You've Designed for Energy Efficiency, So Specify Bearing Protection for Sustainability

Overview

By allowing motors to run at less than full speed, variable frequency drives can reduce the energy required to run them by 30% or more. But VFDs can also damage bearings, shorten motor life, and diminish the reliability of motor-driven systems. To ensure that these systems and the savings they yield are sustainable, designers and engineers must specify proven, long-term electrical bearing protection — AEGIS® Shaft Grounding Rings.

AEGIS®

Introduction

In their quest for energy efficiency, more and more engineers, facility managers, and building owners are turning to variable frequency drives (also known as VFDs, inverters, or adjustable speed drives). One of the most promising "green" technologies available today, VFDs let users run motors at less than full speed, saving 30% or more in energy costs. VFDs, however, are not without their drawbacks. VFD-induced shaft currents can damage bearings, dramatically shortening motor life and severely diminishing the reliability of systems.

To mitigate these currents and realize the full potential of VFDs, proven long-term shaft grounding is essential. Different specs recommend different approaches, but given the wide range of VFDs, motors, applications, and installation requirements, the simplest, most fool-proof way of protecting VFD-driven motors from electrical bearing damage is to install proven AEGIS® Bearing Protection Rings.

How VFDs Cause Motor Failure

Damage to windings and bearings alike is caused by repetitive and extremely rapid pulses applied to the motor by a modern VFD's non-sinusoidal power-switching circuitry. High peak voltages and fast voltage rise times can cause cumulative degradation of insulation and bearings, coil varnish, etc. If the load impedance is higher than the line impedance, voltage pulses are reflected back and forth between the motor and the VFD, creating voltage spikes at the motor terminal that can be twice as high as the DC bus voltage.

If the voltage in the windings exceeds their corona inception voltage, the windings may short out. And the discharge of capacitively coupled shaft voltages through the bearings can cause electrical bearing damage. Identified years ago, the problem with windings has been solved through the use of "inverter" rated windings and Class F or H insulation. In fact, all NEMA Premium® motors manufactured today have windings that are suitable for VFD operation, but these same motors often leave the bearings unprotected. The cumulative bearing damage caused by VFD-induced currents is often overlooked until it is too late to save the motor.

Types of Bearing Damage

Without some form of mitigation, shaft voltages discharge through bearings, causing unwanted electrical discharge machining that erodes the bearings and race walls [Figure 1] and leads to premature bearing/motor failure. Before long, these frequent discharges can leave the entire bearing race riddled with pits [Figure 2] known as frosting.

Figure 1

A new bearing race wall is a relatively smooth surface, marked by nothing but mechanical wear where bearings contact the wall.

In a phenomenon called fluting [Figure 3], the operational frequency of the VFD causes concentrated pitting at regular intervals along the race wall, forming washboard-like ridges. Fluting can cause excessive noise and vibration, which, in an HVAC system, can be magnified and transmitted by ductwork through the entire building. By the time this noise can be heard, bearing failure is often imminent.

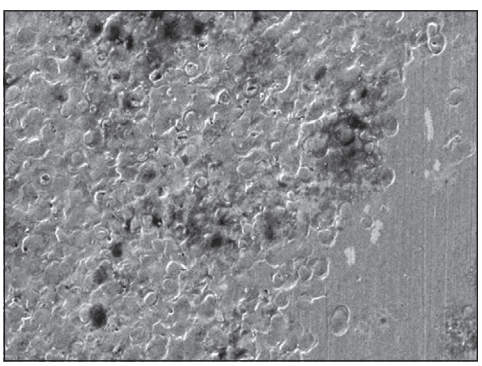


Figure 2

Pitting of a bearing race wall (magnified) is the result of electrical discharge machining (EDM) as shaft currents discharge through the bearings, blasting small craters in metal surfaces..

Figure 3

Voltages arcing through the bearings of VFD-driven motors can create thousands of pits, which increase 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.

