

## GE Generator Fleet Experience and Available Refurbishment Options

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# **GE Generator Fleet Experience and Available Refurbishment Options**

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# GE Generator Fleet Experience and Available Refurbishment Options

## Introduction

Since the 19th century GE has manufactured and placed in service over 8000 medium and large power generators, many of them still in service today. By utilizing progressive designs and developing reliable materials that have been proven in a large number of installations, GE has amassed reliability records for GE generators that have provided decades of sustained service.

The 1980s saw a dramatic growth in the rebuilding and upgrading of turbine-driven generators driven by the need to reduce maintenance on aging fleets—while also adding reliable power at minimal cost. As today’s operators face the same urgent requirements, the pace of the rebuild and upgrade activity continues to accelerate.

## GE Generator Fleet Demographics

Despite a sharp increase in the number of the new generators placed in service during the past few years, many GE generators currently in service are 30 years old or older. *Figure 1* represents all GE turbine-generators in service, regardless of design or size, grouped according to age segments.

All GE turbine generators can be subdivided into two main groups: large and medium turbine-generators designed and manufactured by GE factories in Schenectady, NY and Lynn, MA. GE has manufactured a number of large steam turbine driven generators (LSTG), rated from 100 to 1600 MVA. The nucleus of this fleet are the liquid-cooled stator winding design generators, which have been in service since the late 1950s.

## Reasons for Generator Upgrades and Rewinds

When evaluating generator upgrade alternatives, plant operators must consider many alternatives, including:

- Planned service life
- Base-load or start-stop cyclic duty
- Load requirements (megawatts and megavars)
- Reliability requirements

Using these critical parameters to establish the type and extent of the required upgrade, GE performs a comprehensive review of the total generator design and offers a complex of

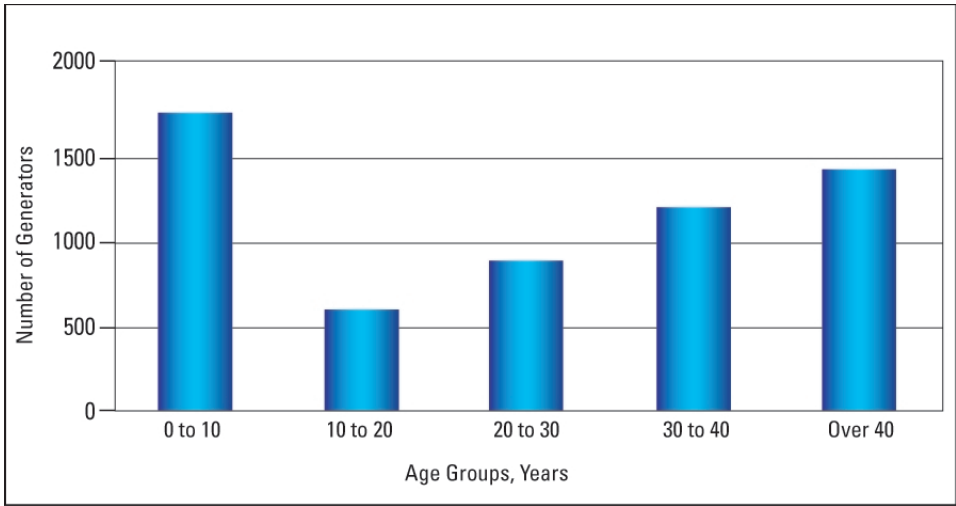


Figure 1. GE generator fleet demographics

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upgrades that can meet the objective. This review includes the requirements for the generator coolers, excitation system, auxiliaries and monitoring systems, as well as the stator and field windings.

While the intended use of the unit will provide guidelines for the rebuild, the existing condition of the equipment is usually an equally important factor in determining the extent of the rebuild that is necessary. Proper maintenance on a regularly scheduled basis as recommended by the OEM will help retain the excellent reliability of GE turbine-generators. Conversely, lack of regular maintenance, not following the manufacturer’s instructions, or operating the generator beyond the prescribed limits can result in accelerated wear and the need for more extensive rebuild at a later date.

This paper also refers the reader to relevant GE publications that address generator reliability concerns in more detail—including GER-4212 (*Generator Rotor Design, Operational Issues and Refurbishment Options*) and GER-3751A (*Understanding, Diagnosing and Repairing Leaks in Water-Cooled Generator Stator Windings*). In addition to these reference publications, GE maintains a continually expanding knowledge base of best

practices and advanced technology procedures—based on our up-to-date experience with worldwide fleets—that can be applied to generator upgrades and rewinds. This enables GE to provide customers with coherent and comprehensive generator protection systems as part of our full service offerings.

In recent years there has been a noticeable increase in the number of generator forced outages. While a variety of reasons contribute to this increase, two key causes have been clearly identified: operational incidents and aging of the generators. Since age is the most common cause of generator failures, this paper primarily focuses on aging generators and optimum solutions to improve their reliability.

## Generator Reliability and Aging

Older units constitute an increasingly higher percentage of installed industry capacity and reserve margins on typical systems—and they represent an important segment of the industry. Examination of industry data reveals several important facts about this segment.

