDC-2X4				16	CX4
161	LDC-2X5				17	◇ CX5
162	GND ◇				18	◇ GND
199	NX1	X0 CTN	***:5 CXXX MRCT'S NEUTRAL	H1 CTD	19	◇ DX1
200	NX2				20	DX2
201	NX3				21	DX3
202	NX4				22	DX4
203	NX5				23	◇ DX5
204	GND		***:5 CXXX MRCT'S MIDDLE 1		24	◇ GND
				H2 CTE	25	◇ EX1
					26	EX2
					27	EX3
					28	EX4
					29	◇ EX5
					30	◇ GND
				H3 CTF	31	◇ FX1
					32	FX2
					33	FX3
					34	FX4
					35	◇ FX5
					36	◇ GND

LAYOUT SET FOR TWO WINDING TRANSFORMER. IF AUTOTRANSFORMER OR THREE WINDING TR MOVE NEUTRAL BCT TO PG 76 AND ADD ADDITIONAL HOT SPOT CT'S

☆

C ☆ C

37	GX1 ◇	H1 CTG			X1 CTP	55	◇ PX1
38	GX2					56	PX2
39	GX3					57	PX3
40	GX4					58	PX4
41	GX5 ◇					59	◇ PX5
42	GND ◇		***:5 CXXX MRCT'S MIDDLE 2	***:5 CXXX MRCT'S UPPER		60	◇ GND
43	HX1 ◇	H2 CTH			X2 CTQ	61	◇ QX1
44	HX2					62	QX2
45	HX3					63	QX3
46	HX4					64	QX4
47	HX5 ◇					65	◇ QX5
48	GND ◇					66	◇ GND
49	JX1 ◇	H3 CTJ			X3 CTR	67	◇ RX1
50	JX2					68	RX2
51	JX3					69	RX3
52	JX4					70	RX4
53	JX5 ◇					71	◇ RX5
54	GND ◇					72	◇ GND
163	KX1 ◇	H1 CTK			X1 CTS	73	◇ SX1
164	KX2					74	SX2
165	KX3					75	SX3
166	KX4					76	SX4
167	KX5 ◇					77	◇ SX5
168	GND ◇		***:5 CXXX MRCT'S LOWER	***:5 CXXX MRCT'S LOWER		78	◇ GND
169	LX1 ◇	H2 CTL			X2 CTT	79	◇ TX1
170	LX2					80	TX2
171	LX3					81	TX3
172	LX4					82	TX4
173	LX5 ◇					83	◇ TX5
174	GND ◇					84	◇ GND
175	MX1 ◇	H3 CTM			X3 CTU	85	◇ UX1
176	MX2					86	UX2
177	MX3					87	UX3
178	MX4					88	UX4
179	MX5 ◇					89	◇ UX5
180	MGND ◇					90	◇ GND

☆

☆ CUSTOMER'S CONNECTIONS THIS SIDE

BCT SHORTING FOR SHIPMENT (WITH SHORTING-TYPE BCT BLOCKS)

◇ SHORT ALL BCTS FOR SHIPMENT FROM #1 TO #5 OR #2 TO 'G' SHORTING BLOCK TERMINALS WITH PROVIDED SHORTING BARS AND PIN SCREWS. BEFORE PLACING TRANSFORMER INTO SERVICE, REMOVE THE PIN SCREWS FROM THE WTI BCT SHORTING BAR.

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.
	XCEL ENERGY			

TRANSMISSION & SUBSTATION STANDARDS

Xcel Energy® — XCEL ENERGY COMPANY WIDE

POWER TRANSFORMER/REACTOR MATERIAL STANDARD — VERSION: 2

FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

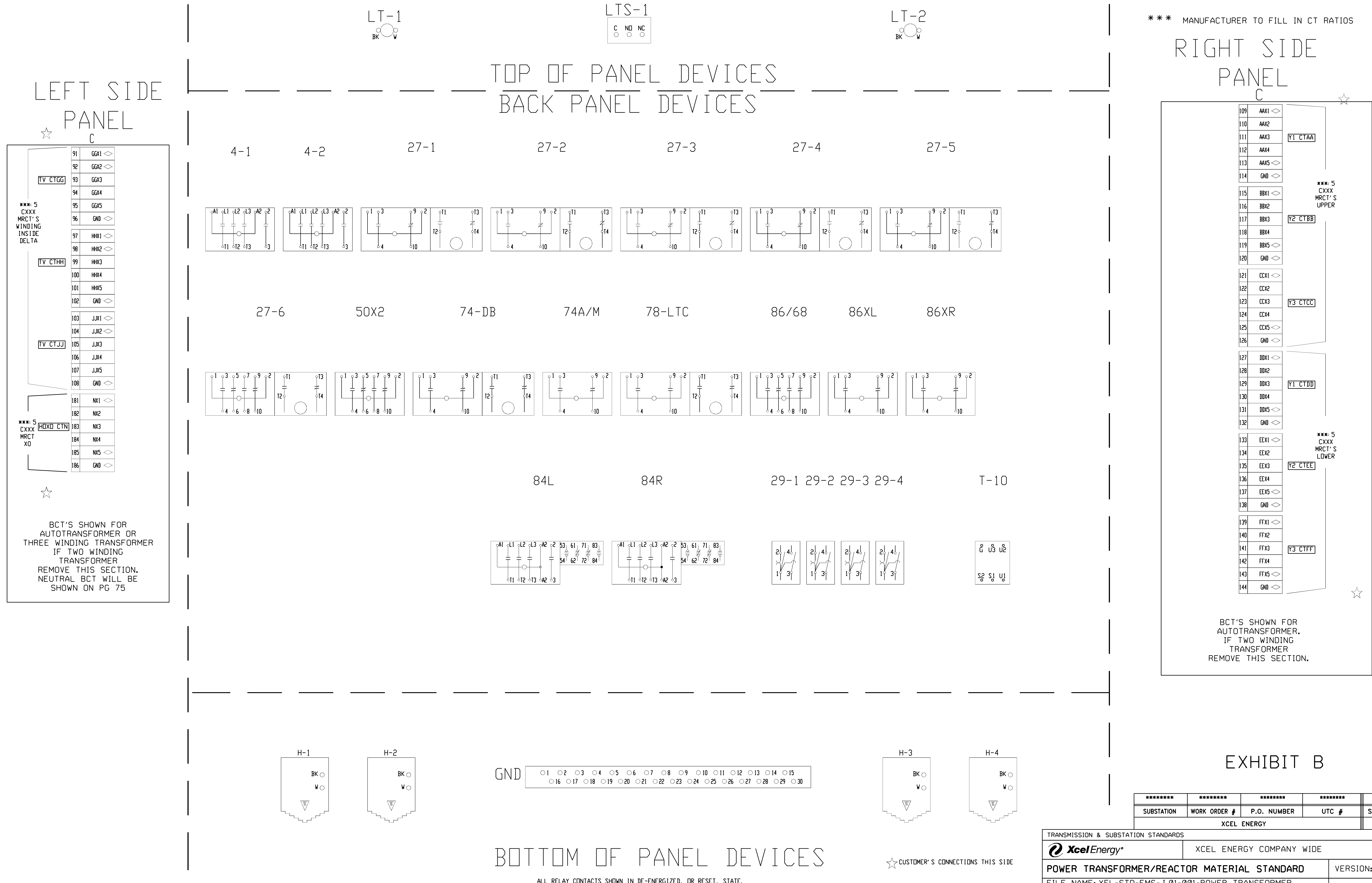


EXHIBIT B

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.
XCEL ENERGY				

TRANSMISSION & SUBSTATION STANDARDS

Xcel Energy — XCEL ENERGY COMPANY WIDE

POWER TRANSFORMER/REACTOR MATERIAL STANDARD — VERSION: 2

FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

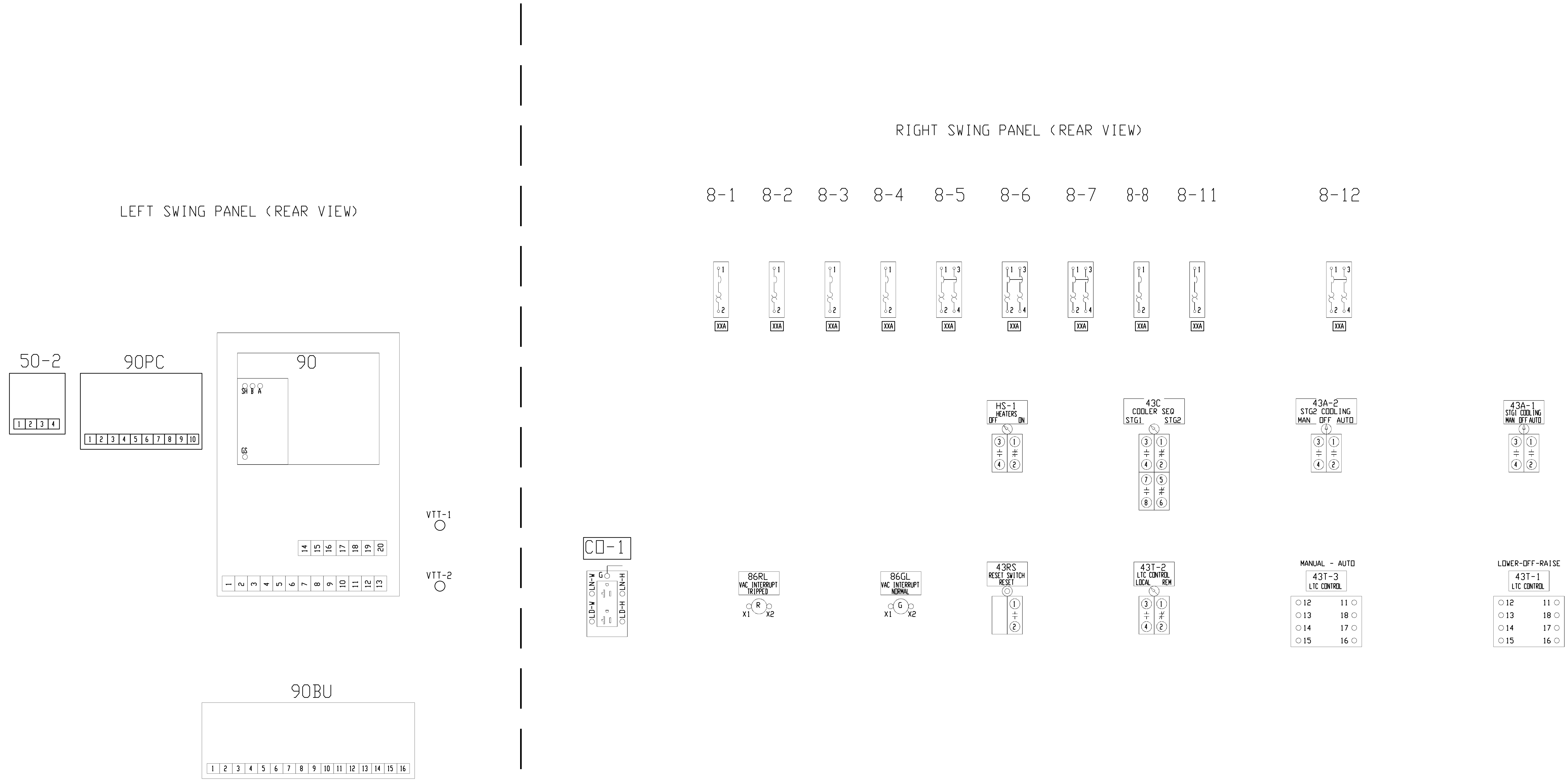


EXHIBIT B

SWING PANEL WIRING NOTES:
1- SEE BACK WIRING DIAGRAM FOR GENERAL WIRING NOTES.

ALL RELAY CONTACTS SHOWN IN DE-ENERGIZED, OR RESET, STATE.

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.
XCEL ENERGY				

TRANSMISSION & SUBSTATION STANDARDS

Xcel Energy — XCEL ENERGY COMPANY WIDE

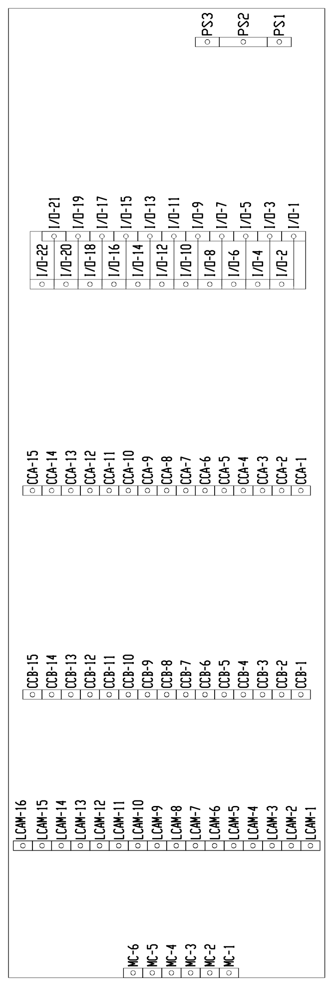
POWER TRANSFORMER/REACTOR MATERIAL STANDARD — VERSION: 2

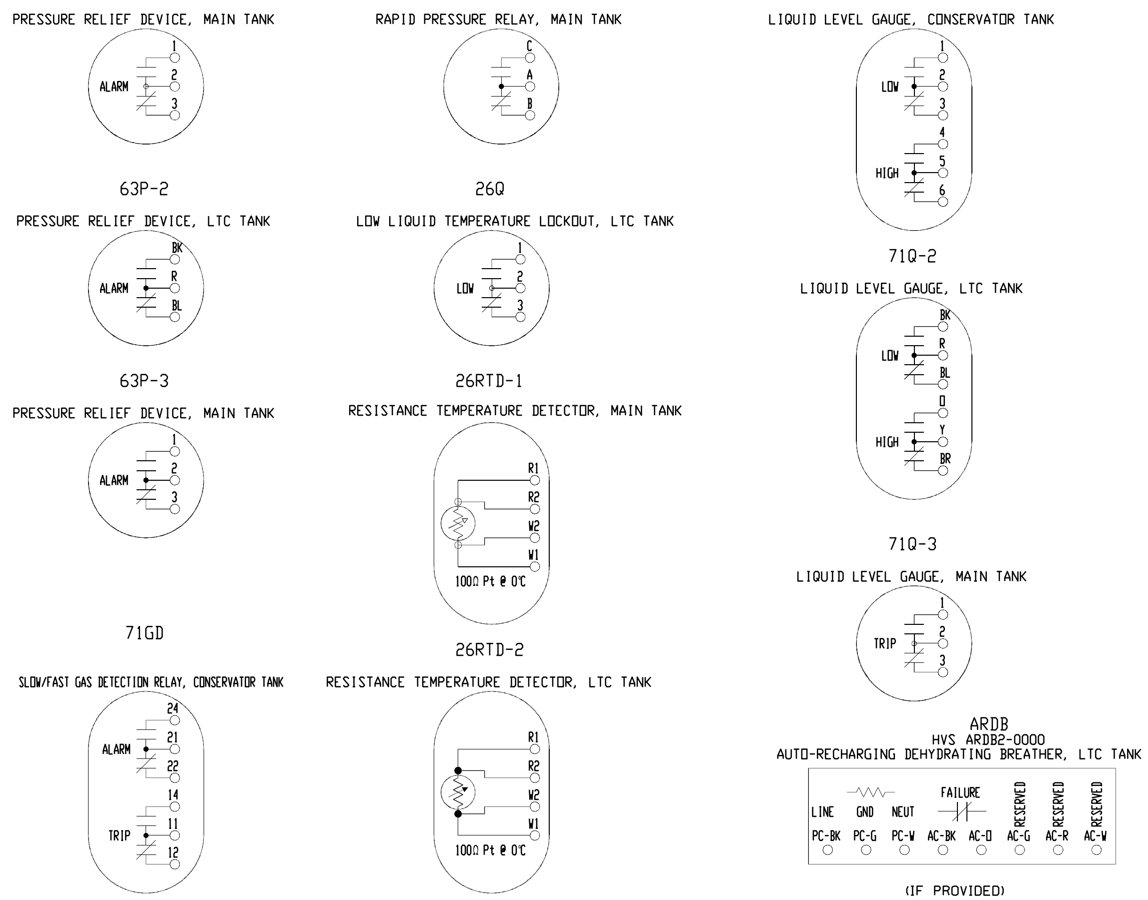
FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

EXTERNAL DEVICES

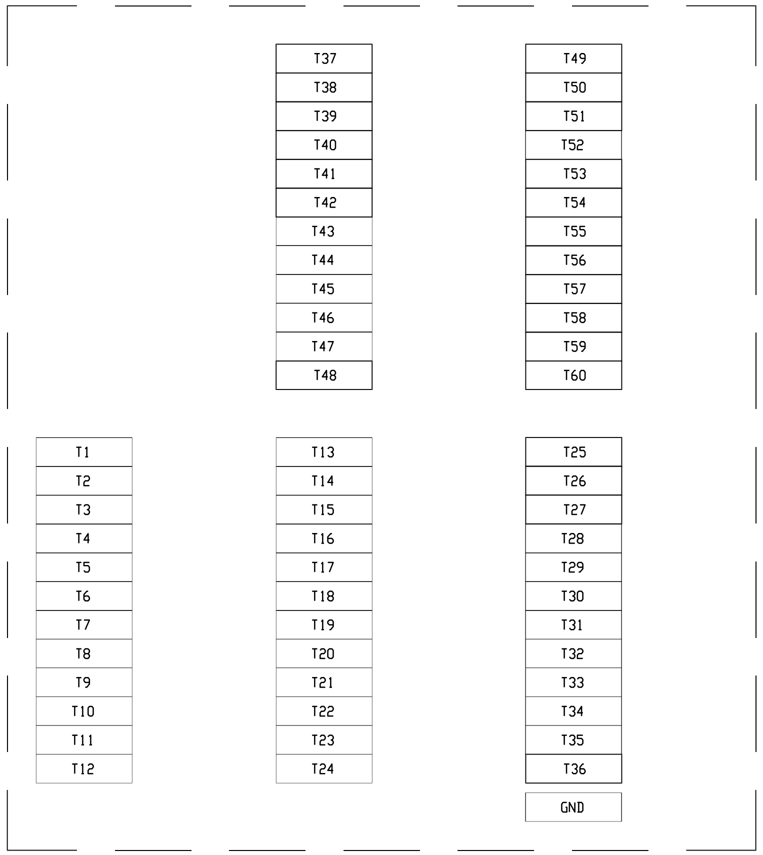
ETM

ELECTRONIC TEMPERATURE MONITOR

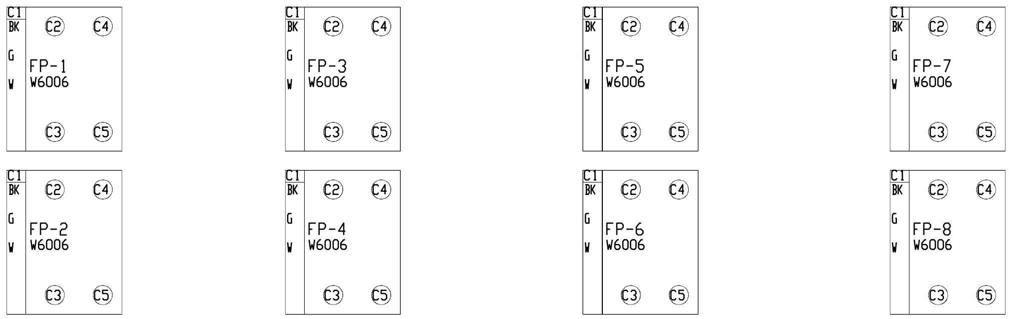




LTC DRIVE CABINET



FAN WIRING



ALL RELAY CONTACTS SHOWN IN DE-ENERGIZED, OR RESET, STATE.

EXHIBIT B

********	********	********	********	********
SUBSTATION	WORK ORDER #	P.O. NUMBER	UTC #	SERIAL NO.
XCEL ENERGY				

TRANSMISSION & SUBSTATION STANDARDS

Xcel Energy® XCEL ENERGY COMPANY WIDE

POWER TRANSFORMER/REACTOR MATERIAL STANDARD VERSION: 2

FILE NAME: XEL-STD-EMS-J.01-001-POWER TRANSFORMER MATERIAL STANDARD

Exhibit C

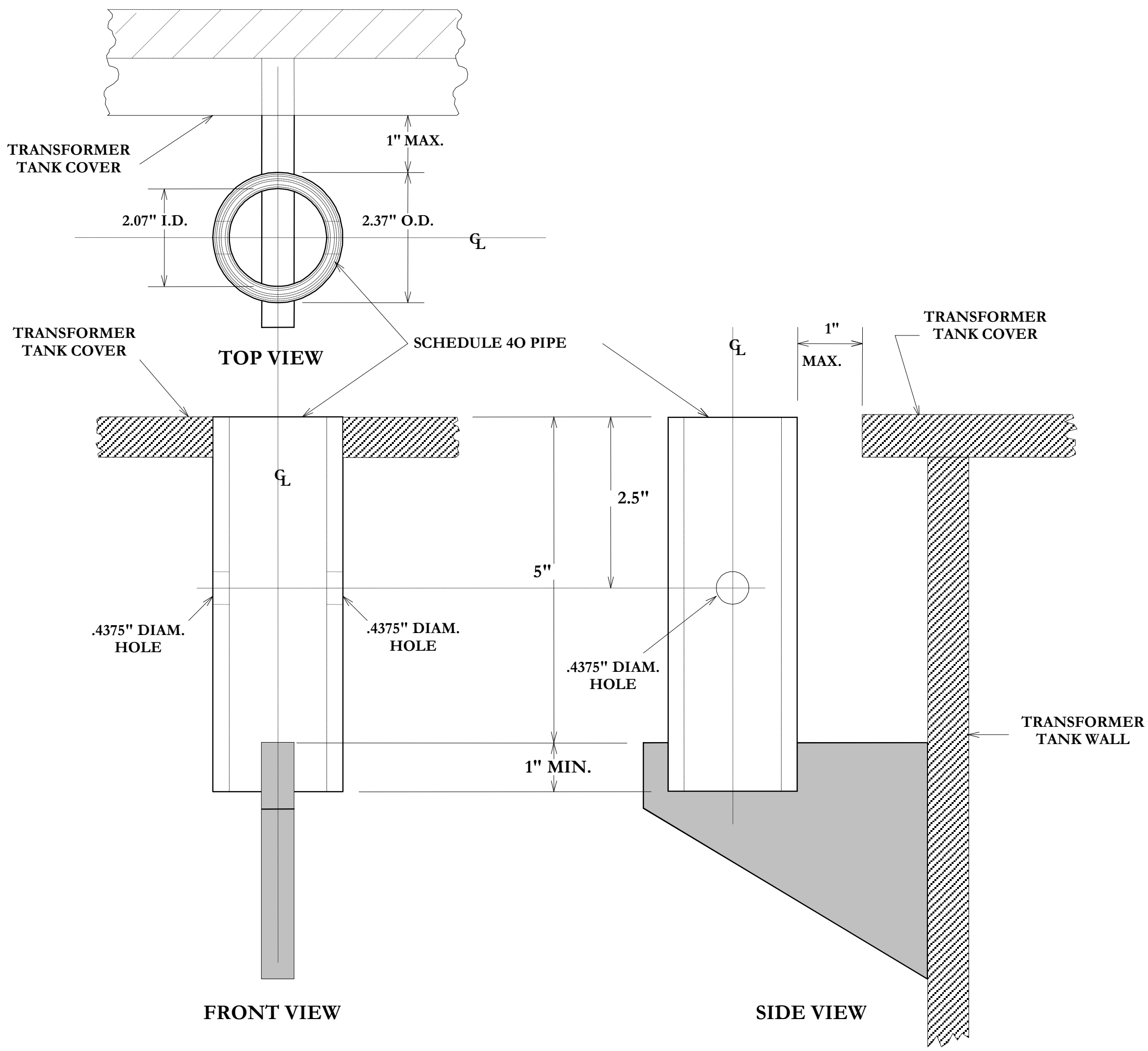


Figure 1

Safety Rail Pocket Detail

Exhibit C

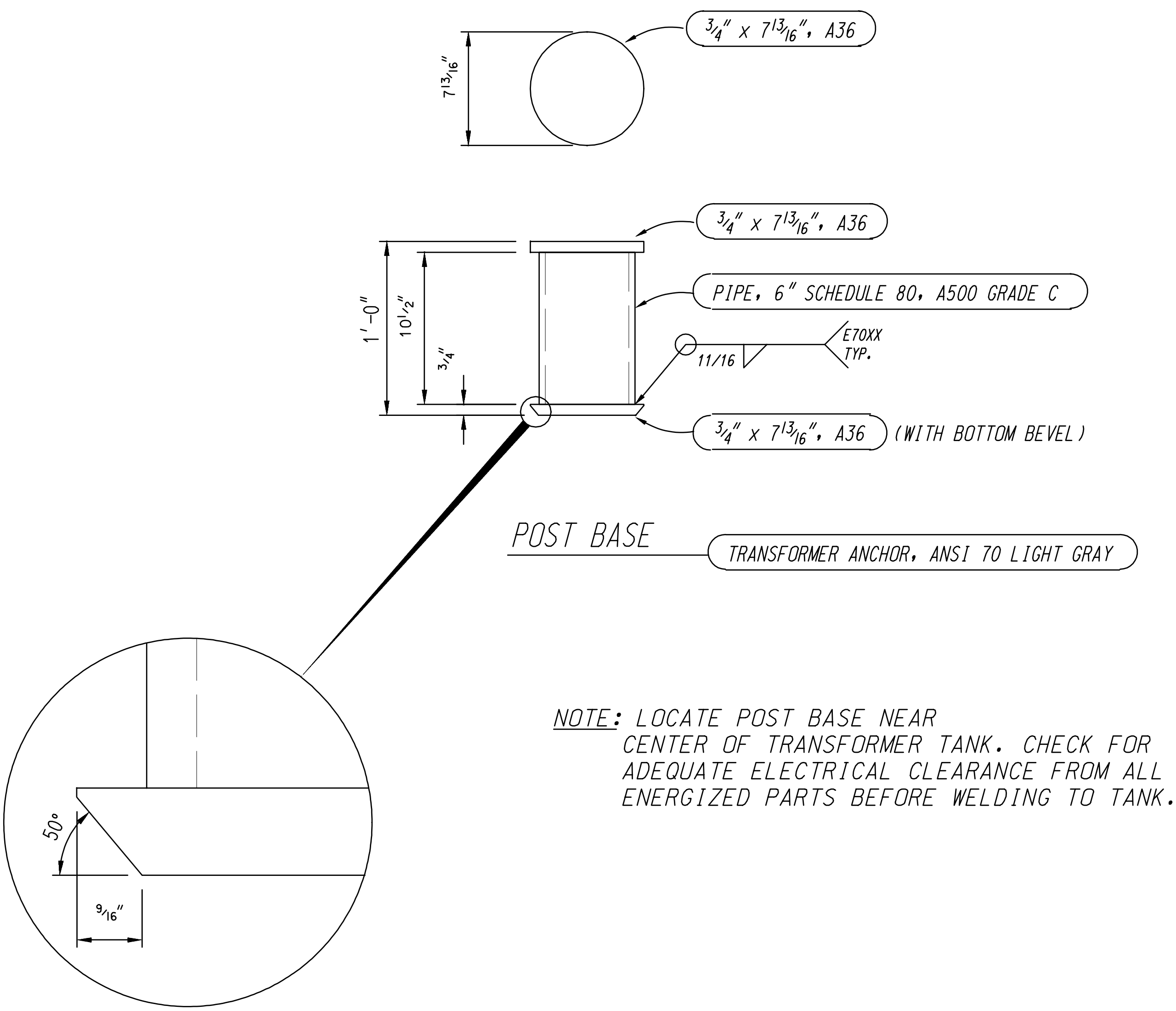
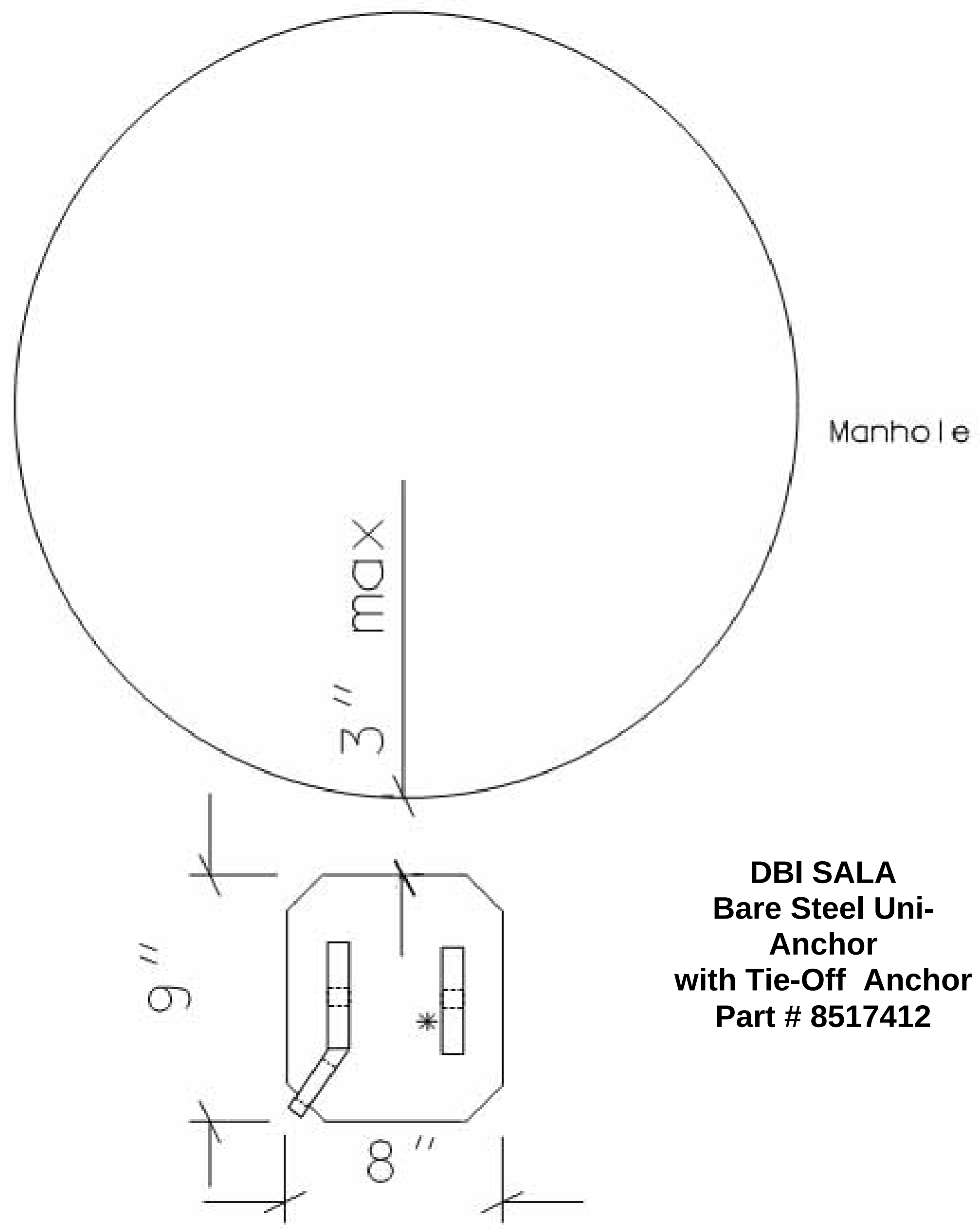


Figure 2

Tether Pole Base Plate Detail

Exhibit C



DBI SALA
Bare Steel Uni-Anchor
with Tie-Off Anchor
Part # 8517412

∗ Note: Orientation of pin-holes

Figure 3
Portable Fall Arrest - Weld-on Base Detail

Exhibit D

Personal Protective Grounding Bracket Detail

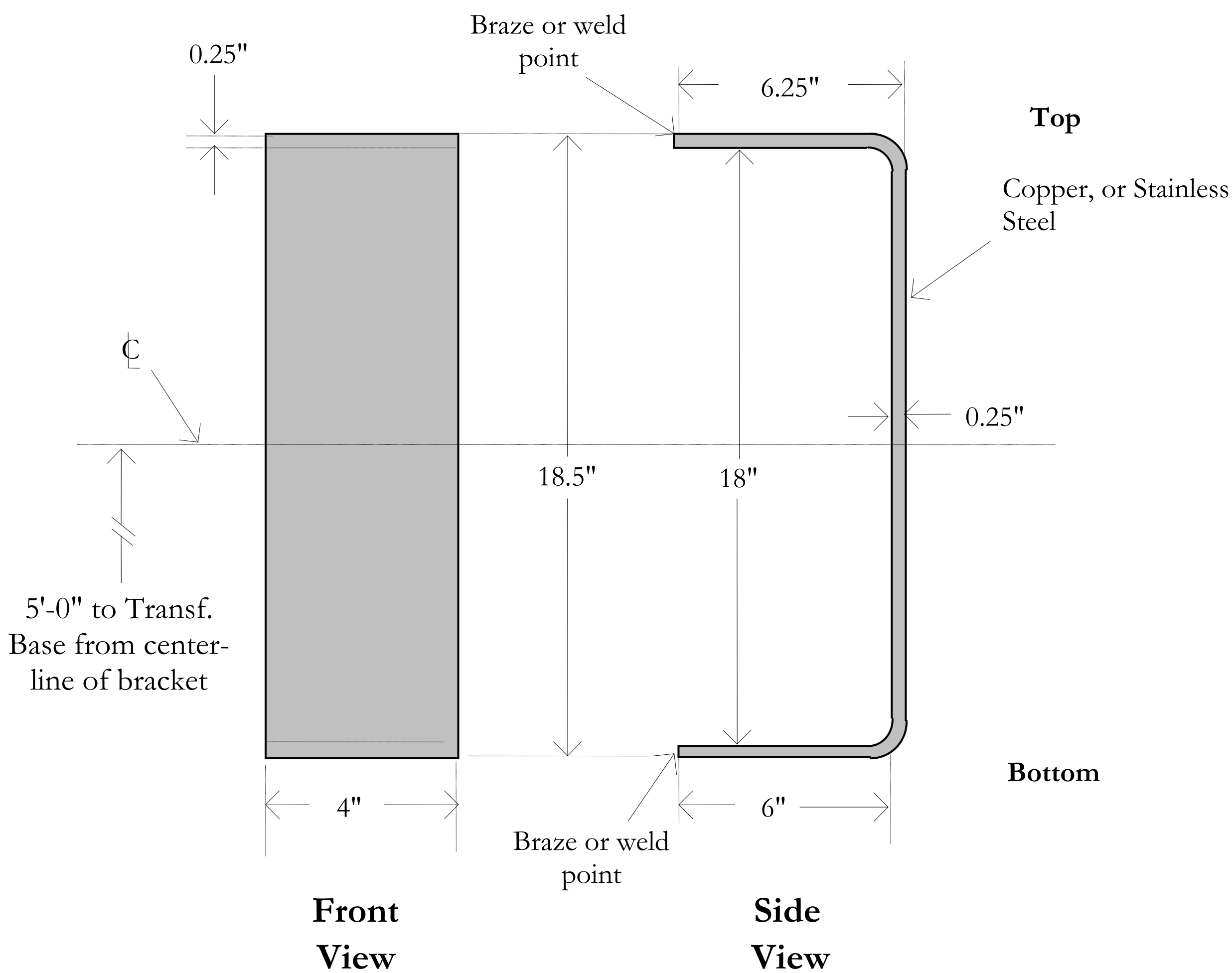


Exhibit E

Nitrogen Blanket System

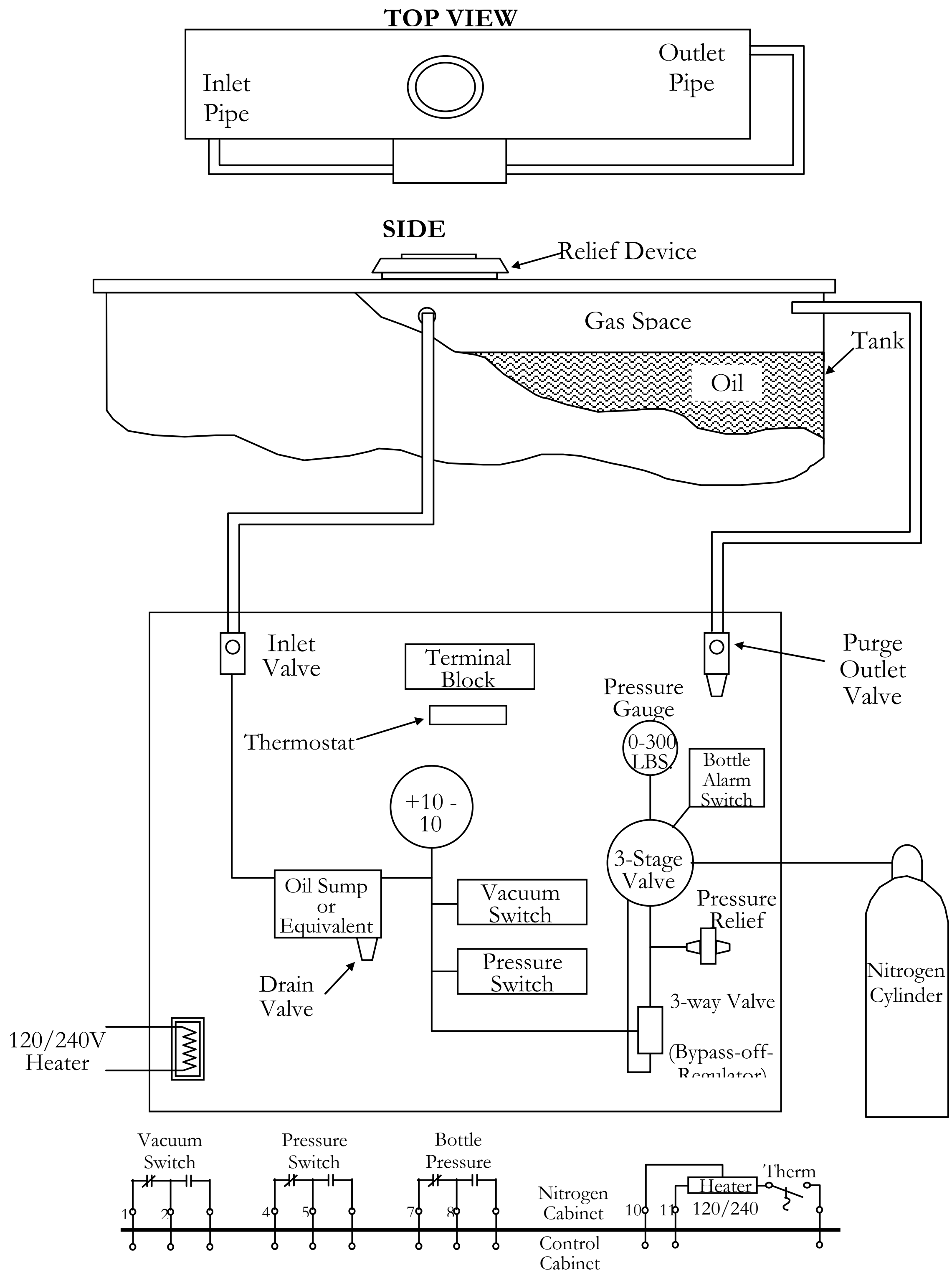


Exhibit F

Field Receipt - Internal Inspection Checklist

A check mark in front of each item indicates that the item was checked. Any condition other than normal shall be identified in the details blank for each item as applicable. If additional space is required, please reference an attached sheet with expanded detail provided.

1. ☐ Check all accessible bolted connections for tightness (including washers)
   Details: ______

2. ☐ Check all current transformer splices for tightness
   Details: ______

3. ☐ Check current transformer mounting brackets for movement
   Details: ______

4. ☐ Check current transformer polarity markings and NPC-ratings
   Details: ______

5. ☐ Check current transformer wire harnesses for proper routing and clearances
   Details: ______

6. ☐ Operate float gauges from inside tank while someone outside verifies correct movement
   Details: ______

7. ☐ Operate DETC and visually and physically confirm each internal contact for proper wipe, location and pressure
   Details: ______

8. ☐ Check low- and high-voltage lead exits from coil assemblies
   Details: ______

9. ☐ Check random axial and radial spacers for tightness
   Details: ______

10. ☐ Check coil blocking for symmetry and tightness
    Details: ______

11. ☐ Check LTC barrier board connections for connection tightness, gaskets and overall integrity
    Details: ______

12. ☐ Check all lead support structures for tightness and cracks
    Details: ______

13. ☐ Check preventive autotransformer, series transformers and associated clamping structure hardware for tightness
Details:

14. ☐ Check main and PA/series transformer core grounds with 5-kV megger
Details:

15. ☐ Check routing of main and PA/series transformer core grounds for proper clearances
Details:

16. ☐ Check symmetry of cores, especially, joints
Details:

17. ☐ Check radiator valve seats
Details:

18. ☐ Check bushing end-terminal and corona ring tightness and clearances to tank walls
Details:

19. ☐ Check hardware on tank shields for tightness
Details:

20. ☐ Photograph core ground terminations, bushings and core for future reference by maintenance and repair crews
Details:

21. ☐ Check symmetry between winding turns and vertical alignment
Details:

22. ☐ Check for debris in core cooling channels
Details:

23. ☐ Check oil box construction if unit is equipment with pumps
Details:

24. ☐ Check tank paint for peeling
Details:

25. ☐ Check bottom of tank for debris of any kind
Details:

26. ☐ Check for foreign objects inside clamping structure beams if hollow in spots (wrenches, bolts, washers, welding rods)
Details:

27. ☐ Check core and coil clamping assembly for proper terminations of grounding straps
Details:

---

28. ☐ Check core insulation for damage or movement
Details:

---

29. ☐ Check PA/series transformers core insulation for damage or movement
Details:

---

30. ☐ Check turn transition point workmanship on windings
Details:

---

31. ☐ Check top and bottom coil clamping rings and static rings for symmetry workmanship and general condition
Details:

---

32. ☐ Perform an internal inspection of the LTC, if unit was shipped without oil (remove shipping braces if used).
Details:

---

33. ☐ Check for nylon tie-raps (these have a habit of loosening over time - replace with linen ties)
Details:

---

34. ☐ Check shields if so equipped
Details:

---

35. ☐ Check core clamping structure spaces for symmetry and tightness
Details:

---

36. ☐ Check barrier tubes for damage
Details:

---

37. ☐ Check angle rings and support washers
Details:

---

38. ☐ Check collar insulation if accessible
Details:

---

39. ☐ Check lock plates and wedges for tightness
Details:

1.0 PURPOSE

- This document is the methodology developed by Xcel Energy to state methods used in calculating equipment ratings.

2.0 APPLICABILITY AND RESPONSIBILITIES

- This policy is applicable to all Xcel Energy Transmission facilities, including transmission lines and substations. A facility rating determined from this policy shall respect the most limiting applicable equipment rating of the individual equipment that comprises that facility.

