101 BASICS SERIES

LEARNING MODULE 7:
LOW VOLTAGE POWER CIRCUIT BREAKERS

Cutler-Hammer

EATON

WELCOME

Welcome to Module 7, which is about low voltage power circuit breakers.

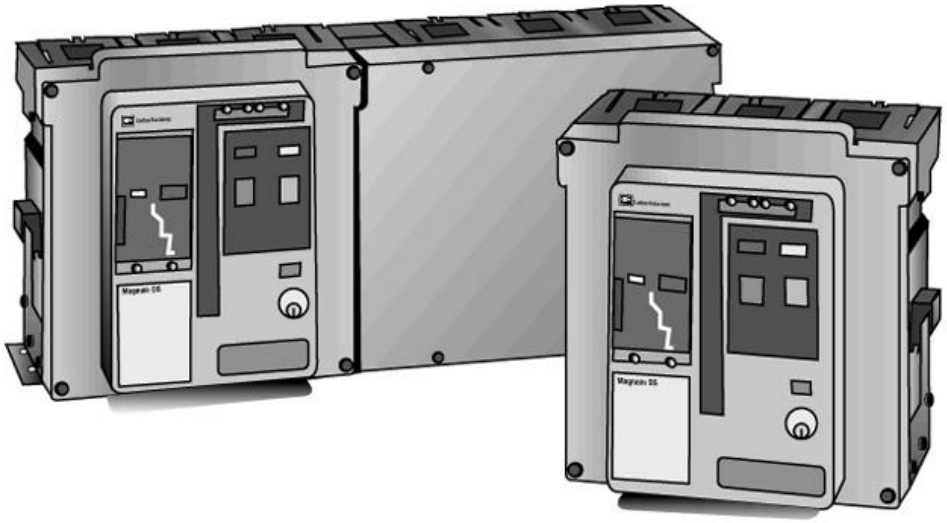


FIGURE 1: MOLDED CASE VERSION OF LOW VOLTAGE POWER CIRCUIT BREAKERS

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 items are italicized and underlined 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 will **step through each of these topics** in detail:

WHAT YOU WILL LEARN (CONTINUED)

INTRODUCTION

There are both low voltage DC power circuit breakers and low voltage AC power circuit breakers. The interruption of direct current is distinctly different from the interruption of alternating current, and generally more difficult at comparable voltages and currents. Large quantities of low voltage AC power circuit breakers are used throughout industry in comparison to very small numbers of DC devices. For this reason and the fact that this is an introduction to low voltage power circuit breakers, only AC designs will be covered. Keep in mind, however, low voltage DC power circuit breakers do exist and are used in a number of specialty applications, such as rapid transit.

Circuit breakers are often classified by certain modifying words, such as low voltage power. Low voltage AC power is considered to be for application at 1000 volts AC and below. For comparison reasons then, medium voltage AC power is considered to be for application above 1000 volts AC. In general, however, low voltage power circuit breakers are viewed as 600 volt circuit breakers applied at a number of different voltage levels, such as 240 or 480 volts.

Sound confusing? Let’s try to clear it up a bit by taking a brief look at why a low voltage power circuit breaker might be used along with some background information.

INTRODUCTION (CONTINUED)

Why use a low voltage power circuit breaker over another type of low voltage circuit breaker? Most often the determination is made by the specific application. Let's consider a number of the more prominent reasons why a low voltage power circuit breaker is ideally suited for certain applications. Keep these reasons in mind as you proceed through this module. You will learn about the features and requirements that support and further explain the following reasons for applying low voltage power circuit breakers:

- **Continuity of Service** - Continuity of service allows for the maximum up time and minimum down time of equipment. A low voltage power circuit breaker has a significant *short time rating* (also: "withstand rating"). This means that the low voltage power circuit breaker has the strength to withstand the stresses of a fault for up to 1/2 second or 30 cycles, instead of opening immediately. This ability to delay opening allows for a circuit breaker nearest the fault to clear the fault. This helps to prevent facility outages or a wide shutdown of facility equipment.

- **Maintainability** - A low voltage power circuit breaker is designed to be maintained in the field. This extends the useful service life of the circuit breaker. Especially for heavy, repetitive duty applications, maintenance of the circuit breaker is quite an important feature. Low voltage power circuit breakers allow for the inspection and replacement of parts on site.

- **Safety** - Low voltage power circuit breakers are tested as drawout devices in an enclosure. As such, four distinct circuit breaker positions relative to its enclosure are provided for maximum operator safety. The four drawout circuit breaker positions allow for the following uniquely different functions:

  Connected Position: The circuit breaker is fully connected and functional.

  Test Position: The circuit breaker's primary connections are disconnected. Secondary connections are not disconnected and testing can be safely performed because the circuit breaker is not energized. This is not possible with a circuit breaker that is permanently mounted.

  Disconnect Position: Neither the primary nor secondary electrical connections of the circuit breaker are made. This position is often used as a storage position for the circuit breaker within its enclosure.

  Withdrawn Position: In this position, the circuit breaker has no electrical connections. It is far enough out of its enclosure, usually on some type of integral extension rails, to permit inspection and maintenance without turning the power off to an entire assembly of equipment.

INTRODUCTION (CONTINUED)

- **Reliability** - Low voltage power circuit breakers are tested for and must be able to meet high electrical and mechanical endurance ratings. Electrical endurance is the number of operations at rated continuous current and maximum system voltage. Mechanical endurance is the number of operations with no voltage applied.

- **Remote Operation and Reclosing** - Low voltage power circuit breakers are designed for operation remotely. They have two-step *stored energy* mechanisms which permit circuit breakers to rapidly reclose after a fault. The two-step stored energy mechanism makes multiple charge-close operations possible, such as the operating sequence: charge-close-recharge-open-close-open.

Custom has led to using phrases such as **low voltage power circuit breaker, low voltage metal-frame circuit breaker, low voltage air circuit breaker, and 600 volt power circuit breaker.** Although these circuit breakers fall into the classification of 1000 volts and below, real world applications are usually 600 volts and below, thus the 600 volt reference. In general, such a device must be built and tested in accordance with a very specific set of standards, such as *ANSI* Standards. A **low voltage power circuit breaker** is a device with both an *interrupting rating* and a short time rating, where the short time rating is comprised of two components:

- Short Delay Current (expressed in kA)

- Short Delay Time (expressed in cycles)

This is the primary differentiating feature between a power circuit breaker and a molded case circuit breaker. The importance of this differentiation will be discussed a number of times later in this module.

INTRODUCTION (CONTINUED)

For many years, low voltage power circuit breakers were essentially an assembly of parts on a welded metal frame, **thus the phrase metal-frame circuit breaker.** Distinguishing one low voltage circuit breaker from another at that point was rather simple. If it was a metal-frame circuit breaker, it was probably a power circuit breaker. If the circuit breaker parts were enclosed by an insulating material, it was called a molded case circuit breaker (Figure 2).

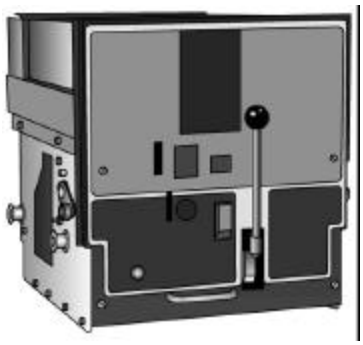


FIGURE 2: METAL-FRAME LOW VOLTAGE POWER CIRCUIT BREAKER

Certain hybrid low voltage circuit breakers were later developed and quite successful in certain markets. These circuit breakers had their parts encased in an insulating material, not unlike a molded case circuit breaker. From a performance standpoint, however, they performed more like a power circuit breaker. They had several of the same physical attributes as the power circuit breaker, but were never able to achieve the short time ratings of a power circuit breaker or pass all the power circuit breaker test standards.

This type of circuit breaker, although not tested to all the same standards as a power circuit breaker, found its application niche to be similar to traditional power circuit breakers. **This design became known as a low voltage insulated case circuit breaker** (Figure 3).

At that point, the line between frame material to identify the type of circuit breaker became blurred. All this said, **the differentiating feature still remains the device's ability to meet power circuit breaker test standards, not the frame's type of construction.**

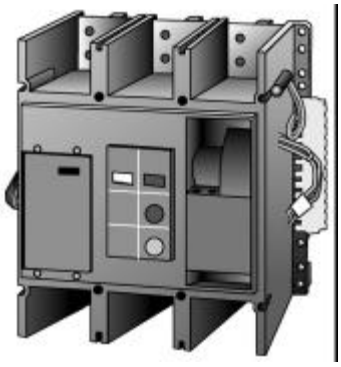


FIGURE 3: LOW VOLTAGE INSULATED CASE CIRCUIT BREAKER

WHAT IS A LOW VOLTAGE POWER CIRCUIT BREAKER?

Like much other terminology in the industry, the designation low voltage power circuit breaker can be confusing at times. For now, let's just say that the set or sets of standards a circuit breaker complies with determines whether or not the circuit breaker can be classified as a low voltage power circuit breaker. Applicable standards will be discussed later in this module.

As you might imagine by now, there is a wide variety of low voltage power circuit breakers available in the market today. We will not concentrate on what circuit breakers are called. Instead, we will look at characteristics, features and governing standards. Then, no matter who the manufacturer or what a circuit breaker is called, you will be better prepared to discuss the subject.

Low voltage power circuit breakers are considered rugged, long-lived, flexible and, to varying degrees, field-maintainable. Let's briefly look as some of the areas that might set a low voltage power circuit breaker apart from other types of low voltage circuit breakers, such as:

- Method used to make and break circuits
- Ratings
- Construction/Maintainability
- Integral Trip Units
- Operating Mechanisms
- Testing

Method Used to Make or Break Circuits

Since they make and break power circuits in air using *arc chutes*, as opposed to *vacuum*, SF_6 or oil, they are considered *air circuit breakers*.

