Substation Primary Design Standard

Summary
This document outlines the primary design standard for Transgrid substations. Transgrid publishes this information under clause 5.2A.5 of the National Electricity Rules.

Document Control			
Date of issue	November 2021	**Update**	Document re-branded and general review and update to include Designated Network Assets.

Contents

1. Introduction

The substation design responsibilities are broadly divided into primary and secondary systems. The primary systems are the high voltage, civil and structural and building elements. The secondary systems are the protection, communication and control, auxiliary supplies and the automation systems that integrate the operation of the substation. This document deals with the design of the primary system of the substation.

2. Reference Documentation

The items below that have also been published on Transgrid's website under 5.2A.5 of the National Electricity Rules, form part of this document and should be read in conjunction with this document:

- Plant List – HV Switchgear and Accessory Items;
- Breaker and a Half - Generic Substation Layout;
- Mesh Connection - Generic Substation Layout;
- Loop In - Loop Out - Generic Substation Layout;

3. Safety in Design

Designs shall be in accordance with the Safe Work Australia Safe Design of Structures Code of Practice as per the WHS Act 2011 and meet the requirements of the Electricity Supply (Safety and Network Management) Regulation 2014 (NSW).

4. Drawing and Documentation Requirements

4.1. Drawing numbering

Drawings shall be numbered as follows.

<site code>-<sequence number>/<sheet number>

<site code>Site specific three letter code

<sequence number>Six digit number within the series specified in table below

<sheet number>Number starting at 1

Sheet numbers shall be used for drawing continuations and drawing sets representing a single item.

Table 1: Drawing sheet numbering

High Voltage design	
Sub package	Drawing number series
Single line diagrams	100001
General arrangements	100101
Sections	100201
Conduits	100301
Earthing	100401
Miscellaneous	100501
Building layouts and services	100601
Safety in Design reports	600001
Technical reports	700001
Civil and Structural design	
Sub package	Drawing number series
Earthworks	200001
Roads	200101
Drainage	200201
Cable trenches and pits	200301
Footings	200401
Structures	200501
Fencing	200601
Miscellaneous	200701
Building architectural and structural	200801
Survey	200901

Drawing file names shall be as specified in Transgrid CAD standards.

An Index Classification number shall be assigned to each document as per Transgrid standard STD-140100.

4.2. CAD Guidelines

High voltage, civil and structural design drawings shall be as per drafting guidelines STD-848530 and STD-848531 which will be provided upon request:

4.3. Documentation

The Connection Applicant is required to uniquely identify all items of equipment and handover the Transgrid all information required for the continued safe operation, maintenance, de-commissioning and disposal of the identified equipment and any system handed over to Transgrid.

All documentation shall be provided in an electronic format, but all of the required documentation shall be provided in one identified package and the contents of the package shall be fully described.

Such documentation and information is expected to include but not be limited to:

- Drawings of individual items
- System Drawings (such as operational diagrams, switching instructions and interlocking)
- Setting information and facilities for any configurable device. This also includes the means by which settings are changed.
- Instruction and Operation Manuals (of both equipment and systems generated by the Connection Applicant)
- Test Reports. In the case of Type Testing of Equipment, Type Test Summaries are acceptable in the first instance. All other Test Reports are to be provided.
- SID information and Residual Risks
- Software and firmware information including licences and media.
- Commercial information that may be of interest to Transgrid such as Defects Liability Periods and other similar responsibilities and commitments.
- The function, size, type and description of any valve or fitting.

5. High Voltage Design

5.1. General

The substation high voltage design shall be to AS 2067 with the additions and clarifications specified in this document. All documents referenced by AS 2067 such as Australian Standards, also apply.

5.2. General design and equipment parameters

General design parameters shall be as follows.

1	Design life: 50 years
2	Maximum ambient air temperature: 40°C (Plant items: 45°C)
3	Minimum ambient air temperature: -25°C
4	Maximum solar radiation: 1100W/m2
5	Pollution level: default is Heavy, should be reviewed to suit site location and environment
6	DC – station battery - 125 V nominal with voltage variation 88 V – 137.5 V
7	AC - three phase, four wire - 415/240V ±10% (this applies to existing substations but also covers the new requirement of 400/230 V -5+10%)
8	Auxiliary Switches Suitable for duty at 125 V DC 10 A slightly inductive
9	Auxiliary Contacts Trip 1 A make at 125 V DC Alarm and indication 50 mA at 125 V DC slightly inductive
10	Minimum height of lowest part of HV support insulators from ground level: 2,440 mm
11	Requirements for Control Cubicles Distance from ground level of any gauge or indicator: 1,200 to 1,800 mm Distance from ground level of all user accessible devices including switches, fuses, contactors, terminals etc. 1,000 to 1,800mm Distance from ground level to base of cubicle: 600mm minimum Distance from ground level of OLTC manual crank axis: 1,000 to 1,600mm
12	Protection for Outdoor Equipment Degree of protection for sealing cubicles, enclosures and terminal boxes against the ingress of water, foreign particles and insects: IP55 Degree of protection for electric motors not enclosed in a cubicle: IP56D Degree of protection for fans: IP2X
13	Altitude: ≤1,000m (subject to review for the installation location)

5.3. Single line diagram

The substation Single Line Diagram shall ensure that all security of supply requirements are met, both for planned and unplanned outages.

The installation shall be designed and constructed such that it is safe to isolate, earth, perform commissioning and testing, operate, and undertake maintenance on any item of HV plant without requiring an outage on the adjacent equipment.

To maintain security of supply, voltage transformers, including power voltage transformers, shall not be directly connected to a busbar without Transgrid approval.

Single Line Diagrams shall be laid out to match the physical arrangement of the equipment on site.

Phases shall be identified as red, white and blue (RWB).

Equipment identification on single line diagram shall be as per following Transgrid standards STD-171831 and STD-813409-1 to 5. All HV equipment shall be identified by two index numbers, an Item Designation and unique Equipment Identifier as detailed in STD-171831. Where the layout of the substation is not constrained, the preferred power transformer numbering sequence is to be such that when standing on the transformer runway facing the higher voltage area, the main transformers are to be numbered 1, 2, 3, 4, etc. from left to right.

Where consideration of an ultimate design is required an Ultimate Single Line Diagram, Ultimate General Arrangement and Ultimate Site Layout are to be produced.

The Single Line Diagram shall be laid out to match the physical arrangement of the equipment on site.

All Single Line Diagrams shall use drawing symbols in accordance to STD-142374. If a symbol for a particular type of component is not shown as an example in STD-142374, AS/NZS 1102 or AS/NZS 1103, it should be possible to produce it from the basic symbols. New symbols should be derived and not created.

All Single Line Diagrams shall reference an Equipment Schedule which identifies each item of HV equipment. The Equipment Schedule must also include the CT information, which captures the unique Equipment Identifier, CT core numbers, purpose, ratio and core type or class.

Phasing arrangements busbars, transformer and line bays within the high voltage switchyard shall be as shown in the diagrams below:

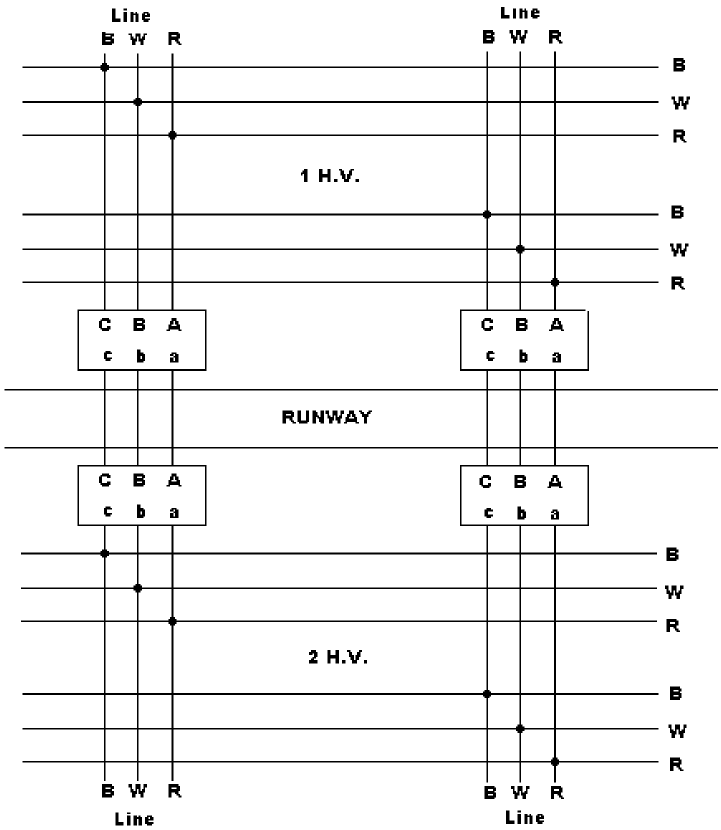

Figure 1: Single busbar, double busbar and breaker and a half switchyards up to 330kV

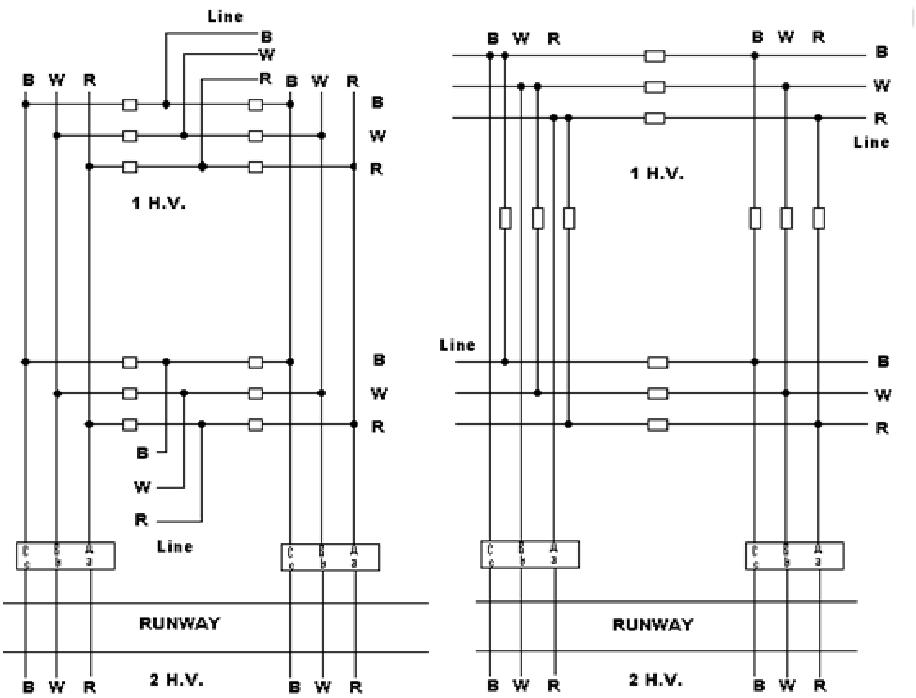

Figure 2: Mesh switchyards up to 330kV

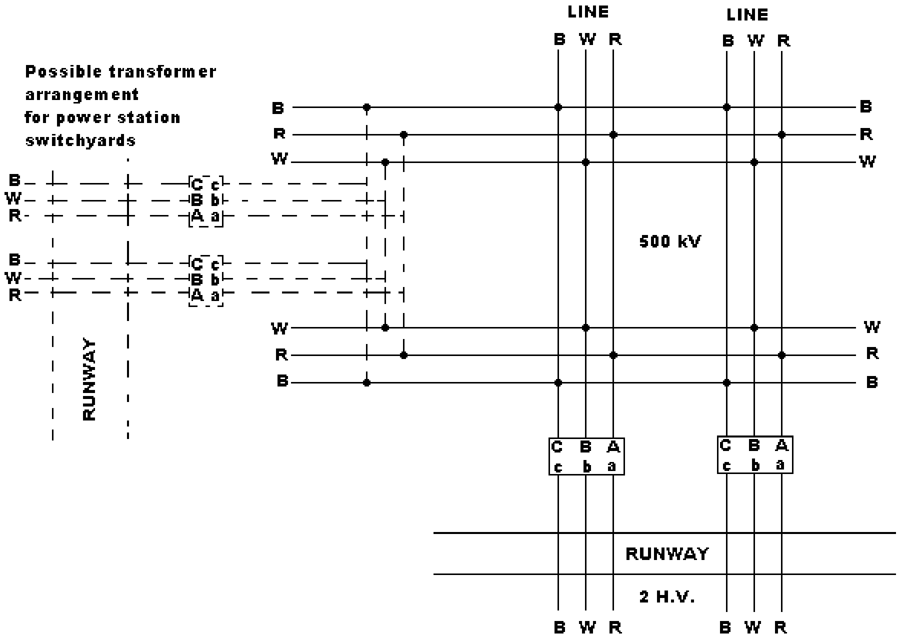

Figure 3: 500 kV breaker and a half switchyards (including power station switchyards)

Disconnectors shall be located to provide isolation on both sides of equipment and each end of lines for maintenance.

Earth switches and portable earth stirrups are required for maintenance of equipment within the substation.

Earth switches shall be located on:

- Line side of line disconnectors;
- Equipment side of equipment disconnectors for 330kV and above;
- Equipment side of equipment disconnectors below 330kV and greater than 40kA;
- Substation side of line disconnectors for line entry bays for 330kV and above;
- Substation side of line disconnectors for line entry bays below 330kV and greater than 40kA;
- Capacitor side of capacitor circuit breaker/current transformer;
- Reactor side of reactor circuit breaker/current transformer;
- Bus side of bus disconnector (one earth switch per four bays of bus).

Disconnectors below 220kV are not required to be motorised except for safety or manual handling reasons or if it is a system disconnector. A system disconnector is a disconnector in a circuit branch that does not have a circuit breaker (motorised in the general case).

5.4. General arrangement

The general arrangement includes the alignment of equipment, infrastructure and facilities required to complete the scope of works. The design for the layout of these items must have regard to the:

- Overall access, operability, and maintainability of the site
- Operational security considerations
- Delivery, installation, and ultimate removal of large and/or heavy items such as power transformers and transportable buildings
- Equipment installation and removal
- Fire protection by segregation
- Equipment layouts
- HV cable route requirements
- Provision of kiosks, marshalling boxes and other enclosures
- Fire and emergency response considerations

The substation general arrangement shall generally be as shown in the typical general arrangements also published on Transgrid's website under 5.2A.5 of the National Electricity Rules as follows:

- Breaker and a Half - Generic Substation Layout;
- Mesh Connection - Generic Substation Layout;
- Loop In - Loop Out - Generic Substation Layout;

The substation earthworks bench shall extend at least 500mm past the perimeter fence external earth grid conductor to protect the conductor from erosion.

Bus disconnectors are not to be installed underneath the busbars.

The switchyard bench shall extend at least 1.5 m beyond the switchyard fence to provide a clear space for installation and maintenance of earth grid and fencing. Where surface drainage systems or vehicle access is required additional space shall be provided.

Maintenance vehicle access shall be provided to prevent multiple outages for maintenance.

Cable trench crossings shall be provided as required.

Landing gantries and poles shall allow for future rearrangement, as follows:

- 330kV - 100m span of twin olive conductor;
- 220kV - 70m span of twin olive conductor;
- 132kV - 50m span of twin olive conductor.

Design of the general arrangement in initial development shall allow for future expansion of the substation if specified in project specifications without major augmentation and or unnecessary outages.

Land acquisition shall allow for a buffer zone. The extent of the buffer zone is typically 20 m however this is to be confirmed on a site specific basis, refer to Section 5.29. The buffer zone is measured perpendicular from the centreline of the perimeter security fence, around the perimeter of the substation external fence to allow for:

- Maintenance access;
- Bushfire protection of the substation asset;

- Earthwork and drainage;
- Earthing system transferred potential to neighbouring properties.

The areas and assets which, will not be owned and operated by Transgrid shall, be fenced off from rest of substation.

Design of the general arrangement shall allow for following external amenities in vicinity of auxiliary and secondary building unless noted otherwise in project agreement:

- Storage container (size 6m (L) x 2.5m (W) unless agreed otherwise);
- Water tank;
- Septic tank;
- Toilet;
- Diesel Generator, if required.

5.5. Layout – Emergency Response Report

A report shall be provided addressing all the emergency response issues associated with the layout of the substation.

The report shall address the assessment of risks and risk management options included in the substation layout with specific attention, but not limited to the following:

- Access – evacuation and emergency services entry
- Emergency services facilities
- Fire ratings
- Oil containment and discharge strategies

5.6. Transformer and Reactor Compounds

For all transformers and reactors, the final compound design should allow for maintenance access (including EWP access) and account for oil leakage with the appropriate spill angle. The bund design shall not be unnecessarily large considering the relationship between bund area and severity of fire.

Any auxiliary or earthing type transformers shall be located outside of the main transformer bund and separately bunded as required. The area inside the auxiliary transformer bund shall be connected via a suitable drainage pit and flame trap to the substation spill oil containment tank. Dry type auxiliary transformers do not need to be installed in a bunded enclosures.

5.7. Transformer and Reactor Design

Transformers and oil filled reactors shall be purchased with a means of relieving excessive internal pressure in the event of a fault within the transformer tank. The pressure relief device shall take the form of a self-resealing valve and sufficient number of pressure relief valves shall be provided to adequately vent the transformer tank.

The pressure relief valve shall discharge within the transformer bund area in such a manner that oil will not be sprayed over adjacent electrical plant.

Oil level gauges on the conservators of transformers or reactors are to be positioned so that in the event of their fracture, oil is not sprayed onto any nearby transformer, building or other potential fire hazard.

5.8. Transformer and Reactor Design Marshalling Kiosks

Marshalling kiosks for significant oil filled plant such as transformers and reactors shall be located so as to minimise the risk of fire damage to both the kiosk and the secondary cabling to the SSB. The kiosk should be located behind the transformer, reactor, or auxiliary transformer fire wall where practical. If the kiosk must be located in an exposed location it should be located as far from the main tank as possible.

5.9. Transformer and Reactor Fire Protection Principles

Fire protection of oil-filled transformers and reactors shall be by passive means. In adopting the requirements of AS 2067, the following principles shall apply:

- A fire in any three-phase transformer or a single-phase transformer shall not cause a fire in an adjacent transformer unit
- A fire in any transformer or reactor shall not spread to any substation building or impede access for emergency services vehicles, access from at least one alternative direction is to be provided.
- A fire in any transformer or reactor shall not cause the destruction of adjacent structures or electrical equipment or connections, which would bring about the loss of other high voltage circuits not associated with that transformer or reactor.
- Spill oil retention shall be provided for all oil filled transformers, coolers, auxiliary transformers, and reactors.
- Transformers or reactors that need to be totally enclosed present difficulties in firefighting and structure design and may require additional controls based on a risk assessment
- Where other than passive systems are determined necessary by risk assessment, these will be specifically described for the site and application
- No windows are to be located in the wall of any building facing the transformer
- Consideration must be given to the planned ultimate development of a substation when determining the location of oil filled equipment to achieve the required fire separation distances.
- The proximity of members of the public and bushfire fuel load to oil filled equipment is to be restricted as far as practical. At a minimum the non-combustible surface clearance (G1) as outlined in AS2067 is to be maintained to the switchyard fence.
- Fire clearances need to be considered for both the main tank and cooler areas, where areas are segregated by a fire wall the areas may be assessed based on volume of oil which may be contained in each bunded area.
- Horizontal fire clearances to be applied considering line of sight between assets

5.10. Auxiliary Transformer Fire Protection Principles

Auxiliary transformers require two hour rated fire walls when they are located:

- Within 7.5 metres of the associated main transformer which itself is not surrounded by firewalls. This is for the protection of the main transformer and applicable to oil filled auxiliary transformers only.

- Within the fire separation distance as defined in AS 2067 of other main transformers or oil filled equipment. This is for the protection of the auxiliary transformer.

5.11. Fire Walls

Transgrid's preference is to provide fire protection by means of separation. However, where oil filled equipment must be mounted closer to other equipment, structures, or buildings than the required fire separation distances, separation shall be provided using two hour rated fire walls. The fire rating shall apply to both the materials used for the fire wall and the support steelwork.

The need for firewalls shall be determined considering both the initial and planned ultimate substation layouts and reference to AS 2067. If fire walls are required, they are to be specified and allowed for by the initial design.

Firewalls or separation distance shall adequately protect any equipment or structures in adjacent bays (not associated with the transformer bay).

In critical network installations with very high reliability risk and where transformers are installed in close proximity to each other, Transgrid may request a fire and blast study to determine the fire wall and/or blast wall requirements.

5.12. Fire Protection of LV Cables

An engineering risk assessment shall be performed to determine the appropriate level of protection for cables in the vicinity of oil filled equipment with an oil volume greater than 1000 litres, typically power transformers or reactors.

Zone segregation of cables, buried conduits, fire retardant coating, fire walls and physical separation are all acceptable methods of providing protection for cables.

All cable conduits in oil filled transformer or reactor compounds shall be sealed to prevent flow of oil out of the compound back to cable trenches

5.13. Buildings

All substation buildings shall comply with the Standard Construction Manual, the National Construction Code (NCC), and relevant Australian Standards.

5.14. Building Layout Fire Considerations

Fire area boundaries shall be provided within substation buildings to separate adjacent areas. Some examples of rooms requiring separation include:

- Communications rooms
- Battery rooms (Excluding VRLA)
- Offices and amenities rooms
- Switchgear rooms
- Cable basements
- Workshop and storerooms
- Operational areas

The fire barriers separating the fire areas shall be of two hours fire resistance rating and run from floor to underside of roof, or where ceilings are fire rated, to the underside of the ceiling.

5.15. Switchgear Buildings

Switchgear buildings shall comply with the following requirements in addition to the standard requirements:

- AS 2067.
- Switchgear manufacturer specific requirements for switchgear delivery, installation, testing and maintenance access.
- High voltage cabling requirements.
- A room Overpressure Assessment Report shall be undertaken to ensure adequate room size, building strength and pressure relief if required.
- Fire zone requirements – Multiple busbar switchboards may require fire ratings between bus sections, for the switchgear and/or the cable area. Importance level and separation of circuits/bus sections shall be considered by the designer with input from Transgrid as required.
- Building thermal design needs to be co-ordinated with equipment requirements, for example ambient temperatures required for switchgear ratings and embedded IEDs and consider heat loads of equipment, etc.

Indoor switchgear and other primary equipment shall be earthed by adequately sized copper strips. At least two earth risers shall provide connection to the earth grid. Earth rises shall be at opposite ends of the equipment and be independent from the structural earthing.