3.0 APPROVERS

Name	Title
Benson, Ian R	AVP*TRANS STRAT & PLNG
Craig, Byron R	DIRECTOR*SUBS/TRANS ENG & DES
Hargreaves, Roger D	DIRECTOR*SR SYSTEM OPERATIONS

4.0 VERSION HISTORY

Date	Version Number	Change
04/19/2007	1.0	• Was written as rev. 3 in document
07/08/2009	4.0	• Clarify transmission to substation jumper ratings • AAC and ACAR conductor temperature maximum updates
07/01/2010	5.0	• Removed Appendices • Condensed descriptions • Provided clarity to Transmission Line Emergency Ratings
07/01/2011	5.1	• Added CAPX IEEE 738 assumptions • Modified winter season for NSP • Removed solar heat gain assumption for indoor conductors
08/31/2012	6.0	• Revised to Comply with FAC-008 • Replaced Dynamic Line Ratings with Ambient-Adjusted Ratings • Added Operational Guidelines
08/01/2013	6.1	• Removed NSP and SPS Unnecessary Assumptions • Added Current Split Methodology • Minor Rewording for Clarification
11/01/2014	7.0	• Added Strain Bus Rating Cases • Added Conservative Rating • Removed SPP CT Rating Criteria
11/01/2015	8.0	• Relocated Ambient Assumptions to General • Relocated Operational Guidelines to General • Added ACCR Rating • Relocated formulation under Proximity Effect of Conductors section to Supplement • Improved Substation Rating Diagram and removed duplicated information
07/18/2016	9.0	• Fixed Header • Revised Table of Contents • Renamed Section 5 title to avoid using “Purpose” twice • Added Default Ambient Temperature table • Modified ACSS 30 Minute Emergency Rating

9/5/2017	10.0	• Section 6.2 - Clarified split path applicability where there are three or more paths. • Section 6.9 – Added table for altitude adjusted ambient temperatures. • Section 9.2 - Changed NSP Winter Day used for Substation calculations to 90.
12/1/2017	10.1	• Section 4.0 – corrected version number for 9/5/2017 • Section 7.1 – Changed maximum operating temperatures for ACCC and ACCR conductor
9/1/2018	11.0	• Section 6.9 – revised wording to allow for use of altitude adjusted ambient temperatures for all equipment. • Section 7.1 – added ZTACSR conductor to the conductor table.
10/1/2019	12.0	• Section 7.0 – added year to IEEE 738 reference and removed PLS CAD reference. • Section 9.9 – rewrite section on line trap ratings to remove differentiation between epoxy and dry type. • Section 9.16 – added statement to assume 5 amp rating if secondary device rating is unknown.
01/01/2020	13.0	• Table of Contents – renumbered sections in 6.0 General Information • Section 6.3 – removed reference to split path method • Section 6.4 – removed reference to split path method • Section 6.5 – removed – split path method no longer used • Section 9.9 – corrected reference to section 6.8

Policy

Xcel Energy

Transmission

Facility Rating Methodology

Version 13.0

January 1, 2020

Table of Contents

5.0 Objective

The objective of this document is to describe the methodologies employed when determining the ratings of transmission facilities on the Xcel Energy Bulk Electric Transmission Systems. The rating methodology includes both Normal and Emergency Ratings. For tables of equipment ratings and example calculations please refer to the Xcel Energy Rating Methodology Supplement. The Supplement is not considered part of the Rating Methodology, because all information pertaining to the method of the calculation is included in the Rating Methodology. The Supplements are in two parts; there are Excel Spreadsheets, which contain tables of calculated ratings, along with word documents explaining the development of the Rating Methodology and example calculations. Xcel Energy is currently developing software to calculate all bulk electric system facility ratings as the primary system. Once the published facility ratings are created with the software, the Supplement tables and example calculations will be secondary.

The Xcel Energy Bulk Electric Transmission Systems includes the combined Northern States Power Company Minnesota and Northern States Power Company Wisconsin (NSPM and NSPW) Transmission System, Public Service Company of Colorado (PSCo) Transmission System, and the Southwestern Public Service (SPS) Transmission Systems.

6.0 General Information

6.1. Updates

Once a revised Facility Rating Methodology has been approved, Xcel Energy will review and update rating information and issue new ratings (if needed) within 18 months.

6.2. Facility Ratings

The Facility Rating shall respect the most limiting applicable Equipment Rating of the individual equipment that comprises that Facility. Ratings of the equipment that comprise the Facility shall be consistent with at least one of the following:

- Ratings provided by equipment manufacturers or obtained from equipment manufacturer specifications such as nameplate rating.
- One or more industry standards developed through an open process such as Institute of Electrical and Electronics Engineers (IEEE) or International Council on Large Electric Systems (CIGRE).
- A practice that has been verified by testing, performance history or engineering analysis. The equipment shall include, but not be limited to, transmission conductors, transformers, relay protective devices, terminal equipment, and series and shunt compensation devices. The rating for each individual piece of equipment considers the (a) Equipment Rating standard(s) used in development of this methodology; (b) Ratings provided by equipment manufacturers or obtained from equipment manufacturer specifications; (c) Ambient conditions (for particular or average conditions or as they vary in real-time); and (d) Operating limitations; in accordance with good utility practice. Operational limitations may result in a de-rating based on good utility practice. The Facility Rating will include both Normal and Emergency Ratings.

Xcel Energy develops a 30-minute emergency facility rating for all Transmission Lines. The emergency rating timeframes available for transformers are published in the Criteria for Power Transformer Loading. IEEE equipment standards have varying time frames for equipment emergency ratings. If the emergency rating developed for a piece of equipment is for a longer duration than that of the reported rating, then the equipment's emergency rating is utilized in determining the Facility's Emergency Rating. For example, it is acceptable to use a switch's four-hour emergency rating when determining the 30-minute emergency rating of a transmission line. However, when the duration of an emergency rating of a piece of equipment is less than the duration of the rating being reported, then the equipment's normal ratings will be utilized. For example, it is not acceptable to use a switch's 4-hour emergency rating when determining the 8-hour emergency rating for a transformer facility. Instead, the switch's normal continuous rating will be used in determining the 8-hour emergency rating for the transformer facility.

6.3. Transmission Line Facility Ratings

When developing a Transmission Line Facility Rating, the set of equipment that comprises the Facility includes:

a. The transmission line.

b. All of the equipment that is used to operate or disconnect the line and operated as part of the line. This includes, but is not limited to adjacent circuit breakers, disconnect switches, conductor, relays, and meters that as a result of switching could be operated in series with the line.

The Transmission Line Facility Rating is calculated as the minimum rating of the equipment described above.

6.4. Transformer Facility Ratings

When developing a Transformer Facility Rating, the set of equipment that comprises the Facility includes:

a. The transformer equipment.

b. All of the equipment that is used to operate or disconnect the transformer and operated as part of the transformer. This includes, but is not limited to adjacent circuit breakers, disconnect switches, conductor, relays, and meters that as a result of switching could be operated in series with the transformer.

The Transformer Facility Rating is calculated as the minimum rating of the equipment described above.

6.5. SPP, WECC and MRO

Where SPP, WECC and MRO have requirements for facility ratings, the more conservative rating should be used.

6.6. Jointly-Owned Facilities

Equipment ratings on Jointly-Owned facilities will be communicated between the owners. The Jointly-Owned Facility Rating shall equal the most limiting applicable Equipment Rating of the individual piece(s) of equipment that comprise the Jointly-Owned Facility.

In cases where a facility is owned in segments (such as a line terminal being owned by one party and the line conductor by another party), Xcel Energy rates only those portions of the line/terminal/transformer that it owns and provides that information to the owner(s) of the other segment(s). Xcel Energy takes into account rating data provided by the owner(s) of the other segment(s) of the line or transformer, and applies the most limiting rating as the Facility Rating.

6.7. Conservative Ratings

A limited number of pieces of equipment may not have all the information necessary for developing an equipment rating. However, in order to provide system ratings, a conservative rating may be applied to this equipment. The conservative rating for the equipment must be documented in the equipment attributes. Conservative ratings are defined as those, which produce an ampacity on the low end of the possible range for that equipment and are based upon engineering judgment. A Rating Exception Form must be on file for all conservative ratings developed.

6.8. Default Ambient Temperature

Design Ambient Temperature	NSP	PSCo	SPS
Summer Ambient Design Temperature	40 °C 104 °F	40 °C 104 °F	40 °C 104 °F
Winter Ambient Design Temperature (used for winter peaking circuits – these circuits peak at very low temps)	0 °C 32 °F	24 °C 75 °F	27 °C 81 °F

For elevations greater than or equal to 5500 feet in the PSCo region, ambient temperatures in the following table may be used for calculating ampacity of conductors & equipment.

Elevation (feet)	Summer Ambient Design Temperature	Winter Ambient Design Temperature
5500-6000	40°C = 104°F	24°C = 75°F
6001-6500	39°C = 101°F	24°C = 75°F
6501-7000	37°C = 99°F	24°C = 75°F
7001-7500	36°C = 97°F	24°C = 75°F
7501-8000	35°C = 95°F	23°C = 73°F
8001-8500	34°C = 93°F	22°C = 71°F
8501-9000	33°C = 91°F	21°C = 69°F
9001-9500	32°C = 89°F	20°C = 67°F
9501-10000	30°C = 87°F	19°C = 66°F
>10001	29°C = 85°F	18°C = 64°F

The Winter Operating Seasons are:

- December 1 – March 1 for NSPM and NSPW
- November 1 – March 31 for PSCo
- December 1 – March 31 for SPS

Ambient temperature assumptions are used for standards that do not state assumptions.

6.9. Ambient-Adjusted Ratings

Ambient-Adjusted Ratings may be used for real-time operations and near-term planning; however, long-term planning should not rely on Ambient-Adjusted Ratings. Typically, these ratings will rely on weather parameters for ambient temperature but may also be based on wind speed or other ambient-based parameters. In real-time operations, these ambient parameters will be obtained from local meteorological stations or from the weather service in the vicinity of the affected facility. In the case where facilities cross areas of differing weather conditions, the more conservative values will be utilized.

Once the ambient parameters are known, the Ambient-Adjusted Rating for one or more elements of the Facility may be determined by various methods. A few of the common methods are listed but other methods may be used.

- Recalculated Ambient Adjusted Rating tables
- Standalone program utilizing comparable rating calculation
- EMS dynamic rating feature
- Line monitors

If Ambient-Adjusted Ratings are applied to some but not all elements of a Facility, then the normal seasonal ratings are to be used for those elements, which do not have an Ambient-Adjusted Rating when determining the overall Facility rating.

The Ambient-Adjusted Ratings are not to exceed the maximum published facility rating unless a detailed review of relay settings is completed.

6.10. Operational Guidelines

Operating Guidelines may be utilized in cases where recent field verification has identified a potential discrepancy in the assumptions used to determine the rating of an element and the resulting facility de-rate would result in significant risk to the operation of the transmission system. These Operating Guidelines will be temporary, with the assumption that once the resulting remediation project is complete, then the Operating Guideline will be removed and the calculated rating will be implemented.

7.0 Transmission Line Rating Methodology

Xcel Energy uses the IEEE 738-2006 standard for calculating bare overhead conductor ratings. Xcel Energy will use the lesser of the Conductor Maximum Operating Temperature and the Clearance/Hardware thermal limits for conductor operating temperature in the IEEE 738-2006 calculation. The remainder of this section lists assumptions.

7.1. Conductor Maximum Operating Temperature

Xcel Energy adheres to the following table for maximum operating temperature of its conductors. The table shows normal and emergency limits.

Conductor type	Normal (Operating Temperature)	30 Minute Emergency Rating
ACSR*	100 °C	Normal Rating X 110%
ACAR	100 °C	Normal Rating X 110%
AAC	100 °C	Normal Rating X 110%
Cu	95 °C	Normal Rating X 110%
Copper Weld	95 °C	Normal Rating X 110%
ACCC	180 °C	200 °C
ACSS	200 °C	250 °C
SCACAR	100 °C	Normal Rating X 110%
ACCR	210 °C	240 °C
ZTACSR	210 °C	240 °C

*ACSR may be permitted to run at higher temperatures see “General Guidelines when considering up-rating ACSR beyond 100 degrees C” in Rating Methodology Supplement.

7.2. Permitting/Other

Conductor may be rated below the maximum operating temperature listed in section 7.1 for the following reasons:

- Permitted ROW agreements (ex. railroad or waterway crossing).
- Ampacity (ex. NESC clearance limitation).
- EMF calculations.

7.3. Clearance/Hardware Limit

The Clearance/Hardware thermal rating of a transmission line is the maximum temperature, (regardless of the current) which a conductor can attain without violating code-mandated clearances or damaging temperature limited hardware. Short-term limitations due to clearance restrictions will be considered on a case by case basis.

7.4. Remaining Assumptions

Variables	NSP – Assumption	PSCo – Assumption	SPS – Assumption
Conductor properties	Southwire Overhead Conductor Manual 2nd Edition and other various sources	Southwire Overhead Conductor Manual 2nd Edition and other various sources	Southwire Overhead Conductor Manual 2nd Edition and other various sources
Cooling Wind	Maximum of 4 ft/sec @ 90deg to conductor *	Maximum of 4 ft/sec @ 90deg to conductor	Maximum of 6 ft/sec @ 90deg to conductor
Elevation	Actual Elevation (or use default of 1100')	Actual Elevation (or use default of 5200')	Actual Elevation (or use default of 3700')
Emissivity	0.5	0.5	0.5
Absorptivity	0.5	0.5	0.5
Latitude	Actual Latitude (or use default of 43°N)	Actual Latitude (or use default of 40°N)	Actual Latitude (or us default of 35°N)
Summer Day Solar Calc	172	172	172
Winter Day Solar Calc	90	90	90
Time of Day	12:00 PM	12:00 PM	12:00 PM
Orientation of Line	Actual Orientation (or use default of East to West)	East to West	East to West
Atmosphere	Clear	Clear	Clear

***Excludes Buffalo Ridge Wind Rated Lines**

7.5. CAPX Assumptions

CapX2020 is a joint initiative of 11 transmission-owning utilities in Minnesota and the surrounding region to construct region transmission lines. These lines are to be owned jointly as a percentage share in the line. The following assumptions have been agreed upon by the utilities for rating calculations.

Variables	CAPX2020 – Assumption
Conductor properties	Southwire Overhead Conductor Manual 2nd Edition and other various sources
Cooling Wind	2 ft/sec @ 90deg to conductor
Emissivity	0.7
Absorptivity	0.9
Summer Day Solar Calc	July 8th
Winter Day Solar Calc	April 30th
Time of Day	12:00 PM
Orientation of Line	East to West
Atmosphere	Clear

7.6. Buffalo Ridge Wind Rated Lines

A few transmission lines in southwestern Minnesota that provide outlet to wind generators have a rating based on a higher wind speed than is typical throughout the rest of the NSP system. Higher output from the wind generators is only available during the time periods where the wind speed is higher than used in normal transmission line ratings. Thus a higher wind speed was used to rate these lines. The higher wind speed was approved at the time of development by the Design Review Subcommittee of the then existing NERC Reliability Region “Mid-Continent Area Power Pool (MAPP).

The transmission line circuits in the NSP Transmission System with wind ratings are the following 115kV lines: Split Rock-Pipestone and Chanarambie-Pipestone.

7.7. Underground Lines

Underground lines have been and will be rated on an individual basis using engineering analysis. The ratings are developed and based on the soil conditions, conductor type, and installation methods.

Underground cable and the associated terminators are engineered as a system and the ampacity rating is determined for the system. The ampacity rating provided for underground cable and terminator systems shall equal the most limiting element of the system.

8.0 Transmission Line Equipment Rating Methodology

8.1. Line Switches

The line switch ratings are based on the manufacturer's assigned nameplate rating and ACCC designation. The maximum ampacity to operate the switch is based on the IEEE C37.37 loading guide.

8.2. Line Jumpers

The rating methodology for line jumpers is the same as that used as for Xcel Energy's Transmission Lines, which references IEEE STD. 738. The ratings communicated for transmission lines will represent the rating of the line including all jumpers in the line. If the rating of a jumper is the limiting equipment in a line, then the rating of the line will be limited to the jumper rating.

Jumpers between transmission lines and the substation equipment should be rated per the transmission line rating methodology unless restricted by the equipment or hardware that the jumper is attached to.

8.3. Hardware

Hardware for transmission lines is temperature limited and is designed for the operating temperature of the line. The equipment manufacturer provides hardware ratings.

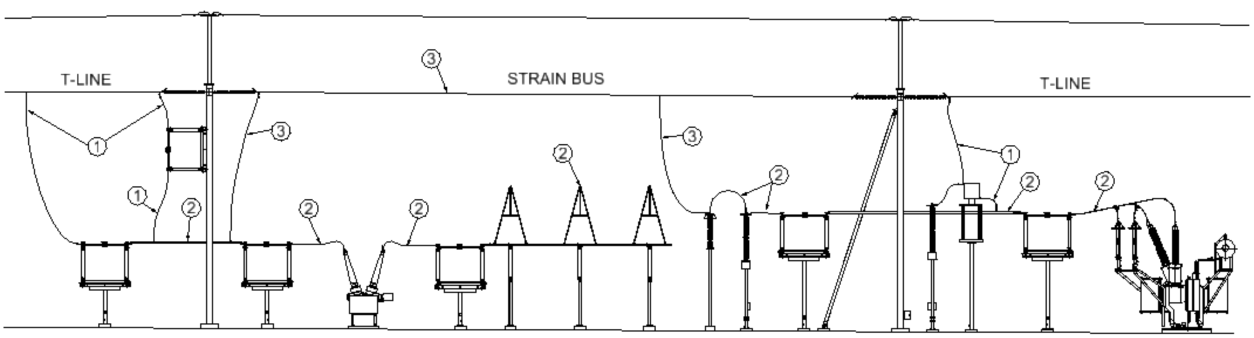
9.0 Transmission Substation Equipment Rating Methodology

Transmission Substations are comprised of several pieces of equipment. Each piece of equipment is identified below along with its ratings methodology.

The following diagrams are to be used as reference for the Substation Equipment Rating Methodology.

9.1. Substation Rating Diagrams

SUBSTATION RATING DIAGRAM



① T-LINE TO SUBSTATION EQUIPMENT - RATE ONLY FLEXIBLE CONDUCTORS PER *TRANSMISSION LINE RATING METHODOLOGY* SECTION;
DERATE CONDUCTORS WHEN CONNECTED DIRECTLY TO:

DEVICES WITH BUSHINGS	-	NORMAL 85°C	EMERGENCY 100°C,
LINE TRAPS	-	NORMAL 135°C	EMERGENCY 135°C,
SWITCHES	-	NORMAL 200°C	EMERGENCY 200°C;

ALL CONDUCTORS' RATINGS SHALL FOLLOW *CONDUCTOR MAXIMUM OPERATING TEMPERATURE* TABLE.

② SUBSTATION OR STRAIN BUS TO TUBE, BUSHING OR EQUIPMENT:

ALL CONDUCTORS	-	NORMAL 85°C	EMERGENCY 100°C

③ REFER TO THE CRITERIA UNDER *BUS CONDUCTORS AND EQUIPMENT JUMPERS* SECTION TO DETERMINE WHETHER SUBSTATION OR TRANSMISSION RATING METHODOLOGY IS APPLICABLE.

9.2. Bus Conductors and Equipment Jumpers

The rating methodology is as outlined in IEEE Standard 605 for tubular bus and IEEE Standard 738 for wire bus and jumpers. Assumptions made for conductors are as follows:

Variables used for Bus Conductor (Tube, Wire & Jumpers) Ampacity Calculations			
Variables	**NSP**	**PSCO**	**SPS**
Summer Ambient Temperature (Deg. C)	See Default Ambient Temperature under General section		
Winter Ambient Temperature (Deg. C)			
Emissivity Outdoors(e)	0.5	0.5	0.5
Emissivity Indoors(e)	0.35	N/A	N/A
Absorptivity (a)	0.5	0.5	0.5
Degrees North Latitude	Actual (or 43)	Actual (or 40)	Actual (or 35)
Time	12	12	12
Atmosphere	Clear	Clear	Clear
Elevation (ft.)	Actual (or 1100)	Actual (or 5900)	Actual (or 3700)
Wind Speed (ft./S) – indoor	0	0	0
Wind Speed (ft./sec.) - enclosed substation	2	2	2
Wind Speed (ft./sec.) - open substation	4	4	6
Wind Direction Factor (deg.)	90	90	90
Azimuth of Conductor (deg.)	90	90	90
Day of the year - Summer (Variable N from IEEE 738)*	172	172	172
Day of the year - Winter (Variable N from IEEE 738)*	90	90	90

*No solar heat gain for indoor conductors

All tube and bare overhead conductors inside the substation will have a normal rating of 85° C and an emergency four hour rating of 100° C. Jumpers between transmission lines and the substation equipment should be rated per the transmission line rating methodology unless restricted by the equipment or hardware that the jumper is attached to. Strain bus consisting of bare overhead conductor may be rated per the Transmission Line Rating Methodology if all of the following are true:

1. The strain bus is considered an extension of the transmission line due to the fact that one end of the strain bus terminates on the transmission line dead-end structure.

2. The strain bus terminations inside the substation are at the same height as or higher than the transmission line termination into the substation or minimum conductor ground clearance greater than 25 feet above surface grade.
3. The strain bus is in an open substation and is expected to be exposed to the same wind speed as the transmission line.
4. Structures and hardware used to install the strain bus are rated for the maximum conductor temperature and tension as outlined by the Transmission Line Rating Methodology.
5. Clearances to ground and other substation equipment can be maintained at maximum sag based on company standards when designed.

Connectors and terminations used on substation conductors will be given a rating equal to that of the conductor to which they are attached. Therefore, the ratings communicated for substation conductors will include the rating of the conductor itself as well as the connectors and terminations connected to it.

9.3. Proximity Effect of Conductors

Conductors spaced less than six inches apart are subject to reductions of capacity due to proximity effect. Xcel Energy has used Engineering Analysis to develop proper ratings for these conductors. Xcel Energy has developed ratings on these conductors based on three sources. “Skin Effect and Proximity Effect in Tubular Conductors”, “Skin Effect in Tubular and Flat Conductors,” and “Bessel Functions for A-C Problems” were used in formulating the calculation.

9.4. Circuit Breakers, Circuit Switchers, and Line-Switchers

The rating methodology is as outlined in ANSI/IEEE C37.010**.** Breakers pre 1964 utilize a 55 degree C Hot Spot temperature rise and 1964 – present utilize a 65 degree C Hot Spot temperature rise.

9.5. Disconnect Switches

The rating methodology is as outlined in ANSI/IEEE C37.30 and ANSI/IEEE C37.37**.** Xcel Energy has contacted switch manufacturers about connecting conductors, which will operate at 200ºC to switch pads. The manufacturers have provided test data and have stated that this will not adversely affect the operation of the switches.

9.6. Transformers

The rating methodology is as outlined in ANSI/IEEE C57.12.00. Loading/rating for loading above transformer nameplate is in accordance with ANSI/IEEE C57.91. The ratings for transformers are determined by the Criteria for Power Transformer Loading.

9.7. Current Transformers (CT's)

The overload capacity of a Current Transformer (CT) is determined by its continuous thermal rating factor (RF). The continuous thermal rating factor is defined in IEEE C37.110. The maximum secondary current of a CT is the rated value of the CT secondary*RF or as limited by other elements in the circuit.

$Itap = Itap_r * RF$

Itap = adjusted rated continuous current of specific CT tap under consideration

$Itap_r$ = rated continuous current of tap

RF = Continuous thermal rating factor (Manufacturer should be consulted for value of continuous current rating factor. Assume 1 if not available.)

9.7.1. Autotransformer neutral winding CTs

CTs on the neutral winding of an autotransformer do not experience the same current flows as the H or X windings. The method of calculating the flow in the common winding uses the following formula:

$$CommonWindingAmps = \frac{TopRating(KVA)}{\sqrt{3} * V_{lowside}(kV)} - \frac{TopRating(KVA)}{\sqrt{3} * V_{highside}(kV)}$$

This formula is applied to find the amperage flowing through the common winding when the transformer is operating at its top rating.

9.8. Power Apparatus Bushings

This section applies to power apparatus bushings as defined by IEEE C57.19.00 that have basic impulse insulation levels of 110 kV and above for use as components of oil-filled transformers and oil-filled reactors. Bushings supplied with other equipment will be rated using the same methods as the equipment they are attached to.

Bushings can be loaded up to their specified ampere rating. The overload rating of the equipment on which the bushing is installed could be limited by the bushing ampere rating. If the bushing rating cannot be confirmed by name plate or contacting manufacturer, the equipment will be rated at its nameplate rating or calculated rating with no overload. However, if the equipment was specified to have an overload rating, or if the equipment manufacture has documented an overload rating, this overload rating may be used.

9.9. Line Traps

The terms Line Traps and Wave Traps are used interchangeably throughout this document.

The ratings methodology for the wave trap is according to IEEE Std C93.3-2017 The wave trap allows for loadability to change due to ambient temperature and emergency operating conditions. The maximum terminal temperature for a wave trap is 135 degrees C. Altitude derating factors in C93.3-2017 include an elevation adjustment with a lower mean (24 hour) maximum temperature. Line traps should therefore not be ambient adjusted per the elevation table in section 6.8 above.

9.10. Shunt Reactors

The ratings methodology for shunt reactors (oil filled) is according to ANSI/IEEE C57.21. There is no emergency or overload rating for shunt reactors. Shunt reactors may be operated up to 105% of the rated voltage.

9.11. Shunt Capacitors

IEEE standard 18 specifies the technical requirement of individual capacitor units and IEEE 1036 provides the application guidelines for shunt capacitor banks.

9.12. Series Capacitors

All series Capacitors will be rated per manufacture specifications for normal and emergency conditions.

9.13. SVC (Static Var Compensators)

SVC's will be rated per the manufacturers recommended ratings for normal and emergency conditions.

9.14. DC Tie Equipment

DC Tie equipment will be rated per the manufacturers recommended ratings for normal and emergency conditions.

9.15. GIS Equipment

All Gas Insulated Substation (GIS) equipment will be rated per manufacture specifications for normal and emergency conditions.

9.16. Protective Relay & CT Secondary Devices

All secondary devices will be operated within their specified manufacturer limits. If the rating for a secondary device cannot be determined then assume the rating is 5 amps.

Protective relay settings on all equipment in the bulk electric transmission system should be designed and set to permit the emergency loading of equipment per NERC standard PRC-023 where applicable. PRC-023 shall be followed with respect to any settings that may affect facility ratings.

The over-current relays on the transmission lines used for “switch-onto-fault” should be designed and set above the maximum loading of the line.

Over-current relays on transformers should be designed and set above the maximum emergency loading.

1.0 Purpose:

1.1 This policy defines the responsibilities of Performance Optimization to meet certain requirements established by NERC Standard FAC-008. The policy ensures Energy Supply develops and applies a facility rating methodology.

2.0 Applicability:

2.1 This policy applies to all Xcel Energy generating facilities and Energy Supply-owned synchronous condensers connected to the Bulk Electric System. Facility ratings for jointly owned units will be determined by the generating unit operator.

3.0 Responsibilities:

3.1 Performance Optimization, Fleet Engineering management is responsible to:

3.1.1 Compile Normal and Emergency electrical ratings for the generators, transformers, relay protective devices, and terminal equipment, as applicable, for each unit in all regions.

If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

3.1.2 Determine the most limiting and next most limiting applicable equipment rating of each unit. Identify and document the most limiting and next most limiting component.

3.1.3 Maintain the records required by 5.1, 5.2 for the generating plants.

3.1.4 Review and update ratings data annually. Upon receipt of request to supply facility ratings, Performance Optimization, Fleet Engineering will review and update ratings prior to submittal in accordance with EPR 5.220P01 NERC Facility Rating Methodolgy. Reviews shall include all new facilities, modified facilities, or any changes in operational limitations of in scope equipment.

4.0 Requirements:

4.1 Performance Optimization, Fleet Engineering shall maintain, in an approved document repository, a spreadsheet, by region, of electrical component and unit ratings.

4.1.1 The equipment and unit ratings will include Normal and Emergency ratings, as well as the most limiting component rating.

If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

4.2 Performance Optimization, Fleet Engineering shall maintain, in an approved document repository, the methodology used to develop the facility ratings. Any superseded portions of the methodology that had been replaced, changed, or revised must be retained for 12 months.

4.3 Performance Optimization, Fleet Engineering shall provide, on request, each facility rating methodology, and rating, to those Reliability Coordinators, Transmission Operators, Transmission Planners, and Planning Coordinators that have responsibility for the area in which the associated facilities are located, within 21 calendar days of receipt of a request.

4.4 Performance Optimization, Fleet Engineering shall respond, within 45 calendar days, in writing, to written comments from those Reliability Coordinators, Transmission Operators, Transmission Planners, and Planning Coordinators that have responsibility for the area in which the associated facilities are located. The response shall indicate whether a change will be made to the facility rating methodology and, if no change the reason why.

4.5 Performance Optimization, Fleet Engineering shall provide its Facility Ratings and the identity of the most limiting equipment to the Reliability Coordinators, Planning Coordinators, Transmission Planners, Transmission Owners, and Transmission Operators as scheduled by these entities.

4.6 Performance Optimization, Fleet Engineering shall provide the identity of the second most limiting equipment and its thermal rating within 30 calendar days of a request from its Reliability Coordinators, Planning Coordinators, Transmission Planners, Transmission Owners, and Transmission Operators.

5.0 Required Records:

5.1 Performance Optimization, Fleet Engineering shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Authority the facility rating methodology and facility ratings requested within 21 calendar days.

5.2 Performance Optimization, Fleet Engineering shall have evidence it responded to comments from the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Authority within 45 calendar days.

5.3 Performance Optimization, Fleet Engineering shall retain the spreadsheet required by section 4.1, and methodology required by section 4.2 in an approved document repository in accordance with the corporate non-nuclear records retention schedule, record class code AUD1040.

6.0 References & Definitions:

6.1 References

6.1.1 EPR 5.220P01 – NERC Facility Rating Methodology procedure found on XpressNet.

6.1.2 Corporate non-nuclear records retention schedule found on XpressNet.

6.2 Definitions

6.2.1 **North American Electric Reliability Corporation (NERC) -**The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 **NERC Reliability Standard FAC 008 –** NERC Standard applicable to Facility Ratings

6.2.3 **Bulk Electric System** – As defined by the Regional Reliability Organization, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100kv or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.

7.0 Revision History

Date	Revision	Change
04/02/2007	Draft	Draft for FERC Reliability Standard – FAC 008, 009
04/10/2007	0	
06/07/2007	1	Added requirement to review and update ratings every 12 months or as facilities are added, modified or re-rated. Added reference to EPR-5.220. Added requirement to retain superseded portions of the methodology fro 12 months.
06/21/2007	2	Revised applicability “Facility ratings for jointly owned units will be determined by the generating unit operator.”
11/09/2007	3.0	If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.
09/20/2012	4.0	Revised the policy to align with NERC Standard FAC-008-3 which replaces FAC-008-1 and FAC-009-1. Changed Maintenance Resources to Technical Resources and Compliance. Changed Production Resources to Technical Services in the header. Removed reference to Performance Monitoring.
01/01/13	4.1	Added language to specify that operational limitations be included in the review and reporting.
08/19/2013	4.2	Modified header and footer to reflect current standardized format. Updated author to current responsible employee. Corrected effective and approval dates to reflect the most recent major revision.
10/04/2016	4.2	Completed triennial review. No content change required.
10/07/2019	4.3	Updated department names to reflect current organization. Combined sections 3.1, 3.1 and 3.3 (region-specific) into a single section encompassing all regions. Updated references.

1.0 PURPOSE

1.1 This standard defines responsibilities and requirements to meet certain requirements established by NERC Standards, MOD-025, “Verification and Data Reporting of Generator Real and Reactive Power Capability and Synchronous Condenser Reactive Power Capability”, MOD-026, “Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions”, MOD-027, “ Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions”, and MOD-032 “Data for Power System Modeling and Analysis”. This standard ensures Energy Supply provides generator steady state and dynamic modeling design data to the Transmission Planners as required.

2.0 APPLICABILITY

2.1 This standard is applicable to all Energy Supply generating facilities including hydro units and synchronous condensers included in the definition of Bulk Electric System.

The following additional qualifiers are applicable to MOD-026 and MOD-027:

2.1.1 In the WECC region, MOD-026 and MOD-027 are applicable to generating or synchronous condenser units >75 MVA and facilities with aggregate rating >75 MVA.

2.1.2 In the MRO and SPP regions, MOD-026 and MOD-027 are applicable to generating or synchronous condenser units >100 MVA and facilities with aggregate ratings >100 MVA.

3.0 RESPONSIBILITIES

3.1 The cognizant Plant Engineering and Technical Support (PETS) Engineer and/or Engineering & Construction (E&C) Project Manager/Engineer are responsible to:

3.1.1 Notify Technical Resources and Compliance (TR&C) of any proposed modifications to, or new installations of, excitation control system or plant volt/var control function equipment for applicable units. With TR&C’s guidance, provide TR&C with the verified model, documentation and data for the new or modified excitation control system or plant volt/var control function equipment installed. Data shall be provided within 335 days of the facility being released for Commercial Operation.

3.1.2 Notify TR&C of any proposed modifications to, or new installations of, turbine/governor and load control or active power/frequency control equipment for applicable units. With TR&C's guidance, provide TR&C with the verified model, documentation and data for the new or modified turbine/governor and load control or active power/frequency control equipment installed. Data shall be provided within 335 days of the facility being released for Commercial Operation.

3.1.3 Notify TR&C of any changes in generator steady state net real or reactive power design ratings, or any changes in design dynamic characteristics resulting from alterations of generator excitation or turbine governor equipment. This notification should be made at least 3 months prior to project installation.

3.2 PETS is responsible to provide support to Performance Testing and Analysis and TR&C in coordinating and performance of testing required to verify modeling of applicable units or facilities.

3.3 Plant Directors or designee are responsible to notify TR&C when they become aware of any changes in generator steady state net real or reactive power design ratings. Furthermore, any changes in design dynamic characteristics resulting from alterations of generator excitation or turbine governor equipment or control functions that alter the equipment response characteristic.

3.4 Performance Testing and Analysis is responsible to:

3.4.1 Verify and provide TR&C with Real Power capability of applicable units or facilities within 30 days of verification, as requested

3.5 Regional TR&C personnel are responsible to:

3.5.1 Provide overall compliance guidance and support as needed to execute activities and verify timely completion.

3.5.2 Maintain information, provide information upon request, and communicate changes of that Operating Company's power plant steady state modeling data to the regional Transmission Planning organization. This information will be maintained and promulgated per the region specific processes described in Section 4.0 below.

3.5.2.1 Evidence of correspondence with Transmission Planning concerning steady state modeling data shall be stored in the appropriate MOD-032 Documentum folder.

3.5.3 Maintain information, provide information upon request, and communicate changes of that Operating Company's power plant dynamic modeling data to the regional Transmission Planning organization. This information will be maintained and promulgated per the region specific processes described in Section 4.0 below.

3.5.3.1 Evidence of correspondence with Transmission Planning concerning dynamic modeling data shall be stored in the appropriate MOD-032 Documentum folder.

3.5.4 Verify and provide the Transmission Planner with Real and Reactive Power capability of applicable units or facilities.

3.5.4.1 Evidence of correspondence with Transmission Planning concerning Real and Reactive Power capability shall be stored in the appropriate MOD-025 Documentum folder.

3.5.5 Verify and provide the Transmission Planner with the generator excitation control system or plant volt/var control function model, including documentation and data for each applicable unit or facility.

3.5.5.1 Evidence of correspondence with Transmission Planning concerning generator excitation control system or plant volt/var control function modeling shall be stored in the appropriate MOD-026 Documentum folder.

3.5.6 Verify and provide the Transmission Planner with the turbine/governor and load control or active power/frequency control model, including documentation and data for each applicable unit or facility.

3.5.6.1 Evidence of correspondence with Transmission Planning concerning the turbine/governor and load control or active power/frequency control modeling shall be stored in the appropriate MOD-027 Documentum folder.

4.0 REQUIREMENTS:

4.1 Regional Technical Services personnel shall fulfill their MOD-032 responsibilities as follows:

4.1.1 Northern States Power (NSP), Southwestern Public Service (SPS), Public Service Company of Colorado (PsCO)

4.1.1.1 TR&C shall maintain a database of generator steady state modeling design data including minimum and maximum net real and reactive power ratings. This database shall be maintained in Documentum and provided to Transmission Planning upon request or when changes are made

4.1.1.2 TR&C shall maintain a database of generator design modeling design data. This database shall be maintained in Documentum and provided to Transmission Planning upon request or when changes are made.

4.1.1.3 TR&C personnel shall provide steady-state, dynamic, and short circuit modeling data to its Transmission Planner and Planning Coordinator according to their modeling data requirements and reporting procedures. For data that has not changed, an email notification confirming the data has not changed is sufficient. Email notifications will be maintained in Documentum.

4.1.1.4 Upon written notification from the Planning Coordinator or Transmission planner regarding technical concerns with data submitted above, TR&C will:

4.1.1.4.1 Provided either updated data or an explanation with a technical basis for maintaining the current data;

4.1.1.4.2 Provide the response within 90 calendar days of receipt, unless a longer time period is agreed upon by the notifying Planning Coordinator or Transmission Planner.

4.1.1.4.3 Evidence or correspondence will be maintained in Documentum. If no written notification(s) received, a statement that it has not received written notification regarding technical concerns with the data submitted may be posted to Documentum as evidence.

4.2 Technical Services personnel shall fulfill their MOD-025 responsibilities as follows:

4.2.1 Performance Testing and Analysis Department shall, when requested, verify the Real Power capability of each applicable units or facility in accordance with Attachment 1 of MOD-025. Performance Monitoring Department shall provide TR&C a completed Attachment 2 of MOD-025 or a form containing the same information as identified in Attachment 2, within 30 calendar days of either (i) the date the data is recorded for a staged test; or (ii) the date the data is selected for verification using historical operational data.

4.2.2 TR&C shall verify the Real and Reactive Power capability of each applicable units or facility in accordance with Attachment 1 of MOD-025. Technical Resources and Compliance shall provide the Transmission Planner a completed Attachment 2 of MOD-025 or a form containing the same information as identified in Attachment 2, within 90 calendar days of either (i) the date the data is recorded for a staged test; or (ii) the date the data is selected for verification using historical operational data.

4.3 Technical Services, TR&C personnel shall fulfill their MOD-026 responsibilities as follows:

4.3.1 Shall provide for each applicable unit, a verified generator excitation control system or plant volt/var control function model, including documentation and data as specified in 4.5.1.1 to the Transmission Planner in accordance with the periodicity specified in MOD-026 Attachment 1.

4.3.1.1 Each applicable unit's model shall be verified using one or more models acceptable to the Transmission Planner. Each verification shall include the following:

4.3.1.1.1 Documentation demonstrating the applicable unit's model response matches the recorded response for a voltage excursion from either a staged test or a measured system disturbance,

4.3.1.1.2 Manufacturer, model number (if available), and type of the excitation control system including, but not limited to static, AC brushless, DC rotating, and/or the plant volt/var control function (if installed), 4.3.1.1.3 Model structure and data including, but not limited to reactance, time constants, saturation factors, total rotational inertia, or equivalent data for the generator,

4.3.1.1.4 Model structure and data for the excitation control system, including the closed loop voltage regulator if a closed loop voltage regulator is installed or the model structure and data for the plant volt/var control function system,

4.3.1.1.5 Compensation settings (such as droop, line drop, differential compensation), if used, and

4.3.1.1.6 Model structure and data for power system stabilizer, if so equipped.

4.3.2 Shall provide a written response to the Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit:

4.3.2.1 Written notification from the Transmission Planner (in accordance with MOD-026, R6) that the excitation control system or plant volt/var control function model is not usable,

4.3.2.2 Written comments from the Transmission Planner identifying technical concerns with the verification documentation related to the excitation control system or plant volt/var control function model, or

4.3.2.3 Written comments and supporting evidence from the Transmission Planner indicating that the simulated excitation control system or plant volt/var control function model response did not match the recorded response to a transmission system event.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification.

4.3.3 Shall provide revised model data or plans to perform model verification (in accordance with MOD-026, R2) for an applicable unit to the Transmission Planner within 180 calendar days of making changes to the excitation control system or plant volt/var control function that alter the equipment response characteristic.

4.3.4 Shall provide a written response to the Transmission Planner, within 90 calendar days following receipt of a technically justified unit request from the Transmission Planner to perform a model review of a unit or plant that includes one of the following:

4.3.4.1 Details of plans to verify the model (in accordance with MOD-026, R2) or

4.3.4.2 Corrected model data including the source of revised model data such as discovery of manufacturer test values to replace generic model data or updating of data parameters based on an on-site review of the equipment.

4.4 E&C personnel shall fulfill their MOD-026 responsibilities as identified in XES 7.400 and XES 7.405.

4.5 Technical Services, TR&C personnel shall fulfill their MOD-027 responsibilities as follows:

4.5.1 Shall provide for each applicable unit, a verified turbine/governor and load control or active power/frequency control model, including documentation and data as specified in section 4.6.1.1 to the Transmission Planner in accordance with the periodicity specified in MOD-027 Attachment 1.

4.5.1.1 Each applicable unit's model shall be verified using one or more models acceptable to the Transmission Planner. Each verification shall include the following:

4.5.1.2 Documentation comparing the applicable unit's MW model response to the recorded MW response for either:

4.5.1.2.1 A frequency excursion from a system disturbance that meets MOD-027 Attachment 1 Note 1 with the applicable unit on-line,

4.5.1.2.2 A speed governor reference change with the applicable unit on-line, or

4.5.1.2.3 A partial load rejection test.

4.5.1.3 Type of governor and load control or active power control/frequency control equipment, 4.5.1.4 A description of the turbine,

4.5.1.5 Model structure and data for turbine/governor and load control or active power/frequency control, and

4.5.1.6 Representation of the real power response effects of outer loop controls that would override the governor response if applicable.

4.5.2 Shall provide a written response to the Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit.

4.5.2.1 Written notification from the Transmission Planner (in accordance with MOD-027, R5) that the turbine/governor and load control or active power/frequency control model is not usable,

4.5.2.2 Written comments from the Transmission Planner identifying technical concerns with the verification documentation related to the turbine/governor and load control or active power/frequency control model, or

4.5.2.3 Written comments and supporting evidence from it Transmission Planner indicating that the simulated turbine/governor and load control or active power/frequency control response did not approximate the recorded response for three or more transmission system events.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification (in accordance with MOD-027, R2).

4.5.3 Shall provide revised model data or plans to perform model verification (in accordance with MOD-027, R2) for an applicable unit to the Transmission Planner within 180 calendar days of making changes to the turbine/governor and load control or active power/frequency control system that alter the equipment response characteristic.

4.6 E&C personnel shall fulfill their MOD-027 responsibilities as identified in XES 7.400 and XES 7.405.

5.0 REQUIRED RECORDS

5.1 TR&C shall maintain evidence of correspondence with Transmission Planning documenting:

5.1.1 Modeling data was provided in response to requests and that Transmission Planning was notified of changes in any steady state or dynamic modeling data.

5.1.2 Real and reactive power verification was provided.

5.1.3 A verified generator excitation control system or plant volt/var control function model, including documentation and data was provided.

5.1.4 A verified turbine/governor and load control or active power/frequency control model, including documentation and data was provided.

6.0 REFERENCES AND DEFINITIONS

6.1 References

6.1.1 Glossary of Terms Used in NERC Reliability Standards

6.1.2 XES 7.405, Screening of Projects for Impact on NERC Compliance Program (found on the Energy Supply Policies web page)

6.1.3 XES 7.400, NERC FAC-002 Coordination of Plans for New Facilities (found on the Energy Supply Policies web page)

6.2 Definitions

6.2.1 North American Electric Reliability Corporation (NERC) – The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 Bulk Electric System (BES) – See definition in Glossary of Terms Used in NERC Reliability Standards.

