Standard

Substation Lightning Protection and Earthing Standard

R522692

Version 1.0, June 2018

Tasmanian Networks Pty Ltd (ABN 24 167 357 299)

Authorisations

Action	Name and title	Date
Prepared by	Michael Verrier, Senior Asset Strategy Engineer	June 2018
Reviewed by	Santosh Dhakal, Asset Engineer	June 2018
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Review cycle	30 months	

Responsibilities

This document is the responsibility of the Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

Please contact the Asset Strategy Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

Minimum Requirements

The requirements set out in TasNetworks' documents are minimum requirements that must be complied with by all TasNetworks team members, contractors, and other consultants.

The end user is expected to implement any practices which may not be stated but which can be reasonably regarded as good practices relevant to the objective of this document.

Record of revisions

Section number	Details
Entire doc	Copied over verbatim from superseded Transend to TasNetworks template. Updated Transend to TasNetworks document reference numbers where known including Australian Standards.

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1 General

Lightning protection and earthing systems are an essential part of the transmission system. They are required to constrain earth potential gradients to safe voltage and current levels, for both system normal and fault conditions, without posing a risk to personnel, public or equipment and to provide a low resistance path to ensure protection relays operate correctly.

The earthing system provides a common earth for all electrical equipment, fences, cables, metallic structures, etc and minimises interference to internal and external telecommunications and control systems.

Lightning protection systems, in tandem with the earthing system dissipates and controls lightning strikes and other over voltages that may adversely affect the transmission system.

1.1 Purpose

To define the requirements for substation lightning protection and earthing systems under the responsibility of Tasmanian Networks Pty Ltd (hereafter referred to as 'TasNetworks').

1.2 Scope

This standard applies to all substation lightning protection and earthing systems under the responsibility of TasNetworks and is applicable to new installations as well as redevelopment of part or all of existing installations.

This standard contains requirements for:

(a) system analysis studies and design;

(b) supply;

(c) installation; and

(d) testing and commissioning with complete documentation of substation lightning protection and earthing systems.

1.1 Objective

TasNetworks has developed this standard to ensure:

(a) personnel and public safety;

(b) environmental hazards are identified, analysed and eliminated or control measures adopted;

(c) that the requirements of the Tasmanian Electricity Code, National Electricity Rules, and relevant Australian legal requirements are met;

(d) risks to TasNetworks' assets are minimised;

(e) ease of operation and maintenance;

(f) minimum disruption to the electricity transmission system following network disturbances;

(g) that the requirements of TasNetworks performance objectives are met; and

(h) that TasNetworks meets its obligations in its connection agreements to its customers.

1.1 Precedence

Any apparent conflict between the requirements of this standard and the law, mandatory requirements, industry standards, project specifications, non-statutory standards or guidelines, and any other associated

documents should be brought to the immediate attention of TasNetworks for resolution and no action must be taken that might result in a breach of law or mandatory requirement.

Where there may be a conflict between the requirements of this standard and any:

(a) law, mandatory requirement or industry standard, then that law or statutory requirements will prevail over this standard;

(b) non-mandatory standard, or guideline, then this standard will prevail over that standard or guideline; and

(c) project specification, then the contract documentation will prevail over this standard.

Except that, the selection of equipment, design and all works associated with substation lightning protection and earthing systems must conform to the requirements as specified in document R522687 General Substation Requirements standard.

Approval for a deviation to this standard may only be accorded if it does not reduce the quality of workmanship, pose a safety risk to personnel or equipment and does not deviate from the intent of this standard. Deviations if any must be specifically requested and approved in writing by TasNetworks' Network Performance and Strategies Manager.

1.1 References

As a component of the complete specification for Substation Lightning Protection and Earthing, this standard is to be read in conjunction with other relevant standards as applicable. Unless otherwise specified in the project specification, the equipment shall be in accordance with the latest edition and amendments of the standards listed below. The following documents, without reservation, contain provisions that, through reference in the text, constitute the requirements of this standard:

1.1.1 TasNetworks Standards

R522696	Surge Arrester Standard
R527693	Network Transformer Standard
R586396	Extra High Voltage Disconnector and Earth Switch Standard
R565984	AC Distribution System Standard
R522693	DC Distribution System Standard
R590634	Substation Civil Design and Construction Standard
R527890	Supply Transformer Standard
R522687	General Substation Requirements Standard
R579297	Security Fences and Gates Standard
R246497	Testing, Commissioning and Training Standard
R590630	HV and LV Cable Systems Standard
R565983	High Voltage System Standard
R574178	Substation Lightning Protection and Earthing Information to be provided with Tender
R574177	Substation Lightning Protection and Earthing Deliverables
R522697	Temporary Earthing of Substation Equipment Standard
R565990	Extra High Voltage Indoor Gas Insulated Switchgear Standard

R1063711	Transmission Line Design Standard
R1047217	Transmission Line Construction Standard

