Grounding & Bonding Code
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Purpose

The fundamental purpose of temporary grounding and bonding is to provide a safe path to ground for current, available from induced voltages, switching errors, accidental re-energization or accidental contact with live lines and equipment, thereby keeping workers and the general public from being injured. Good grounding practices also ensure rapid tripping of the circuit in the event of accidental energization by providing a low resistance path through which sufficient current can flow to operate circuit protection devices.

The subject is a complex one. This Code defines minimum basic grounding and bonding required to trip the circuits and provide worker protection. It also provides sufficient background information to allow staff to make informed decisions on methods to be used in their day to day operations. All tools and equipment referenced in this code shall be approved Newfoundland Power tools and equipment.

All matters involving interpretation of the code, or requiring clarification on application of the code, shall be referred to and resolved by the Grounding & Bonding Code Team.

Grounding & Bonding Code Team

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Definitions

Apparatus
Term used to describe lines and collectively all devices connected to it. Apparatus refers to conductor, circuit, electrical equipment, conductive parts, etc.

Bond
Electrical connection which causes conductive parts to be at an equal potential.

Bonding
Method of physically inter-connecting conductive parts to maintain an equal potential with the objective of avoiding harmful shock currents by minimizing any potential difference across a worker’s body.

Capacitive Coupling (Electric Field Induction)
Condition whereby the voltage of an energized line produces a voltage level on an adjacent isolated line or piece of equipment due to the existence of capacitance between the two objects. Capacitance exists due to the phenomenon of the electric field.

Check for Potential
The testing of an apparatus for the presence of voltage or energized state. A check for potential must always be completed before a ground is installed on any apparatus.

Conductor
A wire or combination of wires not insulated from one another, suitable for carrying an electric current. It may be bare or insulated.

Dead
See De-energized.

De-Energized (Dead)
Term used to mean that a system, line or equipment is disconnected, isolated and grounded and at a potential equal to or not significantly different from that of ground at the work site.
Disconnected
The state of an apparatus or line when no energy is being intentionally applied. The apparatus or line has been removed from service by the operation of a breaker, recloser, switch or other switching apparatus. A disconnected apparatus or line is not grounded and may not be adequately isolated. NOTE: The disconnected apparatus or line may be affected by electromagnetic induction, capacitive coupling or static charge.

Earth
See Ground.

Electromagnetic Induction
Produces an induced voltage and current. When the predominant effect is due to current, this is known as magnetic field induction.

Energized (Live)
The state of electrical systems, lines and equipment connected to a source of electric energy at a potential significantly different from that of ground (earth) at the work site and which presents an electrical hazard.

Equipotential
The state of having all objects in a work area at the same potential.

Equipotential Bonding
Provision of electrical connections between conductive parts, intended to ensure they are equipotential.

Equipotential Zone (EPZ)
A work area, the bounds of which are set by the outermost point of conductive parts which are connected by an equipotential bonding or grounding system. A form of worker protection.

External Hazard
Conditions that can cause accidental energization of the apparatus to be worked. Such conditions may include but not be limited to: line crossings (over/under), parallel lines, neutrals, communications messengers, back feed from customer owned generation, etc.

Fault
A physical condition that causes a device, a component, or an element to fail to perform in a required manner, for example, a short circuit or a broken wire.
Fault Current
The current that flows from one conductor to ground or between conductors owing to contact between them and generally produces a very high current flow and an electric arc fault currents are usually caused by failure of an apparatus or contact of a line or apparatus creating a path to ground or between conductors. Protective relaying and devices operate to limit fault currents to short durations to minimize damage to lines and equipment.

Ground
Reference for zero potential. Possessing no electrical energy.

Ground Electrode
Any metallic apparatus such as a ground rod, pole ground or anchor rod that serves as a ground terminal.

Ground Potential Rise (GPR)
Ground potential rise is an elevation in voltage on the surface of the earth, a ground grid, on the system neutral or at a ground electrode caused by fault current flowing into the ground. This voltage rise is the product of fault current and resistance of the path to ground and exists for the short period of time that fault current flows. GPR is greatest at the point of entry of fault current into the ground where it can approach the apparatus operating voltage. GPR can create step and touch potential hazards (see OPR300.12 Ground Potential Rise Hazards).

Ground Rod
A rod that is driven into the ground to serve as a ground terminal, such as a copper-clad rod, or galvanized iron pipe. Galvanized steel rods are commonly used to provide a means of obtaining an electrical ground using portable grounding devices.

Grounding
Connecting lines or apparatus to ground. Grounding has the following attributes:
1. Provision of a continuous conductive path to the earth that has sufficient ampacity to carry any fault current that may be imposed on it.
2. Has a sufficiently low impedance to limit the voltage rise above ground potential.
3. Facilitates the operation of the protective devices in the circuit as quickly as possible.
4. Bleeds any access energies induced by electric and magnetic fields or static sources.
Grounding Clamp
A device used in making a connection between the electrical apparatus and the ground bus or grounding electrode.

Isolated
The state of all systems, lines and equipment that is separated from all sources of electric energy by an adequate air gap or barrier.

Isolation Grounding
Disconnected, isolated from external hazards and grounded. A form of worker protection.

Live
See Energized.

Minimum Approach Distance (MAD)
The minimum distance in air to be maintained between any part of a worker’s body, including any object (except appropriately rated live line tools) being directly handled, and energized lines and apparatus or ungrounded lines and apparatus.

Ohms Law
Physical law defining the relationship between voltage, current and resistance where Voltage = Current x Resistance.

Portable Ground Mat (Portable Bond Mat)
A mat that creates an equipotential zone for the worker to stand during various energized and de-energized work practices.

Running Ground
A portable device designed to connect a moving conductor or wire rope, or both, to an electrical ground. These devices are normally placed on the conductor or wire rope adjacent to the pulling or tension equipment located at either end of a sag section. Primarily used to provide safety for personnel during stringing or reconductoring operations.

Separate (Electrical)
See Isolate
**Shall (Must)**
A requirement; something that must be done in order to comply with a standard.

**Should**
A recommendation; something that is advised but not required.

**Static Charge**
Even in the absence of an ac electric and magnetic field, a charge can accumulate on isolated systems by such effects as dc circuits, wind, cloud movement or solar flares.

**Step Potential**
The potential difference between two points on the earth’s surface that could be expected to appear across the feet of a person (assumed standing with feet one meter apart) in the direction of maximum voltage gradient. This potential difference exists when current flows through the earth or over the surface of the ground upon which a person is standing.

**Tagged Ground**
A ground installed to establish a form of protection as specified by the Worker Protection Code.

**Touch Potential**
The potential difference between a grounded structure or object and a point on the earth’s surface that could be spanned by the reach of a person (assumed one meter apart). This potential difference exists and is maximum under fault conditions and may exist due to induction from nearby live lines or capacitive coupling effects. Touch potential can be experienced from hand to foot or from hand to hand.

**Visible Air Gap**
A visible space of suitable size to provide adequate protection from all live portions of the system.

**Work Area**
The geographic location where work takes place. Separate work areas require separate grounds (apparatus identification). A work area could contain several work sites.
Work Site
An immediate location within the work area where a worker works or is likely to be engaged in work and includes any vehicle or mobile equipment used by a worker when at work.

Working Ground
A portable device designed to connect a disconnected conductor or piece of equipment, or both, to an electrical ground. Distinguished from a tagged ground required to establish a protection guarantee, a working ground is utilized at the immediate area where work is to be performed.

Zone Of Influence
An area of elevated potential around a ground electrode resulting in GPR.
SECTION 1 - INTRODUCTION

As in all other phases of electrical work, job planning carried out by competent workers is of prime importance. Persons in charge must be knowledgeable and experienced in temporary grounding practices and familiar with Corporate Safety and Occupational Health and Safety Rules pertaining to this subject.

