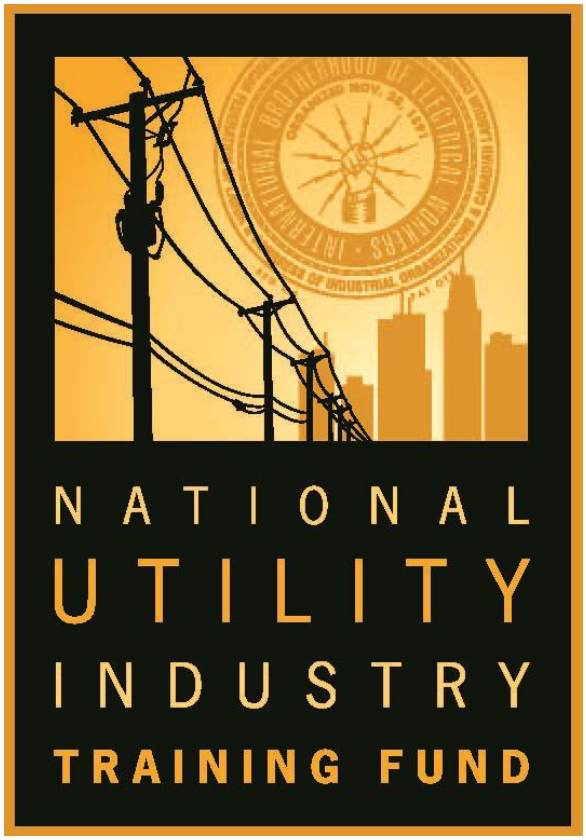
ELECTRICAL TRAINING ALLIANCE OUTSIDE LINEMAN APPRENTICESHIP

Third Year
Lesson Learning Objectives



Outside Lineman Apprenticeship

3rd Year – Level 1

Lesson Learning Objectives

Level I opens with lessons on taking pride in the industry, an introduction to the COMET program, and productivity. Students will then learn about distribution circuits, alternating current, inductance, and capacitors. The course closes with lessons on transformers—3-phase voltages and connections and single-phase connections. Students also will learn about troubleshooting 3-phase banks.

Lesson 1 Almost a Journeyman

Introductory Information

Apprentice Electrical Workers have worked hard to get to this point, and will soon be entering the third year of study in the *electrical training ALLIANCE* Apprenticeship Program. This is a good time to reflect on the training received this far, and to think about what it means to be a Journeyman Electrical Worker.

Being a Journeyman Electrical Worker is a career that can be very rewarding, both financially and as a member of society, but a lot depends on attitude. On the way to becoming a true craftsman in the trade, one's attitude towards fellow workers and the trade itself will be how one is measured.

When reflecting on one's progress, one may find areas where improvement is needed. The last year of the apprenticeship is a good place to address those improvements. Apprentice Electrical Workers tend to work towards becoming experts on the technical side of the industry and neglect becoming an active member in the industry. Now is the time to prepare to be the type of Journeyman Electrical Worker that any employer would be willing to hire.

Learning Objectives

After completing this lesson, you will be able to:

1. Explain the "why" and "how" of apprenticeship.
2. Describe why all workers in the industry need to be highly productive and efficient.
3. Assess how much training is needed before becoming a Journeyman Electrical Worker.

Lesson 2 Pride in Your Industry

Introductory Information

By now, most apprentices have had the opportunity to work with several different Journeymen on many different types of jobs. They have been able to observe the diversity of tasks that skilled craftsmen are required to perform. Moreover, they have had an opportunity to witness first-hand how Journeymen with different personalities, opinions, and skill levels perform the many tasks of the trade.

Also by this time, apprentices have begun to form opinions as to which types of work they enjoy the most, and which ones they would rather not do day-in and day-out, although they are all extremely important to the success of the craft. As Apprentices journey toward becoming skilled craftsmen, they will naturally form ideologies that will remain with them throughout their careers. They will have a chance to contemplate what it takes to develop the type of attitude that will allow them to use the skills and knowledge developed in apprenticeship to enable them to perform at their very best as Journeyman craftsmen. Remember, a true Journeyman has developed a discipline which allows him or her to enjoy performing all aspects of the trade equally well and with the utmost pride and dignity.

Each apprentice should take this time to explore what he or she can do, as an individual and as an apprentice in this program, to further develop and mature as he or she approaches Journeyman status. Remember, the educational foundation, commitment, and attitude formulated during apprenticeship will be with each apprentice for the rest of his or her life. If apprentices conscientiously and sincerely develop these characteristics, they will serve the industry well, both today and in the future.

Challenging times require preparedness and readiness to compete. Make the decision today to be prepared and ready to meet the challenges of tomorrow.

Learning Objectives

After completing this lesson, you will be able to:

1. Define the word *pride*.
2. List the qualities inherent to pride.
3. Discuss the positive personal and occupational benefits of developing pride.
4. Explain how the industry's future is impacted by pride, or the lack thereof.

Lesson 3 An Introduction to the COMET Program

Introductory Information

The IBEW's Construction Organizing Membership Education Training (COMET) Program is an ideology and "call to action" based on the acute need for eccentric change. If this sounds like serious business, there is a reason for that; it *is* serious business! In fact, of all the pressing matters facing the electrical industry today, there is not one more important than the need to organize. That is what the COMET Program focuses on.

The IBEW's COMET Program was conceived and designed to meet the extraordinary "need to know" that has developed within the industry. The industry needs to know:

"Why do we need to organize?"
"How do we need to go about organizing?"
"Where did this need come from?"
"Did it just develop overnight?"
"What will happen to our industry if we fail to or refuse to organize?"
And, most importantly: "Whose job is it to organize?

The COMET Program addresses some crucial issues facing the industry today. Apprentices will become more familiar with the COMET Program and will hopefully be inspired to become much more involved with it in their own local areas. The only way constructive change can be realized is through constructive involvement.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe the IBEW's COMET Program.
2. List six basic elements of construction that apply to the need to organize.
3. List ten or more ways that an apprentice can assist in the organizing effort in the local area.

Lesson 4 Productivity

Introductory Information

A Journeyman Electrical Worker is hired to perform a dangerous job. A good Journeyman Electrical Worker produces quality work safely and on-time. The factors that affect productivity and what can be done to maintain a high level of productivity without sacrificing safety must be discussed.

Learning Objectives

After completing this lesson, you will be able to:

1. State the cost of a job in regards to labor, materials, and equipment.
2. List two factors that contribute to lost crew time on the job.
3. List two factors that define a good line crew.
4. Define professionalism.

Lesson 5 Distribution Circuits

Introductory Information

A voltage such as 4,160 volts was not arbitrarily selected as a distribution voltage; it was arrived at by properly connecting certain standard transformers. The reasons for various voltages that Journeyman Electrical Workers work with and their relationship with each other should be discussed.

Knowledge of square roots will be helpful. Journeyman Electrical Workers will find that 1.73, or the square root of three, appears many times in working with 3-phase circuits.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify different types and characteristics of distribution circuits.
2. Calculate voltages and currents in wye and delta distribution circuits.
3. List advantages of each type of distribution circuit.

Lesson 6 Review of Alternating Current

Introductory Information

Apprentices were previously introduced to alternating current (AC). Now it may be beneficial to review what has been learned related to the properties of alternating current. Qualified Electrical Workers need to understand reactive components to effectively work with distribution apparatus, such as regulators and capacitors. These are among the most challenging concepts in the entire apprenticeship and will require increased study to master. It may be wise to secure help from someone familiar with this subject to assist with these lessons. Refer to all previous theory lessons studied in the first and second years of the apprenticeship in addition to the references.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss the characteristics and advantages of alternating current.
2. Know the differences between peak, effective, and average values of voltage and current.
3. Compute peak, effective, and average values of voltage and current.
4. Discuss the phase relationship of voltage and current in resistive, inductive, and capacitive circuits.

Lesson 7 Alternating Current Theory: Terms and Definitions

Introductory Information

All circuit calculations, whether AC or DC, can be made using Ohm's Law when the load is a resistive one. However, all connected loads are not purely resistive. Motors, transformers, and regulators contain coils, and are therefore an inductive load. A Qualified Electrical Worker will be required to connect many capacitors to offset this inductive condition, and these capacitors constitute a capacitive load.

It is important to be familiar with the definitions and terms used to explain AC theory. Do not expect to understand these terms at this time; first, focus on learning the definitions. Study the groups of reference pages as a unit in the order they are listed. Do not read beyond the references given.

Learning Objectives

After completing this lesson, you will be able to:

1. Define the terms used in AC theory.
2. Identify the units of measurement used with AC theory.
3. Recognize the symbols used in AC Theory.

Lesson 8 Inductance

Introductory Information

Many pieces of distribution apparatus, including transformers, have coils that operate on the principle of induction. It is imperative that Qualified Electrical Workers understand inductance if they are to work on this equipment intelligently. Another reason that inductance must be understood is that it is one of the factors that are relevant to AC theory.

It is also necessary to review magnetic induction and inductance, and their effects on AC circuits.

