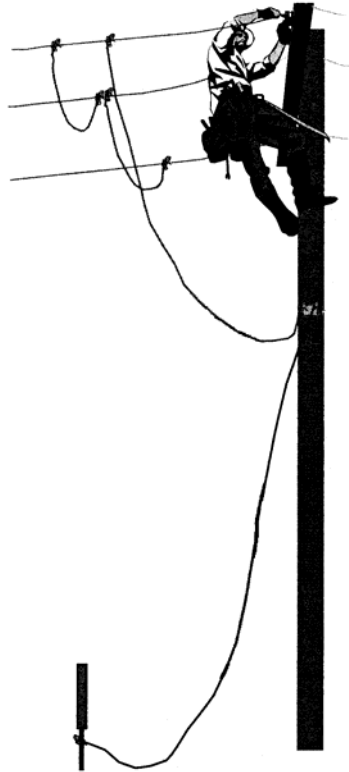


**EQUIPOTENTIAL BONDING & GROUNDING
FOR OVERHEAD TRANSMISSION AND
DISTRIBUTION FACILITIES**

STANDARD & APPLICATION GUIDE



EQUIPOTENTIAL BONDING & GROUNDING FOR OVERHEAD TRANSMISSION AND DISTRIBUTION FACILITIES

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ATCO Electric
Engineering and Construction Department
Standards Group
10035 - 105th Street
Edmonton, Alberta Canada T5J 2V6
Phone: (780) 420-3426
Fax: (780) 420-3440

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TABLE OF CONTENTS

STANDARD

Section 100: Standard

101	General.....	1
102	Reason for the Standard	2

APPLICATION GUIDE

Section 200: Developing a Safe Work Plan

201	Identify Potential Hazards.....	3
202	Establish the Work Practices / Barriers for the Job to Manage the Hazards	4

Section 300: Background and Definitions

301 What is The Difference Between Grounding
and Bonding?..... 5

302 Applying Grounding..... 5

303 Applying Bonding 6

304 Power System Source..... 8

305 Job Site and Work Area..... 9

306 Downlead..... 9

307 Induction..... 10

Section 400: Procedures and Guidelines

401 Things to Watch For 13

402 Working from the Structure..... 14

403 Working on the Ground..... 15

404 Splicing Conductor..... 15

405 Equipment / Material Entering or Leaving
the Equipotential Zone 17

406 Working from a Bucket 17

407 Single Phase Line with System Neutral..... 18

408 Working Procedures for Bonded Sections
of Two or Three Phase Lines..... 18

409 "Butt Down" / Tie-Down Locations 20

410 Wood Poles with Downleads..... 22

411 Steel Towers / Steel Poles / Concrete Poles 22

412 Cutting Open Wire or Jumpers..... 22

413 Guyed Structures 22

414 Grounding Inside a Substation 23

SECTION 100: STANDARD

101 General

Equipotential bonding and grounding (EB&G) is the standard practice for working on isolated electrical overhead circuits above 750 volts.

Grounding standards and practices for working on isolated underground systems are located in the Nisku Training Centre Work Procedures.

Who is qualified to use EB&G?

- a journeyman who has completed training
- an apprentice who has completed training and is authorized by his work leader

- **102 Reason for the Standard**

This standard was developed to manage electrical safety hazards effectively for staff, contractors and the public when dealing with isolated electrical circuits above 750 V. Some of the key risk factors addressed in this standard are:

- A. Trip grounding practices, which do not prevent hazardous electrical shocks in the event a line becomes accidentally energized.
- B. Accidental energization of circuits despite diligent efforts to isolate circuits.
- C. The increase in induction situations as facilities are built closer together and electrical loading on circuits continues to rise.
- D. Current construction practices for stringing new lines which expose the public to hazards by not controlling the accessibility of the conductors.

SECTION 200: DEVELOPING A SAFE WORK PLAN

201 Identify Potential Hazards

When you first consider a job, you should run through a checklist of potential hazards and identify where and how these hazards might affect your situation.

