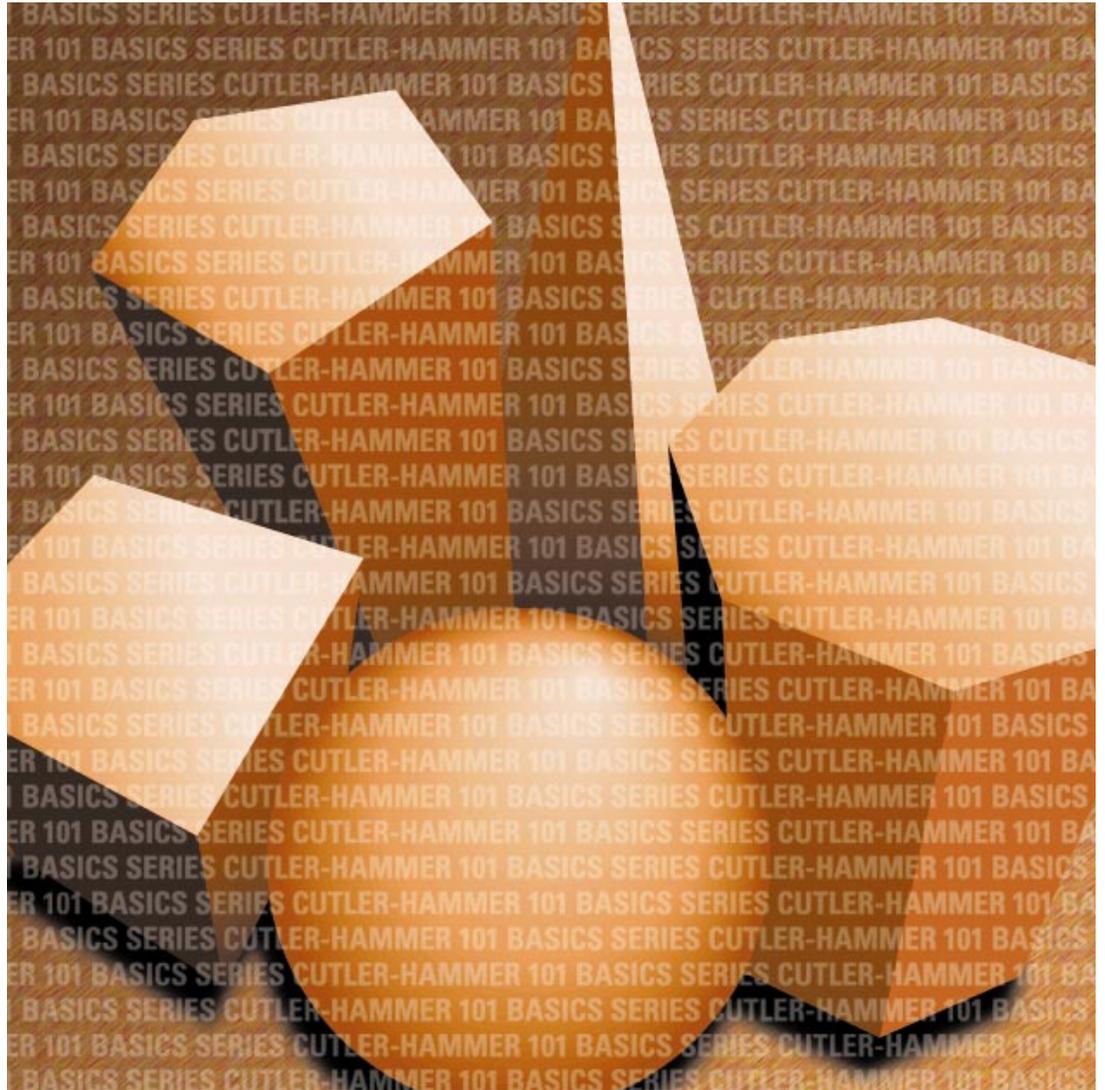


# 101 BASICS SERIES

## LEARNING MODULE 3: FUNDAMENTALS OF ELECTRICAL DISTRIBUTION



Cutler-Hammer

**EATON**

# FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

## WELCOME

Welcome to **Module 3, Fundamentals of Electrical Distribution.**

If you have successfully completed Module 2, Fundamentals of Electricity, you are prepared to begin learning about electrical distribution systems and the associated equipment. **If you have not completed Module 2, Fundamentals of Electricity, we recommend that you complete that module before you begin this one.**

This module will present a number of different topics, phrases and terms common to the world of electrical distribution. You will be introduced to information that will be used in later modules.

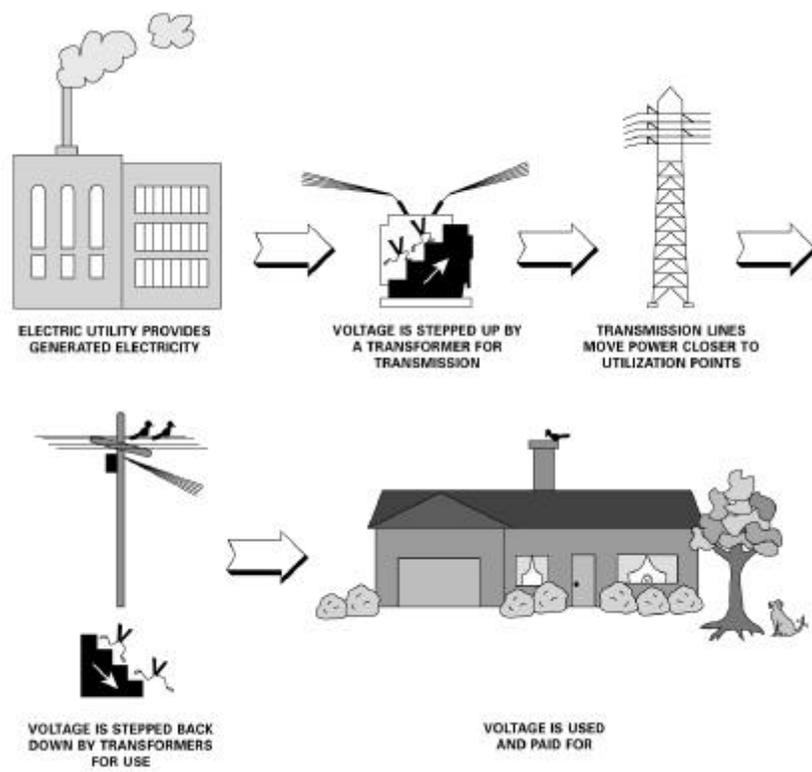


FIGURE 1: SIMPLE ELECTRIC DISTRIBUTION SYSTEM

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.*

# FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

## WHAT YOU WILL LEARN

We will **start with an overview** to introduce you to the main points about these devices, and the parts that make them. Then we will **step through each of these topics** in detail:

Section Title	Page Number
• Electrical Distribution System	3
• Radial Distribution System	3
• Loop Distribution System	4
• Network Distribution System	5
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## ELECTRICAL DISTRIBUTION SYSTEM

An electrical distribution system is a series of electrical circuits that delivers power in the proper proportion to homes, commercial businesses and industrial facilities. Regardless of the size and applications, the ultimate goal remains universal: **the economic and safe delivery of adequate electric power to electrical equipment.**

In general, there are three types of distribution systems: *radial*, *loop* and *network*. The type used by the utility company depends on the services required, location and economics.