Learning Objectives

After completing this lesson, you will be able to:

1. Explain the properties of inductance.
2. Identify the factors that affect inductance.
3. Discuss inductive reactance.

Lesson 9 Capacitors

Introductory Information

Installing a capacitor on an electrical system has numerous benefits, mainly decreasing losses. However, installing a capacitor is not as simple as just putting it on the system. Improperly placing capacitors may result in adding to losses.

Understanding how capacitors work and why they are an important component of an electrical system is knowledge every Qualified Electrical Worker should have. The theory of capacitors is

explained in the *AC Theory* textbook, accompanied by a discussion on reducing power factor explained in the Reference.

Learning Objectives

After completing this lesson, you will be able to:

1. State two causes of system low power factor.
2. List the ways a capacitor functions.
3. Describe how a capacitor reduces power factor.

Lesson 10 Distribution Capacitors

Introductory Information

Capacitor banks may be installed on transmission circuits and located at generating stations and transmission substations. Capacitors installed on distribution circuits will be studied and discussed. The efficiency of utility distribution circuits is enhanced by the addition of a blend of fixed and switched capacitor banks. Adding capacitive reactance offsets the inductive reactance present on all AC circuits. By reducing inductive reactance, the power-factor is improved. From an economic standpoint, power-factor correction is alternative to replacing circuit conductors, adding voltage regulators, or building additional substations.

To begin with, focus on how capacitors operate and the special precautions necessary when working on or near these units. Follow these safety rules when working on distribution capacitors:

• Distribution capacitors are considered to be charged at full voltage until they have been disconnected from the line, the terminals have been short-circuited, and they have been discharged to ground.
• After de-energizing distribution capacitors, wait at least five minutes before short-circuiting the terminals. This is an OSHA 1910.269 Law.
• Workers are not to come in contact with ungrounded capacitor cases until the capacitors have been de-energized and the terminals short-circuited.
• Distribution capacitors in storage are to have their terminals shorted.
• Know the company and area safety rules, and use the appropriate PPE.

Learning Objectives

After completing this lesson, you will be able to:

1. State two ways a capacitor helps with voltage problems.
2. List two safety precautions when working on distribution capacitors.
3. Describe how a capacitor is designed and how it functions.

Lesson 11 Transformers --- 3-phase Voltages

Introductory Information

The higher voltages available on the modern distribution grid are the result of greater load density and reach. The evolution from single-phase to delta three-phase, and finally the four-wire wye systems common today will be presented. The advantages and disadvantages of system types and voltages are a part of this lesson.

An understanding of the various voltages and circuit system types is the foundation of transformer training. Transformer banks can only be properly installed or maintained by trained professionals like you.

Learning Objectives

After completing this lesson, you will be able to:

1. Explain voltages across and currents through transformer coils and lines in delta systems.
2. Explain voltages across and currents through transformer coils and lines in wye systems.
3. Discuss the advantages and disadvantages of higher voltage distribution systems.
4. Explain the advantages of poly-phase systems.

Lesson 12 Transformers – 3-phase Connections

Introductory Information

Single-phase transformers can be banked to provide 3-phase power. Three of the six basic transformer bank types will be analyzed: the wye-wye, delta-delta, and open-delta–open-delta bank types. The wye and delta laws will be used to calculate voltages across points in transformer banks and to determine currents through various transformer bank components. An introduction to banking with phasors is presented. Electrical vector line drawings of transformer banks are included with the schematics to deepen an understanding of bank connections.

Learning Objectives

After completing this lesson, you will be able to:

1. Apply the wye and delta voltage and current laws to banking single-phase transformers.
2. Calculate full load currents at various points in wye-wye and delta-delta banks.
3. Identify angular displacements and vector line drawings of wye-wye and delta-delta banks.

Lesson 13 Transformers - Single-phase Connections

Introductory Information

Single-phase transformers are the most common type of transformer Qualified Electrical Workers work with because there are more single-phase residential customers than any other type. A careful study of the reference material will provide a valuable resource to draw from in order to properly wire single-phase transformers to meet a customer’s needs.

It may be a good idea for the student to test his or her pre-existing knowledge of single-phase transformer connections before reading the reference material. After studying the reference material, make any corrections needed. This process will help to give the student a clearer understanding of how the voltages and requirements of the load determine the transformer specifications and the wiring of the transformer.

Because single-phase transformers are so common, improper connections of single-phase transformers are also the single greatest cause of damage to a customer’s equipment. Qualified Electrical Workers should always check their work before energizing a transformer and always check for proper voltage before connecting a load.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss applications where single-phase transformers are installed.
2. State two conditions that govern single-phase transformer connections.
3. Identify three connections for single-phase transformers.

Lesson 14 Transformers --- 3-phase Connections II

Introductory Information

To calculate voltages across points on wye-delta, open wye-open delta, and delta-wye type transformer banks, the wye and delta laws should be applied. These laws can also be used to determine the full load currents through transformer windings and bank conductors. Schematics will show where to make connections, and vector line drawings will be used to reinforce the transformer banking principles. When given the voltage of the primary line, the required secondary output voltage, and the anticipated load, a Qualified Electrical Worker can select the proper transformers and make the appropriate connections.

Note: Take advantage of the *Transformer Simulator*, which is a remarkable learning tool. In the program, transformer banks can be virtually built, energized, and analyzed.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify the connections for various 3-phase transformer banks.
2. State secondary voltages available from different 3-phase banks.
3. Using wye and delta laws, calculate full load currents through coils and leads on transformer banks.
4. Calculate how individual transformers in banks share 3-phase and single-phase loads.
5. Identify angular displacement and vector line drawings of transformer banks.

Lesson 15 Troubleshooting 3-phase Banks

Introductory Information

At some point in every Qualified Electrical Worker's career, he or she will be called out to troubleshoot a 3-phase bank. Three-phase customers are among the largest users of electrical power and deserve to have their problems solved in a timely and professional manner.

Qualified Electrical Workers should know how to calculate load checks on delta and wye banks and should be familiar with some of the many ways to physically troubleshoot a 3-phase bank. The method presented for troubleshooting a 3-phase bank is not the only acceptable method, and Qualified Electrical Workers should question their Foremen and Journeymen for their methods, as well.

Learning Objectives

After completing this lesson, you will be able to:

1. Calculate the total kVA load of wye and delta banks.
2. State the capacity rating of 3-phase banks after they are converted to an open configuration.
3. State two factors that might solve a customer's voltage complaint.
4. State the formula for calculating the kVA load on a single transformer.

3rd Year – Level 2

Lesson Learning Objectives

Level II starts with a lesson on labor-management relations, but is primarily about personal protective grounding. Topics covered include body currents, basic electric circuits, grounding history, equipotential zone grounding, equipment selection, installation of grounds, and step and touch potential. Including lessons on induced voltage and multiple grounds, truck grounding, underground distribution grounding, and grounding in substations. The last two lessons are on testing ground resistance and lightning protection.

Lesson 1 Labor-Management Relations/LMCCs

Introductory Information

Regardless of how much one is paid – a job is not a good job unless one works in an atmosphere of harmony. It takes effort on the part of everyone to bring about this condition.

Labor-management relations from crew level to the Council on Industrial Relations will be discussed.

Learning Objectives

After completing this lesson, you will be able to:

1. Recognize the importance of labor-management relations.
2. Identify the terms that are used in negotiations.
3. Explain the methods that can be used to resolve issues of a labor agreement.

Lesson 2 PPG --- Body Currents

Introductory Information

When working on or near high voltage power lines, it is imperative for Qualified Electrical Workers to remember that if electrical current flows through their bodies, they may be killed or severely injured. The amount of current and its path through the body are both critical variables that determine the extent of injury. The current available in modern-day distribution lines may range from a few amperes up to and including 10,000 amperes in industrial areas.

Qualified Electrical Workers should be aware that even very small levels of current flow though the body can cause death, as can very large body currents. The current that may flow through a worker during a contact may vary from a few milliamperes to very large currents measured in kiloamperes. To maintain safety, one must remain focused on both the correct work method, as discussed during the tailboard meeting, and the proper use of safety equipment. Those who take their safety lightly are often the ones who are injured.

There are many lessons covering these best practices. The lessons are identified with asterisks in the lesson title and the partnership logo on the introductory page. It is critical that employees are familiar with and practice these best practices every day on the job. Lives depend on it.

The practices are provided and broken down by category. See Web Resources for a link to the ET&D Partnership web page.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the impact of current on the human body.
2. Describe the importance of maintaining and providing adequate protection levels against electrical shock.
3. Recognize the relationship between current level and time of duration in current flow and the human body.

Lesson 3 PPG --- Basic Electrical Circuits

Introductory Information

Qualified Electrical Workers should know that if a worker's body bridges between two different potentials and current flows through the body, the worker may be severely injured or killed.

In order to have a long and successful career, Qualified Electrical Workers must have a basic understanding of electric circuits and know how to protect themselves. When the body bridges across two different potentials, the body becomes part of the circuit. The worker must remain focused on the correct work methods and the proper use of safety equipment supplied by the employer.

There are many lessons covering these best practices. The lessons are identified with asterisks in the lesson title and the partnership logo on the introductory page. It is critical that employees are familiar with and practice these best practices every day on the job. Lives depend on it.

