Common Mistakes Made in Selecting & Using Power Monitors

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I. Introduction

"So you want to buy a power monitor."

This statement can be the start of a very long, frustrating and complex process. Just looking at the number and variety of power monitoring equipment available in the market place is staggering. This paper is not intended to present the reader with an evaluation of each and every power monitor available out there, but provide the potential purchaser with an organized approach to determining needs, evaluating alternatives, suggestions in monitoring strategy and data analysis/report preparation.

II. Selecting a Power Monitor

a) Needs Assessment

The first step in the process is to determine what your monitoring needs really are. There is a big difference in cost between a power monitoring a system that "does everything' versus an energy logger/recorder. Some of the items to consider in determine needs (capabilities) are:

- Single vs. 3-phase monitoring/recording

  Obviously there is a big difference in cost between single-phase versus 3-phase monitoring equipment. If the application deals strictly with single-phase loads as opposed to the poly-phase supply (or poly-phase loads) then a single phase unit would suffice. If there is a need to monitor the single-phase load as well as the poly-phase source then a 3-phase monitoring system should be selected.

  Once the single vs. three-phase decision has been made there is the decision as to the input channel configuration…common reference vs. differential channels

  Voltage channels…

  - Three-phase with a common reference…no ground connection for neutral-ground measurement (Photo 1).
  - Three phases with a common reference plus ground for neutral-ground voltage measurement (Photo 2 and 3).
  - Three phases with a common (non-isolated) reference plus a 4th isolated (differential) voltage channel (Photo 4).
  - Four isolated (differential) voltage channels fully configurable for 3-phase plus neutral-ground or connection to different power sources (Photo 5).

Current channels…

- **3 channels with a calculated neutral**—should be sufficient for general energy and load studies (Photo 1).
- **4 channels with a measured neutral**—added benefit in a measured neutral is that with a little work the calculated neutral can be subtracted from the measured neutral and provide the user with net (ground/leakage) current (Photo 2, 3 and 5).
- **5 channels with ground current measured**—allows for the direct measure of a 5th current channel, usually ground. It could still be possible to calculate the net current and compare that with the measured ground (5th channel) current (Photo 4).

There is also the issue of the ability to measure direct current (d-c) voltage and current. This capability is especially useful in work with UPS equipment or d-c motor drives.

In addition, differential channels offer the opportunity to monitor different power sources simultaneously on the same monitor. This feature, like the d-c capability, is useful when working with UPS equipment, d-c drives and automatic transfer switches (ATS).

The following series of photo's show examples of the various channel configurations.

Photo 1 - Three-phase voltage with common reference (phase-neutral), no neutral-ground voltage, 3-phase currents and calculated neutral current. AC measurements only, no DC capability.

Photo 2 – Three-phase voltage with common reference, ground connection provides capability for neutral-ground voltage, 4-current channels (3-phases plus neutral). AC measurements only, no DC capability.

Photo 3 - Three-phase voltage with common reference, ground connection provides capability for neutral-ground voltage, 5-current channels (3-phases plus neutral and ground). AC measurements only, no DC capability.

Photo 4 - Three-phase voltage with common reference (U- not fully isolated between channels 1, 2 and 3), neutral-ground can be measured on channel 4, 4-current channels (3-phases plus neutral). The 4th channel is completely isolated and can support DC measurements.

Photo 5 – Four independent voltage channels can support 3-phase voltage measurements plus neutral-ground voltage, 4-current channels. All voltage and current channels can support DC measurements.

In summary, if the usage is going to be single-phase only then it is a relatively simple decision. If load studies and energy logging is the primary focus then the less expensive units with common input voltage channel references and three current channels (calculated neutral) will be sufficient. Should the usage be focused on more complex issues…UPS testing, motor drive troubleshooting, etc….then the more fully featured units would be required.

- Real-time vs. long-term recording

  There are some applications where the primary need is that of a real-time measurement with limited recording and logging capabilities. This situation is generally associated with service technicians involved in the routine servicing and adjustment of equipment

and only limited recording or event capture would be required. In this situation the need for software to post-process the monitoring data, if any, would be limited to simple plotting functions.

