POWER MONITORS INC.

Eagle Class PQ Wireless™ Recorder

User's Manual

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This version: November 2003
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Foreword

We founded Power Monitors Inc. (PMI) to provide state-of-the art, easy-to-use, and affordable electronic test equipment to the power industry. Our products have been developed by working directly with electric utilities to determine their specific needs. These products are designed for only one purpose: to collect and assist in the analysis of field-recordable data for electric utilities.

The Eagle Class Recorder™ were developed with your needs in mind. We created them to meet the needs of a large utility, and based their unique capabilities on our years of experience building versatile voltage recording and analysis equipment. Inside lightweight, weatherproof, rugged enclosures, state-of-the-art electronics measure and record true RMS voltage and current on four channel connections. The units require so little power; they operate on the voltage from one of the attached lines. There are no batteries to recharge prior to use. Each unit has been individually calibrated to ensure high accuracy and stability over a wide range of temperatures.

PMI recorders remain the only products on the market that will allow both electronic "stripchart" recording and a number of specialized recording modes tailored to the power industry. The specialized reports are merged with unique data collection techniques to provide accurate information that is easy to understand. Features such as flicker monitoring, event recording, and min/max/Avg recording of both voltage and current make PMI recorders the ideal products for distribution monitoring.

The Recorder features:

- True RMS voltage and current measurement on each of four channels
- Programmable abnormal voltage recording
- On-site, real-time display of voltage, current and power via Palm PDA & PMIScan or PMIView Software
- Single-cycle response (16 msec)
- More than 122,000 samples per second
- 0-600 volt RMS operating range
- 0-10, 100, 500, 1000, and 5000 Amp current input ranges
- Up to 4,096K FLASH EPROM memory
- Memory capacity for more than one year of summary data, 500 event records, 500 records of significant change, 500 records of flicker data
- Rugged, weatherproof enclosure NEMA 4X
- All channels captured simultaneously in one cabinet

Recorder/WinScan™ graphs and reports include:

- Stripchart and histogram analysis for RMS voltage, RMS current, power factor, displacement power factor, real power, apparent power, reactive power, volt-amps, frequency, and phase angle
- Power outage report
- Abnormal voltage report
- Current or voltage out of limits report
- Significant change report
- Event change report
- Flicker report

Because of these capabilities, the Eagle Class Recorder™ are the perfect instruments for analyzing and solving power quality and quantity problems. After looking through this manual and using your Recorder, please contact us with any questions about its operation, or with ideas for new features or products. We want you to be happy with this product, and we always appreciate any input that helps us develop products to meet your future needs.

Thank you,

Walter M. Curt
Owner, Power Monitors Inc.

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SAFETY NOTICE

THIS SAFETY NOTICE HAS BEEN INCLUDED TO EMPHASIZE THE DANGER OF HAZARDOUS VOLTAGES ON THE INPUT CONNECTION LEADS **OF YOUR INSTRUMENT.** USE EXTREME CAUTION WHEN CONNECTING OR SERVICING **YOUR INSTRUMENT.**

SIGNAL INPUTS WARNING

USE EXTREME CAUTION WHEN WIRING SIGNAL INPUT CONNECTIONS. HAZARDOUS POTENTIALS MAY EXIST ON SIGNAL INPUT LEADS. THESE HAZARDOUS POTENTIALS MAY BE EXPOSED INSIDE THE INSTRUMENT CASE AND ON THE VOLTAGE CLIPS OF YOUR INSTRUMENT. ANY VOLTAGE POTENTIAL AT THE SIGNAL SOURCE WILL EXIST ON THE INSTRUMENT'S **RESPECTIVE SIGNAL INPUT CABLE.**

SAFETY ISSUES

PLEASE READ CAREFULLY BEFORE INSTALLING OR USING THE RECORDER.

THE RECORDER CONTAINS DANGEROUS VOLTAGE LEVELS DURING OPERATION. DO NOT DISASSEMBLE THE RECORDER. THE RECORDER CONTAINS NO USER-SERVICEABLE PARTS INSIDE.
THIS DEVICE IS MANUFACTURED FOR USE BY TRAINED AND QUALIFIED PERSONNEL ONLY.
DO NOT INSTALL OR OPERATE WHILE IN CONTACT WITH STANDING WATER OR WET GROUND.
WEAR PROTECTIVE GLOVES AND SAFETY GLASSES AT ALL TIMES DURING THE INSTALLATION, OPERATION AND REMOVAL OF THE RECORDER.
DURING INSTALLATION, DISCONNECT POWER FROM ANY LINES TO WHICH THE RECORDER WILL BE ATTACHED.
PMI CURRENT PROBES ARE MANUFACTURED WITH INTEGRAL LEADS AT THE CLAMP-ON PROBE END, PREVENTING ACCIDENTAL DISCONNECTION AND MAXIMIZING SAFETY. ~~**IN ADDITION, THE CURRENT PROBE ASSEMBLIES INCORPORATE A BUILT-IN VOLTAGE-LIMITING FEATURE. THIS LIMITS THE PROBE OUTPUT VOLTAGE TO ONLY A FEW VOLTS SHOULD THE PROBE BECOME DISCONNECTED FROM THE RECORDER WHILE STILL CLAMPED AROUND THE CURRENT-CARRYING CONDUCTOR. THIS FEATURE PREVENTS THE POSSIBILITY OF ELECTRIC SHOCK TO THE USER AT THE DISCONNECTED CONNECTOR END TERMINALS. PROBE CABLES WITH A WATERPROOF CONNECTOR THAT MATES WITH A WATERPROOF RECEPTACLE MOUNTED ON THE RECORDER HOUSING ARE ALSO PROVIDED.**~~
ALTHOUGH THE RECORDER HAS BEEN DESIGNED AND BUILT TO BE AS SAFE AS POSSIBLE, GREAT

CARE SHOULD BE EXERCISED AT ALL TIMES DURING OPERATION AND INSTALLATION.

GENERAL DESCRIPTION CHAPTER 1

1.1 GENERAL

1.1.1 Purpose

This manual is a user reference guide for the Series Eagle Class Recorder™ (Figure 1-1). The manual provides detailed instructions for connection, operation, programming, and communications interface.

1.1.2 Manual Layout

The layout of this Manual is by Chapters and numbered Paragraphs.

A. Chapters

Chapters within this manual are arranged in the following order:
Chapter 1 - General Description
Chapter 2 - Connection Information
Chapter 3 - Operation
Chapter 4 - Configuration
Chapter 5 - Communications Interface

B. Paragraphs

Paragraphs are numbered sequentially with the first number corresponding to the Chapter number, the second number corresponding to the topic, and the third indicating number paragraph within that topic. Alpha characters indicate subparagraphs of the main paragraph.

Figure 1-1: Eagle Class Recorder™

1.2 RECORDER DESCRIPTION

1.2.1 General

The Eagle Class Recorder™ are easy-to-use, true RMS, micro-computer-based voltage, amperage and power recording device that produce accurate readings and professional reports. These recorders can help you resolve customer voltage and power quality complaints, record flicker, conduct long-term voltage and current surveys, and detect voltage and current variations as brief as one cycle. The Recorders will not disrupt normal power supply; rather, it uses a minimal amount of voltage from one of the lines it is monitoring.

Each Recorder gathers and stores stripchart data, recording the average, minimum and maximum readings for a selected interval with one-cycle resolution. Even events lasting less than one cycle are revealed in WinScan™ reports if the Recorder is configured to capture the information. The Recorder also calculates derivative power measurements such as power factor, phase angle, reactive power, and others.

Installing the Recorder is relatively simple, although using the unit requires the same attention to safety as working with any other high-voltage device. Once the unit has been installed and the data you need have been recorded, the data can be downloaded using either serial cable or Bluetooth wireless technology. Real-time data can be checked using a Palm® operating system PDA. Please refer to the PalmView manual for further information.

You can then view and analyze the data using the WinScan™ software. With the software you can create an array of graphs and reports, each of which provides you with useful, clearly presented power data.

