101 BASICS SERIES

LEARNING MODULE 19:
STARTERS AND CONTACTORS

Cutler-Hammer

EATON

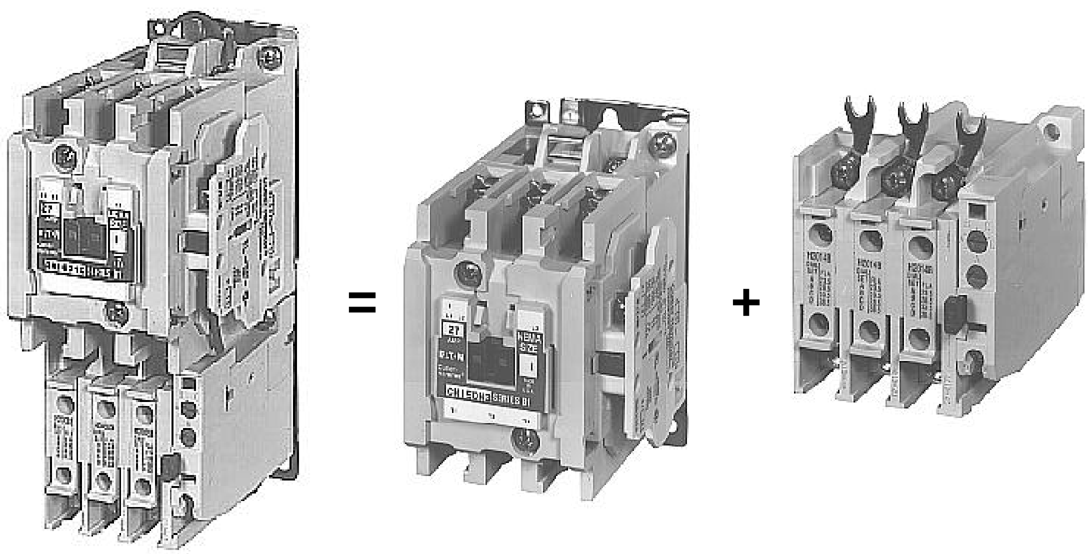
WELCOME

Welcome to Module 19, which is about *starters*, devices that **control the use of electrical power to equipment, usually a motor**.

As the name implies, starters "start" motors. They can also stop them, reverse them, accelerate them, and protect them.

Starters are made from two building blocks, *contactors* and *overload protection*:

- Contactors control the electric current to the motor. Their function is to repeatedly establish and interrupt an electrical power circuit.
- Overload Protection protects motors from drawing *too much* current and overheating, from literally "burning out."



STARTER CONTROLLER OVERLOAD PROTECTION

FIGURE 1. A STARTER IS MADE UP OF A CONTROLLER (MOST OFTEN A CONTACTOR) AND OVERLOAD PROTECTION

Like the other modules in this series, this one presents small, manageable sections of new material followed by a series of questions about that material. Study the material carefully, then answer the questions without referring back to what you've just read.

You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is establishing a solid foundation to build on as you move from topic to topic and module to module.

A Note on Font Styles

Key points are in bold.
Glossary terms are underlined and italicized the first time they appear.

Viewing the Glossary

You may view definitions of glossary items by clicking on terms and words that are underlined and italicized in the text. You may also browse the Glossary by clicking on the Glossary bookmark in the left-hand margin.

WHAT YOU WILL LEARN

We'll start by talking about the building blocks of a starter: the contactor and overload protection. We will then conclude with a discussion on starters. Here are the topics that we will cover:

THE CONTACTOR

A contactor can stand on its own as a power control device, or as part of a starter. Contactors are used in applications ranging from the light switch to the most complex, automated industrial equipment. **Contactors are used by electrical equipment that is frequently turned off and on** (opening and closing the circuit), such as lights, heaters, and motors.

Whatever the application, the function of the contactor is always the same: **to make and break all power supply lines running to a** *load*. Or, as defined by NEMA, to repeatedly establish and interrupt an electrical power circuit.

Knife Blade Switches

The first device used to stop and start electric motors was a simple *knife blade switch*. This was a lever that would drop a strip of metal onto a *contact* to make the electric circuit. In the late 1800's, "throwing the switch" meant exactly that – someone had to stand next to the knife blade switch and lever it into the closed position.

When industry began to demand more powerful electric motors, the knife blade switch quickly became obsolete and was no longer used. Why?

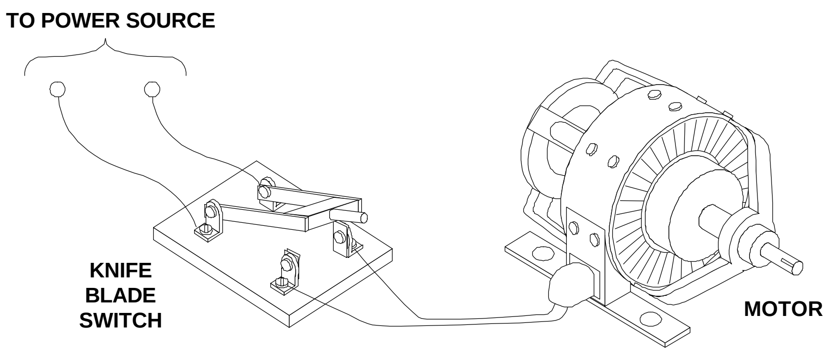


FIGURE 2. A KNIFE BLADE SWITCH USED TO CONTROL A MOTOR

Engineers discovered that the contacts quickly wore out because humans could not open and close the switch fast enough to prevent *arcing*. **Arcing, a condition where high voltage leaps across the open space as the contacts closed in or pulled away from the switch**, corroded the soft copper switches with pits. Dirt and moisture compounded the problem.

More importantly, as motors became larger, the currents to operate them also had to become larger, creating a serious safety concern**. It was physically dangerous to handle the switch.** Willing knife blade switch operators became harder and harder to find.

Knife Blade Switches (continued)

Mechanical improvements were made, but with their dangerous operation and short contactor life, knife blade switches remained at a design dead-end. The knife blade switch certainly wasn't the best solution, but from it, engineers learned what issues needed to be addressed:

- speed of operation
- contactor life
- protection for the motor
- protection for the person who operates the switch (afforded by either remote or automatic operation)

Manual Controller

The manual controller was the next step up the evolutionary ladder, offering several important new features:

- The unit is encased, not exposed
- *Double break contacts* are used, instead of single break
- The unit is physically smaller
- The unit is much safer to operate

Double-break contacts open the circuit in two places simultaneously. Dividing the connection over two sets of contacts allows you to work with more current in a smaller space than you get with a single-break contact. In addition, the mechanical linkage more quickly and consistently opens and closes the circuit, sparing the metal from some of the arcing experienced under knife blade switches.

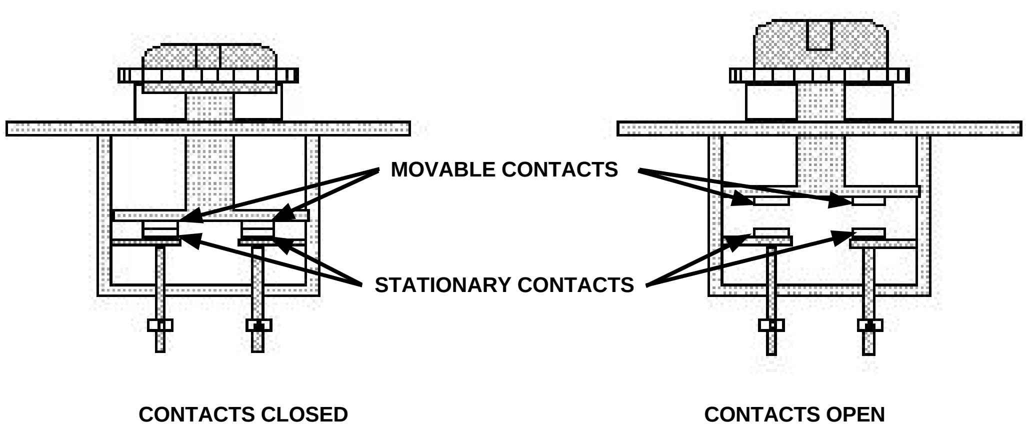
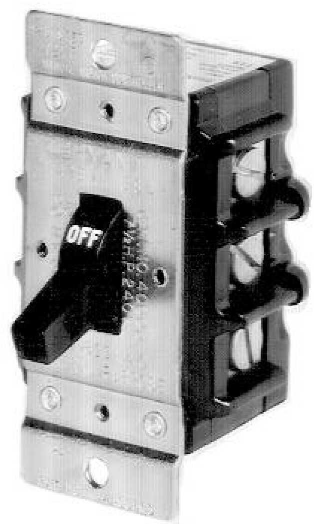


FIGURE 3. DOUBLE-BREAK CONTACTOR

With a manual controller, the operator presses a button or moves a switch that is integral to the electrical equipment being run. In other words, the button or switch is physically attached to the controller itself, and is not operated remotely.