6.2.3 NERC Reliability Standard MOD-025 – NERC Standard applicable to the verification and data reporting of generator real and reactive power capability and synchronous condenser reactive power capability.

6.2.4 NERC Reliability Standard MOD-026 – NERC Standard applicable to the verification of models and data for generator excitation control system or plant volt/var control functions.

6.2.5 NERC Reliability Standard MOD-027 – NERC Standard applicable to the verification of models and data for turbine/governor and load control or active power/frequency control functions.

6.2.6 NERC Reliability Standard MOD-032 – NERC Standard applicable to establishing consistent modeling data requirements and reporting.

6.2.7 Transmission Planner - The Transmission Planning role is performed by Xcel Energy for all fleet generation facilities in the MRO, WECC, and SPP service regions with the exception of : the PSCo Hayden Station in northwest Colorado. The Transmission Planner for this facility is not Xcel Energy, but is designated as the Western Area Power Administration, (WAPA) headquartered in Lakewood, Colorado. The Transmission planner for Pleasant Valley and Grand Meadow wind farms is Great River Energy. The transmission planner for Courtenay wind farm is Otter Tail Power.

7.0 REVISION HISTORY

Date	Revision	Change
02/03/2014	1.0	Original Issue, supersedes XES 1.110 Rev 2.2 Stability Modeling Data Maintenance and Reporting Requirements
07/21/2014	2.0	Modified to include MOD-025, MOD-026 and MOD-027
11/22/2016	3.0	Modified to include MOD-032-1 and delete MOD-010 and MOD-012.

1.0 PURPOSE

1.1 This standard defines responsibilities and requirements to meet certain requirements established by the following NERC Standards:

- PRC-001, "System Protection Coordination"[1]
- PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection"
- PRC-024, "Generator Frequency and Voltage Protective Relay Settings"
- PRC-025, "Generator Relay Loadability"
- PRC-026, "Relay Performance During Stable Power Swings"
- PRC-027, "Coordination of Protection Systems for Performance During Faults"[1]

2.0 APPLICABILITY

2.1 This standard is applicable to the all Energy Supply Bulk Electric System (BES) generating facilities. Requirements of the various NERC Standards referenced above may have applicability to Protections Systems at these facilities for:

2.1.1 Generators

2.1.2 Synchronous condensers

2.1.3 Generator step up (GSU) transformers

2.1.4 Energy Supply owned Generator interconnection facilities that connect the GSU transformer to the transmission system.

2.1.5 Main or unit connected auxiliary transformers capable of feeding plant load when the unit is at power

2.1.6 Reserve or startup auxiliary transformers capable of feeding plant load when the unit is at power.

[1] PRC-001 is effective through 9-30-2020. On 10-01-2020, PRC-027 becomes effective. This policy revision contains requirements necessary to meet both existing PRC-001 and future PRC-027 relay coordination requirements.

2.1.7 Aggregating systems and individual generating resources at dispersed generation facilities such as wind farms.

3.0 RESPONSIBILITIES

3.1 Performance Optimization Fleet Engineering personnel are responsible for the overall administration of the regional NERC Protection System Coordination and Relay Setting program. These responsibilities include maintaining coordination and settings studies for NERC related protection systems at BES generating facilities as well as performing and documenting all required communications with the other NERC Functional Entities concerning protection system coordination issues as required per Section 4.0 Requirements below.

3.2 The cognizant Performance Optimization Reliability Engineering personnel and/or ES Projects group Project Manager/Engineer are responsible:

3.2.1 To provide written notification to the Performance Optimization Fleet Engineering personnel of the installation of any new or planned installation of any NERC related protection systems; or any changes or planned changes to the existing NERC related protection systems as soon as the information becomes available.

3.2.2 To provide written notification to the Performance Optimization Fleet Engineering personnel of the installation of any new or planned installation of equipment, modification of the existing voltage regulating settings or planned modifications of existing voltage regulating settings at BES generating facilities as soon as the information becomes available.

3.2.3 To provide written notification to the Performance Optimization Fleet Engineering personnel of any change or planned changes in BES generator or synchronous condenser equipment capability as soon as the information becomes available.

3.2.4 To provide written notification to the Performance Optimization Fleet Engineering personnel of generator or synchronous condenser step up transformer, main or unit connected auxiliary transformer, or reserve or startup auxiliary transformer changes or replacements.

3.2.5 To provide an updated notification to Performance Optimization Fleet Engineering when previous notification is no longer valid for the changes described in paragraphs 3.2.1-3.2.4 above

3.2.6 As a result of any of the changes described in paragraphs 3.2.1-3.2.5 above, to work with Performance Optimization Fleet Engineering department to assure that any required coordination studies are performed, and relay settings are established and communicated to other entities as required per Section 4.0 Requirements below.

4.0 REQUIREMENTS:

4.1 General

4.1.1 A Protection System Coordination and Relay Setting Study shall be developed for any new NERC related Protection System to be installed at a BES generating facility.

4.1.2 A Protection System Coordination and Relay Setting Study shall be developed or revised to address changes in a NERC related Protection System at a BES generating facility. Examples of changes which may necessitate development or revision of a study include, (but are not limited to), relay replacements, relay setpoint changes, excitation limiter and protection settings, or changes in current or voltage sensing devices.

4.1.3 A Protection System Coordination and Relay Setting Study shall be developed or revised to address replacement of generators or synchronous condensers, generator or synchronous condenser step-up transformers, main or unit connected auxiliary transformers, or reserve or startup auxiliary transformers when the replacement device ratings and/or impedance characteristics deviate from those utilized in the existing coordination study of the protection system for the component to be replaced.

4.1.4 For conventional synchronous machines, there should be only one Protection Coordination and Relay Setting study per NERC related Protection System that addresses PRC-001/027, PRC-019, PRC-024, PRC-025, and PRC-026 requirements applicable to that scheme or unit. This integrated approach will provide for greater clarity and consistency in documentation.

4.1.5 For dispersed generating facilities such as wind farms, the complex topography often requires use of dynamic simulations by vendors to prove compliance with some of the NERC standards. Coordination studies are often performed by architect/engineer firms during construction. As such, a collection of standard specific studies are often performed to address PRC-001/027, PRC-019, PRC-024, PRC-025, and PRC-026 as required.

4.1.6 Prior to performing a Protection System Coordination and Relay Setting Study, data to be used for generator and/or transformer ratings and impedances shall be verified against equipment test reports or design values for new equipment. The following engineering data should be included in the study for reference of report reviewers:

Generator Parameters	**GSU Parameters**	**System Parameters**
Generator MVA Rating	GSU HV KV rating	Assumed system available fault current
Generator kV Rating	GSU High Volt Tap	
Generator pf Rating	GSU LV KV Rating	
Generator X_d	GSU Impedance	
Generator X'_d	GSU BASE MVA Rating	
Generator X“$_d$ (sat)	GSU Neutral Reactance	
Generator X_2 (sat)	GSU Core Type	
Gen Neut Gr Tr Ratio		
Gen Neut Gr Resistance		

4.1.7 Prior to performing a Protection System Coordination and Relay Setting Study, updated transmission system fault current and impedance data shall be obtained. Updated transmission system fault current and impedance data shall be obtained at least annually or more frequently if significant changes are being implemented or have occurred which are anticipated to have a significant effect (>15% change) on system parameters for the substation associated with the generating unit to be analyzed.

4.1.8 All Protection System Coordination and Relay Setting Studies shall have a second engineering review to ensure adequacy of the developed protection system settings.

4.1.9 All Protection System Coordination and Relay Setting Studies shall be re-validated using updated data on a five-calendar year interval to ensure developed and applied settings remain valid for system and generating plant changes. This five-calendar year interval meets the periodic update requirements of both PRC-019 and PRC-027.

4.1.10 Protection system setting changes that do not affect fault coordination with separate interconnected entities can be processed as minor revisions and do not require review and approval by that separate entity prior to implementation. Nonetheless, a courtesy copy of the minor revision of the coordination study should be forwarded to the interconnected entity for documentation purposes.

Note that this does not eliminate the need for follow-up notifications such as those listed in Section 4.4.3 or 4.4.4 below.

4.2 PRC-001/027 Requirements

4.2.1 New or revised Protection System Coordination and Relay Setting studies SHALL be provided to Transmission Operations - Protection System Engineering and the Host Balancing Authority for review. (PRC-001)

4.2.2 General requirements 4.1.6, 4.1.7, 4.1.8, and 4.1.9 above must be met to fulfill NERC PRC-027 program requirements for having an established relay setting process to assure accuracy of input data and output results.

4.2.3 For protection system settings applied on BES elements that electrically join the generating plant to equipment owned by a separate NERC functional entity (i.e. - Transmission Owner, Generator Owner, or Distribution Provider), the following PRC-027 requirements apply:

4.2.3.1 The proposed protections settings developed by the Protection System Coordination and Relay Setting study and applied on the BES Element that electrically joins the generating facility to that owned by a separate functional entity shall be provided to that entity for review. Performance Optimization Fleet Engineering should request that the Interconnecting Entity review the relay settings and associated coordination study within 30 days, or a mutually agreed upon timeframe.

4.2.3.2 That separate functional entity will either notify us of any identified coordination issues or will affirm that no coordination issues were identified.

4.2.3.3 When provided with protection system settings from a separate functional entity and applied on the BES element joining our generating facility to their system, the provided settings shall be reviewed within a mutually agreed to timeframe. Any identified coordination issues shall be communicated to that entity or the entity shall be notified that our review did not identify any coordination issues with the proposed settings.

4.2.3.4 Any identified coordination issues identified by the reviews described in 4.2.2.1 or 4.2.2.2 shall be addressed prior to the implementation of the proposed settings.

4.2.3.5 Any protection system settings revisions for protection applied on equipment that electrically joins the generating facility to that owned by a separate functional entity and which result from unforeseen circumstances that arise during implementation or commissioning, misoperation investigations, maintenance activities, or emergency replacements as a result of a protection system failure shall be communicated to the other owner of the electrically joined facility.

4.3 PRC-019 Requirements

4.3.1 Coordination studies for generators and synchronous condensers shall show coordination for the voltage regulating system controls, including in-service limiters and protection functions, with the applicable equipment capabilities and settings of the applicable Protection System devices and functions. Assuming normal automatic voltage regulator control loop and steady-state system operating conditions, the studies should show that:

4.3.1.1 In-service limiters are set to operate before the Protection System of the applicable Facility in order to avoid disconnecting the generator unnecessarily, and

4.3.1.2 The applicable in-service Protection System devices are set to operate to isolate or de-energize equipment in order to limit the extent of damage when operating conditions exceed equipment capabilities or stability limits.

4.3.2 The study described in Section 4.3.1 shall be reviewed and updated at a maximum of every 5 calendar years or within 90 days following the identification or implementation of systems, equipment, or settings changes that will affect the coordination of devices as described in Section 4.3.1. Possible systems, settings, or equipment changes which could affect this coordination include but are not limited to:

4.3.2.1 Voltage regulating settings or equipment changes;

4.3.2.2 Protection System settings or component changes;

4.3.2.3 Generator or synchronous condenser equipment capability changes;

4.3.2.4 Generator or synchronous condenser step up transformer changes.

4.3.3 Section G of NERC Reliability Standard PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection" (Reference 6.1.5) provides a technical discussion of methods to show possible required coordination, but all voltage regulator settings, limiters and trips shall be reviewed for coordination with protective relays.

4.4 PRC-024 Requirements

4.4.1 Coordination and Relay Settings Studies shall document that generators that have generator frequency protective relays activated to trip applicable units have protective relaying settings such that the frequency protective relaying does not trip the applicable generating unit(s) within the "no trip zone" of PRC-024 Attachment 1, subject to the following exceptions:

4.4.1.1 Generating unit(s) may trip if the protective functions (such as out-of-step or loss-of-field functions) operate due to an impending or actual loss of synchronism or, for asynchronous generators, due to instability in power conversion control equipment.

4.4.1.2 Generating unit(s) may trip if clearing a system fault necessitates disconnecting (a) generating unit(s).

4.4.1.3 Generating unit(s) may trip within a portion of the "no trip zone" of PRC-024 Attachment 1 for documented and communicated regulatory or equipment limitations. See Section 4.4.3 below for additional requirement pertaining to the application of this exception.

4.4.2 Coordination and Relay Settings Studies shall document that generators that have generator voltage protective relays activated to trip applicable units have protective relaying settings such that the voltage protective relaying does not trip the applicable generating unit(s) as a result of a voltage excursion at the transmission voltage side of the generator step up or collector system transformer for which the voltage excursion was caused by an event on the transmission system external to the generating plant that remains within the "no trip zone" of PRC-024 Attachment 2. If the Transmission Planner allows less stringent voltage settings, the protective relays shall be set within the voltage recovery characteristics of a location-specific Transmission Planner's study. The following exceptions apply to this requirement:

4.4.2.1 Generating unit(s) may trip in accordance with a Special Protection System, (SPS) or Remedial Action Scheme, (RAS).

4.4.2.2 Generating unit(s) may trip if clearing a system fault necessitates disconnecting (a) generating unit(s).

4.4.2.3 Generating unit(s) may trip if the protective functions (such as out-of-step or loss-of-field functions) operate due to an impending or actual loss of synchronism or, for asynchronous generators, due to instability in power conversion control equipment.

4.4.2.4 Generating unit(s) may trip within a portion of the "no trip zone" of PRC-024 Attachment 2 for documented and communicated regulatory or equipment limitations. See Section 4.4.3 below for additional requirement pertaining to the application of this exception.

4.4.3 If exceptions are applied in frequency relay settings per Section 4.4.1.3 or in voltage relays per Section 4.4.2.4 above because of known regulatory or equipment limitations, or when a previously documented regulatory or equipment limitation is removed, the change shall be communicated to the Planning Coordinator and Transmission Planner within 30 calendar days of any of the following:

4.4.3.1 Identification of a regulatory or equipment limitation.

4.4.3.2 Repair of the equipment causing the limitation that removes the limitation.

4.4.3.3 Replacement of the equipment causing the limitation that removes the limitation.

4.4.3.4 Creation or adjustment of an equipment limitation caused by the consumption of the cumulative turbine life-time frequency excursion allowance.

4.4.4 Frequency and voltage protective relay trip settings established per Sections 4.4.1 and 4.4.2 shall be provided to the Planning Coordinator or Transmission Planner responsible for modeling the unit within 60 calendar days of receipt of a written request for the data or within 60 calendar days of any change of previously requested trip settings unless directed by the Planning Coordinator or Transmission Planner that the reporting of relay setting changes is not required.

4.5 PRC-025 Requirements

4.5.1 Coordination and Relay Settings Studies for BES facilities identified in Section 2.1 above shall document that all settings applied to load-responsive relays are made in accordance with PRC-025-2 Attachment 1 while maintaining reliable fault protection.

4.6 PRC-026 Requirements

4.6.1 For load-responsive protective relay functions as identified in PRC-026, Coordination and Relay Setting Studies for BES generators, transformers and transmission lines shall document applicability of PRC-026 requirements. In general, these requirements only apply to phase distance (21), phase overcurrent (51), out of step tripping (78), and loss of field (40) settings with time delays of less than 15 cycles. See PRC-026 Attachment A.

4.6.2 Within 12 months of notification from the Planning Coordinator of an ES owned BES element pursuant to Requirement R1 of PRC-026, the associated Protection Coordination and Relay Setting study should be revised to determine and document whether the load responsive relay functions are applied per the criteria of PRC-026 Attachment B. This is only required if such an evaluation has not been performed in the last five years for the load responsive relay in question.

4.6.3 Within 12 months of becoming aware of an ES owned generator, transformer, or transmission line BES element that tripped in response to a stable or unstable power swing due to operation of its protective relays, the associated Protection Coordination and Relay Setting study should be revised to determine and document whether the load responsive relay functions are applied per the criteria of PRC-026 Attachment B.

4.6.4 If the evaluation performed per paragraph 4.6.2 or 4.6.3 above determines that the load responsive relay settings do not meet PRC-026 Appendix B criteria, a formal NERC Corrective Action Plan, CAP, shall be developed within six full calendar months to either:

4.6.4.1 Change settings to meet PRC-026 Attachment B criteria while maintaining dependable fault detection and, if applied, dependable out of step tripping.

Or

4.6.4.2 Modify the Protection System such that it is excluded from applicability to PRC-026 Attachment A criteria while maintaining dependable fault detection and, if applied, dependable out of step tripping.

4.6.5 Any CAP developed per paragraph 4.6.4 shall be implemented as planned. If CAP actions or timetables change, the CAP should be formally updated until all associated actions are complete.

4.7 Implementation Timelines – General Information

4.7.1 A Protection System Coordination and Relay Setting Study shall be developed to address all NERC related Protection Systems at a BES generating facility. All BES units shall have a Protection Coordination and Relay Setting study. Existing studies shall be reviewed and updated as needed per the requirements outlined in this document.

4.7.2 For PRC-026, studies performed in response to Planning Coordinator notifications per paragraph 4.6.2 or upon becoming aware that a BES element tripped because of a protective relay operation in response to a stable or unstable power swing per paragraph 4.6.3 must be completed by the later of 12 months after the notification from the Planning Coordinator, 12 months after awareness of a trip in response to a power swing or January 1, 2020.

4.7.3 For PRC-027, all initial studies for PRC-027 R2 compliance must be completed no later than 6 calendar years after the effective date of PRC-027-1. Based on PRC-027-1 effective date of 10/1/2020, the deadline for initial R2 compliance is 12/31/26.

5.0 REQUIRED RECORDS

5.1 Protection System Coordination and Relay Setting Studies written to address the requirements of this standard SHALL be stored in the regional Protection System Coordination and Relay Setting Study folder in Documentum or other approved regional data repository.

5.2 Copies of correspondence with Transmission Operators, Transmission Planners, Distribution Providers and/or Planning Coordinators concerning these Protection System Coordination and Relay Settings Studies SHALL be stored Documentum or in the regional specific data repository flagged for the applicable PRC-001, PRC-019, PRC-024, PRC-025, PRC-026, or PRC-027 standard. Note that dated sign-off blocks on Protection System Coordination and Relay Setting Study documents may be used as evidence of this communication.

5.3 Any Corrective Action Plan developed per paragraph 4.6.4 or revised Corrective Action Plant per paragraph 4.6.5 SHALL be stored in Documentum or in the regional specific data repository for PRC-026 documentation. The CAP SHALL be retained and available for review for a minimum of 12 months following completion of the implementation of the CAP.

6.0 REFERENCES AND DEFINITIONS

6.1 References

6.1.1 NERC System Protection and Control Subcommittee Technical Reference Document, "Power Plant and Transmission System Protection Coordination," Revision 2 - July 2010. It should be noted that this document does not contain the most up to date information concerning PRC-019, PRC-024, and PRC-025 requirements. The technical bases and guidelines for these specific standards supersede the information contained in the "Power Plant and Transmission System Protection Coordination," Revision 1 - July 2010 document for the affected settings.

6.1.2 IEEE Std C37.102, "IEEE Guide for AC Generator Protection"

6.1.3 IEEE Power System Relay Committee paper, "Coordination of Generator Protection with Generator Excitation Control and Generator Capability"

6.1.4 NERC Reliability Standard PRC-001, "System Protection Coordination"

6.1.5 NERC Reliability Standard PRC-019, "Coordination of Generating Unit or Plant Capabilities, Voltage Regulator Controls, and Protection"

6.1.6 NERC Reliability Standard PRC-024, "Generator Frequency and Voltage Protective Relay Settings"

6.1.7 NERC Reliability Standard PRC-025, "Generator Relay Loadability."

6.1.8 NERC Reliability Standard PRC-025 "Guideline and Technical Basis"

6.1.9 NERC Reliability Standard PRC-026 “Relay Performance During Stable Power Swings”

6.1.10 NERC Reliability Standard PRC-027, "Coordination of Protection Systems for Performance During Faults"

6.2 Definitions

6.2.1 **BES** – Bulk Electric System

6.2.2 **BES Generating Facility** – in general, an individual generator of greater than 75 MVA and that connects to the system at a voltage level > 100 KV or a generating facility that aggregates to greater than 75MVA and that connects to the system at a voltage level >100 KV. See the NERC Glossary of Terms definition of Bulk Electric System for more details

6.2.3 **GSU** – Generator Step Up

6.2.4 **NERC - North American Electric Reliability Corporation** – The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.5 NERC related Protection System – are located at BES generating facilities and consist of the relays, voltage and current sensing devices, DC control circuitry, DC power supply and communication systems used to protect generators, generator step up or main power transformers, synchronous condensers, reactive power sources such as capacitor banks or reactors, Unit Auxiliary or Main Station Auxiliary transformers, Startup or Reserve Station Auxiliary transformers and those portions of dispersed power facility aggregating systems where the power flow aggregates to >75 MVA.

7.0 REVISION HISTORY

Date	Revision	Change
07/21/2014	1.0	Original Issue, supersedes *XES 7.410, "FERC PRC-001 System Protection Coordination"*
05/23/2017	2.0	Revised paragraph 3.2.6 and added paragraph 4.2.3 to clarify that a revised coordination study may be required for changes of the generator and/or GSU, MSA or UST, or RSA or SST transformers. Added section 4.6 to document PRC-026 requirements. Revised section 4.7 to document PRC-026 implementation requirements.

		Revised section 5.0 to document PRC-026 record retention requirements.
06/05/2018	2.1	Corrected section references for PRC-024.
01/02/2019	2.2	Corrected section 4.5 references to current version of applicable standard, PRC-025-2.
06/09/2020	3.0	Updated department names. Added requirements for PRC-027 including requirements for obtaining up to date input data for the performance of coordination studies and specific requirements for coordination of protection applied on equipment that joins the generating facility to that owned by other NERC functional entities.

1.0 Purpose:

1.1 This procedure establishes facility ratings to meet certain requirements established by NERC Standard FAC-008. This procedure ensures that Energy Supply develops and applies a facility rating methodology that complies with the NERC Reliability Standards. Energy Supply Technical Services policy EPR 5.200, Facility Rating and Reporting, establishes responsibilities and requirements for utilizing this procedure.

2.0 Applicability:

2.1 This procedure is applicable to all generating facilities including hydro units and Energy Supply-owned synchronous condensers connected to the Bulk Electric System.

2.2 The facility ratings determined from this procedure shall equal the most limiting applicable equipment rating of the individual equipment that comprises the facility.

If Emergency ratings have not been provided by the original equipment manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.

Facility ratings for jointly owned units will be determined by the generating unit operator.

3.0 Responsibilities:

3.1 Technical Resources and Compliance management is responsible to compile the Normal and Emergency electrical ratings for the generators, transformers, relay protective devices, and terminal equipment, as applicable, for each Bulk Electric System unit.

3.1.1 The point of interconnect between Energy Supply and Xcel Energy Transmission Owners is agreed upon with the Transmission Owner per the XEL-PRO-Facility Rating Coord bet TO and GO.docx.

3.1.2 The point of interconnection between Energy Supply and other Transmission Owners is determined by agreement between the two parties.

4.0 Requirements:

4.1 NERC Facility Rating Methodology

4.1.1 The following methodology is to be used to determine the Facility Rating used for compliance with NERC Standard FAC-008-3.

4.1.2 The facility ratings determined from this procedure shall equal the most limiting applicable equipment rating of the individual equipment that comprises the facility.

4.1.3 To determine the limiting piece of equipment for a facility it is necessary to determine the electrical current (ampere) rating of the following pieces of equipment for conventional generating stations:

- Generator
- Generator Current Transformers
- Generator Disconnect
- Bus or cable conductors that connect the Generator, Generator Breaker (if applicable) and the GSU Transformer.
- Generator Circuit Breaker
- Generator Breaker Current Transformers
- Generator Circuit Breaker Disconnects
- Generator Step-Up (GSU) Transformer – use primary (low voltage) winding current rating for comparison purposes.
- Generator Step-Up Transformer Current Transformers
- Generator Step-Up Transformer Disconnect
- Bus or cable conductors that connect the GSU Transformer or GSU Transformer Disconnect (if applicable) to the Transmission Substation.
- Overcurrent relay minimum pick-up setpoint

4.1.4 The following scope of equipment shall be used for wind farms:

- The combined kVA rating of individual turbines connected to a collector feeder.
- Collector Feeder cable or conductor rating.
- Collector Feeder circuit breaker.
- Collector Feeder circuit breaker disconnects.
- Collector Feeder circuit breaker current transformers.
- Step-Up Transformer
- Step-Up Transformer Disconnects
- Step-Up Transformer Current Transformers

- Conductors that connect the Step-Up Transformer to the Transmission Substation.
- Overcurrent Relay minimum pick-up setpoint.
- Series and Shunt compensation devices

4.1.5 For equipment operating at a voltage other than the generator voltage (or collector feeder voltage for wind farms), for comparison purposes, its current rating shall be adjusted to the equivalent of its rating at the generator (or collector feeder) for the same MVA power level. For example, for a generator rated 10 kV, connected to a generator breaker installed on the high side of the GSU Transformer operating at 100 kV, if the nameplate current rating of the breaker is 1,000 amperes, for the facility rating evaluation, use 100 kV/10 kV times 1,000 amperes = 10,000 amperes.

4.1.6 The rating normally is the manufacturer's nameplate rating. The rating for the nominal generator voltage, normal operating coolant pressure and ambient temperature during summer peak should be used.

4.1.7 For units where the bus or cable does not have a nameplate rating, the current rating of the generator may be substituted.

4.1.8 For bus or conductors in air, use ratings developed based on IEEE 738 for overhead conductors and IEEE 605 for bus. The assumptions used in calculating the ratings are contained in the 'Transmission Line Rating Methodology' and 'Bus Conductors and Equipment Jumpers' sections of Transmission System Policy **XEL-POL-Facility Rating Methodology.** For units with a separate summer and winter rating, the appropriate summer or winter "Normal" current rating should be used. For units with only one seasonal rating, use the appropriate summer "Normal" current rating.

4.1.9 Operating limitations (such as temporary deratings) will be captured in the ratings determination and will be used in finding the most limiting and next most limiting equipment. Temporary operating limitations will be noted as such in the rating documentation.

4.1.10 The identity of the most limiting equipment and the next most limiting equipment shall be identified.

5.0 Required Records:

5.1 Technical Resources and Compliance shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and

Planning Coordinator the facility rating methodology requested within 21 calendar days of receipt of a request.

5.2 Technical Resources and Compliance shall have evidence it responded, in writing, to comments from the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Coordinator within 45 calendar days of receipt of those comments The response shall indicate whether a change will be made to the facility ratings methodology and, if no change will be made to the facility ratings methodology, the reason why.

5.3 Technical Resources and Compliance shall have evidence it provided the Reliability Coordinator, Transmission Operator, Transmission Planner, and Planning Coordinator the facility ratings as scheduled by such requesting entities.

5.4 Technical Resources and Compliance shall have evidence it provided the Reliability Coordinator, Planning Coordinator, Transmission Planner, Transmission Owner, and Transmission Operator with the identity and thermal rating of the next most limiting equipment within 30 calendar days of a request.

6.0 References & Definitions:

6.1 References

6.1.1 **EPR 5.200** Facility Ratings and Reporting Policy
6.1.2 **IEEE 738** IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors
6.1.3 **IEEE 605** IEEE Guide for Design of Substation Rigid-Bus Structures
6.1.4 **XEL-POL-Facility Rating Methodology**
6.1.5 **XEL-PRO-Facility Rating Coord bet TO and GO.docx**

6.2 Definitions

6.2.1 **North American Electric Reliability Corporation (NERC) -**The organization charged with establishing standards for the reliable operation of the North American electric power grids.

6.2.2 **NERC Reliability Standard FAC 008 –** NERC Standard applicable to Facility Ratings

6.2.3 **Bulk Electric System** – As defined by the Regional Entity, the electrical generation resources, transmission lines, interconnections with neighboring systems, and associated equipment, generally operated at voltages of 100kv or higher. Radial transmission facilities serving only load with one transmission source are generally not included in this definition.

7.0 Revision History

Date	Revision	Change
05/31/2007	Draft	Draft for FERC Reliability Standard – FAC 008, 009
06/07/07	Rev 0	Added reference to EPR – 5.200P
06/21/07	Rev 1	Revised Applicability "Facility ratings for jointly owned units will be determined by the generating unit operator."
9/13/07	Rev 2	Revised Section 3 "producing for an eight (8) hour period for three (3) consecutive days during the summer or winter months at reference ambient conditions as defined in PPT – MC – 01."
11/09/07	Rev 3	If Emergency ratings have not been provided by the Original Equipment Manufacturer, the only ratings used will be Normal ratings. Peak and Reserve ratings and Winter/Summer ratings may be used for combustion turbine units that have been assigned such ratings by the original equipment manufacturer.
8/15/08	4.0	Administrative change only. Modified numbering to match Documentum version.
10/2/08	5.0	Clarification of capacity terms
6/17/10	6.0	Added generator disconnects, generator breakers (and associated disconnects and CT's), and GSU CT's to the scope of Facility Rating equipment to be evaluated. Added a procedure to evaluate wind farms.
10/01/12	7.0	Revised the procedure to align with NERC Standard FAC-008-3 which replaces FAC-008-1 and FAC-009-1. Changed Maintenance Resources to Technical Resources and Compliance. Changed Production Resources to Technical Services in the header. Removed references to Performance Monitoring.
01/01/13	7.1	Removed Energy Supply specification from section 2.1 and clarified that only Energy Supply-owned synchronous condensers are covered by this policy. Added section to explicitly call out for consideration of operating limitations in section 4 of the methodology.
08/05/2013	7.2	Changed title wording from "determination" to "methodology". Modified header and footer to reflect current standardized format. Updated author to current responsible employee.

Date	Revision	Change
		Corrected effective date to reflect the most recent major revision.
09/15/2014	7.3	Updated section 4.1.8 to included a statement about the assumptions used in calculating the ratings of bus and conductors in air. Added reference to Transmission's facility rating methodology.
10/10/2016	7.4	Added section 6.1.5 and added sections 3.1.1 and 3.1.2 to the Responsibility section to include policy reference XEL-PRO-Facility Rating Coord bet TO and GO.docx. Added "Series and shunt compensation devices" to wind farm scope section 4.1.4.

1.0 PURPOSE:

This maintenance standard establishes general practices for routine preventative maintenance of batteries and battery chargers utilized at the Company's electric generating plants.

2.0 APPLICABILITY:

2.1 This standard addresses all aspects of routine maintenance and recommended maintenance intervals.

2.2 Xcel Energy Generating Plants have a large variety of battery types and battery applications. This standard is primarily directed toward the maintenance of large strings of flooded cells of either the vented lead acid, lead calcium, lead antimony, or lead selenium type. As such, IEEE Standard 450 – "IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead Acid Batteries for Stationary Applications" provides, in general, the basis for both the content and the frequency of performance of the battery maintenance and testing procedures set forth in this Energy Supply Maintenance Standard. Any deviations between the requirements contained in this standard and the specific IEEE Standard 450 recommendations are within the allowable program considerations discussed in Section 1.2 of IEEE Standard 450. Maintenance activities specific to other types of batteries such as valve regulated lead acid batteries that are used in these applications in power plants have also been included in the program. Proper functioning of battery chargers is validated by observing that the battery charger maintains connected batteries in a fully charged condition by its ability to maintain a proper float voltage on the battery.

For batteries and battery chargers serving as part of a NERC PRC-005 related Protection System, the maintenance activities and maximum allowable intervals of this standard meet or are more restrictive than the NERC Standard PRC-005 for minimum maintenance activities and maximum maintenance intervals for batteries and battery chargers. NERC PRC-005 related batteries and chargers SHALL be maintained per this standard and are on a time-based maintenance program with intervals not to exceed the PRC-005specified maintenance intervals for unmonitored components.

2.3 In particular, this standard applies to batteries and battery chargers used in the following applications:

2.3.1 24 V, 48 V, 125 V or 250 VDC Station Service Batteries

2.3.2 UPS batteries

2.4 Some provisions of this document may be applicable to other battery types and applications. Compliance with this standard for these additional battery types and applications is at the discretion of the power plant for non-NERC PRC-005 related batteries.

3.0 RESPONSIBILITIES:

3.1 The facility director is responsible for ensuring a battery maintenance program is in place for plant batteries. The facility director should designate an individual to serve as a Site Electrical Maintenance Coordinator whose responsibilities will, in part, include administration of the requirements identified in Section 4.0 below.

3.2 Technical Resources and Compliance is responsible to aid the Site Electrical Maintenance Coordinator in initially establishing the program and for providing technical support.

4.0 REQUIREMENTS:

The following maintenance and testing activities are identified for implementation of the battery maintenance program and shall be used by plant management, engineering, operations, and maintenance personnel to assure reliable operations of station DC systems:

4.1 Monthly Inspections:

4.1.1 Plant electrical staff or other knowledgeable battery technician shall perform a monthly inspection of applicable batteries.

4.1.2 The above work should be performed per Technical Resources and Compliance Maintenance Procedure, "Battery – Monthly Testing". This procedure should be set up in the work and asset management program to be performed on each applicable station battery on a monthly basis. A copy of the procedure is available on the Technical Services Maintenance Procedures web page.

4.2 Quarterly Inspections

4.2.1 In addition to the monthly inspections, plant personnel or other knowledgeable battery technician shall also perform a quarterly inspection of applicable batteries.

4.2.2 The above work should be performed per Technical Resources and Compliance Maintenance Procedure, “Battery – Quarterly Testing”. This procedure should be set up in the work and asset management program to be performed on each applicable station battery on a quarterly basis. A copy of the procedure is available on the Technical Services Maintenance Procedures web page.

4.3 Annual Inspections:

4.3.1 In addition to the monthly and quarterly battery inspection requirements, plant electrical staff or other knowledgeable battery technicians shall perform a detailed annual inspection of applicable batteries.

4.3.2 The above work should be performed per Technical Resources and Compliance Maintenance Procedure, “Battery – Annual Testing”. This procedure should be set up in the work and asset management program to be performed on each applicable station battery on an annual basis. A copy of the procedure is available on the Technical Services Maintenance Procedures web page.

4.4 Battery Capacity Tests

4.4.1 Plant electrical staff or knowledgeable battery technicians shall perform a battery capacity test at no longer than a 6 calendar year interval for Vented Lead Acid batteries or a 3 calendar year interval for Valve Regulated Lead Acid batteries.

4.4.2 The above work should be performed per Technical Resources and Compliance Maintenance Procedure, “Battery – Capacity Testing.” This procedure should be set up in the work and asset management program to be performed on each applicable station battery on an interval not to exceed that identified in Section 4.4.1 for that type of battery. A copy of the procedure is available on the Technical Services Maintenance Procedures web page. As battery capacity tests frequently require a plant outage, plants should consider their typical maintenance outage interval when establishing the interval for the performance of battery capacity tests associated with a given unit.

4.5 For newly acquired plants, the following grace period is established to bring the facility's battery maintenance program into alignment with this Standard:

4.5.1 The newly acquired plant's NERC related battery system(s) SHALL have a Monthly and Quarterly Inspection performed per the procedures referenced in Sections 4.1 and 4.2 above within three months of assuming ownership of the facility.

4.5.2 The newly acquired plant's NERC related battery systems SHALL have an Annual Inspection performed per the procedure referenced in Section 4.3 above within the first year of assuming ownership of the facility.

4.5.3 The newly acquired plant's NERC related battery system(s) SHALL have a Capacity Test performed per the procedure referenced in Section 4.4 above no later than the sooner of the end of first scheduled maintenance outage or within two years of assuming ownership of the facility unless test records are available from the previous owner's testing program to justify a later test date.

4.6 For batteries and battery chargers serving as part of a NERC PRC-005 related Protection System, the work and asset management shall call for the use of the Monthly, Quarterly, Annual, and Capacity Procedures or approved equivalent forms.

4.7 Plants shall maintain a listing of NERC PRC-005 related batteries and associated battery acceptance criteria. This Battery Acceptance Criteria document shall be kept current.

4.8 Identify any subsequent Maximo Work Orders issued to address and track any Unresolved Maintenance Issues.

5.0 REQUIRED RECORDS

5.1 The plant shall maintain copies of monthly and quarterly inspection data sheets in the plant maintenance files for at least 3 years. For NERC PRC-005 related batteries, the plant shall maintain copies of monthly and quarterly inspection data sheets for the longer of three years or since the last NERC Compliance audit.

5.2 The plant shall maintain copies of annual inspection completed procedure and data sheets in the plant maintenance files for at least 5 years. For NERC PRC-005 related batteries, the plant shall maintain completed copies of the annual inspection procedure and data sheets for the longer of five years or since the last NERC Compliance audit.

5.3 The plant shall maintain copies of battery capacity procedure and test data sheets in the plant maintenance files for the life of the battery or three years, whichever is longer. For NERC PRC-005 related batteries, the plant shall maintain completed copies of the completed capacity test procedure and data sheets for the longer of the life of the battery or since the last NERC Compliance audit.

6.0 DEFINITIONS & REFERENCES

6.1 Definitions

6.1.1 **Battery Monthly Inspection** – A documented routine inspection of a battery and its charger that should be performed once each month of the year. If scheduling or resource issues prevent completion of a monthly inspection in a given calendar month, the reason for the failure to complete the inspection on the normal monthly basis SHALL be documented on the associated Work Order or maintenance procedure and the monthly inspection SHALL be completed within the next calendar month. Technical Rationale for Monthly Inspection Time Allowance: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Monthly inspection delineated in the associated procedure contains all measurements required on a 4 calendar month interval by the current draft of PRC-005. As such, the one month time allowance discussed in this paragraph still results in inspections on an interval roughly half of that allowed in the NERC PRC-005 standard. Furthermore, a NERC violation only occurs if a Battery Monthly Inspection is missed for 4 consecutive months

6.1.2 **Battery Quarterly Inspection**– A documented routine inspection of a battery and its charger that should be performed once each quarter of the year. If scheduling or resource issues prevent completion of a quarterly inspection, the reason for the failure to complete the inspection SHALL be documented on the associated Work Order or maintenance procedure and the quarterly inspection SHALL be completed in conjunction with the next monthly inspection.

Technical Rationale for Quarterly Inspection Time Allowance for Vented Lead Acid Batteries: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Quarterly inspection delineated in the associated procedure contains measurements required for Vented Lead Acid batteries on an 18 calendar month interval by the current revision of PRC-005. As such, the additional one month time allowance discussed in the above paragraph still results in inspections on a not to exceed 4 month interval which is over 4 times as frequent at the 18 calendar month interval allowed in NERC PRC-005 standard. As such, a NERC violation only occurs if a Battery Quarterly Inspection is missed for 6 consecutive quarters for a Vented Lead Acid Battery and then only if the Annual Inspection for the associated battery was also missed.

Technical Rationale for Quarterly Inspection Time Allowance for Valve Regulated Lead Acid Batteries: The Quarterly inspection delineated in the associated procedure contains measurements required for Valve Regulated Lead Acid batteries on a 6 calendar month interval by the current version of PRC-005. As such, the additional one month time allowance discussed in the above paragraph still results in inspections on a not to exceed 4 month interval which is still more frequent than the 6 calendar month allowed in the NERC PRC-005 standard. As such, a NERC violation only occurs if a Battery Quarterly Inspection is missed for 2 consecutive quarters for a Valve Regulated Lead Acid Battery.

6.1.3 **Battery Annual Inspection** – A documented and detailed inspection of a battery and its charger that should be performed on a one-year interval. If scheduling or resource issues prevent completion of the annual inspection within 12 calendar months of its last completion, the reason for the failure to complete the inspection within the normal annual basis SHALL be documented on the associated Work Order or maintenance procedure and the annual inspection SHALL be completed within the next six calendar months. Technical Rationale for Annual Inspection Time Allowance: IEEE Standard 450, Section 1.2 allows for some minor program deviations. Furthermore, the Annual inspection delineated in the associated procedure contains measurements required on an 18 calendar month interval by the current version of PRC-005. As such, the additional six month time allowance discussed in this paragraph results in inspections on an interval equivalent to the 18 calendar month allowed in the NERC PRC-005 standard.

6.1.4 **Unresolved Maintenance Issue** – a deficiency identified during a maintenance activity that causes the component to not meet the intended performance, cannot be corrected during the maintenance interval, and requires follow-up corrective action.

6.1.5 **Additional Definitions** – see IEEE Standard 450 for definitions and further descriptions of battery terms used in this standard or associated maintenance procedures.

6.2 References

6.2.1 IEEE Standard 450 – "IEEE Recommended Practice for Maintenance, Testing and Replacement of Vented Lead Acid Batteries for Stationary Applications. "

6.2.2 NERC Standard PRC-005

7.0 REVISION HISTORY

Date	Revision	Change
8/1/05	0	Original Issue

Date	Revision	Change
3/12/07	0	Guideline rewritten into a standard
3/26/07	1.1	Clarified requirements for reading cell voltages only on a quarterly basis during performance of monthly inspections. See paragraph 4.1.1.
3/13/08	1.2	Expanded on definitions of monthly and annual inspections to allow for flexibility in scheduling.
4/7/08	1.3	Removed quarterly testing requirements from description of monthly inspection and added a stand alone quarterly inspection requirement.
11/6/08	1.4	Removed inspection detailed guidelines from paragraphs 4.1.1, 4.2.1, 4.3.1 and 4.4.1 of the standard as this information is provided in the respective inspection and test procedures.
9/24/09	1.5	Revised paragraph 2.0 to clarify that IEEE Standard 450 serves as the primary basis of the Energy Supply Battery Maintenance program. Clarified maximum allowable interval for performance of battery capacity tests in paragraph in paragraph 4.4, and in Paragraph 6.0, eliminated definitions and instead referred to IEEE Standard 450 definitions and added IEEE Standard 450 as a reference.
1/26/2010	1.6	Reinstated definitions of monthly, quarterly, and annual inspections at section 6.0 to allow flexibility in scheduling.
05/24/2012	1.7	Updated hyperlinks.
08/26/2012	1.8	Updated hyperlinks, changed department names to reflect current organization.
11/21/2012	2.0	Major Revision to establish and document program alignment with pending PRC-005-2 requirements and to address change in NERC definition to include battery chargers as part of the DC Supply element of a Protection System.
03/02/2015	2.1	Reformatted to comply with XES 1.100P01 'Configuration Management for ES Policies and Procedures'. Minor grammatical revisions and clarification that monitoring attributes are not utilized to extend maintenance intervals.
02/09/2016	2.2	Changed references from revision-specific to non-revision specific NERC standard PRC-005.

Date	Revision	Change
03/13/2017	2.3	Changed Maximo to generic "work and asset management"

1.0 PURPOSE:

1.1 This standard establishes general practices for routine preventative maintenance of Protection Systems and Sudden Pressure Relaying utilized at the Company's electric generating plants.

2.0 APPLICABILITY:

2.1 Included in the scope of this standard are Protection Systems and Sudden Pressure Relaying that protect generators, transformers, switchgear, and the individual loads fed from the circuit breakers on a medium voltage or low voltage bus. The standard addresses all aspects of routine maintenance as well as recommended testing and maintenance intervals. Note that Protection Systems and Sudden Pressure Relaying for generators, generator step-up transformers, generator interconnection facilities, main or unit connected auxiliary transformers, reserve or startup auxiliary transformers, and generator bus connected excitation transformers at Bulk Electrical System (BES) plants or Protection Systems for facilities used in aggregating dispersed BES generation from the point where those resources aggregate to greater than 75 MVA to a common point of connection at 100 kV or above, must be maintained per this standard to meet NERC Standard PRC-005, "Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance," requirements.

