Earthing Design Instruction

Major substation earthing design, construct and commissioning

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Earthing Design Instruction

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1.0 PURPOSE

To set out the minimum standards for the earthing system design of major substations in the company's network. Major substations include all transmission and zone substations and switching stations with transmission and/or subtransmission voltages. This includes the requirement of earthing design in the construction, commissioning, testing, normal operation, maintenance and decommissioning stages of major substations and projects as one means of safeguarding workers and the public from hazards that may be caused by exposed differences in electric potential.

2.0 SCOPE

This document provides the company's minimum earthing requirements and associated procedures for the design, construction and commissioning of all major substations earthing systems. The scope of this document also provides provision in the design stage to assess the minimum earthing safety requirements during construction works inside or adjacent to major substations. This instruction also provides guidelines around the provision for maintenance and testing of major substations earthing systems.

This standard is applicable only to company owned and operated major substation assets. However this standard can be used as a guide for privately owned and operated major substations connected to the company's network.

For privately owned and operated major substations but connected to the company network reference will be made to AS2067-Substations and high voltage installations exceeding 1kV a.c.

For privately owned and operated major substations within mines but connected to the company network, reference will be made to AS/NZS 3007– Electrical Equipment in mines and quarries- Surface installations and associated processing plant and also AS2067 -Substations and high voltage installations exceeding 1kV a.c.

This standard will be read and is complimentary to EDI 001 Earthing Design Risk assessment.

3.0 REFERENCES

Internal
- Company Policy (Governance) 2.0.3 – Compliance
- Company Policy (Governance) 2.0.5 – Risk Management
- Company Policy (Network) 9.2.2 – Network Protection
- Company Policy (Network) 9.2.5 – Network Asset Design
- Company Policy (Network) 9.2.10 – Network Asset Ratings
- Company Procedure (Governance) GRM 0003 – Risk Management
- Company Procedure (Health & Safety) GSY 0026 – Risk Assessment
- Company Electrical Safety Rules
- Network Management Plan 2009-2014
- Earthing Design Instruction EDI 001 – Earthing Design Risk Assessment
- Earthing Design Instruction EDI 100 – Distribution Earthing Design, Construction and Test
- Earthing Design Instruction EDI0005 - Distribution earth test
- Earthing Design Instruction EDI0004 – Earthing design, construction and testing of overhead transmission mains
- Equipment Technical Specification ETS 0020 – Portable Earthing and Short Circuiting Equipment
• Mains Construction Instruction MCI 0006 – Underground Distribution Construction Standards Manual
• Substation Design Instruction SDI 505 – Minimum Design and Construction Requirements for Transmission and Zone Substations and Switching Stations
• Substation Design Instruction SDI 511 – Auxiliary AC Supply and Switchgear
• Substation Design Instruction SDI 517 – Busbars and Support Insulators
• Substation Design Instruction SDI 520 – Lightning Protection and Insulation Coordination
• Substation Design Instruction SDI 523 – Switchyard Surfaces
• Substation Design Instruction SDI 528 – Substation Signs and Equipment Labels
• Substation Maintenance Instruction SMI 100 – Minimum Requirements for Maintenance of Transmission and Zone Substation Equipment
• Substation Maintenance Instruction SMI 104 – Major substation earthing system test

External
• Electricity (Consumer Safety) Act 2004
• Electricity Supply Act 1995
• Work Health and Safety Act 2011
• Electricity (Consumer Safety) Regulation 2015
• Electricity Supply (Safety and Network Management) Regulation 2014
• Electricity Supply (General) Regulation 2001
• Electricity Supply (Corrosion Protection) Regulation 2008
• Work Health and Safety Regulation 2011
• Safe Work Australia: Guide for Major Hazard Facilities: Safety Case: Demonstrating the Adequacy of Safety Management and Control Measures
• Safe Work Australia: Safe design of structures: Code of Practice; July 2012
• Safe Work Australia: How to Manage Work Health and Safety Risks: Code of Practice
• AS/NZS 1768: 2007 – Lightning Protection
• AS 1824: 1995 – Insulation Coordination
• AS 2067: 2016- Substations and high voltage installations exceeding 1kV a.c
• AS/NZS 3835.1: 2006 – Earth potential rise – Protection of telecommunications network users, personnel and plant
• AS/NZS 3835.2: 2006 – Application guide to AS/NZS 3835
• AS/NZS 3000: 2007 – Wiring Rules
• AS/NZS 3007: 2013 – Electrical Equipment in mines and quarries- Surface installations and associated processing plant
• AS/NZS 4853: 2012 – Electrical hazards on metallic pipelines
• AS/NZS 60479: 2010 – Effects of current on human beings and livestock
• AS/NZS 7000:2016 – Overhead line design – Detailed procedures
• BS EN 50122-2:2010 Railway applications. Fixed installations. Electrical safety, earthing and the return circuit. Provisions against the effects of stray currents cause by DC traction systems
• CJC5 / HB101:1997– Coordination of power and telecommunications – low frequency induction – Standards Australia
• ENA Doc 001-2008 National Electricity Network Safety Code
• ENA EG0 – 2010 – Power System Earthing Guide: Management Principles
• ENA EG1 – 2006 – Substation Earthing Guide
• IEC 61936-1 ED 2.1 2014 – Power installations exceeding 1 kV a.c. - Part 1: Common rules
4.0 DEFINITIONS AND ABBREVIATIONS

ALARP
As Low As Reasonably Practicable. The underlying risk management principle whereby risk is reduced as low as reasonably practicable within a risk analysis framework. It means that which is, or was at a particular time reasonably able to be done in relation to health and safety risk levels taking into account various relevant matters including the likelihood, degree of harm, knowledge, suitability of controls and whether costs of controls were grossly disproportionate to the risk. Refer NSW Work Health and Safety Act 2011 section 18.

Argon
Argon is a safety assessment software platform used in conjunction with ENA EG-0 available on the ENA website with registration.

Clearing time (backup)
The longest time taken for the upstream protective devices and circuit breaker(s)/fuses to isolate the source of fault current assuming any one item of the protection system fails to operate. Protection system includes the relay, CT’s, VT’s, communications systems and CB’s.

Clearing time (primary)
The time taken for the upstream protective devices and circuit breaker(s)/fuses to isolate the source of fault current.

CMEN
Common Multiple Earth Neutral System (CMEN) is a system where the combined high voltage and low voltage distribution earthing system is connected to a zone or transmission substation earthing system.

Important Note: Company uses the CMEN terminology for a zone substation bonded to the distribution earthing and potentially LV MEN system either directly or through HV cable sheaths onto common earthed substations – this does not align with the majority of the industry and care must be used when assigning this term.

Common or Combined Earthing
A common or combined earthing system is one in which the HV distribution and low voltage electrical equipment is earthed to a common terminal bar. This is achieved by connecting the MEN system to the HV and LV earth at the distribution substation or other distribution asset.

Company
The company referred to in this document is Endeavour Energy.

Contact criteria: backyard
An area with a contactable metallic structure (e.g. fence, gate) subject to fault induced voltage gradients. This metallic structure is not a HV asset but becomes live due to earth fault current flowing through the soil nearby.

Contact criteria: MEN
Contact with LV MEN interconnected metalwork (e.g. household taps) under the influence of either LV MEN voltage rise through deliberate bonding and/or through soil voltage gradients from a HV asset nearby.
Contact criteria: urban
Network asset outside normal public thoroughfare with low frequency of direct contact by an individual.

DBZS
A Distribution Bonded Zone Substation is a major substation that is intentionally bonded into the distribution earthing system through HV screens and bonded earth wires. The distribution earthing system may or may not be further bonded into the LVMEN system. See CMEN.

Distribution network
Collection of assets (distribution lines, cables, substations and associated equipment) whose purpose is to distribute power from zone substations to distribution substations, which feed the low voltage network.

Document Control
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Earth electrode
Uninsulated conductor installed vertically in electric contact with the Earth (through dirt of intermediate material) intended for the conduction and dissipation of earth current.

Earth fault (EF)
Includes a single phase to ground fault and two-phase to ground fault – a fault caused by a conductor or conductors being connected to earth or by the insulation resistance to earth becoming less than a specified value.

Earth fault current
Current that flows through the main circuit to earth or earthed parts at the fault location.

Earth grid
Interconnected uninsulated conductors installed in contact with the earth (or intermediate material) intended for the conduction and dissipation of current and or for the provision of a uniform voltage reference. A part of the earthing system.

Earth return current
The portion of the total earth fault current which returns to the source by flowing through the earth grid and into the surrounding soil.

Earthing conductor
Conductor intended to provide a conductive path for the flow of earth fault current for the control of voltage rise and reliable operation of protection devices.

Earthing system
Arrangement of earth conductors, typically including an earth grid, earth electrodes and additional earth conductors such as overhead earth wires (OHEW), cable sheaths, earth continuity conductors (ECC’s) and parallel earthing conductors (PEC’s).

ECC
Earth Continuity Conductor.

Ellipse
Company asset management database.
Embedded earth
The use of steel reinforcing bar in concrete structures to interconnect with, and to augment the earthing system. Its purpose may be to lower the earth resistance and create an equipotential plane.

ENA
Energy Networks Association.

EPR
Earth Potential Rise - the maximum voltage on the metallic components of the earth system during an earth fault, reference to remote earth.

Equipotential bond
A bonding conductor applied to maintain continuity of conductive structures and conductors with the main earth grid or structure in order to prevent voltage differences. The equipotential bonding conductor may not be designed to carry fault current.

Frequented or Normal Location
Area where people are expected to regularly gather or remain for extended periods (such as bus stop, farm primary residence, churches, sporting ovals and the like). Any location that does not fall under remote or special location category will be considered as a normal or frequented location.

GPR
Grid potential rise – American IEEE equivalent to EPR.

Hazard
Potential to cause harm.

IDMT
IDMT stands for Inverse Definite Minimum Time - and is the normal type of time/current graded over-current/earth-fault protection used in the HV distribution of electricity.

LV
Low voltage - a voltage exceeding 50V AC but less than 1000V AC.

MEN
Multiple Earthed Neutral. A system of earthing in which the parts of an electrical installation required to be earthed in accordance with AS/NZS 3000 are connected together to form an equipotential bonded network. This network is connected to both the neutral conductor of the supply system and the general mass of earth.

Mesh voltage (Vmesh)
The highest potential difference between a point within the earth grid and the earth grid. This point is usually in the middle of the largest open space within the grid. For practical purposes, this is the maximum touch voltage within the substation earth grid.

Non-power system assets
Metallic non-power system assets refer to assets which could present a voltage hazard to people when a power system asset is affected by an unbalanced condition.
OHEW
Overhead Earth Wire. This refers to the earth continuity conductor installed above the aerial line conductors. An OHEW may also contain non-metallic communication wires. The most common OHEW is an optical fibre ground wire (OPGW).

Power system assets
Power system assets in this standard refer to all assets associated with the distribution of electricity with intentional current carrying components.

Probability
A measure of the chance of occurrence expressed as a number between 0 and 1.

Recordkeeping

Remote earth (reference earth)
Part of the earth considered as conductive, the electric potential of which is conventionally taken as zero, being outside the zone of influence of the relevant earthing arrangement.

Remote location
For the purpose of earthing design, any location where probability of coincidence is considered to be low risk (see low individual risk) that any risk calculation would generally result in a low risk. This is usually the case for rural installations that are not close to a customer’s residence, shed or gate.

Review date
The review date displayed in the header of the document is the future date for review of a document. The default period is three years from the date of approval however a review may be mandated at any time where a need is identified due to changes in legislation, organisational changes, restructures, occurrence of an incident or changes in technology or work practice.

Risk
The change of something happening that will have an impact on objectives. Potential for realisation of unwanted, adverse consequences to human life, health, property or the environment. Note: A risk is often specified in terms of the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred.

Risk assessment
The overall process of identifying, analysing and evaluating the risk.

Risk management
The culture, processes and structures that are directed towards realising potential opportunities whilst managing adverse effects.

Risk treatment
Process of selection and implementation of measures to modify risk. The term is sometimes used to represent the measures themselves.

SDR
Safe Design Report which is prepared by the designer and addresses any potential construction and in service safety risks associated with the design.
SEF  
Sensitive earth fault protection – A type of feeder protection designed to detect small earth fault currents due to high impedance fault paths. This form of protection may take up to 10 seconds to operate.

Soil resistivity  
Specific resistivity of a material which is used to define the resistance of a material to current flow. It is defined as the electric field strength (V/m) divided by the current density (A/m²) which represents the value to one (1) amp flowing into one metre cube of material yielding units of ohm meter (Ωm).

Special location  
The "special" location category implies an area within close proximity to or within a premise where there is a high likelihood that shoes will not be worn and/or the risks associated with the earthing system has the potential to be exposed to a number of people simultaneously through contact with affected metalwork. This includes (but is not limited to) schools, pre-schools, day care centres, aquatic centres, recreational swimming areas and beaches.

