Chapter 8

Specific Requirements of the NESC

Chapter Outline

Published by the IEEE, the National Electrical Safety Code (NESC®) establishes rules to safeguard workers during the installation, operation, or maintenance of electric supply and communication lines and associated equipment. The purpose of the NESC is to provide practical safeguard methods for both utility workers and the public during the installation, operation, and maintenance of electric supply and

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communication lines and equipment. The major risk hazard in this type of work is the high voltage involved in supplying power from stations and substations to property locations. Some of the requirements for electrical supply structures, equipment, and locations share basic similarities to standards for residential, commercial, and industrial systems covered in the NEC.

High voltage power is intrinsically dangerous and results in injuries that are often catastrophic and frequently fatal. It is not just utility workers who are at risk from high voltage power. Anyone working around power lines needs to be mindful not to inadvertently come in contact with the energized circuits. This includes people working on roofs, scaffolding, and bucket trucks and dump trucks. Even though the NESC provides specific clearance requirements for line installations and clearances, a number of circumstances can occur on construction sites that create hazards. For example, at one New England construction site several winter storms had resulted in a large pile of snow next to a commercial construction site. Snowplows drove over the snow repeatedly and compacted the snow several feet thick. A dump truck arrived at the site to deliver a load of crushed stone and, because the top of the snow level was now much higher than the original level of the ground, the dump truck bed contacted overhead power lines when it was raised up. In this case, the power lines had been installed properly; however, the dump truck operator did not take the time to notice that there were overhead lines before he engaged the dump body. This is a perfect example of why anyone working near power lines must be mindful of clearances and currents.

Electric supply installations

High voltage hazards originate at the point of power generation, which is often the electric supply station. Supply stations are required to be enclosed or fenced to restrict access by unqualified workers. Mechanical parts that are located inside a station must also be safeguarded or isolated. NESC 123 requires protective grounding of all non-current carrying metal parts. If a conductor, bus section, or equipment is disconnected for maintenance purposes, it must also be grounded with either permanent grounding switches or portable grounding jumpers (Figure 8.1).

Figure 8.1 Grounded bus bars can be used in a power station to protect non-current carrying metal parts.

NESC Table 124-1 is used to determine the required clearances to energized parts in an electric supply station. Additionally, Rule 124A3 specifies an 8 foot 6 inch clearance requirement to parts with an indeterminate potential. This is the space between the top and bottom of a bushing that has an unknown voltage. The required clearance to live parts in the station is determined based on vertical and/or horizontal clearances. If substation equipment is located on a concrete pad that is large enough to stand on, then the clearance measurement is taken from the top of the concrete pad. Otherwise, the measurement is made from the substation surface.

The NESC does not specify bus-to-bus clearance, conductor to bus clearance, or conductor-to-conductor clearance. Instead, "accepted good practices" are to be used. ANSI C37.32 and NEMA SG6 are used to define accepted good practice.

Current and Voltage Transformers

Electric supply stations generate power. Transformers transfer electric energy from one alternating-current circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage. A current transformer (CT) is used for the measurement of electric currents (Figure 8.2).

CTs are commonly used in metering and protective relays in the electrical power industry. A voltage transformer (VT), sometimes known as a

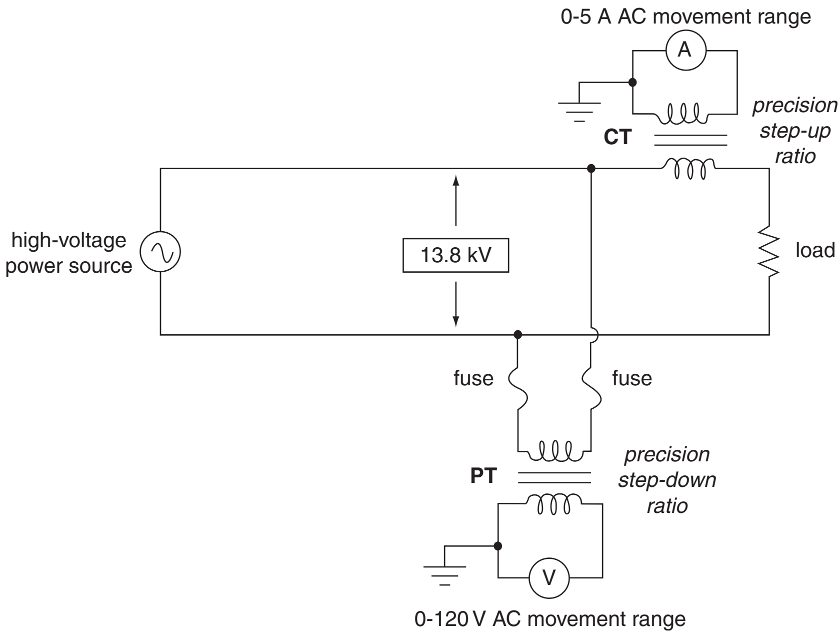


Figure 8.2 A schematic of a typical current transformer.