1.1 Worker Protection

This Code discusses methods and equipment to protect workers from injury due to shock current that may occur while working on or in close proximity to disconnected high voltage electrical apparatus. This includes overhead and underground transmission and distribution circuits as well as electrical equipment and other current carrying apparatus.

Shock current can be classified according to the degree of severity of the shock effect they produce. The effect is the result of the product of exposure time and current magnitude. These effects range from mild discomfort to a point of severe pain accompanied by loss of muscular control (in excess of “let go” level) and ultimately, stoppage of the heart and severe burning of body tissue and bone (see Fig. 1.1(a)).

The SHOCK HAZARD

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Fig. 1.1(a)
Depending on severity of the shock, the action of the heart may cease entirely, or go into ventricular fibrillation, become weak, irregular and incapable of circulating blood. Unless the victim is separated from the source of shock promptly, and CPR is applied immediately thereafter, death is a virtual certainty.

The human body can only withstand a limited amount of current. This amount varies with the individual and the duration of the current flow. Fig.1.1 (b) illustrates the variation of current versus time that the average human being can withstand.

1.2 Grounding and Bonding

"Grounding" is a method of physically connecting isolated electrical apparatus to ground. These grounds serve several purposes. They:

- Remove remaining and induced energy from the lines and equipment;
- Limit voltage rise that could result from accidental energization; and
- Provide a solid connection to ground to trip the circuit as quickly as possible.

Grounding, by itself, does not protect a worker from harmful shock current (see Fig. 1.2(a)).
"Bonding" is a method of physically interconnecting all apparatus within a work area to maintain a common potential in order to limit the current that can pass through the body of a utility worker to a level that will not cause harm.

A standard ground cable is used to tie the electrical apparatus to a common bonding point (i.e. pole band, grounding mat, work platform, etc.) below the worker's feet (see Fig. 1.2(b)).
When contact is made with a live conductor, some current will almost always flow through the body of the worker. The utilization of both equipotential bonding and grounding reduces the electrical hazard to a safe level for utility workers when performing work on electrical apparatus.

1.3 Some Dangerous Perceptions

1.3.1 Path of Least Resistance to Ground

It would be incorrect to perceive that electricity will take only the path of least resistance to ground. In fact, electricity will take all paths to ground including the path through a worker’s body (see figure 1.3.1).

Good grounding and bonding practices are designed to ensure that the portion of current shunted to ground through the worker's body will be limited to an amount that the worker can safely tolerate (should be limited to 50 milliamps or less). This then is the principle of bonding and grounding, a low resistance shunt path around the worker (see figure 1.2(b)) in order to limit current through the body in event of accidental energization. Grounding should also provide for the fast operation of line protection equipment to limit the duration of the hazard.
1.3.2 Grounding as Worker Protection

It would also be incorrect to perceive that if it is grounded, it is safe. :

a) It is sometimes assumed that any grounding conductor connected to a portable ground rod will protect the worker. At some locations the available fault current exceeds 20,000 amps. Only 50 milliamps (.05 amps) through the worker's body may be sufficient to be fatal. That is a very small proportion of the 20,000 amps fault current (less than a millionth). The resistance of the worker's body circuit would need to be more than a million times greater than that of the grounding circuit that protects the worker. That is not always possible to achieve. For example, portable ground rods in frozen or granular soil can have a very high resistance.

b) It is sometimes assumed that if a worker touches a grounded vehicle that he/she is safe even if the vehicle comes in contact with primary voltage. This is not true. The worker will likely be subject to potentially fatal current.

c) It has been assumed that "grounding" on all sides of the work location will ensure worker safety. This is not true. The worker may still be subject to potentially lethal current in event of accidental energization.

1.3.3 Protective Devices

Protective devices; e.g., breakers, relays, reclosers, fuses, etc. do not limit the magnitude of fault current in event of inadvertent energization. Electricity travels at near the speed of light, that is, about 300,000 kilometers per second. Protective devices cannot operate in the time it takes for current to flow between grounding conductors placed one span, or even one kilometer, ahead of the pole or structure being worked. Those protective devices can only limit the duration of the fault current. They cannot be set to limit the current such that the worker would not be injured.
1.3.4 Reclosing Devices

Turning off of automatic reclosing devices in no way limits the magnitude of fault current, nor increases the sensitivity of the tripping devices. It merely prevents re-energization.

1.3.5 Induction

There is a perception that the full effects of induction (voltage and current flow) from adjacent circuits, takes a considerable time period to build-up. This is not so, the full effects are immediate.

1.3.6 System Neutral

It is sometimes assumed that since a system neutral is a good conductor and is grounded at multiple locations that any electrical apparatus bonded to the system neutral is safe to touch. This is not always true. A fault elsewhere on the system could cause a hazardous voltage rise on the system neutral (in the order of kV).

1.4 Hazards of Disconnected Lines

1.4.1 Accidental Energization

Accident - a vehicle striking a pole or a structure for example, may cause a live circuit to contact a de-energized or disconnected circuit. Other examples are back-feed from customer owned generation, tangled lines during an ice storm, etc. (see figure 1.4.1).

Switching Error - although such occurrences are rare, they do happen.

Worker Error - attempts to work on the wrong circuit, operate the wrong switch, etc.
1.4.2 Atmospheric Conditions

Wind – wind driven dust or snow can induce dangerously high static charge on disconnected lines. These DC voltages keep building up over time but the charge is immediately drained by grounding. The discharging current associated with it is relatively low and flows for only a fraction of a second.

Lightning - lightning can produce dangerously high voltages on lines (see Fig. 1.4.2). Work on lines during a lightning storm is covered in OPR106.29 Working in Lightning.
1.4.3 Capacitive Coupling

Voltage - the electric field surrounding any live conductor will induce a voltage in any disconnected and ungrounded conductor in the vicinity (figure 1.4.3(a)). This voltage depends on the magnitude of source voltage and geometric spacing of conductors and the length of the line. For closely spaced 66 kV and 138 kV lines, this voltage could be as high as several kV.

Current - When the disconnected line is isolated and grounded, the initial discharging current can reach a level of several amps for long closely spaced lines. After the initial charge is dissipated the line assumes a lower potential and the capacitive charging current that flows through the ground cables to earth are generally less than 10 milliamps (Fig. 1.4.3(b)).
1.4.4 Electromagnetic Induction

Referring to Fig 1.4.4(a), the live conductor and the nearby disconnected conductor may be viewed as the primary and secondary windings respectively of an air core transformer. If an isolated conductor or a disconnected conductor becomes grounded at one point only, an open circuit secondary voltage to earth will appear on the line. This is not a capacitive charge but rather a voltage known as Ferranti voltage. This voltage will be near zero at the location of the temporary ground. Voltage at other locations on the line will depend on the total length of the parallel configuration and distance from the temporary ground location, the separation distance of the two circuits, and the magnitude of the load or fault current in the live line. These voltages are generally in the order of several hundred volts.
Continuing with the analogy of an air core transformer, if the isolated conductor becomes grounded at two points, the secondary winding will be effectively short-circuited through the earth and current will flow (see fig. 1.4.4(b)). This current will be proportional to current flow in the live line. For closely spaced circuits, the induced current may be up to 10% of current in the live line (except for very short loops). Under fault conditions on the live line this induced current can reach high values. When the ground connection is removed under these conditions, a severe arc could result.
1.4.5 Voltage Rise on Neutral

If an isolated conductor is grounded to the system neutral a voltage can be transferred to the work area at the point of grounding due to a fault elsewhere on the feeder. As a result of the neutral being multi-grounded, voltage on the neutral decreases with distance from the fault location. In the example in figure 1.5, V1 is at a higher voltage than V3. The isolated conductor will remain at the same voltage (V1) as the location where the grounds are installed. Therefore, a voltage difference, up to thousands of volts, could exist across the workers body at location 3.