HV and EHV GIS installations are subject to high-frequency electromagnetic fields and transient earth potentials during switching which are to be considered during design and implementation of the earthing system. Considerations are to include but not be limited to the density of both the substation earth mesh and the reinforcement mesh in the walls and floor, direct low impedance earthing of switchgear parts, cable bonding, screening, and earthing of control cables.

5.16. Internal Arc Classification for Metal Clad Switchgear

If metal enclosed switchgear is offered, the Internal Arc Classification (IAC) shall conform to the requirements of IEC 62271-200 or IEC 62271-201, whichever is applicable. The test requirements of IEC 62271-200 - Annex A, “Accessibility Type A” (as a minimum) shall be met for the protection of persons against the effects of internal arcing faults. Each item of equipment shall have an Internal Arc Classification of Type A, front, lateral and rear (AFLR) at its respective fault rating. AFL may be acceptable if the switchgear is installed against the wall (in accordance with the standard) and the wall is suitably designed for the pressure. In particular, the switchgear shall be of a fault containment type, or be vented in such a manner as to provide a high degree of protection to persons in the immediate vicinity of the front, rear or side of the panel (and to prevent switchgear building damage due to excessive internal pressure.)

Arc Flash risks shall be evaluated considering the overall design and reduce to ALARP as required by the SiD process.

Where vented, the venting shall be to a safe area, generally external to the building. The venting should be to a non-frequented area and signposted as hazardous. Downward venting is generally not acceptable unless personnel access to the vented area is prevented by the design. The design of the switchgear shall ensure safety of personnel in cable basements beneath the switchgear or outside the building, including provision of any requirements to the building design. The switchgear venting design shall ensure no water enters the switchgear compartment due to condensation.

Where practical the switchgear shall be supplied with optical arc fault detection protection, which shall be capable of being AND gated with overcurrent protection to avoid spurious operation. The supplier shall state the means by which detection is achieved. Arc fault clearance time shall be a maximum of 100 ms. This shall not replace protection requirements e.g. full bus zone protection as required by Transgrid Standard Design Manual-Protection and Metering design.

The switchgear shall be of fully segregated construction to enable arc containment protecting the switchgear from the effect of faults in the cable connections and CT connection chambers. It shall be possible to safely work in the cable box of a de-energised circuit where the busbars remain energized. It shall preferably be possible to safely replace a circuit breaker assembly without de-energising the busbars. The design shall clearly document exactly what work can be done on the switchboard without compromising the arc containment, including what outages may be required for certain works.

An Arc Flash Hazard Assessment Report shall be done for medium voltage switchboard installations, including arc flash hazard level calculations i.e. incident energy. The assessments should include for operation and maintenance activities such as hazard level when opening doors, works in a bay including its cable compartment with the bus and adjacent bays energised, accessing non-rated aspects of the switchboards, etc. The assessment should also consider downward venting arc fault hazard levels.

The design shall consider the need to block or turn off the busbar protection or arc flash detection for certain works and ensure that safe clearance times are still achieved.

The switchgear and building shall be clearly labelled to indicate any potentially hazardous zones. All Arc Flash Hazard labels shall include, as a minimum,

- Bus Name or Equipment Name
- Bus Voltage Level
- Activity to be performed
- Incident Energy Level
- Arc Flash Boundaries (Working and Safe Approach)
- PPE protection category required for varying activity

5.17. Electrical clearances

Electrical clearances shall be to AS 2067. Voltage range I and II shall be used. Voltage range II shall only be used by risk assessment. Highest voltage 36kV clearances shall be used for highest voltages below 36kV.

Section safety clearance from ground level, access platforms and elevated surfaces that can be easily walked on (e.g. transformer bund walls, footings) shall be the greater of AS 2067 and Transgrid Power System Safety Rules (PSSR) safe approach distance (SAD) +2440mm.

Electrical clearances for vehicle movement on designated access ways shall be to AS 2067 and PSSR with a safety observer. Electrical clearances for vehicle movement in all other areas shall be to PSSR with a safety observer. The vehicle size shall be fit for purpose (e.g. transformer transporter, EWP for accessing gantries for landing span stringing).

The highest point on a vehicle a person can sit or stand on designated access ways is 1.5m above the access way surface level. The maximum overhang from the designated access way of the highest point on a vehicle a person can sit or stand is 0.35m.

5.18. Insulation co-ordination

An insulation co-ordination study shall be performed to determine surge arrester locations and specifications. Surge arresters shall be provided for each transformer winding as close as possible to the transformer.

Mean Time Between Failure (MTBF) of 400 years for air-insulated substations and 800 years for gas-insulated substations shall be used in insulation the co-ordination study.

5.19. Earthing system

The substation earthing system installed must be designed to limit the effect of ground potential gradients to such voltage and current levels that will not endanger the safety of people or equipment under normal and fault conditions, in accordance with AS-2067 and ANSI/IEEE STD 80, taking the most conservative safety limits of the two standards.

Portable earthing fittings shall be provided for maintenance.

The earth system design shall include, but not be limited to:

- Collection of all information on the installation and surrounding services to complete a safe earthing system design for the works
- Completion of soil resistivity and any other initial investigation tests required to complete the earthing design
- If corrosive soil is suspected in location of the proposed earth grid, testing shall be carried out to determine the pH the soil
- Design of the earthing system, complying with the requirements as stated in relevant Australian Standards to provide:
  - safe step and touch potentials at all locations within the substation site including the property boundary fence, assuming no installation of crushed rock
  - safe touch and transfer potentials to other services and structures e.g. stock fences external and adjoining to the substation site
  - compliance with other utilities requirements for potentials imposed on any other services from the substation
  - completion of an Earthing System Design Report for the installation
- Design of the earthing system is to consider fault current levels as specified by Transgrid, fault current splits and clearance times for all on-site and off-site fault cases, including for close in line faults and line-to-line to earth faults.
- For all new substations and bench extensions a margin of 30% will be applied to the identified fault level (C=1.1pu volts, present fault level + committed connections) as advised by Transgrid. This margin should be applied to existing elements where reasonable. Calculated fault level used for evaluation of step and touch potentials.
- Design shall be completed using current version of CDEGS software. The CDEGS model shall be provide to Transgrid along with submission of the associated Earthing System Design Report. This model and report will be owned by Transgrid without any restrictions on use. The model may be provided to stakeholders as required.

The safety limits shall not rely on crushed rock for safety compliance. Safety limits shall consider natural soil for all construction activities such as excavating, temporary fencing, etc. Any additional earthing risks during construction shall form part of the Safety in Design process. Consideration shall be given to seasonal changes to the sub-surface soil resistivity (e.g. consider periods after rainfall). Where a large amount of fill is to be imported from a remote site for the construction of the switchyard, the resistivity of the imported fill shall be accounted for.

The substation earth grid shall include a grading ring 1 m external to the main switchyard fence. Switchyard fences shall be earthed every 10m maximum.

The substation earthing design shall address all factors that may affect the substation earthing system performance including but not limited to:

- Soil resistivity
- Existing earthing systems within and external to the substation property
- Other services or structures located within the substation property or within the adjacent properties that may impact on the earthing system performance
- Buried depth of earth grid based on site specific conditions
- Electrical continuity of earth wires and cable screens associated with all overhead and underground high voltage circuits connected to the substation
- External counterpoise
- Fences and gates including when in open position
- Earthed items external to the switchyard fence and/or external to the main earth grid such as card readers
- Transformer neutral points and any neutral earthing impedances
- Earth fault level expected at the commissioning of the substation
- Ultimate earth fault level (used for conductor sizing)

Where a large external earth grid is available, such as for a generating plant, the design shall comply whether the external grid is connected or not connected with the substation earthing. This is to allow for future possible removal of the external grid. The design is to include facility for separation to allow testing of each individual earth grid.

5.19.1. Application of AS 2067 for the evaluation of Substation Earthing Systems

AS 2067 refers to ENA EG-0 and AS/NZS 60479 for the evaluation of substation earthing systems. These documents require the earthing designer to consider a number of probabilistic factors when determining the allowable safety limits for step and touch voltages.

For consistency in results, calculations shall be made using Argon Software. The below guidance is provided for the calculation of safety limits inside and outside major transmission substations. This guidance is considered supplementary to that outlined in EG-0.

- Footwear: ‘Typical Public Footwear’ is to be considered for determining the probability of fibrillation for all contact scenarios. This variance from EG-0, Section E.4 is for consistency with the Transgrid PSSR which requires ‘enclosed shoes’ not ‘electrical footwear’
- Note that Argon software will default to the ‘dry body’ curve when footwear is applied, this is considered acceptable as within a major substation environment proper drainage and surfacing is provided.
- Soil Resistivity: The soil resistivity option immediately lower than the upper layer soil resistivity as determined from the site-specific soil resistivity measurements is to be selected. When nominating

the soil resistivity, the designer is to consider seasonal variation in the resistivity of the upper soil layer

- Surface Layer: None
- Fault Duration: Primary fault clearance time
- Fault Frequency: Frequency of faults resulting in an EPR on the substation earth grid is to be determined by the contractor and endorsed by Transgrid
- Member/s of the public: The contact scenario must be selected to best suit the specific site
- Utility Staff: The contact frequency and duration represents the aggregated exposure to metalwork without mitigation considering the worst affected person across all substations. The contact frequency and duration is to be determined by the contractor and endorsed by Transgrid
- Societal Risk: The societal risk scenario is to be considered on a site-specific basis. The population size considered is the number of exposed people who could reasonably be expected to make simultaneous contact with the affected metalwork. The societal scenario considered, number of people, contact frequency and duration is to be determined by the contractor and endorsed by Transgrid

Some examples of a societal risk scenario could be a construction team, commissioning teams at associated generation plant, public gatherings in urban areas, etc.

5.19.2. Earthing System Design Report

An Earthing System Design Report is required to be submitted to Transgrid. The report shall summarise the earthing design proposed, and this shall address all relevant factors associated with the earthing system design including but not limited to the following:

- All source data used to formulate the earthing design
- All test or investigation information obtained during the design process – including other services and soil resistivity test results
- Determination of the design step and touch potentials nominated as safe for the installation, specifying the relevant factors required to assess the safety criteria
- Current splits for the proposed earth grid and the earth return current levels assumed for all fault scenarios considered in the development at the completion of the contract and for the ultimate substation development
- Confirmation that earthing grid conductors selected meet the thermal rating requirements for the substation fault levels for the development under this contract and for the ultimate development of the substation
- Confirmation that the earthing grid materials are suitable for the soil conditions and any other conditions at the site with a view to galvanic corrosion
- Details of the earthing system proposed with calculations in support of the current splits, earth potential rise of the substation, step touch and transfer potentials. The details of the earthing design shall include drawings of the proposed earthing system installation, specification of materials to be used and methods for connections within the earthing system
- Details of potentials that may be imposed on any services in adjoining properties as a result of the operation of the substation earthing system. This includes conductive, inductive and transfer potentials. All services are to be assessed and confirmation as to whether acceptable safety standards are achieved or not. In case where there is an excessive potential on any other services – this should be specifically nominated and a recommendation for remediation of the excessive potential
- An outline for the verification and injection tests for the installation after completion of the installation of the earth grid

5.19.3. Construction Earthing Safety Advice

Where work is carried out in an in-service substation or work is carried out following energisation of a new substation or is within the zone of influence of in-service OHL or substation EPR, all necessary safety precautions should be assessed via an earthing construction risk assessment documented in the 'Construction Earthing Safety Advice'.

The 'Construction Earthing Safety Advice' shall where applicable include but not be limited to:

- Communication of recommended mitigation measures identified in the earthing design report.
- Bonding or isolation requirements during the removal or extension of earth grid including a safety gap between the existing earthing system and the area for the new earth grid work. Where required, this safety gap should be at least 3 m.
- Use of services including LV power and water supply
- Use of conductive temporary fencing, such as 'disconnected apparatus fencing', within the substation including consideration of exposure to hazardous mesh voltages
- High voltage switchyard fence to be extended
- Areas subject to restrictions, for example access and construction sites including work areas, site office and lay down areas.
- Any restrictions on activities, equipment, cables, etc. required to prevent hazardous transferred potentials during construction
- Any other earthing related hazards during construction, for example material handlings (long metallic conductors, etc)
- Earth grid construction sequencing and associated CDEGS evaluation of each stage
- Identified control measures such as non-conductive barricades and signage

This may be submitted as a standalone document or a section of the Earthing System Design Report.

5.19.4. Soil Resistivity Testing

Soil resistivity testing is to be carried out using the 4 pin Wenner method as described in IEEE STD 81.

Measurements should be taken in a number of directions and locations spanning the proposed substation area. Measurements are to be taken and recorded at different pin spacings. The largest spacing should be of similar magnitude to largest the earth grid dimension. At least two traverses at 90 degrees to one another shall be done to account for possible influence of buried underground services such as conductive water pipes or cables.

5.19.5. Earthing System Commissioning Testing

IEEE 81, Section 5 highlights the hazards to personnel undertaking earth tests. Personnel undertaking testing are to comply with the IEEE 81 and the following requirements:

- Transgrid Power Systems Safety Rules
- Traffic Management D2015/09498
- Testing must be halted in the event of a thunderstorm in the area
- AS/NZS 3835.2

5.19.6. Earth System Testing

Prior to commissioning the installed or modified earth grid is to be tested in accordance with AS 2067, Appendix H. All state and performance tests are to be completed. For further guidance on testing procedures refer to IEEE 81.

Testing is intended to verify the Integrity of the earthing system, validate the design, and confirm the effectiveness of the proposed mitigation measures. Test measurements are to include:

Continuity of each connection and component

- Actual earth grid resistance to remote earth
- Step, touch, and transfer voltages
- Voltages on pipelines, fencing, telecoms, etc.
- Rate of fall of surface potential at various locations from the fence line

Earthing commissioning testing shall be conducted under the same earthing conditions that the earthing design was based on. For example, the earthing system must be tested when isolated from the generator earthing system.

5.19.7. Test Documentation

An Earthing System Validation Report comparing earth system test results and the earth system design is to be completed. Testing is to be completed and the report submitted allowing sufficient time for remediation and approval prior to commissioning.

The validation report shall include:

- Test results
- Additional mitigation measures
- Reconsolidation of design
- Diagram including test points and locations
- Revision to the earthing drawings
- Updated CDEGS model

5.19.8. The Earth Grid and Risers

The earth grid shall be installed in accordance with the Electrical Design Earthing Methods Instruction (STD-147230). The main earth grid and risers shall consist of bare annealed copper strip of alloy type designation C11000 to AS-1566.

Earth Grid and risers shall be sized considering the ultimate substation fault level and the back-up fault clearance time including CB Fail and blind spot fault scenarios. Within a substation earth mesh, a fault current split factor of 0.7 may be applied when calculating the earth grid conductor size. This factor cannot be applied to risers, or connections between grids.

The Earthing System Design Report is to contain calculations demonstrating the appropriate size of the copper strip and is to consider the below factors:

- Initial Temperature of buried conductor = 30 °C
- Initial Temperature of above ground conductor = 40 °C
- Maximum Temperature of conductors with bolted or compression connections = 250 °C
- Maximum Temperature of conductors with brazed/exothermic welded connections = 400 °C
- Maximum Temperature of conductors with or in contact with PVC coating = 160 °C

The risers and main earth grid conductor should be selected based on the following standard sizes of copper straps:

Table 2. Earth Grid and Riser Copper Strip Size

Earth Grid and Riser Copper Strip Size (mm x mm)		
40 x 6.3	40 x 4.0	40 x 2.5

It should be noted that unless otherwise specified the grid shall be run across the top of footings. Where the earth grid passes under trenches, roads or foundations, the earthing conductor is installed on the base and up the sides of excavations before concrete is poured or base course placed.

Boxes and cabinets, including SMBs, AC & DC boxes, VT & CT marshalling boxes to be earthed with a minimum 70 mm2 copper cable running from the internal earth bar down to the earth grid riser.

5.19.9. Earthing of Cable Sheaths and Transformer Neutrals

The earthing system design shall consider and clearly identify the following requirements for all earthing connections to high voltage cable sheaths and transformer neutrals:

Clearly identify all above ground earth connections that form a single connection to high voltage cable sheaths and transformer neutrals. This identification should be permanent and clearly indicate – by a permanent tag or other approved method – that the earth connection may not be broken unless under an outage and access authority

Connection to the substation buried earth grid: - all cable sheath earth connections and transformer neutral earth connections where they enter the ground shall have at least two visible substation earth grid connections

Refer to the following figure.

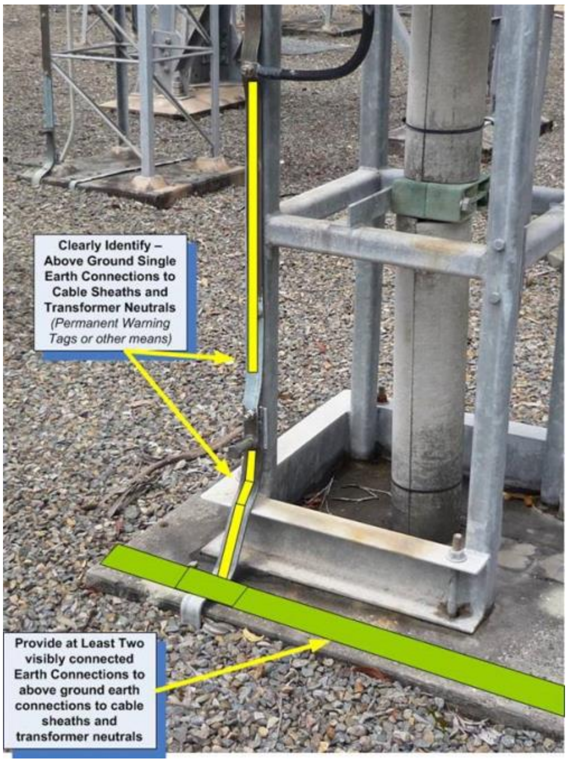

Figure 4 – Example of earthing for cable sheaths

5.19.10. Earthing of Concrete Slabs

Concrete foundations with an above ground surface area of greater than 2 m x 2 m that can be stood on shall be earthed. Concrete slab reinforcing shall have two earth connections at opposite corners of each structurally isolated section of slab. Concrete slab top layer reinforcing bars shall be tack welded at bar laps and crossings along two edges to form a 0.5 m x 0.5 m maximum electrically continuous grid. Earth grid riser conductors shall be brazed to bars at opposite corners of grid and cast in the concrete. The conductor shall exit slab below ground level. Cast in earth points are acceptable providing all connections are in accordance with STD-147230.

5.20. Electric and magnetic fields

Electric and magnetic fields shall be determined at 1.0m above ground level.

Electric and magnetic fields shall be tested after energisation to confirm safety compliance.

5.21. Corona and surface voltage gradients

All components of Substations HV connections shall be designed and installed such that corona is minimised, associated radio noise complies with AS 2344 and audible noise is within EPA guidelines under all weather and load conditions.

After completion of the construction, field measurements of corona and radio noise shall be undertaken Transgrid reserves the right to witness the tests and ask for specific locations within the works to be assessed in the field measurements.

At 220 kV and below the surface voltage gradients shall not exceed 16.0 kV/cm. The minimum conductor configuration is single olive ACSR/GZ configuration dependant on continuous current rating requirements.

At 330 kV, all conductors within the bays for inter-equipment connections shall be a minimum of triple olive ACSR/GZ configuration to maintain surface voltage gradients below the 19.0 kV/cm level. Any overhead 330 kV strung conductor will be a minimum of twin olive ACSR/GZ using a 125 mm conductor spacing.

At 500 kV, all conductors within the bays for inter-equipment connections shall be a minimum of quad parrot ACSR/GZ configuration or quad 800 mm2 AAC configuration to maintain surface voltage gradients below 19.0 kV/cm level. Any overhead 500 kV strung conductor will be a minimum of:

Triple parrot ACSR/GZ using a 250 mm conductor spacing or

Triple 800 mm2 AAC using a 250 mm conductor spacing or

Quad orange ACSR/GZ using 500 mm (square) conductor spacing.

Any alternate conductor configurations shall be identified. A report and/or calculations shall prove that the conductor configuration is within the limits as specified above.

Corona rings and other corona control measures shall be provided to maintain surface voltage gradients to within the limits identified above for each voltage level.

5.22. Switchyard high voltage cables

The HV cables shall be designed as per the "Transgrid HV Cable Design and Installation Manual".

High voltage cable design parameters shall be as follows:

- Ambient air temperature - (refer section 3.2 general design parameters);
- Ambient soil temperature - 25°C;
- Soil and backfill moisture content - 0% (fully dry);
- Load factor - 1.0;
- Screen bonding - Double point preferred.

High voltage cable cover shall be 750mm to the top surface of the mechanical protection (excluding gravel surface layer) minimum.

Unbonded screen ends shall be placed out of reach or shrouded to prevent contact in service but be accessible for testing.

5.23. Switchyard MV Cabling

The requirements listed for HV cables applies for MV cables too. The MV cables shall be designed as per the "Transgrid MV Cable Design and Installation Manual".

Design of high voltage cables shall include the cable route, pulling tensions / sidewall pressure, thermal ratings, terminations, bonding design, fault ratings, short circuit forces, bending radii, and allowance for overvoltage requirements. The construction method shall consider ease of installation and future replacement. The routes for switchyard power cables shall be clearly identified and aligned to be clear of in-service high voltage equipment. The cable routes should be able to be opened at a later date without damage to buildings, high voltage equipment and their support foundations or other cables.

All MV cables shall comply with AS 2067 in regard to the minimum depth of cover and mechanical protection.

The standard cable screen size is 10 kA where cable runs are wholly within the substation. The suitability of the standard cable screen fault rating for the intended application is to be confirmed by the designer.

Where high ratings are required and both ends of the cable are terminated within the same earth grid, single point bonding may be permitted. The design shall confirm the need for and sizing of surge voltage limiters and earth continuity conductors.

In general, short runs of 11 kV and 33 kV cables for auxiliary and/or earthing transformers can be double point bonded within a substation.

For all other cables, double point bonding is preferred, provided required ratings are achieved and there are no transferred potential issues. Single point bonding or special bonding may be permitted with Transgrid approval where double point bonding is impractical.

The cable designer is to demonstrate through the provision of short circuit force calculations that proposed non-conductive cable cleating arrangements are adequate to prevent damage to the cable, its supports and associated equipment/busbar terminals.

Trenches for burying cable shall be designed straight wherever possible.

Where power cables entering buildings are run in trenches, the only other cables that may be run in the trench are communication cables that are directly associated with them.

Where cable routes pass under any construction, e.g. roads, runways and trenches, conduits of an appropriate diameter shall be used to permit future installation or replacement of cables for the crossings.