When the electrical path to the bearings is blocked by insulation, the damaging current seeks another path to ground—typically through a pump, gearbox, tachometer, encoder, etc., which consequently can end up with bearing damage of its own. The solution is a maintenance-free, long-life shaft grounding ring that protects attached equipment as well as the motor's bearings.

Construction Specifications Call for Bearing Protection...

The Construction Specifications Institute in its CSI 2300 Master Spec requires certification that any motor used with a variable frequency drive is compatible with the drive (Subsection 1.5, B3). It goes on to say that "drives shall not impose conditions that can reduce motor life, or compromise motor operation" (Subsection 1.7, A). It also suggests that specifiers contact motor manufacturers prior to purchasing VFDs to verify [their] compatibility [with the motors being used].

But the Devil Is In the Details

CSI 2300 Section 23 05 13 Subsection 2.1.13 refers to NEMA Standard MG1 in discussing "Motors for Use with Variable Frequency Drives." It requires the use of "definite purpose inverter-duty related motors… for all IGBT Pulse Width Modulated drive installations" and goes on to describe the requirements for inverter-duty motors. And although it requires the NEMA Class F or H insulation found in all NEMA Premium® motors to protect their windings when used with inverters, it does not require shaft grounding to protect the bearings. The CSI Specification, however, does require specifiers to "provide [a] shaft ground kit for field installation" on inverter-duty motors.

Neither CSI nor NEMA Standards Require Bearing Protection on New Motors

While NEMA MG1 does not require bearing protection for inverter-duty motors, and CS 23 05 13 requires field installation of shaft grounding, neither standard requires bearing protection on new motors.

Interestingly, in Subsection 2.1, CSI 23 05 13 lists four manufacturers of electric motors — all of which offer motors with AEGIS® Bearing Protection Rings factory-installed inside or outside the motor. These manufacturers — Baldor, General Electric, Marathon, and Reliance — and a growing number of other motor manufacturers including WEG Electric, TECO-Westinghouse, Century, Leeson, and NIDEC have recognized that the best solution is to design motors from the ground up to survive the damaging effects of VFDs. 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. Motors with factory-installed grounding rings are available in both open drip-proof (ODP) and totally enclosed fan-cooled (TEFC) configurations. Other manufacturers, including Toshiba and Siemens, offer rings installed as options by their in-house modification shops.

But unless intentionally specified, motors with factory-installed grounding rings are still exceptions to the rule. Most distributors of motors and bearings sell grounding rings

A New Technology for Electrical Bearing Protection

that can be installed on new, refurbished, or in-service motors. For motors with failed bearings, the rings can be installed along with the new bearings by a local motor repair shop. These shops will also install rings on new motors before they are put in service.

In virtually every case, the most reliable and cost-effective way to minimize electrical bearing damage and ensure the reliability of VFD-driven motors and systems is a motor shaft grounding ring (combined with bearing insulation for motors greater than 100 HP).

Other devices that are meant to provide a path to ground do not perform as well as the AEGIS® Ring. They wear out faster, and none of them works as well at high rpms. There are other reasons for their reduced effectiveness — reasons that limit the effectiveness of all single-point or discrete-point contact brushes.

Metal spring-pressure grounding brushes, for example, are easily contaminated by corrosion or clogged by debris, requiring regular maintenance/replacement.

Carbon-block (graphite) brushes have an additional drawback. They are susceptible to "hotspotting," in which an arc briefly fuses the brush to the motor shaft. And other contact brush designs quickly wear out, allowing shaft voltages to start discharging through the bearings again.

All these technologies have one thing in common — they rely on direct physical contact to transfer current. Regardless of the material, contact brushes wear out and lose their effectiveness — most before the L10 life of the motor bearings. And because they are easily fouled with grease, dust, or other contaminants, they require routine maintenance such as cleaning and adjustment to ensure they remain in contact with the motor shaft. Given these problems, installing a conventional contact brush inside a motor's housing makes no sense. Doing so merely increases the time and cost of maintaining the brushes, as well as the chances that such maintenance will be overlooked, resulting in bearing damage and downtime of the motor and the system it powers.

