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Solving problems after energy upgrades

Application Note

Bottom line

To preserve your energy upgrade savings, learn to troubleshoot and repair associated problems in-house.

Trying to save energy dollars is not always as simple as it seems. Installing variable frequency drives (VFDs) and retrofitting lighting systems are two of the quickest and most widely accepted ways to achieve significant energy savings. Yet, new problems may surface as a result.

One of the first steps in solving these problems is to understand that the energy efficient devices themselves may be the cause. While most energy-saving electronic lighting ballasts, lighting controls and VFDs work just fine on modern electrical distribution systems, this equipment can create troubleshooting nightmares in older facilities.

Electrical problems resulting from high-efficiency, energy savings upgrades fall into one or more of three areas:

- Application
- Installation (including startup)
- Maintenance

VFD mis-matches

One of the most common energy saving applications in facilities is to use VFDs on centrifugal pumps, fans and blowers. Varying motor speeds is a much more efficient way to control flow rates and thereby maintain water temperatures than to run the motor and pump at full speed and throttle a valve to adjust flow rates. But problems will result if:

- The VFD has not been properly sized and selected
- The drive and motor installation was not done with a VFD in mind
- Parameters were not properly set at startup
- The effects of harmonic currents were not considered in design and addressed in maintenance

The non-linear effect of electronic loads

Variable frequency drives are complex electronic devices called nonlinear loads that vary their output voltage and frequency to control motor speed. The distribution system supplies voltage, however, current does not flow into the VFD until the rectifier circuit in the converter section begins to conduct. Since current does not flow linearly as voltage is applied, the equipment is called "nonlinear."

When the diodes suddenly allow current flow, it creates a "notch" on the sine wave that causes sine wave distortion. The VFD rectifier circuit also causes currents to flow back into the distribution system in multiples of 60 Hz. Current that flows back in multiples of the fundamental is called harmonic current. The third harmonic is 3X the fundamental of 60 Hz or 180 Hz. The fifth harmonic current is at 300 Hz, and, so on.

Harmonics

These harmonic currents not only tend to distort voltage throughout the plant, but certain harmonic frequencies create problems unique to that harmonic.

For example, the third harmonic causes overheating in neutral conductors and transformers. The fifth harmonic can cause motor issues, such as, overheating, abnormal noise and vibrations, and motor inefficiency.

Bottom line: All electronic equipment creates harmonics and distorts the voltage distributed in-plant.

Other typical nonlinear loads added during energy upgrades include electronic ballasts, computers, controls (PLCs, etc.), and various components of building automation systems.

Always use a true-rms responding test tool when measuring non-linear loads, especially current. For a backgrounder on why true-rms, visit **www.fluke.com/true-rms**.

Sensitive controls

Here is the root cause of the problem: Modern control systems are quite often sensitive to any quality problems with the electrical power they are supplied. That means nonlinear high-efficiency loads create operational problems not only with other sensitive plant equipment, but with themselves, as well. Ironically, the very equipment installed to save energy often causes inefficiencies and unexpected maintenance costs.

Fortunately, some quick checks and basic electrical troubleshooting can resolve many problems.

VFD troubleshooting examples

Poor motor speed control and/or nuisance trips

For example, a typical VFD problem encountered in the field is that the drive fails to control motor speed properly and may even experience nuisance trips. The two mostly likely causes of this particular problem:

- Voltage unbalance on the three phases supplying the drive
- Harmonics flowing out of the drive, back into the distribution system

For example, a chiller with a VFD installed may experience temperature control problems at specified locations in the system due to distorted sine waves created by the harmonics. This distortion affects the operation of PLCs, temperature controllers and other controls in the chiller.

Another possibility: If tachometer feedback cables are not properly selected and installed, erroneous motor speed information will be fed back into the VFD, making it impossible for the VFD to control real motor speed.

Solution: Run shielded cable for these low voltage signals and ground only at one end.

When routing these low voltage conductors, ensure they are not installed close to power conductors. Electromagnetic induction from power cables can affect low voltage control.

Installation checks

To troubleshoot VFD control problems, first review the installation design. Chances are the proper drive, motor and associated equipment were selected—but verify anyhow. Walk-down and observe the installation. Were correct cable types selected and installed properly? Is the installation suitable for the environment in which it is installed? Are enclosures free of dust and adequate ventilation provided?

Drive parameter checks

Review the parameters programmed into the drive. Does the data entered match the motor nameplate? Has the drive been set for proper operation, such as, variable torque for energy-saving pump and fan applications? If the VFD is not controlling the motor as expected, it could be because operational parameters were either not set correctly, or more than likely, were reset by some well-meaning individual attempting to correct other problems.

Quick measurement checks

Measure VFD input voltage with a true-rms digital multimeter verifying voltage unbalance falls within manufacturer's specifications. Measure harmonic frequencies and levels at the point where power is supplied into the VFD, using a power quality clamp meter or power quality analyzer. Also check for harmonics back at the feeder where the power to the VFD is also supplying other loads.