potential transformer (PT), converts supply voltage to a voltage level suitable for a meter. In this type of transformer, the secondary voltage is substantially proportional to the primary voltage and differs in phase from it by an angle that is approximately zero for an appropriate direction of the connections (Figure 8.3).

The secondary circuits of a CT have to be protected, typically by metal conduit, and secondaries of both CTs and VTs must be effectively grounded. This safety protocol protects against dangerously high voltages and arcing that could occur in open or damaged secondary circuits. Additionally, electric supply station power transformers require a means of automatically disconnecting short-circuit protection.

Conductors

Conductors in an electrical supply station have to be suitable for the location, use, and voltage, and must be sized to provide adequate ampacity. Compliance is based on the ampacity table in the NEC,

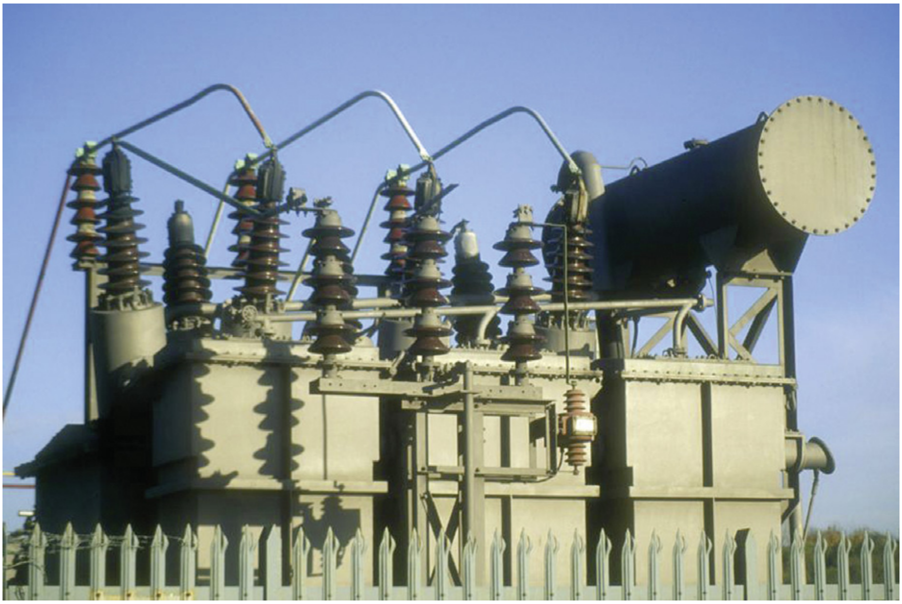


Figure 8.3 A voltage transformer is used to convert high voltage supply current to a lower voltage.

which is also used to determine fuse and circuit breaker sizes. For example, a 120-volt, 20-amp, single-pole, thermal-magnetic circuit breaker used to protect a #12 American wire gauge (AWG) copper, 600-volt conductor serves as both overload protection by means of the circuit breaker thermal element and as short-circuit protection via the breaker's magnetic element.

An electrical protection device may protect the conductor as well as a piece of equipment. For example, the high-side fuse of a substation transformer can also serve as short-circuit protection for the substation bus bars and transformer.

Surge Arresters

Surge arresters are used to protect equipment in electric utility systems from overvoltage due to switching surges. In electric supply stations, surge arrestors are used to limit damage to vital equipment such as

