Allen–Bradley Solid State Motor Protective Devices: Solid State Motor Protective Devices vs. Electromechanical Overload Relays

Rockwell Automation

A Review of Protective Functions, Features, Communications, and User Benefits

Table of Contents

Introduction

The use of electronic components, whether they be discrete or integrated solid state electronics (ASICs or microprocessors), in the construction of overload relays has resulted in enhanced protection, improved features, and communications being offered by those products. These characteristics are not available with typical bimetallic and eutectic alloy electromechanical overload relays. Because many solid state overload relays provide much more than basic overload protection, these devices will be referred to as solid state motor protective devices in the remainder of this document. Enhanced protection, improved features, and communication are very broad categories of benefits provided by solid state motor protective devices. Enhanced protection includes:

- phase loss protection
- phase imbalance
- phase sequence
- jam protection
- ground fault (earth fault) protection

Improved features from electronics include:

- increased accuracy and repeatability
- lower heat generation and energy usage
- wide current adjustment range
- selectable trip class
- control functions

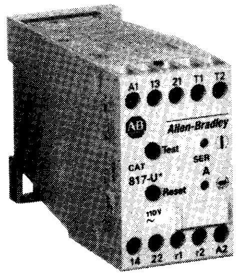
Finally, many solid state motor protective devices provide communication capabilities that enable users to control and monitor process elements to maximize productivity and optimize manufacturing processes.

Solid state motor protective devices 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.

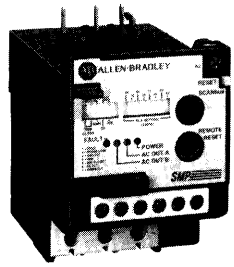
This paper identifies and describes enhanced protection, improved features, and communications in detail and describes typical applications where the benefits of solid state motor protective devices can be realized.

Typical Motor Protective Devices

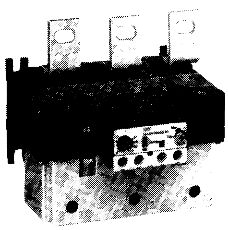
Solid State Motor Protective Devices



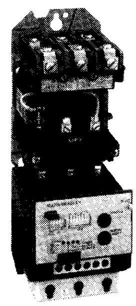
Thermistor Relay



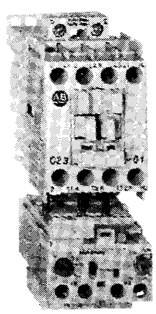
IEC Solid State
Motor Protective Device
with Communication



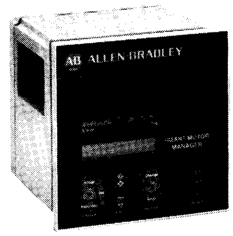
Solid State Motor
Protective Device with
Selectable Trip Class



NEMA Starter with
Communications

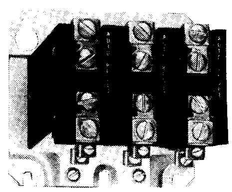


IEC Starter with Solid State
Motor Protective Device

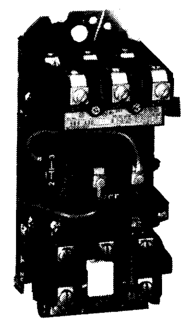


Stand-alone Advanced Solid
State Motor Protective Device

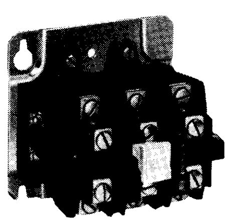
Electromechanical Overload Relays



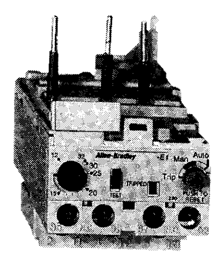
NEMA Bimetallic
Overload Relay



NEMA Starter with Eutectic
Alloy Overload Relay



NEMA Eutectic Alloy
Overload Relay



IEC Bimetallic
Overload Relay

Importance of Motor Protection

Before addressing each of the specific issues associated with enhanced protection, improved features, and communication, it is important to recognize why motors must be accurately protected. 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

