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INDUSTRIAL AUTOMATION WITH PLC

CONTACTOR

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When a relay is used to switch a large amount of electrical power through its contacts, it is designated by a special name: **contactor.**

An electrical contactor is a switching device, widely used for the switching of motors, capacitors (for power factor correction) and lights. As the name indicates it is used to make or break contacts like an ordinary on-off switch. The only difference is that the contactors have an electromagnet that holds the contacts when energized whereas switches do not have it.

Their basic principle of operation is the same as that of electromechanical relays but their contacts can carry much more current than relays. Relays cannot be directly used in circuits where the current exceeds 20 amperes. In such conditions, contactors can be used. They are available in a wide range of ratings and forms. Also, they are available up to the ampere rating of 12500A. They cannot provide short circuit protection but can only make or break contacts when excited.

Constructional features:

Contactor consists of an electromagnet, contacts, and spring enclosed inside an enclosure. In some of them, have built-in economizers that can reduce power consumption. Certain arrangements for arc extinction are also made inside for making and breaking the operation.

Electromagnet Coil:

Conventional Low voltage coil

Hollow Cylindrical Type Coil

An electromagnet is a key component in contactors without which it cannot function. It requires an additional supply for excitation. It drains negligible current from the supply during excitation. These electromagnets will be hollow cylindrical in shape. A rod (armature) with a spring return arrangement will be placed in the hollow cylindrical electromagnet.

In some of them, this electromagnet is split into two halves. One of the halves is fixed and the other is movable. Movable power contacts are fixed to the movable electromagnet. Under normal conditions, these two halves of electromagnets are held apart using a spring in between.

Conventional laminated soft iron Magnetic Core

Solid Steel Core

In contactor with AC coil, the electromagnetic core is made up of laminated soft iron to reduce eddy current losses and in contactor with DC coil, the electromagnetic core is made up of solid steel/ soft ironic core since there is no risk of eddy current loss in DC.

Contacts:

A typical contactor consists of two sets of contacts, of which one is stationary and the other is moveable. Silver tin oxide (AgSnO2), silver nickel (AgNi) and silver cadmium oxide (AgCdO)are the normally used contact materials. These materials have high welding resistance and stable arc resistance. Silver cadmium oxide and silver nickel are used in contactors of less ampere rating whereas Silver tin oxide is used in those of high ampere rating and in DC contactors.

The movable set of contacts is attached to the armature or movable electromagnet. Contact material must withstand mechanical stresses, arcs, erosion, and must have very low resistance.

Enclosure:

Electromagnet and contacts are packed inside an enclosure made of plastic, ceramic, or Bakelite, which protects it from dust and the external environment and ensures safe opening and closing of contacts.

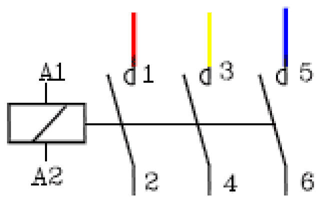
Arc Suppressor:

Arc extinction is one of the key functionalities of a contactor. AC arcs can be easily extinguished since it passes through zero twice for every cycle. Hence arc suppressors can do the job. But in the case of DC arcs, magnetic blowouts or specially designed arc chutes for arc extinction are necessary. Depending upon the application various arc suppression arrangements are made in contactors out of which arc chutes are one of them.

Economizer circuit:

An economizer circuit is the one used to reduce the power consumed by the coil. An economizer circuit supplies a high current during pickup and later it supplies adequate power to keep the contacts closed. It is not mandatory that all of them must have an economizer circuit.

Working principle:



Symbol of contactor

Whenever the electromagnetic coil is energized, an electromagnetic field is produced. This electromagnetic field attracts the metallic rod (armature) towards the gap in the hollow cylindrical magnet.

In contactors with split electromagnets, the movable half of the electromagnet is attracted towards the fixed electromagnet. This action closes the contacts. The contacts remain closed as long as the electromagnet remains excited. When the coil is de-energized, moving contact is pushed back to its normal position by the spring. Every contactor is designed to open and close contacts rapidly. Moving contacts may bounce as it rapidly makes contacts with the fixed contacts. Bifurcated contacts are used in some contactors to avoid bouncing.

The operating power to the coil can be AC or DC (available in various voltage ranges starting from 12Vac/ 12Vdc to 690Vac) or even universal. The universal coils are the ones that can operate on AC as well as DC voltages. A small amount of power is drained by the coil during the switching operations. Economizer circuits are used to reduce the power consumed by the contactor during its operation.

Contactors with AC coils have shading coils. Otherwise, they may chatter every time the alternating current crosses zero. Shading coils delay demagnetization of the magnetic core and avoids chattering. Shading is not required in DC coils as the flux produced is constant.

