Safe Work Practices on High Voltage Substation Apparatus

CONTROLLED DOCUMENT

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Summary

This document supports the Power System Safety Rules and its requirements assembled under 'High Voltage Substation Apparatus Category 5.

The document describes safe work practices for the control of hazardous situations.

This standard applies to all persons working on HV Substation Apparatus.

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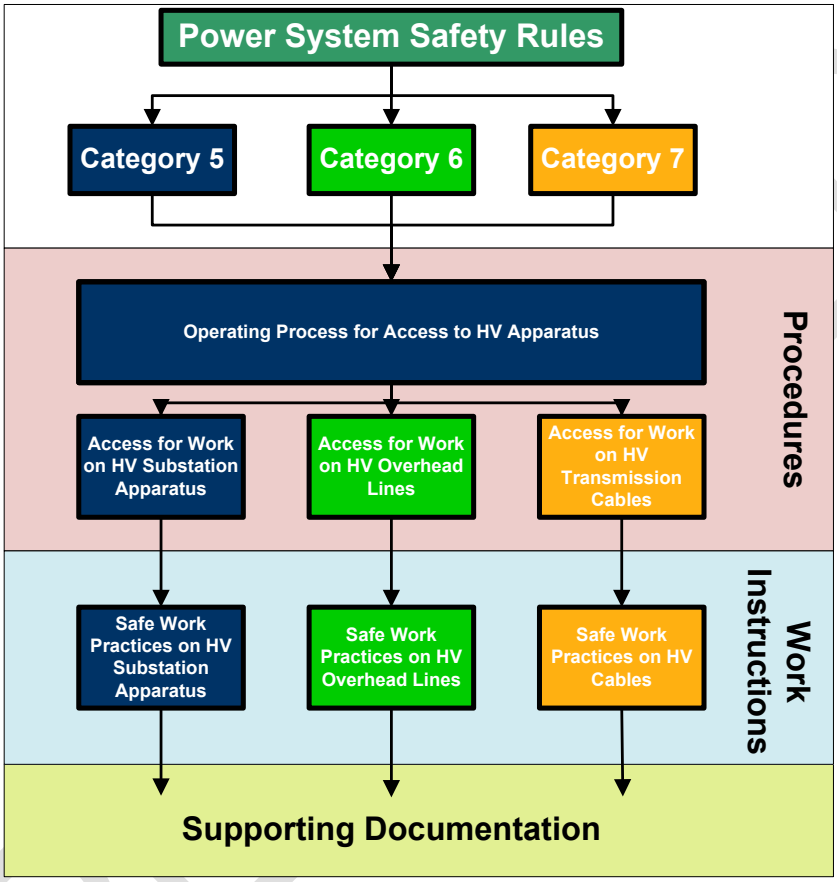
Contents

1. Purpose

This document supports the Power System Safety Rules (PSSR) and its requirements assembled under 'High Voltage Substation Apparatus Category 5. The document describes safe work practices for the control of hazardous situations.

The following block diagram shows the location of this document in relation to other Power System Safety Rules Procedures.



2. Scope

This procedure applies to work practices on all high voltage substation apparatus.

3. Accountability

Title	Responsibilities and Accountabilities
Head of HSE	> Ownership of this procedure
Power System Safety Rules Manager	> Maintenance of this procedure
Training Manager	> Implementation of training programs associated with this procedure

Title	Responsibilities and Accountabilities
Authorised Persons	> Comply with this procedure

4. Introduction

This standard was developed as a guide to assist in selecting the correct safe work practices to be used when performing work on High Voltage (HV) substation apparatus. Work may only commence on HV substation apparatus when it has been made safe for work and an Access Authority has been issued or whilst working on disconnected apparatus as per the requirements of the PSSR.

The safe work practices contained within this document protect staff from the hazardous occurrences or effects that can develop on or around HV substation apparatus and associated equipment, including: Induced voltages and currents; Transfer voltages; and Earthing Systems.

This document sets out a range of hazardous situations, the controls (safeguards) to be implemented and describes the safe work practices which must be observed. The possible safe work practices are referenced for each situation.

This document should be read in conjunction with 'Portable Earthing of High Voltage Electrical Equipment'. This document indicates when various practices should be used and the Portable Earthing document indicates what hardware should be used when implementing the nominated practices.

It is the responsibility of all workers engaged in work on HV substation apparatus to follow all the safe work practices applicable to the work.

These safe work practices are to be used in conjunction with TransGrid's Health and Safety Risk Assessment process. The process may identify that additional controls are required for particular tasks and situations.

5. High Voltage Substation Hazards

This section details the possible hazards that can occur when working on, or installing HV Substation Apparatus and the following sections provide examples of working procedures recommended for use under such conditions.

The following table lists the risks encountered when working on or in the vicinity of HV Substation Apparatus and controls to be implemented.

5.1 High Voltage Substation Apparatus Risks and Controls

Situation	Hazard	Control	Reference
Carrying long items of equipment, e.g. ladders or conduit	Near approach to HV conductors	Carry equipment below shoulder height. If longer than 2 metres use two people	Near Approach

Situation	Hazard	Control	Reference
Excavation	Buried Services	TransGrid Excavation permit Services check Bridging of earth grid Excavation work within 200mm to known underground services or earthing systems requires non-destructive digging methods.	Buried Services Work on Earthing Systems
Un-bonded cable sheaths.	High Voltages from Unusual Sources	Care is necessary when working on low voltage equipment and circuits to ensure that nothing occurs which can bring about such a condition.	HV Cables
Removal, breaking or cutting of Earth or Neutral Connections	High Voltages from Unusual Sources	Connections between apparatus and the earthing system shall not be removed, broken or cut while the equipment is in service. HV Access authority required for such work.	High Voltages from Unusual Sources
Work on isolated electrical apparatus	Induced Voltages due to capacitive coupling	Earth the apparatus to be worked on Working earths, bridges and bonds must be removed before you cancel you Access Authority. Note: Areas with known induction issue an Advice of Alteration can be submitted so notes can be made on the appropriate High Voltage Operating Diagram.	Induced Voltages Advice of Alteration
Work on isolated electrical apparatus from an Elevated Work Platform (EWP)	Induced Voltages	An EWP must always be earthed via the earthing system when being used to access equipment in a switchyard. A bonding lead from the basket of the EWP to the conductor or equipment being worked on is required at all times. This lead shall be a minimum 35mm^2 copper.	Induced Voltages

