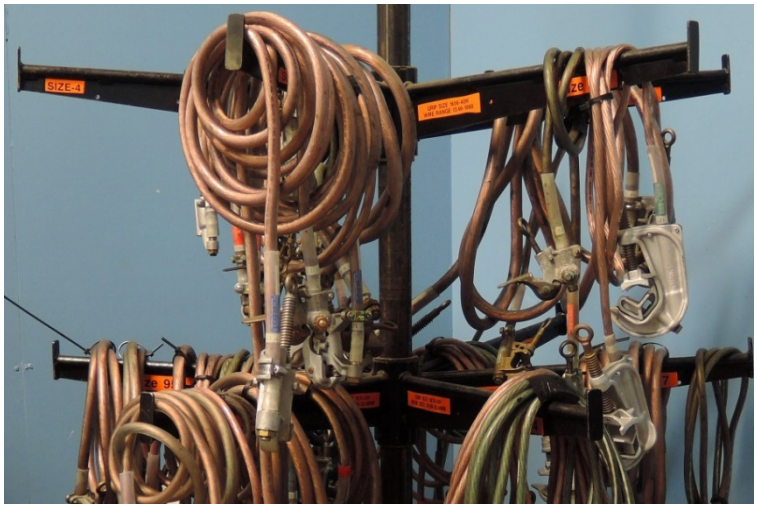
Personal Protective Grounding of Overhead Distribution Lines



1. Table of Contents

2. Scope

This work practice covers the use of personal protective grounds on Seattle City Light's (SCL's) 4, 13, 26.4, and 34.5 kV, overhead distribution systems.

The following topics are outside the scope of this work practice:

- Grounding theory
- Switching and clearance procedures
- Worker training and certification requirements
- Grounding equipment and tool purchasing specifications
- Grounding equipment and tool maintenance procedures
- Traveling grounds
- Voltage detector operation
- Provisions covered under WAC 296-45-325
- Protection of workers outside the established equipotential zone
- Mitigating hazards associated with electric field and electromagnetic field induction
- 2.4 kV delta system at Cedar Falls

3. Application

This work practice is directed at qualified persons who are tasked with applying personal protective grounds on SCL's 4, 13, 26.4, or 34.5 kV, overhead distribution system.

The objective of this work practice is to make the workplace as free from recognized hazards as reasonably possible. Following these rules may sometimes require that employee safety receive a higher priority than speed and work performance.

4. Definitions

Cluster bar – A terminal that is temporarily attached to a structure that provides a means for the attachment and bonding of grounding and bonding cables to the structure. Typically used with grounding jumpers to establish an equipotential zone. *Syn*: **cluster support, pole chain binder**.

Electric field induction - The process of generating voltages or currents to ground or both in a conductive object or electric circuit by means of time-varying electric fields. *Syn*: **capacitive coupling**.

Electromagnetic field induction - The induction process that includes both electric and magnetic fields and generates a circulating current between two grounded ends of a line due to the proximity of an adjacent or close energized and loaded line. *Syn*: **electromagnetic coupling**.

Equipotential - An identical state of electrical potential for two or more items. Also, for the purposes of protective grounding, a near identical state of electrical potential. *Syn*: **equal potential.**

Equipotential zone - Created by applying personal protective grounds, which provide a work space where all material and hardware within the worker's reach is energized at the same potential if the lines accidentally become energized. *Syn*: **equal potential zone (EPZ).**

Grounding jumper - A system of ground clamps and covered cables suitable for carrying fault current. *Syn*: **ground set, ground**.

Personal protective ground - A cluster bar installed on the pole below the work position, and a grounding jumper installed between the neutral and the cluster bar. The objective of personal protective grounds is to create an equipotential zone**.**

Personal protective grounding - Combines working grounds and personal protective grounds in a way that reduces the potential voltage difference at the worksite (voltage across the worker) to a safe level. *Syn*: **worksite grounding**, **single-point grounding**, **equipotential grounding, equal potential grounding**.

Qualified person - A person who is familiar with the construction of, or operation of such lines and/or equipment that concerns his/her position and who is fully aware of the hazards connected therewith, or, one who has passed a journey status examination for the particular branch of the electrical trades with which he/she may be connected. Refer to WAC 296-45-035 for the complete, legal definition.

