Facilities
Tech Tips

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Facility Power Monitoring: Or, Where Did All the Electrons Go?

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Facilities engineers and supervisors may need special tools to analyze electrical power usage as they respond to rising energy costs and mandates to reduce energy consumption. While the monthly bill from the local electric utility indicates total power consumption, the bill does not show the breakdown for lighting, computers, machinery, and heating and cooling. Portable power-quality monitors can record power consumption on specific circuits within a facility, helping engineers and supervisors assess how electrical loads are distributed and where power usage can be altered.

Highlights...

- For studies of energy consumption or to resolve electrical problems, it's necessary to know more than a facility's electrical meter can tell you.
- Permanent power-quality meters may be expensive—not just to purchase, but to install.
- Portable power-quality monitors allow the energy consumption on a building's circuits to be analyzed over a period of minutes or days.
- The portable monitors also may be used to troubleshoot electrical problems.

Permanent and Temporary Metering

A policy requiring permanent power-quality meters in many Forest Service buildings is being drafted in response to the Energy Policy Act of 2005. Such meters record power consumption periodically and can download the information to a computer or deliver it over a network link. The threshold of building size or power consumption that will require installation of a permanent power-quality meter has not been decided. While logging power meters are available for about $1,500, the cost of installing and connecting them can be substantially more than their purchase cost.

Portable power-quality monitors (figure 1) provide the option of monitoring power conditions at a facility long enough to assess power usage on various circuits. Furthermore, the power-quality meters can be used to inspect circuits for load transients and high harmonic content. Portable power-quality meters cost $1,500 to $6,000. More expensive models include graphic liquid crystal displays that

Figure 1—The Summit Technology Inc. PS250 portable power-quality monitor.

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show powerline voltage, current waveforms, and logged data. Less expensive units primarily serve as data loggers, relying on attached computers for waveform displays and usage graphs.

Portable power-quality monitors can be connected to the mains of a circuit breaker panel in a few minutes and programmed to measure a variety of electrical parameters on the circuits for periods of minutes to days. Typical measurement capabilities include monitoring voltage on 480-volt ac three-phase mains with current up to 1,000 amps.

A portable power-quality monitor may be useful for monitoring power conditions and usage throughout a forest or region. It can be used to document *before* and *after* power consumption during a building upgrade or to determine how much power typically is consumed by the occupant of a leased space within a building (even if that space isn't metered separately). If electrical equipment is failing frequently, power-quality meters can be used to monitor voltage transients, the power factor, and harmonics on powerlines that may be responsible for the failures.

Transients, Harmonics, and Phases

Ideally, the voltage at a facility has a pure sinusoidal waveform with a frequency of 60 hertz that doesn't fluctuate even if the load changes. Motors, lamps, and assorted electronic power supplies connected to a circuit change the load as they are turned off or on. For example, when a pump motor turns on, the increased load on the circuit may cause the voltage to sag briefly. Sudden changes in line voltage are referred to as *transients*. Large transients may harm or destroy electronic devices connected to the circuit.

Some loads connected to a circuit do not draw current in proportion to the line voltage. Such loads tend to alter the waveform of voltage on the line and add *harmonics* to it. For example, some loads tend to add *odd harmonics* so that the original 60 hertz sine wave has additional voltage signals with frequencies of 180 hertz (third harmonic), 300 hertz (fifth harmonic), and so on. Electronic power supplies are notorious for generating harmonic signals on powerlines. If the harmonic voltages are relatively powerful compared to the original line voltage, the signal has a *large harmonic content* and may harm or destroy electronic devices.

Residential buildings typically have voltage delivered in two *phases*: the equivalent of two 120-volt ac lines that have opposing phases. The voltage in one line is 180 degrees out of phase with the voltage in the other line. Most large buildings receive line power in three phases. In three-phase systems, two of the three lines carrying power are 120 degrees and 240 degrees out of phase with the other.

High-powered loads, such as large motors, may be driven by all three lines carrying power, but many circuits use only one of the three. For example, a circuit with 207 volts ac in three phases will show 207 volts on a voltmeter connected between any two of the three lines carrying power; the voltage between any one of the three lines carrying power and the neutral line will measure 120 volts. Wall outlets and 120-volt lighting circuits can be fed from any of the three lines carrying power.

