The Challenge of Mission-Critical Bearing Protection for Data Center Cooling

Overview

Because they provide the ability to precisely match cooling capacity to load, variable frequency drives (VFDs) are widely used in mission-critical data center applications. But, if the motors controlled by these drives are to be truly mission critical, they must be protected against electrical bearing damage with AEGIS® Shaft Grounding Rings.

AEGIS®
BEARING PROTECTION RINGS

Introduction

Advances in server technology have led to astonishing increases in the amount of computing power per square foot in today's data centers. But while advanced rack-mounted blade servers have dramatically increased processing capabilities, they have also dramatically increased the amount of heat produced and the demands on data center cooling systems.

In fact, in their quest for energy efficiency, many data centers are now running their servers at higher temperatures, thereby reducing their safety margins for cooling system failures. In these environments, the reliability of data center cooling systems is of mission-critical importance. In the best case, the failure of even a single motor could be extremely costly. In the worst case, it could have dire consequences.

The Problem

Dispersing the heat generated by racks of servers presents a challenge for heating/ventilation/air conditioning (HVAC) system designers. To better match cooling capacity to cooling load, these designers typically specify that motors used in HVAC equipment or systems be controlled by VFDs.

But VFDs have a drawback. They induce voltages on the shafts of the motors they control — voltages which discharge through motor bearings, destroying them and dramatically shortening the motor's life.

Without dependable long-term shaft grounding, the use of VFDs in data center applications can dramatically reduce the reliability of mission-critical cooling systems and jeopardize guaranteed service levels of up to 99.9999%. In fact, the cost downtime due to a single failed motor bearing could be astronomical. Proven in almost a million installations worldwide, the AEGIS® Shaft Grounding Ring provides long-term protection against electrical bearing damage, eliminating such repairs and downtime.

Figure 1

A computer room air conditioning (CRAC) unit in a data center. If data center cooling motors fail, the result could be server failure, loss of data, and tremendous expense. To avoid such emergencies, these motors need to be protected against a little-understood, often misdiagnosed cause — VFD-induced electrical bearing damage.

Many HVAC motors, including those in most computer room air conditioning (CRAC) units (typically 5-15 HP), run continuously, but often at reduced loads (Figure 1). Because the energy consumption of such devices correlates to their flow rate cubed, the motors that drive them will use less power if controlled by a VFD. For example, reducing a fan's speed by half cuts the horsepower needed to run it by a factor of eight. And by allowing motors to run only as fast as necessary to keep servers cool, VFDs can save 30% or more in energy costs.

Bearing Failure

Bearing failure rates vary widely, but evidence suggests that a significant portion of these failures occur only 3 to 12 months after system

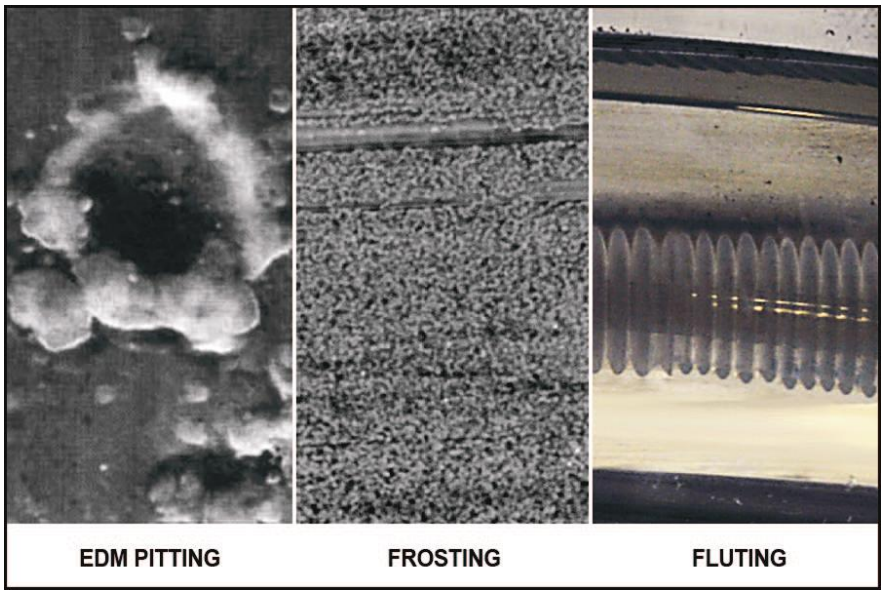
startup. Because many of today's motors have sealed bearings, electrical damage has become the most common cause of bearing failure in AC motors with VFDs.