1.2.2 Available Models

There are several models of the Eagle Class Recorder™ that can be provided. The label on the front cover will designate the model of the unit.

The recorder models available and their corresponding codes are:

220 – 2 Channel (two voltage and two current)
330 – 3 Channel (three voltage and three current)
440- 4 Channel (four voltage and four current)

Figure 1-2: Recorder Label

1.2.3 Inputs

Direct hookups are fed into 2,3, or 4 voltage, 0-600vac, and 4 current inputs. The amount of current that can be monitored is dependant on the current transducer being used. Up two eight direct inputs are available to be recorded and used with reports and strip charts. To record an input, the input must be selected as a strip chart in WinScan™.

1.2.4 Instrument Size

The Recorder is contained in a standard 5-3/8 inch (136.5 mm) long x 2-3/8 wide (60.3 mm) high x 1-3/16 inch (30mm) high NEMA 4x sealed box.

1.2.5 System Description

The Recorder is a system designed to measure and record AC Power parameters using state of the art digital technology. Signal inputs from AC power connections are monitored by the system. No pen, ink or paper are required. The unit can also be used with PalmView software running on a Palm® Personal Digital Assistant (PDA) for real time viewing of waveforms, harmonic bar graphs, vectors, as well as numeric values.

A. Day-To-Day Use

Day-to-day operating measurements are stored and recalled instantly. Up to two MB of standard internal memory allows data to be efficiently and economically stored and retrieved.

B. Configuration

WinScan™ software allows the user to program the unit quickly and efficiently using an Windows operating system PC.

Programming can also be done using PalmScan Software running on a Palm® PDA. It's graphical touch screen interface provides straight forward, user friendly configuration. Strip charts, Event parameters, and Flicker parameters can be easily programmed. Other parameters such as Scales, CT and PT ratios, and engineering units are also easy to program.

C. Applications

A Recorder may be configured by you to record and monitor almost any voltage and current configuration. Typical measurement applications include, but are not limited to:

- Voltage Levels
- Current Levels
- Power Factor
- Harmonics to the 51st
- Phase Rotation
- Flicker
- Power Levels

D. System Technology

This power Recorder is a state of the art system, designed around a microprocessor, with an executable program stored in memory. The memory is used for data and setup storage. Bluetooth Wireless technology is also incorporated to allow users access to data without an actual physical connection.

1.2.6 Memory

Electrically Erasable Programmable Read Only Memory (EEPROM) eliminates the need for a battery back-up. Programming is stored in EEPROM. In the event of a power loss or system reset, the programming will be protected.

1.2.7 Clock

The Time-of-Day clock will be maintained indefinitely after loss of line power by an internal NiMH battery.

1.2.8 Recorder Construction

The Power Recorder features modular construction. All printed circuits boards are sealed for electrical isolation and protection from the elements. *Servicing should only be done by an authorized service center of PMI. The PC boards are conformal coated and high voltage is present, servicing by unauthorized personnel can result in product or bodily damage.*

1.2.9 Communications

The standard RS232 port allows you to plug the Recorder into your computer and download the data from memory. An AC Adapter is also supplied that you can plug into the 9 pin D shell that will power the unit for programming or downloads. This eliminates the need to have AC voltage supplied directly to the voltage leads.

Figure 1-3: Serial Cable

1.3 SUPPLIED EQUIPMENT

1.3.1 Equipment Listing

The following items are supplied with your Recorder:

- the Eagle Class Recorder™
- CD Containing
  - WinScan™
  - This manual
  - a WinScan™ Manual
  - Sample files
- a serial communications cable
- a 12-volt power adapter wall transformer and cord.
- Voltage leads and probes

If any of these items are missing, call PMI immediately.

Current probes are an accessory and should be ordered as a separate line item.

1.4 ACCESSORIES

1.4.1 General

Additional functions and capabilities can be added to the Recorder as accessories. These options are briefly described in the following paragraphs.

1.4.2 Current Clamps

TLAR 10 Amp current clamps are available in sets of 2,3, or 4 clamps.

Figure 1-4: TLAR Clamps

1.4.3 Current Probe

PMI has a wide range of current probes (Flexible CTs) that range in circumference from 24 to 48 inches and have ranges of 100, 1000, and 5000 Amps. All our flexible current probes are powered from the unit itself so no external batteries are needed. See figure 1-5

1.4.4 Adapters

If you have an older PMI unit we have a wide range of adapters available so you can use your existing serial cables with your new unit(s).

Figure 1-5: Flex CTs

1.4.5 Cases

PMI carries a wide selection of cases to carry your new or old unit, cables, CTs, and manuals all in the same container. See figure 1-6.

Figure 1-6: Cases

1.4.6 Spare Parts List

Eagle Class Recorder™

Eagle Class Recorder™ Comm. Cable	90506002000
Voltage Leads	
BLK test lead, straight to Right Angle	30150021
RED test lead, straight to Right Angle	30250022
BLU test lead, straight to Right Angle	30250023
YEL test lead, straight to Right Angle	30250024
WHT test lead, straight to Right Angle	30250025
Jaw Grip, 4mm	30250026

1.4.6 Voltage Clips

PMI carries a wide variety of voltage clips for your application.

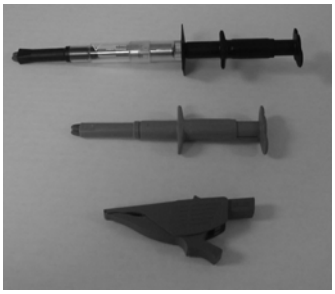


Figure 1-7: Voltage Clips

1.5 SPECIFICATIONS

1.5.1 General

The Eagle Class Recorder™ specifications are shown in Table 1-1.

Table 1-1 Eagle Class Recorder™ Specifications

Eagle Class Recorder™ Recorder Specifications

Input

AC Voltage	0 to 600 VAC
AC Current	0 to 10, 100, 1000 or 5000 Amps
Sample rate: samples per second	
	122,800 all channels
	15,360 per channel (256/cycle)

Channels

2, 3, or 4 voltage
2, 3, or 4 current

Measured Qualities

RMS Voltage	(Volts)
RMS Current	(Amps)
Real Power	(Watts)
Apparent Power	(VA)
Reactive Power	(VAR)
Phase Angle	(Degrees)
Power Factor	(Watts/VA)
Displacement PF	(cos(phase angle))
Power Usage	kWh, kVARh, kVAh
Frequency	Hz

Note: All quantities are measured for each cycle.

Accuracy/Resolution

(-20°F to 135°F)

Accuracy	**Percent of full scale**
Voltage	0.33 % (w/o probe)
Current	1.0 %
Power	1.0 %
Phase Angle	1 degree
Power Factor	±0.02
Displacement PF	±0.02

Resolution: Displayed/Internal

Voltage	1 V / 0.1 V
Current	0.1 A / 0.1 A on 10-amp
	(Displays 1 A on other scales)
Power	10 W / 10 W
VAR	10VAR/10VAR
VA	10VA/10VA
Phase Angle	1° / 1°
Power Factor	0.01 / 0.01
Displacement PF	0.01 / 0.01
Power Usage	0.001 kWh/0.001 kWh

Information Storage

Memory

RAM	128K (battery-backed)
FLASH EPROM	4MB
DSP Waveform RAM	up to 256K
TOTAL MEMORY	2.2 million readings

Waveform capture: Triggered

Capacity

Summary data	Over 1 year
Event data	500 records
Significant change data	1000 records
Flicker data	1000 records
Stripcharts	4 hours to over 1 yr.
Voltage	
Current	
Power Factor	
Displacement PF	
Real Power	
Reactive Power	
Apparent Power	
Phase Angle	
Frequency	
Retention time	> 5 years

Communications

Local

Type	Serial Cable
	Wireless Bluetooth
Standards	RS232 Compatible, Bluetooth
Data rate	1,200 to 56 kbaud
Stripchart settings	1 second to 4 hours
Significant change	1V to 8 V, in 1V steps
Flicker settings	User-defined or standard
Battery voltage check	Automatic

Power Requirements

Recording load	< 1.5 Watts

Environmental

Operating temperature	-20°F to 135°F
Shock	60Hz to 2KHz, acceleration 25G
Vibration	10Hz to 60Hz, amplitude 1.8mm

Physical Dimensions

Size	5.375” x 2.375” x 1.188”
Weight	<1.0 lbs.
Case	NEMA 4X

Power Fail Operation

The device operates with no input voltage for more than 2 hours. This allows it to measure down to 0 volts on all channels during power outage periods.

