PDHonline Course E466 (2 PDH)

Relays and Contactors

Instructor: Joseph E. Fleckenstein, PE

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

Relays and Contactors

Joseph E. Fleckenstein

Table of Contents

COURSE CONTENT

1.0 Relays and Contactors – General

Relays are important in the control and protection of all types of large electrical gear. The more expensive the electrical gear, the greater the number of relays that will generally be used. In particular, large electrical gear as generators, motors and transformers depend on relays for correct and safe operation.

There are numerous types and classifications of relays, some of which are intended for very special and unique applications. The most common type of relay is the control relay. Other types of commonly used relays include the time delay relays, protection relays, solid state relays and reed relays. Generally, control relays are intended for controlling relatively low current applications, more or less in the range of 300 VA to 2000 VA. Mercury-wetted relays were popular years ago and may still be found in existing control circuits. However, today few organizations allow the use of mercury of any amount form in new circuits due to its high toxicity.

By common usage, the term, “contactor” is applied to a special type of device that is functionally similar to the relay. Yet, a contactor is not normally called a “relay.” Rather, the term, “contactor” is used to describe a type of device that is used very much in the same manner as a relay. In general contactors are intended to control higher levels of current.

Relays are typically integrated into a logic circuit together with other relays and controls to perform specific control and sequencing functions. The logic required of a control system is usually described by the logic of a ladder diagram. The proper selection of specific devices to perform the functions described by a diagram can be a challenging task. If selections are not made with due recognition of the capabilities and limitations of electrical devices, the result can be the premature failure of components. Those premature failures can result in the loss of availability of expensive electrical gear and in some instances the loss of protection to expensive electrical gear.

The most commonly used relays and contactors are reviewed below.

2.0 Electromechanical Control Relays

Electromechanical control relays are constructed of both electrical and mechanical components. Thus, the terms "electro" and "mechanical." A basic component of an electromechanical relay is an electrical coil that consists of numerous windings and which, when energized, produces a magnetic field in a ferromagnetic core. When energized, the resulting force moves components that in turn shift a set of electrical contacts. When the magnetic field is collapsed the activating force disappears. In a non-latching relay the contacts shift again when the magnetic force is removed whereas in a latching relay the contacts remain in-place. The two most common types of relay actuating mechanisms are the hinged armature and the plunger. An armature type actuator is shown in Fig. 1. When the coil is energized the magnetic forces generated by the coil act to close an air gap beneath the armature. The resulting motion of the armature shifts an adjacent set of contacts. When the coil is de-energized, collapsing the magnetic field, a spring retracts the armature and it reopens the air gap, reversing the position of the set of contacts.

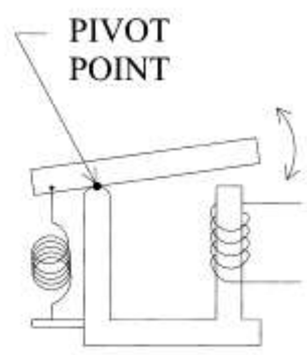

Fig. 1 - Armature Type Actuator

A plunger type mechanism is depicted in Fig. 2. When the electrical coil is energized the magnetic force draws the plunger into the center of the coil against the force of a spring. Movement of the plunger shifts a set of contacts. When the coil is deenergized the spring forces the plunger out of the center of the core of the coil thereby reverting the contacts to the position corresponding to the deenergized position.

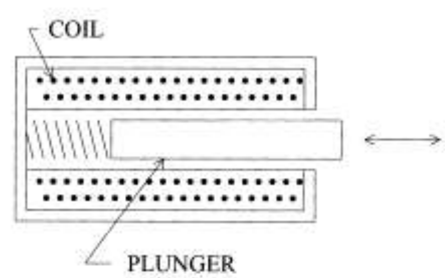

Fig. 2 - Plunger Type Actuator

Relay coils are available in both DC and AC voltages. In all designs of actuators energized by an AC voltage, the magnetic field must be biased with a metallic ring called a "shading ring." Without the shading ring the magnetic field would reverse direction numerous times every second and would not produce a usable force. With the shading ring there is no reversal of the magnetic field. If the activating voltage is DC, a shading coil is not needed as the magnetic field would be consistently in one direction. Because of the time required to shift either an armature or a plunger from one position to another, electromechanical relays are relatively slow acting devices. Closing and opening times are in the range of 5 msec to 15 msec.

Reed relays are considered a type of electromechanical device since they contain components that are both electrical and mechanical. Yet, reed relays are normally treated separately from most electromechanical relays. Reed relays are discussed below.

For many years the electromagnetic relay was the major element used to perform the logic described by a ladder diagram. In fact the term "ladder logic" is often used in reference to the use of relays to perform a sequence or logic. With time, PLC's have been used more and more to perform the functions that had been achieved for years solely with electromechanical relays. This has become the case particularly where a larger number of functions are to be performed. Yet, the electromechanical relays are still the better choice if there are only a few interlocks to be performed. In addition, some organizations prefer the use of electromagnetic relays to a PLC because troubleshooting can be quicker and more readily performed.

