CHAPTER 5

Suggested Practices: Power Line Design and Avian Safety

IN THIS CHAPTER

This chapter address avian electrocution concerns from the engineering perspectives of design, construction, operations, and maintenance. It describes ways of designing new facilities and retrofitting existing facilities to be "avian-safe."

As communities grow, their demand for electricity increases. Additional power lines must be built to supply the additional power. The more miles of power lines there are, the greater the potential for birds to interact with electrical facilities and their inherent hazards.

Biologists and planners must have a basic understanding of power systems, power line designs, and related terminology to identify and implement successful solutions to bird electrocutions. This chapter discusses North American power lines, and the designs and configurations that present avian electrocution risks. For further reference, a glossary of terms is provided in Appendix D.

This 2006 edition of *Suggested Practices* supersedes the recommendations incorporated in the 1996 edition and includes updates based on growing field experience and product performance testing. Despite efforts to present "state-of-the-art" recommendations, users of this manual should be aware that many wildlife protection products have not been tested or rated from an engineering perspective.[20] An IEEE Working Group under project P1656 is writing a guide entitled *Guide for Testing the Electrical, Mechanical, and Durability Performance of Wildlife Protective Devices Installed on Overhead Power Distribution Systems Rated up to 38 kV*. The guide will provide technical guidance for testing wildlife guards and should be available in 2006. Utilities are encouraged to share or publish information regarding avian-safe power line construction and retrofitting experience that can be used to refine future editions of *Suggested Practices*.

[20] However, the recommendations provided in this manual have been field tested by utilities and some results have been published in scientific and engineering journals.

INTRODUCTION TO ELECTRICAL SYSTEMS

DISTINCTIONS BETWEEN TRANSMISSION AND DISTRIBUTION LINES

Power lines are rated and categorized, in part, by the voltage levels to which they are energized. Because the magnitudes of voltage used by the power industry are large, voltage is often specified with the unit of kilovolt (kV) where 1 kV is equal to 1,000 volts (v). Generally, from the point of origin to the end of an electric system, line voltage is used to designate four classes or types of power line (Table 5.1).

TABLE 5.1: Voltage ranges of different power line classes.

Designation	Voltage Range
Generation plant	12 V to 22 kV
Transmission	60 kV to 700+ kV
Distribution	2.4 kV to 60 kV
Utilization	120 V to 600 V

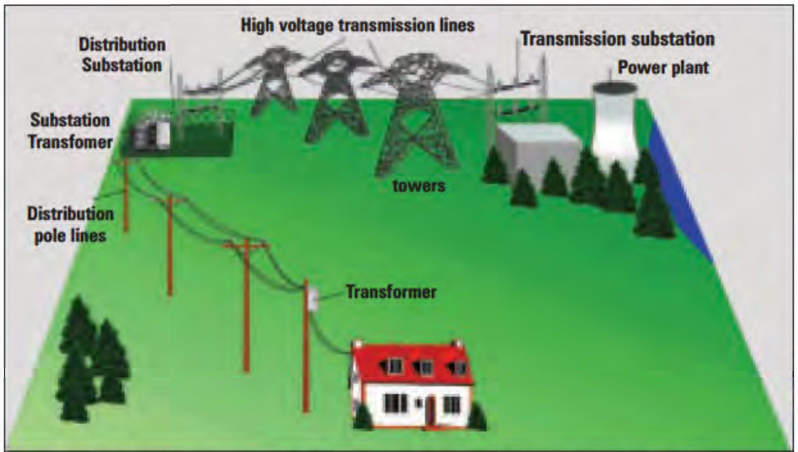

FIGURE 5.1: Schematic of power system from generation to customer.

In addition to the voltage level, power line classification is dependent on the purpose the line serves (as shown in Figure 5.1). This publication is concerned with electrocution hazards that electric distribution and transmission lines may pose to birds. In this manual, lines that are energized at voltages ≥60 kV are considered transmission lines, and lines energized at voltages <60 kV are considered distribution lines, however, this may vary with different utilities. Performance experience indicates that low voltage (secondary) lines—also called *utilization facilities* (≤600 v)—are not often involved in avian electrocutions.

DIRECT CURRENT AND ALTERNATING CURRENT SYSTEMS

Although there are some direct current (DC) power systems where current flows in system conductors in only one direction, most commercial power systems in the United States use alternating current (AC). In AC systems, current flows in system conductors in one direction for 1/120th of a second, going from zero amperes to a peak ampere value and back to zero amperes. It then reverses direction and, for another 1/120th of second, flows in the opposite direction in system conductors, again going from zero amperes to a peak magnitude and back to zero amperes. It then changes direction again and the cycle repeats. If projected on a graph, the current would appear as a sinusoidal curve as depicted in Figure 5.2, that shows at least two complete cycles of current flow on phases A, B, and C of a three-phase circuit. In the United States, there are 60 such cycles each second (also referred to as 60 hertz). There are more AC systems than DC systems because utilities can transmit large amounts of power over long distances on high voltage transmission lines and can take advantage of the alternating magnetic fields associated with AC systems.

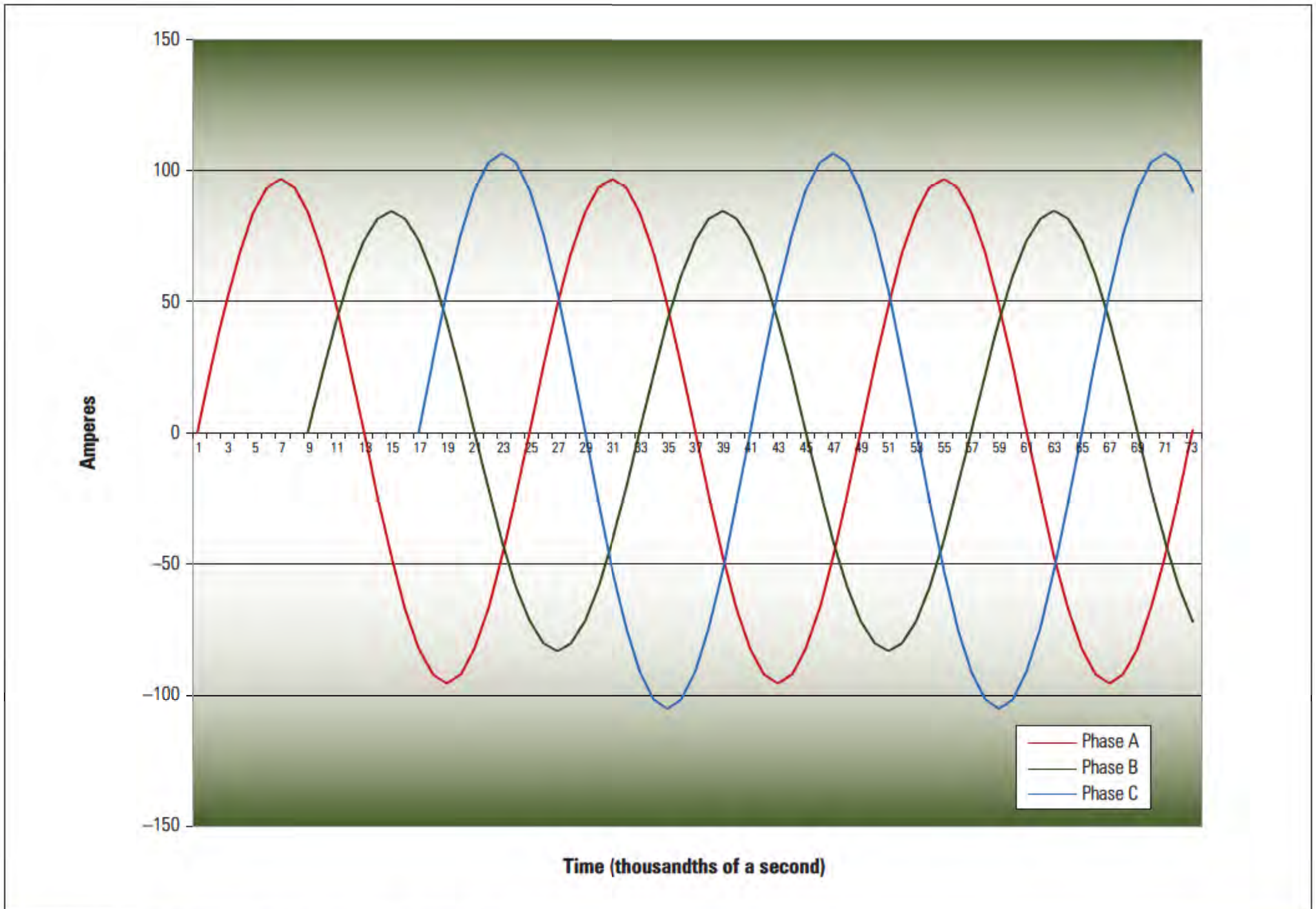

FIGURE 5.2: Three-phase current waveform.

OVERHEAD VERSUS UNDERGROUND

Utilities install facilities either overhead or underground, depending upon numerous factors and concerns. Some key factors include customer needs, terrain and environment restrictions, costs, and code requirements. Cost is a major concern as utilities have a responsibility to serve customers with high quality, reliable electric service at the most reasonable cost possible. Although facilities are installed underground in many areas throughout the country where utilities have found it technically and financially feasible to do so, there are many more areas where utilities have determined that installing facilities underground is not feasible, leaving lines to be installed overhead. If all lines could be installed underground, birds would have little exposure to electrocution hazards and there would be little need for this publication. However, it is neither practical nor feasible to install or convert all overhead lines to underground and it becomes less practical as the voltage of the line increases. The focus of this publication, therefore, is to provide overhead power line designs and modifications that minimize electrocution risk for birds.

SINGLE, TWO, AND THREE-PHASE OVERHEAD SYSTEMS

Most AC commercial overhead power lines utilize some form of support structure from which insulators and electrical conductors are attached. Support structures may consist of preservative-treated wood poles, hollow or lattice steel structures, steel-reinforced concrete poles, or composite poles made from fiberglass or other materials. Insulators are made of porcelain or polymer materials that do not normally conduct electricity. Electrical conductors are usually manufactured from copper or aluminum.

The basic workhorse of the electric utility is the three-phase circuit that consists of structures, as described above, that support at least three electrical phase conductors with or without a neutral (or grounded) conductor. The separate phase conductors are energized at the same voltage level but are electrically 120° out of phase with one another (see Figure 5.3 for a diagram of the three phase voltages and their time relationships). Because of this electrical phase difference, the conductors are called phase conductors. In electrical engineering, the term "phase" has several significant meanings, however, for this publication, it is used to mean an energized electrical conductor with the electrical characteristics described above. Three-phase systems are used for both distribution and transmission lines. One of the primary benefits of three-phase systems is the ability to deliver large amounts of power over long distances. Most electric systems originate as three-phase facilities and,

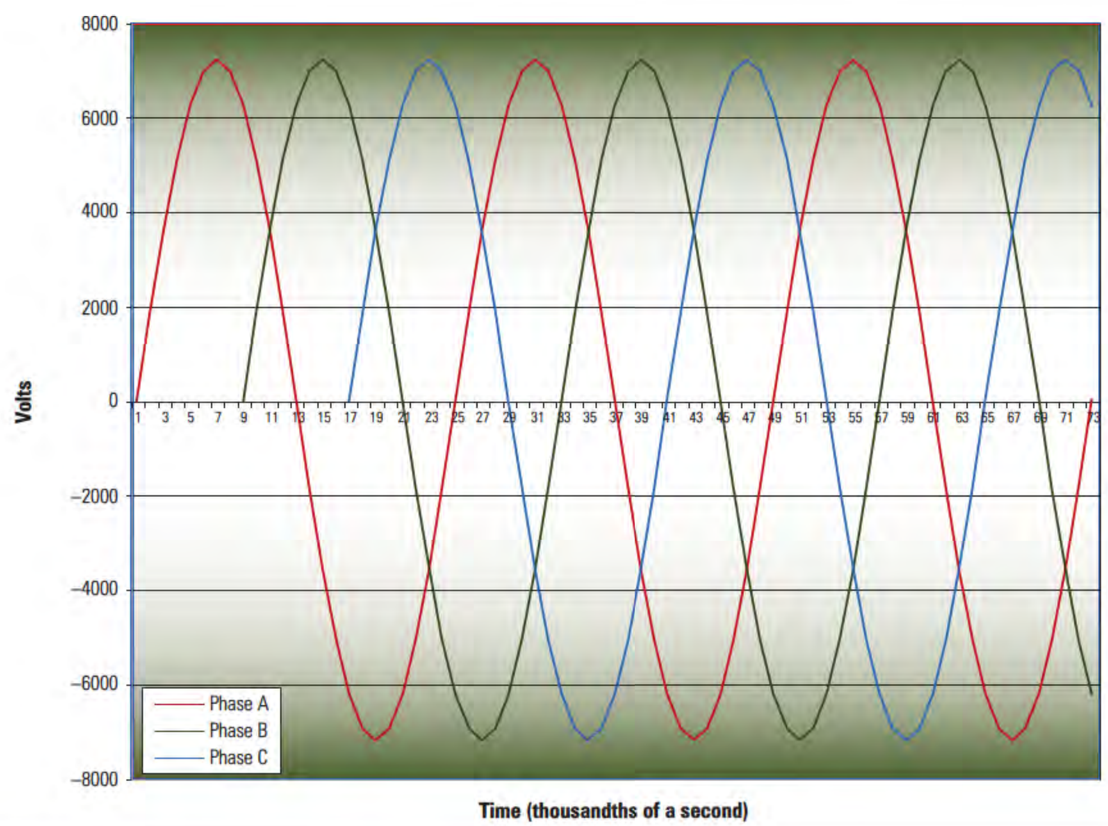

FIGURE 5.3: Three-phase voltage waveform.

out on the power line route, change from three-phase to two-phase (i.e., V-phase) facilities or to single-phase facilities.

Because of limited rights-of-way (ROW) availability and the need to deliver significant amounts of power, some power line structures may carry several three-phase circuits. In some cases, the structure supports two or more three-phase transmission circuits high on the structure while the lower portion supports several three-phase distribution circuits. Structures could also support low voltage utilization circuits for street lighting or electric service to homes and businesses. Distribution circuits installed on the lower portion of a transmission structure are commonly referred to as "underbuilt" distribution.

Transmission line structures always support at least one three-phase circuit. They have three energized conductors (more if bundled), and may have one or two grounded conductors (usually referred to as *static wires*) installed above the phase conductors for lightning protection. Again, there may be more than one three-phase circuit supported on the same structures.

Distribution line structures may support a variety of conductor configurations. A distribution line could consist of three phase conductors only, or three separate phase conductors and a single neutral (grounded) conductor. The neutral conductor could be the top-most conductor on the supporting structure or it could be placed below or even with the phase conductors. Distribution lines could also consist of two phase conductors alone or two phase conductors and a neutral conductor, again with the neutral conductor being above, below, or even with the phase conductors. A distribution line may also have just a single phase conductor and a neutral conductor with the neutral being above, below, or even with the phase conductor. Most distribution lines throughout the United States have the neutral conductor placed below the phase conductors. The neutral conductor is used to complete the electrical circuit and serves as part of the conducting path for phase current flowing from the customer back to the substation where the circuit originates. The earth itself serves as the other part of the return current path.

AVIAN ELECTROCUTIONS AND POWER LINE DESIGN

Birds can be electrocuted by simultaneously contacting energized and/or grounded structures, conductors, hardware, or equipment. Electrocutions may occur because of a combination of biological and electrical design factors. Biological factors are those that influence avian use of poles, such as habitat, prey, and avian species (see Chapter 4). The electrical design factor most crucial to avian electrocutions is the physical separation between energized and/or grounded structures, conductors, hardware, or equipment that can be bridged by birds to complete a circuit. As a general rule, electrocution can occur on structures with the following:

- Phase conductors separated by less than the wrist-to-wrist or head-to-foot (flesh-to-flesh) distance of a bird (see Chapter 4, Size)[21];
- Distance between grounded hardware (e.g., grounded wires, metal braces) and any energized phase conductor that is less than the wrist-to-wrist or head-to-foot (flesh-to-flesh) distance of a bird.

In the 1970s, Morley Nelson evaluated electrocution risk of eagles to identify configurations and voltages that could electrocute birds (Nelson 1979b, 1980b; Nelson and Nelson 1976, 1977; see Chapter 4).

[21] The wrist is the joint toward the middle of the leading edge of a bird's wing. The skin covering the wrist is the outermost fleshy part on the wing.

Because bird feathers provide insulation when dry, contact must typically be made with fleshy parts, such as the skin, feet, or bill. Nelson determined that 150-centimeter (cm) (60-inch [in]) spacing is necessary to accommodate the wrist-to-wrist distance of an eagle. As a result, a 150-cm (60-in) separation has been widely accepted as the standard for eagle protection since the 1975 edition of *Suggested Practices*. Although wingspans can measure up to 2.3 meters (m) (7.5 feet [ft]) for golden eagles *(Aquila chrysaetos)* and 2.4 m (8 ft) for bald eagles *(Haliaeetus leucocephalus)*, the distance between fleshy parts (wrist-to-wrist) is less than 150 cm (60 in) for both species (see Chapter 4, Size). Therefore, under dry conditions, a 150-cm (60-in) separation should provide adequate spacing for an eagle to safely perch. Larger birds such as condors or storks may warrant special consideration by utilities. Utilities in areas without eagle populations may choose to develop separate species-specific construction standards, as may utilities in regions with wet climates or increased air-borne contaminants. A utility's Avian Protection Plan (APP) should identify protected species within the utility's operations area and include design standards appropriate for the species and conditions at issue (see Chapter 7). An APP should also identify circumstances where avian-safe construction is to be used (i.e., in bird use areas, as part of ROW permit conditions, etc.).

Although avian-safe construction minimizes electrocution risk, electrocutions can never be completely eliminated. Because wet feathers and wet wood are conductive, birds can be electrocuted during wet weather on normally benign poles.

With an understanding of how birds can be electrocuted on power lines, utilities can select designs that are avian-safe and help to avoid and/or mitigate electrical hazards to birds. Voltage, conductor separation, and grounding practices are a particular concern when designing avian-safe structures, however, public safety, governed throughout the United States by the current National Electric Safety Code (NESC), is the primary design consideration. State and local governments also may have codes that govern power line design and construction.[22]

SEPARATIONS

The NESC and the codes of some local jurisdictions dictate power line phase-to-phase separations and the clearances of line components above ground. In accordance with the NESC, both the distance between phase conductors and the distance that conductors are hung above ground is based on the line voltage and the activity that does and could take place in the area of the power line. These code requirements are considered the minimum distances and separations needed to be certain that the facilities will not be harmful to the general public or the line crews that have to operate and maintain them. The code requirements are not intended to provide safety to birds and other animals that come into contact with assemblies at the top of electrical structures.

Distribution lines are built with smaller separations between energized conductors and between energized conductors/hardware and grounded line components than are transmission lines. Consequently, avian electrocution risk is greater on distribution lines.

Transmission conductors are generally spaced 1 to 9.1 m (3 to 30 ft) apart, and are supported on poles or towers that range from 15.2 to 36.6 m (50 to 120 ft) in height. A single transmission tower can accommodate more than one circuit. See Figure 5.4 for examples of transmission structures.

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[22] For example, California Public Utility Commission (CPUC) General Order 95 establishes the rules for overhead line construction in California.

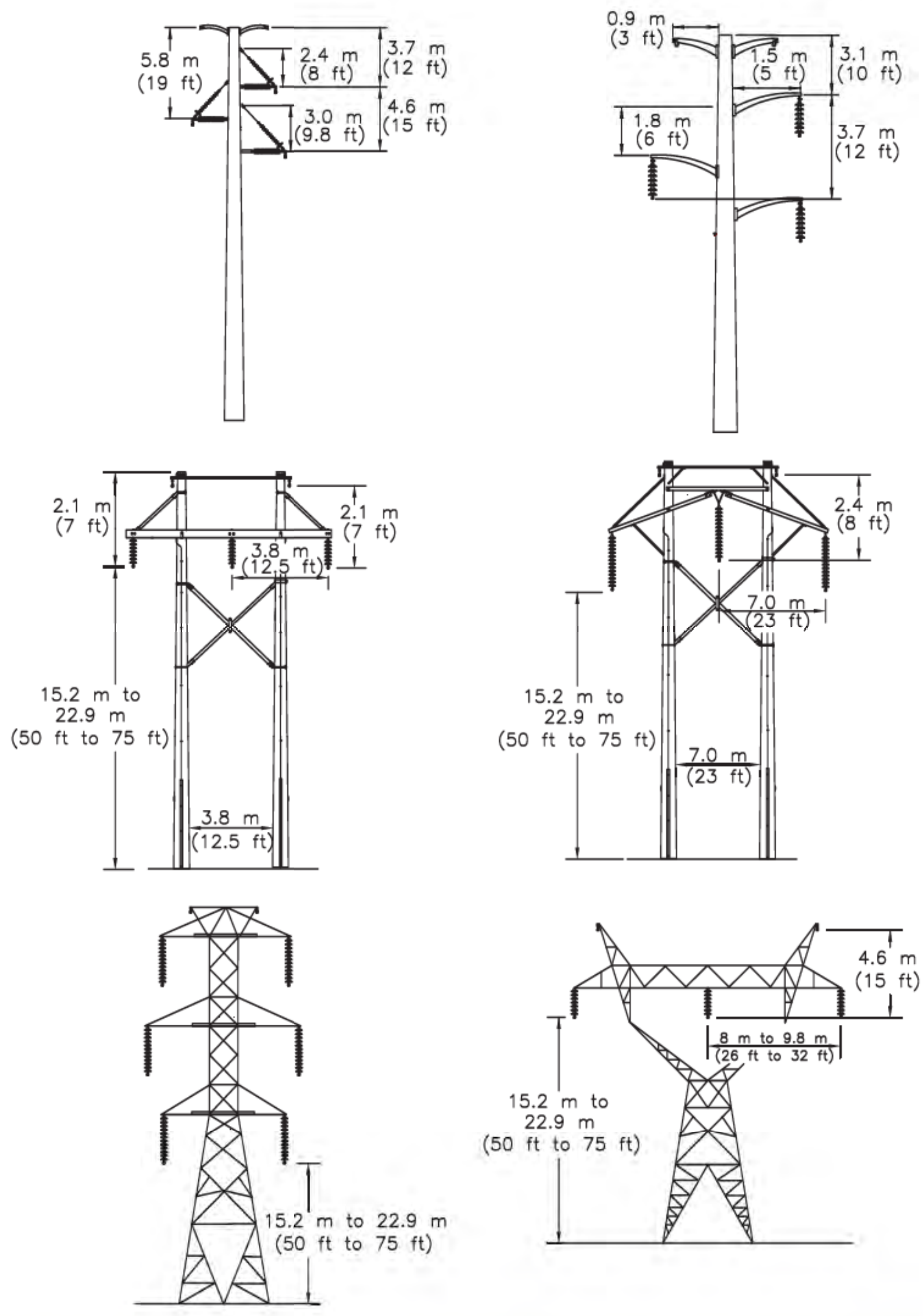

FIGURE 5.4: Examples of transmission structures.

Distribution line conductors are generally spaced 0.6 to 1.8 m (2 to 6 ft) apart, and are supported on wood, steel, composite or concrete poles that range from 9.1 to 19.8 m (30 to 65 ft) in height (Figure 5.5). As with transmission poles and towers, distribution poles can accommodate more than one circuit (Figure 5.5). The addition of jumper wires, transformers, switches, and electrical protective devices (fuses, reclosers, and other circuit sectionalizing equipment), as well as grounded hardware included on pole-top assemblies, increase the potential for avian electrocutions due to close separation of energized and grounded parts.

BONDING AND GROUNDING

Bonding electrically interconnects all metal or metal-reinforced supporting structures—including lamp posts, metal conduits and raceways, cable sheaths, messengers, metal frames, cases, equipment hangers or brackets,

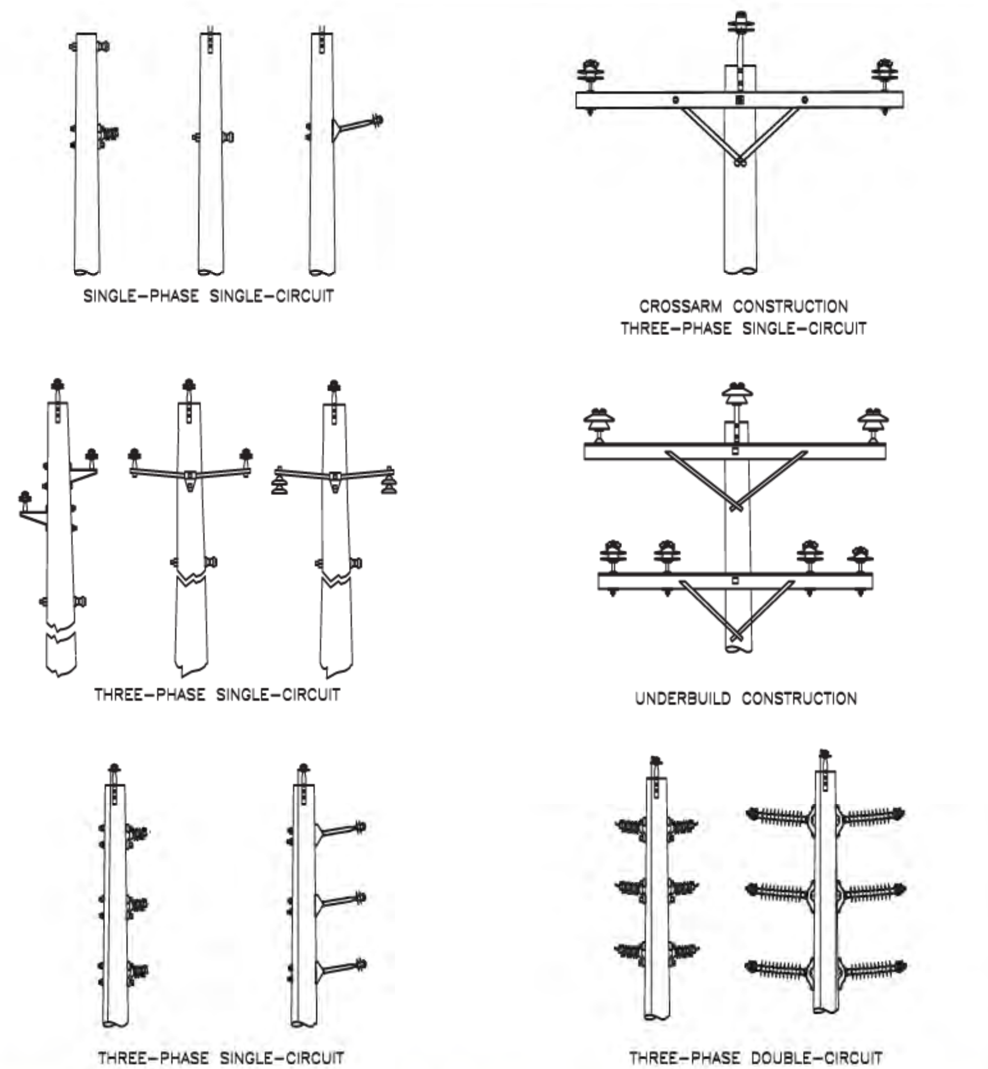

FIGURE 5.5: Examples of typical distribution configurations.

and metal switch handles and operating rods. In most cases these bonded hardware items are grounded in accordance with NESC Rule 215 CI.[23] The NESC requires the grounding of these metallic items to help keep the metal at the same voltage as the earth to which it is grounded. Bonding is particularly necessary in areas (industrial, agricultural, or coastal locations with salt, particulates, or other matter in the air) where excessive leakage currents may cause burning around metal items in the presence of moisture. On multi-grounded neutral power systems, the neutral is grounded by connecting it to a grounding electrode (ground rod) installed in the earth at the base of a pole at least four times in each mile of line. For birds, bonding and grounding provide pathways for contacts from energized conductors or energized hardware to metal items that are grounded.

The position of the neutral depends on the area's isokeraunic level and/or the practices of the utility. For some utilities, the neutral serves as an overhead ground wire (static wire) for lightning protection. If this type of construction is used, the designer should provide avian-safe separation and ensure that appropriate coverings are used on the grounding conductors and bonded hardware.

SUGGESTED PRACTICES

The remainder of this chapter presents configurations that can pose avian electrocution risks and suggested practices for modifying those problem configurations (Table 5.2). Recommendations are based on providing 150-cm (60-in) separation for eagle protection. Other avian species may require more or less separation, depending on the size and behavior of the bird (see Chapter 4, Size). Recommendations are provided for avian-safe modifications of existing facilities, and avian-safe designs for new facilities. These practices either provide birds with a safer place to land or attempt to discourage birds from perching on parts of the structure where optimal separation cannot be provided.

