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

APPLICATION GUIDELINE #43

(What Does 'Inverter Duty' mean to Toshiba)

Brought to you by your Motor & Drive Specialists……

This question has come up a lot recently. There are 3 things that should be considered when reviewing 'Inverter Duty' type applications from a motors perspective.

1) Winding Issues
2) Bearing Issues
3) Temperature Rise Issues

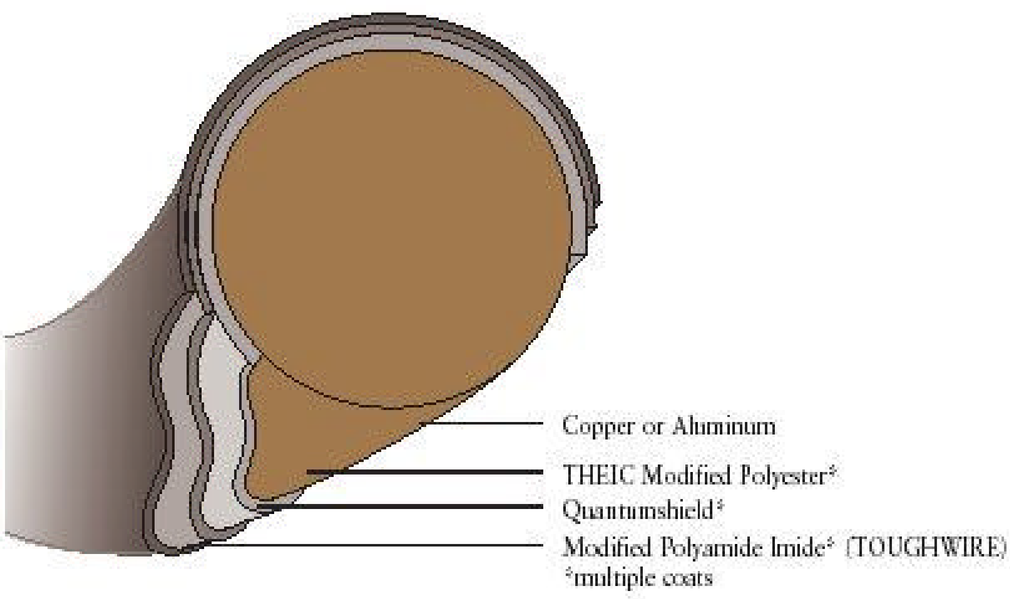
Winding Issues

NEMA MG1 Part 31. Section 31.4.4.2, states: "Stator winding insulation systems for definite purpose inverter fed motors shall be designed to operate under the following limits at the motor terminals."

$$V_{PEAK} \leq 1.1 * 2 * \sqrt{2} * V_{rated}$$
$$V_{PEAK} \leq 3.1 * V_{rated}$$
$$\text{Rise time} \geq 0.1 ms$$

This works out to 1860V spikes max. for a 600V RMS system.

Toshiba has standardized on all their EQPIII design motors with Phelps Dodge Thermalize QTW wire. This wire has superior insulation life in comparison to other magnet wires when exposed to extremely harsh electrical environments typical of inverter-driven motors. Furthermore, QTW wire provides improved insulation protection against transient spikes, high frequencies, elevated voltage levels, and short rise time pulses without increasing insulation thickness. Go to their website for more information: www.pdwcg.com/pdfs/magwire/ThermalezeQTW.pdf regarding their pulse endurance test results, measured thermal endurance and other thermal, mechanical, electrical and chemical specifications.



Motor & Drive Specialists

In addition to using a superior winding wire, there are a lot of other detailed features described in 'Application Guideline#37' that should also be considered for a superior insulation system. It is very important that the winding be held securely in place mechanically (good slot fill, heat shrink lacing material, dip & bakes, epoxy paint) to prevent vibration issues with the insulation system.

For clarification, it is not feasible to specify to motor manufacturers that motors should be built to meet all aspects (completely comply with) NEMA MG1-2003, Part 31. Primarily because the standard was written for 'Definite Purpose Inverter-Fed Polyphase Motors'. The references in Part 31 which make it 'Definite Purpose' and not "standard" include:

- *31.4.3.1 Starting Requirements:* "If across the line starting capability is required by the application, these factors should be considered when selecting the motor and controls." Note: this comment makes reference to the fact that the motor design could potentially be specifically designed to only run on an inverter. Toshiba motors are carefully designed so that both across the line starting and VFD use (suitable for use on VFD's) are acceptable.
- *31.4.4.3 Shaft Voltages and Bearing Insulation:* "Drives can be generators of a common mode voltage which shifts the three phase winding neutral potentials significantly from ground." Note: NEMA goes on to indicate that interruption of this current requires insulating both bearings. Alternately, shaft grounding brushes may be used to divert the current around the bearing. This is an option that is available and not provided as a standard feature, depending on the frame size Toshiba either recommends insulating the bearing journal or using ceramic coated bearings.
- *31.5.1 Nameplate Marking:* "Minimum information necessary to characterize the motor for variable torque applications and other applications shall be given on all nameplates, including HP, V, Current, Speed, Frequency." Note: Toshiba provide basic information with acceptable speed ranges for both constant torque and variable torque applications. May not be as detailed as they request here in this section.

Bearing Issues

As described in detail in 'Application Guideline #12' and briefly above in NEMA MG1 section 31.4.4.3, 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. The path to ground can be through both motor bearings and/or load or auxiliary equipment bearings. 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. 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 (common in HVAC applications to lower audible noise to adjoining rooms).

Temperature Rise Issues

In addition to Toshiba’s low temperature rise motor designs, from 1-200Hp, 1800RPM and 1200RPM, Toshiba labels their nameplates with an inverter duty speed range of 60:1 for Variable Torque applications, and 20:1 for Constant Torque applications.

Overspeed Type Applications: When a motor is operated above the base frequency of 60Hz, the motors impedance continues to increase, while the drives output voltage has reached it’s maximum. At this point there is no more voltage to counter the increasing impedance so the motor torque decreases linearly until approximately 90Hz (1.5x overspeed). Application Guideline #10 describes overspeed Torque issues in detail. This can affect the application on both Variable Torque and Constant Torque type applications.

Variable Torque Applications: The ‘Affinity Laws’ indicate that Head (Pressure) is proportional to the speed squared. There is no real issues with how low a frequency you run these types of applications because there is so little load at the lower speeds. Applying drives on these types of loads really becomes an issue when overspeeds are being considered because the load torque requirements are increasing by the square of the overspeed (ie A 10% overspeed is a 21% increase in Head which is approximately proportional to a 21% increase in Torque and Current requirements) Also as mentioned above because of the overspeed, you must also realize that a motors available continuous Torque at a 10% overspeed has reduced to 90% of the FLT rating of the motor.

Constant Torque Applications: The big issue here is obtaining proper cooling at the lower speeds. In constant torque applications the load current is constant across the speed range, there must be enough thermal margin in the motor to make sure it can sustain continuous operation at a reduced speed without affecting overall motor insulation life, or force premature failure of the drive end bearing. Toshiba can provide ‘thermal damage type curves’ when requested.