Arc Suppression:

Arc occurs between the contacts every time when contacts are closed or opened under load. Arc formed during the breaking of a load is more destructive and may damage the contacts, hence reducing the life of the contactor. In addition to that, the high temperature of the arc degrades the gases surrounding the contacts and forms harmful gases such as carbon monoxide, ozone, etc. This may affect the mechanical durability of the contactors. Several methods are adopted for the control and extinction of arcs.

DC contactors:

DC contactor

As mentioned earlier, DC arcs are more severe when compared to AC arcs. In DC contactors magnetic blowouts are used to propagate the arcs towards specially designed arc chutes and extinguish them by splitting them. In those contactors used in low voltage AC applications (690Volt or less), atmospheric air surrounding the contacts extinguishes the arc and in medium voltage and high voltage applications vacuum contactors are used to avoid the risk of arc.

Vacuum Contactor

Different Types of Contactor Devices:

Knife Blade Switch:

The knife blade switch was used earlier in the late 1800's. It was probably the first-ever contactor that was used to control (start or stop) electric motors. The switch consisted of a metal strip, which would drop onto a contact. This switch had a lever for pulling the switch down or pushing it up. Back then, one had to level the knife blade switch into the closed position by standing next to it.

However, there was a problem with this method of switching. This method caused the contacts to wear out quickly since it was difficult to manually open and close the switch fast enough to avoid arcing. As a result of this, the soft copper switches underwent corrosion, which further made them vulnerable to moisture and dirt. Over the years, the size of the motors increased which further created the need for larger currents to operate them. This created a potential physical danger to operate such high current carrying switches, thus leading to a serious safety concern. In spite of doing several mechanical improvements, the knife blade switch couldn't be fully developed due to the pertaining problems and risks of the dangerous operation and short life of the contacts.

Manual Controller:

Since the knife blade switch became potentially dangerous to use, engineers came up with another contactor device, which offered a number of features that were missing in the knife blade switch. This device was referred to as a manual controller.

These features included:

- Safe to operate
- The non-exposed unit, which is properly encased
- Physically smaller size
- Single break contacts replaced with double break contacts

As their name implies, double break contacts can open the circuit in two places at the same time. Thus, even in a smaller space, it allows you to work with more current. Double break contacts divide the connection in such a way that it forms two sets of contacts.

The switch or button of the manual controller is not operated remotely and is attached to the controller physically.

The power circuit is engaged once the manual controller is activated by an operator. Once activated, it carries the electricity to the load. Soon, manual contactors replaced knife blade switches completely, and even today different variations of these types of contactors are being used.

Magnetic Contactor:

The magnetic contactor does not require human intervention and operates electromechanically. This is one of the most advanced designs of a contactor, which can be operated remotely. Thus, it helps eliminate the risks involved in operating it manually and putting operating personnel in potential danger. Only a small amount of control current is required by the magnetic contactor to open or close the circuit. This is the most common type of contactor used in industrial control applications.

The Life Expectancy of a Contactor or Contact Life:

The life expectancy of a contactor or its "contact life" is one of the biggest concerns of a user. It is natural that the contacts are being opened and closed more frequently, the life of the contactor will decrease. The opening and closing of the contacts create an electric arc, which generates additional heat. The continued production of these arcs can damage the contact surface. Furthermore, the electrical arcs cause pitting and burn marks, which eventually blacken the contacts. However, the black deposit or oxide on the contacts makes them even more capable of conducting electricity efficiently. Nevertheless, when the contacts get worn out and corroded to a large extent, then it is necessary to replace them.

Thus, the faster the contact closes, the quicker the arc extinguishes. This in turn helps to increase the life of the contact. The latest contactor versions are designed in such a way that they close very quickly and energetically. This causes them to slam against each other and produce a bouncing action as they rebound. This action is known as contact bounce. The contact bounce phenomenon creates a secondary arc. It is not only important to close the contacts quickly, but also to reduce the contact bouncing. This helps reduce wear and secondary arcing.

Categorization of contactors:

Few important IEC utilization categories are below:

Contactors are categorized based on the type of load (IEC utilization categories – 60947) and current and power rating (NEMA size).

