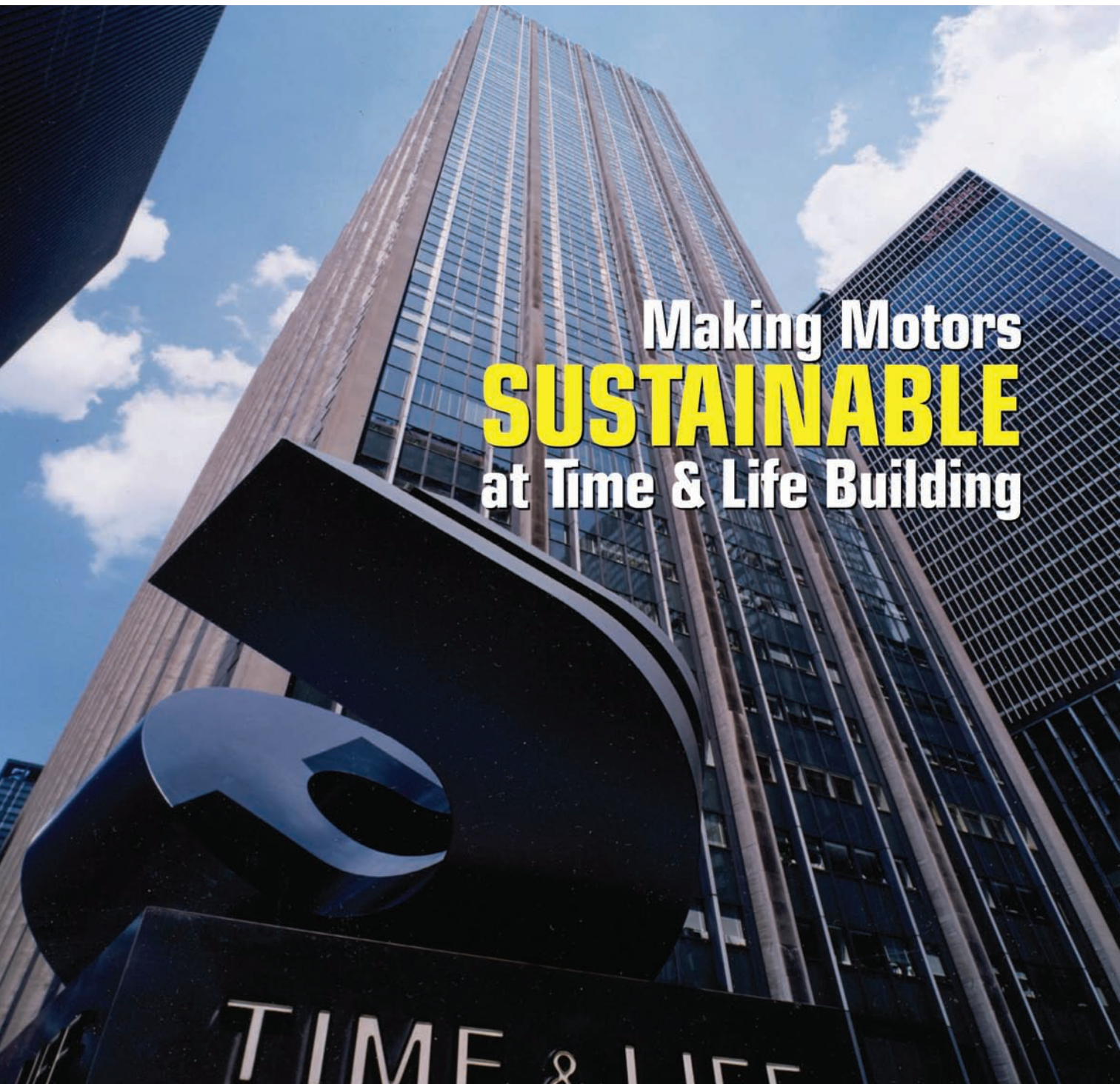
OnlineTES.com
March 2010

TODAY'S Energy® SOLUTIONS



Making Motors SUSTAINABLE at Time & Life Building

Making Motors SUSTAINABLE
At Time & Life Building

A preventive maintenance plan that reduces the total life-cycle cost of operations in a prominent building at the heart of New York City serves as a good example of 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.