When an operator activates a manual controller, the *power circuit* engages, **carrying the electricity to the load.**

The manual contactor was a big improvement over the knife blade switch. Variations of manual contactors are still in use today.



MANUAL MOTOR CONTROLLER

ENCLOSED **MANUAL MOTOR CONTROLLER**

FIGURE 4. TWO TYPICAL MANUAL CONTACTORS STILL IN USE TODAY

Magnetic Contactor

Engineers eventually made a breakthrough with the magnetic contactor.

A magnetic contactor is operated electromechanically without manual intervention. This means that the contactor can be operated remotely, without the need for putting a person in a potentially dangerous location. Magnetic contactors use a small control current to open and close the circuit.

NOTE: From this point forward, the term "contactor" will refer only to an **AC magnetic contactor**.

Contactor Components

If you sat down and took apart a contactor as shown in Figure 5, you would find the following components: an *electromagnet* (E-frame), an *armature***,** a **coil,** a **spring,** and two sets of **contacts**, one movable set and one stationary set.

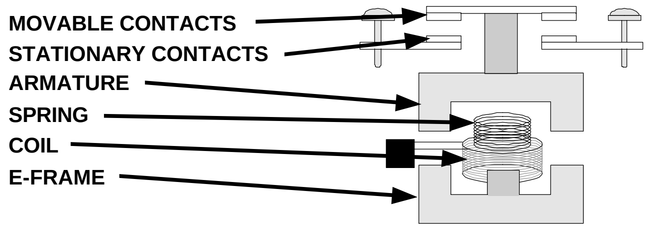


FIGURE 5. MAGNETIC CONTACTOR COMPONENTS

How the Contactor Operates

So, how exactly does the contactor open and close? The **E-Frame**, when energized by the **coil**, becomes an electromagnet. The **armature**, a companion to the E-frame, is connected to a set of **contacts**. The armature is moveable but is held by a **spring**.

When the **coil** is energized, the **moveable contacts** are pulled toward the **stationary contacts**, because the **armature** is pulled toward the **E-frame**. Once the two sets of contacts meet, power can flow through the contactor to the load.

When the coil is de-energized, the magnetic field is broken, and the spring forces the two sets of contacts apart.

In Figure 6 on the next page, we step through the process again, using pictures to help you understand.

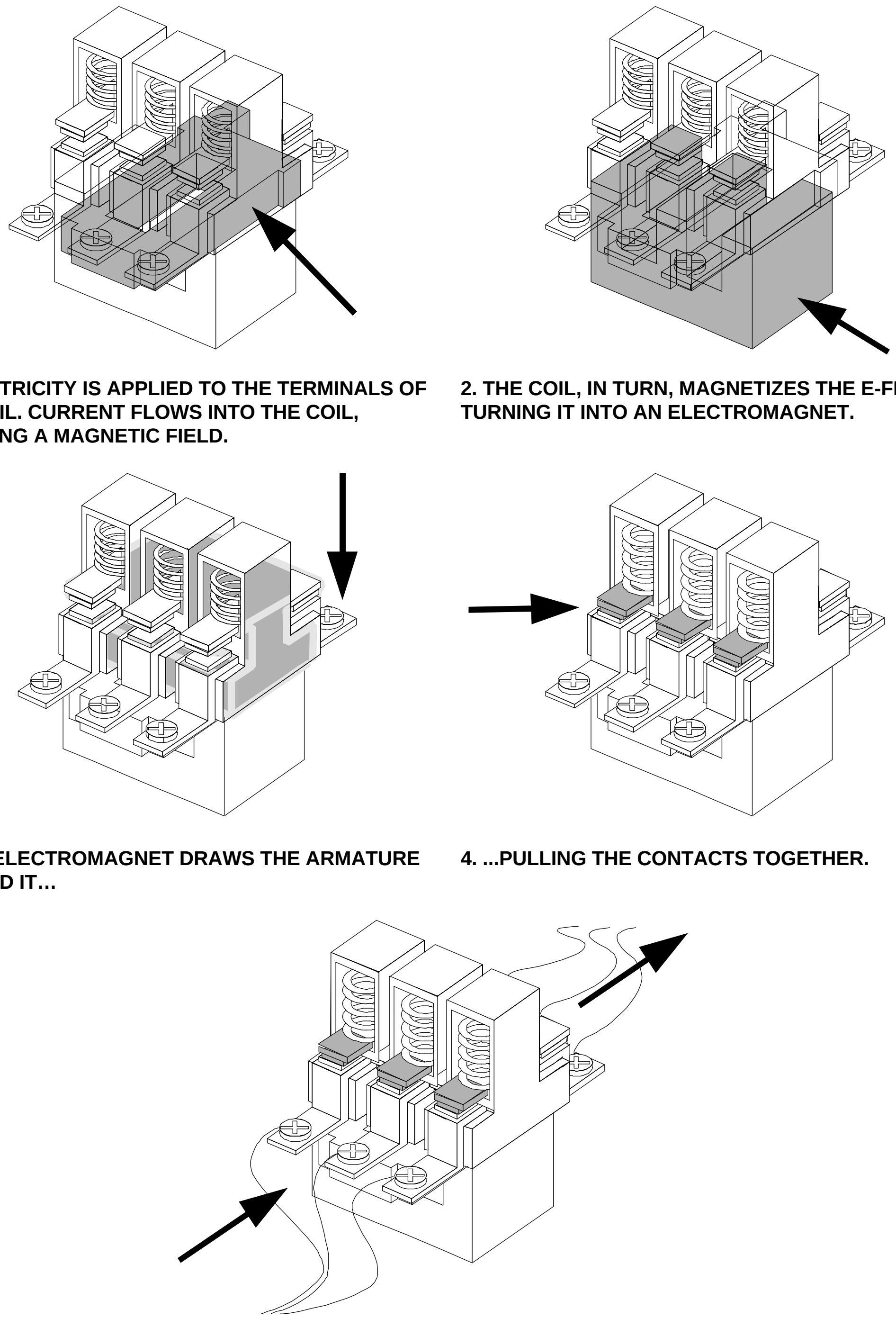
Contactors are used when no overload protection is necessary, and at lower levels of electrical current. Applications include lighting circuits, heaters, and transformers.

In summary, **contactors operate electromechanically and use a small control current to open and close the circuit**. (We will discuss control current in more detail in the section on starters.) The electromechanics do the work, not the human hand, as in a knife blade switch or a manual controller.

IN THE WORKPLACE

Pushbuttons and selector switches, like the ones on this control panel, are used in hundreds of manufacturing industries.

Each button and switch is connected to a contactor, for use in making or breaking an electrical circuit remotely.



1. ELECTRICITY IS APPLIED TO THE TERMINALS OF THE COIL. CURRENT FLOWS INTO THE COIL, CREATING A MAGNETIC FIELD.

2. THE COIL, IN TURN, MAGNETIZES THE E-FRAME, TURNING IT INTO AN ELECTROMAGNET.

3. THE ELECTROMAGNET DRAWS THE ARMATURE TOWARD IT…

4. ...PULLING THE CONTACTS TOGETHER.