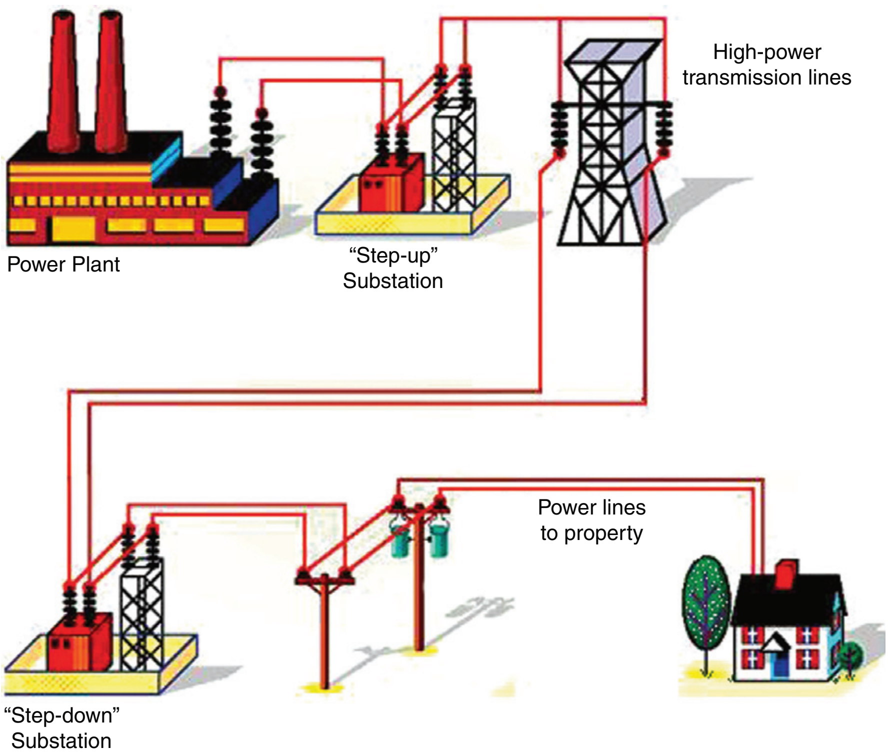


Figure 8.4 This figure illustrates the transition of power from the source at the power supply station to residential use.

power transformers. Surge arrestors should be installed as close as possible to the equipment they protect. Because these arrestors can discharge hot gases and produce electrical arcs, they need to be located away from combustible or energized parts (Figure 8.4).

Communication lines

Communication lines can be affected by voltages induced by power supply lines. However, clearance requirements between power and communication lines are designed for safety, not to eliminate induced voltage. Multiple communication lines on the same structure that are exposed to power contacts, induction, or lightning have to be bonded together, while single communication messengers have to be effectively grounded. If a guy insulator separates a guy, it must be placed on the guy no less than 8 inches above the ground level. Insulators also have to be installed on a guy in a manner that will not permit voltage transfer to the power facility if the guy comes in contact with an energized part or conductor. You also need to install insulators so that if the guy sags down the insulator will not become ineffective.

The communication lines themselves must also be protected by insulation if the conductors exceed 300 V to ground or carry a steady-state induced voltage of a hazardous level. Additional protection should be provided by surge arrestors in conjunction with fusible elements as necessary when severe conditions, such as large supply station current, exist.

> Communication circuits that are located in the same space on a pole as the power supply must be installed and maintained by a qualified person per NESC Sections 42 and 44.

Communication lines belonging to different utilities require a clearance of 4 inches between the cables. This keeps communication circuits owned by one company from sagging onto or below communication circuits owned by another utility company. You are not required to take the temperature of loading conditions and variations into consideration when you determine the required 4 inches. However, if the two independent utility companies agree, they can waive the 4-inch clearance requirement. The clearance standard for separate communication lines is covered under Rule 235H2.

Overhead power lines

In order to be considered current carrying, conductors must be connected to a voltage source. A conductor that is used as a common neutral for primary and secondary circuits must be effectively grounded. Line or service conductors that are not neutrals and which are intentionally grounded must meet the requirements of NESC Section 09. If a surge arrestor depends on a ground connection, it must be grounded. An example of a non-dependent surge arrestor would be one across the phase bushings of a voltage regulator. Non-current carrying parts are items such as guy wires. Guys have to be effectively grounded or insulated; however, you cannot use only the guy anchor as a grounding method. Other non-current carrying parts that need to be effectively grounded include metal parts, lampposts, conduits and raceways, cable sheaths, metal switch handles, and operating rods.

You do not want just anyone climbing up a power pole or lattice tower. For this reason, there needs to be 8 feet between pole steps and standoff brackets. This creates a "not readily climbable" support structure and meets the requirements of NESC Section 02.

