Keep Your Motors Running

By Marty Weil, Contributing Editor

Modern industry has a lot riding on its motors—material handling, flow control, automation, etc.; almost every aspect of production relies on these simple machines. Electronic motors are a critical component in many applications. They are the most recognized prime movers in industry today, and protecting them is serious business, for it is not just the motor that is being protected when the entire operation is at risk.

"Motor protection is required to minimize damage to the motor and associated equipment, enhance safety of personnel in the area of the motors, and maximize productivity," says Scott Lasko, product manager for the Strategy Development Group at Allen-Bradley, Milwaukee.

"In a plant where hundreds of motors are running, saving or extending the life of a motor is a means to an end," Lasko adds. "Our customers are in business to produce a product. If we can keep their motors running and keep them damage free, they can be more effective in their business. That's the bottom line."

So, what causes motors to fail in the first place?

Electric motors can fail for a number of reasons, including the obvious: old age, short circuits, and mechanical problems. Moisture and contamination have also had a hand in the demise of many a good motor. But the real villain—the electromechanical Grim Reaper—is excessive heat.

"The primary cause of motor failure is excessive heat," confirms Paul E. Alwin, manager of strategy development for the Power Components Business at Allen-Bradley. "For instance, when a five-horse motor is asked to drive a 10 horsepower load, the undersized motor will generate damaging amounts of heat."

According to Alwin, excessive heat is the direct result of excess current (current greater than the normal motor full load current), high ambient temperature, and poor ventilation of the motor. In general, a motor protective device alone cannot protect the motor from excessive heat due to all three of those causes. High currents can be caused by massive inertia loads, such as loaded conveyors, locked rotor conditions, low voltage, phase failure, and phase imbalance. If a motor is continuously overheated by only 10°, its life can be reduced by as much as 50%.

WHATEVER COMES YOUR WAY,

PROTECTING YOUR MOTORS

MEANS PROTECTING YOUR BUSINESS.

Extending Motor Life

To extend the life of a motor, protection against the elements that cause its demise must occur before the damage is done. There are varying levels of motor protection, which are based on the application.

"It is important to provide the appropriate type of protection to prevent damage from occurring to a motor," says Alwin. "The majority of the applications require very basic, very reliable motor protection against the most common types of problems, like overloading or long startup time."

Basic overload protection, according to

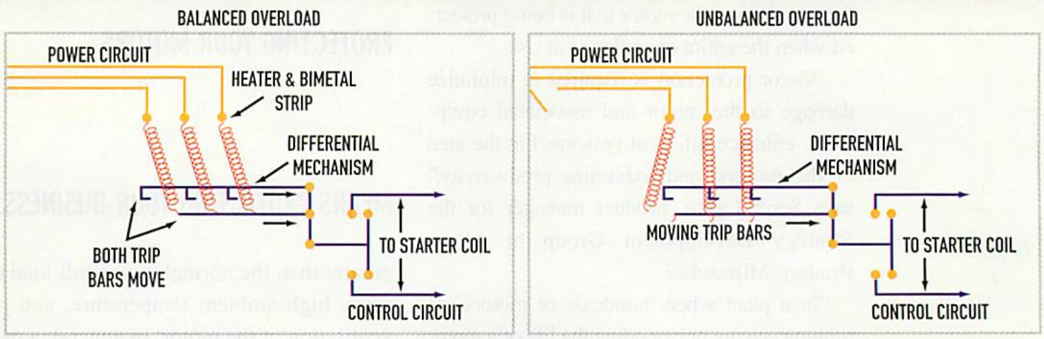
Alwin, calls for the protection of the motor winding against excessive heat. Traditionally, this has been achieved by using a thermal overload relay that includes an on-board heater element that simulates the heating effect the current has on the motor winding. Included in basic overload protection is some form of phase loss protection, normally coming in the form of the overload relay responding to the increase in current caused by the phase loss, which then trips the overload relay.