Unlike older single-point contact brushes, AEGIS® Bearing Protection Rings have continuous circumferential rows of specially engineered microfibers that encircle the motor shaft with contact points, boosting electron transfer rates for far greater effectiveness. Providing a very low impedance path from shaft to frame, these rings safely bleed damaging currents to ground, bypassing the motor's bearings entirely.

The AEGIS® Ring is also unique in that it works both with contact and without direct contact with the motor shaft. Its revolutionary Nanogap Electron Transport Technology™ discharges shaft voltages even if its fibers are not touching the motor shaft, but are merely in nanogap proximity to it. This patented technology makes it the most effective device for redirecting currents from shaft to ground [Figure 4], regardless of rpm.

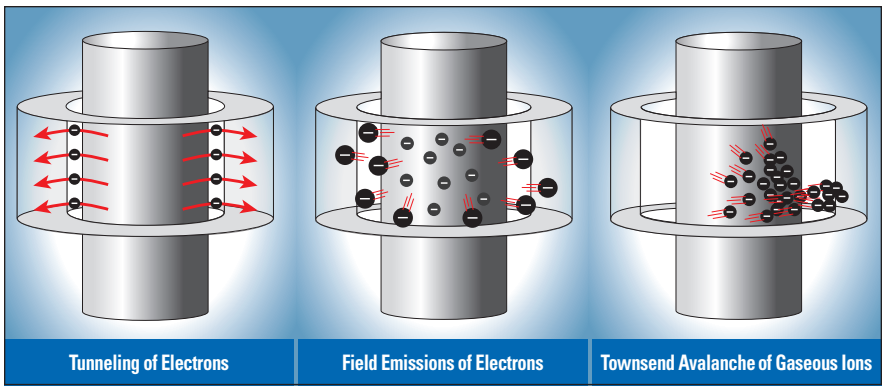


Figure 4

The AEGIS® Bearing Protection Ring's patented Nanogap Technology, ensures effective electrical contact even when physical contact between the ring's conductive microfibers and the motor shaft is broken. Whether in physical contact or merely in nanogap proximity to the motor shaft, the ring's conductive microfibers remain in electrical contact, providing effective grounding.

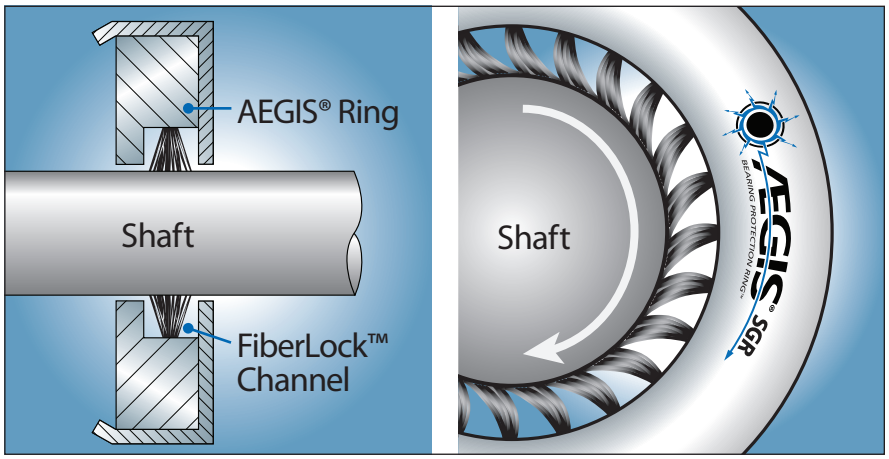


Figure 5

Unlike discrete-point brushes, AEGIS® rings have rows of conductive microfibers that surround the shaft 360˚. They are secured in place by a patented FiberLock™ Channel, allowing them to flex without breaking.