Harmonics (optional)

Voltage	Measures to the 51st
Current	Measures to the 51st
Measures:	
Magnitude	
Phase	
THD	

Implementation of new developments and product improvements may result in specification changes in this document

SAFETY NOTICE

This Safety Notice has been included to emphasize the danger of hazardous voltages on the **INPUT CONNECTION LEADS** of your instrument. **USE EXTREME CAUTION WHEN CONNECTING OR SERVICING** your instrument. Please read the entire contents of the Installation and Wiring Chapter before attempting to connect or service your instrument.

SIGNAL INPUTS WARNING

Use extreme caution when wiring signal input connections. Hazardous potentials may exist on signal input terminals, which are floating, with respect to instrument ground. These hazardous potentials may be exposed inside the instrument case and on the Connectors of your instrument. Any voltage potential at the signal source will exist on the instrument's respective signal input cable.

Connection Information Chapter 2

2.1 INTRODUCTION

2.1.1 General

This chapter provides information and procedures for connection of the Recorder. Included are handling procedures, installation and wiring specifications, and instructions for both standard and optional equipment.

2.1.2 Manual Updates

This manual may periodically be up-dated with addendums that could affect the connection information contained in this section. Review each addendum, if any, in the front of this manual and note changes that pertain to this section.

2.2 EQUIPMENT HANDLING

2.2.1 Initial Inspection

Exercise care when unpacking instruments from the shipping cartons. The instruments are packed in a shock-resistant foam retainer to prevent damage during normal transit. If damage to the shipping carton is evident, ask the carrier's representative to be present when the instrument is unpacked and refer to Limited Warranty Statement, Appendix A.

2.2.2 Unpacking Procedure

Perform the following steps to unpack your Recorder.

1. Remove the foam retainer and instrument from the shipping carton.

2. Carefully remove the instrument from the foam retainer.

A. Detected Damage

If damage is detected after unpacking the instrument, re-pack the instrument and return it to the factory as described **in the following paragraph.**

2.2.3 Equipment Return

Before returning a damaged or malfunctioning instrument to the factory for repairs, a Return Authorization Number must be obtained from the factory.

A. Return Authorization and Required Information

If the instrument is to be returned for repairs, refer to Appendix B, "Return Authorization", for complete instructions on returning instrumentation.

2.2.4 Storage

For prolonged storage before installation, re-pack the Power Recorder in the shipping container. Cushion the Recorder with foam molding or equivalent and store in a cool, dry area. We do not recommend storage of the Recorder for more than one year. If longer storage time is required, contact the factory for additional storage information. See Table 2-1.

Table 2-1: Environmental Precautions

ENVIRONMENTAL PRECAUTIONS

For optimum performance, observe the following precautions when selecting a storing environment for the Recorder.

- Avoid direct sunlight and high temperature. Operating temperature must be within -20°F to 135°F (-29 to 57°C).
- Avoid sudden temperature swings of 10°C or more.
- Avoid locations susceptible to vibration, shock, static electricity, high magnetic, electro-magnetic, or radiation fields.
- Avoid extremely dusty, dirty, or corrosive gas environments.
- Maintain adequate air circulation paths to ensure proper cooling of the unit. Ambient operating temperature should not exceed 135°F (57°C).

Detailed Specifications are included in Chapter 1, Table 1-1,2,3.

2.3 WIRING SPECIFICATIONS AND PROCEDURES

2.3.1 Power Requirements

The Recorder operates on voltages from 80 to 600Vac, 45-65 Hertz.

A. Recorder Operating Power Connection

Power connections to the Recorder are made by connecting the Phase A voltage signal input wiring to an appropriate signal of 80-600Vac. This will automatically charge the batteries (Batteries could take up to 14 hours to fully charge) and power up the Recorder.

B. Batteries and power

The Recorder, when installed, powers itself from the line voltage on Channel 1. It requires less than 1.5 watts. This means the Recorder does not contain large internal batteries that must be recharged or replaced; the Recorder can be retrieved from the field, downloaded, and reinstalled elsewhere minutes later.

A small, AAA NiMH battery takes care of the Recorder's minimal power needs during a power outage while the Recorder is in record mode. This battery recharges off Channel 1 and should be replaced every three years. In addition, a Li memory backup battery allows the Recorder to sit on a shelf for up to three years after being initialized and still be ready for installation. Its memory can also hold recorded data for up to three years.

A 12-volt power adapter is provided to power the Recorder during downloads in the office or in the field if the Recorder has been disconnected from the line voltage.

The AAA battery will run the unit for up to 2 hours if power is lost.

WARNING

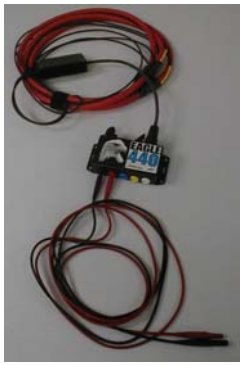
WHEN CONNECTING THE SIGNAL MEASURING LEADS, BE CAREFUL NOT TO TOUCH ANY OF THE CONNECTION POINTS. LETHAL VOLTAGE AND CURRENT CAN EXIST ON ANY INPUT LEAD OR CONNECTION POINT.

2.3.2 Installing the Recorder

This chapter explains the physical installation of the Eagle Class Recorder™. Installing the Recorder is not difficult for a professional familiar with similar equipment, although the same care required when working with any high-voltage equipment must be taken to complete the job safely. Please take the time to read Safety Issues, page 6, before installing the Recorder.

There are two things to connect when installing the Recorder:

1. The current probes, and
2. The alligator voltage clip leads.



Installation of the current probes depends on whether your Recorder is equipped with these items. Please read through the next three sections before installing your Recorder. Disconnect the power from the lines you plan to monitor until the installation is complete. Also, connect channel 1 voltage last, as this will start the two minute countdown for recording.

A. The current probes

1. CTs

The optional TLAR current clamps connect to the nine pin connector on the side of the Recorder housing. The Recorder automatically detects the amperage rating of the clamp connected during the two-minute initialization countdown which starts when power is applied to the unit (see below). The Eagle Class Recorder™ Recorder can be equipped with current clamps rated for 10A (TLAR), or Flexible CTs that have multiple ranges of 100A, 1000 or 5000A.

Once the desired clamps are properly connected to the Recorder, clamp around the line or bus you wish to monitor. The arrow on the body of the current clamps or probes must point toward the customer (away from the utility)—in the direction of the current. The current clamps measure amperage through induction. PMI recommends that current clamps be connected to the Recorder whenever they are attached to a power line.

2. Installation of Flexible CT

Insert the connector of the Flex CT into the 9-pin connector on the side of the recorder. The cable branches to 2, 3 or 4 flexible clamps, each of which is snapped into a loop around each line to be monitored. The "smart box" midway on the cable senses the induced current and processes the information for measurement. The recorder's current range can be set using WinScan or PMIScan.

Remember, Safety is always our primary concern.

C. The voltage clip leads

The Recorder can monitor voltage on up to four channels. Alligator clip leads are provided for each channel. These leads are color-coded as follows:

Table 2-2: Voltage leads color coding

Channel	Lead	Phase
Channel 1	Black	A
Channel 2	Red	B
Channel 3	Blue	C
Channel 4	Yellow	N
Common	White	Common

Attach the alligator clip leads to voltage lines in a pattern which will monitor the phases on which you wish to collect data. For information on several ways to monitor power, see the next section, **Connecting to different types of services**.