1.1.2 Australian Standards

Insulation co-ordination – part 1: Definitions, principles and rules	AS 1824.1
Insulation co-ordination (phase-to-earth and phase-to-phase, above 1 kV) – Application guide	AS 1824.2
Common specifications for high-voltage switchgear and controlgear standards (IEC 60694)	AS 2650
Power installations exceeding 1 kV a.c.	AS 2067
Galvanic (sacrificial) anodes for cathodic protection	AS 2239
Electrical installations – Selection of cables – Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions	AS 3008.1.1
Insulators – Ceramic or glass – Station post for indoor and outdoor use – voltages greater than 1000 V a.c. – Characteristics	AS 4398
Standard voltages	AS 60038
High-voltage test techniques – Definitions and requirements for on-site testing (IEC 60060-1)	AS 60060
High voltage switchgear and control gear - Dimensional standardization of terminals (IEC/TR 62271-301)	AS 62271.301
Lightning protection	AS/NZS 1768
Electrical installations (known as the Australian/New Zealand Wiring Rules)	AS/NZS 3000
Earth potential rise-Protection of telecommunication network users, personnel and plant	AS/NZS 3835
Risk analysis of technological systems – Application guide	AS/NZS 3931
Risk management	AS/NZS 4360
Electrical hazards on metallic pipelines	AS/NZS 4853
Overhead electrical line design, part 1: Detailed procedure	AS/NZS 7000
Effects of current on human beings and livestock – Part 1: General aspects	AS/NZS 60479.1
Electromagnetic compatibility (EMC) -Testing and measurement techniques - Surge immunity test (IEC/TR 61000)	AS/NZS 61000.4.5

1.1.3 IEC documents

International electrotechnical vocabulary	IEC 60050
Insulation co-ordination - Part1: Definitions, principles and rules	IEC 60071-1
Insulation co-ordination (phase-to-earth and phase-to-phase, above 1 kV) – Application guide	IEC 60071-2
Insulation coordination – Part 4: Computational guide to insulation coordination and modelling of electrical networks	IEC/TR 60071-4
Insulated bushings for alternating voltages above 1000V	IEC 60137
Effects of current on human beings and livestock – Part 1: General aspects	IEC 60479-1

Effects of current on human beings and livestock – Part 5: Touch voltages threshold values for physiological effects	IEC 60479-5

1.1.4 Other documents

Building code of Australia	BCA
Code of practice for design of high-voltage open-terminal stations	BS 7354
Overhead lines exceeding AC 45kV – General requirements – common specifications	BS EN50341-1
Power system earthing guide - Part 1: Management Principles	ENA EG0
Substation earthing guide	ENA EG1
National Electricity Rules (AEMC Version)	NER
IEEE Guide for Safety in AC Substation Grounding – The Institute of Electrical and Electronic Engineers	IEEE Std 80
IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System	IEEE Std 81
IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding	IEEE Std 837
IEEE Guide for Direct Lightning Stroke Shielding of Substations	IEEE Std 998
Guide for Temporary Protective Grounding Systems Used in Substations	IEEE Std 1246 IEEE
Guide for Safety in the Installation of Mobile Substation Equipment	IEEE Std 1268 IEEE

1.1.5 Reference drawings

Refer to Appendix A for a list of reference drawings.

2 General requirements

Project specific requirements for substation lightning protection and earthing system requirements will be listed in the project specifications.

Specifications for surge arrestors are detailed in TasNetworks' Surge Arrester Standard, document R522696.

2.1 Service conditions

Service conditions shall not exceed the limits stated in AS 2650, together with the particulars of the Tasmanian Electricity Code, National Electricity Rules, relevant Australian legal requirements, and equipment specific service conditions as stated in the respective TasNetworks equipment standards. Where service conditions are not stated in the equipment specific standards, the service conditions as stated in Table 1 will be applicable.

The following service conditions will be applicable to substation lightning protection and earthing systems:

(a) specific environmental conditions for particular works will either be stated in the project specifications or the project specification will identify a requirement to obtain these by test and measurement;

(b) all elements that form an integral part of the lightning protection or earthing system must have a minimum design life of 60 years. Evidence must be supplied by the manufacturer supporting its claim that the equipment supplied and installation meets this requirement; and

(c) materials selected in the manufacture and installation of the lightning protection and earthing systems must be compatible such that corrosion is minimised at the interface of dissimilar materials and the design life is not compromised.

Specific environmental conditions for particular works will be stated in the project specifications or the project specification will identify a requirement to obtain these by test and measurement.