Ratings

Low voltage power circuit breaker interrupting ratings and frame size designations can vary to some degree from one manufacturer to another or from one part of the world to another. One thing that is common to most power circuit breakers is the fact that they are **rated for continuous operation at 100% of their current rating in their enclosure.** What you see on the nameplate is what you get. There is no derating necessary when enclosed, if they are applied as specified by the manufacturer. This is not the case with all types of low voltage circuit breakers when applied in an enclosure. Low voltage power circuit breakers also have a **short time rating in addition to an interrupting rating** making them naturally suited for selectivity and coordination with downstream devices. Downstream devices are devices, such as other circuit breakers, **farther into the electrical system.**

You will recall from an earlier discussion, and it is worth mentioning again, that the short time rating is comprised of two components - **short delay current** and **short delay time,** which are adjustable (programmable). As far as **selectivity** is concerned, let's say it is the response to a set of circuit or system conditions, usually in terms of current, in a certain time frame. It is really the ability to withstand a certain level of current (kA) for a given time period (cycles) while a downstream device selectively takes care of the problem by interrupting. This is also known as discrimination. The degree of selectivity is usually limited by the sophistication of the trip unit and the physical ability of the circuit breaker to withstand the potentially large thermal and mechanical stresses created by a fault current.

Construction/ Maintainability

Low voltage power circuit breakers are essentially an assembly of parts on a metal frame or in an encased housing of insulating material. It is important to know that **no set of standards dictates the type of frame construction for low voltage power circuit breakers.** That decision is left in the hands of the manufacturer. You could look at it like the frame and body of a car holding all the other parts, like the motor, wheels, bumpers, seats and radio. This type of circuit breaker, to varying degrees, has the ability to be maintained in the field.

FIGURE 4: THE FRAME OF A CAR IS LIKE THE HOUSING OF A LOW VOLTAGE POWER DICTUIT BREAKER

In addition, it is available in either a *fixed* or *drawout* configuration, with drawout being the most commonly used type.

Trip Units

Trip units today used on low voltage power circuit breakers are almost universally of the **solid state, microprocessor-based design.** Years ago this same type circuit breaker used only electromechanical type trip units. Since this type of trip unit used with a low voltage power circuit breaker is almost non-existent, it is only mentioned briefly in this module. It is important to note that **ANSI Standards require that the trip units on low voltage power circuit breakers be integrally mounted.**

Operating Mechanisms

Low voltage power circuit breakers operate through two-step stored-energy spring mechanisms. The springs used to close the circuit breaker contacts, called closing springs, can be manually or electrically charged. The springs used to open the circuit breaker, called opening springs, are usually charged automatically when the breaker is closed.

Because of the increased closing forces required and the closing speed, low voltage power circuit breakers use **two-step, stored energy mechanisms.** That is, the closing springs are charged and remain charged with the breaker open until a "close" button or some other type of release is activated to close the breaker. As mentioned in Module 5, the low voltage power circuit breaker is required by ANSI Standards to provide an **open-close-open duty cycle.** This dictates the need for a **two-step stored energy mechanism.**

IN THE WORKPLACE

Low voltage power circuit breakers are most commonly applied in switchgear assemblies like the one shown here.

Frequently, low voltage power circuit breakers are used to control (and protect against overloads and short-circuits on) fans, pumps and lighting panels.

An assembly such as this one could be used to serve the HVAC needs of a manufacturing facility.

Because they are built to withstand such intense service conditions, low voltage power circuit breakers are ideal for industrial applications such as this.

FIGURE 5: TYPICAL LOW VOLTAGE METAL-ENCLOSED ASSEMBLY

PRINCIPLES OF OPERATION AND TERMINOLOGY

A low voltage power circuit breaker can be applied on any system within the interrupting rating of the circuit breaker. Low voltage power circuit breakers are ideally suited for applications where there is a **requirement for the circuit breakers to be selective** when faced with short-circuit conditions. In addition to our earlier discussion of selectivity, we could also say that “selective” means that the circuit breaker is capable of remaining closed for a certain period of time with a short-circuit present to allow the problem to be cleared up by a downstream device before the power circuit breakers open and the larger system is shut down (short time delay rating capacity). This is the area where short time delay ratings from **0 to 30 cycles** play a key role. Obviously, it is assumed that the circuit breaker is applied properly and will not face short-circuit conditions beyond its capabilities. If it does see a condition beyond its short time rating, it will open instantaneously.

Time will be taken here to introduce several additional principles and common terms associated with low voltage power circuit breakers and their application. This material will be especially helpful from a practical standpoint. These are the types of terms and topics encountered on the job when working with low voltage power circuit breakers and their assemblies. Principles and terms presented here are certainly not all inclusive. Even after this module is completed and you return to your work location, new terms will surface that should be part of your low voltage power circuit breaker vocabulary. The intent here is to provide a solid background on which to build.

Stored Energy

Stored energy was briefly touched on earlier in this module and in Module 5. Since this is a phrase frequently heard with respect to circuit breakers, it deserves some elaboration. All low voltage power circuit breakers, whether manually or electrically operated, **utilize two-step stored energy mechanisms.** Stored energy mechanisms are needed to overcome inherent forces opposed to the closing process. They also make it possible to close the circuit breaker very quickly, 5 cycles or less time.

Stored energy is energy held in waiting, **ready to open or close the low voltage power circuit breaker in five cycles or less.** Designs are such that the energy required to open a low voltage power circuit breaker is always available.

On manually operated circuit breakers, closing springs are charged by hand. For electrically operated circuit breakers, springs are normally charged by a small electric motor, although they can also be charged manually if power is not available (Figure 6).

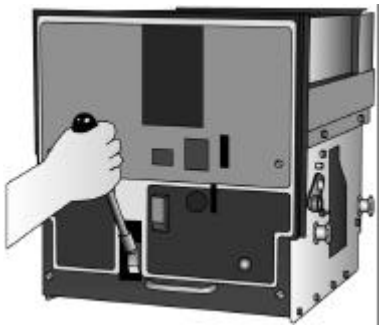


FIGURE 6: TYPICAL LOW VOLTAGE METAL-FRAME POWER CIRCUIT BREAKER BEING MANUALLY CHARGED

Bus

Bus refers to a conductor or conductors, usually made of copper or aluminum bars. Bus bars carry current and serve as a common connection for two or more circuits (Figure 7).

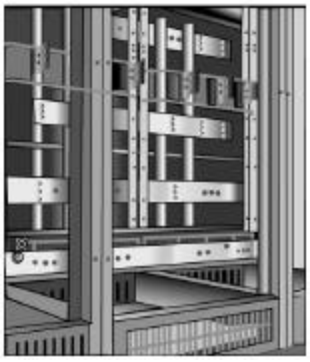


FIGURE 7: REAR VIEW OF TYPICAL LOW VOLTAGE SWITCHGEAR ASSEMBLY SHOWING A MAZE OF BUS BARS INTERCONNECTED

Control Voltage

The *control voltage* (or secondary voltage), is usually secondary with respect to the voltage rating of the circuit in which the circuit breaker is applied. Control voltage is used to operate secondary devices. The voltage used to run the motor that charges a circuit breaker's springs automatically is an example.

Drawout

A drawout circuit breaker refers to a circuit breaker that can be moved within a compartment from one defined position to another without manually disconnecting any connections or turning off the line side power. This is usually accomplished through the use of a mechanical levering device, sometimes in combination with the manual assistance of an operator. This is called racking the circuit breaker into or out of a position. The circuit breaker is first opened, and then automatic main disconnect devices on a drawout circuit breaker allow for the circuit breaker to connect or disconnect from the bus. These automatic main disconnect devices are often referred to as *finger clusters*. The phrase finger cluster comes from the fact that many designs utilize a number of conductive pieces (fingers) assembled into one cluster. The four typical defined positions are:

- Connected
- Test
- Disconnect
- Remove (Withdrawn)

In the **Connected** position, the circuit breaker is into its compartment as far as it will go with both primary and secondary electrical connections made. The circuit breaker is now ready for normal operation (Figure 8).

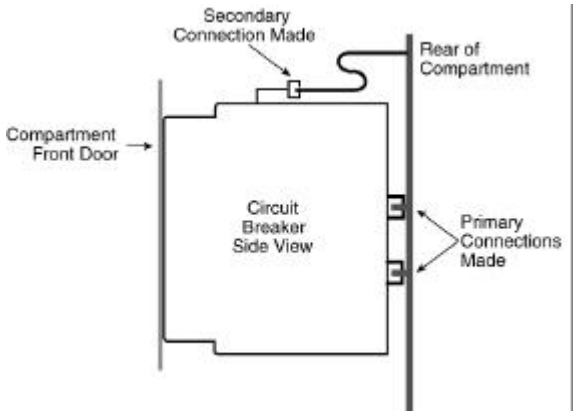


FIGURE 8: CONNECTED POSITION

Drawout (continued)

In the **Test** position, the circuit breaker is farther out of its compartment with the primary electrical connections no longer made (Figure 9). Secondary electrical connections are still made in this position to provide the secondary power required to test the circuit breaker's operation, including the trip unit.

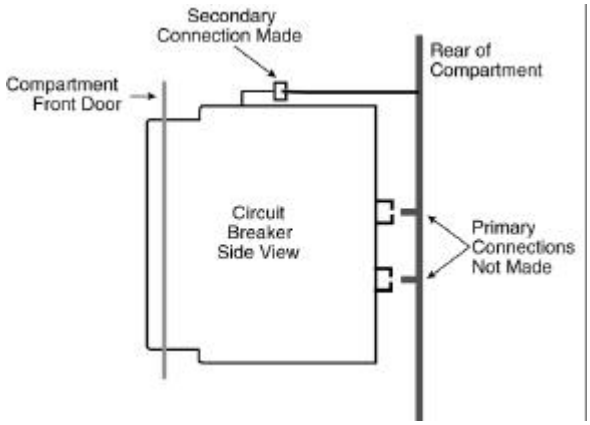


FIGURE 9: TEST POSITION

In the **Disconnect** position, the circuit breaker is even farther out of its compartment with the main *contacts* open (Figure 10). Neither the primary nor secondary electrical connections are made. This is a typical compartment storage position for a circuit breaker not in use.

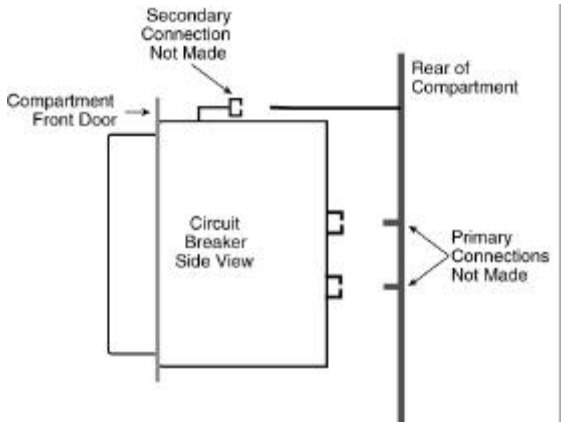


FIGURE 10: DISCONNECT POSITION

Drawout (continued)

In the **Remove** (or Withdrawn) position, the circuit breaker is out of the compartment on extension rails with the main contacts open and the closing springs discharged (Figure 11). There are neither primary nor secondary electrical connections. This is the typical last position for a circuit breaker to be in before it is physically removed from its rails to another location.