Figure 2a illustrates a typical trend of component failure rates with age for one manufacturer. Though highly reliable, turbine-generator units

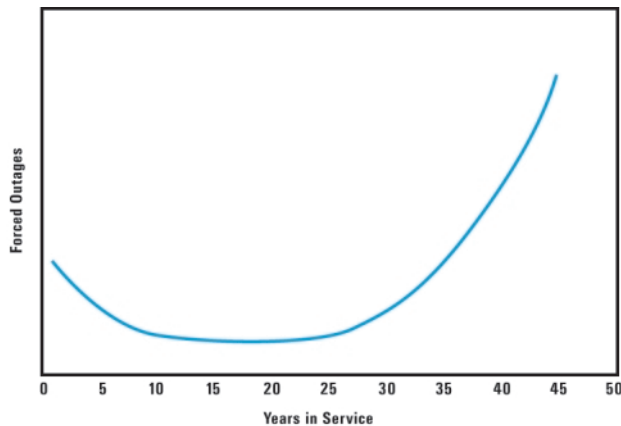


Figure 2a. Turbine-generator reliability trend

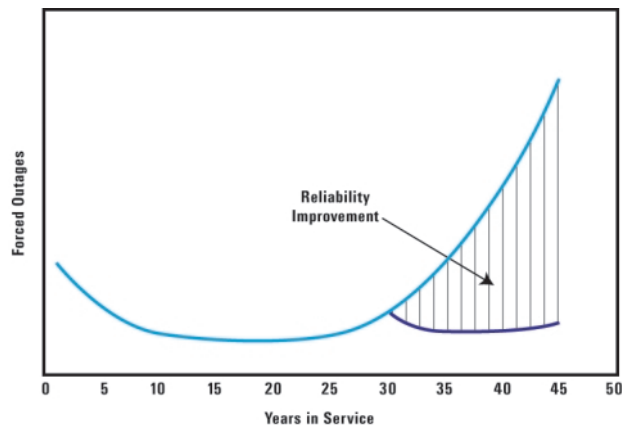


Figure 2b. Turbine-generator reliability improvement trend

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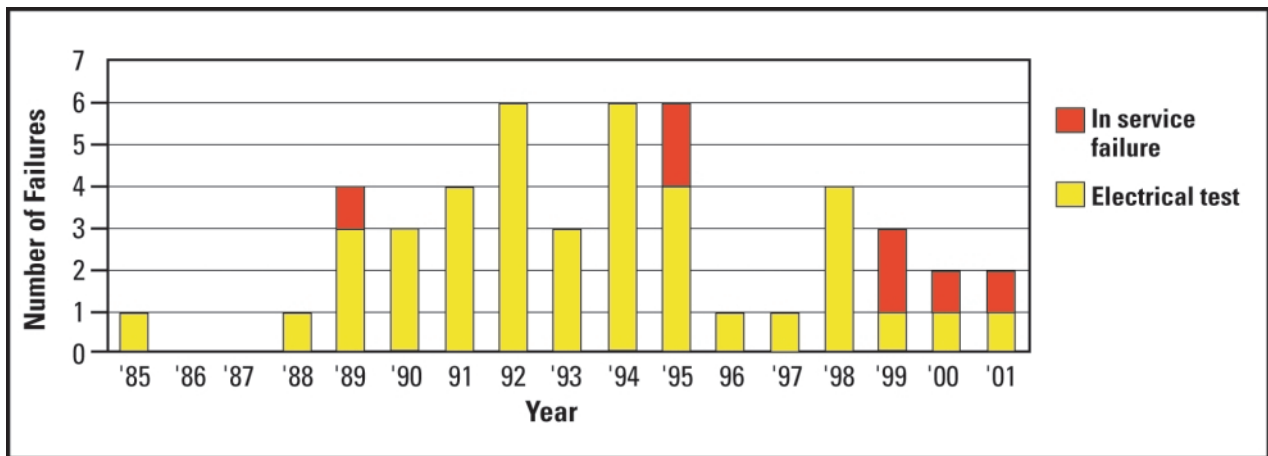
are not immune to age deterioration. During its normal life expectancy most technical equipment exhibits a basic pattern of failure rate, which is commonly referred to as a “bathtub” curve. For example, after an initial operating period called the “debugging” stage, the power generator has a normal operating period where unit reliability remains fairly constant. However, after many years of service the failure rate tends to increase in the “wear-out” period. Replacement of the worn components will improve reliability of the generator, resetting the failure rate, as shown on *Figure 2b*.

Consistent with the increase in the number of older generators in service, there has been an increase in the number of forced outages for GE generators. Currently the generator forced-outage frequency is approximately one a week. This increase in the number of forced outages noticeably coincides with the aging segment of GE’s generator fleet as it moves towards the rising edge of the "bathtub" curve. The following data represents some examples of types of forced outages that occurred in 2003:

- Generator key-bar failure
- Field shorted turns, vibration
- Field winding ground

- Field shorted turns, vibration
- Field top turn break
- Field winding failure due to H<sub>2</sub>S corrosion
- Generator stator winding and core damage
- Stator winding insulation failure
- Field winding failure
- Stator winding ground failure, core damage
- Field motoring incident, shaft damage
- Broken stator key-bar
- Generator rotor failure due to overspeed incident
- Stator phase to phase short
- Stator winding failure due to cooler leak

While there are a number of reasons that can cause generator forced outages—such as improper maintenance and catastrophic events—failures caused by worn generator components can be clearly distinguished. *Figure 3* reproduces GE data for water-cooled stator winding failure frequencies for the affected generators listed in TIL-1098 (*Inspection of Generators*



**Figure 3.** Water-cooled winding failures (TIL-1098)

With Water-Cooled Stator Windings). Many of these stator windings have already been replaced with the new, improved design windings.

### **How to Improve Reliability of Aging Generators**

The preceding information leads to the question, "What is needed to *prevent a forced outage* and to *extend the operating life* of a generator?" To answer this question, and make a meaningful assessment of the condition of an operating unit, a thorough inspection and test must be performed. In addition to these procedures, GE also reviews inspection reports from prior years to look for evidence of mechanical or electrical wear, distress, and aging. By comparing the inspection results of a particular generator with our database of information for similar units, we can identify components likely to impact the generator's future reliability and make corrective recommendations.