Table 1 Service conditions and ratings for lightning and earthing systems

Sr. No.	Parameter	Unit	Value					
1	Nominal system voltage (V_n)	kV	6.6	11	22	33	110	220
2	Rated voltage	kV	7.2	12	24	36	123	240
3	Power frequency withstand voltage	kV_{rms}	20	28	50	70	230	460
4	Lightning impulse withstand voltage	kV_{peak}	60	75	125	170	550	1050
5	Normal voltage variation (criteria for equipment design)	$\%V_n$	$\pm$ 10					
6	Number of phases	-	3					
7	Rated frequency	Hz	50					
8	Normal operating frequency excursion band	Hz	48.8 – 52					
9	Power system frequency range	Hz	44.8 – 52					
10	Future maximum single phase to earth fault current	kA	As per project specifications					
11	Time duration for maximum single phase to earth fault current	s	0.5					
12	Neutral earthing	-	Solidly earthed at supply transformer neutral					
13	Normal combined voltage and frequency variation (criteria for equipment design)	%	$\pm$ 10					
14	Design maximum continuous ambient temperature	°C	40					
15	Design minimum continuous ambient temperature	°C	-5					
16	Altitude	m	$\leq$ 1000					
17	Maximum relative humidity	%	95					

2.1 Performance

The following performance criteria will be applicable to substation lightning protection and earthing systems:

(a) substation lightning protection and earthing systems and their components must be designed and installed to support reliable and secure operation of the power system.

(b) the selection of the equipment must be appropriate to satisfy the design criteria and to meet or exceed the specified performance; and

(c) the selection of the equipment, design and all works must be based on the most onerous of:

(i) requirements mentioned in this standard;

(ii) project specifications;

(iii) design fault levels as stated by TasNetworks in the project specifications; or

(iv) results from system analysis, insulation co-ordination and earthing studies, as stated in this document and TasNetworks' General Substation Requirements Standard, document R522687 and

(v) quality requirements, as stated in TasNetworks' General Substation Requirements Standard, document R522687

2.1 System analysis

Based on the information provided in the project specifications and other documents, a detailed system analysis may be required to be conducted to determine the rating and specifications of all elements provided with the substation lightning protection and earthing system works.

The Contractor will be responsible for all works associated with the collection of data required for a system analysis.

Where stipulated in the project specifications the following studies may be required to be performed to ensure that all possible system conditions including, without limitation, planned and/or forced outages of equipment are adequately catered for in the final design:

(a) an insulation coordination study;

(b) a lightning protection study; and

(c) an earthing study.

System analysis may be required to be conducted for all new works, and for existing works that will be interfaced with. Should the works be staged a system analysis must also be conducted for each stage of works and must support as a minimum the:

(d) design;

(e) selected equipment;

(f) sequence of works;

(g) settings and configuration of protection and control equipment; and

(h) settings and configuration of monitoring equipment.

All system analysis study reports must be submitted to TasNetworks for approval. No detailed designs may proceed unless TasNetworks has approved the system analysis study reports.

3 Insulation coordination study

An engineering study shall be performed to ensure that personnel and equipment are protected by ascertaining the correct ratings of equipment for the specific works and also serves to ensure that all system changers have been incorporated into the overall substation design. Where required in the project specification the study shall include an insulation coordination study and where appropriate a load flow/voltage drop study, a harmonic analysis, and a motor starting study.

An insulation coordination study must be undertaken for the proposed solution, utilising commercially available software packages, to ensure:

(a) the appropriate basic insulation level (BIL) for all the items of the equipment under any operation scenario is maintained;

(b) the applicable specific insulation creepage distance of all the items of plant installed is suitable for the environment it will operate;

(c) the satisfactory location and rating of surge protection devices are considered; and

(d) the compatibility of the proposed solution with the rest of the equipment.

The required minimum BIL will be stated in the individual equipment standards unless specified otherwise in the project specifications.

The report must detail all operational scenarios and list parameters to confirm the applicability of the design insulation levels of all equipment. No equipment, whether existing or new, may be exposed to over-voltages under any circumstances.

4 Lightning protection detailed design parameters

This standard is applicable to conventional lightning protection systems that comprise air terminals, down conductors, earth terminations networks and surge protection devices.

The means of design calculations, together with drawings, schematics and other relevant documentations must form part of the detailed substation lightning protection and earthing system design and must be submitted to TasNetworks for approval.

Lightning protection system must be designed and installed such that:

(a) the design and all drawings for the substation lightning protection shall, as a minimum, be based on the recommendations of AS/NZS 1768 and must be taken as mandatory expect where exceeded by this standard or the project specifications;

(b) all buildings and equipment at the substation be shielded from lightning at all times;

(c) where lightning protection exists at a particular site, the adequacy of the existing lightning protection installation must be verified, to determine if additional lightning protection should be installed;

(d) for all sites where work is performed, an analysis of the need for lightning protection must be performed, as per AS/NZS 1768, and if required, new lightning protection systems must be installed for new and modified buildings and equipment to provide lightning protection for the entire new facility;

(e) lightning protection conforms to either category III for high priority installations or category IV for lower priority installation as per AS/NZS 1768. TasNetworks will nominate the lightning protection category in the project specifications;

(f) lightning protection be provided, where possible, by utilising the highest points on termination tower structures within the switchyard providing strike attachment points, to meet the coverage as determined by the rolling sphere method or collection volume method.