Because they work with little or no contact, AEGIS® microfiber brushes do not wear out like conventional brushes. Secured in the ring's patented FiberLock™ channel [Figure 5], these fibers flex without breaking, and the deep protective channel keeps them away from dust, liquids, and other debris. Testing shows surface wear of less than 0.001" per 10,000 hours of continuous operation and no fiber breakage even after 2 million direction reversals.

The AEGIS® ring makes the energy savings from VFD-controlled systems sustainable by protecting motor bearings from catastrophic failure. The cost of the AEGIS® ring and installation is very low when compared to the cost of the overall system, usually less than 1% of the equipment cost. Yet, by preventing electrical damage to bearings, the ring protects the whole VFD-driven system from costly downtime and unplanned maintenance.

Installation Best Practices

For those designing inverter-driven motor systems, the following measures have proven effective under actual operating conditions:

For motors up to 100 HP, where common mode shaft voltages could cause bearing damage, adding a shaft grounding ring to the motor, either internally or externally, provides effective protection against bearing currents for motor bearings as well as attached equipment [Figure 6].

For motors greater than 100 HP, where both high-frequency circulating currents and common mode voltages could cause bearing damage, combining an insulated

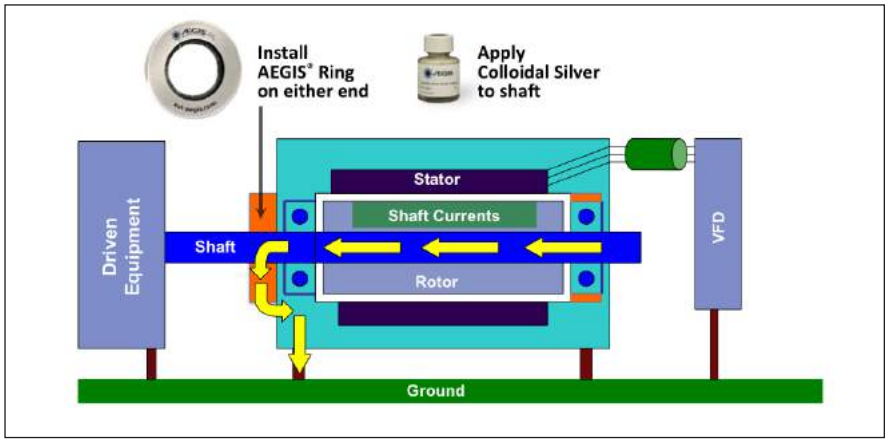


Figure 6

For motors up to and including 100 HP, a shaft grounding ring should be installed on the drive end on the motor shaft—either inside or outside the motor.

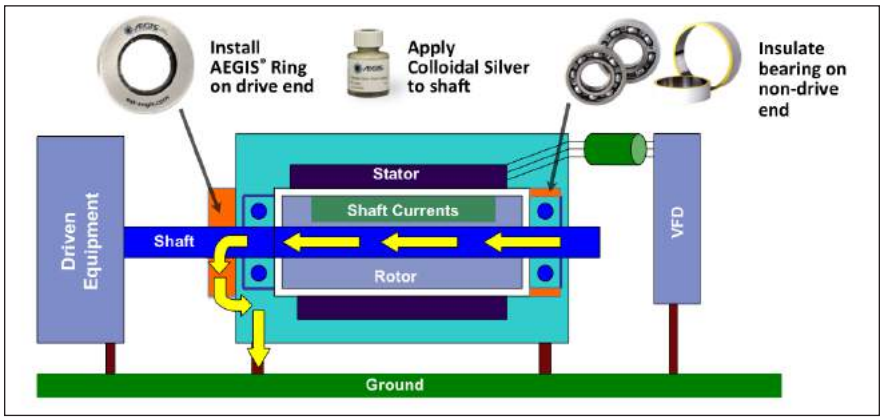


Figure 7:

For motors greater than 100 HP, a shaft grounding ring should be installed on the drive end of the motor shaft, and the bearing on the non-drive end should be isolated with an insulated sleeve or ceramic bearings.

bearing on one end with a shaft grounding ring on the opposite end provides the best protection from electrical bearing damage [Figure 7].