Taking the Compact Model Out for a Spin

The Missoula Technology and Development Center (MTDC) was asked to evaluate a portable power-quality monitor and develop guidelines for its usage. After a brief market survey, the *Power Sight PS250* by Summit Technology, Inc. was selected. Several options were weighed before our selection, such as the maximum rating of the current probes and whether harmonic content measurements were necessary. In the end, 1,000-amp probes were selected and the harmonic analysis option was not. An option for a fourth current probe to monitor neutral line current was not selected. The PS250 with three 1,000-amp probes (figure 2) cost about $2,000.

The PS250 has a two-line alphanumeric display that reports connection status and current measurements. When the device is first turned on and the probes are connected to a circuit, the PS250 checks for phase relationships between line voltage and current on each phase and can recommend reversing the current probe's orientation to obtain the proper measurements.

A personal computer (PC) is required for detailed reports and graphic displays of line voltage, current, and power consumption. The PS250 comes with a software package called *Power Sight Manager* (figure 3) that allows

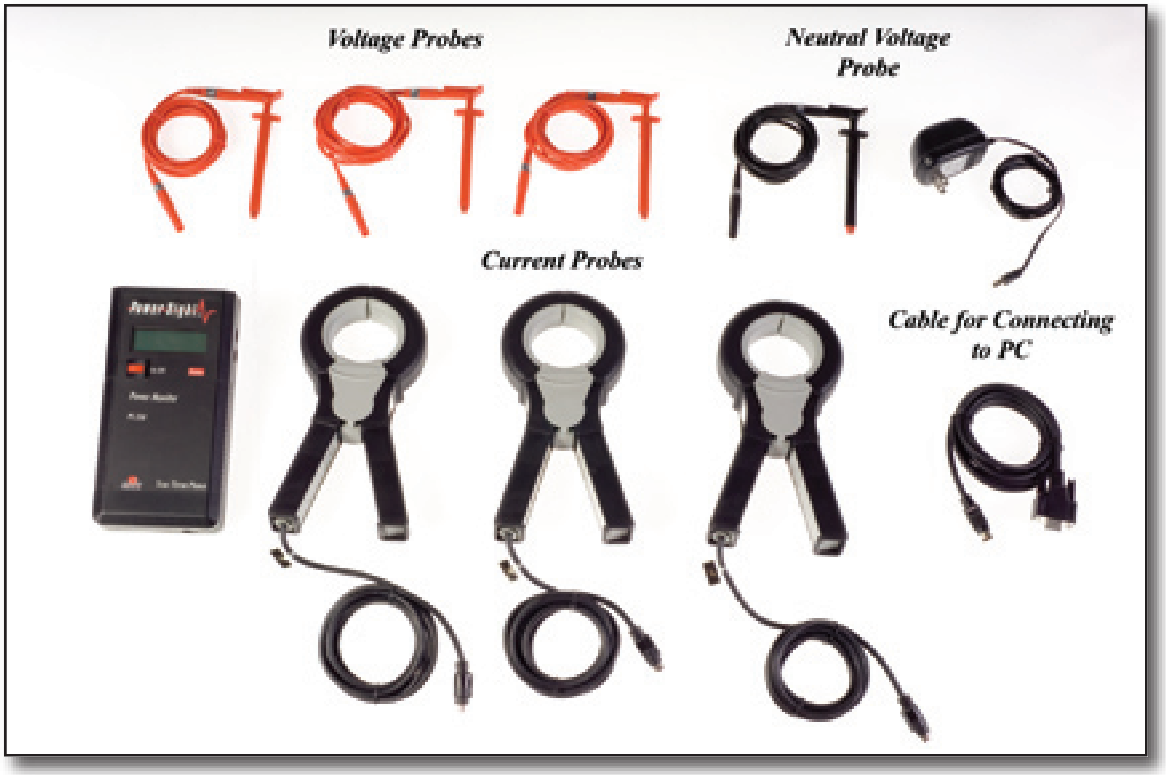

Figure 2—Components needed to monitor power with the PS250 power-quality monitor.

