1. PURPOSE AND SCOPE

The purpose of this Standard Work Practice (SWP) is to standardise and prescribe the method for earth injection testing of a substation earthing system for the purpose of determining current distribution, earth potential rise (EPR) and personnel safety. Personnel safety involves ensuring measured step, touch and reach voltages are in accordance with the relevant earthing standard for the location under test.

The major components of an earthing system are as follows:

(a) the primary earthing system comprising the buried earth grid, and

(b) the auxiliary earth system which includes, but may not be restricted to, the following:

- Cable sheaths/screens – in particular, those that are bonded to the substation earthing grid and to a remote earth.
- Overhead earth wires which are bonded to the substation earth grid and at one or multiple remote earth locations.

2. STAFFING RESOURCES

Adequate staffing resources with the competencies to safely complete the required tasks as 8 Level Field Test Competency - 2597616.

These competencies can be gained from, but not limited to, any or all of the following:

- Qualifying as an Electrical Fitter Mechanic.
- Qualifying as a Technical Service Person.
- Training in the safe use of relevant test equipment.

Requirements for all live work:

- Safety Observer (required for all “live work” as defined in the Managing electrical risks in the workplace).

All resources are required to:

- Have appropriate Switching and Access authorisations for the roles they are required to perform and have the ability to assess and maintain relevant exclusion zones from exposed live electrical apparatus.
- Hold current licences for any vehicles and equipment they may be required to operate.

Required Training

Staff must be current in all Statutory Training relevant for the task.

All workers must have completed Field Induction or have recognition of equivalent prior Ergon Energy Field Experience.

Contractors must have completed Ergon Energy’s Generic Contractor Worker Induction.

3. DOCUMENTATION

ASRIS

Before You Dig Australia

Clearing times should be considered for both single line to ground and double line to ground fault conditions. In particular, protection relay data including characteristic curve, overcurrent setting, time multiplier setting, instantaneous settings etc. are required for all relays that may be involved in clearing an earth fault at the location in question. For Ergon Energy sites, this data can be obtained from the Protection Engineering group and/or the Intelligent Process Solutions™.

Construction Tool - Substation General - 2912940

Earth Resistivity Testing – 2934945

Earth Resistivity Test Results.

Electrical Safety Rules 2022 – 6503074

ENA-EG0 Power System Earthing Guide Part 01

ENERGEX Environmental Management System- Environmental Standard - 2947192

Energex Safety Manual – 2951572

EQL SWMS – Safe Work Method Statements

Fault levels for all voltages at substation or site – these are used to calculate estimated Step, Touch, Reach and Mesh voltages under fault conditions.

HazChat D1 - Static Sites - Substations, Metering Labs

Health and Safety P009 – 692225

IEEE-80 Guide for Safety in AC Substation Grounding

Maps and site plans – used for marking test locations. These may include but not be limited to:

- Local maps - Can give useful information on the surrounding area.
- Civil Drawings – Substation plans and elevations, earth mat layout drawings etc.
- Google map images.

Operate the Network Enterprise Process – 2909674

Queensland Electricity Entity Standard for Safe Access to High Voltage Electrical Apparatus (SAHV - Orange Book) - 2904212

Queensland Government Environmental

Substation Earth System Injection Analysis Tool – 2941578

Substation Primary Plant and Secondary Systems Field Testing – 2902800.

Test Equipment Manuals.

4. KEY TOOLS AND EQUIPMENT

All equipment used is to be calibrated and within test due date.

4.1. Current Source

Stable AC current injection source capable of injecting off frequency (i.e. non 50Hz) current into the earthing system under test. The earth injection current to be attained should be a minimum of 6A. To achieve a reasonable current level, a step up transformer and / or series tuning capacitors may be required depending on the impedance of the earth system under test and the associated injection circuit.

- Surge protection, such as an Omicron CP GB1, when injecting via a feeder to provide additional protection.

4.2. Current Distribution Testing

- Frequency tuneable ammeter or Spectrum Analyser coupled with a phase angle meter or equivalent capable of measuring off frequency (i.e. non 50Hz) currents and associated phase angles.
- Rogowski Coil.