When you layout power lines for support structures, caution should be used to avoid conflict between various types of lines, such as supply phase lines and communications lines. An ideal configuration that achieves sufficient separation of lines would be as follows:

- Starting at the top of the pole, install power supply phase and neutral lines
- Moving down the pole, install communications lines such as cable TV and telephone (Figure 8.5)

The phase and neutral power lines that run on the same structure are considered "collinear construction." The term "joint use construction" would apply to two or more different kinds of utilities that use the same structure, such as the power lines combined with the communication lines. The basic rule of thumb is to separate lines based on the type of circuit, total number and weight of conductors, the number of branches (taps) and service drops, and any encroaching obstacles such as trees or right of ways.

Power Line Spans

Probably the most frequently referenced part of the NESC is Rule 232 in Section 23, which refers to vertical clearance requirements for above ground wires, cables, conductors, and equipment. Two of the most important clearance safety considerations are sag and tension of conductors. Sag results from environmental elements such as wind, ice, as well as conductor temperature, and is influenced by support structure spans. Sag values are commonly calculated at the center of a span.

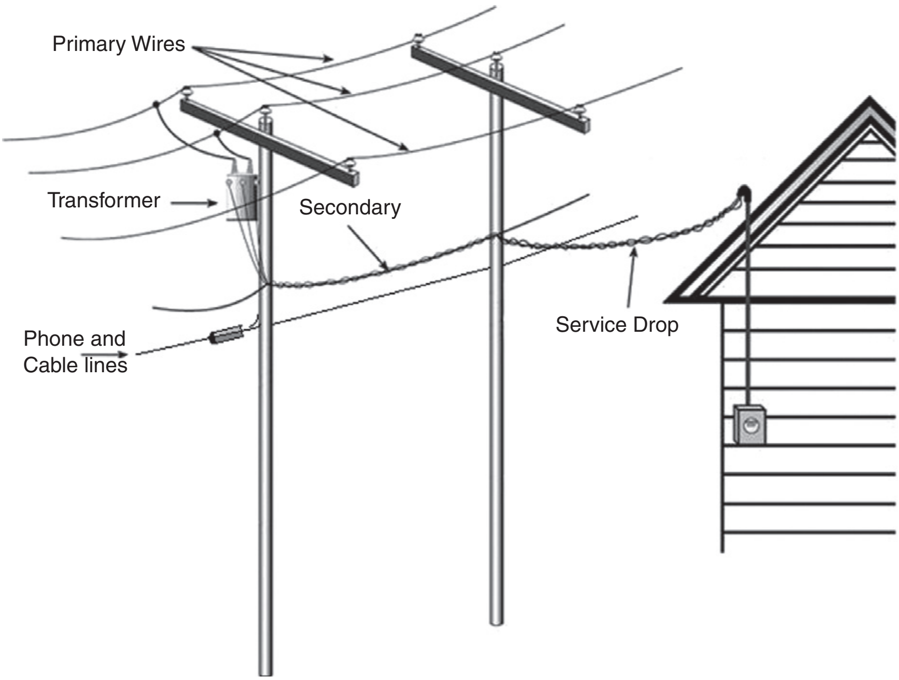


Figure 8.5 Power lines must be separated on the pole from equipment and communication lines.

> A "ruling span" is the span that governs, or rules, the actions of all of the spans between two conductor deadends. Span lengths are critical in correctly calculating tension and sag potentials.

The first step in determining line clearances is to calculate the ruling span by using a formula based on span lengths between the conductor deadends. Each span is assigned a consecutive number where S1, S2, S3... are the span lengths between deadends as illustrated in the following formula:

$$\text{RULING SPAN} = \sqrt{\frac{S_1^3 + S_2^3 + S_3^3}{S_1 + S_2 + S_3}}$$

The NESC contains a sag and tension chart based on a span length that is equal to the ruling span, but to estimate the sag for spans that are longer or shorter than the ruling span, use this formula:

$$\text{Sag in feet} = \left(\frac{\text{Span length}}{\text{Ruling span length}}\right)^2 \times \text{Ruling span sag in feet}$$

Conductor temperatures are based on the amount of electrical current carried by the conductor and environmental factors such as the ambient air temperature, cooling effects of wind, and radiant heating effects of the sun. The maximum sag for a conductor usually occurs at 32°F with ice, 120°F final, or greater than 120°F. The minimum tension occurs at the maximum sag due to the high temperatures at the final tension point. Increasing tension will decrease sag. Characteristics of the conductor that affect sag and tension calculations include the AWG rating, cross-sectional area (Area), diameter (Dia), weight (Wt), and rated tensile strength (RTS).