The high switching frequencies of today's VFDs produce parasitic capacitance between a motor's stator and rotor. By now it is widely understood that, once the resulting shaft voltages overcome the dielectric properties of bearing grease, they discharge along the path of least resistance — typically through the bearings.

These discharges are so frequent that they create millions of tiny fusion craters. Before long, the entire bearing race wall can become marked with countless pits known as frosting (Figure 2). As the bearings degrade, the tiny metal particles blasted from the fusion craters intensify friction and abrasion, heat up the bearings, and burn the contaminated grease.

Figure 2

Voltages arcing through the bearings of VFD-driven motors can create thousands of pits, which cause increased friction and noise and the potential for costly unplanned downtime as bearing grease deteriorates. Widespread pitting is called frosting. In a process called fluting, pits form washboard-like ridges on a bearing race wall — ridges that cause still more noise and vibration and accelerate bearing failure.



A phenomenon known as fluting may occur as well, shaping the frosting into washboard-like ridges across the bearing race. This causes increased friction, vibration, and noise that can reverberate through ductwork. By the time such damage can be heard, bearing failure is often imminent.

NEMA Standards Call for Shaft Grounding

Although they have not been updated to include the latest bearing protection technology, standards issued by the National Electrical Manufacturers Association (NEMA) highlight the need for extra bearing protection for VFD-driven motors.

NEMA Standard MG1, Section IV, Part 31, Definite-Purpose Inverter-Fed Polyphase Motors, recommends bearing insulation at one end of the motor if the NEMA motor frame size is 500 or larger and the peak shaft voltage is greater than 300 millivolts. In these larger motors, bearing damage may be due in part to magnetic dissymmetries that result in circulating end-to-end shaft currents.

For smaller motors, the same standard recommends insulating both bearings with high-impedance insulation or installing shaft grounding brushes to divert damaging currents around the bearings. This common mode voltage oscillates at high frequency and is capacitively coupled to the rotor. This results in peak pulses as high as 10~40

volts from shaft to ground, running through either or both bearings. For these motors, the standard explains, VFDs can generate high-frequency common mode voltage, which shifts the three-phase-winding neutral potentials significantly from ground. Because the damaging voltage oscillates at high frequency and is capacitively coupled to the rotor, the current path to ground can run through either one bearing or both.

The NEMA standard is quick to point out, however, that bearing insulation will not prevent damage to connected equipment. When the path to the bearings is blocked, the damaging current seeks another path to ground. That other path is often through a gearbox, pump, fan, encoder, or other piece of connected equipment that can consequently wind up with bearing damage of its own.

Diagnosing the Damage

Cutting and carefully inspecting the bearings of motors needing repair will often provide information that can be used to prevent a recurrence of the problem. Following established safety precautions, technicians should:

1) Inspect the bearing cavity, retaining a sample of the grease for analysis.
2) Cut the outer race in half.
3) Clean the bearing's components with a solvent.
4) With a microscope, inspect the race walls for electrical pitting, frosting, and fluting.

Figure 3

As bearings degrade, tiny metal particles blasted from fusion craters contaminate grease, intensify friction and abrasion, heat up the bearings, and burn the grease.

Protecting Motors for the Long Term

Many so-called "inverter-duty" motors offer beefed-up winding insulation, but that insulation does nothing to guard against bearing damage. If they are to be truly ready for use with VFDs, these motors also need bearing protection. If inspection of the old bearing indicates electrical damage, the most reliable and cost-effective way to protect replacement bearings is to install a modern shaft grounding ring — the AEGIS® Ring.

Unlike older single-point contact brushes, AEGIS® Rings completely surround a motor's shaft with contact points, boosting their electron transfer rate and providing a very low impedance path from shaft to frame. Conductive microfibers line the ring's entire inner circumference (Figure 4), safely bleeding off damaging voltages to ground and bypassing the motor's bearings entirely. And because the microfibers work with little or no contact, they will not clog or wear out like conventional grounding brushes. AEGIS® Rings provide the longest life of any bearing protection system and allow bearings to achieve their L10 design life.

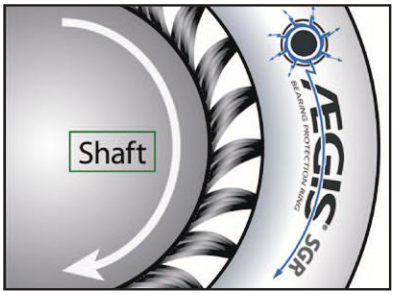


Figure 4

The best grounding rings are lined with flexible, conductive microfibers that completely surround the motor shaft.