Some of the symbols associated with electromechanical control relays are shown in Fig. 3. The Joint Industrial Council (JIC) symbols shown in the figure are used mostly in North America and the IEC symbols are used primarily in Europe.

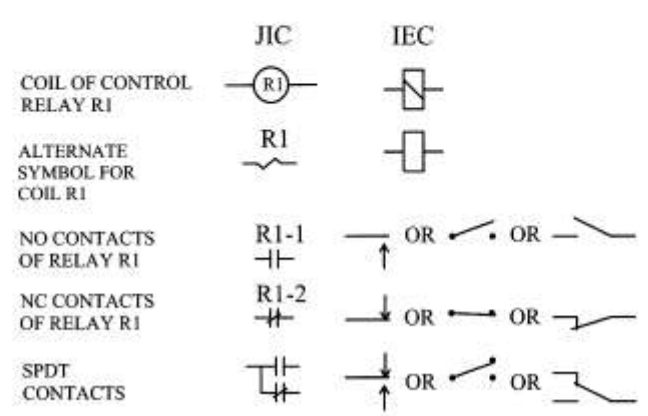

Fig. 3 - Control Relay Symbols

The “control relay” is one of the oldest type of relay and perhaps the best known. There are various types of control relays including “machine tool relay”, “industrial relay” and “general purpose relay.” Control relays are available in numerous configurations. Some of the more common variations are mentioned below.

Cube Relays – Cube relays are also called “ice cube relays” by some manufacturers and “general purpose relays” or “industrial relay” by others. The term “cube” comes from the shape of the relays which is similar to that of some shapes of ice cubes. Although the devices are in the shape of an ice cube they are nevertheless larger than a conventional ice cube and typically in the range of 1.7 inches X 1.7 inches X 2.4 inches high. Cube relays use the armature type actuator and are available in several mounting configurations. One popular type of mounting uses a mounting base that is fixed in-place and which accepts conductor terminations. The relay is then plugged into the base. Two common types of plug-in mounts are the octal (also called socket or tube) and the spade. A plug-in type relay can be readily removed from its base and replaced with another plug-in relay in a matter of seconds as no conductors of a circuit need to be moved. Another type of relay mount is the “surface mount” which accommodates mounting of the relay on a flat sheet metal surface. With a surface mounted relay conductors must be connected to terminals on the relay.

Compared to other types of relays, the cube relays are relatively inexpensive and are readily available worldwide. Popular models of cube relays are available in one pole to four pole configurations and NO, NC and DT. Coil power is in the range of 1.5 VA to 2.5 VA. Cube relays are also available in a number of coil voltages. Contacts typically have a rating that is between 3000 and 7000 VA - resistive. The relays are generally well suited to most control circuits as well as the control of motors up to 2 HP. The operating components of cube relays are protected to some extent by a dust cover and in some models the terminals are receded to minimize the potential for fingers to come in contact with live electrical parts. A cube type relay of the plug-in type, with 3/16 inch spade terminals, is shown in Fig. 4 along with the

Fig. 4 – Cube Relay with Plug-in Base

matching plug-in base. (Photograph by the author.) Smaller versions of cube relays known as “miniature cube relays” are actually near the size of ice cubes. One popular model of a miniature cube relay measures 0.82 in W X 1.09 L X 1.46 high. The VA capabilities of the miniature cube contacts are often comparable to that of the larger ice cube relays. The coil power consumption of the miniature cube relays is normally in the range of 1.5 VA.

Machine Tool Relays – The term “machine tool relay” is applied to a type of relay that has traditionally been used in the manufacturing industries. Machine tool relays are also called “industrial relays” or “heavy duty relays.” The machine tool relays are generally considered as better suited to industrial and manufacturing requirements than the less expensive cube type relays. The automotive manufacturing industry in particular has been a regular user of this type of relay. Machine tool relays differ in appearance and construction from cube relays. Unlike cube relays, machine tool relays very often have field-replaceable contacts as well as replaceable coils. In most designs of machine tool relays, for example, a NO contact can generally be replaced in the field with a NC contact and vice-versa. Some designs of machine tool relays are available with up to 12 poles. Many machine tool relays can be expanded in the field to add poles. In many designs, for example, a two pole relay can be readily changed to a three pole relay by merely adding contact “cartridges.” Contacts in machine tool relays are enclosed to exclude to some extent the entrance of dust, debris and liquids. Machine tool relays usually have a plunger type actuator. A popular type of machine tool relay is shown in Fig. 5. (Photograph by the author.)