4.3. Earth Potential Rise Measurement

- Frequency tuneable voltmeter or spectrum analyser.
- Spool(s) of cable (distance required will depend on recorded measurements). In excess of 1km may need to be available dependent on the site under test.
- Earth test electrode (e.g. earth rod).
- Type I or Type II RCD as required in EPR cable to provide additional protection.
- Snake bite protection (e.g. gaiters) as required.

4.4. Step, Touch, Reach and Mesh Potential Measurements

- Frequency tuneable voltmeter or spectrum analyser.
- Earth test electrodes (rods).
- 2 of 8 cm radius discs used when carrying out effective (Loaded) voltage measurements when using the IEEE80 standard.
- 5m test leads.

4.5. Switching and Access Operating Equipment:

- PEDs, Live Line Tester, Class 0 gloves. All equipment to be inspected and confirmed within test date prior to use.
- Suitable barriers and warnings signs for erection at the source and the remote earth to prevent inadvertent contact with 'LIVE' equipment.
- PPE including full-length protective cotton clothing, safety footwear, helmet. Additional PPE as required: brim for safety helmet, leather work gloves, Class 00 gloves, hearing protection, safety eyewear, high visibility clothing when working on or near roadways. All PPE to be inspected and confirmed within test date (where applicable) prior to use.
- Sun protection to be used when working outdoors.
- Helmet light when working in low visibility conditions.

5. WORK PRACTICE STEPS

5.1. Preparation work

Prior to performing an earth injection test, the following preparation work should have been completed:

5.1.1. Earth grid continuity test

To prove that all connections to the earth grid under test are sound. Continuity testing of all earth connections should be carried out to a known reference point. The preferred reference point in a substation is the neutral earth bond on a power transformer. Special attention is to be made on those installations that have an added earthing impedance e.g. Neutral Earthing Resistor (NER). These are installed between the transformer neutral and the substation earth grid. In these cases, the continuity tester is always to be connected to the substation earth side of the NER. Figure 1 below shows the correct connection point for a continuity tester for an installation comprising a NER.

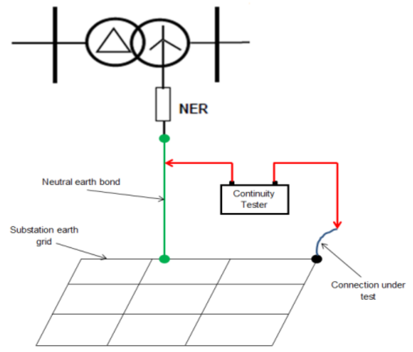

Figure 1: Continuity Testing - NER Installed

IMPORTANT: Any access to the connection between the NER and the transformer neutral bushing will, under normal conditions, require the issue of an Access/Test Permit under requirements of the Electrical Safety Rules / Operate the Network Enterprise Process – 2909674.
Results for the Continuity testing are to be recorded in Substation Earth System Injection Analysis Tool – 2941578.

5.1.2. Soil resistivity test

If the injection test is being performed with no prior investigations of the soil structure, then a soil resistivity test of the location should be carried out in accordance with Earth Resistivity Testing – 2934945. Particular care should be taken to obtain an accurate value for the surface layer resistivity. This may require consultation with the

Substation Design group who can carry out more detailed analysis via computer modelling.

If no soil resistivity data is available from the Substation Design group and it is not possible to carry out a soil resistivity test, the top layer soil type should be determined through the ASRIS website. This service provides detailed information on the soil types of surface layers throughout Australia down to approximately 2m. Conductivity data for each soil type is available through the Queensland Government Environmental website.

Note: This method will only provide an indicative figure for soil resistivity for the particular location and as such should be treated with caution.

5.1.3. Choose injection method

The fundamental principle of earth injection is that off mains frequency (i.e. non 50Hz) AC current is injected into a remote earth, with the injected current returning to the earth grid under test either through the earth's mass or alternate paths.

Choose the most appropriate injection path for current based on the following guidelines:

5.1.3.1. Injection by overhead feeder into remote earth

This method involves an injection source (generator) connected to the substation earth system under test and also to an out of service feeder that is bonded at the remote end to a robust earth grid. The connection to the earth system under test should be via a robust earth tail that has been checked for continuity to the remainder of the earthing system by use of a suitable continuity tester. Hazards involved with this method to consider include:

- Possible high induced voltages on the out of service feeder from adjacent energised feeders.
- Exposure to lightning strikes in adverse weather conditions. For long feeders, it is necessary to use aids such as the lightning tracker and/or weather radar to ensure good conditions exist for the entire length of the feeder.

