SIEMENS

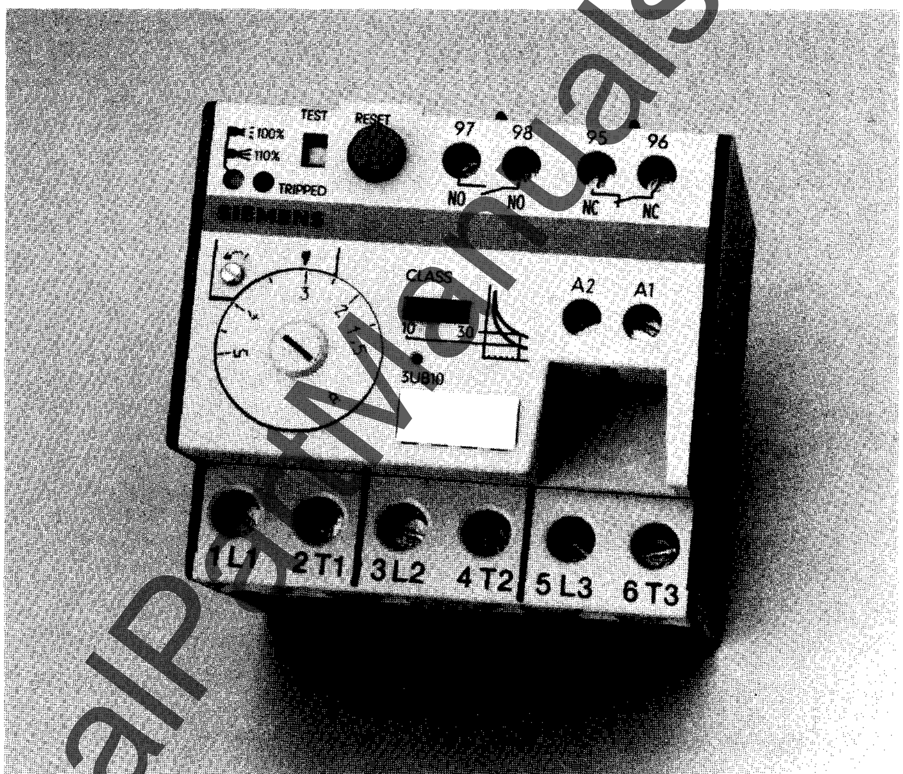
Electronic Overload Relays Make Their Mark

Frank Gelbrich

Selecting the right overload relay in the past depended on a variety of factors. For example, the reliability required of the device as tested by UL, as well as the type of load and ambient conditions in which the relay would be expected to perform were taken into consideration. In addition, evaluation often included calculating the probability of the number of overloads and the motor type and size to be protected. These—plus economic considerations—dictated to a large extent which type of relay would be specified.

Today, there is an additional criterion affecting both protection needs and device selection. To illustrate, improvements in motor design and manufacturing capability have resulted in decreasing motor size to obtain the same horsepower. The smaller physical dimensions of the devices have made them more sensitive to overloads. In essence, this is equivalent to a corresponding reduction in overload withstand capability. Previous motor designs had a high tolerance for overloads and made application of electromechanical overload devices satisfactory for protection. The newer designs require increasingly sophisticated protection techniques, such as higher relay speeds, more precision, and a host of additional performance characteristics.

These needs, plus the growing demand for building more protective functions into a reasonably-sized device, have spurred development of the microprocessor-based overload relay. Faster, more accurate and more reliable protection against overloads, overtemperatures, stalled rotors, long acceleration times, phase unbalance and single phasing, internal motor failures and motor reenergization after power interruption characterize these new electronic devices.



Solid State Overload Relay

Basing their tripping "decisions" on measured input from the motor current, and making calculations of real and reactive power, phase angle, power factor and impedance, they offer rapid and accurate tripping on a precisely defined basis.