> The phase and neutral conductor of the same circuit may operate at different temperatures because they can carry different levels of electrical current. For this reason, you need to consider them separately from the power conductor.

Ice and wind conditions are divided into three geographical location zones. Zone 1 includes the north central and northeast areas of the United States and Alaska. Zone 2 consists of the northwestern, mid-central, and mid-eastern portions of the United States. Zone 3 is comprised of the southwestern, south central, and southeastern areas of the U.S. These loads are used to determine the physical loading limits for conductors; however, sag is checked at the ice condition only provided in NESC Table 230-1. The minimum permissible sag clearance for phase conductors is 18 feet 5 inches from any point, not just the mid-span. For the neutral conductor, the minimum sag is 15 feet 5 inches, and 16 feet for any secondary duplex, triplex, or quadruplex lines. Communication line sag cannot be less than 15 feet 5 inches to any roads, streets, or other travel areas that could support truck traffic (Figure 8.6).

Supply Employee Safety

Sections 42 and 44 relate to worker safety guidelines and requirements. Personal protection precautions are provided regarding protective devices, equipment, and guidelines. For example, the section on emergency methods indicates that all power line workers should be familiar with first aid, rescue techniques, and fire extinguishing methods.

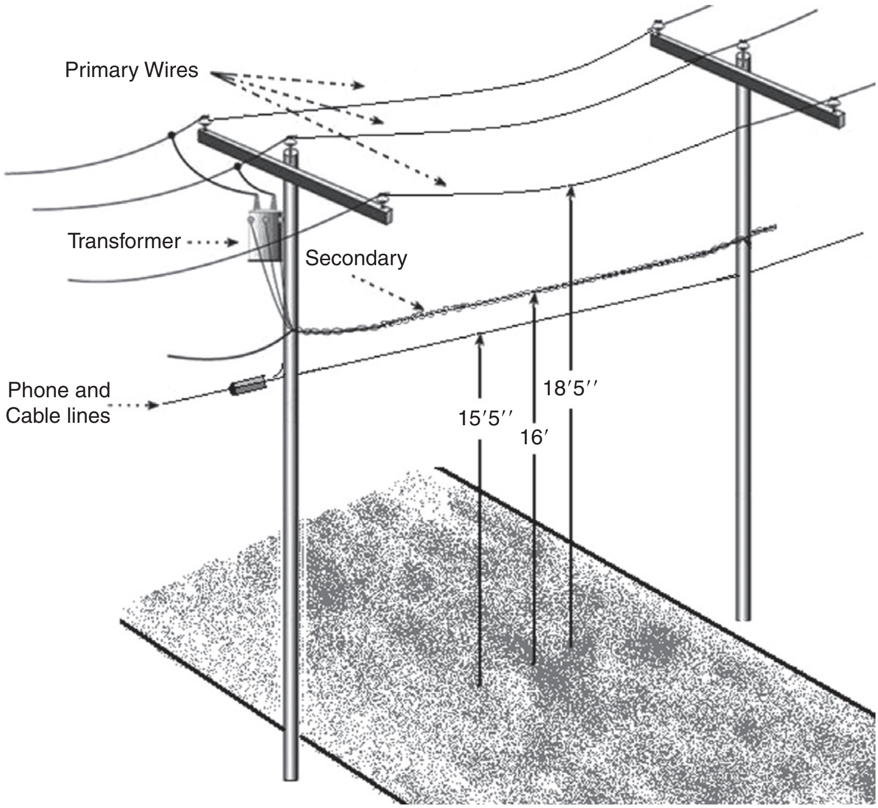


Figure 8.6 Clearances are required to account for line sag and separation.

Section 42 also explains your responsibility to safeguard yourself and others. You are required to report any line or equipment defects, such as low clearances and broken insulators, observed while working on supply lines. This applies to any supply lines, not just the ones you have been assigned to work on. Employees who work on energized lines must consider the effects of their actions and account for their own safety as well as the safety of other employees on the job site. This includes simple things, like not bringing a travel mug up in a bucket with you when you are working. If you were to drop something like this from 30 or 40 feet in the air, you could create a hazard for others on the ground.

