Ducted Systems
Technical Services
Service Tips Letter

Letter: **ST-009-2016**

Date: May 29, 2019

To: Ducted Systems (Factory Direct) S1 HVAC Branch Service, Sales, Warranty Managers, Ducted Systems (UPG/Applied) Distribution Service, Sales, Warranty Managers

Subject: **Application Engineering Observations on Errant Current Protection for Electric Motors in HVAC / Refrigeration Systems**

Product: Residential and/or Commercial products with Variable Frequency Drives (VFDs)

Summary: This letter provides information and considerations for current protection on electric motors in certain HVAC systems.

Effective: **May 29, 2019** Expires**: May 29, 2022**

With the increased emphasis on efficiency in the HVAC industry and growing concerns associated therewith, the introduction of variable frequency drives (VFDs) into standard field offerings is becoming a common occurrence. These offerings pose a different challenge with regard to motor protection and the potential for decreased bearing life due to high voltage carryover through the bearing raceway and roller assemblies.

Further information is warranted so service personnel can make accurate observations on motor wear and conditions that would be detrimental to trouble-free operation and product lifespan.

VFDs:

VFDs are wonders of electrical engineering and current/voltage manipulation. Being able to manipulate current, phasing, power factor, and voltage is useful to gain electrical efficiency in modern HVAC systems.

Variable Frequency Drives induce voltages into the shaft of the driven motor due to the extreme high-speed switching of the insulated gate bipolar transistors (IGBT). This produces the pulse width modulation used to control AC motors in heating, ventilation, air conditioning, and refrigeration systems. These drives have to work in varied locations, conditions, and voltages over a range of loading requirements in order to equalize compression requirements and balance loading for efficient equipment operation and air introduction.

To gain efficiency over a broad range, the indoor blower motor is only run as fast as the compression requirement dictates. This lowers power consumed by the motor and subsequently lowers total power.

Corona Effect:
HVAC technicians must possess a working knowledge of electrical theory and how it gets implemented during normal operation. Every electrical motor generates an electromotive force (EMF) back into the electrical system. This “back-EMF” poses no significant concern with regard to discharge IF the system is grounded, a strong neutral is present, and the system is able to act as a shock absorber in response to this phenomenon.

In systems with VFDs, an entirely different scenario takes place as the VFD rests between the motor and the system. So the EMF goes back to the drive or at least tries to. The VFD is a one-way device that has protection through circuity. The IGBTs are very fast semiconductor switches that are actuated electronically, in some case as fast as 20,000 times per second, to prevent current from leaking back into the electrical system. This protection is through “electronic chokes” that only allow current to flow in one direction. IGBTs take a lot of back currents (usually ten times the amount normally seen in most systems) to make sure no errant voltage gets back to the primaries in the drive circuity.

The build-up of rotational corona within the motor actually induces current back into the rotor because it becomes capacitively-coupled and it has nowhere else to go. Inductive circulating currents could also be present if the ground is floating but are only present in higher HP 100 /75kw motors. (See Figure 1)

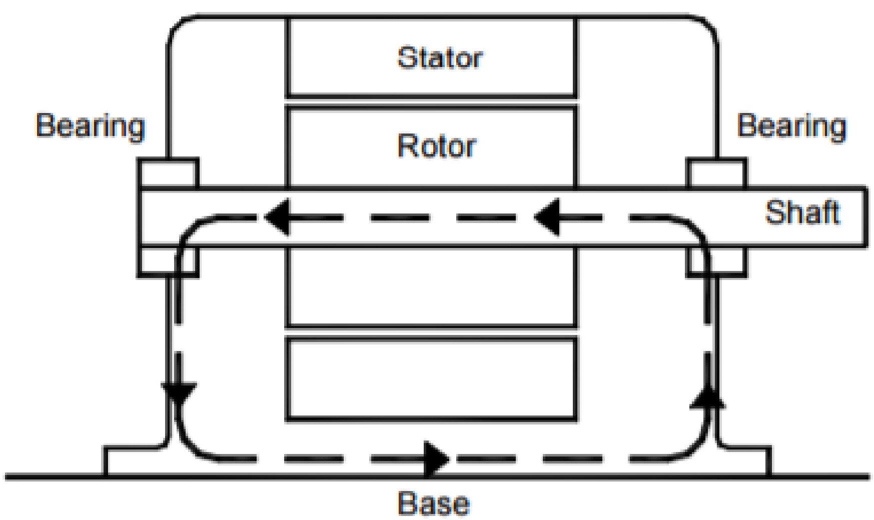

Fig. 1 Inductive circulating currents

Source: Toshiba – TOSBEC Power Products Monthly Informative Application Guidelines, with respect to Motors & Drives to keep you better INFORMED. APPLICATION GUIDELINE #12 (Bearing damage related to PWM Drives). www.landbelectric.com

If currents are high enough, they will “leak” back through the bearing’s rotational components such as the races, balls, and rollers; they will make their way to the outer race and finally into the motor body and then to ground if connected (see Figure 2). This is electrical discharge machining (EDM) where a continuous, high-capacitance discharge is greater than the dielectric strength of the oil film within the bearing. Unless mitigation is employed for shaft voltages, the motor bearings may become damaged from the electrical currents in the form of pitting and fluting. Fluting will exhibit excessive bearing noise and eventually result in motor failure.

