# To Be Considered "True Inverter-Duty", Motors Need Bearing Protection

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All major manufacturers of 3-phase AC induction motors offer "inverter-duty" or "inverter-ready" models, but while these motors have inverter-rated insulation to protect the windings, their most vulnerable parts — the bearings — are too often ignored. Without some form of mitigation, shaft currents can discharge through bearings, causing motor failure and downtime. To be considered truly "inverter-ready", a motor must have proven long-term bearing protection — an AEGIS® Shaft Grounding Ring — in addition to inverter-rated insulation. Unfortunately, many purchasers of these motors do not understand this. And, mission-critical facilities, in which downtime can have disastrous consequences, are especially vulnerable to motor failures.

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 have recently added factory-installed AEGIS® Bearing Protection Rings as standard or optional features on certain models. They include:

- Baldor
- NIDEC
- GE
- TECO-Westinghouse
- Regal (Marathon, Century, Leeson)
- WEG Electric

Other manufacturers, including, Toshiba and Siemens offer rings installed as options by their in-house modification shops.

By precisely controlling motor speed or torque, inverters, also known as variable frequency drives (VFDs) or adjustable speed drives, provide a means of fine-tuning key systems in mission-critical facilities. They can also save 30% or more in energy costs. But VFDs are not without their problems. VFDs can induce unwanted motor shaft voltages that, without effective mitigation, can destroy bearings, causing premature motor failure.

And although the National Electrical Manufacturers Association (NEMA) has yet to recommend that new motors have bearing protection against damaging electrical discharges, electrical damage has become the most common cause of bearing failure in VFD-controlled AC motors. The costly repair or replacement of failed motor bearings can wipe out any savings that a VFD yields and severely diminish the reliability of mission-critical systems.

## 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. The names used to describe this phenomenon include harmonic content, parasitic capacitance, capacitive coupling, electrostatic buildup, and common mode voltage. Regardless of the name used, high peak voltages and fast voltage rise times can cause cumulative degradation of insulation and bearings, coil varnish, etc.

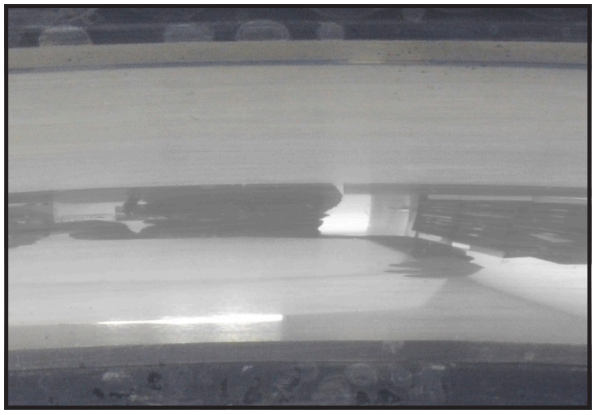


*Figure 1: A new bearing race wall has a mirror-smooth surface to minimize friction.*

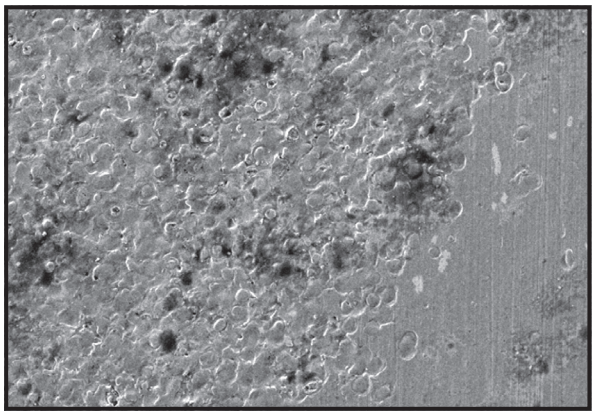


*Figure 2: Pitting of a bearing race wall (magnified) is the result of electrical discharge machining (EDM) as shaft currents discharge through the bearings, blasting small craters in metal surfaces.*

If the load impedance is higher than the line impedance, current is reflected back toward the VFD, creating voltage spikes at the motor terminal that can be twice as high as the DC bus voltage.

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

Bearings, which normally have mirror-smooth surfaces [Figure 1], can become damaged by electrical discharges. Without some form of mitigation, shaft currents discharge through bearings, causing unwanted electrical discharge machining ("EDMing") that erodes the bearings and race walls [Figure 2] and leads to premature bearing/motor failure. Before long, these frequent discharges can leave the entire bearing race riddled with pits known as frosting.