PVC ducts for substation circuits shall be heavy duty, light orange coloured. Joints and fittings shall be solvent welded.

Mechanical protection requirements shall be as per AS-2067 and AS-3000. The primary warning on top of installed cable circuits and pits shall be achieved using appropriately designed polymeric cable covers to AS 4702. The polymeric covers shall cover the entire width of the trench, leaving no gaps.

Where cables are mounted above the ground, they shall be protected from sunlight by enclosing them in covered cable tray or shall be protected by other means as approved by Transgrid.

Where cables are installed in the vicinity of oil filled equipment an engineering risk assessment shall be performed to determine the appropriate level of protection. See Section 5.5 for considerations.

All cable conduits in oil filled transformer or reactor compounds shall be sealed to prevent flow of oil out of the compound back to cable trenches.

5.24. Equipment Terminal Loads

5.24.1. Short Circuit Forces, Wind Loads, and Weight

Equipment terminal loadings shall be applied in accordance with AS2067 which includes reference to AS1170.

In the design of three-phase structures for balanced three-phase short circuits, the short circuit forces shall be assumed to act in one bay and on two phase conductors as either attractive or repulsion forces at any one time, all three phases shall be subjected to 25 % wind pressure.

Short circuit forces acting on single conductor and bundle configurations shall be calculated in accordance with IEC 60865-1 Short circuit currents – calculation of effects – Part 1: Definition and calculation methods. Calculations shall be submitted to Transgrid, at a minimum these shall provide visibility of all inputs and assumptions.

Load combinations and factors to be used in the wind load calculations shall be in accordance with AS 2067 Table 2.1.

For horizontal conductors, per IEC 60865, Clause 6.2.6, if the span length is less than 100 times the diameter of the single conductor, the calculated drop force can be neglected. For Olive conductor, the drop force does not apply for lengths < 3.1 m. For multiple conductors the designer may justify increased lengths of up to 130 times the diameter where drop forces do not apply.

5.24.2. Dropper Force Calculations

Formula 49 in IEC 60865 shall be used for dropper calculations where applicable within the limits stated. Where the dropper cable length is less than 1.4 times the width of the dropper, the standard calculation method for horizontal droppers shall be used.

For steep droppers where the cable length is more than 3.3 times the width of the dropper, the following formula shall be used

$$F_{sc} = \frac{\mu_0}{2\pi} \frac{(I_k")^2}{a} \frac{L^2}{4S}$$

Where S is the sag or transverse slack of the dropper, and the other inputs are as per Formula 49.

In addition, the pinch force Fpi is calculated as 1.1 x Fsc.

As for inter-equipment connections droppers shall have sufficient sag and as few spacers as practicable to reduce the forces.

Ultimate wind loads need to be calculated for droppers as they may be the worst case.

Where a dropper is to a surge arrester or voltage transformer only, short circuit forces may be neglected. Wind loads should still be calculated. Where such droppers tee off a main circuit dropper, the connection design should allow sufficient slack to allow for the movement of the main dropper. Short circuit forces are to be considered for tee off droppers to earth switches.

5.24.3. Terminal Loads at Major Structures

In the case of overhead strung bus connections, the loads shall apply at the conductor anchoring point in the conductor take-off direction. Structures shall be designed for conductor take off angles of up to 30 degrees from the direction perpendicular to the structure beam.

5.25. Conductor Design

5.25.1. Bundle Configuration on Inter-Equipment

Transgrid’s preferred type of conductor for strung bus and inter-equipment bus is ACSR/GZ to AS 3607.

Conductor bundles shall be selected to meet the requirements of thermal ratings (continuous and overload), short circuit ratings, and surface voltage gradient limitations. Short circuit forces to comply with equipment manufacturers who specify the maximum forces that may be applied at terminal palms.

For regular bundle configurations up to four sub conductors, spacers shall be positioned at calculated intervals to limit the increased conductor tension force experienced on equipment palm terminals by pinch effect due to intra-phase short circuit forces. The number of spacers should generally be minimised. Another option is to increase the slack in the span, provided this does not compromise clearances. The design shall take these limits into consideration when determining the shape of flexible droppers and connections to or between equipment.

Horizontal conductors shall be sagged a minimum of 5%. Larger sags are recommended where practicable as they reduce the pinch forces and sometimes the drop forces. They also provide flexibility for equipment movement during ground movement. Care should be taken to ensure clearances are maintained. It should be noted that shorter jumpers, less than 4 m (for Olive) can be shaped upward to improve the ground clearance.

It is important that actual conductor design sags and shapes are specified and shown accurately on the design drawings. When evaluating clearances consideration should be given to conductor rigidity and sufficient margin allowed to account for conductors drooping over time.

5.25.2. Bundle Configuration on Strung Bus

Spacers for bundled conductors on overhead strung bus shall be positioned at calculated intervals to limit the total tensile forces in the span occasioned by the increased tension due to pinch effect.

Short circuit force on overhead strung bus and droppers shall be calculated in accordance with "Equipment Terminal Loading" section of this standard with reference to IEC 60865-1-2011 Short circuit currents – calculation of effects – Part 1: Definition and calculation methods.

5.25.3. Stranded and Tubular Conductor Ratings

The following should be considered in conductor rating calculations:

- For all rating calculations operating voltage shall be taken into account
- Terminal palm arrangement is to be considered separately

Table 3.Stranded Conductor Ratings

Conductor Arrangement	Rating[1]	Normal Usage[2]
1 x Lemon	625	132 kV and lower
1 x Olive	1110	132 kV and lower
2 x Olive	2220	330 kV and lower
3 x Olive	3330	330 kV and 132 kV
3 x Venus	3690	330 kV
3 x Parrot	4050	500 kV
3 x 800 AAC	4110	500 kV
4 x Parrot	5400	500 kV
4 x 800 AAC	5480	500 kV

Table 4.Tubular Busbar Ratings

Conductor Arrangement	Rating[1] (A)	Normal Usage[2]
100 x 4	1985	132 kV and lower
100 x 10	3040	132 kV and lower
160 x 10	4235	330 kV and lower
200 x 12	5370	330 kV and 132 kV

Notes:

1. Ratings apply for summer days and to be used to meet the required ratings in Planning Schedules
2. All busbar configurations are to comply with corona requirements

5.25.4. Standard Fittings for Flexible and Tubular Conductors

Fittings shall comply with AS 62271.301.

Fittings for use at voltages of 330 kV and above shall incorporate corona control measures of a type that is proven by type test or by extended in-service experience.

The preferred fittings are listed in Transgrid standard STD-822217. If the Transgrid standard fittings are not used, relevant type and routine test certificates shall be provided upon Transgrid request.

5.26. Busbar Design

5.26.1. Busbar Loads and Deflection

All tubular aluminium busbar and post insulator shall be designed for the loads specified in AS 2067 and shall include the following:

- Dead loads
- Wind loads
- Short circuit loads

Wind Loads shall be assessed in accordance with AS 1170.2-2011 considering the serviceability wind speed.

Short circuit force on busbars shall be calculated in accordance with IEC 60865-1-2011 Short circuit currents – calculation of effects – Part 1: Definition and calculation methods.

The sizing of tubular busbar and station post insulator shall be assessed against the load combination as stated in AS 1170.0-2002 under serviceability limit state. Tubular busbar shall be designed to withstand the bending stress. Station post insulator shall be designed to ensure loading is below the minimum failure load under bending.

The following standard tubular aluminium busbar configurations shall be used:

Table 5. Standard Tubular Busbar Sizes

Standard Busbar Sizes (mm)
100 x 4
100 x 10
160 x 10
200 x 12

Tubular busbar deflection shall be calculated in accordance with IEEE 605-2008 under loading conditions. The allowable vertical deflection of tubular busbar shall be designed such that the ratio of busbar deflection to span length is no more than 1:200.

Span lengths shall not exceed those nominated in STD-142772.

5.26.2. Busbar Vibration Damping

Long lengths of rigid tubular busbar can experience vibration due to the effects of wind or from alternating current. Over time vibration can have a damaging effect on both the busbar itself and associated fittings and connections. In order to dampen vibration and dissipate vibration energy, stranded conductor of equal length and same material as the busbar shall be inserted inside the hollow tubular busbar as specified in IEEE 605–2008 Clause 12.7.

Refer to drawing STD-822196 for further guidance of the damping elements used.

5.26.3. Busbar Expansion Arrangements

Length of aluminium tubular busbar is subjected to thermal expansion with varying temperature. To allow for this variation and ensure the tubular busbar operates within the design parameters, busbar expansion arrangements shall be used.

5.26.4. Aluminium Welding

Welded joints should not be made in the middle 1/3 of any supported tubular span. Site welding shall be minimised.

5.27. Switchyard lighting

The minimum requirement for Switchyard lighting:

- Lights shall be provided for walking in open areas likely to be accessed;
- Lights shall be provided near the substation security fence in areas unlikely to be accessed as a deterrent only;
- Lights shall be provided for walking in closed or constrained areas (e.g. equipment enclosures, stairs) for increased safety only;
- Lights shall not obstruct access for operation and maintenance.

Lights shall be manually controlled and automatically controlled by the substation security system.

Substation lighting for outdoor areas shall meet the following:

- Minimum 2.5 lux throughout substation; and
- Transgrid’s Standard Design and Construction Manual – Physical Security; and

In general, switchyard lights shall be positioned in an optimal position to maximize illuminance level at the HV plant areas where the reading of equipment labels is required.

The preferred switchyard lighting is Beacon LED lights, the following type should be used:

- VPS-48L-110/5K7/5W/UNV/MAF/LGS

All switchyard light fittings shall be mounted on 4 m steel poles. Pivoting poles are not required for LED substation lights. Switchyard lighting shall be located to allow for maintenance without outages on HV switchbays.

Note that minimum lighting requirements apply within enclosed outdoor areas, e.g., transformer bund with noise walls or fire walls. Alternative light fittings may be considered in these locations.

For indoor type applications in locations such as Secondary System Buildings (SSB), in general, normal internal lighting requirements should be as per AS/NZS 1680.1:2006.

5.28. Switchyard lightning protection

Switchyard lightning protection shall use lightning masts or overhead earth wires using the rolling sphere method with a 24m sphere radius. At a minimum Lightning protection should be applied to:

- High voltage conductors;
- High voltage equipment (including transformer radiators);
- Buildings (air terminals mounted on buildings may be used);

Where practical earth wires shall not be strung above live equipment. Earth wires shall not span over multiple busbars, feeders, transformer, reactors or capacitor bank bays that could cause multiple outages in the event of an earth wire failure. Multiple failures shall be considered where multiple earthwires terminate on a common structure.

Substation earth wires are only required to carry current associated with a lightning strike and not the full fault earth return current of a transmission line. As such a standard earth wire size can be used independent of substation fault level.

Typical substation installations should use 7/3.75 SC/GZ conductor as the earth wire. Where corrosion is considered an issue 7/4.25 SC/AC conductor may be used. Other sizes or types of earth wire may be considered where there is a demonstrated technical reason.

For augmentation works at existing substations the earth wire used shall match the existing substation earth wire where the existing earth wire is of type SC/GZ or SC/AC.

Typical lightning mast height inside substations are 18 m (STD-817973) and 20 m (STD-814373). Two meter high lightning rods are to be added to the lightning mast heights and considered by the lightning study.

5.29. Switchyard fire protection

An initial assessment of the site specific fire risk shall be undertaken as part of the Site Suitability Workshop, and then evaluated throughout the SiD process as outlined in Section 3.

5.29.1. Bushfire

The risk of substation assets resulting in a bushfire and the risk of a bushfire damaging substation assets shall be assessed and addressed as part of the design process. These bushfire risks shall be mitigated to as low as reasonably practicable in accordance with Transgrid's Electricity Network Safety Management System (ENSMS).

Standard design risk controls are generally sufficient to reduce the risk to ALARP, however site specific hazards are to be evaluated to determine if additional controls are required to reduce the risk to ALARP. Site specific considerations would include the following and shall be discussed during the Site Suitability Workshop and throughout the design process:

- Location within bushfire prone land
- Surrounding vegetation, landscape and slope
- Consultation with relevant authorities (e.g. Rural Fire Service)
- External obligations (e.g. environmental and regulatory approvals)
- Proposed structures and equipment

Depending on the site specific risks, additional controls to be considered include buffer zone distance, equipment insulation types and substation layout and spacing. Evaluation of these controls are likely to require the engagement of a specialist fire risk assessment.

The risk assessment shall document that the bushfire risks have been reduced to ALARP and this will form part of the SiD report.

5.29.2. Fire Protection

In outdoor substations it is preferred to provide passive fire protection by means of segregation over protective measures such as fire walls. Outdoor substations generally do not require an active fire protection system (e.g. hydrants, tanks, pumps). However, in some cases equipment failure modes, environment and/or location will result in the requirement for either a specialist fire risk assessment and/or the introduction of active fire protection.

Where required fire protection for all substation and switching stations shall conform to Transgrid Fire Protection Standard, drawing STD-169565.

Substation building fire systems shall comply with the Building Code of Australia (BCA) e.g. hydrants for buildings with floor area larger than 500 m2.

The requirement for an active fire protection system for 33 kV or below switchgear buildings (e.g. gas suppression) shall be determined by a risk assessment.

Where an active fire protection system is not required the remaining requirements of Transgrid Fire Protection Standard, drawing STD-169565, shall apply.

5.30. Switchyard security

Switchyard physical security requirements shall be dependent on a *Site Security Criticality Assessment* to be carried out by Transgrid. Switchyard physical security shall include perimeter intrusion monitoring and detection, CCTV cameras, thermal imaging, card and biometric readers and infrared night-time floodlighting as a minimum. The system shall incorporate complete monitoring and detection of switchyard perimeter and entry points as a minimum. Switchyard security shall incorporate an appropriate security level of fencing to meet assessed site criticality.

5.31. Acoustic noise

The substation shall comply with relevant local, national and state acoustic noise requirements. Prior to construction, a noise study shall be performed and provided to Transgrid for review. Acoustic noise shall be tested after energisation to confirm compliance.

5.32. Electric and Magnetic Fields' Levels

The substation magnetic and electric fields' levels shall be as outlined in the "Transgrid Power Frequency Electric and Magnetic Fields Management Policy" document. Magnetic and electric fields shall be tested after energisation to confirm compliance.

5.33. Switchyard Fencing

A minimum of 6 m clearance is required from primary equipment to the fence for general public safety consideration for voltages 132 kV and under. At 330 kV and 500 kV the minimum distance from HV equipment will increase either due to section safety or vehicle access. In this case, the greater of section safety clearance as per AS 2067 or vehicle access clearance should be achieved.

A minimum of 2 m clearance is required from all other fixed structures and equipment including lights, lightning masts, junction boxes, structures, etc. to the fence. All items are to be positioned such that access is not restricted.

5.34. Documentation

As a minimum the following documentation shall be provided:

- Initial single line diagram;
- Ultimate single line diagram;
- Equipment schedule;
- Initial site layout;
- Ultimate site layout;
- Initial general arrangement;
- Ultimate general arrangement;
- Bay and bus plan and elevations;
- Conductor and fittings schedule;
- Earth grid and riser layout;
- Conduit layout;
- Conduit sections;
- Miscellaneous equipment layout
- High voltage design parameters design report;
- Electrical clearances design report;
- Insulation coordination design report;
- Earthing system design report;
- Earthing system test report;
- Conductor and high voltage cable design report;
- Equipment and structure conductor mechanical loads design report;
- Lighting design report;
- Lightning protection design report;
- Fire protection design report;
- Acoustic design report;
- Acoustic test report.
- Electric and magnetic fields calculation report;
- Electric and magnetic fields test report;
- Line rating advices

6. High Voltage Equipment Requirements

6.1. General Equipment Requirements

Transgrid's HV network is designed to provide very long term reliable operational service and high availability. This is achieved by a total design concept that allows the operation and maintenance of the Network without interruption to supply and in accordance with the Transgrid's Power System Safety Rules and operating procedures.

This includes but not limited to the provision of access and facilities for operation; the ability to carry out maintenance on any item of plant or equipment with no or minimal disturbance to other systems; facilitate emergency response at any time and in all weather conditions and efficient fault finding for restoration purposes.

As part of the Safety in Design process, the Supplier's design shall be assessed to ensure these concepts are not compromised, and in no way should the Connection Applicant's design and assets introduce any risk to Transgrid's workers and assets.

All equipment shall be designed and manufactured in accordance with relevant Australian standards or appropriate international standards. If an appropriate Australian standard does not exist then the relevant international standard shall be applicable. Where no relevant standard exists, the design and manufacture shall comply with recognised standards of best practice.

Where the requirements of this primary design standard conflict with any other standard, this design standard shall take precedence.

The requirements described in this document are on a very high level only. Detail requirements for each type of equipment can be provided upon request.

6.2. Design Life

The Supplier's design must incorporate such materials, features and components as necessary and appropriate to:

- Minimise the extent, frequency, duration and cost of maintenance for each Item throughout its design life, and
- Ensure ease of use and safety for personnel whilst installing, operating and maintaining each Item.

Transgrid requires that all information provided in support of the above extends to and includes subcomponents and sub-suppliers, and that account of the design life and maintenance requirements of sub-components has been made for the published design life and maintenance requirements for the Item.

6.3. Seismic Design Requirements

The equipment shall be designed in accordance with AS 1170.4-2007 "Structural design actions – Earthquake actions in Australia". The analysis shall be carried out on the system comprising the equipment and the structure on which the equipment is to be mounted. Systems comprising equipment mounted on structures are generally irregular, eccentric or top-heavy systems for which dynamic analysis is required.

The following parameters shall apply:

a. Structure importance factor = 4
b. Hazard factor (Z) = 0.12
c. Probability factor Kp = 1.8
d. Soil classification = Ce
e. Earthquake design category = II

6.4. Reinforced Security and Explosion Proof Design

All HV equipment insulation is required to have composite insulation, except for post insulators.

The equipment design shall include features intended to reduce the safety risk in the event of an internal insulation failure. The Connection Applicant shall provide details of these features and/or supporting test data in the relevant handover documentation.

6.5. Direct Earthing

Transgrid adopts a philosophy of 'Direct Earthing' of equipment. Earthing terminals shall be directly connected to the earth grid (general mass of earth) via suitably sized copper strap. Examples of earthing terminals requiring direct earthing are:

- The neutral / earth terminal of Items such as Instrument transformers, bushings and surge arresters
- Disconnectos and earthing switches
- Control cubicles

It is not acceptable to 'earth through the tank'.

6.6. Arc Fault Protection

Transgrid requires all equipment to have sufficient level of arc fault protection in order to protect adjacent asset and personnel and reduce health and safety risks to as low as reasonably practicable in accordance with the Safety in Design procedure. The considerations in AS/NZS 62271 series, especially 62271.200, regarding the risk and mitigation of internal arc and possible damages shall be considered applicable to all indoor metal enclosed switchgear, as well as other equipment with similar design philosophy. Examples include but not limited to RMUs, Power/battery/energy management systems for Battery Energy Storage System (BESS), and other types of LV/HV switchgear. Transgrid requires the equipment to be able to contain expected arc fault based on its rating and any damages as a result of the arc fault, and does not pose risks to people or other asset in the front, lateral or rear of the equipment.

Evidences such as arc fault containment test report shall be provided to Transgrid to prove that the equipment satisfies this requirement.

6.7. Accessibility of User Features

Operator accessible components such as any fuse, link, switch, contactor, indicator, handle, operation counter etc. shall be at a height greater than 1000mm but not exceeding 1800mm from ground level or operating platform such that the user does not have to crouch down or otherwise adopt a contorted stance to perform the action.

Any point required to be accessed for operation, maintenance or repair shall be readily viewable and readily accessible.

All indicators shall be readily visible from the ground such that position, status or value information can be easily determined. Examples include:

- Equipment oil level or pressure gauge indicators
- Position indicators

6.8. Equipment Design Review

A design review meeting shall be arranged with Transgrid to review the proposed equipment designs with the manufacturer, especially for major and complex equipment such as power and auxiliary transformers and metal enclosed switchgear, to ensure they are designed in accordance with Transgrid's requirements.

Examples of items to be discussed at the design review shall include, but not be limited to, the following;

- Design standards
- Winding design (material, shielding, short circuit forces and support structure)
- Core design and support structures
- Tap change switch capacity
- Short circuit, impulse and impedance calculations
- Dielectric design and performance
- Thermal performance
- Mechanical layout
- Testing
- Operation and maintenance

6.9. Fuses, Miniature Circuit Breakers and Links

All fuses shall be HRC cartridge type and the cartridges shall comply with AS 60269 "Low-voltage fuses", "Part 1: General requirements" and "Part 2: Supplementary requirements for fuses for use by authorised persons (fuses mainly for industrial application)".

Miniature circuit breakers may be used instead of fuses and shall comply with AS 3111 "Approval and test specification - Miniature overcurrent circuit-breakers".

Where two independent LV supplies are specified, all miniature circuit breakers shall be either 2 pole (single phase – active + Neutral) or 4 pole (three phase + Neutral) as in these cases Transgrid requires a switched Neutral for protection grading purposes.

Independent isolation facilities shall be provided on each side of all trip and close coils and shall be located adjacent to their respective fuse or miniature circuit breakers on the front of the main control panel. Suitable points of isolation shall be provided such that it shall be possible to de-energise and isolate every circuit so that every circuit can be made safe for work.

Within any cubicle, independent electrical isolation links shall be provided:

- on each side of all trip and close coils and operating mechanisms and,
- on either side of any fuses or miniature circuit breakers.

All links shall be physically located on the front of the main control panel and, where feasible, adjacent to the associated fuse or circuit breaker such that the isolation of the circuit device is clearly established.

Links shall be mounted in a white cartridge type fuse carrier, complying with AS 60269 “Low-voltage fuses”, “Part 1: General requirements” and “Part 2: Supplementary requirements for fuses for use by authorised persons (fuses mainly for industrial application)”, for AC applications.

Links for all other circuits shall be of the Phoenix URTK/S type of size appropriate to the cable size and must include a hexagonal head link-securing screw in lieu of the standard screw supplied.

Links shall be positioned either horizontally or vertically and shall fall to the closed position when in vertical orientation. For a vertically mounted link, the incoming / outgoing wires (the X terminal side) shall be connected to the bottom of the link.

Fuses, miniature circuit breakers and links shall be grouped together and clearly identified with a description of their function on a plate mounted nearby inside the control cubicle.

6.10. Pressure Vessels Approval

The designs of all compressed gas pressure vessels shall be to the approval of the Workcover Authority of NSW and evidence shall be provided of the approval process.

Inspection of equipment shall also be to the requirements of the Workcover Authority of NSW.