Motors With AEGIS® Rings Factory Installed

Recognizing that the best solution is to design motors from the ground up to survive the damaging effects of VFDs, a growing number of forward-looking motor manufacturers, including Baldor Electric Company, Regal-Beloit Corporation (Century, Marathon, and Leeson brands), WEG Electric, TECO Westinghouse, and General Electric, have recently added the factory-installed AEGIS® Shaft Grounding Ring as a standard or optional feature on certain models (Figure 5). Internal mounting of the ring eliminates the need to retrofit the motor in the field, protects the motor against bearing damage from the outset, and minimizes the ring's exposure to moisture, dust, and other contaminants.

Figure 5

AEGIS® Shaft Grounding Rings can be installed internally by the motor's manufacturer, to protect a motor's bearings from the outset.

Motors with factory-installed grounding rings are available in both open drip-proof (ODP) and totally enclosed fan-cooled (TEFC) configurations.

But while motors with factory-installed grounding rings are still exceptions to the rule in most data centers, distributors of motors and bearings sell grounding rings, such as AEGIS® uKITS, that can be installed on new, refurbished, or in-service motors. For motors with failed bearings, rings can be installed along with new bearings by a local motor repair shop. (These shops will also install rings on new motors before they are put in service.)

Retrofitting Existing Motors

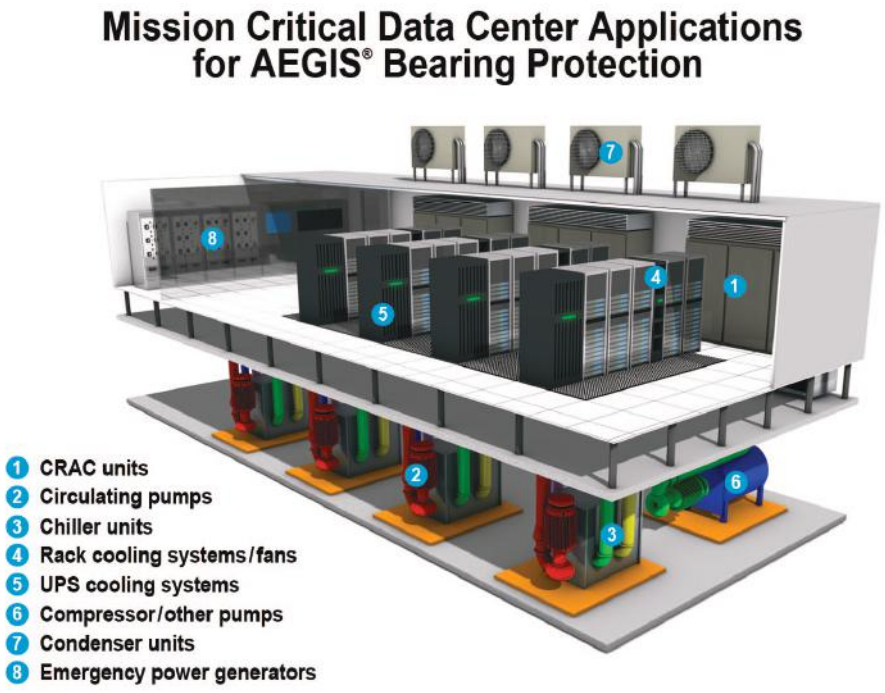
NOTE: Installing AEGIS® Rings on in-service motors may extend their bearing life, but will not reverse existing damage. In time, bearings may still need to be replaced.

Data center maintenance personnel can purchase the rings through a local industrial supply house or through a national distributor such as Applied Industrial Technologies, Grainger Industrial Supply, Johnstone Supply, or Motion Industries.

Data center cooling applications include computer room air conditioner (CRAC) units, water-cooled chillers, chilled-water and other pumps, compressors, condensers, air distribution units, active tiles, rack-based containment systems, fan walls, cooling fans, UPS cooling systems, etc. (Figure 6).

Figure 6

To save energy and help make data centers more energy-efficient, the AC motors in many types of HVAC equipment today are controlled by variable frequency drives and therefore are vulnerable to bearing damage. This diagram shows some of these applications where shaft grounding can help make motors and systems sustainable.



