VFD APPLICATION GUIDELINES

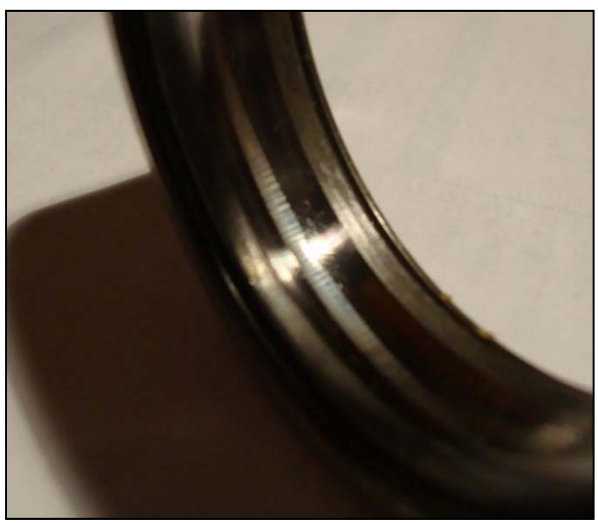
Background

The application of Variable Frequency Drives (VFDs) in heating and cooling units is becoming more common every day. VFDs work by converting an AC voltage to DC voltage and then pulsing the DC voltage to simulate an AC sine wave at the required frequency to control motor speed. VFDs are an effective way to reduce energy usage but Colmac's experience has shown that there are several design considerations to be accounted for in order to produce a successful application. These considerations are particularly important for extending motor life by reducing the potential causes of bearing currents and insulation breakdown that may arise with the use of VFDs.

Failure Modes

Bearing Current Failure – Improperly configured VFD systems can contribute to high shaft voltages which may result in Electric Discharge Machining (EDM). EDM occurs when voltage levels on the rotor/shaft exceeds the dielectric rating of the bearing lubrication and an arc is drawn across the bearings to ground. Every time this arc occurs a pit is created in the bearing race which, over time, will cause a fluted pattern in the bearing race. As the EDM continues to deteriorate the bearing surfaces the motor will experience vibration, increased noise levels, overheating, hard starts, overloads, and eventually, bearing failure.

Figure 1
Bearing Race Fluting From EDM



There are several ways to mitigate the effects of EDM, however, these do not address the root cause. Such solutions include insulated or ceramic bearings and shaft grounding systems. While effective for mitigating EDM, these can have a high initial cost and represent an ongoing maintenance burden for the system.

Insulation Failure – The DC voltage pulses produced by VFDs travel down the conductors to the motor and can be reflected back to the drive. The reflected wave can increase in magnitude to the point where a partial discharge can occur (corona). This corona effect falls short of an actual insulation breakdown but can act to produce ozone which leads to carbon tracing and insulation degradation. Left uncorrected, the corona effect will eventually result in insulation failure and equipment damage.

Figure 2
Motor Insulation Failure Resulting From Corona Effect

Application Recommendations

System – When utilizing VFDs care must be taken to coordinate all components and to confirm their compatibility. The system designer and installing electrical contractor are responsible for designing the VFD electrical system to protect the specific motor(s) being controlled by the VFD.

Cabling – Conductors supplying motors should be rated and sized appropriately for the motor load, voltage drop, and environmental conditions. Line lengths between the VFD and motors(s) should be minimized wherever possible. Shorter line lengths will reduce the magnitude of reflected waves and, in general, benefit the longevity of the installation. Always follow the VFD and motor manufacturer's specifications when selecting and installing conductors for a VFD installation.

Motors – Colmac motors are specified to comply with the National Electrical Manufacturers Association (NEMA) standard MG1 part 31 requirements for inverter duty motors.

Grounding – It is essential the electrical system, building steel, motor and VFD be properly grounded. The National Electric Code (NEC) describes the minimum requirements for grounding and bonding an electrical system for safe operation. In addition to providing a ground from the drive chassis and motor frame to earth ground, Colmac recommends a separate ground conductor from the motor frame to the VFD ground bus. Proper grounding is a critically important means of mitigating reflected waves and bearing current failures.

Carrier Frequencies – Colmac recommends setting the drive carrier frequency as low as possible (typically 2 kHz). Lower carrier frequencies result in higher levels of audible VFD noise but will help to reduce destructive bearing currents.

Motor Speed – Generally it is not recommended to over-speed motors or to operate motors at less than 25% of the motor rated speed.

Filtering – The VFD's DC output waveform is typically jagged and can be strongly influenced by the electrical equipment it supplies and the length and type of cables used to supply that equipment. It is important to keep this waveform within a safe range to protect both the VFD and the supplied equipment. External filters can be applied to the line and load side of the VFD to smooth out the DC waveform and protect the system from damage. In general, line side filters protect the VFD while load side filters protect the motor. Load side filters can extend motor life by decreasing bearing wear and by lowering the motor operating temperature. Three common types of load side filters are available today. These are Load Reactors, dV/dT filters, and Sine Wave filters. dV/dT and Sine Wave filters are more effective than Load Reactors at reducing reflected waves and voltage spikes. The use of dV/dT or Sine Wave filters ensures the longevity of the installation by mitigating reflected waves, voltage peaks, and other potentially damaging transient effects. Colmac requires load side dV/dT filters or Sine Wave filters on all VFD applications.

Conclusions

There are many factors that can contribute to the success or failure of VFDs applied to Colmac equipment, most of which are the direct responsibility of the system designer and installing electrical contractor. The general design requirements listed above represent the minimum criteria for proper VFD system design. Care should be taken to follow all the drive manufacturer's recommendations and all applicable electrical codes and standards.

References

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