6.11. Support Structure Design Certificate

The following shall be provided to Transgrid prior to energisation:

- Certificate for each type of support structures (standard and non-standard) that demonstrates they were designed and manufactured in accordance with the relevant Australian standards, and
- The certificates should include reference to the drawings, equipment and the standards that it complies to.

Transgrid expects that the certification is a part of design compliance check that proves the item in its entirety meets Transgrid requirements and standards, and anticipates that this information should already be available in accordance with good practice and basic SID requirements.

6.12. Spare Parts, Tools and Appliances

The Connection Applicant shall list, package for long term storage and handover to Transgrid any Spare Parts, Tools and Appliances necessary for the operation, maintenance and disposal of the equipment.

Any spare part, tool or appliance requiring indoor storage must be clearly and permanently labelled on all four vertical sides of the crate or clearly on any package with the words “Must Be Stored Indoors” or a globally accepted equivalent symbol.

6.13. Documentation

The complete documentation packages of equipment shall be delivered to Transgrid prior to energisation. This includes but not limited to:

- Any equipment drawing (2D and 3D)
- Any equipment manual (product/operation/maintenance etc.)
- Full Type test report, applicable for the exact type of equipment provided
- Inspection and test plan (factory and site)
- Factory routing test report
- Site test report (if any)
- Datasheets
- Safety in Design report

6.14. Power Transformer Requirements

6.14.1. Rating and Overload Capacity

The transformer shall be capable of having a defined load and overload capacity as stated in the project specific contract/agreement. All ancillary equipment on the transformer, e.g., tap-changers, bushings, etc., shall have rated currents of at least this percentage of the transformer overload current.

6.14.2. Short-Circuit Strength

The transformer, when on any tapping, shall be capable of withstanding, without deformation or injury, the thermal and mechanical effects of external short-circuit conditions, with such fault currents as may arise from any type of fault, with full voltage maintained on all other windings (zero source impedance) unless otherwise specified.

6.14.3. Temperature Rise Limits

The transformers shall be capable of operating continuously at maximum rated power, with the tapping switch in the position corresponding to maximum losses, without exceeding the Australian Standard limits of temperature rise. In addition, the main tank wall hot spot temperature rise shall not exceed 70 °K.
For the purpose of design and testing, the main tank is not to be considered for losses. All losses are to be assumed to be dissipated via the cooler bank. The main tank may be installed in a noise enclosure that does not have any ventilation ducts and comprises four walls without a roof. Hence, additional tank losses shall be considered during testing.

6.14.4. Lifting

Lifting lugs shall be provided for lifting (by means of a crane) the complete transformer filled with oil.
Designs of any necessary lifting devices (e.g., for tap-changers, bushings, main tank lowering devices, etc.) are the Proponent's responsibility and shall be in accordance with the NSW Government Construction Safety Act, obtainable from the Government Information Service of NSW.

6.14.5. Handling

The transformer shall be fitted with jacking pads for lifting the complete transformer filled with oil and with haulage lugs for hauling it on skates. Jacking pads shall be not less than 400 mm and not more than 550 mm from ground level with the transformer standing on its base.

6.14.6. Transport and Mounting within Substation

The transformer shall be suitable for transport by skates. The transformer base shall be designed to locate the skates on the underside pads having minimum dimensions of 400 mm x 400 mm.

The transformer base shall be mounted on anti-vibration pads for noise reduction.

6.14.7. Design of Transformer to Suit Enclosure

The fully erected transformer shall be able to be immersed up to a level of 600mm to facilitate testing of the bunded area. The bunded area is filled with water to test its integrity. It is preferential that no exposed electrical connections or transformer accessories shall be less than 600 mm from ground level. Any special arrangements to be made for items not able to withstand this test shall be submitted to Transgrid for approval.

The design shall consider splash angles from highest points with oil (for both main tank & cooler bank) in accordance with Australian standards, without requiring attachments on the transformers (e.g. splash guards) and the maintenance of safe walking clearances and the maintenance access requirements.

6.14.8. Maintenance Access and Safety

The transformer shall be designed to the appropriate Australian standards (refer AS 1657 as a minimum) to provide safe access to items such as bushing terminals and Buchholz relay that require inspection or maintenance work during a maintenance outage.

The design shall assume that noise walls are present, and make allowances for suitable access in this circumstance.

The measures shall include but not be limited to the following:

- Where personnel are liable to a fall of two (2.0) metres or more a fall prevention solution, or where fall prevention is not possible, a restraint system shall be provided comprising:
  - For work of a minor nature, a fall arrest system of suitably nominated attachment points to be nominated by the Proponent and approved by Transgrid. The fall arrest system shall consider the specification for these attachment points to comply with relevant Australian standards. The placement of these points shall consider possible pendulum effect or other risks that can be presented based on the Proponent nominated locations.
  - For work of a more involved or longer duration, (e.g. tap-changer diverter maintenance), Transgrid prefers the use of EWP for working at height. If platforms are provided, they shall be level with the transformer lid with fixed rigid rails that are not easily fallen through, with no horizontal gaps greater than 150mm other than access points. These rails shall be constructed and tested to AS 1657. These platforms shall be arranged and located so access can be gained using a removable ladder (refer to ladder attachment point below). Preference is given to access solutions that are permanently affixed, but if they require removal of sections to maintain electrical clearances during operations then those sections shall be readily removable, made of lightweight aluminium and have alternate attachment points available to facilitate their installation/removal. If aluminium is deemed not be strong enough, an alternative material may be proposed for Transgrid's assessment. Each section shall be less than 25 kg in weight so it can be manoeuvred by one person. On three phase transformers, platforms are required to provide access to all of the work area and not sectionalised to separate phases.
- Facilities for the temporary attachment of:
  - The left and right side of ladders such as tie points where a ladder is required for access to an elevated platform; and
  - Of the climber prior to ascending onto the ladder.
- Any access point to work areas at height (i.e.> 2.0 m from ground level) shall be provided with a ladder attachment point to safely secure the ladder and adjoining attachment point to alight from the ladder. All ladder attachment points shall be suitable to capture a ladder of minimum width 460 mm.

- Facilities for reduction in risk :
  - Use of non-skid paint on access areas;
  - Mesh over exposed pipes in traffic areas to reduce trip hazards; and
  - Locating pipe work, cable trays and lid stiffeners appropriately to facilitate easy access.
- Clear identification of attachment points, access areas and other height safety system elements.
- Alternate design options such as a larger main tank lid and position of bushings.
- Guard rails with a toe-board are required on both permanent and temporary handrails.
- The gas-and-oil actuated relays and bushing taps shall a suitably positioned to facilitate safe access via an EWP for any maintenance activities. The safety in design review shall consider the positioning of these items.
- All valves shall be located and oriented so that they are readily accessible from ground level, transformer lid or using EWP.
- Major maintenance activities will be assisted by mobile crane or EWP, so no provision for dedicated lifting derricks is necessary.
- Consideration shall be given to providing ‘captured’ man-hole and hand-hole facilities on covers for when they are to be removed from the service position such that the transition of weight does not cause a hazard. Alternative such as lugs or other facilities that enable safe removal shall also be included. The removal of the covers from the service position and the complete removal of the cover from the transformer shall be included in the SID report and / or Instruction Manual. All removable covers shall have the weight indelibly stamped on them in accordance with Australian Standards.

Each safety facility (ladder tie point, fall arrest attachment point etc.) must be painted or otherwise highlighted with yellow paint of a paint system compatible with the system used on the main tank and cooler bank.

The implementation of the facilities must be fully described to Transgrid.

A facility is required to be included on the main tank or cooler bank support frame for the local storage of the removable hand-rails or guard-rails and other facilities used for maintenance access. The facility shall consider the weight of the components for lifting onto any storage structure or fitting.

6.14.9. Main Tank and Support Structure Earthing

All main components connected to the main tank by bolts shall be formally earthed to the main tank, by an earth strap. Examples of this are bushings, turrets and pressure relief devices. Minor accessories need not be formally earthed in the same manner. An example is the thermometer pockets.

Provision shall be made on the main tank and cooler bank and pipework support structures for the attachment of 50 x 6mm flat copper earthing strip.

For the main tank, provision shall be made at positions close to each of the four bottom corners in the form of two 18 mm diameter holes at 50 mm centres, in a vertical line, on a minimum 90 mm x 60 mm flat stainless steel lug at least 10 mm thick, welded to the main tank.

For the cooler bank and pipework support structures, provision shall be made for earthing similarly to the main tank.

Tapped holes and studs are not acceptable.

6.14.10. Surge Arrester Brackets & Earthing

For HV voltages ≤ 145 kV, surge arrester brackets are required to be included in the supply with the transformer. A common Earthing Bar shall be installed across the surge arrestor bracket. An Earthing Strap shall then be run from the Earthing Bar to a location at the bottom of the main tank, and shall be supported on stand-off insulators.

Stand-off insulators should be appropriately rated to prevent flashovers to the tank (at least 5 kV).

Each of these Earthing Straps shall terminate about 150 mm off ground level, with the nearest standoff insulators about 100 – 150 mm away from the end point (i.e. 250 – 300 mm from ground level).

6.14.11. Bushings

The bushing type shall be resin impregnated paper (RIP) with silicone rubber shed design.

For all RIP bushings, Transgrid has previous experience and the supply of these components shall be from:

- ABB, Sweden;
- Trench, France;
- Micafil, Switzerland;
- HSP, Germany;
- Moser-Glaser, Switzerland.

The colour of all bushings shall be light grey – similar to colour N35, Light Grey to AS 2700.

Each palm shall be able to be rotated 360° about the axis of the bushing, to suit the external lead orientation.

The material of terminal palm shall be selected to prevent galvanic corrosion with the high voltage conductors connected.

6.14.12. LV Cable Box

Transgrid generally does not prefer the use of LV cable box and would avoid it if possible.

6.14.13. In-Built Current Transformers

Terminals for metering CTs shall be segregated and provided with 'tamper proof covers' similar to 'Phoenix Cover AP 3-TNS 35' or 'Wago Cover Carrier Type 2 (including positioning and attachment screw and nuts)' for the purpose of sealing off the metering CT circuits.

This shall apply to any item that includes a metering CT requirement.

Transformer bushing CTs shall include test loops to facilitate periodic primary injection accuracy checks of each revenue metering CT. It is anticipated a simple solution can be engineered (e.g. a straight conductor that is expected to pass 120% of CT's maximum current for 60 seconds through the CTs and terminated on each bushings' turret via stand-off insulators or similar).

6.14.14. Valves

Butterfly, locking type butterfly and ball type valves are not acceptable, except for use with radiators

6.14.15. On-Load Tap-Changer

Transgrid has previous experience and preference for the supply of these components from:

- ABB, Sweden;
- MR, Germany.

6.14.16. Insulating Oil

The transformer is be filled with new uninhibited insulating mineral oil in accordance with AS 1767, or other insulating medium in accordance with their own AS / IEC standards, for example, ester fluid in accordance with IEC 61099, IEC 61203 and IEC 62770.

6.14.17. Test Requirements

Transgrid has the following desire for the sequence of tests:

- Thermal Tests
- Dielectric tests
- IVPD.

6.15. Circuit Breakers

The circuit breakers shall be three-phase, 50Hz, SF6 outdoor type, capable of operation on an effectively earthed system and shall include all accessories and components necessary for this purpose.

The circuit breakers shall have polymer insulation (support and interrupter).

Transgrid has a preference for circuit breakers:

- without high voltage auxiliary capacitors,
- with spring operating mechanisms,

Electronic devices (e.g. semiconductors, microprocessors, opto-couplers and other instrumentation / control devices) shall not be included in the control and alarm circuits of the circuit breaker. Conventional control devices such as pressure, limit and other switches, contactors and relays are not considered to be electronic devices in this definition.

6.15.1. Circuit Breaker Accessories

The circuit breaker shall be supplied complete with all accessories necessary including, but not limited to, the following:

- Lifting lugs or the facility to use soft slings for lifting.
- Gas sampling valve (DILO size DN8 or DN20), gas pressure gauge graduated in Pa, if applicable to the circuit breaker type.
- Manual Spring Charge Handle.

6.15.2. Operating Mechanism Accessories

The following accessories shall be provided with each operating mechanism in addition to any facilities that may normally be provided by the manufacturer:

- A mechanical position indicator that is clearly visible from ground level and external to the mechanism enclosure. The indicator shall indicate "I" (red background) - closed; "O" (green background) - open.
- A trip operation counter that is clearly visible from ground level. A trip counter is defined as one that will increment on completion of a trip operation. This is distinct from a close counter which increments on completion of a close operation. Transgrid has a preference for electronic trip operation counters.
- A device for manual slow closing and opening of the circuit breaker during maintenance. The circuit breaker shall be designed so that the spring charging motor is prevented from providing a force to the manual charging handle if it is inadvertently energised during the manual charging operation. The manual operating device shall be clearly labelled and located inside the operating mechanism box.
- A separate push button for operating any trip coil locally. Local operation shall not block a remote trip operation, e.g. operation due to a protection trip. Transgrid requires the ability to negate (e.g. by bridging out) the local / remote switch.
- One "CLOSE" push button, for each three-phase breaker.

- Lifting lugs.
- Trip coils that are separated mechanically, electrically and magnetically. The number of trip coils shall be in accordance with Transgrid's standard drawings (e.g. for single pole CBs, THREE (3) OPEN coils).

The SF6 Equipment requirements shall be satisfied.

6.15.3. Design Standards

The circuit breakers, associated assemblies and ancillary equipment shall comply with the following Standards, unless otherwise stated:

Ref. No.	Title	Standard no.
1	High-voltage Switchgear and Controlgear - Alternating-current Circuit-breakers	AS 62271.100
2	High-voltage Switchgear and Controlgear - Common Specifications for Alternating Current Switchgear and Controlgear (IEC 62271-1:2017, MOD)	AS 62271.1
3	Substations and high voltage installations exceeding 1 kV a.c.	AS 2067

Where the requirements of this Specification conflict with the above Standard, this Specification shall apply.

Any departures from or comments concerning the technical requirements outlined, including testing, shall be stated to Transgrid.

6.15.4. Composite Bushings

Transgrid requires the supply of composite bushings and insulation. Information shall be provided that details the composite materials proposed and relevant in-service experience.

6.15.5. Reinforced Security Design

Design features such as rupture disks intended to reduce the safety hazard in the event of an internal failure shall be provided. These features shall be supported by test data.

6.15.6. Electrical Clearances

All electrical clearances on the completed circuit breaker shall be in accordance with Transgrid's Power System Safety Rules Document Number GD SR G1 100, and Section 5.17 of this document.

6.15.7. Condition Monitoring

6.15.7.1. General

The circuit breakers shall be supplied with the specified condition monitoring noted in the clause "Functionality" below.

Condition monitoring facilities shall be of the on-line type and be in the form of modules that can be shown to provide measurable benefits to Transgrid.

Transgrid has a requirement that the monitoring functions be separated from any control or alarm function of the circuit breaker. Transgrid shall not accept any condition monitoring facility where the control functions and monitoring functions are incorporated or configured, such that a failure of the monitoring functions or associated facilities (like software or device power supplies) could prevent the issue of circuit breaker alarm information or could prevent a circuit breaker control function.

6.15.7.2. Functionality

The following devices shall be supplied with each circuit breaker:

- SF6 densimeters and transducers. The shall be capable of providing data suitable for trending SF6 density with respect to time and for predictive "time for top up" and "low level gas" alerts.
- Interrupter travel/motion transducers on >/=330kV circuit breakers. Incremental digital encoded rotary devices are preferred with either optical distance or analogue potentiometer operation.

Additional functionality will be considered.

6.15.7.3. Interfacing

Detail interfacing arrangement requirements including alarm and communication system details can be requested from Transgrid.

6.15.8. Maintenance and Reliability

Transgrid has the expectation of reliable long-term mechanical and electrical performance.

Circuit breakers shall be of a proven low maintenance reliable design. Maintenance tasks, frequency and spares requirements regarding maintenance intervals and criteria shall be provided to Transgrid.

Curves or equivalent data shall be provided which relates fault current with the number of interruptions before major service including contact reconditioning is required. The basis of establishing this curve including a statement of any test program shall be provided.

Operating mechanisms and controls should not require major service for the maximum achievable period and in this respect evidence of mechanical endurance test of 10,000 cycles shall be provided.

The circuit breaker shall be provided with a DILO size DN8 or DN20 fitting/coupling valve to allow evacuation and refill of gas without evacuation of any other section. If the gas leak rate cannot be guaranteed with the use of such a valve, then a suitable adaptor shall be supplied subject to approval by Transgrid. The fitting/coupling valve shall be accessible by persons from ground level.

Provision shall be made for gas filling and extraction to be performed by a person standing at ground level.

6.15.9. Support Structures

Hot dipped galvanised steel support structures having an open type construction without the need for cross bracing shall be provided.

Full seal welding shall be used on joints that are galvanised.

All support structures shall be designed to satisfy the electrical clearance requirements defined in Section 6.15.6,"Electrical Clearances".

As part of the Safety in Design requirements, the support structure design for every 'type' shall be certified and the certification included on submitted drawings.

6.15.10. Circuit Breaker Switching Duty

In accordance with AS 62271.100 Transgrid has a preference for class C2 (very low probability of restrike) and in addition requires class M2 (extended mechanical endurance, mechanically type tested for 10,000 operations), for each circuit breaker covered by this design standard.

6.15.11. Rating Plate – Circuit Breaker

A rating plate shall be supplied for each circuit breaker in accordance with AS 62271.100. It shall also display:

- The Manufacturer's Serial Number;
- Break time in milliseconds;
- Duration of Short Circuit (if different from 1s);
- Minimum SF6 gas pressure in MPa for operation;
- Accessory Power Consumption (i.e. heater, motor and coil power in Watts at rated voltage); and
- Note of any unusual features or OH&S precautions.

For dead tank circuit breakers with current transformers a separate rating plate detailing the current transformers details, for each circuit breaker, shall also be supplied in accordance with AS 60044.1.

6.15.12. Control Cubicles

The degree of protection for sealing cubicles, enclosures and terminal boxes against the ingress of water, foreign- particles and insects shall be IP56 to AS 60529, "Degrees of protection provided by enclosures (IP code)". The protection category for electric motors not enclosed in the cubicle shall be IP56 to AS 60529, "Degrees of protection provided by enclosures (IP code)".

All items in the control cubicle shall be adequately labelled for identification. All 230 V a.c. circuits shall be clearly labelled as such and have insulated covering.

The height of any fuse, links, switches, contactors, etc. in the erected cubicle shall be 1000 mm to 1500 mm from the operating surface. All links and fuses shall be labelled to identify the circuit it is protecting or isolating and shall be readily accessible (not obscured by other components) on the front face of the open cubicle. The labelling shall be on white traffolyte style backing with engraved black writing depicting the circuit details securely fixed adjacent to the item it refers to.

The terminals for external connections shall be Phoenix type as per Transgrid drawings STD 208128 and STD-208129 unless prior written acceptance is given by Transgrid for the use of an alternative equivalent terminal type.

A standard general purpose switched socket outlet ('GPO') is not required.

6.15.13. Pre-Insertion Resistor (PIR) CBs

Transgrid uses EHV PIR CBs for:

- Transformer energisation to reduce inrush currents
- Transmission Line energisation

Routine Test reports are required to capture the timing parameters of the PIR CBs supplied.

6.15.14. Controlled Switching – Relay Based

It shall be possible to suppress high voltage switching transients by the provision of controlled switching (referred to in this specification as point-on-wave or POW control) for both opening and closing operations upon various reactive loads, e.g., earthed and floating neutral capacitor installations, shunt reactors, transmission lines and transformers.

The accuracy of the instant of switching shall be maintained over a wide range of variables, examples of which include supply voltage, temperature and wear and tear on the circuit breaker components due to age. Alarms shall be provided when deviations occur from the intended operating parameters.

The circuitry for the relay shall satisfy the requirements of Transgrid drawing STD-208128/3, otherwise agreement and acceptance shall be obtained from Transgrid.

6.15.15. Test Requirements

6.15.15.1. General

All type and routine tests as listed in AS 62271.100 "High-voltage Switchgear and Controlgear - Alternating-current Circuit-breakers (IEC 62271-100: (ED. 2.2)/COR1, MOD)", are required to be carried out in accordance with that standard for the circuit breakers that are to be supplied.

Type test reports for the full range of type tests required shall also be submitted.

Where such tests are for equipment not exactly as that specified, additional information in support of the relevance of such type tests to the equipment specified shall be provided. Type Tests shall be applicable to the factory of manufacture of the circuit breakers.

6.15.15.2. Site Testing on Completion of Erection

Site tests shall be carried out on completion of erection using the test requirements as set out in AS 62271.100 Clause 10.2 "Installation" and its sub-clauses as a minimum. *Testing in accordance with Transgrid's document "Testing of High Voltage Equipment Prior to Energisation" shall also be performed for the given equipment unless otherwise agreed.*

Inspection and Test Plan for Site Acceptance Testing shall be provided to Transgrid.

Mechanical operating tests shall be carried out on the complete breaker at site and auditable documentation of the test results shall be provided.

For all routine tests and where routine tests are incorporated into site commissioning programs it is essential that the results obtained fall within guaranteed limits and for this to be readily verified, the guaranteed values and tolerances shall be provided within the documentation.

6.16. Auxiliary Transformer Requirements

6.16.1. General Design Criteria

The transformers shall be designed in accordance with AS 60076. They shall be designed to operate outdoors under normal service conditions.

Transgrid prefers dry type design only.

Design efficiency should meet or exceed AS 2374.1.2 – 2003 Minimum Energy Performance Standard (MEPS) requirements for distribution transformers.

The design shall be completed such that the auxiliary transformer and the substation is constructible, operable and maintainable during its life.

Materials used in the construction of the transformers shall be selected, positioned or treated to prevent corrosion due to atmosphere conditions or due to electrolytic action between dissimilar metals.

All outdoor external ferrous surfaces are to be hot dip galvanized in accordance with AS4680.

All outdoor external surfaces shall have colours consistent with other substation equipment and agreed by Transgrid.

The designs of all systems shall be such that any item of plant or equipment can be isolated and maintained without requiring interruption to supply from the substation and with minimal impact on other systems within the substation.

Wherever practicable, all plant shall be designed to allow maintenance activities to be carried out at local ground level. With regards to enclosures and LV circuits, all points of operation and access should be no higher than 1.5m above ground level.

All metal combinations shall be designed to avoid galvanic corrosion.