5.1.3.2. Injection by cable into remote earth

If it is not possible to get access to a feeder and associated remote end earth grid, an alternate remote earth may be used e.g. a distribution or SWER transformer HV earthing system with a compliant earth measurement. If this is not available, a temporary remote earth may need to be installed to be used as a remote earth. Both of these latter methods will further require the running of an insulated lead of suitable voltage and current rating from the injection generator, located at the earth mat under test, out to the remote earth location.

This method introduces hazards such as possible exposure of the public to potentially high voltages on the injection cable as well as issues with slips, trips, falls, traffic control etc.

5.1.4. Determination of relevant earthing standard

The following guidelines are to be followed in selection of the appropriate earthing standard to be applied:

5.1.4.1. Inside the substation

When carrying out analysis on Step, Touch, Reach and Mesh voltages for locations inside the substation fence, use either IEEE-80 or EG0 dependent on what the substation was designed to. Design reports indicating what standard a substation has been designed to may be sourced either through the Substation Design Group or EDMS. If no data is available, use EG0 as the relevant standard.

5.1.4.2. Outside the substation

In general, locations outside the substation fence should be analysed using either IEEE-80 or EG0 dependent on what the substation was designed to.

5.2. Carry out an onsite risk assessment

Prior to performing this activity any hazards associated with pre-requisite tasks at the worksite shall be identified and assessed with appropriate control measures implemented and documented in accordance with HazChat D1 - Static Sites - Substations, Metering Labs using reference document EQL SWMS – Safe Work Method Statements.

If any risks cannot be managed or reduced to an acceptable level, do not proceed with the task and seek assistance from your Supervisor.

The following information may be helpful in identifying the hazards encountered and appropriate control measures when carrying out earth injection testing.

5.2.1. Principle of earth injection

The fundamental principle of earth injection is that off mains frequency (i.e. non 50Hz) AC current is passed along either an the out of service feeder or insulated cable into a remote earth, with the injected current returning to the earth system under test either through the earth's mass or alternate paths including, but not limited to:

- overhead earth wires,
- cable sheaths,
- buried metallic pipes etc.

This return current, in conjunction with the earth system impedance, results in a voltage rise of the earthing system under test. Measured Step, Touch, Reach and Mesh voltages using injected current can be scaled relevant to actual fault levels to determine compliance with relevant standards.

5.2.2. Current injector capabilities

A generator / current source capable of maintaining a stable frequency off 50Hz is used as an injection source to avoid errors introduced by any standing 50Hz ground current. Typically 48Hz or 56Hz is used.

To achieve a reasonable current level, a step up transformer and/or series tuning capacitors may be required depending on the impedance of the earth system under test and the associated injection circuit. The injection voltage may therefore be in the order of 1-2kV. Appropriate barriers and warning signs must be erected at the injection source to prevent inadvertent contact with dangerous voltages.

5.2.3. Additional hazards and control measures

If a feeder is used for injecting current into a remote earth, it must be either decommissioned / non-commissioned or under a Test Permit as defined in the Electrical Safety

Rules / Operate the Network Enterprise Process – 2909674.

If a feeder is used for remote injection, possible high induced voltages may exist from adjacent energised feeders. Always maintain an earth on the remote end of the injection feeder and verify that the voltage on the source end is safe for the connection of injection equipment

5.2.3.1. Temporary remote earth considerations

Careful attention should be made in site selection for a temporary remote earth if required. Installation in the vicinity of other services should be avoided at all costs both from a safety perspective and possible interference with measurements. Contact "Before You Dig Australia" service using web based enquiry at https://www.byda.com.au/ to obtain all relevant plans and information about other entity services that may be located at the site in question. Information to obtain should include but not be necessarily limited to:

- the location of the service.
- the type of service.
- the depth of the service.
- for an electrical service, whether the service is live or not.
- the restrictions to be followed in doing the work.