Working grounds - Grounding jumpers installed between the phase conductors and system neutral conductor, at or near the worksite. The objective of working grounds is to ensure the circuit opens in the fastest available clearing time. If the system is three-phase, the grounding method must short circuit all three phases. *Syn*: **grounds**.

5. Introduction

Voltage may appear at a worksite due to accidental energization either through the isolating device or due to contact with another energized circuit. Voltages or currents may be present due to electric or magnetic induction from adjacent energized circuits or due to a direct or indirect lightning stroke.

When a hazard exists that is not covered by this work practice, the lead worker and employees are expected, in good faith, to mutually discuss the hazard and agree how to perform the work with the greatest degree of safety.

Experience has proven that the majority of injuries and deaths are preventable. Most injuries and deaths are not due to defective equipment but are due to failure on the part of the employees and those in authority to observe safety rules and failure to use safety devices. This work practice is a compilation of experience and common sense.

In general, the safest way to ground distribution lines and equipment is to create an equipotential zone by using personal protective grounds (a combination of working grounds and personal grounds). This limits the voltage across and the current that flows through the worker to minimum levels. Workers are best protected when personal protective grounds are installed at the worksite. However, there will be situations where this is impractical or impossible. In these situations, personal protective grounds shall be installed as close to the worksite as possible.

Workers on the ground may be exposed to higher step and touch potential when personal protective grounds are used. While work is in progress, ground personnel can protect themselves by staying away from the pole or temporary ground rod, where step and touch potential are higher.

Personal protective grounds also are intended to protect the worker from induced voltages created by parallel lines or static charge. This grounding method also insures the quickest operation of protective devices (relays and circuit breakers or fuses).

6. General Procedures

6.1 General

To work on exposed energized live parts, or near enough to them to expose any employee to any hazard they present, the provisions of WAC 296-45-325 shall apply.

To work lines or equipment as de-energized, the lines or equipment shall be de-energized under the provisions of WAC 296-45-335 and grounded as specified in this work practice. For specific exceptions to this rule, refer to Section 6.12 of this document.

6.2 Equipotential Zone

Temporary protective grounds shall be placed at such locations and arranged in such a manner as to prevent each employee from being exposed to hazardous differences in electrical potential.

6.3 Protective Grounding Equipment

Protective grounding equipment shall be capable of conducting the maximum fault current that could flow at the point of grounding for the time necessary to clear the fault.

Grounding jumpers shall have approved ferrules and grounding clamps that provide mechanical support for jumper cables independent of the electrical connection.

Protective grounds shall have an impedance low enough to cause immediate operation of protective devices in case of accidental energizing of the lines or equipment.

CAUTION! In no case shall a grounding cable or grounding jumper be connected directly to another grounding cable or jumper (otherwise known as “daisy chaining”).

6.4 Testing

Before any ground is installed, lines and equipment shall be tested and found absent of nominal voltage, unless a previously installed ground is present.

Grounding equipment shall be given a visual inspection and all mechanical connections shall be checked for tightness before each use.

The surface to which the ground is to be attached shall be cleaned before the grounding clamp is installed. The grounding clamp shall be a self-cleaning type (serrated jaw) clamp.

6.5 Order of Connection

When a ground is to be attached to a line or to equipment, the ground-end connection shall be attached first, and then the other end shall be attached by means of a live-line tool.

6.6 Order of Removal

When a ground is to be removed, the grounding device shall be removed from the line or equipment using a live-line tool before the ground-end connection is removed.

6.7 Additional Precautions

When work is performed on a cable at a location remote from the cable terminal, the cable may not be grounded at the cable terminal if there is a possibility of hazardous transfer of potential should a fault occur.

6.8 Removal of Grounds for Test

Grounds may be removed temporarily during tests.

During the test procedure, insulating equipment shall be used. Workers shall be isolated from any hazards in case the previously grounded lines and equipment become energized.

6.9 Conductor Separation

In cases where the conductor separation at any pole or structure is so great as to make it impractical to apply shorts on all conductors, and where only one conductor is to be worked on, only that conductor which is to be worked on needs to be grounded.