Two basic principles should be considered when attempting to make a structure avian-safe: *isolation* and *insulation*. The term *isolation* refers to providing a minimum separation of 150 cm (60 in) between phase conductors or a phase conductor and grounded hardware/

TABLE 5.2: Summary of figures and pages for problem configurations and suggested solutions.

Configuration	Problem Figure	Solution Figure	Pages
Single-phase	Figures 5.6, 5.8	Figures 5.7, 5.9, 5.10	61–66
Three-phase	Figures 5.11, 5.15, 5.17, 5.20	Figures 5.12, 5.13, 5.14, 5.16, 5.18, 5.19, 5.21	66–76
Corner poles	Figure 5.22	Figures 5.23, 5.24, 5.25	76–80
Steel/concrete distribution poles	Figures 5.27, 5.29	Figures 5.28, 5.30, 5.31, 5.32, 5.33	81–88
Problem transmission designs	Figures 5.34, 5.36, 5.40, 5.42	Figures 5.35, 5.37, 5.38, 5.39, 5.41, 5.43	88–99
Transformers and other equipment	Figures 5.44, 5.45	Figures 5.46, 5.47	99–102

[23] In some jurisdictions, bond wires are not grounded if the facilities comply with the exceptions of NESC Rule 215 CI.

conductor.[24] Using the principle of isolation may be most applicable for new or rebuilt structures in areas where avian electrocution risk is a concern. The term *insulation* refers to covering phases or grounds where adequate separation is not feasible. Although equipment that is covered with specifically designed avian protection materials can prevent bird mortality, it should not be considered insulation for human protection. Examples of such coverings are phase covers, bushing covers, arrester covers, cutout covers, jumper wire hoses, and covered conductors. In addition, perch discouragers may be used to deter birds from landing on hazardous (to birds) pole locations where isolation, covers, or other insulating techniques cannot be used. Many equipment poles necessitate using a combination of techniques to achieve avian safety.

Both avian-safe modifications of existing structures and avian-safe new construction should be employed if circumstances indicate they are necessary. In areas with known populations of raptors or other birds of concern, new lines should be designed with adequate separations for birds. Given the diversity of line designs and voltages used by power companies, across-the-board standards and guidelines are not possible. It is not realistic to expect to eliminate all hazards to birds. However, it is feasible to reduce known and potential hazards.

MODIFICATION OF EXISTING FACILITIES

In recommending remedial actions for a particular problem, the following generalizations can be made:

- In areas with vulnerable avian populations, power lines built to past construction standards may present serious threats to birds. Such lines are characterized by closely separated, energized components including bare conductors, equipment bushings, primary transition terminations, arresters, and cutout tops. In addition, all of these energized sources may be close to grounded steel brackets, metal crossarm braces, conductors, or guy wires.
- The phase-to-phase and phase-to-ground separation of most transmission lines is typically greater than 150 cm (60 in) and, therefore, the likelihood of electrocutions occurring at voltages greater than 60 kV is low.
- Priority should be given to poles preferred by raptors or other birds that have a high electrocution risk.
- Raptors may use any pole located in homogenous areas of suitable habitat. In these areas, poles of like configuration may pose similar electrocution risks. These areas can be assessed to prioritize structures for corrective actions.
- Electrocutions that have occurred on distribution lines with crossarm construction should be evaluated closely. Although remedial actions should be made at structures with avian mortalities, modifications of entire line sections are generally not recommended in response to an electrocution, which may be an isolated event. Risk assessments should be conducted to determine the likelihood of multiple electrocutions on a given section of line and to identify the poles that pose that risk. Criteria could include electrocuted birds found near a pole, prey availability, proximity to active nests, terrain advantage, and/or consistent use of preferred poles for perching or still-hunting.
- Poles supporting additional electrical equipment (e.g., transformers and switches)

[24] The drawings and text in this chapter refer to providing 150-cm (60-in) separation for eagle protection. Dimensions can be modified for other species (see Table 4.1 for measurements of other avian species). A utility's APP may include approved construction standards for avian protection; this may be particularly necessary for designs that do not provide 150-cm (60-in) separation.

in avian use areas are more likely to cause electrocution (Olendorff et al. 1981; APLIC 1996; Harness and Wilson 2001; Liguori and Burruss 2003; Idaho Power Co., unpubl. data). Retrofitting these structures can reduce avian electrocution risk and improve power reliability.

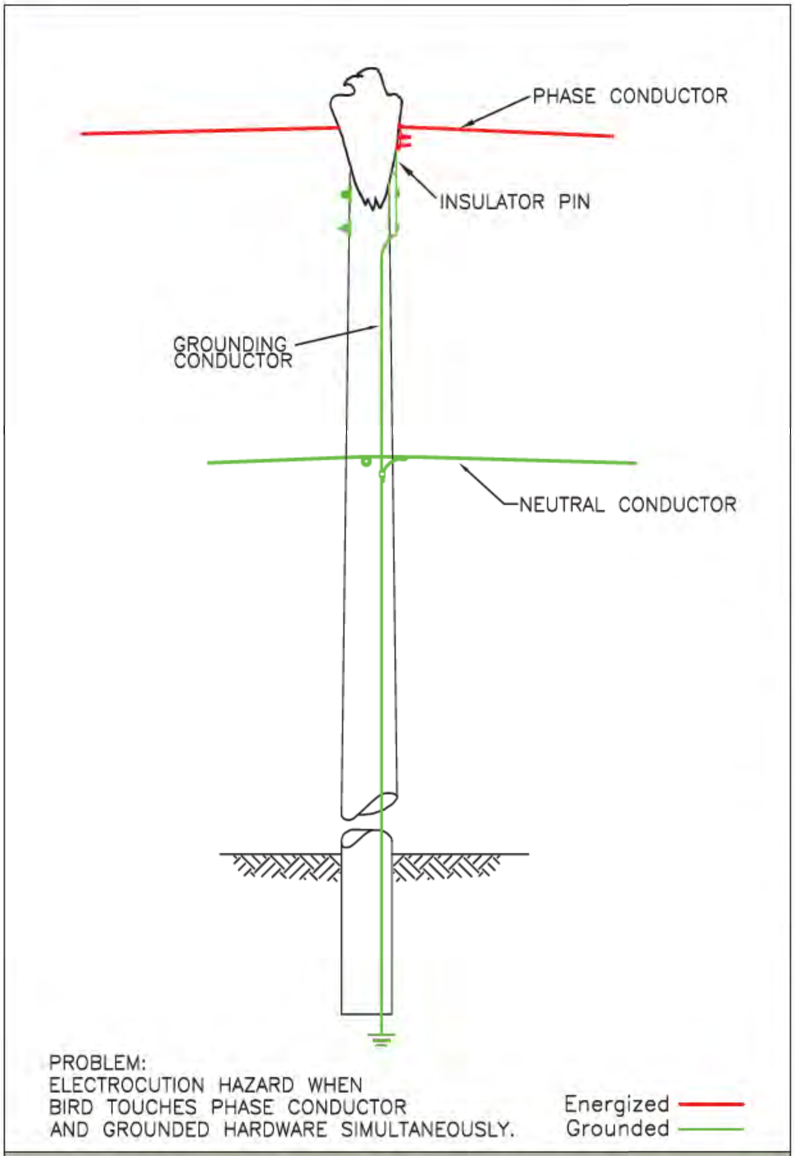

FIGURE 5.6: Problem single-phase with grounded pole-top pin.

AVIAN-SAFE DESIGN OF NEW FACILITIES

Concepts used to modify existing power lines also apply to new construction. Again, two basic considerations are conductor separation and grounding procedures. As with retrofitting, the objective is to provide a 150-cm (60-in) separation between energized conductors or energized hardware and grounded conductors/hardware. If enough separation is not possible, appropriate covers can be used to prevent simultaneous contact between energized and/or grounded facilities.

When planning the construction of new power lines, it is important to consider the safety of the public and utility personnel, biological aspects, ROW permit requirements, service reliability, and other economic and political factors. Although biological significance cannot be overlooked, it may not be possible to site lines outside high-quality bird habitat. In many instances, ROW permits will require avian-safe construction on federal lands. Biologists and engineers should cooperatively consider all factors when developing recommendations for preventing avian mortality problems.

SPECIFIC DESIGN PROBLEMS AND SOLUTIONS

Distribution

WOODEN POLES

Single-Phase Lines

Figure 5.6 shows a typical single-phase line with the phase conductor mounted on the top and the neutral mounted on the side of the pole.[25] In this example, the pole bond (grounding conductor) extends up to the top of the pole to ground the metal bracket. With this configuration, the feet of a large bird perched on the pole top could touch the grounding conductor or grounded insulator pin, while its breast or other body parts contact the phase conductor. In 1971, 17 dead

[25] Note that in this and subsequent figures, grounded conductors and hardware are shown in green and energized conductors and hardware in red. The designs presented in this section apply to poles of a non-conducting nature (i.e. wood or fiberglass). See Steel/Concrete Poles for avian-safe designs of steel/concrete poles.

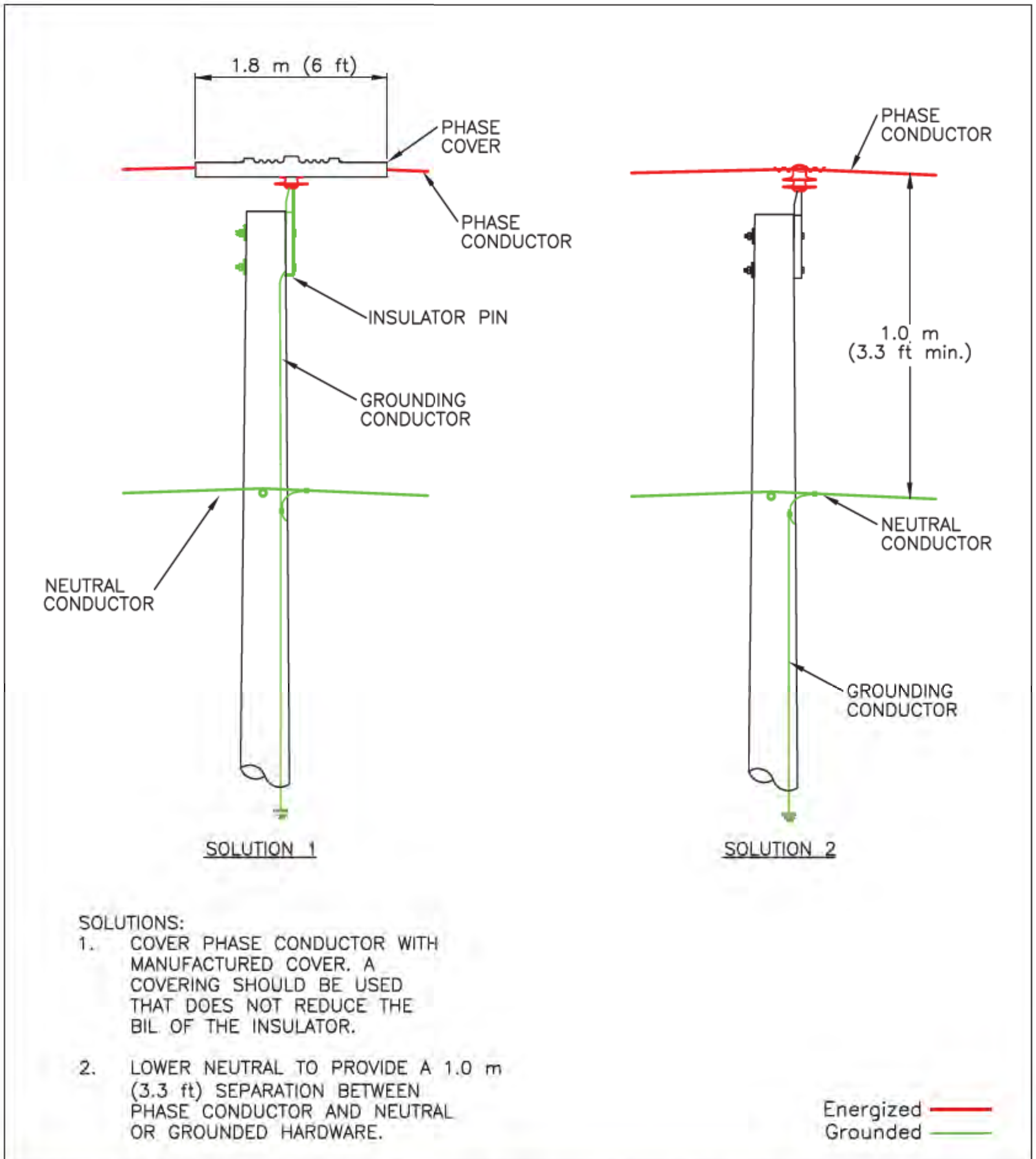

FIGURE 5.7: Solutions for single-phase with grounded pole-top pin.

eagles were found below poles of this configuration in the Pawnee National Grasslands and adjacent areas in Colorado, where habitat and prey attracted wintering eagles (Olendorff 1972a). One retrofitting option for this configuration is to place a cover manufactured for this purpose over the phase conductor to help prevent simultaneous phase-to-ground contact (Figure 5.7, Solution 1). For further information on the use of cover-up products see Precautions (page 102).

If the pole bond or grounding conductor does not extend above the neutral conductor and there is at least 100 cm (40 in) of vertical

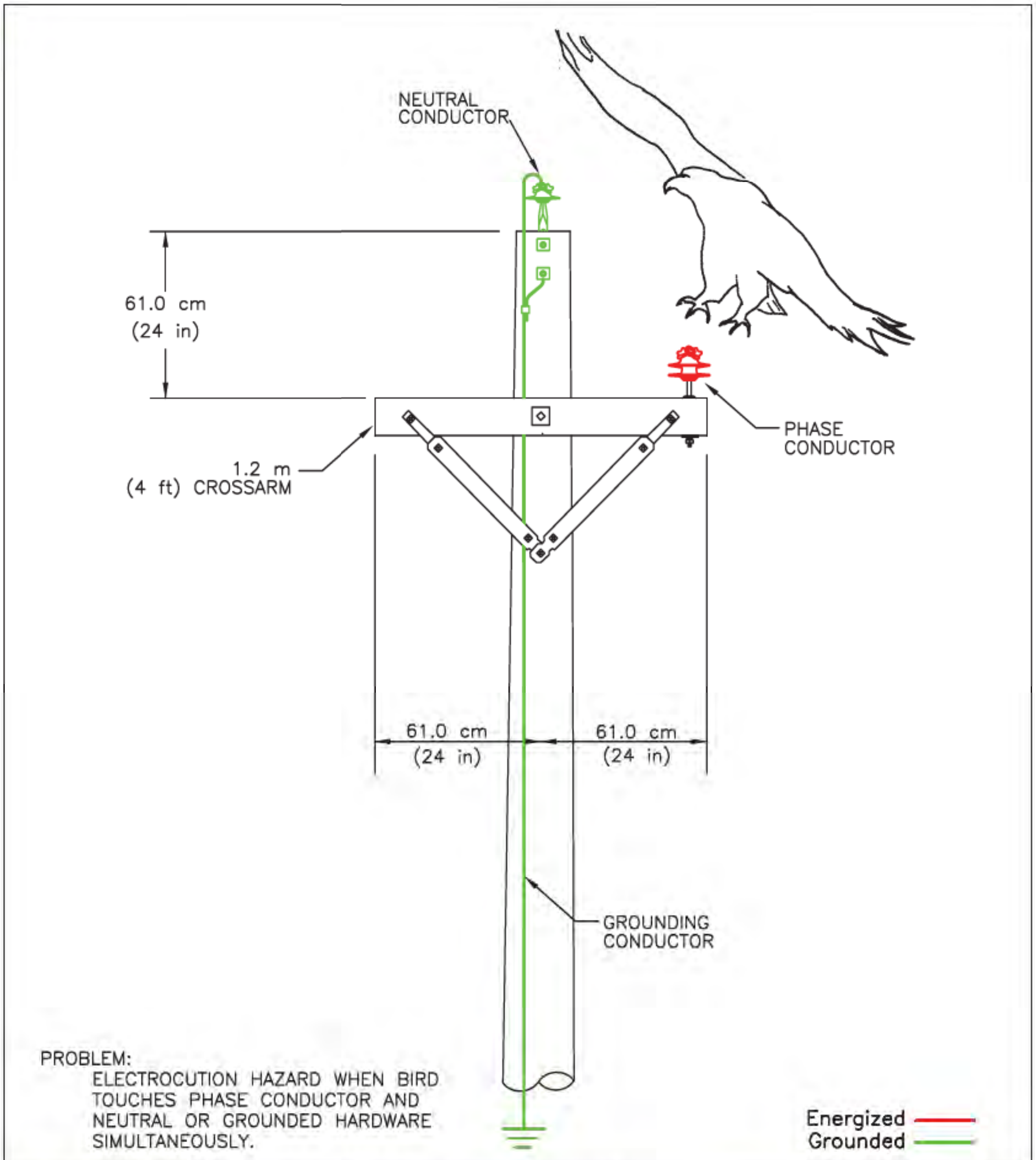

FIGURE 5.8: Problem single-phase configuration with crossarm and overhead neutral.

separation between the phase and neutral conductors, then no further avian protection action should be needed (Figure 5.7, Solution 2).

Figure 5.8 shows another problem single-phase power line, where a pole-top neutral conductor was mounted 61 cm (24 in) above an energized conductor that was supported on a 1.2-m (4-ft) crossarm. In 1992, 17 dead eagles were found below poles with such a configuration along a 24-kilometer (km) (15-mile [mi]) stretch of distribution line in central Wyoming (PacifiCorp, unpubl. data). When the eagles tried to perch on the

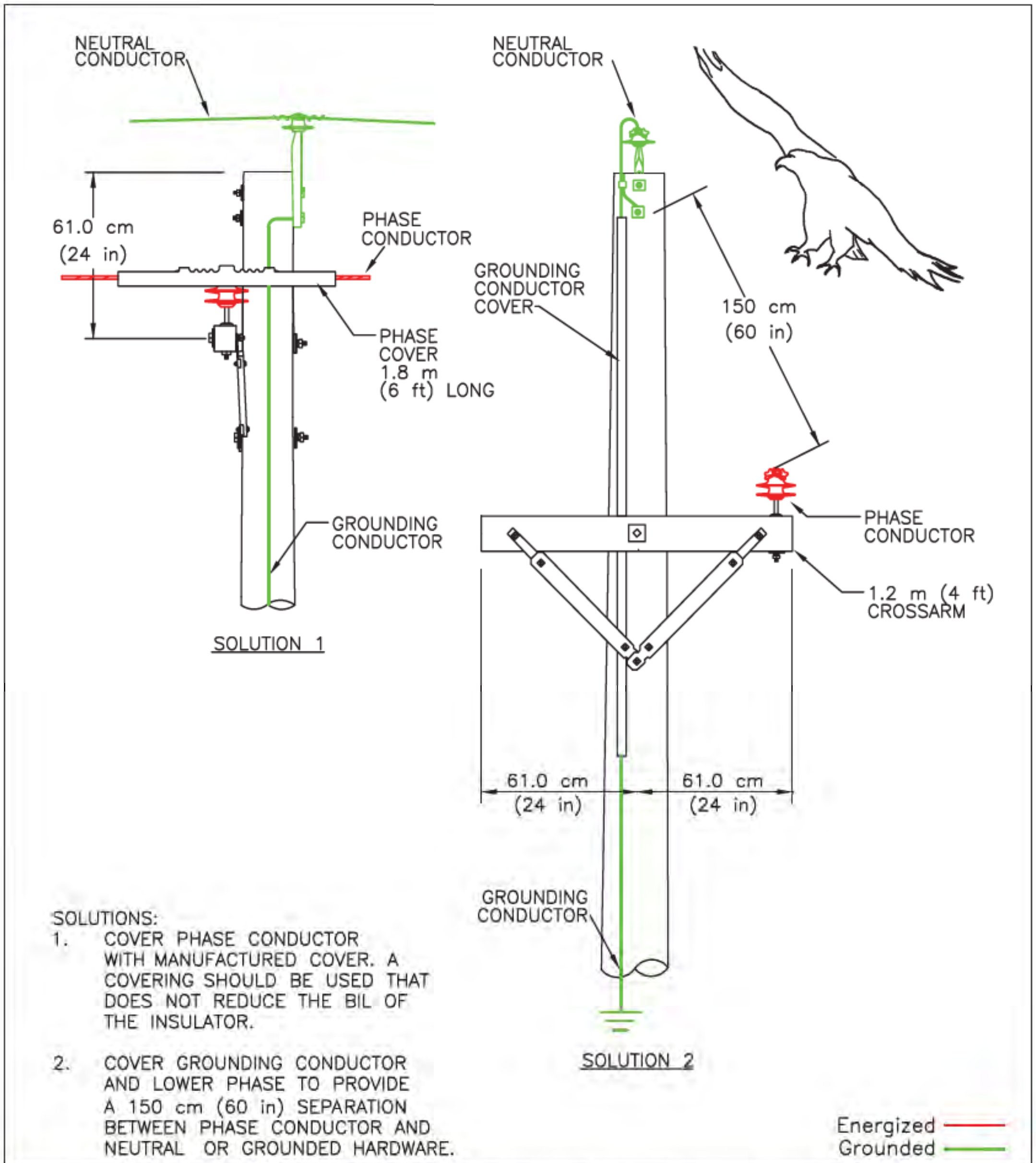

FIGURE 5.9: Solutions for single-phase configuration with crossarm and overhead neutral.

conductor end of the crossarm where there was less than the wrist-to-wrist separation between the phase and neutral conductors, the birds were electrocuted. Surveys conducted in 2002 found that, although this configuration is now uncommon (only 3.9% of 10,946 poles surveyed), it accounted for a disproportionate number (6.4%) of raptor mortalities (n=94) (PacifiCorp, unpubl. data). For this single-phase crossarm configuration (Figure 5.8), the phase conductor can be covered to prevent avian electrocutions (Figure 5.9, Solution 1). Another option is to lower the crossarm and cover the grounding conductor

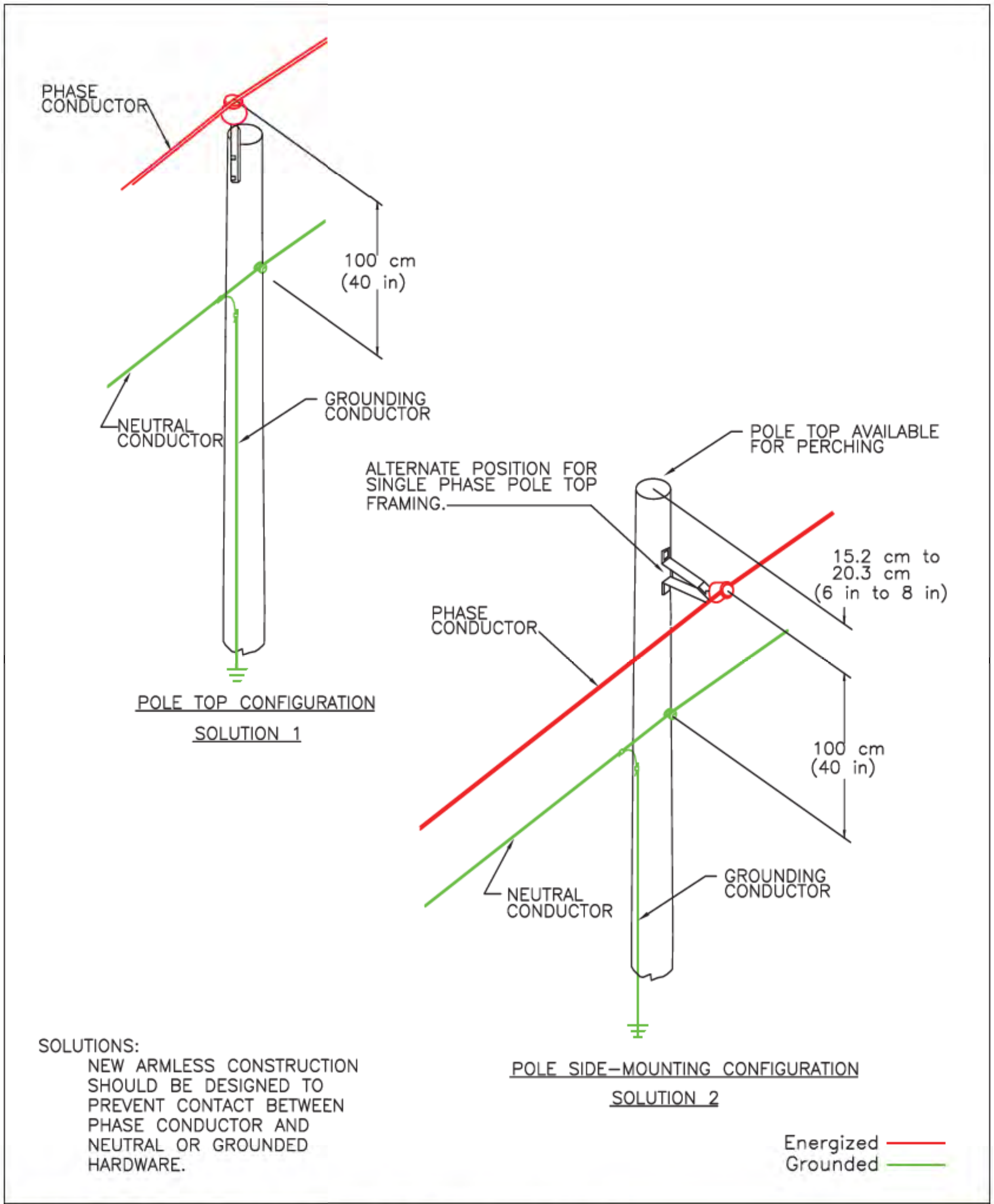

FIGURE 5.10: Single-phase avian-safe new construction.

for avian-safe phase-to-ground separation (Figure 5.9, Solution 2).

When constructing new armless single-phase lines in bird concentration areas, structures should be designed to prevent contact between energized phase conductors/hardware and grounded conductors/hardware (Figure 5.10). If the pole bond and grounding conductor do not extend above the neutral conductor and there is a 100-cm (40-in) spacing between the phase conductor and the neutral conductor, then no further avian protection should be needed (Figure 5.10, Solution 1). Figure 5.10 (Solution 2) shows a single-phase configuration with the phase conductor mounted on the side of the pole. This provides the pole top as a perch.

Three-Phase Lines

Crossarms of 1.8 or 2.4 m (6 or 8 ft) are typically used for most single-pole, three-phase configurations (Figure 5.11). For raptors, the crossarms can provide excellent perching opportunities between phases, but the phase conductor separation is often insufficient to safely accommodate wrist-to-wrist distances of large birds. Utility use of grounded steel crossarm braces[26] may further reduce ground-to-phase separation, increasing the risk of avian electrocution. Although the Rural Electrification Administration (REA)[27] specifications were changed in 1972 to increase conductor separation and include the use of wooden crossarm braces (U.S. REA 1972; see Appendix B) many pre-1972 poles are still in use today. The center phase is supported either on a pin insulator on the crossarm (Figure 5.11, Problem 1) or with a pin insulator attached to the pole top (Figure 5.11, Problem 2).