Fig. 5 –Machine Tool Relay

Open Relays – In most applications, relays of any design are enclosed within a cabinet. Sometimes a cabinet that houses relays would be locked primarily for the purpose of preventing inexperienced persons from coming in contact with the voltage present on metallic components within the cabinet. A cabinet might also be locked to avoid malicious tinkering. Because of the protection afforded by a cabinet some organizations use relays that are considered of an “open” design. Open relays do not have covers or enclosures of the types used with cube relays or machine tool relays. Some models have terminals that are located atop the device and which are much more exposed than the terminals on either the cube relays or the machine tool relays. While the exposed terminals on open relays present a greater potential for shock to personnel who open the cabinet the design more readily accommodates fabrication in a high volume manufacturing process. The HVAC manufacturing industry in particular uses great numbers of the open relays. Open relays are available in a variety of contact configurations and ratings. Much to the credit of the open relay manufacturers, open relays are available with a variety of pilot duty contacts. Some designs of open relays use the plunger type actuators whereas others use the armature actuators. (Pilot duty contacts are treated in detail below.)

A design of an open type relays is shown in Fig. 6. (Photograph by the author.) The relay in the photo is intended for surface mounting. It has screw type terminals and an armature actuator. This particular model is called a "power relay" by the manufacturer. It has two poles that are NO and rated 1.5 HP each pole.

Fig. 6 - Open Type Power Relay

Latching Relays – The types of electromechanical relays mentioned above are described as "non-latching relays." Non latching relays are said to have a normal, or shelf, position. For example, if a set of contacts is said to be normally open, that set of contacts will be in the open position when the relay is either on a shelf or when the coil is in a deenergized electrical circuit. Whenever the relay's coil is energized the contacts will be shifted to the opposite position - NO contacts will be closed and NC contacts will be opened. Latching relays have a different mode of operation. A latching relay remains in its last position and it will remain in that position indefinitely until it is moved to the opposite position. A momentary pulse of power is required only to shift the relay's contacts from one position to an opposite position. Power is not necessary to hold the contacts in any of the two possible positions. Various means are used to hold contacts in-place. Some designs use magnets and other designs use an over-center spring. Obviously latching relays require a logic circuit that is different from that which would be used for a non-latching relay. Worldwide there are far fewer installations of latching relays than non-latching relays. Nevertheless, there are some control configurations to which latching relays are ideally suited. Latching relays are well suited to circuits that require contacts to be closed for long periods of time.

Time Delay Relays – Time delay relays are used in control circuits to momentarily postpose a control action. The most common version of time delay relays are of the electromechanical design. A set of contacts is moved by a timing device of some type. The timing mechanisms can be either mechanical or electronic. One type of mechanical timing mechanism that has been used for many years uses a pneumatic diaphragm. The two most commonly used types of time delay relays are the "on delay" time delay relay and the "off delay" time delay relay.

On-delay time delay relay – The function of an on-delay time delay relay is to provide a delay after a control signal is received. When, say, voltage is applied to the coil of the relay, the relay's contacts do not shift immediately. Rather the contacts shift only after a predetermined time delay. The contacts could be normally open (NO), normally closed (NC), single pole double throw (SPDT) or multi-pole. If voltage is removed from the coil, the contacts immediately shift to the normal position. If the contacts of a time delay relay are NO, the contact action would be NOTC - normally open timed closed. If the contacts are NC, the contact action would be NCTO – normally closed timed open. On-delay relays are often designated as TDE relays, or "Time Delay on Energization" relays. The action of a TDE relay is best be described by a graph of the type shown in Fig. 7. At time "0" there is no power applied to the relay's coil and the contacts are in the normal state. At time 1 power is applied to the coil and timing begins but the contacts remain in-place. After time delay T elapses, the contacts shift from the normal position - at time 2. NO contacts close and NC contacts open. If power is removed from the coil, say at time 3, the contacts immediately return to the normal position.

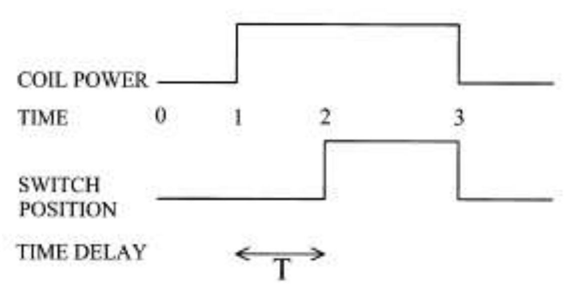

Fig. 7 – TDE Relay

Off-delay time delay relay – The function of an off-delay time delay relay is to provide a delay on deenergization. When voltage is applied to the coil of the relay, the contacts immediately shift from the normal position. The NO contacts close and the NC contacts open. The contacts could be NO, NC, SPDT or multi-pole. The contacts will remain held in those positions until time T after power is removed from the relay's coil. Off-delay relays are often designated as TDD relays, or "Time Delay on Deenergization" relays. The action of a TDD relay is described by the graph of Fig. 8. At time "0" there is no power applied to the relay's coil and the contacts are in the normal state. At time 1 power is applied to the coil and the contacts immediately shift from the normal positions. At time 2 power is removed from the coil but the contacts remain in-position until after time T when the contacts revert to the normal position. Except for some time delay relays with very short timing periods, TDD relays require a continuous power source in order to hold contacts in-place after the signal voltage has been removed.