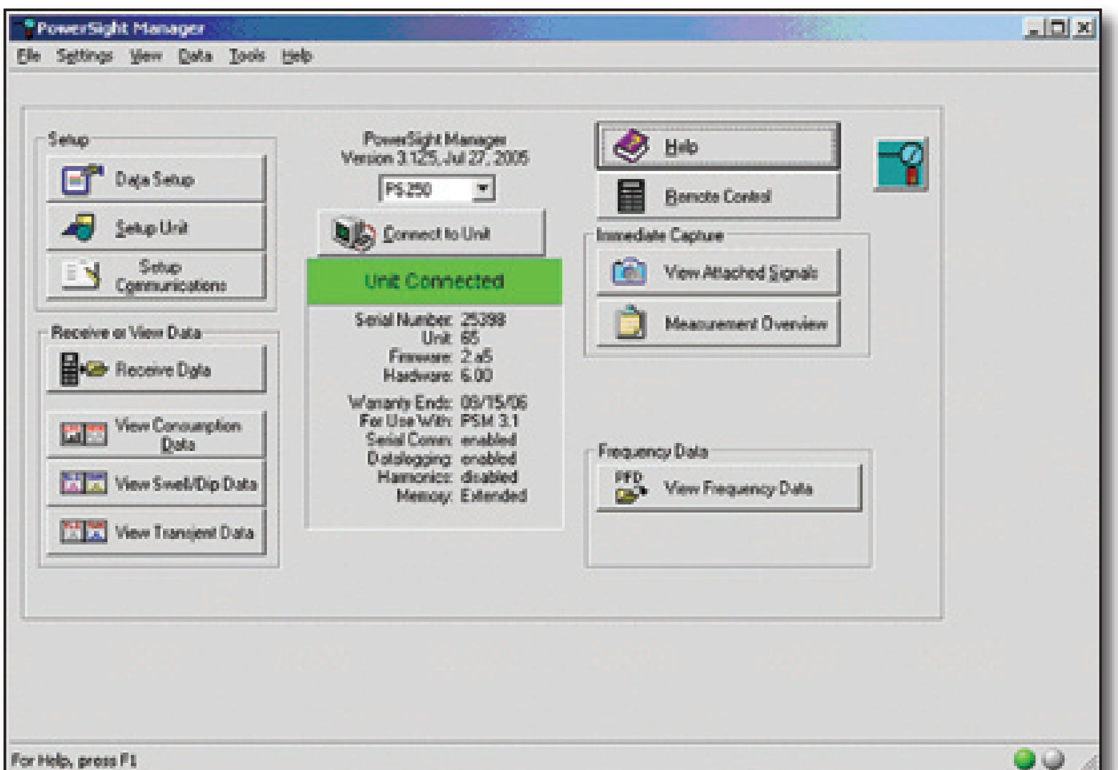

Figure 3—The initial screen of the PowerSight Manager software that displays data logged by the PS250 power-quality monitor.

the PC to control measurement and logging parameters of the PS250 in addition to displaying waveforms and data logged by the meter. The PS250 connects to the PC through the PC's serial data port.

The PS250 monitors voltage and current simultaneously to calculate and record power and waveform statistics such as the power factor and crest factor. The current in each phase of a circuit is measured with a split-core current probe. Voltage is measured by a clip lead attached to an exposed lead for each phase plus an additional lead for the neutral leg.

The voltage probes' insulated alligator clips permit connections to be made between the PS250 and the circuit while it is energized. **An exposed circuit represents an extreme electrical shock hazard**. While the voltage and current probes are well insulated, a user can accidentally come into contact with exposed high-voltage circuits. When working near the panel (figure 4), it's best to keep one hand in your pocket to prevent touching two exposed lines and completing the circuit with your body. Turning off power upstream may be advisable if there is any difficulty in establishing reliable test lead connections.