- Logging (periodic recording…i.e., load studies) vs. event capture (problem investigation)

  This is the area where most people tend to error on the side of more capability. If the application is dominantly energy (load studies) related then it is foolish to go with the top-of-the-line power quality analyzer…typically $10,000+. Depending on the energy analyzer/logger selected it may be possible to buy 2 to 4 instruments for the same price as a single, fully featured, power analyzer. It may be much more cost effective to rent the more capable/complex monitoring equipment when the need arises along with applications support.

- The number of locations/activities requiring power monitoring (energy recording)

  In today's environment there is an increased interest (and need) for energy monitoring. In many cases there is such a demand that purchasing multiple units makes sense. As a general rule if the monitoring equipment is used on a regular basis--weekly, monthly, etc.--it probably makes sense to purchase the equipment. If on the other hand, the monitoring equipment is only used infrequently then it may be better to rent the equipment when needed

b) Features & Specifications

The user's needs assessment (intended usage) will drive the desired equipment feature set. Generally the more features and capabilities a meter/recorder/analyzer has the more expensive the unit. The following is an abbreviated listing of the more basic features:

- Integrated display for programming and set up of the instrument versus set-up via external device (laptop computer, PDA, etc.).
- Memory storage…removable or is it necessary to connect a computer/PDA to recover recorded data. In addition it is important to consider how large file sizes will be handled, both from the ability to transfer the data to the computers ability of process the files.
- Networking capabilities for remote operation and downloading of recorded data.
- Mounting/installation options…permanent or semi-permanent, weatherproof, etc.
- Other I/O capabilities…sensor channels for temperature/humidity, pressure, flow, etc.
- Operating temperature for most recorder/analyzers is 32° to 122°F (0° to 50°C). Any planned usage of monitoring equipment outside these temperature ranges should be evaluated as special conditioning or packaging may be required.

- Current channel interface…proportional voltage or current input. Proprietary input connector?
- Internal battery run/recharge time.
- Input Channels: Number of voltage channels and configuration (independent or shared reference), voltage range and DC capability, if any. Number of current channels, input characteristics (proportional voltage signal or current), connector type, DC capability and if proprietary current probes/transformers are required.
- Sampling (digitizing) rate…can typically range from 16-samples/cycle to 512-samples/cycle for the 50/60Hz waveform. It is also important to understand if the sampling is on a cycle-by-cycle basis or a periodic sampling of a few cycles each second.
- High-speed Sampling: Some equipment has a second higher speed digitizer for transient capture. The high speed digitizer is generally triggered by a peak detection circuit (and associated threshold setting) which then digitizes the signal at between 1MHz and 5MHz depending on the design of the instrument.
- Event triggering: does the unit offer the capability of cross-channel-triggering…in other words, will a threshold on any channel result in the recording of all channels…which is a very useful feature.

c) Measurement Capabilities

The required measurement capabilities will depend on the intended application and use. Simple energy logging applications will require less capabilities that an event recorder/analyzer. Most of the modern event recorder/analyzers accumulate energy information as well as respond to event triggers when specific threshold limits are exceeded. The following is an abbreviated listing of the more basic measurement capabilities and concerns:

- Standards -- There are a number of standards that list and define the measurement methods for power quality instruments. If the intended use of the equipment is in applications where the standards apply then it is important to select an instrument which was designed to comply with these standards. The following a list of the appropriate standards:

    - IEC 61000-4-30 Testing and Measurement Techniques—Power Quality Measurement Methods
    - EN50160 Voltage Characteristics of Electricity supplied by Public Distribution Systems
    - IEEE 1159 Recommended Practice for Monitoring electric Power Quality
    - IEEE 519-1992 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

  - IEEE 1459-2000 Trial Use Standard Definitions for the Measurement of Electric Power quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions
  - EN 61010 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use, General Requirements. [Cat. IV, III, II or I]

- Sampling or digitizing of the voltage and current waveforms will determine the accuracy of the recorded information. Measurement (sampling) of every cycle will result in a higher accuracy of the measured and calculated values. Some energy/power logging equipment only sample a few cycles every second which is probably adequate for load centers and service entrance monitoring, but may under report individual loads with high duty-cycle rates.
- Event recording controlled by either specific thresholds settings or periodic timed recordings. Depending on the equipments design philosophy the threshold setting may or may not be user selectable.
- Variable pre/post event trigger capture is helpful in evaluating motor inrush and some fault conditions.