If a unit has not had an inspection for several years, or there has been a recent incident that potentially affected the condition of the generator, it would be prudent to perform an inspection *before* making any final decisions on rebuild workscope. This could avoid a forced outage and an extended rebuild workscope. If a customer has several GE generators we may also perform a fleet study, addressing the upgrade and reliability options applicable to all of them.

### **Rewinding for Higher Output and Efficiency**

While nearly all of the generator components may be upgraded during the service life, stator rewind and field rewind are by far the most convenient and powerful means of achieving both a higher efficiency and a higher output. Rewinds always present an opportunity for the

original equipment manufacturer to enhance the performance of the machine and support a turbine uprate. The economics of such design upgrades can often help to justify the cost of the rewind activity. By considering the vintage and type of the original machine design, turbine output, and uprate objectives, GE can develop an optimized solution that is specific to the generator.

### **Rewinding for Reliability**

#### **Stators**

Advances in the area of non-metallic materials, insulation systems and composites allow significant reliability improvements and life extension to be achieved by replacing old materials that are approaching the end of their useful lives. An example of this type of enhancement is the replacement of an asphalt-insulated stator winding with a modern epoxy-based insulation system. Since the insulation is life-limited, by replacing the stator winding with a new one—often of a higher thermal class insulation system—it is possible to reset the "time clock" on the stator winding. Beyond simple replacement of materials, significant reliability enhancement can be obtained through upgrading the design of the winding insulation and the winding support system. With the new winding GE will design and supply the new stator slot support system as well as the endwinding support. Depending upon the generator design, a new wedging system may include pressure wedges that are made of non-shrinkable non-abrasive material, top and side ripple springs. These components will effectively secure winding in the slot, while allowing certain axial movement of the endwinding basket due to the normal thermal growth or abnormal currents.

One goal of this paper is to detect a trend in the stator rewinds, based on GE rewind experience.



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Figure 4 represents the experience data for conventionally-cooled stator rewinds performed by GE for the last decade, using Class F epoxy-glass insulation systems. Major drivers for these rewinds were output increase and reliability increase. Other reasons included test failures, operational incidents, system faults, and environmental causes.

Though a variety of reasons forced these stators to be rewound, the histogram in Figure 5 clearly shows the peaks at two distinct age groups within the total lot of data. Further breakdown by a generator-cooling medium detects the sub-

groups of the air- and hydrogen-cooled generators, suggesting that hydrogen-cooled generators sustain a longer time between rewinds (TBR). Though hydrogen gas indeed provides a cleaner environment, this is partly due to the mode of operation. Most of these hydrogen-cooled generators are base load steam turbine driven generators, whereas some of the air-cooled generators were the gas turbine driven, cycling generators.

The same main objectives—reliability and/or updates—were pursued by GE customers effecting liquid-cooled stator rewinds. Figure 6 repre-

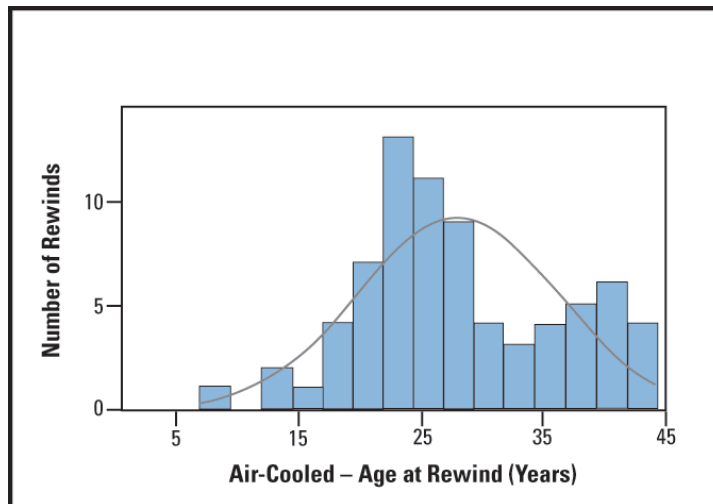


Figure 4. Air-cooled stator rewind orders

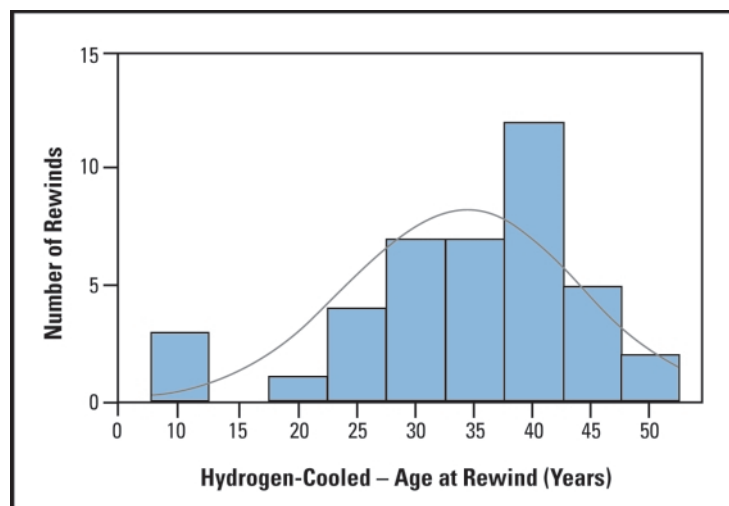


Figure 5. Hydrogen-cooled stator rewind orders

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sents the frequency of liquid-cooled rewinds performed by GE for its customers in the past decade. An age histogram of the water-cooled generators rewind by GE shown below indicates that currently, the peak rewind frequency occurs mostly in the generator age group from 20 to 30 years in service.