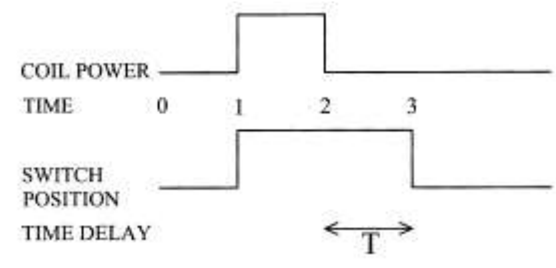

Fig. 8 - TDD Relay

The symbols used in ladder diagrams for the coils and contacts of TDE relays and TDD relays are shown in Fig. 9. The TDE and TDD types of relays are the most common types used in control circuits but there are other less common types of relays available for a variety of special timing functions.

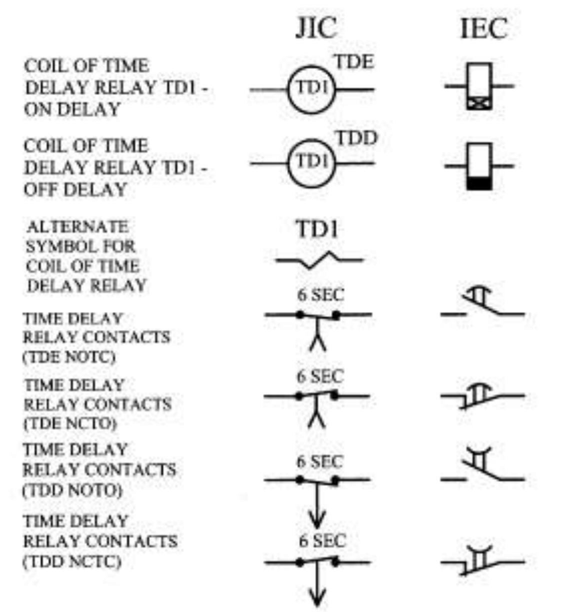

Fig. 9 - Time Delay Relay Symbols

Options and Accessories – Electromechanical relays are available with a number of options. Many designs of relays have manual operators that allow a person to manually shift the contacts from the normal position. Other relays have flags or small lights that indicate the position of a relay. Both of these features can be an aid in troubleshooting.

Selecting an Electromagnetic Relay – The selection of an electomechanical relay should be carried out in recognition of a number of considerations. First, there is the circuit voltage which is a starting point. In North America the circuit voltage for the control of most motors is 120 VAC. However, for many types of installations the control voltage is 125 VDC. This is the case in nuclear plants and in the control of transmission and distribution gear. Many engineers in the electrical generating industry will argue that the 125 VDC power is better because a DC coil is a more dependable actuator. DC coils are less likely to chatter, burn out or fail. Yet, it can be argued that a set of contacts can better interrupt an AC current than a DC current. The arc in DC contacts tends to linger whereas an AC current automatically goes to zero value numerous times every second. Another significant factor is the speed of response. Protection relays are usually designed to accept and produce a DC signal. The reason is that DC devices, in solid state designs, can respond in microseconds compared to the milliseconds characteristic of AC devices. When a fault of some sort appears, the fastest possible response is preferred. Naturally the faster acting component would be preferred.

Once the coil voltage has been determined for an electromechanical relay, the next consideration is the suitability of a prospective relay's contacts to the load. Literature pertinent to most relays will state a current capability, as "6 amps," at a particular voltage. Unless specifically stated the current rating given for a relay may be assumed to be the relay's capability if used with the least demanding of all loads, namely a resistive load. It is perhaps important to understand that the relay manufacturing business is a very competitive business and, so, relays are fabricated to have very little extra capacity. A relay with an advertised capability of 6 amps would be capable of reliably closing contacts with an inrush of 6 amps, of maintaining a constant 6 amps and of breaking a current of 6 amps. The relay would be capable of somewhere in the region of 50,000 to 200,000 cycles in an average environment but only when cycling a pure resistive load that is no greater than 6 amps. For reactive loads a "6 amp" relay would have a much lower current capability.

For applications other than resistive loads, a relay's current interrupting capability is much less than its resistive load rating. A typical set of recommended reductions in capability is shown in Table 1. Say, for example, that a relay with an advertised rating of 6 ampere is considered for the control of incandescent lighting. Its maximum current capability, according to Table 1, would be 10% of 6 ampere or 0.6 ampere.

Table 1
Recommended Contact Current Capability For Long Contact Life

Service	Percentage of Advertised Current Rating
Resistive (e.g. heater)	75
Inductive	40
Capacitive	75
Motor	20
Incandescent	10

While the contacts of a relay have a maximum capability there is also a minimum capability that is of relevance. Consider, for example, the possible use of relay with a 6 ampere resistive, 120 VAC rating in a panel to operate another relay that has a 3 VA coil rating. The coil current would be 3/120 ampere or 0.025 ampere. The adjusted maximum capability of the contacts for an inductive load would be 0.40 X 6 or 2.4 amperes. The current draw of the coil would be (0.025/2.4) (100) % or 1.04% of the contacts rating. This would be considered a poor application. True, when initially installed the relay and the circuit would function as expected. In time, however, there could be a problem. Basically the contacts would lack adequate wiping action. While excessive arcing between contacts can cause premature failure of contacts, inadequate arcing can likewise result in failure. A gentle arc between contacts is highly desirable for the reason that it creates an action that cleans the surfaces of the contacts. Without the wiping action, in time contacts very well may accumulate a film or dust that will prevent continuity.

