# NATIONAL UTILITY INDUSTRY TRAINING FUND

# SUBSTATION APPRENTICESHIP

## Third Year Lesson Learning Objectives

# SUBSTATION APPRENTICESHIP
# 3RD YEAR – LEVEL 1
# LESSON LEARNING OBJECTIVES

Power transmission construction is one of the fastest growing electrical industries. Substations and switchyards are key components of power transmission. The substation technician has to be highly trained in electrical construction and also be a productive leader. Level I opens with lessons on taking pride in the industry and understanding union by-laws and parliamentary procedures. Students then will have an introduction to the COMET program and learn about the National Electrical Benefit Fund and labor management relations. They then will learn about the hazards of cell phone use in the workplace and the economics of unemployment. The remaining lessons cover motivation and leadership, foremanship, and Journeyman responsibilities.

**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: Understanding Local Union Bylaws**

Introductory Information

Local union bylaws are the rules under which local unions operate. They must not conflict with the IBEW Constitution and they should establish the guidelines for conducting the business of the local union.

Members should take an active part in the affairs of their local union. To do so, they should acquire a copy of the Constitution, their union bylaws, and the negotiated working agreement. Becoming familiar with and understanding these documents will help them to become informed participants at union meetings.

**Note:** Answer the questions using the bylaws provided in the Reference: Understanding Local Union Bylaws (see CourseWare). Do not use any other bylaws as a reference.

The bylaws provided in Reference are generic in nature. They provide a standard reference regardless of local union affiliation. These generic bylaws were developed using pattern language provided courtesy of the International Brotherhood of Electrical Workers. They are not meant to represent the bylaws of any particular local union and are to be used for training purposes only.

Learning Objectives

After completing this lesson, you will be able to:

1. Know what topics are addressed in local union bylaws.
2. Use the bylaws to answer questions regarding local union policies and procedures.
3. Explain how the bylaws affect the operation of the local union.

## Lesson 4: Parliamentary Procedure and How It Works

Introductory Information

Many times, a member comes away from a meeting feeling that the meeting had not been properly conducted or that he or she had not been given proper treatment on the floor. Often this feeling is the result of that member's lack of knowledge of procedure. The member may not know how to present a motion.

Obtain a copy of Robert's Rules of Order and study it. The information gained from reading the book and group discussion should help to instill a working knowledge and understanding of how Parliamentary Procedure works.

Learning Objectives

After completing this lesson, you will be able to:

1. Demonstrate a knowledge and understanding of parliamentary procedure.
2. Understand the responsibility, authority, and role of the chairperson.
3. Abide by parliamentary rules when granted the privilege to attend and participate in local union meetings.

## Lesson 5: 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 6: 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 7: 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 8: Hazards of Cell Phone Use in the Workplace**

Introductory Information

It is morally wrong to steal from an employer. Workers and employers alike universally accept this statement, but it is the definition of stealing that sometimes comes into question. In today's society, cell phones have become commonplace and can be found in worker's vehicles or hanging from their belts at every job site. Using a personal cell phone during work hours is stealing the time an employer is paying for. It is not the same as taking equipment home, but it is stealing nevertheless. An employer is paying for a certain amount of time in which workers are expected to use their time, talents, training, and expertise for the employer's benefit. This lesson points out some of the safety, legal, and economic issues associated with using electronic devices for personal use while on employer time.

Learning Objectives

After completing this lesson, you will be able to:

1. State two dangers associated with cell phone use while driving.
2. Discuss some of the statistics associated with traffic accidents and cell phone use.
3. State the financial toll of cell phone-related crashes in the U.S.

## Lesson 9: 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 10: 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 11: 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 12: 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 13: 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 14: 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 15: 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.

# SUBSTATION APPRENTICESHIP
# 3RD YEAR – LEVEL 2
# LESSON LEARNING OBJECTIVES

There are many facets to substation construction that must be mastered. Safety is primary in both deenergized and energized situations. One of the significant dangers is arc flash. Level II discusses guidelines to prevent arc flashes, utilization of rubber protective devices, and general safety in substations and switchyards. Grounding of all components, including vehicles, is also covered. In addition, power quality and distribution circuits are explained.

**Lesson 1: OSHA 1910.269(u)**

Introductory Information

Occupational Safety and Health Administration (OSHA) 1910.269(u) provides guidelines on substation safety, but it is not the only source one should consult when working in substations. Workers should always consult the employer's safety book and policies in addition to the OSHA standards that apply to the work. Substations contain unique electrical hazards not found in the ordinary outside work environment. Where a line Qualified Electrical Worker might deal with 14,400 volts 40 feet off of the ground, a substation Qualified Electrical Worker may be dealing with the same voltage on top of a substation breaker, nine feet off of the ground. By recognizing hazards and taking proper precautions, substation work can be performed safely and efficiently.

Lesson Objectives

After completing this lesson, you will be able to:

1. State two safety precautions to take when working on energized substation equipment.
2. State the OSHA standard that applies directly to substations.
3. Discuss the safety procedures to be taken when operating a draw-out type circuit breaker.

**Lesson 2: Arc Flash Compliance**

Introductory Information

Future substation Qualified Electrical Workers should know that they will be working in close proximity to equipment that can generate an arc flash due to the nature of the work. It does not take voltage levels in the tens of thousands to produce an arc flash that can result in a serious injury or fatality. A devastating arc flash and accompanying blast can occur when simply racking in a 2.4-kilovolt metal-clad substation breaker or upon opening secondary panels. It is important that workers study their employers' arc flash compliance programs and take the time to comply with these requirements every time they are called on to work within the boundaries the programs outline.

Lesson Objectives

After completing this lesson, you will be able to:

1. State the standard where personal protective equipment (PPE) requirements for arc flash protection can be found.
2. List two effects of an arc flash that can cause injury.
3. Discuss the physical characteristics of an arc flash.

**Lesson 3: Temporary Grounding for Substations**

Introductory Information

Knowing how to properly apply temporary grounds when working on station circuit breakers, power transformers, and switches is a basic skill that every Qualified Electrical Worker should know. It is also important to be aware of the dangers that might be encountered when working with temporary grounds in a substation. Having a basic understanding of the hazards involved will allow workers to develop a grounding scheme that will keep them and their fellow workers safe, while also allowing completion of work on time and within budget.

Lesson Objectives

After completing this lesson, you will be able to:

1. State one safety procedure when grounding a vehicle in a substation yard.
2. Discuss the proper placement of temporary grounds at a substation.
3. Discuss how to properly ground a portable ground mat at a substation.
4. State the main danger from grounding leads when they are subjected to a ground fault.

**Lesson 4: 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.

Lesson 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 5: Selection of Equipment and Installation of Grounds

Introductory Information

The job of properly selecting and maintaining grounding equipment is as important as knowing how to maintain any other types of personal protective equipment, as the worker's life may depend on its condition and size. However, the best protective equipment is useless unless workers also know how to apply the equipment and know its limitations. Selecting and applying temporary personal protective grounds in a switchyard or substation should be discussed. For future Qualified Electrical Workers, knowing how to use the proper grounding equipment for the job can help to prevent a serious injury or a fatality. The employer's grounding procedures should be carefully reviewed when establishing a temporary grounding scheme.

