**Electronic vs. Electromechanical Overload Relays**

Application Note

New Information
August 2007

**Introduction**

The use of electronic components in the construction of overload relays has resulted in enhanced protection, improved features and communications not available with typical bimetallic and eutectic alloy electromechanical overload relays.

Enhanced protection includes:
- Phase loss protection
- Phase imbalance
- Phase sequence

Improved features from electronics include:
- Increased accuracy and repeatability
- Lower heat generation and energy usage
- Wide current adjustment range
- Selectable trip class
- Control functions
- Less inventory

Finally, many electronic overload relays provide communication capabilities that enable users to control and monitor process elements to maximize productivity and optimize manufacturing processes.

Electronic overload relays addressed in this document include motor protective devices that are an integral part of a motor starter, and stand-alone devices that are installed separately on a control panel or in an enclosure door, but used in conjunction with a contactor.

**Importance of Motor Protection**

The proper protection of motors is required to:
- Minimize damage to the motor and associated equipment
- Enhance safety of personnel in the area of the motors
- Maximize productivity

All of these areas are affected not only by the motor itself and the application, but also by the environment in which the motor is installed.

Electric motors are a critical component in many applications. Motors fail for a number of reasons, including:
- Excessive heat, moisture and contamination
- Short circuits
- Mechanical problems
- Old age

The primary cause of motor failure is excessive heat, which is caused by excess current (current greater than the normal motor full load current), high ambient temperatures and poor ventilation of the motor. In general, a single motor protective device alone cannot protect the motor from excessive heat due to all three of those causes. Currents greater than normal motor full load current can be caused by high inertia loads, such as loaded conveyors, locked rotor conditions, low voltage, phase failure and phase imbalance. **Figure 1** shows the reduced life of a motor at various levels of overtemperature. If a motor is continuously overheated by only 18°F, its life can be reduced by as much as 50%.
All of these problems can be accounted for and measured to provide the very highest level of protection to the motor, so that the motor achieves the longest possible electrical and mechanical life in the application. Protecting motors against these various problems can be achieved with the functionality that electronic overload relays now provide. By measuring parameters such as current, temperature and phase imbalance, damage to the motor’s stator and rotor can be prevented, as well as providing an early warning that there may be trouble with another part of the mechanical system, such as conveyors, belts, gears and bearings. The accurate protection of motors is important because the replacement of motors, especially large motors, is expensive, and users generally want to avoid replacing motors.

Protective Functions

Solid-state electronics in overload relays not only provide traditional overload protection against the overcurrents that the motor is subjected to, but they also provide more information and protection against other fault conditions. Enhanced protection from the electronics includes:

- Phase loss
- Phase imbalance
- Overtemperature protection

This enhanced protection and increased functionality enables customers to more accurately and effectively protect motors in critical and special applications (for example, motors with long run-up times). Additionally, data collected by the overload can be utilized to improve the performance of the process.

Phase Loss Protection

Under a phase loss condition, the motor current in the remaining two phases of a fully loaded motor increases to 1.73 times the normal motor full load current. A phase loss can occur due to a blown fuse or a poor electrical connection. With electronic overload relays, the device can be designed so that it will trip, dropping out the starter within a 2 second period of time, providing improved protection to the motor. Traditional electromechanical overload relays may take 40 seconds or longer after a phase loss before the heat generated in the bimetals or the eutectic alloy heater element is sufficient to cause the overload relay to trip. See Figure 2 for a comparison of trip times under phase loss conditions.
Phase Imbalance Protection

Electronic overload relays also have the ability to sense phase imbalance, which also causes an increase in current in the motor. A phase imbalance of only 5% requires a reduction in the permissible motor output of 25%. In other words, a 5% phase imbalance (for example Phase A 438V, Phase B 438V, and Phase C 460V), would require a 10 horsepower motor to be derated to 7-1/2 hp. Therefore, very small phase imbalances cannot be tolerated because damage to the motor may occur, or the required output of the motor may not be achieved. Figure 3 shows the decrease in motor output for an increase in phase imbalance.

![Figure 3. Reduction in Motor Output Due to Phase Imbalance](image)

\[ F_R \] Reduction Factor for Motor Output

\( \Delta \mu \): Voltage Imbalance in %

Overtemperature Protection

Motor failure is most often caused by excessive heat. However, excessive heat is not only caused by increases in current, but it can also occur for other reasons, such as the ambient environment around the motor. Severe ambient conditions where there may not be sufficient ventilation to the motor or where severe changes occur in the ambient temperature would be applications where sensing only current would not be sufficient to properly protect the motor. In these types of applications, a temperature input from a positive temperature coefficient sensor or a resistance temperature detector (both of which are embedded in the motor windings) can be utilized to provide temperature input to the electronic overload relay. This additional information, utilized in conjunction with the motor current, will properly protect the motor even when there may not be sufficient cooling.