The Recorder will borrow its power from the voltage on Channel 1. As soon as voltage is applied to the Channel 1 lead, the Recorder begins a two-minute countdown. During this countdown, the Recorder will sample the voltages on each channel in order to set the nominal voltage for the recording period. The Recorder also uses this time to detect which probes are connected to it—see the information on current probe connections above. While the countdown continues, you may adjust some Recorder settings. However, making a change to the Recorder settings will restart the countdown at two minutes.

During the two-minute countdown, you may exchange one type of current clamp for another (on the Eagle Class Recorder™ only). However, if you change the probes, you must restart the two-minute initialization countdown by interrupting and then restoring power to the Recorder. If probes on an operating Recorder are exchanged with probes of a different type without re-initializing the Recorder, the unit will retain the setting of the first probes as the operating type. This may result in incorrect measurements.

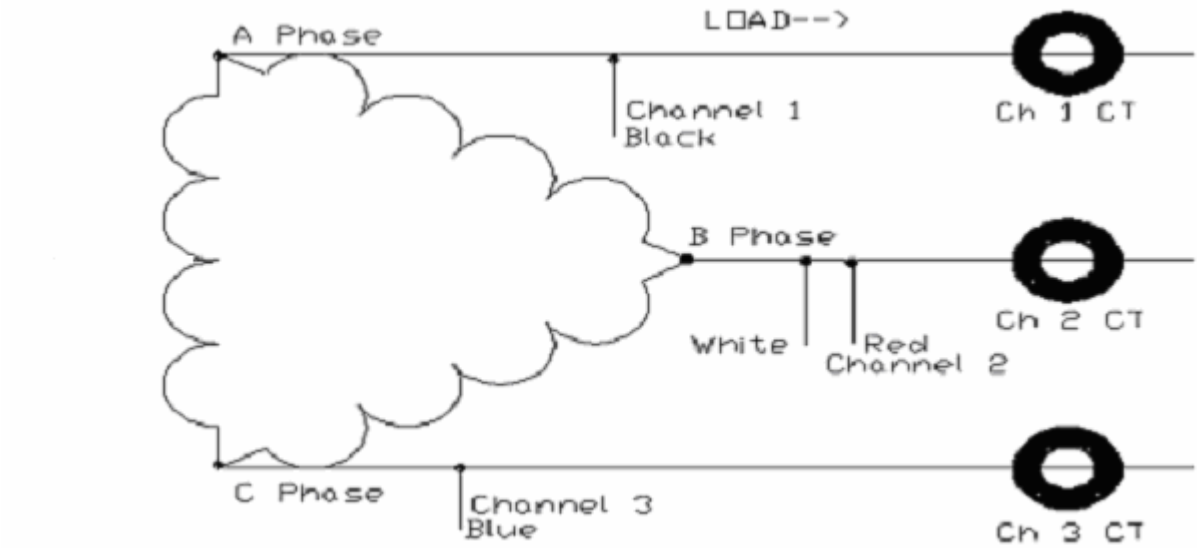
1. Connecting to different types of services - When planning how to connect your Recorder, keep the following things in mind:

- The banana jacks are color-coded by channel: black is Channel 1, red is Channel 2, blue is Channel 3, yellow is Channel 4, and white is common.
- The unit is powered from the voltage between Channel 1, the black jack, and common, the white jack. For this reason, even if you are not connecting all the input wires, Black and White must be connected.
- Be aware of the input voltage warning label on the Recorder, do not exceed the maximum input voltage. The limits are 600 volts RMS channel to channel or channel to common for the Eagle Class Recorder™.
- You may use four-channel units to monitor five-channel systems; naturally, you will record data for only four of the channels. Conversely, you can use a four-channel unit to monitor a single-phase system: either unplug the unused leads, connect them in parallel so that all channels are recording the same information, or clip together to avoid noise readings. Again, the Channel 1 leads must be connected in order to power the unit..

Below are diagrams showing several basic circuits and possible ways to connect them:

To connect a Recorder to monitor a **delta service**, connect one of the clips leads for three channels to both corners of the phase. Clip lead for Channel 1 (black) will be connected to one corner (A). Clip the White lead to the next corner (B), and clip the blue lead to the third corner (C).

Figure 2-1: 3 Wire Delta



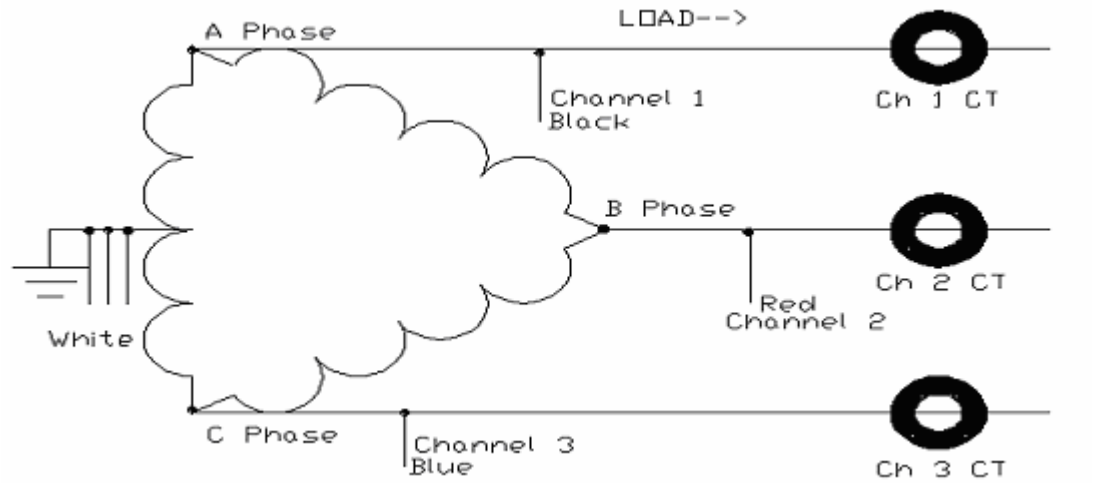


Figure 2-2: 4 Wire Delta

You can connect the clip leads phase-to-phase on a Wye service in the same manner you would when monitoring a delta service.