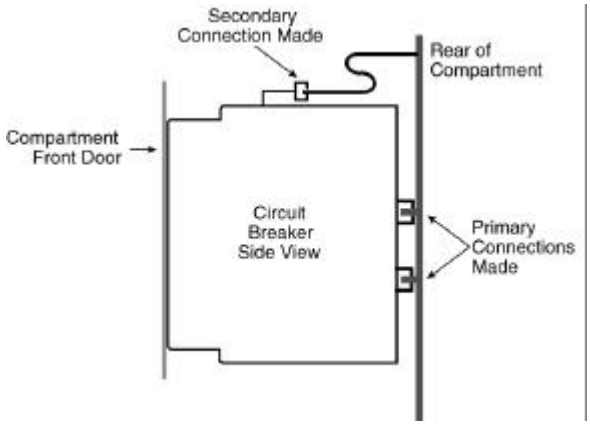


FIGURE 11: REMOVE (WITHDRAWN) POSITION

Behind Door Drawout

This is related to the specific drawout breaker design (Figure 12). Behind the door drawout means that the breaker compartment door usually must be opened to *lever* (or “rack”) the breaker from one position to another as just discussed under “Drawout.”

The breaker normally has a *faceplate shield* (or “deadfront shield”) to protect the operator from dangerous voltages while the door is open. This type of design usually permits the breaker to be in any of three positions **(Disconnect, Test, Connected)** with the door closed. This design does not permit an individual to know the status of the circuit breaker or its trip unit without opening the compartment door.

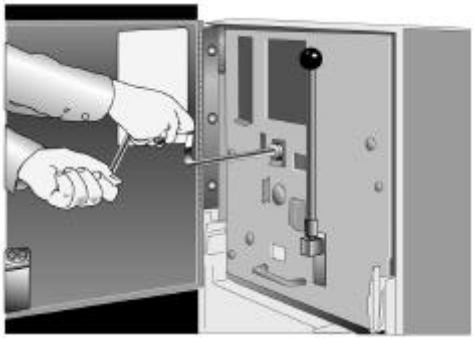


FIGURE 12: TYPICAL BEHIND THE DOOR DRAWOUT TYPE LOW VOLTAGE METAL-FRAME CIRCUIT BREAKER BEING LEVERED FROM ONE POSITION TO ANOTHER

Through Door Drawout

This is also a drawout related circuit breaker design (Figure 13). **Through the door drawout permits the operator to lever the circuit breaker from the "Connected" position to the "Test" position to the "Disconnect" position and vice versa without opening the compartment door.** The door has a hole in it to accommodate protrusion through the door of some small portion of the circuit breaker as it reaches a position well to the front of the compartment. The operator is also protected by a deadfront shield, usually a combination of the door and the faceplate of the circuit breaker. The benefits associated with this design are that a full view of the circuit breaker front is given along with access to the racking (drawout) device without opening the compartment door.

CONNECTED POSITION (CIRCUIT BREAKER IS FLUSH WITH COMPARTMENT)

TEST POSITION (CIRCUIT BREAKER PROTRUDES PARTIALLY THROUGH COMPARTMENT FRONT)

DISCONNECT POSITION (CIRCUIT BREAKER PROTRUDES FARTHER THROUGH COMPARTMENT FRONT)

FIGURE 13: THREE TYPICAL THROUGH-THE-DOOR DRAWOUT POSITIONS OF LOW VOLTAGE POWER CIRCUIT BREAKER IN ITS COMPARTMENT

Continuous Current Rating

The *continuous current rating* of a circuit breaker is the maximum current rating the breaker is designed to carry on a continuous basis and remain within the applicable guidelines for the breaker. It is also referred to as the "Frame Rating" or the "Frame Size."

100% Rated

ANSI specifies that low voltage power circuit breakers are to be rated for continuous operation at 100% of their current ratings in their compartment. To meet these requirements, they are tested for operation within a specific enclosure and, therefore, do not need to be de-rated.

Interrupting Rating

The interrupting rating is the maximum short-circuit current that the circuit breaker can safely interrupt. ANSI prescribes its minimum preferred ratings for power circuit breakers to meet.

Short Time Rating

The short time rating of a low voltage power circuit breaker is the **maximum value of current the circuit breaker is designed to handle safely for a short period of time (30 cycles or 0.5 seconds)** in the closed position, without damage to the circuit breaker. This test is repeated twice for a total of one (1) second. The short time rating is usually equal to the 600 volt interrupting capacity. This attribute is one of the **main features that differentiates a power circuit breaker from other types of circuit breakers** and allows for system selectivity. The short time rating was also discussed earlier in this module.

Trip Free

When a circuit breaker is in a *trip free* condition, **it cannot, by design, be closed.** Even when intentional efforts are made to close the circuit breaker and it is in a trip free condition, the main contacts will not touch and the circuit breaker will automatically return to the tripped position. This is an important safety feature specific to power circuit breakers.

Current Sensor

Sensor, as used with respect to a circuit breaker, is a common term for a **current transformer** which steps current down to useful levels for a specific purpose, such as providing an input to a trip unit (circuit breaker's intelligence package).

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. A power circuit breaker has either an interrupting rating or a short time rating.

   TRUE FALSE

2. While inside their compartments, most low voltage drawout power breakers can be in any of the following positions with compartment doors closed:

   1. Connected Position
   2. _____ Position
   3. _____ Position

3. Both manually and electrically operated low voltage power breakers use stored energy mechanisms for opening and closing.

   TRUE FALSE

4. The frame rating or the frame size of a low voltage power breaker refers to the _____ _____ rating of the breaker.

5. All low voltage power breakers that meet applicable ANSI Standards are capable of continuous operation at 100% of their current rating.

   TRUE FALSE

6. The _____ _____ Rating of a power breaker is one of the main features that differentiates a power breaker from other types of circuit breakers.

7. Circle the letter next to the testing standard that most influences the design and testing of low voltage power circuit breakers used in the United States.

   (a) ANSI C50.51 (b) UL1866 (c) IEC 947-2 (d) ANSI C37.50

8. ANSI Standards requires low voltage power breakers to have integrally mounted trip units.

   TRUE FALSE

9. One reason a low voltage power breaker utilizes a two-step stored energy mechanism is so that it is able to provide an _____-_____-_____ duty cycle.

DESIGN AND FUNCTIONAL CONSIDERATIONS

In Module 5, you learned that all circuit breakers have a number of design and functional characteristics in common:

- Compliance with Specific Standards
- Set of Open/Close Contacts
- Means to Open and Close the Contacts
- Means to Extinguish an Arc
- Means to Respond to Overcurrents/Commands
- Method for Enclosing Circuit Breaker Components
- Method For Mounting Circuit Breaker

Specific methods used for mounting and using low voltage power circuit breakers will be covered in the next section. In this section, the concentration will be on how low voltage power circuit breaker operate to accomplish their tasks and what accessory items are available to enhance their capabilities.

Basic low voltage power circuit breakers are generally comprised of:

- Frame or Chassis
- Primary Contacts
- Arc Extinguishers
- Operating Mechanism
- Integral Trip Unit
- Accessory Items

Let’s take a look at each.

Frame or Chassis

You will recall from Module 5 that all circuit breakers utilize some method to hold all the parts that make up a circuit breaker, usually called the **frame or chassis.** A low voltage power circuit breaker chassis today will be one of two types (Figure 14 and 15):

- Open Type Metal-Frame (Older Designs)
- Molded Frame of Engineered Thermoset Composite Resins (Newer Designs)

FIGURE 14: MOLDED FRAME CONSTRUCTION

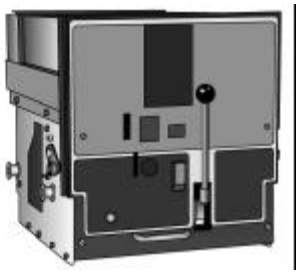


FIGURE 15: METAL-FRAME CONSTRUCTION

The **open type metal-frame** has a number of pieces welded and/or bolted together on which the different circuit breaker components are assembled. Components have a tendency to be larger, heavier, and may need adjustment.

IN THE WORKPLACE

The new Magnum DS power circuit breaker utilizes a rigid frame molded from engineered thermoset composite resins.

Molding improves the structural rigidity of the frame, allowing for higher interrupting and short time ratings.

Many individual circuit breaker parts are molded as integral assemblies. This improves the design by making it smaller and stronger with fewer individual parts, unlike the metal-frame approach.

FIGURE 16: MAGNUM DS POWER CIRCUIT BREAKER

Primary Contacts

Primary open/close contacts in a low voltage power circuit breaker provide a means for isolating or connecting a part of a circuit from or with the rest of the system. **The design of the primary contacts is one of the most critical design considerations relative to the efficiency and overall effectiveness of any low voltage power circuit breaker.** These contacts are used to carry or break the main continuous load current associated with the system in which the circuit breaker is applied. Each phase has an associated primary contact. A three-phase low voltage power circuit breaker, for example, would have three sets of primary contacts. Keep in mind that primary contacts come in a wide variety of designs and appearances. All designs do not use the same number of parts nor are all designs equally efficient. However, all designs act to provide the same general service.

Low voltage power circuit breaker primary contacts usually have separate arcing and main current carrying parts. **This does not mean that they are necessarily separate pieces.** They could both be part of the same component piece, although the arcing and main contacts act as individual pieces and perform distinctly different functions.

In Module 5, the discharge of electric current crossing a gap between two contacts was discussed (Figure 17). This phenomenon, on a small scale, can occasionally be observed when pulling a plug from a wall socket.

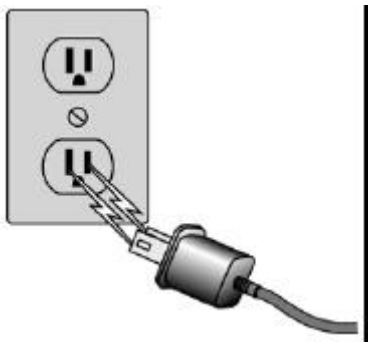


FIGURE 17: ELECTRICAL CURRENT CROSSING A GAP

Arcing also occurs when opening and closing low voltage power circuit breakers under load, except to a much larger degree. The primary contact design challenge is to **ensure that the arcing is dealt with first to protect the surface of the main contacts from arc damage.** For this reason, primary contacts are mechanically designed such that on closing of the circuit breaker, **the arcing contacts touch (make) before the main contacts.** Also on opening of the circuit breaker, **the main contacts part (break) before the arcing contacts.** This construction assures that arcing takes place on the heat resistant arcing contacts. Usually, primary contacts are replaceable on low voltage power circuit breakers, which can be needed in time if the operating duty of the breaker is severe enough.