### Radial Distribution System

The **Radial Distribution System** has one power source for a group of customers. If there is a power failure, the entire group loses power. In addition, a circuit failure somewhere in the system could mean a power interruption for the entire system.

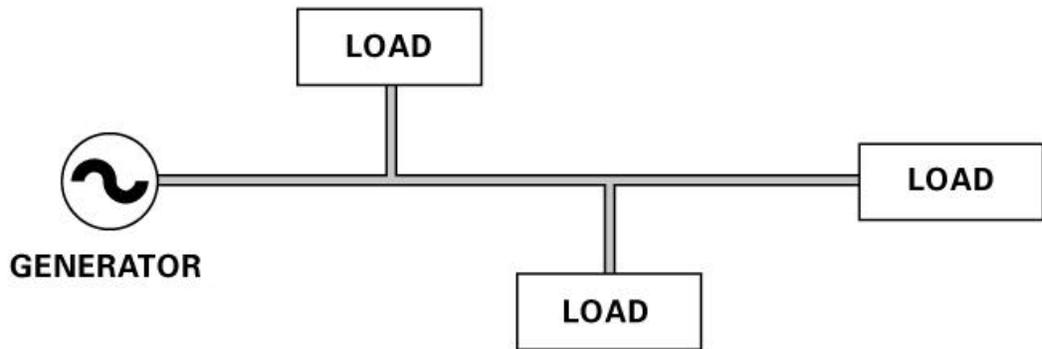


FIGURE 2: SIMPLE RADIAL DISTRIBUTION SYSTEM

This is the most economical and widely used system. It is used for residential homes where the supply of electricity is not critical if the power is disrupted.

## FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

### Loop Distribution System

The **Loop Distribution System** loops through the service area and returns to the point of origin. The strategic placement of switches permits the electric company to supply power to customers from either direction. If one power source fails, switches are opened or closed to obtain power source.

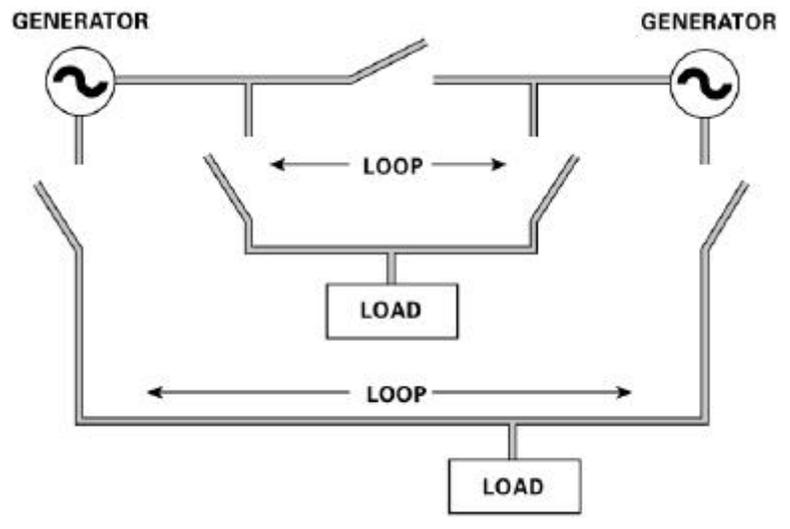


FIGURE 3: SIMPLE LOOP DISTRIBUTION SYSTEM

Obviously, the loop system provides better continuity of service than the radial system, with only short interruptions of service during switching. Since the system requires additional equipment for switching, it is more expensive than the radial system. As a result, it is used for commercial buildings and shopping centers where it is necessary to minimize interruptions.

## Network Distribution System

The **Network Distribution System** is the most expensive, and the most reliable in terms of continuity of service. This system consists of a number of interconnecting circuits operating at the same utilization voltage. The customer is connected to two or more power supplies. If one power source fails, the customer gets power from the other sources, without interruption.