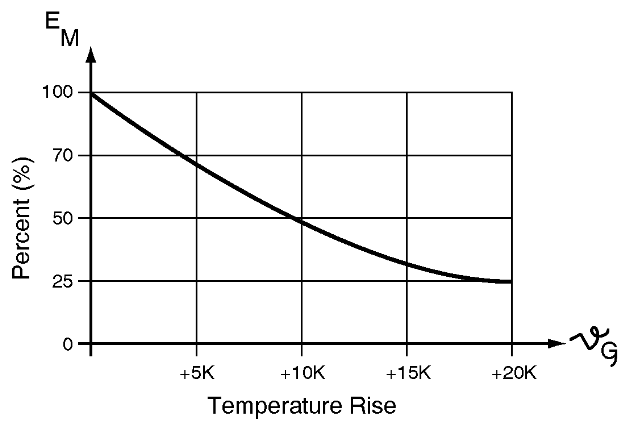
All of these areas are affected not only by the motor itself and the application, but also by the environment in which the motor is installed.

Electric motors are a critical component in many applications; they are the most recognized prime movers in industry today. 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 over-temperature. If a motor is continuously overheated by only ten (10) degrees, its life can be reduced by as much as 50%.

Figure 1 Reduction in Average Life of a Motor, E_M, When the Winding is Continuously Overheated



ϑ_G : Temperature limit of the insulation

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 electronics now provide in solid state motor protective devices. 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 at all reasonable costs.

Enhanced protection of personnel in the area of the motor is equally as important as protecting the motor against damage. Enhanced protection of personnel in the area of the motor includes protecting them against ground faults inside the motor, high overload (jam) 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.

Construction of Solid State Motor Protective Devices vs. Electromechanical Overload Relays

There are significant differences in the construction and the performance of electromechanical overload relays and solid state motor protective devices that must be addressed to identify the benefits that solid state motor protective devices can provide. These differences include the principles of operation of the two types of devices, the reduced heat dissipation, and the energy savings that can be realized with solid state motor protective devices.

Traditional electromechanical overload relays (eutectic alloy or bimetallic) do not measure current directly. These devices operate by passing current through a heater element, which simulates the actual heating effect that is taking place in the motor. During overload conditions, the heat generated within the heater element reaches a level that causes a mechanism to operate and an auxiliary contact to open. In typical installations, the contactor coil is wired in series with this contact. When the auxiliary contact opens, the contactor is de-energized, removing current from the motor.

Solid state motor protective devices, on the other hand, actually do measure current directly. Current can be measured in a variety of ways, but the most typical method of measuring current is using current transformers. Once an overload condition is reached, the electronic circuit of the motor protective device operates due to the increased level of current, causing a contact to open (similar to the electromechanical overload relay), de-energizing the contactor and removing current from the motor.

Protective Functions

Solid state electronics in motor protective devices 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
- jam protection
- ground fault (earth fault) protection
- underload protection
- over-temperature protection

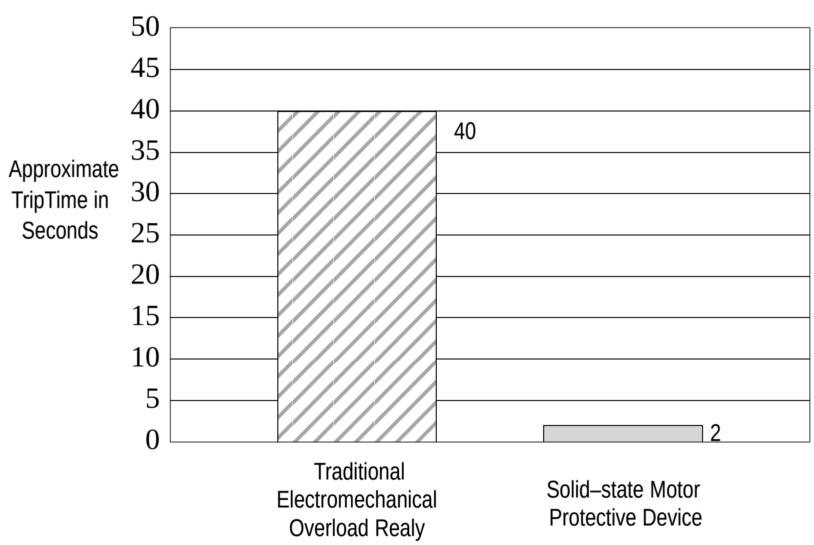
This enhanced protection and increased functionality enables customers to more accurately and effectively protect motors in critical and special applications (for example, motors with long run-up times). Additionally, data collected by the solid state motor protective device can be utilized to improve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