Several remedial measures are available to achieve avian-safe separation between phases

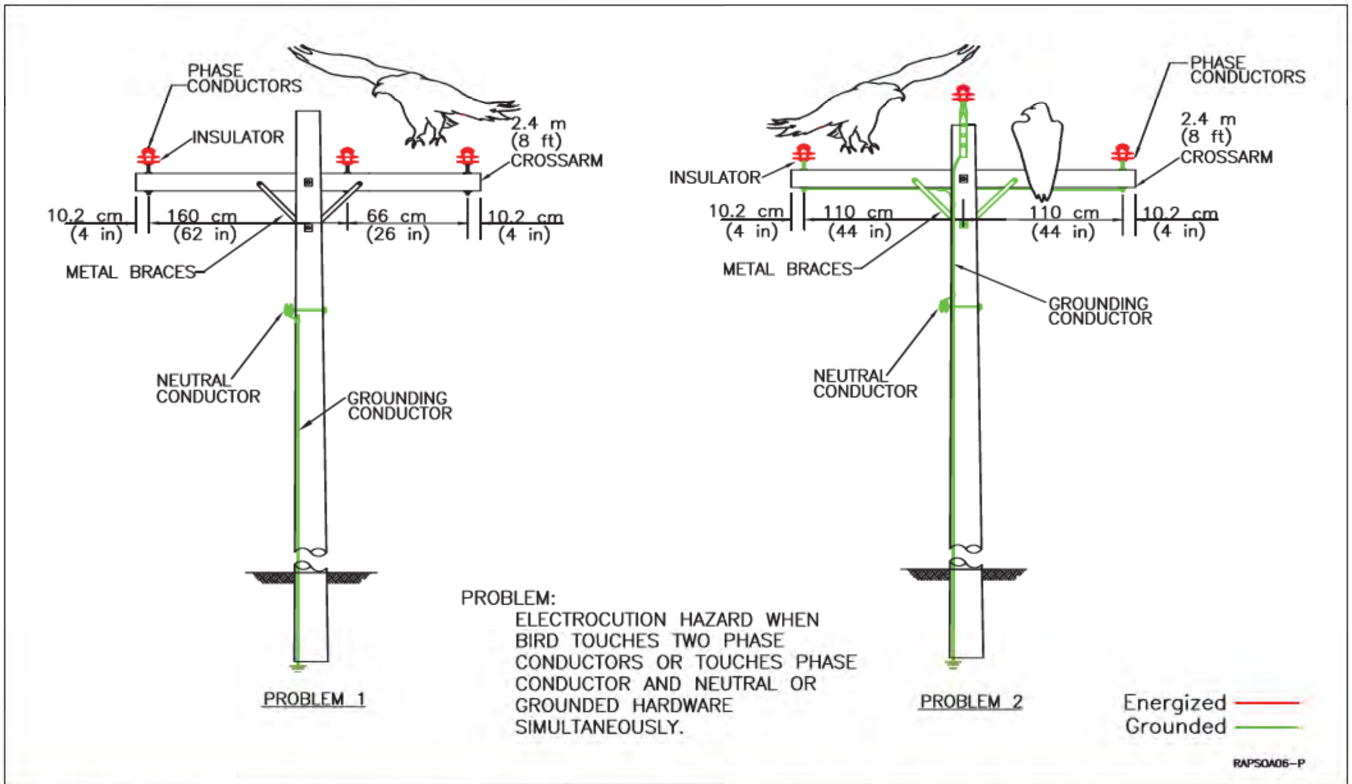

FIGURE 5.11: Problem three-phase crossarm designs with and without grounded hardware.

[26] Grounded to prevent pole fires resulting from insulator leakage currents.

[27] REA, the predecessor to the Rural Utilities Service (RUS), provides financing assistance to rural electric utilities that agree to install facilities in accordance with the standards and specifications established by REA/RUS.

or between phase and ground where all hardware is bonded (as shown in Figure 5.11):

- Install covers over the insulator and conductor on the center phase and remove bonding down to the neutral (Figure 5.12, Solution 1). For further information on the use of cover-up products, see Precautions (page 102).
- If bonds are not removed, install phase covers over all three insulators and conductors (Figure 5.12, Solution 2).
- For pole-top pin construction, the crossarm can be lowered and/or replaced with a longer crossarm (Figure 5.13).[28] A 2.4-m (8-ft) crossarm should be lowered 104 cm (41 in) to achieve 150-cm (60-in) conductor separation. A 3-m (10-ft)

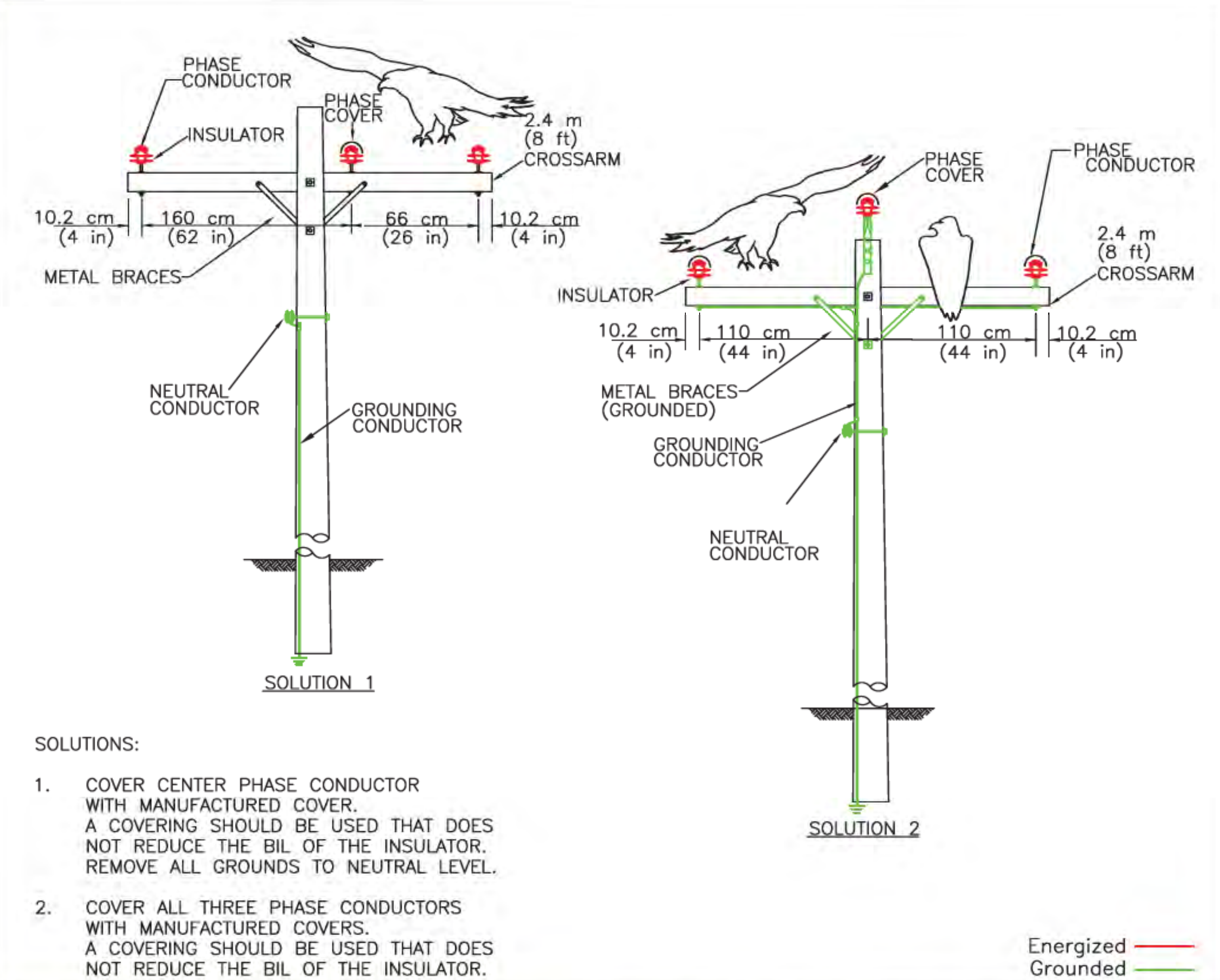

FIGURE 5.12: Solutions for three-phase crossarm designs with and without grounded hardware.

[28] Provided that NESC requirements can be met.

crossarm could be mounted 55 cm (21.5 in) below the top of the pole to provide 150 cm (60 in) of conductor separation between the center and outer phase conductors. In addition, the bond wire must be lowered to the neutral position. This lowered arm configuration can also be used for avian-safe new construction.

On three-phase crossarm construction where there is no grounding conductor above the neutral, and the center phase is on the crossarm, a perch discourager may be installed to deter perching between closely separated phase conductors (Figure 5.14). If there is less than a 150-cm (60-in) spacing between the center and outer phases (opposite the perch discourager), a phase cover should be installed on the center phase instead of using a perch discourager. Design consideration must be given to meet minimum NESC clearances on the supporting structure (pole, crossarm, insulator and perch discourager).[29] Proper distance between the perch discourager and the phase conductor is required and increases as the system voltage increases. In addition, to prevent birds from perching between the discourager and phase conductor, no more than a 12.7-cm (5-in) space should be allowed between a perch discourager and the insulator skirt. When these two parameters conflict, the perch discourager

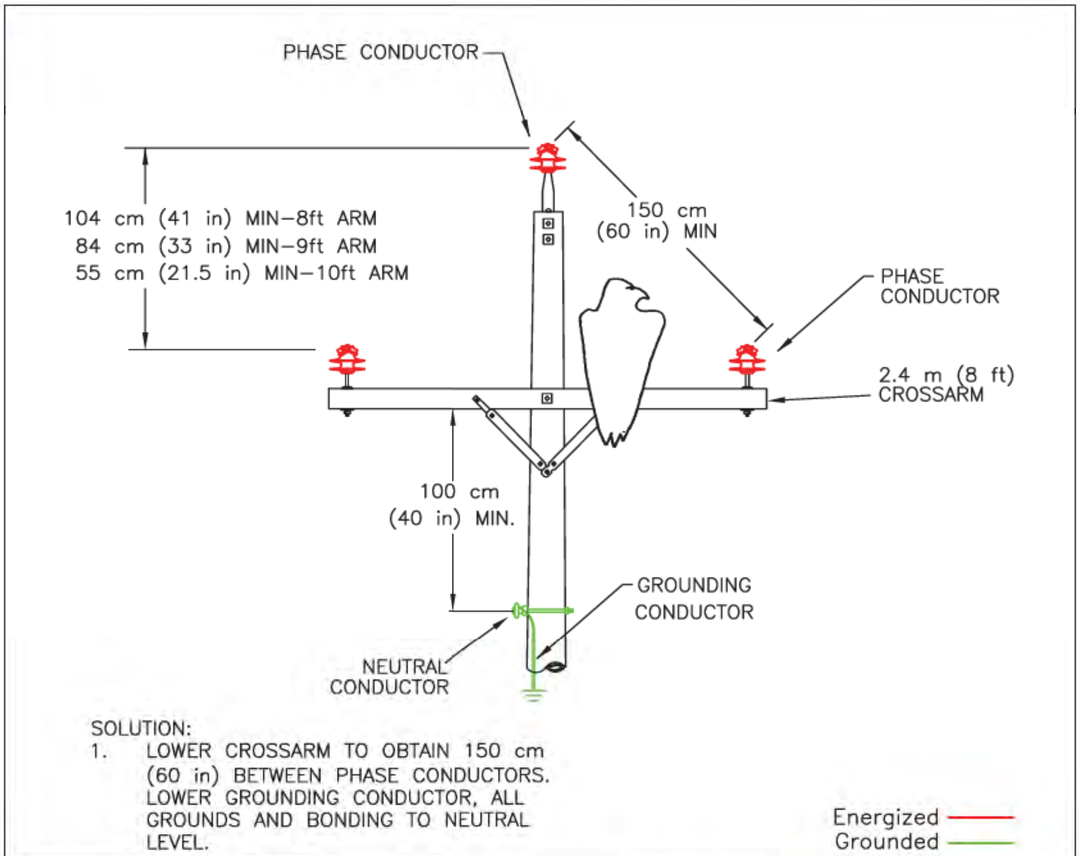

FIGURE 5.13: Avian-safe three-phase construction for different length crossarms.

[29] NESC Rule 235E, Table 235-6.

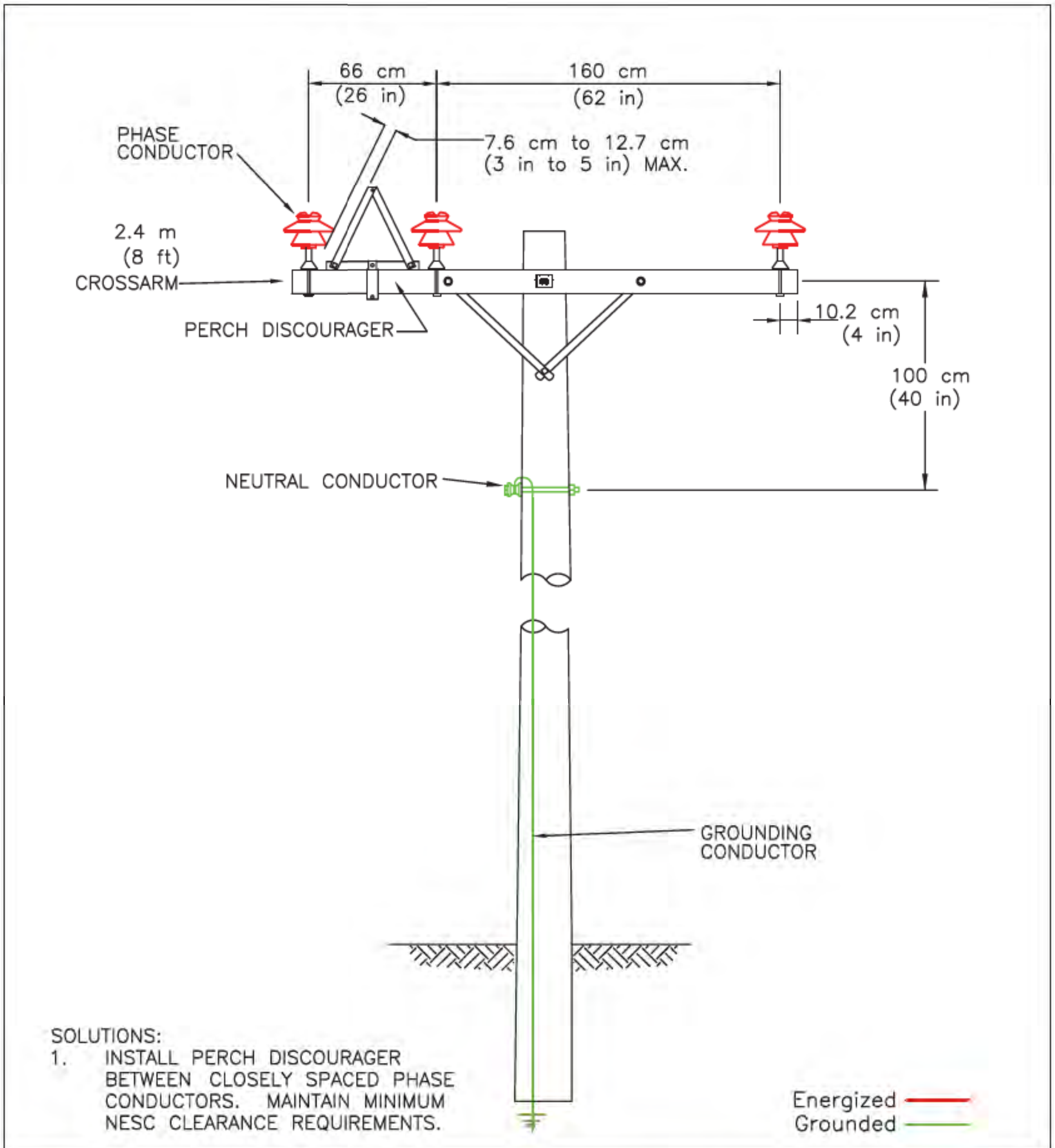

FIGURE 5.14: Solution for three-phase crossarm using perch discourager.

is not an acceptable mitigation tool. For example, on system voltages exceeding 18.7 kV phase to phase, electrical clearance will require greater than 12.7 cm (5 in), which exceeds the maximum avian-safe physical spacing and would not be effective. If spacing and system voltage are not compatible with a perch discourager, a phase cover should be used instead. See page 17 for a discussion of appropriate uses of perch discouragers for deterring birds.

Dead-end distribution structures accommodate directional changes, line terminations, and lateral taps. These structures handle greater loads, usually use anchor and guy wire assemblies, and have energized jumper wires.

These characteristics can pose electrocution risks to birds. Figure 5.15 depicts a three-phase, double dead-end pole in which jumper wires extend over the crossarm. On such a configuration, a bird can be electrocuted by simultaneously touching two of the phase jumpers. To reduce this risk, use dead-end covers on both sides of the center conductor

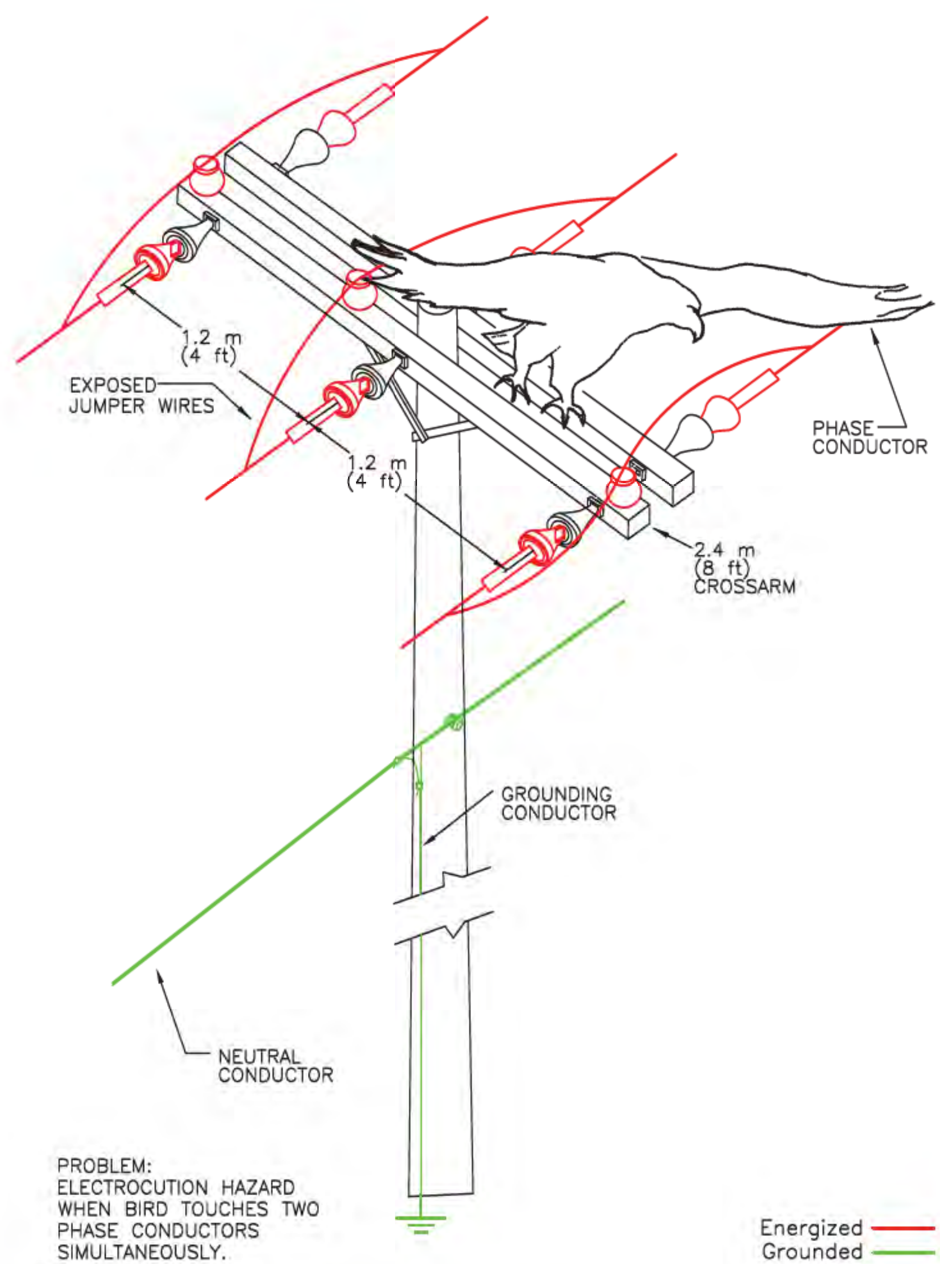

FIGURE 5.15: Problem three-phase double dead-end with exposed jumper wires.

and cover the center phase jumper wire with a material designed for the purpose. A covered conductor can also be used (Figure 5.16), as can insulated links or insulators that move the energized conductor 91 cm (36 in) from the center of the pole.

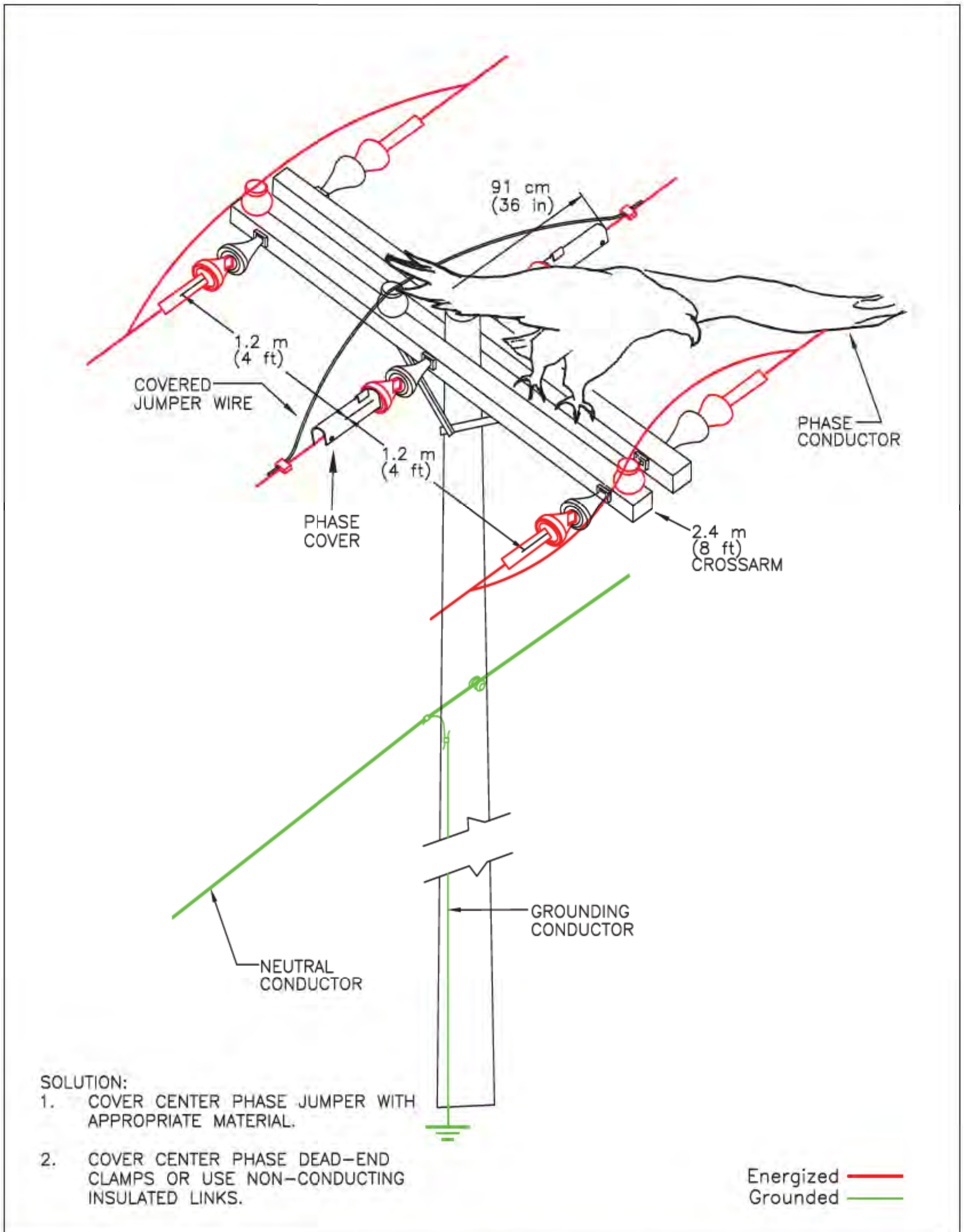

FIGURE 5.16: Solution for three-phase double dead-end with exposed jumper wires.

Compact Designs

The three-phase compact design shown in Figure 5.17 was not originally considered a high-risk configuration (Olendorff et al. 1981; APLIC 1996). However, raptors and other large birds may be electrocuted when flying in to perch on the short fiberglass arms that support the phase conductors. Interestingly, this configuration presented a significant eagle electrocution problem on a line in southern Utah, while a nearby line of the same construction did not electrocute any eagles (PacifiCorp, unpubl. data). Overall, streamline poles comprised 10% of poles surveyed in Utah and Wyoming from 2001 to 2002 (*n*=74,020) and accounted for 13%

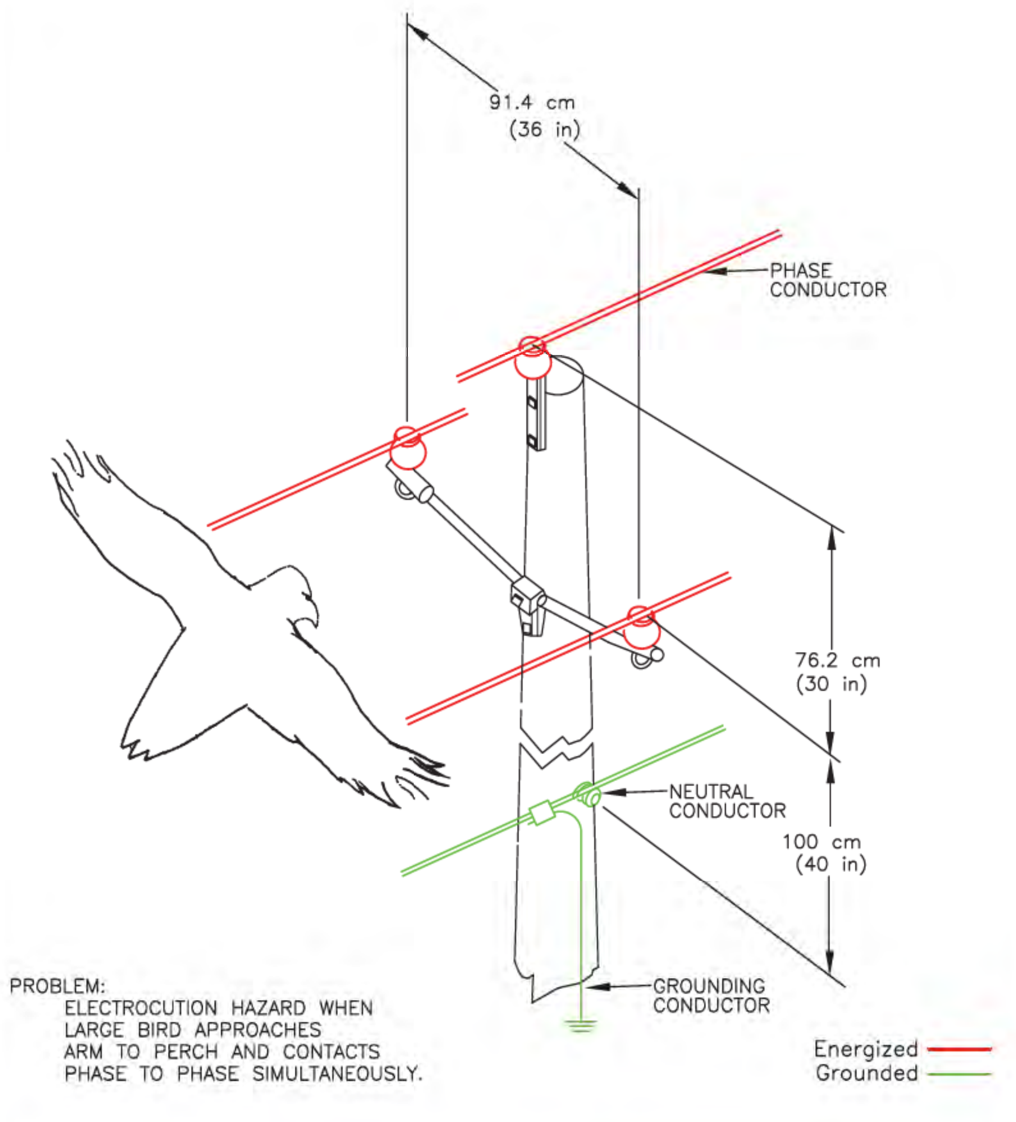

FIGURE 5.17: Problem compact three-phase design.

of avian mortality (n=547) (Liguori and Burruss 2003).

Solutions for the problem compact design shown in Figure 5.17 include the following:

- Install phase covers over the lower, outer phase conductors (Figure 5.18). Note that phase covers may not fit on compact designs with side-tied conductors or angled insulators.
- Replace the existing epoxy bracket with a longer bracket and lower it to achieve a 150-cm (60-in) phase separation (see Figure 5.19, Solution 3).