The practices are provided and broken down by category. See Web Resources for a link to the ET&D Partnership web page.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand series circuit principles as they relate to Ohm's Law.
2. Understand parallel circuit principles as they relate to Ohm's Law.
3. Understand combination circuit principles as they relate to Ohm's Law.
4. Consider how the placement of a very low-resistance path in parallel with the line worker forms the basis of personal protective grounding.

Lesson 4 PPG – Grounding History

Introductory Information

Grounding is a very controversial subject. It was controversial in years past, and it will probably remain so in the future. A primary reason for the controversy is that people resist change. Often the "old timers" will ask, "Why should we change? We have only had a small number of accidents." What that question does not consider is whether those accidents could have been avoided. It is impossible to tell for sure without knowing the details, but in many cases the answer would be yes.

Myths about grounding also contribute to accidents, as is often the case when discussing pole grounds. Many "old timers" believe that a grounding scheme is not needed if no pole ground is present since a pole is an effective insulator. The truth is that all structures will carry some amount of current to earth. A worker on a pole that has no pole ground may be slightly safer than a worker on a pole that has a pole ground, but there would be little difference in the case of an accident. An accident in this scenario could be avoided if a proper grounding scheme is used.

Why have there been so many different methods of safety grounding? There is no firm answer, but changes probably followed accidents which showed that a method being used was not really safe after all. Most changes have been based upon “best guess” rather than detailed analysis.

It is critical that employees are familiar with and practice these best practices every day on the job. Lives depend on it.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the problems with earlier grounding methods.
2. Identify and avoid old methods that are known to be unsafe.
3. Learn and understand the best-practice protection methods.

Lesson 5 PPG --- Equipotential Zone Grounding

Introductory Information

Qualified Electrical Workers are closest to the work done in the electrical industry, and they are the ones most likely to come into contact with a line that can become energized. It is up to every Qualified Electrical Worker to maintain focus and to remember the things that they have been taught that will help protect them as they work.

Bracket grounding is used as part of equipotential grounding, but these grounds are trip grounds that protect a worker by making sure that protective devices operate in case the line is energized. The equipotential method (personal ground) of grounding has been shown to be the method that offers the best protection. Equipotential grounding uses a cluster bar, which is connected to the grounding scheme by providing an electrical contact around the pole. If the line should become energized, the cluster bar maintains the equipotential voltage difference above the bar.

When using personal grounds, a connection to earth makes no difference if the grounding equipment is sized correctly and a cluster bar is properly connected. If an earth connection is to be established, do not use the pole ground because it might fuse (fail) under fault current. The equipotential method of grounding is the recommended method to use whenever possible.

Learning Objectives

After completing this lesson, you will be able to:

1. Define an equipotential zone.
2. Recognize the benefits of an equipotential zone over other methods of grounding.
3. Use your equipment to establish an equipotential zone of protection.

Lesson 6 PPG --- Selection of Equipment

Introductory Information

Unless a worker is working a line as if it is energized and using rubber gloves and cover-up or hot line tools, the line must be fully deenergized and grounded to maintain a safe work environment. The safety of the worker is then dependent upon the equipment selected and installed at the worksite. A great deal of care must go into the selection of equipment. Much of the selection is based upon information not generally available to the worker, but known to the employer. The company must be involved in the selection and provide the equipment used.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the electrical sizing of grounding equipment.
2. Understand, examine, and question the equipment provided.
3. Understand the placement of personal protective grounding items.

Lesson 7 PPG --- Installation of Grounds

Introductory Information

It is important for apprentices to keep in mind that having the properly rated grounding equipment is only part of the total equation. For apprentices, and later for workers in the field, it is important to remember the proper safety and grounding procedures. Installation of grounds is one subject of key importance to workers' continued safety. If personal protective grounds are installed incorrectly, or in the incorrect order, then the safety of the worker is in jeopardy.

Learning Objectives

After completing this lesson, you will be able to:

1. Know the correct order of the installation of grounds.
2. Identify the factors that affect both the installation and the removal of grounds.
3. Have a basic understanding of how to "put on grounds."

Lesson 8 PPG --- Step and Touch Potential

Introductory Information

Step and touch potential are two different, yet similar hazards. They both involve a Qualified Electrical Worker's body bridging across a hazardous difference of potential. Step potential involves the worker's feet making the connection. Touch potential involves the worker making the connection from hand to foot. Both hazards result from a current flow through the earth, and the related voltage drop across that part of the earth's resistance.

Step potential may be large or small. Touch potential is often quite large and very hazardous. Both are a result of the worker's position in relation to the point of contact where the current enters the earth.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand both step potential and touch potential, and the difference between them.
2. Understand the protection methods available for these hazards.
3. Understand that contact with the earth is not always V = 0.

Lesson 9 PPG --- Induced Voltage and Multiple Grounds

Introductory Information

An improper use of grounding equipment for worker protection fails to protect the worker when there is an accidental re-energization of a previously deenergized conductor. If grounding equipment is not properly used during such an event, large fault currents will flow, and these can be very dangerous. The protective equipment used must be capable of withstanding these large currents and mechanical forces. Fortunately, this type of on-the-job accident is not as common as the danger of induced voltage.

Induced voltage is a more common hazard to Qualified Electrical Workers than re-energization and has resulted in far more fatalities. The hazards of induced voltage and currents will be discussed.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the difference between induced and fault current levels.
2. Identify some of the sources of induced voltage and current.
3. Understand the protection needed for induced voltage and current.

Lesson 10 PPG --- Truck Grounding

Introductory Information

Trucks, with or without insulated booms, seem to be at the center of many job site accidents. Accidents happen to workers in buckets mounted on uninsulated booms, to ground workers around trucks, and to workers in buckets mounted on insulated booms. Many of these accidents could be prevented. The focus of the worker is the key to safety.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the worker's part in the total circuit.
2. Know what is required to maintain worker safety when working around trucks.
3. Understand truck grounding.

Lesson 11 PPG --- Underground Distribution Grounding

Introductory Information

Protective grounding while performing maintenance on underground residential distribution (URD) systems is similar to that used during overhead work. However, there are significant differences and limitations regarding the locations where such protection may be used. The establishment of an equipotential zone is limited to local sites, such as vaults, transformers, or metal enclosed switches. Insulation may be used for some applications in areas where such a zone is impractical. The insulation can be in the form of rubber gloves or mats, but it must be within the voltage rating at the site to be effective.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand when insulation is the better method.
2. Understand when the establishment of an equipotential zone can be used.
3. Understand the use of portable ground mats.
4. Understand the unique hazards encountered while working underground.

Lesson 12 PPG --- Grounding in Substations

Introductory Information

Substations present a unique grounding situation. Substations contain many objects that can be used for connecting personal protective grounding equipment. However, seldom is an entire substation deenergized. Because of the closeness of the spacing between energized and deenergized items, induced voltages and currents are common, and the fault current levels are typically much larger than at a remote work site. These larger fault current levels require larger clamps and cables, which are heavier and more difficult to use than ordinary grounding equipment used by Qualified Electrical Workers.

In substations, the magnitude of fault current is a major consideration. The mechanical forces that result from such currents may physically break the clamps before any adverse effect from the heating due to current flow is seen.

Learning Objectives

After completing this lesson, you will be able to:

1. Recognize the different grounding requirements between substation work and remote site work.
2. Know the importance of placing the grounds close to the worker.
3. Be able to recognize the hazards from the current and voltages present.

Lesson 13 PPG --- During Construction Activities

Introductory Information

Maintaining a safe work environment involves applying many of the principles presented thus far. This includes the establishment of an equipotential zone, avoiding both step and touch hazards, and the selection of suitable equipment. Making these principles work tends to be difficult because of the number of vehicles often involved, the spacing of vehicles around the worksite, and the possibility of contacting an energized conductor during the work. Vehicles may consist of tensioning trucks, reel trailers, or splicing trucks. The vehicles are connected together by the conductor being strung. If one becomes energized, they all become energized, and the need for protection is increased. The grounding devices are all specialized to allow a conductor to move through them while they maintain the ground.

Learning Objectives

After completing this lesson, you will be able to:

1. Apply the known protective measures to a construction worksite.
2. Understand the special grounding equipment employed at these sites.
3. Understand the placement of vehicles and the evaluation of worker safety around these vehicles.

Lesson 14 Testing Ground (Earth) Resistance

Introductory Information

There is an old saying about electrical grounds: All electrical grounds are earth, but not all earth is an electrical ground. This can be verified by any Qualified Electrical Worker who has found a primary phase lying on the ground, still energized. Because of high ground resistance or poor system grounding, not enough current is flowing to operate the protective equipment. Good system grounding has many benefits, such as reduction in system noise, lightning protection, personnel safety, and helping to control unwanted voltages, currents, and power surges. Without proper low-resistance grounds, protective devices will not sense the current flow involved when a phase does hit the ground.

It is important to be familiar with the subject of testing ground (earth) resistance and the two testing methods most commonly used in the electrical industry.

Learning Objectives

After completing this lesson, you will be able to:

1. State three factors that influence the resistivity of the earth.

2. State two regulations or standards pertaining to ground rods.
3. List two methods used to measure or improve resistivity of ground rods.