Before examining electronic relays more closely, however, it is important to review the purpose of overload relays in motor circuits, and to recall conventional types in terms of performance characteristics. This will help gain an accurate picture of the whole selection process, i.e., conventional overload relays will continue to find a place in modern electrical protection practice.

What Overload Relays Should Do

Monitoring the current passing through a motor or transformer is the principle function of an overload relay. An overload relay is supposed to either provide a signal *and/or* cause disconnection of the load from the power supply at a preset value of overcurrent. Article 430 Part C of the National Electrical Code (NEC) requires motor overcurrent protection for virtually all electrical motor installations. The relay is part of an overall protection scheme (Figure 1), put there to protect the motor, the branch conductors and motor control apparatus against sustained overloads by interrupting the power to the contactor coil, which disconnects the motor from the power line. It does not interrupt the motor power independently. Its role is to protect the motor, controller and conductors through detection

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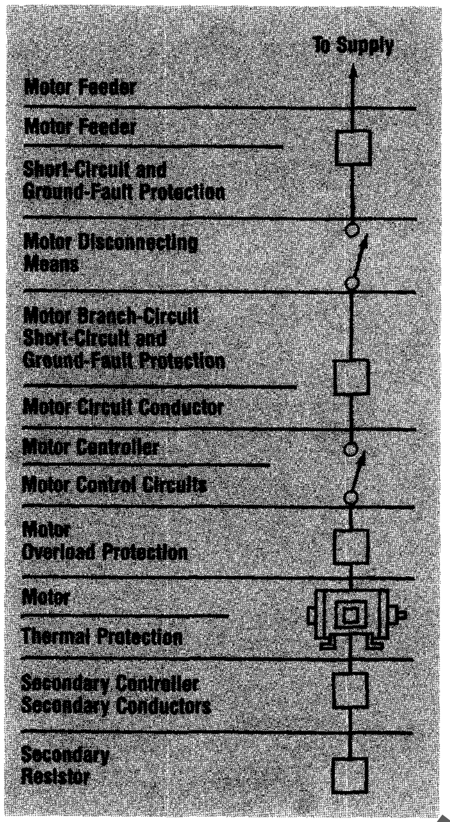

Figure 1 *Motor Protection Scheme*

of overcurrents up to 10 times the full load motor current.

It is *not,* for example, expected to offer protection for normal failures after service life expectancies. Nor is the overload relay expected to protect against voltage spikes due to lightning, arcing faults, switching, or blown fuses.

An overload relay *is* expected to perform, however, during a sustained current overload situation. A motor's vulnerability lies in its insulation, since motor heating increases with the square of current and causes deterioration of insulation. Drawing excessive mechanical loads or operating with low line voltage increases the current drawn by the motor and increases the temperature. Overheating would result unless the overload relay performs its design function: interrupting the control voltage which in effect disconnects the motor from the line.

Three-phase voltage unbalance can cause current unbalance up to 15 times the voltage unbalance, resulting in motor overheating. Overload relays are being assigned the task of monitoring and responding to these situations.

Single phasing—when one line opens in a three-phase circuit while the motor is running—is another condition being assigned to the overload relay to monitor. Single phasing can increase the motor slip. With excessive current in the uninterrupted lines amounting to $\sqrt{3}$, or 1.73 times the normal running current. Overload relays are being asked to deal with such conditions as well as severe duty cycling and long acceleration durations, which cause motors to be operated at below normal speeds.

Conventional relays offer some features, either standard or as options, that enable the relay to perform some of these added functions to a degree. On the other hand, conventional overload relays respond to overcurrent only; they do not normally detect phase loss though the Siemens Type 3UA overload relay does. For example, a lightly loaded motor drawing 70% FLA experiences a phase loss. The current will increase $\sqrt{3}$ times to approximately 120% FLA, which is more than the current trip rating (115%) of the overload relay.