Primary Contacts (continued)

A primary contact assembly is comprised of:

- fixed (stationary) part
- moving part

A rigid insulating piece through a pushing or pulling motion is used to operate the moving part of the primary contact assembly.

The fixed and moving main and arcing portions of the assembly can be in any number of configurations, some more efficient than others (Figures 18 and 19). Usually the designs for a particular type circuit breaker are the same. The only variable is the number of parts used to handle the amount of current available. Larger circuit breaker frames require more and/or larger arcing and main contact pieces.

Keep in mind that the design goal is to efficiently handle arcing through the heat resistant arcing contacts so that the main contacts are protected from unnecessary damage. This approach permits the main contacts to be made from low resistance materials, such as silver or silver alloys to minimize the heat developed during normal operation.

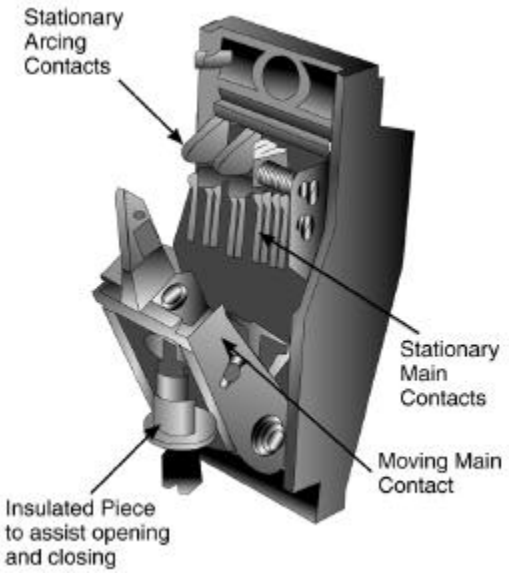


FIGURE 18:
CONTACT ASSEMBLY MOUNTED
(FRONT VIEW)

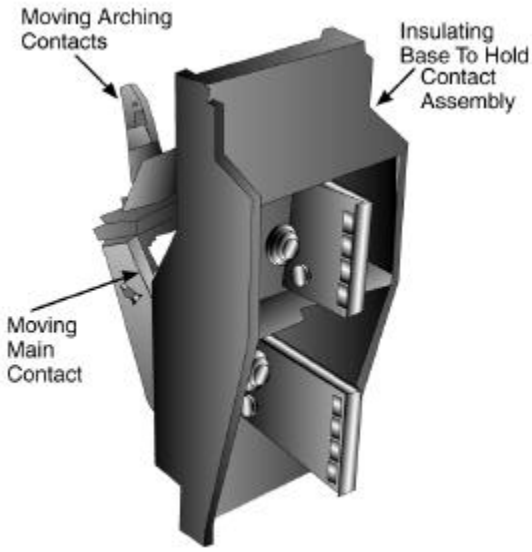


FIGURE 19:
CONTACT ASSEMBLY MOUNTED
(REAR VIEW)

Finally, it was pointed out in Module 5 that some newer low voltage power circuit breaker designs take full advantage of certain natural facts of physics to assist with the opening process. You will recall that the concept centers around magnetic fields established in conductors when current is flowing in the conductors.

Primary Contacts (continued)

The low voltage power circuit breaker design takes full advantage of this electromagnetic force to assist with opening and keeping the circuit breaker closed. **In certain configurations, the force and also the insulator are used to help hold the contacts closed temporarily during a fault condition, which is where a power circuit breaker's short time rating comes from.** Circuit breaker designs taking advantage of this concept can be smaller and lighter and still maintain the higher withstand (short-time) capabilities associated with low voltage power circuit breakers. When it is time for the contacts to open, this same force can be used in the opposite direction to **speed the opening action.**

Think about the concept of electromagnetic assistance with opening and closing of contacts in the following fashion (Figure 20). A door could be viewed as the movable contact. Our super-hero can be considered the rigid insulator used to push closed or pull open the door (contact). Assistance from the wind (electromagnetic force) in the proper direction would help our super-hero open or keep the door closed.

FIGURE 20: ELECTROMAGNETIC FORCE CAN BE USED TO HELP WITH OPENING AND CLOSING

Arc Extinguishers

In Module 5, a number of ways or combinations of ways to extinguish an arc was discussed. Low voltage power circuit breakers use some type of *arc extinguishers* (arc chutes or arc chambers) mounted above and around the main contacts to extinguish arcs in air (Figures 21 and 22). This leads to the name low voltage power air circuit breakers.

Arc chutes, in some form, have been used to extinguish arcs for more than a half century. The primary purpose of an arc chute is to **extinguish an arc each time a circuit breaker interrupts a current.** This is accomplished by **confining, dividing and cooling** the arc. This accomplished, the arc is not able to sustain itself through current zero.

Not all arc extinguishers are created equal and, therefore, some are more efficient than others. Efficiency is very important, since the amount of contact damage caused by arcing is directly related to how fast or efficiently arcs are extinguished. More efficiency leads to **longer contact life.**

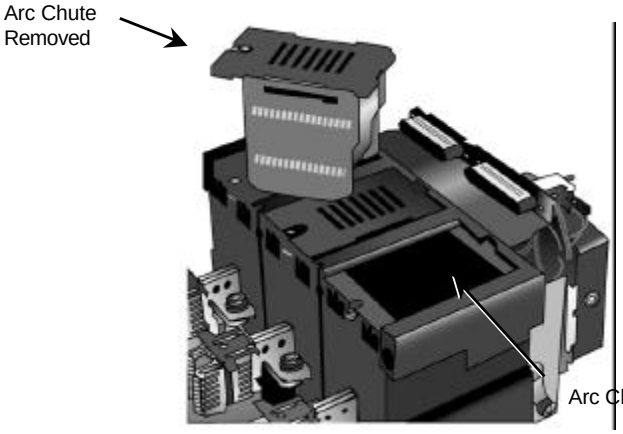


FIGURE 21: TOP REAR VIEW MAGNUM DS CIRCUIT BREAKER SHOWING ARC CHAMBERS AND ONE ARC CHUTE REMOVED

FIGURE 22: ONE ARC CHUTE SHOWN REMOVED FROM A MAGNUM DS CIRCUIT BREAKERS (BOTTOM VIEW)

During the arcing process, ionized gases are generated and normally vented, in some fashion, harmlessly away from the circuit breaker, breaker compartment, and any operator who might be in close proximity to the equipment. It is also known that the high pressure created by these gases, if controlled properly, can be put to good use during interruption.

To this end, the molded case low voltage power circuit breaker design, for example, utilizes this **gas pressure to help with the interruption process** while minimizing gas leakage back into the circuit breaker itself. This improvement is accomplished through the use of seals in the arc chamber and a close fit of pieces and parts. This can only be accomplished with molded frame designs. Obviously, the design and process is a bit more involved that just described. For now, the most important thing to remember is that the original arc extinguisher concept is still used today, but great strides have been taken to improve upon the original concept with significant improvements in overall efficiency.

Operating Mechanism

You learned in Module 5 that some type of a mechanism is provided with all circuit breakers for opening and closing. Low voltage power circuit breakers are no exception. A low voltage power circuit breaker operating mechanism is comprised of a number of different parts, assemblies and accessories, all dedicated to ensuring that the circuit breaker opens and closes consistently.

The mechanism is a **two-step spring charged stored energy type** providing three basic functions:

- A means to charge the closing springs
- A means to close/open the circuit breaker using the stored energy of the closing and opening springs
- A means to perform an Open-Close-Open duty cycle

Two varieties of the mechanism exist:

- Manual
- Electrical (Motor Operated)

Operating Mechanism (continued)

The **manually operated circuit breaker** has its closing springs charged manually through the use of some type of charging handle. The circuit breaker is closed using a manual close button which is a mechanical process. As the circuit breaker closes, a set of smaller opening springs are charged. The circuit breaker is opened using a manual trip (open) button, which is a mechanical process.

Safety interlocks, accessory items and trip units can also cause the circuit breaker to trip through mechanical means. Most manually operated power circuit breakers can be equipped with an optional device to electrically release the spring's stored energy, thus closing the circuit breaker.

Previously, it was not practical or even possible to convert manually operated low voltage power circuit breakers to electrically operated circuit breakers in the field. This is no longer impossible with newer low voltage power circuit breaker designs. Such designs permit **manually operated circuit breakers to be converted to electrically operated circuit breakers** by field installing UL Listed electrical operators.

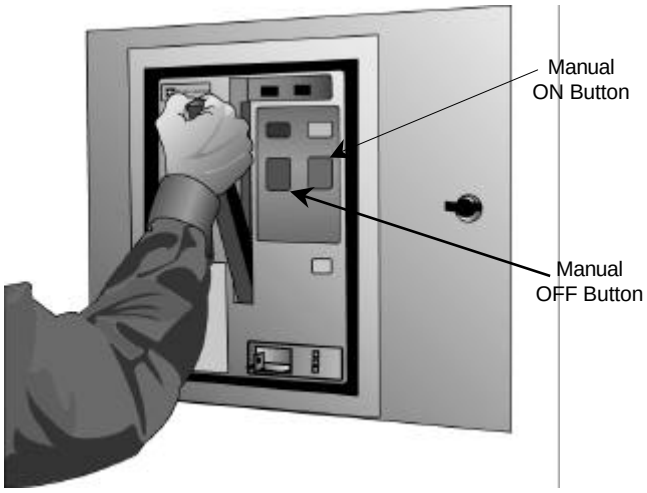


FIGURE 23: MAGNUM DS POWER CIRCUIT BREAKER BEING MANUALLY CHARGED

An **electrically operated circuit breaker** can be operated every way a manually operated circuit breaker can be operated. In addition, a small electric motor is normally used to automatically charge the closing springs, and an electrical means to close or trip (open) the circuit breaker is provided.

