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Extending Motor Life With Sustainable Shaft Grounding

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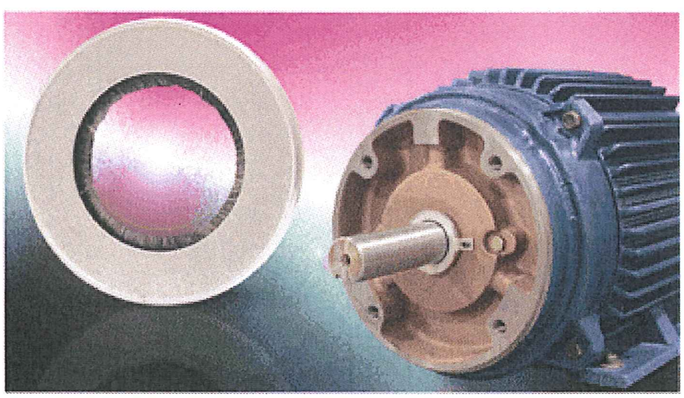
Realizing the full energy-saving potential of variable-frequency drives

With the rising cost of energy, the use of variable-frequency drives (VFDs), also known as inverters, is growing. By optimizing electrical flow to an alternating-current (AC) motor, a VFD can provide substantial energy savings. Within the field of flow control, the potential for increased efficiency with VFDs is especially dramatic. Many centrifugal fans and pumps run continuously, often at reduced loads. Because the energy consumption of such devices correlates to their flow rates cubed, the motors driving them will use less power if controlled by a VFD. In fact, if a fan's speed is reduced by half, the horsepower needed to run the fan drops by a factor of eight. In constant-torque applications (reciprocating compressors, conveyors, mixers, etc.), in which more-accurate process control is the main objective, a VFD can be programmed to prevent a motor from exceeding a specific torque limit.



A bearing-protection ring, which diverts shaft voltages to ground.

Currents induced on motor shafts by VFDs can wreak havoc with motor bearings, dramatically shortening motor life and causing costly repairs, even with motors marketed as "inverter-ready." One solution is to design systems with motors with built-in bearing protection. Minimal voluntary standards issued by the National Electrical Manufacturers Association (NEMA) for insulated-gate-bipolar-transistor- (IGBT-) inverter-controlled motors rated for 600 v or less state that such motors should be designed to withstand repeated surges of 1,600 v (or 3.1 times the motor□s rated voltage) and rise times of 0.1 microsecond.

For VFD-controlled motors already installed, shaft grounding can be a cost-effective way to achieve sustainability.

How VFDs Can Cause Motor Failure

Typically, the most vulnerable parts of motors controlled by VFDs are windings and bearings. The cause of their damage is repetitive electromagnetic interference (EMI) arising from the non-sinusoidal current produced by a VFD's power-switching circuitry. EMI passed through wiring is known as high-frequency line noise, harmonic content, eddy currents, parasitic capacitance, capacitive coupling, magnetic dissymmetry, electrostatic buildup, high-voltage ringing, reflective voltage, overshoot, steep voltage wavefronts, and common mode voltage. EMI passed through radiated waves is known as radio frequency interference (RFI). These unwanted currents can cause degradation of insulation, bearings, coil varnish, etc., and lead to motor failure. Causes of such failure include high peak voltages, fast voltage rise times, the corona effect, and induced shaft currents.

High peak voltages arising from the high switching frequencies of modern VFDs are a major concern, especially if a single VFD is used to control multiple motors or if the line connecting a VFD with a motor is more than 50 ft long. As a rule, the longer the cable, the lower its impedance. If load impedance is higher than line impedance, current is reflected back toward the VFD, creating voltage spikes at the motor terminal that can be twice as high as the direct-current (DC) bus voltage.

Often overlooked until it is too late to save the motor, cumulative bearing damage is caused by VFD-induced shaft currents. Hard to predict but preventable, these currents are best addressed during the design 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.

A Closer Look at Bearing Damage

Short of dismantling a motor, there are two main ways to check for bearing damage: measuring vibration and measuring voltage. Because of the number of possible variables, neither method is foolproof. By the time vibration tests confirm bearing damage, it usually is too far advanced for the motor to be saved. If a baseline voltage measurement is taken right after a VFD has been installed, subsequent monitoring may provide early warning of harmful current loops.

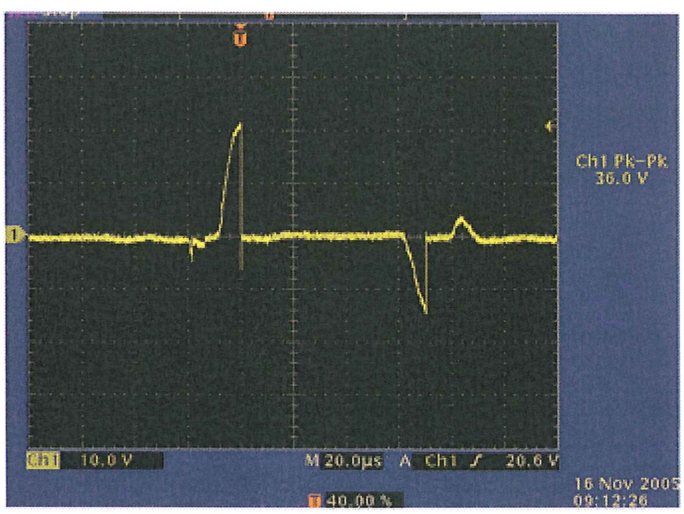


FIGURE 1. Measurement of shaft currents.

Shaft currents can be measured by touching an oscilloscope probe to the shaft while the motor is running (Figure 1). These voltages repeatedly build up on the rotor to a certain threshold, then discharge in short bursts along the path of least resistance, which all too often runs through a motor's bearings.

Serious cumulative electrical bearing damage can be attributed to the extremely fast voltage rise times (dV/dt) associated with the IGBTs found in typical pulse-width-modulated VFDs. Discharge rate tends to increase with carrier frequency. Discharges through bearings can be so frequent that, before long, the entire bearing race wall becomes riddled with fusion craters known as frosting. Because many current motors have sealed bearings to keep out dirt and other contaminants, electrical damage has become the most common source of bearing failure in VFD-controlled AC motors.