Step voltage (loaded)  
Voltage between two points on the earth’s surface that are 1m distant from each other while a person is making contact with these points.

Step voltage (prospective)  
The voltage between two points on the earth’s surface spaced that are one (1) metre distant from each other, which is considered to be the stride length of a person. (Often referred to as "Prospective Step Voltage").

Structural earth electrode  
Metal part, which is in conductive contact with the earth or with water directly or via concrete, whose original purpose is not earthing, but which fulfils all requirement of an earth electrode without impairment of the original purpose.

Substation  
Part of a power system, concentrated in one place, including mainly the terminations of transmission and/or distribution lines, switchgear and housing which may also include transformers. The reference to "major substation" in this document refers to all zone substations, transmission substations and switching substations with transmission voltages.

SWMS  
Safe Work Method Statement.

Touch voltage (loaded)  
Voltage between conductive parts and/or nearby soil at the feet when touched simultaneously influenced by the impedance of the person in electric contact with these conductive paths.

Touch voltage (prospective)  
Voltage between simultaneously accessible conductive parts and/or nearby soil at the feet when those conductive parts are not being touched. The term touch voltage refers to prospective touch voltages unless otherwise stated.
Transfer voltages
Transfer voltages are a more specific form of touch voltage that can occur when a long metallic object such as a metallic fence transfers a voltage from one location to another closer to remote earth potential. Conversely a transfer-in touch voltage can occur when for instance a conductive tap bonded to the LV MEN system transfers-in a low voltage close to the area of a fault point. The local soil voltage caused by that fault point results in a high touch voltage to the conductive tap.

Transmission system
The collection of assets (transmission lines, cables, zone substation and associated equipment), whose purpose is to transmit power in bulk from a Transgrid supply point to a sub-transmission substation. The transmission voltage in company’s network is typically, but not exclusively, 132kV.

Zero sequence source
The source of zero sequence currents in a circuit for instance the solidly earthed star point of a distribution transformer.

5.0 ACTIONS
5.1 General requirements
5.1.1 General
Earthing systems for major substations are required to manage the transfer of unbalanced network energy by low impedance paths to limit the risk to people, protection of equipment and network reliability/operational security.

The design, selection and installation of the earthing systems for major substations will meet the performance and functional requirements below. When assets are augmented or improved, the integrity and safety of the existing earthing system must be evaluated in accordance with this standard. The performance requirements for major substation earthing systems include:

a) Proper functioning of electrical protective devices by an adequate earth impedance path is available for lightning, switching surges and power frequency current.
b) Managing the risks associated with step, touch and transfer voltages in accordance with this instruction, applicable regulations, standards and guidelines.

In addition to the performance requirements, it is imperative that the integrity of the earthing system and values of earthing impedance are continuously effective over the planned lifetime of the installation. This means, as far as practicable:

c) Fault current can be conducted without damage to the earthing system components.
d) The possibility of mechanical damage is minimised.
e) Inadvertent interference and theft can be avoided.
f) Redundant systems are available that the earthing system can perform as designed for the failure of any one (1) item.
g) Chemical deterioration is minimised.

Major substations will be designed with due consideration for both present and foreseeable future impacts to nearby infrastructure that can be exposed or expose the earthing system to further hazards. This requires, so far as reasonably practicable that attention is given in the design process to the impact of network and earthing condition changes such as increases in fault level, clearance times, reduced easement sizes, urban interface with electrical systems future urban developments, nearby telecommunications or pipeline infrastructure, prevalence of conductive
structures and/or the continual replacement of the conductive water reticulation system with insulating pipe.

5.1.2 Impact to earthing

Part of the company’s network is undergoing rapid development and urbanisation. This and a number of other external factors are developing the need for a transition in the company’s traditional earthing philosophy. This is to effectively manage risk and cost impact earthing decisions for major substations have to nearby metallic infrastructure and to the assets these substations supply. The bonding of major substation assets into other earthing systems and in particular the distribution earthing system will be a risk decision based on both local risk associated with the major substation and the impact of the bonded assets it supplies or is supplied from. Risk assessment detail is provided in 5.2.4.

5.1.3 Power frequency safety risk management

The occurrence of earth faults on power systems causing hazardous voltage differences and the presence of human beings in simultaneous contact with these differences in voltage are both probabilistic in nature.

Earthing risk assessments must be conducted by those who both create and those who control the extent of the risk. At the time of asset inception, it is the responsibility of the designer to assess and provide evidence through calculation and confirm through test of the risk level caused by the asset and appropriate mitigation applied. In the case of new transmission or distribution systems, an analysis of hazardous events will also take into account hazardous events occurring during construction, commissioning, maintenance, operation, testing, decommissioning and dismantling.

This standard requires major substations sites to comply with the touch, step and transfer voltage limits of the company standard EDI 001- Earthing Design Risk Assessment. In addition to this, sites are required to demonstrate the impact they have to the surrounding areas and the earthing risk of the assets they supply. Further details of the risk management requirements for earthing risks and relevant codes of practice and standards for other utilities infrastructure are provided in EDI 001. The requirements of EDI 001 for major substation assets will be met.

5.1.4 Transient / lightning reliability and safety risk management

It is necessary to coordinate lightning protection system and insulation coordination design with the earthing system design, particularly with regard to the embedded earthing requirements. The risk associated with lightning/ transient current flowing to ground through the earthing system will be managed to meet the requirements of SDI 520 - Lightning Protection and Insulation Coordination. Refer to SDI 520 for approval and design requirements.

The earthing requirements for the lightning protection system for a major substation will be incorporated with the earthing design drawings.

5.1.5 Earthing design

The earthing design process for major substations is set out in 5.2 and is based on industry best practice. The earthing design process is complementary to EDI 001- Earthing Design Risk Assessment.

A new or review of the earthing design is required:

a) For all new major substations.
b) For an existing substation due to equipment or building upgrades or installation.
c) Where feeder or transformer arrangements vary and affect an existing substation fault level or protection clearance times beyond the designed conditions of the existing earthing system.
d) Where protection clearance times exceed the design conditions due to increased needs for grading with downstream electrical plant.
e) Where periodic current injection testing (CIT) as required by SMI 100 - Minimum Requirements for Maintenance of Transmission and Zone Substation Equipment reveals that the earthing system of the existing substation is inadequate.
f) As substantial changes occur to the main earth grid such as relocation or installation of a new fence.
g) As new buildings and metallic infrastructure are built closer to the substation site beyond the design levels for the major substation.
h) Where another utility is proposing infrastructure in the vicinity of the major substation.

5.1.6 Robustness

Earthing systems for major substations will be constructed to in such a way that they remain continuously effective for the life of the substation and that the condition of the earthing system can be continually monitored and maintained.

The earthing system and its components will be capable of withstanding and conducting the expected fault current without exceeding material or equipment limitations for thermal and mechanical stresses. This is set out in 5.2.7 including provisions for the level of redundancy required to maintain an acceptable level of reliable performance.

Attention will also be given to the impact of corrosion on the lifetime of conductors and the connections. This is set out in 5.2.8.

5.1.7 Test requirements

Testing of earthing systems will be carried out as specified in SMI 104 – Major substation earthing system test and in accordance with the applicable SWMS documentation.

Provisions in the design will allow for all earthing terminations to be located with reasonable test access. This includes locating terminations such that employees/contractors can reach the termination without additional equipment. Additionally, earthing cables will be spaced 60mm from each other and from fixed walls and objects to allow test instruments to be temporarily installed around conductors. This clearance can take into consideration the flexibility of cables in achieving this requirement. Terminations will be located inside the substation fence boundary.

5.1.8 Earthing safety in stages

During testing, construction, commissioning, dismantling and decommissioning, particularly of major transmission lines and/or substations, the increased exposure to construction staff of electrical shock hazards requires additional controls for risk management. As part of the design of the major substation earthing system, it is essential that the construction safety requirements be identified and risk controls be recorded in the design report to transfer from the design phase to the next stages of the lifecycle. Also they are required to appear in appropriate work method statements (SWMS). Further detail is provided in 5.5.

Design for safe construction, commissioning, dismantling and decommissioning details are found in section 5.2.5.1 of EDI 001- Earthing Design Risk Assessment.
5.2 Major substation earthing design process

5.2.1 Design process

Major substation projects will be initiated by the organisation and opportunity reviews attended by the Earthing and Power Quality Manager.

A simplified design process for major substation earthing design is provided in Table 5-1 below. A flow chart is provided in annexure A. The earthing design will form part of the safe design report SDR for a major substation.

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5.2.2 Design context and consultation

When new or existing major substation earthing systems are being designed or reviewed, the Earthing Designer will coordinate the earthing system design aspects of the substation with affected stakeholders. This may include the owners of any adjacent telecommunications, water, gas, railway and petroleum products systems as well as local councils and planners.

Consideration to the future development around any major substation is essential in developing a robust earthing design with provisions for the risk changes and cost impact as development occurs. The Earthing Designer will consult with the company’s network planners early and throughout the design process to include such provisions in the earthing design.

5.2.3 Data gathering

As part of the initial design process, the following input data is required to assess the major substation earthing design:

- Fault data and clearance times.
- Soil resistivity and corrosion impact data.
- Details of current and future planning associated with the surroundings.
- Design information.
5.2.3.1 Protection data

The Protection Manager will provide fault level, protection clearance times (primary and backup) sequence impedances and other relevant staging considerations required for the design of the earthing system.

The earthing system design will be based on the most onerous supply arrangements in terms of fault levels and clearing times and must assess the potential staging configurations. However for the continuous operation, where an alternative supply arrangement is for emergency backup supply only and likely to be utilised for no greater than 1% of the year, then it need not be taken into account in the design.

The system information supplied will include voltage factor of 110% as set out in AS 3851.

The following system information will be supplied:

- Primary and secondary sequence impedances (Thevenin').
- The value of neutral earthing impedance installed.
- Fault current and duration (backup and primary) based on bolted fault level.
- Fault current and duration based on one (1) ohm fault applied at the secondary busbar for distribution voltage assessment.
- Fault current contribution from various sources and stepped clearing times where applicable.
- Zero sequence configurations for determination of fault current return paths.
- Distribution feeder earth fault settings with relevant clearing time equations.
- Nodal fault information on connected distribution assets.

In order to achieve a safe earthing design, the earthing designer will coordinate their design with the protection section to obtain clearing times that are as fast as reasonably practicable.

The Earthing Designer will determine the sensitivity to variations in protection clearing times particularly in regards to steep protection curves and/or non-linear protection elements. For instance where instantaneous protection elements are used, small variations in fault current can result in significant changes to clearance time and therefore risk at the change-over point. An example is provided in Annexure C. Sensitivity analysis is required in so far that the Earthing Designer and the Earthing & Power Quality Manager are satisfied that slight variations in current to not cause large variations in risk. The sensitivity analysis will also include provisions for future foreseeable impacts of additional loading and the need of protection grading particularly with large customers.

The earthing design will assess the applicable asymmetrical fault current and the impact on safety and conductor ratings. The symmetrical decrement factor will be used to assess earthing system safety and conductor ratings by deriving the equivalent ‘energy’ to apply allowing for DC offset. Guidance on the calculation and application is provided in ENA EG-1 section 6.5.

For stepped fault clearing situations generally applicable to transmission circuit fault scenarios, the total fault duration and the equivalent RMS value of the fault current will be applicable. However, consideration for the highest current and its duration will also be assessed and the most onerous condition applied to the design case. Details for the calculation of equivalent RMS value of stepped faults are given in ENA EG-1 section 6.4.2.

5.2.3.2 Soil electrical characteristics

An accurate soil electrical resistivity model and test is necessary to determine the electrical characteristics surrounding the site and is essential in determining safety, sensitivity and reliability of an earthing system.
The soil resistivity tests will be carried out as a part of the earthing design. Knowledge of the location of underground services at the test site is essential prior to soil testing to minimise and understand potential sources of errors and also to avoid damage and the risk associated with existing underground services. Details of soil resistivity testing requirements for the company are provided in EDI 0005 - Distribution earthing test.

In addition and depending on the soil resistivity testing, the pH level of the soil needs to be tested at a number of locations. Further details on the corrosion protection of assets and the need for pH testing are provided in 5.2.8.

5.2.3.3 Surroundings

It is essential that an earthing design is built with due consideration for the surrounding area and future development that could be reasonably expected. Provisions and suitable arrangement will be made in the earthing design for future bonding configurations that keep pace with surrounding development to manage earthing risk continually over the life time of the asset. The design will manage current and potential high transfer voltage risks. In some circumstances this may require consultation with local councils, the company network planners and other utilities.

