How Power Quality Issues are Killing our Machines

Application Note

Figure A. Motor Insulation Burnt.

A mystery is occurring in today's office buildings and manufacturing plants. Transformers supplying seemingly average loads are overheating. Neutral conductors in balanced circuits are overheating from excessive loads.

Circuit breakers are tripping for no apparent reason. Yet the standard troubleshooting procedures show everything to be normal. So what's the problem?

These are all the problems generated from non-linear loads that form part of the advance automation systems.

New Technology, New Challenges

Harmonics are the byproducts of modern electronics. They are especially prevalent wherever there are large numbers of personal computers, adjustable speed drives, and other types of equipment that draw current in short pulses. This equipment is designed to draw current only during a controlled portion of the incoming voltage waveform. While this dramatically improves efficiency, it causes harmonics in the load current. And that causes overheated transformers and neutrals, as well as tripped circuit breakers.

If you were to listen to an ordinary power line, you'd hear a monotone hum. When harmonics are present, you hear a different tune, rich with high notes. The problem is even more evident when you look at the waveform. A normal power line voltage appears on the oscilloscope as a near sine wave (Figure 1). When harmonics are present, the waveform is distorted (Figure 2A and 2B). These waves are described as non-sinusoidal. The voltage and current waveforms are no longer simply related-hence the term "non-linear."

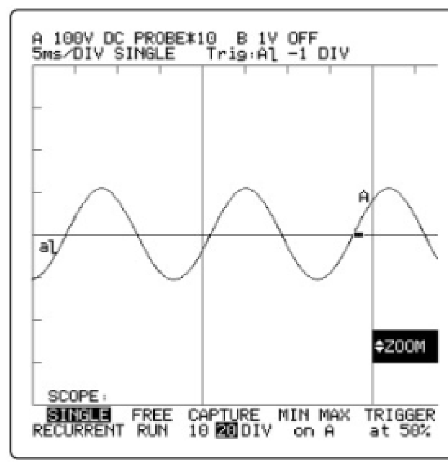

Figure 1. Near sine wave.

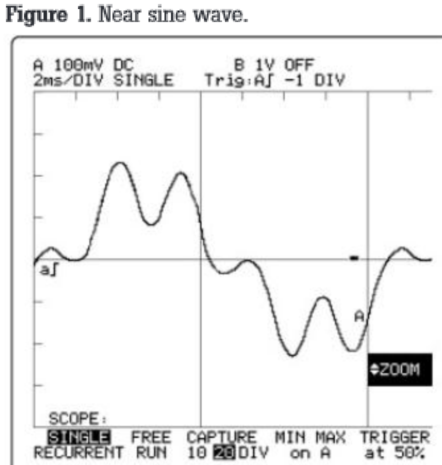

Figure 2A. Distorted current waveform.

Defining the Problem

Harmonics are currents or voltages with frequencies that are integer multiples of the fundamental power frequency. For example, if the fundamental frequency is 50 Hz, then the second harmonic is 100 Hz, the third is 150 Hz, etc. Harmonics are created by non-linear loads that draw current in abrupt pulses rather than in a smooth sinusoidal manner. These pulses cause distorted current wave shapes which in turn cause harmonic currents to flow back into other parts of the power system.

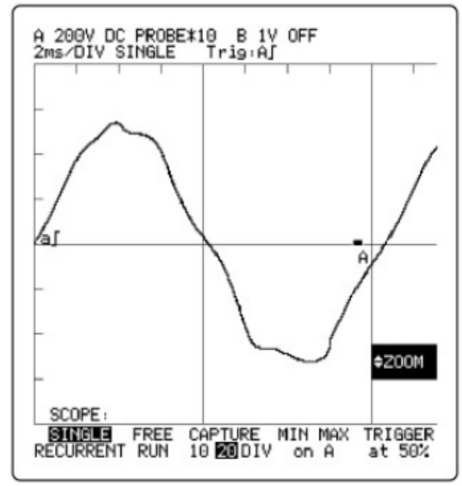

Figure 2B. Distorted voltage waveform.

The Inside Story

This phenomenon is especially prevalent with equipment that has diode-capacitor input power supplies; i.e., personal computers, printers and medical test equipment. Electrically what happens is the incoming ac voltage is diode rectified and is then used to charge a large capacitor. After a few cycles, the capacitor is charged to the peak voltage of the sine wave (e.g., 170 V for a 20 V ac line). The electronic equipment then draws current from this high dc voltage to power the rest of the circuit.

The equipment can draw the current down to a regulated lower limit. Typically, before reaching that limit, the capacitor is recharged to the peak in the next half cycle of the sine wave. This process is repeated over and over. The capacitor basically draws a pulse of current only during the peak of the wave. During the rest of the wave, when the voltage is below the capacitor residual, the capacitor draws no current.