Many generators referenced in TIL-1098 and recommended for inspection and rewind are still operating with the original winding in place. GE recommends that inspection of these generators should be performed. GE publication GER-3751A (*Understanding, Diagnosing and Repairing Leaks in Water-Cooled Generator Stator Windings*) provides details regarding recommended maintenance, inspection and testing, and test data.

### Field Rewinds

Experience has shown the generator field is a component that requires maintenance. This is not surprising considering that it is operating under very high centrifugal load and thermal cycling. Also, typical operating incidents have the greatest impact on the field (motoring, contamination, etc.). Rebuild of the field normally focuses on re-insulation of the field winding.

However, owners should not lose sight of other considerations. Load level, type of duty, and number of stop-start cycles are the main factors affecting the wear of the generator field. Other factors include prime mover type (gas or steam turbine), ambient air conditions (for air-cooled generators), cooling and maintenance of a generator.

It is common for older units to be operated at lower power factors to carry more reactive power. Frequent load cycling common for the peaking units also may contribute to accelerated wear and distortion of the field winding, and, at times, lead to a field current sensitive vibration – thermal sensitivity. (GER-3809 [*Generator Rotor Thermal Sensitivity: Theory and Experience*] provides a detailed description of this phenomena). A complete replacement of the old field winding may be preferred as a retrofit option in such cases.

Reliability of the generator field is increased with a rewind. New modern insulating material will replace the original worn out insulation and address the latest service concerns. The new copper coils would usually have a higher cross section, reducing the current density and heating. Conversion from indirect to direct cooling of the rotor may also be effected in order to per-

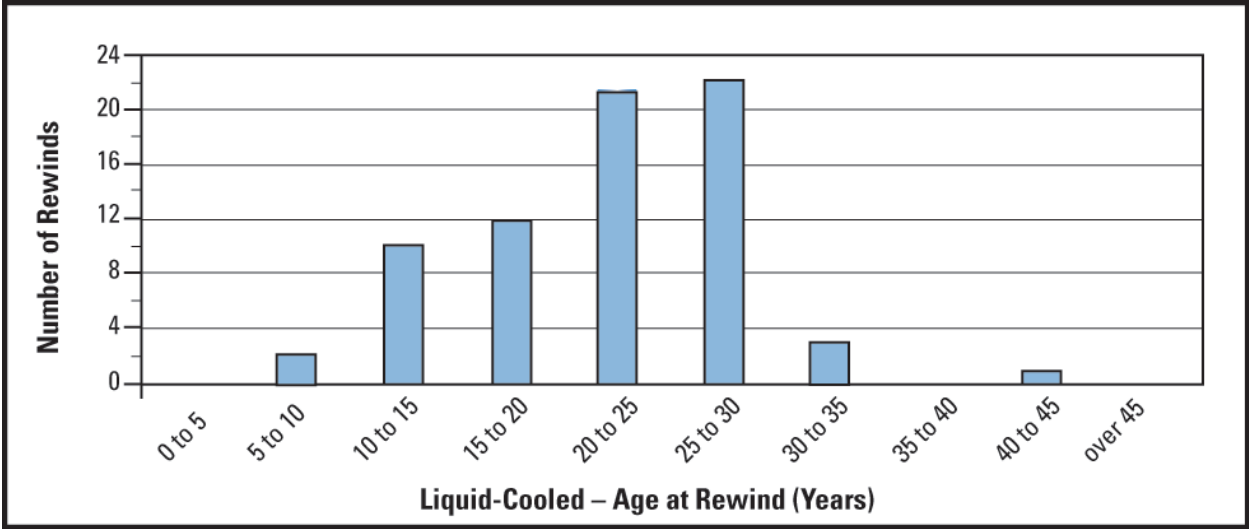


Figure 6. Liquid-cooled stator rewind orders

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mit uprating the generator. GE publication GER-4212 may serve as a good guide to selection of a proper field retrofit option. The following list of recent examples of field refurbishment jobs performed by GE Energy Services represents some popular retrofit options selected by GE customers.

- Gas turbine drive, peaking unit, shipped in the 70s.  
(Forced outage. Field ground due to end turn distortion. Rewind with new copper coils).
- Large steam turbine driven conventionally-cooled generator.  
(Planned field rewind with new copper, main leads and bore copper).
- Gas turbine drive.  
(Forced outage. End turn migration per TIL-1308. Field exchange).
- LSTG conventionally-cooled generator.  
(Field rewind with top turn isolation per TIL-1005).
- Medium steam turbine generator.  
(Field rewind with new copper to effect the generator uprate).
- Gas turbine drive.  
(Shorted turns, thermal sensitivity. Field rewind reusing the original copper).
- Medium steam turbine generator.  
(Shorted turns, vibration. Field rewind reusing the existing copper).
- Gas turbine drive.  
(Exchange field to effect a generator uprate).
- Large steam turbine generator.  
(Field rewind with layer separators to prevent copper dusting).
- Air-cooled steam turbine driven generator, frequent load cycling, end

turn migration.

(Field rewind with the new insulating materials).

- Large steam turbine generator.  
(Rotor wedge replacement per TIL-1292).
- Steam turbine driven generator. Steel mill, load cycling.  
(Field rewind reusing the existing copper).
- Medium steam turbine driven generator.  
(Forced outage due to the overspeed. Field rewind with new copper, replacement of compromised components. Shaft stress analysis).
- Medium steam turbine generator.  
(Contamination of the field winding, erosion of brazed joints. Field rewind with the new copper coils, braze protection).
- Medium steam turbine generator, late 60s vintage, peaking unit.  
(Forced outage. Distortion of end copper turns, shorted insulation. Full field rewind with new copper coils).