In the area of overload protection, Allen-Bradley has three basic types of protection. These overload relays are referred to as bimetallic, eutectic alloy, and solid-state.

The bimetallic and eutectic alloy are considered traditional thermal overload relays, as they use the current passing through them to generate heat, which in turn causes the overload trip.

The most common relay, the bimetal overload relay, works on the principle that current is passed through a heater element that is wrapped around a bimetallic strip. As the heater warms up, it causes the bimetal to expand at different rates causing a deflection, similar to the way a thermostat works (Figure 1).

Figure 1: Bimetal Overload Relay Operation



The most common relay, the bimetal overload relay, works on the principle that current is passed through a heater element that is wrapped around a bimetallic strip. As the heater warms up, it causes the bimetal to expand at different rates, causing a deflection, similar to the way a thermostat works.

The eutectic alloy overload relay, on the other hand, relies on a eutectic alloy heater element. When a predetermined temperature is reached, the eutectic alloy changes from a solid to a liquid, thus allowing an imbedded spindle to turn freely and trip the overload relay (Figure 2). Eutectic alloy overload relays respond to phase loss by measuring the heat generated in the remaining legs of the overload relays. Since any element can trip the overload relay, there is no loss of functionality under phase loss conditions.

"With the application of traditional thermal overload relays, the motor is protected against the damage that occurs when current increases within the motor," says Lasko. "These traditional overload relays are a reactive device responding to the over-current situation. When conditions like phase losses occur, the overload relay reacts to the increase in current and not the condition itself."

The Solid State of the Art

Unlike the traditional thermal overload relays, solid state overload relays do not generate heat to model the windings within the motor; rather they measure the current or change of resistance to create their protective functionality. In addition, the solid state overload relay offers a variety of current sensing and protective operations that provide additional benefits that go beyond what is available with typical bimetallic and eutectic alloy electromechanical overload relays.

"With the coming of age of solid state overload relays, we are at the threshold of a new era," says Lasko. "Because solid state relays have become more affordable, the level of motor protection now available to the average user is at an all-time high. In regard to phase loss, for example, up until a few years ago you had to buy a specific phase loss overload relay that was several hundred dollars or more to protect against phase loss. That's no longer necessary."

The use of electronic components, whether they be discrete or integrated solid-state electronics, in the construction of overload relays has resulted in enhanced protection, improved features and communications capabilities including increased accuracy and repeatability, lower heat generation and energy usage, wide current adjustment range, selectable trip class, and control functions. Furthermore, many solid-state motor protective devices provide communication capabilities that enable users to control and monitor process elements to maximize productivity and optimize manufacturing processes.

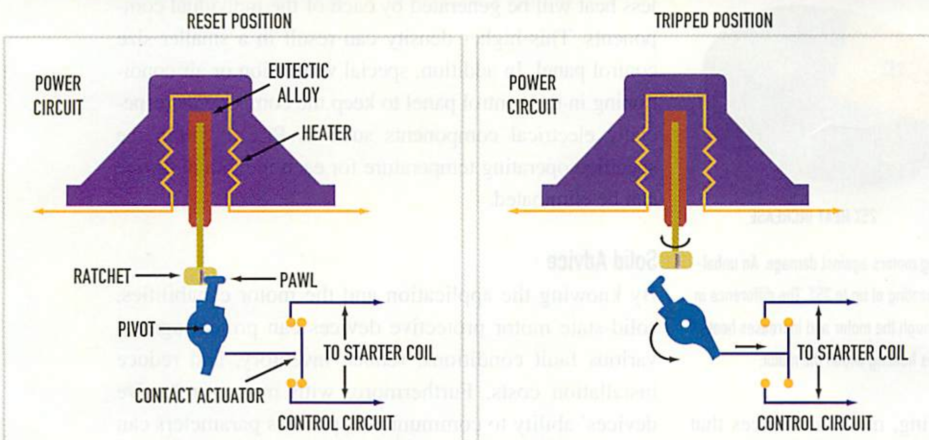
"The solid state device, through its advanced communications, provides unique intelligence capabilities," says Allen-Bradley's Alwin. "For instance, in the past, with an electromechanical device, if an overload current was produced, the motor protection device tripped and caused the motor to shut off. With solid state devices, it is now possible to set warning levels that alert the supervisor to a potentially bad condition. The decision to stop the motor is now in the hands of the supervisor."