The problem is all too common in AC motors controlled by variable frequency drives (VFDs), which are also known as inverters, adjustable speed drives, etc. These drives are widely used because they can save energy, especially in applications with varying loads. Because many centrifugal fans and pumps run continuously, their motors will use less power if the input is modulated by VFDs. For example, a 20% reduction in fan speed can reduce energy consumption by nearly 50%. With rising energy costs, the use of throttling mechanisms to restrict the work of a motor running at full speed would be wasteful.

However, efficiency alone is not enough if equipment keeps breaking down. That is what has been happening for two decades at the 48-story Time & Life Building, one of 19 buildings in the Manhattan business and entertainment complex built and partially owned by the Rockefeller Group and known as Rockefeller Center.

The building's HVAC system can be powered by either natural gas or electricity, enabling management to switch back and forth to take advantage of whichever source costs less at the time. More than 100 VFDs control the speeds of the 240 motors that run the building's HVAC fans and pumps. Unfortunately, a large portion of the savings from these systems has been wiped out by maintenance costs because, in addition to their intended function, VFDs induce powerful, unwanted currents which cause electrical bearing discharges and, ultimately, premature motor failure.

SHAFT GROUNDING

Proper tuning of a drive's frequency output range and proper grounding of a VFD-controlled motor's frame are paramount. Only recently has it become clear that without an effective shaft-grounding device as well, stray currents can wreak havoc with bearings, causing premature motor failure. Ironically, some products designed to protect bearings, such as conventional metal grounding brushes, require extensive maintenance themselves. Others, such as insulation, can shift damage to connected equipment.

One of the newest and most promising bearing-damage mitigation devices uses patented advanced electron transport technology to safely bleed off these damaging currents to ground. Engineered with special conductive microfibers, the AEGIS SGR Bearing Protection Ring safely discharges VFD-induced shaft voltages by providing a very low-impedance path from shaft to frame, bypassing the motor's bearings entirely.

For more than 20 years, since the installation of the first modern VFDs, the Time & Life Building's maintenance department has dealt with chronic motor and bearing failure. At times, the bearing damage had advanced to the noisy stage, at which an unpleasant, high-pitched sound was transmitted through ductwork. Thanks to the efforts of AKF Analysis & Testing LLC (AKFA&T), an engineering firm hired by the Rockefeller Group Development Corp. to periodically test and tune (with harmonic filters) the building's VFDs, the rate of motor/bearing replacements has dropped from 90 to 20 per year, but in today's economy that is still too costly. Other attempts to mitigate the problem, including the installation of ceramic bearings on some motors, have produced mixed results, usually

< Tenants of the Time & Life Building, in New York's Rockefeller Center, now work in a building that is more friendly to the environment. In an effort to "green" the building, shaft grounding rings have been installed to protect the bearings of HVAC fan motors.

proving too costly for the meager improvements gained.

THE SOLUTION AT LAST?

Finally, late in 2007, Tom O'Connell Jr., a partner in AKFA&T, read about the AEGIS SGR Bearing Protection Ring in a magazine and began the process that could eventually end the bearing damage problem at the Time & Life Building once and for all. He called the ring's manufacturer, Electro Static Technology, and spoke with Adam Willwerth, the company's sales and marketing manager. Soon after, the two met face to face, and O'Connell decided to recommend the installation of a single SGR shaft grounding ring on the most problematic of all the HVAC motors at Time & Life.

Ron Perez, the building's manager of engineering, consented to the experiment, and follow-up testing showed the ring to be so successful at diverting harmful shaft currents that O'Connell decided to make his company a distributor for the ring.

It was an unprecedented move. AKFA&T specializes in vibration monitoring and analysis, acceptance testing, critical speed testing, and motor current waveform analysis for preventive maintenance and energy management on behalf of government agencies and businesses in a multitude of East Coast buildings, including hotels, hospitals, laboratories, and office buildings. Never before had the company endorsed a particular product.