6.16.2. Overload Capacity

The transformer shall be capable of having its inherent cyclic overload capacity utilised generally in accordance with AS 2374, AS 3953 or AS 60076. All ancillary equipment on the transformer, eg, off-circuit tap change switch, bushings, etc., shall have rated currents of at least the inherent overload capacity of the transformer.

6.16.3. Short-Circuit Strength

The transformer, when on any tapping, shall be capable of withstanding, without deformation or injury, the thermal and mechanical effects of external short-circuit conditions, with such fault currents as may arise from any type of fault, with full voltage maintained on all other windings (zero source impedance).

The off-load tapping switch shall be capable of sustaining such fault currents without damage or malfunction.

The strength of the stabilising winding shall be conservatively designed.

6.16.4. Design of Transformer to suit Compound

The transformer shall be cable connected in a compound with cables passing through the concrete supporting slab via conduits.

The compound shall be suitably sized according to the maintenance dimensional and clearance requriements of the auxiliary transformer. These information shall also be provided to Transgrid.

6.16.5. Auxiliary Terminals

Auxiliary terminals shall be of the Phoenix UK rail mounted insertion type or equivalent and suitable for connecting single 16 mm^2 cables. Minimum voltage rating shall be 500 V a.c. and 750 V d.c. in industrial atmosphere conditions.

The terminals shall have a positive locking feature provided by spring washers or spring clamping saddles. Insulation materials shall be non-hygroscopic, non-tracking, non-burning, chemically inert and mechanically strong.

Auxiliary terminals required for connection to Transgrid's 415/250 V a.c. and 125V D.C. circuits shall be provided with transparent insulating safety covers. These terminals shall be grouped together and clearly separated from other terminals.

Pinch screw type terminals where the screw bears directly on to the conductor shall not be used except where it is an inherent feature of small items of control equipment in which case it may be acceptable subject to the approval of Transgrid.

6.16.6. Terminal Board

The terminal board shall be sufficiently sized to allow for easy installation and connection of all control, indication, trip, alarm and current transformer secondary circuits for operation and maintenance purposes.

The terminal board shall be arranged so that terminals of similar functions are arranged in groups.

The terminal board on an oil-immersed design shall be provided with two additional pairs of terminals to accommodate the alarm and trip circuits of the gas and oil actuated relay (if supplied) or one additional pair of terminals to accommodate the circuit of the pressure relief device.

6.16.7. Wiring

All control and secondary wiring in the transformer shall be in PVC insulated 0.6/1 kV grade cables having 7/0.50 mm annealed copper conductors or conductors of at least seven strands and of at least equivalent cross section. Single stranded conductor will not be acceptable.

Identification ferrules shall be of white insulating material and shall be provided with glossy finish to prevent the adhesion of dirt. The ferrules shall be clearly and indelibly marked in black and shall be attached so the ferrule cannot fall off when the wire is removed from the terminal. Identification ferrules shall be attached to both ends of each wire.

Identification ferrules and cable colours shall preferably be in accordance with Transgrid's schematic drawing STD150013 B1.

Green or combined green/yellow colour sheathing shall only be used for earth wires.

Wiring, other than current transformer (CT) connection wiring, may be one colour.

Conductors between 450V bushings, disconnector and circuit breaker shall be suitably rated.

All external wiring shall armoured PVC sheathed cable or vulcanised acrylic nitryl rubber base insulated and sheathed cable.

Cables shall be adequately supported and shall be protected against damage by persons working on the plant.

All wiring shall be mechanically sound and suitably braced to withstand the shocks and stresses of transportation.

All cable ties installed externally shall be stainless steel.

6.16.8. Earthing Terminals

Provision shall be made on the transformer tank or enclosure steelwork and the HV terminal box for the attachment (by others) of 50 x 6mm flat copper earthing strip.

The earthing provision on the base support steelwork of the enclosure or transformer main tank shall be in the form of two clearly accessible 18mm diameter holes within two 70mm long x 50mm wide bare stainless steel lugs, 10mm thick, welded to diagonally opposite corners of the support steelwork. Each lug shall be electrically continuous.

Each lug on the dry-type enclosure shall be electrically continuous via conductor with bolted connections, to all earth conductors and bars within the transformer enclosure. Hinged or removable enclosure panels shall not form any part of this continuous earthing system.

The earthing provision for the HV cable box shall be in the form of one 18mm diameter hole in the lower portion of the side panel adjacent to the corresponding neutral bushing within the box. An M16 x 50mm stainless steel bolt & nut with flats and spring washers shall be installed in this hole to facilitate attachment of earth strap.

Tapped holes and studs are not acceptable.

6.16.9. Earthing of Neutral Conductors

Earthing connections to any neutral conductors shall be made on the P2 side of the neutral current transformer.

6.16.10. Metal Work

6.16.10.1. Dry Type Enclosure

The enclosure of a dry type transformer shall suit the requirements of an air (A) cooling medium and a natural (N) form of circulation. It shall satisfy the protection for electrical equipment (IP) requirement of IP34. All external potentially horizontal surfaces shall be sloped to prevent accumulation of water.

Dry type transformer enclosures may consist of hot-dipped galvanised steel, bare or painted aluminium or bare or painted stainless steel with an alloy suited to long-term outdoor installation in a medium pollution environment.

Suitable maintenance access shall be provided through the enclosure. Maintenance access shall consist of doors with internal hinges secured with bolts or latches with provision for locking using a 45mm standard shank padlock. The doors shall be provided with stays to prevent swinging in the wind when open.

All fasteners, washers, hinges & latches shall be either hot-dip galvanised or stainless steel of suitable grade of austenitic chromium-nickel alloy.

Passivated steel fittings are not acceptable.

6.16.10.2. Oil-immersed Transformer Tank

The main tank in an oil-immersed transformer shall be double-side welded steel plate construction and shall be designed and constructed to withstand, without leakage or distortion, prolonged service conditions and all pressure and vacuum tests.

The inside of the tank covers shall be suitably domed or sloped and shall present no obstruction to the passage of gas bubbles to the gas and oil actuated (buchholz-type) relay (if provided). The outside of the tank or protective enclosure shall not allow the accumulation of water.

Provision shall be made for adequate venting via the buchholz-type relay (if offered) of all portions of the tank and tank attachments to eliminate gas pockets and to permit a free passage for gas through the relay.

Where a sealed tank design is provided the lid gasket shall be located below oil level.

All covers and oil pipes shall be secured to the tank by bolts or studs, and joined with gaskets. Where oil tightness is required, screwed joints shall not be used. All screwed plugs shall be of the flanged type fitted with sealing gaskets. Tapered screwed plugs are not acceptable.

6.16.11. Piping

All flanges shall be fitted square with the pipe and shall mate accurately with the companion flange to which they connect. All flanges shall be in accordance with AS 2129 "Flanges and Bolting for Pipes, Valves and Fittings" and to the table appropriate to the working pressure involved.

All piping in oil immersed designs shall have continuous fall to drain points.

6.16.12. Gaskets

All gaskets for oil immersed designs shall be impervious to, unaffected by and have no harmful effect on hot insulating oil. Flat gaskets shall be trimmed flush with the flanges and the outer edge of the gasket shall be painted with a suitable sealing product.

6.16.13. Core Design

The core shall be designed and constructed to withstand, without deformation, the stresses imposed by service conditions, lifting, transport and handling.

The magnetic circuit shall be earthed to its support structure which shall in turn be earthed to the tank or enclosure. A removable link shall be provided between the core clamp and the core to facilitate individual testing. The earthing connection between core and tank or enclosure and the removable link between the core clamp and the core shall be accessible. For oil immersed design, these shall be accessible from the top of the main tank with the lid removed.

The core shall be equipped with facility for lifting.

6.16.14. Windings

The terms M.V. winding and L.V. winding shall refer to the windings associated with highest and second highest operating voltages respectively of the transformer. The term T.V. winding shall refer to the tertiary delta stabilising winding, if present.

Tap switch positions shall be numbered such that position No.1 gives the highest turns ratio M.V to L.V.

Facilities shall be provided for locking the tap selector switch in each position with a 45 mm standard shank padlock.

6.16.15. Bushings

Two-piece bushings are <u>not</u> acceptable on oil immersed designs.

6.16.16. Cable and Terminal Board Boxes

Each external box, including M.V and L.V cable box, tertiary winding bushing/link box and terminal board box shall be air insulated and comply in all respects with the requirements of any relevant standard. Normal electrical clearances in air shall be maintained within each box.

Each box shall offer no less protection than IP 55 in accordance with AS 60529

An adequate vermin and insect proofed flow-through ventilation and drainage system shall be provided in each M.V. and L.V. cable box to minimise the formation of condensation whilst eliminating rodents and insects from entering the box. This system shall also be designed such that any condensation in the bottom of the box does not accumulate and can drain freely through the ventilation system.

6.16.16.1. Medium Voltage Cable Box & Controls

The high voltage cable box shall be designed to accommodate the M.V. line and neutral bushings, M.V. terminals, removable isolating links and cable sheath earthing bar.

The isolating links are required to enable independent testing of the cables or the transformer without the need to disconnect the cables. To achieve this, the terminals shall be supported on an insulator with a suitably rated removeable link to the M.V. bushing.

The cable sheath earthing bar shall be located near the rear base of the box. It shall be rigidly supported and suitably dimensioned to facilitate earthing of cable sheaths.

To facilitate cable connection the cable entry gland plate shall be located no less than 500mm below the M.V. terminals and no less than 600mm above ground.

6.16.16.2. Low Voltage Cable Box & Controls

The low voltage cable box shall be designed to accommodate the L.V. line and neutral bushings, disconnector, circuit breaker or fused switch as applicable and cable sheath earthing bar.

In addition, on oil filled designs, the L.V. neutral shall be connected to a separate outdoor type bushing located adjacent and externally to the L.V cable box and suitable for connection with flat copper earthing strip. The terminal on this L.V. external bushing shall be electrically continuous with the terminal on the L.V. bushing within the box.

To prevent inadvertent contact with bare LV conductor connections within the L.V. box a rigid removeable panel is required to provide a degree of protection not less than IPXXB or IP2X as per AS3000. The panel shall be designed to allow for manual access to all switchgear operating mechanisms without the need to remove the safety panel. The panel shall also be designed to allow for clear visibility of the status of all switch gear including the visible breaks. The panel shall have a removable portion to allow access to the temporary earthing studs.

The disconnector switch shall be four pole, suitably rated and provide a break, visible to the human eye when open. The switch status shall be clearly indicated. It should be lockable in both the open and closed position with a 45mm standard shank padlock. Where the operating handle connects to the disconnector body via an extension shaft, both the handle and shaft shall be firmly fixed such that removal shall not be possible without disassembly of the handle and/or removal of fixing screws.

The circuit breaker (CB) shall be a four pole moulded case type and shall comply with AS2184. It shall have a current rating and minimum fault level capability suitable for the required duty at 450V AC symmetrical. It shall be capable of shunt tripping only and therefore have no thermal or magnetic protection elements. It shall be capable of operating and remaining in either state whilst de-energised. It shall be provided with a 125 V D.C. operated shunt tripping mechanism, two normally open (N/O) and two normally closed (N/C) auxiliary contacts. The CB trip coil and all contacts shall be wired to the terminal board.

The fused switches shall be four pole and provide a break visible to the human eye when open.

The cable sheath earthing bar shall be located near the rear base of the box. It shall be rigidly supported and suitably dimensioned to facilitate earthing of cable sheaths.

The cable box shall have doors with latches and internal hinges and provision for locking with a 45mm standard shank padlock. The doors shall be provided with stays to prevent swinging in the wind when open.

6.16.16.3. Terminal Board Box

A separate terminal board box shall be conveniently located adjacent to the L.V. cable box.

The terminal board shall be positioned within the box to facilitate manual access and connection of the control cables using standard tools.

6.16.16.4. Terminations

There shall be adequate locking of nuts or screws on all terminations. Locking of terminations using nuts shall be by stainless steel spring washers.

Lock nuts are not acceptable except in terminations under oil. All nuts shall be full nuts.

6.16.16.5. Stabilising Winding Bushing Box

A discrete stabilising winding bushing box, where required, shall be designed to accommodate the stabilising winding bushings, link and stabilising winding earthing point.

The bushings may be outdoor or indoor type. The two bushing terminals shall be interconnected by a removable link for testing the stabilising winding. The link may be located between any two windings of the delta stabilising winding. The bushings and link shall be suitably rated for purpose.

The transformer shall be supplied with the link attached and bonded to earth.

Electrical clearances in air shall be maintained within the box.

6.16.17. In-Built Current Transformers

All In-built current transformers (CTs) shall be arranged and located for convenient removal and replacement.

Any cable joint made between a CT and the terminal board box terminal shall be made on a terminal board with screwed terminals. Compression joints in CT cables are not permitted.

The L.V. neutral CT in oil immersed designs shall be located to protect both neutral terminals.

The Contractor shall supply the open-circuit magnetisation curves for all CT's. They shall indicate values of winding resistance and shall be included in the instruction manual.

6.16.18. Conservator

If a conservator is provided, for inspection and repainting of the conservator interior, one end of each compartment, where applicable, shall be completely removable.

The conservator shall be fitted with a filler pipe and drain valve having a male Camlock fitting lockable with a 45mm standard shank padlock and an oil-level gauge.

6.16.19. Breather

If a conservator oil preservation system is offered, the conservator shall be fitted with a silica gel breather of suitable capacity and having an oil seal to prevent continuous contact between the atmosphere and the silica gel crystals.

The silica gel crystals shall be of the grade giving positive colour identification of wet and dry states. Cobalt Chloride indicating silica gel is not acceptable.

The silica gel breather shall consist of a sturdy transparent cylinder which permits a clear view of the silica gel crystals contained therein and shall be mechanically strong. Where possible, it shall be visible from both the H.V. and L.V. sides of the transformer.

6.16.20. Valves

For oil immersed transformers, butterfly, locking type butterfly and ball type valves are not acceptable.

All valves shall include the ability to be locked in the open and closed positions. The mechanism of locking shall be by set screw, bolt or other approved means.

6.16.21. Pressure Relief Device

A pressure relief device shall be located on the main tank. It shall be positioned such that any oil discharged from the device is directed away from the L.V. cable box.

The pressure relief device shall be a self re-sealing valve, not an explosion vent.

6.16.22. Thermometer Pockets

One thermometer pocket shall be provided on the tank for measuring the top oil temperature.

6.16.23. Lifting, Handling and Transport Provisions

Lifting lugs, suitable for lifting by means of a crane, shall be provided. The lugs shall be sufficiently rated for lifting the complete transformer (filled with oil if oil-immersed).

The lugs shall be located to prevent lifting slings from binding on any external surfaces.

Designs of any necessary lifting devices shall be in accordance with the NSW Government Construction Safety Act, obtainable from the Government Information Service of NSW.

The transformer shall be suitable for transport by means of a road vehicle presently available in New South Wales and properly licensed for road transport of such transformers.

Suitable means shall be provided on the sides and the ends of the transformer, near its top, for attachment of lashing down chains.

6.16.24. Insulating Oil

The insulating oil shall not contain poly-chlorinated biphenyl (PCB).

6.16.25. Test Requirements

Type tests shall be carried out in accordance with AS 2374 or AS 60076 as applicable.

Type Tests shall also include:

- Zero-Phase-Sequence Impedance Test – MV and LV.
- Short-circuit test (secondary winding shorted).
- Ability to withstand short time neutral current concurrent with full auxiliary load.

Routine tests shall be carried out in accordance with AS 2374 or AS 60076 as applicable.

Routine tests shall also include:

- Temperature Rise Test.
  A temperature rise test shall be performed on each transformer. The losses that shall be included in the test are:
  - No Load Loss (core loss at rated voltage)
  - Winding Loss at rated continuous Neutral current
  - Load Loss associated with the load on the auxiliary winding.
- Measurement of Voltage Ratio and confirmation of vector relationship
- Measurement of short circuit impedance and load loss
- No Load Losses and Excitation Current measurements.

No load losses and excitation current shall be measured at voltages corresponding to 100%, 105% and 110% of rated voltage. Excitation shall also be performed at 240 V ac.

- Dielectric Tests
  Lightning impulse withstand tests are required as routine tests and shall be carried out on each HV line and neutral terminal. The HV Line terminals shall also be subject to chopped wave impulses. The impulse tests shall follow the induced over-voltage tests.
- Magnetising Current Waveform
  The magnitude of 3rd, 5th and 7th harmonic of the magnetising current shall be determined and recorded at 100%, 105% and 110% of rated voltage.
- Pressure Test for oil immersed transformers

The transformer shall be fully assembled and filled with oil with all valves in position, as would be the case when the transformer is in-service. The complete transformer shall be submitted to an incremental pressure test of 35 kPa for a minimum of 24 hours duration.

6.17. Disconnector and Earth Switch Design Requirements

The general arrangements of the equipment shall be as stated following:

- Disconnector: Horizontal Double Break (HDB)
- Earthing Switch: Single Vertical Break (SVB) with blade horizontal in open position

Each disconnector shall be designed so that an associated earthing switch may be mounted on either or both ends of the phase beam. Each associated earthing switch shall be designed so that it may be mounted on either end of the phase beam.

It is preferred that the direction of operation of the associated earthing switch blades is such that the open blades remain in the plan view shadow area of the disconnector.

Easy adjustment facilities shall be provided for alignment of insulators and contacts.

All disconnectors and earthing switches shall be capable of being locked by means of a 45mm standard shank padlock in both the open and the closed positions.

It is required that for the full manual operation of both power and manually operated mechanisms that the operator does not have to leave the earth mat.

Manual operating handles shall be free of any insulating covering. Manual operating mechanisms for earthing switches shall comply with the specifications tabulated in the following:

	Manual Operating Mechanism for Disconnector	Manual Operating Mechanism For Earthing Switches
Acceptable mechanisms	Horizontal lever, hand-wheel, hand-crank, geared device	Preferred: horizontal lever Alternative: spade type handle, crank handle.
Plane of movement	Horizontal	Preferred: horizontal Alternative: vertical, crank handle
Direction of movement from open to closed position	Clockwise (when viewed from above) and not exceeding 110º	Horizontal Lever: either direction Spade type handle: upwards

The following shall also apply:

- Maximum length of simple horizontal motion bar type handle or lever shall be 1200mm.
- Maximum height from ground level of simple horizontal motion bar type handle or lever shall be 1200mm.
- Maximum operating force using simple horizontal or spade type handle shall be 250N.
- Maximum operating force for using a geared device shall be 90N.

Manually operated disconnectors shall be designed such that inadvertent operation of the disconnector is not possible. This may involve the provision of a latching mechanism that prevents the inadvertent operation of the disconnector operating handle.

When manually operating disconnectors or earth switches, facilities shall be provided to ensure the operator does not become a path for any fault current. This facility can be of the form of a clearly visible and direct equipotential bonding between operating handle and an unearthed operating mat, for example.

6.18. Mounting and Handling of Current and Voltage Transformers

For interchangeability purposes, CTs are required to be able to be provided with mounting arrangemnets which are compatible with Transgrid’s standard support structures as outlined in the following standard drawings (which will be provided up request):

a. For 362 kV CTs - Drawing No. STD-352537
b. For 145 k V CTs - Drawing No. STD-352541
c. For 72.5 kV CTs - Drawing No. STD-352540

If adaptor plates are required to meet the required mounting arrangements they must be approved by Transgrid and shall be fitted to the CT prior to the dispatch of plant.

All mounting arrangements shall be clear of secondary cable runs and allow ready connection of cables to terminal boxes.

The VTs shall have four (4) 20 mm diameter holes on a 660 mm square for mounting.

6.19. Quality of Supply Requirements

The Connection Applicant shall provide the performance requirements of the relevant instrument transformers.

6.19.1. Harmonic Distortion Testing

This test shall be performed in accordance with the requirements specified in Transgrid documentation. A copy can be provided on application.

The method employed for the harmonic distortion testing shall be described in the documentation package along with some details of the associated test equipment and experience of the testing contractor in carrying out harmonic distortion testing.

6.19.2. Frequency Response Testing

This test shall be performed in accordance with the requirements specified in Transgrid documentation. A copy can be provided on application.

The method employed for the frequency response testing shall be described in the documentation package along with some details of the associated test equipment and experience of the testing contractor in carrying out frequency response testing.

6.20. Metal Enclosed Switchgear Requirements

6.20.1. Interface details to be provided to Transgrid

In addition to the standard documentation requirements, the following interface design details shall be provided to Transgrid:

- Switchgear general arrangement: The general arrangement and detail drawings, including 2D CAD files (and 3D CAD models if available), for the switchgear shall be provided. The drawings shall include physical size, dimension and weight of the switchgear, worst case dynamic loads caused by concurrent circuit breaker operations, maintenance corridor dimension requirements (including space required to remove breakers or complete switchbays) and other details. The loading diagrams for all equipment supplied, which indicate location of applied load magnitude and direction shall also be provided. The loads shall be categorised in: Dead Loads, Live Loads, Short-circuit loads, Impact loads, Construction loads and Maintenance loads. They shall be presented in Working load format.
- Earthing: Details necessary in order to effectively earth the switchgear to the main earth grid shall be provided. Details of all connection points and the methodology in which the connections are to be made shall be shown.
- Switchgear secondary connection details: Details of the schematics design including terminal and wiring diagrams in order to successfully commission the switchgear shall be provided. As such, sufficient information including detailed drawings of switchgear, IED mounting arrangement / panel layout, and block diagrams shall be provided as part of supply. Connection details, wiring diagrams, terminal diagrams and cable schedules shall also be provided to Transgrid.
- LV cable connection requirements: The connection and cable penetration details for LV cabling, including inter-panel / bay wiring shall be provided to Transgrid.
- Installation and replacement Requirements: Details of any installation requirements, including but not limited to space required, floor and fixing requirements, mounting frame horizontal tolerance requirements, the method of delivering the switchgear into switchgear building and unloading them in the building, and any special tools required shall be provided to Transgrid.
- Switchgear Mounting Arrangement: The requirements of switchgear baseframe and the tolerance on the switchgear building design for both transport and installation of the switchgear shall be provided to Transgrid.

- Installation Procedure: The detailed installation procedure of the switchgear shall be provided to Transgrid.
- Overpressure Calculation and Blast Venting requirement: The gas and overpressure calculation and the blast venting requirement of the switchgear and the switchroom design that satisfies the requirement shall be provided to Transgrid.
- Space and power outlet requirement: The testing space and power outlet requirement for testing purpose shall be provided to Transgrid.
- End Caps for Busbar and allowance for expansion: The of end caps for busbar and the allowance for future expansion including arrangement of spare bays shall be provided to Transgrid.
- Maintenance Space: The requirements for the maintenance space and detailed maintenance procedure, taking into account of any components and accessories installed, such as cables, surge arresters, external CTs, extra operation and control cubicle shall be provided to Transgrid.
- Operating Environment Requirements: Any requirements to the operating environment, such as light, power, temperature, humidity and dust shall be provided to Transgrid.
- Interlocking: The interlocking proposal for the completed switchboard shall be provided to Transgrid.
- Transport Configuration of the Switchgear: The proposed transport arrangement and configuration of the switchgear panels shall be provided to Transgrid.
- Acceptance Testing: The standard ITP for FAT and SAT which shows the standard acceptance tests for all high voltage equipment as well as the switchboard as a whole system shall be provided to Transgrid.