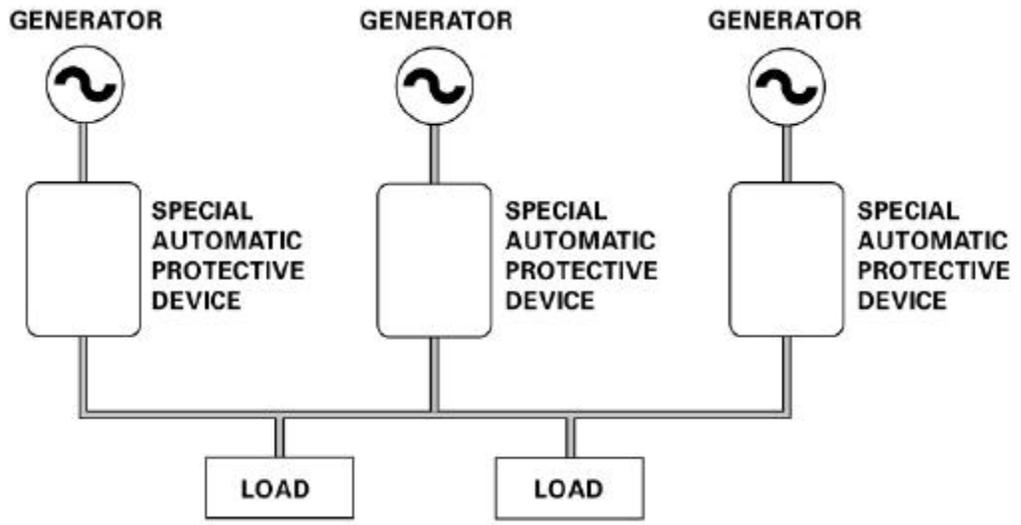


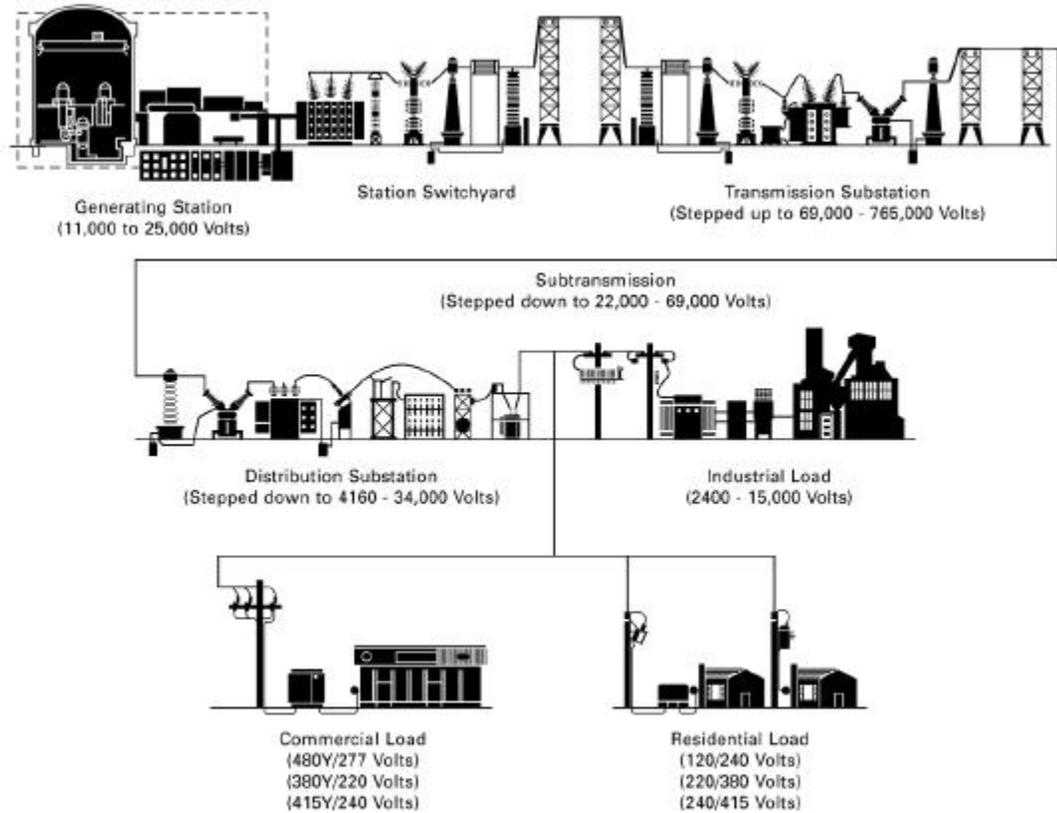
FIGURE 4: SIMPLE NETWORK DISTRIBUTION SYSTEM

It is utilized in areas with high and/or critical demand, such as large critical manufacturing process complexes and centralized computer installations.

# FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

## Electrical Utility Systems

To understand the Electrical Distribution System, you need to understand the flow of electricity from generation to the end user. To do this let's follow the simple electrical distribution system in Figure 5 in steps:



*Note: Illustration voltages are examples only.*

FIGURE 5: ELECTRICAL DISTRIBUTION SYSTEM

STEP 1: The flow of electricity begins at the utility company where it is created at the **generating station**.

STEP 2: The **voltage** is then stepped up (increased) by a **generator transformer** at the **Station Switchyard**. This is done to minimize the cable size and electrical losses.

STEP 3: The **Transmission Substation**, increases the voltage by a step-up transformer from 69,000 to 765,000 volts. The voltage increase depends on the distance it will go and the type of facilities it will ultimately supply. The power is then distributed in multiple directions to the proper **subtransmission station**.

STEP 4: The subtransmission station is located closer to its end customer and as a result the voltage is decreased by a step-down transformer to between 22,000-69,000 volts.

**Electrical Utility Systems (continued)**

STEP 5: The electricity is then sent to the **Distribution Substation** where the voltage is stepped down by the Step-Down Transformers to useful voltages. The power is then distributed to homes and facilities that the Substation supplies.

STEP 6: At or near each home and facility are transformers that adjust the voltages down to the proper level for use. For example a large industrial plant will receive voltage level from 2400 – 15,000 volts. It will use it's own on-site step-down transformers to produce the different voltage levels needed in the facility.

**Cabling**

One of the most important parts of the electrical distribution system is the conductor or cable that carries the power from its source to its destination. The cables going across the country are relatively small in diameter compared to the high voltages they carry. How can that be? To understand why, we need to look at the formula for power:

$$P = V \times I$$

**V= voltage    I = current    P= power**

Since power is equal to the voltage times current and the equation is always equal on both sides, we cannot change the voltage without changing the current. So when Voltage is increased, current has to be decreased. Reducing current allows the power to be transmitted through smaller diameter (gauge) conductors. Reducing the conductor size reduces the cost and makes the system more efficient.

**Power System Types**

Now that you know about how power is transmitted, we need to discuss the two types of AC power: three-phase and single-phase.

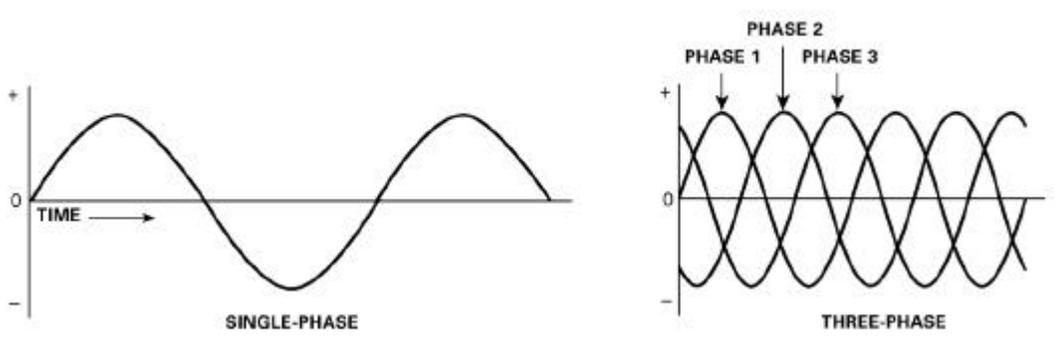


FIGURE 6: TYPES OF AC POWER

**Single-Phase System:** This system is standard for residential service. It can consist of two or three wires entering the home where the power will be used. The three-wire system (1 $\phi$ 3W) is most common today and will be discussed here. (The two-wire system (1 $\phi$ 2W) is common in older construction.)

# FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

## Power System Types (continued)

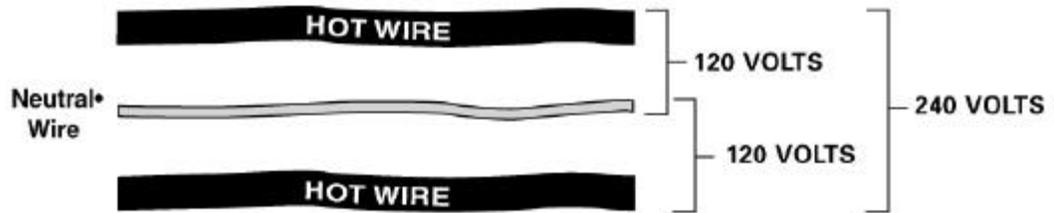


FIGURE 7: SINGLE-PHASE, THREE-WIRE (1φ3W) SYSTEM

Although the modern single-phase system uses three wires, it is single-phase, not three-phase. It actually consists of three wires coming into the house: two hot wires and one neutral wire.

Use of the three wires in different electrical combinations can provide different voltages. For example, one circuit can be made up of one of the two hot wires and the neutral wire. This circuit provides 120 volts AC, the voltage required for most household lights and small appliances.

Another circuit can be made up of both hot wires to provide 240 volts AC, the voltage required for larger appliances like clothes dryers.

**Three-Phase System:** The electric company produces three phase power, by rotating three coils through a magnetic field within a generator. As they rotate through the magnetic field, they generate power. Each phase is 120 degrees apart (out of phase) from each other.

Each phase flows from the generator in a separate cable. These phases are delivered to end users as either a three-phase power or a single-phase power.