Lesson 15 Lightning Protection

Introductory Information

According to the National Weather Service, approximately 22 million cloud-to-ground lightning strikes occur every year in the United States, causing over $2 billion in property damage. A study conducted from 1959–1994 by the National Oceanic and Atmospheric Administration (NOAA) found the states with the highest number of cloud-to-earth lightning strikes are Pennsylvania, Kansas, New York, North Carolina, and Oklahoma, but all states were found to have their share of lightning strikes.

When lightning strikes a transmission or distribution line, the overvoltage lightning produces must be drained from the system to prevent damage. Lightning has the power to explode concrete, tear poles apart, explode transformers, and shatter insulators unless the line is properly protected. Properly installed lightning protection, in the form of lightning arrestors, helps direct the lightning safely to the ground, sparing equipment and customers the damage. There are several different types of lightning protection used in the industry to dissipate the excess voltage and current from the system.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe two characteristics of a lightning strike.
2. State three characteristics of lightning arrestors.
3. List two types of lightning arrestors used in different applications.

3rd Year – Level 3

Lesson Learning Objectives

Level III focuses on live-line tools and work practices. The beginning of the course covers applying rubber protective devices and the identification and care of tools. The next lessons are on maintenance with hot sticks. The students then will learn about insulator and crossarm changes, helicopter timber changes, and special practices. The course closes with lessons on primary and single-phase revenue metering.

Lesson 1 Applying Rubber Protective Devices

Introductory Information

As a Qualified Electrical Worker, it is important to keep in mind that any rubber or plastic protective devices applied to an energized line should be considered as partial protection only. Rubber and plastic protective devices are installed in case an accidental contact is made between two different potentials. In no case should these devices be depended upon for complete protection from energized conductors or equipment.

OSHA 1910.269(c) requires that a job briefing take place on site and before work has started. Part of the job briefing should include which types of protective devices will be used, when and where they will be applied, and who is responsible for applying them. Every energized live-line job requires a certain number of rubber protective devices in case of an accidental contact, which may include extensive use of cover-up or rubber gloves while setting a pole, but all workers should know what is required. The use and care of rubber and plastic protective devices should be an integral part of every crewmember's job, as an accidental contact could injure several workers.

Learning Objectives

After completing this lesson, you will be able to:

1. State the purpose of applying protective devices.
2. Describe the procedures for testing protective devices.
3. List two factors that affect the application of protective devices.

Lesson 2 Live-Line Tools --- Introduction, Identification, and Care

Introductory Information

Qualified Electrical Workers and especially live-line workers are members of the trade who, with proper training, will use a "stick" to work voltages most Electrical Workers would consider too dangerous to approach.

At some point in every Qualified Electrical Worker's career, someone will hand him or her a "stick" and tell them to reach out and work high voltages with it. The Qualified Electrical Worker's safety at that point may depend on something as simple as housekeeping; how well taken care of is the stick he or she is about to use? It is vital to be familiar with the identification and care of live-line tools. When working distribution and transmission voltages, knowing what "sticks" will support the weights and voltages involved is critical.

OSHA 1910.269(j), Live-line tools, does not differentiate between live-line tools used for distribution work or for transmission maintenance; it simply concerns live-line tools. Paragraph (j)(2) of this OSHA section states, "Each live-line tool shall be wiped clean and visually inspected for defects before use each day." OSHA 1910.269(j)(2)(ii) also calls for live-line tools used for primary employees' protection to be removed from service every two years for examination, cleaning, repair,

and testing. OSHA requires that IEEE (Institute of Electrical and Electronics Engineers) Standard 978-1984 be followed for electrical testing of all live-line tools.

In distribution live-line work, most employers require Qualified Electrical Workers to wear rubber gloves, but in transmission live-line work, the stick is the primary protection. Being able to properly identify, use, and care for live-line sticks may be the deciding factors in whether a Qualified Electrical Worker has a safe day or not.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify equipment used in live-line maintenance.
2. State safety requirements of equipment involved with live-line work.
3. State procedures for repairing live-line tools.

Lesson 3 Live-Line Tools --- Using Hot Sticks

Introductory Information

Live-line maintenance using sticks is historically the safest work practice a Qualified Electrical Worker can undertake. It is also a task not every Qualified Electrical Worker can do. Being part of a hot stick crew requires extensive training and a certain type of Qualified Electrical Worker: one who has good manual skills and a calm, even temperament. Live-line maintenance is no place for showboating. With proper training and a good job briefing, a well-trained stick crew can, in some cases, accomplish the job safer and faster than by any other method.

Knowing where to place equipment and what equipment is needed for a particular weight is normally practiced on cold structures until the crew is working well together. In order to achieve the high level of skill it takes to be part of a hot stick crew, it is necessary to first learn some of the fundamentals of how live-line tools are used.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss the proper application of various live-line tools.
2. State which tools are needed for tying or untying a hot conductor.
3. State the operating characteristics of various equipment.

Lesson 4 Live-Line Tools --- Maintenance with Hot Sticks III

Introductory Information

The practical uses of live-line tools must be discussed. Changing out poles, insulators, and crossarms are among the most common tasks assigned to a live-line crew. Many systems now use live-line methods with jibs installed on bucket trucks and boom trucks, but the methods, clearances, and many of the tools are the same as those used when working from the pole only. Proper training and the care of live-line tools are the keys to successfully completing the job.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe the proper method of using an auxiliary arm.
2. State two safety distances associated with live-line work.
3. Identify methods and individual sticks used to perform various live-line work.

Lesson 5 Live-Line Tools --- Maintenance with Hot Sticks IV

Introductory Information

The methods used to replace poles using sticks will become familiar to any Qualified Electrical Worker on a live-line crew. These methods may have variations from one system to another with the addition of modern equipment, but the fundamentals are the same. As with all live-line work, a thorough job briefing is critical if the job is to be done in a safe and timely manner.

Learning Objectives

After completing this lesson, you will be able to:

1. List various live-line tools needed when replacing a pole.
2. Identify live-line tools needed for various size conductors and angles.
3. State the procedures to be followed when replacing a vertical 3-phase deadend.

Lesson 6 Live-Line Tools --- Maintenance with Hot Sticks V

Introductory Information

Because of similarities in work procedures, Qualified Electrical Workers should understand insulator change-out on deadends and running corners.

In order to safely move deadend conductors, the strain must first be addressed. The two most common methods of taking strain off insulators are the two-pole strain carrier and the rural strain carrier. The rural strain carrier is no longer manufactured but may still be found in some hot stick trailers. If properly maintained, the rural strain carrier is an effective piece of equipment, but other methods should be used when possible, as using obsolete equipment can be counterproductive. There are other methods that can be used to relieve the strain on insulators, and it is not necessary to focus on the rural strain carrier.

As with all live-line procedures, extensive practice on cold structures should take place in order to build up the confidence needed to ensure that these pieces of equipment do the job they are designed to do. Two-pole strain carriers are most commonly used on transmission lines of 69 kilovolts and above, while the “distribution” two-pole strain carrier or web hoist method is widely used on distribution voltages up to 46 kilovolts.

Learning Objectives

After completing this lesson, you will be able to:

1. State rated working load limits of various tools used when changing insulators using live-line tools.
2. Identify tools used to take the strain off insulators.
3. State the differences between the two-pole strain carriers used on transmission and those used on distribution lines.

Lesson 7 Live-Line Tools --- Maintenance with Hot Sticks VI

Introductory Information

Most Qualified Electrical Workers will never work on aesthetic towers but they should be discussed to stress the point that live-line work is basically the same, regardless of the voltages involved. The main difference between live-line work on 14.4 kilovolts and on 230 kilovolts is approach distances, insulator cradle use, and the type of strain poles used.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify special tools that are used to change insulators on 138- and 230-kilovolt lines.
2. State the requirements for ladders and work platforms used on aesthetic towers.
3. State two safety factors on aesthetic towers.

Lesson 8 Live-Line Tools --- Maintenance with Hot Sticks VII

Introductory Information

Live-line work is a safe form of hot work because, if properly done, the approach distances are always maintained. However, the workers' personal safety and the ability to complete a job in a safe manner depends on the condition of the equipment and being able to calculate the load that live-line equipment will be handling.

Qualified Electrical Workers should know how to calculate the weights and tensions of conductors to be lifted or pulled. Loads on equipment change as conductors are moved, and failure to account for this shift in weight can lead to equipment failure and serious injury. In preparation for with live-line tools, know that the inspection of equipment and calculating load is as important as making sure the method to be used will maintain minimum approach distances.

Learning Objectives

After completing this lesson, you will be able to:

1. State the working load limit of various live-line tools.
2. Calculate tension on live-line tools from conductors and moving conductors.
3. State two safety procedures used when doing live-line work.

Lesson 9 Live-Line Work Practices --- 138KV Insulator and Crossarm Changes

Introductory Information

Qualified Electrical Workers should become familiar with the most common live-line techniques used to change out insulators and crossarms on H-frame and wishbone structures on 138-kilovolt lines. Be aware that many employers have developed techniques that are just as safe and effective as those discussed during the apprenticeship. It is up to the live-line worker to adapt to the circumstances, tools, and work practices available.

Learning Objectives

After completing this lesson, you will be able to:

1. State the equipment needed to change timbers on wishbone and H-frame structures.
2. State clearances for various equipment from a 138-kilovolt line when changing insulators.
3. List the sizes of sticks and the ratings of various equipment used to change insulators on a 138-kilovolt line.