Tips & Tricks for Ring Installation

As preventive maintenance for fan, condenser, and pump motors already in service, the AEGIS® grounding ring can be quickly and easily retrofitted onto any NEMA or IEC motor regardless of shaft size, horsepower, or end-bell protrusion using conductive epoxy and/or a new universal mounting kit. A split-ring version slips around an in-service motor's shaft instead of over its end, eliminating the need to decouple attached equipment (Figure 7). Some AEGIS® Ring models like that pictured in Figure 7 are attached with high-strength adhesive disks. A grounding wire channels currents to the motor frame and to ground. Other mounting options include screw mounting or conductive epoxy. Installed on VFD-controlled motors, AEGIS® Rings qualify as sustainable technology under the Federal Energy Management Program.

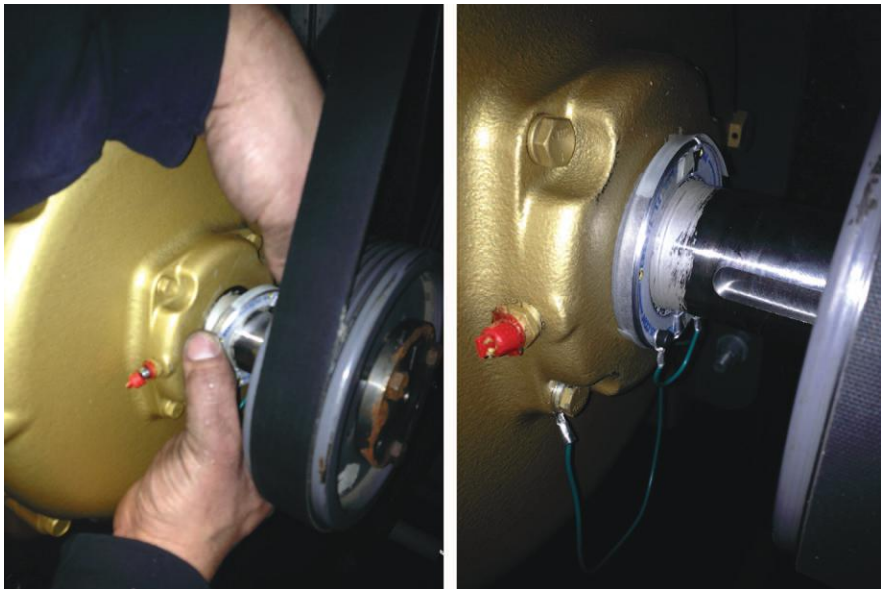


Figure 7

Left: The split-ring version of the AEGIS® Shaft Grounding Ring can be installed on an in-service motor without detaching coupled equipment. Right: After installation, a "pigtail" wire can be installed to facilitate subsequent voltage measurements with a portable oscilloscope.

To maximize a grounding ring's effectiveness, all electrical paths must be conductive. The motor's shaft must be clean down to bare metal. Scrubbing the shaft with an emery cloth and wiping it with a non-petroleum-based solvent will remove unseen residues. After cleaning, the conductivity of the shaft should be checked with an ohm meter. If the reading at the section that will contact the ring's microfibers is higher than 2 ohms, the shaft should be cleaned again.

A grounding ring should never operate over a shaft keyway, which has sharp edges that could reduce conductivity. On some motors, the dimensions of the spacer and mounting screws can be adjusted/changed to avoid a keyway. If this is not feasible, the portion of the keyway that will contact the ring's microfibers should be filled with epoxy putty.

Conductivity should be further enhanced by lightly but evenly coating with colloidal silver any portion of the shaft that will contact the ring's microfibers. This will also help retard corrosion (Figure 8).

Threadlocking gels and liquids other than conductive epoxy are not recommended for the screws that mount the ring to the motor, as they might compromise the conductive path to ground.

Rings should be centered on the motor shaft so that microfibers contact the shaft evenly.

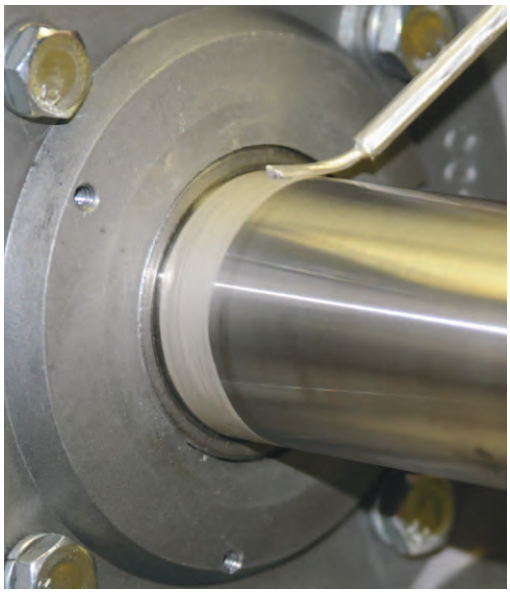


Figure 8

Prior to installation of a grounding ring, the motor shaft must be cleaned down to bare metal, free of any nonconductive material. Conductivity can be further enhanced by coating the part of the shaft that will contact the ring with colloidal silver.

