Power Quality... Troubleshooting Basics

By: Colin Plastow

Advancements in solid state technology have delivered countless benefits in recent years. At the same time, the microelectronics that lie at the heart of this technology have dramatically increased the need for clean power. Faster speeds and lower voltages mean that there is less and less tolerance for shortcomings in power quality (PQ).

PQ covers a wide range of issues, from voltage disturbances like sags, swells, outages and transients, to current harmonics, performance wiring and grounding. Symptoms of poor power quality can include intermittent lock-ups and resets, corrupted data, premature equipment failure, overheating of components for no apparent cause, and more.

Power quality culprits are equally diverse and can appear at any point in the power "chain" - from the transformer or electrical panel, to the receptacle or floor equipment. Causes can include lightning, automatic breaker reclosures, excessive voltage distortion on electronic control circuits, inrush currents from high torque motor loads, cabling errors, miswiring and high frequency noise, among others.

With such a diverse range of problems and potential causes, power quality troubleshooting can be a challenge. But with the right tools, and a methodical approach, PQ problems can be sourced and addressed relatively quickly and easily.

Begin at the Beginning

The most practical approach to troubleshooting PQ problems is to use a bottom-up approach. In other words, start as close to the victim load (i.e. the sensitive load that is malfunctioning). Alternatively, you can start at the entrance using a three phase monitor and work back to the victim load. This latter approach is most useful if the problems originate with the utility.

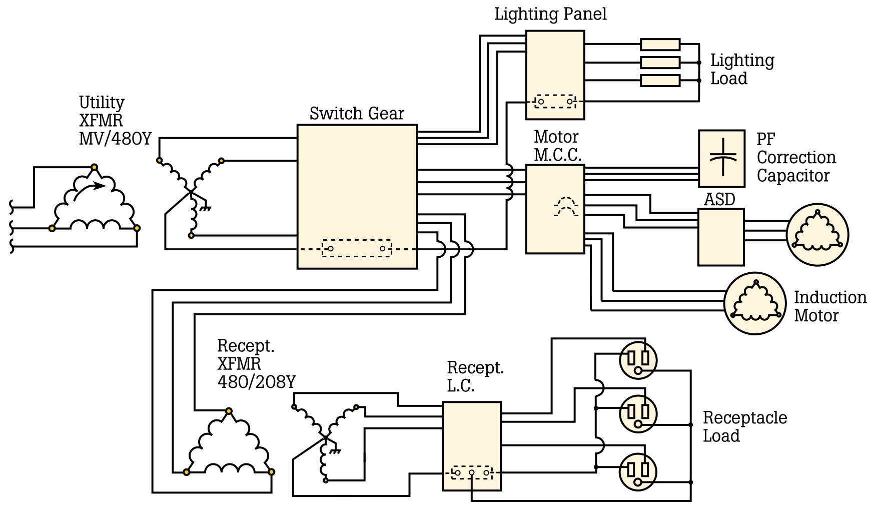
Since the majority of PQ problems originate within the facility, most experts agree that a logical troubleshooting flow is to first diagnose the electrical infrastructure of the building, then monitor if necessary.

Whatever process you choose, you must first ensure that you gain a working knowledge of the site by locating or reconstructing a one-line diagram of the site to identify the AC power sources and the loads they serve.

Also take the time to do a walk around the site to check for such items as hot transformers, discolored wiring or connections, receptacles with extension strips daisy-chained to extension strips, signal wiring running in the same trays as power cables, extra neutral-ground bonds in sub-panels and grounding conductors connected to pipes that end in mid-air.

Interviewing the people operating the equipment is also helpful in understanding the problem and generating clues.

Regardless of the nature of the PQ problem, these preliminary steps provide a solid groundwork for subsequent, more detailed PQ troubleshooting procedures. The following will outline some of the specific areas within a facility distribution system where one can perform troubleshooting and provide a very brief and basic outline of the techniques and equipment to use.