The diode/capacitor power supplies found in office equipment are typically single-phase, non-linear loads (Figure 3A). In industrial plants, the most common causes of harmonic currents are three-phase, non-linear loads which include electronic motor drives, and uninterruptible power supplies (UPS) (Figure 3B).

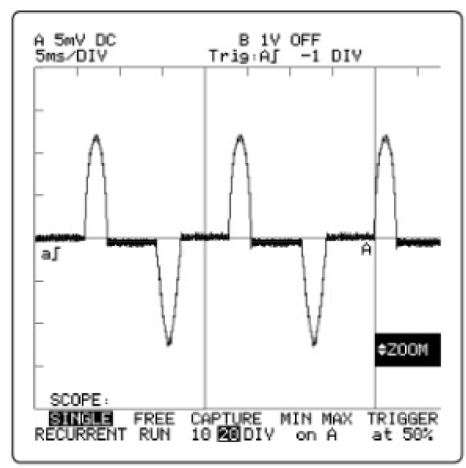

Figure 3A. Single-phase, non-linear load current waveform.

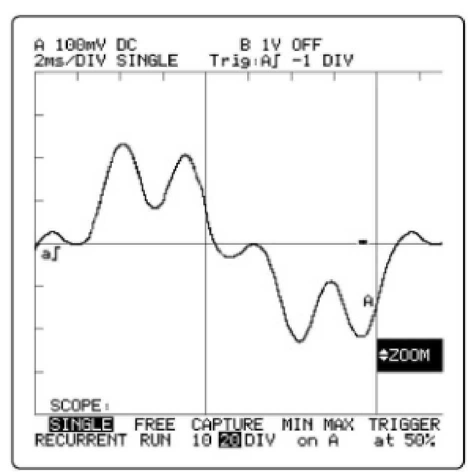

Figure 3B. Three-phase, non-linear load current waveform.

A Harmonic Survey Gives You a Good Idea if You Have a Problem and Where It is Located

Here are a few guidelines to follow.

Figure B. Fluke 435 Series II Power Quality and Energy Analyzer.

1. Load inventory.
Make a walking tour of the facility and take a look at the types of equipment in use. If you have a lot of personal computers and printers, adjustable speed motors, solid-state heater controls, and certain types of fluorescent lighting, there's a good chance that harmonics are present.

2. Transformer heat check.
Locate the transformers feeding those non-linear loads and check for excessive heating. Also make sure the cooling vents are unobstructed.

3. Transformer secondary current.
Use Fluke 435 Series II Power Quality Analyzer to check transformer currents.

- Verify that the voltage ratings
- Measure and record the transformer secondary currents in each phase and in the neutral (if used).
- Compare the kVA delivered to the load against the nameplate rating. (If harmonic currents are present, the transformer can overheat even if the kVA delivered is less than the nameplate rating.)
- Use the k-factor measurement from 435 Series II Power Quality Analyzer to determine de-rating or transformer replacement.
- Measure the frequency of the neutral current. 150 Hz would be a typical reading for a neutral current consisting of mostly third harmonic.

4. Sub-Panel neutral current check.
Survey the sub-panels that feed harmonic loads. Measure the current in each branch neutral and compare the measured value to the rated capacity for the wire size used. Check the neutral bus bar and feeder connections for heating or discoloration. A Thermal Imager, like the Fluke Ti 400, is useful for detecting excessive overheating on bus bars and connections.

5. Receptacle neutral-to-ground voltage check.
Neutral overloading in receptacle branch circuits can sometimes be detected by measuring the neutral-to-ground voltage at the receptacle. Measure the voltage when the loads are on. Two volts or less is about normal. Higher voltages can indicate trouble depending on the length of the run, quality of connections, etc. Measure the frequency. A frequency of 150 Hz would suggest a strong presence of harmonics.

Solving the Harmonics problem

The following are suggestions of ways to address some typical harmonics problems. Before taking any such measures you should call a power quality expert to analyze the problem and design a plan tailored to your specific situation.

In overloaded neutrals

In a three-phase, four-wire system, the 50 Hz portion of the neutral current can be minimized by balancing the loads in each phase. The triplen harmonic neutral current can be reduced by adding harmonic filters at the load. If neither of these solutions is practical, you can pull in extra neutrals —ideally one neutral for each phase—or you can install an oversized neutral shared by three phase conductors. In new construction, under carpet wiring and modular office partitions wiring should be specified with individual neutrals and possibly an isolated ground separate from the safety ground.

De-rating transformers

One way to protect a transformer from harmonics is to limit the amount of load placed on it. This is called "de-rating" the transformer. The most rigorous de-rating method is described in ANSI/IEEE standard C57.110-1986.

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