5.2.3.4 Design information

The Project Manager will provide the following information required for the earthing design:

- Project Definition (PD) and any relevant change controls.
- Site layout and equipment drawings.
- Details of the existing earthing systems.
- Details of the project staging including protection implications for construction safety consideration.
- Details of associated projects that could impact on the earthing system design such as nearby transmission mains projects.

5.2.4 Power frequency hazard assessment

5.2.4.1 Low risk touch, step and transfer voltage limits

Transmission and zone substations, as the typical zero sequence source for their associated supply systems, are subject to frequent faults of varying magnitudes and durations. The hazards caused by, and those in close proximity to the zone substation require a detailed assessment and analysis of associated risks. EDI 001 – Earthing Design Risk Assessment provides the earthing risk management requirements for major substation assets and the impact on the network assets they supply.

The most onerous (slowest) primary protection clearing time for both the primary and secondary fault scenarios along with lowest resistivity value amongst the different soil layers that could be reasonably expected on the surface with provisions for the variation in soil resistivity due to moisture will be used for safety voltage limit determination. In addition to these limits on other assets detailed in 5.2.6 require compliance.

Major substations within 1km of other major substations also require a review of the risks transferred between each major substation. The limits will be in accordance with EDI 001 - Earthing Design Risk Assessment.

5.2.4.2 Risk mitigation

A list of engineering risk controls commonly used for major substations earthing hazards include:

- Spacing of earth grid to control mesh voltages – 5.7.1.1
• High resistivity surface layers such as crushed rock – 5.7.3
• Auxiliary system bonding – 5.7.4

Additional risk management controls and concepts are provided in 5.7 and EDI 001 - *Earthing Design Risk Assessment*.

### 5.2.5 Distribution and services associated with major substations

No distribution voltages will be reticulated into major substations without approval from the Earthing & Power Quality Manager. This includes the earthing at the major substation end and the first asset being supplied.

Additional provisions are required for the management of major substation bonding. These provisions apply to major substations:

a) All telecommunications brought into the substation will be intrinsically isolated (for example, fibre optic) or through an approved telecommunications isolation device (refer 5.7.10.1).

b) No metallic pipe work will be brought into the substation which is not addressed by the earthing design (refer 5.7.10.2). Any LV service and associated neutrals from the street for station LV backup supply will be through isolating transformers unless the earthing design identifies otherwise and approved by the Earthing & Power Quality Manager (refer 5.7.10.3).

#### 5.2.5.1 Distribution bonding of zone substations (also referred to as CMEN):

Particularly in urban areas, zone substations bonded into the distribution earthing system can be effective at reducing risk at the zone substation while also grossly reducing distribution earthing risks and costs. The bonding strategy for any major substation is based on the necessary assessment of risk on a case-by-case basis.

The HV power cable screen or earthing conductor will not be bonded from the zone or transmission substation to the distribution system unless approval for a CMEN connected system is obtained from the Earthing & Power Quality Manager prior to the commencement of works.

CMEN connected zone or transmission earthing systems will be prominently fitted with a label attached to each end of the power cable or each interconnecting earthing cable at the zone or transmission substation and first asset out such as switching station, distribution substation or UGOH pole. The label will be in accordance with SDI 528 – *Substation Signs and Equipment Labels* and have a typical size of 75mm x 25mm and will remain clearly visible when the cable is in service. When the label cannot be practically fitted to the cable, it will be permanently attached to the switchgear in a prominent position such as on the outside of the cable box cover that houses the cable.

#### 5.2.5.2 Non distribution bonded zone substations (also referred to as non-CMEN)

Substations that are not deliberately bonded will incorporate any isolation, separation and insulation requirements in the earthing system design.

Where a major substation is not bonded into the distribution earthing systems, the 11/22kV feeder cable screens will be appropriately isolated from the earthing system of the first padmount substation/switching station. Where UGOH’s are the first asset being supplied, their design is incorporated with the major substation earthing design. In both circumstances, consultation will be made with the Earthing & Power Quality Manager in accordance with EDI 100 - *Distribution Earthing Design*. The separation requirements to other assets will be provided as part of the earthing design.
Non distribution bonded zone substations require appropriate isolation of services as set out in 5.7.10. Non distribution bonded zone substations also require appropriate land and spacing around the periphery of the substation to allow for fence grading rings and to manage the risk of encroachment related touch voltages. The required spacing depends on site specific conditions including the soil model and fault data and will therefore be determined on a case-by-case basis.

5.2.6  **Limits on other assets and relevant codes of practice**

Details of the earthing equipment integrity and risk mitigation levels for other utility assets are detailed in EDI 001 – *Earthing Design Risk Assessment*. These risk mitigation levels for other utility assets will be met.

5.2.6.1  **DC Traction**

Electrical railway systems use DC traction systems which can expose the system to stray DC current which leak from the rails through the earth, with the possibility of causing electrolytic corrosion to assets within the rail environment and nearby assets.

If DC traction systems are located within 100m from the earthing systems or an asset is bonded to a railway substation a study must be carried out to determine the possibility of electrolytic corrosion of the earthing installation in accordance with 5.2.8. The allowable limits stated in BS EN 50122-2:2010 must be met. Each assessment will be coordinated with Transport for NSW through the NSW Electrolysis Committee.

Where required, passive and active corrosion mitigation measures will be incorporated into the earthing design.

5.2.7  **Earthing conductors and connectivity**

5.2.7.1  **Conductor rating**

The conductors and associated joints used for earthing must be rated to withstand the maximum short circuit currents without damage or deterioration for the life of the asset. The ratings will be provided for the backup clearance time assuming one item of the protection system fails to operate. Protection system includes the relay, CT’s, VT’s, D.C. supplies, communications systems and CB’s. The earthing design will assess the applicable asymmetrical fault current and the impact on safety and conductor ratings as set out in 5.2.3.1.

Unless otherwise specified in a site specific earthing system design, current carrying elements of a substation earthing system will be capable of carrying the nominal fault level summarised in the Table 5-2.

<table>
<thead>
<tr>
<th>Network component</th>
<th>Voltage</th>
<th>Short circuit current (kA)</th>
<th>Backup clearance time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone substations and network</td>
<td>11kV</td>
<td>20.0</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>22kV</td>
<td>20.0</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>33kV</td>
<td>25.0</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>66kV</td>
<td>24.0</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>132kV*</td>
<td>31.5*</td>
<td>0.43</td>
</tr>
<tr>
<td>Transmission substations</td>
<td>33kV</td>
<td>31.5</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>66kV</td>
<td>31.5</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>132kV*</td>
<td>40.0*</td>
<td>0.43</td>
</tr>
</tbody>
</table>

* 40kA fault rating is required in close proximity to grid exit points (BSP’s)

For conductor rating calculations, ambient temperatures of 25°C will be used for underground or embedded conductors and 40°C for overhead and aboveground conductors. For bolted or
compression joints, the maximum temperature that the earthing conductor will reach must not exceed 250°C. A maximum temperature of 450°C is allowed for earthing conductors that are welded (cad weld) or brazed. A maximum temperature of 90°C is allowed for steel reinforced conductors embedded in concrete (applicable for indoor substations and GIS installation). Due to the melting of insulation and risk of ignition, insulation degradation and emission of gases, the allowable maximum temperature of insulated conductor is 160°C.

Buried conductors in an earth grid can be rated to lower fault currents as the fault current will disperse through the ground or into bonded metallic paths. Bare buried conductors can be rated to 70% of the maximum fault current.

Where fault levels and backup clearance times are known, conductor sizing can be derived from the formulae from ENA EG-1 (section 10.2.2.2) and EDI 001 – Earthing Design Risk Assessment.

The rating of auxiliary earthing conductors such as cable sheaths and OHEW also needs to be assessed in a major substation earthing design.

5.2.7.2 Conductor connectivity

Metal structures and equipment may be livened to dangerous voltage levels as a result of an earth fault. For this reason depending on access, location and exposure levels, metal structures and equipment will be bonded to earth by permanent connections to electrodes and/or the earth grid in contact with the general mass of the earth. As a guiding principle, metalwork with a foreseeable direct or indirect energisation risk that is, from direct energisation to clear faults, electromagnetic induction or electrostatic charging will be bonded to earth.

Connections that are considered could become part of the primary fault path will require a redundancy of N-1. Connections that cannot become part the primary current path during an earth fault or connections that have significant parallel current paths already do not require additional redundant connections. In assessing whether sufficient parallel current paths are available, N-1 redundancy may be interpreted as the ability to withstand a failure of any one single earth conductor or element of primary protection failure.

Where multiple connections are made to the same structure to satisfy redundancy and/or thermal requirements, they will be made physically at displaced locations to different sections of the earth grid to increase reliability.

Refer to the relevant section for specific information about earth connections for the following:

- Power transformers 5.7.5.1
- GIS installations 5.7.6
- Fence installation 5.7.7
- Equipotential operating earth mats 5.7.5.6
- Indoor air insulated switchgear 5.7.5.2
- Power cables 5.7.5.3
The following table provides other common major substation equipment and the requirement for redundancy and bonding.

### Table 5-3: Example equipment connectivity requirements

<table>
<thead>
<tr>
<th>Category</th>
<th>Connectivity</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category 1 - Fault current carrying connections</td>
<td>Connectivity = (N-1) connections</td>
<td>- Auxiliary transformer tank&lt;br&gt;- LV Isolating transformer tank&lt;br&gt;- Disconnector/ Earth Switch&lt;br&gt;- CT tank&lt;br&gt;- VT tank&lt;br&gt;- VT secondary&lt;br&gt;- Triple surge diverter&lt;br&gt;- Single surge diverter on a column&lt;br&gt;- Triple busbar support steel column&lt;br&gt;- Indoor air insulated switchgear steel frame&lt;br&gt;- Outdoor Circuit breaker tank&lt;br&gt;- Switchboard/control panel&lt;br&gt;- Oil containment metallic items&lt;br&gt;- Cable screen termination&lt;br&gt;- Steel reinforcements in concrete 10m² and above&lt;br&gt;- Metallic cable trays via bare cable or copper strap (Ref 5.7.5.5)&lt;br&gt;- Landing span metallic structure&lt;br&gt;- Lightning mast (refer to 5.7.8.2)</td>
</tr>
<tr>
<td>Category 2 - Non fault current carrying connections</td>
<td>Connectivity = (N) connections</td>
<td>- Each control, protection and communication cabinet&lt;br&gt;- Yard lighting metallic column&lt;br&gt;- Metallic permanent bollard&lt;br&gt;- Deluge shower (Ref 5.7.9.1)&lt;br&gt;- Toilet showers, taps, SS Zink connection via metallic pipe system (Ref 5.7.10.2)&lt;br&gt;- Metallic water, sewerage and fire hydrant&lt;br&gt;- Single busbar support structure&lt;br&gt;- Metallic cabinet for storing portable earths.&lt;br&gt;- Any steel cabinet door&lt;br&gt;- Metallic racks&lt;br&gt;- Metallic vertical cable support stand&lt;br&gt;- Metallic brackets installed on the wall vertically for anchoring cables&lt;br&gt;- Steel reinforcements in concrete below 10m²</td>
</tr>
<tr>
<td>Category 3 - No connection required</td>
<td></td>
<td>- Steel brackets installed on the floor for anchoring of cables&lt;br&gt;- Wall mounted metal brackets to hang different items such as stationary, miner tools and the like.&lt;br&gt;- Door jam&lt;br&gt;- Metallic handrails (Where there is no risk of energisation)</td>
</tr>
</tbody>
</table>

All above ground earths will be frequently saddled to the structures to prevent mechanical movement under fault conditions.

All joints installed above ground, inside ground or concrete will have continuity readings to a common source (that is, the neutral point of the solidly earthed power transformer) as follows.
• DC resistance not exceeding 5 mΩ for assets that could become directly or indirectly energised will be required.

• There is a risk of energising substation fences from falling HV aerial mains connected to it. Hence for these major substations with overhead HV mains, DC continuity of the fence earth terminations must be below 5 mΩ. For substations connected with all underground HV mains DC continuity readings for fence earth terminations below 20mΩ are acceptable.

• For joints for non-fault current carrying conductors, these items will have DC resistance not exceeding 20 mΩ. In each circumstance, trending must indicate sources of increased resistance and issues clearly understood and identified.

If above earth continuity limits for category 2 connections are not achieved for existing major substations, these connections will be assessed based on risk criteria in EDI 001-Earthing risk assessment with exposure rate equivalent to ‘urban interface’.

5.2.7.3 Standard conductor sizes

To limit the impact and provide standardisation, standard conductor sizes provided in Table 5-4 will be used for the earthing design.

