POWER MONITORS INC.

Stray Voltage Monitor Scanner
User's Manual

Power Monitors Inc.
1661 Virginia Avenue
Harrisonburg, VA 22802 USA
http://www.powermonitors.com

1-800-296-4120
540-434-4120
Fax: 540-432-9430

This version: April 2002

Corrections or ideas for this manual please e-mail: lbarker@powermonitors.com

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 SVM-10™ was 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 on four channel connections. The units require so little power; they operate on the voltage from one line cord. 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 scanners 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 min/max/Avg recording of voltage make PMI scanners the ideal products for distribution monitoring.

The Scanner features:

- True RMS voltage measurement on each of four channels
- Programmable abnormal voltage recording
- On-site, real-time display of voltage
- Single-cycle response (16 msec)
- More than 122,000 samples per second
- 0-10 volt RMS operating range
- Up to 2,048K FLASH EPROM memory
- Memory capacity for more than one year of summary data, 500 event records, 500 records of significant change
- Rugged, weatherproof enclosure NEMA 4X
- All channels captured simultaneously in one cabinet

Scanner/WinScan™ graphs and reports include:

- Stripchart and histogram analysis for RMS voltage report
- Daily Profile
- Significant change report
- Waveforms (optional)

Because of these capabilities, the SVM-10™ Scanner is the perfect instruments for analyzing and solving power quality and quantity problems. After looking through this manual and using your Scanner, 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.

Table of Contents

This page Left Blank Intentionally

SAFETY ISSUES

Please read carefully before installing or using the Scanner.

- The Scanner contains dangerous voltage levels during operation. Do not disassemble the Scanner. THE ONLY USER-SERVICEABLE PARTS INSIDE ARE THE BATTERIES! Insure power is completely removed from the unit prior to changing the batteries.
- 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 Scanner.
- During installation, disconnect power from any lines to which the Scanner will be attached.
- Although the Scanner 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 SVM-10™ Scanners (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

Figure 1-1: SVM-10™ Scanner

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.

1.2 SCANNER DESCRIPTION

1.2.1 General

The SVM-10 Scanner is easy-to-use, true RMS, micro-computer-based voltage recording device that produce accurate readings and professional reports. These scanners can help you resolve customer stray voltage complaints, conduct long-term voltage surveys, and detect voltage variations as brief as one cycle. The Scanner will not disrupt normal power supply; rather, it uses a minimal amount of voltage from one 120 vac outlet.

Each Scanner 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 Scanner is configured to capture the information.

Installing the Scanner 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 a modem (if your Scanner is so equipped) or serial cable. Real-time data can be checked using the keypad and liquid crystal display (LCD) on the unit's front. An optional Palm® interface is also available for viewing real time data from the unit. 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 Inputs

Direct hookups are fed into 4 voltage, 0-10vac inputs. Four 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™.

1.2.3 Instrument Size

The Scanner is contained in a standard 6.5 inch (165.1mm) wide x 6.5 inch (165.1mm) high x 4.25 inch (107.95mm) deep NEMA 4x lockable case.

1.2.4 System Description

The Scanner is a system designed to measure and record AC Voltage 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; a graphics display shows the information. 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. Screens and Displays

Screen display styles are available to present data in a familiar format. User instruction and data entry screens feature easy to use menus, with easy to understand terms. Operating display screens show information in a logical and easy-to-read format.

B. 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.

C. Configuration

WinScan™ software allows the user to program the unit quickly and efficiently using an IBM Windows based compatible 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, and Event parameters can be easily programmed. Other parameters such as Scales, and engineering units are also easy to program.

D. Applications

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

- Voltage Levels
- Harmonics to the 51st

E. System Technology

This Power Scanner 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.

1.2.5 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.

1.2.6 Clock

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

1.2.7 Scanner Construction

The Power Scanner features modular construction. All printed circuits boards are conveniently accessible for fast and simple troubleshooting and/or removal via a lift-out chassis. The lift-out chassis also facilitates easily changing the LCD. All viewing controls and indicators are located on the front panel. *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.*

1.2.8 Communications

The standard RS232 port allows you to plug the Scanner 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

Figure 1-3: Serial Cable

supplied directly to the
voltage leads.