Situation	Hazard	Control	Reference
Stringing conductor on landing span to Substation	Transferred earth potential	Bridging leads applied using insulated methods. Set up equipotential work are area and controls	Stringing conductor on landing span to Substation
Overhead conductors/earth wires, metallic communication, control and protection circuits, cable sheaths and pulling ropes, fences, water, sewage and storm water service pipes all provide a means for "remote" earth potentials to be transferred	Switchyard Earth Grid Voltage Rise and Transferred Earth Potentials	Equipment that may be subject to transferred earth potentials shall be either: insulated, isolated, or otherwise rendered safe.	Switchyard Earth Grid Voltage Rise and Transferred Earth Potentials
HV Power Capacitors may retain an electrical charge	Retained electrical charge hazardous to persons even after the apparatus has been isolated from the source of supply.	Equipment shall be fully discharged before approaching, or working on or near the apparatus, and after electrical testing has been performed.	HV Power Capacitors
HV Transmission and Pilot Cables may retain an electrical charge	Retained electrical charge hazardous to persons even after the apparatus has been isolated from the source of supply.	Equipment shall be fully discharged before approaching, or working on or near the apparatus, and after electrical testing has been performed.	High Voltages from Unusual Sources
Working near Fault Earth Switches (FES)	This apparatus contains a charged spring that operates a swinging arm.	Barrier FES out of the work area when work is not required on the fault earth switch. Discharge or Close the FES whenever it is included inside a work area.	Fault Earth Switches
Work in HV Substations by instructed persons	Near approach to HV conductors	Either supervised by person Authorised Category 5.2 or set up safe work area for Disconnected Apparatus	Near Approach Disconnected Apparatus

6. Safe Work Practices

Safe work practices are applicable to all HV Substation working situations and are to be used (as applicable) for all work.

It is essential when developing safe working procedures to carefully assess the possibility of hazardous situations occurring at the work site and where appropriate, give consideration to the following basic safe working practices and safeguards.

These safeguards (controls) are to be used in conjunction with TransGrid's Health and Safety Risk Assessment.

7. Work on High Voltage Substation Apparatus - General

For all work associated with HV Substation Apparatus, in the charge of a controller, an Request for Access (RFA) shall be submitted in accordance with section 2 of the Power System Safety Rules (PSSR).

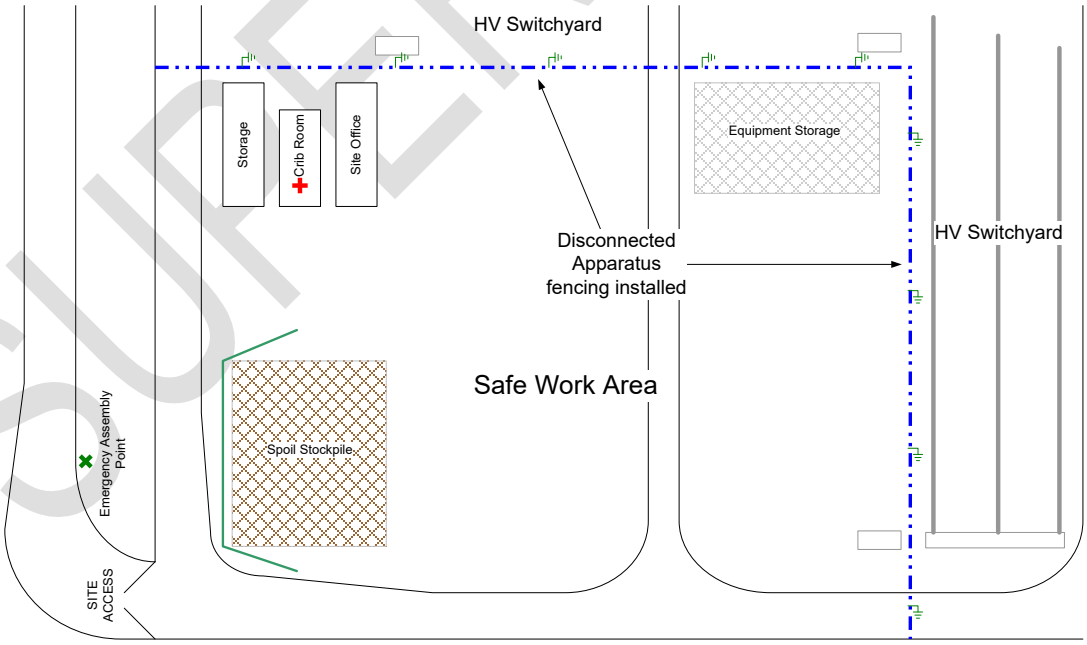
7.1 Work with High Voltage Substation Apparatus Isolated and Earthed

Work that requires the HV Apparatus be made safe for work shall have either a HV Access Authority or a HV Testing Access Authority issued in accordance with TransGrid's 'Power System Safety Rules' and 'Access for Work on HV Substation Apparatus'.

7.2 Work on High Voltage Substation Apparatus as Disconnected Apparatus

If a long outage of HV Substation Apparatus is proposed it may be possible to disconnect it temporarily from the system to enable work without an Access Authority. In such a case, the Power System Safety Rules requirements for making Disconnected Apparatus Safe for Work Rule 5.5.3 must be complied with if work is to proceed without an Access Authority.

A typical Safe Work Area for disconnected apparatus is shown in the following diagram.



8. High Voltage Power Capacitors

Shunt connected HV power capacitors are used for power factor correction and voltage control. Most such capacitors comprise banks of multiple cans mounted on racks and connected in double star or H pattern configuration.

8.1 Capacitor Residual Charge

Capacitors are able to retain an electrical charge of sufficient magnitude to be hazardous to persons even after the apparatus has been isolated from the source of supply. Such equipment shall always be fully discharged using a suitable means of earthing before approaching, or working on or near the apparatus, and before working on the apparatus after electrical testing has been performed.

When working on capacitors or associated circuits, all components are to be continuously earthed. If the work requires removal of the earthing, this must not be done until at least five minutes after the initial application. The earthing should be restored as soon as practicable and retained until the work has been completed.

Where work requires the disconnection of individual capacitor cans, the terminals of these cans must be short circuited before disconnection.

NOTE: Because of induction effects from overhead conductors and the like, HV DC voltages could also occur during installation work. The work party is to ensure adequate earthing of terminals and bank connections to reduce the likelihood of dangerous conditions.

9. Fault Earth Switches

Fault Earth Switches have been installed in some locations to provide back up for primary protection schemes. They automatically apply a permanent, solid, single-phase earth connection to the conductors so that the distance protection at the remote end of the circuit will see the fault and trip the remote end circuit breaker.

Fault earth switches in service are OPEN. This apparatus contains a charged spring that operates a swinging arm and is capable of being actuated by protection and automatically closed. Whilst set and ready to operate on in service equipment, no part of a fault earth switch is to be locked.