Lesson Objectives

After completing this lesson, you will be able to:

1. State one of the OSHA standards that governs grounding for employee protection.
2. State the proper order of applying and removing temporary grounds.
3. Discuss the types of grounding clamps that are allowed to be used as part of grounding assemblies.
4. State one of the dangers of using temporary grounds that are too long, should they become energized.

## Lesson 6: Vehicle Grounding

Introductory Information

The majority of electrical contact injuries involving vehicles that occur in substations are brought about by step and touch potentials. It is a mistake to think that the substation ground grid upon which the worker and the vehicle are standing will protect the worker if the truck is not properly grounded. The difference in potential between the energized vehicle body and the ground grid caused by the vehicle tires will be enough to cause serious injury to anyone touching the vehicle. Fundamental principles involved in grounding vehicles in a substation yard should be discussed and understood. Employers' policies should always be consulted.

Lesson 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 7: Applying Rubber Protective Devices

Introductory Information

A Qualified Electrical Worker working in a substation will at times have to work on the distribution side of a substation while the lines or equipment are energized. He or she may be called to troubleshoot a 3-phase switch or to replace damaged insulators near the substation. A more common task for substation Qualified Electrical Workers is covering up lower voltages in control houses and on equipment. For their

own safety and the safety of their fellow workers, it is essential that Qualified Electrical Workers know the limitations of rubber protective equipment and know the correct equipment to use when working under different circumstances.

Lesson Objectives

After completing this lesson, you will be able to:

1. State the voltage levels that may be worked with rubber gloves.
2. State the two types of cover-up protective equipment.
3. Discuss a safe working position when working with rubber gloves.

**Lesson 8: 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.

Lesson 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 9: Live-Line Tools --- Using Hot Sticks**

Introductory Information

Qualified Electrical Workers working in substations do not perform the same jobs with live-line tools as line workers. However, substation workers need to develop the same live-line tool inspection and care habits as any live-line crew. When using a live-line tool in a substation, the Qualified Electrical Worker is usually standing on the station ground grid, which makes the condition of the live-line stick even more critical.

There are several different tasks a Qualified Electrical Worker might perform using live-line tools. Always inspect live-line tools before use by checking to see if they have a sticker indicating they have passed their scheduled electrical tests. Reading the employer's stick testing and care policy is mandatory before using any stick to contact an energized conductor.

Lesson Objectives

After completing this lesson, you will be able to:

1. List two of the most common sticks used by a Qualified Electrical Worker working on a substation.
2. Discuss how to use a telescoping stick to cut a small tree branch.
3. Discuss how to apply a heavy ground set to a substation bus.

**Lesson 10: Power Quality**

Introductory Information

The issue of power quality is important in an electrical career. In the early days of the electrical industry, just getting the power to the customer was a problem, and the question of power quality was largely left up to the engineers. Today, the average house may have sensitive electronic equipment, and power quality issues are often handed off to Qualified Electrical Workers to solve.

Experience shows where problems on a system may exist and training provides the tools to solve power quality issues. It is important to be familiar with some of the causes of power quality problems and how to fix them.

Lesson Objectives

After completing this lesson, you will be able to:

1. State the minimum voltage a 120/240-volt customer should have.
2. List two ways a power provider can improve power quality.
3. State two of the factors that might result in television interference.

**Lesson 11: Substation Voltages**

Introductory Information

For a Qualified Electrical Worker working in a substation, upgrading equipment in the substation and switching yard to accommodate higher transmission line voltages as they are introduced is part of the job. The upgrading of the North American grids is a job with which most Qualified Electrical Workers will be involved during their electrical careers. It is important to start studying why upgrading and uprating lines and equipment is important.

Engineers take into account multiple factors when determining the loading a particular line can withstand. These factors include environmental considerations particular to the location of the line, potential consumer growth, and future industrial growth.

Lesson Objectives

After completing this lesson, you will be able to:

1. State the three divisions of transmission voltage.
2. Calculate the current-carrying capacity difference between two levels of transmission voltages.
3. Discuss the reasons why increasing voltage is cheaper than building a new transmission line.

## Lesson 12: Distribution Circuits Overview

Introductory Information

Qualified Electrical Workers should have a basic understanding of the electrical distribution circuits and systems in use throughout the industry. There are variations of these systems throughout the country that were built as the industry grew, and they all have one thing in common: they do a good job of delivering power to everyone.

The different systems that should be discussed are systems that Qualified Electrical Workers work on every day. Learning about the "system" as a whole ensures a better understanding of the role that a Qualified Electrical Worker plays in supplying power to the customer.

Depending upon the local terminology, the word *distribution* is used to mean different systems. Some refer to distribution as only those lines that leave a substation and are normally at 35 kilovolts or lower. As a whole, the industry refers to distribution as any line that leaves a substation where ultra-high voltage is reduced to serve smaller substations. With this definition, distribution would include voltages of 66 kilovolts, 69 kilovolts, and 115 kilovolts. To begin with, study the distribution types of distribution systems that are 35 kilovolts and below. Transmission and sub-transmission lines may be studied separately.

Lesson Objectives

After completing this lesson, you will be able to:

1. List three of the voltages that are typically found on distribution circuits.
2. Identify the different types of distribution systems most commonly in use.
3. Discuss why an electrical provider would find it cheaper to increase the voltage in a distribution system from 7,200 volts to 13,800 volts than from 2,400 volts to 13,800 volts.

## Lesson 13: Substations --- Operation and Maintenance

Introductory Information

A substation ties together a transmission and distribution power delivery system. They are used to house the equipment required to increase the voltage for transmission, decrease voltage for distribution, and ensure the lines between the generation and load are operated at maximum efficiency and safety. Where voltage changes are not needed, switchyards are used. A switchyard differs from a substation because it does not include a transformer.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the basic terminology used in substations.
2. List the major pieces of equipment used to create a substation.
3. Explain the equipment used to monitor and control a substation.
4. Understand a few key items to inspect when maintaining a substation.

## Lesson 14: Safety in Substations and Switchyards

Introductory Information

Substations and switchyards are inherently dangerous locations. They have electrical, chemical, and personal hazards. When construction or maintenance is being performed in a station, each employee needs to remain aware of the activities being performed around him or her. Even the activity adjacent to a worker may be harmful. For instance, if the proper precautions are not taken, a worker may inadvertently close a switch that energizes the bus that another worker is working on. It is very important to take a few minutes before starting each task to review the procedure and ensure that safety precautions are met.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the basic substation hazards.
2. Ensure a worker is qualified to work unescorted in an energized station.
3. Perform work in a safe manner.
4. Know how to react when danger is imminent or an incident should happen.

The lessons in Level III cover cable splicing and the components of safety, materials and tools, cable preparation, terminations, elbows, grounding, and all phases of testing. The final three lessons provide an introduction to fiber optics, optical fiber, and connectors and splices. Fiber optic cables are quickly becoming the primary communication path of control and data throughout the entire transmission network.

