Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #12

(Bearing damage related to PWM Drives)

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BEARING DAMAGE RELATED TO PWM DRIVES

The following are exerts from an IEEE report titled "Practical Guide to Understanding Bearing Damage related to PWM Drives" written by IEEE members and Toshiba International employees Don Macdonald, and Will Gray.

Abstract – **The performance and reliability of AC Adjustable Speed Drives (ASDs) is continually improving. One of the key reasons for improvement has been the advent, development and use of Pulse Width Modulated (PWM) drives utilizing faster switching devices, primarily Insulated Gate Bipolar Transistors (IGBTs). As with many other developments, improvements in some areas may cause problems in others. An increased bearing failure rate in motors is one of the negative effects of these types of drives. To mitigate bearing current damage in motors, as well as in loads and other auxiliary equipment attached to the motor shaft, it is important to understand how these currents are generated. In addition to theoretical explanations, actual field cases and solutions will be reviewed.**

The phenomenon of motor shaft voltages producing circulating shaft currents has been recognized since the 1920s. When a motor is operated by sinusoidal power, shaft voltages are caused by alternating flux linkages with the shaft. The linkages are associated with flux unbalance caused by:

· rotor static or dynamic eccentricity
· rotor and stator slotting
· axial cooling holes in the stator and/or rotor laminations
· shaft keyways
· rotor core support arms
· joints between segmental laminations
· directional properties of magnetic materials
· supply unbalance
· transient conditions.1

Fig.1 Inductive circulating currents

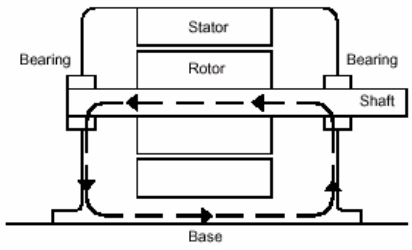

Fig. 1 Inductive circulating currents

Shaft voltages exceeding 300mV require one bearing of the motor to be insulated to prevent circulating current damage to the bearings (see Fig. 1 above). Typically this phenomenon only occurs on 500 frames and larger machines. Normally the Opposite Drive End (ODE) bearing is chosen. If the Drive End (DE) is insulated, the driven load can provide an electrical path that completes the loop to allow current to flow. ***PWM drives can cause increased circulating currents to flow due to a high-frequency flux produced by common-mode currents which link the stator, rotor and bearing loop***. This is an inductive rather than capacitive effect. Motors become more asymmetrical at high frequencies because the high-frequency capacitively coupled currents depend heavily on the location of the first few turns within the slot. Since placement of the turns in random-wound motors is not well controlled by any manufacturer, even a motor which is symmetrical at low frequencies becomes asymmetrical at high frequencies.

In addition to the preceding, PWM drives utilizing Bipolar Junction Transistors (BJTs) or IGBTs can cause Electric Discharge Machining (EDM) currents. PWM inverters excite capacitive coupling between the stator windings, the rotor and the stator frame. This common mode current does not circulate but rather travels to ground (see Fig. 2). The path to ground can be through both motor bearings and/or load or auxiliary equipment bearings (see Fig 7). The paper written by the authors investigates induced shaft voltages caused by PWM, AC variable-speed drives and discuss' methods of mitigating their harmful effects.

Fig.2 Capacitively coupled current flow

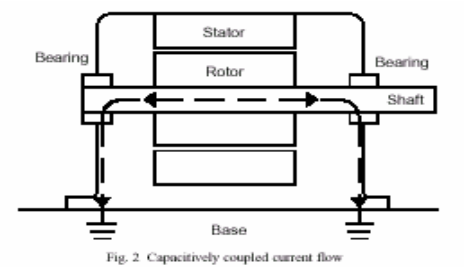

Fig. 2 Capacitively coupled current flow

Fig.7 Paths for common-mode currents to ground

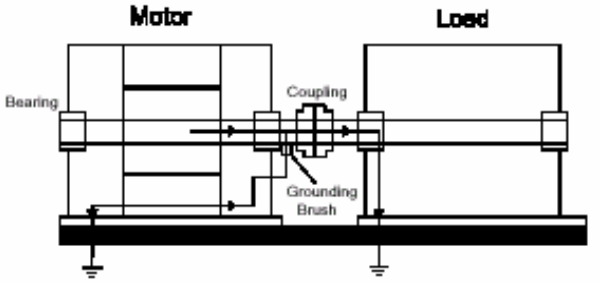

Fig. 7 Paths for common-mode currents to ground

The existence of EDM currents with PWM voltage source inverter drives depends on the presence of all of the following conditions:

1. Excitation, which is provided by the source voltage to ground
2. A capacitive coupling mechanism, between stator and rotor
3. Sufficient rotor voltage build-up which is dependent on the existence of bearing capacitance

CONCLUSIONS MADE IN THE IEEE REPORT

When a bearing fails, especially on a motor being powered by a PWM ASD, the bearing and lubricant should be examined to determine the cause of failure. If the damage is due to EDM, corrective measures should be considered.

There are several possible practical solutions to mitigate bearing currents which include:

1. Selecting a carrier frequency which is between 1500 and 3000Hz if practical. This significantly reduces the energy transferred to the rotor.
2. Adding a common mode filter to mitigate common mode noise. The ratio of common-mode noise caused by a PWM drive compared to a sine wave is in the order of 10:1 or more. The addition of a filter which combines both common-mode and differential-mode filtering can reduce this ratio by as much as 70%. A common-mode filter connects the wye point of the filter to a "neutral" point on the DC bus. This filter arrangement provides a low-impedance path from the output of the ASD back to a neutral point on the DC bus instead of through the motor. (Note that further research has shown that the wye point of the filter can be connected to the negative DC bus with similar results).
3. Insulating both motor bearings to prevent current flow plus isolating all mechanical load and/or auxiliary equipment bearings (such as tachometers).
4. Adding a shaft grounding brush or brushes to shunt common mode currents (ideally with the ODE bearing being insulated).
5. Making sure that the motor frame is suitably grounded for high frequency currents. This prevents stator frame currents from flowing through the connected mechanical load or auxiliary equipment bearings via the motor bearings (or grounding brush).
6. Changing the cable to the recommended type to minimize the common mode current. Testing has shown that cables which have a continuous shield or continuous armor provide the lowest common-mode current plus relatively low frame voltage. The recommended cable for PWM ASD application has six symmetrical conductors, 3∅ and 3 ground conductors) with a continuous corrugated-aluminum armor-type sheath
7. As a temporary measure, using conductive grease. When a high-resistivity grease is used and the bearings are "floating" on the oil film, the equivalent-circuit characteristic changes from a resistor to a capacitor. If the rotor voltage exceeds the threshold voltage of the oil film between the balls or rollers and the races of the bearing, the oil film's dielectric strength is exceeded. At this point, destructive EDM currents and arcing occur.

New installations should be designed with the bearing current phenomenon in mind and take into account the issues discussed in this paper. This is particularly important if high carrier frequencies are planned to be used.

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