Integral Trip Unit

For a circuit breaker to do its job, a means must be provided enabling the circuit breaker to perform automatically or in response to other commands. In short, the circuit breaker is a rather dumb device without a brain (intelligence source). **This source of intelligence is the trip unit.**

As required by ANSI Standards, low voltage power circuit breakers must be provided with an *integrally mounted trip unit***.** This means that the trip unit must be inside of, or part of, the circuit breaker. Prior to the advent of the first solid state trip unit, electromagnetic type tripping devices, commonly called dual-overcurrent magnetic trips, were used with all low voltage power circuit breakers. In recent times, this type of tripping device on low voltage power circuit breakers has disappeared from the scene. For this reason, only microprocessor-based trip units will be discussed in this module.

A typical microprocessor-based trip unit used with low voltage power circuit breakers offers the following capabilities (Figure 24):

- Programming
- Monitoring
- Diagnostic
- Communication
- Testing

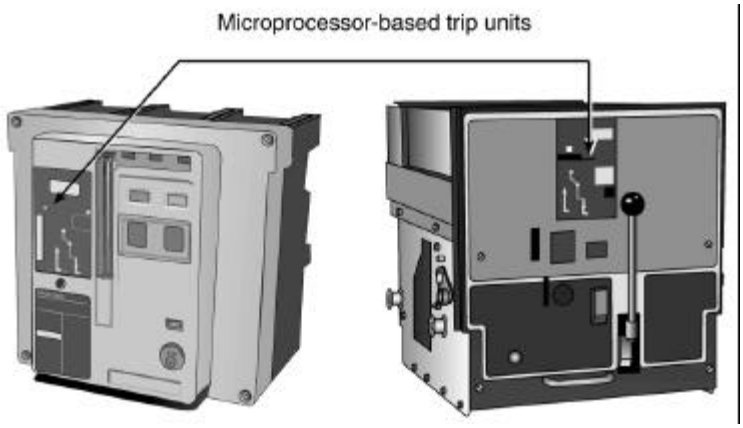


FIGURE 24: INTEGRALLY MOUNTED TRIP UNITS

Integral Trip Unit (continued)

The capabilities of a particular trip unit depends on the trip unit design itself and system requirements. Some trip units can only offer basic features, while others can offer basic features or, if required by the system, additional sophisticated and highly advanced features.

The operating response of a trip unit is graphically represented by **time-current characteristic curves.** These curves show **how and when** a particular trip unit will act for given values of time and current. A characteristic curve is represented by a band created by a minimum and maximum value of time or current.

The **programmable or adjustable features of a trip unit** permit movement of its characteristic curve or parts of the curve (Figure 25). This movement can be done in both a horizontal and vertical direction. Some trip units even allow the shape of the curve to be changed.

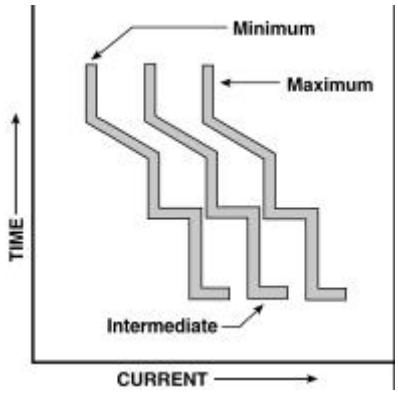


FIGURE 25: TYPICAL TRIP CURVE HORIZONTAL MOVEMENT

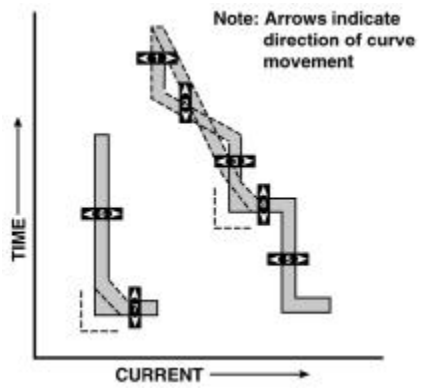
Most trip units offer protection combinations of:

- **(L)** Long delay protection - protection against overloads and short circuits
- **(S)** Short delay protection - protection against short circuits
- **(I)** Instantaneous protection - protection against short circuits
- **(G)** Ground fault protection - protection against ground faults

A trip unit offering all four of these protection at one time is commonly called an **LSIG Trip Unit.** Other combinations are also available, such as **LI, LS, LSI, LIG and LSG.**

Integral Trip Unit (continued)

The long, short and ground functions would have programmable values of current and time. Obviously, **instantaneous has no associated time** because the trip is instantaneous (Figure 26). Trip units have these different programmable features programmed so they coordinate with one another and with the requirements of the system being protected to provide the closest possible system coordination and protection against all eventualities. This coordination discipline is where you start hearing phrases like **curve shaping and close coordination.** No attempt will be made in this module to get into the details of this discipline. It is quite specialized and best left to individuals with the proper training.



#	Programable Adjustment
1	Long Delay Pickup
2	Long Delay Time
3	Short Delay Pickup
4	Short Delay Time
5	Instantaneous Pickup
6	Ground Fault Pickup
7	Ground Fault TIme

FIGURE 26: ADVANCED TRIP UNIT TIME-CURRENT CURVE ADJUSTMENTS

More advanced trip units are able to **monitor and display currents, energy, power, power quality and power factor.** They also may be able to **diagnose problems and provide advance warnings** of potential problems, such as harmonics. **Two way communications for remote monitoring and control** is also available. This affords the user a cost effective way to monitor and control expansive, multi-location facilities with a wide array of protective equipment and operational machinery.

Trip and no trip tests can usually be performed on the trip unit and circuit breaker utilizing **integral testing capabilities or separate test kits.** Normally, the tests can be performed with the circuit breaker in service and full protection provided during the testing. This type of testing is secondary testing. Primary testing involves specialty testing equipment and a testing expertise, and is not discussed in this module.

Accessory Items

Accessories used with low voltage power circuit breakers are usually added to the circuit breaker to provide additional features, such as status indication and remote operation. It is possible, however, that some accessories for some circuit breaker designs might be mounted remotely from the circuit breaker. These devices might be totally mechanical, totally electrical or a combination. The intent here is to briefly discuss the function of commonly used accessory items, although all low voltage power circuit breakers do not necessarily offer all of the devices being discussed, nor is this list all inclusive.

- **Electrical Operator** - This is an assembly of devices including a small spring charging motor that when added to a manually operated circuit breaker **converts it to an electrically operated circuit breaker.** This allows for remote operation (open/close) of the circuit breaker. The ability to field install this device is more common with newer low voltage power circuit breakers. Power circuit breakers normally use to be either manual or electrical by design, and could not be easily converted.

- **Operations Counter** - An operations counter is a counting device, usually linked in some fashion to the operating mechanism. It is used to **count the open and close operations** of the circuit breaker, and serves as a maintenance aid.

- **Auxiliary Switch** - An auxiliary switch consists of **"normally open" (NO) and "normally closed" (NC) contacts** (Figure 27). The contacts on some switches are convertible from NO to NC and vice versa. The contacts are frequently referred to as "a" or "b" contacts. The **"a" being open when the circuit breaker is open and the "b" closed when the circuit breaker is open.** In short, these auxiliary contacts change "state" when the circuit breaker main contacts change "state." An auxiliary switch is normally mounted on the circuit breaker. Contacts from these switches are frequently used for electrical operation of a circuit breaker, remote signaling, and electrical interlocking.

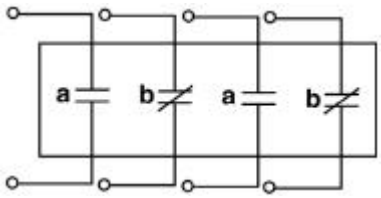


FIGURE 27: GRAPHICAL REPRESENTATION OF A 4 CONTACT AUXILIARY SWITCH (2A AND 2B)

- **Undervoltage Release (UVR)** - An undervoltage release, normally a circuit breaker mounted electromechanical device, trips the circuit breaker when the **voltage falls below a predetermined level.**

Accessory Items (continued)

- **Shunt Trip (ST)** - A shunt trip is an electromechanical device which is standard on most electrically operated power circuit breakers. When added to a manually operated circuit breaker, it **provides for remote controlled electrical tripping.**

- **Spring Release (SR)** - The spring release device is standard on most electrically operated power circuit breakers. When added to a manually operated circuit breaker, it **permits the circuit breaker to be closed electrically from a remote location.**

- **Bell Alarm (OTS)** - The bell alarm, frequently called an **overcurrent trip switch (OTS)** on a power circuit breaker, is normally circuit breaker mounted. Its function is to **provide a signal to indicate that the circuit breaker has tripped open automatically (trip unit command).** It will not operate if the circuit breaker is tripped open by other means, such as the use of a manual trip button, an electrical control switch, or the operation of an undervoltage release device.

- **Locking Devices** - Low voltage power circuit breakers normally have a wide array of mechanical locking devices to **prevent unauthorized circuit breaker operation** (Figure 28).

FIGURE 28: PADLOCK SHOWN MOUNTED ON FRONT OF MOLDED FRAME TYPE POWER BREAKER PREVENTING UNAUTHORIZED USE OF OPEN AND CLOSE BUTTONS

- **Mechanical Interlocks** - These devices provide a way to mechanically interlock two circuit breakers. A typical use for such a device is to **prevent one circuit breaker from closing while another circuit breaker is already closed.**

Accessory Items (continued)

- **Capacitor Trip Device** - A capacitor trip device is normally mounted externally from the circuit breaker. It uses a small storage capacitor for **AC control of the circuit breaker** to ensure reliable tripping power during fault conditions.

- **Lifting Device** - Since some low voltage power circuit breakers can be sizable and heavy, a variety of devices is usually available to **lift and move the circuit breaker** once it is out of its compartment (Figure 29).

FIGURE 29: RAIL MOUNTED LIFTING DEVICE BEING USED TO LIFT A MAGNUM DS POWER CIRCUIT BREAKER FROM ITS COMPARTMENT EXTENSION RAILS

- **Truck Operated Cell Switch (TOC)** - A TOC switch is usually mounted in the circuit breaker compartment and is **activated by movement of a drawout circuit breaker into and out of the "Connected" position.** As the circuit breaker moves, the contacts are activated providing a means for remote indication of the circuit breaker's position.

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. For many years low voltage power circuit breakers were open type metal-frame circuit breakers. Today, newer low voltage power circuit breaker designs are _____ frame type designs.

2. When a low voltage power circuit breaker opens, its arcing contacts part before the main contacts part to draw any arcs formed away from the main contacts

   TRUE FALSE

3. Low voltage power circuit breakers are considered air circuit breakers and use _____ _____ to eliminate the arc by confining, dividing and cooling it.