9.1 Fault Earth Switches and Work Areas

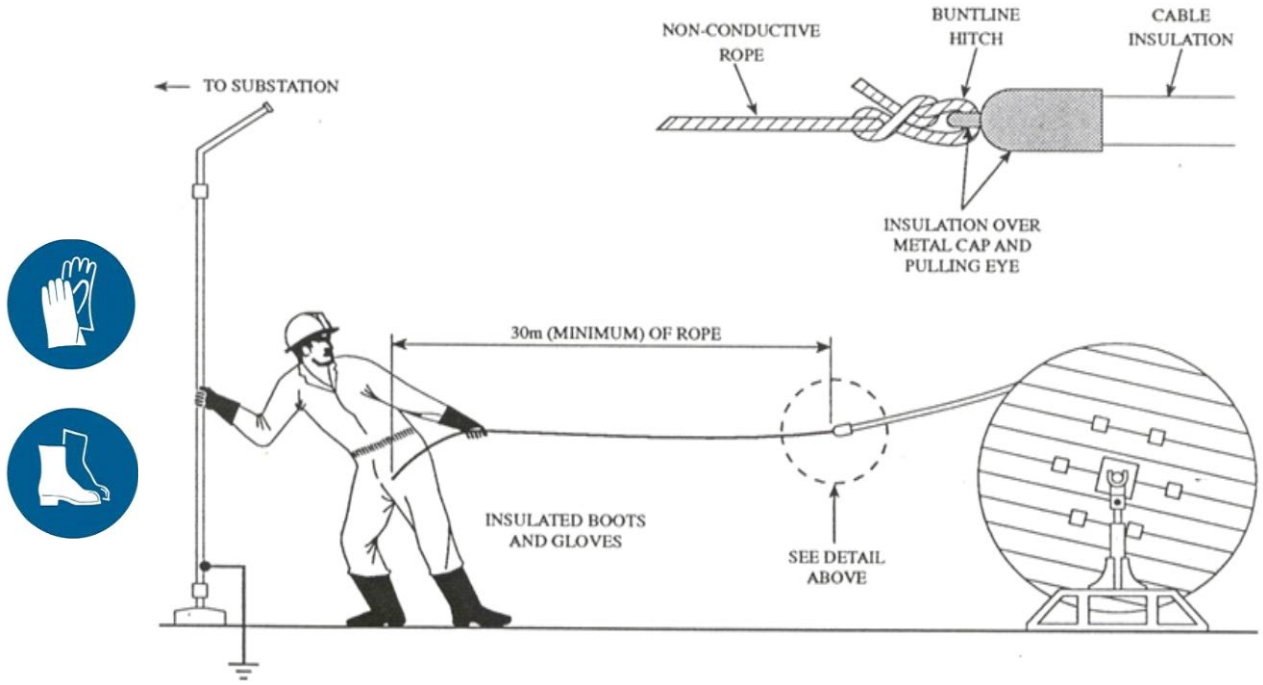
See Access for Work on High Voltage Substation Apparatus.

10. Switchyard Earth Grid Voltage Rise and Transferred Earth Potentials

Substations and the circuits connecting them may be subject to dangerous rises in electrical potential due to faults either locally or elsewhere in the network.

Overhead conductors/earth wires, metallic communication, control and protection circuits, cable sheaths and pulling ropes, fences, water, sewage and storm water service pipes all provide a means for "remote" earth potentials to be transferred to or from the substation.

Insulated work methods are used to control hazards from earth grid voltage rise and transferred earth potentials, as shown below.



Pulling Cable into Substation

10.1 Stringing Conductor on Landing Span to HV Substations

Staff working on the stringing of conductors and overhead earth wires up to the landing span in the substation, i.e. between a HV overhead line and a structure in a HV substation can be subject to significant hazards from the rise in voltage of the substation earth grid under system fault conditions or system switching activities.

Earth grid voltage rise can be transferred to persons outside the switchyard and may occur at any time. Similarly, staff working within the switchyard can become connected to a remote earthing system which can lead to a hazardous voltage during a rise in the voltage of the substation earth grid.

10.1.1 Standard Safeguards

a) All Landing Span works require an Engineers Assessment to determine specific controls.

b) It is best practice for all work on the HV overhead lines to be completed before the landing span is erected. If this cannot be done it may be necessary to temporarily install a single disc insulator in the overhead earth wire at the first structure and to leave the conductor jumpers completely disconnected or tied back onto the landing spans.

These precautions will limit the extent of transfer voltage effects.

a) The connection and disconnection of jumpers is to be carried out using the standard bridging process.

b) All terminations to conductor or overhead earth wire made at ground level in the general vicinity of the landing spans are to be carried out under bonded work area conditions.

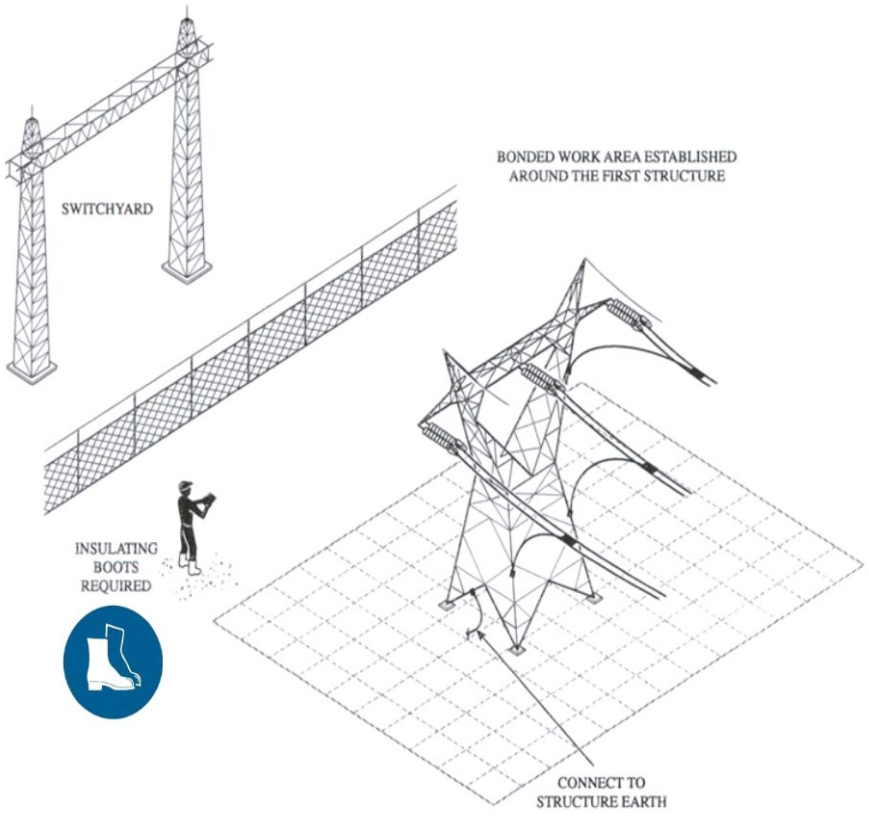
c) The person in charge of the work is to ensure that the Controller is advised prior to the commencement and on completion of stringing operations involving landing spans.