In addition, there are several avian-safe design options for new construction that may

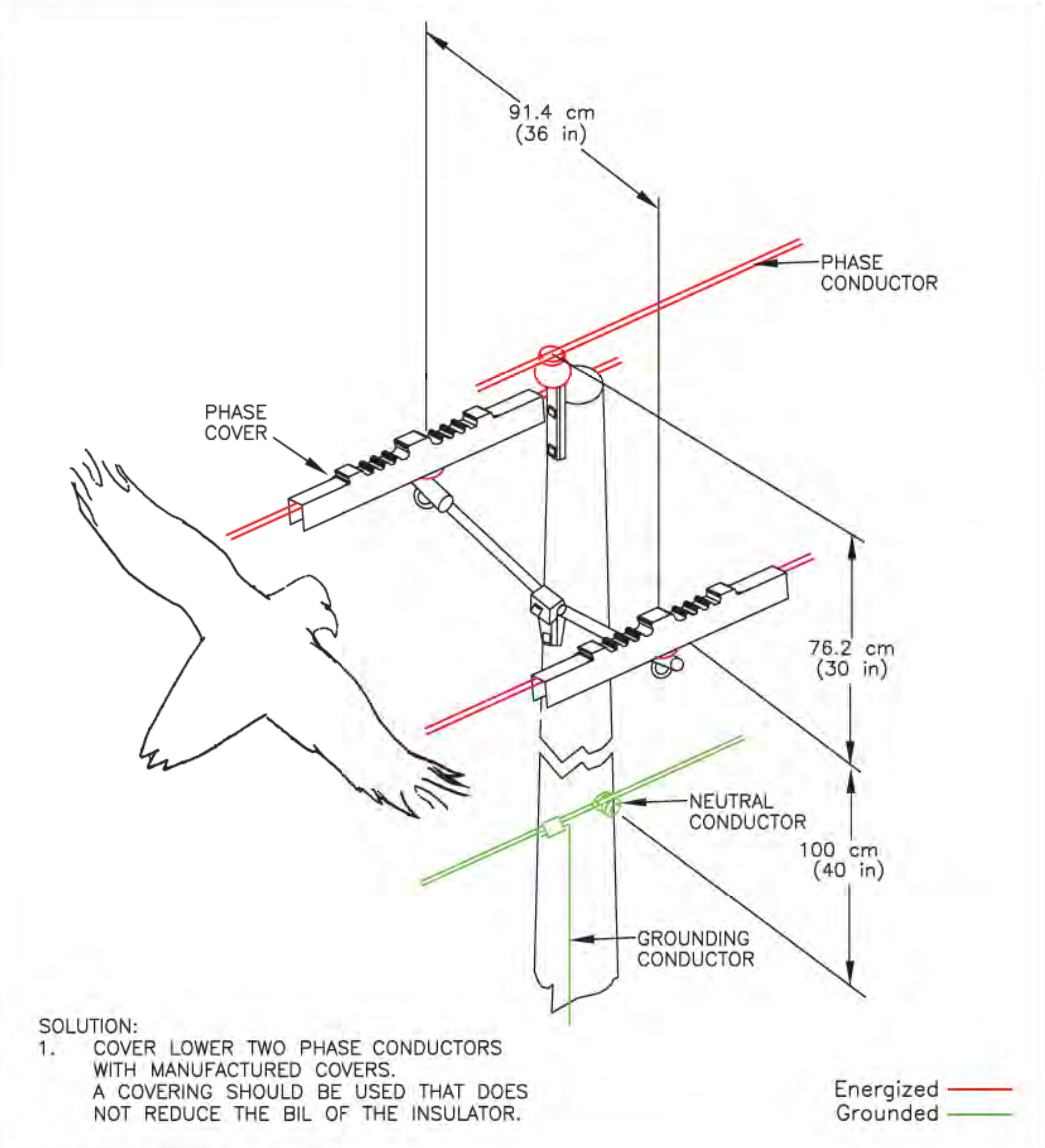

FIGURE 5.18: Solution for compact three-phase design.

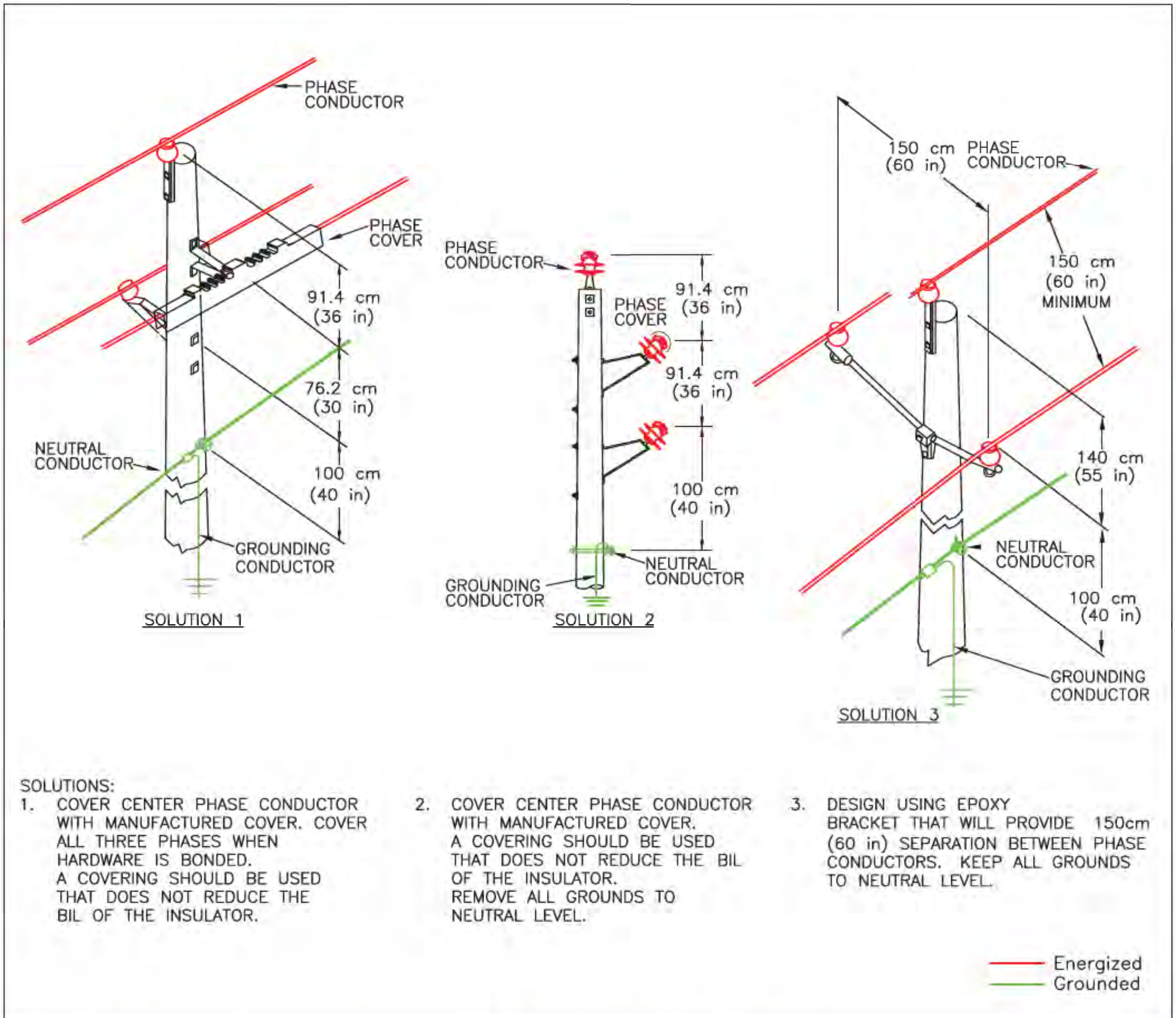

FIGURE 5.19: Avian-safe compact three-phase designs for new construction.

be used where ROW restrictions require compact configurations in areas that attract large birds (Figure 5.19). Inventories of avian populations, food sources, locations preferred by birds, alternative configurations, electrical reliability requirements, and other data should be obtained before determining the final design.

The armless configuration, in which conductors are mounted on horizontal post insulators, can be used for distribution lines (Figure 5.20). In utility service areas subject to high lightning levels, lightning protection on such lines may include an overhead conductor that must be grounded. On some installations with wood poles, utilities, particularly in salt spray or other contaminated areas, may bond the bases of the post insulators to the pole-grounding conductor to prevent pole fires. A bird perched on the insulator can be electrocuted if it comes in contact with the energized conductor and either the grounded insulator base or the bonding conductor. Solutions for avian-safe horizontal post designs are provided in Figure 5.21. Solution options include:

- Covering the vertical grounding conductor from the overhead grounding conductor clamp to 30 cm (12 in) below the lowest phase and disconnecting insulator bracket bonds (Figure 5.21, Solution 1);

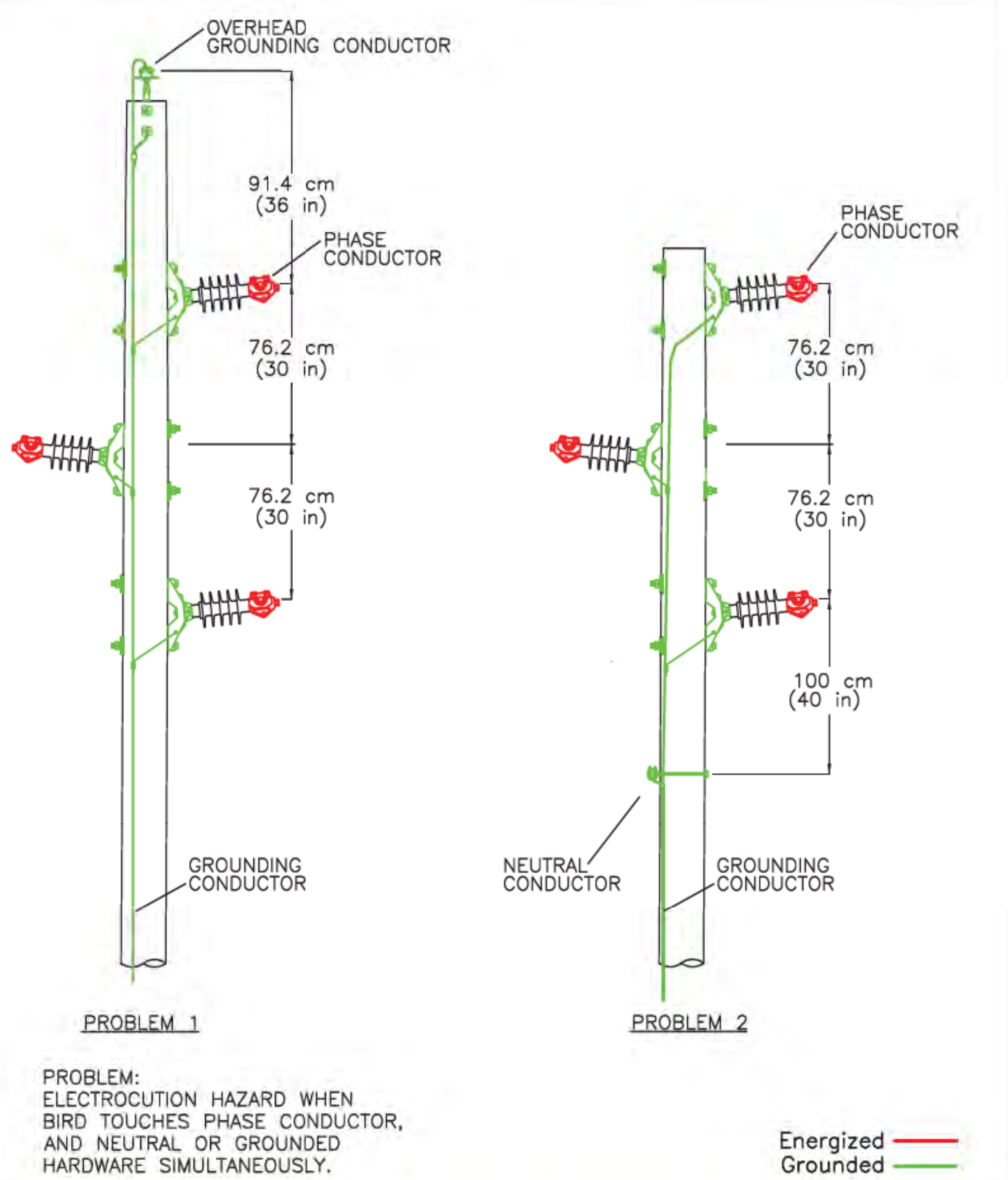

FIGURE 5.20: Problem distribution horizontal post insulator designs.

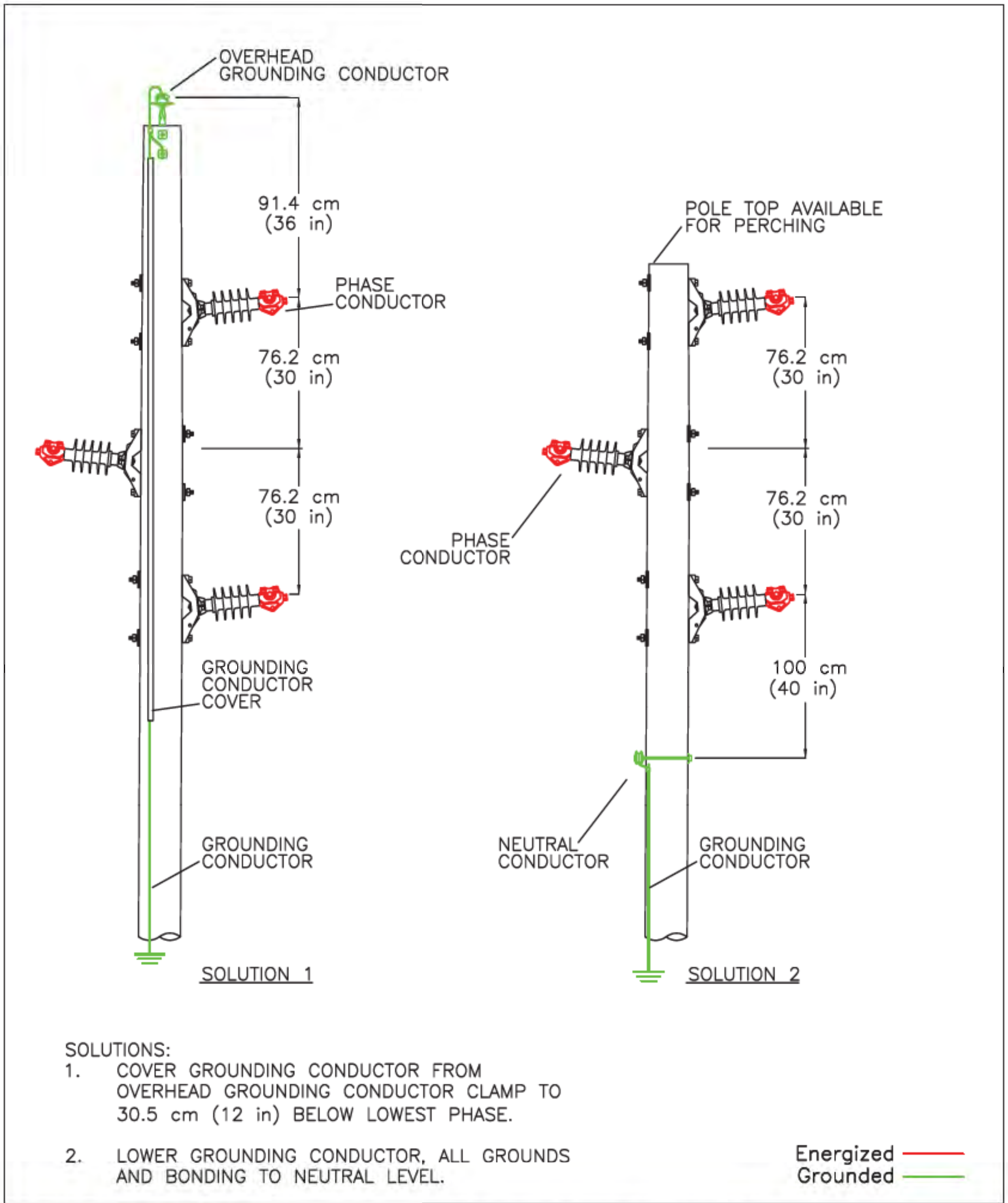

FIGURE 5.21: Solutions for distribution horizontal post insulator designs.

- Removing all bonds and the grounding conductor to the neutral (Figure 5.21, Solution 2); or
- Installing phase covers on all three phases if hardware is bonded and grounding conductor is uncovered.

Corner Poles

Poles designed to accommodate directional changes in power lines (Figure 5.22) can create hazards for birds. On these poles, uncovered jumper wires are normally used to complete electrical connections and connect the phase conductors. In this case, the typical 110-cm (42-in) or less horizontal separation between conductors is insufficient to protect large birds. If grounded metal crossarm braces, grounded guying attachments, and uncovered grounding conductors are present, the avian electrocution risk may be further increased.

On corner poles, the center phase conductor can be attached to the top set of crossarms with additional insulators or

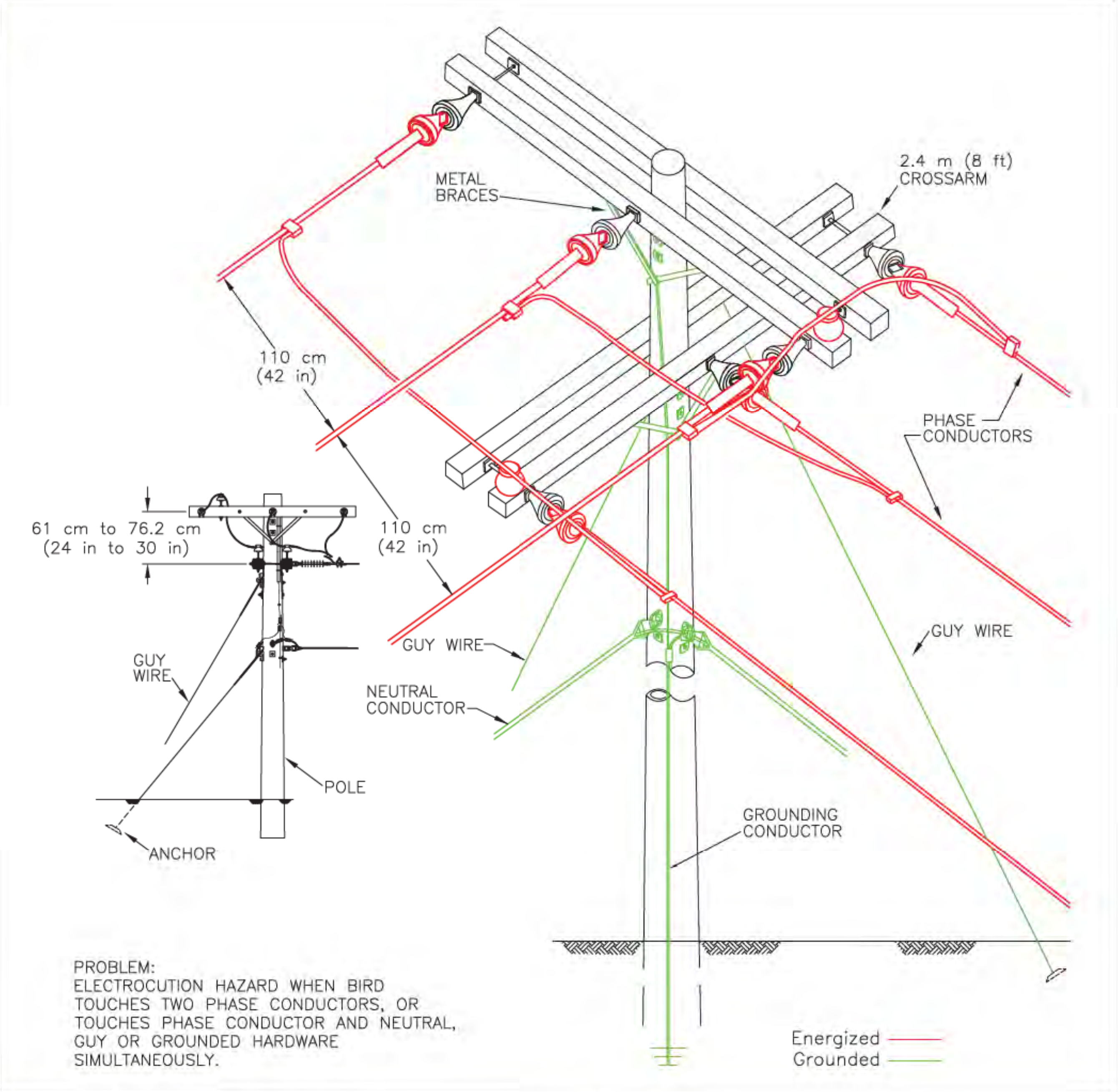

FIGURE 5.22: Problem three-phase distribution corner configuration.

with a non-conducting extension link to prevent contact by birds. An alternative to using an extension link may be to install a phase cover on the center phase (Figure 5.23). The extension link or phase cover should extend 91 cm (36 in) from the pole to the conductor. Bare jumper wires should be covered with a material designed for the purpose or replaced with covered conductors. In addition, all down guy-wires should have guy strain

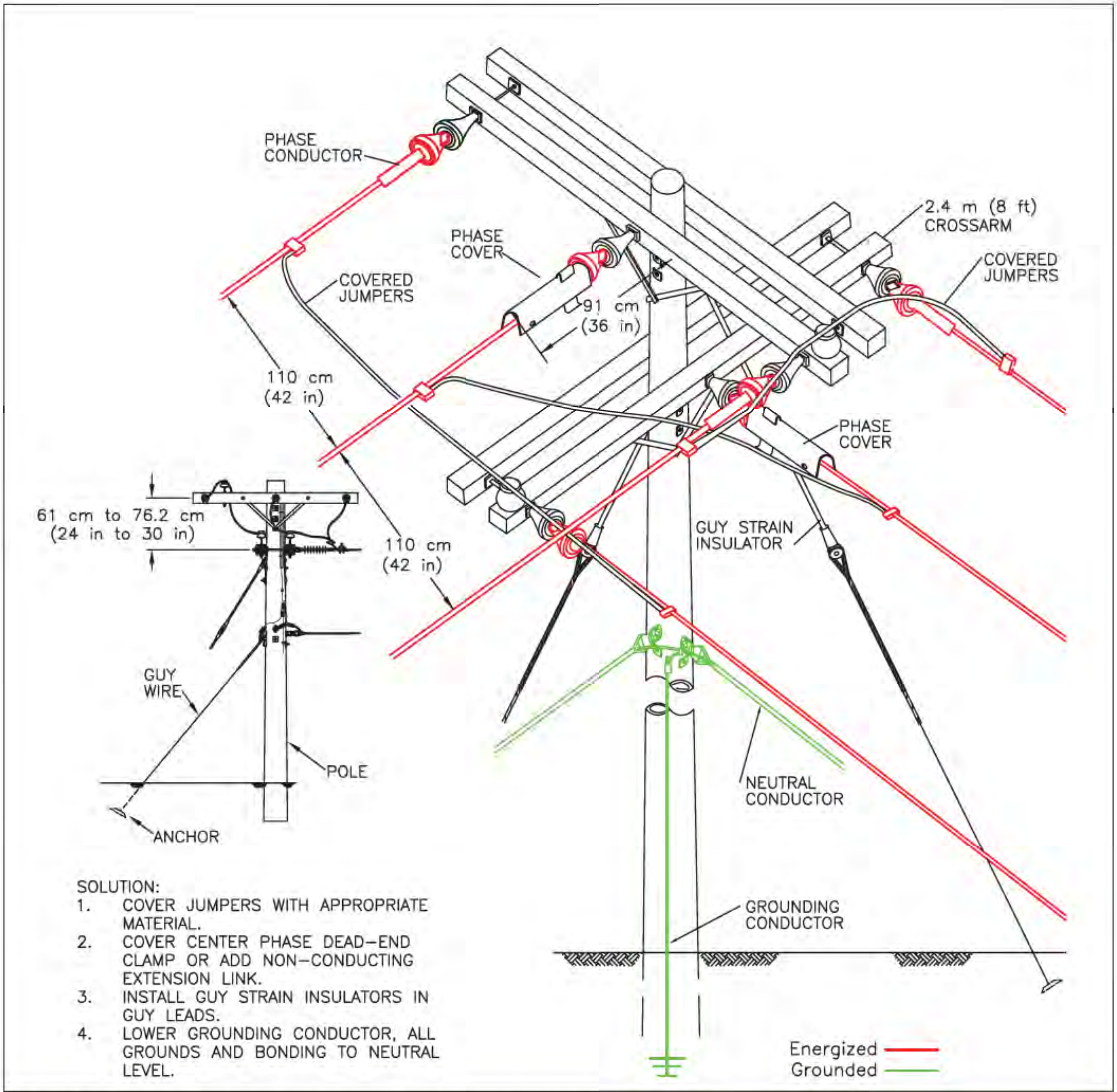

FIGURE 5.23: Solution for three-phase distribution corner configuration.

insulators to prevent them from acting as grounds.

For new structures, corner poles can be constructed with lowered crossarms (i.e. 104 cm [41 in] from the pole top if using 2.4-m [8-ft] arms) that provide 150 cm (60 in) of phase-to-phase separation. Conventional corner poles can be constructed in the manner depicted in Figure 5.23. Other alternatives are the vertical designs shown in Figures 5.24

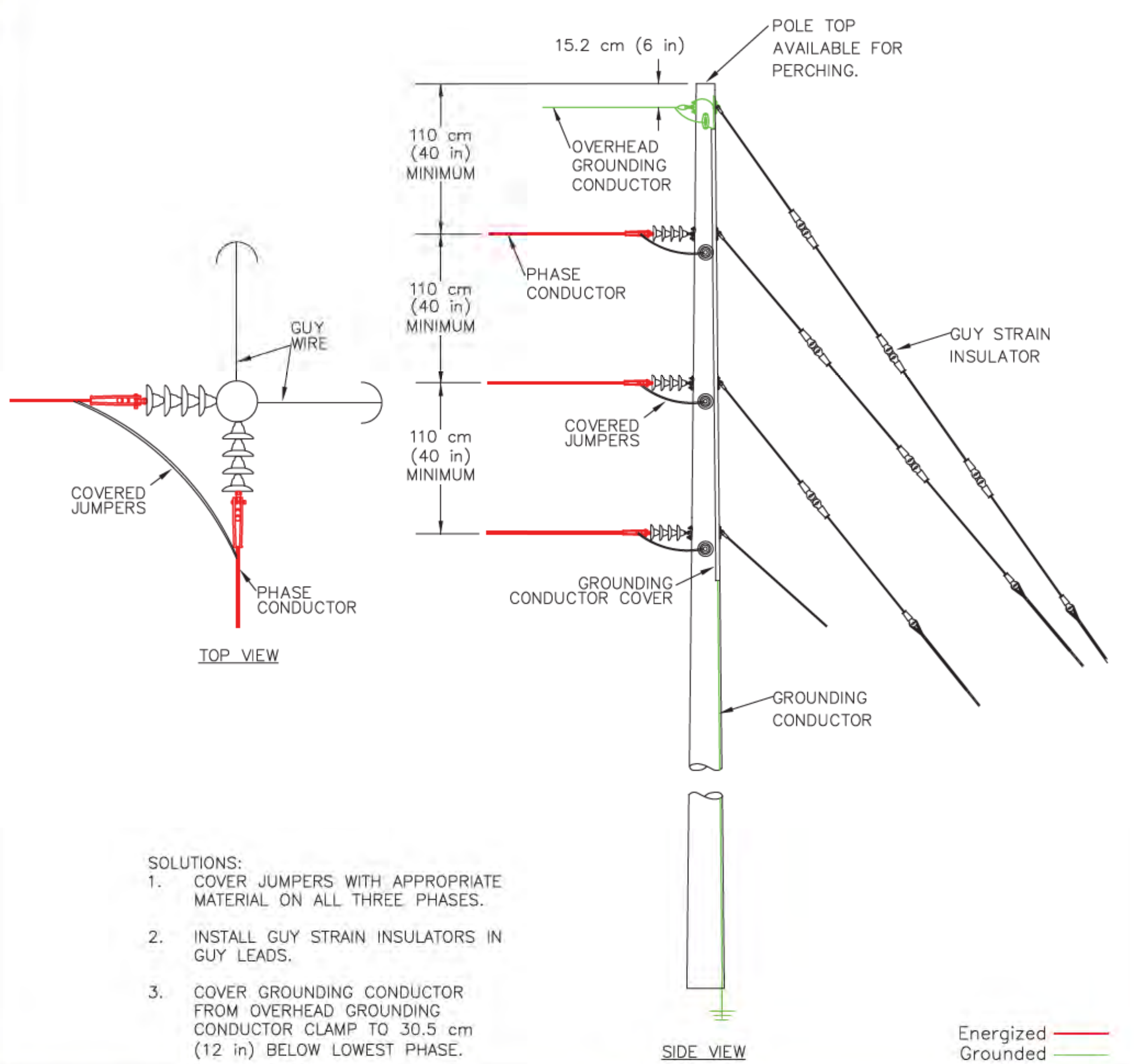

FIGURE 5.24: Three-phase vertical corner configuration—overhead grounding conductor on pole top.

and 5.25, which prevent simultaneous contact by birds. In Figure 24, the grounding conductor should be covered with a material appropriate for avian protection. Taller poles are usually required, but vertical avian-safe corner designs eliminate crossarms and unwieldy jumper wire arrangements. They can also accommodate overhead grounding conductors.

