Suggested Actions

- Obtain information from drive and motor manufacturers about inverter rise times and cable length effects, and use this information to evaluate the ability of existing motors to withstand drive-induced voltage stresses.
- Damaging reflected waves are generally not a problem when the distance between the motor and the drive is less than 15 feet.
- Voltage overshoots are more likely to occur with smaller motors and drives with faster rise times.
- The potential for damaging reflected waves is especially high when multiple motors are run from a single ASD.

Resources

U.S. Department of Energy—For additional information or resources on motor and motor-driven system efficiency improvement measures, visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices, or contact the EERE Information Center at (877) 337-3463.

National Electrical Manufacturers Association (NEMA)—Visit the NEMA Web site at www.nema.org for information on motor standards, application guides, and technical papers.

When Should Inverter-Duty Motors Be Specified?

Electronic adjustable speed drives (ASDs) used to be marketed as "usable with any standard motor." However, premature failures of motor insulation systems began to occur with the introduction of fast-switching pulse-width modulated (PWM) drives. The switching rates of modern power semiconductors can lead to voltage overshoots. These voltage spikes can rapidly damage a motor's insulation system, resulting in premature failure of the motor.

Effects of ASDs on Induction Motors

The non-sinusoidal variable frequency output of PWM drives results in increased motor losses, inadequate ventilation at lower speeds, increased dielectric stresses on motor windings, magnetic noise, and the creation of shaft currents. These effects can combine to damage a motor's insulation and severely shorten a motor's useful operating life.

High switching rates of modern power semiconductors lead to rapid changes in voltage in relatively short periods of time (dv/dt, quantified in units of volts per microsecond). Steep-fronted waves with large dv/dt or very fast rise times lead to voltage overshoots and other power supply problems.

When the motor impedance is larger than the conductor cable impedance, the voltage wave form will reflect at the motor terminals, creating a standing wave (see Figure 1). Longer motor cables favor the formation of higher amplitude standing waves. Voltage spikes have been reported with peak values as high as 2150 volts in a 460 V system operating at 10% over-voltage. High voltage spikes can lead to insulation breakdown, resulting in phase-to-phase or turn-to-turn short circuits, with subsequent over-current trips by the drive sensor.

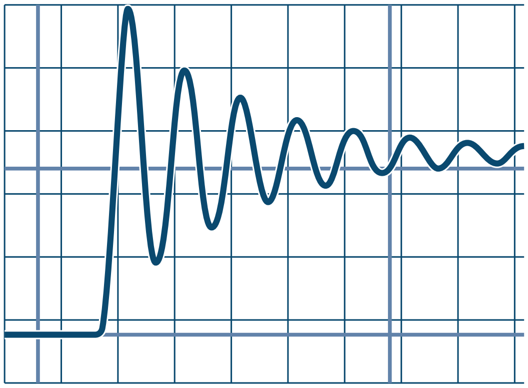

Figure 1. PWM pulse with reflected voltage or ringing

Inverter-Duty Motor Designs

Solutions used to prevent motor failures due to voltage spikes include the use of power conditioning equipment (filters, load reactors, and isolation transformers) and placing restrictions on the distance or lead length between the drive and the motor. Some drive installers also specify oversized motors or high-temperature-resistant Class H insulation.

Inverter-duty motors are wound with voltage spike-resistant, inverter-grade magnet wire to minimize adverse effects of ASD-produced waveforms. Improved insulation systems do not degrade as readily when subjected to transient voltage spikes. A greater thickness or build-up of premium varnish (through multiple dips and bakes) minimizes the potential for internal voids, and a lower heat rise design results in improved resistance to voltage stresses. Quality manufacturing also affects the corona inception voltage (CIV) of a motor. The CIV is a measure of the ability of the motor's windings to withstand voltage stresses and is the voltage at which partial discharges begin to occur.

Many manufacturers offer "inverter-friendly" insulation in their NEMA Premium® motors. These inverter-ready motors are suitable for variable torque loads over a wide speed range. The National Electrical Manufacturers Association (NEMA) specifies that insulation systems for low voltage (<= 600 V) inverter-duty motors be designed to withstand an upper limit of 3.1 times the motor's rated line-to-line voltage. This is equivalent to an upper limit of 1,426 peak volts at the motor terminals for a 460 V rated motor. Rise times must equal or exceed 0.1 microsecond.

The insulation system on a 208/230 volt motor is identical to that of a 460 V motor. Thus, voltage spikes produced by inverters on 208 V or 230 V systems are unlikely to cause insulation damage at any cable length or drive carrier frequency.

Larger inverter-duty motors often have a constant speed auxiliary blower to provide adequate cooling at low motor operating speeds. Above the 500 frame size, inverter-duty motors should have both bearings insulated, and be equipped with a shaft grounding brush with a ground strap from the motor to the drive case.

Motor Selection Guidelines

- NEMA MG 1-2006 Part 30 provides performance standards for general-purpose motors used with ASDs. When operated under usual service conditions, no significant reduction in service life should occur if the peak voltage at the motor terminals is limited to 1000 V and rise times equal or exceed 2 microseconds. Contact the motor manufacturer for guidance relating to motor/drive compatibility when peak voltages or rise times are expected to exceed these limits. A definite-purpose inverter-duty motor and/or filters, chokes, or other voltage conditioning equipment may be required.
- Specify inverter-duty motors when operating at extremely low speeds or when operation over base speed is required.
- When an inverter-duty motor is required, ensure that it is designed and manufactured to meet the most current specifications defined by NEMA MG 1 Section IV, "Performance Standards Applying to All Machines," Part 31 "Definite-Purpose Inverter-Fed Polyphase Motors."

BestPractices is part of the Industrial Technologies Program Industries of the Future strategy, which helps the country's most energy-intensive industries improve their competitiveness. BestPractices brings together emerging technologies and best energy-management practices to help companies begin improving energy efficiency, environmental performance, and productivity right now.

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