"The whole phenomenon of electrical bearing damage is so misunderstood that some maintenance managers have lost their jobs over it," O'Connell explains. "Replacing a fan motor is a big expense. And let me make it clear – it is not just a motor. In an office tower, a motor can be running critical equipment that supplies air to 30 floors where the tenants are paying as much as $110 a square foot. They have the right to expect the temperature and quality of their air to remain constant. Now, with the AEGIS SGR, I can show a customer, in person, how the ring improves his equipment – immediately. The before and after are dramatic and indisputable. The SGR is the answer. It is that simple. It is the only thing I rep or distribute."

Tests showed that shaft currents on this fan motor in the Time & Life Building dropped to negligible levels following installation of the AEGIS SGR Bearing Protection Ring.

O'Connell is so convinced of the ring's effectiveness that he has recommended it be eventually installed on all HVAC motors in the Time & Life Building and in other buildings for which he has contracts. Estimating it will reduce repair costs by approximately 10%, he also recommends the ring be included in the HVAC specifications for new buildings.

Because AKFA&T usually visits a client's building three or four times a year to run diagnostic tests on the HVAC equipment and tune the VFDs, they have seen the progression of motor bearing damage. Now, the typical procedure is to install an SGR whenever a replacement motor is installed or a motor's bearings are replaced, taking advantage of the warranty offered by Electro Static Technology. Follow-up testing and more critical frequency tuning ensure that harmful shaft currents have been eliminated and the VFD is running at its optimal performance. AKFA&T does no actual repairs or installations themselves, to avoid a potential conflict of interest.

THE EXPERIMENT

Notorious for running hot and making a lot of noise due to short-lived bearings, the 50hp fan motor that O'Connell convinced Perez would be a good candidate for the first SGR was "one of the most annoying motors in the building," Perez recalls. Three times the motor had failed. The Rockefeller Group had replaced the motor twice, the bearings

once. Vibration analysis by AKFA&T indicated the failures were due to shaft currents induced by the VFD controlling the motor. The maintenance crew tried different lubricants and line reactors, to no avail. With this motor, even AKFA&T's VFD frequency tuning did little to stop the destructive currents.

Today, the motor (pictured left) is quiet and runs at least 100°F cooler, O'Connell reports. Oscilloscope tests show that shaft currents have dropped to a negligible voltage. There is no doubt as to the reason – the AEGIS SGR.

O'Connell and AKFA&T employee Brian Melvin, a vibration analyst, have both seen electrical bearing damage again and again, wherever motors are controlled by VFDs. "The problem exists in every building we have worked in, which is more than 200 buildings in New York City alone," Melvin states.

Every drive/motor interface is different, so sometimes the damage starts when the motor is two months old, sometimes when it is six years old, but it is too often a problem. The two men are equally familiar with other mitigation measures; their periodic testing shows how ineffective such measures usually are over the life of a motor.

"Other devices do not have the maintenance-free capability, the ease of installation, or the overall quality of the SGR," Melvin says. "We were very impressed with it."

On February 6, 2008, before the ring was installed on the problematic motor, AKFA&T used a voltage probe and an oscilloscope to measure the discharges from the motor shaft at 59.2V (peak-to-peak) and 37.2V (peak-to-peak), at two different oscilloscope settings (10µsec/div and 2µsec/div, respectively), for an average of 48.2V (peak-to-peak). The oscilloscope screen showed rapid dv/dt voltage collapse at the trailing edge of the waveform – typical of the electrical discharges that damage bearings.

On February 20, 2008, two weeks after the ring was installed, AKFA&T took a ground-reference reading, for baseline comparison, of 9.21V (peak-to-peak) with the oscilloscope set at 40ns/div. Minutes later, AKFA&T took two more shaft-current readings at the same setting: 8.86V (peak-to-peak) and 11.2V (peak-to-peak).

A little more than a year later, on March 9, 2009, the motor was checked again by AKFA&T technicians. This time the shaft voltage was even lower: 4.8V (peak-to-peak).

"The readings may speak for themselves, but I still have to say these results are absolutely great," Melvin observes. "The bearings are much, much, much healthier than they were before."