Lesson 10 Live-Line Work Practices --- Insulator and Crossarm Changes

Introductory Information

Because live-line work practices are so similar from one structure to another, the differences between insulator and crossarm change outs between 60 kilovolts and 230/287 kilovolts must be understood. The practices may seem similar, but it will quickly become evident that the greater weights and higher tension involved with the higher voltages must be taken into consideration and

addressed. Equipment that is well maintained and workers who are well trained in live-line work can go from one extreme to the other and complete the job in a safe and efficient manner.

Learning Objectives

After completing this lesson, you will be able to:

1. State the size of live-line sticks used to move conductors on various size lines.
2. State two distances that conductors must be moved to allow for clearance when changing timbers on various voltages and structure configurations.
3. List auxiliary equipment needed in addition to live-line sticks when moving conductors or insulators.

Lesson 11 Live-Line Work Practices --- Tower Insulator Changes

Introductory Information

Qualified Electrical Workers should know how to change out the outside phase suspension insulators of steel towers in voltages ranging from 69 kilovolts to 500 kilovolts. The hot line tools involved are the same as would be used on wooden structures for the size and weight of the conductor; the difference is the type of wire thong saddles, which are made to clamp onto a tower's steel structure. Wire thong saddles and other equipment made for wooden pole applications should never be "jury rigged" to work on steel structures.

Learning Objectives

After completing this lesson, you will be able to:

1. State two rules that should be followed when using ladders from towers.
2. Identify two work practices that pertain to insulator changes on 500-kilovolt towers.
3. State how equipment is used to safely move phases when changing out insulators.

Lesson 12 Live-Line Work Practices --- Helicopter Timber Changes

Introductory Information

Russian-born Igor Sikorsky (1889-1972), considered to be the "father" of helicopters, began work on helicopters as early as 1910. By 1940, Igor Sikorsky's successful VS-300 became the model for all modern single-rotor helicopters. He also designed and built the first military helicopter, the XR-4, which he delivered to the U.S. Army in 1941.

The electrical industry quickly realized the advantage of using helicopters for patrolling and building transmission lines. Early, lightweight helicopters were used for patrolling, but it was not until the heavy lift capabilities of the Choctaw helicopter that the helicopter could be used to build power transmission lines. Today, the electrical industry makes use of a full range of versatile helicopters, from the dependable Choctaw to the Huey, the Chinook, and the heavy-lift Skycrane, which can lift up to 20,000 pounds.

OSHA 1910.183 pertains to the use of helicopters and should be reviewed by anyone involved in this type of work. The hand signals shown in the OSHA standard should be the only ones used by ground crews when directing the helicopter pilot. While helicopters have multiple roles in the electrical industry, one of the most common roles involves using a helicopter to change out transmission line timbers on an H-frame structure.

Learning Objectives

After completing this lesson, you will be able to:

1. State two safety rules that should be followed when changing timbers with a helicopter.
2. Discuss the placement of equipment and workers when replacing timbers with a helicopter.
3. Discuss the purpose of a striker pole used when changing timbers by helicopter.

Lesson 13 Live-Line Work Practices --- Special Practices

Introductory Information

Every Qualified Electrical Worker will encounter special working conditions at some time during his or her career. Without a proper job briefing and proper training, special conditions can be some of the most dangerous situations Qualified Electrical Workers find themselves in. An example of a special condition is working with 6 AWG copper wire. This may not seem particularly dangerous at first glance, but 6 AWG copper wire can be easily broken when it is under tension and in poor condition.

The age and condition of conductors and all equipment should be taken into consideration any time live-line methods are used. Concerns should be voiced at the job briefing if a worker is unfamiliar with a particular work method, such as sagging aerial cable. Live-line work is no place to “figure it out as you go,” as a mistake can lead to serious consequences.

Learning Objectives

After completing this lesson, you will be able to:

1. State where and when safety grounds are to be applied.
2. Discuss work procedures when working with 6 AWG copper conductors.
3. Discuss tension stringing procedures for insulated distribution cable.

Lesson 14 Primary Metering

Introductory Information

Every part of an electrical system is metered. Meters are found in transmission and distribution substations to record voltage, current, power, reactive power, and other data needed to operate and monitor the system. High voltage and high current can be measured using transformer-rated meters and instrument transformers.

Installing and removing revenue meters is a common task for power line workers on distribution systems. Understanding how meters work and how they are connected will reduce the risk of explosive faults that can occur when installing and removing meters. Primary metering has some specific additional hazards because a worker can be exposed to high voltage when working with current transformers.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the purpose for primary revenue metering.
2. Recognize and construct a primary revenue metering installation.
3. Understand how high voltage is measured in revenue metering.
4. Understand how current is measured with revenue metering.

Lesson 15 Single-Phase Revenue Metering

Introductory Information

Every part of an electrical system is metered. Meters are found in transmission and distribution substations to record voltage, current, power, reactive power, and other data needed to operate and monitor the system. Much of the metering is telemetering used to monitor remote generating stations and substations.

To begin, it is important to become familiar with single-phase revenue metering. Related topics, such as instrument transformers and 3-phase metering, will be discussed elsewhere.

Installing and removing revenue meters is a common task for powerline workers on distribution systems. Understanding how meters work and how they are connected will reduce the risk of explosive faults that can occur when installing and removing meters.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand what is measured by revenue metering.
2. Understand how a meter measures electrical energy consumption.
3. Recognize types of single-phase revenue meters.
4. Install and connect single-phase revenue meters.

3rd Year – Level 4

Lesson Learning Objectives

Level IV covers substation construction. Instruction includes safety procedures, federal regulations, print reading, making connections, and function and types of stations. The student will then move on to spill prevention, containment, and countermeasure plans. The remaining lessons cover foundations, installing grout, underground power cables, grounding grids, steel superstructure assembly, and installing insulators, control cables, and devices.

Lesson 1 Introduction to Substations

Introductory Information

With approximately 100,000 substations in the United States, every Qualified Electrical Worker should have a solid understanding of substations, their functions, equipment, and safety procedures involved. Study this information carefully, as most Qualified Electrical Workers will be working in substations at some point in their career.

Learning Objectives

After completing this lesson, you will be able to:

1. List two methods used in substations to interrupt an arc and thereby protect a feeder.
2. List two types of substations.
3. Discuss three types of equipment found in substations.

Lesson 2 Substations --- Safety Procedures

Introductory Information

Qualified Electrical Workers are required to do a wide variety of jobs when working with and around high-voltage electrical lines and equipment. Substations pose particular dangers to workers because of the clearances involved and the equipment that may not be familiar to the Qualified Electrical Worker. OSHA 1910.269(u) and 1926.957 pertain to substation safety. All Qualified Electrical Workers are encouraged to become familiar with the OSHA standards and to carefully study Chapter 1 of *Substation Construction Guidelines*.

All Qualified Electrical Workers should have a thorough knowledge of their employers' substation safety rules and regulations in order to safeguard themselves, their co-workers, and other workers inside the substation fence.

Learning Objectives

After completing this lesson, you will be able to:

1. List two safety procedures used when deenergizing a substation transformer.
2. State three characteristics of the gas or oil that may be encountered in substation electrical equipment.
3. State two safety requirements in the OSHA standards pertaining to substation safety.

Lesson 3 Substation Construction --- Safety and First Aid

Introductory Information

Substation accidents can be prevented if appropriate safety procedures are followed. Because substation hazards may not be familiar to all Qualified Electrical Workers, on-site job briefings become a critical component for all jobs. An example of an item that should be covered in a daily job briefing would be how to perform a rescue off of the top of a transformer, or in the lattice work of a substation.

Along with the reference materials for this lesson, the following studies should be studied to obtain a firm understanding of the safety and first aid requirements when working in substation yards: OSHA 1910.269(b), 1910.151, 1926.950(e), 1926.50, NESC 410.B, and NESC 420.A.

Learning Objectives

After completing this lesson, you will be able to:

1. State two requirements when administering first aid.
2. List two distances, in feet, workers may approach an energized line or piece of equipment.
3. Discuss two requirements of safety equipment.

Lesson 4 Substation Construction --- Federal Regulations

Introductory Information

It would take a significant amount of time to cover all of the Federal regulations that pertain to building an electrical substation. In the same way that OSHA incorporates various standards from other agencies and makes it mandatory that those standards be followed, the process of building a substation incorporates standards from many areas. For example, when building a substation fence, one IEEE standard lays out the requirements for an eight-foot chain-link fence, while OSHA 1910.269(u)(3) calls for grounding of the fence, and another IEEE standard states specific grounding requirements.

It is important to be familiar with the Federal regulations that must be followed and how they apply to the worker.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss two items of general knowledge pertaining to OSHA.
2. State two OSHA regulations that cover substation construction.
3. Discuss two practices that OSHA uses to establish its regulations.

Lesson 5 Substation Construction --- Print Reading

Introductory Information

Every substation starts with 18 or more construction and reference drawings that must be translated into a completed station. Each diagram involved is different and should be discussed separately, but every substation print has common elements. Being able to identify these commonly-used symbols and knowing the vocabulary used in print reading are the first steps in building a substation.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify three pieces of equipment used in a substation by their representative drawings.
2. List two type of diagrams used in substation construction.
3. State two methods used to define the symbols or clarify a substation drawing.

