

University Improves Sustainability OF HVAC Motors IN Platinum LEED Building

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Introduction

A new preventive maintenance program at a leading New England Ivy League university demonstrates how the push for more sustainable “green” building management has led to a growing awareness of a chronic, widespread problem with HVAC motors—electrical bearing damage and failure.

Variable frequency drives (VFDs), also known as inverters, adjustable speed drives, etc., are widely used because they save energy—especially in applications with varying loads. Because many centrifugal fans and pumps run continuously, their motors use less power if the input is modulated by VFDs. For example, a 20 percent reduction in fan speed can reduce energy consumption by nearly 50 percent.

But if efficiency increases are not sustainable, their savings vanish. Shaft currents induced by VFDs can wreak havoc with bearings, dramatically shortening motor life and caus-

ing costly repairs. To mitigate these currents and realize the full potential of VFDs, a reliable method of shaft grounding is essential.

And the problem is all too common. According to a recent survey of 1,323 construction projects valued at \$5 million to \$50 million each, the number of such projects specifying VFD-driven motors rose by 21 percent between June 2009 and November 2010. But only a fraction (about one out of six) of those sites installing new VFDs will protect their motors’ bearings through shaft grounding. Consequently, there is a ticking time bomb out there—many of the motors recently fitted with VFDs are headed for trouble.

The referenced university’s maintenance department has spearheaded a push for sustainability campus-wide through the renovation of its own headquarters. When completed in 2006, this complex received a Platinum Leadership in Energy and Environmental Design (LEED) rating—the highest rating awarded by the United States Green Building Council. More recently, the university also had the highest score on the College Sustainability Report Card, an annual grading of the “green credentials” of 300 colleges and universities.

One of the maintenance department’s most significant efforts to foster sustainability at the more than 300 buildings it services is a testing program for HVAC motors controlled by VFDs. Many of the buildings have their own maintenance managers; whenever such a manager requests testing on a motor in his/her building, technicians from maintenance headquarters use portable oscilloscopes and voltage-measuring probes to determine whether or not shaft voltages are present—voltages that cause electrical discharges through the motor’s bearings.

If harmful discharge levels are detected, the maintenance department may recommend the installation of a proven bearing-protection device that bleeds off the damaging currents—for example, the Aegis SGR Bearing Protection Ring. This shaft grounding ring safely redirects VFD-induced shaft voltages by providing a very low impedance path from shaft to frame and bypassing the motor bearings entirely. Key to the ring’s success are conductive microfibers that line the entire inner circumference of the ring in two rows, completely surrounding the motor shaft. A protective channel in the ring allows the fibers to flex without breaking and keeps out debris.

The university maintenance department has already used the Aegis ring successfully for fan and pump motors in several new buildings on campus. Manufactured and sold by Elec-

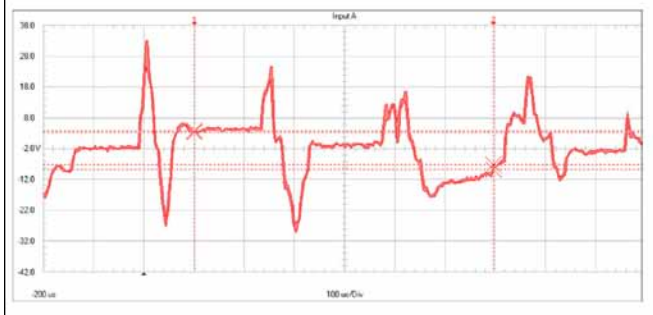


Figure 1 – Motor #1 powers a chilled water pump with the VFD set at 60 Hz and motor running at 1,776 rpm (7.2 amperes).

tro Static Technology, the ring is available in two versions—a continuous ring or a split. Designed for installation with either brackets or conductive epoxy, the split ring (used in the university’s retrofit program) simplifies and speeds field installations because it can be installed without uncoupling attached equipment.

The Importance of Shaft Grounding

The need to ground motor frames has long been recognized, but the need to ground motor shafts has only recently become clear. Along with proper tuning of a drive’s frequency range output, an effective shaft grounding device is needed to prevent premature bearing failure. Ironically, some products designed to protect bearings—such as conventional grounding brushes—require extensive maintenance themselves. Others—such as insulation—can shift damage to connected equipment.

As a demonstration of the university maintenance department’s new program, Aegis rings were installed in December 2009 by the ring’s manufacturer on two VFD-controlled HVAC motors in the basement of the maintenance headquarters, which is cooled in the summer by ground-source heat pumps. Motor No. 1 powers a chilled water pump; Motor No. 2 is an identical motor that runs an air supply fan. Both were 3-year-old Baldor 7.5 hp motors (NEMA frame size 213T, shaft diameter 1.389"). Unfortunately, both motors made a high-pitched whining sound, indicating that “fluting”—i.e., bearing damage caused by electrical discharges—had already occurred. Obviously, shaft grounding provides the best protection when installed on a new motor or a motor with recently replaced bearings.