6.20.2. Manuals

In addition to the standard manual requirements, as a minimum, the following manuals shall also be supplied:

- Commissioning Manual;
- Switchgear Operating Manual;
- Switchgear Maintenance Manual and
- Condition Monitoring Manuals.

Instruction manuals for the equipment offered shall be suitably bound and include, but not limited to, the following:

All approved drawings required for erection, maintenance and repair of the medium voltage equipment;

- Detailed instructions and warnings for installation, commissioning, and dismantling of each type of medium voltage equipment supplied;
- Details of the insulating medium used, including volume/weight, toxicity, brand, composition, special handling requirements, operating pressure at ambient temperature and pressure of alarm and lockout;
- Detailed instructions and warnings for the operation and maintenance of the equipment. This shall include all routine and non-routine tests maintenance instructions and inspections including intervals of recommended maintenance; and
- Complete parts list including drawings, manufacturer and manufacturer’s part number.

The Commissioning Manuals shall provide commissioning details of all substation plant and ancillary systems and include Factory Test Reports, Type Test Certificates, Inspection and Test Plans and Completed Checklists.

The Operating Manuals shall be supplied in accordance with the following general format:

- A general description of the plant outlining its general function, supported by functional arrangement drawings, system description and block diagrams to show how it works as well as how it is constructed;
- A design and technical data section, which shall include:
  - Detailed descriptions of plant components and systems, including detail drawings;
  - Technical plant data for the plant as installed;
  - Design limits for loadings, pressures, pressure differentials, temperatures, temperature differentials, rate of change of temperature, voltage, current, vibration, operating limits, settings, etc;
  - Details of all materials that may be toxic and associated MSDS's;
  - Test and performance data;
  - A list of electrical interlocks and a statement of their functions; and
  - A list of alarms detailing alarm initiator location and settings for alarm operation and reset.
  - For all equipment that is filled with SF6 the following details;
    - Volume of SF6 filled in kilograms
    - Quality of SF6 in equipment – dewpoint, percentage SF6 and purity.

    This is required for all SF6 encapsulated equipment for each gas compartment and in a format agreed with Transgrid.
- Normal operating procedures set out in step-by-step instruction with each step numbered in correct logical sequence and including In-service checks and limits including routine test procedures for alarms; and emergency and abnormal conditions procedures, set out in step-by-step instructions.

The Maintenance Manuals shall be supplied in accordance with the following general format:

- A design and technical data section which shall include;
  - Serial numbers of plant items and rating plate details of electrical equipment, as a both a spreadsheet and a photo.
  - A photo of each name plate for all high voltage equipment installed with each photo labelled with bay number, equipment type and phase installed in. The photos provided shall be of high resolution and all name plate details shall be legible when printed on a 6x4 inch photo standard;
  - Weights of switchgear plant and other large components;
  - Details of materials and parts required for normal overhaul;
  - Details of special tools, jigs and gauges and their uses;
  - Details of all materials that may be toxic and associated MSDS's;
  - Limits of deterioration of electrical insulation and windings;
  - Type test certificates covering the performance of individual plant items (eg. motors) incorporating or supported by information as to the method of testing used so that Transgrid could carry out check tests to determine whether performance has deteriorated;
  - Parts Lists giving full description and part numbers to enable identification in case of replacement, including spare parts provided;
- Reference drawings and diagrams comprising sectional arrangement drawings with part numbers and material specification and including, where appropriate, exploded sections and isometric views necessary to carry out normal maintenance procedures; and
- Normal maintenance procedures and frequency for every component set out in step-by-step instructions with each step numbered in correct logical sequence and including:
  - List of special tools and equipment required;
  - Check list of operations prior to dismantling;

- Dismantling sequence, with particulars of methods to be adopted;
- Inspection of components and checking of permissible tolerances;
- Reconditioning, replacement and adjustment procedures; and
- Re-assembly sequence, with particulars of methods to be adopted;

- A trouble shooting program based on symptoms and including suggested frequency of inspection of components and frequency of routine maintenance. The program shall include details of the points at which measurements should be taken, details of the normal readings at those points and the possible reasons for abnormal readings. Electrical trouble shooting details shall include voltage level maximums for solid state equivalent or other equipment as appropriate;
- Re-commissioning procedures set out in step-by-step instructions and including:
  - List for checking of settings prior to re-commissioning;
  - Procedures for preparing for service those items of equipment which are required to be "tuned" or otherwise adjusted at re-commissioning following a major overhaul; and
  - Procedures for setting reference CTs, phasing checks, in-service balance and direction changes, post–erection CT and VT burden, accuracy and VT cable drop checks.
- A section recommending routine preventative and diagnostic maintenance required to ensure reliability of operation of the switchgear over its expected in service life, including details of any items of equipment that it considers will require replacement and/or major refurbishment during the design life.

The Condition Monitoring manuals shall be supplied in accordance with the following general format:

- A description of all switchgear components (including but not limited to HV, LV and ancillary systems such as building temperature and ventilation systems).
- A listing of all the planned routine preventative maintenance tasks for each of the items listed above, and the intervals. This shall include time based and operation based maintenances.
- Detail of the tests, checks and inspections or maintenance tasks to be completed at the noted intervals. The details of these checks as applicable shall be included in the as built plant maintenance manuals. Note for gas insulated switchgear system, requirements shall be defined for the as-installed systems or bays as well as the individual components such as circuit breakers, disconnectors, current transformers, voltage transformers, interconnecting equipment, earth switches, etc. Individual equipment manuals for the components are deemed not adequate if they do not cover the as-built systems.
- Check sheets for all the maintenance tasks noted above including acceptable test or inspection values or tolerance limits for the maintenance tests or inspections required. These shall be provided in Microsoft Excel format.
- Where specific tests and inspections are to be completed, a test instruction with detailed exploded view photos and step by step instruction on the performance of those tests and inspections for the as installed system or bay shall be provided.
- A specific procedure that includes a documented risk assessment shall be provided for SF6 gas top ups and when this can be completed with equipment in service or when equipment will need to be taken out of service, if applicable. The procedure shall provide step by step instruction with photos of all connections and checks for filling of SF6 including any precautions to be taken prior to filling. The procedure shall provide step by step instruction with photos of all connections and checks for filling of SF6 including any precautions to be taken prior to filling.

6.20.3. Testing and Commissioning

The detail scope of testing and commissioning work expected to be completed by the Connection Applicant shall generally include, but not be limited to:

- Provision of a Testing and Commissioning Plan covering each location at which testing is performed (for example switchgear originating factory and switchgear building manufacturer Site).
- Provision of a detailed set of testing and commissioning instructions, procedures, checksheets and Inspection and Test Plans for each individual switchgear panel, and also for the entire switchboard installation at site.
- Verification that all statutory and regulatory requirements are met.
- Completion of all factory acceptance testing
- If applicable, performing in-service measurements of electric and magnetic field strength, full (D.C. upwards) spectral emissions and thermal infrared imaging tests.
- Commissioning and testing of High Voltage plant, including checks to ensure that the switchgear, including all equipment and systems are fully operational and fit for purpose.
- Testing and commissioning of communication systems.
- Provision and maintenance of a commissioning log book.
- Provision of all QA and testing documentation on completion of testing and commissioning.
- Provision of a complete set of marked up “as built” designs. The original marked up drawings shall be retained on Site.
- Documentation of all testing and commissioning

6.20.4. Training

Transgrid may request, prior to Service Voltage Testing of the switchgear, an on Site theoretical and practical training for Transgrid’s maintenance and operations staff, depending on the switchgear provided.

Provision of training shall include, but not be limited to, the following:

- Submission of proposed training program and schedules for acceptance by Transgrid a minimum of three (3) months before training is to commence. The training plan shall detail all particular sessions being provided, breakdown of contents of each package and expected period of theory and practical component of each package being delivered;
- Provision of training for maintenance and operation of all switchgear installed in the switchgear building;
- Provision of all training materials in the form of training packages. That is, session plans for each package, trainer notes (any presentation material including notes on what the trainer will cover per slide), trainee notes (full details that is to be provided to the trainee as a hard copy during training sessions), and assessment criteria. Training packages shall be developed in the above format and final drafts provided for review by Transgrid’s trainers. The completed packages shall become the property of Transgrid;
- Maintenance of training records and sign-on sheets for all staff trained.
- Carrying out of training by personnel experienced in training on the type of equipment installed.

The training program shall result in those attending gaining:

- Familiarity with the functions and workings of each component of the switchgear, building systems and associated systems including an overview for the system as a whole.
- An understanding of all procedures, functions, inputs, outputs, and processes to allow operators to effectively and efficiently operate the switchgear,
- Experience in the isolation, proving de-energised and earthing of the equipment for maintenance and repair access,

- An understanding of all technical aspects of the equipment including the system inputs, outputs, fault-finding diagnostics and maintenance procedures required to maintain and repair all equipment failures and malfunctions.
- Experience in bay equipment replacement and detailed coverage of methods, considerations especially with gas zones, barriers, isolations and premise of design of switchgear to facilitate service continuity if applicable. This shall be covered as a full aspect of a session.
- Practical experience on the installed equipment with familiarisation provided on components, isolating points for supplies and trial operations. For SF6 equipment filling and isolation procedures shall also be covered during the practical sessions.

All training shall be competency based with associated assessment criteria validated by Transgrid. Training in all phases shall include comprehensive “hands-on” experience.

The Training Plan and associated training materials shall be provided to Transgrid for review in accordance with the agreed program for each project. A period of four (4) weeks shall be allowed for review of the training materials by Transgrid.

Three (3) hard copies and three (3) electronic copies of the final training packages shall be provided to Transgrid, along with one (1) hard copy and one (1) electronic copy of the training record attendance sheets, and assessment records at the conclusion of the training.

No less than three (3) sessions of each training course shall be allowed, with each session to be attended by eight (8) staff. A session is defined as the period of time an individual is required in attendance to complete a scheduled training course.

The training shall be provided as detailed outlined in table below.

Item	Training Objective
Switchgear Introduction Program	General Overview, Premise of Design and safety in design features, Service continuity provisions, associated systems, switchgear general operation, design and maintenance principles including SF6 handling if applicable, risks and hazards of switchgear equipment and design considerations.
On-the-job training during construction and commissioning	The objective of this program is to enable technicians to acquire the competencies necessary to monitor commissioning. The program shall be competency based and developed in conjunction with Transgrid trainer. It is envisaged that this program will include a combination of face to face sessions conducted by a suitably qualified trainer and on the job training facilitated by work with the installation and commissioning staff.
Operation and Maintenance program	The objective of this program is to enable staff to acquire the competencies necessary for the performance of all operational and maintenance activities. The package should cover operation and maintenance of all components of the switchgear and associated systems as well as detailed sessions on replacement of components and principles for assessment of safe methods for internal & gas works on the switchgear. Any plant and equipment provided in the contract shall also be covered in theoretical and practical sessions.

6.20.5. Metal Enclosed Switchgear Requirements

Connections, including bolts and nuts, shall be adequately protected from corrosion and readily accessible.

Operator and maintenance personal safety must be guaranteed. The entire switchgear panel shall be designed safe-to-touch from the outside. All housings shall be made of corrosion resistant material. Live parts shall be insulated against the earthed enclosure by means of insulation coordination, and the insulation integrity shall be proven by type and routine tests.

Lifting points shall be fitted in order to off-load units from truck to switchgear building and remove from any pallet or skid.

Operating mechanisms and all control/protection and monitoring elements shall be readily accessible for operation and maintenance purposes. All locking points (e.g. control cabinet, disconnector / earth switch locking points, etc) shall be readily accessible from floor level.

Insulation properties of SF6 gas must remain constant throughout the operating life.

The disconnector shall be used for make proof earthing in combination with the circuit-breaker. Transgrid has a preference for disconnectors and earth switches to provide means for a visible break and method for visual verification.

All terminals shall be labelled in such a way that the labelling is permanent, not effected by heat, and is mechanically attached by means of fasteners.

Current transformers are to be designed as exchangeable ring core/toroidal current transformers. Details of arrangement of current transformers and the extent of work required in order to access the current transformers for replacement or maintenance shall be provided.

Transgrid has a preference to maintenance-free switchgear however adequate means of maintenance shall be provided if required;

Shipping sections that are tested in the factory shall be joined in the field or building manufacturer’s site by using bolted and sealed flange connections. Field welding of enclosures is not acceptable.

6.20.6. Internal Arc Classification for Metal Enclosed Switchgear

If metal enclosed switchgear is offered, the Internal Arc Classification (IAC) shall conform to the requirements of IEC 62271-200 or IEC 62271-201, whichever is applicable. The switchgear shall be designed to withstand internal arcs.

Each item of equipment shall have an Internal Arc Classification of Type A, front, lateral and rear at its respective fault rating. In particular, the switchgear shall be of a fault containment type, or be vented in such a manner as to provide a high degree of protection to persons in the immediate vicinity of the front, rear or side of the panel.

Further to the A/FLR requirement, Transgrid also requires consideration of the protection required for persons underneath the panel, for example working on the HV cables under the switchroom floor. This shall be achieved by either providing evidence such as type test reports to demonstrate that the offered switchgear in conjunction with the switchroom design does not pose any arc fault risk to the persons underneath the switchgear, or provide and implement control measures to ensure that the arc fault risk to persons underneath the switchgear is eliminated or reduced, following the Safety in Design principle. Any evidence and control measures are required to be documented in the Safety in Design report provided, along with any residual risks and suggested additional controls to be implemented by Transgrid.

Possible failure mode and associated safety impact of the surge arresters used shall also be considered. For instance, Transgrid has a preference of using Pfisterer CONNEX plug in surge arresters part number 827

523 360 for 36 kV applications. The provided design shall properly address any safety concerns and the residual risks are to be highlighted to Transgrid's attention.

6.20.7. Pressure and Arc Relief

A system shall be provided for relieving excessive pressure and/or arc in the event of an internal fault. Appropriate alarm contacts shall also be provided to indicate an event of pressure/arc relief operation. In the case where pressure/arc relief is provided by bursting discs, alarm contacts are not required from the bursting discs, however suitable alarming shall be provided by other means, such as from densimeters with high-speed overpressure contact.

The system shall be designed to minimise danger to personnel in the event of an operation.

Details of the pressure/arc relief system shall be provided to Transgrid. The offered leakage rate shall not be affected by installation of the pressure relief device. If any maintenance measures are required after operation of pressure relief device to comply with the leakage rate nominated, the measures shall be clearly included in the manuals.

The pressure vessel registration according to WorkSafe NSW requirements and as defined by SDM – Equipment – PV Compliance shall also be provided.

6.20.8. Switchgear Enclosures

All switching devices are to be operated from the panel front. The circuit breaker shall also be capable of remote operation.

The design principles and benefits for any flange connections (including via external cross-bonding); and details of earthing connections including components to be earthed from inside the switchgear enclosures and method of earthing the switchgear enclosures including cubicle doors with the substation main earth grid shall be provided to Transgrid.

6.20.9. Partial Discharge

The switchgear shall be routinely tested for partial discharges and an acceptable level of partial discharge at 1.5 x Um√3 shall be provided to Transgrid. A description of how the routine PD test can be performed and any equipment or accessories required to perform the test shall also be provided.

6.20.10. Support Insulators and Section Barriers for Gas Insulated Switchgear (GIS)

Insulators manufactured from high quality epoxy resin shall be free of all voids and be designed to reduce the electrical stress on the insulators to a minimum. The mechanical strength must be sufficient to ensure appropriate clearances when short circuit faults occur.

For gas insulated switchgear, gas barrier insulators sealing to the conductors and the enclosure wall shall, as a minimum, be designed to withstand the maximum pressure differential that could occur across the barrier, i.e. maximum operating pressure at one (1) side and vacuum on the other side. The maximum operating pressure and the operating limitations in such an instance shall be provided to Transgrid.

Maintenance or repair/replacement work may be performed in any GIS compartment that could result in contact with adjacent gas barriers. Details of any requirements when working adjacent to gas barriers that are at full pressure, including considerations for adjacent panels, shall be described to Transgrid. For example, the adjacent compartment must be reduced in pressure, the value of this pressure and if equipment is available for service.

6.20.11. Gas Filling points

Each metal enclosed switchgear section shall preferably be provided with a DILO size DN8 or DN20 fitting/coupling valve to allow evacuation and refill of gas without evacuation of any other section. If the SF6 leak rate cannot be guaranteed with the use of such a valve, or if the manufacturer’s standard fitting/valve is different, then a suitable adaptor shall be supplied subject to acceptance by Transgrid.

All points where devices are fitted shall be self-sealing preferably DILO type connections for testing, calibration or replacement of gauges and transducers to be achieved without lowering of gas pressures within compartments.

6.20.12. Work Involving SF6 Gas

Work involving SF6 gas shall be carried out in accordance with the requirements of IEC 62271-4: “High-voltage switchgear and controlgear - Part 4: Handling procedures for sulphur hexafluoride (SF6) and its mixtures” as applicable.

A suitable work method shall be provided for Transgrid that allows work to be carried out on a portion of the GIS without risk of injury due to failure of a gas compartment barrier. Details of such work system shall be included in the training provided.

6.20.13. SF6 Gas Filling - Evacuation Equipment

All apparatus necessary for filling and evacuating the SF6 gas into and from any compartment shall be supplied to Transgrid for installation and commissioning and for any future maintenance work. The apparatus for filling or evacuating all gases to be used shall be provided with all necessary hoses, couplings, flexible tubes and valves for coupling with each compartment.

All SF6 filling and evacuation equipment shall be DILO unless specific approval has been granted by Transgrid.

6.20.14. SF6 Gas Testing and Sampling Equipment

A moisture, purity and decomposition tester capable of recovering tested SF6 gas shall be provided as per IEC standards for testing of SF6 gas for reuse.

Transgrid has a preference for RH Systems testers. Alternative tester units which deliver this functionality shall be subject to Transgrid’s approval.

Transgrid requires the provision of two (2) sampling devices per site.

6.20.15. Condition Monitoring

Any condition monitoring features included in the switchgear shall be described to Transgrid and the operating and maintenance instructions included in the manuals and trainings provided. The monitoring includes but not limited to:

- Gas monitoring and abnormal pressure alarm
- Partial discharge monitoring
- Circuit breaker monitoring

6.20.16. Inspection and Maintenance

The maintenance required shall consider the number of operations at no load, rated continuous current and short-time current.

Any inspection activities shall not require the high voltage equipment to be out of service. Completing any maintenance or operating task shall not require access to an unearthed item of equipment within a compartment containing other live HV equipment.

All equipment that requires access for operation, regular routine maintenance and maintenance inspections shall be accessible from ground level or fixed platforms in accordance with AS 1657:2018, “Fixed platforms, walkways, stairways and ladders - Design, construction and installation”.

Where personnel are liable to a fall of two (2) metres or more, from any fixed platform supplied, a fall prevention solution, or where fall prevention is not possible, a restraint system shall be provided comprising:

- For work of a minor nature, a fall arrest system of suitably nominated attachment points to be approved by Transgrid;
- For work of a more involved or longer duration, fixed rails that are not easily fallen through.

Platforms and access walkways if offered shall be so located that access to any component is not restricted. Platforms that impede the removal of any equipment shall be designed so that they are easily removed.

Platforms and access walkways shall be accessed in accordance with AS 1657:2018, and Transgrid has a preference for access by means other than rung-type ladders.

Transgrid requires ready access to each component of each switchgear panel which serves as a maintenance or safety feature or serves the purpose of viewing (eg. viewing windows, gauges). Obstacle free access is required to the operational equipment and cabinets for isolation/locking & tagging purposes and other activities such as gas work and testing. Details shall be provided of any platforms access walkways, including fixed platforms, offered and any cubicles located at heights that require access to filling points, gauges, windows and for operation, testing or replacement of any components (including switchgear and relays).

A means of handling components of the switchgear in the case of de-assembly is required to ensure that personnel are not exposed to risks associated with high voltage and manual handling of large items shall be detailed to Transgrid. A system to lift out components of the switchgear and to move them in/out of the equipment and on/off site is required. This needs to be achievable without affecting adjacent panels if possible, and if not, the access and spacing requirements of moving adjacent panels shall also be considered. Examples could include the use of a crane or the use of suitable rail and pulley block system.

The switchgear layout design is to specifically consider removal and replacement of any component of the switchgear, and provide space and facilities requirements that shall be considered in building design, including:

- handling of the equipment to and from the service position,
- its passage through the building,
- movement of equipment into and out of the building,
- delivery to and receipt from the transport vehicle.

6.20.17. Proving Isolated and Earthed

Transgrid requires that the offered switchgear can be isolated and earthed in preparation for maintenance activities by two independent methods. The two methods are required to be accessed independently of the SCADA system and from within the switchgear room. How the position of the switchgear can be determined in order to meet this requirement shall be described to Transgrid.

Such detail shall describe a system for providing two independent mechanisms of position indication and how all three phases in HV encapsulations can be proven de-energised. Documentation is to include general arrangements/layouts, photos, schematics and other relevant documentation.

External mechanically connected position indicators shall be provided showing either open or close position of each pole. The position indicator shall be visible from ground level and externally to the mechanism enclosure, marked "I" (red background) – closed and "O" (green background) open. The visibility of the position indicator shall not be obstructed by adjacent bays, other operating mechanisms, cubicles etc.

Two independent voltage detection methods are required. Voltage detection shall meet the following requirements:

- Voltage detection methods shall use both:
  - a portable handheld device and/or local indication AND
  - a permanent localised sensor integrated into the switchgear housing;
- Voltage detection to be accessible by person on the switchgear room floor;
- Voltmeter to be provided in local control cubicles on voltage transformer outputs;

Voltage detection not to take inputs from switchgear status / SCADA inputs to operating system

6.20.18. Interlocking

By design or interlock, maintenance and high speed earthing switches shall be prevented from closing onto an energised line or bus section. Disconnect switches shall also be prevented from making or breaking load or closing onto an earth causing an earth fault except for high speed make-proof earthing switch.