As part of the design, the adequacy of fault current rating of these conductors used in various sections of the earthing installation will be assessed. The maximum current on the selected conductors against the calculated allowable limits will also be included. In some circumstances two (2) 95mm² may be specified to withstand the fault level and clearance time associated, in this case three (3) 95mm² conductors would be required to achieve a redundancy of N-1.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Conductor</th>
<th>Short circuit current (kA) for 1 second</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main earth grid with crimped joints*</td>
<td>Bare copper stranded 95 sq.mm</td>
<td>24.1</td>
</tr>
<tr>
<td>Main earth grid with welded joints*</td>
<td>Bare copper stranded 95 sq.mm</td>
<td>30.4</td>
</tr>
<tr>
<td>Earth Riser</td>
<td>Cu 95sq.mm Insulated Green yellow</td>
<td>12.8</td>
</tr>
<tr>
<td></td>
<td>Cu 120 sq.mm Insulated Green yellow</td>
<td>16.2</td>
</tr>
<tr>
<td></td>
<td>50x3mm tinned copper strap *</td>
<td>24.7</td>
</tr>
<tr>
<td></td>
<td>50x6mm tinned copper bar *</td>
<td>49.5</td>
</tr>
<tr>
<td>Earth continuity conductor ECC</td>
<td>Cu 240 sq.mm Insulated Black</td>
<td>27.0</td>
</tr>
<tr>
<td>Counterpoise Conductor outside the substation</td>
<td>Bare copper stranded 95 sq.mm</td>
<td>16.8</td>
</tr>
<tr>
<td>Counterpoise Conductor insulated section</td>
<td>Insulated (green-yellow) copper stranded 95 sq.mm</td>
<td>12.8</td>
</tr>
</tbody>
</table>

* based upon 70% required rating  
# bolted connection limitation (250°C)

Cable for bonding equipotential earth mat to isolator/earth operator handle must be 95mm² copper insulated ultra-flexible. This is based on standardisation of earth cables. Refer to drawing 385820.

The size of equipotential earth bonding cables supplied with the equipment, such as ‘bonding of metallic door to control panel’ is the size determined by the equipment designer based on adequate mechanical strength.

5.2.7.4 Bolted connections

Stainless steel bolts and nuts will be used to secure the earth connections installed above ground. Refer Figure 5-1. No bolted connections will be direct buried in ground or concrete.
To prevent the nut from becoming loose due to vibration, temperature cyclic variations etc. a stainless steel spring or Belleville washer along with the stainless steel nut must be used. The addition of a lock nut is required on connections prone to vibration. The lug or copper bar will make direct contact with the surface to be earthed. The nut or washer must not be in the fault current path. Cable lugs must not be doubled up under the same bolt. One lug against another lug joint is not an accepted practice.

All lugs and pressure fittings will be fitted using the correct crimping die, crimping pressure and procedure as recommended by the manufacturer.

![Figure 5-1 Standard bolt connection](image)

During installation and prior to commissioning, all bolted earth connections will be thoroughly inspected. Additionally, DC continuity measurements are required at all bolted and CAD weld joints in major substations. Refer 5.4.

5.2.7.5 Crimp connections

Use of crimped earth connections is the preference of the company. Two types of crimp connectors ‘single crimp connector’ and ‘dual crimp connector’ are approved to be used in the company network. For adequate sealing inside the connection a conductive compound is required to be applied inside the crimp connector before crimping.

**Single Crimp connectors:**
Where single crimp connectors are used, two (2) connectors must be provided for each joint with a separation of 50mm between connectors as shown in Figure 5-2. Care must be taken to select the correct die and to apply the crimping pressure recommended by the manufacturer. When crimping onto copper-clad steel electrodes, the electrode must be pre-crimped with a hexagonal die prior to applying the crimp connector to prevent the electrode rotating within the crimp as recommended by the connector manufacturer.

**Dual crimp connectors**
If dual crimp connectors are used one connector is sufficient for each joint. Care must be taken to select the correct die and to apply the crimping pressure recommended by the manufacturer.
5.2.7.6 Exothermic welding

Exothermic products and moulds may be used for joints in the earthing system. Joints must be checked for secure connection and strength of the weld and DC continuity measurement must be taken before burial.

Exothermic products approved for the company are provided in 5.8. The exothermic mixtures must only be used with manufacturer approved moulds. Exothermic mixtures from a particular supplier must not be used in moulds from a different supplier. The expired moulds will be replaced according to manufacturer’s guidelines.

Exothermic welding must only be performed by operators who have been specifically trained by a suitably qualified representative of the equipment supplier.

Exothermic welding will only be used where the earthing design has requested such a connection.

5.2.7.7 Brazing / Welding

Refer to 5.7.2 for further details on embedded earthing and welding arrangements. Additional mechanical retention such as rivets may need to be used for brazed joints. Welds will be done on both sides and will be a minimum of 50mm in length.

5.2.7.8 Earth bars and stranded cable system or earth strap system

One of the following earth cabling systems will be used to make robust earth cabling system that facilitates testing and tracing of connections.

**Earth bar and stranded cable system:**

The earth bar will be incorporated in the earthing design for the termination of multiple earth conductors. The earth bar will be flat tinned copper and 50mmx6mm cross section with length to suit depending on the number of connections. The earth bar will either be mounted on 6.6kV insulators or directly on to the brick wall or to concrete floor to suit application and testing requirements. Details on where the earth bar is required are provided in 5.7.5. The earth bar will be provided with two (2) minimum spare holes for future earth connections. Typical separation between holes is 70mm.
Earth strap system:
Tinned copper 50mmx3mm strap ring around primary equipment such as power transformer, GIS etc. can be used. This ring around system suits all fault current ratings within the network and minimises trip hazard and with facility for unrestricted number of connections. Earth risers and other earth connections are to be connected to the nearest ring around earth strap as shown in Figure 5-4. Refer to drawing 385812.

5.2.8 Corrosion
A corrosion (chemical or biological attack, oxidation, formation of an electrolytic couple, electrolysis, etc.) assessment may be required as part of the design. An initial assessment based...
on soil electrical resistivity testing performed must be assessed against soil pH and sulphide data sourced from NSW Government Natural Resource Atlas. In areas of heightened risk as set out below, soil characteristics based on further samples taken 100mm below the final surface will be taken around the substation site. Tests generally need to identify upper layer soil resistivity (see 5.2.3.2), soil pH values and detection tests for sulphides.

As an indication for further investigation, soil resistivity less than 25Ωm, pH values less than 4.0 (acid) or greater than 8.5 (alkaline) and positive traces of sulphides are indicators of heightened concern for corrosion. Annexure D provides risk factors for heightened corrosion risk. Any area with testing results including or exceeding 100% from Annexure D require a corrosion assessment and remediation report which will need to be approved by Earthing and Power Quality Manager.

If the area is prone to corrosion, suitable bedding arrangements around copper conductors, appropriate (larger) conductor sizes, additional redundancy, additional levels of concrete cover and sealing around earth connections to embedded earth will be incorporated in the earthing design in coordination with the civil design. This coordination is the responsibility of the Earthing Designer.

5.2.9 Theft protection

Actions including the following are required to reduce the likelihood of copper theft for major substations for all conductors located outside the substation fence:

- Wherever practical, above ground earthing conductors will be concealed by an enclosure such as ducting or conduit.
- Earth connections will be chosen out of sight to minimise the likelihood of theft but still identifiable for test and inspection.

The use of copper clad steel theft deterrent earthing systems may be used for major substations assets if approved by the Earthing & Power Quality Manager on a case-by-case basis.

5.2.10 Earthing design layout

The earthing design layout will include a number of key considerations. Table 5-5 lists a number of them.

<table>
<thead>
<tr>
<th>Earthing design consideration</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth grid layout including embedded earthing</td>
<td>5.7.1</td>
</tr>
<tr>
<td>High resistivity surface layers for touch voltage control</td>
<td>5.7.3</td>
</tr>
<tr>
<td>The bonding of auxiliary earthing systems</td>
<td>5.7.4</td>
</tr>
<tr>
<td>Bonding of primary substation equipment, civil supports and other ancillary plant</td>
<td>5.7.5</td>
</tr>
<tr>
<td></td>
<td>5.2.7.2</td>
</tr>
<tr>
<td>Fences</td>
<td>5.7.7</td>
</tr>
<tr>
<td>Lightning protection system</td>
<td>5.7.8</td>
</tr>
<tr>
<td>Services</td>
<td>5.7.10</td>
</tr>
<tr>
<td>Portable earthing provisions</td>
<td>5.7.11</td>
</tr>
<tr>
<td>Special provisions for GIS earthing</td>
<td>5.7.6</td>
</tr>
</tbody>
</table>

The earthing design layout needs provision for:

- the staged construction (and decommissioning) safety requirements 5.5;
- commissioning and test 5.4;
- and design for continual and effective maintenance 5.3.
5.2.11 Review and design acceptance

All earthing designs for major substations will be approved by the Earthing & Power Quality Manager. If the design is accepted an approval will be given to proceed with the construction. Final approval will be given after confirmation of current injection testing provided the minimum designed values have been achieved.

Additional details on the documentation requirements are provided in 5.6.

5.3 Design for safe maintenance

Maintenance requirements of earthing systems for major substations are covered in SMI 104 – Major substation earthing test and SMI 100 – Minimum Requirements for Maintenance of Transmission and Zone Substation Equipment. All earthing terminations will be located with provisions for test and inspection access. This includes locating terminations such that employees/contractors can reach the termination without additional equipment.

5.4 Testing and commissioning

All testing and commissioning programs will follow the appropriate safety rules, safe work method statements and SDR. The Earthing Designer will identify any site specific testing and commissioning hazards and incorporate them into the associated safety plans, SDR and commissioning procedures.

5.4.1 Pre inspection

The Project Manager/Project Supervisor will arrange and carry out for the following inspection according to the company standards, and as-built final drawings:

1. Inspection of all embedded earthing conductors and earthing tags prior to the pouring of concrete.
2. Inspection of switch building roofing bonds prior to the placement of roof sheeting and fascia’s.
3. Inspection of all laid and jointed earth systems (earthing conductors and grid electrodes) prior to backfilling.
4. Report the actual depth of installation and location of earthing in as built drawings.

The Project Manager will also arrange with Operation Manger Testing and Instruments to complete the following tests and inspections according to the company standards and the design drawings.

1. Inspection and compliance of the completed above ground earthing bonds and connections.
2. Carry out continuity test for joints using a 4-wire high current (>1A) micro-Ohm resistance tester.
3. Inspection and check all design recommendations have been implemented (for example, CMEN connections, OHEW upgrade and bonding, counterpoise installation, concrete apron, and the like)

Testing requirements for major substations are set out in SMI104 – Major substation earthing system test.

5.4.2 Design verification current injection test

As a part of the commissioning process, the performance of all newly designed or modified earthing systems will be verified by current injection test. The test will be carried out in accordance with the minimum procedures set out in SMI 104 – Major substation earthing system test. For this test all available auxiliary earths must be bonded according to the earthing design or be based on the test staging set out in the earthing design. The project manager will consult with the Earthing
Designer and Operation Manager Testing and Instruments to determine when acceptance testing is appropriate based on the staging of works. Nearby telecommunications equipment and pipeline asset owners may need to be involved in the site testing and will be engaged by the Operations Manager Testing and Instruments. The final test report and confirmation will be provided to the Earthing & Power Quality Manager for final approval.

Where non-compliances are determined in the current injection testing process, high risk situations are required to be temporarily mitigated and rectified as soon as practicable. The Earthing & Power Quality Manager and Regional Transmission Manager must be advised in this situation.

Final copies of the test reports will be submitted to:

a) Regional Transmission Managers for information
b) Earthing & Power Quality Manager for design verification and final approval
c) Project Manager for design verification
d) Network Planner for information and ongoing compliance
e) Operations Manager Testing and Instruments for ongoing testing
f) Telstra power coordination and nearby pipeline authority owners for ongoing electrical hazard risk management plans.

Service Providers are permitted to witness current injection tests; however there will be no deviation from the minimum test requirements given in SMI 104 – *Major substation earthing system test*.

### 5.5 Construction safety requirements

#### 5.5.1 General

During construction and commissioning of major substations, there is an increased risk of employees being exposed to electrical and earthing hazards. As part of the design of an asset it is essential that the construction safety requirements be identified and controls are listed in the appropriate safety documentation, SDR and safe work method statements (SWMS). This will include but not be limited to the following items for a site:

a) Power supply to construction areas and site sheds and offices:
   i. Substation auxiliary power supply
   ii. LV street supply
   iii. Appropriate use of portable generators and inverters
   iv. Use of isolation transformers
b) Location of site sheds and offices
   i. Within the earth grid and substation boundary
   ii. Outside the substation at a minimum separation
c) Material storage areas (particularly for conductive construction material)
   i. Within the earth grid and substation boundary
   ii. Outside the substation at a minimum separation
   iii. Guidance and requirements on carrying the materials
d) Vehicle earthing requirements for plant such as:
   i. Cranes near exposed HV
   ii. Concrete pumping vehicles
   iii. Trucks in live yards
   iv. *Tanker vehicles for pumping out sewerage, storm water etc.*
e) Earthing requirements for temporary fencing and scaffolding
f) Personnel Protective Equipment
   i. Insulating gloves
   ii. Footwear (use of rubber boots)
iii. Equipotential bonding leads
iv. Isolating/ insulation mats
g) Conductive material handling
h) The bonding of various earthing systems, grids and auxiliary earthing components
i) Specific controls for specific work areas

Particularly for major brownfield sites, the commissioning and staging of the works has a large impact on the risk of shock to workers and the public. The staging of the works will consider and provide the safe methods of performing the following tasks:

- Staging of and safe bonding of OHEW, cable sheaths, ECC, and the like.
- Bonding of existing to new earth grid(s).
- Bonding of fencing.