10.1.2 Outline of Procedure for Stringing Landing Spans

Access Authority procedures must be implemented prior commencement of the work.

Procedures to be followed for stringing landing spans are:

a) A bonded work area shall be established around the first structure and connected to the structure earth, as shown right. Insulating boots are to be worn by all persons working at ground level during the course of the work. (This will be a safeguard from possible step and touch voltage which could arise when the structure is connected to the switchyard earth grid).



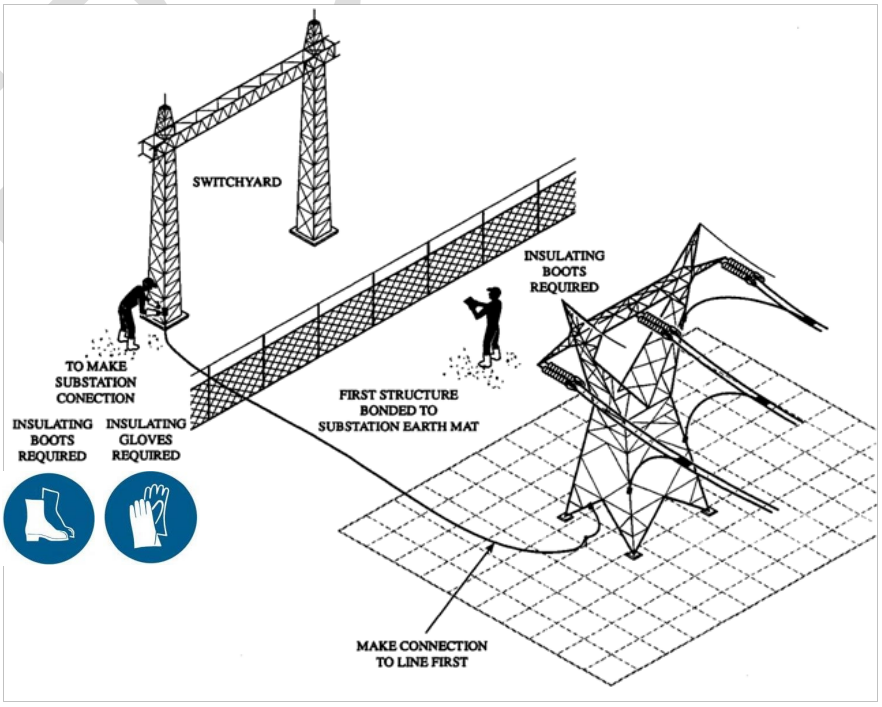
b) The first structure shall be bonded to the switchyard earth mat in the following way:

   i. using a standard portable earthing lead, the lead shall be connected to the first structure outside the switchyard;

   and then:

   ii. under insulated working conditions, the lead shall be run out towards and into the switchyard;

   iii. under insulated working conditions, persons shall connect the lead to the switchyard earth grid as shown in the following diagram.



c) Winches, brakes and other equipment associated with the stringing operation are to be connected to the switchyard earth mat directly or via the earthing of the first structure. The connection shall be carried out using the procedure outlined in (b) above.

d) Stringing of each conductor or overhead earthwire shall be carried out in such a way that neither the conductor nor the overhead earthwire makes contact with the switchyard earth grid whilst the conductor is being handled by persons outside the switchyard.

For additional information refer to "Safe Work Practices on HV Overhead Lines".

11. Buried Services

Any excavation or digging in a switchyard has the possible danger of contact with buried services and could include earth grid, gas, water, sewer, communication and HV or LV cables.

11.1 Excavation Permit

An Excavation Permit is required for any excavation in a switchyard and excavating plant shall be earthed per Section 9 whilst digging in a substation.

Refer TransGrid Excavation Permit

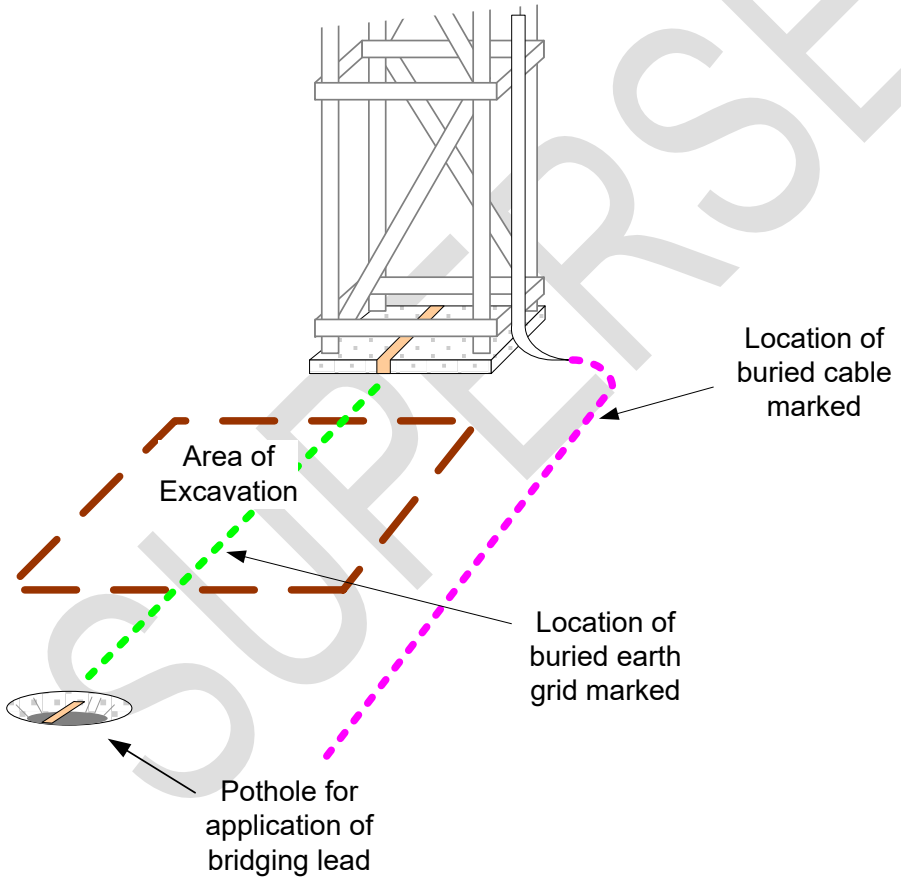
11.2 Earth Grid

Refer "Earthing Systems".

11.3 Services check

All known buried cables, earth grid and other services within 1m of the proposed excavation shall be highlighted on the drawings and marked on site prior to excavation as shown below.

Removal of ground material within 200 mm clearance to known earth grids must utilise non-destructive excavation methods (hand/hydro vac excavation).