Communication messengers are bonded to the system neutral and will therefore be at the same voltage as the neutral. Hazardous voltage rise on the neutral or communication messenger will exist for the time that it takes to clear the fault current (typically less than 1/2 second).

Workers should also be aware that the neutral may operate continuously at a voltage above earth due to neutral current on single phase taps, two phase taps and unbalanced three phase line sections. This neutral voltage rise is normally not high enough to pose a shock hazard. Neutral voltage rise from the flow of load current in the neutral is an unavoidable characteristic of multi grounded distribution line systems.
1.5 Ground Potential Rise (GPR)

GPR is an elevation in voltage on the surface of the earth, on a ground grid, on the system neutral or at a ground electrode caused by fault current flowing into the ground. This voltage rise is the product of fault current and resistance of the path to ground and exists for the short period of time that fault current flows. GPR is greatest at the point of entry of fault current into the ground where it can approach the apparatus operating voltage. GPR can create step and touch potential hazards (see OPR300 - 12 Ground Potential Rise Hazards and section 1.6 below).

GPR can occur when live power lines experience faults or when isolated and grounded lines become accidentally energized.

When an isolated and grounded transmission or distribution line becomes energized for whatever reason, fault current flows to earth via all paths to ground including all working grounds, any substation grounds and line tagged grounds. If EPZ bonding is being used, fault current will also flow to earth via any guys and anchors, pole grounds and all other ground electrodes bonded to the zone.

This will cause GPR at the ground connection points relative to the surrounding earth surface in accordance with Ohms Law. This voltage rise presents a shock hazard to all persons in the vicinity of the ground connection points (see figure 1.5.1) due to the voltage gradient that develops from the current flow through the soil.

![Fig. 1.5.1 Grounding on Transmission](image)
The ground rod could rise to near the full line operating voltage depending on the system impedance and then voltage drops off rapidly with distance from the ground rod. However, the size of the Zone of Influence is dependent upon the fault current, soil conditions and ground resistance in the area.

The risk of step potential on transmission lines is significantly greater than on distribution due to the presence of a multi-grounded neutral on distribution. Multi-grounded neutrals are bonded to pole ground wires, guy wires, telecommunications messengers and community water systems that provide a shunt for fault current.

1.6  **Touch and Step Potential Hazards**

A hazardous current may flow through a workers body if they are in contact with a transmission guy wire that is grounded or bonded to the EPZ (as in figure 1.5.1) when an accidental re-energization occurs. Worker A in figure 1.6.1 is clearly exposed to a shock hazard if the boom contacts the line during hot line work. This hazard is referred to as "touch potential hazard". Touch potential shock can be experienced from hand to foot or from hand to hand and results in current flowing through the chest/heart area which increases the risk of fatal consequences.

![Diagram of worker and transmission line](image-url)
The worker may not actually need to touch the guy wire or ground rod in figure 1.5.1 to receive a shock. A worker walking away from the ground rod in figure 1.5.1 with one foot closer to the ground rod than the other could be straddling a voltage difference which may be sufficient to cause a hazardous current to flow through his/her body. This hazard is referred to as "step potential hazard" and the current flows through the feet and legs.

Worker B in figure 1.6.1 could be exposed to a step potential hazard depending on how close he/she is from the vehicle ground in the event the boom makes accidental contact with a live phase.

The operator of the boom in fig. 1.6.1 (Worker C) is protected when working on the raised operator platform attached to the vehicle. The worker is bypassed by a low-resistance metallic circuit created by the vehicle maintaining his hands and feet at the same potential. This is a form of "bonding" to form an "equipotential zone".

1.6.1 Minimizing the Risk of Exposure to Step and Touch Potential Hazards

For transmission line work, workers on the ground should minimize the time that they are within 5 meters of ground rods, pole ground wires, guys, anchors and grounded vehicles.

For work on distribution lines with multi-grounded neutrals, workers on the ground should minimize contact with pole ground wires, guys, anchors and grounded vehicles to avoid the risk of touch potential hazard.
SECTION 2 - PRINCIPLES OF GROUNDING

2.1 Three Phase Grounding

The purpose of grounding the apparatus being worked on is to trip the circuit in event of accidental energization. All three phases of the apparatus being worked shall be grounded. In the event of accidental energization, line tripping will be accelerated.

2.2 Line and Equipment Identification

Before starting work ensure that the line or piece of equipment has been correctly identified, isolated and tagged. Grounds must be installed in the work area and be visible from the work site before work commences. Tagged grounds or working grounds can be used for this purpose.

2.3 Check for Potential

A check for potential using an approved potential indicator must be performed before installation of grounds. An approved electronic potential indicator is required to check for potential at voltages of 138 kV and below. The practice of "teasing" or "buzz testing" the isolated conductor with the metal end of a hot stick as a test for potential is not acceptable. Testing must be performed at the appropriate voltage setting and if voltage is not detected, test again at the next lower voltage setting as per manufacturer instructions. Always check the operation of the potential indicator, both before and after the check for potential.

On high voltage circuits, the charging current indicated may only be induction from other live circuits and thereby mistaken for actual line potential. In these situations, circuit de-energization and work location must be re-verified before installing grounds.

2.4 Application of Grounds

When the check for potential has been completed grounds are installed by first connecting to the ground point. All ground connections to phase conductors must be installed using hot sticks.
2.5 Cleaning Conductor and Equipment

The surfaces of conductors are usually contaminated or corroded. These high resistance coatings must be removed to ensure a good electrical connection. One way of cleaning the conductor is to use a wire brush before installing grounding clamps. A properly installed serrated jaw ground clamp (rotated while being tightened to penetrate conductor corrosion) eliminates the need for cleaning with a wire brush. However, it is a good practice to always brush conductors before installing any grounding clamp or making any connection to conductors. Clamps with serrated jaws shall be checked for wear and replaced if worn.

2.6 Minimize Cable Slack

Tremendous mechanical forces are exerted on grounding cables and clamps during fault conditions. Short grounding cables not only reduce resistance in the grounding circuit, but also reduce “whipping” under fault current conditions. Long leads, if they must be used, shall be lashed with rope either to the structure or to the insulator string to reduce “whipping” and possible contact with the worker and/or clamp dislocation. Do not wrap the grounding cable itself around structural steel. If a fault occurs, the jacket may puncture on the corners of the steel structure and the grounding conductor could burn off.

2.7 Grounding Path

Switches which form part of the conductive grounding path shall be closed. As per the Worker Protection Code, these switches must be tagged in the closed position. The opening of the switch in the conductive grounding path would place the worker in extreme danger, in the event of accidental energization, by removing the worker’s protection.

Under no circumstances shall fuse links, power transformer windings or regulator windings form part of the conductive grounding path. Only under extreme conditions can breaker contacts form part of the conductive path between the worker and a grounding point. If breaker contacts are to be used in the conductive grounding path, then the operating voltage supply to the breaker must be opened and tagged.
2.8 Transmission Grounding

When work is carried out on a transmission circuit all phases shall be grounded on both ends at the substation. These grounds shall be manually operated grounding switches or standard grounding cables connected to the substation ground grid. A three phase grounding set shall be installed in the work area (see Appendix B). Ground transmission lines outside of a substation using standard ground cables connected to a driven or screwed ground rod. Locate the ground rod as far away from the work area as practical, preferably greater than 5 meters so that workers on the ground can minimize the time they are within close proximity to the ground rod.