4. The operating mechanism springs of both manually operated and electrically operated low voltage power circuit breakers can be charged manually.

   TRUE FALSE

5. A low voltage power circuit breaker's source of intelligence is its _____ _____.

REVIEW 2 (CONTINUED)

6. Current transformers used in a low voltage power circuit breaker to monitor and reduce the current to useful levels are also known as _____.

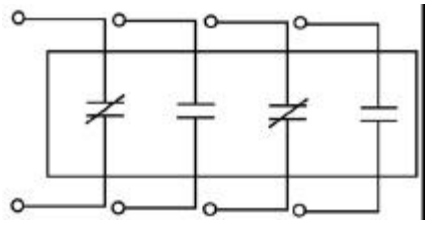
7. Time-current characteristic curves graphically represent the operating response of the _____ _____.

8. Circle the type or types of protection from the four types listed below that offer some degree of protection against short circuits.

   (1) Long Delay Protection (3) Short Delay Protection

   (2) Instantaneous Protection (4) Ground Fault Protection

9. An auxiliary switch is graphically represented below. On the graphic, label each of the four contacts as either “a” or “b” type contacts.



10. A _____ _____ is an electromechanical device used to provide for remote controlled tripping of a manually operated low voltage power circuit breaker.

11. A bell alarm on a low voltage power circuit breaker, also referred to as an overcurrent trip switch, provides a signal to indicate when a circuit breaker has tripped open for any reason.

    TRUE FALSE

12. A TOC switch is activated by movement of a circuit breaker into and out of the “Connected” position. Indicate next to each letter below what word the letters represent.

    T _____ O _____C _____ Switch

MOUNTING METHODS

As briefly discussed earlier, low voltage power circuit breakers are usually available in the two following mounting configurations:

- Fixed
- Drawout

Total usage of low voltage power circuit breakers today is **dominated by the drawout configuration because it provides for easier maintenance and continuity of service.** Most circuit breaker manufacturers, however, offer both types.

Fixed Circuit Breaker

Fixed low voltage power circuit breakers usually have fixed primary conductor stabs protruding from the rear of the circuit breaker. The circuit breaker is bolted in position within its assembly compartment, and the rear conductor stabs are bolted to primary bus connections (Figure 30). Secondary connections are also made manually. **Power must be turned off** to the assembly to connect a fixed circuit breaker into the system or to remove it from the system.

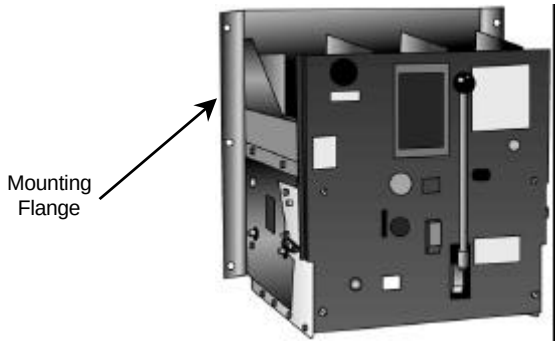


FIGURE 30: FIXED TYPE DSII CIRCUIT BREAKER

Drawout Circuit Breaker

Drawout low voltage power circuit breakers have a levering device to move the circuit breaker from one compartment position to the next. Usually part of the levering mechanism is on the circuit breaker with a corresponding part is in its compartment. Working together, they provide the mechanical means required to move the circuit breaker. Drawout circuit breakers are designed to be removed and connected without cutting power to the entire assembly under load conditions, since the circuit breaker, by design, automatically opens before racking can take place. This means that power to the assembly does not have to be turned off when a circuit breaker is removed from or inserted into the assembly, thus ensuring continuity of service.

Drawout Circuit Breaker (continued)

Drawout circuit breaker compartments are provided with extension rails which, when not in use, are stored inside the compartment (Figure 31). The extension rails provide a means by which a drawout circuit breaker can be easily removed from its compartment for inspection, maintenance or movement to another area.

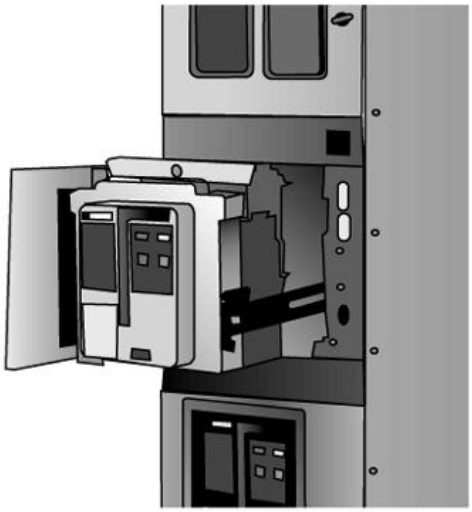


FIGURE 31: DRAWOUT MOLDED CASE CIRCUIT BREAKER SHOWN ON COMPARTMENT EXTENSION RAILS

Drawout Circuit Breaker (continued)

Primary electrical connections between the circuit breaker and the primary bus are **automatically made or broken as the circuit breaker is moved into or out of the "Connected" position** within the circuit breaker compartment. Primary connectors mounted to the back of the circuit breaker slide onto the primary bus connectors. These primary connectors, often called **finger clusters or disconnect contacts,** are frequently comprised of a number of spring loaded fingers (contacts) (Figure 32). The number of fingers (contacts) used is dictated by the amount of current they will carry. Fingers (contacts) are made of an excellent conducting material or material combination, such as silver plated copper.

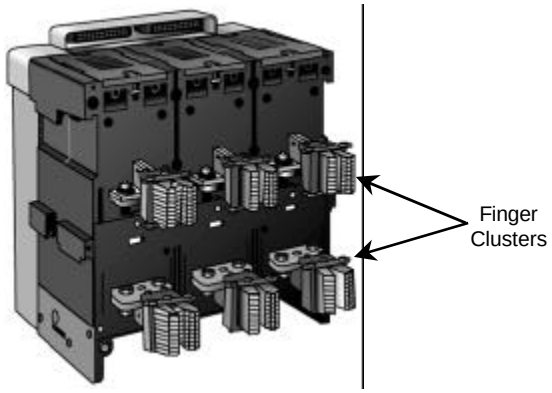


FIGURE 32: REAR VIEW OF MAGNUM DS POWER CIRCUIT BREAKER SHOWING SIX PRIMARY FINGER CLUSTERS

Secondary electrical connections are usually automatically made or broken as the circuit breaker is moved into and out of its compartment. As the circuit breaker is moved **into the "Test" position from the "Disconnect" position, the secondary connections are made** providing the required secondary power for testing or operating the breaker, but no primary power. The secondaries **remain connected as the breaker moves into the "Connected" position.** When the circuit breaker is moved out of the "Connected" position, the secondaries remain connected and stay connected until the circuit breaker is moved farther out of its compartment past the "Test" position. The graphics of the four positions presented earlier in the module demonstrate the movement and connections.

GOVERNING STANDARDS

You will recall from Module 5 that circuit breakers are designed, built and tested in accordance with one or more specific sets of standards. In this module, you will be introduced to the standards specific to low voltage power circuit breakers. The intent here is not to present and study the different applicable standards word for word. That type of undertaking would be a course unto itself. Our goal is to understand a little about low voltage power circuit breaker related standards, where they were, and where they are today.

FIGURE 33: MANY STANDARDS

You will hear many people repeat specific standards designations. Many of those same people do not have an intimate knowledge of what the standards actually say, nor are we saying they should. The actual product selection based on standards compliance should be left to the experts. It is helpful, however, to know what specific standards your products comply with and what general topic a specific standard addresses.

Keep in mind that a standard exists for almost everything. There are specific standards for circuit breakers and others for the structural assembly. Compliance with these exacting standards ensures customers of the very best possible product selection with a high degree of comfort. **There is no room for compromise when performance, quality and safety are involved.**

GOVERNING STANDARDS (CONTINUED)

A number of years ago, low voltage power circuit breakers and most other types of equipment were designed and built primarily with only domestic standards in mind. This approach also was taken by foreign suppliers. A manufacturer would offer a circuit breaker designed, tested and manufactured in keeping with applicable standards for that part of the world or even particular country. Trying to play a significant role in other world markets was, at best, extremely difficult. If manufacturers today expect to be global participants, they must offer products that comply with the standards applicable to a variety of different markets around the world. This will require that you become familiar with both domestic and international nomenclature, ratings, procedures and governing standards. The task is greater, but so is the reward.

Some of the lines separating different types of low voltage circuit breakers were at times blurred in the past. Low voltage metal-frame power circuit breakers were built and tested to certain ANSI and UL specifications, while some low voltage encased circuit breakers were tested to UL specifications specific to molded case circuit breakers. The newest low voltage power circuit breakers today, like **Magnum DS,** are tested to specific low voltage power circuit breaker standards, like ANSI. They are also tested to standards that cover a much broader product scope, like IEC. The primary testing standards associated with low voltage power circuit breakers today are:

ANSI

The American National Standards Institute's **ANSI C37.50** is a specific North American testing standard entitled "Low Voltage AC Power Circuit Breakers Used In Enclosures." This standard specifies rigorous tests for product performance. There are additional **C37** standards which govern power circuit breaker and trip unit construction, such as C37.13 and C37.17 respectively.

UL

Underwriter's Laboratories, Incorporated's **UL1066,** for the most part, calls for testing to demonstrate compliance with ANSI C37.50 just mentioned. A UL Label is affixed to the breaker to indicate successful compliance.

IEC

The *International Electrotechnical Commission*'s **IEC 947-2** is a more general international testing standard covering a variety of devices, including circuit breakers of all types, and is entitled " Low Voltage Switchgear and Controlgear."

Closing Comments on Standards

Before concluding this section, it might help to minimize confusion if you remember that there is often a great deal of referencing to other standards that takes place within a specific standard. Successful testing with respect to one standard often includes automatic compliance with other standards.

Example 1 - ANSI C37.13 details the physical attributes, such as stored energy, that a low voltage AC power circuit breaker must have, while ANSI C37.50 references C37.13 and details how the described breaker should be tested. The key here is that successful testing in keeping with ANSI C37.50 brings with it compliance to C37.13.

Example 2 - In a similar fashion, IEC 947-2 references IEC 947-1 (General Rules). Compliance with IEC 947-2, therefore, brings with it IEC 947-1 compliance.