**Lesson 1: Cable Splicing --- Safety**

Introductory Information

The subject of safety should be very important to every Qualified Electrical Worker. Cable splicing takes safety concerns to a higher level due to the higher voltages involved. As there are many aspects to the subject of safety, a thorough review of reference materials will provide additional information. Every cable splicing job must start with a briefing at the job site, as required by federal law. The jobsite should be prepared according to standard procedures, and the Qualified Electrical Worker must wear the appropriate protective clothing. Hard hats and eye protection should be considered part of a Qualified Electrical Workers' normal work attire. Rubber gloves should be used when working with live-line tools for such jobs as making and breaking a loadbreak elbow connection. If a splice or elbow is to be installed in a manhole or vault, OSHA safety rules for enclosed or confined spaces will apply. The general entry procedures should include four separate aspects: (1) testing, (2) ventilation, (3) a minimum of two workers with continuous communication, and (4) cleaning.

When installing a termination from an aerial bucket, a safety harness (fall arrest system) must be worn. Qualified Electrical Workers should be aware of bucket rescue procedures as well as applicable safety practices when making an aerial installation from a ladder or scaffold.

When set-up preliminaries are completed, the deenergized state of the cable must be confirmed. Lockout/tagout procedures must be understood and followed.

Preparation of the cables and installation of the splices and terminations or elbows will require working with various tools. Care must be taken when using cutting tools, crimping tools, and when working with sharp edged shielding, drain wires, and so forth. By following established procedures and rules, being careful, and using common sense, cable splicing can be a safe and rewarding job.

Lesson Objectives

After completing this lesson, you will be able to:

1. Define electrical job safety.
2. Understand what is involved in cable splicing safety procedures.
3. Understand the basic steps for preparing to work underground in a manhole or aerially in a bucket.
4. Work safely around medium and high voltages.

## Lesson 2: Cable Splicing --- Material and Tools

Introductory Information

An important factor in cable splicing and terminating is understanding how the cable is constructed. There are different types of materials used in the construction of medium voltage cable and cable splicing, and Qualified Electrical Workers will typically encounter different types of conductors in the field.

Many of the tools and materials used in the field by Qualified Electrical Workers will also be used when making a splice or termination. There are several tools that can be used, such as a splicer, which may be new to some workers.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify the different types of material used in making a medium voltage splice or termination.
2. Discuss the different types of tapes used in making a splice or termination.
3. List the tools used in making a medium voltage splice or termination.
4. Identify the different types of stranded conductors used in medium voltage cable.

## Lesson 3: Cable Splicing --- Cable Preparation

Introductory Information

Failure of cable accessories is one of the most common causes of underground electrical system outages. There have been many studies made of such failures, with most concluding that the majority of failures occurred due to poor workmanship performed during cable preparation. However, most well-trained, experienced installers work for an entire career without any failures being attributed to their work. Cable accessories, both traditional and contemporary, require installation by skilled craftsmen trained in the theory and practice of installing splices, terminations, and elbows.

An analysis of failures reveals that most of the workmanship failures involve the use of cutting tools, such as knives, scoring tools, and stripping tools. The cause of failure usually related to cuts that were made too deep into the underlying layer, which forms an air void, resulting in corona discharges and, ultimately, failure. Along with being a trained and skilled worker, a key to good cable preparation is the proper use of sharp, high quality tools. These tools include traditional hand tools, as well as specialized, mechanical, cable preparation tools.

Cables are prepared by carefully removing the jacketing, shielding, and insulation layers in cutback steps. The removal starts on the outside diameter with the jacket, and steps down through the layers to the conductor. The dimensions for these cutbacks can be critical. The student must become familiar with calculating the correct dimensions from the manufacturer's instruction sheet and accurately executing them on the cable. Once the cable is prepared, it must be properly cleaned before the accessory is installed. Special cable preparation solvents are available for cleaning the cable insulation. In some cases, an abrasive may be necessary. A non-conductive, electrical grade abrasive is then used before cleaning with solvent.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify the workmanship causes of cable accessory failures.
2. Describe cable preparation steps, starting with the jacket and ending with the conductor.
3. Select and use the proper traditional hand tool or special mechanical cable preparation tool.

4. Understand the critical importance that cable preparation plays in cable accessory installations.

**Lesson 4: Cable Splicing --- Terminations**

Introductory Information

If cable runs did not have ends, terminations would not be necessary. All cable runs have two ends (more if the cables contain tap splices, such as a tee splice), each requiring a termination.

A cable termination performs two functions: (1) provides an end to the cable conductor, the insulation, and the grounded insulation shielding, and (2) provides an appropriate means of connecting the cable to the electrical apparatus, overhead line, etc.

A termination differs from a splice in that it discontinues the cable's insulation shield, while a splice continues the shielding across the splice, from cable to cable.

The key to building a proper termination is in the understanding of where the electrical stress will be when the shielding is removed. By applying stress control at the voltage stress area, stress concentration can be reduced and the possibility of an electrical failure will be decreased considerably.

Lesson Objectives

After completing this lesson, you will be able to:

1. Distinguish between low-voltage and high-voltage terminations.
2. Identify the important parts of a termination.
3. Identify the best lug application for a termination.
4. List the atmospheric considerations when building a termination.

**Lesson 5: Cable Splicing --- Splicing**

Introductory Information

A splice can be defined as two or more conductors joined with a suitable connector, re-insulated, re-shielded, and re-jacketed with compatible materials applied to a properly prepared surface. This basically translates to the rebuilding of a short section of cable.

There are several common types of splices available today, such as hand-wrapped tapes, pre-molded push-on, heat shrink, cold shrink, 600-ampere elbows, and three-conductor splices. The splicing product should be selected based on matching the cable (type, size, voltage rating, etc.). Regardless of the selection, there are five basic steps involved in building a splice.

1. Prepare cables
2. Join conductors with connector(s)
3. Re-insulate
4. Re-shield
5. Re-jacket

Good cable preparation, paying close attention to the dimensions, and following the manufacturer's instructions are critical. Good workmanship is the key to a reliable medium or high voltage splice installation.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the importance of good cable preparation.
2. Discuss all of the functions of a splice as they relate to the functions of cables.
3. Select a splice kit to match the cables being joined.
4. Calculate cable preparation dimensions from a manufacturer's instructions.

**Lesson 6: Cable Splicing --- Elbows (Separable Connectors)**

Introductory Information

The elbow is often referred to as the erector set of cable accessories. It can be used in a variety of applications and configurations, such as dead-front terminating, splicing, switching, sectionalizing, live dead-ending, and branching. Elbows are available in two general categories: 200-ampere and 600-ampere. The 200-ampere elbow is designed for distribution class cables, while the 600-ampere elbow is for feeder cables. The 200-ampere and 600-ampere names indicate the maximum continuous current rating of the elbow.

The 200-ampere elbows come in two configurations: load-break and dead-break. These elbows have different operating interfaces and are not compatible with each other. The load-break elbow is the most common and can be operated in both load-break and dead-break modes. By contrast, 600-ampere elbows are operated in a dead-break only. The standard live-line tool for operating elbows is referred to as a "shotgun stick."

It is very difficult to determine if a dead-front connection is deenergized. Elbows are available with an optional test point, which has a capacitive coupling with the elbow's conductor. After de-energizing and removing the cap, a special high impedance voltage sensor can be used to check voltage status. Any voltage reading would indicate that the elbow connection is not ready to operate, and further investigation is necessary.