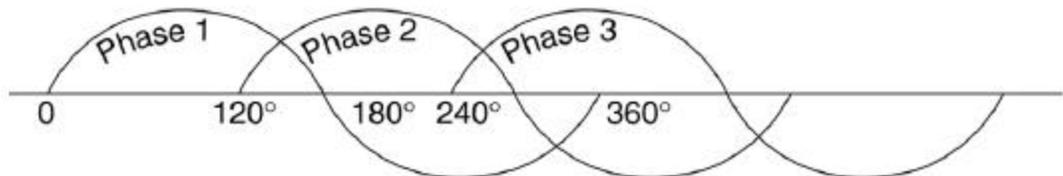


FIGURE 8: THREE-PHASE SINE WAVE

Commercial and industrial facilities use three-phase power because, it is efficient and makes the equipment run more smoothly than single-phase. The reason is since each phase is 120 degrees apart, the equipment does not see a zero point. This is especially important when running motors because each new phase keeps the motor turning.

In addition, single-phase power is available from a three-phase system by use only one of the phases. This is beneficial for supplying power to lights, receptacles, heating and air conditioning.

## Power System Types (continued)

There are two types of three-phase system: **three-phase, three-wire** ( $3\phi 3W$ ) and **three-phase, four-wire** ( $3\phi 4W$ ). The main difference between the two is the  $3\phi 4W$  system has a neutral.

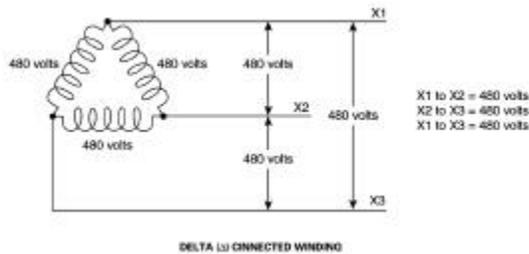


FIGURE 9: THREE-PHASE THREE WIRE

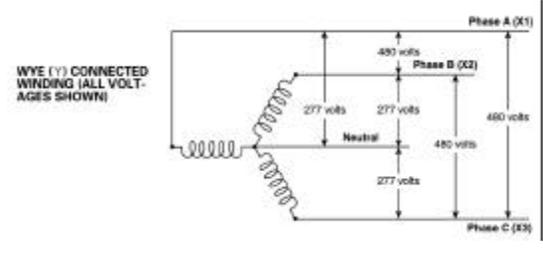


FIGURE 10: THREE-PHASE FOUR WIRE

These systems offer a wide range of possible voltages, including 208, 240, 277, 480 and 600 volts. The voltages available are determined by the wiring configuration within the transformer. A number of these wiring configurations will be covered in Module 4, Transformers. **Three-phase power systems have a number of advantages:**

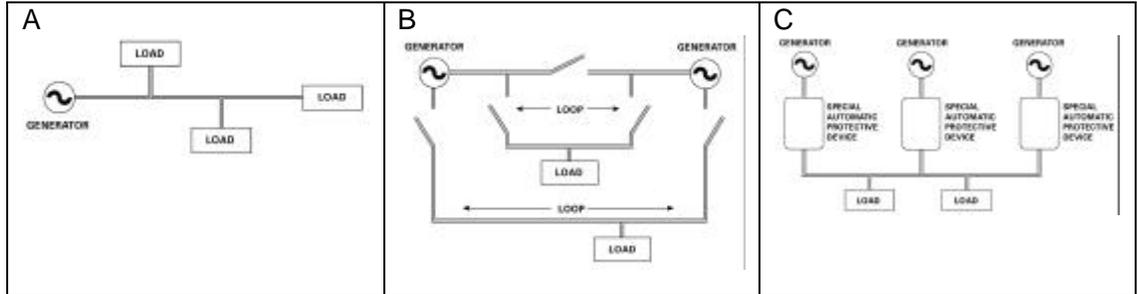
- They provide power to large industrial sites and commercial facilities efficiently.
- Single-phase electricity is available from a three-phase system.
- Three-phase power allows heavy industrial equipment to operate smoothly and efficiently.

# FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

## 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.

- Which of the three distribution systems used by the utility company illustrated below offers the greatest continuity of service, and which is the most economical to build and maintain?



Greatest Continuity: \_\_\_\_\_

Most Economical: \_\_\_\_\_

- The piece of electrical equipment used to step up or step down the voltages is a \_\_\_\_\_.
- When the electric company generates electricity, it usually reduces the voltage before it enters the transmission system because it is safer and more economical to move lower voltages to the points of utilization.

TRUE FALSE

- A transformer that makes the voltage lower is called a \_\_\_\_\_ transformer.
- Being able to get single-phase electricity from a three-phase system is one of the advantages of a three-phase system. State two other advantages of a three phase power system.

\_\_\_\_\_  
\_\_\_\_\_

## ONE-LINE DIAGRAMS

### Electrical Symbols

We usually depict the electrical distribution system by a graphic representation called a *one-line diagram*. A one-line can show all or part of a system. It is very versatile and comprehensive because it can depict very simple DC circuits, or a very complicated three-phase system.

We use universally accepted *electrical symbols* to represent the different electrical components and their relationship within a circuit or system. To interpret one-lines you first need to be familiar with the electrical symbols. This chart shows the most frequently used symbols.

INDIVIDUAL ELECTRICAL SYMBOLS		
Symbol	Identification	Explanation
	Transformer	Represents a variety of transformers from liquid filled to dry types. Additional information is normally printed next to symbol indicating winding connections, primary/secondary voltages, impedance and KVA or MVA ratings.
	Removable/drawout circuit breaker	Normally represents a drawout circuit breaker 5kV and above.
	Future removable/drawout circuit breaker position	Represents a structure equipped to accept a circuit breaker in the future, commonly known as provisions.
	Non-drawout circuit breaker	Represents a fixed mounted low-voltage circuit breaker.
	Removable/drawout circuit breaker	Represents a drawout low voltage circuit breaker.
	Disconnect Switch	Represents a switch in low or higher voltage applications (open position shown).
	Fuse	Represents low voltage and power fuses.
	Bus Duct	Represents low and higher voltage bus duct.
	Current transformer	Represents current transformers mounted in assembled equipment. A ratio of 4000A to 5A shown.
	Potential transformer	Represents potential transformers usually mounted in assembled equipment. A ratio of 480V to 120V shown.
	Ground (earth)	Represents a grounding (earthing) point.
	Battery	Represents a battery in an equipment package.
	Motor	Represents a motor and is also shown with an "M" inside the circle. Additional motor information is commonly printed next to symbol, such as horsepower, rpm and voltage.
	Normally open contact	Can represent a single contact or single-pole switch in the open position for motor control.
	Normally closed contact	Can represent a single contact or single-pole switch in the closed position for motor control.
	Indicating light	The letter indicates the color. The color red is indicated.
	Overload relay	Protects a motor should an overload condition develop.
	Capacitor	Represents a variety of capacitors.
	Ammeter	A letter is usually shown to designate the meter type (A = ammeter, V = voltmeter, etc.).
	Instantaneous overcurrent protective relay	The device number designates the relay type (50 = instantaneous overcurrent, 59 = overvoltage, 86 = lockout, etc.).
	Emergency generator	The symbol is frequently shown in conjunction with a transfer switch.