Accuracy of information provided on location of underground services should not be relied on. Other asset owners may not be a member of the BYDA service.

If it is not possible to install the temporary remote earth at a location that is free of other services, the following additional items need to be considered:

- Use appropriate locating equipment to indicate the location of any underground service. Select locating equipment based on sensitivity, accuracy and discrimination.
- Electronic locating equipment provides an indication of the underground services location only and should not be relied on fully to accurately locate a service
- Pothole by hand or other appropriate techniques at key locations to positively identify underground service location, depth and direction
- Review all site drawings of underground services.
- Be aware that existing services may not be installed to standard with respect to depth, coverage or protection.
- If drawings are unclear, obtain assistance from the relevant asset owner.
- Clearly mark underground service locations on the ground surface.
- Isolate supply to existing services where possible prior to driving earth stakes.

Ensure that the temporary remote earth is suitably barricaded and affixed with appropriate warning signage. A Safety Observer may be required to control possible contact with exposed portions of the temporary earth grid.

If a temporary lead is used to connect between the current source and the remote earth, additional safety precautions may need to be implemented. These could include traffic and pedestrian control as well as Safety Observers patrolling the temporary injection path.

- Where a mobile generator and coupling transformer are used for current injection, they may present manual handling hazards. Use appropriate mechanical assistance e.g. vehicle loading crane where appropriate.
- Ensure all landowners and/or relevant authorities are contacted, and permissions obtained prior to installation of a temporary remote earth.
- Carrying out earth injection testing may require access to adjoining properties. Ensure all relevant landowners are contacted prior to entry and appropriate permissions obtained. Prior to entering the properties for testing purposes, assess for:
    - Dog, insect and snake infestations.
    - Quarries, steep banks, eroded tracks etc.

In addition to the above checks, the following rules apply:

- No climbing and/or jumping fences or gates.
- Do not enter sites where there is a savage dog alert unless it can be verified the dog is securely restrained.
- Where possible, drive or walk on tracks, paths and roadways provided. Avoid driving on other areas unless directed by the property owner.
- Do not drive or walk through overgrown access areas before ensuring the route is safe for self, property and vehicle.
- Do not climb through a barb wired fence before assessing the method is safe to self and property.

- Injection current should not pass through any current transformers that may inadvertently operate protection.
- There is a possibility that a system earth fault may occur when tests are being carried out, thereby exposing test staff to dangerous step, touch and transfer voltages. Class 00 gloves must be worn as a minimum when carrying out voltage measurements relative to a remote earth (e.g. when carrying out voltage measurements whilst doing an EPR run).

5.3. Current injection to remote earth

The following guidelines are to be adopted when carrying out current injection into a remote earth.

5.3.1. Injection via existing feeder and remote substation

This method involves injecting a test current onto an out of service or non-commissioned/ decommissioned feeder that is bonded at the remote end to a robust earth grid. If this option is adopted:

- Check for no adverse weather conditions for the entire length of the feeder and review regularly. Under no circumstance should injection via overhead feeder be carried out if threat of storms and associated lightning activity is predicted.

- Following Electrical Safety Rules processes, isolate and earth the relevant feeder at both the local (i.e. site under test) and remote ends and issue a test permit. The earth connection at the remote end is not to be removed throughout the test procedure.
- Ensure the feeder bays at both the local and remote ends are suitably barricaded with appropriate warning signs affixed.
- Apply a suitably rated three phase grounding box (e.g. Omicron CP GB1) to the feeder at the local end to allow for safe discharge of high voltages that may, under adverse conditions, be impressed on the out of service feeder. Ensure barricading is extended to include the connection leads from the out of service feeder to the grounding box.
- If an earth switch is used for the operating earth of the feeder at the local end, apply a set of working earths consisting of three individual cables to the feeder at the local end.
- If applicable, open the earth switch at the local end only and measure the phase currents (by clip on ammeter) in each of the individual working earths. Where no earth switch is used and operator earths are thus in place, measure the currents in each phase of the individual operator earths.
- Calculate the estimated open line voltage using the following formula:
- $V_{est} = I_{meas}(\text{amps}) \times 0.4(\Omega/\text{km}) \times 2 \times L_{line}\ (\text{km})$

  where:

  V_{est} = estimated open loop voltage in volts.