6.10 Ground Personnel

In cases where ground rods or pole grounds are utilized for personal protective grounding, personnel working on the ground should maintain sufficient distance from such equipment or utilize other approved procedures designed to prevent "touch-and-step potential" hazards.

6.11 Covered Overhead Primary

CAUTION! Covered overhead primary conductor, such as tree wire, shall be approached and handled the same as bare conductor.

This covering is not to be considered "insulation." Removal of the cover shall be done using a hotline tool appropriate to the conductor size. Only SCL-approved versions of such tools shall be used.

6.12 Exceptions

If it can be demonstrated the installation of a ground is impracticable or that the conditions resulting from the installation of a ground would present greater hazards than working without grounds, the lines and equipment may be treated as de-energized provided ***all*** of the following conditions are met:

A) The lines and equipment have been de-energized under the provisions of WAC 296-45-335.

B) There is no possibility of contact with another energized source. For example:

- No energized lines, such as double circuits or overbuild, are installed on same pole.
- No energized lines cross the line to be worked.
- The wind is not blowing broken tree limbs in the air.
- The unexpected failure of an insulator, mounting hardware, tool, or piece of equipment will not result in energizing the line to be worked.
- The unexpected failure or inadvertent movement of a barrier board, insulating blanket, or guard will not result in energizing the line to be worked.

C) The hazard of induced voltage is not present. For example, there are no transmission lines or other distribution lines parallel to the line to be worked.

In general, there are very few situations in which ungrounded lines or equipment may be worked as if they were de-energized. Tying in new wire installed on new insulators, arms, and poles for a circuit extension not connected to the existing system in any way is one such situation.

7. Tools and Equipment

DANGER! The electromagnetic forces on grounding cables during a fault increase with increasing cable length. These forces can cause the cable to move violently during a fault and can be high enough to damage the cable or clamps and cause the cable to fail. In addition, flying cables can injure workers. Consequently, cable lengths should be as short as possible, and grounding cables that might carry high fault current should be in positions where the cables will not injure workers during a fault.

Refer to Table 7 for an example of the recommended number and length of cables that would make up a typical ground set employed at a typical SCL 26.4 kV, three-phase, tangent, overhead distribution pole with a common neutral.

Table 7 - Recommended ground set example

Quantity	Connection	Recommended cable length (ft)
1	Cluster bar to neutral	4
1	Cluster bar to center phase	13
2	Phase to phase	7

A 2003 study concluded the appropriate conductor size of overhead working ground to use when working on SCL's 26 kV looped radial distribution system is 4/0 AWG copper. Refer to SCL Work Practice 0056.05, Sizing Overhead Working Grounds.

CAUTION! Maintenance of grounding equipment is essential. Corrosion in the connections between grounding cables and clamps and on the clamp surface can increase the resistance of the cable, thereby increasing potential differences.

The following tools and equipment are required to implement personal protective grounding. They are available from the Tool Room:

- Protective ground assemblies, consisting of self-cleaning clamps, ferrules, and flexible 4/0 AWG stranded copper, jacketed cable. See Figure 7a.
- Cluster bar (cluster support, pole chain binder). See Figure 7b.
- Multi-range voltage detector. See Figure 7c.