Employees cannot take conductive objects closer to energized parts than the gap that is allowed by the approach distances outlined in

Tables 441-1 through 441-4. Even if you think lines should be de-energized, you need to consider equipment and lines energized unless you are positive that no current is present. This applies to underground lines as well. You also need to assume that ungrounded metal parts are energized at the highest voltage to which they are exposed. This means that before you start working on any lines or equipment, you need to determine the operating voltage for them.

As with any other type of electrical worker, power line employees must use PPE that is appropriate for the work conditions, equipment, and devices involved in the task that they need to perform. Climbers must use fall protection systems if they will be working more than 10 feet off the ground.

> If you will be working from a wooden ladder, do not reinforce it with metal of any kind.

Another aspect of work that you need to be mindful of is working underground. When working in a manhole, you need to test for combustible or flammable gases before entering and NEVER ever smoke in a manhole. Besides the potential for explosions from residual or trapped gasses, cigarette smoke will diminish the oxygen supply.

Approach Safety

Section 44 provides additional safety rules for supply employees. For example, communication line workers must adhere to a minimum approach distance of 2 feet 2 inches to a 12.47/7.2 kV line. There is a 40-inch clearance requirement between a power supply line and a communication line. If this clearance does not exist on a pole, then a communication line worker would have to call a trained supply employee to perform the communication line work.

Other workers, such as roofers, painters, or chimney sweeps, working in the vicinity of a power line must maintain a minimum 10-foot clearance from any supply line. This may be something that they are completely unaware of, and so, based on Section 42, it becomes your responsibility to inform them of the clearance requirement.

Approach distances when working from a pole or bucket include both an electrical component and an inadvertent movement consideration. For voltages up to 0.750 kV, the inadvertent movement component is the electrical component plus 1 foot. For voltages between 0.751 kV and 72.5 kV, the consideration is the electrical component plus 2 feet. Protective clothing also needs to be rated to accommodate the voltage of the circuits you will be working around. If you are working on a line with a voltage between 51 and 300 V, you must wear cover-alls that are rated for the phase-to-phase or phase-to-ground voltage of the circuit, depending on the exposure of the circuit (Figure 8.7).

Support Structure Clearances

Supply lines are not the only installation elements that have clearance requirements. There are specific distance rules from the supporting structure to a variety of other interferences. For example, a grounded

Figure 8.7 Line workers are required to adhere to approach minimums and inadvertent movement allowances.

streetlight pole must provide 15 feet of clearance from the bottom of the grounded luminaire to the top surface of a road or street that is subject to truck traffic. If a supporting structure is up to 15 feet above the road surface it cannot be installed less than 6 inches behind the street side of a redirectional curb and it must be behind a swale-type curb.

Clearances for “pedestrian-only” areas are 14 feet 5 inches, 12 inches, and 9 feet 5 inches consecutively. But be careful using these lower sag limits in locations such as rural or forested areas accessible to horseback riding because then the pedestrian-only criteria will not be met.

Power line safety for electricians

Power supply and communication line workers are not the only people who find themselves exposed to high power voltage hazards. As a commercial or residential electrician you may be exposed to power line risks at their worst and you need to have an overall understanding of how to react. First and foremost, always assume power lines are live. This applies to power lines near homes and buildings, not just lines on poles (Figure 8.8).

Not all energized power lines bounce around the ground sparking or starting fires. Even though you may see a covering on a line, never assume it is safe to touch. All it takes is a second of contact with power lines to cause injury or death. Remember all of the electrical hazards we have already addressed, such as the fact that electricity will cause your muscles to clench, making it impossible to break free from contact with a high voltage current.

Never setup a ladder near power lines. As an electrician, you do not necessarily know what the safe clearances are around power supplies. When you do have to work from a ladder, keep the ladder, tools, and anything else you may be carrying at least 10 feet from power lines. Sometimes you may need to work higher than a ladder and that is when you need to stop first and look for power lines. Use a spotter to ensure that you are complying with safe line clearances. Keep all cranes, scaffolding, and high reach equipment away from supply lines so that you can avoid accidental contact that will cause serious burns or electrocution (Figure 8.9).

Figure 8.8 Downed power lines that are still energized can spark and cause fires. It is easy to tell that this line is still energized.

When you are performing any construction activities, keep equipment at least 10 feet from power lines and 25 feet from transmission tower lines. Do not climb or trim trees that are close to power lines, and NEVER try to dislodge or knock down a broken tree limb that is stuck on a power line. Maybe that sounds like a no-brainer, but just recently an electrician was electrocuted when he tried to pull a broken tree branch off the power line running to a house he was working on.