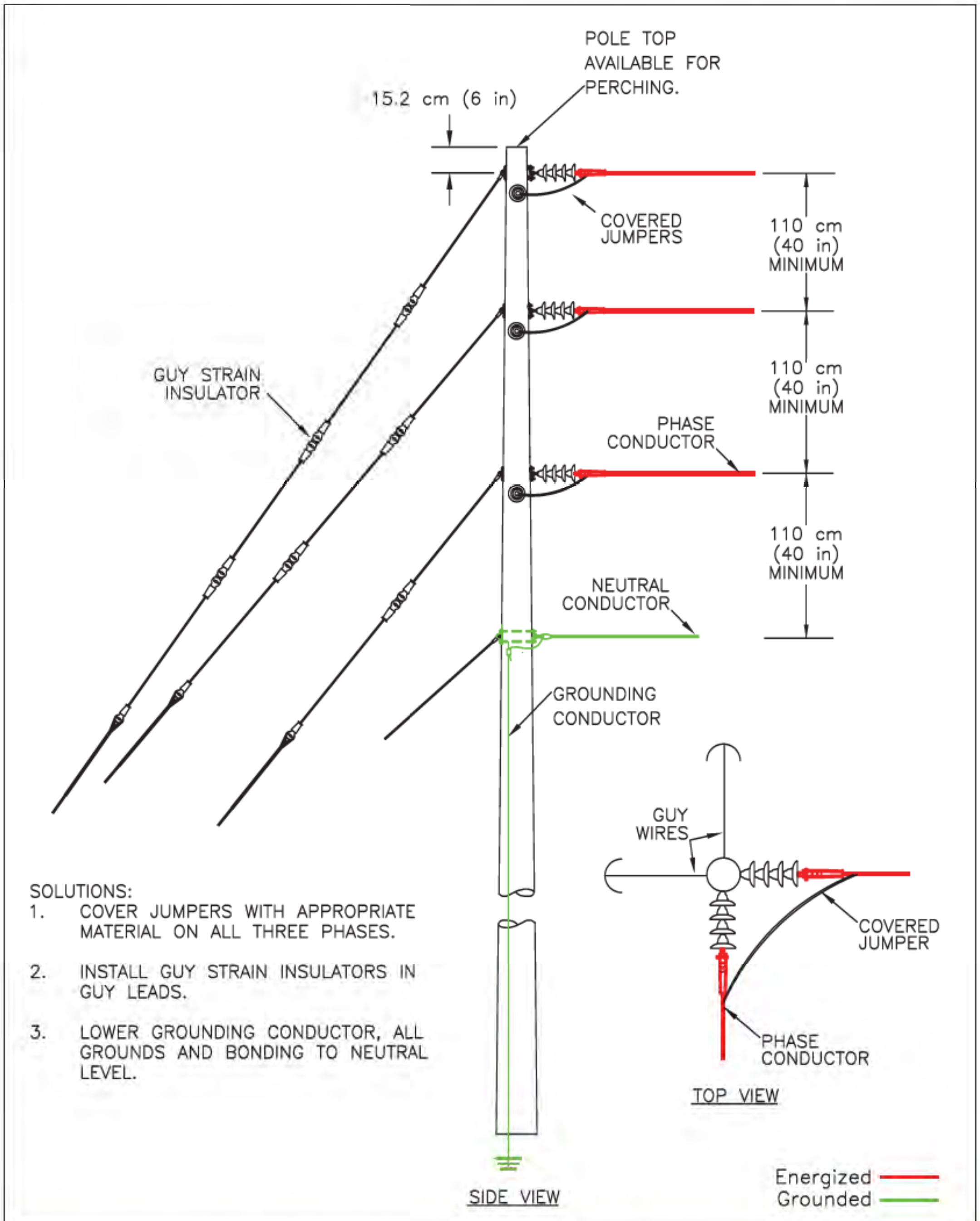

FIGURE 5.25: Three-phase vertical corner configuration—neutral below phases.

STEEL/CONCRETE POLES

Steel/Concrete Pole Construction Worldwide

Most distribution power poles in the United States are made of wood, a nonconductive material.[30] In contrast, steel and concrete poles are commonly used in distribution line construction in Europe and other parts of the world. In Western Europe, it is estimated over 90% of the distribution poles are metal with grounded metal crossarms (Janss and Ferrer 1999). On such configurations, electrocutions can occur from phase conductor to pole or phase conductor to metal crossarm, placing both large and small birds at risk (Bayle 1999; Negro 1999; Janss and Ferrer 1999). Accordingly, European electrocution mitigation methods differ from those of the United States because measures effective on wooden power poles have not solved electrocution problems on conductive poles (Janss and Ferrer 1999). However, covering conductors with a dielectric material appropriate for avian protection is typically more effective in preventing electrocutions than is perch management, regardless of whether the pole is wooden, steel, or concrete (Negro 1999). Covering conductors is the preferred method on new or retrofitted steel and concrete poles in Europe (Janss and Ferrer 1999).

Concrete poles, with their internal metal rebar support structure, pose similar electrocution risks to metal poles. Concrete poles also provide a pathway to ground, further increasing their electrocution risk, especially when wet or when fitted with conductive crossarms. The largest remaining black-tailed prairie dog *(Cynomys ludovicianus)* colony complex in North America is in northwestern Chihuahua, Mexico (Ceballos et al. 1993). This complex supports a high density of raptors and nearby power lines are constructed with reinforced concrete poles with steel crossarms. In 2000, 1,826 power poles were surveyed and 49 electrocuted birds were found, including Chihuahuan ravens *(Corvus cryptoleucus)*, ferruginous hawks *(Buteo regalis)*, red-tailed hawks *(B. jamaicensis)*, prairie falcons *(Falco mexicanus)*, American kestrels *(F. sparverius)*, and golden eagles. The number of electrocutions led researchers to conclude that these poles represent a serious risk for wintering raptors (Cartron et al. 2000). The subsequent replacement of steel crossarms with wooden arms on over 200 poles in this area significantly reduced the electrocution risk of these structures (Cartron et al. 2005).

Steel/Concrete Pole Construction in the United States

Historically, utilities in the United States have primarily used wood for distribution poles and crossarms. Accordingly, many avian retrofitting techniques today are designed for use on wood structures. Fiberglass, concrete, and steel poles are now being used more in distribution line construction for a variety of reasons. Sometimes non-wood poles are used because they are not susceptible to damage by woodpeckers. In some regions of the United States, woodpecker damage is the most significant cause of pole deterioration (Abbey et al. 1997). Steel poles and concrete poles are harder for animals such as squirrels, raccoons, and cats to climb. By keeping these animals off structures, utilities can help reduce outages. Non-wood poles may also be used because they are not susceptible to fungal, bacterial, or insect damage.

Distribution power lines constructed with steel or concrete poles using standard utility configurations can significantly reduce phase-to-ground separations. Fiberglass poles have a higher insulation resistance than steel, concrete, and wood poles.

Single-phase lines are usually constructed without crossarms and support a single energized phase conductor on a pole-top insulator.

[30] The insulation value of wood poles and crossarms is variable based on age, condition, contamination, and wetness.

Wood or fiberglass distribution structures, without pole-top grounds or pole-mounted equipment, generally provide adequate separation for birds (Figure 5.26).

When steel or concrete poles are used (Figure 5.27), a bird perched on the pole top can touch its body to the conductor while simultaneously contacting the grounded pole

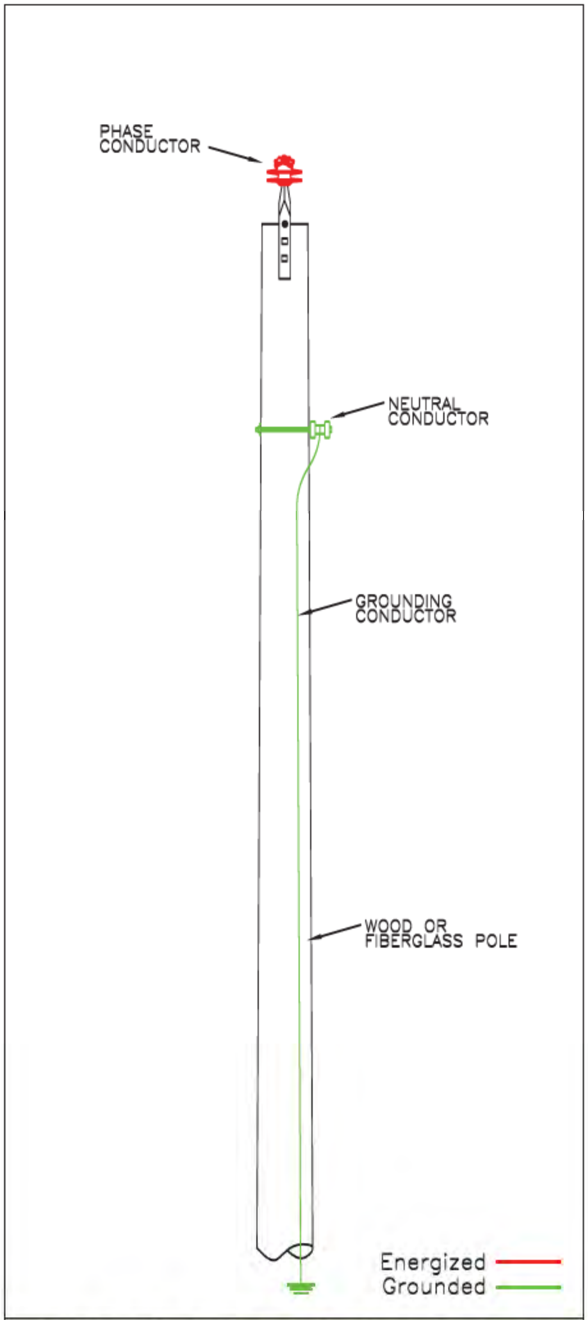

FIGURE 5.26. Typical single-phase distribution configuration on a wood or fiberglass pole.

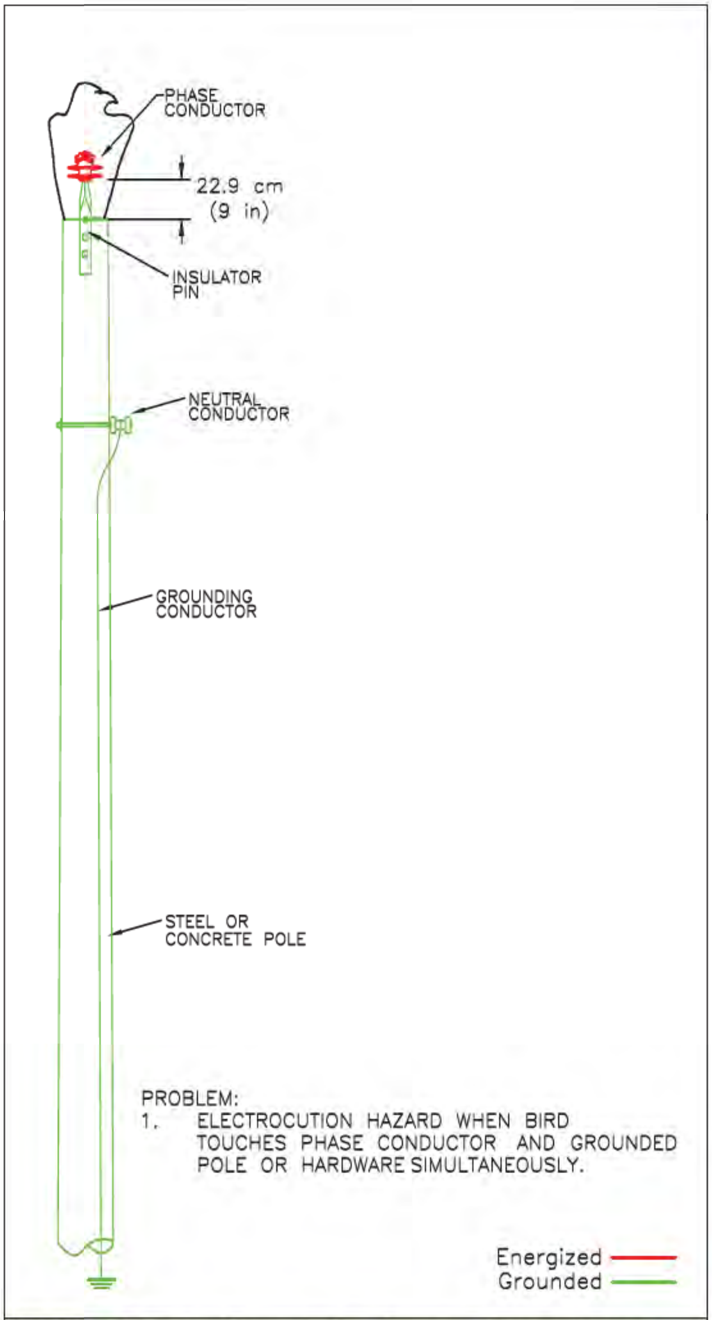

FIGURE 5.27: Problem single-phase configuration on a steel or reinforced concrete pole.

top or hardware with its feet, resulting in electrocution. One solution to this problem is to install a phase cover (Figure 5.28, Solution 1). Another solution is a two-step process: (1) place the phase conductor on an insulator installed on an extended fiberglass-reinforced pole-top pin to increase the separation between the phase conductor and the pole top, (2) install a pole cap to deter birds from perching on top of the pole (Figure 5.28, Solution 2). In tests with captive raptors at the Rocky Mountain Raptor Program, a pole cap's slick surface discouraged birds from perching (Harness 1998).

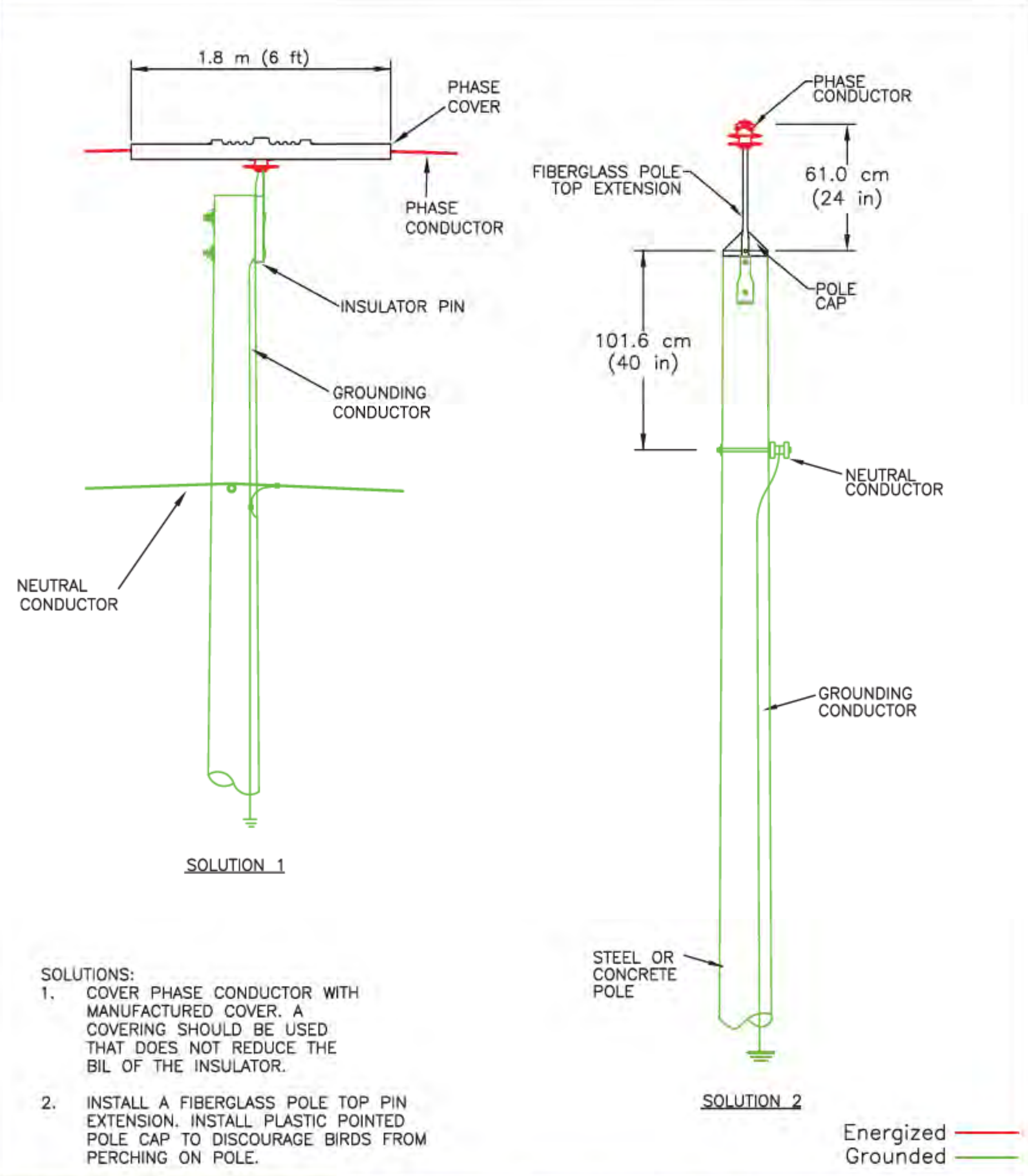

FIGURE 5.28: Solutions for single-phase configuration on a steel or reinforced concrete pole.

When steel or concrete poles are used for multi-phase structures, the critical separations for birds are both the phase-to-phase and the phase-to-pole (i.e., phase-to-ground) separation (Figure 5.29). Although the phase-to-phase issues are the same as encountered on wood poles, the phase-to-pole issue is not.

As on the single-phase structure (Figure 5.28, Solution 2), additional separation should be provided for the center pole-top phase conductor by placing it on an extended fiberglass reinforced pole-top pin and adding a pole cap to discourage perching. Additionally, wood or fiberglass crossarms should be used. Steel crossarms mounted on steel poles should be avoided because their minimal phase-to-ground separations make them extremely hazardous. Birds landing on grounded steel arms become grounded and need only touch one energized conductor or piece of hardware to be electrocuted.

The reduced phase-to-ground separations found on existing steel or concrete poles can be mitigated in several ways. One method is

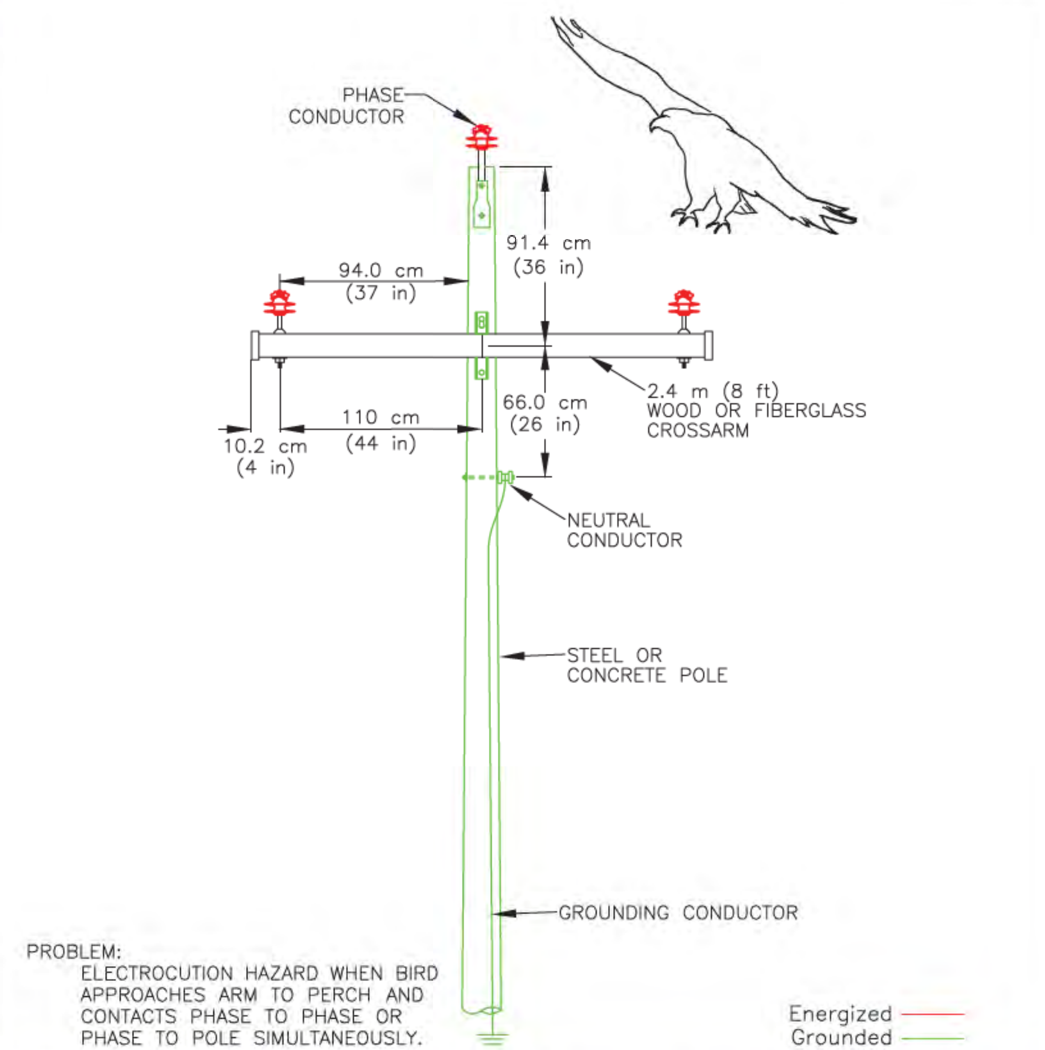

FIGURE 5.29: Problem three-phase configuration on a steel or reinforced concrete pole.

to cover the pole from the crossarm to the pole top with a material designed for this purpose (Figure 5.30). This can be achieved by wrapping a band of 40-mil thermoplastic polymer membrane backed with a pressure-sensitive adhesive around the pole from the crossarm up to and including the top of the pole, or by spraying the same area with a protective coating that has sufficient dielectric strength. A utility performed a dielectric test of a thermoplastic wrap, and determined that a 46 x 167-cm (18 x 66-in) piece allows no appreciable current leakage at 35 kV for a three-minute duration. The thermoplastic wrap also can effectively increase phase-to-ground separations on narrow profile configurations.

As an alternative to wrapping the pole top, perch discouragers can be mounted on the crossarm to deter birds from perching on the crossarm (Figure 5.31). Crossarms fitted with perch discouragers are effective in reducing

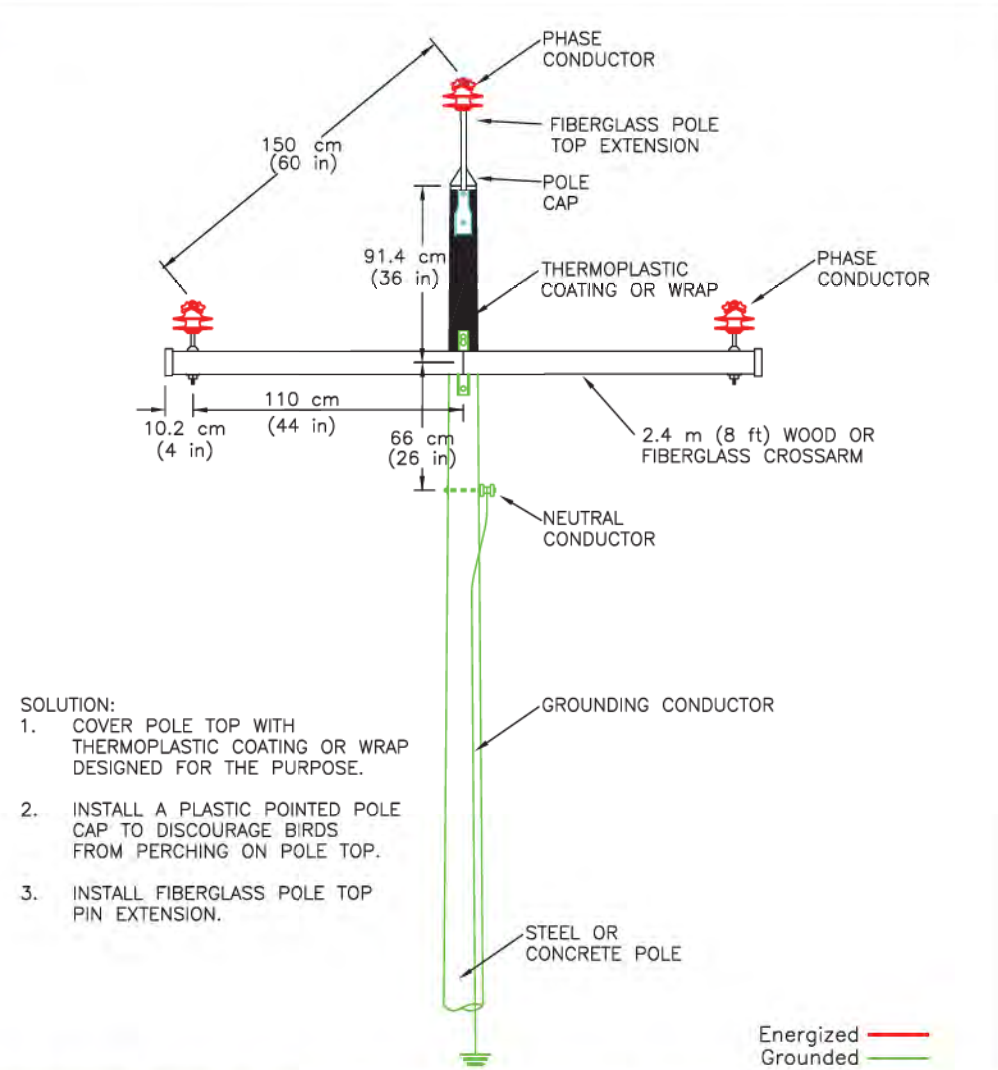

FIGURE 5.30: Solution for three-phase configuration on a steel or reinforced concrete pole using thermoplastic wrap.