2.2 Energy Supply does not utilize Automatic Reclosing and as such, maintenance of Automatic Reclosing components is not addressed in this standard. Furthermore, Energy Supply has no RAS, UVLS or UFLS systems and therefore maintenance of those systems is not addressed.

2.3 The maintenance activities and associated maximum maintenance intervals established within this policy are based on those contained in the current version of NERC Standard PRC-005 and associated documents as they exist at the time of the approval of this standard.

2.4 For NERC Standard PRC-005 related schemes all Relays, Voltage and Current Sensing Devices, Associated Control Circuitry Protection System Component Types, as well as Sudden Pressure Relaying, are maintained per a time-based maintenance program with intervals not to exceed the PRC-005 specified maintenance intervals for unmonitored components.

2.5 For NERC Standard PRC-005 related schemes, Communication Protection System Components maintained per this Energy Supply program are maintained per a time-based maintenance program for continuously monitored Communication Protection Systems with intervals not to exceed the PRC-005 specified maintenance intervals for monitored communication components. All present Communication Protection System Components alarm to an operator for communication system failure.

2.6 For NERC Standard PRC-005 related schemes, Battery and Battery Charger Protection System Components are maintained per EPR 5.704S.

3.0 RESPONSIBILITIES:

3.1 The facility director is responsible for ensuring a Protection System maintenance program is in place for the plant. The facility director should designate an individual to serve as a Site Electrical Maintenance Coordinator whose responsibilities will, in part, include administration of the requirements identified in Section 4.0 below.

3.2 Technical Resources and Compliance is responsible to aid the Site Electrical Maintenance Coordinator in initially establishing the program and for providing technical support.

4.0 REQUIREMENTS:

The following maintenance and testing activities are identified for implementation of the Protection System maintenance program and shall be used by plant management, engineering, operations, and maintenance personnel to assure reliable operation and performance of the Protection Systems:

4.1 Development and Management of the Site Protection System Maintenance Program.

4.1.1 Plant and regional Technical Resources and Compliance personnel should work together to identify all protective relays, voltage and current sensing devices (PTs and CTs/DC shunts), and associated control circuitry used in Protection Systems and Sudden Pressure Relaying on a site and to group these devices into protective schemes for the purposes of scheduling and performing maintenance.

4.1.2 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, Plant personnel and regional Technical Resources & Compliance personnel SHALL develop scheme specific Protection System maintenance procedures. These procedures SHALL

4.1.2.1 Clearly identify all relays, voltage and current sensing devices, associated control circuitry trip paths and Sudden Pressure relaying to be tested in conjunction with the maintenance of that particular NERC PRC-005 Related Protection System.

4.1.2.2 Provide adequate guidance to assure that the maintenance activities specified in paragraph 4.2.2 below are performed and documented for each component type utilized within that particular Protection System scheme.

4.1.2.3 Identify any subsequent work and asset management system Work Orders issued to address and track any Unresolved Maintenance Issues - issues identified but not corrected during the performance of the procedure

4.1.2.4 For any Protection System modifications, Plant personnel and regional Technical Resources & Compliance personnel SHALL review the scheme specific Protection System maintenance procedures and update them as applicable.

4.1.3 The plant is responsible for maintaining documentation of the desired setpoints of all protective relays and to have this information available for technician reference during maintenance. The Technical Resources and Compliance Department can help the plant develop a method of documenting this setpoint information. Technical Resources and Compliance should strive to develop consistent setpoint documentation at all plants in a given region. Consistency in the methods of setpoint documentation will make maintenance much easier for the technicians who travel from site to site throughout the region to perform relay calibration.

4.1.4 Plant personnel shall ensure that plant protective system component maintenance and testing as described in this standard is performed within the intervals established in Table 1, “Maximum Allowed Protection System Maintenance Intervals.”

4.1.4.1 Plant personnel and regional Technical Resources and Compliance personnel shall schedule the maintenance and testing of Protection Systems within the intervals prescribed in Table 1. Under no circumstance shall the period between tests of any particular device exceed the timeframe prescribed in Table 1, except that maintenance and testing of a device may be completed any time within a calendar year (i.e., the interval is based on calendar years and not anniversary dates).

4.1.4.2 The plant overhaul schedule should be taken into consideration when scheduling protection system maintenance and testing.

4.1.4.3 Equipment outages may be required to maintain and test certain devices; therefore, equipment outage schedules should be considered when scheduling protection system maintenance and testing.

4.1.4.4 In scheduling the maintenance and testing activities, priority should be driven by the criticality of the equipment, the cleanliness of the environment, the type of relay involved (electromechanical, solid state, or microprocessor based), and past maintenance history. While prioritization of scheduling may be appropriate, in no event shall the period between maintenance and testing of a specific device exceed the applicable interval set out in Table 1.

4.1.5 Once all of the protective relay schemes have been identified and appropriate maintenance intervals have been identified for each of the individual schemes, the plant should enter this information into the work and asset management system PM program so that protective relay maintenance of all protective relay schemes will be automatically scheduled to be performed on a recurring basis.

4.1.5.1 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, the work and asset management system PM shall call for the performance of the scheme specific procedures developed per Section 4.1.2 above

4.1.6 Periodically, the plant should review as found vs. as left test data recorded during performance of maintenance. Based on the findings of this review, the plant may elect to lengthen or shorten the maintenance interval assigned to a particular scheme. However, for NERC PRC-005 related protection and sudden pressure relaying systems, the interval cannot be extended beyond that specified on Table 1.

4.2 Performance of Protection System Maintenance

4.2.1 Effective Program Start Date. For compliance purposes, the relay maintenance program effective start date is the original effective date of this standard, 3/12/07.

4.2.1.1 For those protection systems for which maintenance activities meeting the requirements of paragraph 4.2.2 were performed prior to 3/12/07, initial maintenance may be scheduled based on the last completion date and the appropriate Table 1 maximum allowed interval.

4.2.1.2 For newly installed or modified Protection Systems, initial maintenance should be scheduled based on the final commission/acceptance test date and the appropriate Table 1 maximum allowed interval.

4.2.2 **Maintenance Activities.** The following maintenance activities should be performed for the various component types making up a Protection System. For PRC-005 related schemes, these maintenance activities must be performed to meet the maintenance activity requirements of PRC-005.

4.2.2.1 Maintenance Activities for Electromechanical Protective Relays

Perform the following as appropriate:

- Perform and record a single point, as found calibration check of the device prior to cleaning or adjusting the relay.
- Clean, inspect, and adjust the relay as necessary.
- Perform an as left calibration check of the device. For time overcurrent relays, this as left check should be at a minimum of three points on the time characteristic curve.
- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.
- Verify the relay as left settings are as specified

4.2.2.2 Maintenance Activities for Analog Electronic Protective Relays

Perform the following as appropriate:

- Perform and record a single point as found calibration check of the device. The results of this initial test should be recorded.

- If the results of the as found test or relay self test were acceptable, the technician need not perform any as left testing. If the results of the initial test were unacceptable, the technician should adjust the relay and perform as left testing. If performed, the results of the as left testing should be recorded.
- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.
- Verify the as left relay settings are as specified

4.2.2.3 Maintenance Activities for Microprocessor Based Protective Relays

Perform the following as appropriate:

- Verify that the relay output contacts will act to trip the associated circuit breaker or actuate any associated lockout device.
- Verify proper functioning of the input analog/digital converters.
- Verify proper response to relay inputs critical to Protection System performance.
- Verify the as left relay settings are as specified.

4.2.2.4 Maintenance Activities for Current Transformers (CTs) and DC shunts

A CT/Shunt Verification Test should be performed at the interval listed in Table 1. Acceptable methods of CT Verification include:

- CT Feedback (Saturation) Test
- CT/Shunt Load Check Test
- CT/Shunt Comparison Test

4.2.2.5 Maintenance Activities for Potential Transformers (PTs)

A PT Verification Test should be performed at the interval listed in Table 1. Acceptable methods of PT Verification include:

- Turns Ratio Test
- Phase Comparison Test

- PT Comparison Test

4.2.2.6 Maintenance Activities for Associated Control Circuitry

4.2.2.6.1 For NERC PRC-005 related schemes, control circuitry between the protective relay output contacts and the trip coil(s) of the interrupting device(s) actuated by the protection system must be tested. This includes actuation of lockout devices and auxiliary tripping relays and verifying that each trip coil can trip the associated circuit breaker.

4.2.2.6.2 When testing control circuits, it is not necessary to test each individual path completely from the relay all the way to the trip coils of the interrupting device. However, each segment must be functionally tested and overlap of testing will assure functionality of the entire circuit. For example, if several different protective relays can cause a lockout device to actuate and that lockout in turn actuates a circuit breaker trip coil, it is only necessary to prove that each individual relay can actuate the lockout and only once prove that the lockout can actuate the breaker trip coil.

4.2.2.6.3 For NERC PRC-005 related schemes, testing of associated control circuitry SHALL be performed and documented using the scheme specific testing procedures discussed in Sections 4.1.2 and 4.1.5.1 above.

4.2.2.7 Maintenance Activities for Batteries and Battery Chargers Associated with Protection Systems

4.2.2.7.1 Batteries have many critical functions at power plants beyond those served in Protection Systems. Furthermore, maintenance of batteries is vastly different in scope and process than that for other Protection System devices. As such, requirements for the maintenance and testing of battery and charger systems is provided for in a separate stand alone document, EPR 5.704S, “Battery Maintenance Standard”

4.2.2.7.2 Plant personnel SHALL assure that batteries and chargers associated with NERC PRC-005 Related Protection Systems are maintained per EPR 5.704S.

4.2.2.8 Maintenance Activities for Protection System Communication Systems

4.2.2.8.1 Verify that the communications system meets performance criteria pertinent to the communications technology applied (e.g. signal level, reflected power, or data error rate)

For Fiber Optic Systems perform the following:

- Perform equipment alarm function test back to station DCS
- Single end testing utilizes the local relay and looped back communication equipment to verify local scheme functionally.

4.2.2.8.2 The trips via the communications shall be maintained per the DC Control Circuitry maintenance requirements at an interval of 6 years. This includes verification of communication system inputs and outputs that are essential to proper functioning of the protection system.

4.2.2.8.3 In lieu of the above, Protection System Communication Systems, if present, at the interface between power plants and the substation may be maintained per the Substation/Transmission Protection System Maintenance Program for communication systems.

4.2.2.8.4 Synchronized and Non-synchronized end to end protective system testing shall be done in coordination of the authority on the other end of the communication line.

4.2.2.9 Maintenance Activities for Sudden Pressure Relaying

4.2.2.9.1 Sudden Pressure Relaying should be performed at the interval listed in Table 1 and verify:

- The pressure or flow sensing mechanism is operable.
- Electrical operation of associated electromechanical lockout devices.

- Functionality of all associated paths of the trip circuits inclusive of all auxiliary relays through the trip coil(s) of the circuit breakers or other interrupting devices.

4.2.2.9.2 For NERC PRC-005 related schemes, testing of Sudden Pressure Relaying SHALL be performed and documented using the scheme specific testing procedures discussed in Sections 4.1.2 and 4.1.5.1 above.

4.3 Implementation Schedule for Newly Acquired Plants

For Protection Systems acquired through acquisition or merger process there will be a transition period from the previous entity's program to Xcel Energy Supply's program. PRC-005 related protection systems reviews SHALL be completed before commercial operation begins under Xcel Energy's control. The initial performance of all the maintenance activities required by Section 4.2 must be completed no later than the sooner of the end of first scheduled maintenance outage or within two years of assuming ownership of the facility. However, if test records are available from the previous owner's testing program and the requirements of Section 4.2 are met; the first scheduled maintenance may be based on the completion date of those records.

For batteries, see Section 4.5 of EPR 5.704S 'Battery Maintenance Standard (NERC)'

5.0 REQUIRED RECORDS

5.1 Each plant SHALL have a method to identify all protective relay schemes and to document the individual relays, CTs, and PTs making up a particular scheme. Note that scheme specific procedures can be used to fulfill this requirement.

5.2 Each plant SHALL maintain documentation of the desired setpoints of all protective relays and baseline CT, DC shunt and PT verification test data.

5.3 For every protective relay, voltage and current sensing device, calibration or testing history should be maintained in the program maintenance files for the last three test intervals. For NERC PRC-005 Related Protection Systems, calibration and/or test history SHALL be maintained at least for the last 2 completed test intervals

5.4 For NERC PRC-005 Related Protection Systems and Sudden Pressure Relaying, the plant SHALL maintain the last 2 completed scheme specific maintenance procedures in the program maintenance files

6.0 DEFINITIONS & REFERENCES

6.1 Definitions

6.1.1 **As Found Setting** – a check of a relay setpoint that is taken prior to performing any cleaning, adjustment, or maintenance on a relay.

6.1.2 **As Left Setting** – a check of a relay setpoint that is taken after all cleaning, adjustment, and maintenance has been completed on a relay.

6.1.3 **Automatic Reclosing –** Includes the following Components:

- Reclosing relay
- Supervisory relay(s) or function(s) – relay(s) or function(s) that perform voltage and/or sync check functions that enable or disable operation of the reclosing relay
- Voltage sensing devices associated with the supervisory relay(s) or function(s)
- Control circuitry associated with the reclosing relay or supervisory relay(s) or function(s)

Automatic Reclosing is not installed or used in Energy Supply owned facilities.

6.1.4 **Bulk Electric System (BES) Plants –** plants which connect to the transmission system at voltages $\geq$ 100 KV at the point of interconnection and are either individual units sized at >20 MVA or aggregate site size of > 75 MVA. Additionally any units used for black start restoration, regardless of the size or the voltage at which they connect to the system are included in the BES. See NERC BES definition for BES classification of dispersed generating assets such as wind or solar farms.

6.1.5 **Communication Systems** – Communication Systems in Protection Systems are typically defined as relays at remote ends of transmission lines communicating via various mediums in order to transmit data such as current values and trip signals. Communication Systems types such as Carrier and Tone, are not used with Protection Systems maintained by Energy Supply Power Plants. Digital Equipment type Communication Systems are occasionally used. Digital Equipment is typically defined as follows:

6.1.5.1 Digital Equipment types self monitor channel integrity and will alarm back to the control center through DCS equipment notifying of channel issues or problems.

6.1.5.2 Communication Processors that act as a RTU (remote terminal unit) to communicate relay status are not applicable to this standard as long as no digital bits are passed between relays for protection functions.

6.1.6 **Current Transformer (CT)** – an instrument transformer that has its primary winding in series with the current to be measured and which produces a small signal current in its secondary winding that is proportional to the current in its primary winding. This secondary current is used to provide inputs to protective relaying and/or metering that requires a current signal to operate.

6.1.7 **CT/DC shunt Verification Test** – any type of test or observation that provides some level of assurance that a CT or DC shunt is functioning properly. The verification test should include the CT secondary wiring or shunt MV signal wiring between the relay panel and the location of the CT or DC shunt. Some possible methods of verifying proper CT/DC Shunt function include:

6.1.7.1 Performance of a CT Feedback test (Saturation Test) – an offline test in which a voltage is impressed on a CT and current is measured and compared to previous test data. This test can detect developing problems with the CT or with the wiring that interconnects the CT to the meter or relay that it feeds. The CT is considered acceptable if the excitation current is within +/- 50% of the baseline value for a given input voltage.

6.1.7.2 Performance of CT/DC shunt load checks – observation of secondary currents on in service CTs or millivolt signals from DC shunts to verify currents are as expected for a given load. A three-phase set of CT's is considered acceptable if the current from each CT is within +/- 5% of the average of the set of CT's. A DC shunt is considered acceptable if within 5% of the anticipated value for the given operating point for the DC circuit being monitored.

6.1.7.3 CT/Shunt Comparison Test – For CTs, a comparison of the outputs of 2 separate CTs monitoring the same current. This may be accomplished by observing current, Volt-ampere, watt, or VAR indications fed from two separate sets of CTs. The CT is considered acceptable if the current from the CT is within +/- 5% of the CT to which it is being compared. For DC shunts, comparison of the output of a DC shunt to current measured by use of a DC clamp on ammeter and is acceptable if within 5%

6.1.8 **Electromechanical Relay** – any relay that relies on interaction of electromagnetic forces and moving parts such as springs, disks, or pneumatic diaphragms to establish the relay setpoint. Electromechanical relays often have tight mechanical clearances and rely on low friction jewel bearings to allow movement of the relay disk. As such, these relays are quite sensitive to the presence of coal dust and other environmental factors. Relays located in dusty or dirty areas will require more frequent maintenance than similar relays located in cleaner environments. Electromechanical relays also make use of magnets whose magnetic properties degrade over time resulting in setpoint drift that necessitates periodic re-calibration of the relay. For the above reasons, electromechanical relays require more frequent maintenance than do electronic or microprocessor based relays.

6.1.9 **(Analog) Electronic Relay** – a relay whose setpoint is controlled by analog electronics such that there are no moving parts involved in establishing the setpoint. These relays are much less affected by dust and dirt and exhibit significantly less setpoint drift than do electromechanical relays. Electronic or solid state relays require less frequent and less extensive maintenance then do electromechanical relays.

6.1.10 **Generator Interconnection Facility -** a sole-use facility that interconnects the generator to the grid. Typically this would be a >100 KV line, owned by the Generator Owner, from the high voltage side of the GSU transformer to the point of interconnection to the Transmission System.

6.1.11 **Microprocessor Based Relay** - a relay that uses digital electronics and has a programmable microprocessor to control trip and alarm features. These devices are equipped with alarming self check features that are constantly monitoring relay performance and condition. As such, microprocessor relays are highly reliable and require much less frequent and extensive maintenance than either electromechanical or analog electronic relays.

6.1.12 **NERC PRC-005 Related Protection Systems–** protection system relays, communication systems, associated trip circuits and instrument transformers which protect and act to trip generator, generator step up transformer, generator interconnection facilities, main or unit connected auxiliary transformers, reserve or startup auxiliary transformers at BES plants, or Protection Systems for facilities used in aggregating dispersed BES generation from the point where those resources aggregate to greater than 75 MVA to a common point of connection at 100 kV or above.

6.1.13 **Potential Transformer (PT)** – an instrument transformer that is intended to have its primary winding connected in parallel with a power circuit such that the small voltage signal induced in the secondary is proportional to the voltage on the power circuit and primary winding of the transformer. The secondary winding voltage signal is then used in metering and relays.

6.1.14 **Protection System -** NERC's official definition of a Protection System is:

- Protective relays which respond to electrical quantities,
- Communications systems necessary for correct operation of protective functions
- Voltage and current sensing devices providing inputs to protective relays,
- Station dc supply associated with protective functions (including batteries, battery chargers, and non-battery-based dc supply), and
- Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices

6.1.15 **PT Verification Test -** any type of test or observation that provides some level of assurance that a PT is functioning properly. The verification test should include the PT secondary wiring between the relay panel and the location of the PT. Some possible methods of verifying proper PT function include:

6.1.15.1 Turns Ratio Test. A turns ratio test is performed by injecting a voltage into one of the windings and the resultant output is measured on the other winding. The test is acceptable if resultant voltage is within +/- 2% of expected values.

6.1.15.2 Phase Comparison Test. A test where each of the phase outputs of a set of PT's is compared to the average of the set. A three-phase set of PT's is considered acceptable if the voltage from each PT is within +/- 5% of the average of the set of PT's.

6.1.15.3 Comparison Test – comparison of the outputs of 2 separate PTs monitoring the same current. This may be accomplished by observing current, Volt-ampere, watt, or VAR indications fed from two separate sets of PTs. The PT is considered acceptable if the voltage from the PT is within +/- 5% of the PT to which it is being compared.

6.1.16 **Scheme** – a grouping of protective relays applied together to protect a device such as a generator, transformer, bus, or load. Typically, all relays in a relaying scheme will require many of the same isolation points and equipment outages in order to perform maintenance or calibration of the relay. As such, maintenance of protective relaying is planned and scheduled on the basis of protective schemes rather than by individual relays.

6.1.17 **Sudden Pressure Relaying** – A system that trips an interrupting device(s) to isolate the equipment it is monitoring and includes the following components:

- Fault pressure relay – a mechanical relay or device that detects rapid changes in gas pressure, oil pressure, or oil flow that are indicative of faults within liquid filled, wire-wound equipment
- Control circuitry associated with a fault pressure relay

6.2 References

6.2.1 PRC-005-6, "Protection System, Automatic Reclosing, and Sudden Pressure Relaying Maintenance"

6.2.2 NERC PRC-005 Supplementary Reference and FAQ

7.0 REVISION HISTORY

Date	Revision	Change
8/1/05	0	Original Issue
3/12/07	0	Revised into a standard
3/20/07	1	Revised Table A Plant identifiers to Coal/RDF and Gas/CT/Hydro
5/21/08	1.1	Corrected policy number in heading on Appendix A and reference to Appendix A in ¶4.4
11/17/08	2.0	Reformatted numbering of section 4.2 and provided for alternative methods of current and potential transformer verification. Added paragraph 4.2.1 to clarify program start date

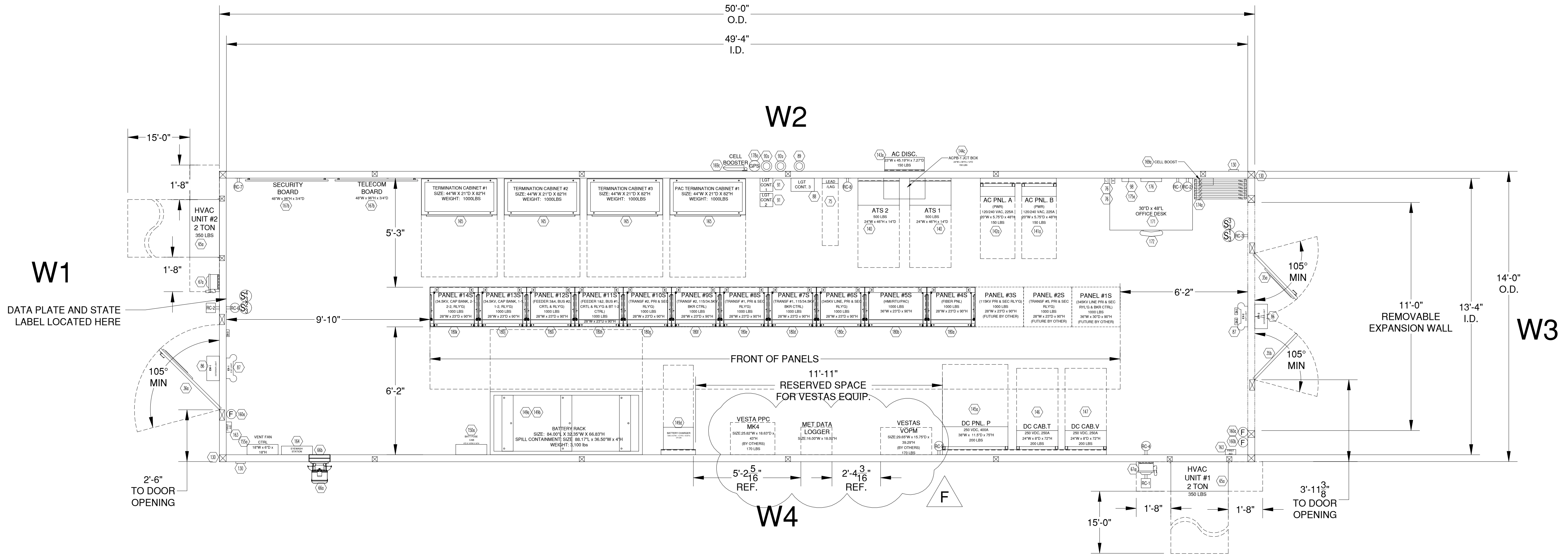
Date	Revision	Change
6/1/09	2.1	Added definition of microprocessor based relay and delineated requirements for microprocessor vs. analog electronic relays in paragraphs 4.2.3 and 4.2.4 and Table A. Added further clarification of the bases of Table A intervals in paragraph 4.1.3
7/21/10	2.2	Added sentence to paragraph 4.2.1 to clarify intent of requirements for scheduling of initial maintenance necessary to fulfill program initiation requirements
11/21/2012	3.0	Major Rewrite to meet requirements of pending NERC standard PRC-005-2. Significant changes include: -change in title to clarify scope of standard is for Protection Systems rather than just protective relays. -moved program bases description up to Section 2.0. Establish draft PRC-005-2 materials as the basis for the program. -changed departmental references from "Maintenance Resources" to "Technical Resources & Compliance" to reflect organizational changes. -added paragraphs 4.1.2, 4.1.5.1, and 5.3 to discuss new requirements for scheme specific testing procedures for NERC PRC-005 Related Protection Systems -added paragraph 4.2.2.6 and modified Table A to Table 1 and provided greater clarity for requirements for testing of associated control circuits. -added paragraph 4.2.2.7 to recognize and emphasize that batteries and battery chargers are part of a protection system but are maintained per requirements delineated in EPR 5.704S, Battery Maintenance Standard. -added paragraph 4.2.2.8 to recognize that Communication Systems are part of protection systems but to document that they are not utilized within Protection Systems maintained by Energy Supply
03/26/2013	3.1	– Removed Supersedes EPR 5.714G from title block – Removed references to PRC-005-2 and made all references to PRC-005 throughout document – Added UAT/RAT and SU transformers back in section 2.0 – Updated section 2.0 applicability for a communication device maintenance program, defining types and monitoring statuses. – 4.1.2.4 added for updating procedures for changes in relaying – 4.1.5.1 added 'of' for clarification in the statement 'for the

Date	Revision	Change
		performance of' – 4.2.2 the statement 'requirements required by' was changed to 'requirements of PRC-005' – Completely rewrote 4.2.2.8 and added subsections for fiber optic communication systems in all regions – Updates to section 4.3 for acquired plants – Added 6.1.14 definition of a communication system – Updated Section 6.2 references – Updated Table 1 to include communication systems
05/07/2013	3.2	– Added wording in section 2.0 that was inadvertently deleted in previous revision.
11/04/2013	3.3	– Added wording to address generator interconnection facilities in the following sections: Section 2.0, new definition 6.1.8, modified definition 6.1.10, and Table 1
08/03/2015	3.4	– Revised section 2.0 to more accurately describe in scope protection systems at dispersed BES generation facilities per PRC-005-2(i) applicability – Deleted section 4.4 which referenced a non-existent specification for performance of relay testing by vendor personnel
02/09/2016	4.0	– Major re-write to address requirements of NERC standard PRC-005-6, including adding Automatic Reclosing and Sudden Pressure Relaying.
11/07/2016	4.1	– Minor re-write to include: ▪ use of the generic term "voltage and current sensing device" instead of "instrument transformer" or "CTs/PTs" and to include DC shunt testing for new AVR systems which have Protection System trips derived from DC shunt signals for generator field current. ▪ Re-organization of Table A to clarify applicability for dispersed generation assets. ▪ Deletion of references to Maximo and addition of generic term "work and asset management system". ▪ Clarified in applicability that ES does not have RAS, UFLS or UVLS systems.

Table 1 – Maximum Allowed Protection System Maintenance Intervals

Relay Application	Environment	Device Type	Maximum Allowed Maintenance Interval*
Generator, Generator Interconnection Facility, and Dispersed Gen Aggregating Facility Protective Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	6 years
GSU, MSA RSA/Startup Transformer Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	6 years
MV & LV Switchgear Protection Relays	All	Electromechanical or Electronic (Analog)	6 years
	All	Microprocessor based	12 years
Voltage and Current Sensing Devices	All	Current	12 years
	All	Potential	12 years
Communication Systems	All	Communications	12 years
Associated Control Circuits	All	Trip Paths	6 years
Sudden Pressure Relaying	All	Pressure and Flow Sensor, Associated Lockout Devices and Control Circuits	6 years

*Maximum allowed interval is based on calendar years.



GENERAL NOTES:

1. ALL CONDUIT FITTINGS TO BE SET SCREW TYPE.

SYMBOLS & LEGEND: ("#" DENOTES ORDER OF CIRCUIT)

S#	THREE-WAY SWITCH: 20A, 120 VOLT
F	FIRE EXTINGUISHER
RC-#	120 VOLT INTERIOR DUPLEX RECEPTACLE
RC-#	GFCI 120 VOLT EXTERIOR DUPLEX RECEPTACLE
EWL-#	EXTERIOR WALL PACK LIGHT
DI-#	DOOR ALARM CONTACT
EX-LT#	EMERGENCY LIGHT EXIT SIGN
	IN FRONT OF EQUIPMENT DENOTES 36" WALKWAY CLEARANCE
	DENOTES MIN. REQUIRED 20" CLEARANCE FOR HVAC

N

SCALE IN ft.

0 1 2 3 4

W2
W1 W3
W4

ELEVATION KEY

BLAZING STAR 1 WIND FARM
NSP DWG# NX-240579-4-1

This map/document is a tool to assist employees in the performance of their jobs. Your personal safety is provided for by using safety practices, procedures, and equipment as described in safety training programs and manuals.

Mortenson
700 MEADOW LANE NORTH
MINNEAPOLIS, MN 55422
PHONE: (763) 522-2100
FAX: (763) 287-5163

I certify that revisions F and G of this plan, specification or report was prepared by me or directly under my supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

Signature: [signature]
Typed or Printed Name: Kevin Lennon
Date: July 14, 2020
License Number: 24655

ANCHOR CHART

DETAIL	MOUNTING LOCATION	ANCHOR SIZE	ANCHOR METHOD	QTY (MIN)
ATS	WALL MOUNT	3/8-16 x 1.50" LONG, ASTM A307, BOLT	MOUNT TO W200 STRUT ON WALL, WITH 12-24 SCREWS @ 6" O.C.	4
PANEL BOARDS	WALL MOUNT	3/8-16 x 1.50" LONG, ASTM A307, BOLT	MOUNT TO W150 & W200 STRUT ON WALL, WITH 12-24 SCREWS @ 6" O.C.	4
TERMINATION CABINETS	FLOOR MOUNT	1/2-13 x 1.50" LONG, ASTM A325, BOLT	DRILL AND TAP INTO BUILDING FLOOR PLATE	4
COMM & SECURITY BOARDS	WALL MOUNT	3/8-16 x 1.50" LONG, ASTM A307, BOLT	MOUNT TO W200 STRUT ON WALL, WITH 12-24 SCREWS @ 6" O.C.	4
JUNCTION BOXES	WALL MOUNT	#12-24 x 1.50" LONG, SELF TAPPING SCREW	MOUNT DIRECTLY TO WALL	4
BATTERY RACK	FLOOR MOUNT	1/2-13 x 1.50" LONG, ASTM A325, BOLT	DRILL AND TAP INTO BUILDING FLOOR PLATE	4
BATTERY CHARGER	WALL MOUNT	3/8-16 x 1.50" LONG, ASTM A307, BOLT	MOUNT TO W150 & W200 STRUT ON WALL, WITH 12-24 SCREWS @ 6" O.C.	4
RELAY PANELS	FLOOR MOUNT	1/2-13 x 1.50" LONG, ASTM A325, BOLT	DRILL AND TAP INTO BUILDING FLOOR PLATE	4

RESERVED FOR ENGINEER SEAL

ENGINEER OF RECORD:
PLUMP ENGINEERING, INC.
RICHARD PLUMP, P.E.
(714) 385-1835 FIRM #: 15214

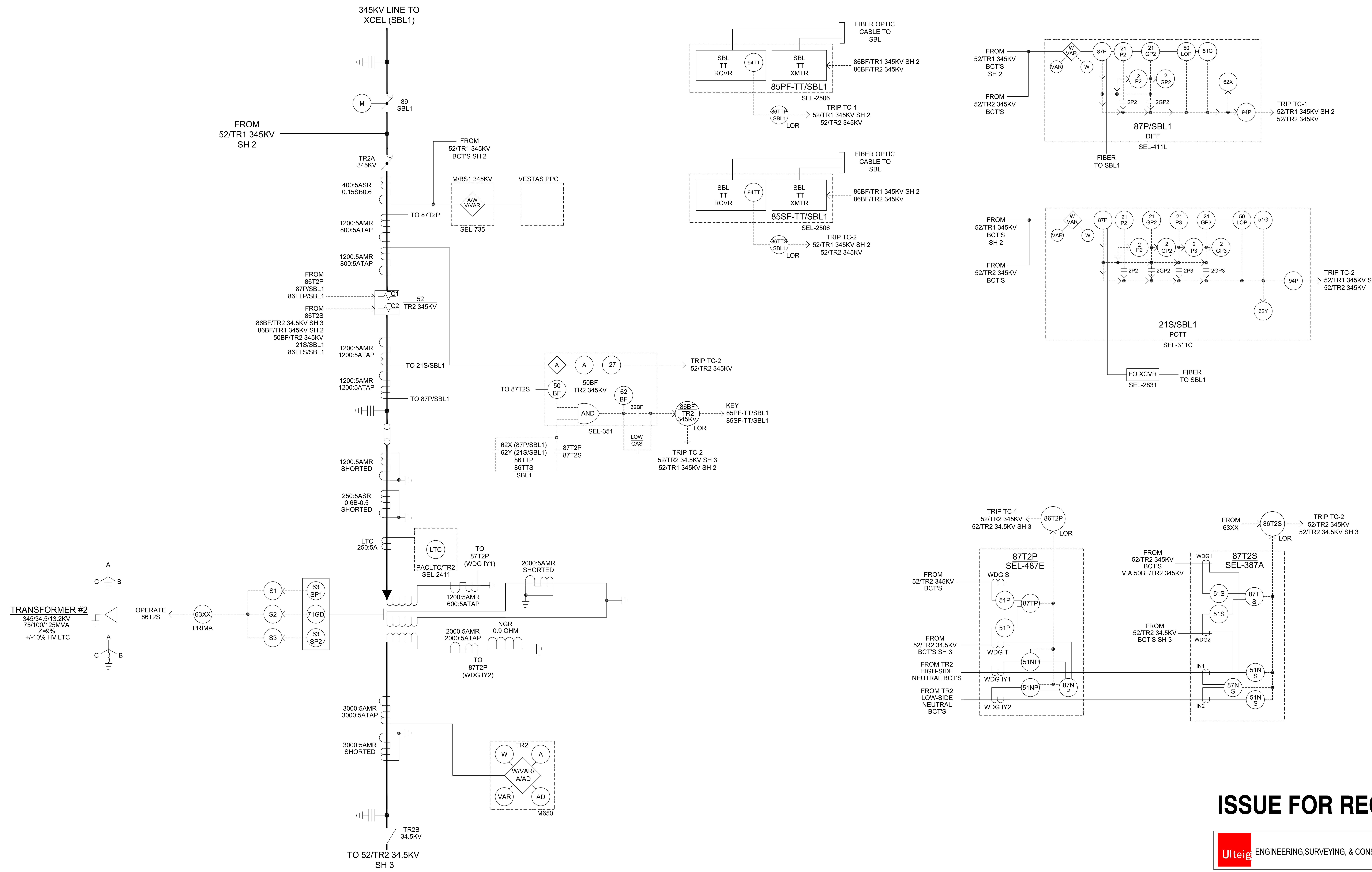
CROWN
TECHNICAL SYSTEMS
13470 PHILADELPHIA AVE
FONTANA, CA 92337
PH:(951)332-4170

NO.	DESCRIPTION	DATE	INITIAL
G	MET TOWER DATA LOGGER - ISSUED FOR CONSTRUCTION	07/13/20	MHF
F	MET TOWER DATA LOGGER - FOR REVIEW	07/01/20	MHF
E	AS-BUILT	08/14/19	RA
D	ADDED TEMP ALARMS AND SPLIT LIGTING CIRCUIT, ADDED CELL BOOST, REVISED BATT FUSE J-BOX SIZE	07/22/19	RA
C	REMOVED LIGHT SWITCH #3 & #4	06/06/19	RA
B	UPDATED BATTERY RACK, MOVED RELAY PANELS	05/01/19	RA
A	RFC, UPDATED EQUIPMENT DESCRIPTION	12/3/18	GL
1	UPD RELAY PANEL LABEL, UPDATED AC PNL VOLTAGE RATING, ADDED LIGHTING CONTACTORS, UPD EQUIPMENT SIZES	7/30/18	GL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES:
.XXX ±.125 .XX ±.25 ANGLES ±1.0°
SCALE:
DRAWN BY: G LEAL
CHECKED BY: C BOYER
ENGINEER: G LEAL
APPROVED BY: C BOYER
DATE: 7/30/18
SHEET NUMBER:

PROJECT NAME:
BLAZING STAR 1 SUBSTATION
DRAWING DESCRIPTION:
PLAN VIEW
DRAWING NUMBER:
218084-B01-P1
REVISION:
G

	A	B	C	D	E	F	G	H	I	J



ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1A	MPT UPDATES - FOR REVIEW		09-06-19	LML	PS	KJD
2	MPT UPDATES - FOR CONSTRUCTION		09-27-19	LML	PS	KJD
3	ISSUED FOR RECORD - BLAZING STAR 1 - 22571		02/14/2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
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ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

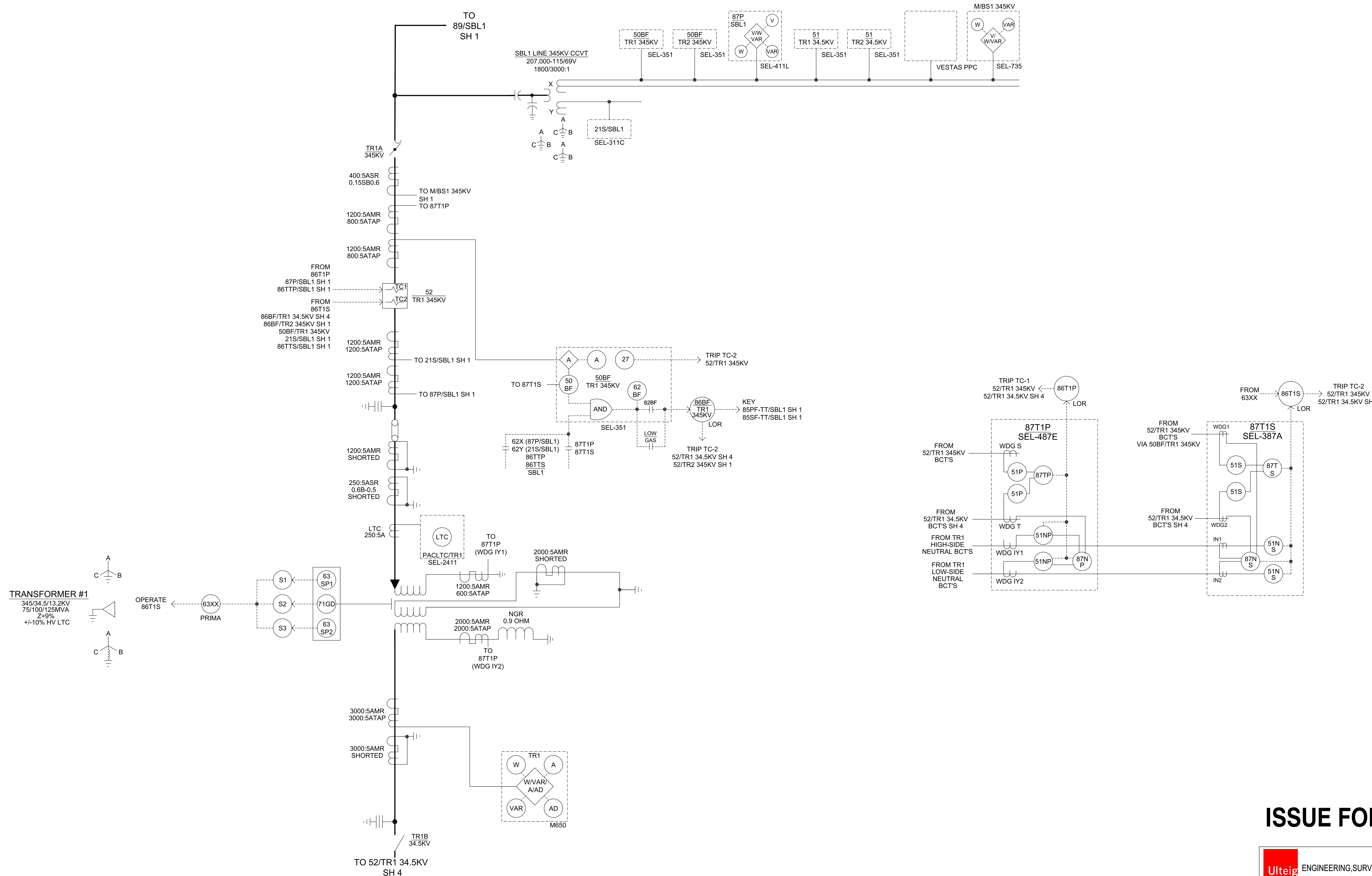
UNIT 0

345-34.5KV

METERING AND RELAYING DIAGRAM

NH-275116-1

REV 3



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ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

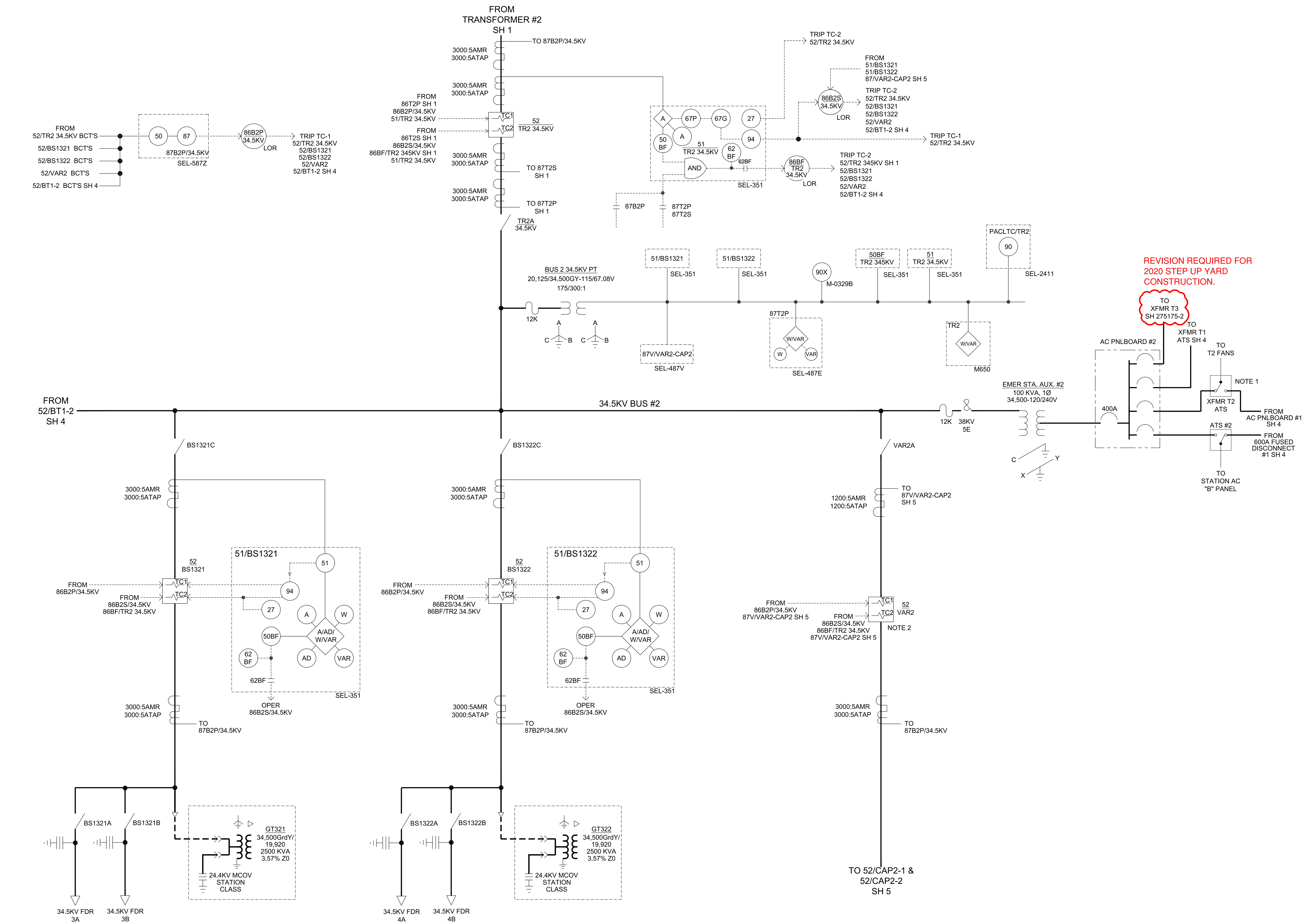
UNIT 0

345-34.5KV

METERING AND RELAYING DIAGRAM

NH-275116-2

REV 3



NOTES

1. XFMR T1 ATS AND XFMR T2 ATS ARE PRE-INSTALLED ON TRANSFORMER BY VENDOR.
2. 52b CONTACT FROM 52/VAR1 TRIPS CAPSWITCHERS 52/CAP1-1 AND 52/CAP1-2. 52b CONTACT FROM 52/VAR2 TRIPS CAPSWITCHERS 52/CAP2-1 AND 52/CAP2-2.