Receptacle Branch Circuit

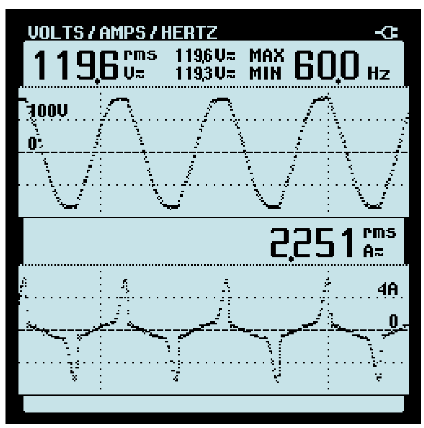
Many PQ problems show up at the branch circuit level, because that is where most of the sensitive loads are located. It is also the end of the line of the electrical system, and the place where shortcomings cannot be hidden.

The primary focus with troubleshooting at the receptacle level is to determine if the Line-Neutral (L-N) voltage available is of sufficient stability and amplitude to supply the needs of the load(s).

Measurements include:

- Waveform – for a quick snapshot of information. An ideal waveform would be a sine wave. Flat-topping (see Figure 1) is typical of a building with many non-linear loads such as computers and other office equipment.
- Peak Voltage – The peak value is critical to electronic loads because the electronic power supply charges its internal capacitors to the peak value of the line voltage.
- RMS Voltage – Nominal line voltage is measured in RMS (root-mean-square) which corresponds to the effective heating value. RMS voltage can be too high or too low, but it is usually the low voltage that causes problems. Low RMS voltage combined with flat-topping (low peak) is a deadly combination for sensitive loads.
- Recording (short term) –Many loads require more current, usually referred to as inrush current when they are first turned on, which may cause a momentary low voltage (sag)To check for recurring sags, use a meter with a trending feature that will continuously capture sags over a four-minute to a one-hour recording time.
- Recording (long term) – For longer term recording, a voltage event recorder can be used to track sags,

Figure 1



Voltage Measurements	Look For	Instrument
1. Waveform	Snapshot of severity of voltage distortion	Power Quality Analyzer Harmonics Analyzer
2. Peak Voltage	Extensive flat-topping	Power Quality Analyzer Digital Multimeter (DMM) with Peak MIN MAX features
3. RMS Voltage	Low rms (steady-state low rms or intermittenly/ cyclical sags)	Power Quality Analyzer DMM with MIN MAX
4. Recording (short-term)	Sags, swells, interruptions while troubleshooter remains on site (4 minutes to 1 hour typical recording time	Power Quality Analyzer
5. Recording (long-term)	UP to 4,000 sags, swells, outages, transients	Voltage Event Recorder
6. Neutral-ground	N-G voltage too high (or close to zero)	Power Quality Analyzer DMM

Table 1: Measurements on Receptacle Branch Circuits

swells, outages, transients and frequency deviations over a period of time (days or weeks).

- Neutral-to-ground (N-G) Voltage - N-G voltage is an easy way to measure the loading on a circuit. This can be helpful in determining and comparing voltage drops in hot and neutral conductors with the source voltage.

Service Panels

The procedures to follow when checking out a service panel are:

- Visual inspection
- Feeder conductor current test
- Neutral conductor current test (feeder and branch)
- Phase-to-neutral voltage test (feeder and branch)
- Neutral-to-ground voltage test (feeder)
- Circuit breaker voltage drop and current on branch phase conductors

During a visual inspection look for such things as an illegal Neutral-Ground bond in sub-panels, signs of overheating (such as discolored connecting lugs), shared branch neutrals, tightness of the conduit connections, etc. Of particular concern is the size of the feeder neutral conductor. Many experts recommend that the neutral be double the size of the phase conductor.

Measurements to be taken are demonstrated in Table 2.

Transformers

Transformers are subject to overheating from harmonic currents and are also critical to the integrity of the grounding system. Those supplying non-linear loads should be checked periodically to verify operation within acceptance limits.

Measurements to be taken are outlined in Table 3.