1.3 SUPPLIED EQUIPMENT

1.3.1 Equipment Listing

The following items are supplied with your Scanner:

- the SVM-10™ Scanner,
- CD Containing
  - WinScan™ Software
  - This manual
  - a WinScan™ Manual
  - Sample files
- a serial communications cable
- a 12-volt power adapter wall transformer and cord.

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

The package may include these optional items:

- a modem cable (if your unit is equipped with a modem).

1.4 ACCESSORIES

1.4.1 General

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

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).

1.4.5 Cases

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

1.4.6 Spare Parts List

SVM-10™ Series

(*R-models only)

- -

SVM-10™ Manual PMI#XXXXXXX
Serial Adapter PMI#30550106
Wall Transformer PMI#31100008
*Modem Cable PMI#20506001
SVM-10™ Comm. Cable PMI#20506002

Figure 1-6: Cases

1.5 SPECIFICATIONS

1.5.1 General

The SVM-10™ Scanner specifications is shown in Table 1-1.

Table 1-1 SVM-10™ Specifications

SVM-10™ Scanner Specifications

Input	
AC Voltage	0 to 10 VAC
Sample rate: samples per second	
	61,440 all channels
	15,360 per channel (256/cycle)
Channels	
4 voltage	
Measured Qualities	
RMS Voltage	(Volts)
Note: All quantities are measured for each cycle.	
Accuracy/Resolution	
(-20°F to 135°F)	
Accuracy	**Percent of full scale**
Voltage	0.33 %
Resolution: Displayed/Internal	
Voltage	0.01 V / 0.001 V internal
Input Impedance	
Channels 1,2,3	12kOhms
Channel 4	500 Ohms
Information Storage	
Memory	
RAM	128K (battery-backed)
FLASH EPROM	512K to 2,048K
DSP Waveform RAM	up to 256K
TOTAL MEMORY	1.1 million readings
Capacity	
Summary data	Over 1 year
Event data	500 records
Significant change data	500 records
Stripcharts	4 hours to over 1 yr.
Voltage	
Retention time	> 5 years
Communications	
Local	
Type	Serial Cable
Standards	RS232 Compatible
Data rate	1,200 to 38,400 baud
Modem (optional):	14.4 kbps
Local Output	

Type	Wide-temperature LCD
Size	4 lines by 20 characters
Interface	Menu-driven

SVM-10™ Specifications Continued..

Controls

Stripchart settings	1 second to 4 hours
Significant change	1V to 8 V, in 1V steps
Battery voltage check	Automatic
Keypad	4-key membrane

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	6.5” x 6.5” x 4.25”
Weight	5.0 lbs.
Case	NEMA 4X

Power Fail Operation

The device operates with no input voltage for more than 30 minutes. This allows it to measure down to 0 volts on all channels during power outage periods.

Harmonics (optional)

Voltage Measures to the 51st

Measures:

- Magnitude
- Phase
- THD

Waveform capture: Triggered

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

Connection Information Chapter 2

2.1 INTRODUCTION

2.1.1 General

This chapter provides information and procedures for connection of the Scanner. 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 Scanner in the shipping container. Cushion the Scanner with foam molding or equivalent and store in a cool, dry area. We do not recommend storage of the Scanner 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 external 120Vac power with to the line cord.

A. Scanner Operating Power Connection

Power connections to the Scanner are made by connecting line cord to a 120Vac outlet. This will automatically charge the batteries and power up the Scanner.

B. Batteries and power

The Scanner, when installed, powers itself from the line cord. It requires less than 2.5 watts. This means the Scanner does not contain large internal batteries that must be recharged or replaced; the Scanner can be retrieved from the field, downloaded, and reinstalled elsewhere minutes later.

A small, coin-shaped lithium battery takes care of the Scanner's minimal power needs while the Scanner is not connected to a power source. This battery never needs recharging and only needs replacing every five years. With this battery intact, the Scanner can literally sit on a shelf for up to five years after being initialized and still be ready for installation. Its memory can also hold recorded data for up to five years.