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

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1A	90% SUBMITTAL-EDITS FOR STEP UP YARD		07-31-19	LML	PS	KJD
2	FOR CONSTRUCTION - MPT AND STEP UP YARD		09-25-19	LML	PS	KJD
3	ISSUE FOR RECORD - BLAZING STAR 1 - 22571(2019 WORK ONLY)		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

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DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

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BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
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ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0

34.5KV

METERING AND RELAYING DIAGRAM

NH-275116-3

REV 3

NOTES

1. XFMR T1 ATS AND XFMR T2 ATS ARE PRE-INSTALLED ON TRANSFORMER BY VENDOR.
2. 52b CONTACT FROM 52/VAR1 TRIPS CAPSWITCHERS 52/CAP1-1 AND 52/CAP1-2. 52b CONTACT FROM 52/VAR2 TRIPS CAPSWITCHERS 52/CAP2-1 AND 52/CAP2-2.

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REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®
NORTHERN STATES POWER COMPANY
BLAZING STAR 1 COLLECTOR SUBSTATION
LINCOLN COUNTY, MINNESOTA

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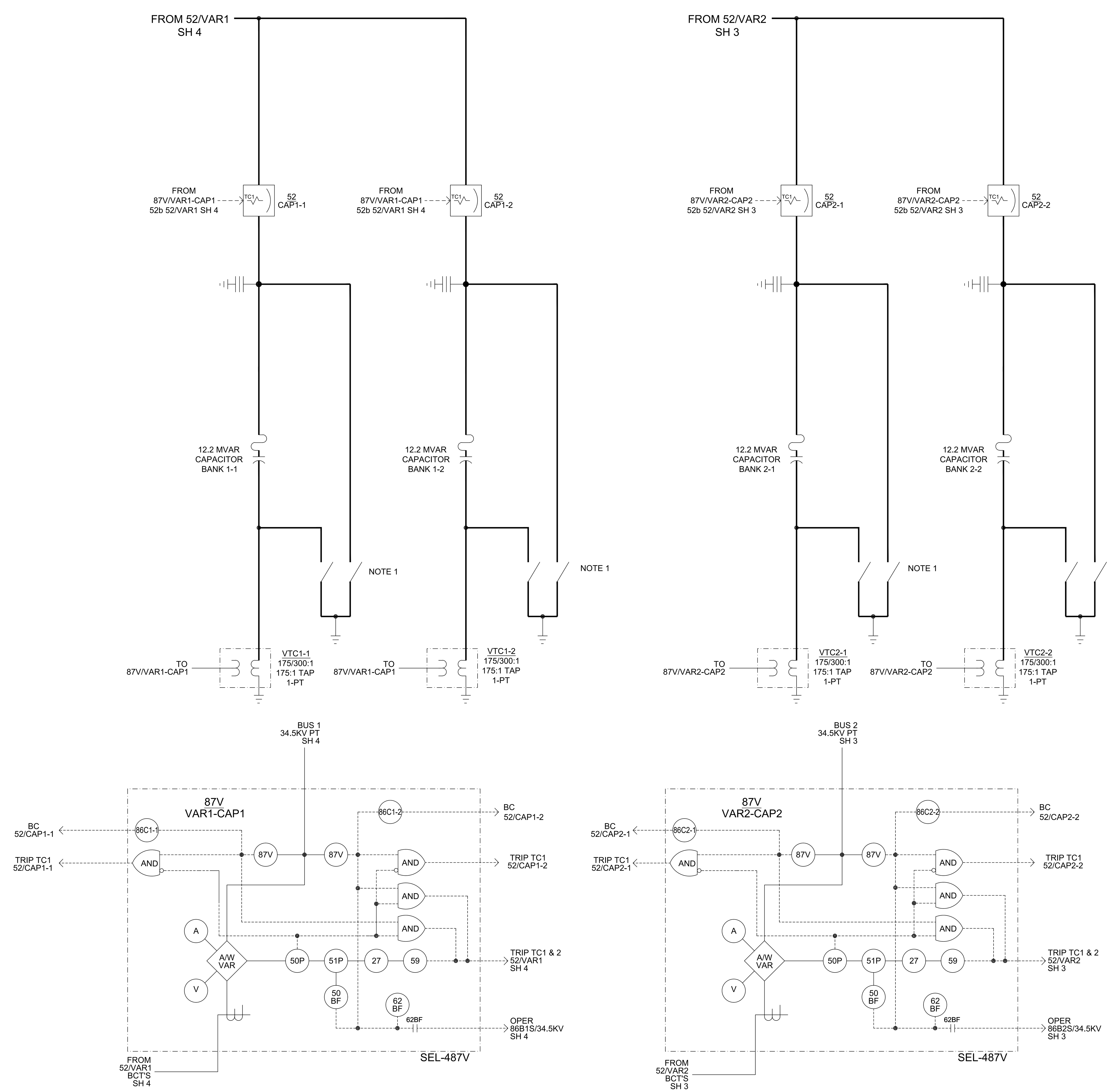
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
34.5KV
METERING AND RELAYING DIAGRAM
NH-275116-4
REV 2



NOTES

1. KIRK KEY INTERLOCK SYSTEM IMPLEMENTED. EACH CAPACITOR BANK GROUNDING SWITCH SHALL ONLY BE CLOSED WHEN ITS RESPECTIVE UPSTREAM CAPSWITCHER IS OPEN

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG	NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD							
1	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW							

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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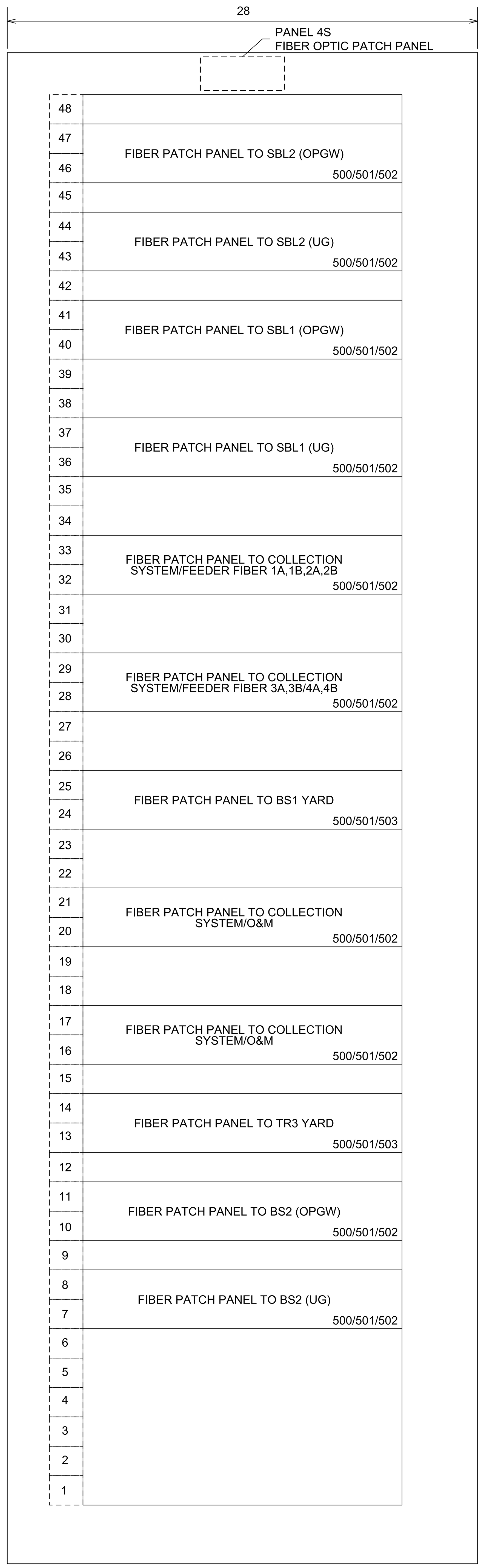
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
34.5KV

METERING AND RELAYING

NH-275116-5

REV
1



FRONT VIEW

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL COUNT DETAIL 3300.1-1)
500	PATCH PANEL	12	72/288-F RACK-MT ENCLOSURE 19" 2U EMPTY, ADD 4 CCH PANELS OR MODULES, CCH-02U
501	PATCH PANEL	12	FLUSH MOUNTING BRACKET FOR CCH-02U
502	PATCH PANEL	40	CCH PIGTAIL SPLICE CASSETTE, 12F, LC UPC, DUPLEX, SINGLE-MODE, CCH-CS12-A9-P00RE
503	PATCH PANEL	8	CCH PIGTAIL SPLICE CASSETTE, 12F, ST UPC, MULTI-MODE, CCH-CS12-G5-P00BE

ITEM	DEV	QUAN	DESCRIPTION

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

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0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
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NO	REVISION	ZONE	DATE	BY	CHK	ENG

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Xcel Energy®
NORTHERN STATES POWER COMPANY
BLAZING STAR 1 COLLECTOR SUBSTATION
LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
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APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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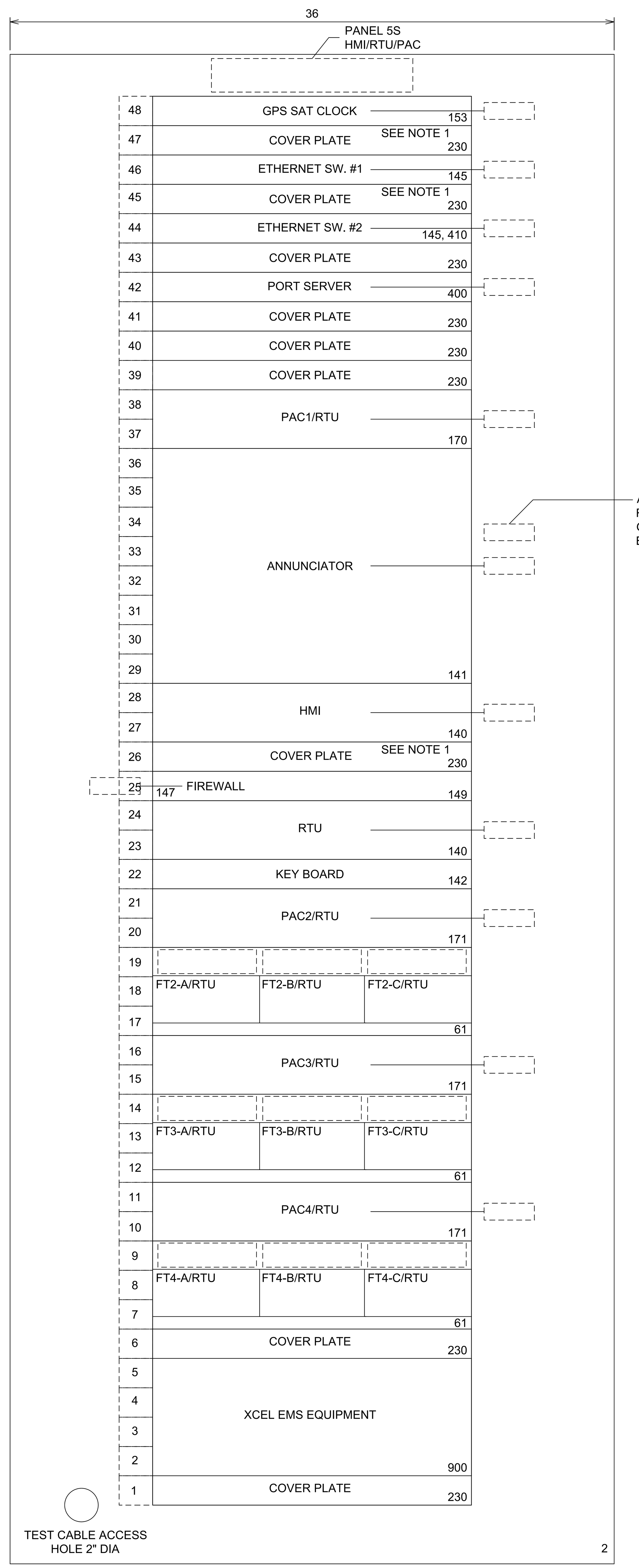
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
345KV/34.5KV
PANEL 4S
FIBER OPTIC PATCH PANEL
PANEL ELEVATION

NH-275117-4

REV 1



FRONT VIEW

ANNUNCIATOR ALARM COLOR DESCRIPTION
RED = ACTIVE UNACKNOWLEDGED ALARM
GREEN = CLEARED UNACKNOWLEDGED ALARM
BLACK = ACTIVE ACKNOWLEDGED ALARM

ITEM	DEV	QUAN	DESCRIPTION
2	PANEL	1	90"H X 36"W (PANEL CONST DETAIL 3300.1-1-1)
61	FT-19R	3	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493493AX08
140	RTU HMI	1 1	ORIONLX AUTOMATION PLATFORM, NOVATECH MODEL#ORIONLX-E3-ENEN-CPX-MMB-XM4-IHV-HVXX-01-03-04-07-42-44-47-52-57-70-35-83-95-101 STANDARD HARDWARE AND SOFTWARE COMPONENTS: ONE FIXED DIAGNOSTICS/MAINTENANCE RS-232 PORT (STANDARD) ONE CONFIGURABLE RS-232 PORT (STANDARD) THREE USB MEMORY PORTS DUAL COPPER ETHERNET PORTS (ENEN) SINGLE 48-125VDC/120VAC POWER SUPPLY (HVXX) IRIG-B PORT ETHERNET CLIENT PROTOCOL NTP ETHERNET SERVER PROTOCOLS TELNET, SSH, FTP, SFTP, HTTP, HTTPS, NTP COMPLETE CYBER SECURITY PACKAGE HARDWARE INCLUDED: THREE CONFIGURABLE RS-232 EXPANSION SERIAL PORTS (E3) HIGH PERFORMANCE CPU (CPX) (INCLUDES XM4) MULTIMEDIA BOARD (MMB) EXPANDED FLASH MEMORY (XM4) (INCLUDED WITH CPX) 48VDC/125VDC DISCRETE INPUT VOLTAGE (IVH) MASTER (IED) PROTOCOLS INCLUDED: DNP3.0 SERIAL (01) DNP3.0 IP (TCP & UDP) (03) MODBUS ASCII/RTU SERIAL (04) MODBUS TCP/IP (07) SLAVE (SCADA) PROTOCOLS INCLUDED: DNP3.0 SERIAL SLAVE (42) DNP3.0 IP SLAVE (TCP & UDP) (44) MODBUS ASCII/RTU SERIAL (47) PUSHER (52) WEBSERVER XML (57) SPS (70) SOFTWARE OPTIONS: LOGIC PAK (35) ORION MATH AND LOGIC (83) ALARM/ARCHIVE/RETENTIVE (95) IEC6-1131 LOGIC (101)
141	ANN SCREEN	1	19" TOUCHSCREEN MONITOR WITH 19" RACK-MOUNT BRACKET, TRANSDUCTION INC., CAT# TR-LCD1900-RM-TOUCH-125VDC, 125VAC/VDC
142	KEYBOARD	1	RACK-MOUNT USB KEYBOARD/DRAWER WITH TOUCHPAD, ADESSO, PN# ACK-730UB-MRP
145	ENET SW	2	ETHERNET SWITCH/ROUTER, RUGGEDCOM RUGGEDBACKBONE RX1501, CAT# RX1501-L2-RM-HI-L3SECL2HW-6TX01-6TX01-6TX01-6TX01-6TX01-6TX01-XX, LAYER 2 SWITCH, 19" RACK MOUNT, SOFTWARE: LAYER 3 SECURITY EDITION (WITH L2 HW), 88-300VDC OR 85-264VAC POWER SUPPLY WITH SCREW TERMINAL BLOCK, 6 X 10/100Tx RJ45 ETHERNET PORTS (LINE MODULES 1, 2, 3, 4, 5 & 6)
147	FIREWALL	1	SECURITY APPLIANCE: FIREWALL, IPS, APPLICATION CONTROL AND ANTIVIRUS, CHECK POINT SOFTWARE TYPE CIP-1200R, WITH MULTI-PROTOCOL SUPPORT, 4 X 10/100/1000BASE-T RJ45 LAN PORTS, 1 X 10/100/1000BASE-T RJ45 OR 1 X 1000BASE-F WAN PORT, 1 X 10/100/1000BASE-T RJ45 OR 1 X 1000BASE-F DMZ PORT, -40C TO +75C, 100-240VAC/12-72VDC POWER SUPPLY WITH SCREW TERMINALS, WITH STANDARD DIN RAIL MOUNT PROVISIONS (CAT #CPAP-SG1200R-NGTP), WITH ADDITIONAL 2-YEAR BLADE/LICENSE PACKAGE (CAT #CPSB-NGTP-1200R-2Y), WITH 3-YEAR 24X7 SUPPORT (CAT #CPES-SS-PREMIUM-3Y)
149	SHELF	1	CUSTOM RACK SHELF FOR FIREWALL SEE DETAIL 3300.1-1-6
153	GPS CLOCK	1	GPS SATELLITE-CONTROLLED CLOCK, SCHWEITZER ENGINEERING LABORATORIES INC. MODEL# SEL-2407, CAT# 24070003B, POWER SUPPLY INPUT RANGE: 18-300 VDC AND 85-264 VAC (50-60 HZ), CLOCK WITH 19 INCH RACK MOUNT BRACKET,
★ 154	ANT	1	SCHWEITZER ENGINEERING LAB. CAT #9524A, GPS ANTENNA
★ 155	CABLE	1	SCHWEITZER ENGINEERING LAB. CAT #C961-075, 75FT GPS ANTENNA CABLE
170	PAC	1	SCHWEITZER ENGINEERING LAB. TYPE SEL-2440, CAT #24402H12A1A11630.
171	PAC	3	SCHWEITZER ENGINEERING LAB. TYPE SEL-2440, CAT #24402H11A6X11630.
230	COVER PLATE	9	COVER PLATE 19"W X 1 3/4"H
★ 250	FB	26	FUSE BLOCK, 1 POLE, 250V, 30A, BUSSMAN, #BMM603-1SQ
★ 252	FUSE	16	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 5 AMP, CAT# KLM-5
★ 253	FUSE	10	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
★ 255	TB	32	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
★ 285	DC-DC	1	DC-DC CONVERTER PHOENIX CONTACT, 90-350VDC INPUT, 24VDC OUTPUT, 5A, TYPE QUINT-PS-100-240AC/24DC/S CAT #2938581
★ 300	XCVR	2	SEL 2812 MR FIBER OPTIC TRANSCEIVER MULTIMODE CAT #2812MRX0.
400	PORT SERVER	1	SCHWEITZER ENGINEERING LAB. TYPE SEL-3610, CAT #3610XHA0XXX0
410	SFP	1	RUGGEDCOM 4 MULTIMODE 1300NM LC FIBER OPTIC PORTS TO BE INSTALLED IN ETHERNET SWITCH 2, CAT # 6GK6015-0AL20-0BC0
900	EMS	1	XCEL EMS EQUIPMENT

NOTES:

1. 1 RACK UNIT SPACE IS REQUIRED ABOVE THE ETHERNET SWITCH AND FIREWALL TO ALLOW FOR HEAT DISSIPATION.

SYMBOLS

★ REAR MOUNTED EQUIPMENT.

NAMEPLATES PRODUCED AND MOUNTED PER PANEL NAMEPLATE DETAIL 3300.1-1-11

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
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Xcel Energy®
NORTHERN STATES POWER COMPANY
BLAZING STAR 1 COLLECTOR SUBSTATION
LINCOLN COUNTY, MINNESOTA

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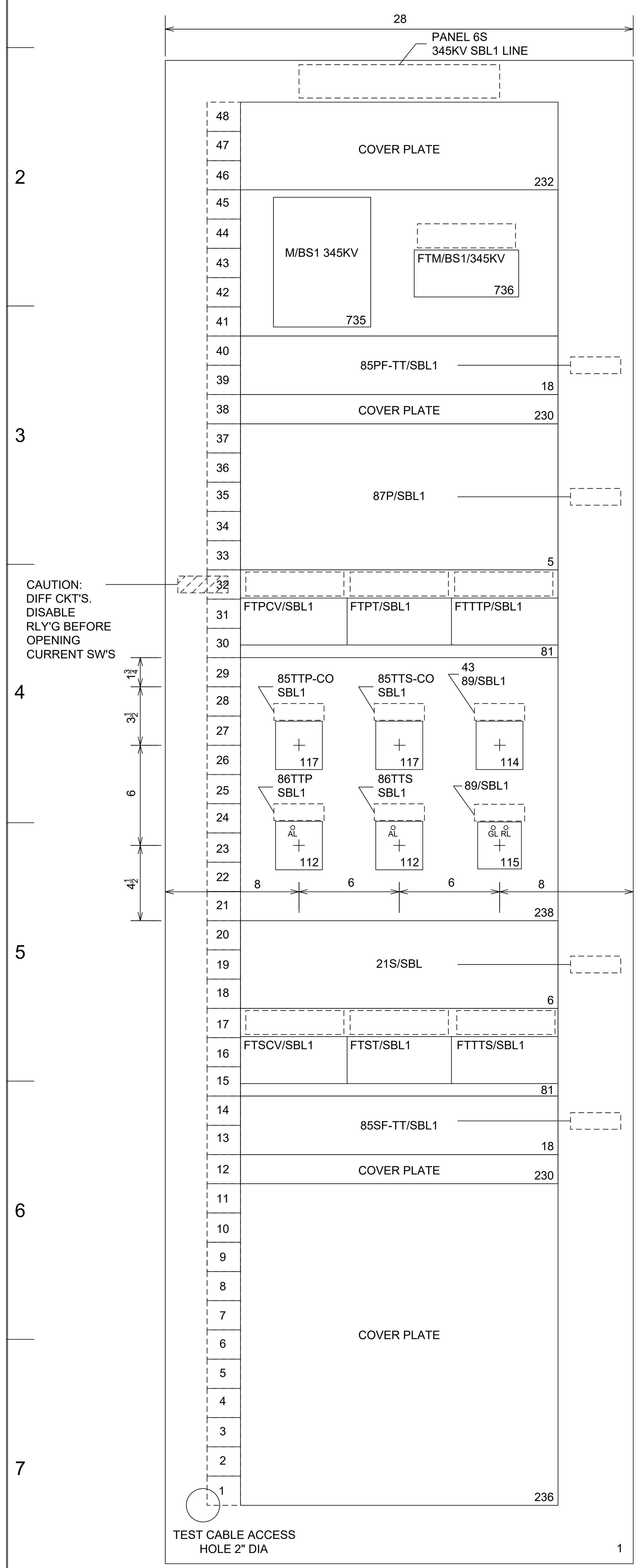
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
345KV
PANEL 5S
HMI/RTU/PAC
PANEL ELEVATION

NH-275117-5

REV 1



FRONT VIEW

SYMBOLS

* REAR MOUNTED EQUIPMENT.

NAMEPLATES PRODUCED AND MOUNTED PER PANEL NAMEPLATE DETAIL 3300.1-1-11

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
5	87P	1	SCHWEITZER ENG. LAB. TYPE SEL-411L; CAT. #0411L1X4X5B8ECXH57424XX
6	21S	1	SCHWEITZER ENG. LAB. TYPE SEL-311C; CAT# 0311C31HP3J5421
18	85F	2	SCHWEITZER ENG LAB TYPE SEL-2506; CAT #250603514X
81	FT-19R	2	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 10" EXTENDED DEPTH. STYLE #FRXG137493493AX10
112	86TT	2	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR-ER, CAT# 78PA35LE, ELECTRIC RESET, HIGH SPEED TRIP, MANUAL TARGET RESET, 125VDC "D" COIL TRIP, 125VDC RESET, 5 DECK 10 N.O. & 10 N.C. CONTACTS, TITLE "TRANSFER TRIP", ENGRAVING CODE: 00N-0L13, OVAL-SHANK HANDLE LIGHTED NAMEPLATE LED: AMBER(LEFT)
114	43	1	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE
115	1	1	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PB202QS, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: RED(RIGHT) GREEN(LEFT)
117	85TT-CO	2	OFF-ON SWITCH, ELECTROSWITCH SERIES 24 LSR, CAT# 9202DD DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, 125VDC LOW LEVEL CONTROL, PANEL MOUNT, "NORMAL" AT 12:00, "OFF" AT 1:30, TITLE "TT CUT-OFF", ENGRAVING CODE: 010D-2T18CX, PISTOL GRIP HANDLE
230	COVER PLATE	2	COVER PLATE 19"W X 1 $\frac{3}{4}$"H
232	COVER PLATE	1	COVER PLATE 19"W X 5 $\frac{1}{4}$"H
236	COVER PLATE	1	COVER PLATE 19"W X 19 $\frac{1}{4}$"H
238	COVER PLATE	1	COVER PLATE 19"W X 15 $\frac{3}{4}$"H
* 251	FB	12	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
* 253	FUSE	9	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
* 255	TB	14	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
* 256	TB	7	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504 SC
* 313	XCVR	1	SCHWEITZER ENG LAB TYPE SEL-2831; CAT #2831M

ITEM	DEV	QUAN	DESCRIPTION
735	M	1	SCHWEITZER ENG LAB. TYPE SEL-735; CAT 0735VX00944CXXXXXX16101XX
736	FT	1	SWITCH BOX, ABB CORP., FT-1, SCREW TERMINALS, 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, BLACK COVER, STYLE #714B325G32

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
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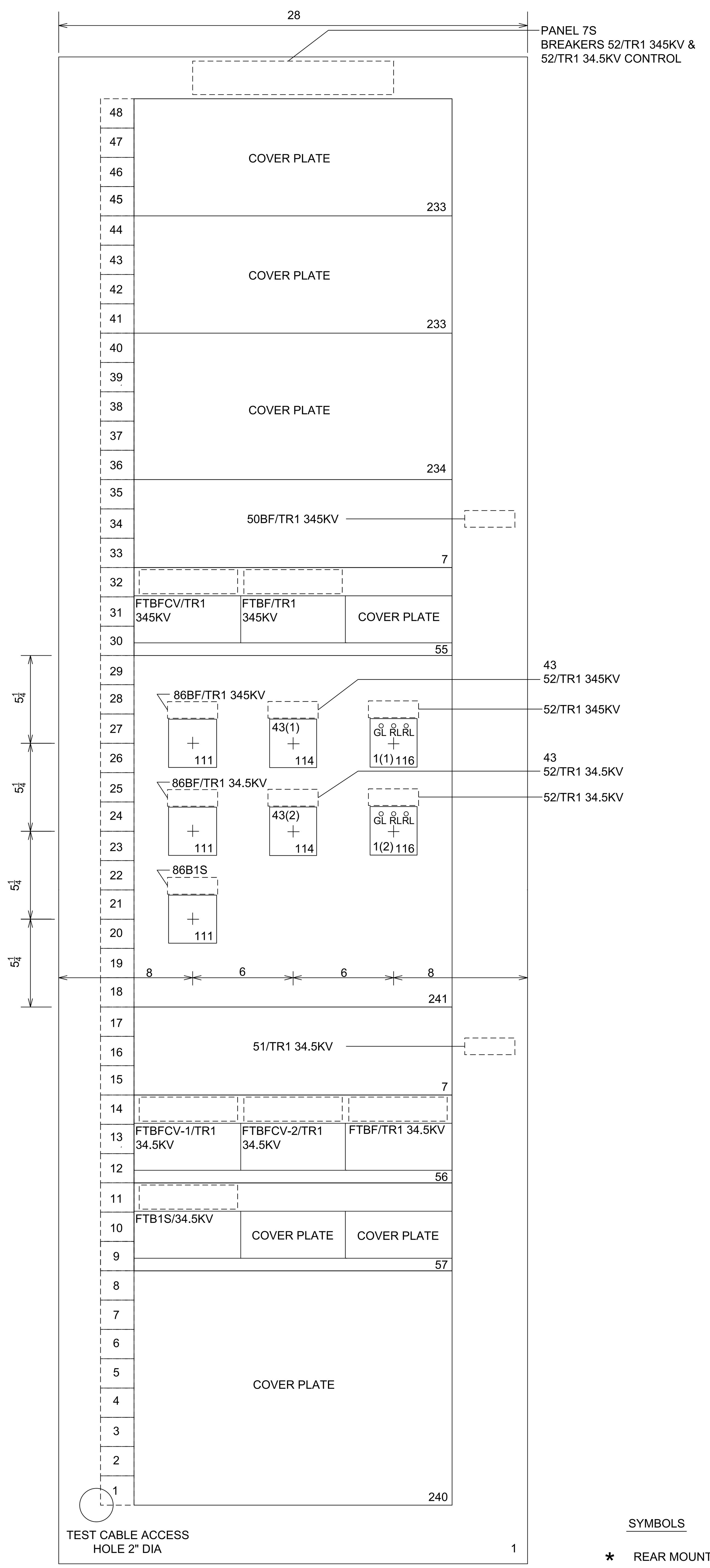
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0

345KV
PANEL 6S
SBL1 LINE RLYG
PANEL ELEVATION

NH-275117-6

REV 1



FRONT VIEW

SYMBOLS

* REAR MOUNTED EQUIPMENT.
NAMEPLATES FOR DEVICE
NAMEPLATE DENOTING CIRCUIT CAUTION

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
7	50BF 51	1 1	SCHWEITZER ENG. LAB. TYPE SEL-351; CAT. #035163C3J542X1
55	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493000AX08
56	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137137493AX08
57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - COVER PLATE OVER FT-1 CUTOUT, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493000000AX08
111	86BF 86B1S	2 1	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 10 N.O. & 10 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22 OVAL-SHANK HANDLE
114	43	2	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE
116	1	2	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)

ITEM	DEV	QUAN	DESCRIPTION
233	COVER PLATE	2	COVER PLATE 19"W X 7"H
234	COVER PLATE	1	COVER PLATE 19"W X 8 $\frac{3}{4}$"H
240	COVER PLATE	1	COVER PLATE 19"W X 14"
241	COVER PLATE	1	COVER PLATE 19"W X 21"H
*251	FB	10	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
*253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
*254	TB	15	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
*256	TB	2	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC

CONSTRUCTION

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
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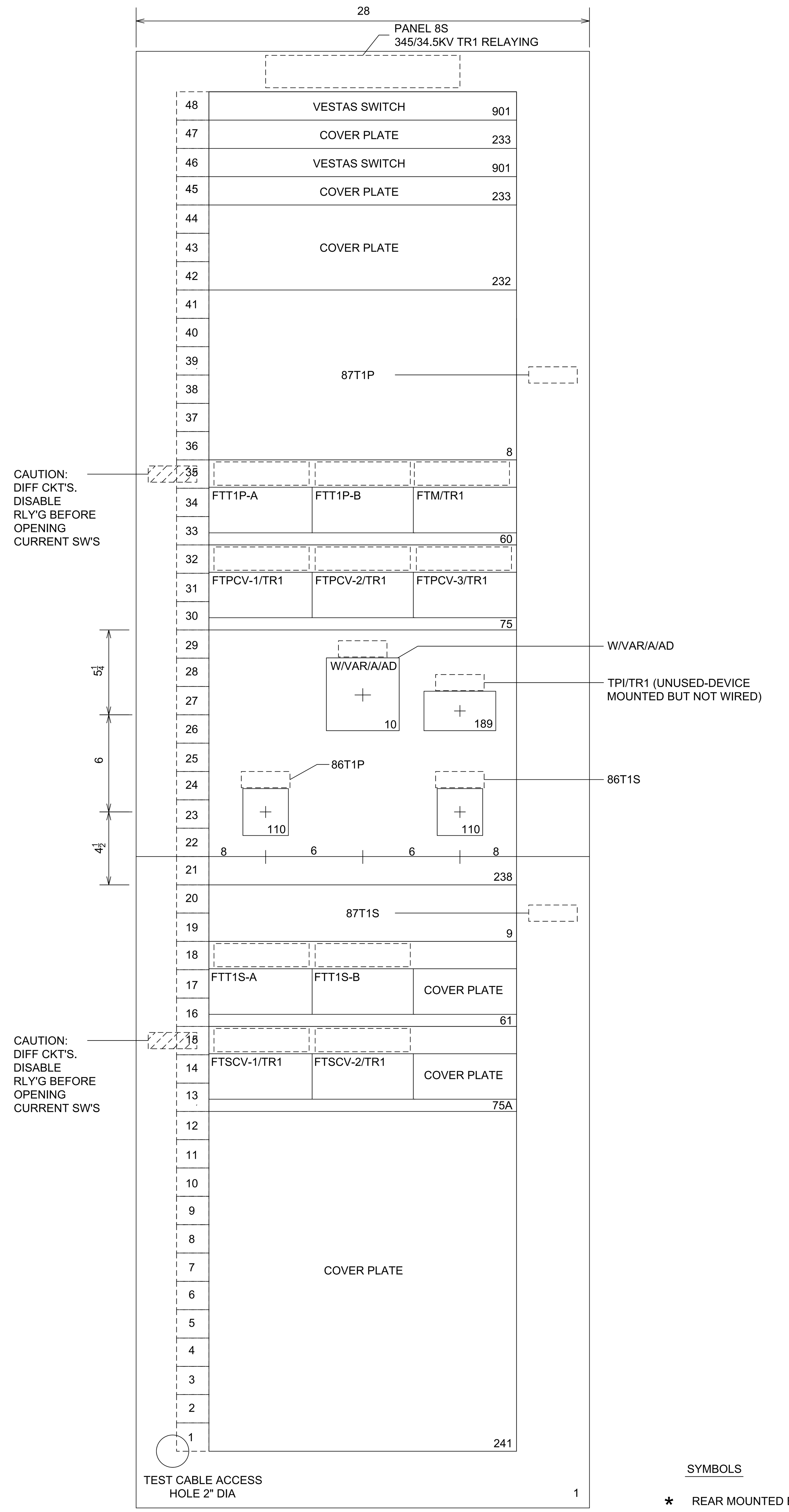
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
345/34.5KV
PANEL 7S
BKR 52/TR1 345KV & 52/TR1 34.5KV CONTROL
PANEL ELEVATION

NH-275117-7

REV 1



FRONT VIEW

SYMBOLS

* REAR MOUNTED EQUIPMENT.
NAMEPLATES FOR DEVICE
NAMEPLATE DENOTING CIRCUIT CAUTION

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
8	87T1P	1	SCHWEITZER ENG. LAB. TYPE SEL-487E; CAT. #0487E3X411XXB0X4H624XXX
9	87T1S	1	SCHWEITZER ENG. LAB. TYPE SEL-387A; CAT. #0387A010HX4X341
10	W/VAR/A/AD	1	MULTIFUNCTION AMP/DEMAND AMP/VOLT/WATT/VAR METER, BITRONICS TYPE M650, CAT# M650B3U511, 2, 2 1/2 OR 3-ELEMENT 0-5A AND 0-120VAC NOM, INPUT, UNIVERSAL PWR SUPPLY 55-240VAC/48-250VDC, THREE 5-DIGIT RED LED DISPLAYS, 4.5" SQUARE FACEPLATE, 6.5" DEEP BY 4" ROUND CASE, PORT 1: CONFIGURABLE RS-232/485 SERIAL, PORT 2: 10/100BASE-TX ETHERNET WITH MODBUS OR DNP3 OVER TCP/IP PROTOCOLS, VOLTAGE TO BE DISPLAYED IN PHASE TO PHASE PRIMARY UNITS.
60	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493137AX08
61	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493000AX08
75	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, FULL BLACK COVER, 10" EXTENDED DEPTH. STYLE #FRXG084084137AX10
75A	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT FULL BLACK COVER, 10" EXTENDED DEPTH. STYLE #FRXG084084000AX10
110	86T	2	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 20 N.O. & 20 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22, OVAL-SHANK HANDLE
189	TPI/TR1	1	INTELLIGENT CONTROL INC., PROGRAMMABLE TAP POSITION MONITOR, M#1250B-1-I 110VAC UNIT, -1 TO +1 MA ANALOG OUTPUT, LED DISPLAY, ISOLATED INPUT CARD, SEMI-FLUSH MOUNT, COMPATIBLE TO RECIEVE INPUT FROM SELSYN TRANSMITTER.

ITEM	DEV	QUAN	DESCRIPTION
232	COVER PLATE	1	COVER PLATE 19"W X 5 $\frac{1}{4}$"H
233	COVER PLATE	2	COVER PLATE 19"W X 1 $\frac{3}{4}$"H
238	COVER PLATE	1	COVER PLATE 19"W X 15 $\frac{3}{4}$"H
241	COVER PLATE	1	COVER PLATE 19"W X 21"H
* 251	FB	11	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
* 252	FUSE	2	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 3 AMP, CAT# KLM-3
* 253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
* 254	TB	15	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
* 256	TB	6	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC
901	VESTAS	2	VESTAS ETHERNET SWITCH

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1A	MPT UPDATES - FOR REVIEW		09-06-19	LML	PS	KJD
2	MPT UPDATES - FOR CONSTRUCTION		09-27-19	LML	PS	KJD
3	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

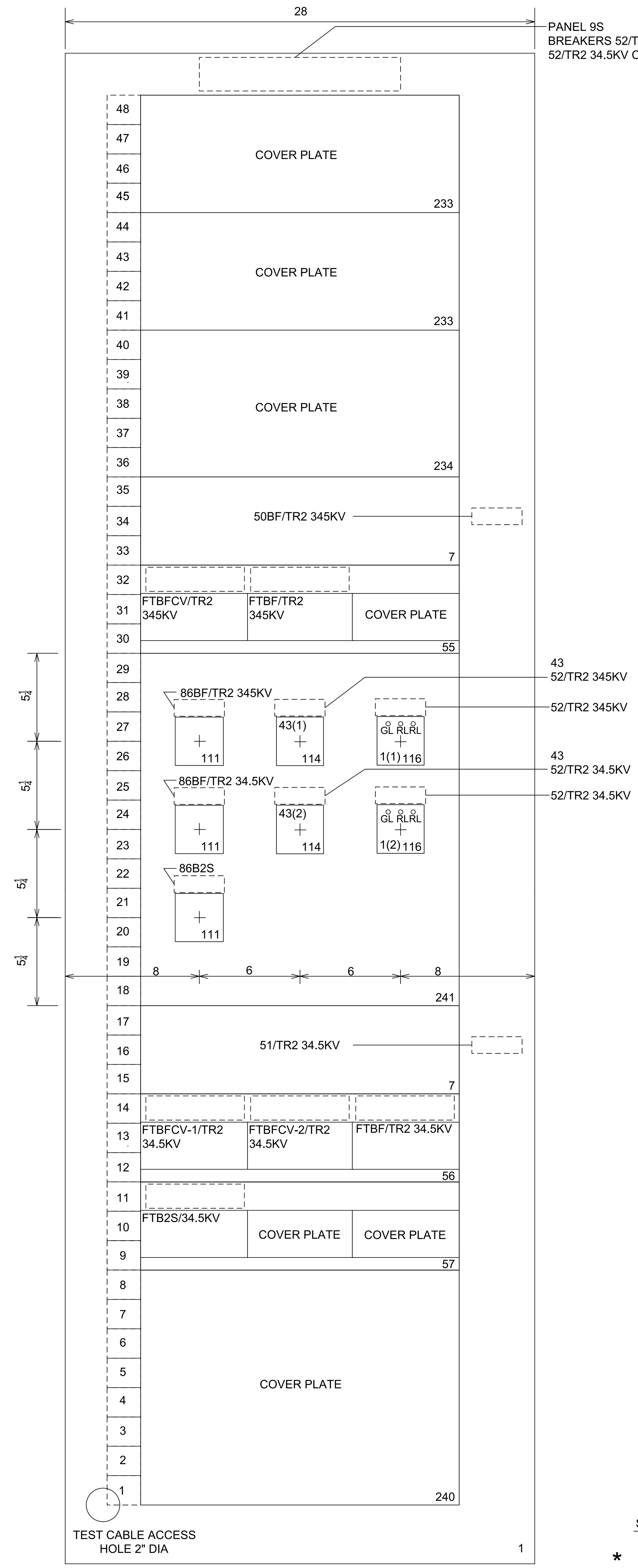
DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
345/34.5KV
PANEL 8S
TR1 PRI AND SEC PROTECTION
PANEL ELEVATION

NH-275117-8

REV 3



FRONT VIEW

SYMBOLS

* REAR MOUNTED EQUIPMENT.