5. POWER FLOWS THROUGH THE CONTACTOR TO THE LOAD.

FIGURE 6. HOW A MAGNETIC CONTACTOR OPERATES

Contact Life: Arcing

A major customer concern is the life expectancy of a contactor. It has been said that, “The worst thing you can do to a car is start it.” The same is true for contacts. The more frequently the contacts are opened and closed, the shorter the life of the contactor.

As contacts open and close, an electrical arc is created between them. The arcs produce additional heat, which, if continued, can damage the contact surfaces.

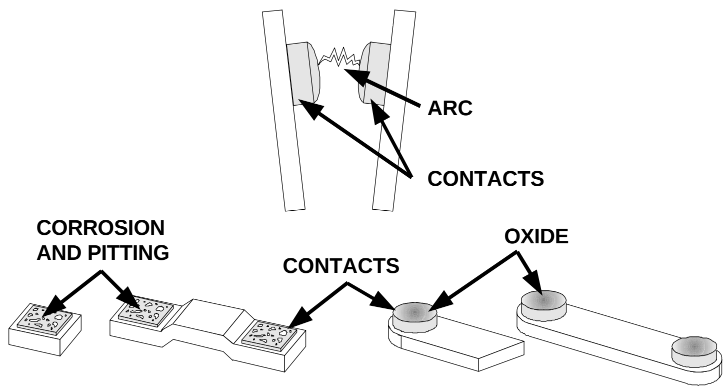


FIGURE 7. ARCING CAUSES CORROSION, PITTING AND OXIDE BUILD-UP

Eventually, the contacts become blackened with burn marks and pitting made by the electrical arcs. This is not a reason for contact replacement. In fact, this black deposit (*oxide*) helps them to make a better “seat” to conduct the electricity. However, contacts do need to be replaced once the surface is badly corroded or worn away.

Contact Life: Bounce

Applying some logic, you can conclude that **the faster the contact closes, the sooner the arc is extinguished, and the longer the life expectancy of the contact**. But, modern contactors have been designed to close so quickly and with such energy that **the contacts slam against each other and rebound, causing a bouncing action.** This is referred to as *contact bounce*. When the contact bounces away, a secondary arc is created. The contacts slam together again and again, each time the bouncing and arcing become less and less.

So, in addition to closing the contacts as fast as possible, you also want the contacts to bounce as little as possible, to reduce secondary arcing and wear.

REVIEW 1

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. Explain the two problems with knife blade switches that caused engineers to seek other solutions.

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2. What is the function of a contactor?

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3. Explain the difference between a manual contactor and a magnetic contactor.

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4. Explain the two main concerns with contact life.

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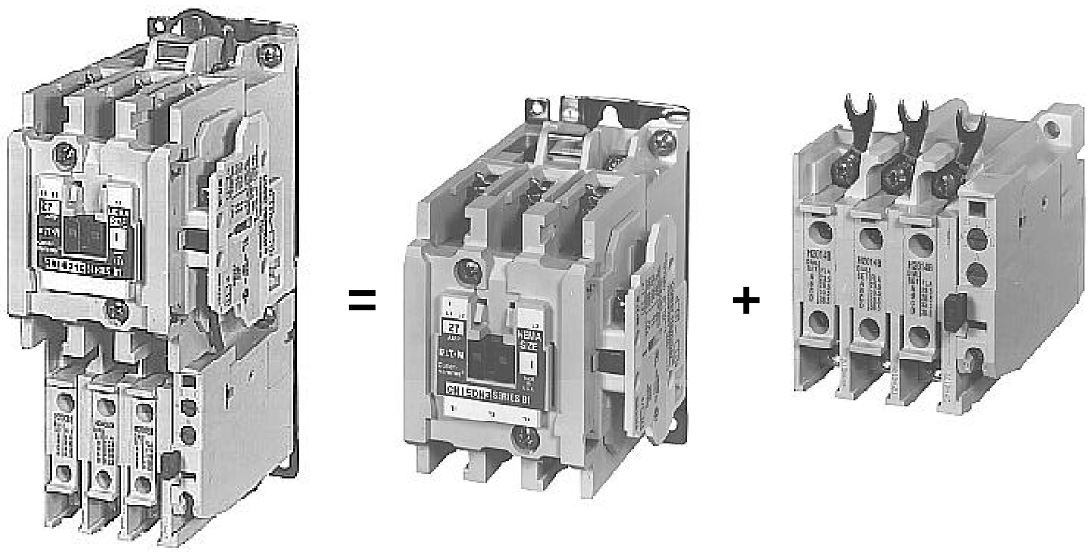
OVERLOAD PROTECTION

Now that you have a good understanding of what a contactor is and how it works, let's move on to a discussion of overload protection. As we mentioned at the beginning of this module, **overload protection prevents an electric motor from drawing too much current, overheating, and literally "burning out."**

Like a contactor, overload protection is a building block of starters. Remember the starter equation:



STARTER **CONTROLLER** **OVERLOAD PROTECTION**

FIGURE 6. A STARTER IS MADE UP OF A CONTROLLER (MOST OFTEN A CONTACTOR) AND OVERLOAD PROTECTION

Let's begin this section by learning how a motor works, and why overload protection is needed. Then we will move on to the different types of overload protection.

How Motors Work

Part of understanding overload protection is understanding how motors work. **A motor goes through three stages during normal operation: resting, starting, and operating under load.**

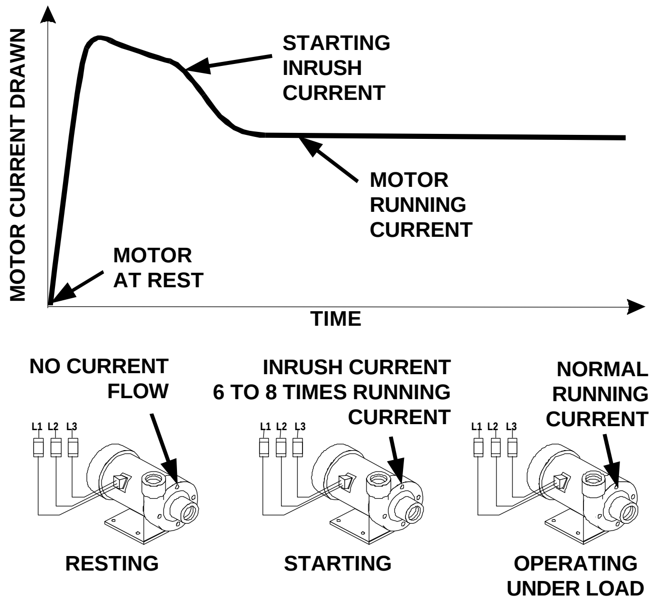


FIGURE 9. MOTOR OPERATION STAGES

A motor at rest requires no current because the circuit is open.

But **once the circuit is closed**, the motor starts drawing a tremendous *inrush* current; as much as 6-8 times its running current.

Here is the problem: **this large inrush current can cause immediate tripping of the circuit breaker**. A fuse or circuit breaker sized to handle the normal running load of the motor will open the circuit during startup.

You might think that sizing the fuse or circuit breaker for the spike in current draw would solve the problem. But if you did this, once the motor was running, only the most extreme *overload* would open the circuit. Smaller overloads would not *trip* the breakers, and the motor would burn out.

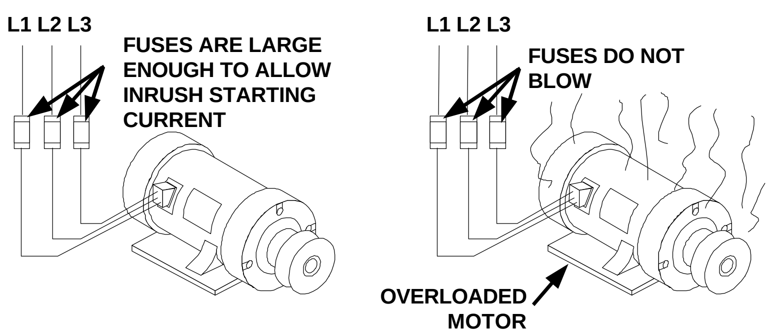


FIGURE 10. THE PROBLEM WITH OVERSIZED FUSES

What Is An Overload?