(g) overhead earth conductors or active terminals such as dynaspheres must not to be used for shielding busbars or circuits, including transformer circuits within future substations. Shielding must be provided either by masts or a combination of masts;

(h) where lighting masts are to be provided they must be strategically located within the substation boundaries to ensure lightning protection coverage is optimised;

(i) lightning masts must be connected by a dedicated insulated conductor directly to the substation earth grid. The conductor must be supported to the tower/structure with the necessary clamps;

(j) any overhead transmission line earth wire or any Optical Fibre Ground Wire (OPGW) must be terminated with a single disc insulator between the helical wrap attachment fitting and the termination tower structure. A removal conductor or link must be provided at the base of structure/tower to solidly earth the overhead earth wire or OPGW to the ground mat. The necessary operational earthing point must be provided at the top of the link to facilitate the need for the link to be disconnected while the substation is in service. This is to provide temporary isolation for testing the station earthing system independent of remote earth connections while the substation remains in service as shown conceptually on drawing number TSD-SD-808-0077-001; and

(k) all transmission line circuits exiting from and entering the substation must be effectively shielded with an earth wire or OPGW to prevent lightning strikes on phase conductors within the vicinity of the substation and conform to the requirements as stated in the TasNetworks' Transmission Line Design Standard, R1037048. The type and minimum length of earth wire or OPGW on each transmission line will be specified in the project specifications.

A complete detailed report with all associated calculations and drawings must be submitted to TasNetworks for approval prior to award of the contract.

5 Earthing system general design criteria

An earthing system study must be conducted. Where applicable a report, detailing the criteria used for selection of the size of the earthing busbar and the verification of the size, must be presented to TasNetworks for approval.

TasNetworks requires its earthing systems to be designed and installed to ensure:

(a) effective operation of protection equipment under earth fault conditions;

(b) a system of equipotential bonding is provided for protection of personnel;

(c) step and touch potentials are kept to safe levels;

(d) the transfer of voltages out of the substations is controlled; and

(e) interference to telecommunication systems is limited.

An earthing system must be provided for all buildings and switchyards. Equipment to be connected to an effective earth shall include, without limitation the following:

(f) the earth grid;

(g) all accessible exposed metal parts containing or supporting extra-high and high voltage conductors, including metal parts mechanically connected to the exposed metal parts;

(h) metallic substation enclosures of all extra-high and high voltage and low voltage equipment;

(i) surge protection devices;

(j) cable sheaths/screens/armouring;

(k) exposed metal of all floor and wall reinforcing;

(l) metallic fences, both internal and boundary;

(m) fixed metal items within the substation building, eg door frames, metal roofs and down pipes; and

(n) metal pipes, eg water pipes, within the substation boundary.

5.1 Earthing system detailed design parameters

The means of design calculations, together with drawings, schematics and other relevant documentation must form part of the detailed substation lightning protection and earthing system design and must be submitted to TasNetworks for approval.

Substation earthing must be designed and installed such that:

(a) the substation earthing design must be based on the methodology as described in AS 2067, AS/NZS 3000, ESAA Guide to Substation Earthing EG(1), and IEEE Std 80 and must be taken as mandatory except where the requirements of this standard or the project specifications are more onerous;

(b) earthing of Gas Insulated Switchgear (GIS) substations must be designed to minimise the effects of touch and step potentials plus the effects of electromagnetic radiation. TasNetworks' Extra High Voltage Indoor Gas Insulated Switchgear Standard, R565990and the relevant IEC standards shall apply;

(c) the earthing design shall be undertaken by computer analysis and not by empirical calculations. However, simple sites with homogeneous soils and no significant local underground services may be designed using the manual calculation methods defined in IEEE 80 and ESAA EG(1);

(d) the earthing system must be designed so that it can withstand the future maximum earth fault current for the minimum duration of 2 seconds without suffering thermal and mechanical damage. The calculation of future maximum earth fault current must be based on the data supplied in the project specifications;

(e) TasNetworks must approve the method to be adopted and the type of software to be used prior to commencing the design. The approved packages are:

(i) Current Distribution, Electromagnetic Fields, Grounding and Soil Structure Analysis (CDEGS); and

(ii) Safearth SafeWin2.

(f) the connection of equipment to the earth grid must be made by a dedicated earthing conductor and not through steel support structures;

(g) all metalwork and metal parts of equipment within the substation that do not carry current under normal power system conditions, but may be inadvertently energised from the electrical system or exposed to lightning, with the exception of concrete reinforcing steel, must be earthed directly and independently to the substation earth grid, as detailed in TasNetworks drawing TSD-SD-809-0002-001. Concrete reinforcing steel within new transformer plinths, oil bunds, termination tower structures and building foundations may be considered as part of the earth grid. Reinforcing in other concrete may be earthed if required as part of the earthing design;

(h) all underground metallic pipes (eg. water) entering a substation shall be electrically isolated by the permanent installation of an approved isolating joint one metre outside the substation boundary. Isolation is to provide protection against electrolytic corrosion especially where there is DC traction in the nearby vicinity; and

(i) the earthing system analysis and design must be submitted to TasNetworks for approval prior to commencement of works. This design information must include as a minimum the following details:

(i) earthing of both existing and new buildings, including extensions to the existing buildings;

(ii) the location of concrete reinforcing connections to the earthing system; and

(iii) the types of earthing conductor and connection and jointing methods to be employed.