FIGURE 11: COMMON ELECTRICAL SYMBOLS

## Electrical Symbols (continued)

COMBINATION ELECTRICAL SYMBOLS		
Symbol	Identification	Explanation
	Fused disconnect switch	The symbol is a combination of a fuse and disconnect switch with the switch in the open position.
	Low voltage motor control	The symbol is a combination of a normally open contact (switch), overload relay, motor, and disconnect device.
	Medium voltage motor starter	The symbol is a combination of a drawout fuse, normally open contact (switch) and motor.
	Meter center	A series of circle symbols representing meters usually mounted in a common enclosure.
	Load center or panelboard	One circuit breaker representing a main device and other circuit breakers representing feeder circuits usually in a common enclosure.
	Transfer switch	<ul style="list-style-type: none"> <li>• Circuit breaker type transfer switch ①</li> <li>• Non-circuit breaker type transfer switch ②</li> </ul>
	Current transformer with connected ammeter	The instrument connected could be a different instrument or several different instruments identified by the letter.
	Protective relays connected to current transformer	Device numbers indicate types of relays connected, such as: <ul style="list-style-type: none"> <li>• 87 = Directional overcurrent</li> <li>• 51 = Time overcurrent</li> </ul>

### NOTES:

- Some devices, especially newer devices, may not have universally accepted symbols. These devices could be represented in a number of ways, usually a matter of personal choice. In such instances the symbol is usually accompanied by a verbal description. Examples of this situation are:

Addressable  
Relay

End Cable  
Tap Box
- In a number of instances the same symbol can represent a number of components. They are usually distinguished from one another by letters or numbers, such as  $\text{M}$ ,  $\text{W}$ ,  $\text{A}$ , and  $\text{C}$  representing a motor, watthour meter, ammeter and overcurrent protective relay respectively.

- Universally accepted symbols frequently have additional information provided near the symbol. This distinguishes like symbols from one another. The following examples are typical:

- 1200 A identifies the drawout circuit breaker represented by the symbol as a 1200 ampere circuit breaker.
- 225A/3P indicates the fixed circuit breaker represented by the symbol as a 225 ampere, 3-pole breaker.
- indicates that the transformer represented by the symbol is connected "Delta-Wye."

FIGURE 12: COMMON ELECTRICAL SYMBOLS (CONTINUED)

## Interpreting One-Line Diagrams

Now, that you are familiar with electrical symbol, let's look at how they are used in interpreting one-line diagrams. Below is a simple electrical circuit.

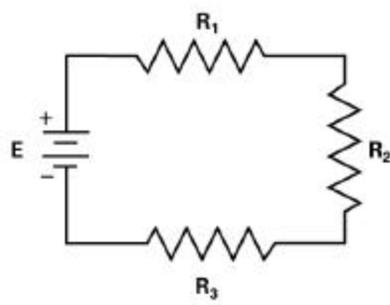


FIGURE 13: SIMPLE ONE-LINE DIAGRAM

You can tell by the symbols that this one-line diagram has three resistors and a battery. The electricity flows from the negative side of the battery through the resistors to the positive side of the battery.

## FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

### Interpreting One-Line Diagrams (continued)

Now, let's go through an industrial one-line diagram. When interpreting a one-line diagram, you should always start at the top where the highest voltage is and work your way down to the lowest voltage. This helps to keep the voltages and their paths straight.

To explain this easier, we have divided the one-line into three sections.

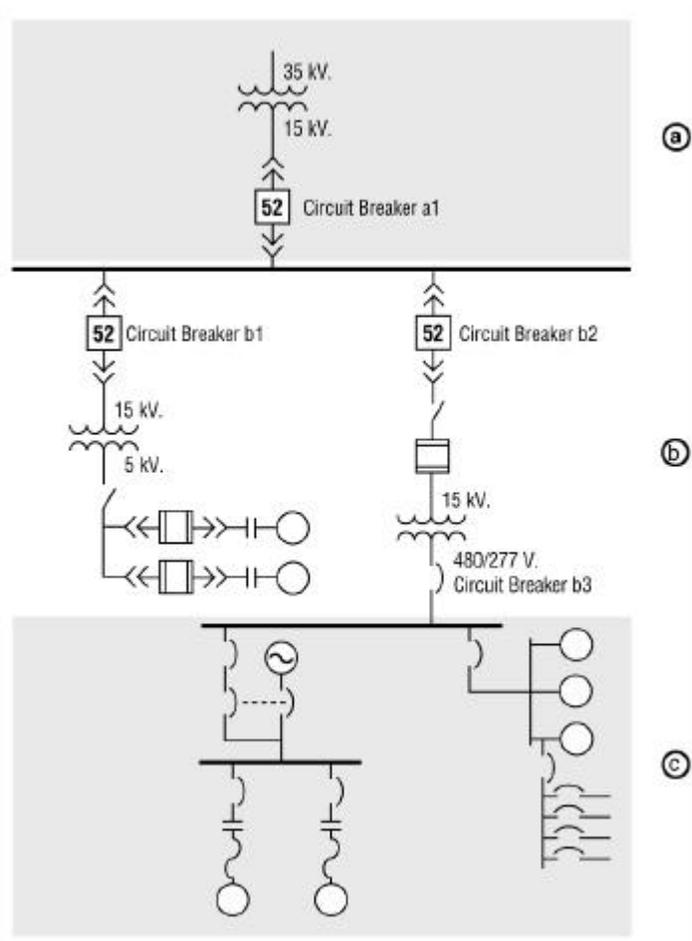


FIGURE 14: A TYPICAL INDUSTRIAL ONE-LINE DIAGRAM

#### Area a

Starting at the top, you will notice that a transformer is feeding power to the whole system. The transformer steps the voltage down from 35kV to 15kV, as indicated by the numbers next to the transformer symbol.

Once the voltage has been stepped down, a removable circuit breaker (a1) is encountered. Do you recognize the removable circuit breaker symbol? You can assume this circuit breaker can handle 15kV, since it is attached to the 15kV side of the transformer, and nothing different is indicated on the one-line.

## Interpreting One-Line Diagrams (continued)

Following the removable circuit breaker (a1) from the transformer, it is attached to a heavier, horizontal line. This horizontal line represents an *electrical bus*, which is a means used to get electricity to other areas or circuits. (More information about Busway can be found in Module 14).

### Area (b)

You will notice that two more removable circuit breakers (b1 and b2) are attached to the bus and feed other circuits, which are at 15kV, since there has been no indication of voltage change in the system.

Attached to the removable circuit breaker (b1), a step-down transformer is used to take the voltage in that area of the system from 15kV down to 5kV.

On the 5kV side of this transformer, a disconnect switch is shown. The disconnect is used to connect or isolate the equipment below it from the transformer. The equipment below the disconnect is at 5kV, since nothing indicates the contrary.

Do you recognize the equipment attached to the lower side of the disconnect switch as being two medium-voltage motor starters? A number of starters could be connected depending upon the particular system requirements.

Now locate the second removable circuit breaker (b2). This circuit breaker is attached to a fused disconnect switch and it is connected to a step-down transformer. Notice that all the equipment below the transformer is now considered low voltage equipment, because the voltage has been stepped down to a level of 600 volts or lower.