12. High Voltage from Unusual Sources

There are some ways in which high voltage can occur on apparatus which normally carries low voltage and particular care is necessary to ensure that nothing occurs which can bring about such a condition. For example, dangerous voltages may exist on un-bonded cable sheaths.

12.1 HV Cables

This apparatus is able to retain an electrical charge of sufficient magnitude to be hazardous to persons even after the apparatus has been isolated from the source of supply. In addition, connections between the earthing system and high voltage cable sheaths are not to be disconnected except under a Cable Access Authority.

During system fault or system switching the potential of the substation earth grid may rise and be transferred via cable pulling equipment and/or cable conductors or metallic parts of the cable to working parties remote from the substation. Similarly, persons working in high voltage areas connected via pulling equipment and/or cable conductors or metallic parts to remote earth may be in danger.

Refer to 'Safe Work Practices for Work on High Voltage Cables' for further information.

12.2 Pilot Cables

During a system fault or system switching the potential of the substation earth grid may rise and be transferred via cable pulling equipment and/or cable conductors or metallic parts of the pilot cable to working parties remote from the substation. Similarly, persons working in high voltage areas connected via pulling equipment and/or cable conductors or metallic parts to remote earth may be in danger.

When working on pilot cables the work party must remain insulated from the Substation Earthing System.

Refer to 'Safe Work Practices for Work on High Voltage Cables' for further information.

12.3 Earth or Neutral Connections

Refer "Earthing Systems".

13. Earthing Systems

If earthing systems are damaged, electrical performance may be affected and dangerous voltages may occur.

13.1 Removal of Earth or Neutral Connections

If an earth or neutral on high voltage apparatus which is in service is removed, cut or broken, a dangerous voltage may occur. Connections between apparatus and the earthing system shall not be removed whilst the apparatus is in service.

13.2 Work on Earthing Systems

Where work includes the connection, cutting, disconnection or potential to break or damage any part of an earthing *system* (the point of work), then prior to the work commencing a *bridging lead shall* be applied across the point of work. The *bridging lead shall* be applied by a person authorised category 5.5 in accordance with PSSR Section 5.5.5 'Bridging of Earthing Grids'.

All persons *shall* comply with the requirements of *Do Not Operate Tags* attached to *bridging lead*s. Any damage caused to the *substation* earth grid or connections which could adversely affect its electrical performance *shall* be repaired on the same day.

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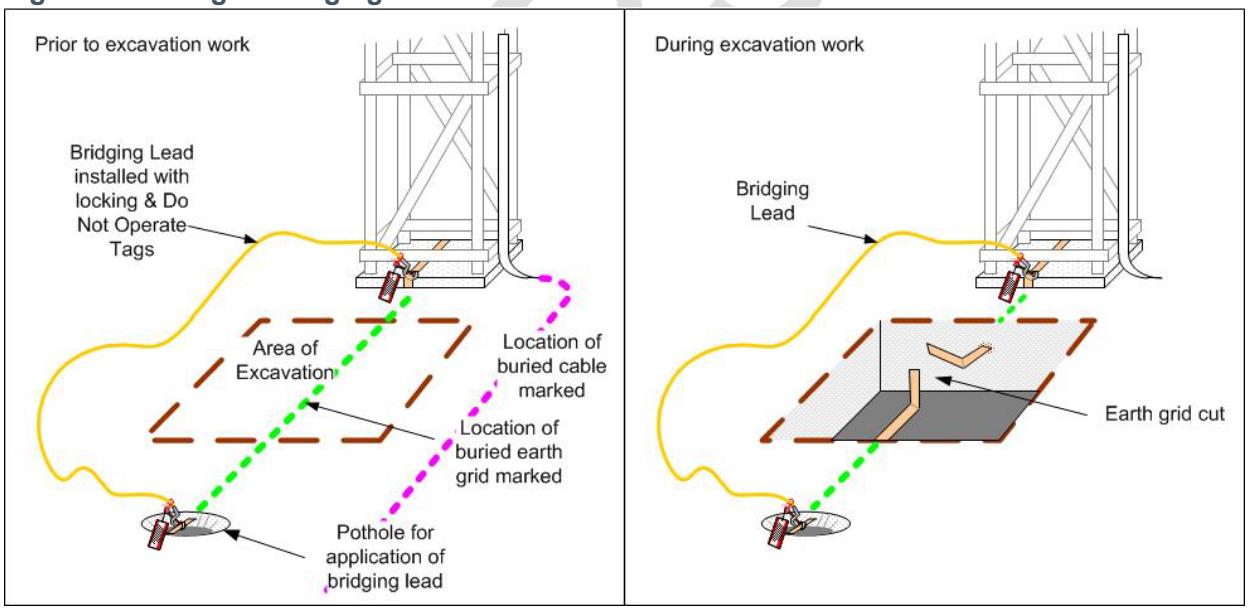
The bridging lead shall be applied using an approved insulating handle, as shown below, or another approved insulated working method.

The following diagrams display the step by step method by which a bridging lead is applied where work includes the connection, cutting, disconnection or potential to break or damage any part of an earthing *system* during excavation work.