Where low contact VA's are encountered, pilot duty contacts are recommended to enhance long contact life. Pilot duty contacts are specifically designed to prolong contact life in those applications where low currents are encountered. The contacts of pilot duty relays are much smaller than the regular relay contacts and have a high contact pressure. Many are made of silver or, at least, have silver plating. One popular relay on the market with pilot duty contacts has an advertised rating of 25 VA maximum and a 3 VA minimum. A relay with contacts of this description would be a good match with a relay that has a coil power between the minimum and maximum coil power draw. Current ratings should be certified as uncertified ratings might be lacking in capability. Certifications are discussed in below in Section 10.0.

3.0 Solid State Relays

Solid state relays (SSR's) are increasingly being used in applications that not many years ago used only electromagnetic relays (EMR's). Today, roughly one in every five relays manufactured is a solid state relay. SSR's are available in current ratings to at least 150 amps and potentials to 600 volts. As the name suggests, SSR's perform their function by means of electronic, or solid state, components. More specifically, SSR's turn current on or off with thyristors. SSR's have a very long cycle life. Whereas electromagnetic relays might have a cycle life that is somewhere around 50,000 to 200,000 cycles, SSR's can easily be expected to withstand many millions of cycles. A typical SCR relay is shown in Fig. 10. (Photograph by the author.)

Fig. 10 – Solid State

Because of the absence of moving parts SSR's are not affected by vibration or shock. SSR's are especially suited to the control of heaters. With a matching controller SSR's can send pulses of current to a heater thereby maintaining the heater at a nearly constant temperature. The controlled medium would also be controlled at a more constant temperature.

Much as EMR's, SSR's also have limitations. In particular, SSR's are susceptible to high voltage spikes. An electromagnetic relay might very well be able of withstanding voltage spikes that could be as high as 1000 volts or more. High voltage spikes of a certain high value can instantly destroy a SSR. So, in most applications precautions must be taken to protect an SSR against excessive voltage spikes. Surge protectors are one solution. When turned off, SSR's have a small leakage current that can pose a problem in some circuits. When current passes through a thyristor heat of some magnitude is generated. For solid state relays with a relatively low current rating, a firm mount to a vertical sheet metal surface is often sufficient to remove the heat that is generated. For higher current levels

SSR's must be attached to metallic heat sinks to maintain the relay within an acceptable temperature range.

4.0 Reed Relays

Reed relays function somewhat in the manner of an electromechanical relay. A reed relay has a coil and a set of contacts that are shifted from one position to another when the coil is energized. In its most simple form, a reed relay consists of two ferromagnetic strips, or reeds, that are partly sealed within a glass capsule. A design of a single pole, normally open reed relay is represented in Fig. 11. A portion of each reed extends outside the capsule so that electrical connections may be made to that part of the reeds external to the capsule. Portions of the reeds within the capsule that act as contacts are usually plated, sometimes with gold. An electrical coil surrounds the glass tube. When the coil of a NO design is deenergized there is a gap between the two reeds and the contacts are open. When voltage is applied to the coil a magnetic field is generated, drawing the reeds together and establishing contact closure. When the coil is deenergized the reeds separate, opening the circuit. Usually the capsule is either evacuated or charged with an inert gas to prolong contact life. The reeds of a reed relay are hermetically sealed and for this reason the contacts are impervious to contaminants, as dust or deleterious gases. Because of the hermetic design some models of reed relays are approved for use in environments containing explosive gases or explosive dusts. The coils of reed relays accept only DC voltage. Designs of reed relays are available in NO, NC and double pole configurations. Some models are also available as latching relays. Reed relays respond more quickly than electromechanical relays and typically respond in approximately 1 msec. Most reed relays are encapsulated and intended for mounting on circuit boards.

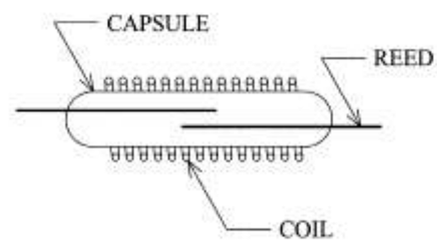

Fig. 11 - Reed Relay

5.0 Environmental Requirements

Relays used in industrial or utility installations are very often exposed to elevated levels of gases or dusts that tend to deteriorate relay parts and contacts. A number of measures may be taken to help ensure that degradation of relays will be avoided or minimized. Solid state relays or reed relays are possible candidates as these designs have only the exterior terminals exposed to the ambient. Hermetic relays are another approach to protect the moving parts and contacts of relays.