Due to the multiple causes for the field degradation, the age of a generator may not serve as a primary factor to determine the time to refurbish. Distribution of the medium generator field rewind frequencies is presented by age in *Figure 7*.

Monitoring the generator condition, testing and inspections performed on regular intervals as recommended in TIL-1154 and other GE publications will determine the actual condition of the field and other generator components.

If a generator is due for an upgrade—which may not be performed immediately—a good practice would be to stock a rewind kit. This will reduce the downtime in the event of emergency.

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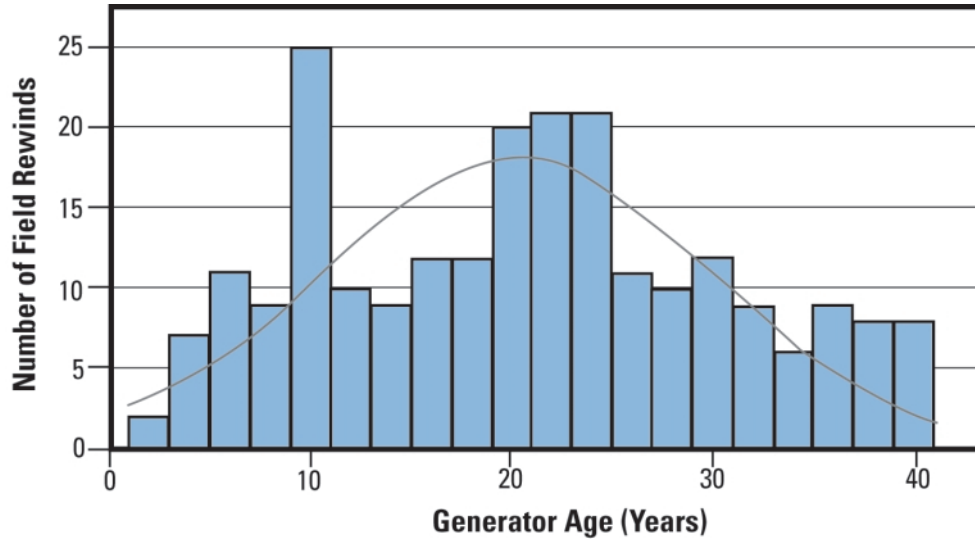


Figure 7. Medium generator rewinds

If not used for an emergency, the kit may be used later at the time of scheduled outage.

## Generator Service Issues and GE Recommendations

Not all generator service concerns may be solved with rewinds. Careful attention must be paid to the generator auxiliaries, exciter, collector and brushes, hydrogen seals, frame, end shields, water-cooling system, and hydrogen system. Time and wear of the generator components has a combined effect on the generator availability. Based on statistics for recent months, the

Pareto charts shown in *Figure 8* and *Figure 9* may illustrate the contribution of various stator and field components to the overall number of the generator stator and generator field service issues.

## Generator Monitoring

Monitoring generator condition and parameters on-line provides the opportunity to detect a trend in behavior of a monitoring parameter; assess the rate of deterioration and possibly predict the time to failure; and detect faults of the generator components. While an array of gener-

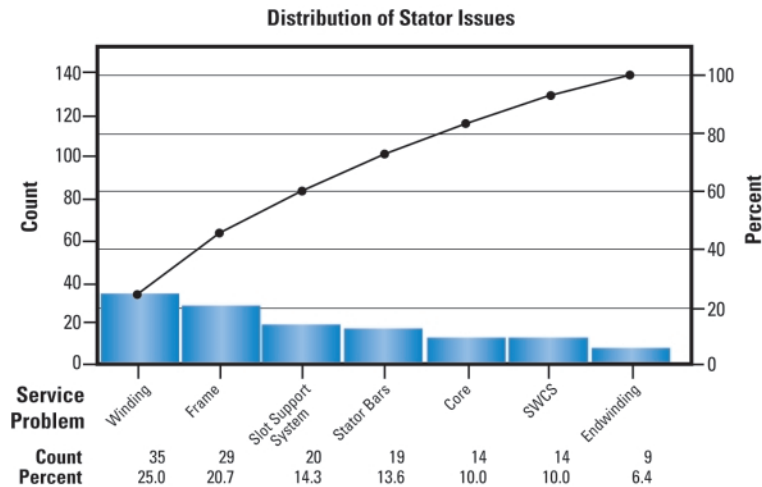


Figure 8. Stator components service issues

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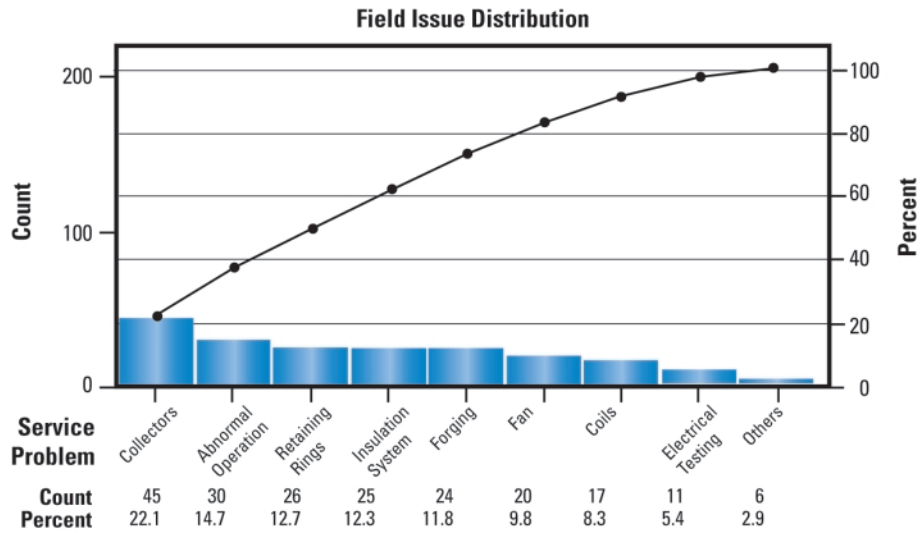