Figure 2-3: 3 wire wye phase to phase

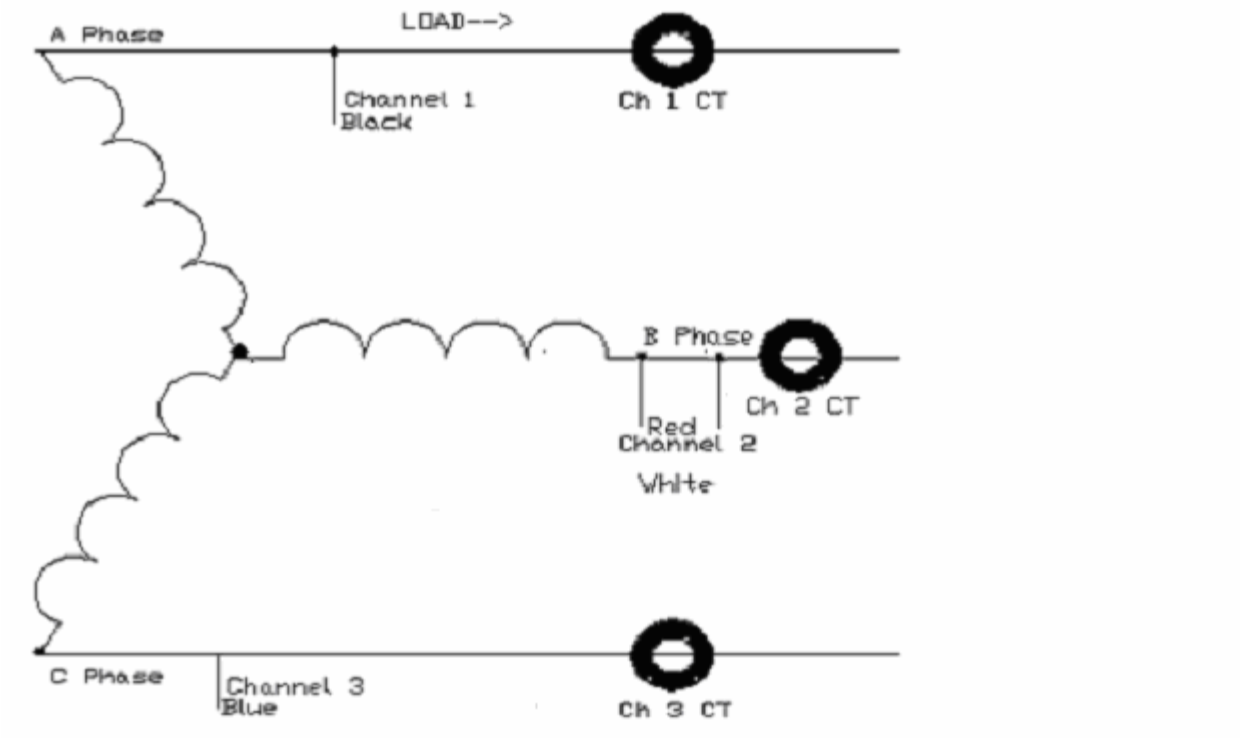
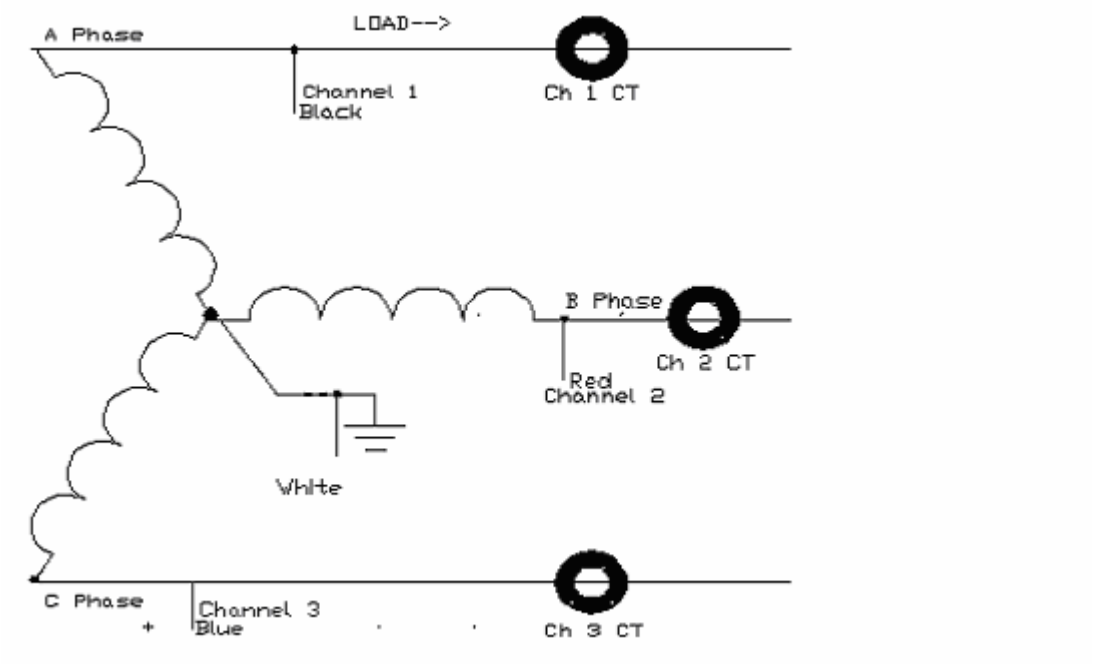


Figure 2-4: 4 wire wye



You can also connect the unit to monitor phase-to-neutral references by connecting one lead (the hot side) for each channel to the respective phase in the circuit, and connect the white lead (common) to the neutral. In the diagram, Channel 1 is represented by the black lead, Channel 2 (red) , and Channel 3 (blue).

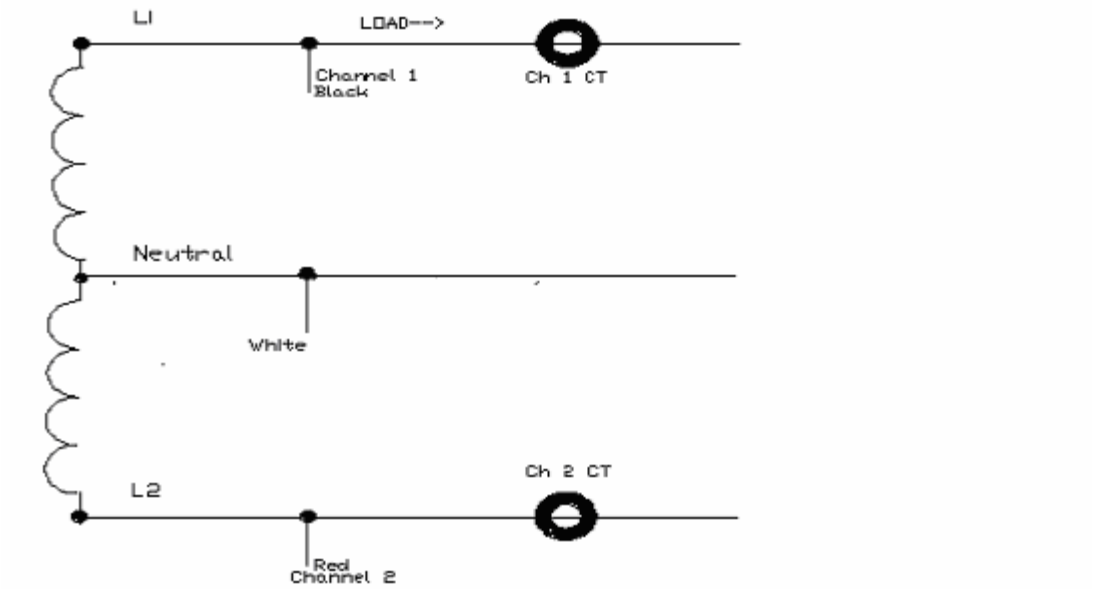


Figure 2-5: Two phase three wire

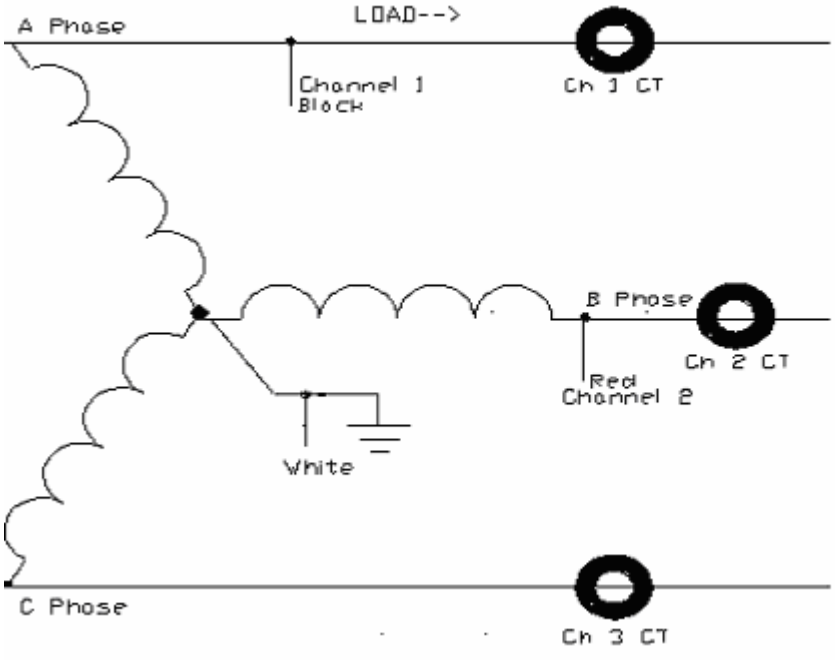


Figure 2-6: 2.5 Element Z-coil

2.3.3 Communications Port Connections

A. General

Designed into the Recorder is a Communications Port. The standard interface cable is an RS232 Serial type used to interface with a remote terminal or computer. The Communications Port allows you to access and manipulate the recorded information on the Recorder.