In addition to grounding at the substation, all phases shall be grounded in the work area, as noted above, except in the following case:

When work is to be performed on one or two phase(s) of a transmission circuit, and minimum approach distance can be maintained from the non worked phase(s) and two three phase grounding sets have been installed which are electrically connected to the worksite, only the phase(s) to be worked on need be grounded. If the minimum approach distance cannot be maintained from the non worked phase(s) then they shall also be grounded.

2.9 Distribution Grounding

When work is carried out on distribution circuits, all isolated phases shall be grounded at the work area (see Appendix C).
SECTION 3 – APPLICATION OF GROUNDING & BONDING PRINCIPLES

3.1 Equipotential Zone (EPZ) Protection

Equipotential Zone (EPZ) protection is the preferred method for working on transmission and distribution lines. The EPZ method of protection provides the maximum protection for the worker under any condition that would produce a voltage rise with respect to ground in the work area.

EPZ requires visible air gaps. A porcelain cutout may be used as a visible air gap for EPZ.

EPZ is required for all emergency work and any work not planned in advance. Planning in advance requires a site visit and preparation of a Steps and Conditions Plan prior to crews being dispatched to the job. Planning by the crew on the tailboard conference form, prior to the start of a job, is not considered “planned in advance”.

In situations where it is not possible or practical to initially apply EPZ protection, grounds must be applied on both sides of the work area as a safe alternative until EPZ can be practically established. All reasonable efforts must be made to eliminate external hazards.

An EPZ provides protection to workers by ensuring a hazardous voltage difference cannot exist across any part of the workers body while positioned within the zone. An EPZ is created by bonding together the structure being worked with all conductors and conductive paths to ground (guys and pole grounds) within the work area. This is shown in figure 3.1(a) for single phase distribution, figure 3.1(b) for single pole transmission and figure 3.1(c) for three phase distribution.
In figure 3.1 (b), the worker is protected by bonding to a pole band below his feet. This provides an equipotential zone around the worker. The worker should try and keep some pole between his feet and the pole band. As a guideline, the pole band should be installed approximately 0.6 m below the feet to minimize the risk of stepping outside the zone.

Figure 3.1(c) shows the proper cable configuration for connection to the neutral.

Fig. 3.1(b)

Fig. 3.1(c)
3.2 Bonding of External Ground Points in the EPZ

All points of external ground potential must be electrically connected to the EPZ. Points of external ground potential would include neutral, guy wires, pole ground wires, overhead ground wires and any other conducting object that brings external potentials into the zone.

Fig. 3.2

On distribution and transmission, all phase conductors, neutrals and overhead ground wires above the pole band shall be connected to the EPZ utilizing standard grounds. All other bonding connections can be made using a minimum #4 AWG copper conductor.

When possible, secondary conductors and telephone messengers should be below the pole band. When secondary conductors or telephone messengers are above the pole band, they must be bonded into the EPZ. When the secondary is above the pole band, the secondary must be isolated. If the secondary is connected to the transformer and the secondary connection is Wye Grounded (e.g. 120/240 single phase, 120/208, 347/600) then the secondary conductors are bonded to the EPZ through the transformer secondary winding connection to the neutral.
Standard construction requires the pole ground wire to be connected to the neutral and for the guy wire to be connected to the pole ground wire. If these connections are made, both the pole ground wire and guy wire are connected to the EPZ when the neutral is connected to the pole band. These connections must be confirmed. If these connections are in doubt, the external ground point must be connected to the pole band.

3.2.1 EPZ in a Pole

The following is the general procedure for creating an EPZ:

(a) Check line with a potential indicator to confirm it is not live.
(b) Install pole band (pole band must be low enough so that grip-all can be used in steps f and g while above band).
(c) Connect the pole band to the neutral or ground rod if neutral not available.
(d) Ensure all external ground points are bonded in the EPZ including communications messenger, guy wire, pole ground wire or overhead ground wire if required.
(e) Move above pole band.
(f) Connect pole band to the phase conductor.
(g) Connect phase conductors together.

An EPZ will exist above the pole band.

Standard grounds must be installed and removed in the proper order. Errors in procedure can and has resulted in fatalities. The following diagrams Figs. 3.2.1(a) and 3.2.1(b) illustrate the proper order of installation on some typical structures. Apply in the order (1), (2), (3) etc. and remove in the reverse order.
3.2.2 EPZ in Steel Structure

For EPZ in a steel structure, a pole band is not required. Use a grounding point on the structure in place of the pole band.
3.2.3 EPZ while Stringing Conductor

When stringing conductor above the neutral on distribution, where external hazards exist, EPZ must be established.

When stringing between the neutral and communications cable or within 2 meters of the neutral where there are no communications cable attachments, EPZ must be established at conductor reels and contact with the conductor must be minimized during stringing operation.

When stringing below the communications cable or more than 2 meters below the neutral where there is no communications cable, grounding is required. When pulling conductor out on the ground, grounding is not required.

When stringing communications messenger where a multi-grounded neutral exists, grounding is required. When stringing communications messenger on transmission where no multi-grounded neutral exists, EPZ is required.

When stringing conductor on transmission, where external hazards exist, EPZ must be established.

3.3 Isolation Grounding

Isolation grounding may be used for new construction and non-emergency work where the work has been “planned in advance” through completion of a site visit and a Steps and Conditions Plan prior to a crew being issued the job. Planning by the crew on the tailboard conference form, prior to the start of a job, is not considered “planned in advance”. Isolation requires that there is no possibility of sources energizing the work area. This means there are no lines crossing (either over or under) the line being worked on, no lines parallel to the line being worked on, and there is a suitable air gap (see Appendix D) between the source and the work area. With isolation in effect, grounds are to be installed as per Appendix B and C.

3.3.1 Distribution

Isolation on distribution requires suitable air gaps and verification that the communications messenger is bonded to the neutral. A porcelain cutout is not an acceptable air gap. If a porcelain cutout is used for an air gap, a second visible air gap
(E.g. riser removed from cutout) must be achieved. A set of tagged grounds must be installed at both ends of the isolated work area. Work units must install working grounds in the work area such that the maximum work distance from a set of grounds is 250 meters.

When working on a fused tap using isolation, working grounds must be applied on the tap, down line of the fuse or the fuse disconnect must be jumpered.

Grounds must be applied to a pole mounted transformer in accordance with the grounding requirements in Appendix A; when opening a fused disconnect and/or removing the HV lead for a pole mounted transformer in a section of line during isolation.

For new construction, working grounds must be applied as each new conductor is installed.

3.3.2 Transmission

Isolation on transmission lines cannot be achieved using the disconnect switch located at the substations or by removing the switch jumpers. GPR during a fault would be transferred to the transmission line via the substation termination grounds. The air gap used for isolation must be located a minimum of one (1) km from the substation. Any work to be performed between the substation and open jumpers must be completed using EPZ for worker protection.

GPR could also be transferred through the earth to a transmission line from a fault on an adjacent live line. Isolation can only be achieved where the isolated section is a minimum of 250 m from a live distribution line and 1000 m from a live transmission line.

Tagged grounds must be installed at both ends of the isolated work area. If there is a neutral conductor, overhead ground wire or a communications messenger on the transmission line isolated section, then work units must install working grounds in the work area such that the maximum work distance from a set of grounds is 250 meters.

3.4 Recognition of Hazards

Sometimes because of the nature of the task it is not possible or practical to create an EPZ or to use Isolation. It is important that for these tasks personnel are aware of the possible hazards and minimize their exposure to them. Proper work procedures and planning will minimize these hazards.
3.4.1 EPZ Crossing

There is a touch potential hazard when crossing in and out of the EP zone. Minimize the time crossing the zone or disconnect the cable between the pole band and the phase conductors before crossing the pole band.