The last piece of electrical equipment in the middle portion of the diagram is another circuit breaker (b3). This time, however, the circuit breaker is a *fixed low voltage circuit breaker*, as indicated by the symbol.

Moving to the bottom area of the one-line, notice that the circuit breaker (b3) in the middle is connected to the bus in the bottom portion.

### Area (c)

To the bottom left and connected to the bus is another fixed circuit breaker. Look carefully at the next grouping of symbols. Do you recognize the automatic transfer switch symbol?

Also, notice that a circle symbol which represents an emergency generator is attached to the automatic transfer switch. This area of the one-line tells us that it is important for the equipment connected below the automatic transfer switch to keep running, even if power from the bus is lost. You can tell from the one-line that the automatic transfer switch would connect the emergency generator into the circuit to keep equipment running, if power from the bus were lost.

### Interpreting One-Line Diagrams (continued)

A low-voltage motor control circuit is attached to the automatic transfer switch through a low-voltage bus. Make sure you recognize these symbols. Although we do not know the exact function of the low voltage motor control in this circuit, it is obvious that it is important to keep the equipment up and running. A written specification would normally provide the details of the application.

On the right side of the third area there is another fixed circuit breaker connected to the bus. It is attached to a meter center, as indicated by the symbol formed by three circles. This indicates that the electric company is using these meters to keep track of power consumed by the equipment below the meter center.

Below the meter center is a loadcenter or panelboard that is feeding a number of smaller circuits. This could represent a load center in a building that feeds power to the lights, air conditioning, heat and any other electrical equipment connected to the building.

This over-simplified analysis of a one-line diagram gives you an idea of the kind of story such diagrams tell about electrical system connections and equipment. Just keep in mind that although some one-line diagrams may appear overwhelming by virtue of their size and the wide variety of equipment represented, they can all be analyzed using the same step-by-step method.

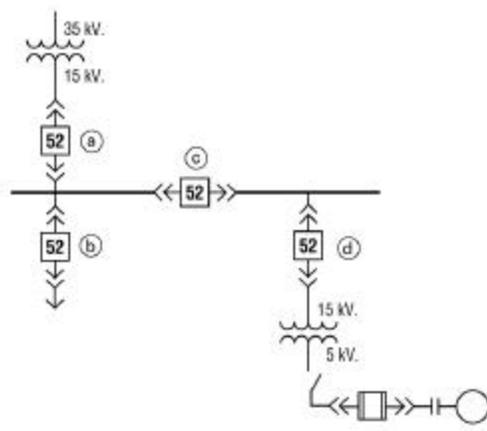
REVIEW 2

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. A one-line diagram shows the components, electrical relationships and connections with a single-phase circuit only, thus the name one-line diagram.

TRUE FALSE

2. In the one-line diagram illustrated below, the disconnect switch shown would have to have a voltage rating of how many volts, assuming you have no additional information? \_\_\_\_\_



3. The four removable circuit breakers shown in the one-line diagram for question 2 are lettered a, b, c, and d. How many of the four circuit breakers are 5kV class circuit breakers? \_\_\_\_\_

4. Next to the electrical symbols illustrated below, enter the name of the electrical component it represents.

a.		_____
b.		_____
c.		_____
d.		_____
e.		_____
f.		_____

### SYSTEM PROTECTION

The primary goal of all electrical power distribution systems is to provide power to electrical equipment with the utmost safety. System protection is designed to add the remaining goals of equipment/conductor protection and service continuity at the most reasonable cost.

Protective equipment, such as molded case circuit breakers, during *overcurrent* conditions, must quickly isolate the affected section of the power system to maintain service to other sections. They must also minimize equipment damage and limit the extent or duration of outages. We will first discuss what overcurrent conditions are and then talk about system coordination.

### Overcurrent Conditions

**Overcurrent:** This is a current that is higher than the amount of current a conductor or piece of equipment can carry safely. An overcurrent condition left unchecked can cause insulation and/or equipment damage as a result of excessive temperature and/or dynamic stresses. **The cable insulation is the most vulnerable to overcurrent conditions.** The conductor itself may be able to withstand extremely high heat, but the insulation around the conductor cannot.

There are three types of overcurrent conditions:

- Overloads
- Short circuits
- Ground faults

**Overloads:** *Overloads* are the result of placing excessive loads on a circuit, beyond the level the circuit was designed to handle safely. Insulation deterioration in electrical conductors is most often the result of such overload conditions.

When an overload condition exists, a temperature buildup occurs between the insulation and the conductor.

How many times have you had to go to the loadcenter in your house and reset a circuit breaker? An overload condition is created, heat builds up, and the circuit breaker opens to protect the cable and, ultimately, the house.

**Short Circuits:** *Short circuits*, frequently called *faults*, are usually caused by abnormally high currents that flow when insulation on a conductor fails. When the insulation that protects one phase from another or one phase from ground breaks down, short circuit currents can be expected to flow. The short circuit condition must be eliminated quickly to protect against damage to the system.

## Overcurrent Conditions (continued)

A simple water analogy can be used to compare the current that normally flows in a circuit to a short circuit current.

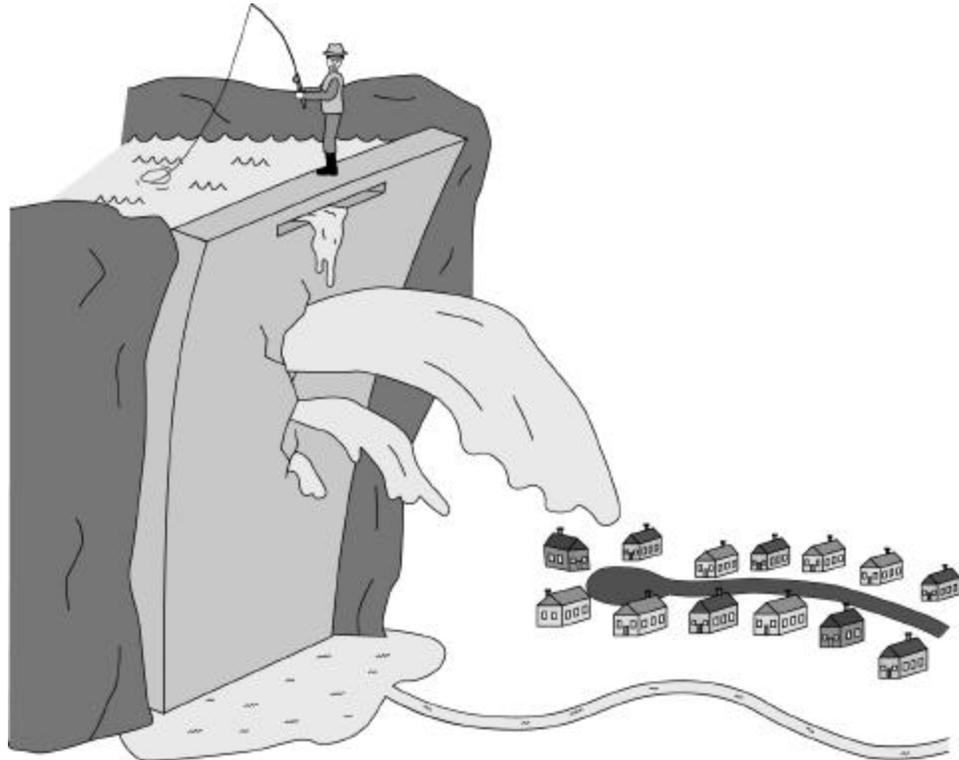


FIGURE 15: SHORT-CIRCUITING OF A DAM

A large dam is built and feeds a controlled amount of water into a small river. Downstream, a small town is built along the river's banks. The amount of water permitted to enter the river safely is independent of the amount of water behind the dam. Should the dam break and suddenly release the water behind it, the town could be severely damaged or even washed away. This sudden rush of water is like the flow of current in a circuit under fault conditions. The amount of damage done depends on the amount of water stored behind the dam or the amount of current available to feed the fault.