Relays located within hazardous areas preset some unique requirements. Hazardous areas are defined as those areas that may contain flammable gases, liquids, fibers or dusts. If a conventional electromagnetic relay is located in a hazardous area and the contacts of that relay either close or open an arc will be generated. That arc, if it is of an adequately high energy level, can ignite gases and cause an explosion. In short, conventional electromagnetic relays are generally not suited for use in a hazardous area. Special precautions are needed when using arc-generating devices in a hazardous area. One approach is to use an enclosure that is suitable for hazardous areas. Both explosion proof enclosures and purged enclosures are suitable for hazardous areas. Some of the other possible alternatives for a hazardous area are:

1. Hermetically Sealed Devices – A number of electrical devices, including switches, controls and relays, are available in hermetic designs. A hermetic device has its contacts entirely contained within a sealed can. The seal excludes gases or dusts surrounding the relay from entering into the can. Hermetic relays are also a prudent choice for environments that contain corrosive gases that are not necessarily explosive but which over time may cause deterioration of relay parts or contacts.
2. Intrinsically Safe Devices – Intrinsically Safe (I.S.) devices operate on the principle that an electric arc within a hazardous area will not necessarily cause an explosion. For ignition to occur an electric arc must be of a minimal energy level. Intrinsically safe devices are made to operate below those energy levels. Intrinsically safe systems use barriers that are located outside a hazardous area. Wiring to devices within the hazardous area must pass through the I.S. barriers which limit voltages and currents within the hazardous area. As mentioned above a minimum current level is recommended for relays to cause wiping of the contact surfaces. So, for I.S. applications attention should be given to contact designs and currents with the dual objectives of both avoiding an explosion as well as prolonging contact life.

6.0 Enclosures

To enhance contact life, relays should be mounted in an enclosure of a type suitable for its environment. A variety of enclosures are available for housing relays. Some enclosures are relatively simple in design and suited only for the relatively benign surroundings of an indoor installation. Other enclosures are intended for more challenging environments as outdoors or hazardous locations. Most enclosures are fabricated of sheet steel but, to enhance the life of an enclosure, some enclosures are fabricated of stainless steel or fiberglass. To accommodate the mounting of relays, an enclosure should have a backplane that extends slightly from the rear of the enclosure. In North America the requirements for enclosures are defined by the guidelines of NEMA. Some of the more commonly used types of NEMA enclosures are the types 1, 4, 12, 7, 10 and 9. Briefly these are defined as follows:

NEMA 1 – General purpose indoor. Possibly vented. Prevents human contact with electrical parts when the door is closed. Excludes falling dirt. The least expensive of enclosures. For indoor use only.

NEMA 4 – Watertight. Excludes rain, snow or sprayed water. Suitable for indoors or outdoors.

NEMA 12 – Dust tight. Openings are sealed. Excludes dust. For indoor installations only.

NEMA 7, NEMA 10 – Explosion proof. Suitable for explosive gases.

NEMA 9 – Explosion proof. Suitable for explosive dusts.

Hazardous environments present some unique requirements for relays. The NEMA 7 and NEMA 9 enclosures are available to house conventional switches or relays. Housings are available in various sizes to contain either individual devices or groups of devices. These enclosures are mostly of a design that does not exclude explosive gases or dusts. Rather, the enclosures prevent the hot gases of an explosion within the enclosure from escaping to the surrounding area and thereby igniting an explosion outside the enclosure. Explosion proof enclosures are made of cast steel or aluminum and are designed with small flame paths. The principle of the design is that exploded gases within the enclosure will be cooled upon passing through the flame paths and therefore not be able to ignite gases outside the enclosure. To meet code, the enclosures must be of an approved design. Explosion proof enclosures tend to be heavy and expensive. Explosion proof enclosures also require maintenance by qualified personnel so as to keep flame paths clear and in the original configuration.

An acceptable alternative to an explosion proof enclosure is a purged enclosure. Codes accept a purged enclosure as a safe alternative in hazardous areas. A purged enclosure has relatively tight seals around doors and openings. Air from an area outside the hazardous area is forced, through ducts, into the enclosure and the interior of the enclosure is maintained at a slight positive pressure with respect to its environment. A purged enclosure allows use of conventional electrical devices within the enclosure since explosive gases or dusts are not allowed to enter into the enclosure. Whenever a large number of electrical devices are involved a purged enclosure is drastically less expensive than an explosion proof enclosure. Precautions are appropriate to guard against the possible situation in which purging of the enclosure might be interrupted at a time when explosive gases are in the proximity of the enclosure.

