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Troubleshooting power problems on HVAC equipment

Application Note

A variable frequency drive (VFD) fails to vary the discharge-air fan speed. A motor overheats and fails prematurely. Programmable controls that generally operate without issue suddenly experience problems when operating on standby power. A VFD trips for no apparent reason in a chilled water system resulting in a high temperature alarm. A circuit breaker trips, leading to a system shutdown; yet, a clamp meter reading reveals no abnormal current flow in the system after restart.

While each troubleshooting problem in an HVAC system presents its own unique set of circumstances, HVAC professionals may recognize such problems as possible power quality issues.

Large three-phase generators supply standby power to HVAC loads during loss of normal power. Such generators, quite often because of the large amounts of digital loads they must supply, may have difficulty maintaining sufficient power quality for proper VAV terminal operation.

Electronics are the foundation of modern control systems. Programmable controls, solid state relays, sensors, transducers, variable frequency drives on fans and chilled water pumps, and electronic controls on actuators all are susceptible to problems that older, purely electro-mechanical controls did not have. These problems are often the result of the quality of the voltage and current being supplied to the HVAC equipment. Poor "power quality" is electric power that does not meet specified parameters.

As with all forms of HVAC troubleshooting, technicians must understand the sources of potential problems in order to solve them. Unexplained problems are often attributed to faulty electronic equipment. However, the real cause may not lie in the electronic equipment at all.

Sine wave distortion can result in inaccurate readings when not using a true-rms DMM. Compare the average reading meter (left) with the true-rms DMM reading (right) in the same control system.

False or deceptive clues

For example, a VFD that fails to properly vary discharge-air fan speed can be the result of various system issues—from a DDC override initiated on the VFD, to a faulty static pressure sensor, to excessive duct leakage. While the cause of the initial failure rarely lies with the VFD itself, the VFD may in fact be causing other system problems. Motors overheat, nuisance trips of circuit breakers or unexplained blown fuses happen, and spurious alarms can occur elsewhere in the digital control system. Since these can all be characteristics of normal VFD operation, the technicians must always trace the problem back to the source.

In one instance, a fan-supplied VFD would inadvertently trip in a chiller system when power was transferred from the usual source to the standby source. The result was high-temperature alarms on the supplied equipment because of inadequate cooling. VFDs are designed to ride-through a certain amount of voltage interruption in a system. However, if VFD specifications for such faults are exceeded, the VFD will shut down.

In this case the electronic drive was first thought to be at fault. However, investigation into the VFD operating parameters and the logging of voltage and current values during transfers of system power revealed the true cause of the problem: Transfer switch time was often too long to support VFD operation.

In another case, a VFD in a VAV terminal would trip offline when supplied power from the standby power source. The problem was found to be the inability of the standby generator to provide sufficient power quality to operate the VFD. Voltage fluctuations when on standby power resulted in trips on the VFD. The solution was to place the VFD into bypass operation when on standby power, thus bypassing the electronic variable speed controls.

The root of power-quality problems

Electronic equipment operates by taking in alternating current and converting it to direct current for use by electronic components. This process creates harmonic currents that flow back into the system. These harmonic currents can cause overheating and also distort the sine waves upstream of the electronics.

Harmonic currents are currents that appear at multiples of the fundamental 60 Hz frequency. For example, the third harmonic is current that flows at 180 Hz (60 x 3); the fifth harmonic is current that flows at 300 Hz (60 x 5), and so on.

How to measure harmonics

Technicians measure the levels of the various harmonics and the amount of distortion created to determine if the harmonics are creating problems. Use a power quality analyzer to measure harmonic levels and distortion. The key measurement is Total Harmonic Distortion (THD) of voltage.

Set the analyzer according to instructions and read THD directly on the meter face. THD should not exceed 5 % when measured at the point where the feeder that supplies the VFD is also supplying other loads. This is the point of common coupling (PCC).

If THD of voltage exceeds limitations, then consult with the VFD manufacturer to determine the best solution. This may include the installation of a line reactor or isolation transformer. Learning to use a power quality analyzer is not difficult and such efforts typically far outweigh the cost of HVAC system downtime.

Motor failure

Another power quality issue experienced in HVAC systems is motor failure, especially those supplied by VFDs. This failure rate may increase if the motor tends to run at the slower speeds typical of many applications. Failures often include overheating, insulation breakdown or premature bearing failure.

All such failures can be attributed to normal operating characteristics of VFDs. The electronic drive varies the voltage and frequency to the motor, to vary its speed.

Unfortunately, harmonic currents are also supplied to the motor, which can result in overheating. This "pulse width modulated" voltage and current supplied to the motor can also damage insulation, resulting in premature breakdown and motor failure. Currents can also flow through motor bearings, greatly shortening their life. The best solution to all these problems is to use Inverter Duty Rated motors specially designed for use on variable frequency drives.