  I_{meas}(amps) = the highest measured current in amps.

  L_{line} (km) = the length of the line in kilometres.

  If the calculated voltage exceeds 50V AC and/or exceeds the safe voltage rating of the current injection test set, do not proceed and obtain further guidance.

Note: A remote substation may not be suitable as a remote earth if there is any return electrical connection to the earthing system under test. This can arise in a number of ways, including but not limited to overhead earth wires, LV distribution neutrals etc. This must be thoroughly investigated before any injection is carried out.

5.3.2. Injection into temporary remote earth

This option is to be used if a feeder is unavailable for injection purposes and/or the risks associated with overhead injection are deemed unacceptable.

- Ensure the feeder bay at the local end and the remote earth are suitably barricaded with appropriate warning signs affixed.
- Run out a suitably rated insulated lead taking into account:
  - The current that will be injected.
  - The voltage output from the current source.
- Implement appropriate traffic control on road crossings, driveways etc.
- Engage Safety Observers to maintain surveillance over the remote earth and injection cable path as required.
- If the risks involved in running out an injection cable are not manageable (e.g. in heavily populated urban areas), do not proceed and obtain further guidance.

5.4. Current distribution

Carrying out a current distribution test on the earthing system under test is vital in determining:

- The proportion of fault current that flows into the buried earth grid via the earth mass (I_g) which subsequently allows a calculation of grid resistance. This is critical in determining a grid's performance over time. As an earth grid deteriorates its resistance increases, so monitoring the resistance allows the buried system to be monitored.
- Likely voltage hazards e.g. the current distribution test is essential in identifying paths/points where high transfer voltages may exist under fault conditions.
- Points or paths of consideration are metallic systems passing beyond the boundary of the earthing installation, such as:
  - Overhead earth wires.
  - Cable sheaths on power and communications circuits.
  - Pipelines (water and gas).
  - Telecommunication systems.
  - LV neutrals.
  - Structures (cable trays, railways lines, conveyor systems).

The following steps are to be carried out when undertaking a current distribution test:

- Using an existing layout drawing or one prepared for the site, document all possible paths for return current flow back to the earthing system under test.
- Inject current as per Section 5.3.
- Using a Rogowski coil, frequency tuneable meter and phase angle meter, determine the test current through each identified path noting:
  - Current magnitude.
  - Turns used on the Rogowski coil.
  - Phase angle between the injected current and the return path in question.
- Record results on the worksheet "Current Distribution" in the Substation Earth System Injection Analysis Tool – 2941578.
- Carry out a vector summation of the individual return current paths to allow accurate determination of the current flowing into the buried earth grid via the earth mass (I_g).
- Note: special attention should be made to ensure consistent orientation of the current measuring Rogowski coil to ensure proper phase angle measurements of distributed current are obtained.

5.5. Earth Potential Rise

The Earth Potential Rise (EPR) test is used to determine the maximum potential rise of the earthing installation with respect to a remote earth, produced by fault current that flows via the earths mass to or from the installation under earth fault conditions.

The results of the EPR test can also be used in conjunction with those of the current distribution test, to determine the impedance of the earth grid under test.

The method used to determine the EPR of a system is referred to as the "Fall of Potential method". The test circuit for such a test is shown in Figure 2.

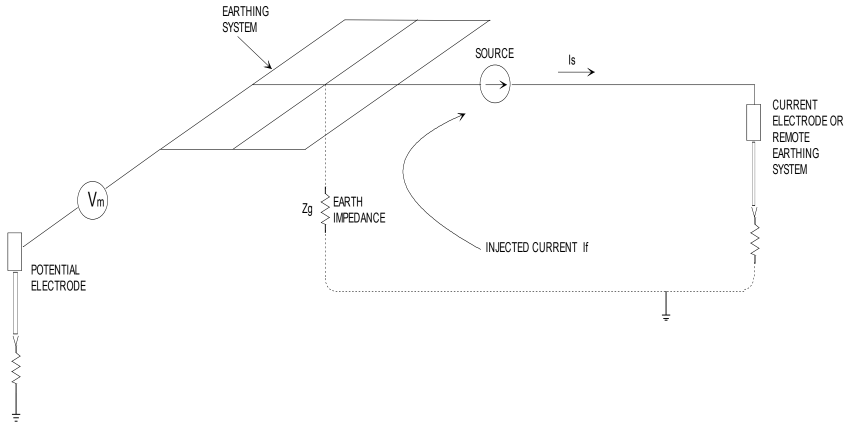

Figure 2: Basic Circuit for "Fall of Potential Method"

