TS 03882:1.0

T HR EL 99002 ST

Standard

Substation Minimum Construction

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Document information

Owner: Professional Head of Energy Networks and Systems
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Document history

Revision	Effective date	Summary of changes
1.0	02 March 2018	First issue as T HR EL 99002 ST.
1.0	09 March 2026	Renumbered as TS 03882:1.0. Version number recommenced in line with new designation. Changes to previous content include incorporation of the technical direction TD 00043:2024, addition of the provision for electronic locks, modification of Emergency push button sections, addition of provisions for 125 V dc circuit breakers, clarification of the ceiling space requirements for DCCBs not installed in a metal enclosed switchgear, and conversion of the standard to PAM format and style.

Preface

This standard is the first issue with new designation TS 03882:1.0 and supersedes T HR EL 99002 ST *Substation Minimum Construction Standard* version 1.0 and TD 00043:2024 *Updates for prefabricated substations, rail-earth contactor and system transformers – Amendment to T HR EL 99002 ST (TS 03882) Substation Minimum Construction Standard*.

This document provides the requirements for the substations for use in the TfNSW metropolitan heavy rail network.

The change from the previous content includes the following:

- incorporated the technical direction TD 00043:2024
- added in the provision for electronic locks
- modified Emergency push button sections
- added in provisions for 125 V dc circuit breakers
- clarified the ceiling space requirements for DCCBs not installed in a metal enclosed switchgear.

The terms ‘normative’ and ‘informative’ are used in PAM documents to define the application of the appendices to which they apply. A ‘normative’ appendix is an integral part of an asset standard, whereas an ‘informative’ appendix is only for information and guidance.

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1 Scope

This standard specifies the requirements for the construction of substations (supervisory control and data acquisition (SCADA) controlled), sectioning huts and equipment installation for use in the TfNSW metropolitan heavy rail network, HV ac distribution network and 1500 V dc traction system.

2 Application

The requirements of this document apply to the installation of all new substations (SCADA controlled) and sectioning huts in the TfNSW metropolitan heavy rail network.

The following are locations within the TfNSW metropolitan heavy rail HV ac distribution network that are classified as substations for the purpose of this document:

- any location that includes a HV circuit breaker (except pole top distribution substations)
- traction substation
- HV switching station
- HV switch room.

The above four bullet points are all SCADA controlled substations.

Ring main unit (RMU) locations that have an alternating current circuit breaker (ACCB) for the transformer, pole top and other distribution substations that use HV fuses for protection are not classed as substations for the purpose of this document.

Existing locations that have major equipment upgrades or installation shall comply with this standard where it is reasonably possible. It is acknowledged that where new equipment is being installed in an existing location, it may not be possible to comply with all the requirements of this document. However, requirements driven by safety and operational reliability shall be complied with.

In addition to the requirements of this standard, asset decisions shall take into account the life cycle cost considerations specified in TS 01505 *Life Cycle Costing*.

If, when using the standard, it is considered that the intent of stated requirements is not clear, a clarification should be sought from the Director Energy Networks and Systems, PAM.

3 Referenced documents

The following documents are cited in the text. For dated references, only the cited edition applies. For undated references, the latest edition of the referenced document applies.

International standards

ASTM E1155M *Standard Test Method for Determining FF Floor Flatness and FL Floor Levelness Numbers* (Metric)

Australian standards

AS 1170 (all parts) *Structural design actions*

AS 1319 *Safety signs for the occupational environment*

AS 1530.4 *Methods for fire tests on building materials, components and structures – Part 4: Fire-resistance tests for elements of construction*

AS 1657 *Fixed platforms, walkways, stairways and ladders – Design, construction and installation*

AS 1668.2 *The use of ventilation and airconditioning in buildings – Part 2: Mechanical ventilation in buildings*

AS 1670.6 *Fire detection, warning, control and intercom systems – System design, installation and commissioning – Part 6: Smoke alarm systems*

AS 1768 *Lightning protection*

AS 1940 *The storage and handling of flammable and combustible liquids*

AS 2067 *Substations and high voltage installations exceeding 1 kV a.c.*

AS 2419.1 *Fire hydrant installations – Part 1: System design, installation and commissioning*

AS 2444 *Portable fire extinguishers and fire blankets – Selection and location*

AS 2676.1 *Installation, maintenance, testing and replacement of secondary batteries in buildings – Part 1: Vented cells*