**Ground Faults:** A *ground fault* is a particular type of short circuit. It is a short circuit between one of the phases and ground. It is probably the most common low level fault experienced, especially on lower voltage circuits.

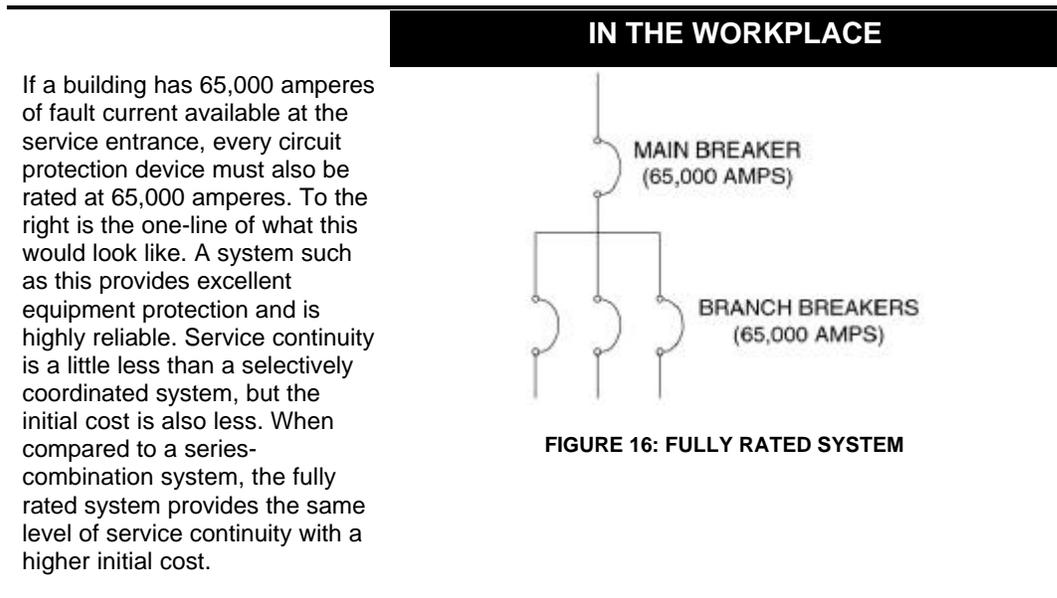
Ground fault currents are often not large in magnitude and can go undetected for a period of time. This type of fault might occur in the electrical outlets located in the bathroom or in other areas where water could be present.

## System Coordination

Because of the overcurrent conditions that can occur in distribution systems, thought has to be put into properly coordinating that system. There are three types of system coordinations: *Fully rated*, *selectively coordinated* and *series rated*.

**Fully Rated Systems: In a fully rated system, all circuit breakers are rated to operate independently. They all have an *interrupting rating* adequate for the maximum *fault current* available at their point of application. All of the breakers are equipped with long time delay and instantaneous overcurrent trip elements.**

The fully rated method selects circuit protection devices with ratings equal to or greater than the available fault current.



**Selectively Coordinated Systems:** As with the fully rated system, all circuit breakers are fully rated to interrupt the maximum fault current available at their point of application. The selectively coordinated system maximizes service continuity because only the breaker nearest the fault operates to isolate the faulted circuit.

Each upstream breaker in the power distribution system incorporates short time delay tripping. The upstream breaker must be capable of withstanding the thermal and magnetic stresses delivered by the fault current for the time period required by the breaker nearest the fault to trip.

The selectivity of the system can be based, up to a point, on:

- Magnitude of the fault current providing current selectivity.
- Fault withstand time providing time selectivity.
- Both current and time providing complete selectivity.

**System Coordination (continued)**

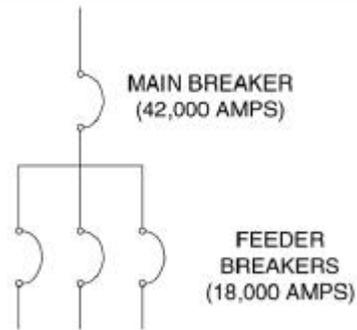
The selectively coordinated system is the most costly of the three basic systems. However, it provides the best overall protection of equipment and maximum continuity of service.

**Series Rated System:** The series rated system states that **the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current** of the system, but **downstream devices connected in series can be rated at lower values**. Under fault conditions, both the main device and the downstream device would open to clear the fault.

Series rated breaker combinations must be tested in series in order to be UL listed.

## IN THE WORKPLACE

For example, a building with 42,000 amperes of available fault current might have the breaker at the service entrance rated at 42,000 amperes and the additional downstream breakers rated at 18,000 amperes. Series rated systems are intended for use on systems where the branch circuits are primarily lighting and other resistive loads. If the branch circuits supply motor loads, fully rated or selectively coordinated systems should be used.



**FIGURE 17: SERIES RATED SYSTEM**

The major advantage to this system is it allows you to use lower-cost branch breakers. However, because both breakers trip on a major fault, service continuity may not be as high as the other systems.

The three basic systems offer protection of electrical conductors and equipment with equal effectiveness. The initial cost and continuity of service are the varying factors. The decision of which protection system to use should be based on the application variables and needs.

### STANDARDS AND CODES

The electrical industry is guided by a set of *standards* and *codes* for designing, manufacturing and supplying electrical equipment, and since we are part of a global economy, both domestic and international considerations must be included. There is no room for compromise when performance, quality, and safety are involved. Exacting standards and codes are established to provide a set of guidelines relative to the design, testing and manufacture of all types of electrical equipment.

#### Standards

A number of standards are established through a consensus process within a particular industry. Once the consensus is achieved, the standards are published by an independent standards organization, such as ANSI (American National Standards Institute).

Some standards are not required, but it may be impossible to sell a particular piece of equipment in a certain area of the world unless the relevant standard is met.

Today, many standards from different countries stipulate similar guidelines. A piece of equipment meeting one set of standards might very well meet another set with minor changes. In most instances, however, meeting the requirements of any set of standards must be proven and certified through testing.

Testing is frequently carried out at independent testing laboratories. For example, you are probably already familiar with UL (Underwriters Laboratories, Inc.). A great deal of equipment is designed, built and tested in accordance with UL Standards. Appliances in your house display the UL approval. You may not know exactly what UL requires of that appliance, but the UL approval gives you confidence that it will function safely, if used correctly.