Solid state motor protective devices can monitor phase current that is used to provide phase loss and phase imbalance protection.

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 solid state electronics in the motor protective device, the device can be designed so that it will trip, dropping out the starter within a 2 second period of time, thereby 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. Increased temperature of the motor due to the resulting increase in current as a result of phase loss will eventually reduce the motor's life.

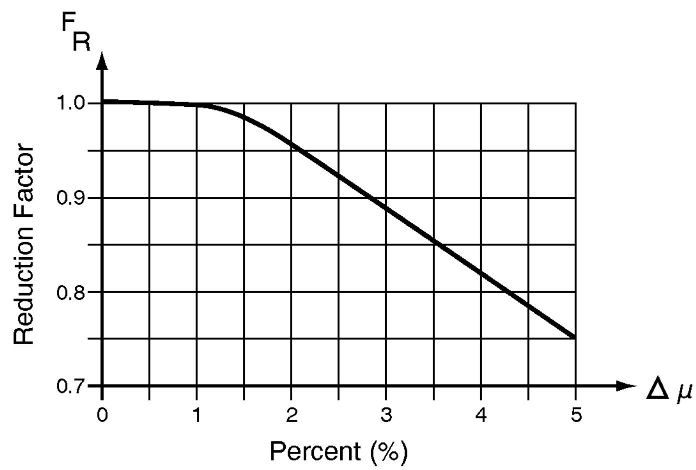
Figure 2 – Comparison of Single Phase Trip Times under Full Load Current Conditions



Phase Imbalance Protection

Solid state motor protective devices 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 7.5 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

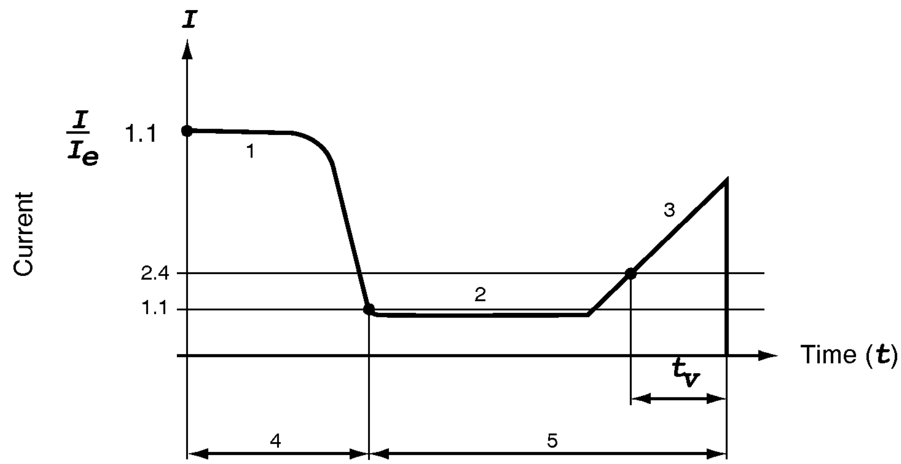


$\Delta\mu$: Voltage imbalance in % F_R: Reduction Factor For Motor Output

Jam Protection

A solid state motor protective device's ability to sense and respond to motor jam conditions or extremely high overload conditions also provides enhanced protection to the motor. A high overload or jam condition can put unnecessary mechanical and thermal loading on the motor and the transmission elements and might occur when a bearing seizes or parts are jammed in a conveyor. By sensing this jam current, the motor can be taken offline to prevent damage to components in the mechanical system. Jam protection is particularly useful in applications such as conveying systems, mills, mixers, crushers, and saws. Figure 4 is a graphical representation of the time-current characteristics of jam protection. After the motor is up to speed and drawing normal motor full load current, a sudden increase in current (due to a jam condition) causes the motor protective device to trip.