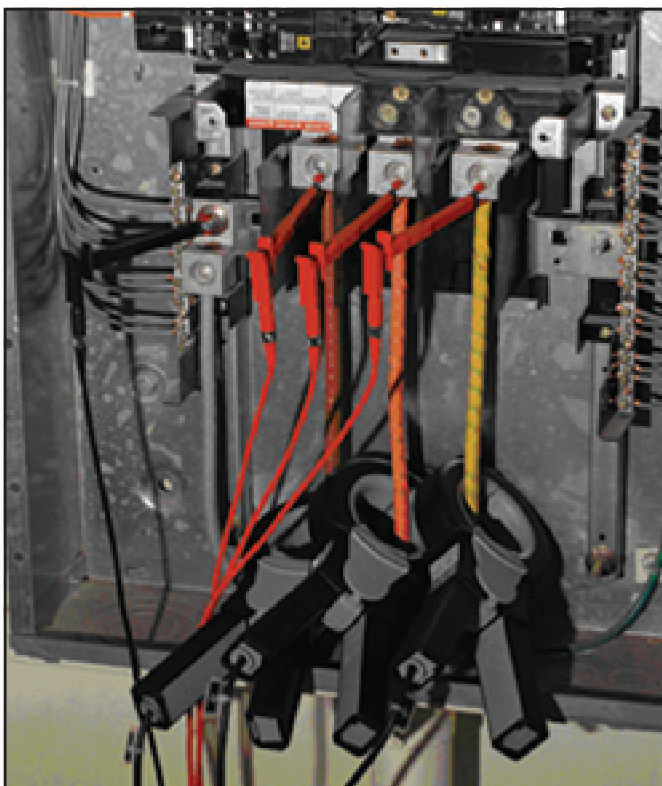

Figure 4—These voltage and current probes are logging data on this three-phase electrical panel.

Power Measurements

If most of the available power and quality measurements are recorded, the PS250 can store about 4,600 records. If such data were sampled every 3 minutes, the memory could store data for nearly 10 days of continuous operation.

Figure 5 shows an example of power consumption logged over 2 days. Power consumption was measured on one phase of the three-phase 480-volt ac lighting circuit at MTDC. Timers turn on much of the center's lighting at about 5 a.m. Power usage fluctuates throughout the workday, then drops off at 5 p.m. It peaks again at 6:30 p.m. when the cleaning crew comes in, then drops for the night at around 8 p.m. when the cleaning crew departs.

Figure 6 shows power consumption on all three phases of another lighting circuit. Note a recurring load on the A-phase circuit late at night. This indicates the power consumed by exterior building lights that are controlled by a timer.

Although figures 5 and 6 show instantaneous power consumption at prescribed time intervals, it is possible to calculate and display power consumption in kilowatt-hours.