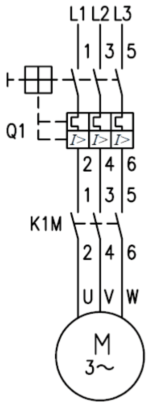
- AC-1: Non-inductive or slightly inductive and resistive heating type of loads
- AC-2: Starting of slip ring induction motor
- AC-3: Starting and switching off Squirrel-cage motors during the running time
- AC-15: Control of AC electromagnets.
- AC-56b:- Switching of capacitor banks
- DC–1: Non-inductive or slightly inductive and resistive heating type of loads
- DC-2: Starting, inching, and dynamic braking of DC shunt motors
- DC-3: Starting, inching and dynamic breaking of DC series motors
- DC-13: Control of DC electromagnets

NEMA sizing:

NEMA size is based on the maximum continuous current and horsepower rating of the induction motor controlled by the contactor. In NEMA standard contactors are designated as size 00,0,1,2,3,4,5,6,7,8,9.

Application of Contactors:

Motor Starters:



DOL-Motor Starter

Contactors are used in motor starter either Direct-on-line or Star Delta along with thermal overload relays or motor protection circuit breakers. Even in our homes, one can find it inside the pump starters. Normally in a motor starter circuit, they are used for switching, along with overload relay and short circuit protection devices.

Switching of capacitor Banks:

In capacitor banks, capacitor switching contactors are used to switch capacitors based on the reactive power requirements. Capacitor switching contactors are specially designed to control high transient currents formed during switching.

Lighting control:

Contactors are also used in the switching of the street, commercial, and residential lights. They are commonly used in timer controlled lighting systems. Latch type contactors are also available. In this type, two coils are available, one for opening and the other for closing. Closing coil closes the contacts, when excited, and cuts off the supply to the coil. Contact is then held closed mechanically. The second coil is used for opening the contacts.

Selection of contactors:

Contactors are selected based on the following:

- Application-based on IEC utilization category.
- Load current and voltage.
- Control voltage available – For selecting coil voltage.

How to check a contactor?

A contactor can be checked whether it is “open” or “closed” using an ohmmeter. If the resistance between the input and output terminals is infinite then the contactor is opened and if the ohmmeter reading is zero then it denoted that the contacts are closed.

Testing Procedure:

Contactors are used to remotely switch electrical power. The coil-actuated switch operates exactly like a relay, but a contactor typically handles higher amperages in the switch mechanism itself. The coil consists of many winds to a wire and is energized by a smaller voltage. A movable solenoid, called a plunger, is mechanically connected to a set of spring-loaded copper discs. These discs are called contacts. When the coil is energized, the solenoid pushes against the spring and closes the contacts. When the coil voltage is removed, the force of the spring returns the contacts to their normally open position. Typically the contacts, two each to a switch, are identified as the line and terminal. The line, or L, is the voltage feed, and the terminal, or T, is connected to the electrical device being controlled. Contactors can have many sets of contacts or switches.

Step-1: Remove all electrical power to the L or line side of the contactor. Use the screwdriver and pull the wires from the line-side screws. Identify the wires, if needed, with the clear tape and pen. Place identifier marks such as L1, L2 and L3 with the pen over the tape. Adhere the tape to the corresponding wires.

Step-2: Loosen and remove the wires from the T or terminal side of the contactor. Identify each wire as in Step 1, but with a T1, T2 and T3. Wires left in place on the contactor can lead to a false reading in the following procedure.

Step-3: Energize the contactor's coil by turning the control switch to the "on" position. You should hear an audible "click," and a humming sound will emit from the contactor. Some contactors may have some form of visual aid or manual actuator that will physically move when the coil is energized.

Step-4: Switch the volt ohmmeter on and to the ohms position on the front selector switch. Place the red lead into the "ohm" connector and the black lead into the "common." Touch the two leads together. The meter short read 0 ohms or a direct short.

Step-5: Test each set of L1-to-T1 contacts. Place the red lead to the L1 and the black lead to T1. The meter should read 0 ohms. Perform the test on each separate set of contacts. Keep each set test together-L1 to T1, L2 to T2 and L3 to T3. Each set should read 0 ohms. If any set does not, then that contact is bad. The contacts may have to be replaced.

Step-6: Observe all readings on the meter. If all the readings are not 0 ohms or a direct short, the coil may not be properly connecting the contacts. Cycle the control switch for the coil. Can you hear an audible click? If not, check the voltage to the coil.

Step-7: Switch the meter to volts and place the red lead in the volts connector on the meter. Apply power to the coil. Touch each lead of the meter to each connector on the coil. The meter should read the supplied voltage. Read the specification for the circuit to find the voltage supplied. If the voltage is correct and the coil still does not close, shut all power off to the coil.

Step-8: Remove the wires to the coil with the screwdriver. Reset the meter to read ohms again as in Step 4 above. Touch each lead to the coil connectors like reading the voltage, but with the meter in the ohms position. The meter should read from 10 to 100 ohms. If the meter does not, the coil is bad and must be replaced.