Mitigation of associated hazards during construction may include sectionalising of bus sections to reduce prospective earth fault current, introduction of temporary high-speed protection and the disabling of auto-reclose functions.

The earthing design report will include site specific construction earthing hazards and any special requirement for mitigating risks when working inside or adjacent to the energised substation. The staging of works will be assessed in this assessment of risk.

When drilling or cutting sealed steel pipes special care will be taken to prevent injuries from igniting trapped flammable gases.

5.5.2 LV power supply

Power will not be sourced from the major substation when working outside the buried earthing system associated with the major substation, and power from outside the major substation must not be used within the substation and associated buried earthing system unless suitable arrangements are specified and approved in the earthing design report.

A low voltage portable generator supply may be used in accordance with AS/NZS 3000, AS 2790, AS/NZS 3012 and the manufacturer’s instructions. The generator neutral earthing must be installed as close to the worksite it will supply as possible, and the location of this earth must be considered in the earthing design for safe operation of the portable generator.

5.5.3 Conductive site sheds

Temporary conductive site sheds can be hazardous depending on the LV supply arrangement as the metallic objects and frame of the shed are generally bonded to the neutral of the LV supply to the shed.

The electricity supply arrangement to the site shed and specific location of site sheds will be determined in the approved earthing design construction report (that is, either completely inside the buried earthing system if supplied from the substation supply or some minimum distance from the buried earthing system if LV supply is sourced from the street).

5.5.4 Construction of temporary security fencing

The earthing of temporary security fences must be considered in the earthing design. Touch voltages on temporary fences are mitigated and the risk of metallic fences developing a capacitive coupling to overhead mains is addressed.
5.5.5 Safety footwear

Good quality, dry footwear can provide a high insulation resistance and voltage withstand characteristic which can greatly reduce shock risk to workers. All personnel working on a site must wear appropriate safety footwear with a rubber or elastomer sole in good condition. Condition of safety footwear will be checked by the supervisor at an interval not less than one month. Details of footwear insulation and voltage withstand characteristics is provided in ENA EG-0 table B5.

5.5.6 Conductive material handling

People carrying conductive materials onto the substation site while the substation is energised can be subjected to hazard voltages.

Where safe to do so, only one worker must carry material into the work area. When two workers carry conductive construction material (such as steel mesh, fence panels and structures) onto the work site, care must be taken so that the two workers carrying the material approach the work site while maintaining the same distance from the substation fence. When working near outdoor equipment, the risk of conductive equipment contacting live components must also be assessed and materials must be carried below shoulder height where possible.

5.5.7 Conductive material storage

Where conductive materials are stored below any live equipment, temporary earth bonds must generally be used to avoid static charge build up. The earthing design will assess and provide suitable material lay-down areas within or external to the substation earth grid.

5.5.8 Earthing requirements for scaffolding

Metallic scaffolding installed inside or adjacent to a major substation can pose a transfer voltage risk. Within the substation earth grid – scaffold will generally be bonded to the earth grid at strategic locations for continuity to earth. Outside the earth grid may require local earthing depending on site conditions.

Metallic scaffolding construction safety requirements will be identified in the earthing design.

5.5.9 Transfer earth potential hazard from metallic long flexible hose connections

When required tanker vehicles are brought to the vicinity of major substations for connecting and pumping out septic sewerage, trapped water mixed with oil, storm water etc.

Earthing design must address the transfer potential hazards and corrective actions for the connection of outlets in the substation to tanker vehicles. New major substations must be designed to have these outlets with non-metallic pipes. For hazardous sites, only non-metallic flexible hoses must be used.

5.6 Design documentation

All electronic copies of the design reports, commissioning reports and drawings (in both PDF and CAD format) are provided to the Earthing & Power Quality Manager as part of the initial approval process.

The following design documentation will be electronically provided for earthing design associated with the company’s network:

a) Earthing design report including comprehensive details of initial testing, all design assumptions used, design approach, construction staging, expected EPR, step, touch and transfer voltages.
The designer will reference the information specified in annexure B as a typical minimum requirement.

b) Company earthing design includes:
   i. Earth grid layout including lightning protection system
   ii. Embedded earthing layout and specific equipment configurations
   iii. Simplified auxiliary earthing system diagram
   iv. Non-standard earthing hazard mitigation or configuration drawings for construction

c) Earthing construction safety design report and program report identifying inspection, verification, modification, connection and testing requirements throughout the construction period.

Following commissioning:

d) Post commissioning report demonstrating compliance of the installation with design requirements. It will include photographic evidence of key connections (OHEW terminations, cable screen terminations, major earth bars) and signed ‘as-built’ drawings. Photographic evidence will also be provided for defects including rectification plan.

The Project Manager must also check that all as built earthing drawings and design/compliance reports are uploaded and available in the company drawing system and Content Server.

5.7 Specific requirements for specific infrastructure and equipment

5.7.1 Layout

The earth grid will be installed in a manner that will limit the effect of earth potential gradients to such voltage and current levels that will not endanger the safety of people or equipment under fault conditions as well as normal operating conditions. The system will serve for the full life of the substation.

5.7.1.1 Earth grid

The main earth grid will consist of a mesh of horizontal copper conductors installed at a depth of 500mm in the ground and typically bonded with vertically driven earth rods. Sufficiently long earth rods penetrating different soil resistivity layers will stabilise the performance of this combined system due to soil resistivity variations. Electrode inspection pits are not required.

![Figure 5-5: Trench cross section](image)

The earth grid is generally completed with equal size rectangles or squares. Rectangles or squares compressed towards the perimeter can be used to enhance the performance of the earth grid. A concept main earth grid is provided in drawing no. 385819-page 1.
As a standard, 95 mm² annealed bare copper stranded conductor will be used for the earth grid. All connections made underground must be exothermic welded or crimped. Refer 5.2.7 and Drawing no. 385809.

Each earth rod must be terminated to the earth grid or to the fence or to grading ring using an insulated green-yellow cable to facilitate testing.

Conductors, earth rods and joints forming the earth grid must be inspected and tested prior to burial by the Project Manager/Work Supervisor.

5.7.1.2 Earth electrode installation

Depending on the ground conditions, vertically driven earth rods may be installed. The rods will be driven by hand or by hand operated mechanical/electric hammers. The rods must be completed with hardened driving point attachments and friction couplings (refer Drawing no. 348244). Earth electrodes will be 15mm diameter copper clad steel with minimum 250µm thick layer of copper coating (refer Table 5-6 for approved products). The crimped connectors will be positioned 50mm from the tip of the earth rod. The exposed steel at the end of the rod will be fitted with a PVC end cap containing high melting point grease (or similar) to prevent corrosion.

A deep drilled earthing system will be used where the driven rods are not practical, such as in sandstone ground. These drilled bores are generally 70 mm in diameter. Any deep drilled bores must be back filled with conductive and contact improving compound after inserting the electrode. Refer 5.8 for approved products. Any other chemicals such as salt must not be used as backfill as these chemicals can accelerate corrosion of earth rods. If the hole is over 5m in depth, a 2.4m copper clad steel rod bonded with 95 mm² bare stranded copper cable can be used as the electrode inside the deep drilled hole. Refer Drawing no. 385809.

5.7.2 Embedded earthing

Reinforcement steel bars in concrete slabs where used will form part of the earthing system. Typically the outermost structural reinforcement bars with 5m mesh spacing as shown in Figure 5-6 require continuous bonding. Where tanking membranes are not required around slabs to maintain the integrity of the civil design, they must not be used. This will maximise the continuity and benefits of the embedded earthing configuration. The Earthing Designer & Project Manager are required to coordinate with the civil design team to achieve this outcome.

![Figure 5-6: steel mesh welding configuration](image-url)
Reinforcement bars used for the earth continuity will be welded to form current carrying circuits. Welds will be done on both sides and will typically be a minimum of 50mm in length. Where the reinforcement bars are to be bonded together at 90° a piece of reinforcement, not less than the size of the bars being jointed, will be bent at right angles to weld the two lengths together. This is shown in the Figure 5-7.

Where there are two reinforcing layers, the embedded earth conductor arrangement is only required for the top layer, but the bottom layer may be bonded to top layer to maintain electrical continuity and improve performance.

![Figure 5-7: Welding; top: right angle welding, bottom left: overlap welding, bottom right: typical ‘u’ welding](image)

A minimum 40mm concrete cover over the steel reinforcement is required to minimise corrosion. Concrete columns, piles and walls are also to be bonded to the earthing system in the same manner. In areas with increased salt levels or high ground corrosion risk, coverage must not be less than 75mm.

At least two (2) connections, each with full fault current carrying capability, will be made between the building frame (embedded steel) and the main earth grid. Connections will be placed at opposite ends of the building and connected to different sections of the main earth grid.

Electrical connectivity across expansion joints and across joints without continuity of steel reinforcing will be provided. Refer 5.5 and 5.6. This will be accommodated by at least two (2) PVC covered stranded copper connections with fault current capability with an appropriate crimp termination. The conductor is to be laid so that it does not suffer damage due to movement of the expansion joint. Only PVC covered earthing conductors will be used traverse the concrete interface to reduce the risk of corrosion. Where adjacent slabs are being poured at different times, direct buried connections must be planned in advance so that tails will be available to provide continuous reinforcement over the entire concrete surface. A set of standard embedded earthing connections is provided in Drawing no. 385810.
MAJOR SUBSTATION EARTHING DESIGN, CONSTRUCT AND COMMISSIONING

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Figure 5-8: Earth connection to steel reinforcement

Figure 5-9: Earth connection at expansion joint

All cable / conductor sizing within concrete will satisfy conductor rating requirements 5.2.7.1.

The steel reinforcing used in the foundations of a concrete structure, such as a transformer bund, drains, access road, pathway and all other equipment, will be electrically continuous by welding adjacent sheets of mesh. The reinforcing will be connected and bonded to the nearest main earth grid at a minimum of one (1) point. However, where reinforcing is used in large areas that exceed a typical area of 10m², it will be bonded at a minimum of two (2) diagonally opposite points.

A galvanised steel connection earth tag required for horizontal slab connections is provided in Figure 5-10. The tag will be fabricated from nominally 190mm x 40mm x 8mm mild steel bracket with one (1) centred hole of 14mm diameter. The tag will protrude 60mm out from the face of the concrete to allow for testing. The tag is to be sealed where it meets the concrete and solidly bonded to the continuous embedded reinforcement earthing using two (2) 40mm welds either side. As an alternative to earth-tag, per-fabricated earth connection points shown in Figure 5-13 can be used. Refer to earthing component list in Annexure E.

Contractors will give a minimum of three (3) working days' notice to the company Project Manager/Contract Supervisor and the Earthing Designer to inspect and approve all solidly bonded reinforcement connections before concrete is poured. If a significant change has occurred, the design may need to be reassessed by the Earthing Designer.

5.7.3 High resistivity surface material

5.7.3.1 Crushed rock

An outdoor switchyard will be covered with crushed rock, such as river gravel or crushed igneous rock (blue metal), with resistivity not less than 3000Ωm when wet. The rock will be washed and clean, with minimum 20mm diameter single size aggregate, and laid to a minimum depth of 100mm (refer SDI 523 – Switchyard Surfaces).
5.7.3.2 Asphalt
Where a high resistivity surface layer is required to control step and/or touch potentials in areas outside the perimeter fence, a compacted road base, hot mix asphalt layer laid to a depth of 60mm will be used in lieu of crushed rock.

5.7.4 Auxiliary earthing systems

The auxiliary or secondary earthing system is a key part of a substation earthing system and will be incorporated into the substation earthing design.

Auxiliary earthing systems will be terminated to an earth bar accessible from ground level or in the basement of the substation to allow disconnection for testing purposes. A typical earth bar is given in Figure 5-3. The earth bar must be connected to at least two (2) earth risers in accordance with 5.2.7. All connections to the earth bar will be labeled (refer to drawing 385821).

5.7.4.1 Overhead earth wires (OHEW) and earth continuity conductors (ECC)

Generally, OHEW and ECC will be bonded to the earthing system of a major substation when adequately rated. The connection of the OHEW of the transmission line will further enhance the performance of this auxiliary earth system by providing both a conductive and inductive path to the source. Older (HARDEX) or discontinued earth wires must be considered for possible future upgrades and replaced at least few spans with suitably rated OHEW.