So, what is an overload? **The term literally means that too much load has been placed on the motor.** A motor is designed to run at a certain speed, called its *synchronous speed*. If the load on the motor increases, the motor draws more current to continue running at its synchronous speed.

It is quite possible to put so much load on a motor that it will draw more and more current without being able to reach synchronous speed. If this happens for a long enough period of time, the motor can melt its insulation and burn out. This condition is called an overload.

In fact, the motor could stop turning altogether (called a *locked rotor*) under a large enough load. This is another example of an overload condition. Even though the motor shaft is unable to turn, the motor continues to draw current, attempting to reach its synchronous speed.

While the running motor may not draw enough current to blow the fuses or trip circuit breakers, it can produce sufficient heat to burn up the motor. This heat, generated by excessive current in the windings, causes the insulation to fail and the motor to burn out. **We use the term** *locked rotor amps* **to describe when the motor is in this state** and is drawing the maximum amount of current.

So, because of the way a motor works, **an overload protection device is required that does not open the circuit while the motor is starting, but opens the circuit if the motor gets overloaded** and the fuses do not blow.

Overload Relay

The *overload relay* is the device used in starters for motor overload protection. It limits the amount of current drawn to protect the motor from overheating.

An overload relay consists of:

- A current sensing unit (connected in the line to the motor).
- A mechanism to break the circuit, either directly or indirectly.

To meet motor protection needs, overload relays have a time delay to allow harmless temporary overloads without breaking the circuit. They also have a trip capability to open the *control circuit* if mildly dangerous currents (that could result in motor damage) continue over a period of time. All overload relays also have some means of resetting the circuit once the overload is removed.

IN THE WORKPLACE

The blower motor on this furnace uses an overload relay to protect the motor when the blower turns on and current inrush begins.

A circuit breaker could not provide both running and inrush protection.

The inrush continues until the blower fan reaches full speed, or, more technically, the motor's synchronous speed.

Let's take a look inside a few overload relays to see how they work. We'll review the following overload relay types:

- Eutectic (melting alloy)
- Bimetallic
- Solid State

The Eutectic Overload Relay

The melting alloy (or eutectic) overload relay consists of a *heater coil***,** a *eutectic alloy***,** and a mechanical mechanism to activate a tripping device when an overload occurs. The relay measures the temperature of the motor by monitoring the amount of current being drawn. This is done indirectly through a heater coil.

Many different types of heater coils are available, but the operating principle is the same: **A heater coil converts excess current into heat which is used to determine whether the motor is in danger.** The magnitude of the current and the length of time it is present determine the amount of heat registered in the heater coil.

Usually, a eutectic alloy tube is used in combination with a ratchet wheel to activate a tripping device when an overload occurs. **A eutectic alloy is a metal that has a fixed temperature at which it changes directly from a solid to a liquid.** When an overload occurs, the heater coil heats the eutectic alloy tube. The heat melts the alloy, freeing the ratchet wheel and allowing it to turn. This action opens the normally closed contacts in the overload relay.

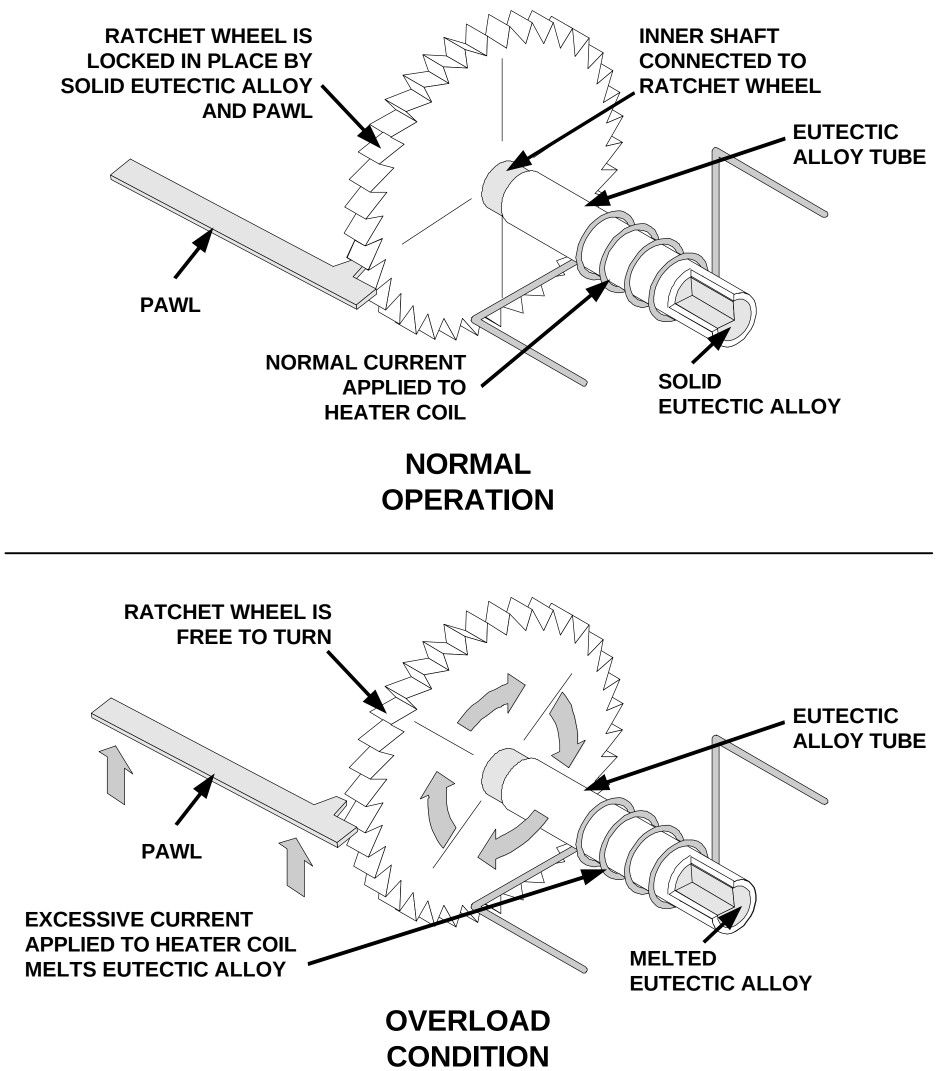


FIGURE 11. EUTECTIC OVERLOAD RELAY: RATCHET WHEEL AND EUTECTIC ALLOY COMBINATION

The Bimetallic Overload Relay

A bimetallic device is made up of two strips of different metals. The dissimilar metals are permanently joined. Heating the *bimetallic strip* causes it to bend, because the dissimilar metals expand and contract at different rates.

The bimetallic strip applies tension to a spring on a contact. If heat begins to rise, the strip bends, and the spring pulls the contacts apart, breaking the circuit, as shown in Figure 12.

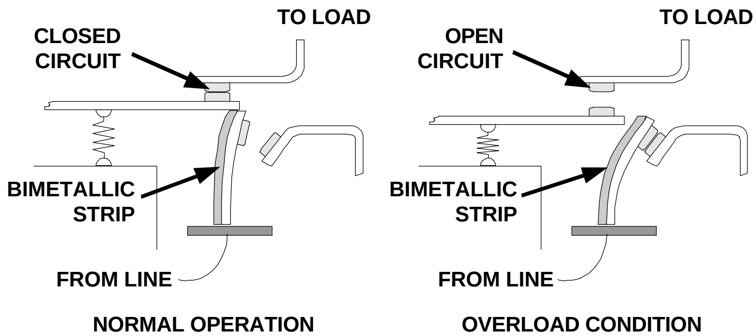


FIGURE 12. BIMETALLIC OVERLOAD RELAY: THE WARPING EFFECT OF THE BIMETALLIC STRIP

Once the tripping action has taken place, the bimetallic strip cools and reshapes itself, automatically resetting the circuit. The motor restarts even when the overload has not been cleared, and will trip and reset itself again and again. (This assumes an automatic reset. This type of relay can also be equipped with a manual reset.)