An IEC standard defines a set of criteria for enclosures that is different from the NEMA descriptions. While there is no identical match between the IEC and NEMA descriptions, a few of the enclosures are somewhat similar. Specifically, the IEC IP10 approximates the NEMA 1. The IEC IP56 approximates the NEMA 4 and the IEC IP52 approximates the NEMA 12. A NEMA 12 type enclosure (dust tight) is shown in Fig. 12. (Photograph courtesy of State Motor and Control Solutions, St Louis)

Fig. 12 - NEMA 12 Enclosure with Motor Controls

7.0 Protection Relays

Protection relays are a class of relay designed mostly to protect larger electrical gear as generators, motors and transformers. Older protection relays were of the electromechanical design but gradually these designs were replaced with faster acting microprocessor-based units. Protection relays are commonly identified by a device number. The numbers refer to a detailed description published in ANSI /IEEE Standard C37.2, *Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations.* Device numbers run from "1" to "94." Each of the device numbers describe a specific kind of protective relay that is intended to detect a particular type of condition or malfunction and provide an output that can be used to protect guarded equipment. An output can be in the form of a contact opening or closing or activation of a thyristor.

One well known manufacturer of protection relays recommends that for the protection of important motors below 1500 HP that approximately 13 protection relays should be used to ensure adequate protection. The list of recommendations includes the following device numbers: 2, 27, 37, 38, 46, 47, 49, 49R, 49S, 50, 57, 66, 86 and 87M. Following are some representative descriptions of the mentioned device numbers.

Device #2 – Time Delay Starting

Device #27 – Undervoltage relay that operates when its input voltage is less than a predetermined value.

Device #37 – Undercurrent or underpower relay that functions when the current or power flow decreases below a predetermined value.

Device #38 – Bearing protective device. Provides interlock in the event of a high bearing temperature.

Device #46 – Reverse-phase or phase-balance current relay that functions when the polyphase currents are of reverse phase sequence or when the polyphase currents are unbalanced or contain negative phase-sequence components above a given amount.

Device #47 – Phase sequence or phase balance voltage relay

Device #49 – Machine or transformer thermal relay that functions when the temperature of a machine armature winding or other load carrying winding or element of a machine or power transformer exceeds a predetermined value.

Device #49R – Winding over temperature relay.

Device #49S – Locked rotor relay.

Device #50 – Instantaneous overcurrent relay that functions instantaneously on an excessive level of current.

Device #57 – Short circuit or grounding relay .

Device #59 – Overvoltage relay

Device #66 – Notching or jogging relay that functions to allow only a specific number of operations within a given time of each other. Or, device can be used to energize a circuit periodically or for fractions of specified time periods.

Device #86 – Lockout relay that is an electrically operated hand or electrically reset auxiliary relay that is operated upon the occurrence of abnormal conditions to maintain associated equipment out of service until it is reset.

Device 87M – Differential protective relay that functions on a percentage, or phase angle, or other quantitative difference between two currents or some other electrical quantity.

Obviously, with the large number of protective relays available for the protection of electrical gear there are any number of possible combinations that might be used in any specific application. Briefly stated, protective relays have an important role in the protection of electrical equipment of a great variety.

8.0 Contactors

A contactor is also called an "electromagnetic contactor" although it is most often merely called a "contactor." Contactors have a coil and a set of contacts arranged in a configuration that approximates what is found in control relays. When voltage is applied to the coil of a (normally open) contactor the contactor's contacts are closed to deliver power to the controlled electrical gear. The main difference between a relay and a contactor is that the latter is used to connect and interrupt higher levels of power. Typically contactors control power to electrical gear as motors, heaters, lighting and capacitor banks. Contactors are required in those applications where electrical power must be repeatedly applied and subsequently interrupted. Control of power to the very largest types of electrical gear is controlled by circuit breakers and not contactors. One significant difference between contactors and circuit breakers is that circuit breakers are designed to interrupt short circuit currents but contactors do not have that capability.

Contactors are available in two pole, three pole and four pole configurations. Both enclosed and open designs are common. The open design is intended for mounting in a customer's enclosure. Most contactors are normally open although normally closed contactors are also available for specialized applications. Auxiliary contacts, which would have a lower current rating than the main contacts, are available with most contactors. The auxiliary contacts are often used for the purpose of interlocking in control circuits or for the purpose of remote indication of contactor position. Contactors are also classified as either "general purpose" or "definite purpose." Definite purpose contactors are mostly intended for the OEM (Original Equipment Manufacturer) market and are to be used in a specific, defined application. Definite purpose models are usually less expensive than the nearest equivalent general purpose design. In addition to the electromechanical types of contactors, there are solid state models that are said to offer long service lives.

For motor applications, NEMA rates contactors according to sizes 00, 0 and 1 to 9. IEC has its unique system of rating contactors for motor applications and those sizes range from AC-1 to AC-4. A typical IEC contactor is shown in Fig. 13. (Photograph by the author.)

Fig. 13 - IEC Contactor

9.0 Terminals and Terminations

By common usage, a "terminal" could be a point on a device where a conductor is landed to complete an electrical connection. A terminal could also be a small component that is affixed to the end of a conductor to facilitate the connection of that conductor to a terminal. Conductors are "terminated" on terminals and a conductor can have a "wire termination." As is typical of many English language words, the significance of the word "terminal" is best understood by its use in a sentence.