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

2.3.2 Installing the Scanner

This chapter explains the physical installation of the SVM-10™ Scanner, and shows how certain settings may be altered using the Scanner keypad. Installing the Scanner is not difficult for a professional familiar with similar equipment, although the same care used 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 9, before installing the Scanner.

There are two things to connect when installing the Scanner:

1. the line cord
2. the voltage leads.

Installation of the modem cable of course depends on whether your Scanner is equipped with these items. In any case, please read through the next three sections before installing your Scanner. Disconnect the line cord until the installation is complete. Also, you want to connect line cord last, as this will start the two minute countdown for recording.

A. The Line cord

Your Scanner is equipped with a line cord, connect the cord from the Scanner (on top of the Scanner housing) to a standard 120vac outlet.

C. The voltage leads

The Scanner can monitor voltage on up to four channels. Banana jacks are provided for each channel. These jacks are color-coded as follows:

Table 2-2: Voltage jack color coding

Channel	Phase	Jack color
Channel 1	A	Black
Channel 2	B	Red
Channel 3	C	Blue
Channel 4	Cow contact (500 ohm impedance)	White

You will need male banana plugs that are not supplied with the unit. These types of plugs are readily available at such stores as Radio Shack (part numbers 278-321 or 278-307). You will need to attach leads to the plugs. There is no limit on conductor lengths for our inputs.

Attach the leads to voltage lines in a pattern which will monitor what you wish to collect data.

The Scanner will borrow its power from the line cord. As soon as voltage is applied, the Scanner begins a two-minute countdown, displayed on the LCD. During this countdown, the Scanner will sample the voltages on each channel in order to set the nominal voltage for the recording period. While the countdown continues, you may adjust some Scanner settings using the keypad (see ***Changing Scanner settings using the keypad***). However, making a change to the Scanner settings will restart the countdown at two minutes.

1. Connecting to different types of services - When planning how to connect your Scanner, 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, and white is Channel 4. Keep in mind that one of the two same-colored boots is the "hot side," and the other is the neutral. See the table in the previous section for wire colors.
- The unit is powered from the line cord. For this reason, even if you are not connecting all the input wires, the line cord must be connected.
- Be aware of the input voltage, do not exceed the maximum input voltage. The limits are 10 volts RMS for the SVM-10™. (protected to 20 vac max)
- Unused jacks should be clipped together to avoid noise readings.

A typical setup to investigate and monitor stray voltage is as follows:

CH1 - Utility Primary Neutral to a reference rod 150+ feet away from buildings and utility poles.

CH2 - Farm Secondary Neutral to the same reference rod.

CH3 - Primary Neutral to Secondary Neutral
(voltage drop from XFMR to customer service panel)

CH4 - Cow Contact Voltage
(Waterline to rear hoof area copper plate held in place under a jack post to provide similar weight of the animal)

2.3.3 Communications Port Connections

A. General

Designed into the Scanner 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 Scanner.

B. RS232 Serial Cable

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

Connect the round, black end of the cable to your Scanner and the rectangular (RS232) end of the cable to your computer serial port

If the Scanner's line cord is not connected to 120Vac, connect the AC adapter provided to 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 and front panel keystroke commands for your Scanner. Explanations of the front panel displays and menu selections are included.

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 Scanner presents information through the display and the WinScan™ program. The front panel uses a LCD display and four key membrane switch to allow operator inputs to lead you through instrument setup.

3.2.2 Operator Controls

All controls are on the front panel of the Scanner. On the next few pages, the figures illustrate and define all of the Operator accessible Scanner controls. The initial Scanner display is illustrated in Figure 3-1 and explained in the following Paragraphs.

A. LCD menus and keypad

Like WinScan™, the liquid crystal display (LCD) on the Scanner faceplate also uses menus. Choices are made using the four keys on the Scanner's faceplate:

LEFT ARROW (□): Moves cursor to the left across a menu bar.

RIGHT ARROW (□): Moves cursor to the right across a menu baSET

KEY: Selects the highlighted option.