Figure 7a. Protective Ground Assembly

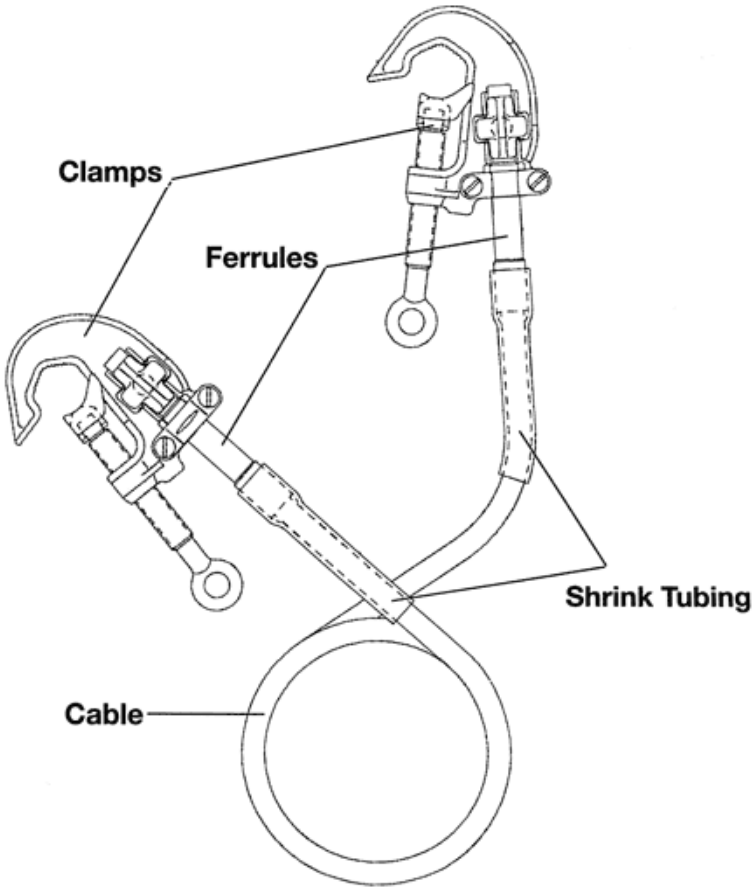


Figure 7b. Cluster Bar

Figure 7c. Multi-Range Voltage Detector

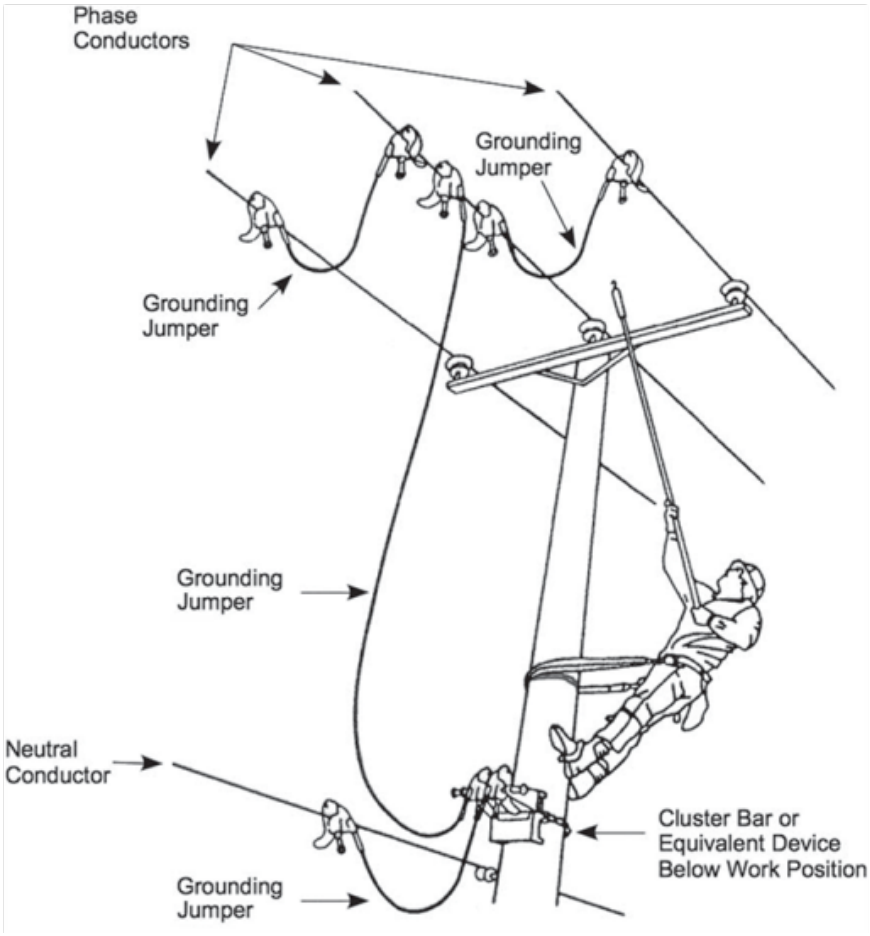
8. Detailed Procedures

8.1 Distribution Lines with Common Neutral

Follow these steps to apply personal protective grounds to distribution lines with a common neutral (Figure 8a).