Measurement	Look For	Instrument
1. Feeder phase current	Overloading and balance	Power Quality Analyzer Harmonic Analyzer DMM True-rms clamp meter
2. Feeder neutral current	High currents from unbalanced fundamental and 3rd harmonics	Power Quality Analyzer Harmonic Analyzer DMM
3. Feeder N-G voltage	High voltage indicates excessive current, near-zero indicates possible sub-panel N-G bond	Power Quality Analyzer Harmonic Analyzer DMM
4. Branch L-N voltage	Low voltage	Power Quality Analyzer Harmonic Analyzer DMM
5. Branch neutral current	Shared neutrals	Power Quality Analyzer Harmonic Analyzer DMM
6. Voltage drop accross breaker contacts. Hot breakers.	Worn contacts. Breakers in need of replacement.	Power Quality Analyzer DMM

Table 2: Service Panel Measurements

Measurement	Look For	Instrument
1. kV	Transformer loading. If loading exceeds 50%, check for harmonics and possible need for derating	Power Quality Analyzer Harmonic Analyzer
2. Harmonic Spectrum	• Harmonic orders/amplitudes present • Resonance of higher order harmonics • Effectiveness of harmonic trap filters	Power Quality Analyzer Harmonic Analyzer
3. Total Harmonic Distortion	Harmonic loading within limits	Power Quality Analzyer Harmonic Analyzer
4. K-Factor	Heating effect on transformer from harmonic loads	Power Quality Analyzer Harmonic Analyzer
5. Ground currents	• Objectionable ground currents • Neutral-ground bond in place • ESG (Electrical Safety Ground) connector to ground electrode (typically building steel) in place	Power Quality Analyzer Harmonic Analyzer True-rms clamp meter

Table 3: Measurements at the distribution transformer

Electrical Noise and Transients

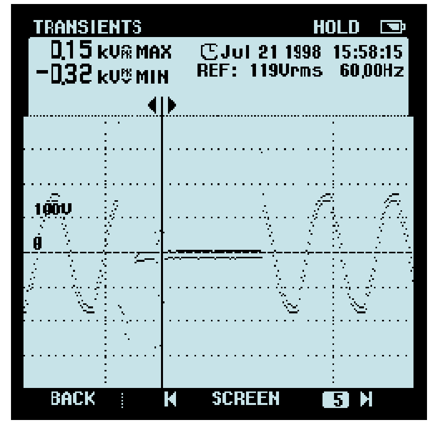
Electrical noise is one of the more mysterious subjects in PQ. Electrical noise is the result of random electrical signals getting coupled into circuits where they are unwanted – i.e. where they disrupt information-carrying signals. Signal and data circuits are particularly vulnerable to noise because they operate at fast speeds and with low voltage levels.

Depending on the nature of the currents being measured, troubleshooting will require a current clamp and/or a DMM, Power Quality Analyzer or Scope.

Voltage transients are lower energy events than surges, and are typically caused by equipment switching. Surges are a special case of high-energy transient that results from lightning strikes. Transients can deteriorate solid state components, trash logic, and affect loads at all levels of the distribution system, and are a well-known cause of nuisance tripping of adjustable speed drives (ASDs).

Transients can be captured by time and date with a Digital Storage Oscilloscope (DSO). A Voltage Event Recorder will also capture transients at the receptacle, and provide peak voltage and real time stamps. (See Figure 2)

Figure 2



The Tools of the Trade

Obviously, within any facility distribution system, there is a wide range of troubleshooting challenges to address. Although we have touched on some very basic PQ problems that can be encountered within a facility, there are many more areas that fall under the PQ umbrella that require tests and toolsets that are specific to those tasks.

The overall key to succeeding with any troubleshooting task is to ensure you follow a methodical, proven approach and use the correct tools that are properly rated for the job. Minimum requirements for PQ troubleshooting tools are:

- A safety rating that is appropriate for measurements on power circuits – i.e. CAT III-600V or higher (CATIII-1000V) according to the IEC 61010 international safety requirements
- Certification by independent testing labs that meet IEC 61010 specifications (e.g. UL, CSA, TÜV, VDE, etc.)
- True-rms to ensure accurate measurement with harmonics and distorted waveforms
- Recording capability, waveform display and specialized measurements (such as harmonics, sages and swells, transient capture, high frequency noise, etc.)

Above all else, work safely. Measurements in PQ troubleshooting should always be made by qualified personnel who have been trained to make them in a safe manner, using proper procedures and test tools rated for work on electrical power circuits. **Ω**

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