SASKATCHEWAN ENERGY MANAGEMENT TASK FORCES

TECHNOLOGY INFORMATION SHEET

ADJUSTABLE SPEED DRIVE MOTORS

Background

Motors operate at relatively constant speed, varying only slightly with load. If the motor speed or torque does not match the load requirements, mechanical or electrical means are generally used to control the output of the driven equipment. Gearboxes, adjustable pulleys, control valves, and eddy-current clutches are relatively inflexible, inefficient means of adjusting drivepower to meet load requirements. If these load requirements are reduced during operation, the efficiency of the motor is reduced.

Adjustable speed drives (ASDs), also known as variable frequency drives (VFDs), can be used to directly control the speed and / or torque output of induction and synchronous motors to precisely match load requirements. The use of an ASD-motor system allows the motor to operate at a higher efficiency than that of a stand-alone motor run at less than full load.

Figure 1 demonstrates the efficiency of the ASD-motor system versus a stand-alone motor at various loading levels.

Types of ASDs

Four basic types of ASDs exist: inverter-based, cyclo-converters, wound-rotor slip recovery, and voltage-level controls. For applications less than 200 HP, inverter-based ASDs predominate.

Four types of inverter-based ASDs are available: current-source inverter (CSI), voltage-source inverter (VSI), load commutated inverter (LCI), and pulse-width modulated (PWM) inverter. The PWM type is becoming increasingly dominant for loads under 200 HP.

How ASDs Work

All inverter-based ASDs have the same basic structure which includes a rectifier, a filter, and an inverter. The rectifier converts three-phase AC power to DC power. The filter smoothes and regulates the voltage and current. The inverter varies the frequency, amplitude, and / or duration of the voltage, and / or current supplied to the motor. This controls the motor speed and torque.

Applications

ASDs do not improve the actual efficiency of the motor. They provide savings by optimizing the motor output / load relation-ship.

For motor systems that operate at or near full-rated output most of the time, ASDs are actually less efficient than the motor alone. Therefore, a determination of the motor duty-load is required to determine whether or not the application of an ASD will result in electrical savings.

Systems that operate on a high-duty cycle (many hours per year), at levels usually throttled from full rated output, are ideal candidates for ASD-motor systems. Systems that routinely vary their output from 10 to 100% are also potential ASD applications. An output profile of any motor should be prepared in order to determine the potential energy savings from the use of an ASD.

It is estimated that 80% of all ASDs presently in use are installed on pumps and fans. HVAC systems are prime candidates for the incorporation of ASD-motor technology due to the varying heating / cooling requirements of most buildings.

The Benefits of ASDs

The benefits of ASDs are best emphasized by the following example: A pumping system consists of a 100 l/s water pump (at full rated output) and a flow control valve controlling the system output by throttling the flow. When the system is pumping at 30 l/s, the system output level is 30% of maximum. The actual motor load is not 30% but closer to 70% (the rate of flow to motor load is not linear). The added energy input by the pump is dissipated as a pressure drop across the control valve.

If the pump in this situation operates at lower than full rated output for a large percentage of its duty cycle, an ASD would be a beneficial energy saving improvement. With the addition of an ASD, the pump motor load would drop from 70% to approximately 4%. The result is a large energy savings and reduced energy costs.

The Cost of ASDs

The cost of ASDs are generally reported on a per HP basis. The costs per HP tend to decrease with increasing motor size. The design and particular application of the ASD has a great impact on its cost. Installation costs can vary widely and therefore wide ranges of installed costs for ASDs are reported. This is especially true for smaller motors where ASD installed costs may range from $500/HP to $1200/HP for a 10 HP motor. For larger motors, the costs per HP decrease rapidly. Reported installed costs per HP for a 100 HP motor range from $250/HP to $500/HP.

The return on investment of an ASD is dependent on the duty cycle of the motor (hours of operation per year), the average loading of the motor, the percentage of time operated at lower than full load, and, of course, the installed cost of the ASD itself. Simple payback times can be well under 2 years for certain applications (e.g. fan motor operating for 6570 hours/year, operating at an average of 60% of rated output, ASD installed cost of $375/HP, and cost of electricity of 6¢/kWh).

Special Points to Note Regarding ASDs

When an induction motor is coupled to an ASD, the torque output is limited by the ASD, not the motor. ASDs are typically oversized to produce comparable starting torque. Equivalent break-down torque and full-load torque are also usually accommodated by the slight oversizing of the ASD.

All mechanical systems have an internal resonance frequency that must be avoided to prevent equipment damage from vibration. This frequency must be determined to prevent the ASD from operating a motor at that frequency for any length of time.

The motor must be compatible with ASDs so that overheating does not occur.

Excessive distances between the ASD and the motor cannot be tolerated. Standing waves created in the cabling can cause voltages to double and stress and insulation failures will result.

Voltage transients may adversely affect motor and cable insulation. Minimizing the cable length linking the ASD and the motor also addresses this problem.

Capacitive coupling can also occur in long cable conduits linking the ASD with the motor. Capacitive coupling is the coupling of the conduit wall with the conductor due to the high frequency switching of the current and/or voltage in the conductor. The currents produced from this effect can produce damaging heat effects. The use of PVC conduit or larger than normal conduit spacing (from wall, other conduits etc.) can prevent this occurrence.

For loads that cycle widely and continually, other motor options are presently available that may better suit such applications. These include switched reluctance motors and electronically commutated permanent magnet motors.

Figure 1: Motor Efficiency (%) vs. Load for ASD-Motor System & Stand-alone Motor