NAMEPLATES FOR DEVICE

NAMEPLATE DENOTING CIRCUIT CAUTION

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
7	50BF 51	1 1	SCHWEITZER ENG. LAB. TYPE SEL-351; CAT. #035163C3J542X1
55	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493000AX08
56	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137137493AX08
57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - COVER PLATE OVER FT-1 CUTOUT, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493000000AX08
111	86BF 86B2S	2 1	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 10 N.O. & 10 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22 OVAL-SHANK HANDLE
114	43	2	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE
116	1	2	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)

ITEM	DEV	QUAN	DESCRIPTION
233	COVER PLATE	2	COVER PLATE 19"W X 7"H
234	COVER PLATE	1	COVER PLATE 19"W X 8 $\frac{3}{4}$"H
240	COVER PLATE	1	COVER PLATE 19"W X 14"
241	COVER PLATE	1	COVER PLATE 19"W X 21"H
*251	FB	10	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
*253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
*254	TB	15	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
*256	TB	2	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

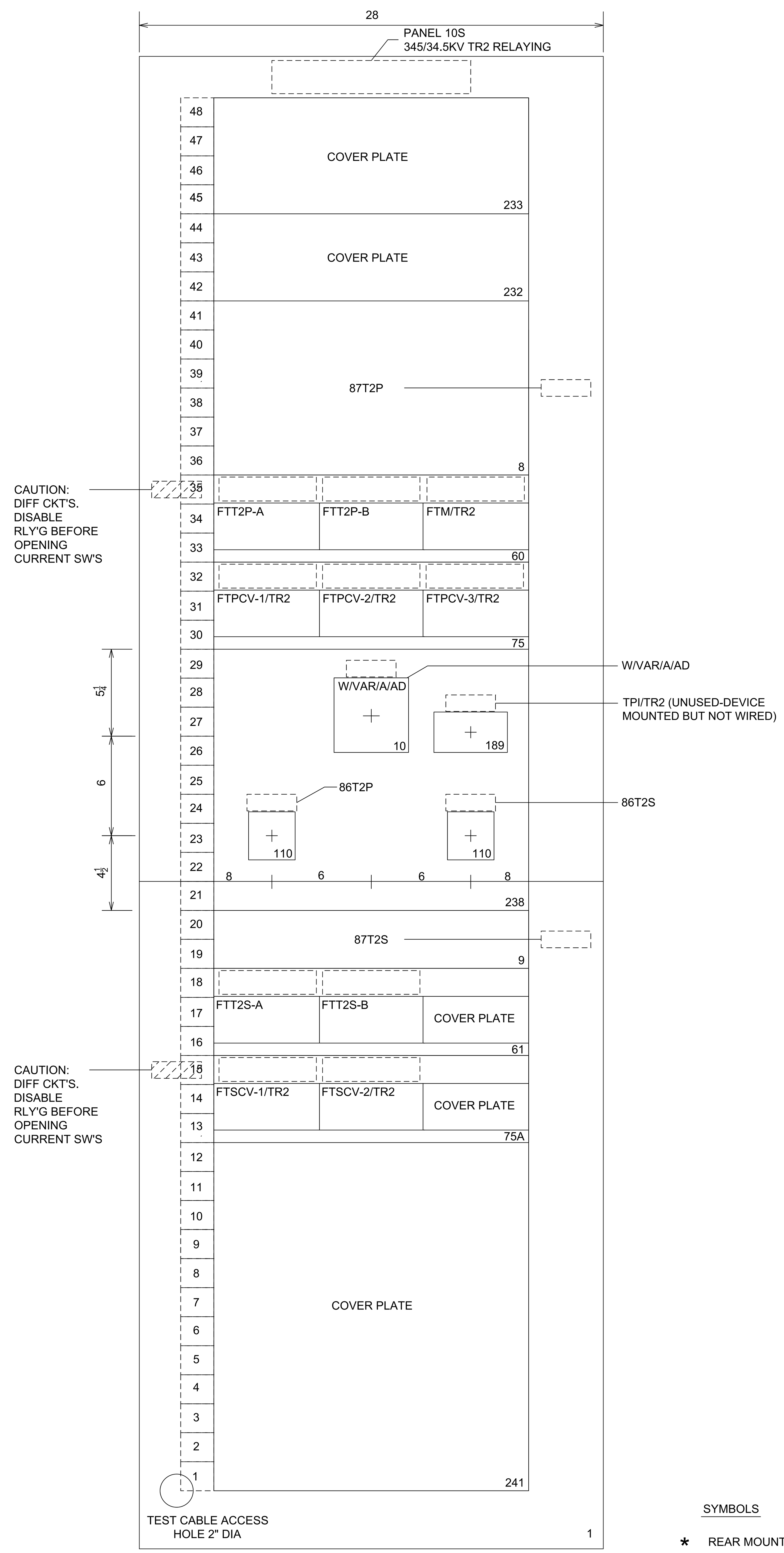
UNIT 0

345/34.5KV
PANEL 9S
BKR 52/TR2 345KV & 52/TR2 34.5KV CONTROL
PANEL ELEVATION

NH-275117-9

REV 1

A	B	C	D	E	F	G	H	I	J



FRONT VIEW

SYMBOLS

* REAR MOUNTED EQUIPMENT.
NAMEPLATES FOR DEVICE
NAMEPLATE DENOTING CIRCUIT CAUTION

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
8	87T2P	1	SCHWEITZER ENG. LAB. TYPE SEL-487E; CAT. #0487E3X411XXB0X4H624XXX
9	87T2S	1	SCHWEITZER ENG. LAB. TYPE SEL-387A; CAT. #0387A010HX4X341
10	W/VAR/A/AD	1	MULTIFUNCTION AMP/DEMAND AMP/VOLT/WATT/VAR METER, BITRONICS TYPE M650, CAT# M650B3U511, 2, 2 1/2 OR 3-ELEMENT 0-5A AND 0-120VAC NOM. INPUT, UNIVERSAL PWR SUPPLY 55-240VAC/48-250VDC, THREE 5-DIGIT RED LED DISPLAYS, 4.5" SQUARE FACEPLATE, 6.5" DEEP BY 4" ROUND CASE, PORT 1: CONFIGURABLE RS-232/485 SERIAL, PORT 2: 10/100BASE-TX ETHERNET WITH MODBUS OR DNP3 OVER TCP/IP PROTOCOLS, VOLTAGE TO BE DISPLAYED IN PHASE TO PHASE PRIMARY UNITS.
60	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493137AX08
61	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493000AX08
75	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES FULL BLACK COVER, 10" EXTENDED DEPTH. STYLE #FRXG084084137AX10
75A	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 8 CURRENT (BLACK) AND 2 POTENTIAL (RED) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT FULL BLACK COVER, 10" EXTENDED DEPTH. STYLE #FRXG084084000AX10
110	86T	2	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 20 N.O. & 20 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22, OVAL-SHANK HANDLE
189	TPI/TR2	1	INTELLIGENT CONTROL INC., PROGRAMMABLE TAP POSITION MONITOR, M#1250B-1-I 110VAC UNIT, -1 TO +1 MA ANALOG OUTPUT, LED DISPLAY, ISOLATED INPUT CARD, SEMI-FLUSH MOUNT, COMPATIBLE TO RECIEVE INPUT FROM SELSYN TRANSMITTER.

ITEM	DEV	QUAN	DESCRIPTION
232	COVER PLATE	1	COVER PLATE 19"W X 5 1/4"H
233	COVER PLATE	1	COVER PLATE 19"W X 7"H
238	COVER PLATE	1	COVER PLATE 19"W X 15 3/4"H
241	COVER PLATE	1	COVER PLATE 19"W X 21"H
*249	FB	1	FUSE BLOCK, 3 POLE, 250V, 30A, BUSSMAN, CAT#HM25030-3SR
*250	FB	1	FUSE BLOCK, 2 POLE, 250V, 30A, BUSSMAN, #H25030-2SR
*251	FB	11	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
* 252	FUSE	2	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 3 AMP, CAT# KLM-3
* 253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
* 254	TB	15	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
* 256	TB	6	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1A	MPT UPDATES - FOR REVIEW		09-06-19	LML	PS	KJD
2	MPT UPDATES - FOR CONSTRUCTION		09-27-19	LML	PS	KJD
3	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®
NORTHERN STATES POWER COMPANY
BLAZING STAR 1 COLLECTOR SUBSTATION
LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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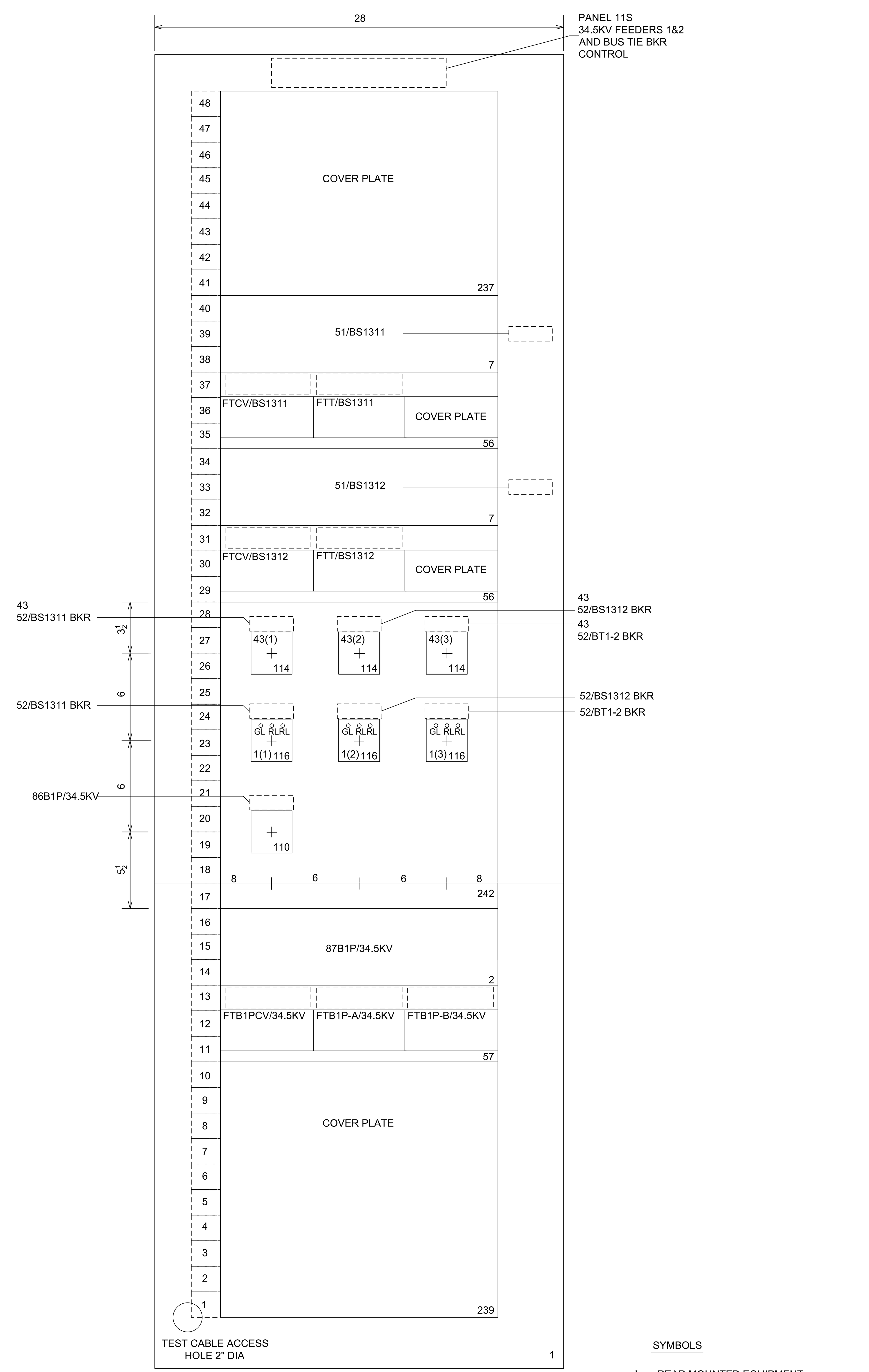
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
345/34.5KV
PANEL 10S
TR2 PRI AND SEC PROTECTION
PANEL ELEVATION

NH-275117-10

REV
3

1	2	3	4	5	6	7



FRONT VIEW

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
2	87B1P	1	SCHWEITZER ENG. LAB. TYPE SEL-587Z; CAT. #0587Z0X325H12XX
7	51	2	SCHWEITZER ENG. LAB. TYPE SEL-351; CAT. #035163C3J542X1
56	FT-19R	2	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493000AX08
57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493493AX08
110	86B	1	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 20 N.O. & 20 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22, OVAL-SHANK HANDLE
114	43	3	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE
116	1	3	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)
237	COVER PLATE	1	COVER PLATE 19"W X 14"H
239	COVER PLATE	1	COVER PLATE 19"W X 17 $\frac{1}{2}$"H
242	COVER PLATE	1	COVER PLATE 19"W X 21"H
* 251	FB	8	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ
* 253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
* 254	TB	16	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
* 256	TB	4	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC

ITEM	DEV	QUAN	DESCRIPTION

SYMBOLS

* REAR MOUNTED EQUIPMENT.
NAMEPLATES FOR DEVICE
NAMEPLATE DENOTING CIRCUIT CAUTION

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1	ISSUE FOR RECORD - BLAZEING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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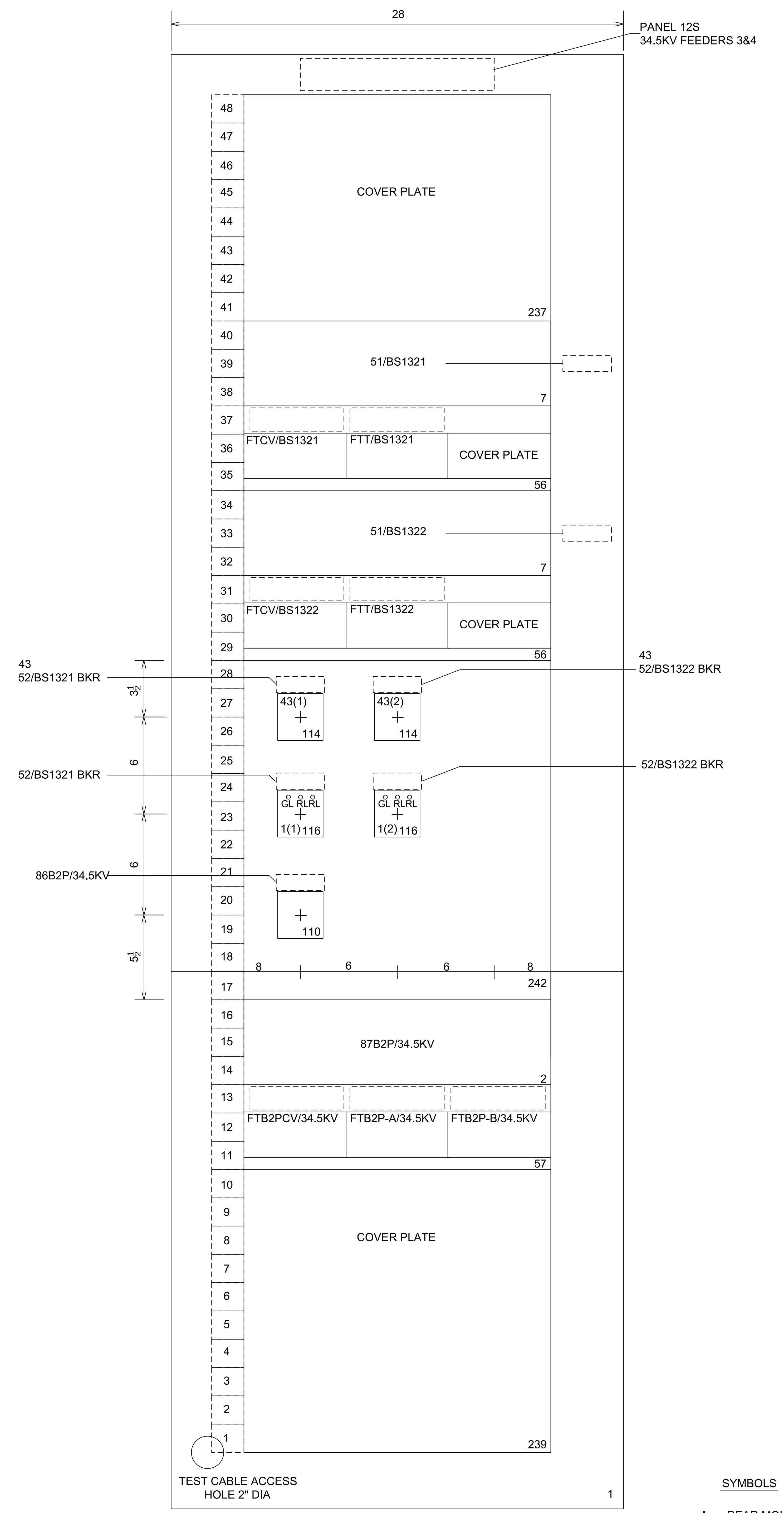
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
34.5KV
PANEL 11S
FEEDERS 1&2, BUS TIE CTRL AND RLY'G
PANEL ELEVATION

NH-275117-11

REV 2



FRONT VIEW

ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)
2	87B2P	1	SCHWEITZER ENG. LAB. TYPE SEL-587Z; CAT. #0587Z0X325H12XX
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56	FT-19R	2	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - COVER PLATE OVER FT-1 CUTOUT, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493000AX08
57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493493AX08
110	86B	1	LOCKOUT RELAY, ELECTROSWITCH, SERIES 24 LOR, CAT# 7810D, 125VDC "D" COIL, 10 DECK 20 N.O. & 20 N.C. CONTACTS, TITLE "LOCK-OUT RELAY", ENGRAVING CODE: 17C-2L22, OVAL-SHANK HANDLE
114	43	2	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE
116	1	2	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)
237	COVER PLATE	1	COVER PLATE 19"W X 14"H
242	COVER PLATE	1	COVER PLATE 19"W X 21"H
239	COVER PLATE	1	COVER PLATE 19"W X 17 $\frac{1}{2}$"H
* 251	FB	8	FUSE BLOCK, 1 POLE, 250V, 30A, BUSSMAN, #BMM603-1SQ
* 253	FUSE	6	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10
* 254	TB	16	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
* 256	TB	4	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC

ITEM	DEV	QUAN	DESCRIPTION

SYMBOLS

- * REAR MOUNTED EQUIPMENT.
- NAMEPLATES FOR DEVICE
- NAMEPLATE DENOTING CIRCUIT CAUTION

ISSUE FOR RECORD

Ulteig ENGINEERING,SURVEYING, & CONSULTING SERVICES

NO	REVISION	ZONE	DATE	BY	CHK	ENG
0	FOR CONSTRUCTION		06-25-19	LML	JAS	KJD
1	ISSUE FOR RECORD - BLAZING STAR 1 - 22571		02-14-2020	LML	KJD	JJW

NO	REVISION	ZONE	DATE	BY	CHK	ENG

REFERENCE DRAWINGS

DWG NO.	MANUFACTURER	DESCRIPTION

Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

DWN: LML	DATE: 06-25-19	CHK:	DATE:
ENG: KJD	DATE: 06-25-19	CHK:	DATE:
PM: ML	DATE: 06-25-19	PROJ. NO: 22571	
APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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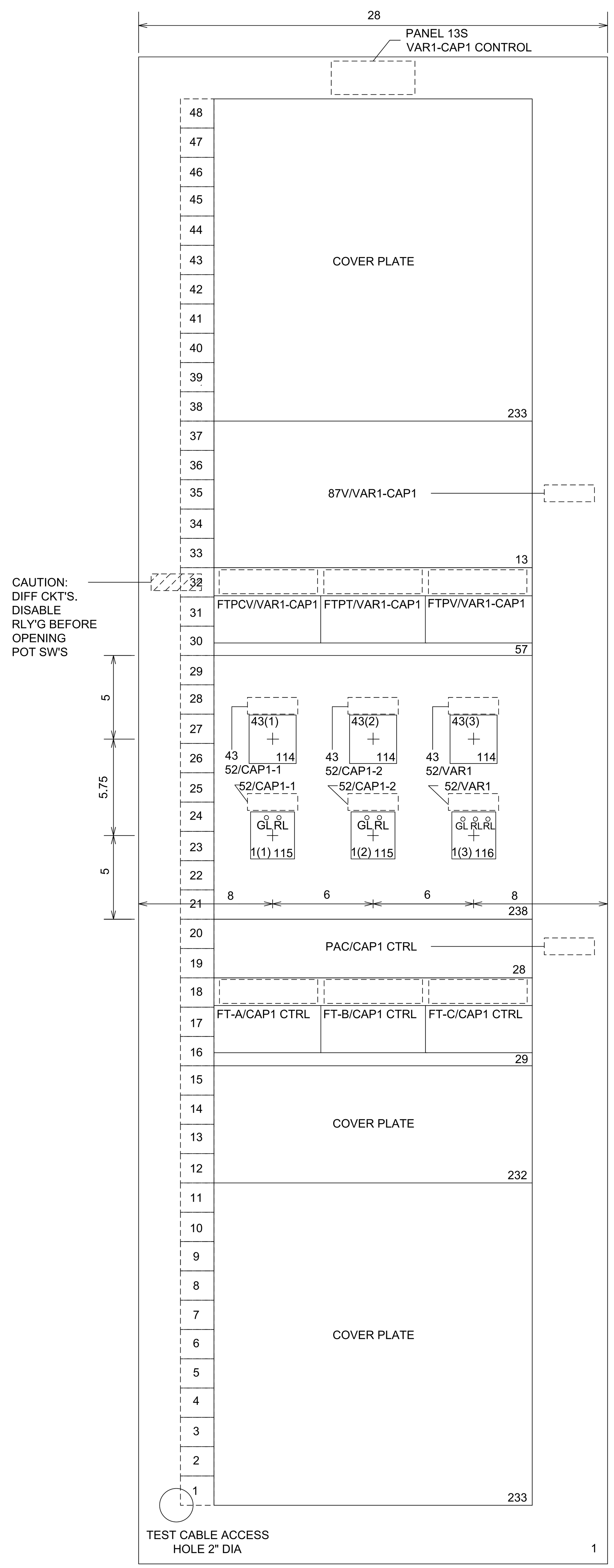
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0

34.5KV
PANEL 12S
FEEDERS 3&4 CTRL AND RLY'G
PANEL ELEVATION

NH-275117-12

REV 1



FRONT VIEW

ITEM	DEV	QUAN	DESCRIPTION	ITEM	DEV	QUAN	DESCRIPTION
1	PANEL	1	90"H X 28"W (PANEL CONST DETAIL 3300.1-1)				
13	87V	1	SCHWEITZER ENG. LAB. TYPE SEL-487V; CAT. #0487V1X4151XB0X4H54424X				
28	PAC	1	SCHWEITZER ENGINEERING LAB. TYPE SEL-2440, CAT #24402H11A6X11630.				
29	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG493493493AX08				
57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (RED) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493036AX08				
114	43	3	AUTO-MANUAL TRANSFER SWITCH, ELECTROSWITCH SERIES 24, CAT# 24902D DETENT ACTION ROTARY SWITCH, 2 POSITION, 2 DECK, 4 DOUBLE CONTACTS PER DECK, "AUTO" AT 12:00, "MAN" AT 1:30, TITLE "AUTO-MANUAL", ENGRAVING CODE: 010D-2A21K, PISTOL GRIP HANDLE				
115	1	2	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PB202QS, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: RED(RIGHT) GREEN(LEFT)				
116	1	1	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPARATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)				
232	COVER PLATE	1	COVER PLATE 19"W X 7"H				
233	COVER PLATE	2	COVER PLATE 19"W X 19 $\frac{1}{4}$"H				
238	COVER PLATE	1	COVER PLATE 19"W X 15 $\frac{3}{4}$"H				
*251	FB	10	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ				
* 253	FUSE	7	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10				
* 254	TB	12	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD				
* 256	TB	1	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC				

SYMBOLS

- INSTRUCTION LEAFLETS TO BE FURNISHED BY PANEL FABRICATOR.
- * REAR MOUNTED EQUIPMENT.
- NAMEPLATES FOR DEVICE
- NAMEPLATE DENOTING CIRCUIT CAUTION

ISSUE FOR RECORD

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REFERENCE DRAWINGS

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Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

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APVD: KJD	DATE: 06-25-19	SCALE: NONE	

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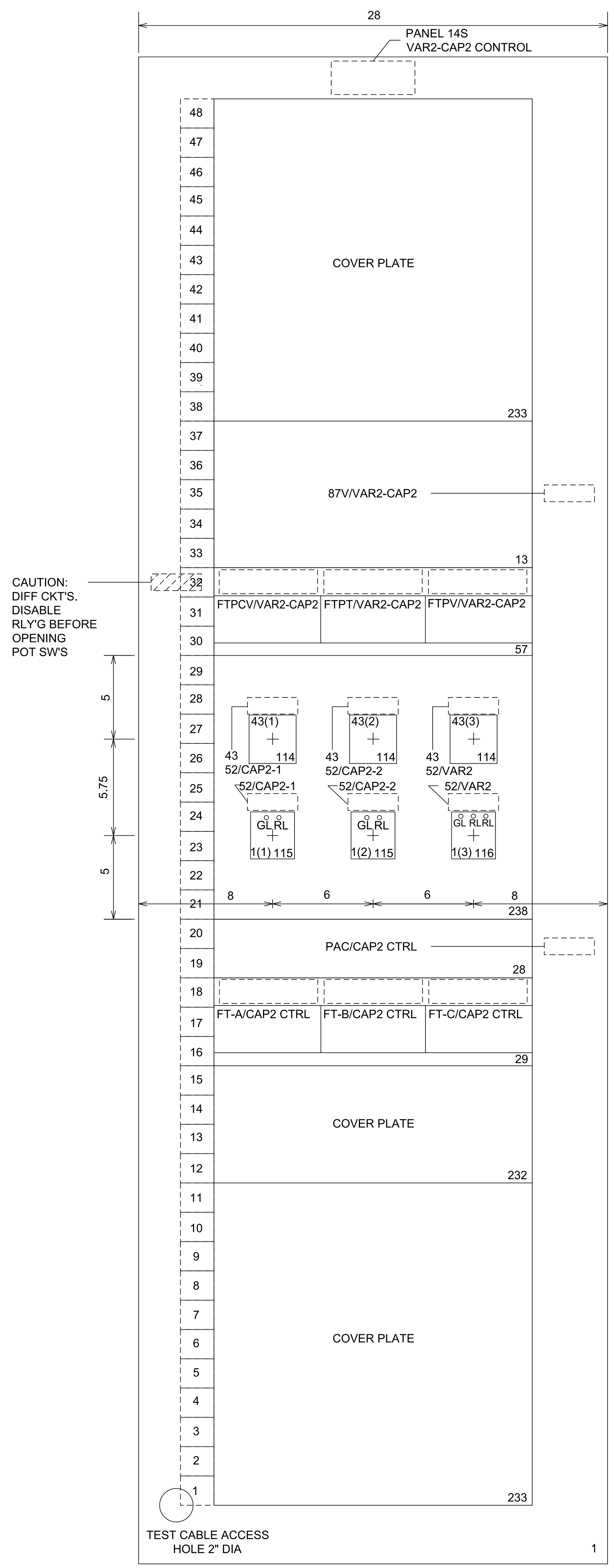
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0

34.5KV
PANEL 13S
VAR1-CAP1 CONTROL & RLY'G
PANEL ELEVATION

NH-275117-13

REV 1



FRONT VIEW

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28	PAC	1	SCHWEITZER ENGINEERING LAB. TYPE SEL-2440, CAT #24402H11A6X11630.				
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57	FT-19R	1	SWITCH BOX, ABB CORP., TYPE FT-19R, 3RU(LO) HEIGHT, SCREW TERMINALS, INCLUDES: POSITION A - 6 CURRENT (BLACK) AND 4 POTENTIAL (RED) HANDLE SWITCHES, POSITION B - 0 CURRENT (BLACK) AND 10 POTENTIAL (BLUE) HANDLE SWITCHES, POSITION C - 0 CURRENT (BLACK) AND 10 POTENTIAL (RED) HANDLE SWITCHES, FULL BLACK COVER, 8" EXTENDED DEPTH. STYLE #FRXG137493036AX08				
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115	1	2	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PB202QS, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPERATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: RED(RIGHT) GREEN(LEFT)				
116	1	1	CONTROL SWITCH, ELECTROSWITCH SERIES 24, CAT# 74PDGRRX202LB, BREAKER CONTROL SWITCH, 2 POSITION, 2 DECK, ELECTRICALLY SEPARATED CONTACTS, "TRIP" AT 11:00, "CLOSE" AT 1:00, TITLE "CONTROL", OVAL-SHANK HANDLE, LIGHTED NAMEPLATE LEDS: 2 RED(RIGHT, MIDDLE) GREEN(LEFT)				
232	COVER PLATE	1	COVER PLATE 19"W X 7"H				
233	COVER PLATE	2	COVER PLATE 19"W X 19 $\frac{1}{4}$"H				
238	COVER PLATE	1	COVER PLATE 19"W X 15 $\frac{3}{4}$"H				
*251	FB	7	FUSE BLOCK, 1 POLE, 600V, 30A, BUSSMAN, #BMM603-1SQ				
* 253	FUSE	5	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 10 AMP, CAT# KLM-10				
* 254	TB	12	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD				
* 256	TB	1	TERMINAL BLOCK, 4 POINT, MARATHON CO., CAT #1504SC				

SYMBOLS

- ⬡ INSTRUCTION LEAFLETS TO BE FURNISHED BY PANEL FABRICATOR.
- * REAR MOUNTED EQUIPMENT.
- NAMEPLATES FOR DEVICE
- NAMEPLATE DENOTING CIRCUIT CAUTION

ISSUE FOR RECORD

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REFERENCE DRAWINGS

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Xcel Energy®

NORTHERN STATES POWER COMPANY

BLAZING STAR 1 COLLECTOR SUBSTATION

LINCOLN COUNTY, MINNESOTA

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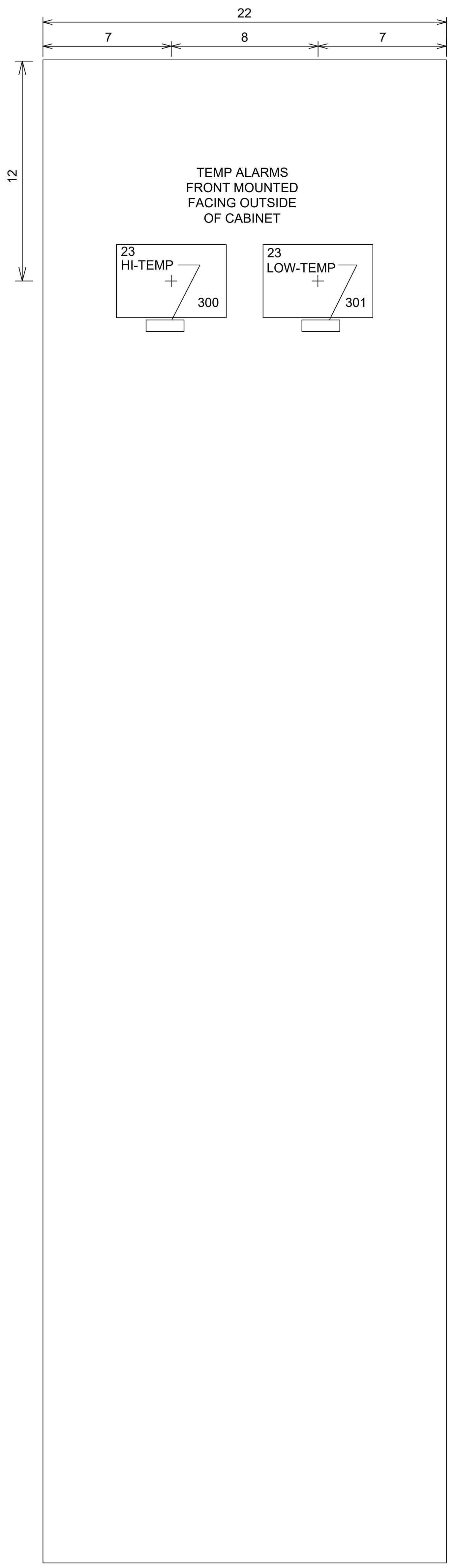
ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0
34.5KV
PANEL 14S
VAR2-CAP2 CONTROL & RLY'G
PANEL ELEVATION

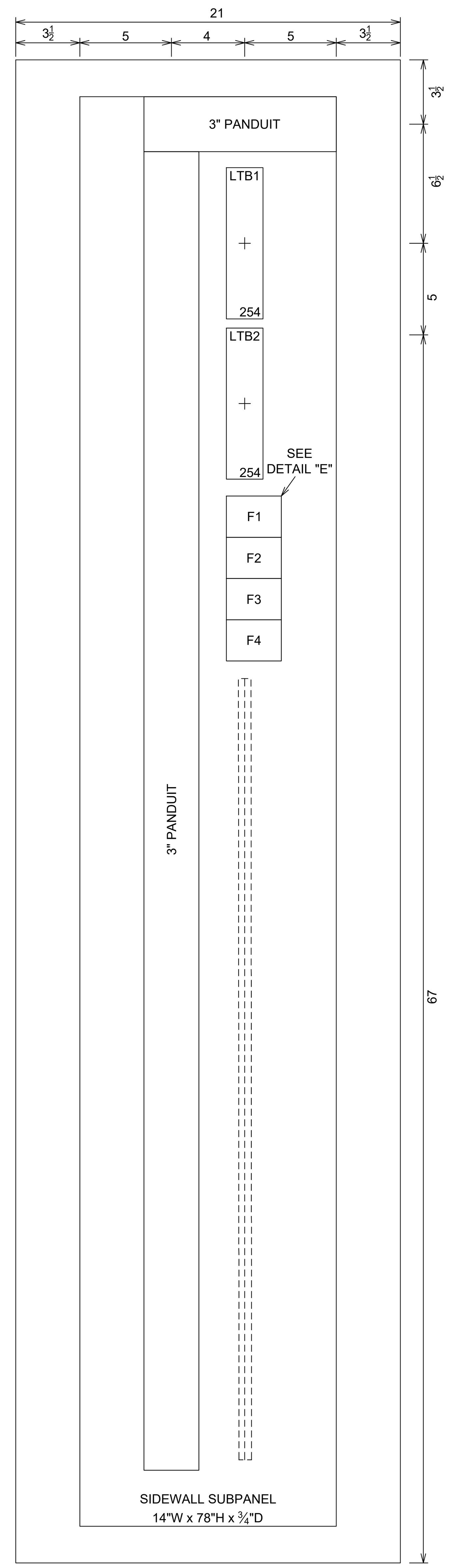
NH-275117-14

REV 1

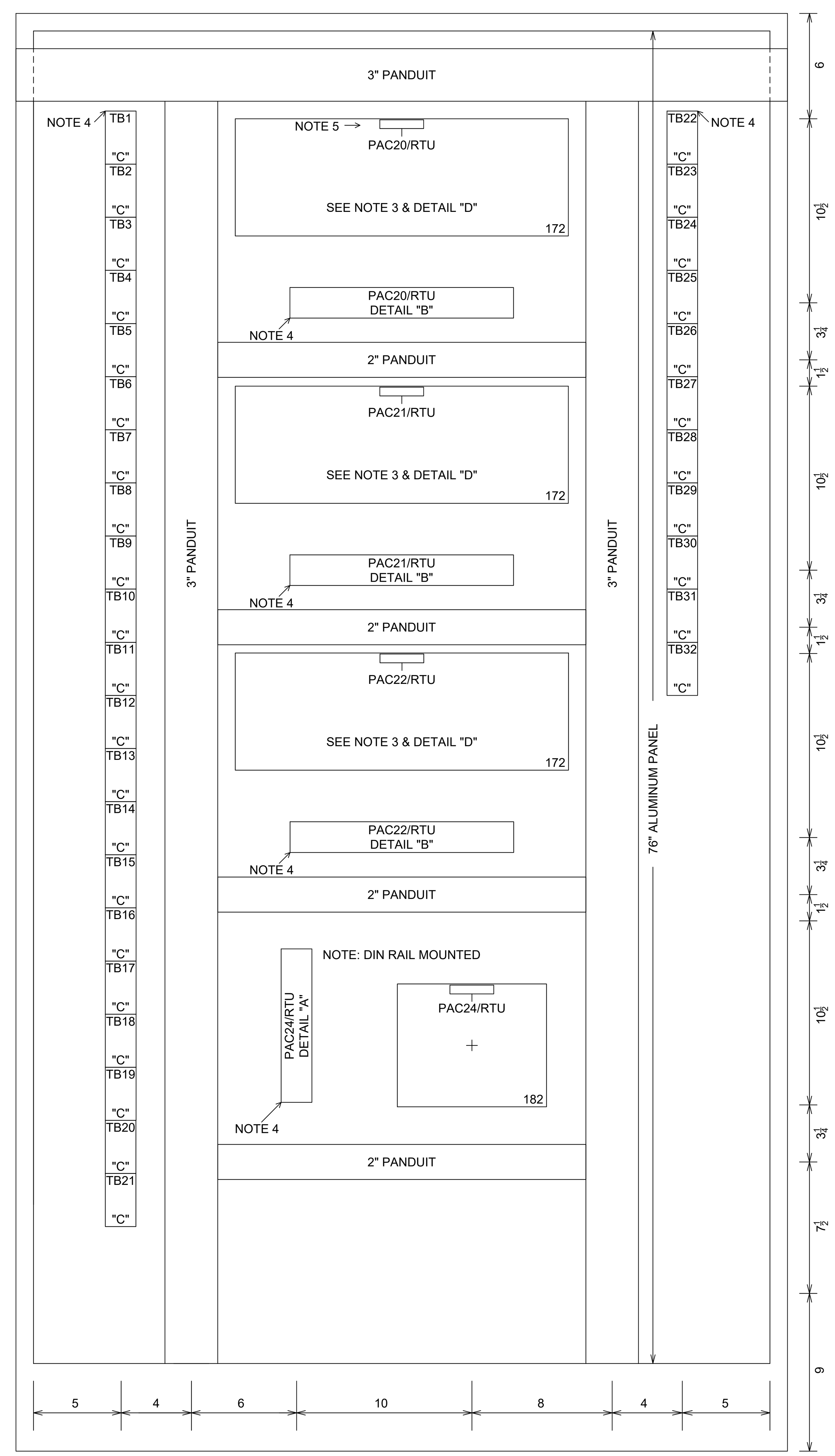
ITEM	DEV	QUAN	DESCRIPTION
4	TERM CAB	1	TERMINAL CABINET, INDOOR, GALVANIZED STEEL, 6'-10 H X 3'-8 W X 1'-9 D, PER DRAWING 3300.1-1-2
172	PAC	3	SCHWEITZER ENGINEERING LAB. TYPE SEL-2440, CAT #24402W12A1A11630.
182	PAC	1	SCHWEITZER ENG. LAB. TYPE SEL-2411, CAT. # 241111A3A3A3A520130.
251	FB	4	FUSE BLOCK, 2 POLE, 250V, 30A, BUSSMANN, CAT#HM25030-2SR
251A	FUSE	8	FUSE, COOPER BUSSMANN, 600V FAST-ACTING SUPPLEMENTAL, 5 AMP, CAT# KLM-5
254	TB	2	TERMINAL BLOCK, 12 POINT, MARATHON CO., CAT #1512 STD
270	END STOP	72	ENTRELEC END STOP (GREY), TYPE BAM, PART #206351.16
271	TB	36	ENTRELEC TERMINAL BLOCK, TYPE M 10/10.RTS, PART #115572.10
272	GRD TB	64	ENTRELEC TERMINAL BLOCK, TYPE M 4/6.P, PART #165113.16, TERM BLOCK FOR GROUND WIRES, MARKING GREEN + YELLOW BODY WITH RAIL CONTACT
272A	END SECT	32	ENTRELEC END SECTION (YELLOW), TYPE FEM6, PART #103062.21 (USE WITH ITEM 272)
273	SW	160	ENTRELEC SWITCH TERMINAL BLOCK, TYPE M 4/6. SNT, PART #115438.12
274	TB	48	ENTRELEC TERMINAL BLOCK, TYPE M 4/6.T, PART #115224.13
274A	END SECT	32	ENTRELEC END SECTION (GREY), TYPE FEM6, PART #118368.16 (USE WITH ITEM 274)
275	TEST PLUG	1	ENTRELEC TEST PLUG, TYPE FC2, PART #0007865.26
276	TB	172	ENTRELEC TERMINAL BLOCK, TYPE D 1,5/6.ADO, PART #199055.22
277	NAME-PLATES	1 LOT	ENTRELEC TERMINAL BLOCK NAMEPLATES
280	PANDUIT	1 LOT	PANDUIT 2"
281	PANDUIT	1 LOT	PANDUIT 3"
282	DIN RAIL	1 LOT	DIN RAIL, SQUARE D CLASS 9080, TYPE NSYSDR200
300	23/HI	1	HIGH-TEMPERATURE ALARM, HONEYWELL, FARM-O-STAT, M#T631A, TEMPERATURE RANGE 70-140 DEGREES FAHRENHEIT, S#T631A1022 (FIELD TO SET AT 110°F)
301	23/LO	1	LOW-TEMPERATURE ALARM, HONEYWELL, FARM-O-STAT, M#T631A, TEMPERATURE RANGE 35-100 DEGREES FAHRENHEIT, S#T631A1006 (FIELD TO SET AT 55°F)
302	RESISTORS	4	5 KOHM SCALING RESISTORS



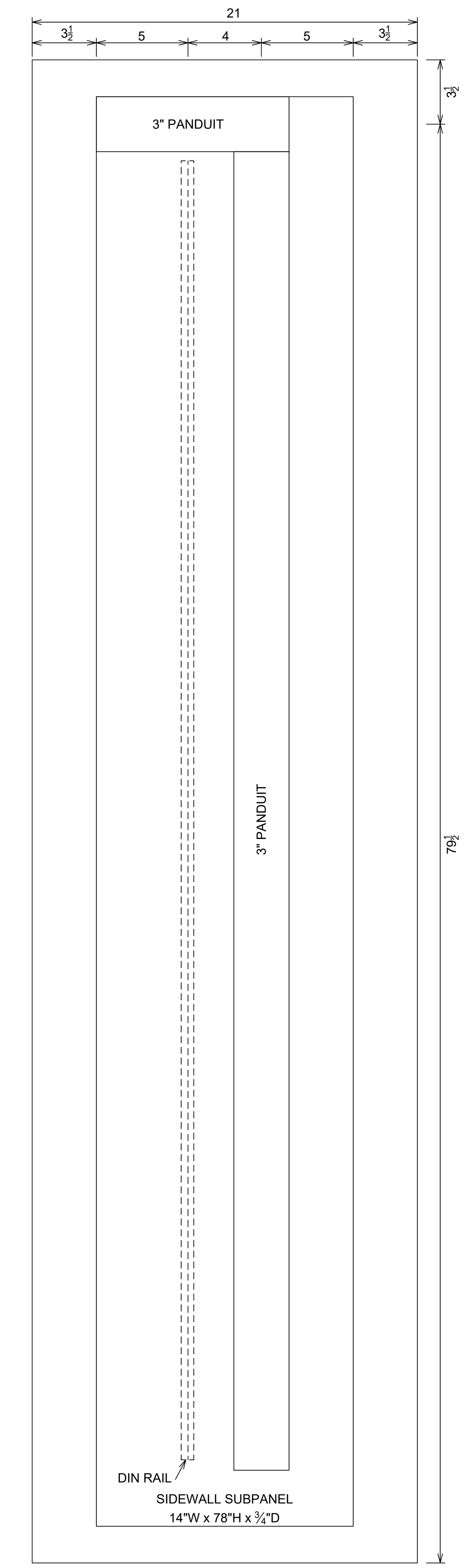
FRONT VIEW OF LEFT CABINET DOOR



LEFT SIDEWALL OF CABINET



FRONT VIEW OF CABINET WITH DOORS OPEN



RIGHT SIDEWALL OF CABINET

ITEM #	NAMEPLATE
270	(END STOP)
271	PAC*/RTU
273	+AI401
274	-AI401
273	+AI402
274	-AI402
273	+AI403
274	-AI403
273	+AI404
274	-AI404
273	+AI405
274	-AI405
273	+AI406
274	-AI406
273	+AI407
274	-AI407
273	+AI408
274	-AI408
273	+AI501
274	-AI501
273	+AI502
274	-AI502
273	+AI503
274	-AI503
273	+AI504
274	-AI504
273	+AI505
274	-AI505
273	+AI506
274	-AI506
273	+AI507
274	-AI507
273	+AI508
274	-AI508
270	(END STOP)

TYPICAL TERMINAL BLOCK ARRANGEMENT FOR SEL-2411

DETAIL "A"

ITEM #	NAMEPLATE
270	(END STOP)
271	PAC*/RTU
273	I101
273	I102
273	I103
273	I104
273	I105
273	I106
273	I107
273	I108
273	I109
273	I110
273	I111
273	I112
273	I113
273	I114
273	I115
273	I116
273	I201
273	I202
273	I203
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273	I210
273	I211
273	I212
273	I213
273	I214
273	I215
273	I216
273	I301
273	I302
273	I303
273	I304
273	I305
273	I306
273	I307
273	I308
273	I309
273	I310
273	I311
273	I312
273	I313
273	I314
273	I315
273	I316
270	(END STOP)

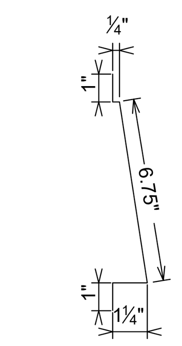
TYPICAL TERMINAL BLOCK ARRANGEMENT FOR SEL-2440

DETAIL "B"

ITEM #	NAMEPLATE	
270	(END STOP)	
271	TB*	
274	PAC INPUT POS	SEE NOTE 1
274A	(END SECT)	
276	3 TB FOR 2PR/SH CABLE 7 TB FOR 4PR/SH CABLE 15 TB FOR 8PR/SH CABLE	
272	PAIR SH	SEE NOTE 2
272	CABLE SH	
272A	(END SECT)	
270	(END STOP)	

TYPICAL TERMINAL BLOCK ARRANGEMENT FOR TWISTED PAIR CABLE

DETAIL "C"



SEL-2440 SHIM PANEL

DETAIL "D"

NAMEPLATE	251
FUSE	251
FUSE	251

2 POLE FUSE BLOCK ASSEMBLY

DETAIL "E"

NOTES

NOTE 1 : THIS TERMINAL BLOCK IS TO BE USED FOR THE PAC INPUT POSITIVE AND JUMPERED TO OTHER PAC INPUT POSITIVE BLOCKS AS NECESSARY ON THE INTERNAL SIDE OF THE BLOCK. (SEE CSUC-E21018-1)

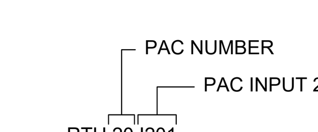
NOTE 2 : CABLE MAY NOT HAVE INDIVIDUAL PAIRS. IF THIS IS THE CASE THE PAIR SHIELD BLOCKS WILL BE SPARE.