TESTING

The testing required and the standards that must be met by a low voltage power circuit breaker depend on the area of the world where the circuit breaker is applied. To play a major international role, low voltage power circuit breakers should be able to meet the **requirements of ANSI, UL and IEC** (Figure 34).

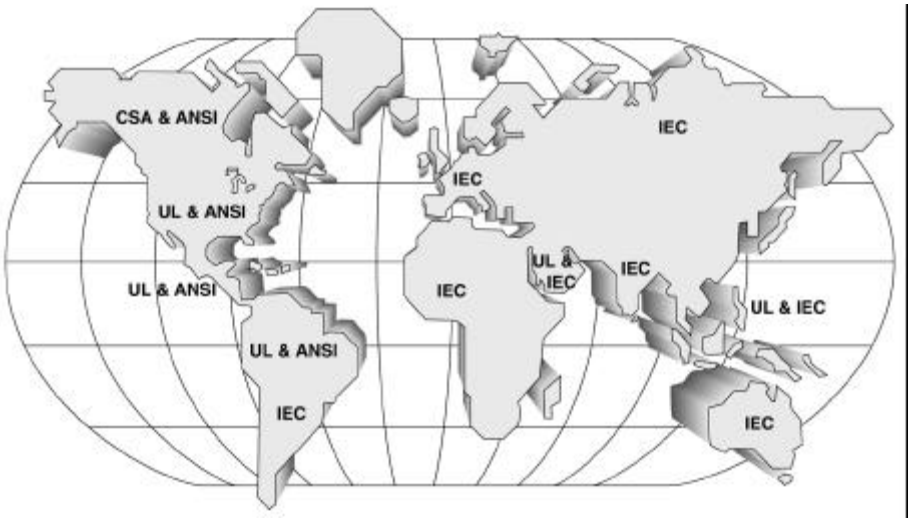


FIGURE 34: DOMINANT WORLDWIDE STANDARDS

As you continue through this module, you will become well aware that the required testing is the key factor in defining the type of circuit breaker. In a very general and simplistic way, low voltage power circuit breakers undergo a sequence of four rigorous tests.

1. The first sequence consists of a temperature rise, an overload, and a short-circuit test.
2. The second sequence is a series of short-circuit tests.
3. The third sequence is an endurance test.
4. The fourth is a momentary rating test.

Molded case circuit breakers, for example, are subjected to tests similar to numbers 1, 2 and 3. The fourth test sequence, **momentary rating test,** is specific to power circuit breakers and to some IEC molded case circuit breakers.

Specific testing details will not be covered in this module. It should be pointed out, however, that the momentary rating test just mentioned (test sequence 4) subjects the circuit breaker to tremendous physical forces and severe heating effects. Very simply speaking, the circuit breaker is subjected to its full short time current rating for two (2) time periods up to 30 cycles each. The **short time rating indicates what magnitude of current the circuit breaker can stand with its contacts closed for a short period without being damaged.** The circuit breaker's short time rating is often equal to its 600 volt interrupting capacity. A low voltage power circuit breaker must be strong enough to survive this test and function properly after completion.

HELPING THE CUSTOMER

Selection of the proper low voltage power circuit breaker for a specific application is not a difficult process. There are some important questions, however, you must be able to answer. Fortunately, the most difficult part of the job has already been done by other qualified individuals when they determined the requirements of the system. This includes determining things like:

- Circuit Breaker type required
- Application voltage
- Maximum fault current system could see
- Continuous current for the system and each branch
- System frequency
- Types of trip unit capabilities
- Programmable functions
- Accessory needs
- Mounting configuration
- Special requirements

Your job is to make sure these types of questions are answered. The more familiar you are with what a particular circuit breaker line has to offer, the easier the task. Let's start by looking at what circuit breaker manufacturers do to help.

Manufacturers normally provide a great deal of assistance in the way of printed material, computer accessible information and direct contact. This does not mean, however, you should not put forth that extra effort to know personally what is available. Learn to use all the information provided.

Most selection factors fall into one of two categories:

- Standard selection factors
- Special selection factors

Standard Selection Factors

Standard selection factors normally are associated with the circuit breaker's ratings/standards, operation method, accessory items, and how the breaker will be mounted. The most common points to consider will be discussed.

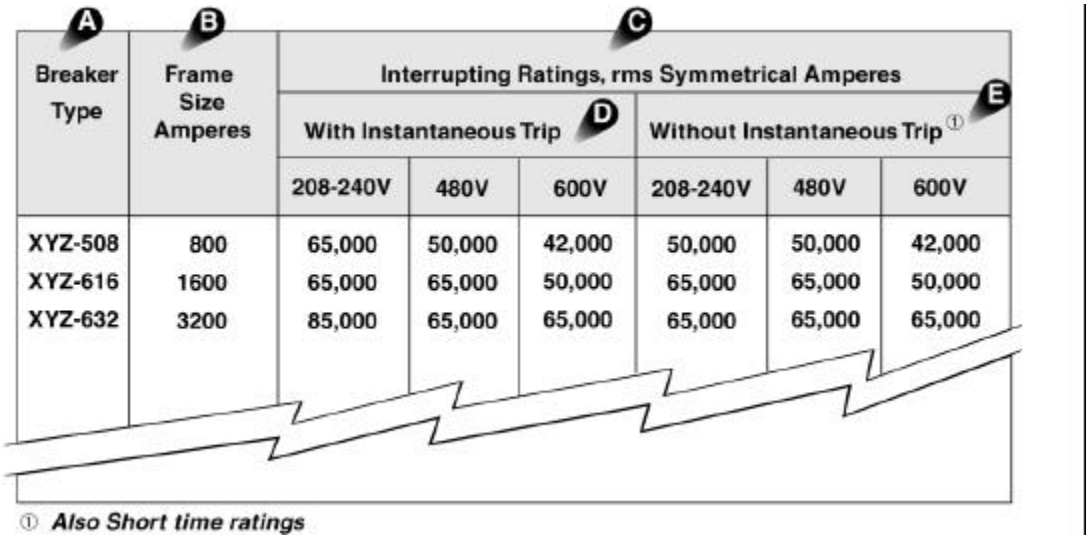
1. **Standards** - Applicable standards were discussed in this module and earlier modules. You should be told or it will appear in a written specification what standards the circuit breakers must meet. Newer low voltage power circuit breakers meet a wide array of standards which will make them acceptable in most parts of the world. In addition, make sure you are aware of any special local requirements and/or standards.

2. **Ratings** - This is a critical part of the selection process. You should already know what is required. Now you must determine what specific circuit breakers will meet the rating requirements. Manufacturers normally provide easy to read tables outlining the ratings of every circuit breaker frame. Keep in mind there could be more than one table. This is especially true for newer circuit breaker designs that meet both ANSI and IEC requirements. A manufacturer might choose to present it as one combined table or two tables. If you know what is required, you will be able to make a selection from the tables under normal circumstances.

ANSI Example

Let's take a look at a typical type ANSI table for a low voltage power circuit breaker and see what it has to offer (Figure 35). The table used in this example will not cover every circuit breaker rating for a particular design.

Enough of the table is presented to give you a good working knowledge on how to proceed. Each area of the table that is discussed is identified by a circled letter to simplify the discussion. One last important point should be made before beginning. **Always read footnote references carefully.** They provide important information and could be critical to the proper selection.



A Breaker Type	B Frame Size Amperes	C Interrupting Ratings, rms Symmetrical Amperes					
		D With Instantaneous Trip			E Without Instantaneous Trip ①		
		208-240V	480V	600V	208-240V	480V	600V
XYZ-508	800	65,000	50,000	42,000	50,000	50,000	42,000
XYZ-616	1600	65,000	65,000	50,000	65,000	65,000	50,000
XYZ-632	3200	85,000	65,000	65,000	65,000	65,000	65,000

① *Also Short time ratings*

FIGURE 35: EXAMPLE ANSI RATINGS TABLE

A: The "Breaker Type" is usually the name given to the circuit breaker by the manufacturer along with some general information about the ratings of that specific circuit breaker type. In the example ratings table shown, **XYZ-508** is the first circuit breaker listed. The **XYZ** is the circuit breaker's name. The first number **"5"** gives you a general idea what the interrupting rating is of the XYZ-508 circuit breaker at a voltage of 480 volts. This is a common presentation method, since the widest used application voltage domestically is 480 volts. The last two numbers, **"08"** in this case, usually tell you the maximum continuous current rating of the circuit breaker. XYZ-508 can, therefore, carry 800 amperes continuously, and interrupt 50,000 amperes at 480 volts.

B: This column outlines specifically the maximum continuous current the circuit breaker will carry. Notice that circuit breaker type **XYZ-616** in the example table will carry a maximum continuous current of **1600 amperes.** Notice also that the last two numbers of the circuit breaker type XYZ-616 (**"16"**) give you the same information, with 16 meaning 1600. Take the time to make this same comparison with circuit breaker type **XYZ-632.**

ANSI Example (continued)

C: Notice that the rest of this table is devoted to the interrupting capabilities in amperes of the different circuit breaker types at different application voltages. Also notice that the application voltages listed are:

- 208-240 volts
- 480 volts
- 600 volts

The nominal voltage range for the **ANSI market is 208 to 600 Volts AC at a frequency of 50 or 60 hertz.** Get comfortable with seeing these voltages when talking about ANSI rated low voltage power circuit breakers.

D: You will notice that these two columns are labeled differently. The first column entitled **"With Instantaneous Trip"** outlines the interrupting capabilities of each circuit breaker frame at the different application voltages. These ratings are **applicable when the circuit breaker's trip unit provides instantaneous protection.** In other words, the circuit breaker can be applied to safely handle faults of the magnitudes shown.

You will also notice in the column entitled **"Without Instantaneous Trip"** that some of the interrupting ratings are somewhat lower than the left column under 208-240 volts. These ratings are the magnitudes that the circuit breaker can **tolerate safely for a short delay period of time (30 cycles) before opening at the short delay current ratings shown.** This might sound like a contradiction. It really is not for a number of reasons. Consider the following points.

1. You will recall from material presented earlier that a low voltage power circuit breaker's short time rating is normally the same as its interrupting rating. The key word here is **normally.** The partial ratings table being considered here already indicates that there are some very limited times when a low voltage power circuit breaker could have a higher interrupting rating if it has instantaneous protection versus just short time protection and no instantaneous. This was probably the result of a conscious decision to meet some very specific application requirement for a particular customer or industry, knowing the fact that a circuit breaker had to have instantaneous to be applied at these somewhat higher ratings.