Figure 9. Field components service issues

ator monitoring schemes and devices are used by the industry, the following three are employed most widely: Generator Flux Probe, Stator Leak Monitoring System, and Partial Discharge Analysis:

### Generator Flux Probe

In order to provide an effective early-detection system, GE developed the Flux Probe to detect shorted turns that might exist in the field during operation. The permanent Flux Probe permits continuous on-line monitoring of the field. The pickup coil is mounted to a stator wedge; no rewedging is required. Electrical leads from the pickup probe are brought out through the end windings to an electrical pressure connector that is welded to the wrapper. This allows conditions in the field coils to be monitored while the generator is operating, so problems can be discovered early enough to avoid major operational issues—such as rotor vibration caused by linear thermal sensitivity.

### Stator Leak Monitoring System

To help prevent catastrophic stator winding failure, GE developed the Stator Leak Monitoring System (SLMS). This system has two functions: on line detection of water-cooled stator winding leaks and maintaining cooling water oxygen

content. It consists of a flow meter, gas analyzer, data acquisition and control system and a system piping modification package. Since on-line leak detection is important in avoiding catastrophic stator winding failure from wet insulation and in outage planning, the SLMS is designed to detect developing water leaks in a water-cooled stator winding and maintain the cooling water's oxygen content.

As described in TIL-1098, GE has identified the potential for water leaks to develop in this class of generators. When a leak develops, higher pressure hydrogen escapes into the water system and can accumulate in the water storage tank on the cooling water skid. As the hydrogen accumulates, it creates a "blanket" effect, keeping atmospheric oxygen from entering the water and leading to deoxygenated water and the problems described above.

Addition of an SLMS will require a modification to the Stator Water Cooling System (SWCS). The SLMS module will be mounted to the SWCS hydrogen detraining tank and will connect to a gas analyzer and a flow meter which are added to the existing piping. The system will induce fresh filtered air into the cooling water, which provides a measurable gas flow and maintains

water oxygen content. Measurement of the hydrogen content and gas flow will provide an accurate measurement of hydrogen leakage through the stator winding. The level of hydrogen leakage is directly related to a leak in the water cooled stator winding. Recent upgrades included the on-line oxygen monitoring and updated data acquisition system.

### **Partial Discharge Analysis**

High frequency (40 KHz – 100 MHz) low voltage (micro volts) partial discharge activity exists in essentially all high voltage equipment. Phase Resolved Partial Discharge Analysis (PRPDA) is a powerful tool to monitor this activity on-line and identify trends on specific machines and/or compare activity in identical machines that can be used for condition-based maintenance and forced outage avoidance. Recent developments in measurement hardware, software and analysis techniques show great potential for identifying the specific sites of partial discharge activity within generators and quantifying the partial discharges at each site in order to discriminate between normal and destructive activity.

There are several conditions which can occur within a generator that can generate PD activity that is of interest and relates to the condition of the generator:

- Stator bar vibration
- End winding contamination
- Damage to the end winding voltage suppresser system
- Connection ring vibration
- Broken conductors
- Insulation delamination/damage
- Slot discharge
- Collector brush sparking

These are some typical conditions that would be

investigated during a maintenance outage test and inspection program. On-line PDA testing gives a relative assessment of the generator condition that can augment more conventional tests and inspection methods in order to plan condition-based maintenance outages and to help avoid forced outages. The PRPDA method detects discharges with sophisticated signal processing, noise gating and pulse shaping, and displays the activity as it occurs in relation to the 50/60 Hz power sine wave. The resulting phase-resolved patterns allow for discrimination between internal discharge activity, external discharge activity, and noise activity. The superior signal discrimination of PRPDA simplifies methods for coupling to the generator, while the enhanced signal presentation of PRPDA simplifies using partial discharge for condition-based maintenance and forced outage avoidance.

### **Conclusion**

A recent increase in the number of forced outages can be attributed to the aging of GE's generator fleet. With many of these generator units 30 years or older, early diagnosis and correction of a problem is important for reliable operation. The best approach in preventing forced outages is a proactive one.

Based on the expertise and knowledge base accumulated from our worldwide fleet of generators, GE has the ability to help customers determine the optimum reliability solution for their specific units—with a comprehensive range of offerings that provide everything from maintenance and monitoring through upgrades and rewinds.

Though there is no hard data pointing to a date when a generator must be rewound, GE recommends to follow relevant publications such as Technical Information Letters and reference manuals that correspond to a particular unit.

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(GE Recommended Test and Inspection schedules are included in the Appendix. *See Table B-1 and Table B-2.*)

Some data material presented in this paper may also be used as a trend indicator. The most common and proven generator upgrades and repair solutions offered by GE have been formalized in our Generator Source Book offerings. A list of these Generator Source Book articles (along with a sample article) is presented in the appendix for your reference. These articles are available through your area sales representative or through the Outage Optimizer tool on [gepower.com](http://gepower.com).

The authors express special thanks to the following individuals who contributed to this publication: Ron Zawoyski, Rod Rumer, and Michael Kavney.