Selection of elbow products is made in accordance with the equipment it is to be connected to. Dead-front switchgear and transformers are available with 200-ampere or 600-ampere bushings to match the appropriate elbows. Installing an elbow onto the cable is very similar to that of a push-on molded rubber splice or termination. Properly installed, elbows have proven to be very reliable.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the terminology used with elbow products.
2. Select between 200-ampere and 600-ampere elbows.
3. Distinguish between deadbreak and loadbreak installations.
4. Operate (make or break) an elbow connection using a shotgun stick.
5. Describe proper kit assembly procedures used for installing an elbow.

## Lesson 7: Cable Splicing --- Grounding Cables

Introductory Information

There are many aspects to the subject of grounding. A ground establishes a common reference for the system voltage, and provides safety for personnel and a return path for fault currents, switching surges, lightning surges, etc. However, there is one fact that stands out when it comes to installing a medium or high voltage shielded power cable: the cable's metallic shield MUST be grounded for safety and operation.

Because of their shared installation locations, splice, termination, and elbow kits are usually used for making the cable ground connections. The accessory-to-cable shield connections were traditionally soldered in the field. Today, most of the manufacturers' kits contain solderless connectors, the most common being the constant force spring. Kits usually include a ground braid sized to fit the job.

Grounding is a very important part of a cable and cable accessory installation. It is mandatory to ground the cable. Safety and the dissipation of voltage surges are improved through proper grounding.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the importance of grounding a shielded power cable.
2. Explain the advantages and disadvantages of single-point grounding, double-end grounding, shield breaks, cross bonding, quarter mile grounding, and concentric neutral grounding.
3. Make a decision for selecting a grounding method for a specified job vs. a non-specified job.
4. Install a cable ground using a constant force spring and ground braid.
5. Connect a concentric neutral cable to ground and to a pre-molded accessory grounding tab.

## Lesson 8: Cable Splicing --- Insulation Testing

Introductory Information

In many parts of the country, underground cables that were designed for a service life of 30 years have surpassed that life by decades. Knowing the condition of the insulation protecting the cable allows its owner to do preventative maintenance and accounts for the cable's extended life. Qualified Electrical Workers must be aware of the conditions that deteriorate insulation and the tests that are performed to find trouble spots before a catastrophic cable failure occurs.

Lesson Objectives

After completing this lesson, you will be able to:

1. State two purposes of cable testing.
2. State the three types of cable tests most commonly performed.
3. List three conditions that affect a cable's condition.

**Lesson 9: Cable Splicing --- Introduction to Cable Fault Location**

Introductory Information

Knowing how to quickly and safely locate underground faults is an essential skill for every Qualified Electrical Worker. The most common piece of equipment in use for finding residential faults is the thumper method. Remember, all safety and operating manuals particular to the equipment being used should always be studied carefully and all procedures followed.

Lesson Objectives

After completing this lesson, you will be able to:

1. State three safety precautions that must be followed when a thumper is used to locate a cable.
2. Describe the procedure to follow when using a thumper to surge a cable.
3. List two conditions that may exist that will not allow a thumper to locate a fault.

**Lesson 10: Cable Splicing --- Underground Troubleshooting**

Introductory Information

Knowing how to troubleshoot an underground system ensures that customers are brought back online quickly and safely. There are many procedures used to troubleshoot an underground system, but it is equally important to be familiar with and to follow local procedures.

Lesson Objectives

After completing this lesson, you will be able to:

1. List three reasons cable may fault other than lightning or traffic accidents.
2. State the one thing that a Qualified Electrical Worker has control over to prevent cable failure.
3. State the procedure for using a grounding spike.
4. List three things to look for when doing a piece-by-piece system inspection.

**Lesson 11: Cable Splicing --- Manufacturers' Kits**

Introductory Information

The majority of splicing and termination jobs today are performed using manufactured kits. Cable accessory manufacturers generally design kits around modern methods for handling the functions of a splice, termination, or elbow (separable connector). These factory kits are usually much faster and easier to install than traditional methods, such as hand-applied taping. The speed and ease comes at a cost, however, as the kits are generally quite sensitive to proper selection, cut-back dimensions, and unique installation steps. Although kits appear easy to install, skill and training remain necessary for making a reliable installation.

IEEE standards are considered the industry standard for splices, terminations, and elbows. The standards establish the electrical ratings, test requirements, product classifications, etc. of medium and high voltage cable accessories. Most manufactured kits are designed to meet or exceed these standards. Compliance is an assurance that the accessory will not be a weak link in a shielded cable system.

Detailed cable information is necessary for providing the electrical worker information necessary for selecting the proper kit. This information is readily available on new jobs, but may not be for retroactive

jobs. The installer must also have knowledge of the application and environment. The kit selection may not include all of the necessary components, such as connector(s), shield adapter, jacketing, etc., which must then be ordered separately. After verifying the correct kit and accessories are on the jobsite, along with proper tools, the installation can proceed. The key to a quality kit installation is to carefully follow the manufacturer's instructions.

Lesson Objectives

After completing this lesson, you will be able to:

1. Define the importance of training and craftsmanship required for installing manufactured kits.
2. List the IEEE standards that apply to splice, termination, and elbow kits.
3. Identify the different types of manufacturers' kits.
4. Select a proper kit based on cable, application, and environmental information.
5. Follow a manufacturer's kit instructions.

**Lesson 12: 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.

Lesson 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 13: Optical Fiber**

Introductory Information

This lesson covers the heart of fiber-optic technology—the fiber itself. The student will learn how fiber works, the different types of fiber, and important fiber specifications. Like the "jargon" lesson, this section provides important background information for many of the other lessons to come.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe how optical fiber transmits light.
2. Identify physical characteristics of various types of fibers.
3. Understand fiber performance specifications.

## Lesson 14: Connectors and Splices

Introductory Information

In this lesson, the student will study termination and splicing types and techniques for fiber-optic cable. The student should physically examine real world samples of the most popular connectors (ST, SC, LC), if possible. The text has photos of the various types of connectors workers may come across in the field. The student should understand which connectors are used where, the various methods of termination, and ferrule end polishes, as they are important issues in choosing and using connectors.

The lesson covers technical details of both fusion and mechanical splicing, with emphasis being that most single-mode outside plant splicing is fusion, while mechanical splices are used more for restoration and multimode splicing.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the difference between connectors and splices.
2. Understand the requirements for connectors and splices.
3. Identify connector styles.
4. Identify types of connector terminations.
5. Identify splice types.
6. Understand splicing procedures.

# SUBSTATION APPRENTICESHIP

# 3RD YEAR – LEVEL 4

# LESSON LEARNING OBJECTIVES

There is much to understand about power transformer operations in substations. In these Level IV lessons, transformer principles, inspection and testing, tap changers, and oil quality are discussed in great detail. Along with these components, there are many tests to understand, such as insulation power factor testing, resistance testing, temperature indicator testing, and pressure relay testing. Various methods of insulation, including $SF_6$ gas and its proper handling, are also covered.

**Lesson 1: Power Transformer Principles**

Introductory Information

The key item that differentiates a substation from a switchyard is a power transformer. Transformers are used in many capacities in the electrical industry, from increasing voltage for efficient transfer of energy over long distances to decreasing voltage so it can be used at the local level. Both types of stations typically have station service transformers that are used to convert high voltage electricity to a level that can be used to charge the station batteries and power the lights and tools in the station yard. Potential transformers and current transformers are used to meter the flow of electricity in both substations and switchyards.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basics of how a transformer functions.
2. Understand some of the basic terminology of transformers.
3. Differentiate between the different types of power transformers.
4. Describe how different types of power transformers perform their job.