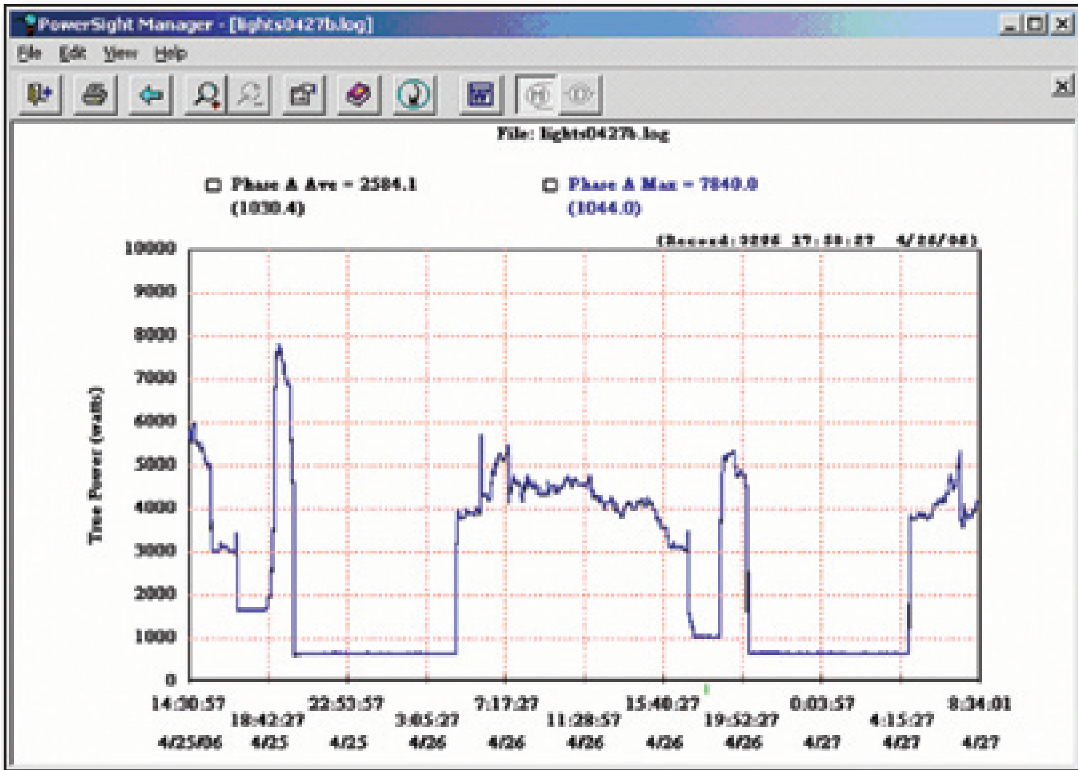

Figure 5—Power logged for one phase of electrical supply over 2 days.

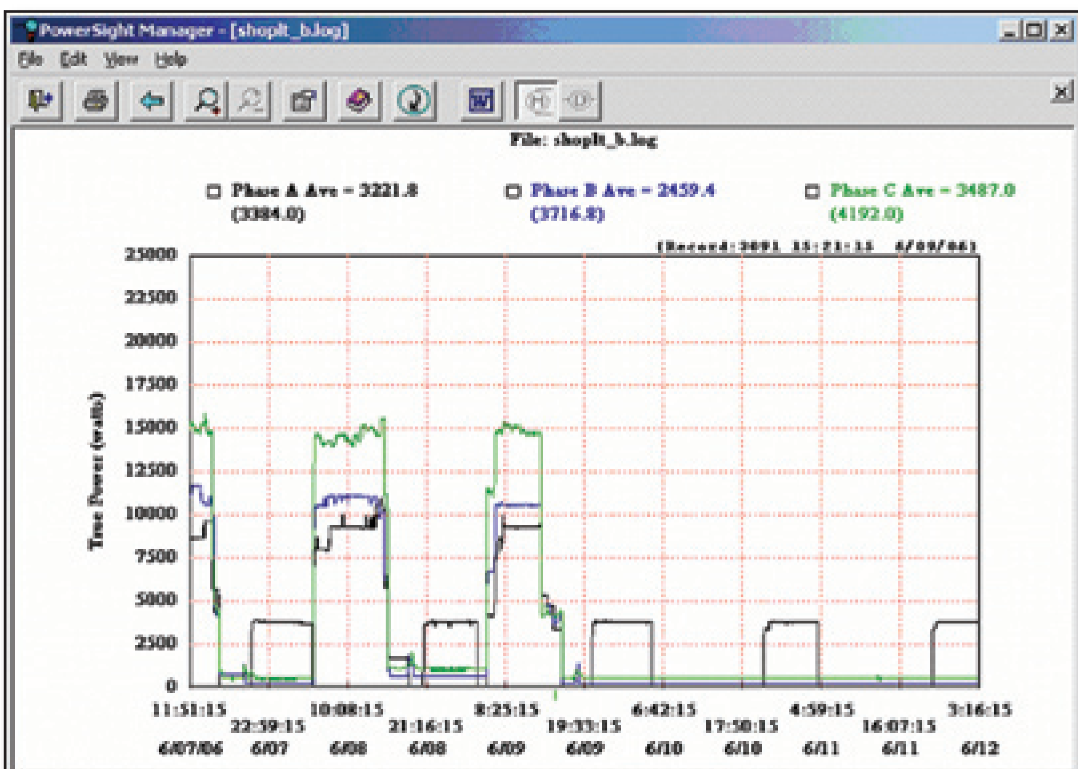

Figure 6—Power logged for three phases of electrical supply over 6 days.

Load Analysis

If a facility is experiencing electrical problems, particularly reliability issues with computers or communications equipment, some form of power quality analysis may be needed. Many electrical devices depend on a stable voltage relatively free of noise and transients. Analysis of load currents and harmonics may identify problems that can be resolved by redistributing loads on a building's circuits or by adding filtering devices such as K-rated transformers.