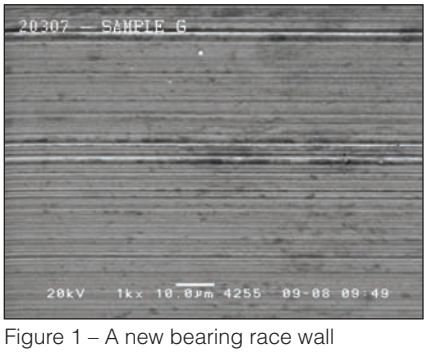


Figure 1 – A new bearing race wall

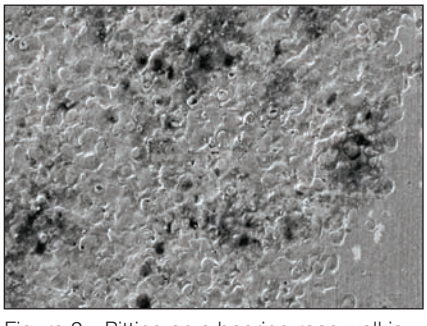


Figure 2 – Pitting on a bearing race wall is called frosting.

Building engineering manager Perez agrees the ring "seems to have resolved the issue." Based on the positive results, he has installed AEGIS SGRs on 13 additional fan motors in the Time & Life Building. Asked if he expects other buildings in Rockefeller Center to follow suit, he replies, "based on our success, I am sure it would be something they would consider."

A CLOSER LOOK

The extremely fast voltage rise times (dv/dt) associated with the insulated gate bipolar transistors (IGBTs) found in today's typical pulse-width-modulated VFD can overcome standard motor insulation and cause a short circuit. Motor manufacturers have focused on improving the design of the windings to withstand the corona discharge, which occurs when the air surrounding the conductors becomes charged.

Often overlooked, until it is too late to save the motor, is the cumulative bearing damage caused by VFD-induced shaft currents. Hard to predict but easier to prevent, these currents are best addressed in the design stages of a system. Without some form of mitigation, shaft currents 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.

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 (Figure 1). 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. 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

The AEGIS SGR Bearing Protection Ring can now be installed with epoxy.

The AEGIS SGR Bearing Protection Ring is available for any size NEMA or IEC motor and comes with a mounting adaptor for fast, easy installation on motors with shaft shoulders, slingers, or other end-bell protrusions.

wall. These discharges are so frequent that before long the entire bearing race becomes riddled with pits known as frosting (Figure 2). The damage eventually leads to noisy bearings, but by the time such noise is noticeable, bearing failure is often imminent. Since many of today's motors have sealed bearings to keep out dirt and other contaminants, electrical damage has become the most common cause of bearing failure in VFD-controlled AC motors.

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

SOME COMMON SOLUTIONS

Measures to mitigate VFD-caused motor failure are numerous and varied. For some applications, a lower system voltage supply is the answer. Many VFDs can be adjusted, and often the switching frequency can be reduced without adversely affecting performance. Some other mitigation measures are shorter cables, shielded cables, power-conditioning accessories, and improved motor design.

Arguably, the best solution would be better motor design at a reasonable cost. Minimal, voluntary standards issued by the National Electrical Manufacturers Association (NEMA) for IGBT-inverter-controlled motors rated for 600V or less state that such motors should be designed to withstand repeated surges of 1,600V (or 3.1 times the motor's rated voltage) and rise times of 0.1 microsecond. For fans, pumps, and a multitude of other applications, several manufacturers of three-phase AC induction motors offer inverter-duty, inverter-ready, inverter-grade, or in-

verter-rated models, but many of these do not live up to their names when it comes to protecting bearings. Beefed-up winding insulation is not enough to guard against bearing damage from VFD-induced shaft voltages. Many of the best motors on the market still need shaft grounding rings to protect their bearings if they are to be truly ready for VFDs, and truly sustainable.

MITIGATING BEARING DAMAGE

In considering the potential for bearing damage, there are various ways a motor designer can provide built-in bearing protection. Techniques range in cost, and some can only be applied selectively, depending on motor size or application. Cost and effectiveness also vary based on the technology. AKFA&T has tried most of these techniques at different times and has found that most yield less than satisfactory results.

As explained above, electrical damage to bearings often begins at startup and grows progressively worse. As a result of this damage, the bearings eventually fail. 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.