Figure 2-7: Serial Connection

B. RS232 Serial Cable

The RS232 Serial Cable is configured and wired to conform to the industry standard RS232 connection.

Connect the 6-pin connector of the comm. cable to your Recorder and the DB-9 (RS232) end of the cable to your computer serial port

If the Recorder's channel 1 voltage leads are not connected to >80Vac, connect the AC adapter provided to the power jack on the 9 pin D shell as shown in figure 2-7. Then plug the adapter into a 120VAC outlet.

You can now use WinScan™ to download and/or set up the unit to record. Please refer to the WinScan™ manual for instructions.

Operation Chapter 3

3.1 INTRODUCTION

3.1.1 General

This chapter contains information concerning system operation

3.2 CONTROL AND PRESENTATION

3.2.1 General

The following paragraphs are intended to familiarize you with the front panel controls and commands along with any other day-to- day operating controls. The Recorder presents information through the display and the WinScan™ program.

3.2.2 Operator Controls

All controls are via the WinScan program or PMIScan.

3.2.3 Initialization

The Eagle must be initialized before recording data. This is done by connecting the Eagle to your PC with the Eagle serial cable or through Bluetooth, and running WinScan. See the section \PC Communications with the Eagle" for information on how to connect the Eagle to the PC. See the WinScan documentation for details on how to initialize a Voltage Scanner. The Eagle may also be initialized with Palm-based PDA using the optional PMIScan software. The connection can be with the serial cable or Bluetooth. Please see the PMIScan manual for further details.

3.2.4 LED Indicator

The unit has an LED that will indicate when the unit is counting down by blinking once per second. The LED will blink once every six seconds when the unit is in record mode. Lastly, the LED will stay lit when communicating with the unit.

An outline of WinScan™ Chapter 4

4.1 RETRIEVING DATA FROM THE RECORDER

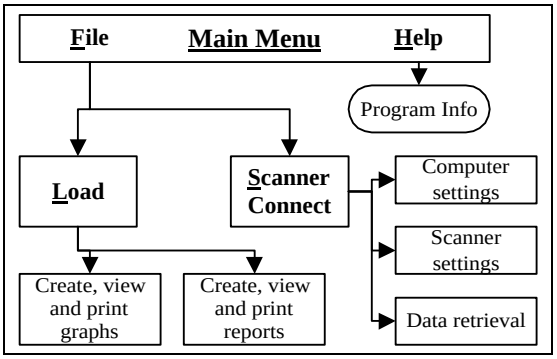


Figure4-2: Software outline

After your Recorder has finished collecting data, you need to download the data in order to analyze it on your computer. This process can be accomplished either over blue tooth (if your PDA or computer have a Blue tooth device) or via a serial cable. As the data is downloaded, your computer will save it in a file which can later be opened and analyzed. Please refer to the WinScan™ Manual for instructions.

Figure 4-1 illustrates the basic structure of WinScan™. As you can see, the main menu option **HELP** leads to information on the program, while the option **FILE** leads to operations involving the Recorder, the data it collects, and the tools needed to interpret that data.

The most useful options in the **FILE** menu are **RECORDER CONTROL** and **LOAD**.

As shown in the diagram, **RECORDER CONTROL** leads to options which adjust settings on the Recorder and computer. These options regulate the collection and retrieval of data by the Recorder.

The other important option, **LOAD**, is the gateway to creating, viewing and printing WinScan™ graphs and reports.

Familiarize yourself with all the operations of WinScan™ as described in this manual before attempting to use your Recorder. After you are familiar with WinScan™, use the **Quick Guide**, in the WinScan™ Manual, as a reminder of the steps required for certain operations. For your own protection, please take the time to read **Safety Issues**, before installing or operating the Recorder.

Appendix 1: PC and Recorder configuration factory settings

PC SETUP

OPTION	*FACTORY SETTING*
Local: Serial Port	Com 1
Local: Baud Rate	28800
Modem: Serial Port	Com 2
Modem: Baud Rate	Auto
Dialing Method	Tone
Auto Recorder Reset	Prompt
Scale Factor: Voltage	1
Scale Factor: Current	1
Auto Clock Reset	On
Auto Data Save	On
Stripchart Report Header	Checked

RECORDER SETUP/INITIALIZE

OPTION	*FACTORY SETTINGS*
LED Indicator	Checked
Interval Recording Overwrite	Checked
Ab. LED Trigger Duration	5 seconds
Interval Data Storage	100 percent
Significant Change Threshold	3 volts
Modem Ring Count	3 rings
Number of Channels	4
Rotary Switch Override	Not Checked
Recording Interval	1 minute

EVENT RECORDING PARAMETERS

Nominal Voltage	120 volts
Threshold Bands	6 volts
Minimum Event Time	10 cycles

Default settings are identical for all four channels.

FLICKER PARAMETERS—*from* ***ANSI/IEEE STANDARD 141***

Period	*Tolerance (%)*	*Limit*
10 seconds	1	5
1 minute	1.5	10
15 minutes	2	10
30 minutes	2.5	10
1 hour	3	10
4 hours	3.5	10
8 hours	4	10
12 hours	5	10
24 hours	6	10

Default settings are identical for all four channels.

ABNORMAL LED INDICATORS

Nominal	*Low Range*	*High Range*
Standard: 120	6	12
Standard: 208	10	20
Standard: 240	12	24
Standard: 277	13	27
Standard: 480	24	48
Custom: 106	5	10
Custom: 203	11	23

Default settings are identical for all four channels.

Appendix 2: Warranty Clause

Power Monitors Inc. (PMI) warrants each new product manufactured and sold to be free from defects in material, workmanship, and construction, and that when used in accordance with this manual will perform to applicable specifications for a period of one year after shipment.

If examination by PMI discloses that the product has been defective, then our obligation is limited to repair or replacement, at our option, of the defective unit or its components. PMI is not responsible for products which have been subject to misuse, alteration, accident, or for repairs not performed by PMI.

The foregoing warranty constitutes PMI's sole liability, and is in lieu of any other warranty of merchantability or fitness. PMI shall not be responsible for any incidental or consequential damages arising from any breach of warranty.

Equipment Return

If any PMI product requires repair or is defective, call PMI at (800) 296-4120 before shipping the unit to PMI. If the problem cannot be resolved over the phone, PMI will issue a return authorization number. For prompt service, all shipments to PMI must include:

1. Billing and shipping address for return of equipment.
2. The name and telephone number of whom to contact for further information.
3. A description of the problem or the work required.
4. A list of the enclosed items and serial numbers.
5. A return authorization number.
6. If possible, a copy of the original invoice.

Equipment returned to PMI must be shipped with freight charges prepaid. After repair, PMI will return equipment F.O.B. factory. If equipment is repaired under warranty obligation, freight charges (excluding air freight or premium services) will be refunded or credited to the customer's account. Return equipment to:

Power Monitors Inc.
1661 Virginia Avenue
Harrisonburg, VA. 22802 USA
Attention: Repair Department

Appendix 3: Troubleshooting

Symptom	Possible Solution
Unit indicates negative real power, wrong phase angle	Voltage leads on this channel may be reversed; also may be due to reversed current CT connection
Unit indicates negative real power, wrong phase angle	Current CT may be reversed, clamped around conductor in wrong direction; also may be due to reversed voltage leads.
Current clamp "buzzes" when connected around conductor.	Clamp jaws not closing completely, or dirt/rust on surface of metal jaws; Clean contacts and retry. Also try a different CT
Unit will not communicate	Make certain that Local and Modem port are set to different com #s, and that Palm Pilot HotSync Manager is turned off!
Unit will not communicate	Insure the serial port is correct and serial cables are correct. Retry at different baud rates. Turn off power management (or power saving) in the Windows control panel and the bios. Retry.
Unit will not download data	Try Different baud Rates, Bring up the task manager in Windows and "end task" for all programs except WinScan™, Systray, and Explorer, Retry.
Recorder downloads to 99% and gives serial comm error	Contact PMI for assistance and/or WinScan™ upgrade
Strip chart shows very high or wildly fluctuating, unrealistic readings or spikes on V and I	Contact PMI for an upgrade and retry.
Waveform capture graph does not plot time axis correctly; 50Hz sinusoidal waveform plotted with 60Hz period.	Contact PMI for WinScan™ Upgrade
Waveform capture graph does not plot time axis correctly; 50Hz sinusoidal waveform plotted with 60Hz period.	Contact PMI for WinScan™ Upgrade
Some current channels do not work on flex CT's.	Possible wires in flex CT are cut or nicked. Try a different set or Contact PMI for Evaluation