5.1 Earth electrodes and earth conductors

The following will be applicable to earth electrodes and earth conductors:

(a) in existing substations, should the existing buried earth grid conductors be required to be replaced in the vicinity of the work site, any existing earth electrodes may be left in ground but must be bonded to

the new earth grid. The new earth grid conductors and new earth electrodes installed shall be clearly distinguishable from existing ones;

(b) the earth electrodes shall not be driven. Drilled holes (50 mm diameter) back filled with a conducting medium mixture, for example bentonite, gypsum and sodium sulphate (50 per cent, 45 per cent, and 5 per cent by weight respectively) mixed to AS 2239 - Cathodic Protection), or similar must be used as a means of installation. The top of each earth electrode is to finish 200 mm below ground level;

(c) all earth conductors that are not directly buried must be secured firmly and supported neatly on supporting walls, structures and concrete surfaces at maximum spacing of 300 mm for the full length. All runs must be straight with no visible sag;

(d) earthing on structures shall comprise either insulated copper conductor or bare copper strip, suitably sized for the future maximum earth fault current at the point of installation as specified in the project specifications. The minimum conductor cross sectional area must be as detailed in TasNetworks drawing TSD-SD-809-0002-001;

(e) Connection of earth electrodes to the earth grid through U-bolts is not acceptable. The stranded copper wire must be brazed to the earth electrode and the other side of the wire must be connected to the earth grid using C-crimps;

(f) all new substations must have a test electrode installed. The test electrode is to be easily disconnected from the earth grid, without any effect on the earth grid, to allow resistance testing of the electrode and to check physical deterioration. The test electrode must be located where it is easily accessible and can be withdrawn without the need to remove supply from any item of live plant. The test electrode must be identified by indelibly marked by inscribing the word "TEST" on the lid; and

(g) all existing earth electrodes shall have their individual resistance to the general mass of earth measured and recorded. This information must be provided to TasNetworks for approval prior to commencement of works.

5.1 Earthing of primary equipment

Earthing of primary equipment must comply with the following requirements:

(a) conductors bonding metalwork to the earthing system must attach to the metalwork via dedicated earthing connection points, earthing plates or similar prefabricated earthing point welded to the structure;

(b) tinned copper is the material that must be used for earth connection points because of its conductivity and durability, however alternative materials may be used if better suited for the environment in which they are to be installed. Recommended alternative materials must be provided to TasNetworks for approval prior to commencement of works. Typical materials for which current carrying components parts can be referenced in AS/NZS 1768;

(c) on site drilling of the equipment casing or other installation structure for earth bonding connection will not be permitted. The earth connection points must be clean and free from paint or corrosion before and after making the connection;

(d) where steel support structures or ground mounted items of equipment covers a surface area of one square metre or greater, then two earth connection points must be provided at diagonally opposite points of the structure or equipment and be connected to the earth grid. For steel support structures or ground mounted items of equipment covering a surface area of less than one square metre, one earth connection point is acceptable;

(e) Where the concrete plinth has a surface area equal to or greater than one square metre but smaller than 12 square metres, the reinforcing mesh must be connected to the earth grid in at least one location. Where the concrete plinth has a surface area equal to or greater than 12 square metres, the reinforcing mesh must be connected to the earth grid in at least two locations at diagonal ends of the

plinth. Where the concrete plinth has a surface area of less than one square metre, the reinforcing mesh (concrete reinforcement) associated with the installation shall be bonded to form part of the earthing system. If not bonded, verification is necessary to ensure that all safety requirements are met. The only acceptable method of verification is to perform the appropriate tests to ensure all safety requirements are satisfied. Theoretical modelling does not constitute a valid method of verification;

(f) the material used for the earth tabs must be of stainless steel (304 or 316). The earth tabs to be welded directly to the reinforcement bar using 309 electrodes;

(g) earthing straps or copper bars leading down from the equipment to the pedestal footings must be secured to the equipment pedestal or support;

(h) non-conductive Nylon spacers must be installed between the equipment pedestal or support and the copper earth strap, at interval of 300 mm, to prevent contact between two dissimilar metals; and

(i) earth connection points on equipment shall be indelibly marked with the symbol for protective earth.

5.1 Earthing of disconnectors and earth switches

Earthing of disconnector and earth switches must comply with the requirements as stated in TasNetworks' Extra High Voltage Disconnector and Earth Switch Standard, document R586396.

Earth switches are used by TasNetworks for the purpose of discharging equipment that is normally energised. Earth switches also act as safety devices and therefore must be rated to carry the specified three phase fault current.

In addition to the requirements stated in the standard the following requirements must be complied with:

(a) disconnectors and earth switch operating handles must be earthed via a flexible copper earth conductor which in turn is directly bonded to a copper earthing strap leading directly to the switchyard earth grid. The flexible earth conductor and earth strap must form a continuous electrical path directly to earth and not use the equipment structure as an earth path;

(b) the flexible earth conductor must not impede the Operator or operation of disconnector or earth switch nor must it be possible for the flexible earth conductor to snag during the opening and closing operation; and

(c) earth switch blades must be bonded directly to the earth grid via an earth conductor that provides a visible short circuit directly between phases.