No protection operations shall be prevented by interlocking except for a gas insulated circuit breaker with low gas pressure lockout stage. Provision of alarm for low gas pressure shall be made before the lockout stage is reached.

Provision shall be made to override any interlocking for manual operation.

A means of indicating that a manual operation of any device was prevented by interlocking shall be provided on the operating and control mechanism.

The method and provisions for interlocking and overriding the interlocking, and details on bus transfer ratings and associated interlocks shall be provided to Transgrid.

Transgrid understands that there are two stages of interlock that need to be considered:

- Individual panel interlock arrangements
- Completed switchboard arrangements.

An Interlock report describing the design and testing of these two stages of interlock shall be included in the commissioning documentation handed over to Transgrid.

- Interlocking design shall in particular prevent:
- The withdrawal or engaging of any movable portion unless the circuit breaker contacts are open;
- The closing of the circuit breaker contacts, unless any movable portion is in the fully engaged or fully withdrawn position;
- The removal of the circuit breaker tank where applicable unless any movable portion is in the fully withdrawn position, and the engaging of the movable portion unless the tank is in place;
- The circuit breaker being closed in the fully engaged position unless the secondary auxiliary circuits between fixed and any moving portions are complete;
- A vertically isolated circuit breaker where applicable being raised unless correctly located;
- Access to the HV voltage transformer fuses (if applicable) unless the voltage transformer is fully isolated;
- The earthing switch of the switch fuse units from being closed unless the fuse switch is open.
- The circuit breaker in feeder panels to be closed on to an earthed busbar. This requires adequate interlock coordination between manual operations of busbar earth switch and feeder bay disconnector / earth switch.

6.20.19. Special Tools

Any special tools needed for installation, operation, inspection and maintenance shall be described to Transgrid. This shall include all tools necessary for the adjustment or removal of any part of the switchgear, its component parts and substation building requirements such as unloading areas, cranes etc.

All special tools shall be supplied with the switchgear.

6.20.20. Circuit Breaker

Transgrid has a preference for circuit breakers with vacuum interrupters.

Both withdrawable and fixed pattern/stationary circuit breakers are acceptable. Any restrictions or requirements for the operation, testing and maintenance of the circuit breakers, including but not limited to sterile areas, maintenance access, testing points and access and any special PPE / procedure required for the activities shall be provided to Transgrid.

6.20.20.1. Operating Mechanism

Transgrid has a preference for electrical motor charged spring operating mechanisms. The mechanisms shall be suitable for remote operation. Transgrid does not prefer local operation of circuit breakers. Possible means of disabling local operation shall be provided to Transgrid and Transgrid may elect to carry out modification to only allow remote operation of circuit breakers. If the local operation cannot be bypassed, then this operation mode shall not prevent remote tripping of the circuit breaker by protection system, except when the circuit breakers are required to be locked closed to allow earthing of busbar.

All circuit breaker mechanisms shall be capable of being locked by means of a 45mm standard shank padlock in both the open and closed positions.

Charging of the operating mechanism shall be possible in the event of failure of the motor drive.

The Connection Applicant shall confirm whether the fault rating and intended operation of the equipment is maintained during manual operation.

The following accessories shall be provided with each operating mechanism in addition to any facilities that may be provided by the manufacturer:

- Trip Operation Counter. It is noted that a Trip counter increments on completion of a Trip operation. This is distinct from a Close counter which increments on completion of each Close operation.
- Device for manual slow closing and opening of the circuit breaker during maintenance. The circuit breaker shall be designed so that the spring charging motor is prevented from turning the manual charging handle if it is inadvertently energised during the manual charging operation. The manual operating device shall be located inside the operating mechanism box.
- Separate push button for energising either trip coil locally.
- One (1) "CLOSE" push button, for each three phase breaker.
- Duplicate trip coils that are separated mechanically, electrically and magnetically.

6.20.20.2. Maintenance

Operating mechanisms and controls shall not require major service for the maximum achievable period. In the operation and maintenance manual the detail maintenance, removal and replacement procedures for circuit breaker shall be provided to Transgrid.

6.20.21. Disconnector and Motorised Earthing Switches

Transgrid requires the provision of remotely controlled earth switches.

The switch shall open or close only due to motor-driven or manual operation. The switch contact shall not move due to gravity or other means, even if a part fails. Once initiated, the motor mechanism shall complete an open or close operation without requiring the initiating contact to be held closed. Any auxiliary status contacts shall only change status after the disconnector or earth switch has completed its movement and reached final position. Limit switches are preferred for this purpose.

The mechanisms shall be suitable for remote and local operation.

Power operated mechanisms shall also be capable of being operated manually. Where this is through a crank, the number of turns required to either fully open or fully close shall be limited to no more than 50 turns. The manual operating handle shall be stored in the control cubicle.

The Connection Applicant shall provide confirmation whether the fault rating and intended operation of the equipment is maintained during manual operation.

Interlocking shall be provided so that the manual operating mechanism will not be driven by the power-operated mechanism. All open and close contactors of power-operated mechanisms shall be provided with both mechanical and electrical interlocking.

All disconnectors and switches shall be capable of being locked by means of a 45mm standard shank padlock in both the open and closed positions. Padlocking facilities shall be provided to permit the circuit and busbar earthing to be locked independently.

The following shall also apply:

- Maximum height of the manual-operating crank for power operated mechanisms shall be 1500mm; and
- Maximum operating force for using a geared device shall be 90N.

6.20.21.1. Three-position Disconnector and Earthing Switch

If a three-position disconnector and earthing switch is used, each switch shall stop and lock at each position:

- Disconnector closed;
- Disconnector and earthing switch open; and
- Earthing switch closed.

6.20.21.2. Visible Break

The integrated disconnector and earth switches shall provide a visible break when they are in the open position.

All panels with disconnectors and earth switches shall be provided with means of visually verifying visible break for maintenance purposes. Transgrid shall be able to clearly view the contacts of all phases in all operational positions of each disconnector and earth switch.

The proposed method of verification, how the proposal can be used to view the contacts including pictorial evidence, and details such as location of viewing windows if offered, operator access, the need for a camera system if applicable and the type of camera system shall be provided to Transgrid.

6.20.22. Current Transformer

The current transformers shall comply with AS 61869.2 “Instrument transformers - Additional requirements for current transformers (IEC 61869-2:2012 (ED 1.0) MOD).

When the switchgear is fully assembled, the current transformers shall remain readily accessible for maintenance/removal/replacement purpose.

It is preferred that CTs be positioned within the switchgear. The detail location of CT, maintenance, removal and replacement procedures shall be provided to Transgrid.

Test points are required for single or three phase testing. The test point is to be located external to the switchgear enclosure with a solid link, for isolation, between the test point and the main earth.

6.20.22.1. Plug In Connectors

Where plug in connectors are used to extend secondary circuits, a fail-safe N/C connection shall be provided to monitor the position of the connector.

6.20.22.2. Earth Lead Connection

Any connection to the main insulation shall be capable of withstanding high frequency currents, which may result from disconnector operation and other normal Substation activities.

6.20.23. Voltage Transformer

The Voltage Transformer shall have an adequate rating such that it does not limit the site test voltage that may be applied to any component of the switchgear. The voltage transformer shall include suitable means of preventing ferro-resonance.

Voltage transformers are to be mounted in such a manner to be readily and safely removed from the high voltage circuit to an isolated position with complete safety without requiring an interruption to the high voltage supply and without interfering with the operating position of any circuit breaker.

The Voltage Transformers shall comply with the requirements of AS 61869.3 "Instrument transformers - Additional requirements for inductive voltage transformers" (IEC 61869-3:2011 (ED.1.0) MOD).

Provision shall be provided for earthing and isolation of Voltage Transformer secondaries.

6.20.23.1. H.V. Neutral Terminal

The neutral end of the high-voltage winding shall be brought out to a terminal through a bushing capable of withstanding a test voltage of 2.5 kV. This bushing shall be adequately protected from mechanical damage. The terminal shall be electrically connected to the main equipment earthing terminal via a bolted link, made as short as possible and removable for test purposes without disturbing the main equipment earth connection. The Tenderer shall describe how the earthing of the neutral terminal is achieved.

This link shall be labelled as follows, with the label mounted in a clearly visible position near the link:

WARNING - H.V. NEUTRAL LINK DO NOT ENERGISE TRANSFORMER WITH THIS EARTH LINK REMOVED

6.20.24. HV Power Cable Connection

The cable end unit design shall include a facility for high voltage AC testing of the connected power cable on site.

Means to safely access and connect a cable sealing end into switchgear which requires allowing appropriate earthing or other work methods to guard against transferred voltages shall be provided to Transgrid. The proposal requires that either a common earth be applied to the cable conductors to create an equipotential work area (preferred), or that insulated working conditions be established.

6.20.25. Earthing

Earthing of switchgear, operating cubicle and panels and any structure shall be in accordance with Transgrid's standard requirements.

Individual earthing conductors shall be suitable for the full short circuit current. Switchgear enclosure, framework, undercarriages or the like shall not form part of a fault current path to earth. Continuity to earth of an earth switch, or local control cabinet earth bar, shall not be achieved through enclosures or metal partitions.

The switchgear enclosure and low voltage cubicle doors shall also be adequately earthed.

6.20.26. Operating and Control Cubicles

Transgrid has a preference for the local control cubicle for each switchgear to be elevated off the ground at a height between 1000mm and 1800mm and it shall be readily accessible. Transgrid has a preference for the operator accessible components such as any fuse, link, switch, contactor, indicator, handle, operation counter etc. to be at a height greater than 1000 mm but not exceeding 1800 mm from ground level or operating platform. If facilities such as operating platform or guard rails are provided, they shall be included in the switchgear envelope.

Transgrid has a preference for the IEDs to be located at a height suitable to be read from the ground level outside of the panels without opening any doors.

The opening of a door shall neither collide with nor limit the opening of adjacent doors.

Where applicable, the panels shall be hinged to allow access to the back of panel wiring.

The rear of the control cubicle shall not form an integral part of the busbar (or other HV) compartment. Any arc product from any arcing fault shall not enter the control cubicle.

The following equipment shall be mounted on the control panel or within the control cabinet and shall be readily accessible by Transgrid:

- Auxiliary LV equipment.
- Instrument transformer secondary terminals.
- Switchgear manual operating handle.

6.20.26.1. Slide Link Test Disconnect Terminals

Slide link test disconnect terminals shall, wherever practicable, be mounted on a horizontal rail and in this case the sliding link shall be positioned to fall closed if the sliding section becomes loosened.

Slide links shall be coloured as follows;

- VT Links – White
- CT Links – Black
- Circuit Breaker Fail (CBF) Links – Red
- All other Links – Grey

6.20.26.2. Segregation and Insulation

Control and protection wiring shall not pass through any fault containment busbar chamber without adequate mechanical and electrical protection which will prevent damage to the wiring caused by any failure of the switchboard.

Facilities are to be provided for control and protection wiring (circular multicore control cables) to enter the switchboard to the instrument panels without risk of damage from vented arc products and maintain isolation between one HV enclosure to another and between HV to LV enclosures. Detail of this facility shall be provided.

Terminals shall be grouped together according to the working voltage of the circuits. Segregation shall be provided between groups, low voltage and extra low voltage circuits by means of insulating barriers or by physical separation.

6.20.27. Testing

The following site acceptance tests may be requested by Transgrid as an option in additional to the standard site acceptance tests proposed. In the switchgear design, the corresponding test points shall be accessible when the entire switchgear installation is in its in-service position with cables and possible surge arrester / external CT connected. Detailed work method statement and instructions to describe how these tests can be readily and safely performed shall be provided to Transgrid.

- Insulation Resistance and / or vacuum integrity measurement
- HV withstand of the whole board in-service position
- HV withstand across CB in open position
- Partial Discharge of the complete board.
- Prove of suitably low contact resistance of all joints, individually or by threshold criteria for measurement path.
- Gas tightness checks and gas testing
- Prove of functionality of gauge alarm set points at nominal gas pressure/density.
- Perform commissioning circuit breaker contact timing, travel curves, static & dynamic contact resistance measurements.
- Testing of interlocking, both within a switchgear panel or across the entire switchboard installation.

7. Civil and Structural Design

7.1. Standards

The designs shall be based on Transgrid's performance requirements specified in this document, the applicable Australian Standards and industry best practice. Refer Appendix A.

7.2. Geotechnical investigations

Where geotechnical investigations are to be undertaken by the Connection Applicant, the Connection Applicant shall ensure the investigations provide all the parameters and information required to design all the civil components of the switchyard and, where applicable, the access road.

The purpose of the investigation is to identify the soil and rock types and profiles and other matters that may influence the civil design and construction of the substation. Where contamination of soil is possible, the geotechnical investigation should undertake all appropriate chemical analyses of the soils on the site.

7.3. Erosion and sediment control

A Soil Management Plan is required for all substation work involving earthworks. Soil conservation and erosion prevention measures shall be in accordance with Landcom, 2004, *Managing Urban Stormwater: Soils and Construction* (Volume 1) (The Blue Book) NSW. The plan shall have a cover sheet that outlines the verification measures employed in preparing the plan as well as the justification of the plan itself.

The Contractor shall plan and carry out the whole of the works to minimise erosion, sedimentation and pollution of the site, watercourses and surrounding areas according to the following principles:

- Avoid unnecessary ground disturbance;
- Control underwater flow paths, volumes and velocities;
- Utilise progressive rehabilitation techniques.

Such measures shall be temporary or permanent, as proposed by the Connection Applicant.

Temporary controls are measures required to provide erosion and sediment control in construction areas.

The Connection Applicant is to comply with Local Government Authority requirements for sustainable stormwater and wastewater management strategies.

7.4. Bench design

Electricity supplies are an essential service and a switchyard should not be affected by flooding.

A switchyard should be located at least 500 mm above the 1:100 flood levels and should not be impeded when the flood level is at the 200 year Return Period where levels are unavoidably less than the 1:100 year level, mitigation measures should be implemented to minimise the effect of flooding.

The switchyard site needs to be accessible under most circumstances to allow fault response and access for operational reasons. The switchyard bench is to provide a stable, dry weather trafficable and free-draining structure and provide a safe platform for personnel, vehicles, cranes and trucks in order to facilitate the maintenance and operation of the switchyard for the duration of its operational life.

Eliminate uneven surfaces and tripping hazards in the switchyard area generally where possible and minimise otherwise. Provide handrails and barriers as needed to minimise hazards associated with steps.

Slopes to earthworks batters that require maintenance, should be such that personnel, equipment and vehicles can safely traverse the area.

The switchyard shall be surfaced with 20 mm crushed, quarried blue metal laid to a depth as required for spill oil control and earthing requirements. This applies to all areas of the switchyard that are not otherwise sealed e.g. roads and pavements. The depth of coverage of the blue metal is subject to earthing studies.

The general arrangement of the switchyard is to take into account the need for vehicle and crane access to all plant. Corridors for vehicle access are to be allowed for between switchbays (including future switchbays), or within the space between the switchbays and other high voltage plant.

7.5. Earthworks

Excavation and filling shall be designed and the compaction specified such that ground settlements are acceptable and will not affect the performance of the substation throughout its service life.

The field dry density of finished earthworks in the switchyard area, generally, will not be less than the value recommended in the Geotechnical Report

The Geotechnical Report will make recommendations on the slope of cut and fill earthworks and embankment slopes in the substation.

The drawings shall show finished earthworks levels, including transition points and sufficient cross-sections to ascertain cut and fill requirements. The existing surface cut and fill lines shall be clearly shown.

An Earthworks Plan is a document generated by the bulk eartworks contractor which details how they propose undertaking scope of works and is required for any significant earthworks on the site.

7.6. Roadways and pavements

7.6.1. General

The substation roads and pavements shall be designed and detailed to provide general vehicular access to, and within, the Substation.

The road design parameters to allow for traffic conditions after the completion of the works, including the installation of all plant associated with the substation.

The design of the area around any building shall allow for delivery, unloading and installation of equipment.

The drawings for roadways and pavements shall show:

- Vertical and horizontal alignments
- Long section on the centre line of the road, including chainage
- Sufficient cross sections to determine cut and fill quantities
- Reduced Level (RL) to Australian Height Datum (AHD) of existing surface, finish level, etc. all drainage requirements adjacent, or under roads, including invert levels

7.6.2. Access road

The alignment, grade, width and strength of the access road shall be designed and constructed to allow for safe transport and delivery of equipment and personnel.

The design parameters for the access road shall be as required by the Local Council and RMS if appropriate, but not less than follows:

- Construction traffic during the works
- Design traffic after completion of all construction works of not less than 200,000 Equivalent Standard Axles (ESA).

The road shall be designed to be maintenance free for a minimum of 20 years after Practical Completion.

The road shall have a minimum width of 5 metres, or as required to allow two large vehicles to pass without running into soft ground on the side of the road. This may require gravel shoulders to be constructed on both sides of the sealed section of the road.

The road shall be designed to drain such that it meets the Drainage section of this document.

Where a wearing surface is specified, the wearing surface shall be a Double/Double seal type in accordance with RMS Form 106 unless otherwise required by the Local Council.

7.7. Parking and hardstand areas

The drainage design shall satisfy the requirements of the Drainage section of this document. Runoff from these areas shall connect to the switchyard drainage systems.

Where supply and installation of secondary system buildings (SSB) form part of the scope, allowance shall be made for hardstands to each of the SSB. The hardstand area to each of the SSB shall be of a size and geometry to allow for access and parking alongside the SSB in all weather conditions for two domestic size vehicles at any one time without obstructing access paths. The hardstands should as a minimum incorporate the full footprint of the SSB including a 2 m wide perimeter all around the building and 2.5 m in front of the veranda at the major access end of the building. The pavement shall be designed to adequately support expected vehicular and heavy vehicular traffic. The hardstand areas shall be sealed. The wearing surface shall be a Double/Double seal type in accordance with RMS Form 106. Runoff from these areas shall connect to the switchyard drainage systems.

The extent of the hardstand area shall be indicated on the bulk earthwork drawings.

7.8. Cable trenches and conduits

The design of cable trenches shall allow sufficient space for cabling for the ultimate development of the substation.

The walls and base of cable trenches shall be of reinforced concrete. Precast concrete units may be used. All cable trenches shall have effective shear keys between adjoining sections. The shear key may utilise galvanised steel dowel bars, or other methods approved by Transgrid. Joints between sections shall be sealed against water leakage.

Non-trafficable trench covers shall not require more than two persons to safely remove. These trench covers shall be so dimensioned such that the weight of individual panels does not exceed 32 kg and comply with the guidelines specified in the Hazardous Manual Tasks Code of Practice.

Trafficable trench covers shall be designed for the traffic loads specified at the following locations:

- All designated roadways;
- All plant access corridors;
- For sites that do not have kerbed perimeter roads a corridor of 6 m from the security fence towards the bays.

The drainage of cable trenches shall comply with the Drainage section of this document..

Conduits shall be laid straight in all planes between conduit pits and shall be self-draining. The spacing of pits should suit the requirements for installing cable to both the initial and final development and must consider typical cable installation constraints.

Cable pits shall be sized to accommodate the bending radius of cables and to allow physical access to install the cables. All pits deeper than 600 mm shall have minimum internal plan dimensions of 900 mm by 600 mm, or greater as required. Step rungs shall be provided where depth of pit is greater than 900 mm. Step rungs may be galvanised steel or plastic encapsulated steel. All step rungs shall comply with the requirements of AS 1657.

Conduits shall be provided with bellmouths at pit entries.

All pits shall have removable covers. The covers shall not require more than two persons to safely remove and comply with the guidelines specified in the Hazardous Manual Tasks Code of Practice by Safe Work Australia. Steel covers shall be free of distortion after fabrication and galvanising to within +/- 2 mm measured across the cover in any direction.

7.9. Drainage

The drainage system shall be designed to efficiently collect and discharge surface and subsoil water that would impair or be the cause of failure of foundations, roads, slopes, retaining walls or drainage structures. The drainage system shall also separately drain oil and oil contaminated water to the appropriate containment structures.

The design of the drainage system shall be based on the Institution of Engineers (Australia) 'Australian Rainfall and Runoff: A Guide to Flood Estimation' Volumes 1 and 2 and AS 3500.3.

Runoff from outside the switchyard shall be intercepted and diverted around the switchyard by catch or table drains and concrete boundary drains. The drains shall be designed for rainfall corresponding to a 50 year average recurrence interval and designed to counter erosion and remain functional due to effects of siltation.

The switchyard stormwater drainage system shall be designed for a rainfall corresponding to a 10 year average recurrence interval. The drainage structures shall not surcharge when subjected to the design rainfall intensity. The runoff coefficient shall be based on commercial development with a runoff coefficient of not less than 0.6 for the unpaved areas and 0.9 for paved areas.

Subsoil drains shall not be used to capture surface runoff when other drainage methods are practical.

Switchyard stormwater drainage design shall comply with the requirements of AS 3500 part 3. The minimum grade on all drains shall be 1%.

All conduit pits shall be drained. The drain pipe shall be a graded at slope of not less than 1:150 between pits. The pit drainage shall connect into the substation drainage system. Where the pit floor is lower than the cable conduit a separate drain pipe shall be installed.

Any surface drainage structures located in trafficable areas shall be designed to accommodate the appropriate to the wheel loads. Reinforced sections shall have dowel bars at joints between sections. Flow in V drains shall be intercepted at regular intervals by pits which shall drain into the stormwater drainage system.

Ponding in localised areas shall be prevented by grading of the switchyard in those areas, or installing appropriate drainage structures. Surface rainwater shall be intercepted and prevented from flowing over switchyard embankments except where contained in appropriate drainage structures.

The runoff from the switchyard, except for potentially oil contaminated water, shall be diverted to the natural watercourse in accordance with EPA guidelines and requirements. Dispersion structures and other measures satisfying the requirements of Erosion and Sediment shall be implemented.

The drainage system of switchyard areas that contain oil-filled equipment and from the bunded areas shall be kept separate from the stormwater drainage system. The design of drainage for the oil containment system shall comply with the applicable requirements of this Section, AS 2067 and AS 1940.

Subsurface drains shall be constructed where permeable water bearing strata are intersected by the earthworks. Where a roadway’s performance may be affected by groundwater, sub-soil drains shall be constructed parallel to the roadway to intercept groundwater. Subsoil drains may also be required to mitigate the effects of groundwater on foundations, retaining walls, drainage structures.

Cable trenches shall drain into the switchyard drainage system either directly into the stormwater system or to the secondary dam or tank, as appropriate. Where a cable trench impedes surface or groundwater flows, subsoil drains shall be constructed adjacent to the cable trench to capture the water. Where a subsoil drain is constructed the cable trench may incorporate drainage weep-holes to the subsoil drain to assist removal of the water from the cable trenches laid across the slope. Water captured in cable trenches shall be prevented from entering the control room underfloor area.