3.4.2 Danger of Open Circuits

One of the most potentially hazardous operations when working on grounded circuits is the opening of a conductor circuit. Workers must not, under any circumstances, allow their bodies to bridge open points on isolated conductors unless the open point has been jumpered out. This work includes dead ending, splicing, cutting in insulators, etc.

An example of the kind of hazard that could be encountered is shown in figure 3.4.2. By opening the "A phase" corner jumper, the worker is now clearly subject to the full effects of induction and the possibility of accidental energization from the left hand (ungrounded) supply circuit.

Using bypass jumpers can avoid the hazards created by open circuits. Points to be opened shall be jumpered with a standard ground.

Fig. 3.4.2
SECTION 4 – GROUNDING EQUIPMENT HARDWARE (OVERHEAD)

4.1 General

When installing grounds, it is important to make every practical attempt to obtain the lowest possible electrical resistance path to ground.

Grounding clamps and conductors must have adequate current carrying capacity to withstand the maximum fault current available for the full duration of current flow. The clamps and cables must also have the necessary mechanical strength to withstand the electro-magnetic (physical) forces that are produced during high current situations (the most critical area of stress is the termination of the conductor into the clamp).

Portable grounds must be inspected prior to use and have a valid test date attached as per OPR106.12 Temporary Grounding. Damaged grounds or grounds that are in very poor condition shall be replaced immediately. Grounds shall not be modified or repaired in the field.

4.2 Standard Grounds Rating

Standard grounds shall comply with ASTM Standard F855-09. There are two standard copper grounding conductor sizes available, 2/0 AWG and 4/0 AWG, for use as standard grounds.

Figure 4.2.1(a) shows 2/0 AWG Cable Symmetrical Ratings (12,000 A) and figure 4.2.1(b) shows 4/0 AWG Cable Symmetrical Ratings (20,000 A). Newfoundland Power uses the Practical Curve rating for 60 cycle duration to determine cable capacity. For those busses and lines that exceed the single 2/0 AWG conductor rating, two 2/0 AWG conductors can be paralleled or a 4/0 AWG conductor can be used. When cables are paralleled the cables should be the same length and installed directly adjacent to one another. Busses with fault levels exceeding 12,000 amps are identified on the substation single line diagram.
The length of cable from the pole band to the conductor creating the zone across the worker should be kept as short as possible (maximum length seven (7) meters).

1. The Fusing Values are derived from ASTM Standard F-855-09, Tables 1-3
2. The Practical Values are 70% of the Fusing Values
3. The Parallel Values are 90% of twice the Practical Values

Fig. 4.2.1(a)

1. The Fusing Values are derived from ASTM Standard F-855-09, Tables 1-3
2. The Practical Values are 70% of the Fusing Values
3. The Parallel Values are 90% of twice the Practical Values

Fig. 4.2.1(b)
4.3 Pole Band

To establish an equipotential zone on a wood pole, a metal pole band must be installed on the pole approximately 0.6 m below the worker's feet. Pole bands are equipped with chain tighteners that attach the pole band to the structure. On other type structures attachment points should be provided.

![Fig. 4.3](image)

4.4 Temporary Ground Rod

When working on delta or wye systems with no multi-ground neutral, the only option for temporary grounding purposes is to utilize the portable temporary ground rod.

The portable ground rod should be installed at least 5 meters from the work site so that workers can work clear of touch and step potential hazards.

4.5 Permanent Ground Grid

All substation/switchyard structures are connected to the permanent ground grid. Structures have copper ground leads connected to one or more legs of the structure. Temporary grounding connections can be made to the copper ground conductor or to the metal structure, as close as possible to the isolated conductor being grounded. Installing grounding studs on structures at locations near the conductors or equipment to be grounded, allows the standard grounding conductors to be as short as possible.

4.6 System Neutral

When working on distribution feeders with a multi grounded neutral, EPZ work would only require the feeder phases, neutral and pole band be tied together (i.e. no temporary ground rod is required).
4.7 Running Ground

Running grounds (Fig. 4.7) are used effectively to ground non-insulated conductors during stringing operations. The running ground is installed on the conductor and secured to a stationary object with ropes; then connected to a ground electrode with a standard grounding conductor. The rollers apply a constant pressure to the conductor as it rolls through the running ground which maintains a secure electrical connection to earth. Running grounds must be sized for the conductor and rated for the maximum available fault current at the location being used.

Fig. 4.7

4.8 Cutout Grounding Clamp

A cutout grounding clamp (Fig 4.8) is used to ground the load side of the cutout.

Fig. 4.8

4.9 Portable Ground Gradient Control Mat (Ground Mat)

The portable ground gradient control mat (Fig. 4.9) will protect workers who must stand on the ground and contact conductors or equipment that could be inadvertently energized. The mat is used to bring the surface where the worker is standing to the
same voltage as the grounded equipment, establishing an equipotential zone. It prevents both step and touch potential. One application would be for workers operating aerial or stringing equipment from ground level.

![Fig. 4.9](image)

### 4.10 Potential Indicator

This is an instrument for detecting alternating-current (AC) fields. Physical contact with electrical conductors is not necessary to test for live or isolated condition, as the operating current is taken from the radiated electric field which surrounds live conductors.

![Fig. 4.10](image)

Potential indicators (Fig. 4.10) have settings for testing underground residential distribution (URD) apparatus and overhead lines up to 230 kV. A potential indicator with the appropriate ratings must be used to test for voltage.

Phasing sticks used to verify phase rotation and phasing of transmission lines or distribution feeders are acceptable instruments for use as a potential indicator.
4.11 Wire Brushes

One method to clean conductor before grounding clamps are installed on the conductor is to use wire brushes (fig. 4.11(a) & fig. 4.11(b)). Brushing removes corrosion and ensures a low resistance connection between the clamp and conductor.

Fig. 4.11 (a)

Fig. 4.11 (b)
4.12 Flat Bus Bar Grounding Clamp

A flat bus bar grounding clamp (Fig 4.12) is used to ground flat bus bar.

![Fig. 4.12]

4.13 Low Quality Ground Electrodes

4.13.1 Pole Ground Wire:

The pole ground wire may be broken or burnt off under the protective covering where it cannot be seen by workers. The ground wire may not be of sufficient size to safely conduct fault current. In rocky terrain or during winter it may be difficult to drive ground rods. In this case the pole ground wire (if available) may be used in addition to the temporary ground rod.

4.13.2 Guy Wire:

The guy wire could burn off during an accidental energization and result in a pole falling over.

4.13.3 Anchor Rods:

The resistance of the anchor rod could be high due to electrolytic corrosion. Wind can cause guying equipment to move in the ground and could result in a poor contact
between the rod and surrounding soil. In rocky terrain or during winter it may be difficult to drive ground rods. In this case an earth anchor (if available) may be used in addition to the temporary ground rod.

4.13.4 Overhead Ground Wire:

Overhead ground wires are not continuous for the full length of the line and may not have sufficient current carrying capacity to be used as a ground electrode.
SECTION 5 – TEMPORARY GROUNDING FOR UNDERGROUND

5.1 Introduction

Work on underground systems requires that workers must be trained in the special equipment and procedures used in the underground system.

5.2 Hazards

5.2.1 Underground Circuits

Underground circuits cannot be visually traced. Because of this, apparatus identification must be verified with the latest Single Line Diagram and schematics before work commences.

5.2.2 Capacitance

Cables act as a capacitor and shall be considered live at line voltage until grounded. When grounds are applied to isolated cables there may be a static discharge.

5.2.3 Sheath Open Points

On PILC cables, the lead sheath is bonded at one end of the cable only (normally the source). When working in the vicinity of the ungrounded end on these cables, workers must be aware of the dangers of bridging open points and guard against this hazard.

The concentric neutral on concentric neutral cable is used as the system neutral and should not be broken or separated.