"For example," Alwin continues, "during the process of filling a holding tank, the motor must continue—even if it is going to overheat—to avoid overflowing the tank. However, the supervisor will want to know about the situation, so that it can be remedied during scheduled maintenance."

Lasko amplifies Alwin's remarks. "Solid-state technology does more than bring better protection and faster response to motor protective overload relays. It makes it possible to design user-programmable features into the solid-state motor protective device, so users can tell the device what they want it to do. Additionally, solid-state technology makes communication possible, enabling programmable controllers to monitor and control the motor protective device, to protect motors and avoid costly downtime."

Lasko adds. "The use of solid-state electronic components in overload relays has led to protective and communications features for these devices that go beyond what is available with typical bimetallic and eutectic alloy electromechanical overload relays. The resulting energy savings and improved maintenance possible with these devices help maximize the automation investment."

Figure 2: Eutectic Overload Relay Operation



The eutectic alloy overload relay relies on a eutectic alloy heater element. When a predetermined temperature is reached, the eutectic alloy changes from a solid to a liquid, thus allowing an imbedded spindle to turn freely and trip the overload relay. Eutectic alloy overload relays respond to phase loss by measuring the heat generated in the remaining legs of the overload relays. Since any element can trip the overload relay, there is no loss of functionality under phase loss conditions.

Smart Motor Protection

A starter or motor protective device's ability to communicate information back to a main processor or controller provides a complete spectrum of new opportunities to optimize processes and maximize productivity. The degree to which productivity can be maximized and processes can be optimized is based on the process conditions that can be communicated from the starter to the main controller, whether it be a PLC or a PC.

Solid-state motor protective devices typically provide a metering or display function to communicate real-time application parameters and store statistical information to provide historical data regarding the application. Communication through a network bus to a PLC or PC is the most common form of communication. Others methods include display of data on an LCD on the motor protective device itself; LCD or LED display on an interface module that might be mounted in the door of an enclosure; or the communication may occur in the form of LEDs or flashing LEDs on the motor protective device, which provide some coded information as to the information that is being communicated.

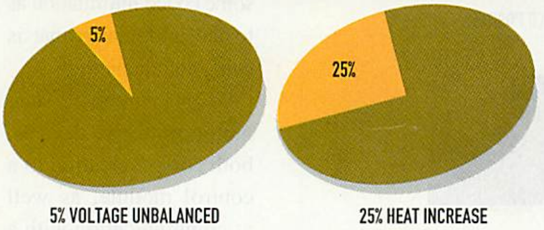
With many solid-state motor protective devices, both communication to a control module, as well as communication with a PLC, can take place simultaneously.

"There is a wide variety of information that can be communicated from a motor protective device to a controller; however, there are types of data needed by virtually all users," says Lasko. "This data typically provides actual information on the average motor current, the status of output contacts or relays associated with the motor protective devices, and device settings; for example, the full load current setting and the percent thermal capacity of the motor protective device. Percent thermal capacity is an indication of how near the device is to tripping due to an overcurrent condition. To provide information to personnel managing an application, motor protective devices also typically communicate the fault type; in other words, why the device tripped and the amount of time that will be required to pass before it can be reset and the starter energized, returning the motor to service."

To maximize the productivity of a particular application, according to Allen-Bradley's Lasko, the data that can be communicated by the motor protective device can be utilized to monitor and manage the process to prevent conditions where the device would trip, interrupting the production. Many motor protective devices have pre-warning levels that are associated with the various causes of trip conditions. These prewarning levels may be for ground fault conditions, starting time conditions, phase imbalance conditions, underload conditions, and high overload or jam conditions. These pre-warning levels can be assigned to output relays that energize alarms or provide information to process operators advising them to change the flow rate or process rate of the application to prevent the motor protective device from tripping. This process modification may include slowing down a conveyor system, reducing the flow rate in a pumping system, unplugging or cleaning a filter, replacing bearings or belts, and replacing cutting tools.