Step	Action
1	Identify and isolate the line. Obtain visible openings on the source side (and the load side if possible) of the line or equipment.
2	Obtain a clearance.
3	Test the line or equipment to be sure it is de-energized.
4	Make grounding connections in the following order: a) Install a cluster bar on the pole just below the work area. Leave adequate working space above it. b) Clamp one end of a 4-ft jumper to the cluster bar, and the other end to the common neutral. c) Jumper from the cluster bar to the closest phase conductor. Jumper the other phases together, working from the nearest to the farthest away.
5	Remove the grounds in the reverse order.

Figure 8a. Distribution Line with Common Neutral

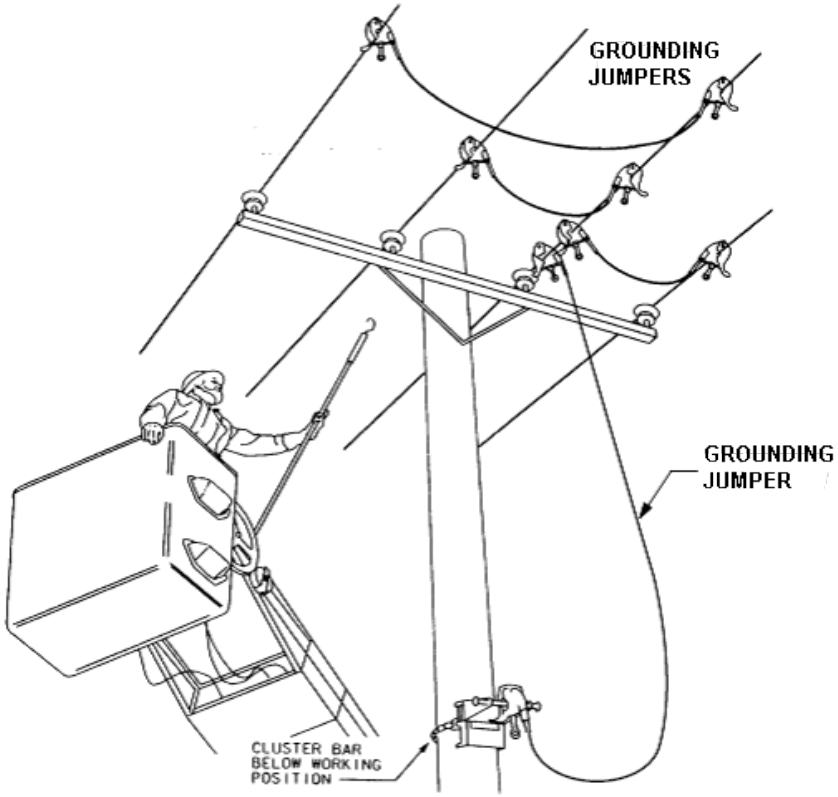


8.2 Distribution Lines with Primary Neutral

Follow these steps to apply personal protective grounds to distribution lines with a primary neutral (Figure 8b).

Step	Action
1	Identify and isolate the line. Obtain visible openings on the source side (and the load side if possible) of the line or equipment.
2	Obtain a clearance.
3	Test the line or equipment to be sure it is de-energized.
4	Make the grounding connections in the following order: a) Install a cluster bar on the pole just below the work area. Leave adequate working space above it. b) Clamp one end of a grounding jumper to the cluster bar, and the other end to the primary neutral. c) Install the proper length jumpers from the primary neutral to the phase conductors.
5	Remove the grounds in the reverse order.