Motor No. 1. Before the grounding ring was installed on Motor No. 1, the shaft guard was removed. With the VFD set at 60 Hz, the motor was running at 1,776 rpm (7.2 amperes). When a voltage probe was held against the motor shaft, the oscilloscope (set at 10 volts and 100 microseconds-per-division) indicated peak-to-peak discharges of 61 volts. The oscilloscope display showed rapid voltage collapses at the trailing edge of the waveform—typical of the electrical discharges that damage bearings.

After the readings, the shaft was cleaned with fine-grit sandpaper and wiped with an alcohol-dampened rag. Paint was removed from the motor end bracket with a Dremel rotary tool and a small wire-brush bit to expose a bare metal surface against which the grounding ring would be mounted with conductive epoxy. In addition to the split-ring Aegis SGR, the manufacturer’s kit contained tubes of conductive epoxy and activator. The tape was then removed from one joint of the ring, allowing it to be opened, to fit over the motor’s shaft without the need to de-couple and realign the motor to the pump.

Equal proportions of epoxy and activator were then mixed, and small amounts were applied to the back of the ring.

Prior to installing the ring, a narrow band of Aegis colloidal silver coating was applied around the shaft where the fibers contact it, to improve the surface conductivity. The ring was then installed on the shaft and re-taped.



Figure 2—Equal proportions of epoxy and activator are mixed and small amounts are applied to the back of the ring.



Figure 3—Narrow band of Aegis colloidal silver coating is then applied around the shaft to improve surface conductivity. Ring is then installed on the shaft and re-taped.



Figure 4—Ring is pushed back against bare metal of end-bracket, maximizing electrical contact via conductive epoxy. To ensure ring is correctly centered on shaft, metal spacers (included in the kit) are inserted into gaps between two halves of ring. Post adhesive cure, spacers are removed. Installation time: about 10 minutes.

continued

Next, the ring was pushed back against the bare metal of the end bracket, maximizing electrical contact via the conductive epoxy. To ensure that the ring was correctly centered on the shaft, small metal spacers (included in the kit) were inserted into the gaps between the two halves of the ring. Once the adhesive cured, the spacers were removed. The entire installation took about 10 minutes.

Approximately an hour after installation the epoxy had cured sufficiently to allow testing of the motor again with the oscilloscope and probe. This time, with the VFD set at 60 Hz, the motor running at 1,775 rpm (7.4 amperes), and the oscilloscope set at 10 millivolts and 100 microseconds-per-division, the discharge plot displayed on the scope was essentially a straight line—indicating that shaft voltage discharges were being diverted by the Aegis ring to ground.

Motor No. 2. Motor No. 2 was more difficult to reach because it was located in a tiny room sealed with bulkhead doors to contain noise and rushing air. Pre-installation shaft dis-

charges were measured at 50.8 volts (peak-to-peak).

The shaft was cleaned and prepared in the same manner as that used for Motor No. 1, but because the motor shaft was difficult to reach and only a couple of inches of it between the end-bell and a sheave were exposed, the versatility of the splitting Aegis SGR and the ease of installation using conductive epoxy became even more apparent—and necessary.

A hand-held heater was used to speed the epoxy's cure, and about a half-hour after installation, the shaft voltage was measured again. This time the reading was only 380 millivolts, peak-to-peak.

A Closer Look at Bearing Damage

The cumulative bearing damage caused by VFD-induced shaft voltages and resulting bearing currents is often overlooked until it is too late to save the motor. The high peak voltages and extremely fast voltage rise times (dv/dt) associated with the insulated gate bipolar transistors (IGBTs) found in today's typical pulse-width-modulated VFD cause non-sinusoidal currents that can overcome standard motor insulation. Hard to predict but easier to prevent, this damage can occur even in motors marketed as "inverter-ready." Without some form of mitigation, shaft currents can discharge to ground through bearings, causing unwanted electrical discharge machining (EDM) that erodes the bearing race walls and leads to excessive bearing noise, premature bearing failure and subsequent motor failure.

When a VFD-controlled motor fails, warranty claims against motor and VFD manufacturers may be invalidated. Because systems that use VFDs are so varied and the potential causes of failure so numerous, even when the VFD and motor are properly rated and perfectly matched to each other and neither is inherently defective, the liability question usually amounts to a circle of pointing fingers. For many years, the problem of VFD-induced bearing damage was often misdiagnosed, until repair shops and testing consultants proved the connection.