All of the functions discussed are functions that were previously available from other control panel components used with the electromechanical overload relays. The electronic overload relay eliminates the need for many of these extra control panel components which increases the system reliability because there are fewer components in the system that can fail. Additionally, installation costs can be reduced because there are fewer points to wire between, there are fewer components to install on the control panel, and the panels can become physically smaller because the protective functions are incorporated into another device, thereby freeing up valuable panel space and space on the machines required to support the control panel.

Product Features

The use of electronic overload relays not only enhances motor protective functions, but it also provides a number of improved features including:

- Selectable trip class
- Increased setting and repeat trip accuracy
- Wider current adjustment range
- Reduced energy consumption
- Control functions
### Selectable Trip Class

Electronic overload relays enable selectable trip class to be incorporated into its design. Selectable trip class can be in the form of selecting Class 5, 10, 15, 20 as with traditional overload relays; or with some microprocessor-based products, the selectable trip class is virtually infinite where the trip time of the motor protective device can be programmed to any specific time that is suitable for the application, whether it be 1 second, 10 seconds, 17 seconds or 99 seconds. With traditional electromechanical overload relays, individual heater elements with specific trip classes must be purchased separately, in addition to the overload relay, to obtain selectable trip class. The primary advantage of the selectable trip class is that customers can minimize their stock, and utilize a single overload relay for standard motor starting applications as well as special motor starting applications where there might be a long motor starting time that would require a slower trip class. An example of this type of application would be a centrifuge, or a pump that was required to pump a very thick fluid.

### Setting and Repeat Tripping Accuracy

Electronic overload relays also provide increased setting and repeat tripping accuracy. Traditional electromechanical overload relays have setting accuracies between 10 and 15%. Electronic overloads, on the other hand, can offer setting and repeat tripping accuracies of 2.5%. Setting the overload protective device is typically accomplished by using potentiometers, DIP switches or keypad entry. Repeat accuracy of electronic overload relays can be as low as 1%, and is achieved by precise manufacturing tolerances of the various electronic components which include resistors, capacitors, transistors, ASICs and microprocessors.

### Wide Current Adjustment Range

As compared to the electromechanical type, electronic overload relays have a wide current adjustment range. Traditional bimetallic overload relays have an adjustment range of 1.5 to 1. This means that the maximum setting of the bimetallic overload relay is generally 1.5 times the lower setting. On a typical overload relay that has a 10 ampere minimum current setting, the maximum setting of that overload relay is generally 15 amperes. Eutectic alloy overload relays have much smaller current ranges for each heater element (typically 1.1 to 1). For example, a Size 1 starter requires 54 heater elements to cover a current range of 0.2 amperes to 27 amperes. Electronic overload relays have adjustment ranges anywhere from 3.2 to 1 up to 9 to 1. This provides users of overload relays a real benefit and enables them to dramatically reduce their stocks. When an electronic overload relay has a 5 to 1 adjustment range, customers can reduce their stocks by up to 60%, because 5 electromechanical overload relays can be replaced with a single electronic device.

### Cost Savings

#### Energy Savings

In today’s energy-conscious environment, a benefit of electronic overload relays is the energy savings gained. Energy consumption is the second largest operating expense in a plant (after raw materials), and thus optimizing the energy consumption of motors is a logical starting point for improvement. By integrating smart motor controls to monitor energy consumption, the factory can remove wasteful energy expenditure, prevent unplanned downtime, and improve overall operational efficiency. Additionally, with the recent amendment to the U.S. Government’s Energy Policy Act (EPAct) in 2005, tax incentives are being offered for implementation of certain energy-savings measures.
Table 1 and Table 2 show the cost savings that can be realized for an individual IEC or NEMA motor starter when utilizing an electronic overload. Obviously, the cost savings realized depends on the number of hours in a year that the motor is operated, and also on the cost of electricity per kilowatt hour. Typical rates for electricity range from $0.03/kilowatt hour to $0.10/kilowatt hour. As shown in Table 1, as much as a $3.51 cost savings per year can be achieved by utilizing an electronic overload instead of an IEC bimetallic overload relay. When using a NEMA starter with an electronic overload relay, as much as a $7.11 cost savings per year can be achieved. While these individual savings per motor starter are not great, many plants have hundreds or even thousands of motor starters. Over a period of 1 year, or the life of a machine (which can be as long as 7 to 20 years), substantial cost savings can be realized by using an electronic overload relay.

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<tr>
<th>Motor Operating Hours per Year (Hours per Day)</th>
<th>Electricity Cost</th>
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<td>$0.03/ hWHR</td>
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<td>$0.09/ hWHR</td>
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<td>$0.10/ hWHR</td>
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<td>2,000 (8)</td>
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<tr>
<td>3,000 (12)</td>
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<td>4,000 (16)</td>
<td>$0.70</td>
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<tr>
<td>5,000 (20)</td>
<td>$0.88</td>
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<td>6,000 (24)</td>
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250 days per year.

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250 days per year.
Special Control Applications

Motor starters that incorporate electronic overload relays are extremely well-suited for special motor applications, those applications that require different performance than typical direct on-line motor starting. These applications include wye-delta applications, and also special control requirements such as emergency starting, warm starting and monitoring starting time of a motor.