Figure 1: Earth grid bridging method



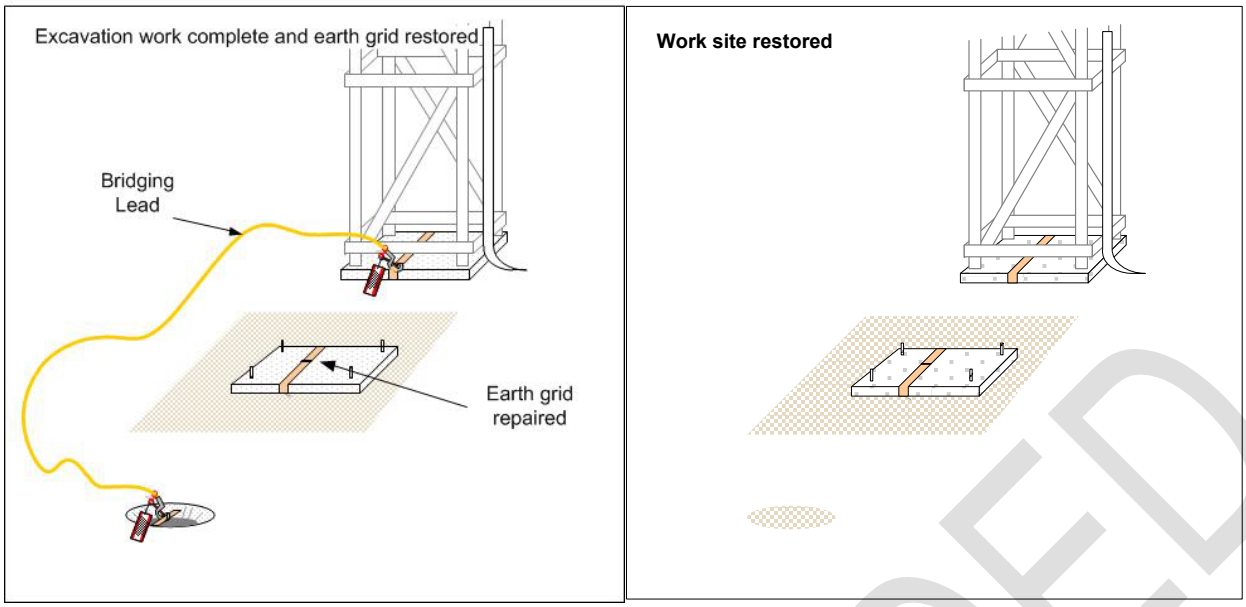
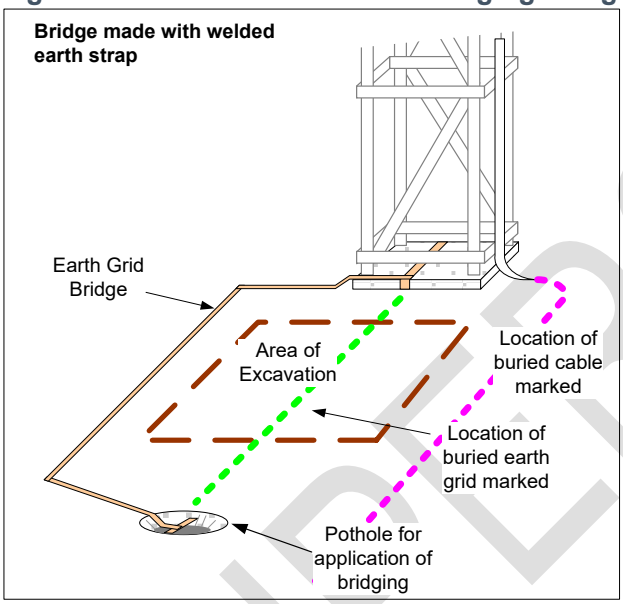


Figure 2: Alternative method of bridging using earth strap welded in place



14. Near Approach

Personnel and plant clearance distances shall be maintained as specified in 'Safe Approach Distances to exposed conductors' refer: Power System Safety Rules Attachment B.

Warning signs (as shown right) shall be erected where there are live high voltage conductors adjacent to the work area from which persons and plant will need to keep clear. See Access for Work on High Voltage Substation apparatus for further information on setting up designated work areas.

15. Induced Voltages and Currents

Induced voltages and currents (induction) can be caused by adjacent in service equipment, high voltage switching or electrical faults in adjacent equipment.

15.1 Induction Hazards – Refuelling

Refueling of equipment and plant should always be carried out in an area where induction from in service equipment is not present. Equipment and plant should be checked prior to use for fuel levels and refuelled only at their storage locations, well away from the risk of induced voltages from the switchyard. Where it is stationary plant which cannot be relocated, a static bonding kit or alternative control measure to eliminate sparks during refuelling is to be used.

15.2 Induction Hazards – Work on High Voltage Apparatus

There a risk of induced voltages when carrying out work on isolated electrical apparatus. The risk could be of the form of either steady state or transient induced voltage and current hazards.

To control the steady state induction hazards, caused by capacitive coupling, all conductors to be accessed must be earthed prior to approach by the work party.
Earthing of conductors shall be achieved by using either of the following methods:

1. If the RFA allows operational access to disconnectors and CB's within the work area, these can be operated to extend the Access Authority earthing through to the unearthed conductors or equipment which needs to be accessed.
2. Working earths applied to unearthed conductors in accordance with approved procedures.

Note: Additional Access Authority earths in areas with known induction issues can be requested on the RFA. In areas which are known to have high induction, operating notes can be added to the High Voltage Operating Diagram to advise the System Operator preparing the HVPRI of the need for additional earths in this area.

The figure below illustrates an Elevated Work Platform (EWP) being used for work on HV substation apparatus made safe for work under an Access Authority. The figure shows an equipotential work area created by the applied Access Authority Earths, the EWP connected to the earth grid using a trailing earth and a bonding lead between the conductive EWP basket and the conductor being worked on.

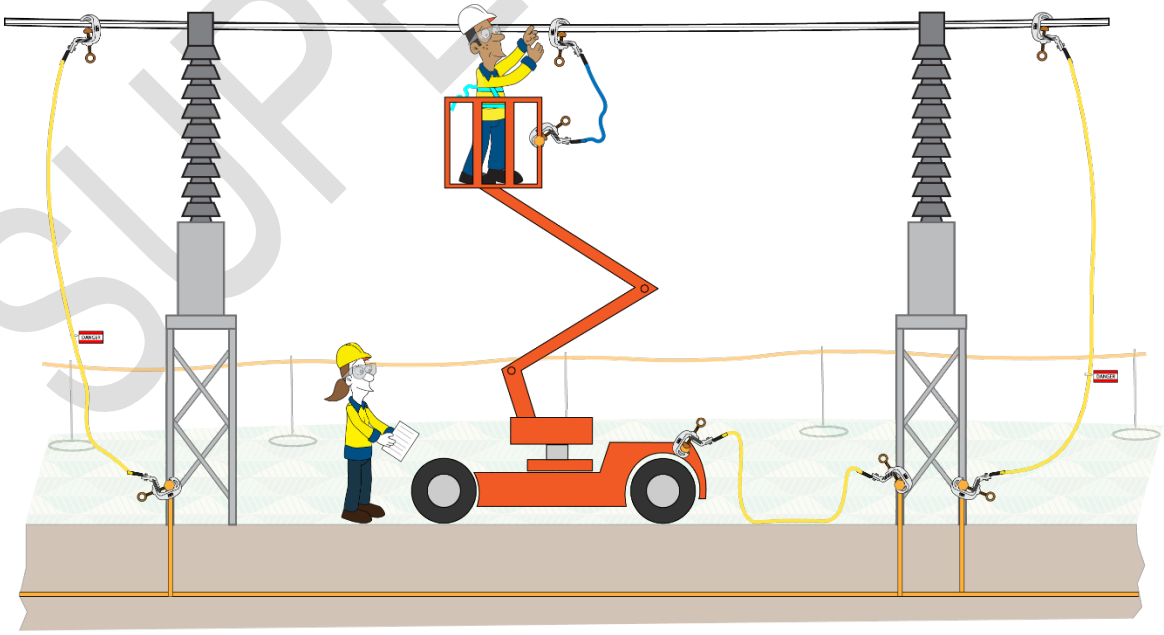


Figure 1: Typical work area with induction controls in place

15.3 Bonding Leads

A bonding lead is a conductor used to ensure equipotential conditions are maintained during work. It provides a low impedance connection between two objects which could be at different voltages and subsequently ensure that those two objects have the same potential. Bonding leads are the primary control for managing transient induced voltages and currents. They can also be used to discharge capacitive voltages off apparatus which is not connected to conductors but which can still be subject to capacitive coupling and subsequent induced voltages.