Additional earthing requirements can be included in the earthing design for the first few transmission poles from the substation to improve impedance of this auxiliary earth system.

The earthing risk assessment criteria and earth wire rating requirements of EDI 001 – Earthing Design Risk Assessment must be met for transmission circuits.

5.7.4.2 Pilot cables with metallic screens

Generally, traditional pilot cables with metallic screens used in parts of the company’s network for communications must be single point bonded and segregated due to insufficient rating and risk of high induced voltages respectively. Metallic parts of the open end must be appropriately insulated to prevent hazardous touch voltages particularly when terminating into major substations. Zone Substation end of the pilot cable screens will be kept open and secured for easy inspection access.

5.7.4.3 Distribution earthing

Cable screens, if adequately rated, can provide a significant conductive and inductive path for fault current to flow for both cable and substation faults in the distribution network. The additional earth paths to the bonded points throughout the earth network can reduce EPR significantly. It is important to assess the sheath current flow due to unbalanced conditions and the impact on overall cable rating in such a design.

Bonding cable screens to earthing systems at both ends (HV earth and/or LVN) is usually beneficial to the transfer of EPR hazards from distribution faults back to ZS neutral points. In areas of the network where UGOH’s segregate the local cable network or areas with only a few padmount substations, cable sheaths can transfer EPR hazards locally and investigation as to the merits of bonding both ends is required in such locations. For further detail refer 5.2.4.

No distribution voltages will be reticulated into major substations without approval of the Earthing & Power Quality Manager. This includes the earthing at the major substation end and the first asset being supplied.
5.7.4.4 Counterpoise earths
Counterpoise earthing can be installed along with proposed underground cable installations utilising the same trench as a low cost auxiliary earthing system. Earth cables will be placed at the bottom of the trench with minimum 500mm below ground level.

5.7.4.5 Satellite earth grid
Installation of earth grids in low resistivity spots and connected to substation earth grid is an acceptable way of reducing overall grid impedance and are common in some older major substations.

5.7.4.6 Connection of earthing systems owned by others
Prior approval required to be obtained from the Earthing & Power Quality Manager for the bonding of earthing systems owned by other parties such as railways, mining companies and the like to the company’s earthing systems. The Earthing Designer must clearly state in the earthing design report; the advantages to both parties resulting from this bonding and also the imposed risk to each party as a result of this bonding. A formal agreement is required between the company and the other party facilitated by the Earthing Designer.

5.7.5 Primary equipment
5.7.5.1 Power Transformer earth bar
If an earth bar and stranded cable system is used the following applies.
There are several earth points on a power transformer that are required to be connected to main earth grid. To facilitate these earth connections a 50mm x 6mm sized copper earth bar (electro-tinned after fabrication) will be used. The earth bar must be connected to minimum two earth risers from two (2) different sections of the main earth grid. These risers must be located in close proximity to the transformer but must meet the connectivity requirements of 5.2.7. The earth bar will have sufficient length to accommodate the expected number of earths for existing use plus two (2) more holes as spares for future use.

The earth bar will be mounted on the floor of the transformer footing adjacent to the transformer and care must be taken to avoid a trip hazard. All cables connected to the earth bar will be traceable and permanently labelled (refer to drawing 385821).

The connection to the main earth grid and to the neutral bushing will be taken from each end of the transformer earth bar as shown in the typical transformer earth bar arrangement (refer to Figure 5-11 below).

A minimum of two (2) dedicated 95mm² black PVC insulated stranded copper neutral cables will be provided from the bushing to individual dedicated bolts at either end of the transformer earth bar. Double hole lugs must be used at either end of each cable for new transformer installations.

Power transformer tanks will be earthed at two diagonally opposite points on the transformer while the tap changer cubicles require earthing at one point, unless the tap changer cubicle is adequately earthed to the transformer tank by the manufacturer.

Earth points of the independently mounted radiator banks will be connected to two different earth risers from different locations of the earth grid.

These requirements are reflected in Drawing no. 385812.
5.7.5.2 Indoor air insulated switchgear (AIS)

If specific earthing information for AIS is not provided, following general earthing arrangements will be followed. At least two (2) connections will be made from the main earth grid to the indoor earth bar on each section of switchgear. Connections will be placed at opposite ends of the earth bar and connected to different sections of the main earth grid. Refer to Figure 5-14 for AIS earthing arrangements.

5.7.5.3 Power cable screens

Inside major substations, to minimise circulating currents and potential damage the screen of a single core power cable must generally be bonded to earth at the source end only.

Copper cable screens from the cable termination must be gathered to form a cylindrical conductor then lugged. The conductor is to be covered with heat shrink or PVC tape, so that a minimum 50mm section is left bare at the bottom of the cable termination for leakage current return path. Refer to product installation instructions and MCI 0006 – Underground Distribution Construction Standards Manual.

Power cable screens may require approved Sheath Voltage Limiters (SVL) connected to the open ends based on the earthing requirements of the cable design. The conductor screens must be terminated to a copper earth bar/strap or to SVLs associated with the cable design.

5.7.5.4 Steelwork supporting equipment

At least two (2) connections will be made between the main earth grid and active equipment structures such as circuit breakers and surge arrestors. At least one (1) connection will be made between the main earth grid and passive equipment such as post insulator stands. Refer to 5.2.7.2.

5.7.5.5 Metallic cable trays

The cable and associated connections (including interconnections between equipment and between adjacent sections of cable tray) will be capable of carrying the designed maximum earth fault current. Cable trays will have properly tightened joints so that the cable trays are electrically continuous. A bare earth cable or earth strap suitable to carry fault current will be installed along the cable tray in a Zig Zag configuration and bonded to earth at both ends. Each section of the cable tray will be bonded to earth cable/strap to carry fault current during a cable fault.

Floor mounted cable support brackets (and associated mounting channels), for securing cables to the floor, do not require connection to the earth grid when they have rated earthed screen cables running across them.
5.7.5.6 **Disconnectors and earth switches**

Equipotential earth mats for the protection of the operator will be installed in major substations for all operational switches with handles. If equipotential earth mats are not provided, particularly for older substations, portable earth mats (stock code 1550722) and appropriate safety procedures will be used when operating equipment.

The operational configuration for operator handles includes a single direct connection between the handle and earth mat (and not further to the earth grid) to reduce the risk of voltage difference between the handle and the earth mat for operator safety. The low risk conceptual connection arrangement for equipotential earth mats to the switch handle is given in Figure 5-12.

Low risk equipotential earth mat installation details are provided in drawing 385820.

In lieu of operator earth mat, the concrete surface that the operator standing on can be considered as low risk equipotential area for operation of switches provided steel reinforcing of the concrete is bonded to the earth grid.

The support post/structure for the earth switches and disconnectors must also be bonded to the earth grid as defined in 5.7.5.4.

The operator earth mat requirement also applies to substations with frame leakage protection however additional precautions are required in this circumstance. The following precautions must be followed:

a) The operator earth mat must be bonded to the operating handle only using a insulated ultra-flexible earthing conductor (Refer to Annexure E for parts and accessory list);

b) The operator earth mat must not be directly bonded to the earth grid;

c) The buried earth grid at the operator mat location is in fact buried and not lying on the surface or exposed nearby interfering the equipotential earth mat;

d) The operator mat is installed in such a manner that it does not bridge equipment that is not connected to the frame leakage system.

e) The operator mat will not be installed on top of metallic guttering or drain covers or exposed earthing which may provide a more direct path to the buried earthing system.

f) The crushed rock layer will have minimum of 100mm depth and in good condition and is consistent with the requirements for crushed rock of section 5.7.3

Where an existing earth mat installation does not meet the standard configuration, a risk assessment is to be performed to determine if any changes are required.
Figure 5-12: Low risk earth connections to equipotential earth mat and operating handle

5.7.6 GIS installations

Particular attention must be given to the bonding of the metallic enclosures of a GIS assembly, as these enclosures carry induced current of significant magnitude, which may be confined as part of the GIS design to specific paths. The number and nature of earth connections for GIS installations are to be made in accordance with the manufacturer’s specification in consultation with the company.

The steel reinforcement in the concrete slab under the GIS will be welded to provide an earth plane under the switchgear. Section 5.7.2 will be used as a minimum guide for the establishment of embedded concrete GIS earths. The size and amount of embedded concrete steel reinforcement to be used with GIS earthing will be decided in consultation with the manufacturer. A high level of interconnection will be provided between the GIS earth leads and the steel reinforcing in the floor under the switchgear. Current carrying capacity of the reinforced steel must be evaluated. An earth bar or earth bars will be installed between the GIS earth connection point and the embedded earth according to Manufacturer’s specification.

The potential electrical breakdown in the insulating gas of GIS, either across the contacts of a switching device during normal operation or in a power system fault can generate very high frequency transients (VHT). These VHT can couple onto the earthing system. Hence in addition to the earthing requirements associated power system frequency faults, the substation earth system will have controls to mitigate hazards and associated equipment impacts associated with transients originated by GIS switching and earth fault conditions.

As a minimum, tinned copper earth bar size 50x6 mm will be. Cable earth screens will generally be connected to the substation earth grid separately to the GIS switchgear earthing to avoid the circulation of enclosure currents beyond the regular path within the GIS assembly.

GIS connection points and copper earth bars will be located to allow as short as possible connection.
5.7.7 Fences and gates

Earthing of the substation fence is important for a number of particular reasons:

- The outside of the fence is accessible to public,
- The surface voltage gradient is highest at the periphery of the earth grid,
- In an event of a HV line falling on to the fence, there must be sufficient fault current will flow for protection activation.

Generally, all substation fences will be connected to the substation's main earth grid. If this cannot be achieved while maintaining safe touch voltages, an appropriately designed isolated fence system may be provided with appropriate controls for the management of internal risks.

The minimum requirements for fences and gates are:

- All substation fences will be electrically isolated from the fences of neighbouring properties. In situations where the neighbouring fence is abutting the substation fence, a clearance of 1900mm must be maintained between the two (2) fences. If this is not practical, the section of the substation fence that comes within the 1900mm clearance area must be constructed of insulated panels and posts. This will eliminate the risk of any hazardous hand to hand voltages.
- Either exothermic welding, or a bolt and tinned copper lugs, will be used to connect the riser cables to the fence posts. Refer Drawing no. 385809.
- All connections across fence panels and earth joints will be verified and tested for continuity. Refer 5.2.7.2.
- Vehicle and personnel access gates will have insulated flexible copper leads (ref Table E-1 for approved products) connecting the moving gate and fixed gate post.
- All entry gates to substations and switchyards will open inwards. In situations where this is not practical, the design will incorporate measures to maintain safe touch voltages when the gate is fully opened outwards. The measures include provision of grading ring one metre outside from the gate opened position and/or a concrete slab with steel reinforcement connected to grading ring/earth grid.
- All fences and their components are either hot dip galvanised or powder coated. Electrical continuity must be maintained in accordance with 5.2.7.2. This can be achieved by masking adjoining sections and components during manufacture. Where the fences have already been constructed, adjoining sections and components will be seam-welded to achieve continuity between sections and components.
5.7.7.1 Fences connected to main earth grid

Fences that are designed to be connected to the main earth grid will be bonded to the earth grid at corners, and at posts on either side of a gate and at every fourth post in the mid-section. The earth bonds will be located inside the switchyard.

If bonding a corner post to the main earth grid is not practical, the posts adjacent to that corner post will be bonded to the main earth grid. Thereafter, every fourth post will be bonded to the main earth grid.

As outlined in the earthing design a grading wire around the fence may be required to mitigate touch potentials on the fence from outside of the substation. The grading wire will be bare stranded copper 95sqmm buried at a minimum depth of 300mm in the ground and at a distance of 1m outside the metallic fence. The fence will be bonded to the grading wire and to the station earth grid at the same intervals of bonding used for fencing as stated above.

5.7.7.2 Fences not connected to the main earth grid or isolated fence sections

As determined in the earthing design, the full fence or part of the fence can be designed to be not directly bonded to the main earth grid. This practice is generally not applicable with overhead circuits crossing the fence unless the fence is of sufficiently low earth impedance and touch voltage hazards are adequately managed. Metallic fences not directly bonded into the main earth grid require careful management of touch and transfer voltages particularly from the inside of the substation as bringing conductive materials or tools toward the fence could present a risk. Adequate controls including signage are required for all substations with fences not bonded to the main earth grid. Signage requirements are provided in SDI 528 – Substation Signs and Equipment Labels.

As a minimum requirement, an isolated fence section will be bonded to a separate grading wire at every second fence post. A minimum of one (1) 2.4m earth rod at either end must be installed and bonded to this section of the grading wire and the required number of additional earth rods is to be determined in the earthing design. The grading wire, earth rods and the fence will not be directly bonded to the substation earth grid.