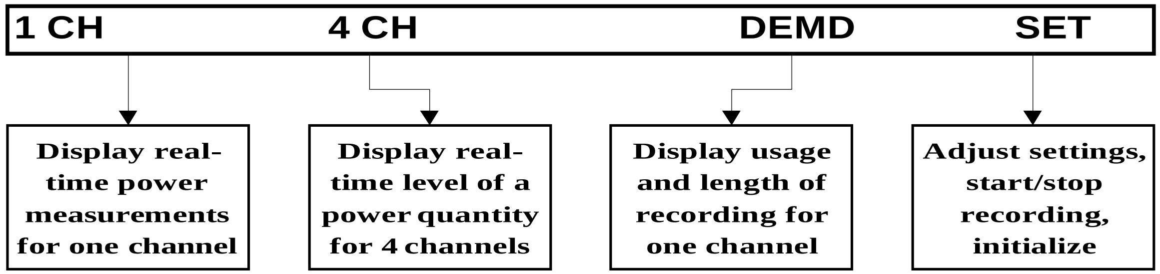

Figure 3-1: LCD Menu

BLUE KEY: Returns the LCD to the most recently used menu, or, if no menu has been used since the Scanner has been powered, brings up the main LCD menu.

When working with the keypad and LCD, first hit the **BLUE** key to bring up the main menu. Then use the **LEFT** and **RIGHT** arrows to move to the option you want to select.

When the option you want is highlighted (blinking), hit the **SET** key to select the option. Notice that only four options are displayed at a time. If other choices are available, the LCD will show an arrow in the lower right- or left-hand corner of the screen. To view more options, hit the arrow keys until the other choices appear.

1. Reading real-time data on the LCD

While the Scanner is recording, you can use the keypad to read data from the LCD. The LCD can display information on voltage, amperage, and other power measurements for all four channels. It can also show summary information for the recording session in progress.

To view the main LCD menu, hit the **BLUE** key. You will see four choices across the top of the LCD. The first three—**1 CH**, **4 CH**, and **DEMD**—can be used to read real-time data.

Figure 3-3: LCD Display

1 CH

Select this option from the main LCD menu by hitting the **SET KEY** when the option is blinking. The LCD will show, for Channel 1, the ongoing readings for voltage.

Use the arrow keys to view the readings for other channels. Or, if you select **AUTO** in the **SET** menu, the Scanner will automatically move from one channel to the next after pausing several seconds on each screen.

4 CH
Select this option from the main LCD menu by using the arrow keys to highlight it, then hitting the **SET KEY**. The LCD will show the ongoing readings for RMS voltage on all four channels.

The fourth option in the main LCD menu—**SET**—is used to initialize the Scanner, to start or stop recording, and to adjust the recording interval and significant change threshold during field installation. Do not confuse the **SET** option with the **SET KEY**, as they are not directly related.

2. Changing settings using the keypad

Using the keypad on the Scanner's faceplate, you can start the initialization countdown, start and stop recording, and adjust the interval and significant change threshold settings. The keypad can also be used while the Scanner is recording to display real-time levels of volts.

To view the main LCD menu, hit the **BLUE KEY** on the keypad. The functions used to initialize the Scanner are found under the **SET** menu option of this main menu. To open the **SET** menu, use the arrow keys to highlight **SET** at the right end of the main menu, then hit the **SET KEY** to select the option.

Five options are available in the **SET** menu. They are:

INIT
Highlighting this option then hitting the **SET KEY** initializes the Scanner; that is, it starts the two-minute initialization countdown discussed earlier in this chapter.

STRT (or **STOP** when the Scanner is recording)
This option starts (or stops) the Scanner recording. If **STRT** is used to begin a recording, the Scanner will use stored settings to determine how it records data. Selecting **STOP** when the Scanner is recording halts recording functions. The time the unit is stopped will appear in reports as a power outage if the unit is restarted using **STRT**.

PARM (Parameters)

Select this option during the two-minute countdown to adjust the settings for recording interval and significant change threshold. Use the **SET KEY** to toggle between the two settings and the arrow keys to adjust the settings up and down.

Note: If the Scanner was initialized with **Rotary Switch Override** selected in the **"Scanner Settings"** dialog box, you cannot change these settings from the keypad.