Lesson 6 Substation Construction --- Making Connections

Introductory Information

Constructing an electrical substation requires that many areas of expertise be brought together to make a finished product. Disciplines as varied as crane operating, concrete pouring, conduit bending, and properly handling SF_6 gas must be performed to high standards and in proper sequence to ensure an electrical substation provides the quality and quantity of electric power over its service life that is expected from such a large investment.

The proper use of substation construction equipment and tools is a learning process that involves both on-the-job and classroom training. It would be difficult to show all the equipment used to construct an electrical substation, but a fundamental understanding of some of the disciplines involved should be provided.

Learning Objectives

After completing this lesson, you will be able to:

1. State three operating factors associated with cranes and self-propelled booms in substation work.
2. Discuss three factors of welding substation aluminum bus work.
3. List two factors associated with making bolt-on connections in substation work.

Lesson 7 Substation Construction --- Function and Types of Stations

Introductory Information

The substation is a key installation in an electrical system. It is also one of the most technical and complex installations in an electrical system. Qualified Electrical Workers should be familiar with the role a substation plays in an electrical system.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the role of a substation within an electrical system.
2. Recognize the role of various elements in a substation.
3. Understand how substation equipment protects an electrical system.
4. Understand the qualifications needed to work in an energized substation.

Lesson 8 Substation Construction --- Spill Prevention, Containment, and Countermeasure Plans

Introductory Information

Federal law, specifically the Code of Federal Regulations, 40 CFR, Chapter 1, Parts 110 and 112, requires the containment of potential oil spills for any facility that contains oil stored above ground in excess of 1,320 gallons, or any single container with a capacity greater than 660 gallons.

Since most electrical substation transformers meet the standards for oil capacity, each substation must have a spill prevention, control, and countermeasure (SPCC) plan in place. The electrical

industry is deeply concerned about preventing oil from reaching prohibited areas, including the groundwater table and any navigable waters. Workers should be acquainted with methods used to implement an SPCC plan at a typical substation.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss specific reasons a substation must have an SPCC plan.
2. State two methods used to contain an oil spill in a substation.
3. List two requirements of an SPCC plan.

Lesson 9 Substation Construction --- Foundations

Introductory Information

The placement and security of a foundation for the heavy equipment and structures in a substation requires very precise and quality work. Much of the hardware in a new substation is modular, and the parts will fit only if the foundations are installed accurately.

Learning Objectives

After completing this lesson, you will be able to:

1. Build a form to specifications.
2. Install anchor bolts and rebar to specifications.
3. Pour concrete to specifications.
4. Finish the concrete to specifications.

Lesson 10 Substation Construction --- Installing Grout

Introductory Information

A quality grouting job is essential to ensure a long-term, maintenance-free substation superstructure. Mixing, applying, and curing grout is very precise work.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the use of grout in a substation.
2. Prepare a surface and build a form to prepare for grouting.
3. Mix and pour grout properly.
4. Ensure grout is properly cured.

Lesson 11 Substation Construction --- Underground Power Cables

Introductory Information

Most distribution feeders coming out of a distribution substation are underground cables, especially for crowded situations when there are more than three feeders that need to exit out of a substation and connect to lines in various locations outside of the substation fence.

It is not uncommon for the source circuits, especially in urban situations, to enter a substation as underground cable. It is essential to recognize the fragile nature of underground cable and to become proficient with work methods involving pulling/laying, splicing, and terminating cable.

Learning Objectives

After completing this lesson, you will be able to:

1. Recognize the fragile nature of underground cable.
2. Describe the proper methods of pulling and laying cable.
3. Describe the proper methods of splicing and terminating cable.
4. Work safely around cables.

Lesson 12 Substation Construction --- Grounding/Ground Grids

Introductory Information

A substation ground grid is a critical component needed to provide quality power and worker and public safety. Workers should understand what a ground grid is, what role it plays, and how it is constructed.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the purpose of a substation ground grid.
2. Construct a ground grid.
3. Understand how a ground grid contributes to worker and public safety.

Lesson 13 Substation Construction --- Steel Superstructure Assembly

Introductory Information

Assembling and erecting a substation superstructure involves the high risk hazards of working at heights and working with rigging. Ensure that training has been completed in these areas before work is started.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe the types of superstructures.
2. Assemble the components of a superstructure.
3. Erect a superstructure.

Lesson 14 Substation Construction --- Installing Insulators

Introductory Information

It is important to be familiar with the types of insulators that are found in a substation and the care needed to install them. Outages due to the incorrect selection or rough handling of insulators are especially costly when they happen in a substation.

Learning Objectives

After completing this lesson, you will be able to:

1. Recognize the types of insulators found in a substation.
2. Recognize the different features of insulators.
3. Know how to inspect and install insulators.

Lesson 15 Substation Construction --- Installing Control Cables and Devices

Introductory Information

Control cables are the “nerves” of a substation. They send the messages to and from switchgear, alarms, relays, etc. A failure of a control cable could prevent a circuit from tripping out during a short circuit and cause damage; it might also be a hazard to the public.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the need for care when installing control cables.
2. Test to identify each end of a control cable.
3. Test to check for open or short circuits in a control cable.
4. Install control cables into a pre-wired relay panel.

3rd Year – Level 5

Lesson Learning Objectives

Level V continues the study of substations. Lessons cover equipment identification, oil circuit breakers, batteries, oil care and filtering, and air switches. Other topics included in this course are fuse principles, reclosers and sectionalizers, fault current, voltage regulations, tap changing, and capacitors. The course closes with lessons on power factor and power harmonics.

Lesson 1 Primary Fusing/Fuse Principles

Introductory Information

Knowledge of fuse principles, how fuses are selected, and how fuses are used to protect primary lines and primary connected equipment is essential to Qualified Electrical Workers. Installing the proper fuse in the proper location is critical to maintaining system coordination and safety.

Fuses, as used in the electrical industry, are relatively simple and cheap devices used to protect equipment. A fuse is a short piece of conducting material with a cross-sectional area that is not capable of carrying currents that would damage the equipment it is protecting. The fuse is sacrificed to prevent the circuit or equipment from being damaged and to limit further damage to sections of the circuit that may have already faulted, such as when a line goes down. Knowing the difference between a K type fuse and a T type fuse could mean the difference between replacing a fuse that costs pennies or replacing a piece of equipment that costs thousands of dollars.

Learning Objectives

After completing this lesson, you will be able to:

1. Figure fuse sizes to be used with various single-phase transformers and 3-phase banks.
2. Describe how a fuse operates to protect lines and equipment.
3. List two properties of fuse links and fuse holders.

Lesson 2 Reclosers and Sectionalizers

Introductory Information

In the electrical distribution industry, reclosers and sectionalizers are the backbone of system coordination. Every Qualified Electrical Worker should have a basic understanding of these two pieces of equipment and how they operate to isolate a fault. Reclosers are hydraulically operated devices that depend on a good maintenance program in order to operate at peak efficiency. Dirty oil or cold weather will slow the operation of a recloser, and this fact should be kept in mind by any Qualified Electrical Workers working an outage that involves reclosers. When properly placed, maintained, and coordinated with primary fusing, these devices can limit the number of customer power outages caused by transit and permanent faults.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe how sectionalizers and reclosers operate to isolate a line.
2. Discuss the differences between types of reclosers.
3. List two amperage ratings for the reclosers.

Lesson 3 Substations --- Equipment Identification

Introductory Information

Due to the complexity and diversity, it is difficult to discuss every type of equipment that might be found in an electrical substation. By studying the reference materials, workers should be able to identify most of the major electrical equipment they will encounter in substations.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss two safety factors associated with substations.
2. State how two pieces of substation electrical equipment perform their functions.
3. Discuss an electrical line inside a substation yard and two pieces of equipment attached to it.

Lesson 4 Substations --- Oil Circuit Breakers

Introductory Information

Oil circuit breakers (OCBs) used in substations are the most used piece of equipment in the electrical switchgear lineup. Oil circuit breakers are mechanical switching devices that carry the full current a substation is required to deliver. OCBs also have the ability to interrupt fault currents as well as normal full current flow.

Oil circuit breakers may operate hundreds of times in a normal year, depending on location. They most often fail due to dirt, corrosion, and fatigued parts. The employer should have a planned OCB maintenance program to ensure that the breaker will perform as designed when called on. Excluding electronic control equipment, oil circuit breaker operation will be explained, as well as some of the maintenance tests that should be performed on a regular basis.

Learning Objectives

After completing this lesson, you will be able to:

1. Discuss the operating characteristics of substation OCBs.
2. Identify the tests and inspections that are routinely performed on OCBs.
3. Describe elements that may be found in the oil of an OCB.

Lesson 5 Substations --- Batteries

Introductory Information

There are approximately 100,000 electrical substations operating in the United States, ranging in size from small rural units serving less than 100 customers to substations serving huge industrial complexes.

Most of these substations have an electrical backup system in order to operate equipment in case of a station outage. Substation DC auxiliary systems are typically used to supply loads such as relaying, supervisory, alarm, and control equipment. DC systems also supply emergency control house lighting and furnish power for circuit breaker trip and close circuits.