Inadequate grounding significantly increases the possibility of electrical bearing damage in VFD-driven motors. Viewed under a scanning electron microscope, a new bearing race wall is a relatively smooth surface (Fig. 10). As the motor runs, tracks eventually form where ball bearings contact the wall. With no electrical discharge, the wall is marked by nothing but this mechanical wear. Bearings are designed to operate with a very thin layer of oil between the rotating ball and the bearing race, but if shaft voltages build up to a level sufficient to overcome the dielectric properties of the lubricant, they discharge in short bursts along the path of least resistance—typically the bearings—to the motor's frame. Without proper grounding, VFD-induced electrical discharges can quickly scar the race wall.

During virtually every VFD cycle, these induced currents discharge from the motor shaft to the frame via the bearings, leaving small fusion craters in ball bearings and the bearing race wall that eventually lead to noisy bearings and bearing failure. In a phenomenon called fluting, the operational frequency of the VFD causes concentrated pitting at regular intervals along the bearing race wall, forming washboard-like ridges. Fluting can cause excessive noise and vibration. In an



Figure 5—One hour after installation, epoxy has cured and motor again tested with oscilloscope and probe. Now—with VFD set at 60 Hz; motor running at 1,775 rpm (7.4 amperes); and oscilloscope set at 10 millivolts and 100 microseconds-per-division—discharge plot displayed on scope is essentially a straight line, indicating shaft voltage discharges were diverted by Aegis ring to ground.



Figure 6—Unlike Motor #1, the Motor #2 shaft is difficult to reach, with only a couple of inches between the end-bell and a sheave exposed; the versatility of the splitting Aegis SGR and ease of installation using conductive epoxy become even more apparent.

HVAC system, the noise may be magnified and transmitted by ductwork throughout the entire building.

Sustainable Shaft Grounding Technology

To guard against such damage and thus extend motor life, the VFD-induced current must be diverted from the bearings by means of mitigation technologies such as bearing insulation and/or an alternate path to ground. But bearing insulation and ceramic bearings do not protect attached equipment and conventional shaft-grounding brushes often create more maintenance problems than they solve.

Because the problem is best addressed in the design stage of a system, the best solution arguably would be a motor with built-in bearing protection, available at a reasonable cost. Although both Baldor Electric and General Electric now offer the Aegis ring on certain models, most standard motors do not provide bearing protection and only specify Class F, G or H insulation for the windings.

Fortunately, bearing damage can be mitigated by retrofitting previously installed motors with a shaft grounding ring such as the Aegis ring.

The versatile ring is available for any NEMA or IEC motor, regardless of shaft size, horsepower or end-bell protrusion. These rings have been successfully applied to fan motors, pump motors, compressors, generators, turbines, AC traction and break motors, and a long list of other industrial and commercial applications.

For VFD-equipped motors of less than 100 hp (75 kW), a single Aegis ring on the drive-end or non-drive-end of the motor shaft is typically sufficient to divert harmful shaft currents. For most motors above 100 hp (75 kW), or motors with roller bearings, a combination of insulation on the non-drive-end with an Aegis ring on the drive-end provides the best protection in order to break a potential circulating current in the bearings while discharging the shaft voltage to ground.

Once installed, the Aegis grounding ring requires no maintenance and lasts for the life of the motor—regardless of rpm. Test results show surface wear of less than 0.001" per-10,000-hours of continuous operation and no fiber breakage after two million direction reversals.

Conclusion

Operations and maintenance costs are often 60–80 percent of the total lifecycle costs of a building. With equipment that does not have to be repaired or replaced as often, that percentage will drop. Energy-saving technology must be sustainable to help reduce these costs. In the case of VFDs, to “bank” cost savings from their reduced-energy usage, users must protect the bearings of motors controlled by the VFDs with proven long-term, maintenance-free shaft grounding such as that provided by the Aegis SGR Bearing Protection Ring.

The university’s maintenance department estimates that several hundred motors campus-wide could benefit from this technology, and they are hoping the test results will entice individual building managers to contact the department for an evaluation. In keeping with its green mandate, the department is aggressively promoting the Aegis ring as a way of realizing the full energy and cost-saving potential of VFDs.



Figure 7—Hand-held heater is used to speed epoxy's cure; post-curing, shaft voltage is measured again, showing a reading of only 380 millivolts, peak-to-peak.



Figure 8—New bearing (left); fluted bearing (right).



Figure 9—Aegis grounding ring requires no maintenance and lasts for life of motor, regardless of rpm.

Adam Willwerth has extensive experience in industrial product development and commercialization. He is named on four patent applications pertaining to conductive microfiber shaft grounding ring technology and has presented seminars on the subject of bearing current mitigation at professional conferences in the U.S. and Europe. He holds a Master of Business Administration degree from Southern New Hampshire University and a Bachelor of Science degree in management from the University of Maryland.