DIAG

This option shows serial numbers and installed options which may be of use. It contains no user-adjustable features.

AUTO/MANL (Manual)

If this option is set on **AUTO**, the LCD will automatically scroll through all four channel displays (when the **1 CH** or **DEMD** option is selected from the main menu) or through all measurements (when **4 CH** is selected from the main menu), pausing several seconds on one display before going to the next. If this option is set on **MANL** (manual), you must use the arrow keys to move from display to display. **MANL** is the default setting.

An outline of WinScan™ Chapter 4

4.1 RETRIEVING DATA FROM THE SCANNER

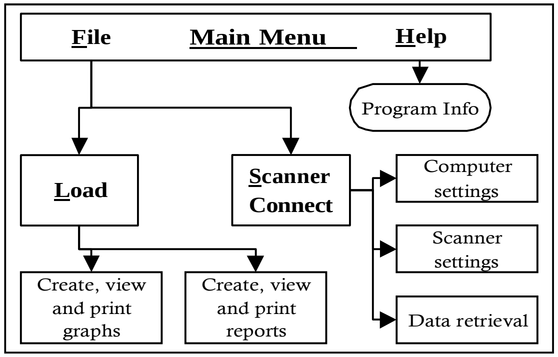

Figure4-1: Software outline

After your Scanner 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 phone lines (if your Scanner and computer have modems) 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 Scanner, the data it collects, and the tools needed to interpret that data.

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

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

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 Scanner. 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 Scanner.

Appendix 1: PC and Scanner configuration factory settings

PC Setup

OPTION	*FACTORY SETTING*
Local: Serial Port	Com 1
Local: Baud Rate	4800
Modem: Serial Port	Com 2
Modem: Baud Rate	Auto
Dialing Method	Tone
Auto Scanner Reset	Prompt
Scale Factor: Voltage	1
Scale Factor: Current	1
Auto Clock Reset	On
Auto Data Save	On
Stripchart Report Header	Checked

Scanner 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.

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
<u>Attention</u>: Repair Department

Appendix 3: Troubleshooting

Symptom	Possible Solution
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.
Scanner downloads to 99% and gives serial comm error	Contact PMI for assistance and/or WinScan™ upgrade
LCD display continuously shows "Charging Battery"	Scanner is in STOP mode (keypad selectable) , take unit out of stop mode. If symptom stays contact PMI for Evaluation
Strip chart shows very high or wildly fluctuating, unrealistic readings or spikes on V and I	Contact PMI for an upgrade and retry.
Partially working; will not count down, erratic behavior	Water may have entered the unit. Insure that latched and gaskets are in normal serviceable condition.

Appendix 4: Formulas (Not all are used in SVM-10)

Vip Formulas for Power and Harmonic Measurements

Christopher F. Mullins

Power Monitors, Incorporated
Harrisonburg, VA 22801

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 $0 \leq n \leq 255$. 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 $0 \leq n \leq 255$, $1 \leq j \leq 4$, and $m \geq 0$.

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

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

Similarly, the current rms value is given by

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

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

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

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

$$\mathrm{VA} = \mathrm{VRMS} \times \mathrm{IRMS}\,. \qquad (4)$$

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

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

and the raw kth harmonic phase angle is

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

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

2.5 Phase Angle

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

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

where $\text{I}\theta[1]$ and $\text{V}\theta[1]$ 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

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

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

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

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

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

2.9 THD

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

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

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:

$$\mathrm{W}_{TOT} = \mathrm{W}_1 + \mathrm{W}_2 + \mathrm{W}_3 \qquad (14)$$

$$\mathrm{VAR}_{TOT} = \mathrm{VAR}_1 + \mathrm{VAR}_2 + \mathrm{VAR}_3 \qquad (15)$$

$$\mathrm{VA}_{TOT} = \mathrm{VA}_1 + \mathrm{VA}_2 + \mathrm{VA}_3\,. \qquad (16)$$

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:

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

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

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

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:

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

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:

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

4.3 Apparent Power

Apparent power is computed by:

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

4.4 Phase Angle

The phase angle, θ, is the angular phase shift between the 60Hz voltage and current sinusoids. 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

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

INDEX