As we mentioned, an overload relay is designed to prevent the motor from overheating. The heat comes from two sources: heat generated within the motor, and heat present in the area where the motor operates (*ambient* heat). Although ambient heat contributes a relatively small portion of the total heat, it has a significant effect on the operation of the overload relay bimetals. A properly designed ambient-compensating element reduces the effects of ambient temperature change on the overload relay.

This type of overload relay is commonly found in applications such as walk-in meat coolers, remote pumping stations, and some chemical process equipment, where the unit is operated in environments with varying ambient temperatures.

The Solid State Overload Relay

Unlike the other two relay types, the *solid state* overload relay does not actually generate heat to facilitate a trip. Instead, **it measures current or a change in resistance.** The advantage of this method is that the overload relay doesn't waste energy generating heat, and doesn't add to the cooling requirements of the panel.

Current can be measured via current transformers, then converted into a voltage which is stored in memory inside the overload relay. If the relay notices that the current is higher than it should be for too long a period of time, it trips.

Another type of solid state overload relay uses sensors to sense the heat generated in the motor. When the sensor senses heat in excess of the preset value for too long a period of time, it trips.

The solid state overload relay also provides some advanced functions.

1. It is possible to provide proactive functionality and improved protection against special conditions. For example, when high ambient temperature conditions exist, devices that use sensors can sense the effect the ambient temperature is having on the motor.

2. Some solid state overload relays offer programmable trip time. This can be useful when a load takes longer to accelerate than traditional overload relays will allow, or when a trip time in between traditional *trip classes* is desired.

3. Some overload relays have a built in emergency override, to allow the motor to be started even when it could be damaging to the motor to do so. This can be useful in a situation where the process is more important than saving the motor.

4. Some solid-state overload relays can detect the change in current when a motor suddenly becomes unloaded. In such a situation, the relay will trip to notify the user that there is an application problem. Normally, this indicates a system problem rather than a motor problem.

Tripping

Many overload protection devices have a trip indicator built into the unit to indicate to the operator that an overload has taken place.

Overload relays can have either a manual or an automatic reset. A manual reset requires operator intervention, such as pressing a button, to restart the motor. An automatic reset allows the motor to restart automatically, usually after a “cooling off” period, as in the case of the bimetallic strip.

Overload relays also have an assigned trip class. The trip class is the maximum time in seconds at which the overload relay will trip when the carrying current is at 600% of its current rating. Bimetallic overload relays can be rated as **Class 10**, meaning that they can be counted on to break the circuit no more than 10 seconds after a locked rotor condition begins. Melting alloy overload relays are generally **Class 20**.

Overload Relays in Action

You will get motor protection with either a manual or a magnetic starter. However, the actual mechanics of the overload protection work differently for each type of starter.

When a manual starter experiences an overload, an overload trips a mechanical latch, causing the contacts to open and disconnect the motor from the electrical line.

In a magnetic motor starter (which we will discuss in the next section), an overload results in the opening of a set of contacts within the overload relay itself. This set of contacts is wired in series with the starter coil in the control circuit of the magnetic motor starter. Breaking the coil circuit causes the starter contacts to open, disconnecting the motor from the line. The motor is stopped and saved from burning out.

REVIEW 2

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. Describe the purpose of overload protection for an electric motor.

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2. A motor goes through three stages during normal operation. Name them, and the typical percentage of full load current they draw.

______________ ______%

______________ ______%

______________ ______%

3. Define and explain the importance of a motor's synchronous speed.

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4. Explain why fuses or circuit breakers cannot properly protect an electric motor.

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5. Compare and contrast the function of the three overload relay types:

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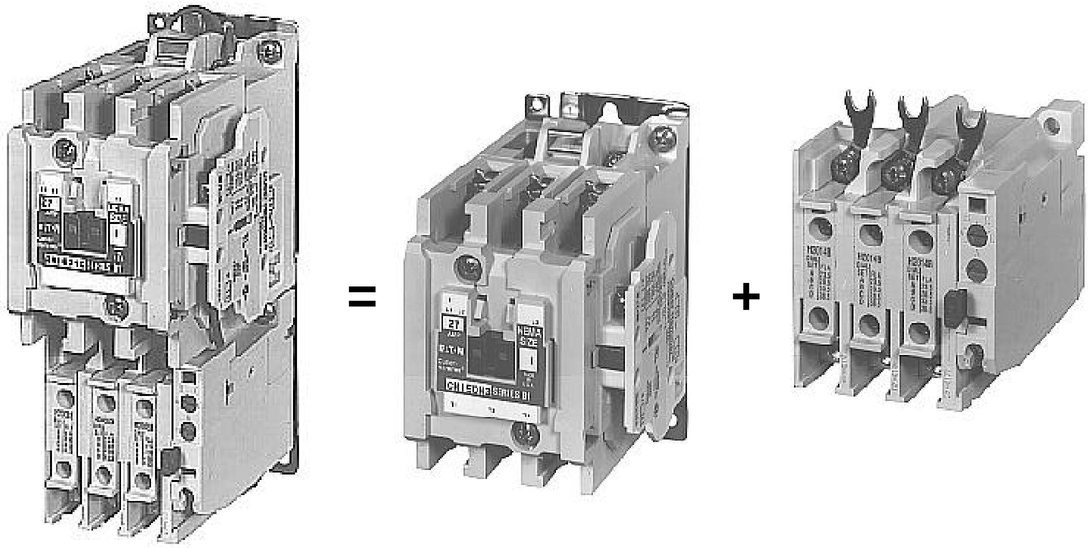
6. Define trip class.

   Trip class is ____.

THE STARTER

By combining the two elements we have discussed so far, the contactor and overload protection, we have a new device: a starter.



STARTER CONTROLLER OVERLOAD PROTECTION

FIGURE 13. A STARTER IS MADE UP OF A CONTROLLER
(MOST OFTEN A CONTACTOR) AND OVERLOAD PROTECTION

A starter lets you turn an electric motor (or motor-controlled electrical equipment) **on or off, while providing overload protection**. It represents another evolution in control. Now, we have a power control device that offers more than just a manual on/off control, such as a knife blade switch. The manual starter also provides a means to protect the motor from burnout: overload protection.

There are two main types of starters: the manual starter and the magnetic motor starter.

Manual Starter

As the name implies, **a manual starter is operated manually**. Operating a manual starter is fairly simple and straightforward: you press a button or toggle (mounted directly on the starter) to start or stop the connected electrical equipment. Mechanical linkages from the buttons or toggle force the contacts to open and close, starting and stopping the motor.

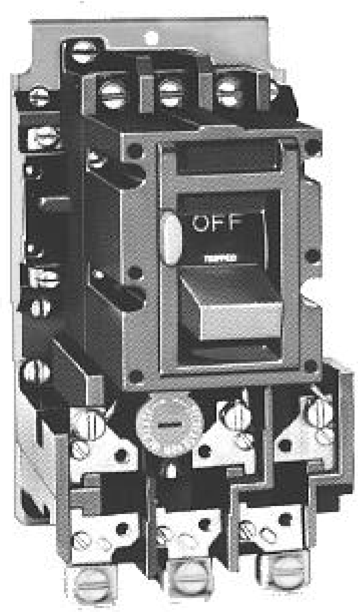


FIGURE 14. TOGGLE OPERATED STARTER

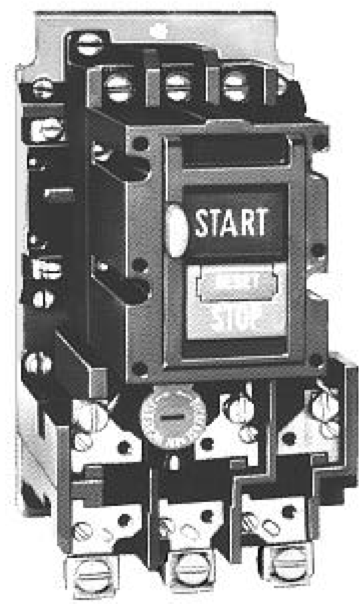


FIGURE 15. PUSHBUTTON OPERATED STARTER

Often, a manual starter is the best choice for an application, because it offers:

- compact physical size
- choice of enclosures
- low initial cost
- motor overload protection
- safe and economical operation

Low-voltage protection (LVP), which prevents automatic restarting of equipment after a power failure, is usually not possible with a manual starter.