Appendix 4: Eagle Class Recorder™ Formulas

Vip Formulas for Power and Harmonic Measurements

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Abstract– *The Vip uses a variety of algorithms to compute RMS voltage and current, real, reactive, and apparent power, true and displacement power factor, phase angle, total harmonic distortion, and harmonic magnitudes and phases. The formulas for these algorithms are detailed here.*

1 Introduction

The Vip samples four pairs of voltages and currents. From these samples it computes RMS voltage and current; real, reactive, and apparent power; power factor and displacement power factor, phase angle, voltage and current THD, and harmonic magnitudes and phases. The raw waveforms are sampled at a rate of 256 samples per powerline cycle (usually 60Hz). Here the complications of A/D quantization, scaling, finite precision math, gain and offset correction, hardware temperature drift compensation, harmonic magnitude and phase corrections, and synchronization with the powerline frequency are not discussed. Thus, assume all measurements are in volts or amperes, with infinite precision, and perfectly synchronized such that 256 samples is exactly one powerline cycle (hereafter called a 60 Hz cycle, though the actual frequency may be from 46 to 70 Hz). The formulas given here are not necessarily those peformed by the Vip, but are numerically equivalent expressions.

1.1 Notation and Sampled Data

The Vip samples four channels of voltage and four channels of current. Let $v_1[n], v_2[n], v_3[n], v_4[n]$ and $i_1[n], i_2[n], i_3[n], i_4[n]$ represent the sampled voltages and currents for the four channels. In a single 60Hz cycle, the samples are indexed in the range $0 \le n \le 255$. Where the channel number is not relevant, the subscript may be dropped. Where multiple cycles of data are needed, a superscript is added: $v_j^m[n]$ is the nth voltage sample for the jth channel for the mth cycle, where $0 \le n \le 255$, $1 \le j \le 4$, and $m > 0$.

2 Independent Channels/Single Phase

In this recording mode, each pair of voltage and current channels are used independently. Three phase wye and delta calculations are extensions to the formulas for the single phase case.

2.1 RMS Voltage and Current

The rms value is computed once per cycle for each channel of voltage and current. The voltage rms value is computed by

$$\mathrm{VRMS} = \sqrt{\frac{1}{256}\sum_{n=0}^{255}\left(v[n]\right)^2}. \tag{1}$$

Similarly, the current rms value is given by

$$\mathrm{IRMS} = \sqrt{\frac{1}{256}\sum_{n=0}^{255}\left(i[n]\right)^2}. \tag{2}$$

2.2 Real Power

Real power is computed once per cycle for each pair of voltage and current channels. The real power value is computed by

$$\mathrm{W} = \frac{1}{256}\sum_{n=0}^{255} v[n]i[n]. \tag{3}$$

Note that real power is signed to indicate direction of power flow.

2.3 Apparent Power

Apparent power is computed once per cycle for each pair of voltage and current channels. The apparent power value is computed by

$$\mathrm{VA} = \mathrm{VRMS} \times \mathrm{IRMS}. \tag{4}$$

2.4 Harmonics

An FFT of each voltage and current channel is computed every cycle. Since harmonics only to the 51st are required, the anti-aliased, sampled data is smoothed and downsampled by a factor of two before a 128-point FFT is performed. The smoothing is done by averaging each pair of data points. The complex FFT result, including the smoothing and downsampling, is given by

$$V[k] = \sum_{n=0}^{127} \frac{1}{2}(x[2n] + x[2n+1])e^{-j2\pi kn/128} \qquad (5)$$

for $k = 0, \ldots, 63$. Here j represents $\sqrt{-1}$. Since the FFT is done on a single 60Hz cycle of data, the index k also represents the harmonic number. The 128 point FFT gives a decomposition into 64 harmonics of 60Hz. For specific channels and cycle numbers, the notation $V_j^m[k]$ and $I_j^m[k]$ denote the FFT value for jth channel, for the mth cycle number, for the kth harmonic. The real and imaginary parts of $V[k]$ are denoted by $V_x[k]$ and $V_y[k]$, respectively. The real and imaginary parts for channel j are $V_{jx}[k]$ and $V_{jy}[k]$.

The harmonic magnitudes and phases are computed once per second, to provide some averaging and to reduce transient effects. The one-cycle FFT values are averaged over the M cycles which comprise each second, to form

$$\overline{V[k]} = \frac{1}{M}\sum_{m=1}^{M} V^m[k]. \qquad (6)$$

The kth harmonic magnitude is then given by

$$\mathrm{VMAG}[k] = \left|\overline{V[k]}\right| = \sqrt{\left(\overline{V_x[k]}\right)^2 + \left(\overline{V_y[k]}\right)^2}, \qquad (7)$$

and the raw kth harmonic phase angle is

$$\mathrm{V}\theta[k] = \angle\overline{V[k]} = \arctan\left(\frac{\overline{V_y[k]}}{\overline{V_x[k]}}\right). \qquad (8)$$

The arctan function is the four quadrant inverse tangent, with a range of −180 to +180 degrees. The current magnitudes and phase angles are computed in the same manner. The voltage harmonic phase angles are referred to the first voltage channel's first harmonic phase angle. The current harmonic phase angles are then referred to their cooresponding voltage 60Hz phase angles. This two-step algorithm proceeds as follows for the jth channel:

1) $\mathrm{V}\theta_j[k] = \mathrm{V}\theta_j[k] - k\mathrm{V}\theta_1[1], \quad k = 1, \ldots, 51$
2) $\mathrm{I}\theta_j[k] = \mathrm{I}\theta_j[k] - k\mathrm{V}\theta_j[1], \quad k = 1, \ldots, 51.$

2.5 Phase Angle

The phase angle, θ, is the angular phase shift between the 60Hz voltage and current sinusiods. It is computed every cycle, and is simply

$$\theta = \mathrm{I}\theta[1] - \mathrm{V}\theta[1], \qquad (9)$$

where $\mathrm{I}\theta[1]$ and $\mathrm{V}\theta[1]$ are the phase angles for the 1st harmonic (60Hz). These phase angles are computed using (8) on the raw FFT outputs instead of the one second average, with $k = 1$.

2.6 Reactive Power

Reactive power is computed every cycle for each pair of voltage and current channels. The result is given by

$$\mathrm{VAR} = \sum_{k=1}^{51} \left(V_x[k]I_y[k] - I_x[k]V_y[k]\right). \qquad (10)$$

Each $V_x[k]I_y[k] - I_x[k]V_y[k]$ term is the reactive power contributed by harmonic k.

2.7 Power Factor

Power factor is computed once per cycle for each pair of voltage and current channels. The result is given by

$$\mathrm{PF} = \left|\frac{\mathrm{W}}{\mathrm{VA}}\right|, \quad \begin{cases} \text{no suffix,} & \text{for } \theta = 0 \text{ or } \theta = \pm 180 \\ \text{lead,} & \text{for } 0 < \theta < 180 \\ \text{lag,} & \text{for } -180 < \theta < 0 \end{cases} \qquad (11)$$

This expression is also known as true power factor, since it includes the effects of harmonics.