- A. Accidental Energization
 - switching error
 - distribution connected generator
 - backfeed from standby generators
 - contact with other lines/phases
 - potential rise on the neutral or shield wire due to a fault elsewhere
- B. Induction
 - static induction (caused by voltage on adjacent circuits)
 - magnetic induction (caused by current flowing in adjacent circuits)
- C. Atmospheric Conditions
 - lightning strikes
 - static charge from storm clouds near lines
 - static charge from wind-driven dust and snow

202 Establish the Work Practices / Barriers for the Job to Manage the Hazards

The best way to deal with hazards, of course, is to avoid them. Although the purpose of protective measures is to guard against unforeseen circumstances, there are also steps that can be taken to minimize the possibility of a hazard, by looking at:

- A. Work Practices
 - i. Sequence activities to minimize the need to climb over an equipotential band.
 - ii. Avoid touching a vehicle if it is tied into your equipotential zone (climbing on and off the vehicle, getting tools, etc.).
 - iii. If equipotential methods cannot be used for some work on the ground, find ways to minimize the length of time and the number of people who have to be exposed to the risk.
 - iv. Minimize voltage rise and duration of fault:
 - Select the best available ground.
 - Bond phases together to limit the voltage difference between the conductors.
 - v. Minimize the current flow through the worker:
 - Maintain ground chains to limit the voltage across the body in a bonded area (i.e., watch for clean connections, broken strands at the clamp).
 - Produce a proper equipotential zone.
 - Use approved tools and equipment.
 - vi. Limit exposure of people to hazards:
 - Select the safest location for the ground to protect workers and the public.
 - Control public access to hazards.
 - Identify hazards before the job begins.
 - Plan the job to minimize the time people are exposed to potential hazards.
 - Identify and take protective measures against known hazards such as induction.

SECTION 300: BACKGROUND AND DEFINITIONS

301 What is the Difference Between Grounding and Bonding?

- A. "Grounding" is a method of connecting an isolated conductor to some type of ground in order to trip the circuit as quickly as possible and minimize voltage rise on the circuit. Grounding, by itself, does not protect a lineman from harmful shock currents.

- B. "Bonding" is a method of physically interconnecting conductive parts to maintain a common potential. The objective of bonding is to avoid harmful shock currents by minimizing any potential difference across the lineman's body. An adequately-sized jumper is used to tie the conductor / circuit / equipment to a bonding point such as an equipotential band or ground mat / grid below the lineman's feet.

302 Applying Grounding

- A. The reason for applying grounds is to trip the circuit, minimize voltage rise in backfeed situations or minimize static induction. Remember – equipotential bonding is required to protect you from harmful shock currents.
- B. When you are applying grounds, consider the following: Connecting a circuit to a "ground" does not mean the voltage will be zero. If a conductor becomes energized at 14,000 V, the voltage at the ground probe will also be 14,000 V, since they are electrically tied together. The voltage in the soil around the ground probe diminishes with distance. Step and touch potential hazards will exist any time there is a source of energy, including induction.
- C. Remember – there is always some resistance associated with a ground. Any time a current flows through this ground, hazardous step and touch potentials could exist.
- D. A ground is always needed to trip circuits when accidentally energized.
- E. When induction is a consideration, the installation of two or more grounding points could cause circulating currents. Be aware that large circulating currents can create step and touch potential hazards around the grounding points.
- F. If in doubt of the integrity of a single, untested ground rod at a structure, use a ground probe in conjunction with it (i.e., watch for possibilities of corrosion and deterioration of the connections and rods).

303 Applying Bonding

Acceptable equipotential bonding methods must be used when you are within the limits of approach of an isolated electrical circuit and there is any possible source of energization. The application of bonding is to protect linemen from harmful shock currents.

When applying bonding, consider the following:

- A. Bonds to phases, neutrals and shield wires must be applied with a hot stick (this does not include downloads). The reason for using a hot stick is to protect yourself in the event any of the wires become energized. Remember – if the neutrals or shield wires are tied to the phases at another location, then all of the wires must be treated as phase conductors.
- B. Bonds between pole bands and downloads can be made by hand. Even though downloads are subject to the same type of hazards as the phases, shield wires and neutrals, there is no practical way to avoid contact with them while climbing the pole. Plan your job to minimize the time you are exposed before your equipotential zone is set up.
- C. On wood poles without downloads, use a jumper to a pole band. The pole band can be positioned anywhere from just below your feet to a distance of 4 m (13 ft) below your feet. This distance was determined for tooling purposes only. If the band is too high on the pole, it is difficult to move around; if it is too close to the ground, it produces a hazard for the groundman.
- D. On poles with downloads, you have two options for setting up equipotential zones:
- Preferably you should use a pole band bonded to the conductors and download for consistency and to avoid confusion.
 - You can create an equipotential zone above bonded through-bolts by bonding the download to the conductors. If you are working below all the bonded bolts, you must use a pole band. Again, the band can be placed up to 4 m (13 ft) below your feet.
- Don't rely on the connection between the shield wire/neutral to downloads to provide bonding. Take a good look at the connection since there are many situations where the connection is questionable. Install a bonding jumper between the overhead and the download when in doubt.
- E. A through-bolt on a pole is an acceptable alternative to a pole band providing:
- the bolt is bonded to the conductors
 - the bolt is tight and snug-fitting
 - you can work comfortably above the bolt