The batteries that provide electrical backup in substations should be studied, along with their purpose, connection, safety procedures, and maintenance.

Learning Objectives

After completing this lesson, you will be able to:

1. State two types of load that substation batteries must support in case of a power outage.

2. List two voltages that are associated with substation batteries.
3. List three safety concerns associated with substation batteries.

Lesson 6 Substations --- Oil Care and Filtering

Introductory Information

There is an old saying about substations: “transformers do not die from old age–they die from neglect.” Neglected transformers will self-destruct eventually, when the paper insulation and mineral oil become contaminated to the point where they no longer serve as insulation. A failure to conduct regular transformer oil testing can allow problems to go undetected until a catastrophic failure occurs and the company may face millions of dollars in repair costs.

If automobile oil is never changed, it will become dirty and lead to a catastrophic failure of the car’s engine. Substation transformers should also be on a regular maintenance schedule to check for contaminants that could lead to transformer failure. Unlike automobile engines, however, one cannot simply change out the filter and replace the 5,000 gallons or more of oil in a substation transformer.

With proper oil maintenance, transformer failure can be postponed. It is not unusual for well-maintained substation transformers to serve for over 50 years.

Learning Objectives

After completing this lesson, you will be able to:

1. State two factors that govern oil sampling of substation transformers.
2. Discuss two processes that affect the condition of transformer oil.
3. List two methods of cleaning substation transformer oil.

Lesson 7 Substations --- Air Switches

Introductory Information

There are several types of high-voltage air switches used in substations. The function of an air switch is stated in ANSI/IEEE Standard C37.100 as “a switching device designed to close and open one or more electrical circuits by means of guided separable contacts that separate in air.” As the name implies, air, at atmospheric pressure, is the insulating medium between contacts when the switch is in the open position.

There are a variety of air switches developed to fulfill special requirements. The manufacturer’s sheet provided with each type of switch should be consulted for proper installation.

The name “air-break switch” is interpreted by many Qualified Electrical Workers to mean that the switch is designed to open a circuit under full load; in fact, the opposite is true. All procedures should be followed prior to opening a switch to take the load off the circuit, and even then, some switches draw spectacular arcs due to the length of line or the size of transformer coil that is being isolated.

Learning Objectives

After completing this lesson, you will be able to:

1. State three types of switches used in substations for isolating or grounding a line.
2. Discuss the method used by sulfur hexafluoride switches to open a circuit.
3. List three safety factors associated with operating switches in a substation yard.

Lesson 8 Substations --- Substation Control Equipment

Introductory Information

Properly installing and marking substation control equipment is critical, and affects how a substation will be operated after it is installed and energized. The general guidelines for installing substation equipment should be followed in all cases. It would be difficult to cover all of the equipment that might be installed in any particular substation, but it will be beneficial to know the proper way of installing certain pieces of equipment shown.

Learning Objectives

After completing this lesson, you will be able to:

1. State two requirements for installing cable in a substation.
2. List two meters used when installing cable and relays.
3. List three characteristics of CTs and VTs.

Lesson 9 Fault Current

Introductory Information

There are many ways a Qualified Electrical Worker can become involved in a ground fault. It is critical that a worker recognizes where ground faults can occur and knows how to provide protection from the touch and step potentials, as well as the explosive nature of the faults. Most no-power trouble calls involve a phase-to-ground or phase-to-phase short circuit. A very high fault current flows during these short circuit conditions. Understanding fault currents is essential to understand how protection schemes such as fuse coordination work.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the characteristics of a fault current.
2. Recognize the hazards involved with fault current.
3. Understand where the magnitude of a fault current is highest.
4. Understand the importance of keeping a fault current circuit intact so that the electrical system’s protective devices can operate.

Lesson 10 Testing For Line Faults

Introductory Information

When trouble occurs on a line, a Qualified Electrical Worker’s job has three parts: to determine the nature of the fault, to locate the fault, and to correct the condition. Knowing how to test for line faults will provide some clarification on the first two steps to be taken.

Learning Objectives

After completing this lesson, you will be able to:

1. Name the three different types of line faults.
2. Explain the differences between the types of line faults.
3. Describe the methods used to locate line faults.

Lesson 11 Voltage Regulators

Introductory Information

Maintaining good voltage to the customer is important. Voltage fluctuates; therefore, equipment on the system is needed to regulate the voltage.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the importance of maintaining good voltage.
2. Understand how voltage is affected by electrical system changes.
3. Explain how the voltage on a line can be regulated.

Lesson 12 Step Regulators and Tap Changing

Introductory Information

Supplying the proper voltage to the customer involves regulating voltage throughout the entire electrical system. Bucking and boosting voltage with substation transformers and with step voltage regulators is a common practice in all electrical supply utilities.

The output of a transformer is dependent on the ratio of the primary coil to the secondary coil. Some transformers allow this ratio to be altered somewhat to raise or lower the output voltage. Most substation transformers have under load tap changers that change the output voltage automatically. Step voltage regulators are also used in some substations and along subtransmission and distribution lines. They are like autotransformers that change the ratio automatically to boost or buck voltage.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the operation of voltage regulating equipment.
2. Make adjustments to regulator settings.
3. Operate step voltage regulators.

Lesson 13 Capacitors and Capacitor Switching

Introductory Information

Qualified Electrical Workers should be familiar with the role and operation of capacitors in an electrical system, including knowledge of distribution line capacitors. Capacitors are one of the more mysterious pieces of electrical equipment. There are some very specific risks involved when energizing, deenergizing, and grounding capacitor banks that must be understood.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the purpose of capacitors.
2. Inspect capacitors.
3. Operate capacitors.

Lesson 14 Power Factor

Introductory Information

An electrical system works most efficiently when the power factor is high. Qualified Electrical Workers should be familiar with what is meant by a high power factor and with the efforts made to control the power factor in an electrical system.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the electrical influences that make up a power factor.
2. Explain the benefits of keeping the power factor of a circuit high.
3. Understand the measures taken to control the power factor in a circuit.

Lesson 15 Power Harmonics

Introductory Information

To supply quality power, an electric utility must deliver a constant sinusoidal voltage and current at a constant magnitude throughout the power supply system. With the increased popularity of electronic and other non-linear loads, there are a lot of interfering waveforms of different frequencies (harmonics) distorting the fundamental 60-hertz sinusoidal waveform. These harmonics result in distorting voltages and currents that adversely affect the distribution electrical system.

Harmonic currents can create problems such as equipment heating, communications interference, nuisance fuse and breaker operations, and conductor heating.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the basics of harmonic interference.
2. Recognize harmonics as a possible source of customer complaints.

3rd Year – Level 6

Lesson Learning Objectives

Level VI prepares the student for life after class. Topics include the economics of unemployment, motivation, and the National Electrical Benefit Fund. Fiber optics, alternative energy sources, and high voltage lines are also covered. The course ends with lessons on foremanship and Journeyman responsibilities.

Lesson 1 The Economics of Unemployment

Introductory Information

It is important that apprentices are prepared to face the realities of working in the electrical industry for the rest of their careers as Qualified Electrical Workers. There are no guarantees that any Qualified Electrical Worker is going to be able to work 40 hours a week, 52 weeks a year throughout their entire career. Just as the economy is constantly changing, the electrical industry can be very cyclic at times. When work is plentiful, things are pretty good for most people in the industry, however, those circumstances cannot last forever. In reality, all those involved in the industry need to be financially prepared for the "slow times."

When times are good, it can be easy to be lured into a false sense of economic security. One may start thinking to oneself that employment will always be this good. And, if that is the case, why not start spending a little more freely? And as far as savings goes, who needs it? There is plenty of work around, so why put anything away?

The hard reality is that consistent employment will not last; it never does. Sooner or later, it will slow down and workers may experience lapses in employment. That is why it is so important to understand that no Qualified Electrical Worker is guaranteed full employment. While it is possible to be one of the fortunate ones who rarely experience unemployment, work could start drying up tomorrow in any given area. Consequently, Qualified Electrical Workers must recognize the importance of developing personal financial responsibilities. That means making realistic budgets and sticking to them, spending sensibly and living reasonably within one's means, and, most importantly, saving. Everyone must learn to deal with the cold hard facts of household economics. Games of chance are not the answer; financial responsibility is.

Hopefully, unemployment will not affect Qualified Electrical Workers very often. But if it does, be prepared. Keep spending within reason and make a commitment to pay oneself—each and every payday—through a deposit to a personal savings plan. Now is the time to develop a serious, sensible economic plan. With proper planning, a Qualified Electrical Worker can eliminate the possibility of economic chaos should hard times find their way to his or her doorstep. Remember, forewarned is forearmed. Learn to save.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe the need for a personal savings plan.
2. Identify qualities that can have a positive effect on continuous employment.
3. Describe the "independence" of working in the construction industry.
4. Explain how unemployment compensation works.
5. Explain the need for a sound, well-thought-out financial budget and responsible spending.

