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Putting the Electrical System to the Test

The right combination of power quality test tools can help you troubleshoot electrical systems.

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In Brief
Using the right tools helps troubleshoot power quality issues.

Related Products:
Digital multimeters, True-RMS clamps, Voltmeters, IR thermometers..

Troubleshooting power quality issues sometimes may feel like searching for a needle in a haystack, but often they can be traced back to a single location: the electrical service panel. The service panel is a convenient first stop for checking the health of the electrical system.

Whether the problem is at the panel itself or elsewhere in the system, measurements at the service panel can tell you where to look next. Some problems can be caught by a quick visual inspection, while others require taking measurements.

Depending on the voltage and measurement requirements, there are a variety of tools for power quality troubleshooting, including digital multimeters (DMMs), digital clamp-on multimeters, and power quality and harmonics analyzers.

Some of the more common power quality problems to check for are voltage level and voltage stability, current balance and loading, harmonics, grounding, hot spots, and bad or marginal branch circuit breakers.

Voltage level and stability

To start, check the voltage levels and stability by measuring voltage levels of the branch circuits, making sure it is phase-to-neutral at the load side of the branch circuit breakers. If voltage levels are low at the breaker, they'll be even lower at the receptacle. This could be caused by low tap settings at the transformer. Other potential problems include loose connections, long feeder runs and overloaded transformers, which create excessively high source impedance (impedance from the load to the source).

If intermittent voltage sags are suspected, start at the panel to isolate the cause of sags. Are the sags the result of loads on the same branch circuit or are they caused by loads elsewhere in the distribution system (including utility-generated sags)? A power quality analyzer can start to isolate the source of the sag.

True-RMS clamp or DMM

To check current balance and loading, measure each feeder phase as well as current on each branch circuit with a True-RMS clamp or True-RMS digital multimeter (DMM) with a clamp-on accessory. When making this measurement, check to ensure the loading among the three phases are as balanced as possible; unbalanced current will return on the neutral. Also, neither feeder nor branch circuits should be loaded to the maximum allowable limit; there should be some derating to allow for harmonics.

Harmonics

To check for the presence and level of harmonics, measure current on the feeder neutral. This will typically be in the 80 percent to 130 percent range of the feeder current, due to the fact that the third harmonic will add up in the neutral. A single-phase power quality analyzer is ideal to capture the waveforms.

A typical three-phase system will have a 120-

Check for the presence and level of harmonics by measuring current on the feeder at neutral, which will typically be in the 80 percent to 130 percent range.

degree separation between each of the fundamental phase angles, causing them to cancel each other out. However, the third harmonic on all three feeders are in-phase with each other, reaching their peaks and zero crossing points at about the same time. This means that the triplens have nowhere to go but to the neutral where all the peaks and valleys add up.

The size of the feeder neutral conductor is important because it must return not only at an unbalanced fundamental current, but at the sum of all the third harmonic currents as well. To handle the load, the neutral should be double the size of the phase conductor.

If there are more black wires than white, there is a good possibility of shared neutrals. At that point, you should measure the branch neutral currents. The same thing is probably happening on the branch circuit as on the feeder level, which is a distinct fire hazard as the neutral has no circuit breaker protection.

A neutral ground voltage measurement will show if the neutral is too heavily loaded or if its source impedance is too great. If under normal loading, and the neutral ground voltage is close to zero then there is probably an illegal neutral ground bond.

Grounding: Clamp-on multimeter

Neutral ground bonds in subpanels are a violation of the *National Electrical Code (NEC)*—they are also quite common. Neutral ground bonds should be made at the transformer. When a neutral ground bond is made at a subpanel or receptacle, the ground path becomes a parallel return path for normal load current resulting in measurable current on the ground.

To check whether the ground current is normal or abnormal, measure the neutral current and then the current on the green wire with a clamp-on multimeter. If, for example, the neutral current is 70A and the ground current is 2A, the ground current is more likely to be normal leakage (and therefore unavoidable).

The smaller the ratio of neutral-to-ground current, the more likely that an illegal neutral ground bond exists. Neutral ground bonds can also exist in receptacles and even in load equipment, so use this same technique to measure for individual branch circuit ground currents.

If an illegal neutral ground bond is found in one panel at a site, it's a good bet there are others as well—all should be removed. This is also a good time to check the tightness of conduit connections, especially if the conduit is being used exclusively as the grounding conductor.

Hot spots: IR thermometers

From the power quality point of view, loose terminations are a major contributor to excessive source impedance. Fortunately, they are easy to locate with an infrared (IR) thermometer. IR measurements are a safe and effective technique for noncontact detection of panel hot spots. They can quickly and easily measure comparative temperature by scanning breakers and lugs to determine if one is significantly hotter than another.

For precise measurements, understand these two concepts:

- **Optical resolution (the ratio of the distance from the measured object to the sampling spot size).** If the ratio is 4:1, it means that if you are four inches from the surface being measured, you're measuring a spot with a one-inch diameter.
- **Emissivity (the ability of an object to emit infrared energy).** Emissivity is the opposite of light reflection, in the sense that darker, non-polished surfaces have higher emissivity. Most low-cost infrared instruments are fixed at an emissivity of 0.95, so the closer the surface being measured comes to this level of emissivity, the more accurate the measurement. Applying black electrical tape to cover any highly polished metallic surface will result in more accurate readings than polished metal.

Circuit breakers: Voltmeter

Circuit breakers wear out over time, so taking measurements of a circuit breaker voltage drop with a voltmeter can help determine the condition of the breaker. It's best to measure across the line-to-load side of the branch breaker. If the voltage drop exceeds 100 mV, the breaker should be replaced. In the 35 mV to 100 mV range, readings should be documented and trended. Measuring power quality with the right test tools starting at the service panel can start you down the right path to locate and fix any problems.

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