NOTE 3 : CREATE PANEL TO SHIM THE BOTTOM OF THE SEL-2440 PAC'S OUT TO ALLOW EASIER CONNECTIONS OF WIRES TO TERMINAL STRIPS. PANEL TO BE 19" WIDE, SEE DETAIL "D" FOR OTHER DIMENSIONS.

NOTE 4 : PANEL SHOP TO SHIM OUT ENTRELEC BLOCKS SO OUTER EDGE IS FLUSH WITH OUTER EDGE OF PANDUIT. EQUIPMENT TO BE DIN RAIL MOUNTED.

NOTE 5 : RELAY NAMES TO BE LABELED WITH SELF ADHESIVE LABEL. 1/2" HIGH BY 2 1/2"" WIDE TAG WITH 1/4" LETTERING. WHITE LABEL WITH BLACK TEXT.

ENTRELEC QUANTITY BY DETAIL								
ITEM #	270	271	272	272A	273	274	274A	276
DETAIL "A"	2	1			16	16		
DETAIL "B"	2	1			48			
DETAIL "C"	2	1	2	1		1	1	3, 7 OR 15



WIRE NUMBER DETAIL

ISSUE FOR RECORD

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ENERGY SUPPLY
ENGINEERING & CONSTRUCTION

UNIT 0

345/34.5KV
PAC TERMINAL
CABINET #1
PANEL ELEVATION

NH-275117-15

REV 1

1. Operations and Maintenance Building

1.1. Design

1.1.1. Contractor shall procure and deliver and provide, in accordance with the Project Schedule and Design Documents, all services, labor, equipment, land rights, Permits, Approvals, and materials necessary to construct, assemble, erect and install a fully finished O&M building and sand shed in accordance with the Outline Specifications in this Section, but not limited to: heated & air conditioned office/SCADA space, heated shop & warehouse space, security system, paved driveway, potable water, septic system, single phase electrical service with a 400 amp minimum rating, communication wiring, exterior water faucets, outlets, and security lighting, 5 acre minimum building site, fenced gravel storage area suitable for large parts such as blades, and landscaping and wind screen. Not all items may apply to sites < 200 MW.

1.1.2. Building type shall be standardized metal panel and steel support and framing by Butler, Morton, or Owner approved alternate.

1.1.3. The minimum building size shall be based on the Project size and may be adjusted slightly to match standard materials:

Plant Rating (MW-AC)	Building Type/Size
< 200	40 ft converted shipping container
200 – 399	1,020 sq ft
400 - 799	4,140 sq ft
800+	5,758 sq ft

1.1.1. Floor plan layouts are shown in Figure 10, Figure 11, and Figure 12.

1.1.2. The site layout is shown in Figure 13 and Figure 14. The building orientation shall be fixed and the entrance road shall enter from the south. Parking lot area will need to be adjusted based on the building used.

1.1.3. The final floor and site plans shall be agreed to within 30 days following execution of the Project agreement. Issued for construction plans and specifications shall be submitted to Owner for review and approval prior to construction. Building design and construction shall be in accordance with all current state and local codes.

1.1.4. Office finished ceiling height to be 9’.

1.1.5. SCADA room ceiling minimum height is 10’.

1.1.6. Mechanical room ceiling to be building height and walls shall extend to the ceiling.

1.1.7. Shop area garage door height to be 12’.

1.1.8. Shop area ceiling height to be high enough to allow room for garage door track and lighting above garage door. Shop walls shall be finished with metal to the ceiling, including around the office area. Ceiling shall be finished in metal.

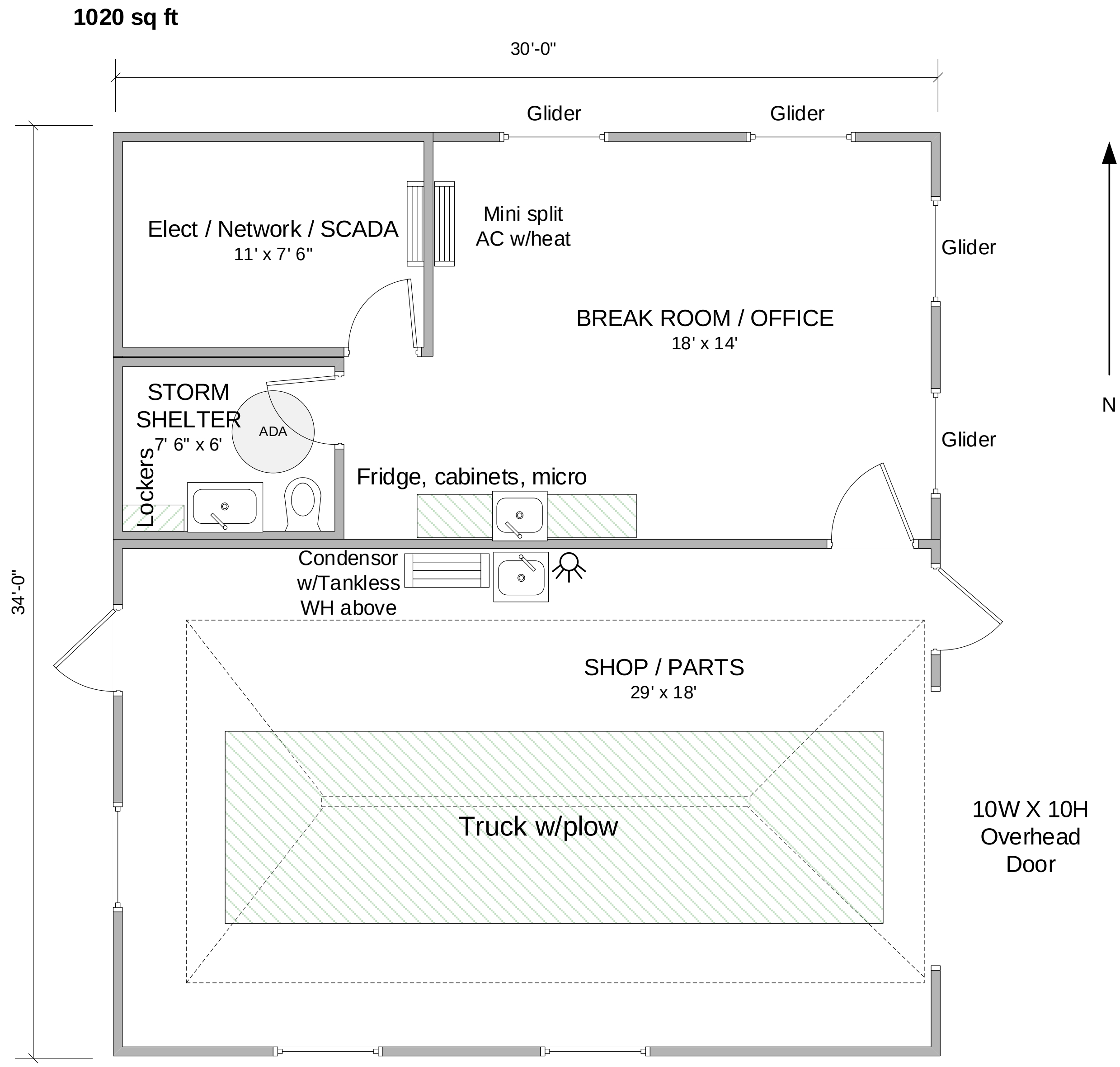


Figure 1: O&M building interior layout - 1,020 sq. ft.

4140 sq ft

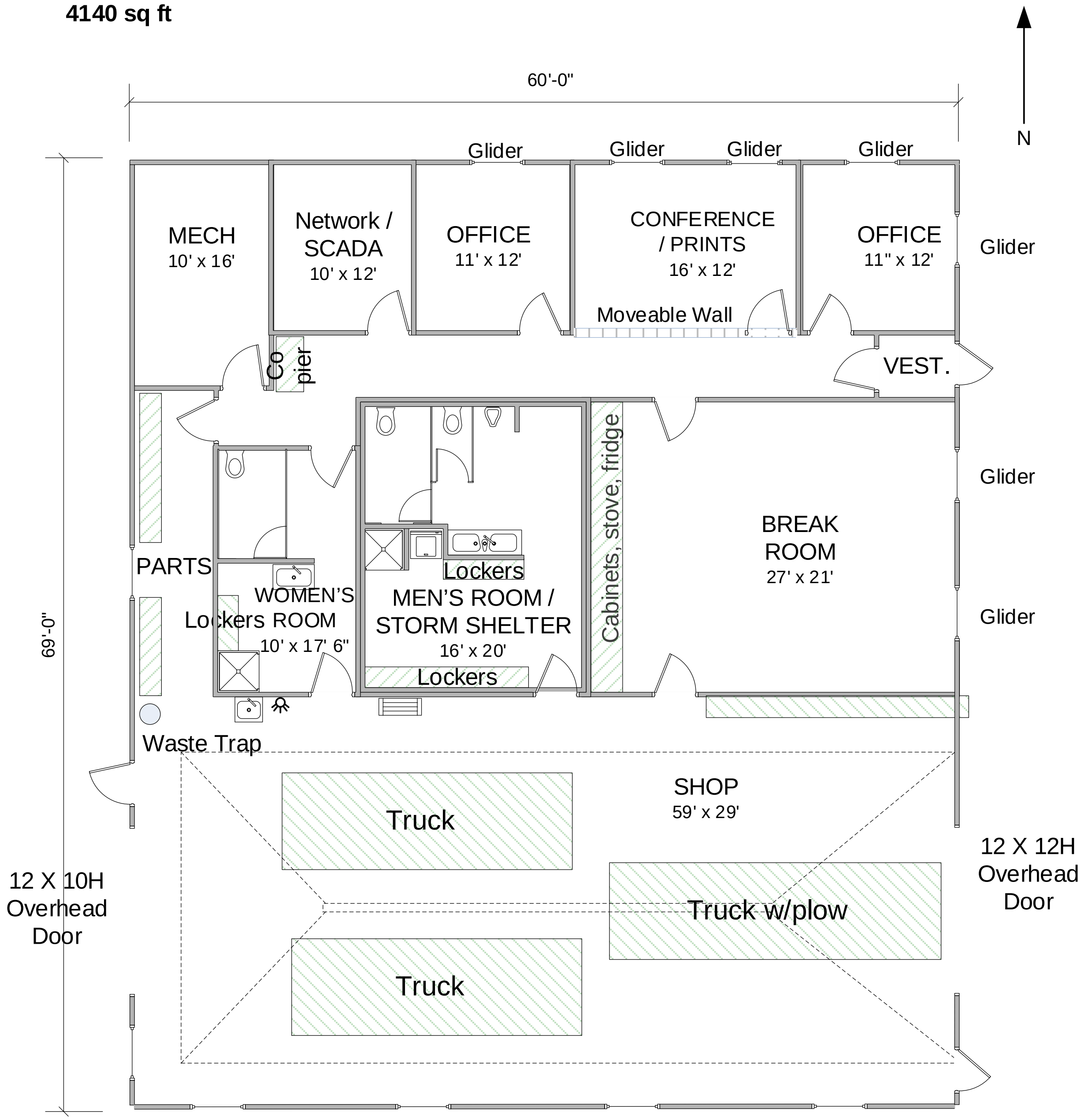


Figure 2: O&M building interior layout - 4,140 sq. ft.

5780 Sq Ft

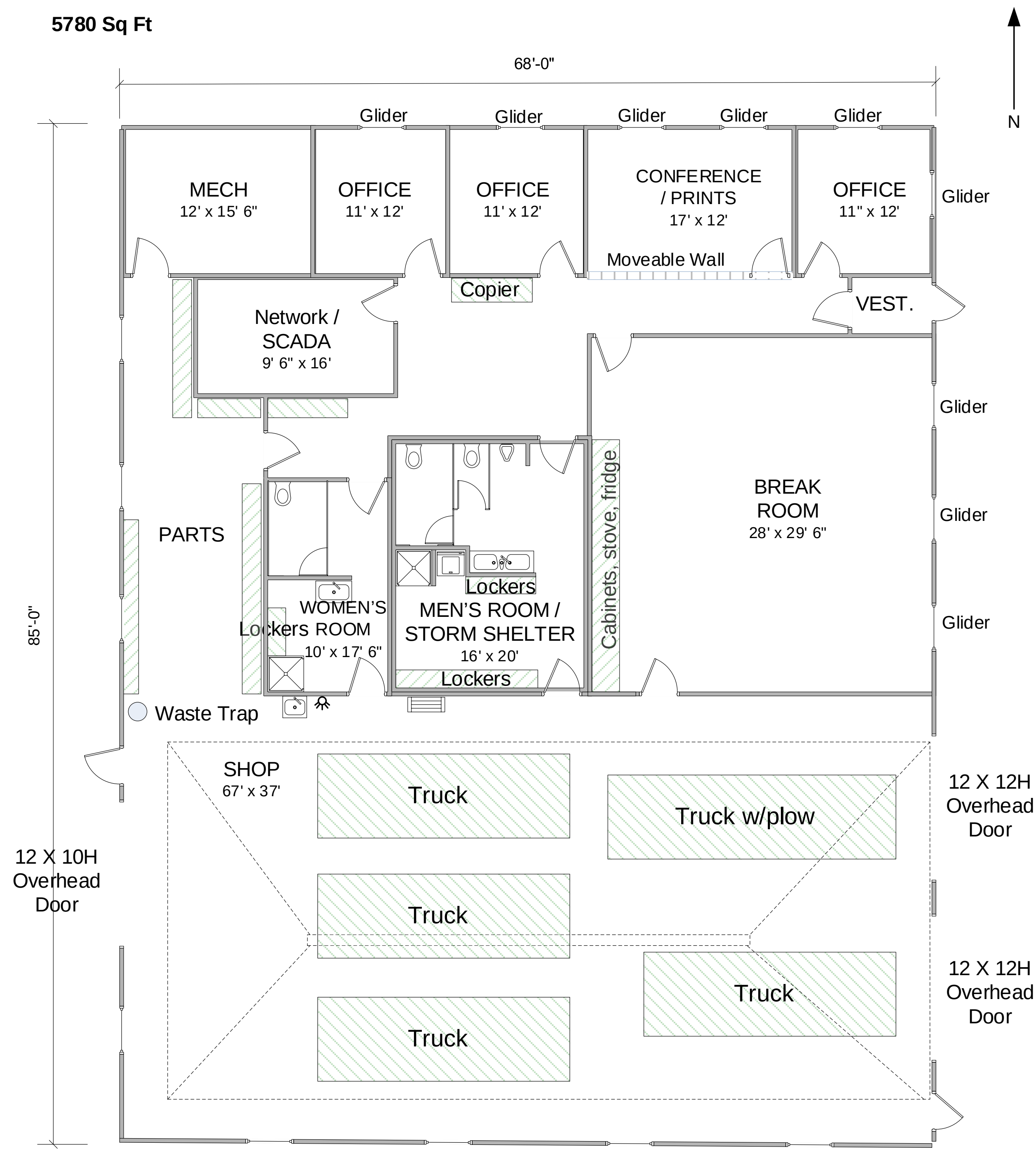


Figure 3: O&M building interior layout - 5,758 sq. ft.

Site Layout

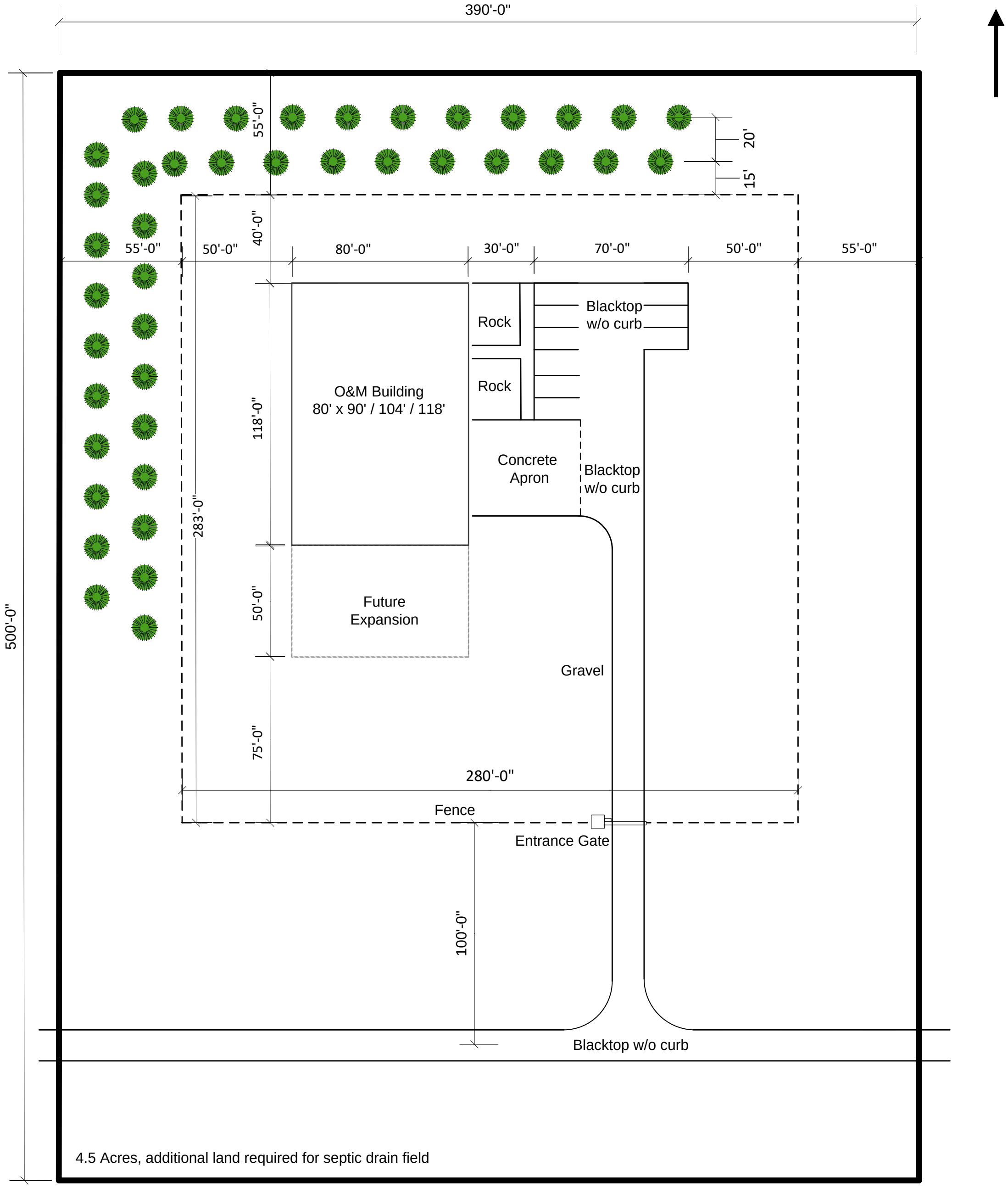


Figure 4: Typical O&M building exterior layout.

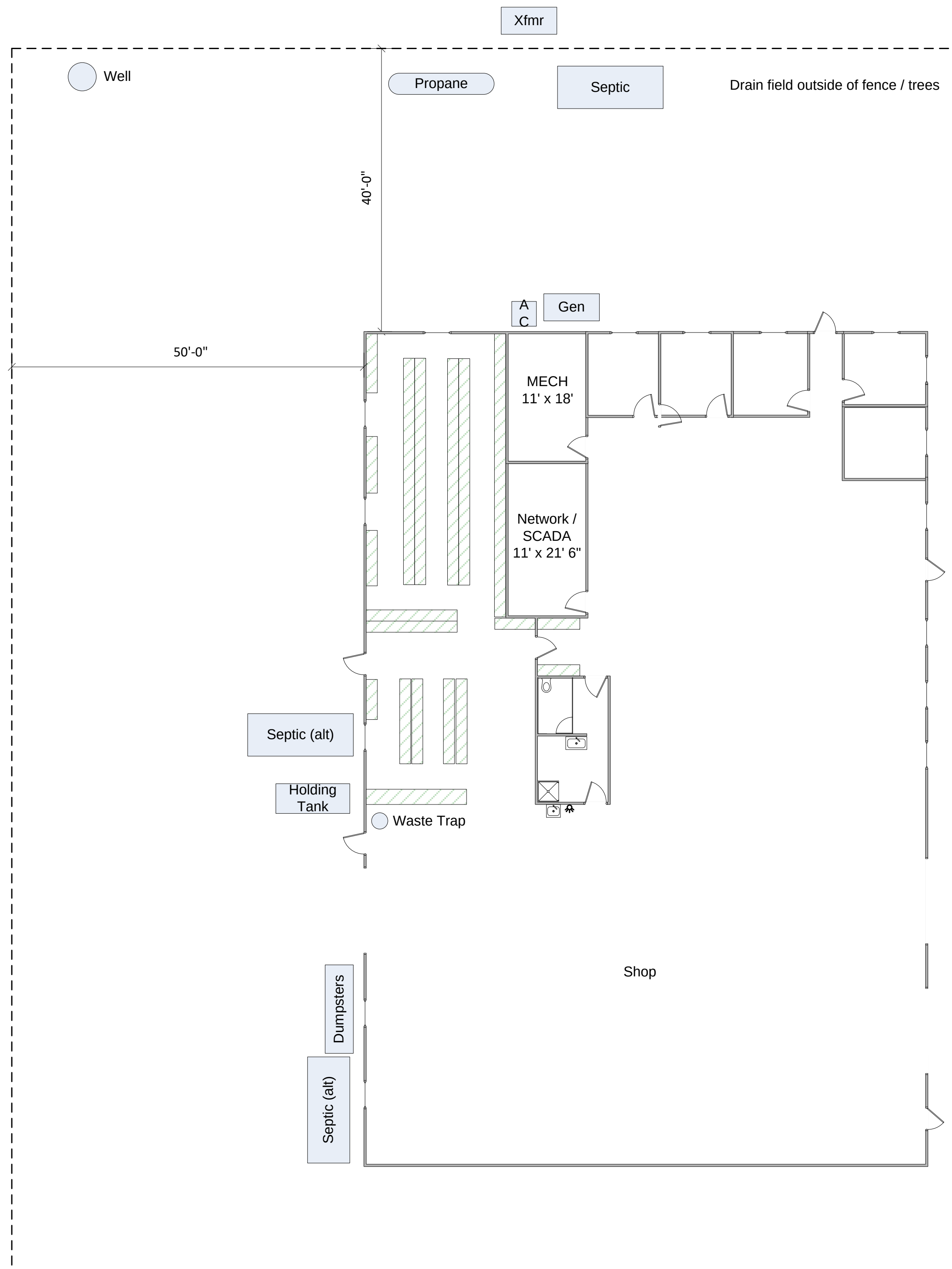


Figure 54: O&M building exterior utility layout.

1.2. Civil/Grading

1.2.1. Provide for excavation, grading, and backfilling as necessary for the construction of the Project, including coordination of installation of all utility services. Provide proper grade so that water shall drain away from the building.

1.2.2. Provide bollards around all exterior septic and plumbing systems including, but not limited to, holding tanks, septic tanks, and drain fields.

1.2.3. Drain field shall be sectioned off and protected from all construction equipment and traffic to prevent unnecessary soil compaction in the area.

1.2.4. Any fill necessary for yard development shall be clean granular fill supplied by Contractor.

1.2.5. Footing design shall be in accordance with the Geotechnical Report and associated soil testing.

1.2.6. Contractor shall provide drive accesses, as required, and shall obtain any necessary permits.

1.2.7. Provide lawns and planting for new building. Work shall be performed as follows:

1.2.7.1. Spread fertile topsoil stripped from site over all seeded grass and sod areas to a minimum of 4”.

1.2.7.2. Select vegetation shall be suitable for the location and climate and be free of weeds. Select vegetation shall be established on all disturbed land on the O&M property outside of the security fence. The Contractor shall submit the select vegetation type to be used for approval prior to planting. Disturbed areas shall be vegetated within the specified time period as indicated in the project SWPPP to minimize/eliminate runoff. All vegetated areas shall be free of weeds.

1.2.7.3. In NSP and PSCo regions, plant evergreen trees around the exterior of the fence enclosure on north and west sides of the building in order to provide protection during the winter season. On the west side of the building, the trees shall extend past the future building expansion area while the trees on the north side shall extend 100 ft beyond the building. Shrubs shall be planted on the remaining sides. Minimum tree height shall be 8 feet. Trees shall be planted every 18 feet in two rows separated by 20 feet, staggered between rows.

1.2.7.3.1. Watering and periodic inspections shall be performed and documented in a maintenance log on a bi-weekly basis.

1.2.7.4. Washed rock with landscaping fabric shall be used between the sidewalk and East wall of the building.

1.2.7.5. Landscape plan shall be submitted for approval by Owner prior to construction.

1.2.8. Provide concrete apron in front of garage doors and bituminous paved driveway and parking area for 8 cars. Work shall be performed as follows:

1.2.8.1. Contractor shall perform final grading as necessary for proper drainage, and furnish and install base and wearing surface complete, compacted, and rolled as per standards of the State’s Department of Transportation.

1.2.8.2. Area receiving concrete or bituminous paving shall have an 8” compacted base meeting Section 4.1.1.1 and the paving shall be applied in two layers: 3” of plant mixed bituminous base and 1 1/2” of plant mixed bituminous surfacing.

1.2.8.3. Concrete and bituminous paving shall meet design and installation requirements per the State’s Department of Transportation Standard Specification in which the project is located.

1.2.8.4. Slope 1/8” per foot away from the building.

1.2.8.5. Stripe all parking positions as required for handicap and standard parking. Handicap parking stall shall be an end stall if possible.

1.2.9. Gravel areas shall have a minimum of 6” of compacted base or crushed gravel per Section 4.1.1.1 and shall have elevations graded to accomplish a proper drainage pattern. Slope 1/8” per foot.

1.2.10. Security fencing information can be found in Section 2.7.

1.2.11. Provide 6” diameter guard posts constructed of 1/4” thick steel pipe, filled with concrete, at overhead doors interior and exterior to building. Guard posts shall be a minimum of 4 feet above the concrete and shall be designed and installed to prevent frost heave at exterior applications. Paint guard posts yellow.

1.2.12. Exterior Walls

1.2.12.1. Exterior walls shall be insulated 26 gauge pre-finished metal panel. Color selected by Owner.

1.2.12.2. Exterior walls shall have an R value in accordance with the current International Energy Code with Local and State Building Code amendments.

1.2.12.3. Exterior office area walls shall be spray foamed at least 1” thick to seal air gaps up to a height of 10 ft in the NSP region.

1.2.13. Roof System

1.2.13.1. Roof to be a standing seam metal-roof sloped with gable ends. All roofing materials are to be installed and constructed to provide a ten-year guarantee against leakage.

1.2.13.2. The roof shall have an overall R value in accordance with the current International Energy Code with Local and State Building Code amendments.

1.2.13.3. Roof sloped to drain.

1.2.13.4. Gutters provided in areas over walkways, doors, exterior equipment, or office windows. Gutters on the east wall shall only have 2 discharge locations, 1 at each end of the building to prevent ice buildup on the concrete and flooding of the rock area. Double down spouts may be required and overtopping of the gutters is acceptable during heavy rain. Include erosion measures, rock and/or splash block, from each down spout on the building.

1.2.13.5. Gutters shall incorporate back-up drain scuppers.

1.2.13.6. Detail roof edge to prevent built up snow drop-off.

1.2.13.7. Provide awnings over building access doors located on non-gable end walls. Awnings are to be directly attached to building walls, i.e. no exterior columns. Awnings shall be constructed of light gage steel.

1.2.13.8. Provide perimeter fascia with factory applied baked enamel finish and constructed of 24 gauge steel minimum. Owner will select color from manufacturer's standard colors.

1.2.13.9. Provide insulated roof curbing as required for all roof-mounted equipment.

1.2.14. Interior Walls

1.2.14.1. All interior walls shall be constructed as shown in the Design Documents.

1.2.14.2. All masonry walls are to be constructed of a minimum of 8" standard weight block.

1.2.14.3. Stud and sheet rock walls are to be framed with 3 5/8" 18 gauge metal studs, 24" o.c., and covered with 5/8" gypsum board taped and sanded to accept paint or vinyl. Provide 3 1/2" thick sound control butt insulation (FHC 25/50) as manufactured by U.S. Gypsum or equal in all walls.

1.2.14.4. All interior shop walls, to include the office/shop wall, shall be finished with white 29 gauge liner panels that extend to the ceiling.

1.2.14.5. Interior shop ceiling shall be finished with white 29 gauge liner panels

1.2.14.6. The SCADA room shall be protected with ½" thick layer of plywood under the drywall.

1.2.14.7. Men's locker room shall be built to provide an effective storm shelter and safe room constructed of 8" reinforced masonry walls or 6" reinforced concrete wall, 6" hollow core precast plank or 18 gauge roof joists and 18 gauge metal roof decking with 6" minimum concrete slab, footing depths to withstand overturning/uplift and designed to withstand wind gusts during an extreme event. Design shall be in accordance with International Code Council 500 (ICC) and FEMA P-361 Safe Rooms for Tornados and Hurricanes – Guidance for Community and Residential Safe Rooms. The locker room roof shall be used for storage and signage with roof deck rating shall be posted.

1.2.15. Doors and Windows

1.2.15.1. All doors and hardware shall comply with table below.

1.2.15.2. All doors and frames shall meet building code requirements for fire ratings. Minimum door width shall be 36".

1.2.15.3. All doors shall have locking capabilities.

1.2.15.4. All exterior doors shall push open to the north and west into the prevailing wind direction.

1.2.15.5. All exterior doors and windows shall be properly insulated to meet current energy code requirements and shall be installed per manufacturer's recommendations.

1.2.15.6. Storm shelter doors shall be equipped with 3 latch points operated by a single handle, and include a deadbolt lock.

1.2.15.7. Steel Frames and Doors

Hollow metal work shall be as manufactured by Steelcraft Mfg. or equal SDI Member, as approved. Frames shall be welded unit type with a minimum thickness of 16 gauge. Exterior hollow metal doors shall be insulated (U value of 0.24 or less). All exterior doors shall be weather-stripped. Interior hollow metal doors shall be a minimum thickness of 18 gauge. Doors constructed of aluminum are not allowed.

1.2.15.8. Interior Wood Doors

Provide flush 5-ply door construction with solid particle core bonded to stiles and rails using Type 1 waterproof glue, conforming to AWI Type PC-5. Quality grade to be AWI Premium, 1 3/4" thickness, with AWI Grade A oak face veneer on all sides and edges. All interior doors except the bathrooms, SCADA, and Mechanical shall have a vertical ¼ light glass.

1.2.15.9. Overhead Doors

Provide 24 gauge factory finished (color selected by Owner) steel insulated overhead doors with 2 foot panel sections. Minimum R value to be 4.0. Doors to have perimeter brush seal weather-stripping, and bottom astragals. Doors to have chain releases so they can be opened and closed by hand in case of power failure. Provide heavy duty cycling springs. Doors to be manufactured by Overhead Door, or equal. Provide power operators with complete control. Provide one set of controls for each door with open-close-stop functions. Provide photoelectric sensors and automatic close function.

1.2.15.10. Door Glass Lights

Provide tempered clear float glass, ASTM C1048, Type I, Class 1, q3, Kind FT, horizontally tempered, 1/4" thick, as required for door glass lights.

1.2.15.11. Door Hardware

Provide the following hardware by the listed manufacturers or approved equals:

1.2.15.11.1. Butts -- Stanley FBB199, US26D, 1 1/2 pair

1.2.15.11.2. Closer -- LCN 4010/4111 Series, Exposed overhead surface type, Alum., see table below for applicable locations.

1.2.15.11.3. Kick Plates -- Hiawatha 10" x 34", US32D

1.2.15.11.4. Stops and Holders -- Ives, US32D

1.2.15.11.5. Push-Pulls -- Hiawatha, US32D, ADA approved

1.2.15.11.6. Lock Sets -- Schlage L9000 Series, US26D, mortised (no substitutions), Function as noted on Design Documents, ADA approved lever. All exterior doors and SCADA room lock sets shall be card reader capable and comply with security system requirements. Owner shall supply additional requirements.

1.2.15.11.7. Passage Sets -- Schlage L9010 Passage Function, US26D, mortised (no substitutions), ADA approved lever

1.2.15.11.8. All locks shall be master keyed with a restrictive key way master keying system as directed by Owner.

1.2.15.11.9. All required blank plates.

1.2.15.12. Door Detail – Install per the following table:

Location	**Material**	**Light**	**Closure**	**Handle**
Breakroom to Hall	Wood	1/4	N	Lever
Breakroom to Shop	Metal	1/4	Y	Lever
Exterior excl Vestibule	Metal	1/4	Y	Lever Lock / Card
Hall to Shop ceiling	Metal	1/4	Y	Lever
Mechanical	Wood	None	N	Lever
Offices & Conference	Wood	1/4	N	Lever Lock
Restroom - Guest	Wood	None	Y	Lever Lock
Restroom – Mens	Metal	None	Y	Lever lock w/3 point
Restroom – Womens	Metal	None	Y	Lever
Restroom – Womens to Hall	Wood	None	Y	Lever
SCADA	Wood	None	Y	Lever Lock / Card
Vestibule – Exterior	Metal	1/2	Y	Lever
Vestibule – Interior	Metal	1/2	Y	Lever Lock / Card

1.2.15.13. Exterior Windows

All windows shall be of vinyl construction. Face shall snap out for easy glass replacement. Windows shall be tinted insulated glass units; IGCC Class CBA when tested per ASTM E773 and E774; dual sealed unit with primary polyisobutylene seal, secondary silicone seal. Provide outer and inner lights of ¼” thick tinted glass conforming to ASTM C1036 Type I, Class 1, q3; and a ½” argon filled airspace; total thickness of 1”. Windows shall have a U value in accordance with the current International Energy Code with state building code amendments.

Operable windows shall be gliding type and shall be located in all offices and break room.

1.2.16. Admin Area Desk

1.2.16.1. Construct a built in reception style desk with studs and drywall for the veritical frame and 24" deep countertops for the sit down desk and 15" deep countertops for the walk up portion. Overall height to be 42".

1.2.17. Finishes

1.2.17.1. Ceramic Tile

1.2.17.1.1. Ceramic tile shall be installed, grouted, cleaned, protected, and cured per standard specifications of the American National Standards Institute (ANSI) and the Tile Council of America (TCA). Grout shall be Latex-Portland Cement Tile Grout as made by Custom Building Products, Mapei Corp. or approved equal. Grout and ceramic tile colors to be selected by Owner.

1.2.17.2. Floor Tile

1.2.17.2.1. Provide ceramic standard mosaic floor tile with smooth, all-purpose edge. Tile shall be 1' x 1' unglazed as manufactured by American Olean or approved equal. Provide all special shapes as required.

1.2.17.3. Wall Tile

1.2.17.3.1. Provide standard glazed 6" x 6" or 4" x 4" wall tile as manufactured by American Olean or approved equal. Provide all special shapes as required. Wall tile shall cover all locker rooms and unisex bathrooms to a minimum height of 4'-6" from the top of finished floor.

1.2.17.4. Ceiling Treatment

1.2.17.4.1. For ceilings outside the high bay area, but excluding the SCADA room, Vestibule, and Mechanical Room, provide a lay-in type ceiling. Lay-in ceiling shall be a 24" x 24" with 15/16" exposed white grid system. Grid system shall be USG Interiors or approved equal. Acoustical panels shall be non-combustible (Flame Spread A), smooth-texture with reveal edge, factory white finish similar to USG Interiors, Millennia ClimaPlus 76705, 2' x 2' x ¾", SLT edge. Acoustical ceiling panels to have a minimum Noise Reduction Coefficient (NRC) rating of 0.7, Ceiling Attenuation Class (CAC) of 35 minimum and Light Reflectance of 85 (LR-1).

1.2.17.4.2. SCADA room and the Vestibule ceiling shall be covered with 5/8 gypsum board taped and sanded to accept paint or vinyl and backed with 3 ½ thick sound control butt insulation (FHC 25/50) as manufactured by U.S. Gypsum or equal.

1.2.17.4.3. Mechanical Room ceiling to be metal panel or drywall at full building height.

1.2.17.5. Resilient Flooring

1.2.17.5.1. Clean and prepare floors as necessary for proper application of vinyl tile. Provide 12” x 12” x 1/8” thick vinyl composition tile (VCT) similar to Armstrong “Excelon” or Tarkett “Expressions.” Owner will select colors from manufacturer’s standard colors.

1.2.17.6. Carpet

1.2.17.6.1. The following manufacturers meet Owner’s standard for carpet tiles:

Constantine Commercial

Mannington

Lees

1.2.17.6.2. Yarn

100% advanced generation nylon such as type 6.6 produce by:

BASF

DuPont

Monsanto

1.2.17.6.3. Minimum yarn wt. 26 oz.

1.2.17.6.4. Minimum construction features

Pile height 0.170 to 0.28 inches

1/8 gauge with 8 stitches per inch or,

1/10 gauge with 10 stitches per inch

1.2.17.6.5. Primary Backing Synthetic

Polypropylene

1.2.17.6.6. Vinyl Base

Provide 4” high vinyl base as manufactured by VPI, Johnsonite or approved equal. Use coved base with vinyl composition tile (VCT) and carpet tiles. Colors to be selected by Owner from manufacturer’s standard colors.

1.2.17.7. Paint

1.2.17.7.1. Strictly follow manufacturer’s recommendations for surface preparation and paint application. Colors to be selected by Owner. Paint to be Benjamin Moore, Sherwin-Williams or approved equal.

1.2.17.7.2. Wood

Sand and prepare surfaces to receive finish. All finished hardwood to receive one coat of stain, one coat of sealer, and two coats of varnish.

1.2.17.7.3. Metal

All metal doorframes and doors and miscellaneous metals shall receive one coat of primer and two coats of enamel.

1.2.17.7.4. Interior Walls

Masonry interior walls shall receive one coat of block filler and two coats of finish paint. Gypsum board walls shall receive one coat of primer and two coats of finish paint.

1.2.17.7.5. Exterior Walls

Exterior walls to be finished as required by the exterior wall material. If exterior walls are masonry, apply one coat of block filler and two coats of enamel.

1.2.17.8. Millwork

1.2.17.8.1. Provide custom millwork in the breakroom consisting of upper and lower cabinets with stove and fridge cutouts in the location shown on floor plan Figures 10-12. Cabinets shall fill the area from wall to wall, include a short upper cabinet for a microwave over the stove, and be similar in arrange to the reference picture at the end of this section. Millwork shall be, of quality fire retardant particleboard core finished with wood veneer (AWI “premium” grade) or plastic laminate (NEMA LD 3, GP-50 for horizontal surfaces and GP-28 for vertical surfaces). Pattern and color selected by Owner. Tops to be 1 3/4” thick and sides to be 3/4” thick. Countertops and Vanities are to have a 4” backsplash. Provide adequate bracing hidden from view.

1.2.17.9. Lockers – 72” tall lockers shall be installed in both restrooms and shall be wall hung with an integrated bench. Owner to specify quantity relative to building size.

1.2.17.10. Finish Schedule – See Table 24, all final colors subject to Owner approval.

Table 1: Finish schedule.

Material	Color	Location
Acoustical grid	White	
Acoustical tile	White w/reveal edge	
Canopy	Brown	
Canopy soffit	White	
Carpet tile	Dark blue speckled w/various	Offices, conference
Ceramic floor tile	Matt dark grey, light black	Restrooms, vestibule
Ceramic grout	Pewter	Restrooms, vestibule
Ceramic wall tile	Matte grey / smoke	Restrooms
Door hardware	Satin Nickel	
Laminate cabinet	Honey oak to light cherry	Break room
Laminate countertop	Matte black marble	Break room, restrooms, admin
Locker	Tan	Restrooms
Locker bench	Honey oak	
Metal roof panel	Galvalume	Roof
Metal trim	Tan	Exterior
Metal wall panel	Tan	Exterior
Metal wall panel	White	Shop/parts walls and ceiling
Outlet cover	Light almond	All but shop/parts
Outlet cover	Steel grey	Shop, parts
Overhead door	Brown	Shop
Paint	SW 6101 Sands of Time	Vestibule, admin, hallways
Paint	SW 7059 Unusual Grey	All other areas
Plumbing fixture	Satin Nickel	
Steel door and frame	Black	
Toilet Partition	Slate	
VCT	Tan	Breakroom, SCADA, hallways
Vinyl base	Black	
Wood door	Light cherry	

1.3. Structural

1.3.1. The Work under this section shall include the complete construction of all concrete work on the Project for concrete footings, floors, sidewalks, and all necessary accessories, setting of anchor bolts, ties, etc.

1.3.1.1. All concrete shall have a minimum compressive strength per Section 4.1.3:

1.3.1.2. Provide two (2) coats of sealer over all concrete slab-on-grade areas per manufacturer’s recommendations, except those areas receiving floor finishes, e.g. VCT tile, carpet, etc. Sealer to be Sonneborn, Tremco, or equal.

1.3.1.3. Provide cork expansion joint material, ASTM D1752-67, Type II in expansion joints for interior work as required, and seal over with Vulkem 116 or equal. Provide fiber expansion joint material, Flexcell or equal in expansion joints for exterior work as required, and seal over with Vulkem 200 or equal.

1.3.1.4. Concrete reinforcement shall be shop fabricated per design drawings. Field bending of reinforcement shall be in accordance with applicable sections of ACI 318. Shop drawings shall be submitted for review prior to construction.

1.3.1.5. Column anchor bolts, dowels, reinforcement, embed plates, etc. shall be supported by chairs, bolsters, bar supports, spacers, etc. prior to concrete placement. "Wet Setting" of reinforcement, dowels, anchor bolts, embed plates, etc. is not allowed.