- Do not allow a small-gauge bonding wire or hardware to become in series with the tripping circuit. If you are unsure of where the zone will be, use the rated pole band.
- F. All conductive paths must be bonded together to form an equipotential zone. To ensure you maintain equipotential zones, the phases and neutral/shield wires must be bonded together either at the site or at a remote location.
 - G. When you bond to steel towers, steel poles, concrete poles and wood poles with downleads, you are also achieving some level of grounding.
 - H. When planning a job, you can usually bond most of the conductors together away from the structure you are working on. Remember – think electrically, not mechanically.

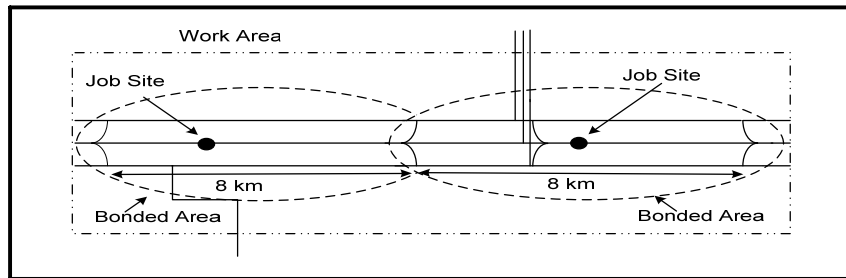
304 Power System Source

A "power system source" is defined as a man-made generator of electricity with high voltage and the capacity to deliver a hazardous current flow, including:

- i. another powerline that could become connected to your circuit through:
 - a switching error (normal and loop feeds)
 - distribution connected generator
 - line crossings
 - overbuilt or underbuilt circuits
 - parallel lines (leaned lines, other circuits in the same corridor)
- ii. transformers of 100 kVA per phase or larger (this assumes there could be some form of back-up generation at these sites that would have the capacity to produce a hazardous current flow in the bonded area)

305 Job Site and Work Area

- A. A "job site" is defined as a specific location where work is being performed. Changing a pole would be classed as a job site.
- B. A "bonded area" is a segment of line where work will be carried out in which all conductors are bonded together and which is no longer than 8 km in length.
- C. A "work area" consists of one or more bonded areas where work will be performed.
- D. Within work areas, make sure you have an appropriate ground to trip the circuit (see Section 302: Applying Grounding).
- E. The definitions of "job site," "*bonded area*" and "work area" were developed in order to define practical areas in which work will be carried out that are not so large that it becomes very difficult to ensure that risks are being managed. *See the following diagram.*

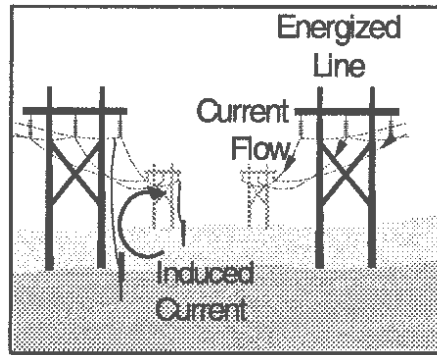


306 Downlead

A "downlead" is a conductor that bonds overhead equipment and/or neutral wire to a ground rod.

307 Induction

- A. The dangers of induction are often underestimated. Induction can kill. With more lines being forced into corridors and operated at higher currents, induction sources must be considered and respected.



- B. Static Induction (caused by the voltage on adjacent circuits)

An isolated line parallel to an energized conductor will act as a capacitor. Depending on the voltage and phase orientation of the energized circuit, a certain voltage will appear on the isolated line. When the isolated line is grounded, a continuous current will flow to ground, which is proportional to the length of the parallel with the energized line and the size of the wire.

- C. Magnetic Induction (caused by current flowing in adjacent circuits)

- An energized circuit parallel to an isolated circuit can act like an air-core transformer. Grounding the isolated line at two or more points acts as a short across the secondary of a transformer, causing a current to flow. The amount of current flowing in the isolated line will depend on the distance between the furthest grounding points (the length of the parallel), the separation between the circuits, the circuit configurations and the current flowing in the energized line.