In wye-delta starting applications, electronic overload relays can be programmed to switch from a wye to a delta wiring configuration as soon as the starting current has dropped to the rated value and the motor has reached its normal speed in the wye configuration. Figure 4 is a diagram showing a wye-delta starting application and shows the motor current over time in the various configurations and when the changeover would take place from the wye operation to the delta operation. This changeover can be achieved with programmed relay outputs.

Figure 4. Diagram of Wye-Delta Starting

The programmability of some electronic overload relays also provides a great deal of flexibility to vary the current levels of both the wye and the delta configuration as well as the starting time. Additionally, if starting has not been completed within the normal time for the application (the maximum wye operation), a change to the delta operation can be made, regardless of the speed attained. In summary, the electronic overload relay is providing the performance and functionality of separate wye-delta timers that would be required in the automatic operation of wye-delta starters.

Another control function that electronic motor protection relays can provide is limiting the number of starts per a specific period of time. Figure 5 demonstrates time current characteristics of limiting the number of starts of a given motor. Configuration of the motor protective device includes setting the rated current, setting the minimum required time before a first warm start is possible, and setting a required minimum waiting time between two or more warm starts. As this function does add extra stress to the motor, it is imperative that the motor manufacturer’s instructions be complied with for restarting the motor under warm start conditions.

Figure 5. Limited Number of Starts per Hour

Applications where limiting the number of starts per hour is required would include those applications where the motor does not have a significant amount of reserve capacity and is extremely sensitive to overtemperature that could result in severe damage to the motor. In many critical process applications, the ability to restart a motor even after an overload condition is mandatory. Restarting the motor is required to ensure that a process is not interrupted for too long a period of time such that the material being produced is not ruined. Other applications where the warm start of a motor is required are mines and tunnels where fresh air is always required. With the ability to set various starting characteristics, the motor protective device can be configured to allow the necessary inrush current, starting time and heat generation that would be required to get the motor started and prevent the relay from nuisance tripping. Figure 6 shows current and temperature curves for warm and cold starts of a motor over a given period of time.

Figure 6. Current and Temperature Curves for Warm and Cold Starts and Tripping Limits

Similar to the warm start characteristics of the motor, there may also be installations where emergency starting of a motor is required even though the overload relay has tripped due to an overcurrent condition.
Communication

A starter’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 parameters or process conditions that can be communicated from the starter to the main controller, whether it be a programmable logic controller or a personal computer.

Electronic overload relays typically provide a metering or display function to communicate real-time application parameters, and also store statistical information to provide historical data regarding the application.

There is a wide variety of information that can be communicated from an overload relay to a PLC; however there are more typical pieces of data that are utilized by virtually all users. This data provides actual information about the application and typically includes the average motor current, the status of output contacts or relays and device settings; for example, the full load current setting, and the percent thermal capacity of the overload relay. 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, overload relays 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, the data that can be communicated by the overload relay can be utilized to monitor and manage the process to prevent conditions where the device would trip. Many motor protective devices have pre-warning levels that are associated with the various causes of trip conditions. These pre-warning levels may be for starting time conditions, phase imbalance conditions, underload conditions and high overload 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
- Replacing cutting tools

An electronic overload can often communicate important system data to a remote monitoring center via a variety of different fieldbus protocols, including:

- EtherNet/IP™
- Modbus®
- PROFIBUS®
- DeviceNet™

An electronic overload relay with a full blown microprocessor can provide a large amount of diagnostic and operating data to help minimize downtime and anticipate motor issues. This data is often available via both communications and a flashing LED (if communications is not used). The flashing LED provides application parameters, diagnostics and device settings to simplify troubleshooting, maintenance and improve application and process management. All this and more is available if communications is used to monitor data.

For applications using communications, a solid-state overload may be able to provide any or all of the following data:

1. A status bit for all possible faults
2. Fault code
3. Motor current in many formats: % FLA, floating point and scaled decimal value — this is actual motor current measured by CTs, unlike traditional eutectic alloy overload relays that indirectly model motor temperature.
4. % thermal capacity
5. Control voltage
6. Motor warnings
7. Field wiring status in a motor control center
8. Breaker status
9. Operating status bits
10. Last 10 faults

Having an electronic overload relay can vastly improve the amount of data you have access to, allowing you to better monitor the actual motor application parameters and maximize productivity.

Conclusion

Electronic overload relays are available in different forms: some devices are starter-mounted and others are panel-mounted devices used in conjunction with contactors. Available products have a wide variety of protective functions, features and communication capabilities. Although the products are not difficult to apply, the key to effectively using these products is knowing the application. By knowing the application and the motor capabilities, electronic overload relays can protect against various fault conditions, reduce inventory and reduce installation costs. Furthermore, with their ability to communicate, electronic overload relays can monitor process parameters to maximize productivity, optimize processes and optimize motor utilization.