The following steps are to be carried out when undertaking an EPR test:

- Inject current into a remote earth as per Section 5.3.
- Place an earth stake on the soil surface at a defined distance from the earth installation under test (refer the Substation Earth System Injection Analysis Tool – 2941578 for standard test distances).
- Using a spectrum analyser or high impedance frequency tuneable voltmeter set at the same frequency as the injected current, measure and record the voltage between the earth stake and the earthing installation under test. Record the reading on the "Earth Potential Rise" worksheet in the Substation Earth System Injection Analysis Tool – 2941578.
- Increase the measurement distance and repeat steps until a definite plateau is observed (Figure 3 shows a typical EPR curve).
- At the most remote location it is required to take a reading from an RMS indicating voltmeter (e.g. Fluke) to double check the results of either the spectrum analyser or the frequency tuneable voltmeter. Record this reading on the "Earth Potential Rise" worksheet in the Substation Earth System Injection Analysis Tool – 2941578.

Points to note:

- Class 00 gloves, or other insulating mediums such as insulated sticks must be utilised when running out the test lead and taking EPR measurements. Failure to do so may expose test personnel to hazardous voltages in the event of an earth fault on the network related to the site under test.
- For added protection, the trailing lead out to the test electrode should be passed through an RCD. Only Type I (30mA) or Type II (30mA) RCDs are to be used and must comply with AS 3190:2011.
- The earth stake used for measurement purposes should be driven to a depth that ensures firm contact. Firm contact with the soil is essential to ensure an accurate reading. If significant deviations in the EPR occur, verify the reading through applying additional pressure to the electrode to ensure that contact impedance is not influence the measurement.
- It is preferred that the test lead used to measure the EPR be extended at an angle of 90° with respect to the current injection line. When the angle is not 90°, mutual coupling may induce voltages in the potential leads which in turn can give erroneous results.
- Additional traffic control and/or safety observers may be required when running out the test lead to facilitate voltage measurements. I f the risks involved in doing this are not manageable (e.g. in heavily populated urban areas), do not proceed and obtain further guidance.

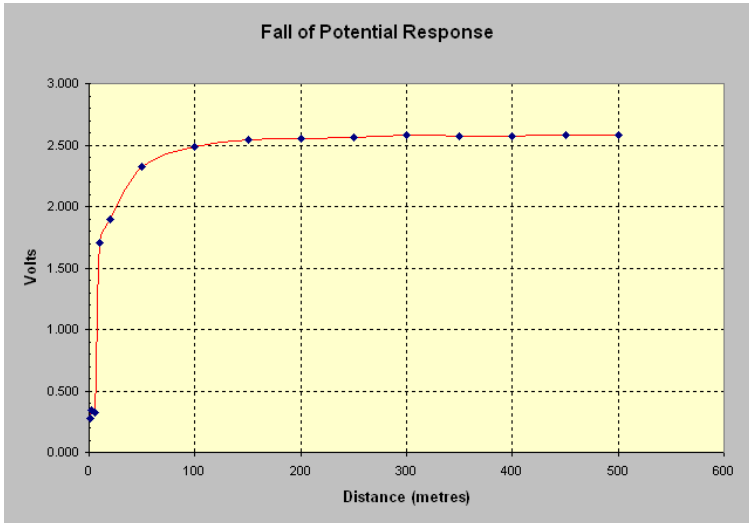

Figure 3: Typical Fall of Potential Curve

5.6. Step, Touch and Reach Voltages

The safety of an earthing system depends on the Step (foot to foot), Touch (hand to foot) and Reach (hand to hand) voltages being less than the allowable voltages as specified in the relevant standard used for analysis of the site under test.