7.10. Pits

All pits shall be accessible and have removable covers. The covers shall not require more than two persons to safely remove. Steel covers shall be free of distortion after fabrication and galvanising to within +/- 2 mm measured across the cover in any direction.

The internal plan dimensions of pits shall not be less than the following:

- Deeper than 0.6 m: 900 mm by 600 mm;
- Deeper than 1.2 m: 900 mm by 900 mm;
- Deeper than 2.4 m. 900 mm by 1200 mm.
- Less than 0.6 m deep: 600 mm by 600 mm, or smaller subject to the approval of the Superintendent.

Step rungs shall be provided where the depth of a pit is greater than 900 mm. Step rungs may be of galvanised steel or plastic encapsulated steel. All step rungs shall comply with the requirements of AS 1657.

7.11. Oil containment

7.11.1. General

A substation oil containment system with Spill Oil Tank shall be provided in accordance with the requirements specified in AS 2067 and Transgrid Substation Oil Containment Procedure (D2008/06285). Design and detailing of oil containment and drainage to comply with AS 2067 and AS 1940.

7.11.2. Bunded areas

Bund walls shall be of reinforced concrete. Suitable construction/control joints, including water stops as necessary, shall be installed to prevent the cracking of bunds. The area inside the bunds shall slope to the drainage points.

7.12. Structure and foundation design

7.12.1. General

The substation structure design requirements specified herein are for equipment and conductor support structures.

Structure and footing types listed for the substation are, for convenience, divided into Minor and Major Structures. Transgrid's substations have a post-disaster function. Accordingly, the structure loads are based on Importance Level 4 and a 50 years design working life (Refer AS/NZS 1170.0 – 2002)

The design of steel structures shall be based the requirements of AS 4100 (Steel Structures) except lattice steel structures which may designed to the requirement of AS 3995 (Design of steel lattice towers and masts).

All steel structure designs utilising base plates shall provide for grouting between the base plate and the concrete footing. The base plates shall be supported using setting nuts or packer plates. The steelwork drawings for major structures shall indicate the permitted support methods for base plates.

The design of concrete structures shall be based on the requirements of AS 3600 (Concrete Structures) unless otherwise specified herein.

7.12.2. Design loads

Load Types

The loads considered in the design of structures and foundations shall include the following:

- Dead loads;
- Live loads;
- Wind loads;
- Ice loads;
- Short-circuit loads;
- Soil loads and pressures;
- Earthquake loads;
- Construction loads, including the stringing of buswork and conductors.

The plant and structures are to be designed for the wind loading specified in AS 1170.2, 'Structural design actions Part 2: Wind actions'. A minimum C_d of 1.2 for insulators shall be used.

Ultimate Loads

Structural elements are to be designed to withstand the following load combinations without permanent distortion and in accordance with the relevant material and design Standards.

- 1.35G
- 1.25G + Q
- 1.2G + W_u + Q
- 1.2G + F_{eq} + Q
- 0.9G + Q
- 0.9G + W_u + Q
- 0.9G + F_{eq}
- 1.5G + 2.0M (refer notes)
- 0.8G + 2.0M

Where

G	=	force due to weight of conductors and structure ie permanent actions.
F	=	Conductor tensions
Q	=	Live Loads
W_u	=	wind loads to AS 1170.2 (a minimum C_d of 1.2 for insulators shall be used)
F_{eq}	=	earthquake loads to AS 1170.4
M	=	maintenance loads including workmen, conductor tension, etc.

Notes

Design load combinations are applied as follows:

- The loads due to weight and conductor tension, if applicable, shall be factored by 1.35 and applied in the combinations (e.g. vertical, longitudinal and transverse directions) that produce the most adverse forces on the structures;
- The initial conductor tension is factored by 1.25. The effect of the short circuit force is calculated for that tension;
- The initial conductor tension is factored by 1.2. The effect of wind and the short circuit force is calculated for that tension. As the wind has much longer duration than the SC force, it is assumed that conductor tensions will be calculated for the design wind pressures and the effect of SC currents will be based on the wind-tension. As the load combinations are extreme, the load factor for wind and SC are 1.0;
- As maintenance loads have a safety element where personnel may be working on, or close to the structure, the factor reflects the potential consequences of a failure. Hence, loads due to maintenance operations shall be factored by 2.0. Note that the factor applies to the conductors or equipment affected by the operation. In this instance it is considered that the factor of 2.0 is adequate to allow for initial stringing errors and that the initial tension may be assumed to be as specified;
- When considering short circuit loading, the load combinations shall be in accordance with AS 2067 and AS 7000.

Serviceability loads

The serviceability limit state is based on the permanent loads and wind loads corresponding to a 25 year recurrence interval. The load factor to be used is unity. Structures shall be designed to limit deflections to the most severe of the following:

- The limits specified by the equipment manufacturers;
- The limits imposed by the strength of adjacent equipment or structures;
- Under serviceability limit states 1/180 of the span or height of the structure, or for masts, 1/100 under every-day conditions and 1/50 under serviceability loads (provided that electrical clearances are not infringed in any circumstance).

7.12.3. Durability

All structural elements shall be designed and constructed such that they do not require repairs for corrosion during the design life of the Substation.

The Designer must consider if the subsoils have aggressive elements and select materials to withstand these elements.

Concrete poles, where used, shall not crack under serviceability loads.

7.12.4. Fire resistance

Materials and construction shall have fire resistance ratings of 2 hours, or as specified. The design fire rating should be indicated on the relevant drawings.

7.12.5. Footing design

Foundation design (each type and size of foundation and permissible soil pressures) shall be based on the ultimate load combinations.

Footings should be designed based on soil properties identified in geotechnical investigations and appropriate standards.

The maximum short and long term settlement and movements of footings is not to have a deleterious effect on the supported structure and equipment, or any connection to other structures or equipment. Foundation settlements shall be such that claddings and linings do not crack or sag and building elements do not open up allowing wind and/or water in (particularly under serviceability conditions). The surface of all footings shall drain freely.

An estimate of foundation movements shall be made. The Geotechnical report will identify soils that are prone to shrinkage and swelling, or are dispersive. If such soils are identified the soils properties are to be modified and/or the foundations design modified accordingly.

Piled foundations shall comply with AS 2159. Reinforced concrete piled foundations are preferred from durability consideration, but other types may be suitable in some circumstances.

The assumed bearing capacity shall be indicated on the drawings.

Reinforcement for crack control in slabs shall be based on the exposure environment applicable to the site, but not less than ‘moderate’ in accordance with AS 3600 Clause 9.4.3. Slabs with thickened edges shall be treated as restrained unless appropriate measures have been implemented to reduce restraint from the soil or other sources of restraint.

The pavement in the transformer compound and reinforced concrete slabs for capacitor banks etc. shall be designed to adequately support the expected loads including loads arising from installation, removal, commissioning and maintenance of the transformer.

8. Building Design

8.1. General

Buildings shall be fully self-contained that utilise materials and structural systems that are suitable for site specific conditions and required design life with all fixings and components being composed of compatible materials with low corrosion rates for the environmental conditions for the specific site.

The soffit/ceiling height to suit the cubicle specific design including, making provision for the installation or removal of cables as required.

The building structure shall be designed in accordance with the following requirements:

- Nactional Construction Code (NCC) requirements for class 8 as per Building Classification in the NCC buildings;
- Durable design that ensures the building remains fully serviceable for its design life;
- Building Ingress Protection Rating detailed in the International Standard EN60529 of minimum IP54, dust sealed and vermin proof for 20 years;
- Insulated against varying temperature conditions;
- Designed in a manner to minimise potential fire hazards;
- Designed to be able to be installed on sloping ground as applicable;
- The maximum deflection allowed shall be the lesser of that permitted by the equipment manufacturer for the equipment installed in the switchroom, or the Australian Standards;
- Sufficient space must be allowed for the installation of cable ladders and associated cables in a safe manner. The clearance shall provide sufficient personnel access complying with WHS legislation;
- Ensure adequate working space around equipment within the building;
- The building shall be designed to be of compact floor area, while making provision for the substation‘s ultimate development;
- The building shall be located in a position that allows for adequate parking and safe access without having to enter the outdoor switchyard areas;
- Foundations shall be constructed in accordance with the NCC and relevant standards for a site classified in accordance with AS 2870, as Class A;
- Building to be constructed of non-combustible materials. The materials and design of the walls shall take into account the loadings for cabinets, cable trays and other equipment that may be mounted on them.

8.2. Design loads

8.2.1. General

The building and all associated structures shall be designed to adequately resist all applied loads i.e. dead, live, wind, earthquake, equipment loads, etc. in accordance with the referenced standards and the load and other structural requirements specified herein.

The building structure shall be considered as being of Importance Level 4 – ‘Building or structures that are essential to post-disaster recovery’ in accordance with NCC Table B1.2 a – Importance Levels of Buildings and Structures.

Live and dead loads shall be developed in accordance with AS 1170 – Structural design actions.

Consideration shall be given to the support of any loads suspended from the roof or walls such as cubicles, false ceilings, cable ladders, air-conditioning equipment, ductwork, light fixtures, distribution boards, and cable.

Wind, snow and earthquake loading shall be developed in accordance with AS 1170.2, AS 1170.3 and AS 1170.4 respectively, and shall be site-specific.

8.2.2. Floor

The floor loading capabilities shall allow for the following as a minimum:

- Equipment loads as defined in the concept design;
- External cable ladders that may be suspended;
- The floor shall be designed to support the control and protection panels along the length of each wall;
- SSB access walkways shall be designed for equipment loads when installing or removing equipment;
- Floors in the building shall be designed to be able to support the movement, installation or removal of all future electrical cubicles and equipment. The floor joists shall be designed to allow transportation and lifting all electrical equipment installed.

8.2.3. Roof

The roof frame shall be designed to resist applied loads including but not limited to:

- Roof live load in accordance with Australian Standards;
- Cable ladders;
- Ceilings;
- Light fittings;
- Air-conditioning;
- Snow loads where applicable;
- The building shall be insulated against hot and cold conditions through insulation batts or equivalent. The thermal efficiency of the walls, roof and floor must be compatible with the air conditioning requirements.

8.2.4. Transportation

Transport loads and carriage impulse loads imposed on the structure or its equipment shall be designed for and furthermore shall be negated wherever possible by temporary or permanent structural bracing. Fit out of cubicles and other equipment/items to be included in transportation loads.

8.2.5. Structural rigidity

The structure shall be sufficiently rigid to ensure that installed equipment is not damaged during transportation and on-site installation of the unit.

8.3. Drainage systems

Drainage to comply with requirements stipulated in AS 3500.

8.4. Wastewater treatment

Where connections to town sewage systems are available, the building wastewater drains shall be connected to the town sewage system. Where this is not possible, the wastewater drains shall be connected to a suitable disposal system, such as a septic tank or a treatment plant with the chlorinate treated water pumped into a suitable area of the landscaped area for irrigation.

The wastewater treatment systems shall comply with the requirements of the Board of Health of New South Wales and the Local Authority.

8.5. Mechanical services

8.5.1. Air-Conditioning plant

Air conditioning shall be installed as per Australian Standard AS 1668.

The air conditioning plant shall provide a suitable environment for staff and the protection relays, communications, metering and other control equipment.

The air conditioning controllers shall be interfaced to the SCADA control system with a series RS 232 communication using MODBUS protocol to provide room and outside air temperatures, air conditioning status and alarm monitoring.

Air conditioning plant shall automatically shut down in the event of a fire signal from the room fire detectors.

Units shall also be designed to take into account temperature conditions at blind spots and be sized to meet the site’s local maximum and minimum ambient temperatures outside conditions.

8.5.2. Battery room ventilation

A natural ventilation system is preferred to ensure that the hydrogen concentration in the air does not exceed 2% and shall be provided in accordance with AS 2676.

The low level inlet and high level outlet vents are to be sized for natural ventilation and be located at opposite ends of each Battery Room. The rate of ventilation, air flow rate and sizing of inlet/outlet apertures shall be designed in accordance with AS 2676.

8.6. Fire protection

8.6.1. Portable fire protection equipment and storage

The Connection Applicant shall supply and install portable fire extinguishers to the Battery Room in accordance with AS 2676.

8.6.2. Fire protection

Each building shall comply with all the current requirements of the National Construction Code, including relevant installer’s statements for compliance certification, as well as relevant Australian Standards.

The Gas Fire Suppression System shall be designed and installed in accordance with AS ISO 14520.1 Gaseous fire-extinguishing systems-Physical properties and system design-General requirements.

Where a VESDA system is required it shall be designed and installed to provide coverage of the whole building.

Details of the systems proposed shall be included in the Technical Schedules.

8.7. Domestic water

Domestic water services shall be sourced from town water mains, or where these are not available, from a Water Tank to be provided.

The domestic water system shall supply water to the locations in Buildings as required.

8.8. Internal lighting requirements

8.8.1. Luminaires

All AC systems are to follow the principles defined in Australian Standard AS 3000 and AS 3008. The location of the light fittings shall be subject to the equipment layout.

With the exception of the battery rooms, the luminaires inside each room of each building shall be located to provide a level of illumination in accordance with the requirements of AS1680. Interior & exterior luminaires shall be located to provide a level of illumination that is at least in accordance with the requirements of AS 1680.

The light fittings in Battery Rooms shall be flame proof fluorescent and comply with the requirements of AS 2676.1.

8.8.2. Emergency evacuation lighting

The emergency evacuation lighting system shall comply with the requirements of Australian Standard AS 2293.1 and must switch on automatically on loss of AC supply.

8.9. Electrical requirements

8.9.1. General

The Connection Applicant shall design and install all the AC and DC systems necessary for the building lighting, power, security systems, and any other purpose required to complete the works.

All electrical installations shall be carried out in accordance with the latest edition and amendments of AS 3000 and other relevant Australian standards such as AS 3008. AC wiring for the SSB shall be chased through internal walls and no exposed conduits or wiring shall be used.

8.9.2. Power outlets

External power outlets shall be provided on the building as follows:

- One off weatherproof double 10 A GPO on the wall adjacent to the switchyard door;
- One off three phase 415 V, 32 A continuous rated switchplug outlets (5 pin) located adjacent to Battery Room door and/or cable access holes.

8.9.3. Earthing and surge protection

The Connection Applicant shall design, supply, install and connect the earthing system required for the safe and effective earthing of the distribution boards, equipment and building structure.

The building installation shall be earthed in accordance with AS 3000 and AS 2067 via the Substation earth grid.

Appendix A Civil and Structural Design Standards

The following Australian Standards (and RMS forms for roads) are applicable to the specified design requirements, or materials and construction requirements for the substation.

A.1 General

AS 1170 Structural Design Actions

AS 2067 Substations and High Voltage Installations exceeding 1kV AC

AS 3600 Concrete Structures

AS 4100 Steel Structures

AS 5577 Electricity Network Safety Management Systems

AS 7000 Overhead line design

ENA 15 Energy Network Australia - National Guideline for Prevention of Unauthorised Access to Electricity Infrastructure

ENA 18 Energy Network Australia - Fire protection of Electricity Substations

COP Code of Practice - Safe Design of Structures

COP Code of Practice - Hazardous Manual Task

A.2 Geotechnical site investigations

AS 1726 Geotechnical Investigations

A.3 Concrete

AS 1012 Methods of testing concrete

AS 1141 Methods for sampling and testing aggregates

AS 1379 The Specification and Supply of Concrete

AS 1478 Admixtures for concrete

AS 2530 Methods for testing Portland, blended and masonry cements.

AS 2758 Aggregates and rock for engineering purposes

AS 3582 Supplementary cementitious materials for use with Portland and blended cement.

AS 3600 Concrete Structures

AS 3610 Formwork for Concrete

AS 3972 Portland and Blended Cements

AS 3799 Liquid membrane-forming curing compounds for concrete

AS/NZ 4671 Steel Reinforcing Materials

A.4 Clay bricks and concrete blocks

AS 3700 Masonry Structures

AS/NZS 4455 Masonry units and Segmental pavers

AS/NZS 4456 Masonry units and Segmental pavers. Method Test

AS 2701 Methods of sampling and testing mortar for masonry construction

A.5 Earthworks

AS 1141 Methods for sampling and testing aggregates

AS 1289 Methods for testing soils for engineering purposes

AS 3798 Guidelines in earthworks for commercial and residential developments

AS 4678 Earth-Retaining Structures

AS 2870 Residential slabs and footings – construction

A.6 Roadworks

AS 1141 Methods for sampling and testing aggregates

AS 1152 Specification for Test sieves

AS 1160 Bitumen emulsions for construction and maintenance of pavements

AS 1289 Methods for testing soils for engineering purposes

AS 1507 Road tars for pavements

AS 2008 Residual bitumen for pavements

AS 2150 Hot Mix Asphalt – A guide to good practice

AS 2157 Cutback bitumen

AS 2758 Aggregates and rock for engineering purposes

AS 2891 Method of testing and sampling asphalt

AS 3798 Guidelines in earthworks for commercial and residential developments

AS/NZS 4671 Steel reinforcing material

AS/NZS 4680 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles

AS/NZS ISO 9000 Quality Management Systems. Fundamentals and vocabulary

AS/NZS ISO 9002 Quality Systems. Model for quality assurance in production, installation and servicing.

RMS Form 76 Supplement to AUSTROADS 1992 Guide

'AUSTROADS' Pavement Design – A guide to the Structural Design of Road Pavements (1992)

RMS Guide Sprayed Sealing Guide (October, 1991)

RMS 106 Sprayed Bituminous Surfacing (with Cutback Bitumen)

RMS 116 Asphalt (Dense Graded and open Graded)

RMS T166 Test method 166. Relative Compaction of Road Construction Materials

RMS 3051 Unbound and Modified Base and Sub base Materials for Surface Road Pavements.

RMS Form 400 Bituminous Surfacing Daily Record

A.7 Concrete pavements

AS 3600 Concrete Structures

AS 4671 Steel Reinforcing Materials

AS 4680 Hot-dip galvanised (zinc) coatings on fabricated ferrous articles

A.8 Water services

AS 1345 Identification of the contents of pipes, conduit and ducts.

AS 1432 Copper tubes for plumbing, gas fitting and drainage applications

AS 1463 Polyethylene pipe extrusion compounds

AS 1477 Unplasticised PVC (UPVC) pipes and fittings for pressure applications

AS 1627 Metal finishing

AS 2280 Ductile iron pressure pipes and fittings

AS 2419 Fire Hydrant installations

AS 2441 Installation of fire hose reels

AS 2544 Grey iron pressure fittings

AS 2941 Fixed fire protection installations

AS 3680 Polyethylene Sleeving for Ductile Iron Pipelines

AS 3681	Guidelines for the application of polyethylene sleeving to ductile iron pipelines and fittings
AS 3688	Water Supply – Metal fittings and end connectors
AS/NZS 4129	Fittings for polyethylene pipes for pressure applications
AS/NZS 4130	Polyethylene pipes for pressure applications
AS/NZS 4158	Thermal-bonded polymeric coatings on valves and fittings

A.9 Drainage

AS 1074	Steel tubes and tubulars for ordinary services
AS/NZS 1254	Unplasticised PVC (UPVC) pipes and fittings for storm and water applications.
AS/NZS 1260	UPVC pipes and fittings for sewerage applications
AS 1289	Method of testing soil for engineering purposes
AS 1477	Unplasticised PVC (UPVC) pipes and fittings for pressure applications
AS 1597	Precast reinforced concrete box culverts
AS 1657	Fixed platforms, walkways and ladders
AS 1646	Elastomeric seals for waterworks purposes
AS 1741	Vitrified clay pipes
AS1940	Storage and handling of flammable and combustible liquids
AS 2053	Non-metallic conduits and fittings
AS 2280	Ductile iron pressure pipes and fittings
AS 2439.1	Perforated Drainage Pipe and Associated Fittings
AS 2544	Grey iron pressure fittings
AS 2876	Concrete kerbs and channels (gutters) - Manually or machined placed.
AS 3735	Concrete structures for retaining liquids
AS/NZS 3500	Plumbing and drainage
AS 4058	Precast concrete pipes (pressure and non-pressure)
AS/NZS 4680	Hot dipped galvanised coatings or ferrous articles
AS 3996	Metal access covers and frames
BS 1256	Malleable Cast Iron Screwed Pipe Fittings

RMS R63 Geotextiles (Separation and Filtration)

RMS R62 Subsurface Drainage – Materials

RMS 3553 Seamless tubular filter fabric

A.10 Concrete pipelines

AS/NZS 4058 Precast concrete pipes

AS/NZS 3725 Design for installation of buried concrete pipe

A.11 Cable conduits

AS 2053 Non-metallic conduits and fittings

AS 3000 Rules for the electrical equipment of buildings, structures and premises

A.12 Footings

AS 1289 Methods for testing soils for engineering purposes

AS 2159 Piling - Design and installation.

AS 2870 Residential slabs and footings – construction

A.13 Fencing

Unless otherwise specified; materials supplied shall comply with the following Standards.

BS 1722-14 Specification for Welded Mesh panel Fences

AS 1725 Chain Link security fencing and gates

AS 4680 Hot Dip Galvanised (Zinc) Coatings on Fabricated Ferrous Articles

AS 4100 Steel Structures

AS 1554 Structural Steel Welding

AS 3016 Electrical Installation – Electric Security Fences

AS 3550.2.76 Safety of Household and Similar Electric Appliances – Electric Fence Energisers

AS 1074 Steel tubes and tubulars for ordinary service

AS 1163 Structural Steel Hollow Sections

AS/NZS 4680 Hot dipped galvanised coatings on ferrous articles

AS 2423 Coated Steel Wire Products

A.14 Structures and footings

The Building Code of Australia – as applicable

AS 1170 Structural Design Actions

ESAA NENS 05 – National Fall Protection Guidelines for the Electricity Industry

AS 4100 Steel structures

AS 3600 Concrete structures

AS 3995 Design of steel lattice towers and masts

AS/NZS 4600 Cold formed steel structures

AS/NZS 1554.1 Structural Steel welding

AS/NZS 1559 Hot dipped galvanised steel bolts and associated nuts and washers for tower construction.

AS 1074 Steel tubes and tubulars for ordinary service

AS 1111 ISO metric hexagon bolts and screws

AS 1112 ISO metric hexagon nuts

AS/NZS 3678 Structural Steel. Hot rolled plates, floor plates and slabs

AS/NZS 3679 Structural Steel. Hot rolled bars and sections

AS/NZS 4680 Hot Dip Galvanised (Zinc) Coatings on Fabricated Ferrous Articles