1.3.1.6. Embeds for shop floor drain shall be galvanized.

1.3.1.7. Floor slab and aprons to be 6" thick minimum, and sidewalks to be 4" thick minimum.

1.3.1.8. Slope exterior concrete surfaces away from the building. Sidewalk slope shall be at least ¼" per foot while driving paths and parking lots shall be sloped at least 1/8" per foot.

1.3.1.9. Concrete Specialties

1.3.1.9.1. Provide concrete steps or aprons at personnel door(s), overhead doors, and at bottom of stairs.

1.3.1.10. Construction

1.3.1.10.1. Contractor shall require that the concrete subcontractor has a minimum of 3 years of experience with commercial concrete construction and concrete floor finishing.

1.3.2. Foundation wall and under slab insulation, when required by location, shall be extruded polystyrene board insulation, ASTM C578, Type IV, 1.6 pcf density minimum, "k" factor of 0.20 at 75 deg. F (R-5), 25 psi minimum compressive strength, 0.3 percent maximum water absorption by volume, square edges, manufacturer's standard board size, such as Styrofoam SM manufactured by Dow Chemical Co., Foamular 250 manufactured by Owens Corning, or approved equal. Thickness noted on Design Documents. Install on the perimeter of the foundation and wrap around under the concrete slab floor 4'-0".

1.4. Electrical

1.4.1. All Electrical Works shall be in accordance with the regulations of the latest edition of the National Electrical Code and all state and local codes. All wiring to be copper and in conduit.

1.4.2. Service Entrance

1.4.2.1. The local utility shall provide a transformer and primary service to the transformer. Contractor shall provide the secondary service into the building and is responsible for verifying the entrance location with the local utility. Contractor shall be responsible for the coordination with the local utility on the placement of the transformer. Contractor shall coordinate with local utility in metering installation.

1.4.2.2. The electrical service to this building shall be single phase and sized to accommodate all electrical loads with 30% contingency and a 400 amp minimum. The service entrance equipment shall be grounded per code, and the grounding conductor installed in conduit.

1.4.3. Power Distribution

1.4.3.1. Provide a Square D or equal panel board type NQOD.

1.4.3.2. Provide panel board identification with an engraved plastic laminate nameplate.

1.4.3.3. Panelboards shall have Square D QO breakers rated for a minimum of 10,000 A.I.C. at 240V Panel boards to be suitable for use as service entrance equipment and shall have a hinged door and lock.

1.4.3.4. Panel boards shall have a minimum of 42 circuits and a 200A minimum bus rating. Contractor shall size breakers and provide power for all electrical loads.

1.4.3.5. Provide a typed directory of circuits mounted behind clear plastic inside the panel board door.

1.4.4. Lighting System

1.4.4.1. Provide lighting throughout the building as follows:

1.4.4.1.1. All rooms except shop, parts storage, and mechanical room: Lay-in type 2, 3, or 4 lamp LED fixtures with parabolic lens, electronic ballasts, T-8 lamps, lighting level 40 foot-candles at 3 feet off floor, Lithonia or equal.

1.4.4.1.2. Shop, parts storage, and mechanical room: Industrial type 2 lamp, 4 and/or 8 foot long LED fixture with baked enamel reflector, electronic ballast, T-8 lamps, lighting level 20 foot-candles at 3 feet off floor, Lithonia or equal.

1.4.4.1.3. Exterior: LED wall mounted fixtures suitable for outdoor wet location centered on each exterior wall (quantity 4), prismatic lens, factory installed photo electric control on each fixture.

1.4.4.1.4. Exit Lights: LED type exit lights.

1.4.4.1.5. Recessed can light with shower trim in each shower stall.

1.4.5. Wiring Devices

1.4.5.1. Shop to have quiet toggle wall switches. Switches shall be rated at 15 or 20 A, 120 VAC. Switches shall be similar to Hubbell 1221 Series. Receptacles shall be similar to Hubbell 5262 Series.

1.4.5.2. Furnish and install occupancy sensors in offices, conference room, break room, mechanical room, SCADA room, small parts room, locker rooms and restrooms.

1.4.5.3. Switches and receptacles shall be light almond in all areas except the shop, which shall be gray. Cover plates shall match switches and receptacles in all areas except for shop and parts storage areas where the covers shall be galvanized steel.

1.4.5.4. Provide a 240 VAC outlet in the shop to the south of the west garage door and to the south of the man door from the office to the parts area.

1.4.5.5. Provide a 240 VAC outlet in the Men's Locker room for the stackable washer and dryer unit.

1.4.5.6. Provide one 120 VAC exterior receptacle on each side and in between the two shop overhead doors and one 120 VAC exterior receptacle on each of the remaining 3 sides of the building.

1.4.5.7. Provide a 120 VAC flush mount floor receptacle in the center of the conference and break rooms.

1.4.5.8. Provide two 120 VAC twist lock 30A receptacles and one 120 VAC 20A duplex receptacle to Owner corporate network rack. Receptacles shall be mounted in 4 square boxes. Owner to confirm mounting locations.

1.4.5.9. Provide two 120 or 240 VAC 30A circuits and one 120 VAC 20A circuit to each Turbine Supplier server cabinet. Confirm size with Turbine Supplier.

1.4.5.10. Provide 5 lug ground bar that is grounded directly to the service ground mounted on the wall of the SCADA room.

1.4.6. Communications/Data Telephone System

1.4.6.1. Contractor shall provide all necessary wire and conduit/raceway including conduit for communications/data needs. Communication circuits shall be ran in cable tray above ceiling with conduit extending down into walls.

1.4.6.2. A single wall box with 2 data ports is required in each office, parts room, admin area, and conference room.

1.4.6.3. The break room shall have 2 wall boxes with 2 data ports each with both located on the wall between the break room and the shop.

1.4.6.4. Flush mounted floor boxes with 3 data ports shall be installed in the center of the conference room.

1.4.6.5. Flush mounted floor boxes with 7 data ports shall be installed in the center of the break room.

1.4.6.6. Provide a telephone jack in each of the wall and floor boxes listed above.

1.4.6.7. All Ethernet wiring shall be Cat 6 type cable.

1.4.6.8. Coordinate installation work with local telephone Owner and Owner's Communication Technicians.

1.4.6.9. Owner will order communication circuits.

1.4.7. Low Voltage Wiring

1.4.7.1. Provide all low voltage wiring for HVAC control and run in conduit.

1.4.8. Back-up Generator

1.4.8.1. Contractor shall supply and install a propane powered Generac, or Owner approved equivalent, back-up generator with the extreme cold weather kit. Generator capacity shall be 40kVA

1.4.8.2. Contractor shall supply and install an automatic transfer switch and a propane vaporizer.

1.4.8.3. All items related to the backup generator require Owner approval.

1.5. Mechanical

1.5.1. Plumbing

1.5.1.1. Contractor shall furnish and install all plumbing work in strict accordance with the State Plumbing Code and requirement of the municipality.

1.5.1.2. Contractor shall be responsible for the proper designing, sizing, and installation of all piping and equipment, specialties, etc. to provide a complete and professional plumbing design and installation.

1.5.1.3. Vehicle parking area of shop shall include a floor trench drain that flows into a minimum 260 gallon oil and water separator located to the south of the west wall garage door and then into a holding tank located outside to the north of the west wall shop door. Minimum trench width shall be 12” and depth shall be 8" below the bottom of the grating at the low point. Grating shall be galvanized.

1.5.1.4. Mechanical Room floor drain shall be positioned to allow all equipment to drain to it without the use of a condensate pump or in the walk path to the slop sink.

1.5.1.5. Provide drain in SCADA room for wall mount AC unit.

1.5.1.6. Drain line from the building to the septic tank shall be at a depth to prevent freezing from HVAC condensate flow.

1.5.1.7. The following piping shall be insulated when required by location: domestic water, refrigerant, roof drain piping.

1.5.1.8. Domestic water and refrigerant piping shall be type L copper tubing with soldered joints and fittings using lead-free No. 95-5 solders. All valves shall have brass bodies and shall be designed for a working pressure of 125 PSI. Alternatively, domestic water pipe material may be PEX type upon owner approval.

1.5.1.9. All water supply lines shall be insulated with foam pipe insulation when required by location.

1.5.1.10. Water closets – furnish floor mount, elongated rim, vitreous china water closet with tank and solid plastic open front seat. Unit to be the Toto brand. Units are to be suitable for the handicapped and mounted in accordance with ADA requirements.

1.5.1.11. Urinal – Furnish wall hung, vitreous china washout urinal and flush valve. Unit to be equal to American Standard Lynbrook 6601 with Sloan Royal Model 180-ESS flush valve.

1.5.1.12. Lavatories – Lavatory consoles are to be furnished per Design Documents. Vanity surface is to be a high-pressure plastic laminate, color and design to be selected by Owner. Lavatory unit to be vitreous china, front overflow unit. Provide fauctet and pop-up drain assembly. Console and faucet shall conform to all code requirements for the handicapped. Stand-alone sink units are not acceptable.

1.5.1.13. Water Heater – Furnish a U.L. listed tank less water heater. Unit and its installation to conform to all code requirements.

1.5.1.14. Slop Sink - Provide a 36" x 24" x 10" molded stone service basin with shelf and vinyl bumper guards on exposed faces. Equip with Chicago chrome plated service mixing faucet with vacuum breaker, wall brace, pail hook, and 3/4" hose thread on spout with 30" long 5/8" rubber hose with 3/4" chrome coupling. Provide 24" high water proof wall boards above sink basin on wall(s) adjacent to the sink along with a mop hanger above unit with three (3) rubber tool grips. Service basin to be Fiat or equal. Sink shall be located in the mechanical room.

1.5.1.15. Wash Tub - Provide a 24" x 24" wash tub in the shop between the bathroom doors. Sink shall have both hot and cold water supplied to it, along with a drain. A separate cold water hose bib shall be located next to the sink.

1.5.1.16. Eye Wash - Provide a wall mount eye wash station with drain next to the shop sink. Eyewash shall meet all applicable OSHA regulations and supply temperate water. Mixing valve shall be near the unit and accessible from ground level.

1.5.1.17. Hose Bibs – Provide freeze less hose bibs, one on each side of the building.

1.5.1.18. Domestic water, waste, and vent piping fittings and joints shall be in accordance with the State Plumbing Code and applicable local ordinances. Insulate hot and cold domestic water pipes with 1" minimum fiberglass insulation by Certainteed or equal insulation when required by location.

1.5.1.19. Break Room Sink -- Provide Elkay LR series or equal Stainless Steel sink with duo strainer and faucet.

1.5.1.20. Shower -- Provide molded fiberglass shower cabinets complete with 32" x 32" base with drain, door, Chicago or equal flow saver shower head with single lever hot and cold water operator, soap dish, and shampoo bottle holder. Cabinet to be approximately 6'-6" high and shall be seamless, rustproof, and leak proof.

1.5.1.21. Washer and Dryer hookups – Provide hot and cold water and drain hookups for stackable W/D unit in the Men's Locker Room.

1.5.1.22. Cleanout -- Provide cleanouts in areas behind water closets and as required by code.

1.5.1.23. Faucets – All faucets shall be dual handle controlled. Auto sensing devices shall not be used.

1.5.1.24. All plumbing faucets, fixtures, etc. shall be of commercial grade. Brand, type, style and color shall be approved by Owner prior to installation.

1.5.2. HVAC

1.5.2.1. Heating, ventilation, and air conditioning work shall be done in strict accordance with all applicable codes, including the State Mechanical Code, requirements of the municipality, and ASHRAE recommendations.

1.5.2.2. HVAC system shall be designed and sized to meet regional climate conditions. See Section 11.5.3.5 for Northern States Power regional HVAC system requirements.

1.5.2.3. Recommended Manufacturers

1.5.2.3.1. Trane

1.5.2.3.2. McQuay

1.5.2.3.3. AAON

1.5.2.3.4. York

1.5.2.4. General

1.5.2.4.1. Multi-zone air distribution using variable air volume (VAV)

1.5.2.4.2. Good indoor air quality design

1.5.2.4.3. All thermostat locations shall be in room programmable units with a minimum 5-2 day program and be hard-wired to a circuit board zone controller. Wireless devices are not allowed.

1.5.2.5. In-floor Heat

1.5.2.5.1. Hydronic in-floor radiant heat system shall be installed in regions subject to prolonged freezing conditions and shall be manufactured by Wirsbo or equivalent, and zoned to match forced air zones (zones to be approved by Owner).

1.5.2.5.2. Propane or gas boiler with at least 92% efficiency

1.5.2.5.3. Radiant or forced air propane or gas heaters shall be installed in the shop area in regions where radiant floor heat is not used. Placement and quantity to depend on climate and be approved by Owner.

1.5.2.6. Forced Air Furnace

1.5.2.6.1. Propane or gas furnace with at least 92% efficiency

1.5.2.6.2. 30% efficient pleated 4 inch throw away filter

1.5.2.6.3. Supply and return casing

1.5.2.6.4. Variable speed supply air drive with premium efficiency motor

1.5.2.6.5. Economizer package

1.5.2.7. Air Conditioner

1.5.2.7.1. Minimum EER or SEER ratings for package cooling unit to meet current Code requirements

1.5.2.7.2. Low-ambient operation control

1.5.2.7.3. 5 year compressor warranty

1.5.2.8. SCADA Room

1.5.2.8.1. Ductless mini-split air conditioning unit. Condensing unit to be mounted on the ground in shop area along the bathroom wall..

1.5.2.9. Shop Ventilation

1.5.2.9.1. Provide shop ventilation system with CO detector with manual override timer.

1.5.2.10. Exhaust Fans

1.5.2.10.1. Provide Greenheck vent set exhaust fans, complete with insulated roof curbs, bird screens, and back draft dampers. Restroom fans shall provide a ventilation rate meeting current Mechanical Code and ASHRAE requirements for restroom areas. Exhaust fans shall be controlled by the room automatic light switch. Provide for make-up air. Units shall be U.L. listed. Exhaust ductwork shall have 1-1/2" exterior insulation with foil extending from the roof curb to at least 6'-0" from the roof curb.

1.5.2.11. Ductwork Systems

1.5.2.11.1. All ductwork, construction, and installation shall be in accordance with latest SMACNA standards. Ductwork shall be isolated from fans and furnace via flexible connections. Ductwork shall be equipped with fire dampers as required by codes. Branch ducts in mains shall be equipped with dampers for balancing. Flex duct shall be used for the run outs to supply air diffusers. Flex duct runs shall be no longer than 5'-0" long. Each run out to each diffuser shall be equipped with a butterfly type balancing damper. Supply air ductwork shall be insulated with minimum 1-1/2" thick glass fiber exterior duct insulation with foil vapor barrier. Insulation conductivity not to exceed 0.25 BTU/in./sq. ft./hr. at a mean temperature to 75° F.

1.5.2.12. Diffusers

1.5.2.12.1. Provide Price, Titus, Hart & Cooley or equal square lay-in 2' x 2' adjustable pattern supply air diffusers.

1.5.2.12.2. Diffusers shall provide ability to manually adjust air flow in each room.

1.5.2.13. Return air ducts shall be wall mounted near the floor.

1.5.3. Security and Fire Alarm system

1.5.3.1.1. Building and Site shall include a security system provided and installed by VTI Security.

1.5.3.1.2. The system shall include card readers, associated door handles and locks, and fixed interior cameras on all exterior doors and all controlled access areas within the building as specified by Owner, two exterior mounted PTZ tower cameras and 1 fixed exterior camera with locations specified by Owner, operable entrance gate with loop detector, photo eye sensor, and call box with external dialing capabilities and pin hole camera.

1.5.3.1.3. The security system shall have a UPS, local control pad and monitor, video recording capabilities, and be linked to Owner's Security Operations Center.

1.5.3.1.4. Smoke detectors shall be installed throughout the building in a quantity large enough to effectively detect a fire.

1.5.3.1.5. Detectors shall be hardwired to a central alarm panel in the Mechanical Room, and be supplied with all necessary equipment to send an alarm signal to the Xcel Energy Security Operations Center.

1.6. Submittals

1.6.1. Contractor shall submit construction drawings for approval by Owner prior to construction.

1.6.2. Contractor shall submit to Owner copies of all equipment operating and maintenance manuals.

1.6.3. Contractor is responsible for submitting all extended warranty certificates of equipment.

1.6.4. Contractor shall submit a training plan for the O&M building operations and conduct training with select Owner personnel after the building is completed.

1.6.5. See Section 1.2 for more submittals information.

1.7. Reference Pictures

1.0 PURPOSE

1.1 To reduce the vulnerability of cyber-attack, specific requirements for cyber-security administration, monitoring, protection and oversight are applied to cyber assets within electric generating facilities.

1.2 This policy implements cyber-security requirements of the NERC Critical Infrastructure Protection (CIP) reliability and compliance program, standard CIP-003-8, “Cyber-Security – Security Management Controls” applicable to facilities designated at the low impact level. In addition, selected principles as recommended by the National Institute of Standards and Technology (NIST) are included, such as: isolation of mission-critical systems from public access; a clear delineation of logical security boundaries; use of a protected, layered architecture; least privilege access control, information protection, and operation under the assumption that any external network connection is insecure. A generalized reference architecture depicting the concepts of this policy is shown in Attachment 1.

2.0 APPLICABILITY

2.1 This policy applies to all Xcel Energy Bulk Electric System (BES) generating facilities that meet the following conditions:

2.1.1 Are identified as CIP regulated at the low impact level under the corporate program for BES Cyber System Identification and Categorization [CIP-002-5.1a].

2.1.2 Contain BES Cyber Systems (BCSs) that provide named reliability operating services. For Energy Supply, these services are in the following categories: Dynamic Response to BES conditions; Controlling Frequency; Controlling Voltage; Monitoring and Control; Restoration of the BES; and Situational Awareness [CIP-002-5.1a].

2.1.3 Utilizes microprocessor based data acquisition systems that collect or store potentially sensitive or proprietary information. This includes, but is not limited to unit and equipment operating status, production and consumption rates and environmental data.

2.2 Facilities regulated by the U.S. Nuclear Regulatory Commission are exempt from this policy.

3.0 RESPONSIBILITIES

3.1 Performance Optimization Fleet Engineering Director is responsible for designating a Regional System Administrator for each operating region (SPS, PSCo, and NSP).

3.2 Regional Systems Administrators (or delegate) are responsible to develop and document a Plant Process Network Cyber Security Plan in compliance with this policy, and initiate review and approval by Regional System Administrators. This shall include, but not be limited to:

3.2.1 Limit BCS access to those staff who need access to perform their jobs; the type and level granted shall be the minimum level required to perform the assigned work. User Name and Password authentication shall be used for all access to any device on a BCS plant network. For these systems, the default manufacturer’s password shall be changed to unique and strong passwords, where technically feasible (exceptions are documented). If a unique login is not technically feasible or will prevent an individual from being able to perform their job responsibilities in a reasonable manner a documented exception will be required.

3.2.2 Provide guidance, development assistance, and approvals for Plant Process Network Cyber Security Plans.

3.2.3 Firewall administration, including final approval and implementation of rule sets and changes to them, as justified by business need.

3.2.4 Documenting the business justification and approval for rules not being logged

3.2.5 Rules that are turned off, including factory defaults, should be properly documented

3.2.6 Compliance review and approval of the plant cyber-security plan every 15 calendar months.

3.2.7 Investigation and disposition of suspected cyber-security incidents, notification of the Cyber Defense Center (CDC) if indicated, and filing of required forms in ProjectWise.

3.2.8 Logical access to each plant BCS network shall be managed by the designated Regional System Administrator and backup, who shall review and approve the rule change form submitted by the plant network administrator where applicable.

3.3 Energy Supply CIP Senior Consultant is responsible for:

3.3.1 Review and update of this policy every 15 calendar months.

3.3.2 Update LMS course: "Plant Network Cyber-Security" every 15 months

3.3.3 Review administrator access for Regional System Administrators every 15 months

3.4 Plant Managers and Directors are responsible to provide equipment, software, and facility resources as needed to support requirements of this policy.

3.5 Plant improvement projects Project Initiators are responsible to plan for cyber-security compliance at the project initiation stage, and incorporate cyber-security implementation tasks required to comply with this policy into the project cost and schedule prior to funding and approval. Project planning for cyber-security shall employ the Enterprise Project Management (EPM) system, in accordance with policy "Screening of Projects for Impact on NERC Compliance Program (XES 7.405)".

4.0 REQUIREMENTS

4.1 CIP 003 – 8 Requirements

4.1.1 Requirement 1.2.1 - Cyber-Security Awareness: All Regional Systems Administrators, delegates, and their management supporting execution of this policy shall maintain current completion status to LMS course: "Plant Network Cyber-Security", ESNERC006, to maintain awareness of cyber-security requirements, on a refresh interval not to exceed 15 months. Corporate Program "XEL-PRO-CIP Training and Awareness Program covers the Awareness requirements for Low-Impact cyber systems.

4.1.2 Requirement 1.2.2 - Physical Security: Adherence to the "XEL-PRO-CIP Physical Security of Low Impact BES Cyber Systems" "policy is required to ensure adequate physical security at BES plants. Electronic locks and keys have been implemented at all of the plant physical security perimeters. Electronic keys have been assigned to plants and are to be logged in and out using electronic logging (eLog). Where keys were not assigned to plants they were assigned to individuals and to be used by that individual only.

4.1.3 Requirement 1.2.3 - Electronic Access Controls: only permit necessary inbound and outbound electronic access when using a routable protocol entering or leaving the asset between low impact BES Cyber System(s) and a Cyber Asset outside the asset containing low impact BES Cyber System(s). Only authorized, authenticated access to plant networks is permitted. All external communication links shall be reviewed, justified by confirmed business need, approved by Regional System Administrators, and documented and stored in the approved secure repository.

4.1.3.1 Plant network connections shall be protected by a stateful firewall, denied by default, with approved access allowed, as approved by the Regional Systems Administrator.

4.1.3.2 Direct internet access by any device on the BCS is prohibited.

4.1.3.3 Firewall ruleset change requests shall be submitted for Regional System Administrator approval and action using the active form “ES Firewall rule change request form, EPR 4.200A02”. The Regional System Administrators or designee shall file the completed forms, after disposition of the request, in the approved secure repository.

4.1.4 Requirement 1.2.4 - Cyber-Security Incident Response: All suspected cyber-security incidents shall be reported to the Regional System Administrators or delegate immediately upon suspicion of anomalous activity.

Anomalous activity is that which remains unexplained after normal plant investigation, and includes the unexpected:

4.1.4.1 loss of execution of system functions;

4.1.4.2 loss of network connections;

4.1.4.3 detection of new, unauthorized external connections;

4.1.4.4 unauthorized system access,

4.1.4.5 antivirus / malware alerts; or

4.1.4.6 general abnormal activity.

The Regional System Administrator has lead responsibility to investigate the suspected cyber incident and complete the investigation within two weeks of identification. Incident responses shall be documented using the EPR 4.200A04 “Energy Supply Cyber-Security Incident Response Checklist”. If the reported cyber incident is suspected to be of malicious intent, and not the result of an inadvertent error or equipment failure, the Regional Systems Administrator shall engage the Cyber Defense Center Hotline at (303) 571-7171, and lead or assist in the subsequent investigation and mitigating actions. Energy Supply shall participate in cyber-security incident response drills at least once every 36 calendar months as led by the involved corporate team

4.1.5 Requirement 1.2.5 - Transient Cyber Assets and Removable Media malicious code risk mitigation: Antivirus software including manual or automatic updates, OR application whitelisting, OR another method to mitigated malicious code shall be used on any device plugged into a BES Cyber System

4.1.5.1 For transient cyber assets managed by party other than Xcel Energy a review will be conducted of antivirus update, OR review of the antivirus update process, OR review of application whitelisting, OR review of use of live operating system and software executable only from read-only media, OR review of system hardening, OR other methods to mitigate the introduction or malicious code

4.1.6 Requirement 1.2.6 - CIP Exceptional Circumstances: Xcel Energy Supply follows the *Exceptional Circumstances Procedure* to review and document situations that may warrant suspension or delay in implementing certain compliance requirements as allowed by CIP standards.

4.1.7 Requirement 2 - Cyber Security Plans: each Regional System Administrator or delegate shall prepare and update a plant process network cybersecurity plan every 15 calendar months.

The Regional Systems Administrator shall review and approve the plan to ensure the required elements as stated in this policy and template EPR 4.200A01 ‘Plant Process Network Cyber-Security Plan Template’ are addressed. The plan shall be filed in a designated document repository location approved for protected Confidential and Confidential Restricted information. Plan content shall include:

4.1.7.1 An inventory of all systems with external connectivity (individual devices do not need to be listed).

4.1.7.2 An inventory of all plant network electronic access points. All assets containing low impact BES Cyber systems shall implement electronic access controls to permit only necessary inbound and outbound electronic access when using a routable protocol entering or leaving the asset between low impact BES Cyber System(s) and a Cyber Asset outside the asset containing low impact BES Cyber System(s). These access controls shall be identified and shown in cyber-security plans.

4.1.7.3 A network diagram that clearly shows the physical connection the electronic access point, the electronic security perimeter, and all devices to which logical access is provided. Plant network communication access points shall be clearly identified if they control BCS logical access. Inbound and outbound traffic through the access point shall be limited to essential communications only. The network diagram may group devices by system or functionality, to show overall connectivity.

4.1.7.4 The plan shall identify and reference procedures to perform system backup and recovery of BCSs. System backup shall be performed at least every 15 months, or, no less than prior to and after every major controls modification. Backup media shall be protected from unexpected catastrophic failure.

4.1.8 Requirement 3 – CIP Senior Manager Approval: The CIP Senior Manager is David Harkness and evidence of this can be found here: XEL-EVD-CIP Senior Manager Delegation

4.1.9 Requirement 4 – CIP Senior Manager Approval Delegation: Adherence to the XEL-PRO-CIP Delegation of Authority Procedure will be observed for the Delegation of Authority for Energy Supply

4.2 Additional Security Practices

4.2.1 Internal Connectivity: Plant control networks containing cyber assets with generation capacity that exceeds 1500 MW in a single Interconnection will be evaluated for a higher classification. Reasonable effort is made in order to maintain a low classification including but not limited to sectionalizing.

4.2.2 Remote Station Control: plant control networks shall not control more than one other BES facility, remote from the facility. Remote plant controls shall be isolated from the host plant network. [CIP-002-5.1a]

4.2.3 Use of Security Zones: Whenever possible, equipment of similar function and security access control needs should be placed in the same subnet

4.2.4 Operating System and Application Whitelisting: BCS servers should be configured so that only those programs that are needed for operation and are trusted are installed.

4.2.5 Remote Access to Plant Networks: Remote access to plant networks shall be restricted to those authorized with an approved business need, documented and controlled. Use of an Xcel Energy computer with current cyber-security endpoint protections, an encrypted connection, and user authentication is required. When available, additional controls should be applied, including:

4.2.5.1 Restriction to only required processes and applications, using role based access control; and

4.2.5.2 Use of an intermediate system, such as a jump server, to limit installed applications to those needed, that has native malware protection, and requires a separate user authentication prior to connection to plant networks.

4.2.6 Current Operating Systems, Applications and Hardware: Plant networks should have current operating, hardware and software systems that are supported by the involved manufacturers to provide current antivirus and malware signatures and operational patches. A plant improvement project request shall be submitted using the EPM system if any plant network equipment is no longer supported by the vendor and requires upgrade in order to maintain current cyber-security protections.

4.2.7 Patch Management and virus/malware definitions: Regional System Administrators or delegate shall update patch and virus/malware definitions for BCS networks, in accordance with instructions provided by systems vendors. A description of patch activity completed each year and reference to instructions used for BCS patches shall be documented per the annual network inspection checklist, EPR 4.200A03. If virus and patch updates cannot be maintained on a current basis, exceptions shall be documented with justification on the inspection checklist. A direct connection from a BCS to an external network for patch and virus/malware signature download is not permitted. Updates shall be performed by use of removable media that are used to transfer the updates from a WAN connection to the BCS network. The media shall be scanned to detect malicious code on Removable Media using a Cyber Asset other than a BES Cyber System; and mitigation of the threat of detected malicious code on the Removable Media prior to connecting Removable Media.

4.2.8 Plant network inspection: At least every 15 months, physical network inspections shall be performed to confirm current configuration of all external connections. The inspection shall be performed in accordance with the "Plant Network Cyber-Security Inspection Checklist" EPR 4.200A03.

4.2.9 Information Security: All outputs of this procedure (plant cyber-security plans, inspection checklists, suspected cyber-security incident checklists, firewall ruleset changes) shall be controlled in accordance with the corporate program for Confidential and Confidential Restricted Information Protection.

5.0 RECORDS

5.1 A cyber-security plan EPR 4.200A01, will be completed and approved by the Regional System Administrator, and filed in the ProjectWise repository designated for Confidential and Confidential Restricted Information.

5.2 Each Regional System Administrator or designee shall maintain records in the Energy Supply ProjectWise folder for Confidential and Confidential Restricted Information as follows:

5.2.1 Firewall connection change requests, approvals, and business justifications as documented in the completed form, EPR 4.200A02.

5.2.2 Completed cyber-security inspection checklists, EPR 4.200A03.

5.2.3 Suspected Cyber Incident investigation and reporting activities, completed form EPR 4.200A04.

6.0 REFERENCES AND DEFINITIONS

6.1 Bulk Electric System (BES) Generators: All units connected to the grid at 100kv or greater and have a gross nameplate rating greater than 20Mva; and dispersed generation facilities with multiple units that have an aggregate gross nameplate rating greater than 75Mva connected to a common bus, and connected to the grid at greater than 100 kV. In depth BES definition with inclusion and exclusions can be found on the NERC website.

6.2 National Institute of Standards and Technology (NIST) Cyber-Security Guides: Engineering Principles for Information Technology Security, NIST Special Publication 800-27; NIST Special Publication 800-82, Guide to Industrial Control Systems Security; and NIST-Guidelines on Firewalls and Firewall Policy.

6.3 BES Cyber Assets (BCAs): Programmable electronic devices essential to the reliable operation of a BES plant, including the hardware, software, and data in those devices. A BCA is a device that if rendered unavailable, degraded or misused, would create a generation outage or de-rate within 15 minutes.

6.4 BES Cyber Systems (BCS): One or more BES Cyber Assets logically grouped into a functional system that perform one or more of the following Reliability Operating Services (BROS):

6.4.1 Dynamic Response to BES Conditions (e.g. Automatic Generation Control (AGC) and Energy Management Systems(EMS), PSS/AVR systems)

6.4.2 Controlling Frequency (e.g. Real Power, such as automatic governors)

6.4.3 Controlling Voltage (e.g. Reactive power, such as AVR/PSS systems)

6.4.4 Monitoring and Control (e. g. Plant BCS)

6.4.5 Restoration of BES (e. g. Blackstart facility BCS)

6.4.6 Situational Awareness (e.g. AGC/EMS/plant DCS)

6.5 Cyber-Security Incident: Any malicious act or suspicious event that: Compromises, or was an attempt to compromise, the Electronic Security Perimeter or Physical Security Perimeter, or, Disrupts, or was an attempt to disrupt, the operation of a BES Cyber System. [NERC Glossary]

6.6 Transient Cyber Asset (TCA): a cyber asset that is: capable of transmitting or transferring executable code, not included in a BES Cyber System, and directly connected (e.g. using Ethernet, serial, Universal Serial Bus, or wireless including near field or Bluetooth communication) for 30 consecutive calendar days or less to a BES Cyber Asset (NERC Glossary modified to exclude high and medium references)

6.7 Removable Media: storage media that: are not Cyber Assets, are capable of transferring executable code, can be used to store, copy, move or access date, and are directly connected for 30 consecutive calendar days or less to a BES Cyber Asset. (NERC Glossary modified to exclude high and medium impact references)

6.8 Security Zone: In networking, a security zone isolates one or more network devices (zone A) from one or more other security zones (zone B,C,D,etc.). Each of these other zones also consists of one or more network devices. Each zone that you define can be as enormous as the entire Internet or as small as a single device (or even as small as the particular individual using a specific device).

6.9 Regional System Administrator: The Fleet Engineering lead for network security monitoring and technical support assigned in each of the three Xcel operating regions: NSP, PSCo, and SPS.

6.10 Plant Network: The interconnected microprocessor based generator control systems and supporting systems that provide functions such as data acquisition, unit and equipment operating status, equipment optimization, performance monitoring, production and consumption rates and environmental monitoring.

6.11 EPR 4.200A01 Plant Network Cyber-Security Plan Template located on the Performance Optimization Policy Index web page.

6.12 EPR 4.200A02 ES Firewall Rule Change Request located on the Performance Optimization Policy Index web page.

6.13 EPR 4.200A03 Annual Plant Network Cyber-Security Inspection Checklist located on the Performance Optimization Policy Index web page.

6.14 EPR 4.200A04 Energy Supply Cyber-Security Incident Response Checklist located on the Performance Optimization Policy Index web page.

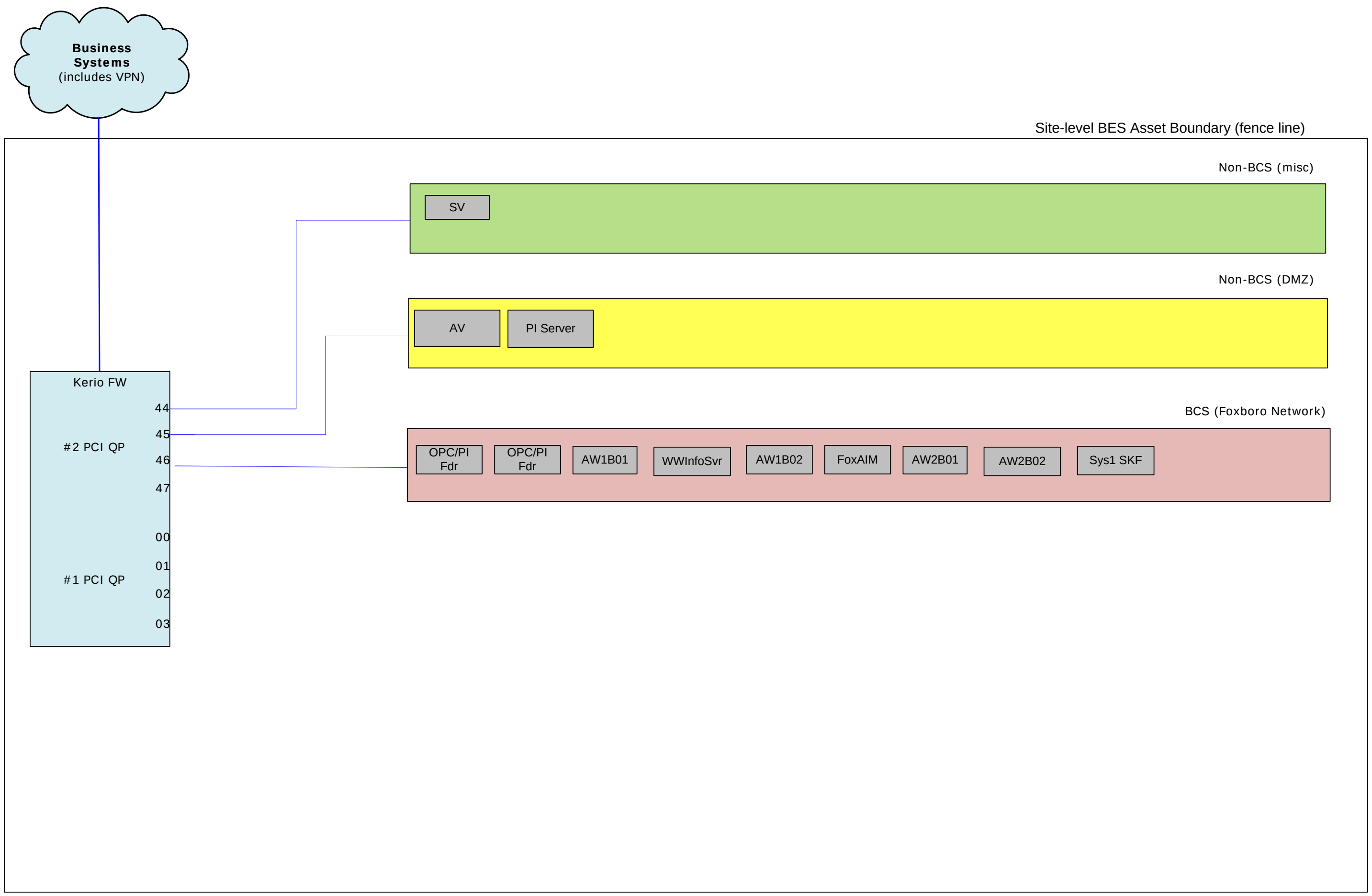
7.0 REVISION HISTORY

Date	Revision	Change
04/12/2013	1.0	Original Issue Supersedes ESO 4.200 to align accountabilities with re-organization. Included best practice security requirements from various sources, including FERC Order and NIST, in preparation step to begin alignment with expected future cyber-security requirements. Detailed requirements moved from this policy to supporting plant cyber-security plan template EPR 4.200_A01.
04/27/2015	1.1	Implementation phase is complete. Deleted note regarding implementation plan in section 1.2. Deleted section 5.0 ‘Implementation Plan’ in its entirety.
09/29/2015	2.0	Updated formatting to comply with XES 1.100P01 Configuration Management for ES Policies and Procedures. Sections re-ordered to improve readability. Revision to align with CIP version 6 requirements and/or Internal Audit Observations as follows: • Revised EPR 4.200A01 Plant Network Cyber-Security Plan Template to document system access and type as required in new NERC terms of LERCs, LEAPs, and BROS;

Date	Revision	Change
		• Added EPR 4.200A02 ES Firewall Rule Change Request to document Energy Supply firewall rule changes; • Added EPR 4.200A03 Annual Plant Network Cyber-Security Inspection Checklist to document patch management instructions and activities; • Added EPR 4.200A04 Energy Supply Cyber-Security Incident Response Checklist to document potential cyber-security incidents and notification of required parties if indicated; and • Added EPR 4.200A05 Modem Session Log to document modem sessions. • Updated definition section to align with NERC terms.
04/11/2017	3.0	• Minor clarifications for accuracy to NERC Standard verbiage. • Changed Annual references to 15 calendar months. • Removed reference to Work Orders in section 4.11 due to move from SAP to Maximo. Added reference to corporate Physical Security Policy and Corporate Awareness Program. Updated formatting to comply with XES 1.100P01 Configuration Management for ES Policies and Procedures. Sections re-ordered to improve readability. Revision to align with CIP version 6 requirements and/or Internal Audit Observations as follows: • Revised EPR 4.200A01 Plant Network Cyber-Security Plan Template to document system access and type as required in new NERC terms of LERCs, LEAPs, and BROS; • Added EPR 4.200A02 ES Firewall Rule Change Request to document Energy Supply firewall rule changes; • Added EPR 4.200A03 Annual Plant Network Cyber-Security Inspection Checklist to document patch management instructions and activities; • Added EPR 4.200A04 Energy Supply Cyber-Security Incident Response Checklist to document potential cyber-security incidents and notification of required parties if indicated; and • Added EPR 4.200A05 Modem Session Log to document modem sessions. • Updated definition section to align with NERC terms.
07/03/2018	4.0	• Revisions to address the new NERC Standard version CIP-003-7. • Removed LERC and LEAP references and definitions, as they

Date	Revision	Change
		are no longer NERC defined terms. • Modified or removed references as necessary to how they are actually being completed. • Updated SOC to Cyber Defense Center • Removed language relating to dial-up and modem commitments • Updated Architecture Diagram • Minor clarifications for accuracy to NERC Standard verbiage. • Changed Annual references to 15 calendar months. • Removed reference to Work Orders in section 4.11 due to move from SAP to Maximo. • Added reference to corporate Physical Security Policy and Corporate Awareness Program.
10/10/2019	5.0	• Updated all CIP version references to CIP 003-8 • Updated architecture of document to capture all responsibilities in one section • Updated CIP requirement for clarity as to what the requirements are and what process is in place to meet these requirements • Added section on Transient Cyber Assets and removable media

Attachment 1 – Reference Architecture



Appendix U - SCADA Responsibility Table

X - Primary Responsibility S - Supporting Responsibility	Task/Item	Completion Date (Estimated)	Buyer SOW	Contractor SOW
O&M SCADA ROOM in Sustation Electrical Enclosure	O&M wall mounted fiber patch panel for fiber from substation (purchase, install, configure, and commission)			X
	Order data connections			X
	Incoming fiber/copper connections to Telco demarc location from Telco pedestal (Install and test)		S	X
	Telco demarc; provides T1, high speed internet, and POTS (install and commission) Contractor is required to make commercially reasonable efforts to procure commercially available internet services. Buyer shall be responsible for costs of such services from 3rd parties.		S	X
	Ethernet jumpers from Buyer corporate network rack to Telco demarc (purchase and install)	After Buyer corporate network rack is installed	X	
	Installation of Buyer corporate network rack (purchase, install, configure, and commission)	After SCADA room is complete	X	
	Power to Buyer corporate network rack and controller server rack (install and test)			X
	RJ11 wall mounted patch panel (purchase, install, configure, and commission)	After SCADA room is complete	X	
	Overhead cable management system (purchase and install)			X
	Server rack (purchase, install, configure, and commission)			X
	Develop and distribute IP scheme	Prior to Buyer corporate network equipment being shipped to site	X	
	VPN access list and site specific requirements	Before Buyer corporate network rack is installed	X	S
	O&M security details (i.e. cyberlocks, cameras, keycard scanners, etc.)	Before security system installation begins	X	
	Security system equipment; the rack mounted equipment is installed in the Buyer corporate network rack (install and commission)	After Buyer corporate network rack is installed	X	
MET Station	Met station controller Cat 6 terminations			X
	1 IP managed met station controller media converter (purchase, install, configure, and commission)			X
	Met station controller data logger (purchase, install, configure, and commission)			X
	Instrumentation wiring, junction box and instrumentation between met station controller and met tower (install, terminate, and test)			X
	Met station controller data points list	Before Installation of met station controller and met tower.	S	X
Substation	Fiber terminations to rack mounted patch panel			X
	OPGW fiber from substation to interconnect substation, if applicable (purchase, install, and commission)			X
	OPGW fiber termination at interconnection substation slice box, if applicable (purchase, install, and commission)			X
	OPGW fiber terminations at substation splice box (purchase, install, and commission)			X
	Attenuation (OTDR) reports for all fiber installations terminated by Contractor			X
	Provide media converter information from interconnection substation	Before T-Line installation	X	
	Buyer corporate network and telephone (purchase, install, configure, program, and commission)	Immediately when substation EEE is available.	X	
	Power and ethernet cable as well as associated raceway and terminal blocks for the Buyer corporate network, telephone, and revenue meter (purchase, install, and test)			X
	Relay, RTU, ORION, check-meters, etc. (purchase, install, configure, and commission)			X
	SEL 735 check meter (procure and install)	Immediately when substation EEE is available.		X
	Fiber patch, ethernet, and serial cables for all communication connections in substation (purchase) solar control system related cables including the serial cable to Turbine Supplier park controller (install)			X
	RTU/EMS points list (develop, upload, and test)			X
	Deliver RTU/EMS points list to Buyer EMS group to incorporate project into the Buyer system	After points list is finalized.	X	
	All communication with substation equipment to include Buyer provided equipment. (install and test)			X
	Develop and distribute IP scheme	Before installation begins	X	
Inverters	Fiber to Inverter Skids			X
	Fiber terminations in inverter splice boxes; terminate all spares (purchase, install and test)			X
	Attenuation/OTDR report			X
	Design optical path diagram; coordinated with Contractor			X
	Fiber commissioning; coordinate with Contractor if issues arise			X