In summary it is important to remember that all monitors measure two things--voltage and current—everything else is calculated either in the meter or post processed. Event the best meter installed or programmed incorrectly will not provide accurate and usable information.

d) Accessories

Many suppliers of power monitoring/recording equipment have an extensive selection of accessory items which can be very useful.

Some MUST have accessories:

- Fused voltage probes
- Current probes appropriate for the application. Flexible (Rogowski coils) current probes are generally safer and easier to use than rigid current clamps.
- Carrying/shipping case(s)
- Extra memory cards (if appropriate)
- Some type of universal voltage adapter that provides power for the monitor from the voltage source being monitored. [Dranetz-BMI PPA-PP1 step-down transformer, Summit Technology LDC (line-to-DC adapter).]

In many cases manufacturers have a proprietary connector for their current channels which tends to restrict usage of other current probes. In most cases the current channels on modern

power monitors accept a proportional voltage signal between 0.5 and 3Vrms. Understanding the characteristics of the specific meters current channels may allow the user to use less expensive current probes/clamps with little, if any, loss in accuracy.

e) Programming & Setup

This where "the money meets the road."

The ability to successfully program and setup (install) the monitor will determine the success of the monitoring activity.

Part of the selection process for the power monitor is determining how much you, the user, are will willing to invest in learning how to setup the meter and become proficient in the use of the associated software. If you can not invest the time in becoming knowledgeable on the software and proficient on the software then HIRE SOMEONE…you will ultimately be much happier.

Contrary to what the salesman and literature claim there are no power monitors our there that do it all by themselves. Yes, there are quick starts, wizards, defaults, etc. but none of these is a substitute for understanding what you are doing.

The software available for post processing the monitoring data comes in all flavors…simple to complex. As with most things in life the more features and capabilities the more complex the software will be and the longer the learning curve. The good news is that if your needs are just simple energy/power logging even the more complex programs are not bad when you do not need all the features.

A number of manufacturer's claim to have report writers as part of their software. Most of these are little more than data summarization utilities which will help you gather and organize various event graphics and summary data for export. The user is still the one that must add the intelligence to the data in the form of analysis and recommendations.

Two things to think about with respect to the software (and monitor) which were mentioned earlier in this paper, are the size of the data file (and associated file transfer) and the ability of the computer to handle the large. Do not be surprised to discover that your old laptop/desktop will need a RAM memory expansion to 2 GB to handle the larger files.

f) Software & Post-Processing Capabilities

Power monitoring software comes in all flavors from simple to complex. Unfortunately the more capabilities a software program has the more complex it is likely to be. Think about what you really need and want to accomplish with the software.

No one has a true report writer…in spite of what the salesman or product literature claims. About the best you can expect is a data summarization tool which will allow you to export a series of graphics and summary numerical—minimum, maximum, average and total—information.

The old Reliable Power Meters (RPM) Power Analysis Software (PAS) had a Report Writer option which many users liked as it could create a 65-page report with the click-of-a-mouse. In reality the report was a complete summary of all of the recorded data and only provided generic comments for various power conditions and events…same comments for every report…and required the reader to provide the analysis.

There have been some efforts to provide commercial power monitoring software with analytical capability over the years. Most notability was AiPower from Kreiss-Johnson Technologies (KJT) which made use of artificial intelligence (AI) in the software. KJT was acquired and the product is no longer available.

Generally the longer a program has been around the fewer operational problems: Newer power monitoring software programs are generally a "works in progress."

There is a tendency in the industry toward the use of larger and larger monitoring files…apparently the belief is that "bigger is better." There are four problems with larger monitoring files:

- Transferring large monitoring files from the monitor to the computer can be a problem with very large data files. Some newer monitors with large internal storage capability can have data files as large as 2-GB. Just getting the data off the monitor can sometimes be a challenge.
- The computer may require additional internal memory to process large monitoring data files. Two GB of internal memory may not be enough to process 256MB data files from some monitors.
- Assuming the computer has sufficient internal memory the ability to display the data plots from large files, the plotting times may be excessively slow resulting in considerable user frustration.
- Very large files (larger than 750MB) cannot be archived on CDs. The entire archiving process becomes very challenging with extremely large files.