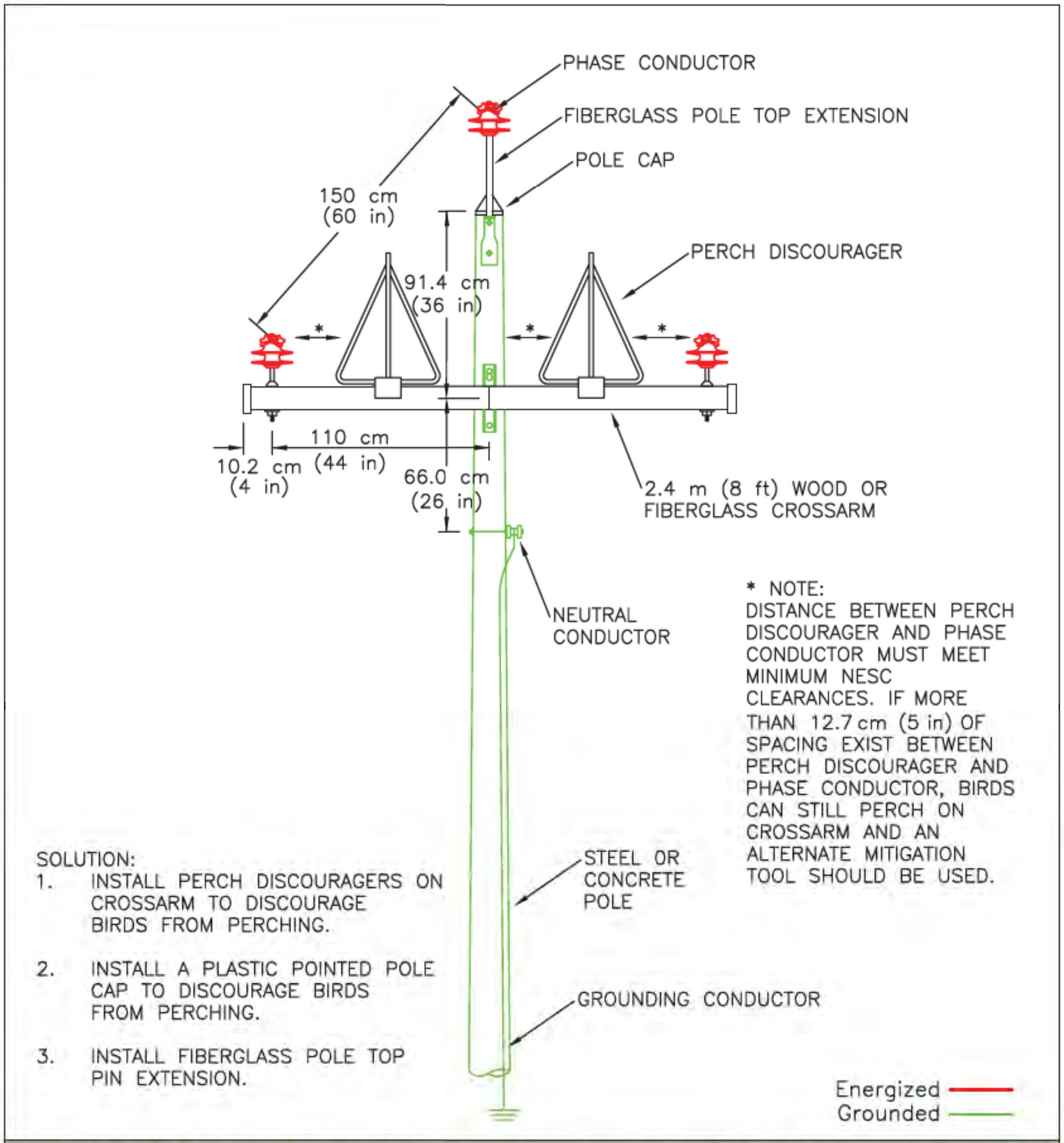

FIGURE 5.31: Solution for three-phase configuration on a steel or reinforced concrete pole using perch discouragers.

some but may not eliminate all avian mortality (Harness and Garrett 1999). Perch discouragers also may shift birds to other nearby poles that might not be any safer. For guidance on the use of perch discouragers from both biological and engineering perspectives, see page 17 and page 68.

Another suitable method for reducing avian electrocution risk is covering the outer two phase conductors to prevent phase-to-pole (i.e., phase-to-ground) contacts (Figure 5.32). On the center phase, a phase cover or a pole cap with extension pin should also be installed.

Another option is to suspend two of the energized conductors from the crossarm, instead of supporting them on the arm (Figure 5.33). Suspending the conductors allows birds to perch on the crossarm without contacting energized conductors. A pole cap and extended fiberglass reinforced insulator pin should still be used to discourage perching on the pole top to prevent contact with the center phase. Suspending the insulators and conductors will also allow utilities to achieve 150-cm (60-in) separation with 1.8 or 2.4-m (6 or 8-ft) crossarms (as shown in Figure 5.33). If vertical construction is used with steel or reinforced concrete poles, phase covers should be installed on all three conductors.

Avian-safe separation can be achieved on steel and reinforced concrete dead-end or corner poles by installing fiberglass extension links or adding additional insulators between the primary dead-end suspension insulators and the pole. This solution is similar to those recommended for three-phase distribution dead-end and corner configurations using wooden poles and crossarms (Figures 5.16 and 5.23). Bare jumper wires are commonly used to connect incoming conductors to the

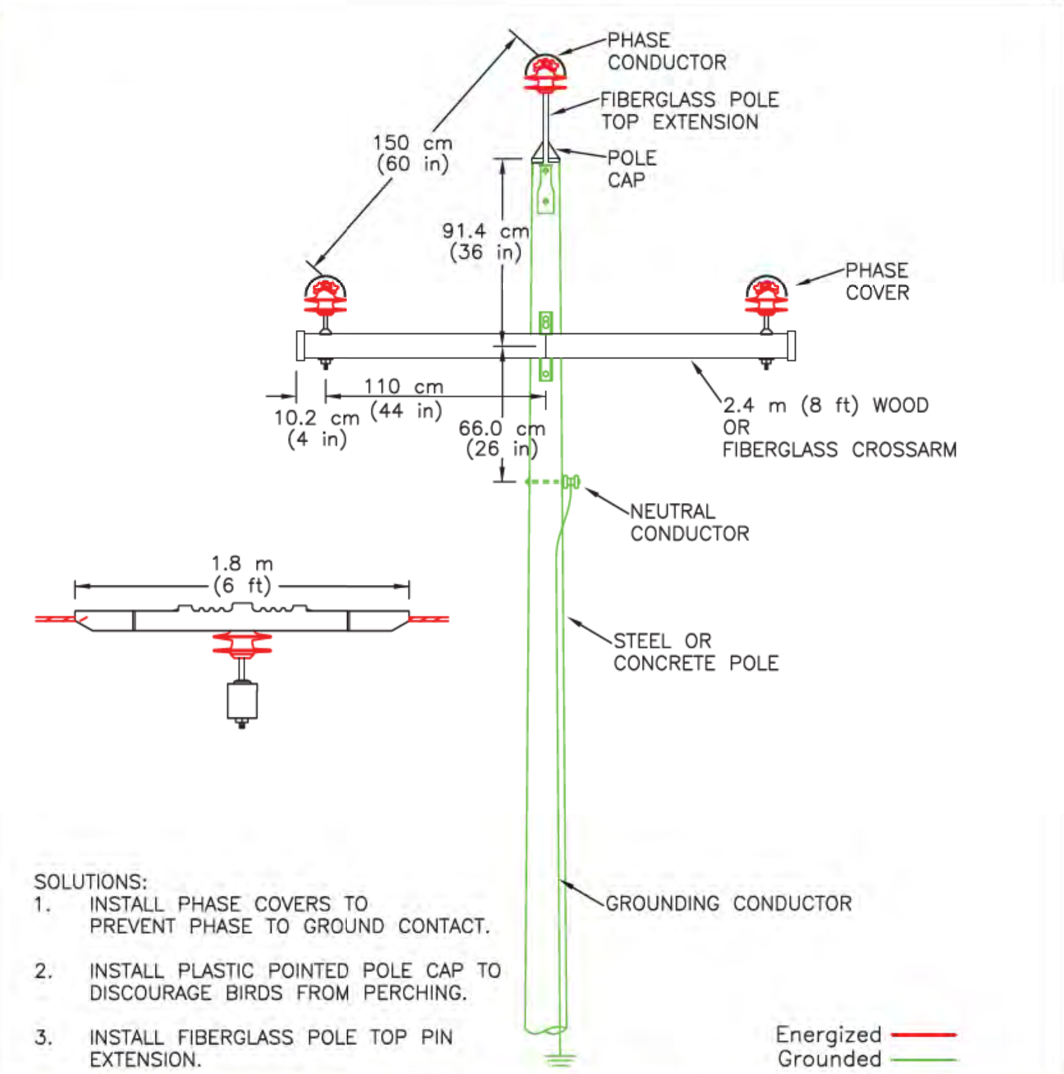

FIGURE 5.32: Solution for three-phase configuration on a steel or reinforced concrete pole using phase covers.

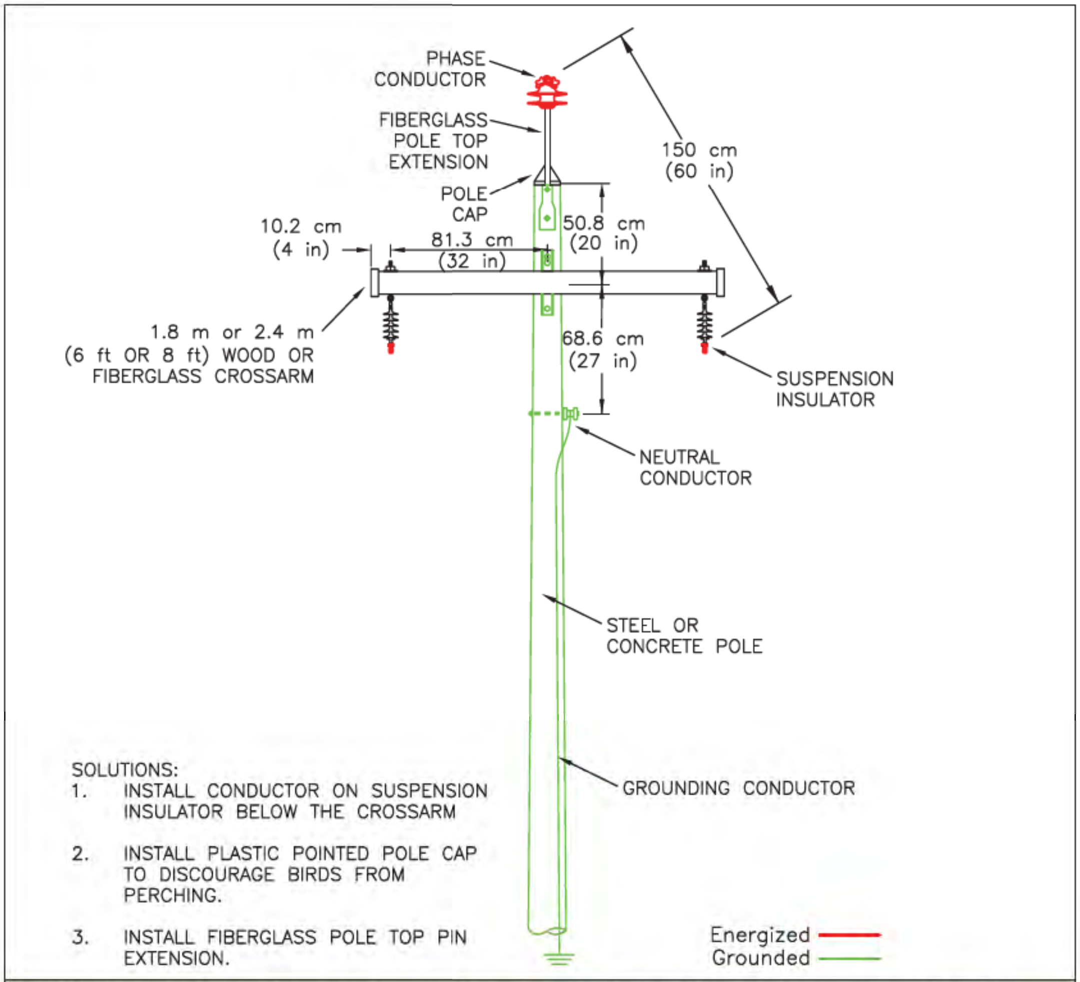

FIGURE 5.33: Three-phase configuration on a steel or reinforced concrete pole with suspended insulators.

outgoing conductors, making the line turn or tapping off the main circuit. Covering the jumper wires with a material suitable for avian protection or replacing them with covered conductor will reduce electrocution risk.

Problem Transmission Designs

Although transmission lines rarely electrocute birds, there are a few exceptions, particularly on lower voltage transmission lines (i.e., 60 kV or 69 kV).[31] The armless configuration, in which conductors are mounted on horizontal post insulators, commonly used for distribution lines (see Figures 5.20 and 5.21), may also be used for some transmission lines below 115 kV (Figure 5.34). In areas subject to high lightning levels, lightning protection may include an overhead static wire that must be grounded. On installations with wood poles, utilities, particularly in salt spray or other contaminated areas, may bond the bases of the post insulators to the grounding conductor to prevent pole fires. A bird perched on the insulator can be electrocuted if it comes in

[31] If distribution underbuild is present on a transmission structure, the recommendations shown previously for distribution configurations should be used to make the underbuild avian-safe.

contact with the energized conductor and either the grounded insulator base or the bonding conductor. From 1991 through 1993, more than 30 golden eagles were electrocuted along approximately 32 km (20 mi) of a 69-kV line with this configuration in central Wyoming (PacifiCorp, unpubl. data).

This configuration was once thought to be avian-safe because it was anticipated that birds would perch on the pole top rather than on the insulators. The 1996 edition of *Suggested Practices* recommended installing perch discouragers on the insulators to prevent electrocutions. However, because birds were still able to fit between the perch discourager and the conductor, the use of perch discouragers alone has been determined ineffective (PacifiCorp, unpubl. data).

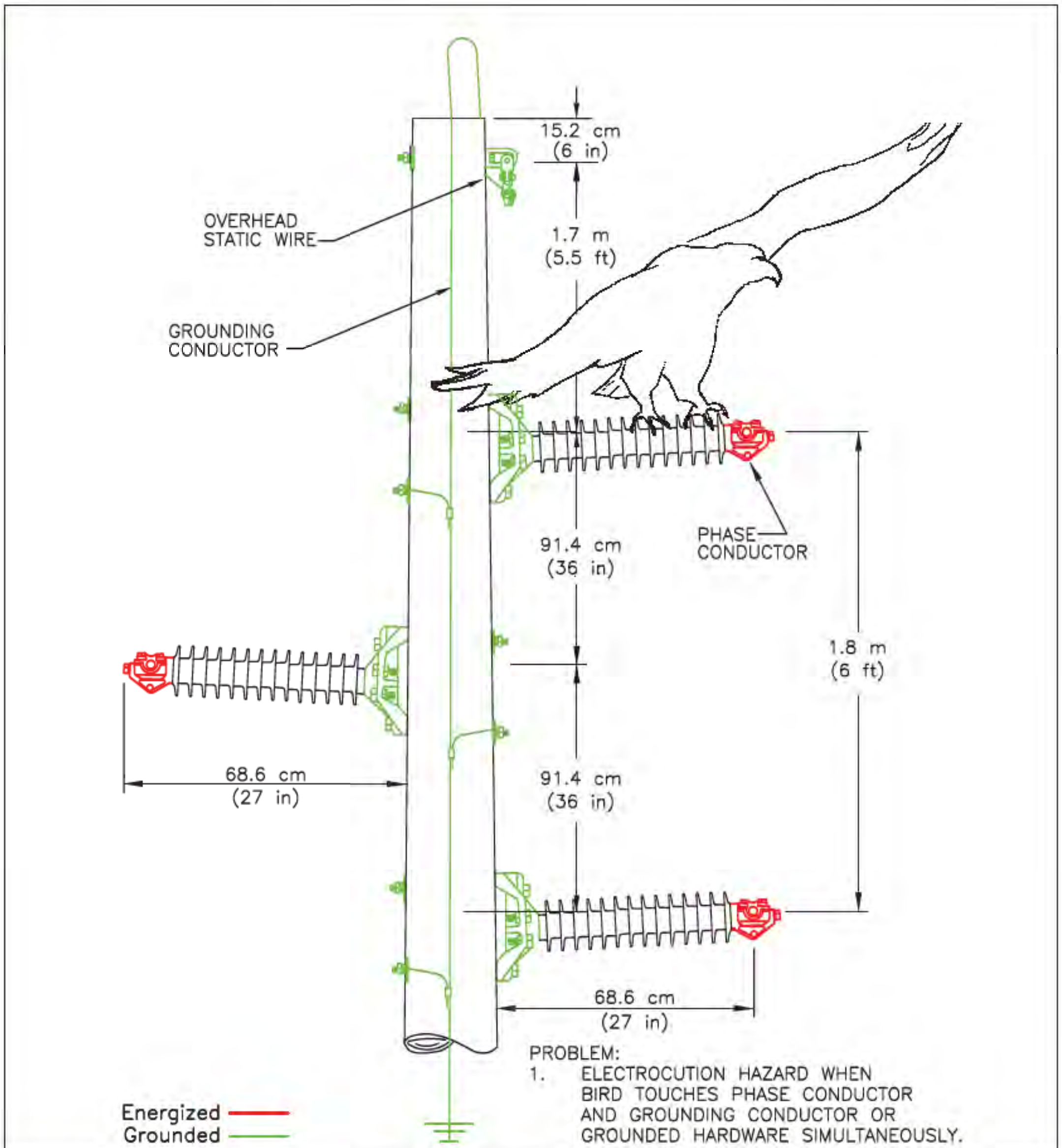

FIGURE 5.34: Problem 69-kV horizontal post insulator design.

Utilities are testing different options (Figure 5.35) for reducing electrocution risk on horizontal post construction. These options include:

- Covering the insulator bases and bolts with cover-up material designed for this purpose.
- Installing an insulated pole grounding conductor or covering the pole grounding conductor with appropriate cover-up material, or wood or plastic moldings. The grounding conductor should be covered at least 30.5 cm (12 in) below the lowest energized conductor.

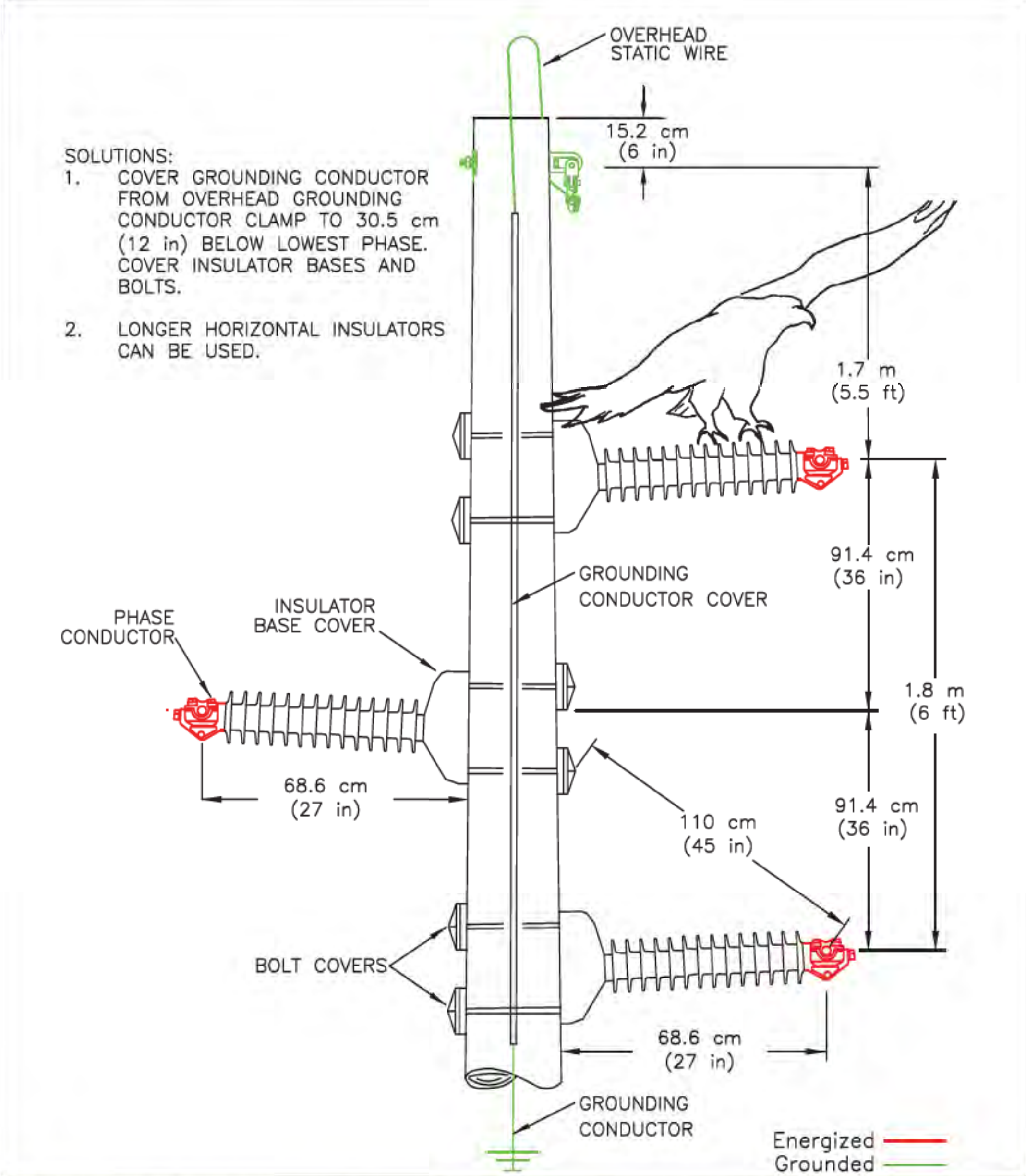

FIGURE 5.35. Solutions for 69-kV horizontal post insulator design.

• Replacing 60-kV or 69-kV post insulators with longer insulators (i.e., 115 or 138 kV) to provide the necessary 150-cm (60-in) separation. Although this may be a costly retrofit option, it can be used for new construction.

The wishbone configuration (Figure 5.36) is commonly used for 34-kV to 69-kV lines. The distance from the top phase to the lower arm can be less than 1 m (3.3 ft), which presents an electrocution hazard when large birds such as eagles or waders touch their heads to the energized conductor while

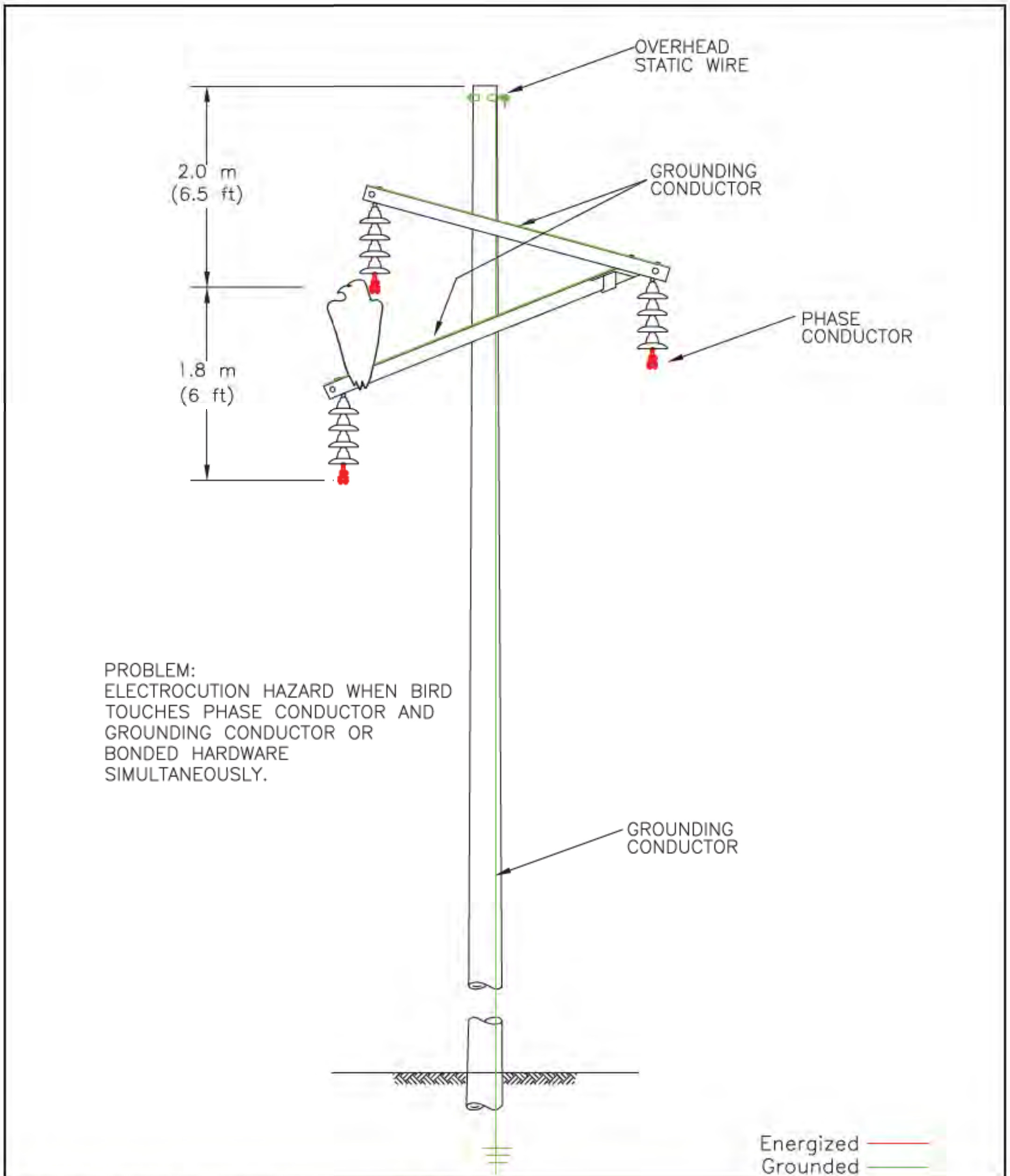

FIGURE 5.36: Problem wishbone design.

perched on the grounding conductor or bonded hardware on the crossarm.

To prevent phase-to-ground contact on the wishbone design, the grounding conductor and bonded hardware should be covered. This can be accomplished by:

- installing a dielectric cover on the lower crossarm (Figure 5.37), and
- covering the grounding conductor with plastic or wood molding or plastic tubing. A covered ground wire may also be used. The grounding conductor should be

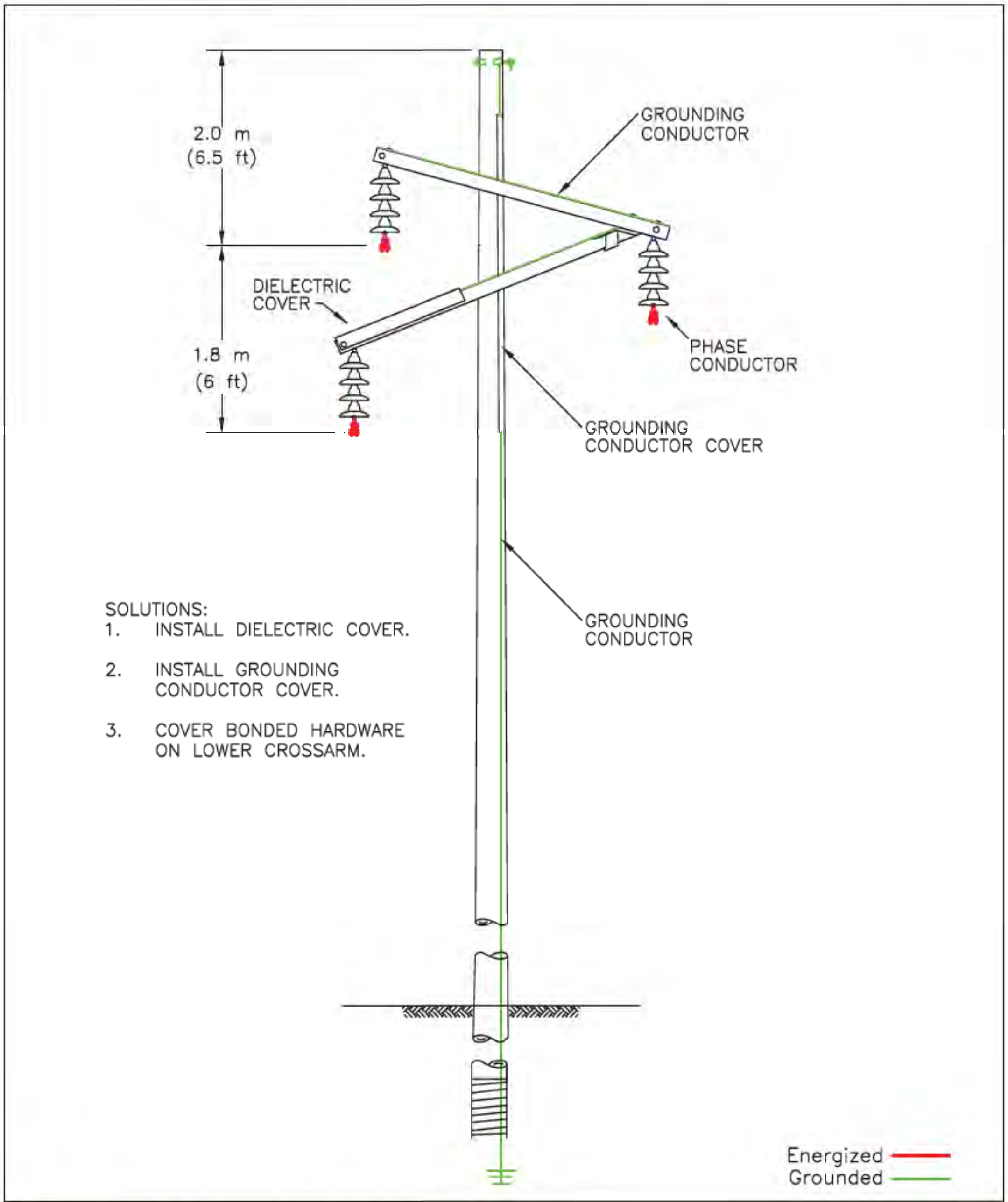

FIGURE 5.37: Solution for the wishbone design.

covered at least 30.5 cm (12 in) below the lowest energized conductor. Bonded hardware on the lower crossarm should also be covered with a material appropriate for avian protection.