The power company in the area where I live runs periodic television ads warning everyone to stay away from fallen power lines. Their motto is "No line is safe to touch, ever." Remember that the earth around a downed line can be energized, so stay away from fallen power lines and be especially careful to avoid metal objects in the area such as street signs, metal handrails, guardrails, or fences that may have become electrified. Because you cannot tell by looking at a fallen power whether it energized or not, it is imperative that you call your local utility right away and report the location of any downed wires. If a line falls on

Figure 8.9 Any equipment that extends above the ground, such as cranes, booms, scaffolding, or ladders can accidentally come in contact with high-voltage lines if you do not take distance requirements into consideration.

your car, stay in your car. There is no guarantee that you can safely get out of the car without accidentally touching any part of the car and the ground at the same time (Figure 8.10).

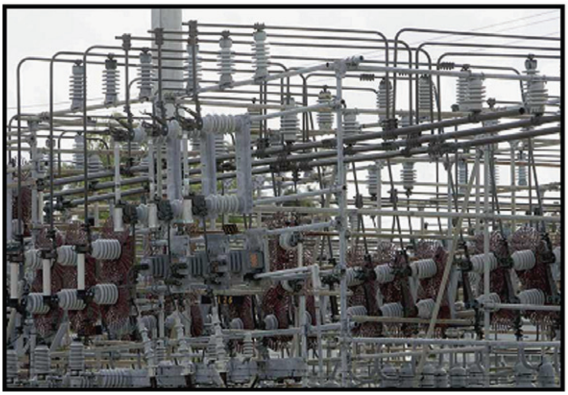
If you have to dig anywhere, for any reason, call your local underground utility locating service first. By law, most states require you to call your local utility to identify any gas, electric, telephone, or other utility lines before you dig. Last year, a nationwide 8-1-1 Call Before You Dig number went into operation. You can't assume that supply cables run underground from a pole to a building service in a straight line. Whether you only have to dig a shallow trench or need to dig down several feet next to a building foundation, any contact you make with a shovel, pick, or other piece of equipment can result in injury or death.

Communication workers know that it is not just power lines that can injure you. Fiber optic cables are becoming a lot more common in most

Figure 8.10 Sometimes fallen power lines appear to be harmless and de-energized because no arcs are occurring, when in fact they are energizing the ground and any other metal objects around them.

areas. They're used by phone companies, cable companies, and others utilities for communications purposes. Like power lines, these cables can be broken or knocked down by storms or accidents, but many people assume they don't carry enough current to cause any harm. What fiber optic lines do carry is laser-like light beams that can cause severe eye damage if someone looks into the end of the cable. And the cable strands are made of extremely fine threads of glass, which can easily cut through clothing and skin. Fiber optic cables are usually from ¼ to ¾ inch in diameter, with black insulation, and have multi-colored plastic buffer tubes inside, lined with glass threads, with an outside insulation that often has orange identifying bands or markings.

Whether you are a basic electrician or a power line worker, your safety is contingent on identifying potential high voltage hazards. As a line worker, you are equally responsible for protecting the public and property by ensuring that any installation or maintenance you perform is in compliance with NESC and any other applicable codes. The risk of serious injury or death is far too great to claim ignorance or imprudence when it comes to working around high voltage systems, equipment, and structures (Figure 8.00).



HIGH VOLTAGE SAFETY FACTS

The International Electrotechnical Commission defines High Voltage circuits as those with more than 1000 volts for alternating current and at least 1500 V for direct current,
Switchgear line-ups and high-energy arc sources are commonly present in electric power utility substations and generating stations. NFPA 70E should be used to evaluate and calculate potential arc flash hazards and select appropriate PPE
Metal ladders, farm equipment, boat masts, construction machinery, aerial antennas, and similar objects are frequently involved in fatal contact with overhead wires
A tree can become electrified when branches contact high voltage lines
Never burn brush or build fires under power lines because the heat and flames can damage or destroy the wires, insulators and supports of the transmission line;
Many states, such as Georgia, Virginia, Delaware, and Maryland have issued independent High Voltage Safety Acts designed to in work or activity in the vicinity of overhead high voltage lines.
If High Voltage power lines are so dangerous, why can a bird land on the line and not get electrocuted? A bird can sit on a high-voltage wire without harm, since both of its feet are at the same voltage and the bird is not grounded (in contact with the earth)

Figure 8.00 Know the facts of potential hazards when working near high voltage systems.