- Remember – if one point is grounded along the parallel, a person touching the conductor may become the second grounding point. Also, watch out for step and touch potential hazards around grounded points such as guy wires, ground rods and tower legs.

SECTION 400: PROCEDURES AND GUIDELINES

This section describes requirements and gives practical advice for common work situations. Although the descriptions provide some options for carrying out work, you may come up with more efficient methods for a particular situation. The general principles and many of the application techniques in this guide apply to both transmission and distribution.

401 Things to Watch For

- A. Be aware of fused disconnects and opening jumpers.
- B. Remember – if guy wires, grounds or neutrals are involved, they must all be bonded into the zone.
- C. If you are working on a rural transformer pole, avoid working on the meter base when there is a zone established on the top of the pole.
- D. Only tie a truck into a zone when needed and remove as soon as the work is completed.
- E. Install all bond leads with a hot stick as isolated conductors and equipment are tied into the zone. Sequence your work so you do not need to use a hot stick when attaching to downleads, guy wires, anchor rods, vehicles and bands.

- F. Be on the lookout for bad connections. These high resistance points could produce a voltage drop in a zone that could be harmful.
- G. Inspect your ground chains on a regular basis. A contaminated connection or clamp could produce a voltage drop in a zone that could be harmful.
- H. If you are working on a structure with a disconnect / recloser / breaker, you should bond across that device.
- I. Make sure that there are no fused disconnects / reclosers / breakers between you and your tripping ground.
- J. Do as much work as you can before you produce a zone. It could make the job safer and less complicated.
- K. Be aware of step and touch potentials for the groundman when you have a vehicle or piece of equipment tied into the zone.

402 Working from the Structure

- A. Always produce a zone on the structure to be worked on.
- B. Make sure that the rebar in concrete structures is bonded into the zone.
- C. A steel tower or pole can be bonded into the zone by using the appropriate clamp attached directly to the structure or an appropriate stud.
- D. Climbing over the band with the bonding jumper(s) in place is a matter of choice. There is a risk of shock while climbing over the band, and it should be done quickly to minimize the hazard. The safest way is to remove the bonding jumper before climbing over the band.
- E. When approaching conductive structures such as steel towers or structures that have conductive components like guy wires or downleads, there may be a risk of step and touch potentials.

403 Working on the Ground

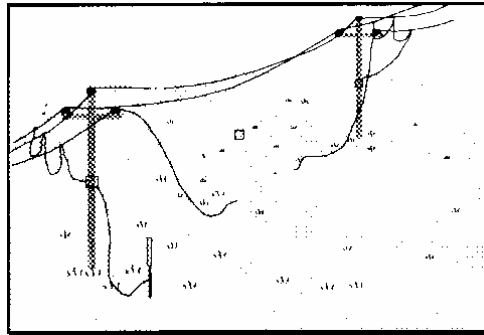
Handling conductors on the ground presents more risk than working on a structure and is more difficult to deal with. The risks include step and touch potentials.

Approved equipotential methods are:

- Using conductive platforms such as a ground mat or the deck of a truck, with all conductors and the platform bonded together.
- If the use of a mat or platform is not feasible, rubber gloves must be used to handle the conductor. Remember – there is still the possibility of step potential so you have to avoid contact between the conductor and other parts of your body.

404 Splicing Conductor

- A. Always bond conductors across the break to avoid dangerous potential differences. Even if a conductor is "grounded" on both sides of a break, each side can be at different potential than induction or some other energy source.
- B. Remember – you can achieve the bond "across" the break in different ways. The diagram below shows one way of creating bonds while minimizing the amount of time needed to handle the conductors on the ground.



- C. Avoid splicing on the ground, if possible.

D. When splicing conductors on the ground, equipotential bonding is difficult to apply, even though it is the only safe, reliable way to protect yourself. Some suggestions to minimize your risk are listed below.

i. Equipotential Method

- Use a ground mat whenever conductor is handled on the ground.
- Use the deck of a truck as a ground mat by bonding the truck to the conductor.
- Perform the work up the structures in your equipotential zones by:
 - cutting the span of conductor out
 - using a new section of wire
 - performing splices up the structures in the equipotential zones

ii. Isolated and Grounded Method (not an equipotential method)

If you cannot use equipotential methods, the best you can do is minimize your risk by considering the following:

- Equipotential methods must still be used when working on the structures.
- Plan the job to minimize your exposure time around conductors on the ground.
- Take extra care in creating your isolation points.
- If you cannot create an equipotential zone on the ground for handling conductors, you must use 30 kV rubber gloves.
- Remember that if you are going to use rubber gloves to splice the conductor on the ground, the risk of injury increases with time.
- While on the ground, possible risks include step and touch potentials if the line becomes energized.
- Take extra care to avoid accidentally contacting the conductor with any part of your body (touch the conductor only with your gloves).