Insulating motor bearings is a partial solution that more often than not shifts the problem elsewhere. Blocked by insulation, shaft voltages seek another path to ground. Attached equipment such as a pump, gearbox, encoder, or tachometer often provides this path, and it frequently falls victim to bearing damage of its own. When an insulated bearing is used, a shaft grounding device should also be included in the installation to protect bearings in the attached equipment and discharge the voltages to ground.

Likewise, nonconductive ceramic ball bearings divert currents from the main motor's bearings but leave attached equipment open to damage. Ceramic bearings can be costly and typically must be resized to handle mechanical static and dynamic loadings. They should also be paired with shaft grounding to safely discharge harmful currents.

Still, another mitigation attempt comes in the form of conductive grease. In theory, this bleeds off harmful currents by providing a lower-impedance path through the bearings. In practice, however, the conductive particles in the grease increase mechanical wear.

Used in the past, spring-loaded metal and carbon-block grounding brushes contact the motor shaft and provide a path to ground. These brushes, however, were not widely adopted because of the many maintenance challenges they presented. To function properly, spring-loaded brushes require frequent maintenance. They wear rapidly, requiring frequent replacement, and the friction they produce can erode and damage the motor shaft. In addition, contamination and corrosion can rapidly reduce effectiveness.

Alternate discharge paths to ground, when properly implemented, are preferable to insulation alone, because they neutralize shaft voltages. The ideal solution would provide an effective, low-cost, very-low-resistance path from shaft to frame and could be broadly applied across all VFD/AC motor applications, affording the greatest degree of bearing protection and maximum return on investment.

SHAFT GROUNDING TECHNOLOGY

One new technology that meets all these criteria is the AEGIS SGR Bearing Protection Ring, which uses the principles of ionization to boost the electron-transfer rate and promote extremely efficient discharge of the high-frequency shaft voltages induced by VFDs.

The versatile SGR (shown in the photos to the left) is available for any NEMA or IEC motor regardless of shaft size, horsepower, or application. A mounting adaptor or new conductive epoxy that allows mounting without hardware facilitates installation of the device on virtually any motor end bracket, even those with shaft shoulders, slingers, bearing caps, or end-bell protrusions. SGRs have been successfully applied to intake and exhaust ventilation fan motors, air conditioning compressors, chillers, cooling towers, pumps, power generators, gas turbines, AC traction and break motors, cleanrooms, and a long list of other industrial and commercial applications.

For VFD-equipped motors of less than 100hp (75kW) a single SGR on the drive end or non-drive end of the motor shaft is typically sufficient to divert harmful shaft currents (Figure 3). For most motors above 100hp (75kW) or motors with roller bearings, a combination of insulation on the non-drive end with an SGR 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 (Figure 4).

For too long, the importance of grounding to protect motor bearings has been underestimated. To minimize harmful currents and realize the full potential of VFDs, a cost-effective method of shaft grounding is essential. Proven advances in technology now make it possible to build motors that are truly inverter-ready. Among other things, these motors should meet NEMA MG1 specifications for inverter applications and should include an economical, long-term grounding device such as a maintenance-free shaft grounding ring.

Used with a VFD, the AEGIS SGR Bearing Protection Ring qualifies as sustainable technology under the Federal Energy Management Program (efficiency standards for federal-government buildings under the Energy Independence and Security Act of 2007).

Furthermore, O'Connell and Melvin expect some of the federal funds referred to as the stimulus package will be used to make VFD-controlled systems more efficient, even in private buildings.

Once installed, the SGR requires no maintenance. Unlike conventional shaft grounding brushes, its conductive microfibers work with virtually no friction or wear; are unaffected by dirt, grease, or other contaminants; and last 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 25 million direction reversals.

VFDs hold the promise of sizable energy savings, but without adequate shaft grounding they are not a sustainable green solution. Operations and maintenance costs are often 60% to 80% of the total life-cycle 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. By significantly reducing the number of costly repairs resulting from the use of energy-efficient VFDs, the SGR provides sustainability, making the motor-VFD system a truly green solution.