There is a staggering variety of motor applications, each different, and each with particular overload protection requirements. Exactly how relays achieve their performance to match these requirements is what is critical and what, essentially, separates conventional relays from the newer, electronic models. Defining "how" relays accomplish their assigned tasks will enable us to fine tune the "when" in the selection process itself as far as using electronic overload relays over conventional types.

For example, thermal relays respond to the heat created by current passing through them. Tripping characteristics of conventional overload relays have a wide tolerance because the physical arrangement of heaters for various current ranges varies widely. Changing the placement of a heater just a few hundredths of an inch in relationship to the bimetal or alloy may change the trip current.

Conventional Overload Relays

Conventional overload relays operate magnetically or thermally on line current flowing to the motor. For proper motor protection, they must possess characteristics similar to the motor's. Conventional relays include a wide range of types, starting with the bimetallic overload relay containing a heater element sensitive to line current and a bimetallic strip of two dissimilar metals with different expansion coefficients. As current increases, the heater dissipates heat in relation to the current. The heat acting on the bimetallic strip, causes the strip to bend. When the strip has bent a predetermined distance, it opens the normally closed (NC) auxiliary contact in the overload relay. The coil of the magnetic motor controller connected in series to the NC contact, is de-energized disconnecting the motor from the line and preventing overheating. The Siemens bimetallic overload relay is also dial-set adjustable— to motor full load current or in a ratio 1:1.6.

Another type of conventional overload relay consists of the heater element, and eutectic alloy element. When the motor draws excessive current, the heat developed within these "melting-alloy" (called "solder pot") type relays melts the eutectic alloy and causes contacts to open. Melting-alloy and bimetallic relays are available as quick-trip or slow-trip models.

The instantaneous trip overload relay has a core which moves inside a coil through which current flows. The normal locked-rotor and full-load currents are not sufficient to lift the core. Excessive overload currents will lift the core and in turn open the NC auxiliary contact on the time delay forms, a spring restrained piston moving in a dashpot delays the motion of the core. The speed of the upward motion depends upon the

The Siemens overload relay can also be matched to specific starting conditions of a motor it is protecting through the CLASS selector switch. The switch controls the trip delay characteristics.

The National Electrical Manufacturers Association (NEMA) has created three class designations for overload relays, indicating maximum time in seconds at which the relay will trip under cold condition when carrying 600% of its current rating. Class 10 (10 seconds or less); Class 20 (20 seconds or less); Class 30 (30 seconds or less). International standards are equivalent to Class 10. In being able to switch from Class 10 to Class 30, the same Siemens relay can be used for normal motor starting conditions or heavy starting requiring run-up times of up to 30 seconds (Figure 4). The wide setting range of the new electronic overload relays is another crucial feature. Using current transformers, the setting range ratio is 1:4. Overload relays without current transformers are used for motor currents up to 25A with a setting range ratio of 1:10. A current range of 0.25 through 630A can be covered with only *five* relay sizes—reducing stocking requirements (about 50 conventional heater elements are required to span 0.5 to 50 amperes). Besides, better motor protection is possible with the device's outstanding tripping accuracy. Tolerances on tripping currents and times-to-tripping are far narrower than for thermal devices.

Another difference between conventional and electronic relays is the "memory" of the devices. A conventional relay, operating continuously at 100% has a bimetal that is already bent and will probably trip when slightly more current is added. Electronic relays, on the other hand, do not contain bimetals. Thus, they do not have a thermal memory.

However, electronic relays do have built-in memory (see Chart A). Therefore, a cold curve would have 0% loading, or a 100% curve. When the relay and motor has been preloaded for 20 minutes with 80% of the relay dial setting, tripping occurs within 55% of the cold tripping time. However, if the motor is preloaded with 100% of dial setting, tripping occurs within only 30% of the cold tripping time. A preloaded motor applied less than 20 minutes will increase the tripping time accordingly.