Bonding leads are not intended to be used in situations where they could conduct fault current and they must never be used as bridging leads.

Bonding leads shall only be applied to conductors after they have been earthed.

15.3.1 Bonding Lead Physical Requirements

A bonding lead shall be of a minimum size of 35mm^2 copper.

It shall be attached to the EWP using a reliable connection such as a permanent connection, an earthing stub or a screw action earthing clamp.

It shall, wherever possible, be connected to the conductors using an MT815S clamp.

NOTE: Where it is not possible to connect the bonding lead and MT815S clamp to equipment such as the T or V join in a circuit breaker head or the centre moving contact of a disconnector, a suitable clamp connection shall be used. The suitable clamp will depend on the location where the clamp will attach to. The clamp used must consider the risk of inadvertent contact and ensure this is controlled. An alternative clamp shall not be used where a MT815S clamp can be used.

So it is not confused with fault rated earthing equipment, a bonding lead must not be yellow.

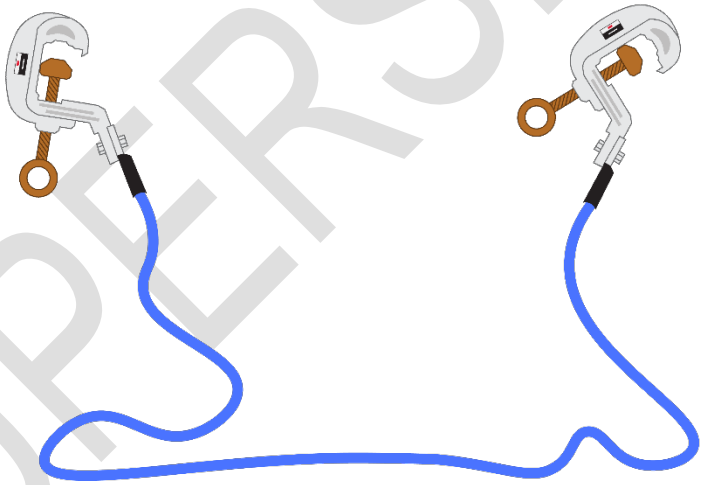


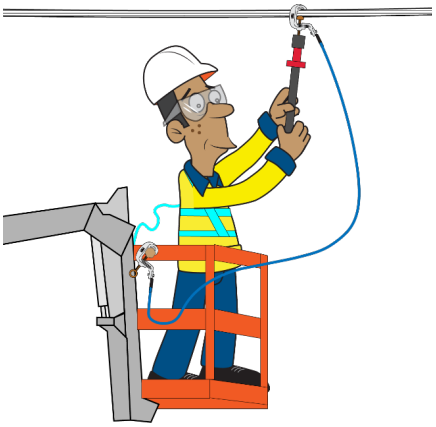
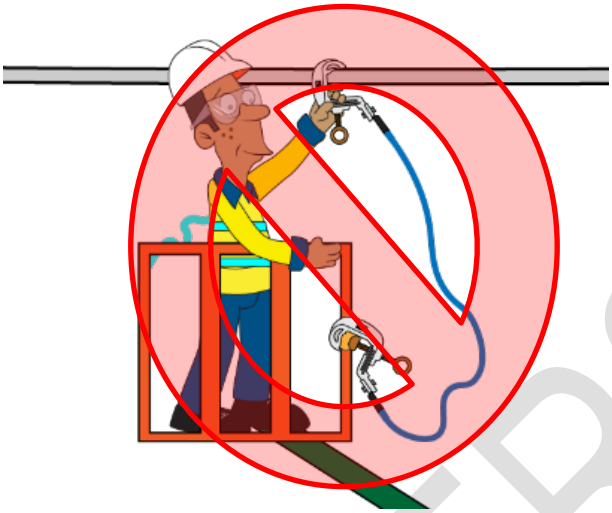
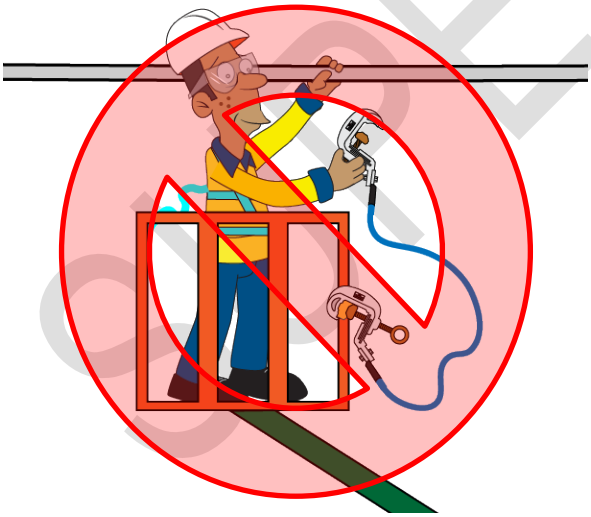
Figure 2: Bonding Lead

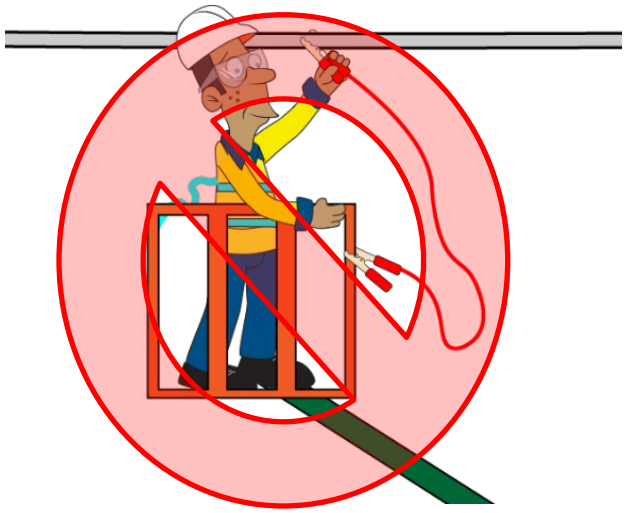
15.3.2 Application and Removal technique

When connecting a bonding lead **DO NOT BECOME PART OF THE CIRCUIT**. When applying or removing the bonding lead to the conductors keep the hand applying the lead and any other parts of the body behind the end of the bonding lead and away from the conductors to be bonded (Use MT815S application handle where possible).

When using bonding leads remain vigilant as the MT815 clamp will not break away in the event that it is left connected to the conductors or equipment.