5.2.4 Cable Sheath Voltage Rise

During fault conditions, the bonded and grounded conductors and cable sheath may be exposed to a voltage rise.

When working on high voltage cable or potheads it is not always possible to maintain an EPZ at the work site. It is recognized that there will be periods, during removal of insulation and application of insulation, when continuous grounding at the point of work is not practical.
5.3 Equipment

5.3.1 Grounding Elbow

The grounding elbow (Fig. 5.3.1) provides an electrical path to ground. This elbow is designed to carry fault current of 10,000 amps for 10 cycles at 35kV.
5.3.2 Test Rod

A test rod (Fig. 5.3.2) is inserted into a bushing well or feed through device and used as a test point when checking for potential.

Fig. 5.3.2

5.3.3 Protective Cap

A protective cap (Fig. 5.3.3) is used to cover the unused side of a feed through device.

Fig. 5.3.3

5.3.4 Feed-Through Device

A feed through device (Fig. 5.3.4) is used as a joiner for connecting two cables together.

Fig. 5.3.4

5.3.5 Cable Spiking Tools

When an underground cable must be cut, a check for potential is required. The check for potential is achieved by spiking the cable with an approved grounded cable spiking tool to ensure that the cable is isolated. There are two cable spiking tools commonly used for spiking cables. One is a clamp type (for use on concentric neutral cables only)
that drives a grounded spike into the cable as the clamp is tightened on the cable (Fig. 5.3.5(a)). The other is an explosive type that drives a grounded spike into the cable being tested (Fig. 5.3.5(b)).

5.3.6 Insulated Bushing

The insulated bushing is used to park a live bushing at an open point. It is designed to mount directly on a standard apparatus parking stand.

5.3.7 Grounding Bushing

The grounding bushing is used to provide a visible ground for an isolated elbow connected cable.
SECTION 6 – TEMPORARY GROUNDING OF SWITCHGEAR AND GENERATORS

6.1 Introduction

Work on switchgear and generators require that workers must be trained in the special equipment and procedures used with switchgear and generation systems.

Work on switchgear and generators do not always allow for simple and universal procedures for grounding, each job must be evaluated separately.

6.2 Hazards

6.2.1 Switchgear

Because of the nature of switchgear, the internal connections cannot be seen. This involves a special hazard that can only be overcome by referring to the switchgear drawings.

6.2.2 Generators

Generator grounding can be extremely difficult because in some installations no exposed connections exist for grounding purposes. Extreme caution should be exercised since in some cases it is not possible to place a ground on the generator until a connection point joint is unwrapped. Minimize hazards by eliminating any confusion between cables and by limiting exposure time to ungrounded leads.

6.2.3 Steel Penstocks

Steel penstocks are physically connected to the turbine and generator housings which are intentionally bonded to the power plant and substation grounding systems. This results in a transferred voltage appearing on the penstock during fault conditions that can create a ground potential rise on these grounding systems.

Contact made with a penstock at a location remote from the substation could result in a touch potential that is higher than inside the substation since the potential of the earth does not rise at this location as it does in the substation. During fault conditions a person standing on the ground and touching a penstock could be exposed to a touch potential hazard.
For work near steel penstocks, workers on the ground should minimize contact to avoid the risk of touch potential hazard.

For work directly on steel penstocks, additional precautions will be required to protect workers from touch potential hazards. To ensure adequate protection for personnel working directly on steel penstocks, Generation Engineering shall be consulted to determine requirements for worker protection.

6.3 Switchgear Connection Devices

Some switchgear installations have switchgear connection devices, commonly referred to as grounding trucks, which are breakers with the interrupting chambers removed.

Grounding trucks normally ground incoming cables, distribution cables or generator cables, not switchgear busses. In some cases, grounding trucks may have movable leads that allow either generator cables or incoming cables to be grounded. Bus connection devices allow connections to the switchgear bus. These devices can be used as a power tap on a bus or as a grounding device on a bus. These devices are similar to a grounding truck, only the positions of the bushings are different.

Extreme care must be used when using a switchgear connection device by ensuring the appropriate bushings are brought out for the intended purpose.
SECTION 7 – TEMPORARY GROUNDING FOR SUBSTATIONS

7.1 Introduction

Work in Substations requires that workers be trained in the special equipment and procedures used in substations.

The importance of proper grounding procedures in substations cannot be over-emphasized. We must consider not only the voltage classes of equipment involved, back feed, open circuit and parallel connection possibilities, but also the number of sources of induced voltage. Also of major concern is the relatively large fault current available at such substations. Work in substations does not always allow for simple and universal procedures for grounding, each job must be evaluated separately.

7.2 Ground Path Continuity

All substation equipment through which continuity cannot be visually verified shall be grounded on all sides. Special precautions are required to ensure that grounding paths do not become open circuits during the progress of work. If the temporary grounding path at the location to be worked on cannot be traced visually (e.g. through underground cables) by the individual performing the task, then a check for potential must be performed and standard grounds installed. Note: If a circuit can be positively identified because there is only one cable in the substation, then grounding on only one end of the cable would suffice if the total length of the ground path is less than 30 meters.

7.3 Length of Grounding/Bonding Conductor

Substation ground grids to which equipment and structures are bonded are thermally stable and of low resistance. The bonding leads brought up above ground and attached to equipment and structures provide a readily available ground electrode of excellent quality. The presence of this grid in switchyards, covered by crushed rock (which acts as an insulator) can also be expected to provide good protection from step and touch potentials.

The total length of ground path from contact point to grid should be as short as possible (max. 30 m).
7.4 Minimum Grounding Requirements

When a complete substation or large section of a substation is de-energized to perform work, all phases must be bonded together and grounded at each source of supply and on each bus or bus section.

Grounds shall be in place on both sides of power circuit breakers, reclosers, regulators and power transformers while workers are inside the equipment tanks or on top of equipment as per Appendix A.

If risers are not installed to the equipment bushings, standard grounds installation is not required. Grounds shall be in place on instrument transformers, coupling capacitors, surge arrestors, and similar substation equipment while workers are within the minimum approach distance of the isolated current carrying components.

Grounds shall be in place on transformers and oil circuit breakers before the oil is drained from the tanks or the tanks are opened.

7.5 Grounding of Bar Type Current Transformers

Bar type current transformers have a continuous high voltage current path through the CT and grounding on only one side of the CT is adequate.

7.6 Capacitor Grounding

At least 5 minutes shall elapse between the disconnection of a capacitor and the installation of grounds. A load bust tool must be used to open the capacitor disconnects. A capacitor shall remain disconnected for at least 5 minutes before it is re-energized. The five minute time interval is required to drain off the capacitor through its internal discharge resistor before it is grounded or re-energized. If the capacitor and load are disconnected, then the capacitor will discharge through the connected load immediately on feeder disconnection and therefore no time interval is required before grounding is installed or feeder re-energized.

7.7 Testing and Commissioning

For tests that require the equipment terminals (66 kV and below) to be ungrounded, the bushing leads may be temporarily ungrounded (using a hot stick) to permit these tests, as long as the ground is reestablished as soon as the test is completed. Do not remove
grounds from equipment if tests can be done with grounds installed. Bushing leads may be disconnected from bushing terminals to permit equipment testing on 138 kV and above. Work clearances and grounding instructions for the test equipment shall be in accordance with the manufacturer's recommendations.

7.8 Lifting Equipment

Vehicles used in substations to lift substation equipment must be grounded. The equipment being boomed must also be grounded before hand contact is made with the piece of equipment (e.g. breakers, reclosers, transformers, etc.). Grounding the equipment being boomed creates an EPZ for the worker when in contact with the equipment.

7.9 Ladders and Scaffolds

Ladders used in the vicinity of electrical equipment must be of a non-conductive type and are not required to be grounded.