Figure 8b. Distribution Line with Primary Neutral



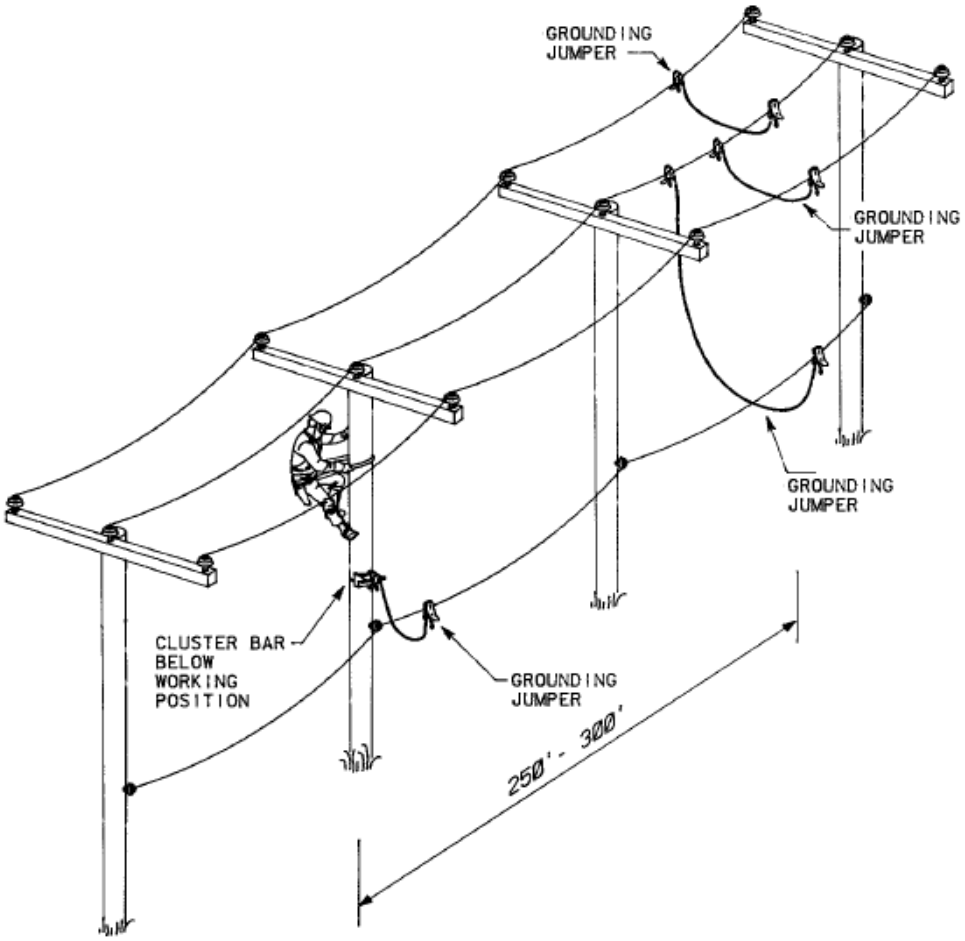
8.3 Grounds Installed One Span Away from the Worksite

DANGER! Grounding jumpers between phase conductors and the system neutral should be installed at the worksite. Where this is not possible, working grounds may be installed within a 250- to 300-ft span of the worksite if this procedure is followed.

Follow these steps to apply personal protective grounds one span (less than 300 ft) away from the worksite (Figure 8c).

Step	Action
1	Identify and isolate the line. Obtain visible openings on the source side (and the load side if possible) of the line or equipment.
2	Obtain a clearance.
3	Test the line or equipment to be sure it is de-energized.
4	Make the grounding connections in the following order: a) One span away from the worksite, where the grounds will not interfere with the work, install a grounding jumper from the common neutral (4-ft jumper) if the neutral is in the primary position) to the closest phase conductor. b) From that conductor, jumper to the other phases with the remaining jumpers, working from the nearest to the farthest away. c) At the worksite, attach a cluster bar to the pole below the work area. Leave adequate working space above it. d) Clamp one end of a grounding jumper to the cluster bar, and the other end to the common or primary neutral.
5	Remove the grounds in reverse order.