FIGURE 18: UL LABEL

### Codes

Electrical codes are sets of rules established by governing bodies which state:

- Type of equipment to be used in a given situation
- Appropriate use
- Installation procedures, including how and where it should be installed

Codes usually carry **mandatory** compliance, and can apply nationally or to a more limited area, such as a single local municipality. In any case, such codes can be used to facilitate the successful installation of equipment, or stop it dead in its tracks. Codes are powerful, and there must be a keen awareness of the various codes and their applications.

One of the best known set of codes is the NEC (National Electrical Code), which works in conjunction with UL requirements. These codes are applicable throughout the United States, and regulate all electrical equipment used in power distribution systems, from the source to private residences, and even to the configuration of the circuits within homes.

As you learn about different types of electrical equipment, you will become very aware of the standards and codes that are most relevant to that particular type of equipment. For now, just be aware of their existence and importance.

Here is a list of the most common standards and codes (but it is far from all-inclusive):

- ANSI (American National Standards Institute)
- BSI (British Standards Association)
- CE Mark (Certified European Mark)
- CEC (Canadian Electric Code)
- CSA (Canadian Standards Association)
- IEC (International Electrotechnical Commission)
- IEEE (Institute of Electrical and Electronic Engineers)
- ISO (International Standards Organization)
- NEC (National Electrical Code)
- NEMA (National Electrical Manufacturers Association)
- UL (Underwriters Laboratories, Inc.)

### Nameplates and Labels

A piece of electrical equipment usually has a nameplate affixed to it that provides valuable information about the equipment ratings and the conditions under which it can operate. In addition, electrical assemblies have nameplates to identify applicable standards and to determine appropriate applicable equipment. Make it a habit to look at nameplates and the information they provide.

Nameplates may be found in the following places:

- Attached to the equipment itself
- Attached to the packing material during shipment
- In literature relating to the equipment

Labels can serve a wide variety of purposes:

- Provide handling and installation instructions
- Provide operational information
- Act as a safety feature by issuing warnings and/or cautions concerning specific dangers or problems

One of the most important uses of labels is as a safety feature. The best way to eliminate hazards is to design foolproof equipment. Since individuals have, from time to time, defeated the best efforts of designers to provide fail-safe designs, it is necessary to warn people about potential hazards.

Safety labels will contain a single enlarged word, such as DANGER, WARNING, CAUTION, or NOTICE. The word used depends on the classification of the potential hazard.



FIGURE 19: TYPICAL LOOK OF WARNING AND CAUTION SAFETY LABELS

**REVIEW 3**

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

1. The most vulnerable part of an electrical circuit to overcurrent conditions is the \_\_\_\_\_.
2. List the three types of overcurrent conditions.
  - a. \_\_\_\_\_
  - b. \_\_\_\_\_
  - c. \_\_\_\_\_
3. Which overcurrent condition usually has the smallest magnitude of current?  
\_\_\_\_\_
4. In your own words explain the function of the NEC.  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

5. Safety labels quickly alert an individual to the degree of a potential hazard or problem by using single enlarged, word like:



List two others

- a. \_\_\_\_\_
- b. \_\_\_\_\_

<b>GLOSSARY</b>	<b>ANSI</b>	Abbreviation for American National Standards Institute. It does not develop standards, but functions as a coordinating body for the purpose of encouraging development and adoption of worthwhile standards.
	<b>Codes</b>	Rules established by governing bodies for the proper and safe use and installation of electrical equipment.
	<b>Electrical Bus</b>	The conductor(s), usually made of copper or aluminum, which carries the current and serves as a common connection for two or more circuits.
	<b>Electrical Symbols</b>	Graphical representations of electrical components.
	<b>Fault</b>	See “Short Circuit.”
	<b>Fault Current</b>	The surge of amperage created during an electrical failing.
	<b>Fixed Low Voltage Circuit Breaker</b>	A circuit breaker rated for less than 1000V and bolted into a fixed position with bus or cable mechanically bolted to breaker terminations.
	<b>Fully Rated</b>	This is a type of system coordination in which all circuit breakers are rated to operate independently
	<b>Ground Fault</b>	A short circuit between one of the phases and ground.
	<b>Interrupting Rating</b>	The maximum short circuit current that an overcurrent protective device can safely interrupt.
	<b>Loadcenter</b>	Low voltage circuit breakers mounted within a common enclosure sharing a common electrical bus.
	<b>Loop Distribution System</b>	The power source is looped through the service area and returns to the point of origin. If one power source fails, switches can be opened or closed to supply the power.
	<b>NEC</b>	National Electric Code — a set of electrical installation standards applicable throughout the U.S. and published by the National Fire Protection Association. The NEC works with UL requirements and usually carries mandatory compliance.
	<b>Network Distribution System</b>	Interconnected circuits connect the customer to two or more power sources. Most reliable for continuity of service.

## FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

<b>One-Line Diagram</b>	A graphical representation of an electrical distribution system.
<b>Overcurrent</b>	A current higher than the current a conductor or electrical component can safely handle.
<b>Overload</b>	A temperature build-up caused by excessive loads on a circuit causing damage to the conductor's insulation.
<b>Panelboard</b>	See "Loadcenter."
<b>Radial Distribution System</b>	One power source for a group of customers. A circuit failure in the system causes a power interruption for all in the system.
<b>Selectively Coordinated</b>	A type of system coordination in which all circuit breaker are fully rated at the point of application
<b>Series Rated</b>	A type of system coordination in which the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current of the system.
<b>Short Circuit</b>	Abnormally high current often caused by insulation failure.
<b>Single-Phase</b>	Only one phase of the three phases is utilized for voltage.
<b>Specification</b>	The detailed descriptions of electrical equipment to be provided for an application.
<b>Standards</b>	Guidelines and regulations for the manufacturing of electrical equipment.
<b>Step-Down Transformer</b>	Decreases the output voltage that is being supplied to it.
<b>Step-Up Transformer</b>	Increases the output voltage that is being supplied to it.
<b>Three-Phase</b>	Three streams of electricity rotated through a magnetic field and distributed on three cables.
<b>UL Listed</b>	Listed by Underwriters Laboratory, an independent laboratory that tests equipment to determine whether it meets certain safety standards when properly used.

## FUNDAMENTALS OF ELECTRICAL DISTRIBUTION

### REVIEW 1 ANSWERS

1. C, A
2. Transformer
3. False
4. Step-Down
5. Allows heavy industrial equipment to operate smoothly and efficiently.  
Can be transmitted over long distances with smaller conductor sizes.

### REVIEW 2 ANSWERS

1. False
2. 5 kV
3. None
4.
  - a. Transformer
  - b. Removable Circuit Breaker
  - c. Fuse
  - d. Normally Closed Contact
  - e. Low Voltage Motor Control (Combination Starter)
  - f. Disconnect Switch

### REVIEW 3 ANSWERS

1. Conductor (Cable) Insulation
2.
  - a. Overload
  - b. Short Circuit
  - c. Ground Fault
3. Ground Fault
4. National Electric Code — a set of electrical installation standards applicable throughout the U.S. and published by the National Fire Protection Association. The NEC works with UL requirements and usually carries mandatory compliance.
5. Any two of the following:
  - Danger
  - Caution
  - Notice

## Cutler-Hammer

Milwaukee, Wisconsin U.S.A.

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