Figure 4 High Overload/Jam Protection



Period 1: Motor Start, I ≥ 1.1Ie

Period 2: Normal Operation

Period 3: High Overload/Jam (tripping threshold)

t_V: Tripping Delay

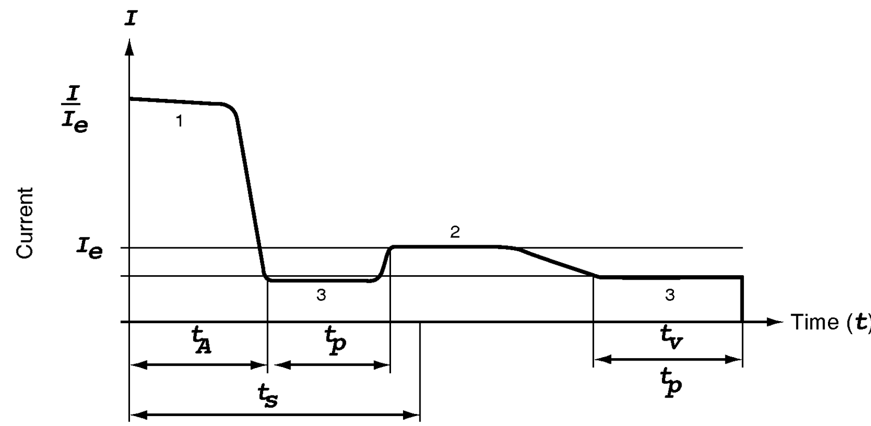
Period 4: High Overload/Jam Protection Inactive

Period 5: High Overload/Jam Protection Active

Underload Protection

A somewhat unique function that solid state motor protective devices can provide is underload protection. Motors (for example, fans, submersible pumps, etc.) that are cooled by the medium handled (such as air, water, etc.) can become overheated in spite of being underloaded by the absence of the medium or insufficient medium (for instance, clogged filters or closed valves). Often times, these machines are installed in inaccessible places, making repair time consuming and expensive. An underload, represented by the consumption of less than normal motor full load current, may indicate that there is a mechanical defect in the installation (torn conveyor belt, damaged fan blades, broken shafts, or worn tools). Such conditions may not harm the motor, but they do lead to loss of production or an interrupted production process. Rapid detection by the motor protective device helps to minimize both the damage and the downtime in these applications. Figure 5 is a graphical representation of what an underload condition would look like as a function of time and current.

Figure 5 Underload Protection



Period 1: Start
Period 2: Normal Operation
Period 3: Underload Operation
t_A: Motor Starting Time

I_T: Tripping Threshold
t_S: Underload Protection Inactive
t_V: Tripping Delay
t_p: Warning

Ground Fault (Earth Fault) Protection

For increased safety of personnel in the area of motors and equipment, solid state motor protective devices can also provide ground fault protection. Ground faults in the motor occur when the insulation of the motor windings is damaged. Insulation can be damaged by high voltage surges (from lightning strikes, switching operations in the network, capacitor discharges, and power electronics equipment), age, and sustained or cyclic overloading or overheating of the motor and its windings. Additionally, motor insulation can be damaged by mechanical vibration and the entry of foreign objects into the motor, such as dust particles. In these instances, leakage to ground can occur. In grounded systems, the fault current can rise rapidly to a very high level, ultimately turning into a short circuit current. Solid state motor protective devices can sense ground fault currents before they rise to dangerous short circuit fault levels, and switch the motor offline before severe damage or severe injury to personnel occurs.