Metal scaffolds may be used providing the minimum approach distance is not violated and providing that each bottom end section is grounded to the substation ground grid using 2/0 AWG standard grounding conductors and approved clamps. Each additional end section of the scaffold shall be bonded with 2/0 AWG standard grounding conductor. The bonding shall be accomplished as each section of the scaffold is erected.

7.10 Surveying Equipment

Metallic measuring tape, leveling rod, range pole (in excess of 2m) etc., are not permitted to be used in substations or within 5.5 meters of other live lines/equipment.

7.11 Grounding during Construction

In substations under construction, temporary grounding shall be installed if there is a transmission line, distribution line or neutral terminated in the substation or an external hazard exists.
7.12 Work on Substation and Fence Ground Grids

When working inside substations, never use the fence ground grid for temporary grounding since not all substations have a tie between substation ground grid and fence ground grid. When work is required on apparatus located within 2.5 meters of the fence, the apparatus must be grounded. The fence ground grid and the substation ground grid must be connected together using standard ground cable.

Unless special precautions are taken when repairing or extending substation ground grids, dangerous potential differences can exist under certain conditions between objects which are grounded to the grid and the nearby earth. When a substation ground grid is to be extended, or an accidentally severed ground grid is to be repaired, or if the ground grid is to be opened or joined for any reason, such work shall be carried out only by workers skilled in this type of work. These precautions also apply to substation metal fencing. Substation fences must never be allowed to be connected to or to contact adjacent metallic fences.

Refer to OPR2100.01 - Extending or Repairing Ground Grids.

7.13 Construction Power

To ensure adequate protection for personnel during construction of yard extensions to existing live substations, construction power must be supplied to the new extension from a portable generator until the extension of the substation ground grid is complete.

Ground Fault Interrupter (GFI) protection is mandatory for all AC equipment use.

7.14 Working with Neutrals in Substations

When working with neutrals in substations including running triplex for station service or handling any conductor in or out of the substation, extra precautions must be taken to avoid open neutral conditions. Open neutral conductors may have differences in potential that can result in neutral current flow from distribution return current or ground potential difference.

Open neutral points must be bonded using an appropriate work method prior to making final connections.
7.15 Grounding for Temporary Generation Sites

To ensure adequate protection for personnel during operation of generation installed outside of substations, a temporary ground grid may have to be installed. Electrical Engineering shall be consulted for discussion of requirements and design of any required ground grid.
SECTION 8 – TEMPORARY GROUNDING OF VEHICLES & MOBILE EQUIPMENT

8.1 Vehicle Grounding for Line Work

Vehicles and equipment such as derrick trucks, cranes, vans and aerial devices shall be connected to ground when working within the minimum approach distance of live apparatus or when EPZ protection is required. Ground connection shall be made using standard grounds. The preference shall be to ground vehicles and equipment to an existing permanent ground (neutral or substation ground grid). If a permanent ground is not available then the vehicle shall be grounded to a temporary portable ground rod.

Vehicles and equipment shall not be grounded when isolation is in effect or when working only on secondary voltage circuits (including street lights) from a bucket.

Whenever an ungrounded vehicle becomes energized, all of the energy would flow to ground through the tires and outriggers. This could impact vehicle stability and would be a hazard for any workers aloft. Vehicle grounding to a multi grounded neutral will provide multiple paths to ground and will divert energy away from the tires and outriggers.

Temporary grounding to a driven ground rod will promote (but not necessarily ensure) the prompt clearing of the circuit in the event of accidental energization and may reduce the time of exposure to the hazard.

Should a vehicle become accidentally energized, there will be touch and step potential hazards for the workers on the ground near the vehicle and in contact with the vehicle. Touch and step potentials will both exist whether the vehicle is grounded or ungrounded. Grounding the vehicle does not provide protection for a person in contact with both the vehicle and the ground. However, connection to the multi grounded neutral will reduce the touch and step potential hazard for the worker on the ground.

For EPZ on distribution, protection to workers on the ground is provided by minimizing contact with the vehicle or equipment when the vehicle or equipment is grounded to the system neutral. For EPZ on transmission, workers on the ground should minimize the time that they are within 5 meters of the grounded vehicle.

During hot line work on distribution and transmission, workers shall not contact a vehicle without applying the procedure outlined in section 8.3 "Accessing Vehicle".
Particular attention will be required to ensure that workers and other members of the public are not exposed to the hazards of accidental energization of the vehicle.

8.2 EPZ in an Aerial Device

The vehicle must be connected to the EPZ. Two configurations are shown in figures 8.2(a) and 8.2(b). The truck ground is normally connected to the pole band. If not connected to the pole band, the truck ground must be connected to the neutral on the load side of the grounding jumper. If the truck ground is connected on the source side of the grounding jumper, an undersized neutral could burn off and break the ground connection and exclude the vehicle from the EPZ.

Fig. 8.2(a)
8.3 Accessing Vehicle

When it is necessary for a person to approach or leave the vehicle during hot line work or EPZ on transmission line work outside the substation, the following steps must be enforced:

1. Communicate with the worker aloft.
2. Stop all work aloft and keep boom in static position.
3. The worker on the ground receives permission from the worker aloft to proceed to the vehicle.
4. The worker on the ground to inform the worker aloft when clear of the vehicle and it is safe to resume work.

If workers are required to remain in contact with a grounded vehicle for extended periods of time, a ground mat bonded to the vehicle shall be installed for the worker to stand on. When it is necessary to step on or off the ground mat, procedures one to four outlined above must be followed.
8.4 Vehicle Grounding for Substation Work

All vehicles working and/or parked inside a substation must be grounded. For these vehicles there are no restrictions necessary for approaching the vehicle because the grounded vehicle and worker are included within the same EPZ and a touch potential hazard does not exist. A Caution Tag (warning of hazardous condition) must be placed on the steering wheel while the vehicle is grounded.

When vehicles are parked inside the substation yard within 2.5 meters of the fence, the fence ground grid and substation ground grid must be connected together using standard grounds. If vehicles are working (not just parked) within 2.5 meters of the fence, outside the substation yard, the vehicle shall be connected to the fence ground grid using standard grounds. Consideration must be given to the touch potential hazard between the vehicle and the ground.

8.5 Vehicle Ground Connection

The following procedure shall be followed for temporary grounding of vehicles:

1. If a conductor reel is used, remove all conductor from the storage reel when grounding the truck.
2. Ensure grounding cable is connected to vehicle.
3. Connect grounding cable to a ground electrode.

8.6 Tension Stringer

Stringing new conductor in the area of live conductor can be a hazardous task if proper work methods and safety procedures are not followed.

During tension stringing operations around live lines it is a hazard for the worker to operate the equipment while standing on the ground. Should contact be made with the live conductor the worker would be exposed to a touch potential.

To avoid this, the tension stringer must be connected to a ground electrode. The conductor must also be connected through a running ground and the worker shall stand on a portable ground mat bonded to the equipment. This will place the worker in an EPZ (see figure 8.6). Stepping on and off the mat should be minimized as it creates a step
potential hazard. If a worker has to enter or leave the EPZ, the tension stringer must be stopped prior to entering or leaving the EPZ. Alternatively, the worker can stay on the equipment instead of using the ground mat.

The equipment in contact with the conductor through a synthetic rope is not a touch potential hazard, provided the rope is clean and in good condition.

8.7 **Vehicle Grounding for Fuelling Trucks**

Fuel trucks parked inside a substation or within 2.5 meters of the substation fence must be grounded as per Section 8.4.

Fuel trucks parked outside 2.5 meters from the substation fence with a fuel hose extending from the truck to the fuelling point inside the substation must be bonded to the substation ground grid using a standard ground.