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5. TIL-1098, "Inspection of Generators with Water-Cooled Stator Windings," GE Technical Information Letter, 2001.
6. TIL-1154, "Generator Test and Inspection," GE Technical Information Letter, 1994.
7. TIL-1292, "Large Steam Turbine Generator Dovetail Inspection Recommendation," GE Technical Information Letter, 2000.
8. TIL-1308, "Generator Field Endwinding Insulation Migration," GE Technical Information Letter, 2002.

## Appendix

### A. 1) Generator Source Book Articles

Many of the following Generator Source Book articles may be accessed online at [www.gepower.com](http://www.gepower.com) by selecting the Online Tools page and choosing Outage Optimizer—or by contacting your GE sales representative.

- Temporary flux probe
- Permanent flux probe
- Generator gas monitoring system
- Exchange gas monitoring system
- Gas analyzer
- Deionizing resin
- Stator cooling water filters
- Shaft voltage monitor
- Collector brush holder retrofit
- Excitation ventilate modification
- Ex2000 + modifications
- Field balance weights
- Collector terminal stud kit
- Replacement field
- Full field rewind with Copper
- Exchange field
- Field rewind w/o Condal
- Full field rewind w/o Copper
- Field high-speed balance
- Main terminal stud kit
- Partial field rewind
- Retaining ring install kit
- Retaining ring non-destructive test
- Field shipping-storage bag
- Thru stud install kit
- Alterrex oil deflectors
- 7A6 oil leak modifications
- Bearing ring insulation kit
- End shield oil leak mod
- Retaining ring TIL-1097
- Liquid-cool bar TIL-1098
- Core ring test
- Test for copper dust per TIL--965
- El Cid test
- In-situ test
- Major inspection of liquid-cooled generator
- Minor inspect of liquid-cooled generator
- Test main lead TIL-1002
- Field non-destruct test
- Partial discharge test
- Field shorted turn test
- End winding freq test
- Telephone influence test
- Thermal sensitivity test
- Stator wedge tight test
- Gen tagging compounds
- Generator uprate analysis
- High voltage bushing repair kit
- Liquid-cooled bar repair kit
- Corona resistant paint
- Full stator rewind
- Gegard 600 stator rewind
- Partial stator rewind
- Liquid flow conversion
- Stator leak monitoring system
- Series loop insulation kit
- Stator re-wedge
- Retaining ring TIL-177
- Collector brush holder retrofit per TIL-813
- TIL-962, space block migration prevention
- Copper dust rewind TIL-965
- Retaining ring TIL-1001
- 7H2 end wedge modifications
- Main lead TIL-1002
- Top turn isolation per TIL-1005
- Alterrex cool tube TIL-1027
- Field re-wedge TIL-1035/1036
- Kopflex cplg TIL-1037
- TIL-1093 5/6a3 limit switch
- Ret ring TIL-1097
- Liquid-cool bar til-1098
- 7H2 end wedge mod
- TIL-1161 9H2 term stud
- TIL-1164 9H2 bore seal
- TIL-1173 9H2 stdoff insul
- TIL-1187 6A3 stator rewdg
- TIL-1195 5/6A3 conn strap
- Liq-cooled stator bar abrasion
- 7FH2 belly band mod
- TIL-1226 strainer basket
- SLMS EPROM upgrade
- H2 detector kit
- 6A3 pedestal vibration mod
- Generrex CPS disabling
- Major inspection of conventionally-cooled generator
- Minor inspection of conventionally-cooled gen
- Performance curve lookup
- Hydrogen seal ring retrofit
- Hydrogen seal ring replacement
- Hydraulic test-winding
- Top turn isolation TIL-1005
- Alterrex cool tube TIL-1027
- Field rewedged TIL-1035/1036
- Kopflex coupling TIL-1037



## A. 2) Sample Generator Source Book Article

**CODE: GFFRCU64**

**DESCRIPTION: FULL FIELD REWIND WITH COPPER**

### INTRODUCTION:

A full field rewind with a new copper winding replaces the old, worn ground and turn insulation with the latest systems and provides for a new field winding. Since these new insulation systems are typically thinner than what they are replacing, additional space is made available and optimized by designing the new field coils with a larger cross-section. This provides an uprate potential for the generator. Even if the customer is not interested in an uprate at this time, a full field rewind with copper will typically reduce the operating temperatures of the field, which will improve machine reliability and the life expectancy of the machine.

### APPLICABLE UNITS:

All generators.

### TECHNICAL DESCRIPTION:

A full field rewind with copper allows for the full implementation of the latest ground and turn insulation systems, along with the latest field winding design technology. Technically, this rewind option provides the greatest potential for improved generator output when the field is limiting. A stator rewind, cooler upgrade or excitation upgrade may be required in addition to the field rewind if their capability is also limiting.

By rewinding the field with new copper, the reliability of the field is greatly increased. New hard coils are installed to reduce coil distortion during operation, while Class "F" insulating materials are installed to improve the temperature capability of the winding design. When the coils are replaced, the field winding design can be

optimized to lower its resistance and net operating temperatures for the same output level. By replacing the old coils with new ones, the design of the winding is improved. Class "F" insulation systems are used to improve the insulation system's temperature capability.

### BENEFITS:

- New Class "F" insulation systems improve temperature capability
- Existing shorted turns can be eliminated
- Possible uprate potential
- Field operating temperature can be reduced
- Reduced down-time, increased reliability
- Increased life expectancy of the insulation system

### REFERENCES:

GER-3707, *Generator Upgrades and Rewinds*

### SCOPE OF SUPPLY:

- New field coils (100%)
- Slot armors (100%) plus two contingency spares for coil #1 above
- Turn insulation - slot and end winding (105%)
- New distance blocks when existing blocks are asbestos or unit is a medium generator (100%)
- Pole-to-pole connectors (100%)
- Coil-to-coil connectors (100%)
- Fan lock plates for axial flow fans (100%)
- Main terminal nuts (50%)
- One retaining ring installation kit (see GFRRIK63)
- Temporary wood (international orders only)

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- Temporary wood drawing (domestic orders only)
- Rewind accessories and miscellaneous materials needed to perform rewind (100%)

### **NOTES:**

A field high-speed balance is strongly recommended (SEE GFHSBN62).