Over-temperature 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 motor protective device. This additional information, utilized in conjunction with the motor current, will properly protect the motor even when there may not be sufficient cooling.

In conclusion, all of the functions discussed in this section of the paper are functions that were previously available from other sorts of control panel components used with electromechanical overload relays or utilizing redundant components. The use of electronics in motor protective devices eliminates the need for many of these extra control panel components. The elimination of these other panel components 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 electronics in motor protective devices not only enhances motor protective functions, but it also provides a number of improved features offered by the motor protective device, including:

- selectable trip class
- increased setting and repeat trip accuracy
- wider current adjustment range
- reduced energy consumption
- control functions

Selectable Trip Class

Solid state electronics incorporated in the motor protective device enables selectable trip class to be incorporated into its design. Selectable trip class can be in the form of selecting Class 10, 20, or 30, 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 motor protective device 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

Solid state motor protective devices also provide increased setting and repeat tripping accuracy. Traditional electromechanical overload relays have setting accuracies between 10–15%. Electronic motor protective devices, 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 motor protective devices can be as low as 1%, and is achieved by precise manufacturing tolerances of the various electronic components that make up motor protective devices, which include resistors, capacitors, transistors, ASICs, and microprocessors.

Wide Current Adjustment Range

Solid state motor protective devices have a wide current adjustment range compared to electromechanical overload relays. 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.

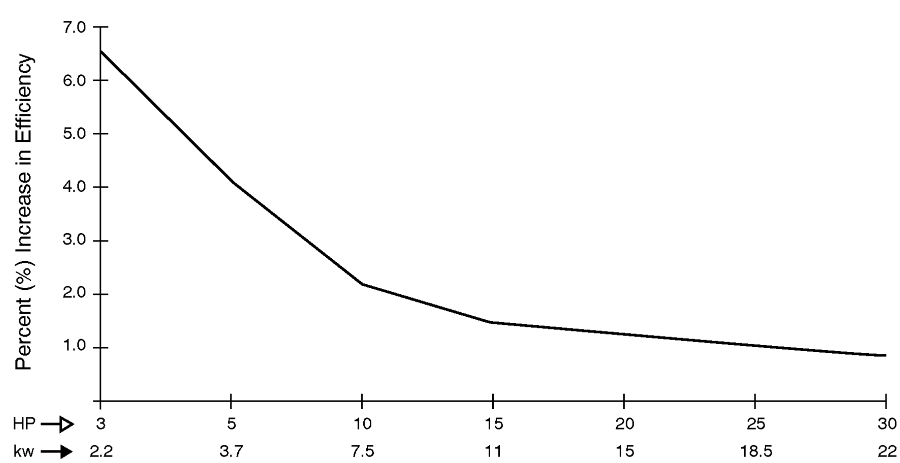
Solid state motor protective devices have adjustment ranges anywhere from 3.2 to 1 up to 9 to 1. This provides users of overload relays a real benefit and enables them to dramatically reduce their stocks. When a solid state motor protective device has a 3.2 to 1 adjustment range, customers can reduce their stocks by up to 60%, because 3 electromechanical overload relays can be replaced with a single solid state motor protective device. With a 9 to 1 adjustment range, obviously they can eliminate even more overload relays and reduce the number of different components that are required for a wide range of applications.

Energy Savings

In today's energy-conscious environment, another benefit of solid state motor protective devices that cannot be overlooked is the energy savings gained. 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. In traditional overload relays, as many as 6 watts of heat are dissipated to perform the protective function. Because solid state motor protective devices use sampling techniques to actually measure the current flowing in the circuit, very little heat is dissipated in the device. Solid state motor protective devices generate as little as 150 milliwatts of heat. This reduction in heat generation not only reduces the total amount of electrical energy consumed in an application or a process, but it can also 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 programmable logic controllers) within the specified operating temperature for each individual device can be eliminated.