405 Equipment / Material Entering or Leaving the Equipotential Zone

- A. Handlines should be kept as clean and dry as possible to avoid leakage currents which could cause a shock hazard.
- B. Steel winch lines must be bonded into the equipotential zone. Operators should remain on the truck or a bonded ground mat.
- C. Bond hydraulic and electric tools where hoses/wires extend outside the zone.
- D. Conductors or wires being sent or used within the zone (e.g., a coil of wire) do not have to be bonded unless they are extending outside the zone.

406 Working from a Bucket

- A. Using a Rated and Tested Boom
 - The boom or truck does not need to be tied into the zone.
 - The conductors to be worked on must have a trip ground on them.
 - The cover must be removed from the boom.
 - The boom must be treated the same as a hot stick and wiped down before use.
 - Within the limits of approach of a structure, an equipotential zone must also be created on the structure. The zone is required since the lineman in the bucket could come in contact with the conductor and the structure at the same time.
- B. Using an Unrated Boom
 - The boom or truck must be tied into the equipotential zone.
 - When a vehicle is tied into the equipotential zone, you must ensure the workers are aware of the hazards of touching or stepping on and off the truck.
 - If the boom has insulated sections, bonding above the insulation will reduce the risk to workers on the ground. Even though the insulation isn't tested, it limits the

potential transferred to the ground if the line became energized.

407 Single Phase Line with System Neutral

Any single phase system with a neutral will require all conductors and guy wires to be bonded together to a band on each structure being worked on.

408 Working Procedures for Bonded Sections of Two or Three Phase Lines

A. Bonded Area - No Neutrals

- Ground at a preferred location.
- Install bonds
 - both ends of your work area
 - and
 - at any location where there is a power system source.
- Place a band at an appropriate location and bond to one phase at the structure where you are working.

B. Bonded Area With Guys and Grounds

- Produce a bonded area as required.
- Ground at a preferred location.
- Place a band at an appropriate location on the structure that you are working on.
- Bond to all phase conductors, guy wires, equipment grounds, lightning arrestors, return "A" ground or any grounded point when working on these structures.

C. Taps Entering Bonded Area

- Bond all phases of the main line where a tap(s) enters the bonded area and the tap is classified as a power system source. Remember – you cannot rely on reclosers / breakers / fuses to maintain electrical continuity.

D. Two and Three Phase Systems with a Continuous Neutral/Shield Wire(s)

This type of job involves some of the more complicated and difficult equipotential practices.

i. The Risk

- If the line becomes accidentally energized, the neutrals/shield wires will cause currents to flow in a way that can result in large voltage differences between conductors and create a hazard for the lineman.

ii. Managing the Risk

- The person responsible for the job must decide the best strategy for managing the risks, in discussion with the crew, before proceeding.
- The preferred way of dealing with these systems is to use equipotential practices and bond all conductors and neutral / shield wires on every pole where you are working. You are accountable to explore the feasibility of equipotential practices before considering other alternatives.
- If the complexities of the job make equipotential practices unworkable, you must use the following practices to manage the risks:
 - Bond and ground all conductors together at power system sources.
 - Identify job sites where there is a possibility of backfeed and take additional precautions to eliminate this hazard .
 - Have each lineman bond into a different phase as the job proceeds. In the event of accidental energization, this will distribute the fault current more evenly over all the conductors, thus reducing the voltage differences between conductors. (This strategy is only effective if there are at least three linemen working together on different structures.)
 - When working on a structure, go from the band to the neutral and to one phase conductor. If you are changing or replacing conductors, bond to one of the new conductors to make it easier to remove the old ones. The risk is reduced, but if the line does become energized there will still be voltage differences between some conductors which could be hazardous.

409 "Butt Down" / Tie-Down Locations

- A. Always consider electrical and mechanical protection at locations where a conductor is handled by an employee or where contact could be made by the public, regardless of whether there is any possibility of accidental energization.
- B. The strategy and practices you apply will depend upon whether you are dealing with:
- temporary situations (within the work day)
 - longer term situations (overnight or longer)

There are two options for tying conductors off:

- at ground level
- overhead

C. Temporary Situations - Ground Level

- Flag, barricade, or supervise the conductors at the butt down location if there is any possibility of the public coming in contact with the conductors.