After installation, testing again with an ohm meter is recommended. The best method is to place one probe on the ring and one on the motor frame. In accordance with applicable standards, the motor and drive must be grounded to a common-earth ground.

For motors with horsepower of 100 (75 kW) or less and single-row radial ball bearings on both ends, a shaft grounding ring can be installed on either end. For any motor in which the bearings at both ends are already insulated, the drive end is preferred for installation of a grounding ring, to protect bearings in attached equipment such as a gearbox, pump, fan, or encoder.

Protection Should Start at Installation

Measuring shaft voltage on a VFD-driven motor provides valuable information for determining whether there is risk of electrical bearing damage. The best time to take such measurements is at start-up of a new or recently repaired motor, but they may also be taken at any time to detect the presence of voltages that could damage bearings. Every motor has its own unique parameters, so baseline data is important. Combined with vibration analysis, thermography, or other diagnostics, results (including saved oscilloscope-screen images) can be presented in a report to the supervisor/customer.The data can then be used to develop preventive and predictive maintenance strategies, such as shaft grounding retrofit programs.

Figure 9

Shaft voltages are easily measured by touching a portable oscilloscope probe to the shaft while the motor is running.

Even VFD-driven motors that show no signs of bearing damage may still be at risk. Shaft voltages are easily measured (using appropriate safety procedures) by touching an oscilloscope probe to the shaft while the motor is running (Figure 9). The best probe will have a tip of high-density conductive microfibers to ensure continuous contact with the rotating shaft. A portable oscilloscope with a bandwidth of at least 100 MHz should deliver accurate waveform measurements. Probe/oscilloscope kits are available.

Just as shaft voltage measurements can show that a motor's bearings are in danger of electrical damage, they can also confirm that a shaft

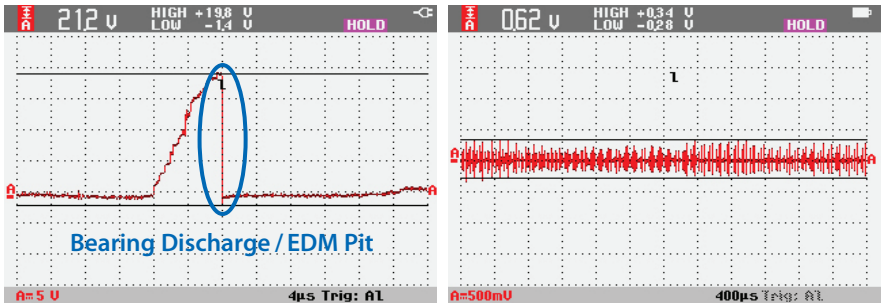


Figure 10

Motor shaft currents before (left) and after (right) installation of an AEGIS® Shaft Grounding Ring on an HVAC motor.

grounding ring is working (Figure 10). If a proven ring has been properly installed, typical discharge voltage peaks should be less than 5 volts (or 10 volts peak-to-peak).

Getting the Most From Your Motors

In summary, data centers that use VFD-driven motors have every right to expect uptime and reliability. After all, VFD-induced electrical bearing damage can now be prevented, not just repaired. Routine inspection, testing, and analysis can provide advance warning and insight into the problem, and when bearings fail, proper repair practices can fix the problem for good. Motor shaft grounding rings such as AEGIS® Shaft Grounding Rings can be installed during motor repairs or on new motors before they are put into service.

VFDs hold the promise of improved cooling control and sizable energy savings, but without effective, long-term bearing protection, those savings could be wiped out by high maintenance costs. By diverting bearing currents safely to ground, AEGIS® Rings extend motor life and thus help ensure 100% data center uptime.

About the Author

Adam Willwerth, Development Manager for Electro Static Technology, has extensive experience in industrial product development. He is named on four patent applications pertaining to conductive microfiber shaft grounding technology and has presented seminars on the subject of bearing current mitigation at professional conferences in the U.S. and Europe.

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For a 44-page handbook on the practices summarized in the above article, contact:

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