The increased use of high efficiency motors goes hand-in-hand with the lower heat generation of the solid state motor protective devices. The use of a solid state motor protective devices can add as much as 6% efficiency to the efficiency increase realized by using a high efficiency motor. Figure 6 shows the increase in efficiency by motor size from 3 HP (2.2kW) to 30 HP (22kW).

Figure 6 Efficiency Increase Using a Solid State Motor Protective Device



The use of a high efficiency motor and a solid state motor protective device can increase total system efficiency by as much as 5.2%, again varying over a range of motor horsepower (kW), as shown in Figure 7.

Figure 7. Efficiency Increase Using a High Efficiency Motor and Solid State Motor Protective Device

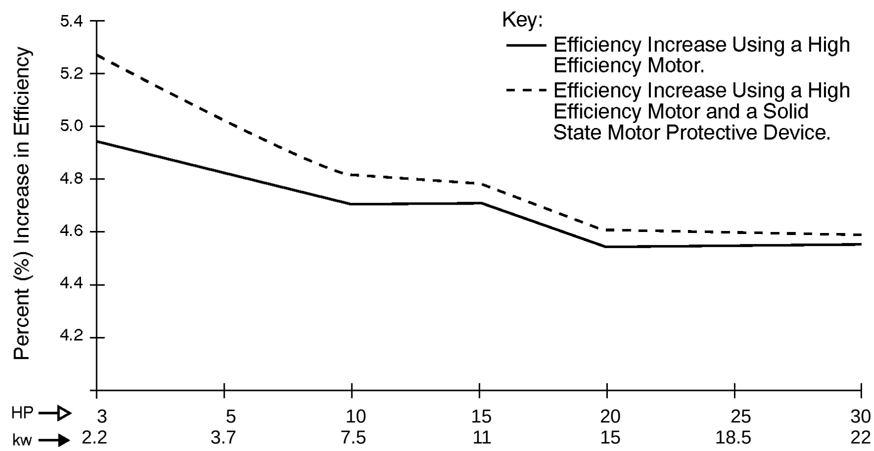


Table 1 and Table 2 show the cost savings that can be realized for an individual IEC or NEMA motor starter when utilizing a solid state motor protective device. Obviously, the cost savings realized depends on the number of hours in a year that the motor is operated, and also on the cost of electricity 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 a solid state motor protective device instead of an IEC bimetallic overload relay. When using a NEMA starter with a solid state motor protective device, 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 a solid state motor protective device. This cost savings also offsets the investment cost in the protective device, and it results in a faster payback of the equipment.

Table 1
Cost Savings Realized by Using a Solid State Motor Protective Device as a Replacement to an IEC Style Bimetallic Overload Relay at Maximum Setting

Motor Operating Hours per Year (Hours per Day) ①	Electricity Cost							
	$0.03/ kWHR	$0.04/ kWHR	$0.05/ kWHR	$0.06/ kWHR	$0.07/ kWHR	$0.08/ kWHR	$0.09/ kWHR	$0.10/ kWHR
2,000 (8)	$0.35	$0.47	$0.59	$0.70	$0.82	$0.94	$1.05	$1.17
3,000 (12)	$0.53	$0.70	$0.88	$1.05	$1.23	$1.40	$1.58	$1.76
4,000 (16)	$0.70	$0.94	$1.17	$1.40	$1.64	$1.87	$2.11	$2.34
5,000 (20)	$0.88	$1.17	$1.46	$1.76	$2.05	$2.34	$2.63	$2.93
6,000 (24)	$1.05	$1.40	$1.76	$2.11	$2.46	$2.81	$3.16	$3.51

① 250 Days per year

Table 2
Cost Savings Realized by Using a Solid State Motor Protective Device as a Replacement to a NEMA Eutectic Alloy Overload Relay at Maximum Heater Element Full Load Current