The waveform in figure 7 is typical of a *reactive* load: the voltage and current are out of phase. Although both the voltage and current waveforms are sinusoidal—the crest factors of 1.4 indicate as much—the true power is about half of what you would calculate if the voltage and current were measured without regard to phase. This type of waveform is typical of an electrical motor when it is being started.

Nonlinear load currents and harmonics are typical of electronic power supplies, especially those on older computers and test equipment. The waveforms shown in figure 8 were recorded on a radio service monitor manufactured in the 1980s.

Note that the load current flows briefly when the voltage is near its peak. The crest factor of 2.4 is an indication of the nonlinear current flow. The power factor of 0.73 also indicates that current is not flowing in conjunction with the line voltage. The crest factor in particular indicates a substantial amount of harmonic energy in the powerline. While the relatively modest power consumed by this device doesn't warrant the installation of a K-rated transformer, a much larger load with similar crest factor and power factor could.

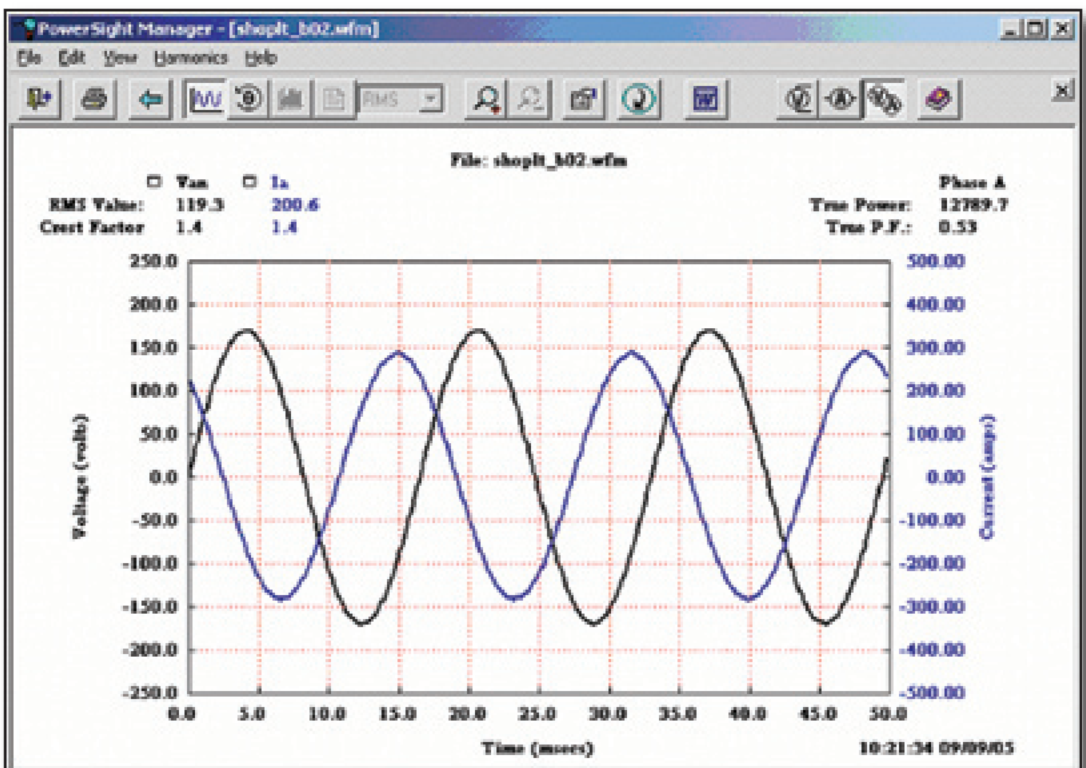

Figure 7—Voltage and current for a reactive load such as an electrical supply motor that is being started (P.F. stands for Power Factor).