This means, if the power fails, the power contacts remain closed (toggle or button in ON position). When the power is restored, the motor automatically restarts itself. This could create a dangerous situation, depending on the application.

Because of this, **manual starters are generally used on smaller loads where low voltage protection is not needed**. On applications like pumps and blowers, where the motor should run continuously, and restart automatically, this is actually an advantage.

IN THE WORKPLACE

Inside this saw mill, a high-speed saw quickly reduces logs to construction beams.

The saw uses a starter on the motor to allow it to get up to speed without tripping the internal circuit breaker.

If the saw were to hit a knot or a nail, and the motor was not able to turn at its synchronous speed, it would attempt to draw more current in order to do so.

The resulting overload would cause the saw to stop until the overload condition was removed.

Magnetic Motor Starter

The other main type of starter is the AC magnetic motor starter. These are so commonly used, that when we use the term “motor starter,” we mean “AC magnetic motor starter” unless specifically stated otherwise.

We will begin with a look into what they are and how they work, and finish up with an overview of specific types of motor starters.

Motor starters offer some additional capabilities not available in a manual starter, most importantly, remote and automatic operation. In other words, the magnetic motor starter did for manual starters what the magnetic contactor did for manual controllers: it removed the operator from the immediate area.

Like the magnetic contactor, the motor starter depends on magnets and magnetism for its operation. These additional capabilities are due, for the most part, to the motor starter’s electromagnetic operation and the control circuit.

Starter Circuitry

Before we go any further, we need to discuss starter circuitry.

The motor starter has two circuits: the power circuit and the control circuit. Figure 16 shows a three-phase, full voltage, non-reversing magnetic starter. The thick lines are the power circuit, and the thin lines are the control circuit.

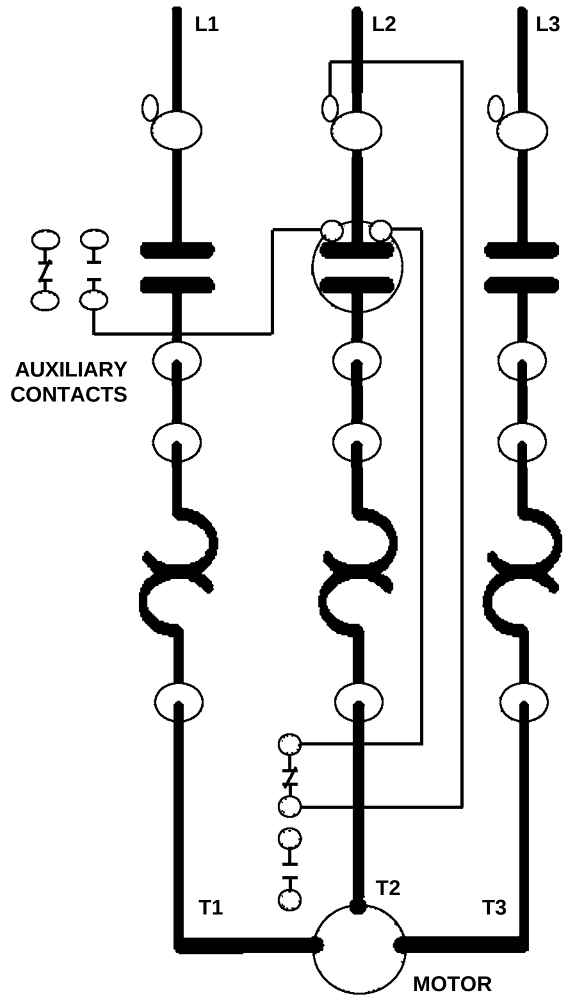


FIGURE 16. CONTROL AND POWER CIRCUITS

The power circuit runs from the line to the motor. Electricity passes through the contacts of a starter, the overload relay and out to the motor. The power (main) contacts carry the motor current.

The control circuit operates the contactor (on/off). As shown in Figure 16, the contacts that interrupt or allow the main current to flow to the motor are controlled by opening or closing the contacts in the control circuit. The control circuit energizes the coil creating an electromagnetic field that pulls the power contacts closed, thereby connecting the motor to the line. **The control circuit makes remote operation possible.**

The control circuit can get its power in one of two ways. If the control circuit gets its power from the same source as the motor, this is termed *common control*. Figure 16 depicts a common control circuit configuration.

The other type is *separate control*. This is the most common form of control. In this arrangement, the control circuit gets its power from a separate source, usually lower in voltage than the motor's power source.

In addition, there are two ways to wire the control circuit. One common method of wiring the control circuit is known as **Two-Wire**. It uses a maintained contact type of pilot device -- such as a thermostat, float switch, or presence sensor. This circuit provides for an automatic operation (start - stop) of the load.

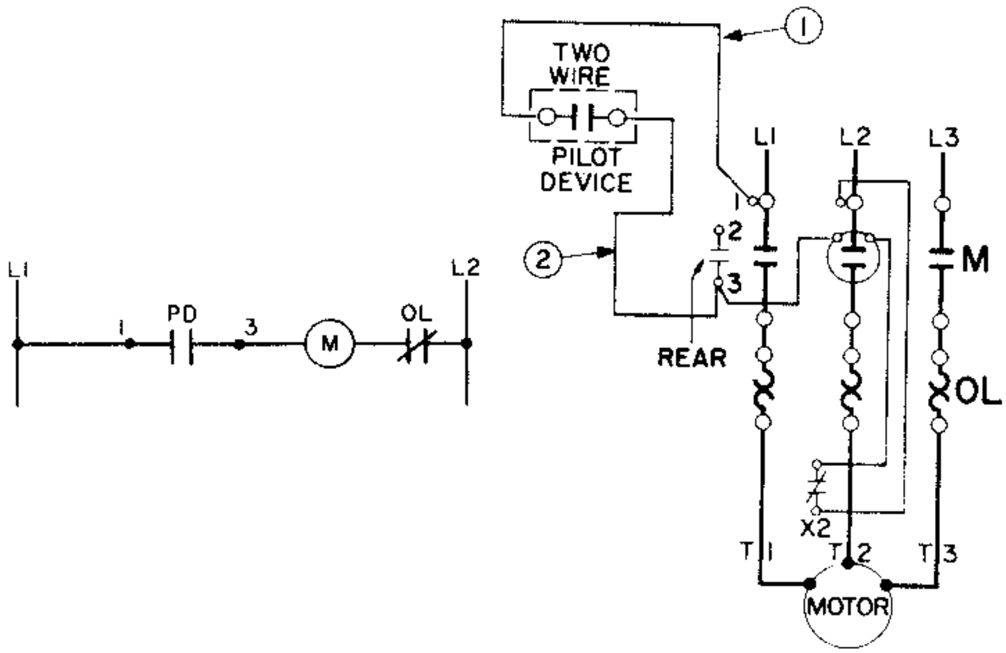


FIGURE 17. TWO WIRE CONTROL

The other common method of wiring the control circuit is **Three-Wire** control. It uses momentary contact pilot devices and a holding circuit contact. The holding circuit contact is commonly an auxiliary contact on the starter or contactor. If circuit power is interrupted, the circuit must be restarted by an operator.