5.6.1. Definitions

The definitions for prospective Step, Touch and Reach voltages are as follows:

Prospective Step voltage: the voltage difference between two points on the earth's surface separated by a distance equal to a person's normal maximum step (approximately one metre).

Effective (Loaded) Step voltage: the voltage across a body, under fault conditions, in a position as described for the prospective step voltage but allowing for the voltage drop caused by a current in the body.

Prospective Touch voltage: the voltage difference between an earthed metallic structure and a point on the earth's surface separated by a distance equal to a person's normal maximum horizontal reach (approximately one metre).

Effective (Loaded) Touch voltage: the voltage across a body, under fault conditions, in a position described as for the prospective touch voltage but allowing for the voltage drop caused by a current in the body.

Prospective Reach voltage: the voltage difference between earthed metallic objects or structures that may be bridged by direct hand to hand contact.

Effective (Loaded) Reach voltage: the voltage across a body, under fault conditions, in a position described as for the prospective reach voltage, but allowing for the voltage drop caused by a current in the body. Theoretically the prospective reach voltage and the effective (loaded) reach voltage should be exactly the same.

The allowable voltages depend on various parameters such as fault clearing time, permissible body current, contact resistance, body impedance and the relevant standard applied. Figure 4 below shows the various contact scenarios of Step, Touch and Reach.

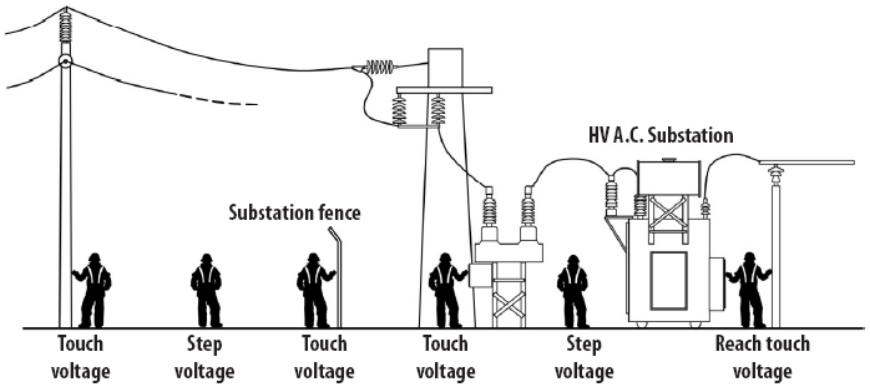

Figure 4: Step, Touch and Reach Voltages

Transfer voltages are a special case of Touch voltage where a voltage is transferred into or out of the substation from or to a remote point external to the substation site. Figure 5 shows an example of a Transfer voltage.

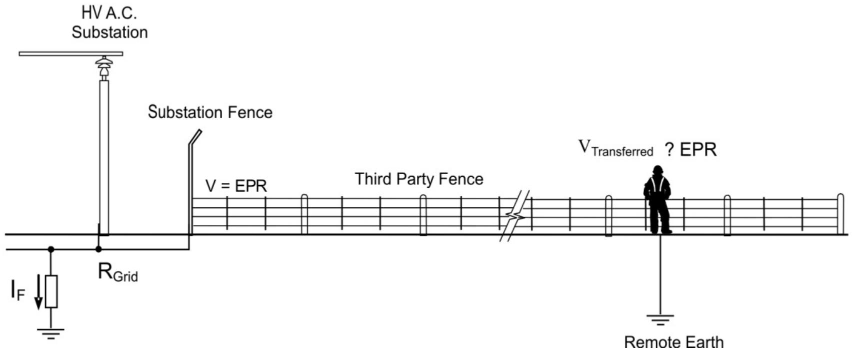

Figure 5: Transfer Voltage

NOTE: It is imperative that as much focus, if not more, be placed on the measurement of step, touch and reach voltages in surrounding areas as compared to measurements inside the substation under test.

Recommended locations to conduct Step, Touch and Reach voltage measurements include:

Within the substation

- At and adjacent to all equipment that may be operated (e.g. operating handles, marshalling boxes, handrails, water taps etc.).
- At regular intervals along the inside perimeter of the substation fence.
- Metallic objects that personnel may come in contact with.