### **SCOPE OF WORK:**

This Scope Of Work lists the required steps to perform the subject installation only. It assumes that generator disassembly is for no other purpose than the installation. Typically, conversions, modifications and uprates are scheduled by a customer to coincide with other turbine-generator maintenance activity.

- Remove field from the stator
- Remove retaining rings
- Strip field of coils and insulation

- Rewind field with new coils and new insulation
- Install retaining rings
- Insert field into the stator

### **SITE INFORMATION REQUIRED:**

- Turbine, generator and field serial numbers
- Notification of any modifications previously performed on the field forging or winding

### **OPTIONS:**

- Retaining Ring Replacement (See GFRRRP67)
- Field High-Speed Balance (See GFHSBN62)
- Generator Tagging Compounds (See GRTGCP52)
- Main Lead Replacement (See GFMLRP63)

# GE Generator Fleet Experience and Available Refurbishment Options

## B) GE Recommended Generator Inspections and Standard Tests

### VISUAL INSPECTION AREAS

		Foreign Material/Contamination	Cleanliness	Loose or Displaced Parts	Movement	Mechanical Damage	Deterioration (General)	Corrosion	Surface Condition and Wear	Water Leaks (Water-Cooled)	Cracks	Worn Parts	Burning	Blocked Ventilation	Bar Sparking	Tape Migration	Broken Tiles	Shorted Core Punchings	Core Tightness
Stator	All Components	X	X	X	X	X	X												
	Bars								X	X	X	X			X	X			
	EW Support System										X	X		X					
	Slot Support System										X	X		X	X				
	Conn. Rgs & Lower Lds.								X	X	X	X					X		
	High Voltage Bushings								X	X		X	X						
Core	All Components	X	X	X	X	X	X	X										X	X
	Core End									X		X	X						
	Ventilation Ducts												X						
	Laminations											X						X	X
	Key Bars																		X
Field	All Components	X	X	X	X	X	X	X	X										
	Body & Wedges										X		X	X	X				
	Retaining Rings										X		X						
	Fans										X								
	Spindles										X	X							
	Winding													X	X				
	Collectors											X	X						

**Table B-1.** Recommended generator inspections

## GE Generator Fleet Experience and Available Refurbishment Options

<b>STATOR</b>			AIR	HYD	LCSW	MINOR	MAJOR
Test	Component	Inspection Objectives					
RTD Element Res	Gas & Winding RTDs	Checks for calibration & poor connection	X	X	X	X	X
RTD Ground Insulation	Stator Winding RTDs	Insulation condition of RTD	X	X	X	X	X
Winding Copper Res	Stator Winding	Checks for calibration & breaks	X	X	X	X	X
Insulation Resistance (aka Megger)	CE Bearing	Contamination and/or deterioration of insulation	X	X	X	X	X
	Hydrogen Seal Casing	Contamination and/or deterioration of insulation		X	X	X	X
Polarization Index	Stator Winding	Contamination and/or deterioration of insulation	X	X	X	X	X
DC Leakage Current	Stator Winding	Contamination and/or deterioration of insulation	X	X	X	X	X
Over Potential/Hipot	Stator Winding	Groundwall insulation integrity	X	X	X	X	X
Wedge Tightness Map	Stator Wedges	Detect wedge tightness deterioration	X	X	X		X
Magnetic Scalar Potential (EICid)	Stator Core Insulation	Weak or damage core enamel	X	X	X		X
Vacuum Decay	Water Cooled Stator Wdg	Hydraulic integrity of entire winding			X*	X	X
Pressure Decay	Water Cooled Stator Wdg	Hydraulic integrity of entire winding			X*	X	X
Capacitance Mapping	Water Cooled Stator Wdg	Wet groundwall bar insulation			X*		X
Helium Tracer Gas	Water Cooled Stator Wdg	Detect minute leaks in the hydraulic circuit			X*		X
<b>OPTIONAL TESTS</b>							
Partial Discharge Analysis	Stator Winding Insulation	Localized deterioration	X	X	X	R	R
Water Flow Verification	Water Cooled Stator Wdg	Restrictions in hydraulic circuit			X		0
Core Ring Test	Stator Core Insulation	Weak or damage core enamel	X	X	X		0
Dynamic Freq Response	Stator End Winding	Potentially damaging resonance	X	X	X		0
Bar Jacking	Slot Support System	Check slot clearance			X		0
<b>FIELD</b>			AIR	HYD	LCSW	MINOR	MAJOR
Test	Component	Inspection Objectives					
Winding Copper Resistance	Field Winding	Checks for poor connections & breaks	X	X	X	X	X
Polarization Index	Field Winding	Contamination and/or deterioration of insulation	X	X	X	X	X
AC Impedance	Field Inter-turn Insulation	Turn shorts & speed sensitive turn shorts	X	X	X	X	X
<b>OPTIONAL TESTS</b>							
Overpotential/Hipot	Field Winding	Groundwall insulation integrity	X	X	X	0	0
Air Gap Flux Probe	Field Inter-turn Insulation	Shorted turns at operating speed	X	X	X	R	R
Bore Pressure Test	Chevron Seals	Sealing capability of Chevron seals		X	X	0	0
0 – Optional test X* – Pertains only to water-cooled units R – These tests are performed while the unit is running							

**Table B-2.** Recommended generator standard tests

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