How to Specify AEGIS® Bearing Protection Rings

More and more design and specifying engineers are recognizing the need for shaft grounding on VFD-controlled motors. So, what is the best way to specify AEGIS® Bearing Protection Rings? Following are examples of how various engineers have included AEGIS® Rings in their specifications.

"Or Equal" Specifications

MINNESOTA DEPARTMENT OF TRANSPORTATION: Motors up to 100 HP

1) *Provide maintenance free, circumferential, conductive fiber shaft grounding ring installed on the motor to discharge shaft currents to ground.*
2) *Bearing protection ring shall be suitable for installation on either the drive end or the non-drive end of the motor in accordance with the manufacturer's installation instructions.*
3) *Install a colloidal silver shaft coating to improve shaft conductivity at the shaft grounding ring location.*
4) *Manufacturer and Model: AEGIS® SGR Bearing Protection Ring or approved equal.*

Although this specification does allow for an "approved equal," the wording is clearly tailored to the AEGIS® SGR Shaft Grounding Ring. The phrase "maintenance free, circumferential, conductive fiber" effectively rules out other forms of shaft grounding and the requirements that "colloidal silver shaft coating" be used is an obvious reference to AEGIS® Best Practices for installing the SGR.

GALT WASTEWATER TREATMENT PLANT: Shaft Grounding Ring Alternative

1) *Provide maintenance free, conductive micro fiber, shaft grounding ring with minimum two rows of circumferential micro fibers to discharge electrical shaft currents within the motor and/or its bearings from the motor shaft to motor case (ground).*
2) *Motors up to 100 horsepower shall be provided with a minimum of one shaft grounding ring installed on either the drive end or non-drive end of the motor. Motors over 100 horsepower shall be provided with an insulated bearing on the non-drive end and a shaft grounding ring on the drive end of the motor. Shaft grounding rings shall be installed by the motor's manufacturer in accordance with the [ring] manufacturer's recommendations.*
3) *Provide AEGIS® Bearing Protection Ring or equal.*

This is another example of an "or equal" specification, written around AEGIS® Best Practices. The phrases "maintenance free," "conductive micro fiber" and "circumferential" leave

purchasers with no viable options other than AEGIS®. Note that unlike the prior spec, this one requires factory installation of the rings by the motor manufacturer.

AEGIS® Only Specifications

KALAMAZOO COUNTY/MICHIGAN COURT FACILITY

Shaft Grounding Ring: Factory or field installed AEGIS® Model SGR Shaft Grounding Ring consisting of maintenance free, circumferential, bearing protection ring with conductive micro fiber shaft contacting material.

Short and to the point, this specification allows the use of only the AEGIS® Shaft Grounding Ring — either field or factory-installed.

FAITH COMMUNITY HOSPITAL

All motors shall be IEEE inverter-duty, premium-efficiency TEAO T-frame motors selected at the specified operating voltage, RPM and efficiency as specified or scheduled elsewhere. Each motor shall be provided with an AEGIS® Bearing Protection Ring to prevent Electrical Discharge Machining (EDM) damage to the motor bearings.

While this specification is fairly short, it demonstrates an in-depth understanding of the problem of electrical bearing damage. Where many engineers would simply specify inverter-duty motors in the belief that such motors are fully protected from damage due to VFD operation, savvy specifiers understand that inverter-duty motors typically have only additional insulation to protect windings, and that effective long-term bearing protection — AEGIS® Shaft Grounding Protection Rings — are needed to protect the bearings from VFD-caused electrical damage.