External to substation

- At regular intervals along the outside perimeter of the substation fence.
- Metallic objects in surrounding properties including but not limited to gates, metal fences, tap fittings etc. Special attention should be given to obtaining touch measurements from domestic and commercial residences switchboards which will be bonded to earth via the MEN system.
- Any metallic pipelines or fences in close proximity to the earthing system. These can often be the worst measurements recorded during a test because a fence or pipeline can be insulated from ground for a significant distance and therefore transfer a remote earth potential into (or adjacent) to the substation under test.
- Exposed and accessible portions of any path identified for current flow in the current distribution test e.g. exposed earth wires on feeder exit poles where feeder cables

are earthed at both ends, exposed overhead earth wire bonds to ground etc.

- Attention should be made to the measurement of step, touch and reach voltages in Special Locations which are defined as locations with high exposure rates and where people are likely to be wet and have no footwear. Such locations include:
    - Within a school ground.
    - Children's playground.
    - Public swimming pool area.
    - Popular water recreation area.
    - Public thoroughfare within 100 metres of the above locations.
- For locations outside the substation, a detailed map or document providing accurate location of tests should be prepared for reference. Areas of concern should be photographed and clearly labelled with a location for future reference.

The following steps are to be carried out when undertaking Step, Touch and Reach voltage measurements:

- Inject current as per Section 5.3.
- Carry out step, touch and reach voltage measurements as per Section 5.7.
- Using an earth grid plan or other means, accurately record the location, contact type and voltage measurements obtained. In addition, record whether the voltage measurements taken were either Prospective or Loaded. Note that Loaded voltages are only relevant when testing an installation to IEEE guidelines.
- Transfer the results onto the appropriate worksheet 'Inside Sub", "Outside Sub" or "Special Location" in the Substation Earth System Injection Analysis Tool – 2941578 where the measured values are scaled to give anticipated levels under actual fault conditions.

5.7. Step, Touch and Reach Test Procedures

Prospective Step Voltages – EG0, IEEE and Electrical Safety Code of Practice

- Measurements to be taken using a high impedance frequency tuneable multi-meter between two stakes / electrodes placed 1 metre apart on the **natural** soil surface.
- Earth stakes / electrodes to be driven into the **natural** upper soil layer to ensure firm contact.
- Contact point of earth stake / electrode should be moistened to achieve good contact.

Effective (Loaded) Step Voltages – IEEE only

- Measurements to be taken using a high impedance frequency tuneable multi-meter between two weighted 8cm radius discs placed 1 metre apart on top of the ground surface layer material.
- A simulated body impedance of 1kΩ is to be placed across the input terminals of the tuneable multi-meter **if** the meter does not have inherent capability to provide this functionality.
- Contact surfaces of discs should be moistened to achieve good contact.

Prospective Touch Voltages – EG0, IEEE and Electrical Safety Code of Practice

- Measurements to be taken using a high impedance frequency tuneable multi-meter between the metallic

object in question and an earth stake/electrode placed at a distance of 1 metre on the **natural** soil surface.
- Earth stake/electrode not to be driven into the **natural** upper soil layer more than a few cms – merely enough to support the electrode.
- Contact point of earth stake/electrode should be moistened to achieve good contact.

Effective (**Loaded)Touch Voltages** – IEEE only

- Measurements to be taken using a high impedance frequency tuneable multi-meter between the metallic object in question and a weighted 8cm radius disc placed at a distance of 1 metre on top of the ground surface layer material.
- A simulated body impedance of 1kΩ is to be placed across the input terminals of the tuneable multi-meter **if** the meter does not have inherent capability to provide this functionality.
- Contact surface of disc should be moistened to achieve good contact.

Prospective Reach Voltages – EG0, IEEE and Electrical Safety Code of Practice

- Measurements to be taken using a high impedance frequency tuneable multi-meter between the two metallic objects in question that are capable of being bridged by direct hand to hand contact.

Effective (Loaded) Reach Voltages – IEEE only

- Measurements to be taken using a high impedance frequency tuneable multi-meter between the two metallic objects in question that are capable of being bridged by direct hand to hand contact.
- A simulated body impedance of 1kΩ is to be placed across the input terminals of the tuneable multi-meter **if** the meter does not have inherent capability to provide this functionality.