TWMC (TECO Westinghouse Motor Company) Suggestions for the Application and Protection of Small VFD Duty Induction Motors

Note:

The following suggestions are applicable to small random wound motors 600V and below, and are intended to suggest steps to protect motors operated on (VFD's) variable frequency drives.

Product Statement:

TECO Westinghouse Small VFD duty rated motors have winding insulation that meet or exceed NEMA MG-1 Part 31 voltage level requirements.

Product Application:

TECO motors are purchased and utilized on other manufactured brands of variable frequency drives, and are suitable for such, as long as proper application, setup, and protection are provided to prevent VFD related failures, from possible harmonics, caused by non-sinusoidal wave shapes, and voltage spikes, resulting in increased heating, decreased torque capability, and excessive shaft voltages if application, setup and protection methods suggested by both the VFD drive and motor manufacturers are not carefully followed. TWMC has a considerable number of customers that are successfully operating motors in the field were IGBT type VFD applications are applied. Many of these applications are TECO motor and drive packages that are specifically tuned to provide problem free operation.

Warranty:

TWMC standard stock motor warranty coverage is three years from the date of manufacture. IEEE/841 motor warranty coverage is 5 years from the date of manufacture. TECO motors packaged with TECO brand VFD drives are covered under warranty for three years after the date of packaged sale. Motors that fail under the control of a VFD sourced from another manufacturer that were not applied, setup, or properly protected per the VFD drive and motor manufacturer's suggestions, will not be covered under warranty.

Inverter VFD Compatibility with Motors

Many variables must be considered when determining the suitability of certain types of motors. The variables are as follows:

- Torque requirements (Constant or Variable)
- Speed range
- Line/System Voltage
- Cable length between VFD & Motor
- Drive switching (Carrier) frequency
- Motor configuration
- Grounding

Vertical Motors on VFD's

The following require consideration by the end user or installation engineer:

- Slowest rpm that can be utilized and not cause the non-reversing ratchet assembly to not operate properly 4:1 /15 Hz (in the range of 200-300 rpm)
- Noise and or vibration levels caused by the torque pulsation characteristics of the PWM waveform, a system critical frequency falling inside the variable speed range of the process or the added harmonic content of the PWM waveform exciting the system components.
- Application related problems related to the controlled acceleration/deceleration and torque of the motor on VFD power and the building of system pressure load.
- The impact the reduction of pump speed has on the down thrust reflected to the pump motor and any minimum thrust requirements of the motor bearings.
- Water hammer during shutdown damaging the non-reversing ratchet.

Grounding and Cable Installation Guidelines

Proper output winding and grounding practices can be instrumental in minimizing motor related failures cause by PWM waveform characteristic and installation factors. The VFD manufacturer's installation instructions should be consulted regarding the acceptable cable lengths for use with their VFD's voltage rise time. VFD drive manufacturers should also be consulted concerning proper system grounding and protective devices (low pass filters, and voltage clippers and snubbers) needed to prevent voltage overshoot.

Electrical Failure from (Line Ringing – Reflective Wave – Voltage Overshoot) is a function of the voltage rise time, (dV/dT), and of the length of the motor cables which behave as a transmission line. Insulated-gate bipolar transistors (IGBT's) are used in nearly all modern low and medium voltage drives. They produce a carrier upon which is contained the useful fundamental voltage and frequency required to drive a motor. IGBT's have extremely fast on-off switching times some in the range of 100 – 200 nanoseconds (ns). The rate of change of voltage with respect to time (dV/dT), can exceed 7500 volts per microsecond. Impedance mismatch at both ends of the cable, (cable-to-inverter and cable-to-motor), cause some portion of the waveform high frequency leading edge to reflect back in the direction it arrived. Reflected leading edges encounter other waveform leading edges, and their values begin to add causing voltage overshoot. As the carrier frequency is increased more leading edges are added resulting in higher voltage overshoots.