All isolated fence sections will be electrically isolated from other fence sections by installing an insulated section on either side of the isolated fence section. The insulated section of the fence will be at least 1900mm in length to avoid hand to hand voltage. Safety voltages on non-earth grid bonded metallic section or sections of the fence must be tested for compliance during CIT. Metallic separation of services is also required, see 5.7.10.

Security camera posts, lights posts and other objects located near metallic fences which are not connected to the main earth grid must be located at a safe distance away from the fence to minimise the H-H touch voltage risks. Consultation with the Earthing & Power Quality Manager will provide these distances.

5.7.8 Lightning protection

5.7.8.1 Surge diverters

The surge diverter locations and earthing requirements are specified in SDI 520 – Lightning Protection and Insulation Coordination, and the equipment design specifications. A typical substation surge arrestor earthing arrangement is shown in Drawing no. 385813.
5.7.8.2 Lightning masts

The location of lightning masts, and lightning earthing system bonds to the earth grid or bonds to a separate earthing system must be carried out according to the lightning design in accordance with SDI 520 – *Lightning Protection and Insulation Coordination*.

The Earthing Designer will incorporate the earthing of the lightning system to the substation earthing design. Depending on lightning protection design, lightning masts will be located close to the main earth grid and bonded to the earth grid at the shortest distance. In addition to the main earth grid connection, an earth electrode will also be located immediately adjacent to the base of the mast as specified in SDI 520 – *Lightning Protection and Insulation Coordination*.

5.7.9 Safety equipment

5.7.9.1 Deluge showers

For switchyard shower installations, a single earth bond will be located within two (2) metres of the showerhead and in a visible location above ground.

For indoor shower installations the bond will be made onto the metallic water pipe in a visible location within the room or basement, typically within five (5) metres of the showerhead.

Earthing bonds will be sized for the fault level at the substation and in all cases they will be a minimum size of 95mm² or 120mm² depending on the earth conductor size determined in the earthing design.

5.7.10 Services

5.7.10.1 Telephone service isolation

The telephone service provided for the substation will be electrically isolated using suitable devices.

A line isolation device providing at least 15kV isolation will be interposed between the telephone instrument and the copper wires leading in from the exchange.

The isolation device will either:

- Use optical fibre isolation techniques described in AS/NZS3835.2:2006, with a line powered exchange side and a locally powered customer equipment (telephone instrument) side.
- Be supplied from an adjacent general power outlet and have 15kV isolating links on the telephone exchange side

The recommended clearances of earthed metallic objects in the substation near the telephone isolation equipment (which includes the conductive walls where applicable) will be in accordance with the recommended practices of AS/NZS3835.2:2006. For instance 1.5m separation and/or insulating locally earthed conductive fixtures within 1.5m to 2.5kV or the maximum value of EPR voltage, whichever is greater.

5.7.10.2 Water service isolation/earthing

Where copper or conductive water pipes are used for water reticulation inside the substation, appropriate controls are required. To mitigate touch and transfer voltage issues on conductive pipes the following procedure will generally be followed:

a) All metallic pipe work inside the substation will be electrically isolated from water authority mains near the boundary of the substation by using an insulated (PVC) section. Refer section 5.8 for approved products. A minimum 6m isolation section is required from the earth grid to the outside water service. The length of this isolated section must be determined in the
earthing design. This isolated section must be extended up to the acceptable EPR zone such that the safety requirements on outside metallic pipes are met in accordance with 5.2.4. In almost all cases, provision will be made to include at least 6m of non-conductive (PVC) pipework for the water service into the substation with 3m minimum radial measurement from the edge of the earth grid.

b) The metallic water pipe system inside substation will be connected to the earth grid at a minimum of two (2) separate locations. For pipes installed in the switchyard pipe risers must be used for earth bonding for easy inspection. Every pipe riser installed in the switchyard will be provided with a visible earth bonding. Ref Table E-1 for approved products.

c) If PVC pipes are used for water reticulation inside the substation there is no earthing requirement associated with the insulated pipes.

The Earthing Designer will provide earthing arrangement for metallic pipes in the design drawings as well as the fence and grading ring arrangement.

5.7.10.3 Electricity service from the street mains

Normally, station backup electricity service to substation auxiliaries is provided from street LV mains through an isolating transformer. This is to avoid inadvertent bonding of major substation earthing and distribution earthing through the LV service neutral. The LV neutral will be terminated at the neutral bar at the auxiliary supply panel inside the substation. Refer to SDI 511 for isolating transformer earthing arrangement.

Electricity service to zone substation without an isolating transformer can be provided for a ‘CMEN’ connected substation if the service neutral is adequately rated to carry fault current and the transfer touch voltage have been adequately managed. Where no isolation transformer has been installed, the LV neutral will be terminated at the neutral bar at the auxiliary supply panel inside the substation. In this situation the incoming neutral will be clearly labelled and the earth point identified on the single line diagram and at the AC supply panel.

5.7.10.4 Auxiliary low voltage (400V/230V) neutral earthing

LV neutral terminals of the auxiliary supply are earthed at following two (2) points as follows using standard earth cable size determined in the earthing design of the substation.

- The auxiliary transformer neutral bushing and
- Neutral bar of auxiliary supply panel.

5.7.11 Portable earthing

5.7.11.1 Outdoor bus bar facility for earthing

Outdoor busbars will have provisions for connecting portable earths when required. Stirrups/bail clamps will be fitted on the flexible and solid busbars to make earth points. The earth stirrup will be used to attach the phase clamp of the portable earth stick. Distinct locations of the stirrups on bus bars and details of the stirrups are provided in SDI 517 Busbars and Support Insulators.

An earthing point will be provided for attaching the portable earths on selected switchyard support structures.

A brass stud earthing terminal as specified in Drawing 385817 will be provided for connecting a T-bar earth clamp of a portable earth. The earthing terminal stub will be firmly fixed at the bottom of a selected support or post and firmly connected to the earth. The mounting height of the stub must be approximately 500mm from finish crushed rock layer level (refer to Figure 5-12) and have no other protrusions surrounding that may interfere with the earth clamp.
For substations where the fault level exceeds 24kA for 0.5 sec fault duration, two (2) earth points will be provided at 200mm apart for connecting two portable earths in parallel.

5.7.11.2 Portable earths

The quantity of portable earths that will be available in a substation depends on the equipment layout. As a minimum, there will be one (1) portable earth set for each outdoor high voltage feeder bay, or one (1) portable earth set for each transformer bay, whichever is the larger quantity.

Technical details of the portable earthing are provided in ETS 0020 – *Portable Earthing and Short Circuiting Equipment*.

5.7.11.3 Portable earth cabinets

Portable earthing devices (leads) storage cabinets will be provided for the storage of the substation portable earthing devices.

Two (2) cabinets will be installed at each transmission substation and one (1) cabinet at each zone substation.

Preferred location for portable earth cabinets;

- Transmission substations: One (1) cabinet directly alongside the driveway at the halfway point of the 132kV switchyard, and the other cabinet directly alongside the driveway at the halfway point of the 33kV switchyard.
- Zone substations: One (1) cabinet installed directly alongside the driveway at the halfway point of the 33kV switchyard.

However, if a stairway has to be used to gain access to the switchyard from the access road, the cabinets will be located adjacent to the switchyard so that portable earthing equipment does not have to be carried on stairways.

Vehicle/plant access and electrical safety clearances must be considered when determining locations for portable earthing cabinets.

The cabinets will be made from non-ferrous material such as aluminium, stainless steel or fibreglass and will be typically 2200mm wide, 2100mm high and 700mm deep. The cabinet will be totally enclosed to protect the earth leads and operating handles from rain, heat and sunlight. Each metallic cabinet must be bonded to earth grid with minimum one earth connection to earth grid.

A bracket or brackets will be provided in these cabinets for proper storage of these earth leads. The earth leads will be coiled and hanged on these brackets to prevent any damage to the earth leads.

5.8 Approved products

A list of commonly used major substation approved products is provided in Annexure E. These products will be read in conjunction with latest parts and accessories list provided on the company standards website.

5.9 Drawings

A list of standard arrangements and their associated drawings are provided in Table 5-6. Standard construction arrangements can be deviated with prior consent from the Earthing & Power Quality
Manager. The reason for the deviation will be stated clearly and objectively for consideration and assessment.

A list of typical arrangements is also provided. The typical drawings are to show conceptual arrangements only.

### Table 5-6: Standard drawing list

<table>
<thead>
<tr>
<th>Drawing no.</th>
<th>Amd no.</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>348244</td>
<td>A</td>
<td>DRIVEN EARTH ELECTRODE ASSEMBLY DETAIL</td>
</tr>
<tr>
<td>385817</td>
<td>A</td>
<td>SUBSTATION STANDARD EARTH STUD INSTALLATION FOR PORTABLE EARTH CONNECTION</td>
</tr>
<tr>
<td>385809</td>
<td>B</td>
<td>SUBSTATION SECURITY FENCE, GATE AND GENERAL EARTHING</td>
</tr>
<tr>
<td>385810</td>
<td>B</td>
<td>SUBSTATION STEEL REINFORCEMENT WELDING AND STANDARD EARTH CONNECTIONS</td>
</tr>
<tr>
<td>385816</td>
<td>A</td>
<td>SUBSTATION MISCELLANEOUS EQUIPMENT EARTHING</td>
</tr>
<tr>
<td>385821</td>
<td>B</td>
<td>SUBSTATION EARTH BAR, EARTH STRAP MOUNTING AND FABRICATION DETAILS.</td>
</tr>
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</table>

### Table 5-7: Typical drawing list

<table>
<thead>
<tr>
<th>Drawing no.</th>
<th>Amd no.</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>385812</td>
<td>B</td>
<td>POWER TRANSFORMER CONCEPTUAL EARTH CONNECTIONS</td>
</tr>
<tr>
<td>385813</td>
<td>A</td>
<td>SURGE DIVERTER/ ISOLATOR – EARTH SWITCH CONCEPTUAL EARTHING LAYOUT</td>
</tr>
<tr>
<td>385815</td>
<td>A</td>
<td>TYPICAL FAULT THROWER EARTHING ARRANGEMENT</td>
</tr>
<tr>
<td>385818</td>
<td>A</td>
<td>TYPICAL ZONE SUBSTATION EARTHING SYSTEM SCHEMATIC DIAGRAM</td>
</tr>
<tr>
<td>385820</td>
<td>A</td>
<td>EARTHING OF EARTH SWITCH AND EQUIPOTENTIAL EARTH MAT</td>
</tr>
<tr>
<td>385819-PAGE 1</td>
<td>A</td>
<td>CONCEPTUAL SUBSTATION EARTH GRID LAYOUT AND EQUIPMENT CONNECTIONS</td>
</tr>
<tr>
<td>385819-PAGE 2</td>
<td>A</td>
<td>CONCEPTUAL SUBSTATION SWITCH ROOM EARTHING</td>
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<tr>
<td>385819-PAGE 3</td>
<td>A</td>
<td>CONCEPTUAL SUBSTATION SWITCH ROOM EMBEDDED EARTHING</td>
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</tbody>
</table>
6.0 AUTHORITIES AND RESPONSIBILITIES

General Manager Asset Management has the final authority and responsibility for:

- approving this standard and the earthing risk management and design methodology major substations associated with the company’s network;
- advising the risk profile and methodology used for major substation earthing design to the Chief Operating Officer and the Board; and
- approving any design with a risk profile exceeding the minimum requirements of company Policy 9.2.5 upon recommendation from Manager Asset Standards & Design and Earthing & Power Quality Manager provided the risk is considered as low as reasonably practicable.

Manager Asset Standards & Design has the authority and responsibility for:

- ensuring this standard meets company policy, regulatory and the health and safety obligations of the company;
- advising on the risk management methodology for earthing hazards associated with the company’s network; and
- endorsing any design with a risk profile exceeding the minimum requirements of company Policy 9.2.5 upon recommendation from Earthing & Power Quality Manager provided the risk is considered as low as reasonably practicable.

Earthing & Power Quality Manager has the authority and responsibility for:

- the content of this instruction is kept up to date based on industry best practice and current research and literature regarding major substation earthing risk management;
- reviewing and approving earthing designs, drawings, commissioning, construction safety and test reports for major substations and providing earthing solutions and risk treatment based on the requirements of this and other relevant standards; and
- approving and endorsing any major substation bonding strategy on review of the risks associated.

Protection Manager is responsible for:

- providing the appropriate protection information for the major substation design as set out in 5.2.3.1; and
- providing information and technical support when the designer identifies an excessive risk which warrants special consideration by protection, and prompts that discussion through protection enquiries inbox for a risk/cost viable solution.