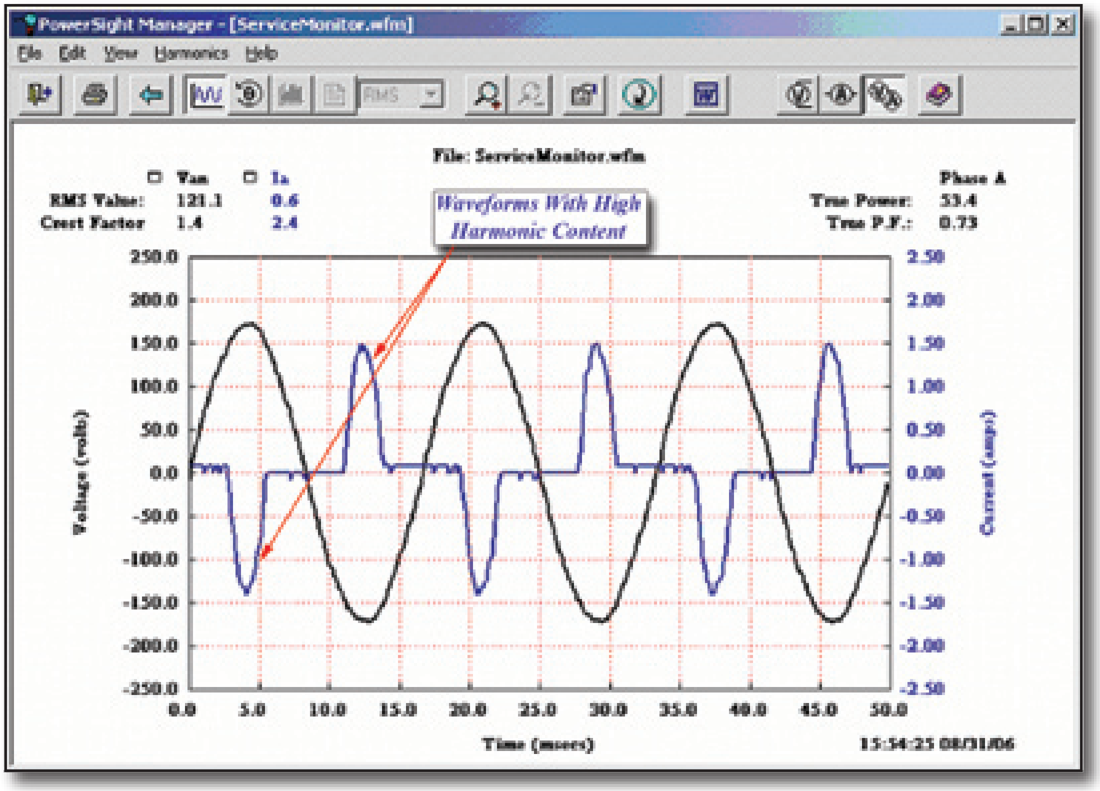

Figure 8—The voltage and current for an electronic power supply show harmonic energy (P.F. stands for power factor).

Conclusions

Portable power-quality monitors are useful tools for gathering information on power consumption that is more detailed and circuit specific than is available on the facility's power meter or from the utility company's bills. Fluke, AEMC, Hioki, GridSense, and Summit Technologies all manufacture products suitable for monitoring the power conditions of electrical circuits with up to 480 volts and with one to three phases.

The most common application anticipated for Forest Service facilities is documenting where and when power is consumed. Such information can be used to review policies or select new technologies that can reduce energy consumption and costs. The monitors also may be helpful when analyzing source and load power if the electrical system requires troubleshooting. In either case, power-quality meters can help Forest Service facility managers optimize electrical power consumption and distribution.

About the Author

Ted Etter joined MTDC in 2002 to work on electronics projects. He has spent more than 25 years working in the areas of electronic instrumentation and display technology. He received a bachelor's degree in mathematics from the University of Oregon in 1992 and a master's degree in teacher's education from Eastern Oregon State University in 1993. Before coming to MTDC, he taught courses in programming, digital circuits, data communications, radio frequency communications, robotics, microprocessors, and operating systems at the University of Montana College of Technology.

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When studying energy consumption or resolving electrical problems, it's necessary to know more than a facility's electrical meter can tell you. Permanent power-quality meters may be required in many Forest Service buildings in the future. Such meters are expensive—not just to purchase, but to install. Portable power-quality monitors may cost no more than a permanent meter to purchase and can be used at different facilities as needed. These monitors can analyze a building's circuits over a period of minutes or days. They also may be used to troubleshoot electrical problems.

Keywords: electric circuits, electric current, electricity, energy conservation, facilities, harmonics, instruments, meters, monitors, quality, reliability, transient voltages

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