Figure 8c. Grounds Installed Less Than 300 ft Away from the Worksite



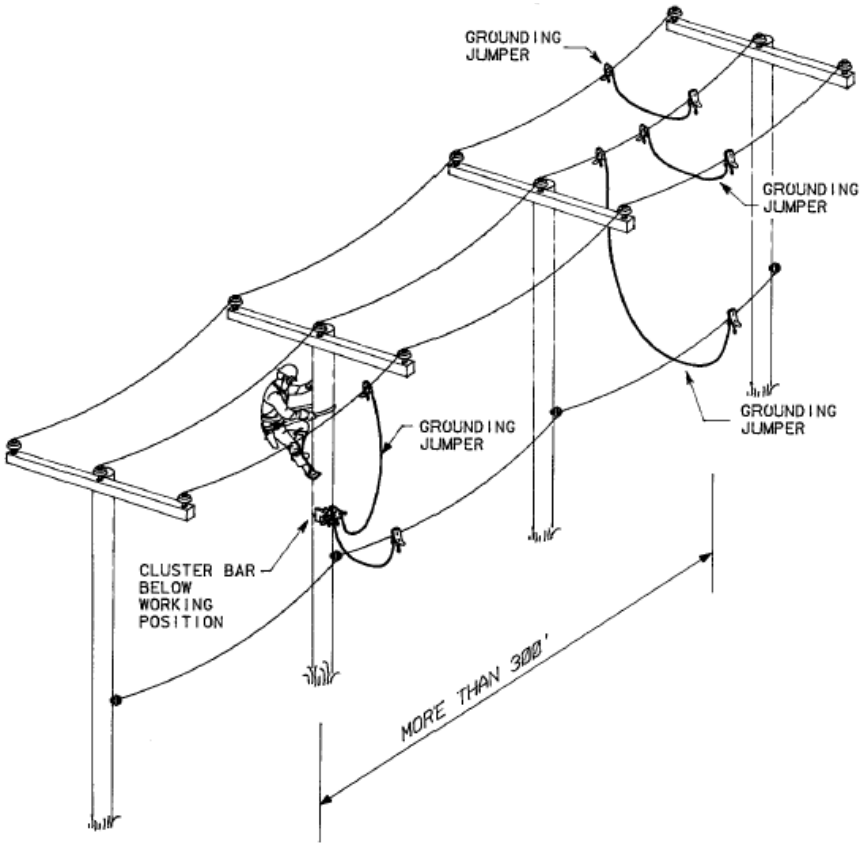
8.4 Grounds Installed More Than One Span Away from the Worksite

DANGER! Grounding jumpers between phase conductors and the system neutral should be installed at the worksite. If the worksite moves to multiple locations along the same circuit (such as when tying in new conductors), working grounds can be installed at one end of the job if this procedure is followed.

Follow these steps to apply personal protective grounds one span (less than 300 ft) away from the worksite (Figure 8d).

Step	Action
1	Identify and isolate the line. Obtain visible openings on the source side (and the load side if possible) of the line or equipment.
2	Obtain a clearance.
3	Test the line or equipment to be sure it is de-energized.
4	Make the grounding connections in the following order: a) At one end of the job, install a grounding jumper from the common neutral (4-ft jumper if the neutral is in the primary position) to the closest phase conductor. b) From that conductor, jumper to the other phases together with the remaining jumpers, working from the nearest to the farthest away. c) At each worksite, attach a cluster bar to the pole below the work area. Leave adequate working space above it. d) Clamp one end of a grounding jumper to the cluster bar, and the other end to the common or primary neutral. e) Install a jumper from the cluster bar to the primary phase being worked. When work moves to another phase on the same pole, move the jumper to the new phase and begin work.
5	When work moves to the next pole, remove the phase jumper, then remove the cluster bar and grounding jumper, and reinstall them at the new worksite.
6	Remove the grounds in reverse order.