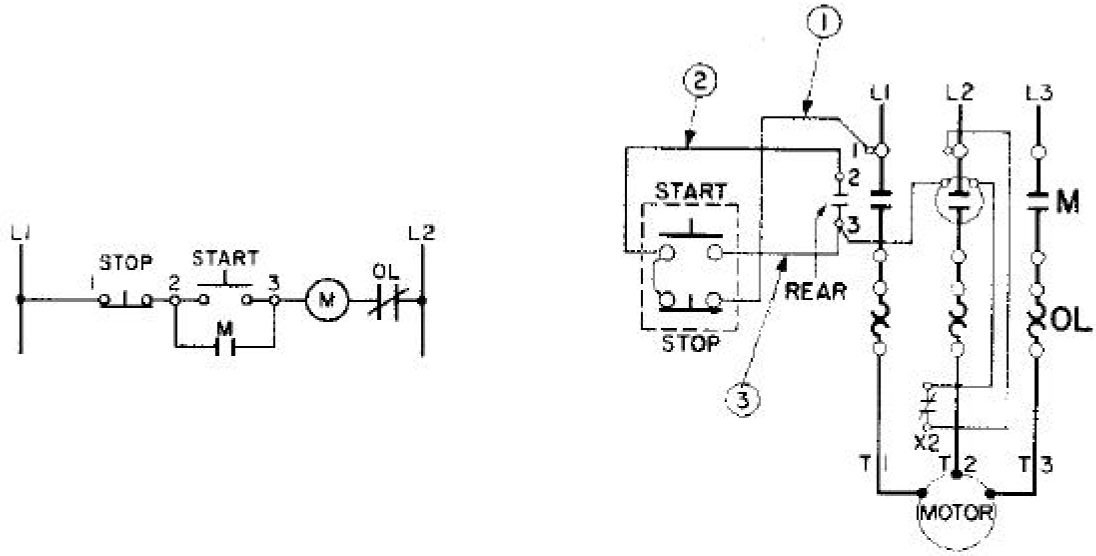


FIGURE 18. THREE WIRE CONTROL

Features of Motor Starters

All motor starters share the following power control functions:

- Rated by current (amperes) or power (horsepower)
- Remote ON/OFF control
- Motor overload protection
- Starting and stopping (electrical life)
- Plugging and jogging (rapid making and breaking current)

Types of Motor Starters

Four particular varieties of motor starters are *across-the-line*, the *reversing starter*, the *multispeed starter*, and the *reduced voltage starter*.

Across-the-line or **full voltage non-reversing (FVNR) is the most commonly used general purpose starter.** This starter connects the incoming power directly to the motor. It can be used in any application where the motor runs in only one direction, at only one speed, and starting the motor directly across the line does not create and “dips” In the power supply.

The reversing starter (**FVR**, for full-voltage reversing) **reverses a motor by reversing any two leads to the motor.** This is accomplished with two contactors and one overload relay. One contactor is for the forward direction and the other is for reverse. It has both mechanically and electrically interlocked sets of contactors.

The multispeed starter is designed to be operated at constant frequency and voltage. There are two ways to change the speed of an AC motor:

- vary the frequency of the current applied to the motor
- use a motor with windings that may be reconnected to form different numbers of poles

The multispeed starter uses the latter option to change speed.

Reduced voltage starters (RVS) are used in applications that typically involve large horsepower motors. The two main reasons to use a reduced voltage starter are:

- reduce the inrush current
- limit the torque output and mechanical stress on the load

Power companies often won’t allow this sudden rise in power demand. The reduced voltage starter addresses this inrush problem by allowing the motor to get up to speed in smaller steps, drawing smaller increments of current. This starter is not a speed controller. It reduces the shock transmitted to the load only upon start-up.

We will look at reduced voltage starters in much more depth in Module 21, Reduced Voltage Starters.

Standards And Ratings

You will undoubtedly run across two acronyms when dealing with contactors and starters : **NEMA** and **IEC**. These are two organizations that recommend design and testing standards for electrical devices such as **contactors** and **motor starters**. It is important to note that neither organization performs actual testing of equipment.

NEMA and IEC

NEMA is the National Electrical Manufacturers Association. It has its headquarters in Washington D.C., and is associated with equipment used in **North America**. NEMA devices are built to a high level of perfection, for use in a variety of applications.

NEMA devices, because of their conservative ratings, can be used in almost any application. Being **less application-sensitive and more durable**, NEMA devices tend to be **larger**, and therefore **more expensive** than IEC devices.

IEC is the **International Electro-technical Commission**. With headquarters in Geneva, Switzerland, it is associated with equipment used **internationally**. IEC devices are commonly used in OEM machines, where specifications are known and not likely to change.

Because of their **greater application sensitivity**, IEC devices sometimes **require more care in selection** than NEMA devices.

As we expand into a global economy, an increasing number of control products are manufactured to IEC standards and conventions. Consequently, there is also more confusion in understanding the differences the IEC and NEMA products. One standard is not necessarily superior to the other, they are just different.

UL and NEC

In addition to IEC and NEMA standards, there is **UL** (Underwriters Laboratories, Inc.). UL provides product standardization and testing. Their goal is to verify (through testing) that equipment will not pose a hazard to personnel or property when properly installed. They are chiefly concerned with **safety issues**.

NEC (National Electrical Code) is a standard for applying electrical equipment in the U.S. In the case of motors and starters, one of NEC's requirements is that **a motor must be protected from destroying itself under overload conditions**. And that is where overload relays come in. The code is adopted and enforced by local electrical inspectors.

CE and CSA

Finally, there are the **CE** and the **CSA**. CE relates the European market. CSA (Canadian Standard Association) is very similar to UL. The CSA mark is required on products for sale in Canada. Products receiving their approval are marked as such, serving as an "**entrance visa**." These marks indicate compliance with harmonized European Standards.

HELPING THE CUSTOMER

Armed with your knowledge of starters, contactors, and overload relays, you are now prepared to help the customer. The two most fundamental questions you need to ask are:

1. Are you controlling a motor?
2. Do you need to remotely control the motor?

Based on the answer to these two questions, you will be able to easily navigate through the various power control devices and accessories to narrow your selection.

Interviewing the Customer

When you are **selecting a device** to recommend to the customer, you will need to get a considerable amount of information about the customer's application.

Consult the chart below for the type of device, and obtain customer data for each topic. Some sample responses are given to help the customer understand what you are asking about.

Contactor	AC Manual Starter	Motor Starter
Type of load (motor, lighting)	Size (HP, amps)	Starter type (FVR, RVS)
Size (HP, amps)	Motor Voltage (230, 460)	Horsepower (starter size or amperage)
Motor voltage (230, 460)	Enclosure type (NEMA 1, 12 etc.)	Motor voltage (230, 460)
Enclosure type (NEMA 1, 12 etc.)		Common or separate control
Control voltage		If separate, control voltage (24, 120)
Number of poles		Enclosure type
		Needed accessories
		Full Load Amps of motor (for heater selection)

NEMA or IEC?

Part of your recommendation to the customer will be choosing a NEMA or an IEC device. You will need to obtain the following information from the customer.

NEMA	IEC
Motor voltage (230, 460)	Motor voltage (230, 460)
Horsepower (5, 10)	Horsepower (5, 10)
Phase (1, 3)	Phase (1, 3)
Common or separate control	Common or separate control
Control voltage	Control voltage
Full Load Amps of motor	Frequency of stopping/starting
Starter type	Full Load Amps of motor
Enclosure type	Starter type
	Enclosure type
	Life expectancy required

There may be other considerations, depending on the application. But, remember the general rule of thumb when dealing with IEC and NEMA: **NEMA is simpler to apply, but more expensive. IEC satisfies specific applications, and is less expensive.**

Checking the Motor Nameplate

The motor nameplate is a source of useful information. You can find the *full load current* (FLC), the *motor service factor* (SF), and the trip class (10 or 20) there.