Tripping Curve Shifts Depending on Preloading of Motor

Preloading in % of Current Setting	Tripping Time in % of Cold Start Time
[illegible]	[illegible]
50	100
80	55
100	30

Chart A

Both conventional and electronic overload relays, in most cases, must be reset after a trip condition. Neither will allow restart until the "cool down" period has been reached (trip free feature). This trip free feature, however, does not come into play if the motor is turned off instead of tripping under overload conditions.

There are two reasons for this "waiting period." First, it is desirable to wait until the motor comes to a complete stop before switching to start. Also, the cool down period permits operating personnel to have time to think about corrective action before attempting a start. Recovery time after tripping in Class 10 is 35 seconds and Class 30 is 95 seconds.

Serviceability of the electronic relay is also refined over conventional types. Essentially, electronic relays can be tested any time by simply pressing the TEST button. Pressing the TEST button causes the yellow LED to light indicating the availability of service. Keeping the TEST button depressed for approximately six seconds, trips the relay indicated by a red LED.

Besides actuating auxiliary contacts—what conventional relays do when tested—all the important functions of the electronic relay are tested by simulation of an overload. In conjunction with the LEDs, precise setting to actual motor full load current is simplified. For example, using the yellow flashing condition (over 100% set current), it is relatively simple to set the overload relay to the current corresponding to the momentary load condition of the motor. From providing proper protection, the electronic relay aspires to the role of being a monitor of manufacturing processes.

And while conventional relays will continue being successfully applied in electrical distribution systems, the future seems to be leaning toward electronic types. The main reason for this is, that logically, the relay could digitally interface with other computers. True, the real world is largely analog. However, that situation is changing rapidly, spurred on by the development and usage of personal computers in industry. Electronic overload relays fit nicely into such a world (i.e., the blinking warning light signal could go directly to a central computer station) because that same world seeks better protection of its process motors and easier adaption to motor start conditions. It demands fewer devices to choose from in obtaining a variety of setting ranges. Electronics have met these demands in delivering higher tripping precision, selectivity in terms of time-lag classes and a wider range of settings in fewer devices than conventional devices. Electronics has delivered the microprocessor-based overload relay, making the protection of motors more a science than ever before. ■

degree of the overload and size of the bypass hole which fluid is forced through by the piston.

Inherent motor protectors complete the group of conventional relays. These devices are installed inside the motor housing to directly sense temperature of the motor windings. The most widely used is the thermostat-type or resistance temperature detector.

Some conventional overload relays, such as Siemens 3UA bimetallic overload relays, offer ambient temperature compensation as standard as well as phase failure protection (Figures 2 and 3). Three directly heated bimetals are used which bend in one direction when heated and move two independent slidebars. As the bimetals heat and cool, the slidebars move back and forth. Bending is uniform when all three see the same increase in current. However, when a failure in one phase occurs, two of the bimetals move a slidebar toward the tripping point. As the third bimetal cools (no current), it pushes the other slidebar in the opposite direction. This zigzag motion magnifies the effect of bending motion by three to one. The net effect reduces tripping time during a phase failure to a fraction of normal Class 10 tripping time.

The heaters in the Siemens overload relay are integrated with the bimetal element. All three poles are factory calibrated and sealed to maintain the close tolerances required by standards. Actual current ratings of different motors of identical horsepower can be very different due to differences in design, enclosure, speed, efficiency and power factor. Selection of the proper heater for conventional heater type relays involves an evaluation of the motor environment. This means studying more than just the motor nameplate rating. Once that is undertaken, it is to the specifier's and user's advantage to simultaneously select an ambient-compensated and phase-protection type relay with the heaters "built-in." Not only does this eliminate "heater switching" down the road, but it also fine tunes the protection process and allows the relay to perform the extra duties of phase protection and ambient compensation.