For new construction, a wishbone design that provides adequate separation for large birds can be used (Figure 5.38). An avian-safe suspension configuration (Figure 5.39) can also be used for new construction as an

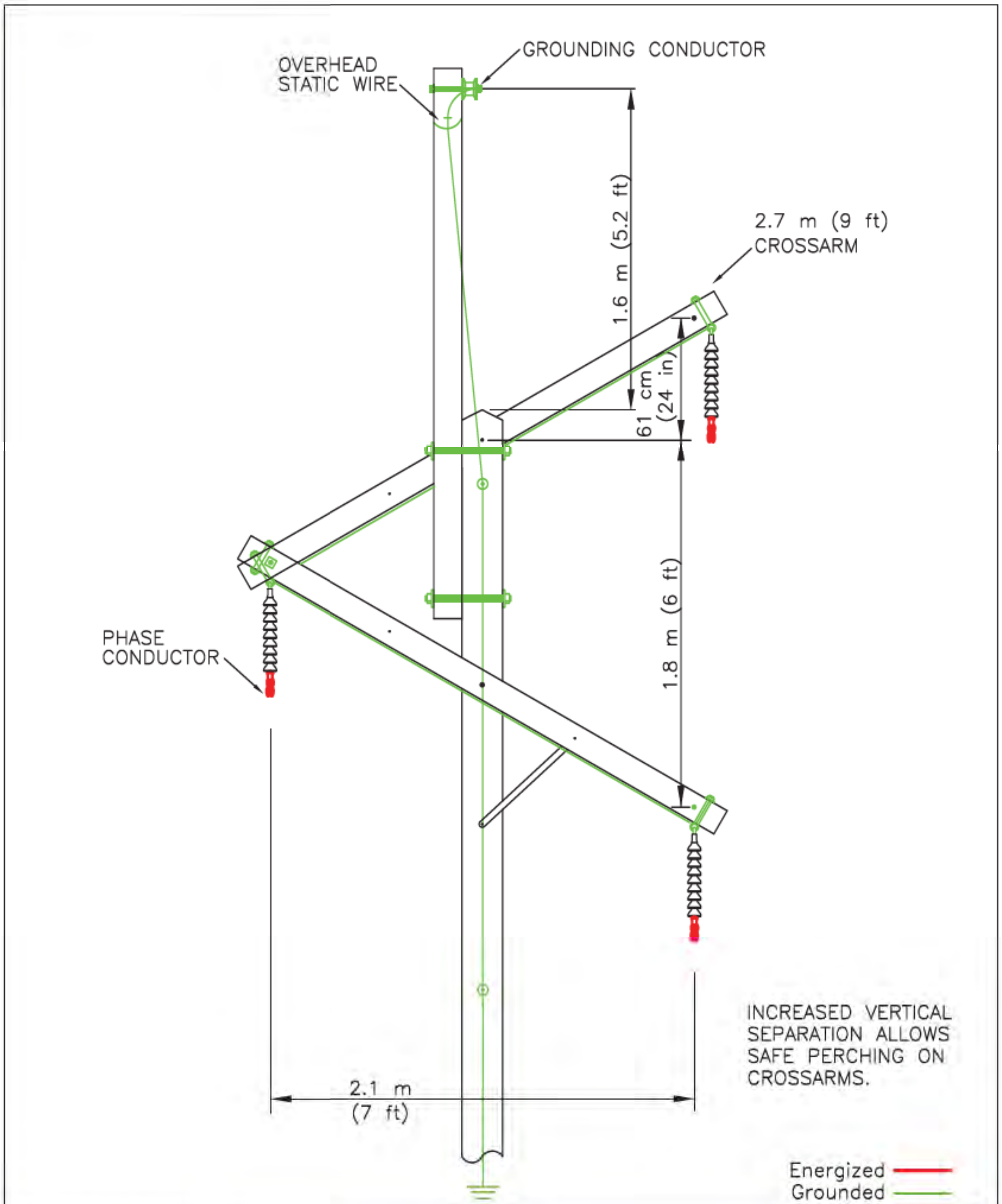

FIGURE 5.38: Avian-safe wishbone construction.

alternative to the wishbone or horizontal post designs. This suspension configuration provides adequate separation between phases and accommodates perching on the davit arms. The ridge pin overhead-grounding conductor attachment may also be replaced with a side-mounted suspension arrangement so the pole top is also available for perching. Although this construction can reduce electrocutions, it may contribute to streamer problems from

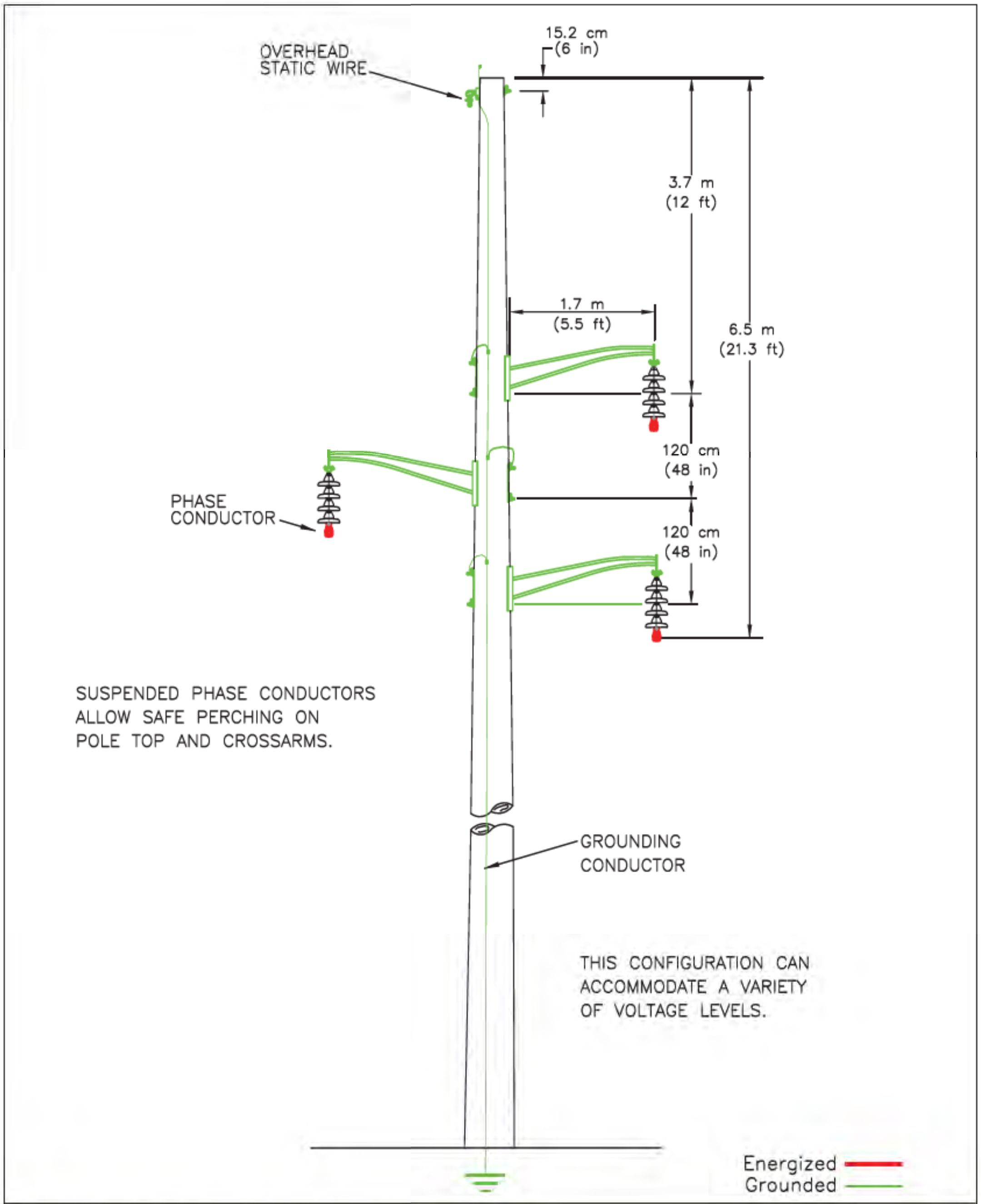

FIGURE 5.39: Avian-safe suspension configuration.

birds perching on a davit arm and defecating on the conductor or insulator below.

Figure 5.40 depicts a 69-kV design with a steel bayonet added as a lightning rod. This rod is grounded and significantly reduces separation between energized hardware and itself. This configuration can pose a phase-to-ground electrocution risk for birds that attempt to land or perch on the crossarms. In one year, 69 raptor carcasses were recovered from under a line of this configuration in southern Idaho (Idaho Power Co., unpubl. data). If

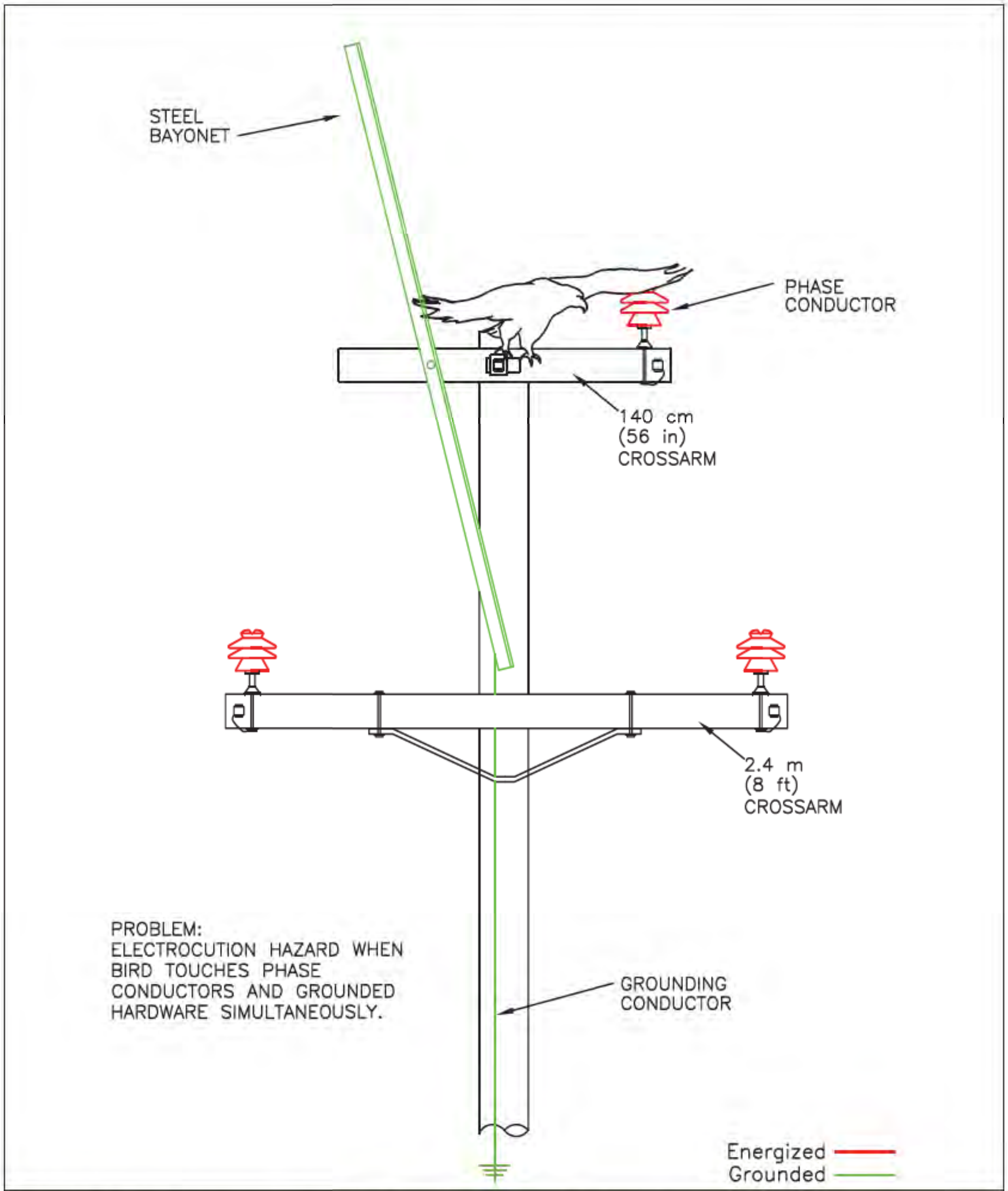

FIGURE 5.40: Problem design with grounded steel bayonet.

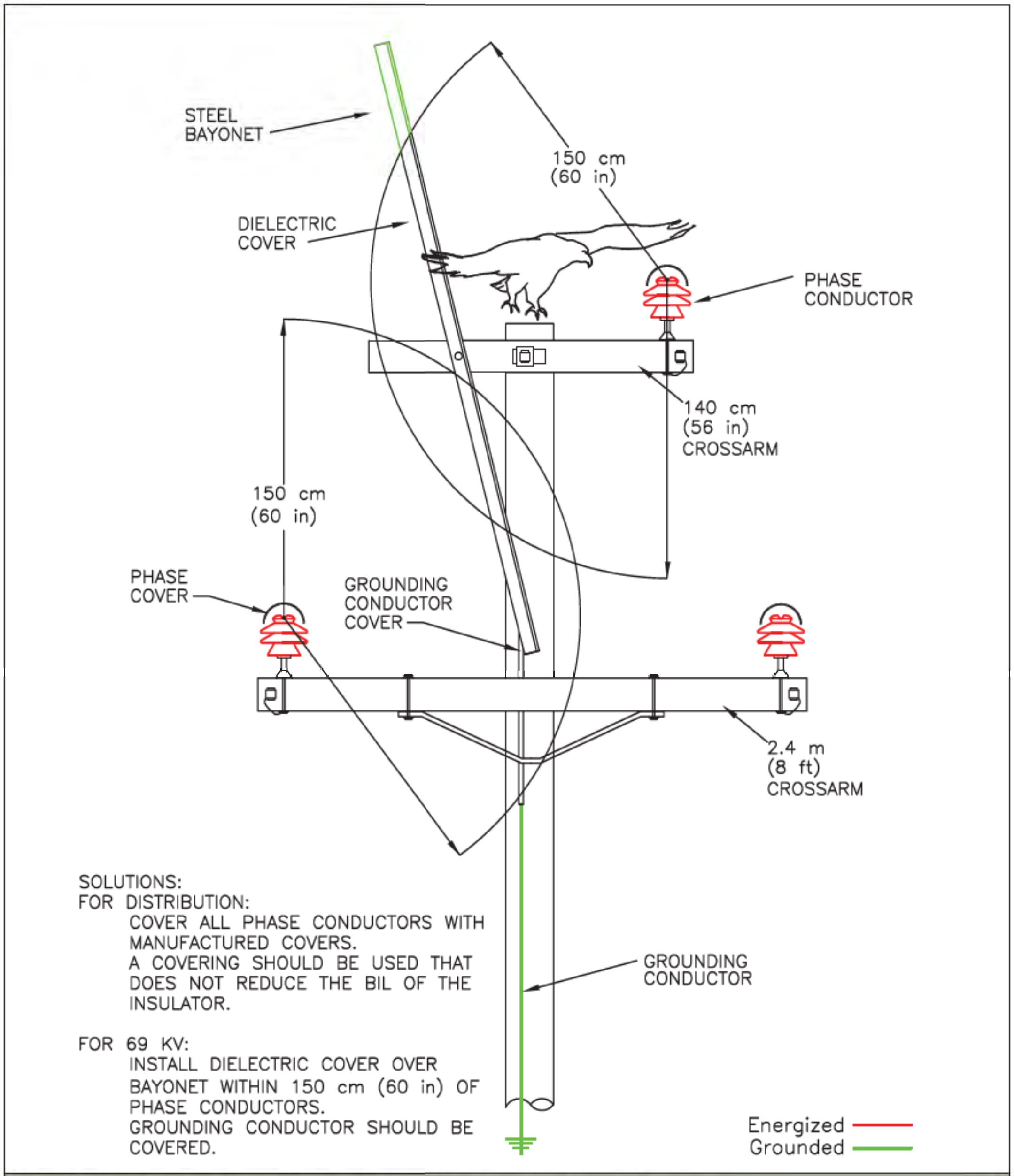

FIGURE 5.41: Solutions for design with grounded steel bayonet.

this configuration is used for a distribution line, phase covers can be installed on all three phases to prevent electrocutions (Figure 5.41). If mitigating a transmission line of this configuration, the bayonet should be covered with a dielectric cover within 150 cm (60 in) of the phase conductors. The grounding conductor should also be covered.

On the corner structure shown in Figure 5.42 (Problem 1), large birds may be electrocuted by making simultaneous contact with uncovered phase jumpers and the grounded structure. A solution to this problem is to install horizontal post insulators to move the phase jumpers further from ground (Figure 5.43, Solution 1).

Raptor mortalities have occurred on double-circuit transmission tower designs with insufficient clearance for perching raptors from the grounded center crossarm brace (also called grounded tension member or wind brace) to the top phase (E. Colson, Colson and Associates, pers. comm. in APLIC 1996) (Figure 5.42, Problem 2). Electrocutions on this configuration may be remedied by covering grounded tension members with dielectric material (Figure 5.43, Solution 2). It may also be possible to replace the tension

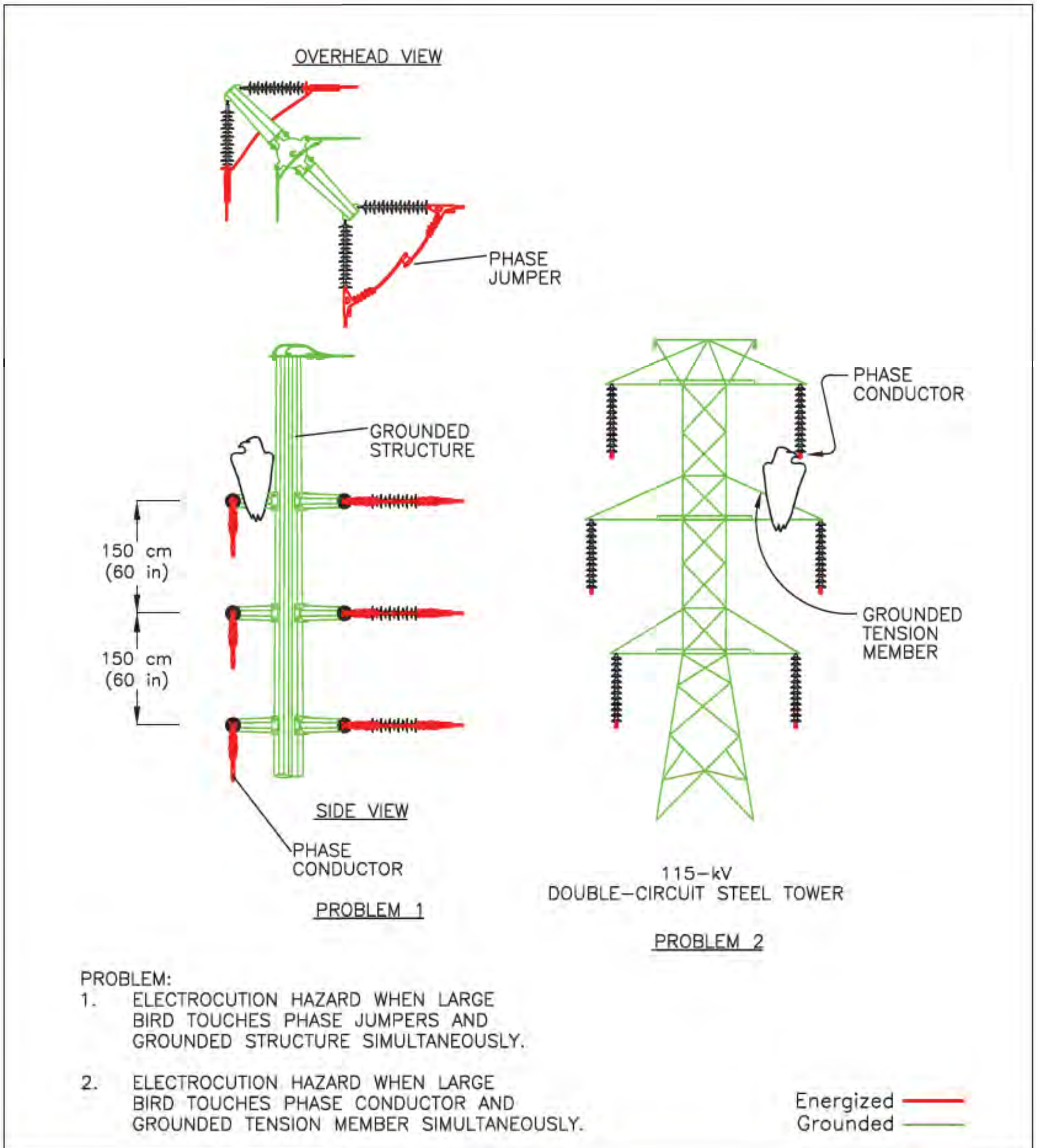

FIGURE 5.42: Problem transmission designs.

member with a non-conducting material (e.g., fiberglass) that meets structural requirements.

Transmission lines may produce arcing, where current jumps, or arcs, from a conductor to a bird on the structure. Though the conductor separation on higher voltage lines is sufficient to avoid this, it can occur on the more closely spaced lower voltage transmission lines. To prevent bird-induced arcing on more closely spaced transmission lines, conductor separation should be increased from 152 cm (60 in) by 0.5 cm (0.2 in) for each kV over 60 kV (see Table 5.3).

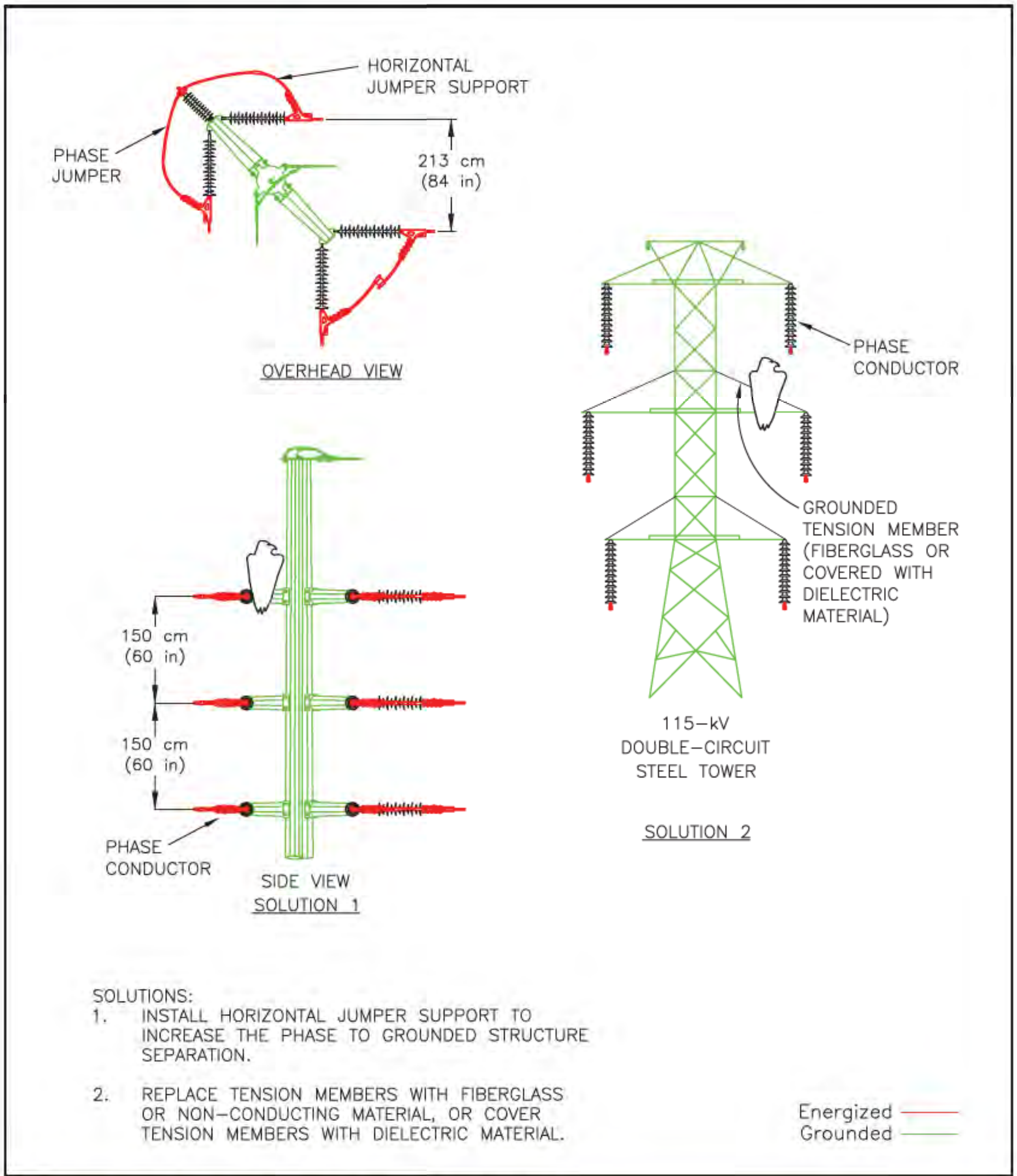

FIGURE 5.43: Solutions for transmission designs.

TABLE 5.3: Recommended conductor separation for transmission lines >60 kV.		
kV	Horizontal Spacing	Vertical Spacing
69 kV	157 cm (62 in)	106 cm (42 in)
115 kV	180 cm (71 in)	130 cm (51 in)
138 kV	192 cm (76 in)	141 cm (56 in)

Equipment Poles

TRANSFORMERS AND OTHER EQUIPMENT

Equipment poles are poles that have transformers, capacitor banks, reclosers, regulators, disconnect switches, cutouts, arresters, or overhead-to-underground transitions (often referred to as *riser poles*). Equipment poles pose increased electrocution risks to birds of all sizes because of close separations between both phase-to-phase and phase-to-ground (Figures 5.44, 5.45).

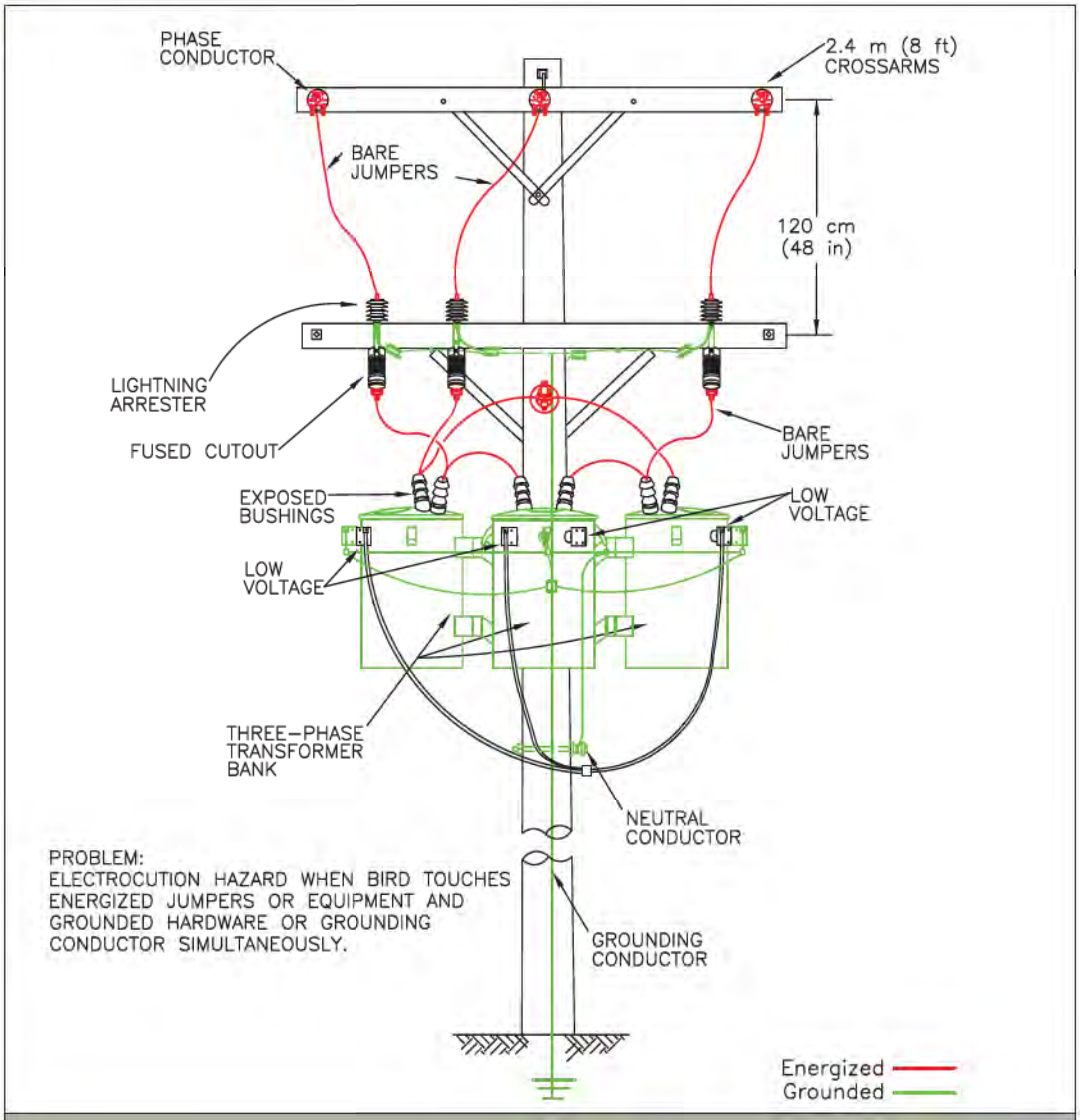

FIGURE 5.44: Problem three-phase transformer bank.