**Lesson 2: Power Transformers --- Inspection and Tests**

Introductory Information

When substations are constructed or modified, the changes usually revolve around a new transformer. A new power transformer is not always brand new from a factory. Often transformers are moved from one substation to another as loads increase. Utilities can also purchase used transformers from other utilities or equipment brokers. Anytime a power transformer is moved, tests and inspections should be performed on the transformer in addition to the tests performed at regular service intervals.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basic physical inspection of a transformer.
2. Describe the internal inspections performed on transformers.
3. Understand the apprehension and shipping of transformers by a utility.
4. Explain the basic inspection of a new transformer.

**Lesson 3: Power Transformers --- Tap Changers and Turns Ration Testing**

Introductory Information

Tap changers are used to keep the secondary voltage from a transformer within acceptable limits when the primary voltage changes. They accomplish this by changing the windings inside the transformer, making small adjustments to the transformer's turns ratio. Load changes will cause the voltage to change on a transmission line, and if the voltage reaching the customers is not within a permissible range, lights will dim, motors will burn out, and electrical components will fail prematurely. A tap changer compensates for these changes.

Insulated conductors inside the transformer's tank may or may not be energized depending on the setting of the tap changer.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the basic functioning of a tap changer.
2. Describe the difference between a load and no-load tap changer.
3. Understand the safe way to perform work on a transformer.
4. Explain the basic principle of turns ratio.
5. Identify a turns ratio test set.
6. Calculate a turns ratio.

**Lesson 4: Transformer Oil Quality/Oil Filtration**

Introductory Information

Transformer oil testing is performed to eliminate problems before they happen. By checking the oil in a transformer, the tester is monitoring the performance of the transformer components and noticing defects before they cause catastrophic failure. If testing is not performed, minor defects such as moisture in the oil can lead to transformer explosions. An incident this catastrophic causes more damage than just the ensuing power outage. Oil and hazardous waste must be cleaned up. Damaged equipment and its byproducts must be disposed of. Most importantly, a new transformer would be needed, and transformers can be difficult to obtain on short notice. Since transformers are so expensive and difficult to replace, transformer oil testing is an important part of any utility's maintenance program.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain why transformer oil requires testing.
2. Explain how to take oil samples.
3. List some of the items found in test results that show transformer malfunctions.
4. Describe basic transformer oil tests and their testing requirements.

**Lesson 5: DC High Potential Testing (Hi-Pot)**

Introductory Information

High potential, or hi-pot, testing is performed on cables and equipment to ensure they have not been damaged during installation and that they pose no electrical shock hazard to Qualified Electrical Workers. By intentionally overstressing the insulation on the cable or equipment, weaknesses are exposed. It is imperative to ensure that these spots are addressed upon completion of a hi-pot test. Otherwise, weak spots will continue to develop and eventually cause a fault at the operating voltage. Even though this test damages the weak spot in the cable or equipment, it is better to cause a fault during controlled testing conditions than to wait for the fault to happen when it will interrupt service.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify basic characteristics of a hi-pot tester.
2. Explain why a hi-pot test is performed.
3. Describe the basics of performing a hi-pot test.
4. Explain safe handling practices while using a hi-pot tester.

**Lesson 6: Insulation Power Factor Test**

Introductory Information

The insulation power factor test is used to test the insulating capacity of equipment. For instance, the bushings on a circuit breaker or transformer may be tested to ensure they insulate sufficiently. A power factor test may be performed on the bushings, oil, and tank at the same time. The power factor insulation test is a nondestructive test that can safely be performed on equipment and will show the status of the equipment's insulation.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basic principles of power factor.
2. Explain why power factor testing is performed.
3. Describe some of the basic characteristics of the power factor test.
4. Explain the basic processes of performing a power factor test.

## Lesson 7: Insulation Resistance Test

Introductory Information

Just like a transformer's oil, the insulation in a transformer helps the transformer during normal operating stresses. The failure of a transformer's insulation will cause transformer failure, which leads to even bigger problems, including the requirement to replace the old transformer, which is very labor intensive and costly. For this reason, a transformer's insulation resistance should be tested on a regular basis.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the purpose of insulation resistance testing.
2. Describe the equipment used to perform insulation resistance testing.
3. Explain the procedures used to conduct the test.
4. Demonstrate how to interpret the test results.

## Lesson 8: Power Transformer Temperature Indicator Testing

Introductory Information

Because heat can damage many of the parts of a power transformer, temperature indicators are used to monitor transformer temperature. The overheating of transformers damages transformer oil and windings. While this damage may not initially be catastrophic, the damage caused over time may be. Utilities use the temperature indicator to monitor heat cycles and determine the need for maintenance and/or replacement.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand the reason power transformer temperature indicators are utilized.
2. Explain the components of a transformer temperature indicator.
3. Explain how a temperature indicator works.
4. Describe the basic principles of testing a power transformer temperature indicator.

## Lesson 9: Power Transformer Pressure Relay Testing

Introductory Information

Rapid expansion of the gas in a transformer is a sign of catastrophic failure. If gas is allowed to continue expanding, that expansion will force the transformer to develop a leak through a seal, a blown-out fastener, or worse yet, an explosion of the tank. Such an event requires replacement and clean up that is very costly. A power transformer pressure relay should note the rise in pressure in the transformer tank and shut down the transformer before any of the above damage takes place. Improper function of the relay coupled with transformer malfunction will lead to certain disaster. For this reason, periodic testing of the pressure relay should be included in any transformer maintenance program.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe how power transformer pressure relays are utilized.
2. Identify the components of a transformer pressure relay.
3. Explain how a pressure relay works.
4. Describe how to test a power transformer pressure relay.

**Lesson 10: SF6 Gas --- Properties**

Introductory Information

Sulfur hexafluoride, otherwise known as $SF_6$, is an inert gas used as an insulator in numerous pieces of electrical equipment. Typically used in circuit breakers and transformers, it can be used to insulate whole gas-insulated substations. As $SF_6$ is a lighter substance than mineral oil, $SF_6$-insulated pieces of equipment are smaller and easier to install than comparably-sized oil-insulated equipment.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basic traits of sulfur hexafluoride gas.
2. Identify the products created by decomposing $SF_6$ gas.
3. List the protective equipment that should be used when working with decomposed $SF_6$.
4. Explain basic treatment applied when coming into contact with decomposed $SF_6$.

**Lesson 11: SF6 Gas --- Handling**

Introductory Information

Utilized in numerous pieces of equipment in a substation, $SF_6$ gas may be encountered when working with new or used equipment. Many times when new equipment is installed in a station, the $SF_6$ gas insulating that equipment will have to be filled. Sometimes equipment will develop a leak, and the $SF_6$ gas must be refilled. If a fault should occur, a white powder and the smell of rotten eggs will indicate that the decomposition product has been formed. The decomposition product is potentially toxic and corrosive and should be handled while wearing the proper PPE. On a well-maintained electrical system, an arc fault should be a rare occurrence, but is always possible.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain how to safely handle $SF_6$ gas and its decomposition products.
2. Describe basic gas handling requirements.
3. Explain the basics of handling $SF_6$ decomposition products.
4. Explain how to clean equipment that has suffered a fault that produced decomposition products.