Table 1: Bonding Lead Application Methods

	**Correct application:** Correct bonding lead applied using an insulated handle with all parts of body clear of conductors
	**Incorrect application:** Use of hand to apply and tighten clamp
	**Incorrect application:** By touching the conductor with their left hand, the worker has made their body part of the discharge circuit.

	**Incorrect application:** Incorrect bonding lead for attaching to the conductors. It places the hand in close proximity to the conductors and introduces a risk of inadvertent contact.

15.3.3 Making and Breaking Connections

When making and breaking connections on high voltage substation apparatus it is important that consideration is given to the management of induction hazards. Wherever possible, both sides of the disconnection must be earthed prior to making or breaking the connection. Multiple bonding leads or a bridging lead in combination with a bonding lead are to be used at the point of disconnection to manage any transient induction hazards on both sides of the disconnection.

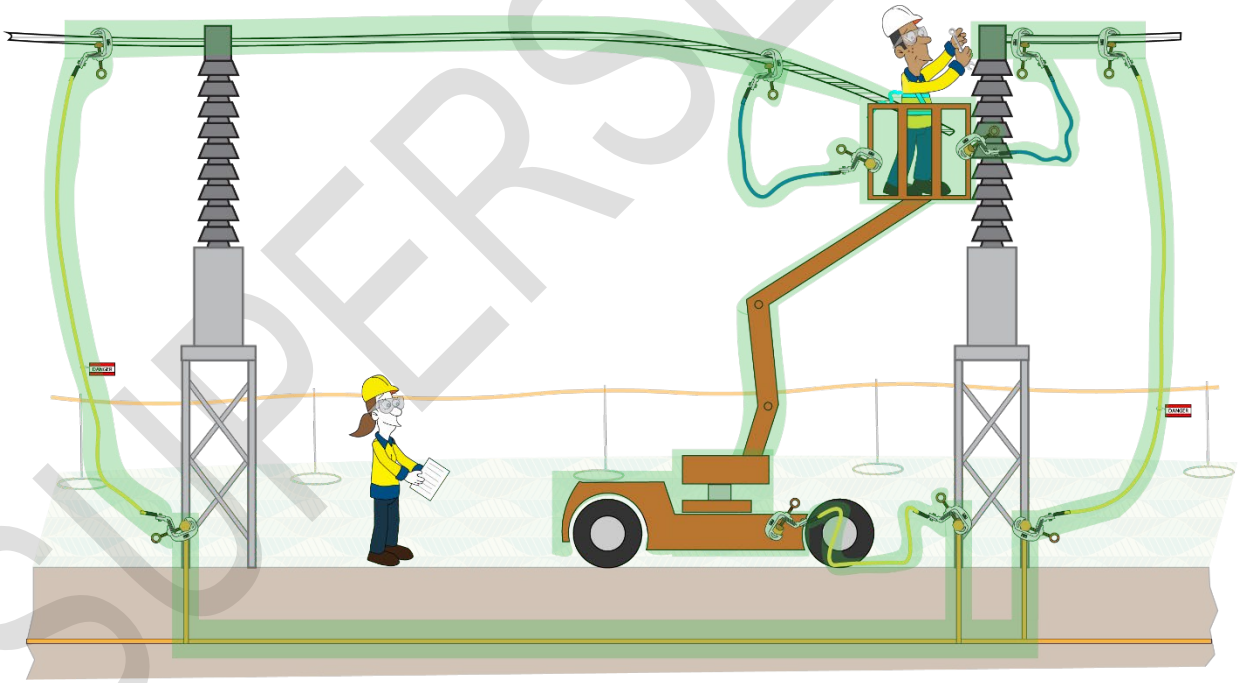


Figure 3: Example of multiple bonding leads used when making and breaking connections. Equipotential equipment shown in green.

15.4 Bridging Leads

A Bridging lead is used to provide a low impedance, fault rated path for current. They are to be used, where necessary to maintain a current path when a conductor is to be broken or disconnected. Typically in substations earthing is established from all points of supply and Access Authority earthing takes account of where conductors will be broken to ensure the risk of inadvertent re-energisation is appropriately managed without the work party needing to maintain current paths to Access Authority earths. Bridging leads can be

used as one method to maintain equipotential conditions when making or breaking conductors. A standard portable earthing lead is used as a bridging lead.

15.5 Working Earths

Working earths are portable earths which are applied by an appropriately qualified person after an Access Authority has been issued. Working earths are used to mitigate potential induction issues relating to staff accessing HV conductors and the equipment connected to them. Whilst Access Authority earths are applied during an HVPRI between all sources of supply and the point of work, they may not provide an earth to all sections of conductor which the Request For Access and Access Authority grant access.

A working earth can only be applied to equipment or conductor(s) which you have access to under your Access Authority and must be removed before the Access Authority is cancelled.

In a Substation, conductors must be proven de-energised prior to the application of working earths. Working earths must only be applied by a person who has been authorised to prove de-energised and apply them.

16. Change history

Revision no	Approved by	Amendment
0	Lionel Smyth, EGM/Network Services & Operations	Revision 0 New Work Instruction
1	Lionel Smyth, EGM/Network Services & Operations	• Section 'Mobile Plant' deleted. • Section 'Disconnected Apparatus' revised • Section 'Work on Earthing Systems' revised • Section 'Switchyard Earth Grid Voltage Rise and Transferred Earth Potentials' revised
2	Neil Smith, GM / System Operations	• Section 11.2 pictures revised for locking of clamps
3	Ken McCall, Manager/HSE	• This procedure has been reviewed and reissued with no changes
4	Michael Gatt, EM, Works Delivery	• Updated to new template • Section 7.2 updated to remove sentence which contradicted other procedures. • Work on Isolated Electrical Apparatus items added to table in 5.1 • Section 15 - Induced Voltages renamed to Induced Voltages and Currents and additional content added. • Requirements relating to designated work area setup referred to Access for Work on HV Substation Apparatus or reference made to this document where requirements are referred to in this procedure. •
5	Krista-Lee Fogarty, Head of HSE	• Updated to new template • Section 5.1 and 11.3 updated to include NND requirements for excavation work near earth grids

17. Implementation

This procedure is to be implemented in conjunction with the implementation of TransGrid's Power System Safety Rules. It will be available as a resource, published on the Wire.

18. Monitoring and Review

The Head of HSE is responsible for the ongoing monitoring and review of the documents associated with the Power System Safety Rules. This can include but is not limited to:

a) Requesting regular feedback on the effectiveness of procedures and work instructions. Appropriate feedback tools include focus groups and online assessments;

b) Where a change has occurred in our processes; and

c) Recommendations arising from incidents.

19. References

Safe Work Practices on High Voltage Overhead Lines

Safe Work Practices on High Voltage Cables

Safe Work Practices on Low Voltage and Mechanical Apparatus

Induced Voltages and Currents Fact Sheet