5.1 Earthing of surge arresters

Surge arresters must comply with the requirements as stated in TasNetworks' Surge Arrester Standard, document R522696. The earthing of surge arresters must comply with the following requirements:

(a) adequate electrical connection from the surge arrester to the earth grid, including the earth conductor, must comply with the requirements as stated in Section 5.3;

(b) electrical connection from the surge arrester to the earth grid, including the earth conductors and connections must be rated for maximum fault current and duration as stated in the project specifications;

(c) surge arresters installed to protect power transformers must be installed as close as possible to the terminals of the transformer they are designed to protect, and have as short and direct a path to the earthing system as practical;

(d) transformers must be supplied with 220 kV and/or 110 kV surge arrester mounted brackets directly attached to the transformer tank. Insulating bases must be provided and fitted;

(e) the earthing points of the surge arresters must be connected together using copper flat bar;

(f) the copper flat bar must be tinned where a bolted connection is made;

(g) an insulated conductor must be used to connect the copper flat bar to the surge counter;

(h) one surge counter must be provided for each three phase set of surge arresters and be clearly readable from ground level, at no greater than 1.1m from the transformer base;

(i) the surge counter must be installed such that the surge counter tail can be connected directly to a transformer earthing point situated below the surge counter;

(j) the transformer earthing point, to which the surge arrestor tail is connected, must be directly connected to an earth electrode and earth grid system via a dedicated insulated earth conductor; and

(k) sharp bends in the earth conductors must be avoided.

5.1 Earthing of secondary equipment

Earthing of secondary equipment must comply with the following requirements:

(a) an earthing terminal must be provided on the frame of every device or enclosure to which electrical supplies are taken, or that could be subjected to fault conditions. An earthing terminal must also be provided for all panel equipment, for example instruments, control switches and relays;

(b) earthing terminals must be manufactured from brass, tinned copper, or stainless steel and must be supplied complete with bolt washers and nuts. The earthing terminal and associated bolt washers and nuts must be appropriately sized to the maximum possible earth fault current at the point of connection. The nuts must be fitted with a locking device;

(c) the construction of the device frames shall ensure electrical continuity of exposed metal is maintained to the earthing terminal;

(d) the earthing terminal on the metallic frame of devices must be connected to the earthing busbar. Earthing terminals of the panel equipment must be connected to the earthing busbar using a minimum 2.5 mm^2 copper conductor of seven strands;

(e) a copper earthing busbar of minimum cross section 25 mm by 3 mm must be provided at the base of electrical equipment enclosures;

(f) for enclosures where only top cable entry is provided, the enclosure must include a minimum 25 mm by 3 mm copper strip connection in the vicinity of the top gland plate for connection of an external earthing conductor;

(g) all switchgear and control panel doors must be connected to the respective panel housing using 4 mm2 flexible copper earth conductor; and

(h) earthing bus bars must be connected to the main earth bus.

5.1 Earthing within buildings

Earthing within buildings must comply with the following requirements:

(a) all buildings within the substation must be earthed as appropriate for the construction and usage of the building. Meeting this requirement may involve refurbishment of earthing systems within existing buildings. Contractors shall make an assessment of the building and existing earthing in order to identify all works associated with such refurbishment and a proposal must be submitted to TasNetworks for approval prior to commencement of works;

(b) in buildings containing switchrooms, the main earth busbar within the switchroom shall form a complete ring and be connected to two different earth grid conductors at opposite ends of the building; and

(c) sections of metallic cable support systems must be electrically bonded at all mechanical joints and positively connected to the earth grid at intervals not exceeding 15 metres. As a minimum, both ends of pipes and metallic cable support systems must be connected to the earth grid.

5.1 Earthing of security fences and gates

Earthing of security fences and gates must be earthed in accordance with TasNetworks' Security Fences and Gates Standard, R579297 and in particular drawings TSD-SD-809-0002-001 and TSD-SD-809-0002-002.

Where required by the earthing design, all exposed metalwork including fence structures and gates within the substation must be directly and independently earthed to the substation earth electrode and earth grid system.

5.2 Earthing of DC distribution systems

Where a dc distribution system is installed at a substation, it shall be independently earthed. The dc distribution system must NOT be earthed to the substation earth grid. The earthing of the dc distribution system must comply with the general intent of this standard.