**Lesson 12: Vacuum Bottle Hi-Pot Testing**

Introductory Information

One basic function of a vacuum interrupter is to extinguish arcs in electrical equipment. Modern circuit breakers, for example, commonly use a vacuum interrupting configuration. These circuit breakers are for medium-voltage use, typically on distribution circuits leaving a substation. Should the vacuum system leak, the operating system will rise to atmospheric pressure, allowing electricity to arc from one contact to another when opened. This defeats the purpose of having a circuit breaker. Should the vacuum breaker not extinguish the arc, the fault will continue to be energized. This could cause catastrophic failure or even a fatality. Ensuring the proper function of vacuum-operated interrupters is important to the equipment and to the operators working on the electrical system.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain why vacuum interrupters are used.
2. List where vacuum interrupters are used.
3. Describe how to safely perform a high-potential (hi-pot) test.

**Lesson 13: Oil Containment**

Introductory Information

Oil containments are common in substations. Not only does the United States government require an oil containment plan for any location where more than 55 gallons of oil is stored, but as good neighbors, utilities do not want oil to escape should a leak occur. Substation oil containments differ in construction and complexity depending on the substation location, geographic conditions, and proximity to water. The proximity to water is perhaps the most important condition to be considered when creating an oil containment, because if oil reaches water it will spread quickly. The contamination of drinking water quickly becomes an emergency that is very difficult to solve.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain why oil containment rules were created.
2. List the materials used to create an oil containment.
3. Describe the different types of oil containments.
4. Explain why different oil containment types are used.

**Lesson 14: Temporary Substations --- Mobile Units**

Introductory Information

Mobile substations are an important part of a utility company’s equipment. Mobile substations are composed of transformers and any other equipment the utility feels is required for the task at hand. That task may be a scheduled maintenance outage or a temporary need caused by a special event or natural disaster.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe why mobile transformers are important in the power grid.
2. Explain what capacities and components make up a mobile substation.
3. Explain the characteristics of a mobile substation.
4. Describe where and why mobile transformers are used.

# SUBSTATION APPRENTICESHIP
# 3RD YEAR – LEVEL 5
# LESSON LEARNING OBJECTIVES

Circuit breakers perform an important role by preventing the enormous available power from destroying equipment, along with protecting human life. In Level V, the various operational, maintenance, and inspection and testing requirements of circuit breakers are covered. Time-travel characteristics of circuit breakers are also explored in respect to proper selective coordination. The lessons also discuss the roles of capacitors, reactors, voltage regulators, and simple components such as raptor protection and animal control. Bus configuration, connections, welding, and infrared thermography lessons are included.

**Lesson 1: Circuit Breaker Operation**

Introductory Information

To connect power generation facilities to the end users, complex transmission and distribution grids are created. In those grids, circuit breakers are used to connect or disconnect loads. The load on the grid is constantly monitored and, should the load exceed the prescribed amount, circuit breakers open to protect the grid. They operate on this large scale in the same manner as the circuit breakers that are used in a home. If a fault should occur on the line that is downstream of the circuit breaker, that breaker trips, protecting any equipment involved with the fault. Should a line need to be disconnected from the grid, a circuit breaker may be manually operated, separating that circuit from others in the operating system. Circuit breakers are an integral piece of equipment in any substation.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basic operating principles of circuit breakers.
2. Determine which breaker types are used at which voltages.
3. Identify and list different types of circuit breakers.
4. Describe the types of operating mechanisms used in circuit breakers.

**Lesson 2: Circuit Breaker Maintenance**

Introductory Information

As the second most expensive piece of equipment in a substation after the transformer, the circuit breaker is commonly subjected to maintenance. The failure of a circuit breaker can cause catastrophic damage to the electrical system and injury or death to operators working on the electrical system. Because there are many different types of circuit breakers and many different manufacturers, there are also many different inspections that may be required. It is important to check the requirements of the local utility and/or equipment manufacturer to ensure all the necessary tasks have been performed when servicing a circuit breaker.

Lesson Objectives

After completing this lesson, you will be able to:

1. Perform a visual inspection of a circuit breaker.
2. Explain how to clean a circuit breaker to allow for an inspection.
3. Describe the steps involved in a circuit breaker inspection.
4. Explain why different circuit breakers require different inspections.

**Lesson 3: New Circuit Breaker Inspections and Tests**

Introductory Information

A "new" circuit breaker is an unused breaker from the factory or a used breaker from another source. In either case, because circuit breakers are responsible for the protection of personnel and equipment on the electrical system, their ability to operate correctly is imperative. Before any circuit breaker is energized for the first time, a utility should properly inspect the breaker's function.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the important parts of a circuit breaker to inspect upon delivery.
2. Explain when to perform new circuit breaker inspections and tests.
3. Describe basic circuit breaker tests.
4. Explain basic circuit breaker bushing inspections and tests.

**Lesson 4 Circuit Breaker Time-Travel Characteristics**

Introductory Information

Just like a clock with numerous parts, circuit breaker operations must occur sequentially and at the proper time. It is necessary to be familiar with the functional characteristics of the circuit breaker and why those characteristics are so important. Exploring the terminology related to circuit breaker time-travel and the tests that are performed to measure it will help to understand circuit breaker time-travel.

Lesson Objectives

After completing this lesson, you will be able to:

1. Define the terminology used to explain circuit breaker operation.
2. List the components that create a circuit breaker operation.
3. Explain some of the signs of a faulty operating system.

**Lesson 5: Circuit Breaker Time-Travel Testing and Analysis**

Introductory Information

Timing is critical to the operation of a circuit breaker. If the contacts should make or break too slowly, the arc will cause damage to the internal components of the circuit breaker. The operation of the contacts is performed by the circuit breaker's operating system. If the time required to open the contacts after the control signal is received is too long, damage can be caused to all the equipment the breaker feeds. To test

the operating system and its timing, a test set is required. The drop-bar recorder, the light-beam recorder, and the digital timer/analyzer may all be used. Upon performing the test with each of these pieces of equipment, the results must be analyzed.

Lesson Objectives

After completing this lesson, you will be able to:

1. Define a time-travel test.
2. Identify the test equipment used to perform a time-travel test.
3. Explain the basics of using each test set.
4. Interpret the test results of a time travel test, and note when the breaker is not operating correctly.

**Lesson 6: Contact Resistance Testing**

Introductory Information

Circuit breakers and disconnect switches can get dirty with age. This dirt, whether it comes from ambient conditions or from arcing inside the circuit breaker, can cause the contacts to develop resistance to the electrical circuit. This resistance is harmful because it creates heat and leads to equipment failure. To increase electrical efficiency, the contacts should have a resistance as close to zero as possible. Periodic maintenance should include the cleaning and inspection of contacts.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the basic parameters of a contact resistance test.
2. Identify a contact resistance test set and correctly use the test set.
3. Explain how to connect the test set to a circuit breaker and perform the test.
4. Explain how to connect the test set to a disconnect switch and perform the test.