Figure 8d. Grounds Installed Over 300 ft Away from the Worksite



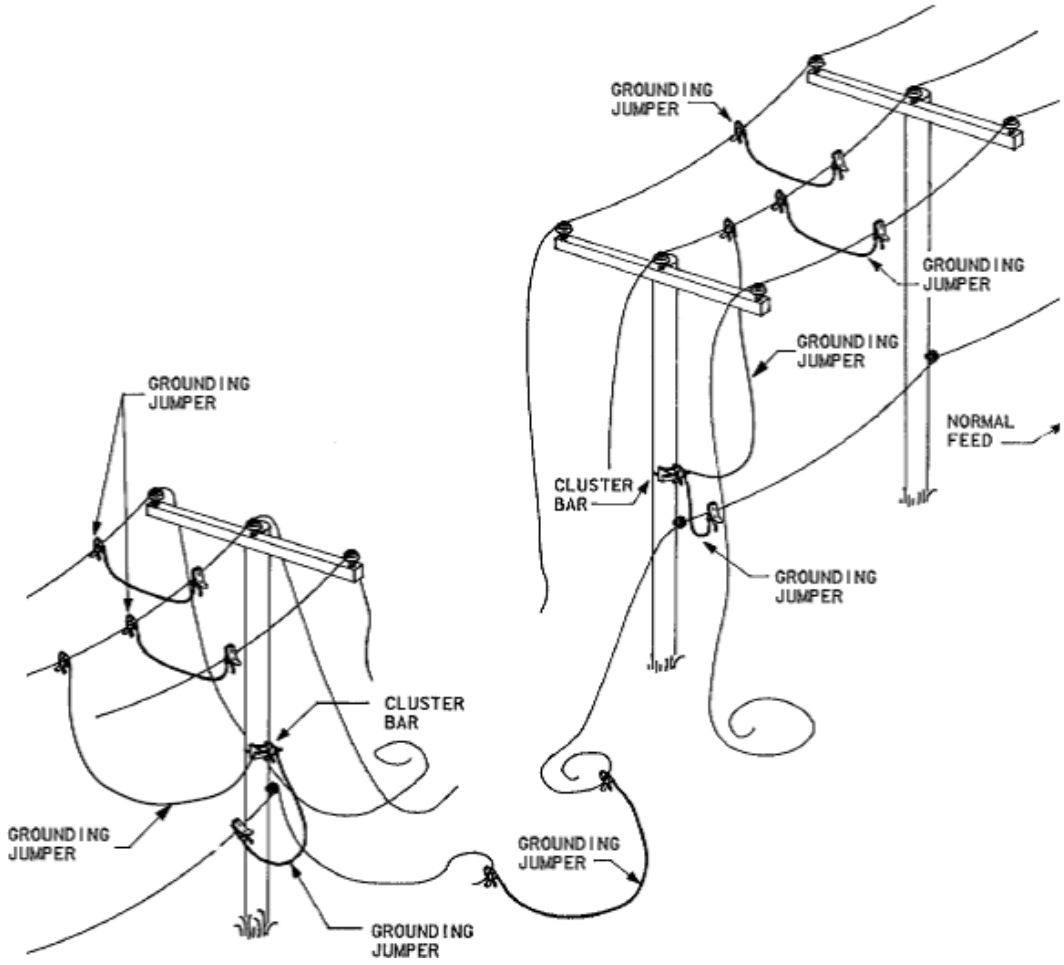
8.5 Grounds for Broken Primary Conductors on the Ground

DANGER! Where work on de-energized and grounded lines and equipment cannot be done within the equal potential zone, approved rubber gloves shall be worn.

Follow these steps to apply personal protective grounds when primary conductors are broken and lying on the ground (Figure 8e).

Step	Action
1	Identify and isolate the line. Obtain visible openings on the source side (and the load side if possible) of the line or equipment.
2	Obtain a clearance.
3	Test the line or equipment to be sure it is de-energized.
4	Install personal protective grounds on both sides of the worksite, at the nearest location where primary and neutral conductors are in their normal positions, and where the grounds will not interfere with the work.

Figure 8e. Primary Conductors Broken and on the Ground



9. References

SCL Work Practice 0056.05, "Sizing Overhead Working Grounds"

10. Sources

Washington Administrative Code; Chapter 296-45 WAC Safety Standards for Electrical Workers

Encyclopedia of Grounding for De-Energized Construction & Maintenance; Hubbell Power Systems (Chance), Bulletin 07-0801, Rev 12/10

Seattle City Light, Power System Engineering Information; 2015

IEEE Std 1048-2003 - Guide for Protective Grounding of Power Lines

ASTM F855-14 - Standard Specifications for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment

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