System resonance - VFD cables, no matter their length, have a natural self resonant frequency and can be influenced by the carrier frequency of the drive. The self-resonant frequency ranges can be at, or below the high frequency components of the voltage waveform produced by the IGBT inverter. When the self-resonant frequency of the conductor (cable unit) approximate the frequency range of the IGBT voltage waveform, the conductors themselves go into resonance, which creates a "Gain" or an amplification of the voltage components at, or near, the conductor's natural resonant frequency. This produces voltage spikes at the waveform transition points, recalling that these voltage spikes can have a rise time in excess of 7500 volts per microsecond. This stresses the motor winding and insulation system, (insulation punch through) or (partial discharge – Corona), and if it not corrected will result in motor failure.

If the motor/stator frame is grounded back to the drive with low impedance (at high frequency) ground conductor then most current will bypass bearings.

Best Methods: VFD Cables

- Symmetrical 3 phase power cables
- 3 Ground Conductors (grounded in both boxes)
- 100% Coverage Shield (grounded to cable glands)

If the high frequency impedance cannot be measured, then a ground conductor and/or shield DC resistance of a maximum of 2 time the power conductor's DC resistance should be sufficient. These ground conductors must be properly grounded to both the motor and the VFD ground bus.

Bearing Fluting from Common Mode Voltage

VFD's can generate a "common mode voltage", which raises the three phase winding neutral potential significantly above ground potential. The sum of the 3-phases equal zero for sinusoidal power. For VFD's each phase is rectified and the common mode voltage is the instantaneous sum of the three phases. When the 3-phase output from the drive is rectified, DC is either positive or negative; and the common mode voltage is approximately equal to the RMS voltage. The inherent magnetic dissymmetry (capacitive coupling) can produce shaft and bearing currents. Common mode voltage oscillates at high frequency and is capacitive coupled to the rotor. The result can be pulses as high as 25 volts from shaft to ground, with the path being through either of both bearings to ground.

It is important to check the frame to shaft voltage. One test method based on NEMA MG-1, is to measure the shaft voltage from end to end of the shaft. NEMA uses 300 mill volts AC limit for any type bearing. The higher the common mode voltage and VFD switching frequency, the greater is the possibility of damaging bearing currents. Motor and drive unit must be effectively grounded to each other and to the electrical system ground. The VFD manufacturer's installation instructions should be consulted to determine the proper grounding setup and necessary filtering required to mitigate common mode voltage and bearing currents.

TWMC Suggestions for Preventing Bearing Fluting

The following recommendations are for cases where the purchasers have indicated that the motor will be operated on a VFD:

- For 444/449 (11 inch shaft height) and larger motors being operated on a VFD, TWMC should suggest the following two options to the customer. Install 2 insulated bearings (except roller bearings) and a shaft ground brush on the drive end of the motor. Option two instead of installing insulated bearings and shaft grounding brush install CoolBlue Inductive Absorbers to reduce or remove shaft current and prevent electrical discharging in the bearings

- For 320 frame up to (not including) 444 frame, TWMC should suggests the following two options to the customer. Install 1 insulated bearing on the NDE and a ground brush on the DE. Option two instead of installing insulated bearing and shaft grounding brush install CoolBlue Inductive Absorbers to reduce or remove shaft current and prevent electrical discharging in the bearings

- For frames below 320, TWMC should suggest the following two options to the customer. Install a ground brush. Option two instead a shaft grounding brush install CoolBlue Inductive Absorbers to reduce or remove shaft current and prevent electrical discharging in the bearings

- Note: SGR's (Shaft ground rings) or CDR's (current diverter rings) are considered wear items and must be serviced and/or replaced once it is detected that the device can no longer reduces shaft current and prevents electrical discharging. Installing CoolBlue Inductive Absorbers are simple to install, They do not wear, and are very effective at reducing or removing shaft current and prevent electrical discharging in the bearings. It is the recommended option.

- For hazardous locations, grounding brushes are not allowed. For such conditions, TWMC should suggest 1 insulated bearing on the NDE for frames 444/449 and larger (and no bearing insulation for smaller frames) and TWMC should inform the end user that it is their responsibility to install common mode voltage mitigation devices, such as CoolBLUE Inductive Absorbers, to reduce or remove shaft current and prevent electrical discharging in the bearings.

It is recommended that a comparison be made between the max operating speeds & over speed for our catalog motors with the chart given in NEMA MG-1 Part 31 to verify compliance.