**Lesson 7: Capacitors and Reactors**

Introductory Information

An electrical system can be capacitive or inductive. Either situation may not be very efficient, so capacitors and reactors can be used to increase the efficiency of the system. If the electrical line gets too far out of phase, the power is no longer usable. Electrical utilities commonly use substation capacitors and shunt reactors to reduce the amount of unusable power and increase usable power. Reactors can also be used to protect electrical equipment and personnel from the effects of excessive current.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the basics of how power factor affects the electrical system.
2. Describe how to safely perform capacitor bank maintenance.
3. Describe how to safely perform reactor maintenance.
4. Explain why reactors are connected differently in different circuits.

## Lesson 8: Capacitor Bank Maintenance and Testing

Introductory Information

Like all equipment in a substation, capacitor banks require periodic maintenance. Capacitor banks are typically user-friendly and easy to maintain, but still require knowledge of the characteristics of a capacitor. Like any capacitor, the bank will remain energized for a period of time after being disconnected. Because of this, capacitor banks should be treated with care. When trouble is identified during maintenance, testing should be performed. This testing should help to find the problem with the capacitor bank and ensure the problem is fixed before the bank is reenergized.

Lesson Objectives

After completing this lesson, you will be able to:

1. Properly prepare a capacitor bank to be worked on.
2. Perform maintenance on a capacitor bank.
3. Test and analyze the results on a capacitor bank.

## Lesson 9: Voltage Regulators

Introductory Information

Just as capacitor banks and reactors are used to improve the efficiency of a transmission line, voltage regulators are used to ensure maximum efficiency of the electrical system. Changes in loads can cause voltage swings above or below the stated voltage of an electrical line. Those swings are damaging to any of the customer's appliances connected to the electrical line. Voltage regulators condition the line to keep the voltage within acceptable limits.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the basics of voltage regulator operation.
2. Explain the basics of voltage regulator controls.
3. Describe how to perform a voltage regulator inspection.
4. Explain how to replace a regulator.

## Lesson 10: Bus Configurations

Introductory Information

The bus used to connect equipment in a substation can be organized in different methods. A simple single bus can be used, but if anything on that bus should fail, the whole substation would lose power. A substation that feeds a critical load may have another style of bus. That bus may be more expensive, but the need may justify the expense. A compromise may be reached between a simple bus and a complex bus due to space limitations. Ultimately one bus design will be chosen that balances needs with expenses and complexity. Whichever bus design is chosen, they all require trained individuals to perform the construction.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify bus configurations from one-line drawings.
2. Describe why one bus configuration is more reliable than another.
3. Define electrical bus and how it is used in a substation.
4. Explain why GIS is chosen as a substation option.

**Lesson 11: Bus Connections**

Introductory Information

Different bus connections are chosen for different reasons. The capacity of the connections, the ease of installation, and the availability of the components are all reasons for choosing one type of bus connection over another. Bolted, compression, and powder actuated connectors will be covered. Before performing any work on electrical bus, ensure that the bus is protected with protective grounds.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe some basics about electrical bus.
2. Identify common bus connection traits.
3. Describe how to perform a bolted bus connection and a compression connection on bus.

**Lesson 12: Bus Welding**

Introductory Information

Bus connections are an important part of substation construction. If the connections are not correctly performed, the bus will develop "hotspots." Bus welds are perhaps the hardest connections to make because they require a specially-trained welder, specialized welding equipment, and an environmentally sound environment while welding. For these reasons, bus welding is usually only chosen as a bus connection method when the station is an extra high voltage station or has higher than normal ampacity.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify the basic properties of aluminum bus.
2. Explain why welded bus connections are used.
3. Describe which tools and methods are used to weld aluminum bus.
4. Determine how defective welds happen.

**Lesson 13: Infrared Thermography**

Introductory Information

Infrared thermography is the process of taking infrared photos of electrical bus to check the condition of the bus and connections. Hot spots develop where the bus has higher resistance than normal, and these hot spots will appear on the infrared photos. The basics of infrared thermography will be addressed. In order

to perform this work and produce the reports showing the results of the testing, the thermographer must have the proper licensing, and the information presented alone is not sufficient to prepare anyone to be a licensed thermographer.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the reasons for performing an infrared thermography survey.
2. Describe what is required to become a qualified thermographer.
3. Determine the examinations that are required to become a thermographer.
4. Explain how to maintain a thermographer's license.

**Lesson 14: Raptor Protection and Animal Guards**

Introductory Information

Some experts believe animals are attracted to substations because they emit heat. Others think animals feel safe in surroundings that have nesting potential and are clear enough that they can see predators at a great distance. Whatever it is that attracts animals to substations, they can quickly become troublesome for utilities and operators. Whether building nests or just moving through a substation, animals can cause outages by compromising the designed phase-to-ground or phase-to-phase distances between energized conductors and grounded equipment. Animals can also spread disease and chew through control cables. When building substations, utilities must decide whether animal protection should be installed and, if so, what type to install.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe why animal protection is important in a substation.
2. Identify which animals cause the most problems in substations.
3. List some common deterrents used in substations.
4. Identify animal protection measures installed in substations.

**Lesson 15: Alternative Energy Sources**

Introductory Information

A recent push for renewable energy in the United States has created new power generation possibilities. New substation construction is currently underway to gather and transport this renewable energy from the area of production to the area of consumption. Alternative energy sources, unlike coal, nuclear, or natural gas, are sources that are renewable and do not have a cost for the fuel itself. The conversion of the fuel to energy, however, may be quite costly, which is the reason these methods are still alternatives and not mainstream energy production methods.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the basics of wind power.
2. Describe how solar power is used to create electricity.

3. Explain why hydroelectric power is used today.
4. Understand why geothermal and hydrogen power are still distant generation sources.

# SUBSTATION APPRENTICESHIP

# 3RD YEAR – LEVEL 6

# LESSON LEARNING OBJECTIVES

Level VI focuses on substation controls and the monitoring of all systems and components. Control devices include protective relays and transmission system controllers. These systems communicate through power line carriers utilizing system control and data acquisition (SCADA) equipment. The monitoring of substation components are not only for observing healthy conditions, but for analyzing short circuits and identifying distribution line faults. These systems must have constant power to operate at all times; therefore, lessons on substation batteries and uninterruptible power supplies – and their maintenance and testing requirements – are included. The final lessons discuss the procedures of commissioning and energizing a substation.

**Lesson 1: Substation Control Rooms**

Introductory Information

The control room is typically located in a building that will house relays, batteries, and similar equipment; some control buildings even include a restroom. The items located inside the control building will be listed and their installation explained. Properly installing and marking substation control equipment is critical, and it affects how a substation will be operated after it is installed and energized.

The general guidelines presented for installing substation equipment should be followed in all cases. All of the equipment that can be installed in any particular substation will not be covered, but the proper way of installing equipment will be explained.

Lesson 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 current transformers (CTs) and potential or voltage transformers (PTs or VTs).

**Lesson 2: Protective Relays**

Introductory Information

Transmission and distribution (T&D) systems are designed to protect themselves against equipment damage or loss of service caused by electrical faults. Protective relays play a major role in this regard and can limit or totally avoid equipment damage or loss of service. Protective relays can also provide added protection for employees working on T&D systems.

Lesson Objectives

After completing this lesson, you will be able to:

1. Identify the different elements of protective relays.
2. Recognize the different types of protective relays.
3. Understand the functions of protective relays.