If the conductors can become accidentally energized, these precautions must also be taken:

- Bond and ground all conductors at the butt-down location and/or on the trailer to prevent a potential difference between the conductors.
- Move the trip ground closer to the butt down location before handling conductors on the ground. If there is an energized parallel line, a large loop will produce a circulating current.
- Keep the trip ground close but out of the job site to prevent step potential problems; no closer than 10 meters to the work location.
- Use a ground mat bonded to the conductors or rubber gloves when handling the conductor.
- Remember – there is still a possibility of step potential.
- When stringing parallel to an energized line, the risk increases due to induction.

D. Temporary Situations - Overhead

- Use an equipotential zone on the pole.
- No marking or barricading is required if the conductors maintain proper AECUC clearances.

E. Long-Term Situations - Ground Level

- Control the situation at the butt down location.
- Barricade or supervise the conductors if there is any possibility the public could come in contact with the conductors. Barricades should extend sufficiently to properly protect the conductors and should be made of a non-conductive material (e.g., a plastic snow fence).

If the conductors can become accidentally energized, these precautions must also be taken:

- When handling conductors, use a ground mat bonded to the conductors. If a mat cannot be used, you must use rubber gloves.
- The conductors must have adequate insulation cut in at a height that ensures the insulation cannot be reached by unqualified persons.
- All temporary grounds must be removed if conductors are isolated from earth.
- If insulation cannot be cut into the conductors, the conductors must be protected mechanically with appropriate fencing:
 - Fencing should be of a non-conductive material and warn of the possible electrical danger.
 - All conductors must be bonded together and grounded by a 10 ohm ground.

F. Long-Term Situations - Overhead

- Maintain proper AECUC clearances for isolated wires and the land use classification.
- A zone must be produced on the pole before handling the conductors.
- The tails or ends of conductors that could reach the ground must be coiled up and attached in a safe, elevated position.
- Conductors must be dead-ended by using temporary insulating dead ends.
- All grounds must be removed from the conductors.

410 Wood Poles with Downleads

- A. Much of the hardware required to be bonded will already be bonded together.
- B. Step and touch potential hazards could exist around the base of the pole and the guy anchor.
- C. If there is no solid connection between the shield wire and downlead, a jumper is required.

411 Steel Towers / Steel Poles / Concrete Poles

- A. Bonding jumpers must be connected to steel towers, preferably using a step bolt or grounding stud bolted to the tower.
- B. Concrete poles must be treated as conductive due to the reinforcing steel.
- C. Steel poles may have some form of coating such as weathering steel, galvanizing or paint. If you are bonding to a coated area, make sure your clamp penetrates the coating.

412 Cutting Open Wire or Jumpers

Any time you cut a conductor or open a jumper / switch / recloser / breaker, you must ensure continuity by bonding the two sides together to prevent voltage differences across the break.

413 Guyed Structures

- A. If guy wires are in the working zone, they must be bonded.
- B. If guy wires are in the working zone, consideration should be given to retrofitting the guy with an insulating guy rod.
- C. Never use the guy wire or anchor rod as a tripping ground.
- D. Bonding jumpers should be installed directly to the anchor rod, if practical. Bonding directly to guy wires is acceptable providing the guy wire is tight.

- E. If a guy wire is to be opened any time during the job, you must install a bond across the break to avoid potential differences.
- F. If a guy is bonded into the zone, stand on a ground mat or use rubber gloves when working with the guy on the ground.

414 Grounding Inside a Substation

- A. For the purpose of creating an equipotential zone inside a transmission substation fence, the grounding grid shall be considered as an equipotential grounding mat.
- B. When working in a substation, you must have a trip ground installed for all possible sources.
 - solid blade disconnects or gang switches visually confirmed closed **can** be relied on for continuity of tripping grounds.
 - fused disconnect switches, reclosers, circuit breakers or transformers **cannot** be relied on for continuity of tripping grounds.
- C. When disconnecting or cutting open primary or secondary connections to isolate equipment (switches, circuit breakers, transformers, etc), trip grounds are not required to be installed on the isolated equipment. When working on the isolated equipment that is not grounded workers must be aware of the potential for induction hazards and eliminate or control the hazard in their job safety plan.
- D. Substation potential transformers (PT) and station service transformers are considered a “source” and must have trip grounds installed on the primary or be eliminated as a source. (cut open or disconnect the secondary leads)
- E. When working from a bucket inside the substation fence, the vehicle must be bonded to the substation ground grid.