Motor Operating Hours per Year (Hours per Day) ①	Electricity Cost							
	$0.03/ kWHR	$0.04/ kWHR	$0.05/ kWHR	$0.06/ kWHR	$0.07/ kWHR	$0.08/ kWHR	$0.09/ kWHR	$0.10/ kWHR
2,000 (8)	$0.71	$0.95	$1.19	$1.42	$1.66	$1.90	$2.13	$2.37
3,000 (12)	$1.07	$1.42	$1.78	$2.13	$2.49	$2.84	$3.20	$3.56
4,000 (16)	$1.42	$1.90	$2.37	$2.84	$3.32	$3.79	$4.27	$4.74
5,000 (20)	$1.78	$2.37	$2.96	$3.56	$4.15	$4.74	$5.33	$5.93
6,000 (24)	$2.13	$2.84	$3.56	$4.27	$4.98	$5.69	$6.40	$7.11

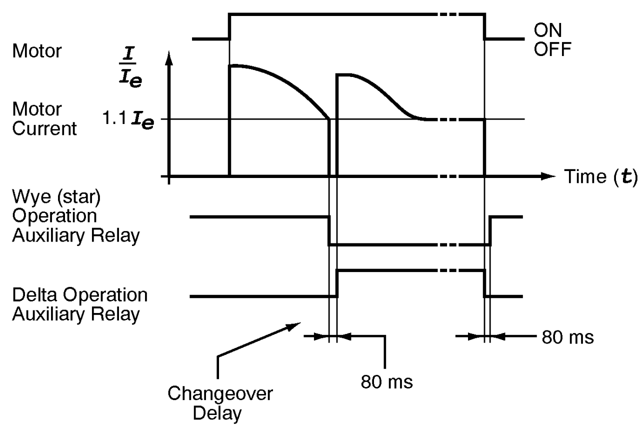
① 250 days per year

Special Control Applications

Electronic motor protective devices or motor starters that incorporate them are extremely well-suited for special motor applications, those applications that require different performance than typical direct online motor starting. These applications include wye-delta (star-delta) applications, and also special control requirements such as emergency starting, warm starting, and monitoring the starting time of a motor.

In wye-delta (star-delta) starting applications, solid state motor protective devices can be programmed to switch from a wye (star) 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 8 is a diagram showing a wye-delta (star-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.

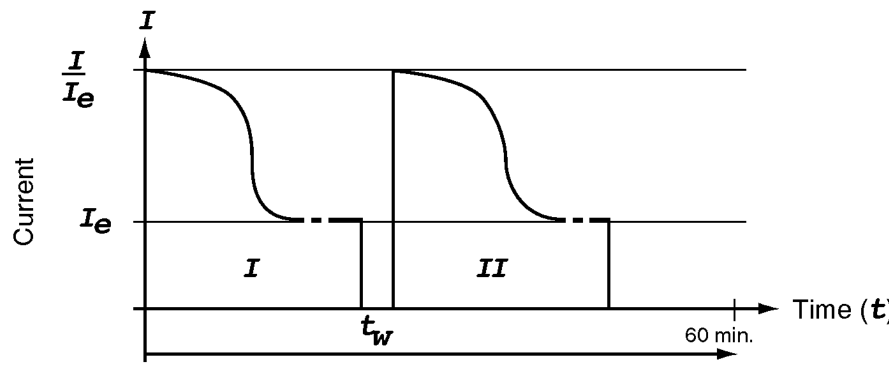
Figure 8 Diagram of Wye-Delta (Star-Delta) Starting



The programmability of some solid state motor protective devices also provides a great deal of flexibility to vary the current levels of both the wye (star) 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 motor protective device is providing the performance and functionality of separate wye-delta (star-delta) timers that would be required in the automatic operation of wye-delta (star-delta) starters.