Before deciding on a monitor and the associated software it may be a good idea to obtain a demo version of the software with data files the size that you might be using. Remember the "demo data files" are generally quite small and usually selected to show off the best attributes and may not reflect real world conditions.

g) Support

- Applications

  What type of initial training is available along with on-going applications support? Remember the salesman will make it look easy—after all he practices using and demonstrating the equipment. Also, a salesman's job is to sell equipment and after sales support is not a responsibility. Generally, the salesman may make be a poor on-going applications support resouce. How many people does manufacturer have assigned to field support? It might be surprising to find out how few there actually are. Is on-going applications support available…most manufacturers are reluctant to provide any data analysis or advice other than something specifically related to the monitoring equipment.

- Repair

  What are typical repair charges for the equipment? (Note: Most units carry a 1-year warranty.)

- Calibration

  What is the cost of calibration? Is the calibration procedure proprietary or can it be performed by a third-party? (Note: In many cases it may only be necessary to verify that the unit is still within specifications and this can usually be done many local calibration labs at substantial savings. If adjustment/repair is required it may be necessary to return the unit to the manufacturer.)

- Updating

  Most of today's products today have updatable firmware which can be done remotely. Hardware upgrades will require return to the manufacturer. (Note: Two things, (1) don't expect the manufacturer to notify you of firmware updates and (2) the field firmware upgrade procedure is not without risk…if the device fails to update it may be necessary to return the unit to the manufacturer.)

III. Using Power Monitors

Many power monitoring project are not well thought out or planned. The following is a brief review of a power monitoring activity.

- **Monitoring Strategy**

What is the objective for the monitoring activity? Answering this will help determine placement and threshold settings and needed accessories. Also there should be a determination as to how long the activity will last…it does not mean that things cannot change, but that there is an expectation of completion.

- **Single (Sequential) vs. Multiple Monitors (Simultaneous)**

Depending on the purpose of the activity multiple (simultaneous) monitors may be appropriate. Using multiple monitors generally speeds up the activity and improves the quality of the data…technology is being substituted for time and labor…always a good trade-off.

Multiple monitor typical placement…service entrance, distribution point and point-of-use. The number and placement of multiple monitors will be determined by the nature of the activity and the size and complexity of the facility.

- **Safety…Installer and Customer**

Monitoring equipment MUST be installed following appropriate safety practices (NEPA 70E, OSHA, etc.) and the equipment cannot pose a hazard for other workers and personnel in the facility.

- **Installation Techniques and Problems**

Use flexible current probes…safer and easier to install.

Hide the equipment inside the enclosure if possible…best practice.

When troubleshooting circuit breaker tripping problems always have at least one voltage lead on the load side of the circuit breaker…sounds obvious, but it is not.

Always label the monitoring location…let people know what is going on. (Note: Full page versions of the DANGER, CAUTION and WARNING power monitoring signs are available from the PowerCET web site… http://www.powercet.com/downloads/index.cfm?list=PQReferences.