For its part, Allen-Bradley has introduced the Smart Motor Protector (SMP) family of solid-state overload relays. The SMPs are space-saving, modular devices that provide basic to advanced motor protection for a wide range of motor starting applications. Compatible with both NEMA and IEC contactors, SMP overload relays are available for NEMA size 00 to 6 starters and IEC 5 ampere to 600 ampere starters.

Figure 3: Voltage Unbalanced



Voltage unbalance is a concern when protecting motors against damage. An unbalance of 5% can cause an effective increase in heating of up to 25%. The difference in voltage causes an unbalanced current flow through the motor and increases heating in one of the windings. This increase causes heating within the motor.

The solid-state design of the three-member SMP overload relay family enables each device to provide a broader range of protective functions and features than traditional bimetallic and eutectic alloy overload relays.

Incorporating an application-specific integrated circuit (ASIC) to optimize size and performance, the SMP-1 and SMP-2 overload relays are self-powered devices and feature wide current adjustment range, choice of manual or automatic reset versions, and phase loss protection. All SMP overload relays will trip within two seconds after a phase loss when the motor is fully loaded. The SMP-3 overload relay design features an on-board microprocessor, fault indicating LEDs, and communications capability.

SMP overload relays can be mounted directly on IEC contactors rated up to 180 amperes for easy installation and space savings, and are integral components of fully assembled NEMA starters.

Turning Down the Heat

Another benefit of solid-state motor protective devices is energy savings. "Because traditional overload relays work on the principle of modeling the heat generated in the motor by generating the same heat in the heater element or bimetallic element, a significant amount of energy is wasted," says Lasko. "In traditional overload relays, as many as six watts of heat are dissipated to perform the protective function. Because solid-state motor protective devices use sampling techniques to measure the actual current flowing in the circuit, very little heat is dissipated. Solid-state motor protective devices generate as little as 150 milliwatts of heat."

According to Lasko, this reduction in heat generation both reduces the total amount of electrical energy consumed in an application or a process and can have a dramatic impact on the design and layout of control panels. The density of motor starters can be much greater, because less heat will be generated by each of the individual components. This higher density can result in a smaller size control panel. In addition, special ventilation or air conditioning in the control panel to keep the components (especially electrical components such as PLCs) within the specified operating temperature for each individual device can be eliminated.

Solid Advice

By knowing the application and the motor capabilities, solid-state motor protective devices can protect against various fault conditions, reduce inventory, and reduce installation costs. Furthermore, with motor protective devices' ability to communicate, process parameters can be monitored to maximize productivity, optimize processes, and optimize motor utilization.

However, as explained, there is more to motor protection than solid-state devices. Complete protection includes the coordination of over-current protection and short-circuit protection. The options available are multiple, and the best choice is to select the levels and types of protection that best meets the specific application.

Protecting motors against damage can be achieved with the functionality that electronics now provide in solid-state motor protective devices. By measuring parameters such as current and temperature and phase imbalance, damage to the motor's stator and rotor can be prevented. These measurements also can provide an early warning that there may be trouble with another part of the mechanical system, such as conveyors, belts, gears, and bearings. Accurate motor protection is important because, the replacing of motors, especially large motors, is expensive, and users generally want to avoid replacing motors at all reasonable costs.

"Protecting personnel in the area of the motor is equally important," says Alwin. "This involves protecting them against ground faults inside the motor, high overload conditions, and preventing the incorrect direction of rotation of the motor."

Finally, accurate motor protection can maximize productivity in any application. Productivity is maximized by ensuring that the motor is always running, and that actions are taken, when practical, to prevent the motor protective device from tripping at a critical stage in a process or when the motor isn't actually being damaged. A·BJ