Solution: If voltage unbalance is the problem, shift and evenly distribute single-phase loads. If harmonics are found to be the cause, contact the drive manufacturer or a harmonic filter manufacturer and determine and install a properly tuned harmonic filter.

Problems with lighting retrofits

Nuisance tripping

Without a doubt, lighting retrofits save money on the monthly electric utility bill. But many facilities invest in lighting upgrades only to find lights flickering or not operating at all. Seemingly unrelated, three-phase motors overheat, servers and computers malfunction, and data is lost. Nuisance trips on circuit breakers suddenly begin occurring. Newly installed electronic equipment mysteriously trips on overvoltage or overtemperature—yet the equipment does not show any signs of such abnormal conditions.

Such problems are generally associated with harmonics. One IEEE study indicates these harmonics can become a significant issue if fluorescent lighting comprises 25 percent or more of the facility load.

Electronic ballasts often introduce harmonic currents back into the distribution system. If the facility is an older one and only one neutral wire was pulled in for each of the three ungrounded phase conductors to the lighting circuit, (sharing neutrals), the result may be overheating neutral conductors, panelboards and transformers. Maintenance often finds and corrects these problems.

Tip: Pull-in additional neutral conductors, one per phase total as needed. Infrared thermography can often identify these issues before failure.

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Problem after energy-savings upgrade	Possible area of concern	Quick checks	Troubleshooting and repair
Overheating neutrals, transformers	Lighting upgrade includes electronic ballasts and CFL's (especially if 25 % or more of total building load)	Are nonlinear loads, (especially lighting) being supplied by equipment and wiring that is overheating? Use thermography to help identify problem areas.	Use true-rms test equipment to check for harmonics. Isolate or shift loads as needed to other panels. Do not share neutrals.
Erratic motor operation	Improper wiring installation. Parameters not set correctly in drive	Verify use of shielded cables if required. Verify control wiring and power conductors separated. Shielded cable grounded only at one end.	Review application design. Verify all drive parametera set properly. Verify correct feedback signal. Verify motor integrity and wiring.
Motor noise	Excessive harmonics at certain frequencies produced by VFD to motor	N/A	Check for higher level harmonics at the motor (11th and up). Add a properly designed load side reactor.
Motor overheats	Is system suitable for environment? Harmonics supplied to VFD driven motors cause overheating and damage insulation. Voltage unbalance to other plant motors	Motor turning constantly at slow speed may not get sufficient cooling from motor fan.	Identify any harmonic issues at VFD driven motor and add load-side filters if necessary. Verify no more than 1 % voltage imbalance. Balance single-phase loads as needed.
Unexplained circuit breaker trips	Harmonics	Verify normal current values through breaker.	Isolate and correct harmonic issues creating excessive heating.
System malfunctions only when on standby generator	Generator may not be suitable for large harmonic loads	Measure loads supplied by generator. Classify nonlinear loads by percentage.	Generators for harmonic loads are typically oversized during design. Limit harmonic loads on generator. Consult with generator manufacturer.
Lighting system malfunctions	Electronic ballasts, CFL's. Lighting controls	Verify proper setup of controls. Verify controls and ballasts types matched.	No shared neutrals if possible. Adjust photosensors for proper operation.

Figure 1. Typical problems reported after energy upgrades and some quick checks to resolve issues.

Dimmer controls

Common retrofits to T-8 lamps with electronic ballasts and the replacement of incandescent lamps with compact fluorescents (CFL's) both create significant energy savings.

For additional energy savings, dim the fluorescent lighting when full light output is not needed. This dimming can be achieved with manual dimmers or, with photosensors that sense light level either indoors or outdoors as required.

Make sure to match the proper type of dimmer control with the ballast and lamp type to be dimmed. Mis-matches here can result not only in improperly operating equipment, but in damaged lighting system components, as well.

Depending on the type of dimming controls used, additional control wiring operating at 0 V to 10 V may be installed. Placing such control wiring too close to power conductors during installation or maintenance can result in erratic lighting control.

Tip: Keep control wiring as short as possible during installation.

Automated lighting controls that switch lighting banks off and on erratically after the installation of energy-saving controls should be checked for proper sensor operation. Some photo sensors may have a deadband adjustment available to change the time between lights-off and lights-on.

Overheating motors

As part of the energy savings lighting upgrades, banks of lighting may be switched to save energy. Depending on the circuits switched, phase unbalances could result on three-phase systems. Maintenance gets the call to replace motors that have been destroyed by overheating.

Tip: Check the voltage supplied to the motor during all phases of plant operation.

Maximum voltage unbalance at motor terminals should not exceed one percent. Operation of a motor at greater than five percent unbalance will probably result in motor damage

Conclusion

The best tool for solving problems, after an upgrade, is a well-trained and properly equipped workforce. Knowledge of how the energy-saving application works is the first step in solving associated problems.

Review the design, installation and any startup procedures to isolate and correct many problems. As maintenance on the equipment is required, use a logical, systematic approach with the right tools to isolate problems. Review Figure 1 for typical problems encountered after energy-saving upgrades and for ideas on where to get started.

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