**Lesson 3: Protecive Relays and Transmission Systems**

Introductory Information

Transmission systems require system protection relays that can go beyond those required by distribution systems. While some of the relays used to protect a transmission system are the same as those used for transmission and distribution systems, there are additional relays that are generally used for transmission systems only. Additional communication requirements for transmission relays will also be discussed.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the type, operation, and function of transmission protective relays.
2. Identify the purpose and operation of "transfer tripping" and the communication channels used to accomplish transfer tripping.
3. Explain the components and operation of a breaker failure relaying system.

**Lesson 4: Control Equipment**

Introductory Information

Control is needed in substations to maintain the efficiency of the electrical system and to protect the system from damage resulting from faults. Substation control is provided by both local and remote control systems.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the different types of control equipment used for control and protection of the components of a transmission and distribution (T&D) system.
2. Identify the control systems needed for the protection of distribution feeders, transmission feeders, station fault control, and station source fault control.
3. Explain how to perform a routine check of control equipment.

**Lesson 5: Power Line Carrier**

Introductory Information

Transmission line conductors are used to send control signals and communication between substations. Power line conductors that transmit these communications are referred to as power line carriers. Although an older technology, power line carriers are still used in many areas that have not been converted to fiber optic communication. A power line carrier system consists of equipment to send the communication

signal, equipment to retrieve the communication signal, and the transmission line conductor that carries the communication signal.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe how a power line carrier system works and why it is used.
2. Identify the equipment needed for a power line carrier system.
3. Explain what function power line carrier equipment performs.

**Lesson 6: Supervisory Control and Data Acquisition**

Introductory Information

The United States operates on three electrical grids; one for the west coast, another for Texas, and a third for everything east of the Rocky Mountains. In order to operate these electrical grids, all the utilities and their substations must operate in sync. To maintain this operation, supervisory control and data acquisition (SCADA) equipment is used. A SCADA system allows a remote operator to monitor and control the status of the electrical equipment in a substation. The first SCADA systems were developed in the 1930s and have evolved tremendously since then. With present day developments in microcomputers, SCADA systems have become faster, smaller, and more efficient.

Lesson Objectives

After completing this lesson, you will be able to:

1. List the equipment required in a SCADA system.
2. Explain the functions of SCADA and why SCADA systems are used.
3. Describe how SCADA systems are configured.

**Lesson 7: Short Circuit Analysis --- Testing for Distribution Line Faults**

Introductory Information

When trouble occurs on a line, there are three steps to follow: determine the nature of the fault, locate the fault, and correct the condition. The first two of these three steps to be taken will be explained.

Lesson Objectives

After completing this lesson, you will be able to:

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

**Lesson 8: Metering**

Introductory Information

All utilities must monitor the production and sale of electricity to ensure they remain in business. Even a nonprofit cooperative must ensure enough revenue is generated from the sale of electricity to keep its

employees working and its overhead paid. Instrument transformers are used for revenue purposes or to ensure the substation remains operating within its limits. Instrument transformers include current transformers (CT) and voltage transformers (VTs or PTs).

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain how metering is performed in a substation.
2. Describe the basic fundamentals of a current transformer and a voltage transformer.
3. Describe the installation practices of metering equipment.

**Lesson 9: AC/DC Generators**

Introductory Information

A substation control room is susceptible to outages just as the lines to customers are. The outages can be planned or due to an emergency. Either way, when the power goes out in a substation control building, the protection, communication, and control systems become powered by the substation batteries. This is acceptable for a while, but if the site is a remote or critical station that cannot be serviced in a timely fashion, a backup generator may be used to ensure that protection and control continues. A backup generator may also be used for the servicing of the station service transformer within a substation. Modern generators output AC and DC power, which makes them convenient in a substation where the AC power can run a building's heating, ventilation, and air conditioning (HVAC) while the DC can be directly wired to the station batteries.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain the basic components of a backup generator and how they perform station backups.
2. Describe the basic maintenance of a generator.

**Lesson 10: UPS --- Uninterruptible Power Supplies**

Introductory Information

Most industrial, commercial, and residential power distribution systems are primarily designed for lighting, HVAC, and motor loads. Information technology (IT) sites, offices, communications sites, and the general adoption of sensitive microprocessor-controlled devices have proven the need for isolating these loads from the inherently electrically "noisy" distribution system. Uninterruptible power supplies (UPSs) are sophisticated electrical devices that use utility power to synthesize a power source isolated and dedicated to the critical load equipment. When there is a power loss or severe disturbance to utility power, the UPS will continue supplying power to the critical load, drawing its energy from an alternative source until input power is restored.

UPSs range from small, single-phase units designed for use on personal computer equipment (200 VA–2 kVA) through medium-sized UPSs used for IT rooms and clusters of equipment in the office environment (5–100 kVA) to large installations such as IT sites or major facilities (200 kVA–1+ MVA).

Lesson Objectives

After completing this lesson, you will be able to:

1. Know what a UPS is.
2. Know what a UPS is for.
3. Be familiar with various types of power disturbances.
4. Be familiar with UPS types and configurations.

**Lesson 11: 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.

Lesson 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 12: Substation Battery Testing**

Introductory Information

Substation batteries perform a critical function in protecting substation equipment, circuits, and the continuous flow of power. The Institute of Electrical and Electronics Engineers (IEEE) has established universally-accepted standards for the testing and maintaining of substation batteries. The standards set forth by the IEEE will be discussed.

Lesson Objectives

After completing this lesson, you will be able to:

1. Explain how to complete voltage and resistance tests.
2. Explain how to complete a specific gravity test.
3. Explain how to complete integrity and capacity tests.
4. Explain how to complete an impedance test.

**Lesson 13: Substation Battery Chargers**

Introductory Information

A substation battery charger plays a key role in the DC control system. It converts AC power to DC and provides the normal DC power to the DC control system. It also provides the DC power necessary to maintain the substation battery at peak operating level.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe the functions and know the components of a substation battery charger.
2. Know the different types of charges available and when each type of charge is needed.
3. Explain how to conduct periodic inspections and make needed adjustments.

**Lesson 14: Substation, Cell and Charger Replacement**

Introductory Information

Substation DC control systems are critical to the protection of substation equipment and transmission and distribution systems. Therefore, the replacement of cells, batteries, and battery chargers is often done with the systems in service.

Lesson Objectives

After completing this lesson, you will be able to:

1. Describe how to replace a cell while continuing to provide DC protection to the system.
2. Explain how to replace a battery while continuing to provide DC protection to the system.
3. Describe how to replace a battery charger while continuing to provide DC protection to the system.

**Lesson 15: Commissioning a Substation**

Introductory Information

Before a new or expanded substation can be put into service, many tests must be performed. The term used to cover the necessary testing is “commissioning a substation.” Commissioning a substation can consist of numerous tests, from visual inspections to ensuring relays operate when a fault occurs. This is a good opportunity to test equipment before it enters service in order to establish baseline criteria against which to compare future testing data.

Lesson Objectives

After completing this lesson, you will be able to:

1. Understand why and when commissioning is performed.
2. List the equipment in a substation that requires commissioning.
3. Explain how to commission the supervisory control and data acquisition (SCADA) system.