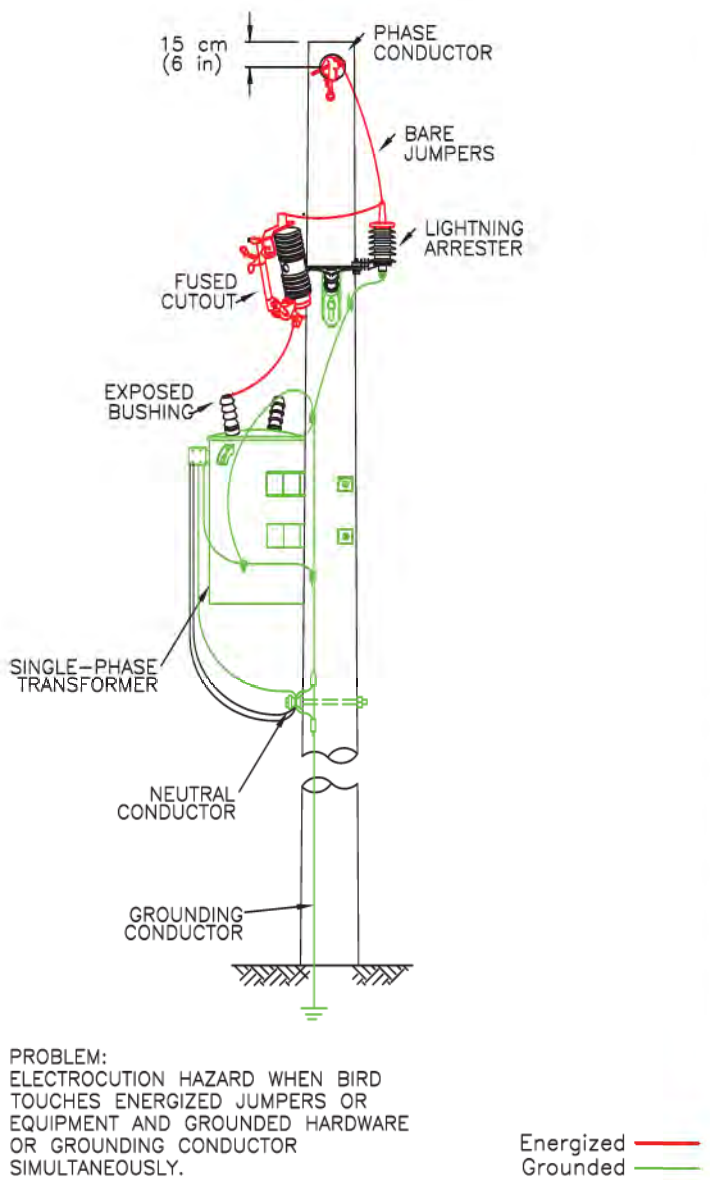

FIGURE 5.45: Problem single-phase transformer bank.

If a line is located in an area of high lightning activity, some utilities may install an overhead (grounded) static wire, requiring the installation of a grounding conductor all the way to the top of some or all structures. To assure the safety of line personnel and the general public, the NESC requires that all electrical equipment such as transformers, switches, lightning arresters, etc., must also be grounded. This grounding usually reduces the separation between energized and grounded parts of the system.

In a review of raptor electrocutions from 58 utilities in the western United States between 1986 and 1996, more than half were associated with transformers (Harness and Wilson 2001). Fifty-three percent of confirmed electrocutions (*n*=421) were associated with transformers, yet only one-quarter of the poles in these areas were transformer poles. Single or three-phase transformer banks were associated with 41% of eagle mortalities (*n*=748), 59% of hawk mortalities (*n*=278), and 52% of owl mortalities (*n*=344). In Utah and Wyoming, poles with exposed equipment accounted for only 32% of all structures surveyed (*n*=74,020), yet 53% of poles with mortalities (*n*=457) had exposed equipment (Liguori and Burruss 2003). In particular, transformers were present on 16% of structures surveyed, yet were found on 36% of poles with mortalities. Small birds (including starlings, magpies, and songbirds), ravens, and owls were more frequently electrocuted at poles with transformers or other equipment than at poles without equipment.

Utilities should be sure to address electrocution risk on the entire pole when retrofitting or designing equipment poles. Electrocution risk on new or retrofitted equipment poles can be reduced by using a variety of cover-up materials including covered conductors, moldings, covered jumper wires, arrester covers, bushing covers, cutout covers, phase covers, and other covers to prevent birds from making simultaneous contact between grounded and energized conductors or hardware (Figures 5.46, 5.47). See the *Precautions* section (below) for a discussion of cover-up materials. When lightning arresters are installed on a wooden crossarm in combination with fused cutouts, the arrester ground wire is normally attached beneath the arm connecting the base of the arresters to ground without bonding or contacting the arrester brackets.

The use of perch discouragers alone on or near equipment poles is not recommended, as perch discouragers may deter birds from landing on the crossarm, leaving equipment arms or transformers as perching alternatives. However, perch discouragers may be used if an alternative perch is provided and exposed equipment is covered with appropriate avian protection devices.

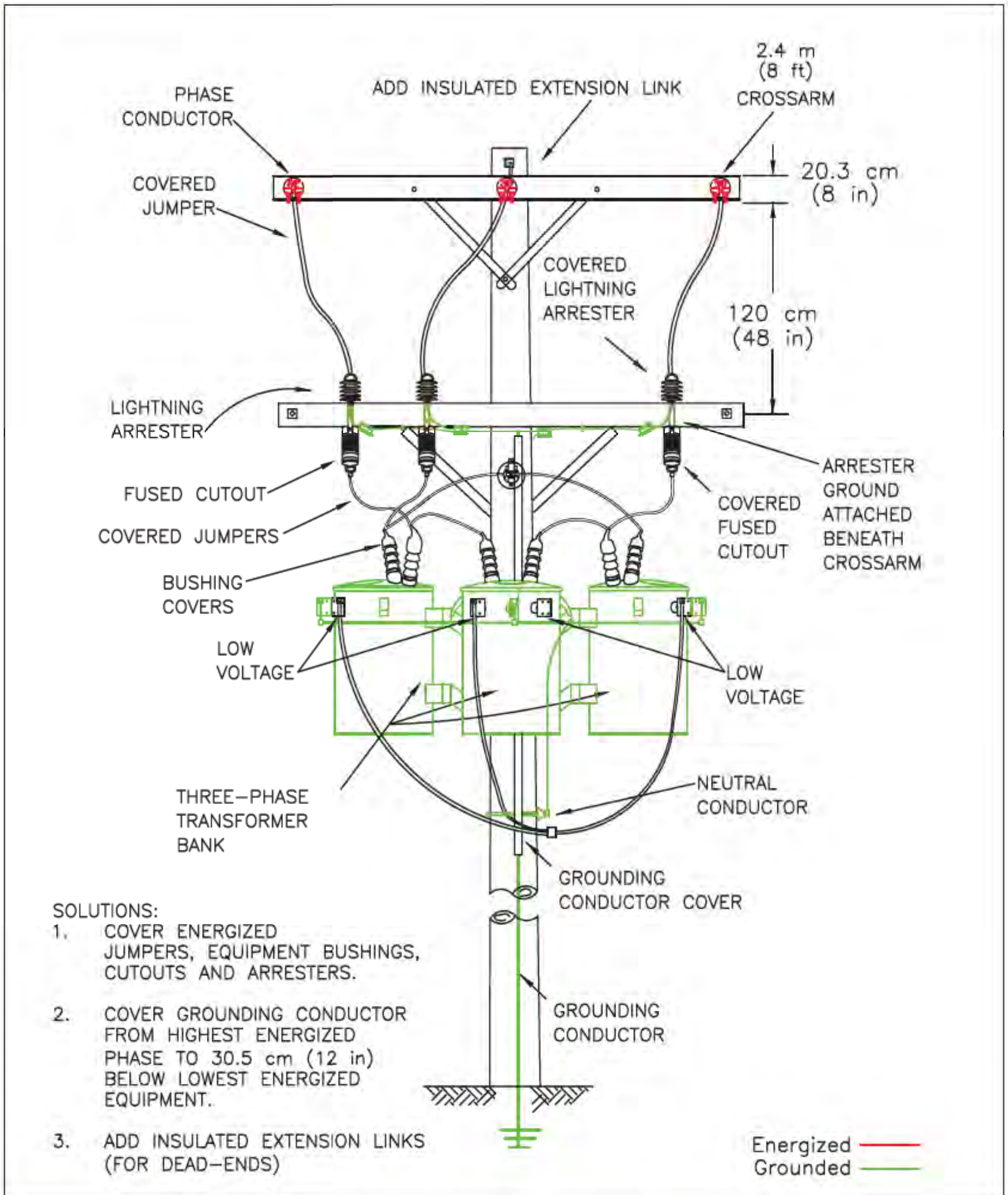

FIGURE 5.46: Solution for three-phase transformer bank.

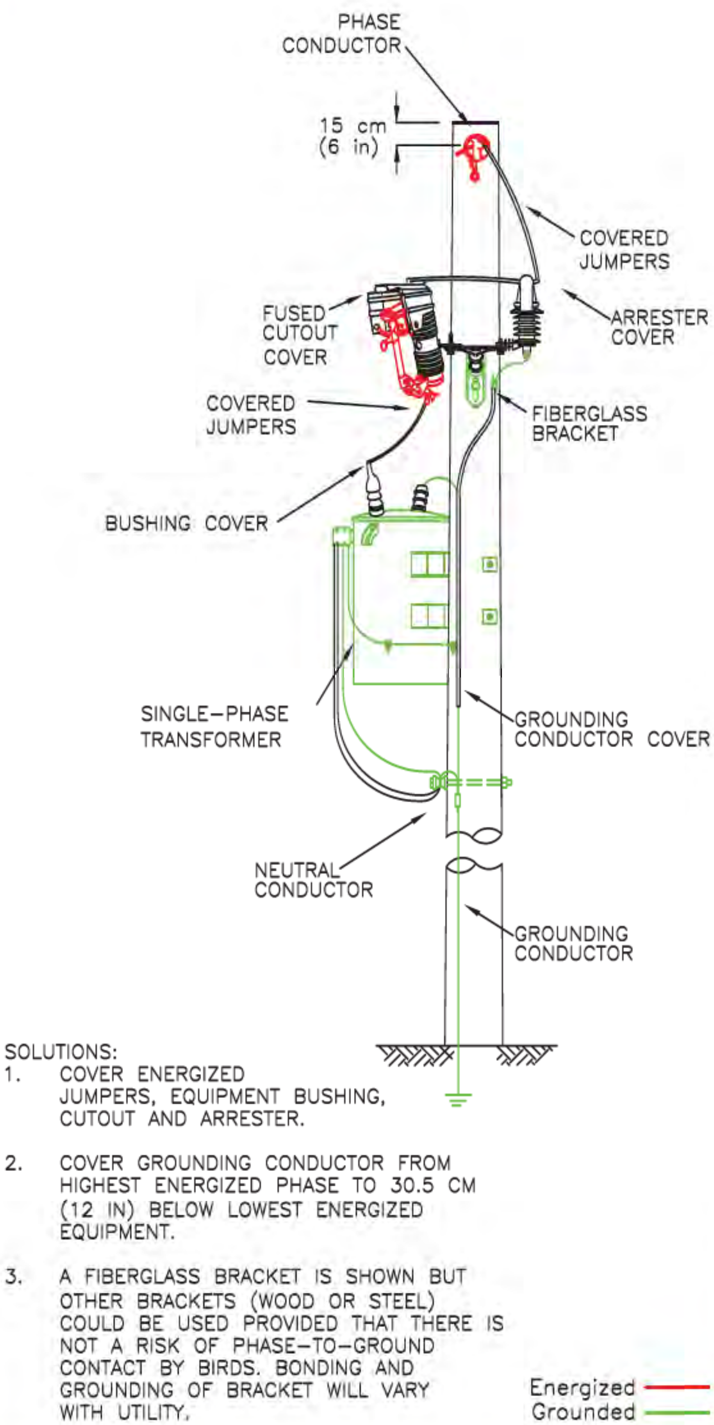

FIGURE 5.47: Solution for single-phase transformer bank.

PRECAUTIONS

When using cover-up products on equipment, a utility should be aware of several important points. First, these products are intended only for wildlife protection; **they are not intended for human protection.** Second, there are currently no standard protocols for testing such products (see page 51 for further information on testing). Utilities are advised to evaluate the products that they select for durability, effectiveness, ease of installation, etc. Finally, wildlife protection products may not be effective or can cause problems if installed improperly. Bushing covers and arrester covers should fit between the first and second skirts of the bushing or arrester. Likewise, phase covers should sit on the top skirt of the insulator and not extend to the crossarm. If covers are pushed down too far, they can cause tracking, outages, or fires. Cutout covers should also be evaluated to ensure that they will not interfere with the operation of the cutouts or the use of a load-break tool. Coverings on jumper wires should cover the entire jumper, because exposed gaps can pose an electrocution risk. See the APLIC website (www.aplic.org) for a current list of avian protection product manufacturers.

SWITCHES

Many types of switches are used to isolate circuits or redirect current for the operation and maintenance of a distribution system. Several examples are shown in Figures 5.48, 5.49, and 5.50. Because of the close separation, it may be difficult to mitigate electrocutions on switch poles. Efforts can be made to either provide birds with safe perch sites on adjacent poles or to make switch poles less hazardous to birds. The installation of unprotected switch poles is discouraged in raptor use areas due to the electrocution risk and difficulty of making these poles avian-safe. Where switches are installed, offset or staggered vertical switch configurations with an

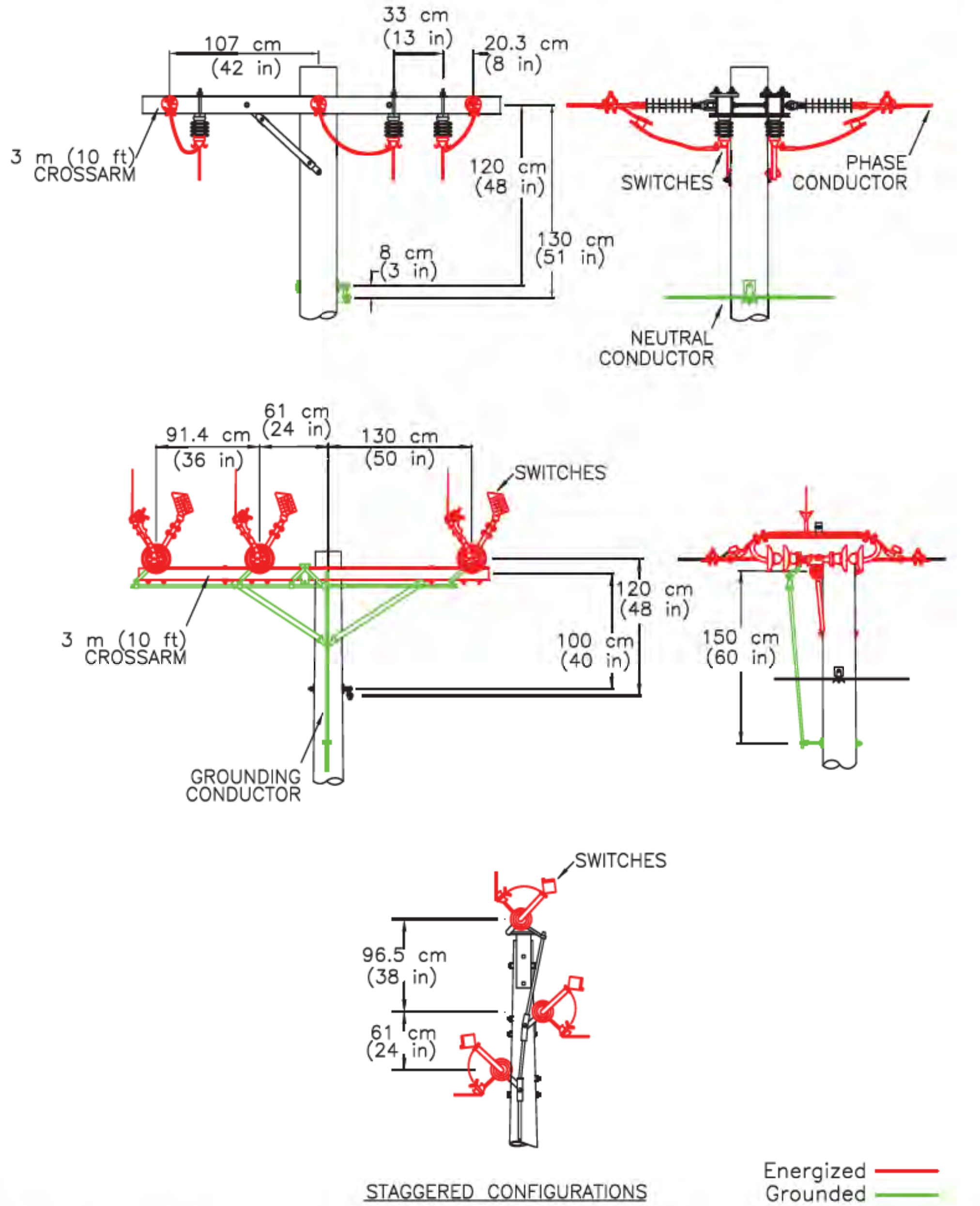

FIGURE 5.48: Pole-mounted switches.

alternate perch above the top switch may provide a safer perching site (see Figure 5.49). Separation is key to making these structures safer for birds. Coverings designed for the purpose should be used on as many of the energized components as possible. Using fiberglass arms for switches may also help reduce electrocutions.

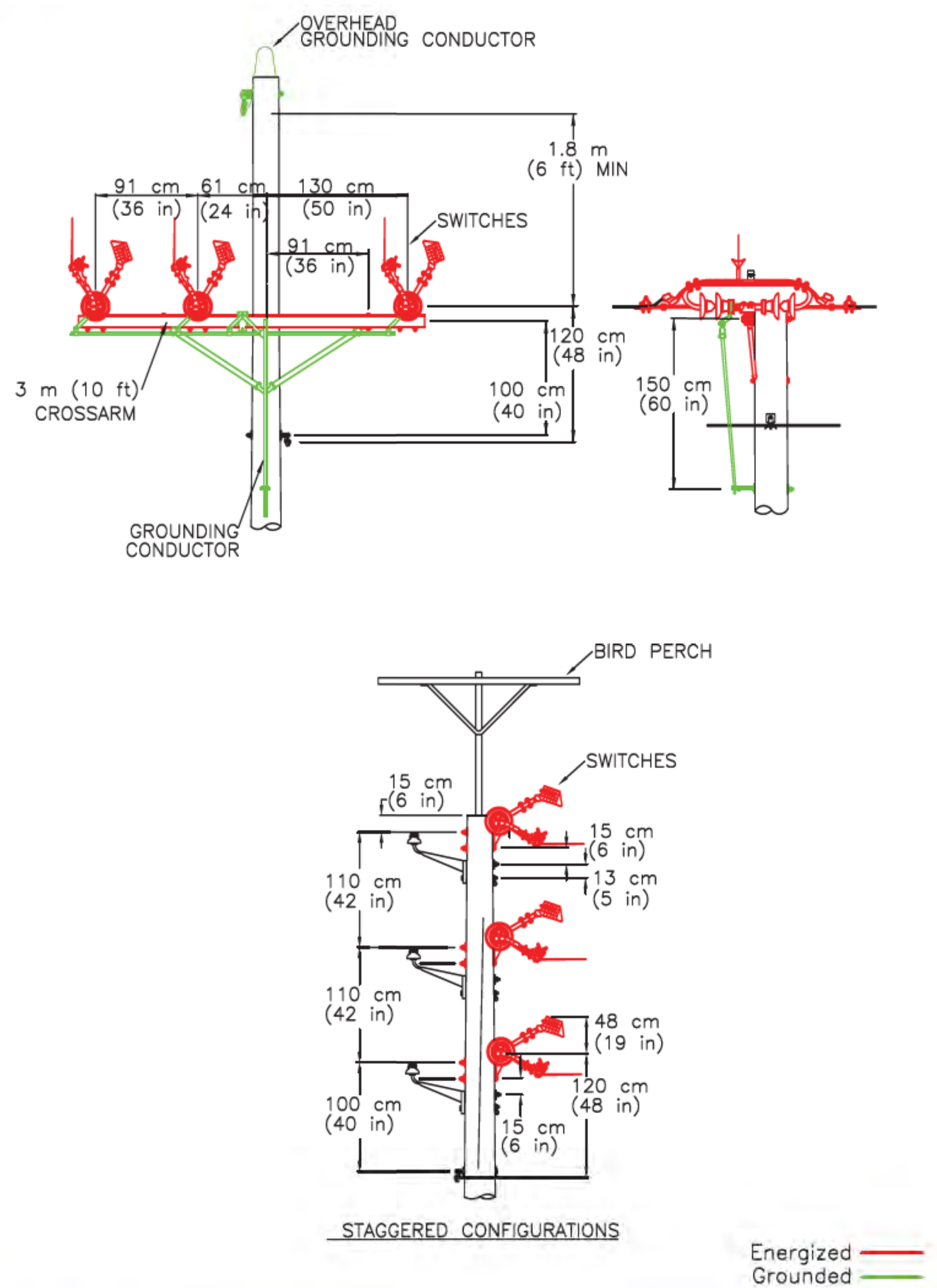

FIGURE 5.49: Pole-mounted switches.

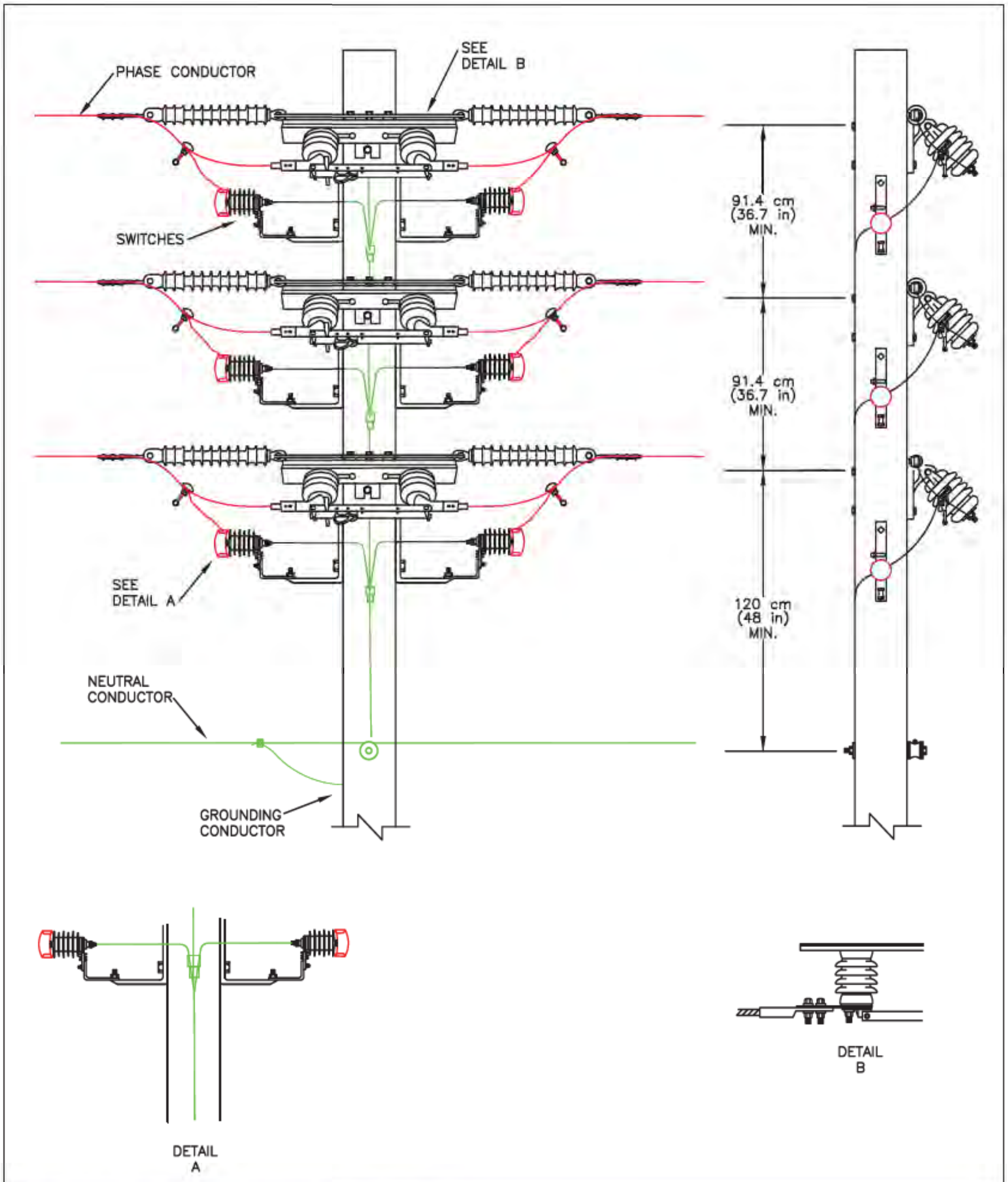

FIGURE 5.50: Pole-mounted switches.

SUBSTATION MODIFICATION AND DESIGN

Substations are transitional points in the transmission and distribution system. While raptor electrocutions at substations are uncommon, smaller birds such as songbirds and corvids may perch, roost, or nest in substations, causing electrocution and outage risks. Numerous bird species have caused substation outages, including great horned owl *(Bubo virginianus)*, American kestrel, black-billed magpie *(Pica hudsonia)*, European starling

(*Sturnus vulgaris*), golden eagle, and monk parakeet (*Myiopsitta monachus*) (PacifiCorp, unpubl. data; Florida Power and Light, unpubl. data). Over an 18-month period, 18 bird-caused outages were documented in substations in six western states, which affected over 50,000 customers (PacifiCorp, unpubl. data).

Over the years, numerous techniques have been used to prevent bird and animal contacts in substations. Such techniques include habitat modification, physical barriers, auditory, visual, olfactory, and pyrotechnic discouragers, and physically removing animals. Many of these practices have had limited success, or are cost-prohibitive or impractical. The most effective method for preventing bird contacts in substations employs the practices used for distribution and transmission structures, "insulate" or isolate (see page 59). For new substations, a combination of framing and covering can prevent contacts by birds and other animals. For existing substations, cover-up materials designed for the purpose can be installed to make substations avian-safe.

SUMMARY

Power line structures can present electrocution hazards to birds when less than adequate separation exists between energized conductors or between energized conductors/hardware and grounded conductors/hardware. This document recommends 150-cm (60-in) separation for eagles. Other separations may be used based upon the species impacted. Avian-safe facilities can be provided by one or more of the following:

- increasing separations to achieve adequate separation for the species involved
- covering energized parts and/or covering grounded parts with materials appropriate for providing incidental contact protection to birds
- applying perch management techniques.

A utility's Avian Protection Plan (see Chapter 7) should identify new construction designs, retrofitting options, approved avian protection devices, proper installation techniques, and other procedures related to avian protection.