Another control function that electronic motor protection relays can provide is limiting the number of starts over a specific period of time. Figure 9 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 9 Limited Number of Starts Per Hour

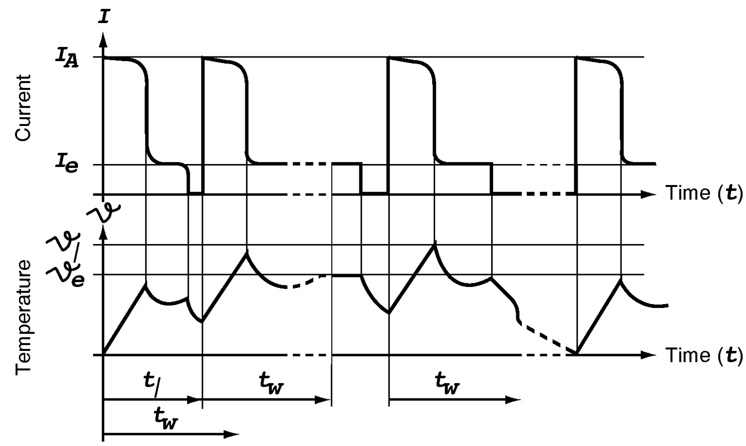


Example: 2 Starts Per Hour
I: First Start
II: Second Start
tw: An auxiliary relay remains tripped until 60 minutes have expired.

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 over-temperature 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 10 shows current and temperature curves for warm and cold starts of a motor over a given period of time.

Figure 10 Current and Temperature Curves for Warm and Cold Starts, and Tripping Limits



I_A: Motor Starting Current

I_e: Operating Current

ϑ_e : Permissible Motor Temperature in Continuous Operation

ϑ_l : Permissible Motor Temperature for a Short-Time

Period 1: First Start (Cold)

Period 2: First Warm Start

Period 3: Second Warm Start

Period 4: Cold Start (after the motor has cooled down)

t_l : Minimum Time Before First Warm Start

t_W: Minimum Time Between Two Warm Starts

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 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 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.

Solid state motor protective devices 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. While communication via a network bus to a PLC or personal computer is the most common form of communication, other methods of communication are also available. These include the display of data on an LCD display 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. Figure 11 and Figure 12 show typical installations where multiple starters may be installed on a control network communicating to a PLC and personal computer or communicating to an interface module that would be installed in the relative vicinity of the starter.

Figure 11

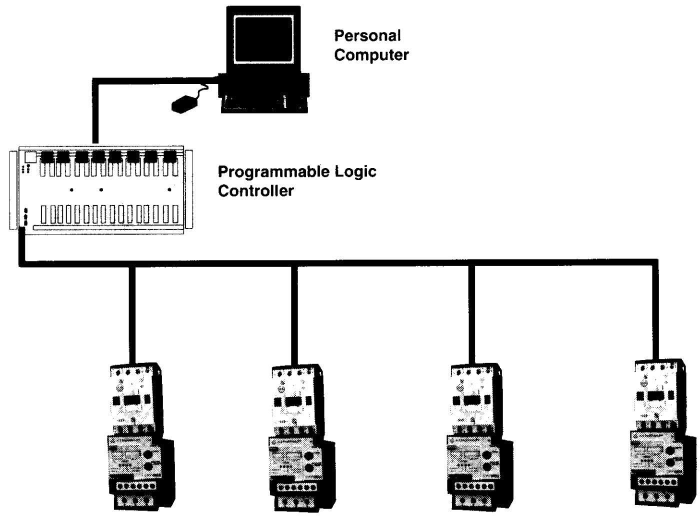
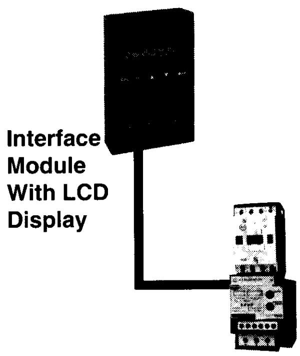


Figure 12



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 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 associated with the motor protective device, 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, 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 pre-warning 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
- replacing cutting tools

Finally, processes and motor utilization can be optimized with the increased functionality of solid state motor protective devices. The ability to set pre-warnings on the motor protective device and to monitor the actual motor application parameters enables the operators to utilize the motor to its maximum capacity. This helps to ensure the greatest production output, as well as helping to ensure that the motor will not be damaged by overcurrent or overheating conditions.

Conclusion

Solid state motor protective devices 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, 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.

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