Voltage unbalance

Three-phase motors that are not supplied by a VFD may also fail due to another power quality problem: voltage unbalance. A phase voltage that is out of balance by as little as one percent can result in a six-to-ten times greater motor current unbalance. Such excessive amounts of current flow can quickly result in overheated motors.

To determine unbalance, measure the voltage from phase-to-phase for each of the phases, A-B, A-C, and B-C. Total the three readings and divide by three. This is the average phase-to-phase voltage. If any of the three individual readings varies by more than one percent from the average, you have a voltage unbalance.

At five percent voltage unbalance, the motor typically overheats and is destroyed. Generally, the problem is too many single-phase loads being supplied by one individual phase. These loads must be evenly distributed amongst phases at the panelboard to correct the problem.

General guidelines

All HVAC electrical and electronic equipment has specified electrical supply parameters. Failure to meet them will simply ensure the equipment will not operate as planned. A fan-powered VAV terminal is a typical example of equipment with specified electrical supply requirements.

When experiencing erratic operation of this equipment, verify the electrical supply parameters are being met. For such equipment, ac input voltage must fall within 10 % of rated voltage at rated frequency. The nameplate will show the equipment's rated voltage. For example, equipment rated at 208 V must have a supply voltage that falls between 187 V and 229 V. It is not uncommon to find low voltages when troubleshooting equipment.

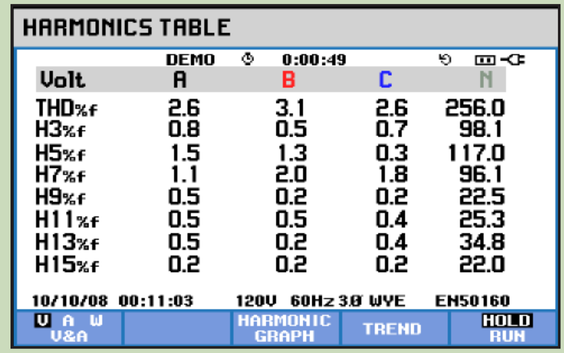
Tools

It's also important to use a true-rms meter when measuring voltage and current values. Today's modern HVAC systems not only produce harmonic currents; they may also operate improperly due to the sine wave distortions created by such harmonics. An average responding meter, used by many HVAC technicians, will not give accurate readings if harmonics are present.

Average responding meters read current and voltage of sinusoidal waveforms at 60 Hz with no harmonics present. Nonlinear loads, such as VFDs, produce non-sinusoidal waveforms and currents and voltages at various frequencies. You must use the right meter to read the values in these supply circuits. Only true-rms meters will give you the correct readings.

Supply voltage

If supply voltage is below the low voltage specification, you can expect two problems with HVAC equipment. First, motor life will be shortened as motors draw excess current to produce the needed horsepower at the lower voltage. Second, electronics will not function properly as the power supply portion of the electronic controls will not have sufficient voltage to charge the capacitors in their filtering circuits.



This screenshot from a power quality analyzer identifies how much total harmonic distortion is created on each phase in the distribution system as a percentage of the fundamental 60 Hz frequency. Also indicated is the distortion created by each harmonic frequency. Harmonic distortion can cause overheating and improper operation of electrical equipment, especially HVAC controls.

Electronic components, which typically operate at only 5 V dc, will now be greatly affected by a low incoming voltage. Expect erratic operation and spurious alarms, depending on the severity of the low incoming voltage. And remember, without the true-rms meter, you may not have an accurate picture of the actual supply voltage.

AC power is also required to be within 5 % of rated frequency at the rated voltage on a typical VAV terminal. Generally, this is not a problem when operating on utility power. However, HVAC professionals report numerous problems with both voltage and frequency when operating on standby generators. Be sure to verify all incoming electrical supply specifications for all power sources required for the HVAC system.

An additional equipment-manufacturer requirement is that the supply "must meet a combined variation in the voltage and frequency of 10 % (the sum of absolute values) of rated values, provided the frequency variation does not exceed 5 % of rated frequency." Once again, the equipment is most likely to exhibit this problem when operating on standby power. Several options are available to stabilize control problems when operating on standby power. While this requires working with the appropriate system engineers and technicians, the first step is to ensure you have accurate readings to back up your claim that the control problem rests with unstable standby power.

In summary

Many HVAC troubleshooting problems will continue to be solved by such routine tasks as checking fuses, testing for the presence of voltage at a contactor, and verifying current flow does not exceed the motor nameplate data. However, systems that contain electronic controls and VFDs will have problems due to power quality issues.

Today, many HVAC professionals are expanding their skills and knowledge into this area. The more controls are used in HVAC and building systems, the more power quality problems will arise. The use of true-rms meters and analyzers that log electrical parameters over time will greatly enhance isolating and correcting poor power quality issues. Proper knowledge, coupled with the right tools, goes a long way in helping HVAC professionals resolve many problems associated with today's HVAC systems.

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