6 Earthing joints and connections

Earthing joints and connections must comply with the following requirements:

(a) jointing of earthing conductors must be in accordance with AS 2067 and drawing TSD-SD-809-0002-001;

(b) joints and connections in the earthing system must be bolted, brazed, welded or made by means of tested and approved proprietary brands of compression type fittings. The contractor shall submit to TasNetworks a list of proprietary brands with a preferred brand for approval prior to commencement of works;

(c) sample joints and test certificates must be submitted to TasNetworks with "detailed design information" for approval. The contractor must submit a sample of a brazed joint for copper strip to copper strip;

(d) copper cable lugs for insulated conductor must be a tin plated sealed palm, outdoor type;

(e) earth plates, earth lugs or prefabricated earthing points must be provided on the equipment casing, structure or any other non-current carrying metal part for earth bonding connections. On-site drilling of equipment casings or support structures to provide an earth bonding connection is not acceptable;

(f) all earth connection surfaces must be free from corrosion or oxidisation before and after the connection is made;

(g) fault current carrying joints and connections must be designed such that they are capable of withstanding the maximum possible earth fault current at the point of connection;

(h) soft-soldered joints are not acceptable in any form;

(i) after jointing is complete, all joints must be protected from oxidisation. For example, by coating with an appropriate oxide-inhibiting compound;

(j) below ground earth grid conductors joints are to be made using a minimum of two compression C-crimp connections per cross-joint and three compression C-crimp connections per tee joint; and

(k) Ductor tests (4–wire DC current injection) must be performed on each joint to ensure continuity and a positive connection. A record of results must be submitted to TasNetworks.

6.1 Jointing techniques

The following proprietary brand(s) and jointing techniques are acceptable for use in TasNetworks' earthing system:

(a) Burndy fittings and/or C-crimps for compression joints;

(b) bolted joints; and

(c) Eutecrod 180 yellow tip for brazing joints.

The following jointing practice must be observed:

(d) all brazed joints in flat copper strips must be lapped by the full width of the strip;

(e) flat copper strip to stranded conductor joints must be formed with the copper strip wrapped round the stranded conductor and compressed before being brazed;

(f) C-crimps to be used for joints between stranded conductors using the appropriately sized die for the C-crimps; and

(g) butt joints are not permitted.

The Contractor may propose an alternative practice and materials. However it must be demonstrated that the proposal meets or exceeds the performance of TasNetworks' methodology.

Details of proposed jointing technique(s) must be submitted to TasNetworks for approval prior to being implemented.

6.1 Compression joints

Compression joints must comply with the following requirements:

(a) compression joints are required on stranded conductors;

(b) compression fittings must be type tested to IEEE 837 to verify the design and their suitability for the intended application;

(c) cable lug connections must be made using a hydraulic crimping tool with a hexagonal die set; and

(d) compression fittings must be applied with the correct tool and dies.

Alternative proprietary brand(s) may be offered. Details of the preferred brand(s), together with fitting(s), must be submitted to TasNetworks for approval.

6.1 Bolted joints

Bolted joints must comply with the following requirements:

(a) aluminium to copper joints shall be of the bolted type made in accordance with AS 2067 and AS 62271.301;

(b) stainless steel bolts, nuts and washers shall be used for all earthing connections. Bolts must be grade 304/A2 70 and nuts grade 316/A4 70 to prevent binding;

(c) each bolted connection for copper cable lugs or bars must have a stainless steel bolt, nut, two flat washers and one vibration washer per connection. Stainless steel washers must be installed on both sides of the bolted connection;

(d) where bolted type joints are used, the effective conductor cross sectional area, after having deducted the area of the hole, shall be adequate for the maximum possible earth fault current at the point of connection;

(e) copper flat bars must be tinned where a bolted connection is made to an equipment or support earthing palm(s);

(f) two hole palm lugs are required if the maximum earth fault current is greater than 16 kA. Each bolt must be capable of carrying the maximum possible fault current at the point of connection; and

(g) U-bolts are not permitted.

6.1 Brazed joints

Brazed joints must comply with the following requirements:

(a) brazed joints between copper to copper, copper to steel, aluminium to aluminium, and steel to steel must comply with AS 2067; and

(b) brazed joints must be made with the contacts under adequate pressure to ensure that the brazing alloy bonds the contact surface throughout its length ensuring there is no air gap between two straps which has to be fully closed and filled with brazing alloy; and

(c) brazing with the alloy around the edges only will be rejected.

6.1 Exothermic welded joints

The exothermic process to be used must be type tested to IEEE 837 for the relevant application. As the quality of the joint is subject to many variables (including cleanliness, condition of the equipment, moisture, etc) each joint must be inspected by TasNetworks.

7 Corrosion prevention

The buried earth grid system and connections to it shall be designed and installed in such a manner that minimises electrolytic corrosion and galvanic action with other services, installations or equipment.

Electrolytic corrosion must be prevented between bare copper conductors and metal structures.

Copper must not be fastened or attached directly to zinc coated surfaces or steel surfaces. All surfaces with connections to dissimilar metals, including stainless steel, shall be tinned for the prevention of possible corrosion in service.

8 Surge arresters

All surge arresters associated with substation lightning protection and earthing systems must be in accordance with TasNetworks' Surge Arrester Standard, document R522696.

9 Temporary earthing of substation equipment

Connections to primary plant for operational earths must be provided. The operational earth attachment points must be supplied as per the TSD-SD-809-0004*** Standard Earthing Drawing series.

All temporary earthing of substation equipment associated with substation must be in accordance with TasNetworks' Temporary Earthing of Substation Equipment Standard R522697.