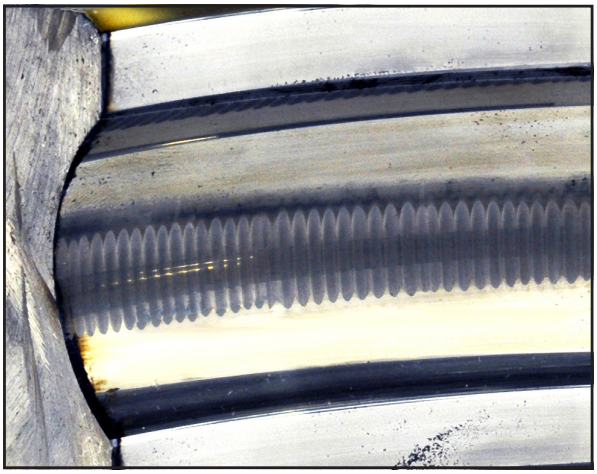


*Figure 3: Taken from a failed motor, the "fluted" bearing race above is the result of VFD-induced bearing currents.*

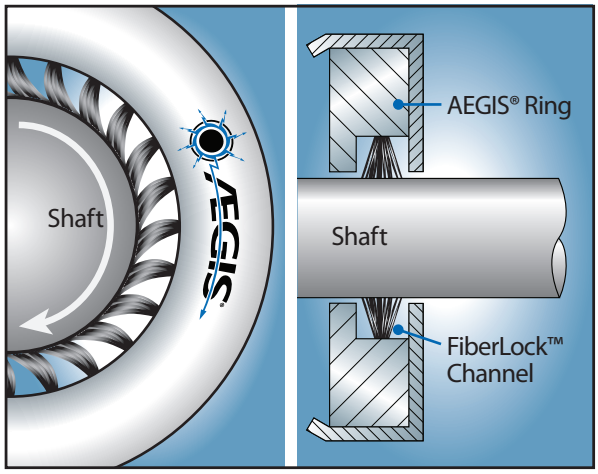



*Figure 4: Unlike discrete-point brushes, AEGIS® rings have rows of microfibers that surround the shaft 360°. They are secured in place by a patented FiberLock™ Channel, allowing them to flex without breaking.*

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 throughout the entire building. By the time this is noticeable, bearing failure is often imminent.

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.

## A New Technology for Electrical Bearing Protection…

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 insulation for motors greater than 100 HP).

Unlike older single-point contact brushes, new grounding rings encircle a motor's shaft with contact points for far greater effectiveness. AEGIS® Bearing Protection Rings have continuous circumferential rows of specially engineered microfibers (secured in a patented FiberLock™ channel) that boost electron transfer rates and provide a very low impedance path from shaft to frame [Figure 4]. These rings safely bleed damaging currents to ground, bypassing a motor's bearings entirely. And because the microfiber brushes work with little or no contact, they do not wear out like conventional brushes. In fact, AEGIS® grounding rings have been proven effective in over a million installations worldwide.

Motors with factory-installed grounding rings are available in both open drip-proof (ODP) and totally enclosed fan-cooled (TEFC) configurations. Factory installation of the ring eliminates the need to retrofit the motor in the field, protects the motor against bearing damage from the outset, and allows facility managers, technicians, and HVAC contractors to select a motor ideally suited to operation by a VFD - a "true" inverter-duty motor.

While there is a wide selection of motors up to 100 HP with factory-installed AEGIS® Shaft Grounding Rings, there are still many applications where rings must be installed by a contractor, motor repair shop, or by maintenance personnel. Most distributors of motors and bearings sell grounding ring kits 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.

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 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 currents to resume discharging through the bearings.

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

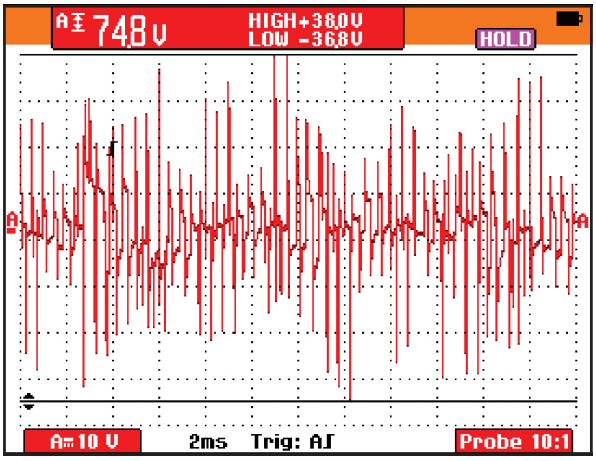
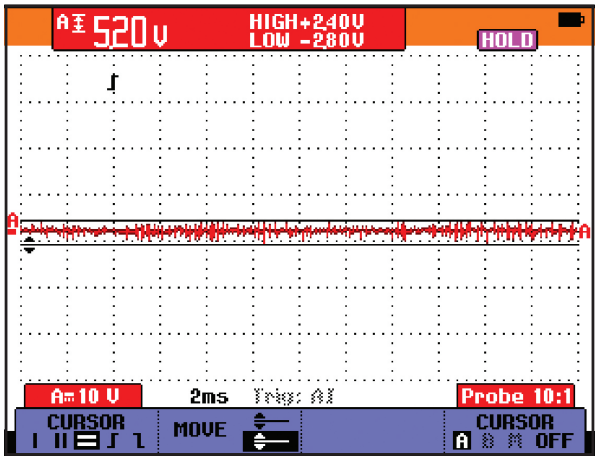



*Figure 5: Measured with an oscilloscope, shaft currents on an HVAC motor without shaft grounding.*




*Motor shaft currents on the same HVAC motor after installation of an AEGIS® Bearing Protection Ring.*

routine maintenance such as cleaning and adjustment to ensure they remain in contact with the motor shaft. Given these factors, 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.