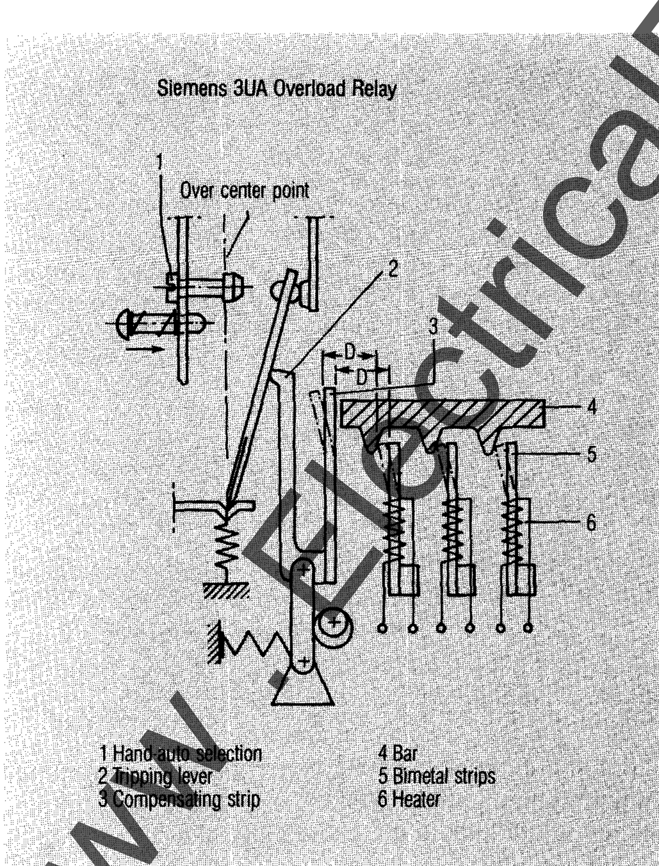

Figure 2 *Triple-Pole Overcurrent Relay With Temperature Compensation And Convertible Reset Mechanism, Basic Function*

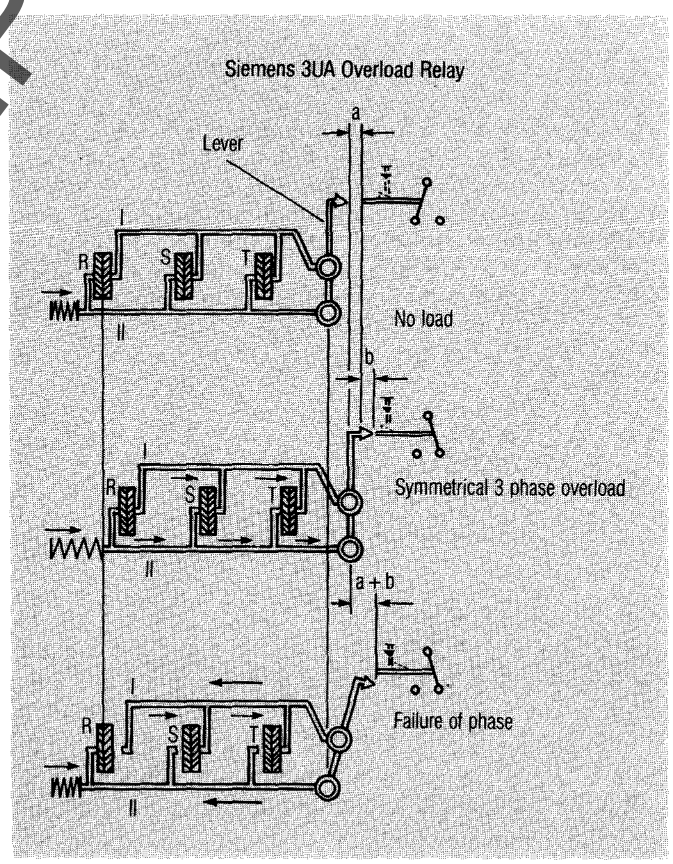

Figure 3 *Basic Function of Three-Phase Overcurrent Relay With Protection Against Phase Failure*

Tripping limits with triple-pole symmetrical loading:	VDE IEC	CSA UL NEMA	3UB1
No Trip	1.05 x I_E 2h	1.00 x I_E	1.05 x I_E 2h
Trip	1.20 x I_E ≤ 2h	1.15 x I_E 1.25 x I_E	1.15 x I_E ≤ 20 min.