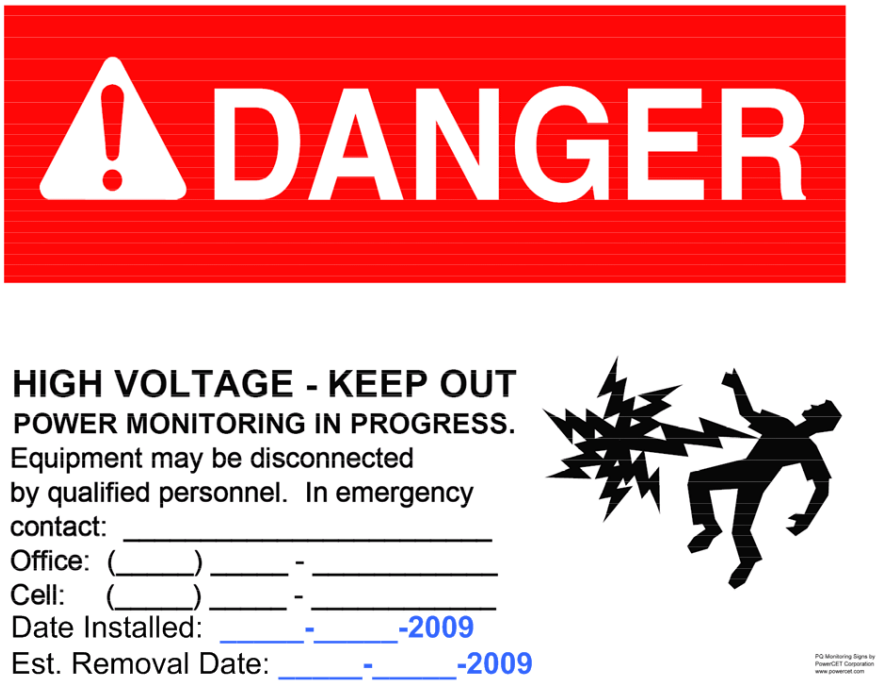

Figure 1 – Power monitoring information sign example.

- **Remote Access**

Depending on the monitoring equipment, the capability for network access may be available. If so, this can be helpful in checking on the progress of the monitoring activity without having to return to the monitoring location and opening up the equipment.

IV. Data Analysis & Report Preparation

When writing a power monitoring report remember QUALITY information is important - NOT quantity. The purpose of the report is to identify and present significant information, findings and recommendations…not bury the reader in paper.

The following is a suggestion for the organization of the monitoring report:

Executive Summary

- Written last, after the main report is complete
- Never ever more than 2-pages…1 page is better…graphics and pictures are OK
- Remember Executive's have a very short attention span!

Introduction/Overview/Background

- Simple statement of the problem or description of the activity and who is doing the work
- . A couple of sentences…short paragraph.

Methodology

- Brief statement of how the activity/investigation was conducted and equipment used

Key Findings & Recommendations

- List the Key Findings (number them)…a brief statement of the findings…use pictures and graphics (power monitoring data). Do not assume that individuals reading the report will understand the word descriptions associated with the pictures/graphics…add arrows, labels, etc to the pictures and graphics to make sure there is no confusion.
- Use summary information…it is easier for people to understand.
- Use waveform data (graphics) sparingly to add emphasis and support recommendations
    - Do not include every waveform recorded as it tends to lessen the value of the data.
- The RECOMMENDATIONS should follow the specific Key Finding immediately. This helps the reader make the connection between findings and recommendations without having to page back and forth. Suggest using a different colored type or bold font for the recommendation to set it apart from the findings.

Summary

- This is a brief summary of the key findings and recommendations. If the report is more than 8 or 10 pages it should have an Executive Summary.

Appendices

- Only if it adds value. Things that might be included…
    - Equipment specifications
    - Equipment brochure
    - Outside lab reports

V. Conclusion

What is the selection process used by individuals (or organizations) when buying a power monitor today?

From years of experience in talking with users, after the purchase, as well as hundreds of students coming through PowerCET's power monitor operational skills classes I have concluded that the majority buy for the following reasons:

- Company reputation (brand recognition)
- Looks / demonstration (the salesman made it look easy…also it is unlikely that they had more than one instrument demonstrated)
- Price (in this case low price…first time buyers generally select the wrong product)
- Liked the salesman (do not under estimate the "people buy from people" factor)

There appears to be little, if any, attempt on the part of the prospective purchaser to determine the needs before setting off on the purchase activity. In addition there is little effort on the part of the prospective buyer in evaluating other instruments or platforms. They are also swayed by a glitzy ad in a magazine or on the web followed up by the good old product demo.

The good news is that the price of the instruments has come down and the capabilities have increased so that in the worst case the buyer will have at least some, if not all, of the features needed.

So what should the prospective buyer do?

- A needs analysis…figure out what is really needed.
- Determine how much time and resource is available to learn the new equipment/software.
- Select some products to consider.
- Demo the products and make a selection.
- Find a supplier that will rent the selected monitor for a month and credit the rental if purchases. (This rental month gives the purchaser an extended period to really use the unit and confirm that it is the right choice. Worst case it costs a months rent as opposed to being stuck with a monitor that does not meet the needs.)

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