Fuel trucks outside the substation require special precautions to protect the public and/or workers who may come in contact with the vehicle. A touch potential hazard may exist.
Fuelling nozzles must be bonded to the fuelling point.
APPENDIX A

Isolation & Grounding by Equipment Type
## APPENDIX A

### Isolation & Grounding Requirements by Equipment Type

In general, disconnect all sources of energization and ground all points.

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<th>Remove Risers</th>
<th>Install Grounds</th>
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<td>Load or Low Voltage</td>
<td>Source(s) or High Voltage</td>
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<td>X (4)</td>
</tr>
<tr>
<td>Bus</td>
<td>X</td>
<td>X (5)</td>
<td>X (5)</td>
</tr>
<tr>
<td>Capacitor</td>
<td>X (6)</td>
<td>X (6)</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Equipment</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

### Legend:
- **X** in cell means perform the operation indicated by the heading description.
- ( ) number in brackets references the itemized note.
Notes:

1) These requirements are for the temporary grounding of individual devices. The requirements will vary when the devices are isolated as part of a larger feeder or substation outage.

2) If the minimum approach distance cannot be maintained from the high voltage bushing(s), a check for potential and grounding of the high voltage of the transformer is required. Grounding of the high voltage bushing is not required when the secondary is disconnected.

3) To work on a switch, it must either be grounded or leads removed.

4) The capacitive charge of an isolated cable will be discharged when installing grounds. The means of isolation (disconnects or risers) and whether both ends must be isolated and grounded will depend on the configuration of the cable. The cable must be isolated from all possible sources of re-energization.

5) One set of grounds is adequate for a bus unless more than two bays or the removal of bus conductor are involved. Any bus tie switches in the grounding path must be tagged in the closed position.

6) When isolating capacitors, a load bust tool must be used to open the capacitor disconnects and five minutes must elapse after opening disconnects before short circuiting and grounding the capacitors. When a section of the line containing capacitors and transformers is disconnected, the capacitors are immediately short circuited through the transformers and no waiting period is necessary.

7) This connection is not necessary where there is no possibility of the equipment being back-energized by a source connected to the secondary.

8) If work is to be performed on the secondary, Class 0 gloves are to be worn or grounds are to be installed. If work is to be performed on the primary (i.e. bushing well) of a radial feed transformer the secondary is to be grounded or disconnected.

9) When work is to be performed on the secondary, grounds are to be installed on the secondary conductor (secondary bushings are not acceptable) or high voltage side of the transformer.
APPENDIX B

Transmission Line Grounding and Bonding
## APPENDIX B

### TRANSMISSION LINE GROUNDING and BONDING

<table>
<thead>
<tr>
<th>Line Type</th>
<th>Phases Worked</th>
<th>Diagram Number</th>
<th>Protection</th>
<th>3 Phase Ground Substation (4)</th>
<th>3 Phase Ground Work Area</th>
<th>EPZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (1)</td>
<td>3</td>
<td>1</td>
<td>Isolation (5)</td>
<td>X</td>
<td>X (3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>EPZ</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>&lt;3</td>
<td>1</td>
<td>Isolation (5)</td>
<td>X</td>
<td>X (2)(3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>EPZ</td>
<td></td>
<td>X</td>
<td>X (2)</td>
<td>X (2)</td>
</tr>
</tbody>
</table>

**Legend:**

- **X** in cell means perform the operation indicated by the heading description.
- ( ) number in brackets references the itemized note.

**Notes:**

1) Radial transmission lines supplying a substation that has feeders that can be supplied from another substation shall be considered as looped lines for the purposes of determining the minimum grounding requirements.

2) When work is being performed on one or two phase(s) of a transmission circuit, only the phase(s) where minimum approach distances cannot be maintained must be grounded and bonded.

3) A set of tagged grounds must be installed at each end of the isolated work area. In addition, there must be a set of grounds installed that are visible from the work site. Tagged grounds can serve as work site grounds if visible from the work site.

4) For a radial transmission line, the line must be grounded at the source substation of...
the line. For a looped transmission line, the line must be grounded at each substation to which the line terminates.

5) Isolation to be achieved by opening jumpers located a minimum of 1 km from the substation and where the isolated section is a minimum of 250 m from a live distribution line or 1000 m from a live transmission line.
GROUNDING & BONDING CODE

Diagram No. 1

Transmission Line with External Hazards – Isolation

NOTE 1
NOTE 2 & 3
NOTE 2 & 3
NOTE 4
NOTE 1
NOTE 1
NOTE 1
NOTE 1

DIAGRAM No. 1
Notes:
1. Substation disconnect switch is not to be used to provide isolation.
2. Isolation to be achieved by opening jumpers located a minimum of one kilometer from the substation.
3. All structures worked between the substation and the open jumpers must be worked using EPZ.
4. A set of Work Site grounds may be required as per reference drawings 5 or 5A if there is no other ground set installed that is visible from the Work Site.

DIAGRAM No. 1
DIAGRAM No. 2

Transmission Line with External Hazards - BPZ
APPENDIX C

Distribution Line Grounding and Bonding
Notes:
1. Install working grounds in the work area such that the maximum work distance from a set of grounds is 250 meters.

2. One set of tagged grounds is to be installed at each end of the isolated work area.

3. A minimum of one set of tagged grounds is required. One set of grounds is required at each work area.

4. When the pole band is above the neutral, a connection between the pole band and the neutral is not required.
APPENDIX D

Insulator Wet Flashover Values
## INSULATOR WET FLASHOVER VALUES

<table>
<thead>
<tr>
<th>Insulator Type</th>
<th>Flashover (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer 15 kV Deadend (DS 15)</td>
<td>45 kV</td>
</tr>
<tr>
<td>Polymer 25 kV Deadend (DS 28)</td>
<td>90 kV</td>
</tr>
<tr>
<td>Inline Switch (deadend clamp type)</td>
<td>70 kV</td>
</tr>
<tr>
<td>Inline Amp Disconnect (DS 28)</td>
<td>90 kV</td>
</tr>
<tr>
<td>Inline Amp Disconnect (DS 35)</td>
<td>110 kV</td>
</tr>
<tr>
<td>1 - 6” Porcelain</td>
<td>30 kV</td>
</tr>
<tr>
<td>2 - 6” Porcelain (3)</td>
<td>55 kV</td>
</tr>
<tr>
<td>3 - 6” Porcelain (3)</td>
<td>80 kV</td>
</tr>
<tr>
<td>1 - 10” Porcelain</td>
<td>50 kV</td>
</tr>
<tr>
<td>2 - 10” Porcelain (3)</td>
<td>90 kV</td>
</tr>
<tr>
<td>3 - 10” Porcelain (3)</td>
<td>130 kV</td>
</tr>
<tr>
<td>15 kV Polymer Cutout (1)</td>
<td>30 kV</td>
</tr>
<tr>
<td>25 kV Polymer Cutout (1)</td>
<td>36 kV</td>
</tr>
<tr>
<td>Link Stick (per foot) (4)</td>
<td>100 kV</td>
</tr>
</tbody>
</table>

### Notes:

1. When a porcelain cutout is used to establish an air gap for isolation, a second visible air gap must be utilized (e.g. riser removed from cutout).

2. The wet flashover values used in the table were taken from the CEA Specification LWIWG-01 for suspension composite insulators. The insulators in Newfoundland Power’s inventory catalogue must meet the minimum requirements of the specification and in most cases they exceed the specified values. If the actual wet flashover values for an insulator type are known then that value may be used as the wet flashover rating.

In order for an air gap to be considered suitable, it must have a wet flashover value greater than the maximum voltage which could be inadvertently applied.
3. Multiple units in series have a reduction in flashover voltage.

4. Dry flashover rating only. No wet flashover rating available.