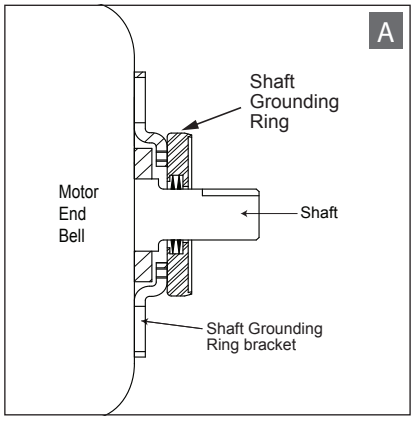
AEGIS® Guide Specification

Construction Specification Institute - Section 23 05 13: 2.1 Motors

A. General Requirements – Shaft Grounding

1) *All motors operated on variable frequency drives shall be equipped with a maintenance free, conductive micro fiber shaft grounding ring with a minimum of two rows of circumferential micro fibers to discharge damaging shaft voltages away from the bearings to ground. [Figure 8A]*

2) *Application Note: Motors up to 100 HP shall be provided with one shaft grounding ring installed on either the drive end or non-drive end. Motors over 100 HP shall be provided with an insulated bearing on the non-drive end and a shaft grounding ring on the drive end of the motor. Grounding rings shall be provided and installed by the motor manufacturer or contractor and shall be installed in accordance with the shaft grounding ring manufacturer's recommendations.*



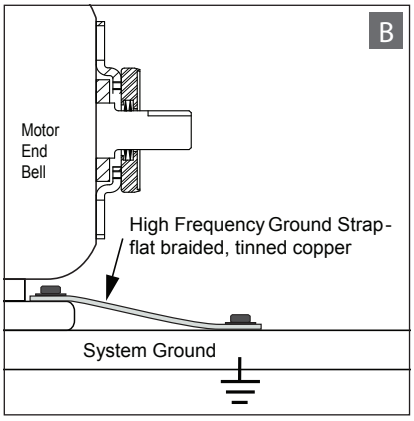


Figure 8A:

To protect a motor against VFD-induced bearing damage that can shorten its life, install a circumferential microfiber grounding ring around its motor shaft.

Figure 8B:

To equalize transient potentials within a VFD-driven motor system and prevent ground loops, install high-frequency ground straps between motor frames and driven equipment as well as between motor frames and an earth ground.

B. General Requirements - High-Frequency Bonding

1) *All motors operated on variable frequency drives shall be bonded from the motor foot to system ground with a high-frequency ground strap made of flat braided, tinned copper with terminations to accommodate motor foot and system ground connection. [Figure 8B]*

2) *Application Note: High-frequency grounding straps must be used to ensure the proper grounding of all inverter-driven induction motor frames.*

a. References: *ABB Technical Guide No. 5*
Allen Bradley Publication 1770-4.1 Application Data, Industrial Automation Wiring and Grounding Guidelines

Recommended parts: *AEGIS® SGR Bearing Protection Ring*
AEGIS® HF Ground Strap

Recommended source: *Electro Static Technology – ITW*
Manufacturer of AEGIS® products
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sales@est-aegis.com | www.est-aegis.com

Conclusion

Running motors on VFDs can save considerable energy and money, but without protection, VFD-induced bearing damage can wipe out any savings, severely shorten motor life, and hamper building system reliability. NEMA specifications call for the use of inverter-duty motors with VFDs, but the NEMA designation "inverter-duty" is confusing and often leaves motor specifiers and buyers with a false sense of security. While these motors have extra insulation to protect their windings, most have no protection against electrical bearing damage. CSI specifications require bearing protection for inverter-duty motors, but neither NEMA nor CSI specifications require such bearing protection on new motors.

Given the number of manufacturers of motor and VFD, models of each, and bearing protection technologies available, finding the right combination to effectively prevent bearing damage can be a daunting and time-consuming task. Yet, savvy specifiers are recognizing that the AEGIS® Bearing Protection Ring is a simple solution to this complicated problem. Proven effective in over a million applications worldwide, AEGIS® Rings safely channel harmful shaft voltages to ground, protecting motors from bearing damage for life and ensuring the reliability of the systems they power.

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