Electro Static Technology
Mechanic Falls, ME
est-aegis.com

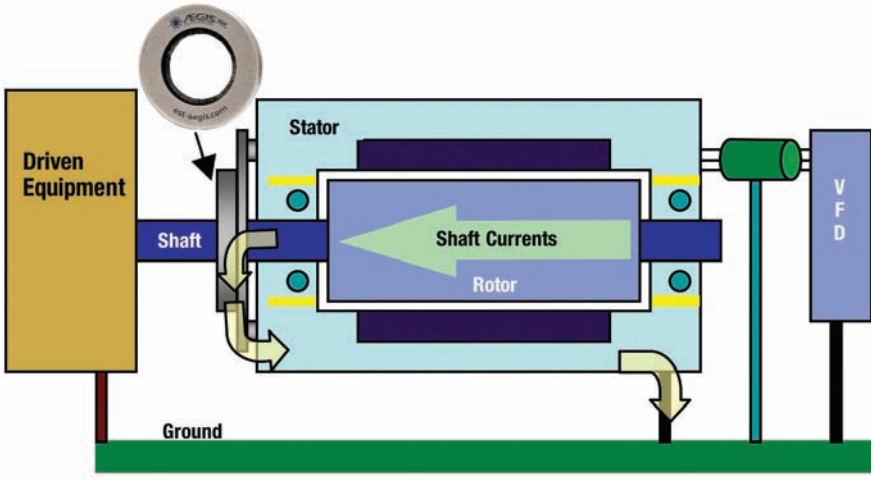


Figure 3 – For VFD-equipped motors of less than 100hp (75kW), a single SGR on the drive end or non-drive end of the motor shaft is typically sufficient to divert harmful shaft currents.

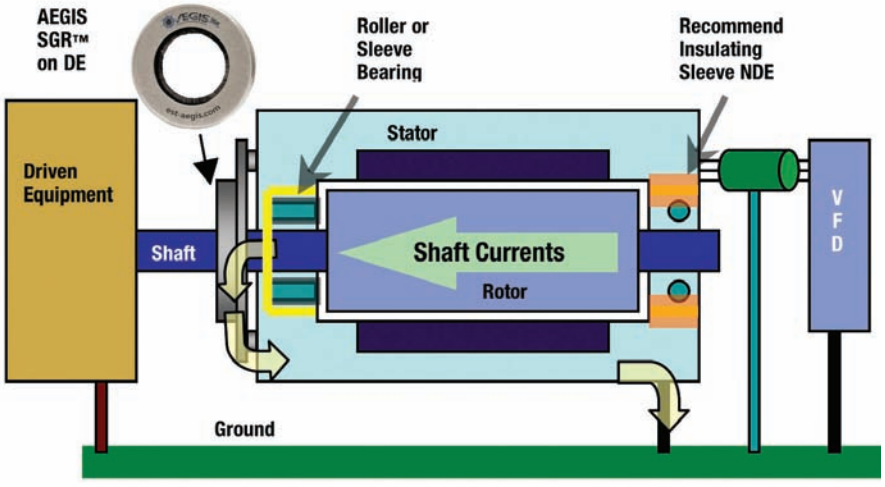


Figure 4 – For motors with roller bearings, a combination of insulation on the non-drive end with an SGR on the drive end provides the best protection in order to break a potential circulating current in the bearings while discharging the shaft voltage to ground.

Reprinted with the permission of *Today's Energy Solutions* Magazine, March 2010.

VFD-Induced Bearing Currents Kill Motors!

Save energy with a VFD, Save your motor with

AEGIS™ SGR
BEARING PROTECTION RING

Proven in hundreds of thousands of installations, the AEGIS™ SGR protects motor bearings from damaging VFD-induced currents and extends motor life. It also dramatically reduces downtime and improves the reliability of motor-driven equipment and systems.

- Safely channels harmful currents away from bearings to ground
- Patented time-tested design
- Maintenance-free, easy to install, lasts for life of motor
- Standard sizes for any motor

Split ring with conductive epoxy mounting simplifies field installation

2009 Plant Engineering PRODUCT of the YEAR WINNER

engineer 2009 PRODUCT OF THE YEAR Finalist

To download a free technical paper on bearing protection technologies, visit our website:

1-866-738-1857 | sales@est-aegis.com | www.est-aegis.com

Electro Static Technology™
An ITW Company