ANSI Example (continued)

2. The fact still remains that low voltage power circuit breakers **must be** and **are** only applied in keeping with their nameplate rating. This, in almost all cases, shows the interrupting rating and the short time rating to be the same. When electrical systems are being considered, fault calculations are done to determine the **maximum fault current** a system can experience. Low voltage power circuit breakers are then selected with ratings that are able to **deal successfully and safely with the worst case fault scenario calculated.** In other words, if a low voltage power circuit breaker with an adequate short delay current rating is applied, it will stay closed for the appropriate short time no matter what. This is true because it will not see (experience) more that it was designed to safely handle. End of that part of the story.

3. On the other hand, a low voltage power circuit breaker, **which is already in the open position,** will trip open instantaneously if an attempt is made to close the breaker on an existing fault. This safety feature prevents damage that could result from closing on a fault. Today, this feature is normally accomplished through circuitry which is part of the trip unit. This self protecting circuitry is often called a discriminator circuit or may be called a **making current release** in newer designs like **Magnum DS.** Its purpose has nothing to do with a circuit breaker that is already closed and functioning.

For now, how this feature is technically accomplished will not be discussed. Just be aware that such a feature exists with low voltage power circuit breakers. Future training material specific to a particular low voltage power circuit breaker design will discuss just how it is accomplished.

Remember:

- Low voltage power circuit breakers are applied at their nameplate ratings.
- Low voltage power circuit breakers are sized and selected for application to handle the maximum fault that could be encountered where they are applied.
- Low voltage power circuit breakers are provided with a means to trip (open) instantaneously if they are closed in on an existing fault.

E: Let's just briefly take a look at the footnote. It tells you that these ratings are also the short time ratings of the circuit breaker. The material in **D** was discussed as though we already knew these were short time ratings, and we did. Suppose we did not know that fact and failed to read the footnote. We would not be as informed as we should be for the proper circuit breaker selection. It could be like making the selection blindfolded. **Be sure to read the footnotes**.

IEC Example

IEC Example - An IEC example similar to the one just presented will not be offered here. Ratings tables and their appearance as to how data is presented can change from country to country and even manufacturer to manufacturer. The information presented, however, is usually similar. You should be aware of some of the noticeable differences in the presented data, and **start now to become familiar with IEC rated breakers.** For now, consider the following to get started:

- The voltage range for the international market is **380 through 690 Volts AC** at a frequency of **50 or 60 hertz.**
- The general continuous current range for low voltage power circuit breakers is **800 through 6300 amperes.**
- The voltage and current abbreviations and names are different, such as:

  U_e – application voltage, such as 380 or 690 volts.

  I_n – rated current such as 800 or 6300 amperes.

  I_{cs} – rated service short circuit breaking capacity.

  I_{cu} – rated ultimate short-circuit breaking capacity.

  I_{cw} – rated short time withstand current (similar to the ANSI short time rating and the circuit breaker is expected to function properly again after having dealt with the I_{cw}).

ANSI and IEC Example

Let's make a quick comparison from a presentation standpoint. Keep in mind, the important things are:

1. Will the circuit breaker being considered do the job?

2. Will the circuit breaker being considered meet the standards in effect where the circuit breaker is to be used?

It is not possible to simply take a product designed and tested to one standard (ANSI or IEC) and certify it to the other standard. A manufacturer must undertake a concerted design effort to satisfy both standards individually.

	Breaker Frame (A)	Rated Voltage (V)	Interrupting (kA)
IEC	800 - 2000	415	40 or 65 or 130
		690	40 or 65 or 85
ANSI	800 - 1600	480	42 or 100 or 200
		600	42 or 100 or 200

This is by far not an all inclusive example. It is only intended to draw some simple ANSI and IEC comparisons between some of the most common selection points that must be considered when selecting low voltage power circuit breakers. You can see that although not exactly the same, it is primarily a matter of familiarization.

3. **Operation Method** - As discussed earlier, low voltage power circuit breakers are either **manually or electrically operated.** You must always specify the method of operation. At some point, you will need to know the secondary control voltage being used for an electrically operated circuit breaker. Even if the circuit breakers are manually operated, it **is a good idea to find out the secondary control voltage.** The control voltage is necessary for the final selection of a number of items, not just electrically operated circuit breakers.

4. **Accessory Items** - Many of the common accessory items associated with low voltage power circuit breakers were discussed earlier. You have to be alert for these items in a specification or ask the customer if any are required. A determination can then be made if a compatible accessory is available to meet the need. Make a **list of the required accessories and the specific requirements** that are appropriate for them, such as control voltage, number and types of contacts and overall function.

5. **Mounting Method** - You will need to know whether the breakers will be **fixed mounted or drawout.** Always check to see if there are any special requirements for either configuration.

Special Selection Factors

There may not be special conditions to consider, although this should be determined as soon as possible. You may be able to deal with certain special conditions and others might call for assistance from the manufacturer. Do not hesitate to ask for help. Some conditions or requirements to look for that might not be considered standard are:

- High or low ambient temperatures
- Moist or corrosive atmospheres
- Altitude
- High shock conditions
- Unusual circuit breaker mounting conditions

REVIEW 3

Answer the following questions without referring to the material just presented.

1. Of the two most common low voltage power circuit breaker mounting methods, the fixed configuration is most commonly used because it is less expensive.

   TRUE FALSE

2. When a drawout type low voltage power circuit breaker is in the "Connected" position, both _____ and _____ electrical connections are made.

3. If you were called upon to select a low voltage power circuit breaker, name at least five selection factors, standard or special factors, you might consider during the selection process.

   1. _____
   2. _____
   3. _____
   4. _____
   5. _____

4. In a low voltage power circuit breaker ratings table, the "Frame Size" indicates the circuit breaker's interrupting rating in amperes.

   TRUE FALSE

5. The nominal voltage range for low voltage power circuit breakers in the domestic market governed by ANSI Standards is _____ to 600 Volts AC.

6. In terms of the international market governed by IEC Standards, U_e stands for the _____ _____, such as 415 volts.

7. In today's global market, standards are usually so similar that a low voltage power circuit breaker designed and tested to IEC Standards can simply be certified to ANSI Standards and vice versa, without the need for additional testing.

   TRUE FALSE

8. A low voltage power circuit breaker is always provided with instantaneous protection against closing in on a fault current

   TRUE FALSE

9. Low voltage power circuit breakers are sized, selected, and applied to safely handle the _____ fault current it could possibly be exposed to.

GLOSSARY

Air Circuit Breaker	A circuit breaker that makes and breaks power circuits in air using arc chutes.
Arcing	The effect generated when electrical current bridges the air gap between two conductors that are not touching.
Arc Chute	A component of the arc extinguisher in a low voltage circuit breaker. It elongates and cools an arc.
Arc Extinguisher	A common method used to extinguish an arc. In general, it confines, divides and cools the arc.
ANSI	American National Standards Institute.
Circuit Breaker	A reusable overcurrent protection device. After tripping to break the circuit, it can be reset to protect the circuit again.
Connected Position	The position in which the circuit breaker is fully connected and functional.
Contacts	Method to open and close the circuit as the contacts come together or separate.
Continuous Current Rating	The amount of current the breaker can carry continuously at 60 cycles without exceeding the temperature rise limit, according to ANSI charts.
Control Voltage	Voltage is used to operate secondary devices
Disconnect Position	The position in which neither the primary nor secondary electrical connections of the circuit breaker are made. This position is often used as a storage position for the circuit breaker within its enclosure.
Drawout	A type of circuit breaker that can be moved into or out of its structure without unbolting, often on a racking mechanism.
Faceplate Shield	A device to protect the operator from dangerous voltages while the breaker door is open.
Finger Clusters	Automatic main disconnect devices for a circuit breaker.
Fixed	A type of circuit breaker that is bolted into a fixed position with bus or cable mechanically bolted to breaker terminations.
Integrally Mounted Trip Unit	The trip unit is inside of, or part of, the circuit breaker.

International Electrotechnical Commission	Abbreviated IEC. This organization is associated with equipment used internationally.
Interrupting Rating	Also “Ampere Interrupting Capacity (AIC).” A rating of the amount of current that a protective device, such as a fuse or circuit breaker, can safely interrupt.
Lever	The act of moving the breaker from one position to another.
Sf_6	An arc extinguishing technology involving the use of sulfur hexafluoride gas.
Short Time Rating	A rating for how fast a circuit breaker with open, expressed in cycles.
Stored Energy	A mechanism used to overcome inherent forces opposed to the breaker closing process, which stores energy until it is needed to help open the breaker.
Test Position	The position in which the circuit breaker’s primary connections are disconnected. Secondary connections are not disconnected and testing can be safely performed because the circuit breaker is not energized.
Trip Free	Breaker cannot be prevented from tripping, even when holding the handle in the ON position.
Trip Unit	Device that trips the operating mechanism in case of a short circuit or overload condition.
Underwriter’s Laboratories	UL. An independent laboratory that tests equipment to determine whether it meets certain safety standards when properly used.
Vacuum	An arc extinguishing technology. Features a pair of separable contacts enclosed in a vacuum-tight envelope. Since the environment inside the interrupter envelope is a vacuum, an arc cannot be sustained easily.
Withdrawn Position	In this position, the circuit breaker has no electrical connections. It is far enough out of its enclosure to permit inspection and maintenance.

REVIEW 1 ANSWERS

1. False
2. Test, Disconnect
3. True
4. Continuous current
5. True
6. Short time
7. D
8. True
9. Open Close Open

REVIEW 2 ANSWERS

1. Molded
2. False
3. Arc chutes, arc extinguishers
4. True
5. Trip unit
6. Sensors
7. Trip unit
8. Circles around 1, 2, and 3
9. Left to right: b, b, a
10. Shunt trip
11. False
12. Truck, Operated, Cell

REVIEW 3 ANSWERS

1. False
2. Primary, secondary
3. Any 5 of the following:
   Standards
   Ratings
   Operation Method
   Accessory Items
   Mounting Method
   High or Low Ambient Temperatures
   Moist or Corrosive Atmospheres
   Altitude
   High Shock Conditions
   Unusual Circuit Breaker Mounting Conditions
4. False
5. 208
6. Application Voltage
7. False
8. True
9. Maximum

Cutler-Hammer
Milwaukee, Wisconsin U.S.A.

Publication No. TR.22.01.T.E
February 1999
Printed in U.S.A. (GSP)