Relays and contactors are available with a variety of terminals where conductors may be landed. Some of the more common terminals are the screw type, quick-connect (also called push-on and fast-on) and the pressure type. Years ago the screw type terminal was the most prevalent type but with time the screw types were mostly replaced with other types. The quick-connect type, which is a blade type terminal, is favored on relays used in high-volume production. The terminals on the relays with quick-connect terminals are usually the female type. (Quick-connect terminals are available in two sizes: 0.187 inch and 0.250 inch.) Otherwise, the pressure type terminal has become the most popular type of terminal. Pressure types of terminals are available in a variety of configurations. In most cases a pressure type terminal consists of two small metallic tabs that are intended to receive a conductor between the tabs. After a conductor is inserted between the tabs, the turn of a screw brings the tabs together and applies pressure to hold the conductor and tabs in close contact.

Fig. 14 – Relay with Quick-connect Terminals

Examples of relay terminals may be seen in the above illustrations. The relays in Fig. 4, Fig. 5 and Fig. 13 have pressure type terminals and the relays in Fig. 6 and Fig. 10 have screw type terminals. A relay with male (1/4 inch) quick-connect terminals is shown in Fig. 14.

Although there are exceptions, conductors used to interconnect relays within a control panel are mostly stranded copper in sizes 16 AWG or 14 AWG. So, these are the types of conductors that must be landed on the electrical devices within a panel. If a conductor is to be landed on a screw terminal it must have either a ring tongue type termination or a split-ring type wire terminal. A conductor intended for landing on a relay with male quick-connect terminals must have a matching female type push-on terminal. A conductor to be landed under a pressure type terminal could have one of two types of ends. One method is to have the end of the conductor stripped of its insulation for approximately 3/8 inch. The stripped portion would be inserted into the pressure type terminal and a screw tightened to hold the conductor firmly in place and establish continuity. Some conductors intended for terminations in pressure type terminals are terminated with a ferrule. The purpose of the ferrule is to keep all strands of copper within the ferrule so that stray strands of copper do not inadvertently make contact with metallic parts other than the target terminal. The ferrule also helps to ensure that terminations within a pressure type terminal will be made correctly. The use of ferrules on conductor ends is especially favored where terminals are located in close proximity to one another.

As is characteristic to most electrical parts, terminals have ratings. This is true of the terminals located on electrical devices as well as terminals of the type used on conductors. For example, ring tongue terminals are restricted to the acceptable size of screw under which the terminal will be located as well as the size of conductor to which the terminal is attached. Pressure type terminals are limited to the number and size of conductors that may be terminated at a single terminal. Terminals also have a current rating. Several types of conductor terminals are shown in Fig. 15. In the top row are two split ring terminals and two quick-connect terminals. Two ring tongue terminal are shown in the bottom row. The insulator color designates the approved conductor size. Yellow colored terminals are for conductor sizes #10 AWG and #12 AWG. The blue colors are for #14 AWG and #16 AWG. The red are for #16 AWG to #22AWG.

Fig. 15 – Various Conductor Terminals

10.0 Certifications

In the evaluation of the capabilities of a prospective relay or contactor for an application, the device's certifications should be considered as an important part of the process. A certification is documentation that essentially confirms that a product has been tested according to a predefined protocol and it has been found to meet the requirements of that protocol. In the United States certifications are typically provided by a third part agency. One well-known testing laboratory is Underwriters Laboratories (UL). The UL is an agency that has offices in over 46 countries and is said to provide safety-related certification, validation, testing, inspection, auditing, advising and training. If an electrical device bears the UL label it may be assumed that the device has been examined and tested to confirm that the device is capable of the claimed capability. In Canada a similar agency is the Canadian Standards Association (CSA).

Within the European Economic Area (EEA) the "CE" mark is the more recognized method of identification for suitable electrical devices. Certain product groups are required to have the CE mark within the EEA. According to the CE protocol, there is no third party validation of a manufacturer's claims. If an electrical device bears the CE mark, it is understood that the claims of capabilities have been certified but that the claims come from only the manufacturer.

Electrical codes often require the use of "approved" devices. The accepted interpretation of "approved" is that the device has a certified electrical capability. In the United States both UL and CSA marked devices are commonly accepted as "approved." Worldwide there are numerous agencies that test and certify devices.

11.0 Common Relay-associated Mistakes

Mistakes often made in the selection and application of relays are:

1. Failure to recognize that a relay's AC current rating is only its resistive rating and not its current capability when used with other, more demanding loads.
2. Use of AC rated relay that has no DC rating in a DC application.
3. Use of a relay with a contact current below the contact's minimum rating.
4. Use of conductor terminations that are not within either the rating of the terminal or the rating of the conductor termination.
5. Use of a relay in a configuration that has the relay unnecessarily energized for long periods of time.

A responsible selection of a relay will be made with the intent of using it in a circuit with components that will provide a long service life. This approach will require close attention to the factors that are involved. And, it goes without saying that efforts should be taken to avoid the mistakes often made in the selection of relays.