2.8 Displacement Power Factor

Displacement power factor is computed once per cycle for each pair of voltage and current channels. This quantity represents only the 60Hz contribution to the true power factor. The result is computed by

$$\mathrm{dPF} = |\cos\theta|, \quad \begin{cases} \text{no suffix,} & \text{for } \theta = 0 \text{ or } \theta = \pm 180 \\ \text{lead,} & \text{for } 0 < \theta < 180 \\ \text{lag,} & \text{for } -180 < \theta < 0 \end{cases} \qquad (12)$$

2.9 THD

Total harmonic distortion, computed every second for each channel of voltage and current, is given in percent by

$$\mathrm{VTHD} \frac{\sqrt{\sum_{k=2}^{51} (\mathrm{VMAG}[k])^2}}{\mathrm{VMAG}[1]} \times 100. \quad (13)$$

Since this THD definition is referred to the fundamental (as opposed to the RMS value), it may be over 100%.

3 Three Phase Wye

In a three phase wye hookup, each pair of voltage and current channels are handled in the same manner as the single phase hookup. The first three pairs are also grouped together to form total power quantities.

3.1 Total Powers

Total real, reactive, and apparent power are computed and displayed but not recorded in wye mode. The three phase totals are the sum of the individual phases:

$$\mathrm{W}_{TOT} = \mathrm{W}_1 + \mathrm{W}_2 + \mathrm{W}_3 \quad (14)$$
$$\mathrm{VAR}_{TOT} = \mathrm{VAR}_1 + \mathrm{VAR}_2 + \mathrm{VAR}_3 \quad (15)$$
$$\mathrm{VA}_{TOT} = \mathrm{VA}_1 + \mathrm{VA}_2 + \mathrm{VA}_3 . \quad (16)$$

All these totals are computed every second from one second averages. The values are displayed on the front panel and then discarded.

3.2 Total Power Factors, Phase Angle

These total quantities are computed as weighted averages of the three phases, weighted by apparent power:

$$\mathrm{PF}_{TOT} = \frac{\mathrm{PF}_1\mathrm{VA}_1 + \mathrm{PF}_2\mathrm{VA}_2 + \mathrm{PF}_3\mathrm{VA}_3}{\mathrm{VA}_{TOT}} \quad (17)$$

$$\mathrm{dPF}_{TOT} = \frac{\mathrm{dPF}_1\mathrm{VA}_1 + \mathrm{dPF}_2\mathrm{VA}_2 + \mathrm{dPF}_3\mathrm{VA}_3}{\mathrm{VA}_{TOT}} \quad (18)$$

$$\theta_{TOT} = \frac{\theta_1\mathrm{VA}_1 + \theta_2\mathrm{VA}_2 + \theta_3\mathrm{VA}_3}{\mathrm{VA}_{TOT}} \quad (19)$$

All these totals are computed every second from one second averages. The values are displayed on the front panel and then discarded.

4 Three Wire Delta

With a three wire delta circuit, individual phase powers and power factors cannot be computed without imposing assumptions such as a balanced load, balanced source, etc. The Vip only computes total quantities in this mode. These values are computed and recorded as channel one data. As in the wye case, these values are computed once per cycle. The fourth channel is treated as an extra single phase channel with power calculations as detailed in Section 2. Real and reactive power are calculated using the two-wattmeter method, using voltage channels 1 and 2, and current channels 1 and 3. The Vip is connected as a delta, with each voltage channel connected from phase to phase.

4.1 Real Power

Real power is computed using the two-wattmeter method. This requires two voltage and current channels to compute the three phase total. Voltage channels one and two are used with current channels one and three:

$$\mathrm{W}_{TOT} = \frac{1}{256}\left(\sum_{n=0}^{255} v_1[n]i_1[n] - \sum_{n=0}^{255} v_2[n]i_3[n]\right). \quad (19)$$

4.2 Reactive Power

Reactive power is computed using the two-wattmeter method. This requires two voltage and current channels to compute the three phase total. Voltage channels one and two are used with current channels one and three:

$$\mathrm{VAR}_{TOT} = \sum_{k=1}^{51} (V_{1x}[k]I_{1y}[k] - I_{1x}[k]V_{1y}[k]) \quad (20)$$
$$- \sum_{k=1}^{51} (V_{2x}[k]I_{3y}[k] - I_{3x}[k]V_{2y}[k]) .$$

4.3 Apparent Power

Apparent power is computed by:

$$\mathrm{VA}_{TOT} = \sqrt{(\mathrm{W}_{TOT})^2 + (\mathrm{VAR}_{TOT})^2} . \quad (21)$$

4.4 Phase Angle

The phase angle, θ, is the angular phase shift between the 60Hz voltage and current sinusiods. Since the actual phase current cannot be measured in a three wire delta hookup, the 60Hz component of the real

and reactive powers must be used to compute a total three-phase phase angle. The 60Hz component of the reactive power, $\mathrm{VAR}_{TOT}[1]$ is computed using (20) with $k = 1$ (since 60Hz is the 1st harmonic), giving

$$\mathrm{VAR}_{TOT}[1] = V_{1x}[1]I_{1y}[1] - I_{1x}[1]V_{1y}[1] - V_{2x}[1]I_{3y}[1] + I_{3x}[1]V_{2y}[1]. \quad (22)$$

The 60Hz component of the real power, $\mathrm{W}_{TOT}[1]$, can be obtained in an analogous fashion using

$$\mathrm{W}_{TOT}[1] = V_{1x}[1]I_{1x}[1] + I_{1y}[1]V_{1y}[1] - V_{2x}[1]I_{3x}[1] - I_{3y}[1]V_{2y}[1]. \quad (23)$$

This results in the following expression for θ_{TOT}:

$$\theta_{TOT} = \arctan\left(\frac{\mathrm{VAR}_{TOT}[1]}{\mathrm{W}_{TOT}[1]}\right). \quad (24)$$

4.5 Power Factors

Power factor and displacement power factor are computed with (11) and (12), with the use of W_{TOT}, VA_{TOT}, and θ_{TOT} instead of the single phase W, VA, and θ.

5 Four Wire Delta

With a four wire delta circuit, individual phase powers and power factors cannot be computed without imposing assumptions such as a balanced load, balanced source, etc. The Vip only computes total quantities in this mode. These values are computed and recorded as channel one. These computations happen once per cycle, as in the wye case. The fourth channel is treated as an extra single phase channel with power calculations as detailed in Section 2. Real and reactive power are calculated using the three-wattmeter method, which uses all three voltage and current channels. The Vip itself is connected as a wye, with each voltage channel measuring from phase to neutral.

5.1 Total Powers

Real and reactive total power is computed as the sum of the individual channels' real and reactive powers, computed as if they were part of a wye circuit. Thus, (14) and (15) can be used, with (3) and (10) used to compute channel powers as in the wye case. Total apparent power is computed with (21).

5.2 Phase Angle

The phase angle is computed with (24). To compute the 60Hz real and reactive power used in (24), all three voltage and current channels are utilized, as per the three-wattmeter methodology. The expressions for $\mathrm{W}_{TOT}[1]$ and $\mathrm{VAR}_{TOT}[1]$ become

$$\mathrm{W}_{TOT}[1] = \sum_{j=1}^{3} V_{jx}[1]I_{jx}[1] + I_{jy}[1]V_{jy}[1] \quad (25)$$

and

$$\mathrm{VAR}_{TOT}[1] = \sum_{j=1}^{3} \left(V_{jx}[1]I_{jy}[1] - I_{jx}[1]V_{jy}[1]\right). \quad (26)$$

APPENDIX 5: Regulatory Information

U.S. FCC Part 15 and Industry Canada RSS 210 Statements

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The letters “IC” have no other meaning or purpose than to identify the Industry Canada certification number/registration number.

FCC Warning

Changes or modifications not expressly approved by Power Monitors Inc. could void the user’s authority to operate this equipment.

Safety Warning

In order to ensure user safety and maintain a water tight, pollution free internal environment, this product, including the enclosure lid, has been sealed shut at the factory. There are no user serviceable parts inside. Any attempt to open the sealed lid could pose a safety hazard, compromise the watertight integrity of the enclosure, and may permanently alter the required electrical isolation between high voltage circuitry and the user. The AC line fuse, MOV, and the internal batteries (memory backup Lithium battery, and the NIMH ride-through battery) are replaceable, but should only be performed by PMI Inc. to ensure continued product safety and performance.

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