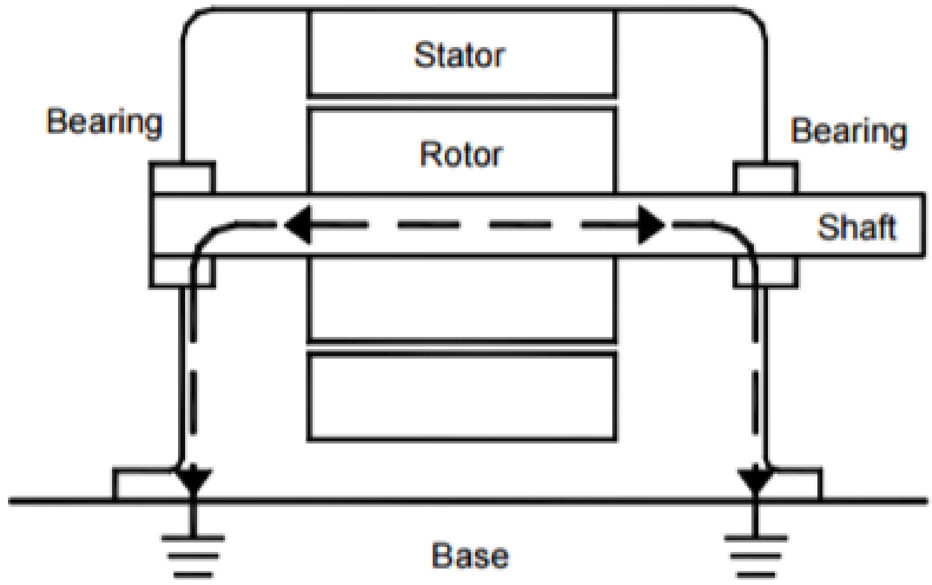

Fig. 2 Capacitively coupled current flow

Source: Toshiba – TOSBEC Power Products Monthly Informative Application Guidelines, with respect to Motors & Drives to keep you better INFORMED. APPLICATION GUIDELINE #12 (Bearing damage related to PWM Drives). www.landbelectric.com

Damage to motor bearings are caused by current discharges from high-speed switching in pulse width modulation (PWM) drives that use insulated gate bipolar transistors (IGBTs). Switching events may occur at a rate of over 10,000 Hz or even greater. The generated voltage pulses induce an AC voltage onto the motor shaft via parasitic capacitive coupling between the rotor shaft and the stator windings. This can even occur in a properly-grounded and suitably electrically-shielded motor.

Because the IGBT’s fast rise time is only 50 ns or less, capacitive coupling may cause the peak motor shaft voltage to reach as high as 60 volts, or higher in some cases, unless a discharge path exists. Typically, when the voltage reaches 20 - 30 volts or more, the oil film in the bearing breaks down and a discharge takes place. This electric spark produces intense heat with temperatures reaching 8000 to 12000 degrees C. This occurs any time the rotor is turning and happens over time with an infinite number of contacts between the roller component and the race material. These discharge events occur continuously while the motor is operating, causing increased electrical bearing damage over time. If not connected to ground, or some other drain, the build-up during normal operation will induce a current of a sufficient magnitude to decompose the protective varnish on motor windings and result in failure due to electrical shorting if the bearing failure doesn't fail first.

In Figure 3, the ball bearing is “floating” on an oil film. When this film breaks down dielectric strength is compromised and arcing occurs blowing away material in the path of the rotating element. Hundreds of thousands of times per minute. Over the course of a very short time, the bearing will have a pathway usually dead center of the race causing extreme wear and a noisy bearing.

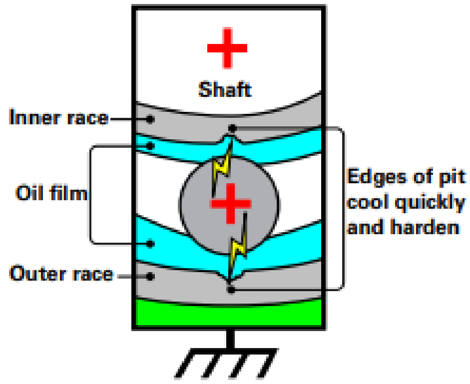

Figure 3. Source: AEGIS Bearing Protection Handbook, Edition 3,
https://www.est-aegis.com/index.php

Note the switching speed of the drive represented in Figure 4 is 20 kHz. This means the switching by the IGBTs are running at 20,000 times per second. (AC is 60 cy per second for reference.) Every time they switch they arc.

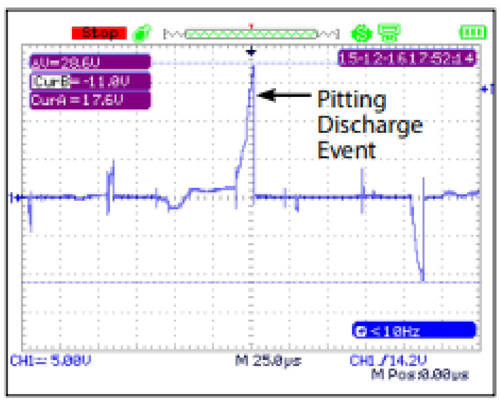

Figure 4. Source: AEGIS Bearing Protection Handbook, Edition 3
https://www.est-aegis.com/index.php

Prevention:
To prevent this type of failure, remove current out of the rotor any time the motor is running. This can be done by several methods. Carbon brush dragging on the shaft, 360° micro-fiber carbon brushes that are in constant contact with the shaft. (Preferred method) This can be either internally or externally connected directly through conductive strapping to the motor base/ground effectively draining the stator of all errant voltage that could possibly leak through bearing races.

Understanding of this phenomenon and its results with regard to high-capacitance discharge through rotational contact is what causes the damage. The higher the voltage the higher the probability this will happen. In some case where voltages approach 480 to 500 or even 575V, line reactors may also be required to stop this from happening, correcting noise on higher voltage installations, and getting the power factor back in phase to drastically reduce back EMF.

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