Lesson 2 Keys to Success --- Motivation and Leadership

Introductory Information

The nature of a career in the electrical industry will bring Qualified Electrical Workers into contact with many people with whom they must work. The ability to work with others in harmony while being productive is an important factor to both employee and employer. Knowing about the levels of human need and basic theories of motivation and leadership will make Qualified Electrical Workers more valuable to themselves, their employers, and the electrical industry.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe and explain three basic theories on motivation.
2. List the levels of human need.
3. Determine which leadership action to choose to deal with various worker attitudes and abilities.
4. Explain why leadership in electrical construction is important.

Lesson 3 The National Electrical Benefit Fund

Introductory Information

The National Electrical Benefit Fund (NEBF) has a rich history and is a very sound program that only union apprentices and Qualified Electrical Workers can enjoy; another good reason to be Union. It is important for Qualified Electrical Workers to understand the valuable information concerning the NEBF pension fund program.

Learning Objectives

After completing this lesson, you will be able to:

1. Demonstrate an understanding of the history, growth, and development of the NEBF.
2. Demonstrate a basic knowledge of benefits paid by the NEBF.

Lesson 4 Introduction to Fiber Optics

Introductory Information

This lesson introduces the student to fiber optics. A history of fiber optics is provided, as well as an overview of where fiber optics is used. There is a discussion of the differences between fiber and copper and what has become the basis for fiber's dominance of the communications industry. Finally, to emphasize their importance, safety and the need for cleanliness are discussed.

Learning Objectives

After completing this lesson, you will be able to:

1. Define "fiber optics."
2. Understand how fiber was developed and used in communications.
3. Identify the difference between "outside plant" and "premises" fiber optics.
4. List advantages of fiber optics.
5. Identify fiber optics standards.

6. Learn how to work with fiber safely.

Lesson 5 Fiber-Optic Network Installation

Introductory Information

The topic of fiber-optic cable plant installation is a very diverse subject since fiber is used in so many different types of installations in so many different environments. This lesson provides an overview of the installation processes for many applications, with an emphasis on safety.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand what is involved in a fiber-optic installation.
2. Understand the role of the contractor and installer.
3. Know how to prepare for the installation.
4. Verify the quality of the installation.
5. Identify safety issues for fiber-optic installations.

Lesson 6 Fiber-Optic Network Design

Introductory Information

This lesson provides an overview of fiber-optic network design. By studying this lesson, the student will begin to understand the process behind fiber-optic network design. Since the FOA has a certification on Fiber Optic Network Design, there is a large amount of reference material on the FOA site that is appropriate for advanced study of fiber-optic network design.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand what is involved in fiber-optic network design.
2. Understand how a fiber-optic project develops from idea to installation.
3. Choose equipment and components for the network.
4. Plan for and complete an installation.

Lesson 7 Fiber-Optic Cable

Introductory Information

This lesson is an overview of the purpose of cables, which is to protect fibers in the outside world. The lesson also covers how cables are used. The student will learn about the different types of cables and their applications. Choosing cable types appropriate for the application is very important for designers of networks, as it affects network cost and reliability, but requires knowing the different types available and their properties that determine the correct choice. Be sure to note the sections near the end on indoor cable flammability ratings and color codes.

Learning Objectives

After completing this lesson, you will be able to:

1. Identify the types of fiber-optic cables and their applications.
2. Describe the differences between outside plant and premises cables.
3. Explain the specifications for fiber-optic cables.

Lesson 8 Alternative Energy Source --- Wind

Introductory Information

Qualified Electrical Workers may be involved in constructing wind power structures because of their familiarity with constructing transmission lines and their ability to work safely at heights. This lesson introduces Qualified Electrical Workers to the design, construction, and operation of wind power.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the concepts involved with wind power.
2. Discuss the pros and cons of wind power as perceived by the public.
3. Understand operational issues when wind power generation is part of the grid.
4. Understand the construction and maintenance involved with wind power.

Lesson 9 Alternative Energy Source --- Photovoltaics

Introductory Information

Even though apprentices may not know what it is called, they are already familiar with the basic elements of the photovoltaic effect. Every day, they interact with the two basic factors of photovoltaics: sunlight and electricity.

Literally, *photovoltaics* means “light volt”, but it is often called PV for short. PV is the conversion of sunlight into electricity. Most people are familiar with solar watches and calculators, but few realize that PV also powers satellites, communications systems, lights, water pumps, and residences.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe a typical photovoltaic system.
2. Understand the developments that have been accomplished in photovoltaics and how they will affect the utility industry.

Lesson 10 Extra High Voltage Lines

Introductory Information

Increased demand for electricity is constantly causing transmission lines to be designed for operation at higher voltages. This happens so often that a new term has crept into electrical terminology: *extra high voltage (EHV)*.

Working on EHV lines means working on larger and higher structures and bundled conductors. EHV generally refers to lines 345 kilovolts and higher. When working near live EHV lines, workers are exposed to touch potentials because high voltage builds on a person’s body and is discharged whenever the worker touches a grounded object. Some of the reasons for design, the characteristics, and the problems associated with EHV will be introduced.

Learning Objectives

After completing this lesson, you will be able to:

1. Understand the advantages of EHV lines.
2. Understand why corona and skin effect are issues in EHV design and work.
3. Recognize issues involved in working near live EHV circuits.
4. Understand the purpose of bundled and expanded conductors.

Lesson 11 After Apprenticeship

Introductory Information

It is important for apprentices to reflect on the past three years of education and training and to look ahead to their future. No doubt, apprentices look forward to completing their apprenticeship indenture and working as a Qualified Electrical Worker.

Along with the advancement to Qualified Electrical Worker will come opportunities to become involved in other areas within the electrical industry as a foreman or steward. It is up to each Qualified Electrical Worker to decide if he or she will be prepared to take that step if called upon.

Learning Objectives

After completing this lesson, you will be able to:

1. Demonstrate an ability to constructively critique and evaluate personal performance.
2. Begin to plan for ways and means to contribute to the electrical industry after completing the apprenticeship.
3. Demonstrate a desire and willingness to be active in the IBEW and in political activities affecting the nation at all levels.

Lesson 12 Foremanship

Introductory Information

Apprentices will soon become Journeyman Electrical Workers and, possibly sooner than they think, Foremen. Whether an individual is an apprentice, Journeyman Electrical Worker, or Foreman, it is important to understand a Foreman's position and responsibility. The Foreman's position is not an easy job. He or she cannot and should not be a "buddy." The Foreman must offer leadership and must have the respect of the workers on the job.

Learning Objectives

After completing this lesson, you will be able to:

1. Describe a responsible Foreman.
2. Recognize the importance of being a responsible Foreman.
3. Name some of a Foreman's duties and how they can affect the outcome of a job.

Lesson 13 Soon to Be an Instructor

Introductory Information

Apprentices have every right to be excited for graduation and filled with anticipation for what lies ahead. After all, they have worked hard to be successful in their chosen career as an IBEW Qualified Electrical Worker, working with pride and dignity for Union electrical contractors. Enjoy the remaining days of apprenticeship and revel in the accomplishment of graduation.

With that accomplishment also comes the privilege of becoming an instructor for future apprentices and future graduates. How well a Qualified Electrical Worker does as an instructor will, most certainly, cast the fate of the electrical industry.

One of the biggest problems the electrical industry faces today is the regressive attitude of the rank-and-file. Complacency, procrastination, and hypocrisy seem to have slowly crept into workers' personal attitudes. The result is a very high price paid by the electrical industry and its future. If this situation is not addressed now, it may be necessary for workers to make a very unpleasant and unwelcome career change. This does not have to happen, and will not happen, if the industry is ready as a whole to get involved in the industry and its future.

New Qualified Electrical Workers must allow their voices to be heard louder than ever as they become instructors in this great industry. Seize every opportunity that is presented to get involved, and cultivate the mentality that: "This is my industry, and I'm proud to be a part of it. Anything done to harm it harms me. Therefore, I will resist, with all my energy, any and all attempts to destroy or weaken that for which I stand."

Learning Objectives

After completing this lesson, you will be able to:

1. Identify the qualities of a competent and conscientious Qualified Electrical Worker.
2. List the essential steps involved in quality instruction.
3. Explain how all Journeymen Electrical Workers are instructors and what their responsibilities are.
4. Describe the need for political activism.

Lesson 14 Your Career --- Journeyman Responsibilities

Introductory Information

The electrical industry would like to thank all apprentices for their efforts, congratulate them on becoming Qualified Electrical Workers, and wish them the best in their chosen careers.

This part of training will soon be over and the real learning will begin: working as a Qualified Electrical Worker. Many believe that that the job of a Qualified Electrical Worker is the best job on the crew: no decisions, no blame, and no responsibilities—just do the job and go home. Nothing could be further from the truth. Qualified Electrical Workers have many responsibilities. New Qualified Electrical Workers will be looked up to by those now entering the industry. After all, they have studied hard and sacrificed a lot of time to attain Qualified Electrical Worker status, and those just starting the apprenticeship will see them as role models.

As new Qualified Electrical Workers go forward in their careers, they should strive to be safe, do a craftsman-like job, and remember that there is a 100-year history of providing quality service behind them.

Learning Objectives

After completing this lesson, you will be able to:

1. List two attributes a Qualified Electrical Worker should have.

2. Discuss the college credits available for Qualified Electrical Workers after apprenticeship.
3. State two responsibilities of a Qualified Electrical Worker.