Major Substation Project Manager is responsible for:

- providing the necessary design inputs and project staging considerations as set out in 5.2.3.4;
- coordinating the earthing design requirements of the major substation with other asset Designers;
- building the earthing system in accordance with the approved design and this instruction; and
- as built drawings and testing is uploaded onto the company’s network system for the ongoing management of the major substation.
Electrical Engineers – Earthing are responsible for:

- reviewing earthing designs, drawings, commissioning, construction safety and test reports and providing earthing solutions and risk treatment based on the requirements of this standard;
- recommending earthing design reports and drawings to the Earthing & Power Quality Manager for approval; and
- reviewing periodic major substation earthing tests and identifying means to reduce risks as low as reasonably practicable.

Manager Network Connections is responsible for ensuring that all earthing designs carried out for contestable network projects are in accordance with this standard.

Accredited Service Providers (ASPs) and Earthing Designers are responsible for:

- their earthing designs comply with this standard;
- seeking clarification of this instruction, where necessary from the Earthing & Power Quality Manager, either directly or through the Network Connections contacts;
- work performed is carried out in accordance with local and statutory requirements;
- standard risk management principles and procedures are followed and public safety is not unduly compromised within their reasonable capability;
- preparing and advising on associated SWMS, SDR and risk management plans for construction and commissioning support; and
- coordinating the appropriate consultation with relevant stakeholders including but not limited to owners of any adjacent telecommunications, water, gas, and petroleum products systems as well as local councils and network planners.

Network Planners are responsible for planning the network with due regard to earthing system safety compliance in accordance with this instruction.

7.0 DOCUMENT CONTROL

Documentation content coordinator: Earthing & Power Quality Manager
Documentation process coordinator: Branch Process Coordinator
Annexure A – Major substation earthing design process

Figure A-1: Major substation earthing design management process overview
Annexure B – Earthing design report/(SDR) requirements
While not intending to limit the issues or strategy of the design report, the earthing report will be succinct and completed with following information for review and approval by the Earthing & Power Quality Manager:

1. Abbreviations and descriptions used in the report other than or contradictory to those stated in section 4.0 of this documents

2. Executive summary
   a. Short summary of design assumptions and results for both primary and secondary voltages:
   - Earth grid resistance, earthing system impedance, earth potential rise, EG-1 allowable touch voltage inside and fence from outside, EG(0) allowable voltages for MEN, Backyard and Urban for outside assets, worst mesh voltage, percentage worst touch voltage to EPR and distance to key voltage contours (430V and 1000V) from earth grid, distance to nearest telecom asset from earth grid, key protection assumptions.
   - Compliance levels and margin by which they will be achieved – particular emphasis will be given to any identified MEN touch voltages.
   - Summary of recommended works and plan with reference to the relevant section of the report for more details.

Remediation earthing designs must include before and after above stated information.

3. Design assumptions
   a. Network and specific information relevant to earthing installation.
   b. Summary of fault levels and fault clearing times for primary and secondary (and other) voltages. Analyse and list the most onerous fault scenario for different voltage levels. If applicable, show fault levels adjusted for DC offset and step clearing.
   c. Site inspection and findings. Other assets adjacent to proposed earth installations either have some interference or no interference from earthing installation.
   d. Planning information and future design consideration
   e. Summary of soil resistivity determination including:
      - Location of nearest weather station, received rainfall information with date and observed soil moisture condition during testing
      - Show soil test traverses shown geographically with reference to the major substations.
      - Tabulated test (data) distance (depths) against resistivity from each traverse. Highlight the traverse(s) identified as most suitable for earthing study.
      - Tabulate the soil layers with different soil resistivity closely matching the soil at the substation site used for the earth modelling.
      - pH and sulphide presence measurements and comments and controls related to corrosive effect of the soil at the site (where applicable)
   f. Calculated compliance level touch, step and hand to hand voltages for primary and secondary voltages for natural ground and high resistivity material layer.
   g. Compliance to Telecommunication assets and metallic pipelines in tabulated form.

4. Earthing system design
   a. Network and specific information relevant to earthing installation.
b. Site specific information and requirements of the main earth grid and embedded earthing.

c. Site specific information and requirements of fencing earthing and grading ring.

d. Information about auxiliary earthing systems and value of impedance of each system.

e. The following computer generated graphs/diagrams:
   i. Geographic view of the modelled earthing installation with adjacent metallic pipes etc. input used for the earthing modelling.
   ii. Graph to demonstrating EPR and soil voltage profile across the main earth grid and to the local surroundings down to 100V.
   iii. An EPR contour diagram superimposed onto a geographical area map to demonstrate the EPR hazard zone limit as given in AS 3835 (applicable 430V or 1000V contour) marking existing communication assets inside or near the contour where applicable.

f. Max EPR of the main earth grid for primary and secondary voltage fault scenarios.

  g. Determination of grid resistance and impedance of the earth system.

h. Cumulative earthing risk assessment of the major substation in accordance Annexure C. Particularly where the design requires the deliberate interconnection of the TS/ZS earth grid with the distribution and/or MEN earthing system.

   i. Fault Current distribution tabulated and vector summation diagram.

j. Conductor size determination: A table showing minimum conductor size for critical earth connections for most onerous fault conditions for primary and secondary voltage levels must be calculated and tabulated.

k. Lightning protection design if carried out including details of the study and recommendations in accordance with SDI-520 - Lightning Protection and Insulation Coordination.

   l. For existing substations, identified installation defects and proposed rectification must be recorded and included in the design report. Refer to the format shown in SMI-104 – Major substation earthing system test.

5. Special information on earthing safety during construction for people working in or near the energised substation that they required to be followed to manage hazardous voltages during earth faults.

6. Earthing design must address the transfer potential hazards and corrective actions for the connection of outlets in the substation to tanker vehicles.

7. If DC traction systems are located within 100m from the earthing systems or an asset is bonded to a railway substation a study must be carried out to determine the possibility of electrolytic corrosion of the earthing installation in accordance with 5.2.8
8. Drawings
   a. Earth grid layout and equipment connection including lightning protection system.
   b. Embedded earthing layout and specific equipment configurations.
   c. Simplified auxiliary earthing system diagram.
   d. Non-standard earthing hazard mitigation instructions
   e. Earthing drawings for construction.

9. Conclusions and recommendations
Annexure C – Distribution coordinated analysis (example)
An assessment of a particular zone substations distribution fault scenarios resulting in EPR and touch voltages around the zone substation is indicated in the figure below.

This assessment above includes consideration of varying secondary faults scenarios:
- **DBZS COM IDMT**: Sites with metallic return to source that are commonly earthed and have primary protection associated with the IDMT relay and associated CB at the zone substation
- **NO COM FUSE**: Sites without metallic return to source that are commonly earthed and have primary fuse protection.
- **NO COM IDMT**: Sites without metallic return to source that are commonly earthed but protected by zone substation IDMT relay and associated CB.
- **NO SEP FUSE**: Sites without metallic return to source that are separately earthed and are protected by primary fuse.
- **NO SEP IDMT**: Sites without metallic return to source that are separately earthed but protected by zone substation IDMT relay and associated CB.

These particular configurations have different clearance times but the sensitivity to protection clearance times is shown in the figure also. The ‘ZS IDMT Settings’ plot indicates the fault level to the maximum potential 13.1kA in accordance with company policy. A cumulative risk plot based on the principles of ENA EG-0 is included below.
The figure below indicates the inclusion of a protection hi-set at 3kA. It is noted that the concern with 'NO SEP IDMT' and ‘NO COM IDMT’ have been mostly reduced. Alternatively, these higher risk sites could have been bonded back metallicly to source to limit risk. Regardless it is prudent to ensure the future management of assets within a certain threshold are maintained (see *EDI 001 - Earthing Design Risk Assessment*).
Annexure D – Corrosion assessment

A corrosion assessment may be required as part of the earthing design (refer 5.2.8). Soil characteristics based on samples taken 100mm below the final surface will be taken around the substation site. Tests generally need to identify upper layer soil resistivity (see 5.2.3.2), soil pH values and detection tests for sulphides.

Risk based on pH testing and surface electrical soil resistivity with negative trace of sulphides:

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</tbody>
</table>

Risk based on pH testing and surface electrical soil resistivity with positive trace of sulphides:

| pH  | 0.0 | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 | 8.0 | 8.5 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| cm  | 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%| 150%|
| 15 | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| 16 | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% | 80% |
| 17 | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% | 70% |

In areas with fair to poor draining and moist soil conditions, the numbers above will be increased by 10%.
Annexure E – Commonly used major substation earthing components
A list of commonly used major substation approved products is provided below.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>GROUP</th>
<th>EE STOCK CODE</th>
<th>DESCRIPTION / DRAWING NUMBER</th>
<th>MANUFACTURER / PART #</th>
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<td>CABLE</td>
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<td>CABLE</td>
<td>1019223</td>
<td>SINGLE CORE 95MM² 19/2.45 ANNEALED CIRCULAR STRANDED NON-COMPACTED COPPER CONDUCTOR SDI 600-1000V PVC INSULATED BLACK CABLE.</td>
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<td>CABLE</td>
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<td>SINGLE CORE 95MM² 19/2.45 ANNEALED CIRCULAR STRANDED NON-COMPACTED COPPER CONDUCTOR SDI 600-1000V PVC INSULATED GREEN/YELLOW CABLE.</td>
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<td>CABLE</td>
<td>1552090</td>
<td>SINGLE CORE 120MM² 37/2.03 ANNEALED CIRCULAR STRANDED NON-COMPACTED COPPER CONDUCTOR SDI 600-1000V PVC INSULATED GREEN/YELLOW CABLE.</td>
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<td>1E</td>
<td>CABLE</td>
<td>1564137</td>
<td>SINGLE CORE 0.6/1.0KV CU 95MM², MULTI STRAND XLPE INSULATED GREEN YELLOW EPR OVER SKEATH ULTRA-FLEXIBLE WELDING CABLE</td>
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<td>2A</td>
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<td>1010335</td>
<td>SINGLE HOLE DOUBLE CRIMP LUG-TO 95 SQMM CABLE &amp; M12 BOLT-TINNED CU HEXAGONAL COMPRESSION.</td>
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<td>CLAMP GROUNDING ALM-TG-12</td>
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<td>CRIMPED CONNECTOR ‘6’ TYPE CO/95</td>
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<td>1552116</td>
<td>CONNECTOR CLAMP, ELECTRICAL ;PARALLEL GROOVE CLAMP BIMETALLIC RANGE 25-150MM2 AL 10-95MM2 CU 2 BOLT</td>
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<td>2I</td>
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<td>1020936</td>
<td>EARTH ROD M15X2400 STEEL COPPER CLAD</td>
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<td>7B</td>
<td>EARTH MAT</td>
<td>1550722</td>
<td>EQUIPOTENTIAL MAT 5'X5' WITH 1.5M BRAID AND CLAMP</td>
<td>THE ENERGY NETWORK</td>
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<td>8A</td>
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<td>LV INSULATOR H50X50MM DIA M12 INTERNAL THREAD</td>
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<td>9A</td>
<td>GENERAL</td>
<td>1069858</td>
<td>EARTHING COMPOUND - GOOD EARTH 50KG BAG</td>
<td>ERICO</td>
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<td>9B</td>
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<td>1563444</td>
<td>CMEN LABELS &quot;WARNING: CMEN EARTH CONNECTION DO NOT DISCONNECT&quot; (REFER SDI528)</td>
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<td>FENCE LABELS &quot;ISOLATED FENCE - DO NOT CONNECT TO SUBSTATION EARTH GRID&quot; (REFER SDI528)</td>
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<td>9D</td>
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<td>PVC PIPE ELECTRICAL ISOLATION (CLASS 18, PVC PRESSURE PIPE)</td>
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<td>9E</td>
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<td>9F</td>
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<td>MUSHROOM HEAD SPIKE-POWERS 6.5MMX50MM SS GRADE 316 FOR FIXING UP TO 19MM MATERIALS TO</td>
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<td>DESCRIPTION / DRAWING NUMBER</td>
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<tr>
<td>9G</td>
<td>GENERAL</td>
<td></td>
<td>CONCRETE OR BRICK PACK OF 100</td>
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<td>9H</td>
<td>GENERAL</td>
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<td>MUSHROOM HEAD SPIKE-POWERS 5MMX38MM SS GRADE 316 FOR FIXING UP TO 6MM MATERIALS TO CONCRETE OR BRICK PACK OF 100</td>
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<td>GENERAL</td>
<td>SC17842</td>
<td>PROTECTOR, ELECTRICAL CABLE ; COVER STRIP 200MM WIDE 4.8MM THICK MIN. ORANGE HEAVY DUTY - 25M ROLL PRINTED WITH &quot;DANGER ELECTRICITY&quot; AND MANUFACTURERS NAME IN BLACK INK</td>
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<td>LIGHTNING MAST 15M</td>
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