10 Cable systems

All cables and cable systems associated with substation lightning protection and earthing systems must be in accordance with TasNetworks' Cable Systems Standard, document R590630.

11 Civil works

All civil works associated with substation lightning protection and earthing systems must be in accordance with TasNetworks' Substation Civil Design and Construction Standard R590634.

12 Data for Asset Management Information System

TasNetworks maintains a comprehensive "Asset Management Information System" (AMIS) that contains design, test results and the condition information of all TasNetworks assets. The AMIS also contains maintenance regimes for all assets.

The Contractor must provide information required to maintain the currency of AMIS for each asset in standard forms. The forms will be provided by TasNetworks to the selected Contractor. Forms are required to be filled for new assets and for decommissioned assets.

The completed forms must be filled in and submitted to TasNetworks as below:

(a) design information and maintenance regime information for all assets must be submitted to TasNetworks before commencing installation on site; and

(b) information on test results for all assets must be submitted prior to commissioning.

13 Testing

Testing, installation and commissioning must comply with the requirements of TasNetworks' Testing, Commissioning and Training Standard R246497.

All components of substation ancillary systems must be duly tested in accordance with relevant applicable Australian and International standards. Where tests are optional in the standards, it will be considered that these tests are required by TasNetworks, unless otherwise requested by Contractor and agreed in writing by TasNetworks at tender stage.

After the new installation or upgrading of an earthing system, a complete earthing audit has to be carried out. It is essential as a validation step for the design and installation process and to set a benchmark or baseline for ongoing supervision. The earthing system commissioning procedure consists of, as a minimum, the following core activities:

(a) visual inspection;

(b) continuity testing of the earthing system and earthing connections to all equipment;

(c) earth resistivity testing of the substation earth mat (ie with all remote earth connection removed);

(d) earth potential rise (EPR) measurements;

(e) voltage gradients in the vicinity of telecommunication cables;

(f) current distribution measurement; and

(g) transfer touch and step voltage testing in each switchyard and outside the security fence.

All test reports must be forwarded prior to commissioning to TasNetworks for approval and acceptance. The tests will be considered as completed, only after, an approval and acceptance of test results by TasNetworks in writing.

13.1 Type tests

Type tests are intended to prove the soundness of design of the systems and their suitability for operation under the conditions detailed in the specifications. Type tests must be carried out before the delivery of the system. A certified test report, detailing the results of such tests along with the procedures followed, must be provided to TasNetworks. These tests must apply to a system of identical design with that offered, or on a system of a design which does not differ from that offered in any way which might influence the properties to be checked by the type test.

Where such tests have already been performed, a copy of the type test report that qualifies for exemption from conducting these tests must be provided with the tender.

13.2 Routine tests

The routine tests must be conducted on the complete system to prove quality of manufacture and conformance with the relevant performance requirements of the applicable standards. Splitting of routine tests into separate phases for individual components of the system is not acceptable.

Procedures for routine tests with supporting documentation must be submitted to TasNetworks for approval and acceptance. Routine tests will not be conducted unless the routine test procedures have been accepted and approved by TasNetworks.

Routine test results and certificates must be submitted to TasNetworks for approval and acceptance. Routine tests will be considered as completed only after TasNetworks approves and accepts the test results.

Routine factory test results must be approved and accepted by TasNetworks prior to dispatch of equipment to site.

14 Information to be provided with Tender

Requirements for information to be submitted as part of the tender are outlined in document R574178.

15 Deliverables

Requirements for project deliverables are outlined in document R574177.

Appendix A – Reference drawings

Standard Switchyard Earthing and Connections Assembly and Details	TSD-SD-809-0002-001
Standard Switchyard Earthing of Fences and Gates Assembly and Details	TSD-SD-809-0002-002
Substation Standard Outdoor Switchyard Operational Earthmat Assembly and Details	TSD-SD-809-0002-004
Standard Operational Earthing 90 Deg Earthing Stirrup Details	TSD-SD-809-0004-001
Standard Operational Earthing 180 Deg Earthing Stirrup Details	TSD-SD-809-0004-002
Standard Operational Earthing Termination Stations For Steel and Concrete Structures	TSD-SD-809-0004-003
Standard Operational Earthing Terminal Stud Details	TSD-SD-809-0004-004
Standard Operational Earthing Sand Bag Details	TSD-SD-809-0004-005
Standard Operational Earthing Equipment Structure Attachments Details	TSD-SD-809-0004-006
Standard Operational Earthing 110 kV Aluminium Stirrup Assembly Details	TSD-SD-809-0004-012
Standard Operational Earthing 110 kV Copper Stirrup Assembly Details	TSD-SD-809-0004-013
Standard Operational Earthing 110 kV Aluminium Tubular Bus Stirrup Details	TSD-SD-809-0004-014
Standard Operational Earthing 110 kV Copper Tubular Bus Stirrup Details	TSD-SD-809-0004-015
Standard Switchyard Earth wire and OPGW Termination arrangement	TSD-SD-808-0077-001