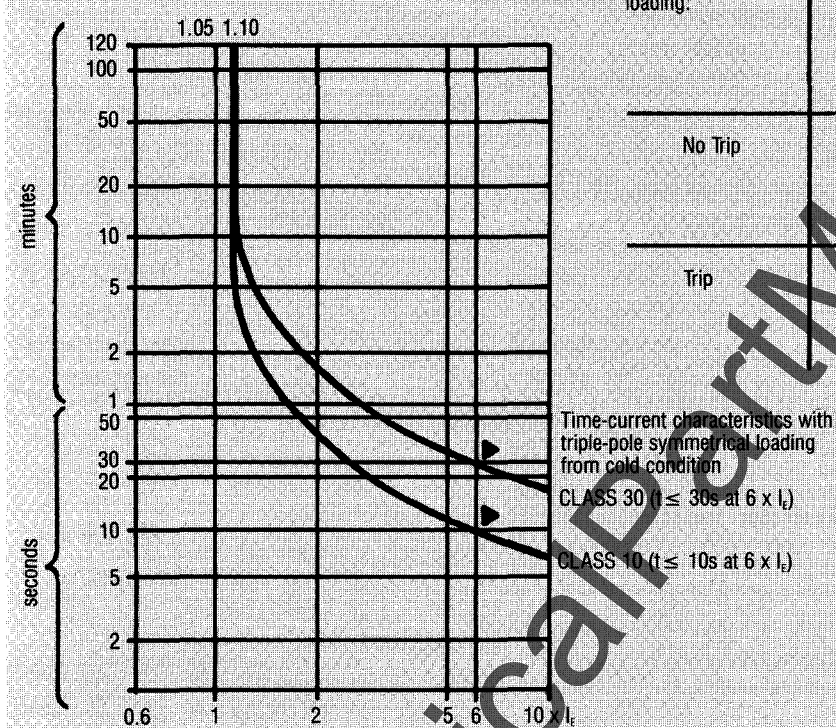

Figure 4 *Tripping Characteristics*

In a majority of cases the specifier is uncertain about a motor's specific characteristics. Conventionally, that has meant recommending protection based on horsepower from standard tables provided by the manufacturer, the NEC, etc. Sound engineering demands motor protection be specified on the basis of actual motor characteristics. While tables are helpful as general guidelines, it is really the responsibility of the specifier to use motor nameplate information in determining protection requirements. And that means a certain amount of flexibility must be built into the relay, to adjust to a variety of situations. This is where the new electronic relays present the advantage. Not only do these devices extend such flexibility in specification; they offer improved accuracy, speed and performance to match today's changing protection needs.

Electronic Relays

The Siemens electronic overload relay is a microprocessor-controlled device that meets UL 508, CSA C22.2, DIN 57660, part 104/VDE 0660 part 104 and IEC 292-1 specifications, and it is specifically designed to protect electrical equipment such as three-phase motors and transformers against excessive temperature rise from overload, single phasing, phase current unbalance or locked-rotor condition.

Current transformers measure continuously the actual motor current in each phase. The outputs are proportionately changed into a voltage. The voltage is compared to a voltage set on the overload relay dial, both voltages are rectified, digitalized and applied to the microprocessor. The microprocessor cyclically calculates and stores the momentary loading of the motor. Loads exceeding the current setting result in a warning: the yellow LED starts flashing (important in process control, i.e., when dealing with liquids with a high viscosity). When the overload exceeds 110% of the current setting, a steady yellow light results. This indicates an impending trip. Finally, when the preset operating value is reached, a trip occurs. This is indicated by a red LED light.

Individual functions of the unit are monitored by a self-monitoring circuit. In the event of internal faults, failure or interruption of power supply, the output relay is set to the tripped position. After restoration of voltage, the relay reverts back to its position prior to interruption.

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