In the case of overload heater coil selection for continuous duty motors, refer to the manufacturer's tables, based on the motor's nameplate FLC rating. The size of the heater coil is based on the FLC, the motor SF, and trip class.

Armed with the right information from the customer, you can make an informed recommendation to meet the customer's needs.

Modifications

Often, a customer will ask if a contactor or motor starter can be modified. Generally, they are looking to change its functionality. The answer is yes, as long as the device does not require replacement.

Contactors and motor starters are easily modified by adding devices to expand their capabilities. The modifications that can be made are analogous to adding accessories to your car, like a CD-player. They change the performance of the control device to meet a specific need.

Some devices that are commonly added include:

- electrical auxiliary contacts
- power poles
- pneumatic timers
- transient suppressors
- control circuit fuse holders

REVIEW 3

Answer the following questions without referring to the material just presented. Begin the next section when you are confident that you understand what you've already read.

1. What is the function of a starter?

 ____

 ____

2. :List the four main starter types.

 ____

 ____

 ____

 ____

3. Write out what organization each abbreviation stands for, then match it to the proper definition.

NEC ____________________________	A. Recommends design and testing standards for North American electrical devices.
NEMA ____________________________	B. Recommends design and testing standards for European electrical devices.
UL ____________________________	C. Provides product standardization and testing.
IEC ____________________________	D. A standard for specific electrical applications.

4. In terms of application-sensitivity, explain the differences between a NEMA-rated device and an IEC-rated device.

 ____

 ____

GLOSSARY

Across-The-Line	The most commonly used general purpose starter. This starter connects the incoming power directly to the motor
Ambient	The environmental conditions around a given piece of equipment, such as a motor. The air temperature around a motor is called the ambient temperature.
Arcing	A condition where high voltage leaps across the open space between the contacts of a switch.
Armature	A component of a magnetic contactor that holds the movable contacts.
Bimetallic Strip	A strip of two dissimilar metals that does the work of tripping the relay on an overload in a bimetallic overload relay.
Common Control	A control circuit that gets its power from the same source as the motor.
Contact	The parts of a contactor that actual make and break the electrical connection.
Contact Bounce	A condition caused by the contacts of a contactor slamming against each other and rebounding, causing a bouncing action.
Contactor	An operating device which connects or disconnects the motor from the power supply. The term is used when the power poles are operated by an electromagnetic circuit, through the use of a coil and magnetic armature frame.
Control Circuit	The circuit that controls a relay or contactor.
Double-Break Contacts	A pair of contacts that can open a circuit in two places simultaneously
Electromagnet	A magnet formed by a coil of wire with an electrical current running through it.
Eutectic Alloy	A metal that has a fixed temperature at which it changes from a solid to a liquid.
Full Load Current	The current required by the motor to produce full-load torque at the motor's rated speed.

Heater Coil	A sensing device that monitors the heat generated by excessive current, and by ambient temperature changes.
Inrush	The amount of current drawn when a motor is first switched on. This can be 6 to 8 times the normal running current draw.
Knife Blade Switch	The first device used to stop and start an electric motor. These were levers that would drop a strip of metal onto a contact to make the electric circuit.
Load	The device being powered, such as a motor or heater.
Locked Rotor	A condition that occurs when a motor is so overloaded that the rotor cannot turn, no matter how much current it draws.
Locked Rotor Amps	The maximum amount of current a motor can draw when it is so overloaded that the rotor cannot turn. This is generally enough current to cause the insulation to fail and the motor to burn up.
Low Voltage Protection	In a three wire control setup, when the voltage on L1 - L2 drops to a low value, and is then restored, the contactor will remain open.
Motor Service Factor	The amount of extra horsepower a motor can generate without overheating. This is typically expressed as 1.15.
Multispeed Starter	A starter designed to be operated at constant frequency and voltage. It uses a motor with windings that may be reconnected to form different numbers of poles to change speed.
Overload	The application of excessive load to a motor.
Overload Protection	A device or system that prevents an electric motor from drawing too much current, overheating, and literally “burning out.”
Overload Relay	A relay that responds to electrical overloads and operates at a preset value.
Oxide	A build-up that forms over time on contacts that are repeatedly opened and closed.

Power Circuit The part of a relay that actually provides power to the output component (such as a motor).

Reduced Voltage Starter A starter used in applications that typically involve large horsepower motors. It is used to reduce the inrush current and limit the torque output and mechanical stress on the load.

Reversing Starter A starter that reverses a motor by reversing any two leads to the motor.

Separate Control A control circuit that gets its power from a separate source, usually lower in voltage than the motor’s power source

Solid State No moving, mechanical parts.

Starter A device that controls the use of electrical power to equipment, usually a motor.

Synchronous Speed The speed at which a motor is designed to run.

Trip/Tripping The action an overload relay takes to protect a motor.

Trip Class The maximum time in seconds at which the overload relay will trip when the carrying current is at 600% of its current rating. A Class 20 relay will trip in 20 seconds or less.

REFERENCE

In preparing this training module, some material was taken from the publication listed below:

Gary Rockis and Glenn A. Mazur, *Electrical Motor Controls* (Homewood, IL: American Technical Publishers, Inc., 1997).

REVIEW 1 ANSWERS

1. Answer should basically say: “1. Arcing corroded the soft copper switches with pits. Dirt and moisture compounded the problem. 2. As motors became larger, It was physically dangerous to handle the switch.”

2. A contactor connects or disconnects the motor from the power supply.

3. Answer should basically say: “A magnetic contactor is operated electromechanically without manual intervention. This means that the contactor can be operated remotely, without the need for putting a person in a potentially dangerous location.”

4. Answer should basically say: “1. As contacts open and close, an electrical arc is created between them. The arcs produce additional heat, which, if continued, can damage the contact surfaces. 2. Modern contactors close so quickly and with such energy that the contacts slam against each other and rebound, causing a bouncing action. When the contact bounces away, a secondary arc is created.”

REVIEW 2 ANSWERS

1. Answer should basically say: “Overload protection prevents an electric motor from drawing too much current, overheating, and literally ‘burning out’.”

2. | | |
   |---|---|
   | Resting: | 0% |
   | Starting: | 600-800% |
   | Operating under load: | 100% |

3. Answer should basically say: “A motor is designed to run at a certain speed, called its synchronous speed. If the load on the motor increases, the motor draws more current to continue running at its synchronous speed. It is quite possible to put so much load on a motor that it will draw more and more current without being able to reach synchronous speed. If this happens for a long enough period of time, the motor can melt its insulation and burn out.”

4. Answer should basically say: “A fuse or circuit breaker sized to handle the normal running load of the motor will open the circuit during startup. Sizing the fuse or circuit breaker for the spike in current draw would not permit smaller overloads to trip the breakers, and the motor would burn out.”

5. Answer should basically say: The eutectic overload relay measures the temperature of the motor by monitoring the amount of current being drawn through a heater coil. The bimetallic overload relay uses a bimetallic strip to apply tension to a spring on a contact. If heat begins to rise, the strip bends, and the spring pulls the contacts apart, breaking the circuit. The solid state overload relay does not actually generate heat to facilitate a trip. Instead, it measures current or a change in resistance. The advantage of this method is that the overload relay doesn't waste energy generating heat.”

6. the maximum time in seconds at which the overload relay will trip when the carrying current is at 600% of its current rating

REVIEW 3 ANSWERS

1. Answer should basically say: “A starter lets you turn an electric motor (or motor-controlled electrical equipment) on or off, while providing overload protection.”

2. Across The Line, Reversing, Multi-Speed, Reduced Voltage

3. NEC is National Electrical Code, matches with letter D.
   NEMA is National Electrical Manufacturers Association, matches with letter A.
   UL is Underwriters Laboratories, Inc, matches with letter C.
   IEC is International Electro-technical Commission, matches with letter B.

4. NEMA is simpler to apply, but more expensive. IEC satisfies specific applications, and is less expensive.

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