All these technologies have one thing in common — they rely on direct contact to transfer current. The AEGIS® ring, however, is 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. And because it works without contact, the AEGIS® ring will not wear out and requires no maintenance, regardless of rpm. Its patented technology makes it the most effective device for redirecting currents from shaft to ground [Figure 5]. Easily installed at the factory or retrofitted later [Figure 6], it makes VFD-controlled systems sustainable by protecting motor bearings from catastrophic failure.

Key to the AEGIS® ring's success are the proprietary conductive microfibers that completely surround the motor shaft. Secured in the ring's patented FiberLock™ channel, 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 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. And, by preventing electrical damage to bearings, the ring protects the whole VFD-driven system from costly downtime and unplanned maintenance.

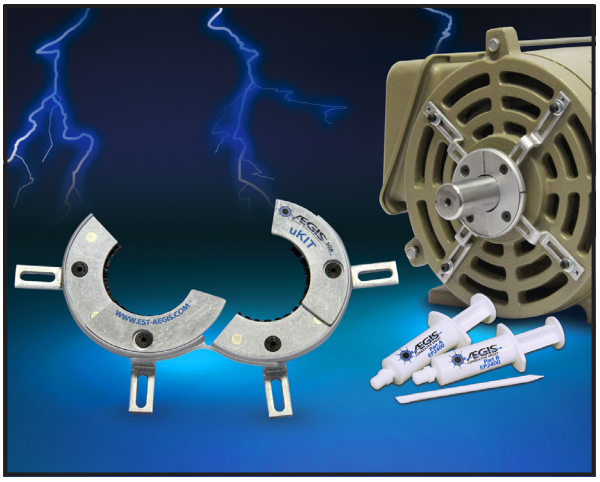




*Figure 6: AEGIS® Bearing Protection Rings are available for any size NEMA or IEC motor. They can be factory-installed inside or outside a new motor or quickly and easily retrofitted — even in the field — using conductive epoxy. A new Split uKIT simplifies and speeds mounting of the ring on motors with shaft shoulders, slingers, or other end-bell protrusions.*

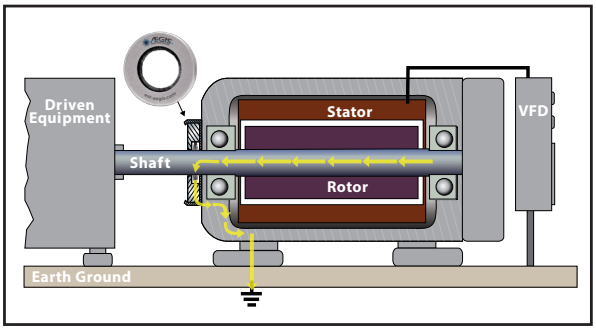



*Figure 7: For motors up to and including 100 HP, a shaft grounding ring should be installed on the drive end on the motor shaft—either inside or outside the motor.*

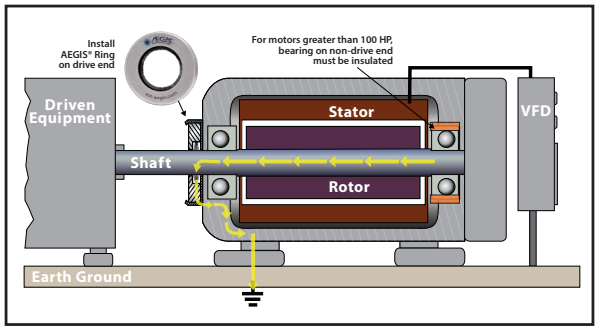



*Figure 8: For motors greater than 100 HP, a shaft grounding ring should be installed on the drive end of the motor shaft, and the bearing on the non-drive end should be isolated with an insulation sleeve or ceramic bearings.*

## 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 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 7].

For motors greater than 100 HP, where both circulating currents and common mode voltages could cause bearing damage, combining an insulated bearing on one end with a shaft grounding ring on the opposite end provides the best protection from electrical bearing damage [Figure 8].

## Conclusion

For motors without adequate bearing protection, the term "inverter-duty" is misleading. It ignores a major potential cause of premature bearing and motor failure — electrical discharge machining. Virtually all VFD-driven motors are vulnerable to bearing damage, but for too long the importance of shaft grounding to protect motor bearings has been ignored or underestimated. To ensure the reliability of "inverter-duty" motors, an effective long-term method of shaft grounding is essential.

And while some leading motor manufacturers are now installing the AEGIS® Bearing Protection Ring in selected models, most motors labeled "inverter-duty" or "inverter-ready" are still not adequately protected. It is thus incumbent on savvy specifiers to make sure that any motor to be used with a VFD is truly inverter-ready — equipped at the factory or retrofitted with a proven shaft grounding ring (and, in certain cases, an insulated bearing), not just with extra winding insulation.

## 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 US and Europe.

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