AS 2676.2 *Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings – Part 2: Sealed cells*

AS/NZS 2865 *Confined spaces*

AS 3011.1 *Electrical installations – Secondary batteries installed in buildings – Part 1: Vented cells*

AS 3011.2 *Electrical installations – Secondary batteries installed in buildings – Part 2: Sealed cells*

AS 3660.1 *Termite management – Part 1: New building work*

AS 3996 *Access covers and grates*

AS 4145.2 *Locksets and hardware for doors and windows – Part 2: Mechanical locksets for doors and windows in buildings*

AS 4775 *Emergency eyewash and shower equipment*

AS 60529 *Degrees of protection provided by enclosures (IP Code)*

AS 62271.200 *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

AS 62271.202:2019 *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation (IEC 62271-202:2014, MOD)*

AS/NZS 2107 *Acoustics – Recommended design sound levels and reverberation times for building interiors*

AS/NZS 3000 *Electrical installations (known as the Australian/New Zealand Wiring Rules)*

AS/NZS 3500 (all parts) *Plumbing and drainage*

AS/NZS 61439 (all parts) *Low-voltage switchgear and controlgear assemblies*

Transport for NSW standards

TS 00003.1 *Concessions to Transport Standards – Part 1 Concession Process*

TS 00006 *HV Earthing Design*

TS 00008.4 *Fire Life Safety – Part 4: Ancillary Facilities*

TS 00011 *Common Requirements for Electric Power Equipment*

TS 00026 *Ambient Environmental Conditions*

TS 00049 *Electromagnetic Energy, Emissions and Compatibility – Fixed Transport Infrastructure*

TS 01466 *Guide to Verification and Validation*

TS 01471:0.0 (T MU AM 06006 ST) *Systems Engineering*

TS 01505 (T MU AM 01001 ST) *Life Cycle Costing*

TS 01515.1 *Asset Information – Part 1: Management of Asset Information*

TS 01547.1 (T MU MD 00006 ST) *Engineering Drawings and CAD Requirements*

TS 01638 (T HR CI 12130 ST) *Track Drainage*

TS 02391 (T HR CI 12200 ST) *Access Roads*

TS 03677 *Low Voltage Distribution and Installations Earthing*

TS 03726 (EP 12 10 00 10 SP, EP 12 10 00 11 SP) *HV Earthing for Substations and Distribution Systems*

TS 03726:1.0 *HV Earthing for Substations and Distribution Systems*

TS 03735 *Protection System Requirements for the 1500 V DC Network*

TS 03736 (T HR EL 19002 ST) *Protection System Requirements for the High Voltage Network*

TS 03741 (T HR EL 00006 ST) *Electrical Power System Signage*

TS 03744 (EP 00 00 00 13 SP) *Electrical Power Equipment – Design Ranges of Ambient Conditions*

TS 03748 (T HR EL 20001 ST) *High Voltage AC and 1500 V DC Traction Power Supply Cable Requirements*

TS 03749 (T HR EL 20002 ST) *1500 V DC Cables and Cable Ratings*

TS 03750 (T HR EL 20003 ST) *Underground Installation Configurations for High Voltage and 1500V dc Cables*

TS 03753 (T HR EL 20006 ST) *High Voltage ac and 1500 V dc Cables – Transitions Between Underground and Above Ground Installation Configurations*

TS 03754 (T HR EL 20007 ST) *Cable Pits*

TS 03755 (T HR EL 20008 ST) *Underground Cables and Cable Enclosures – Location Data Recording*

TS 03869 *Lightning Protection and Insulation Coordination*

TS 03873 (T HR EL 90003 ST) *Heavy Rail Traction System – Current Ratings of 1500 V dc Equipment*

TS 03881 *Substation and Sectioning Hut Commissioning Tests and Processes*

TS 03881:1.0 *Substation and Sectioning Hut Commissioning Tests and Processes*

TS 03883 (T HR EL 99004 ST) *Substation Fencing*

TS 03886 (T HR EL 06001 SP) *System Substation Battery and Battery Charger*

TS 03943 *Trackside Negative Busbar*

TS 04955.7 *Services, Systems and Equipment – Part 7: Lighting*

TS 04955.8:1.0 *Services, Systems and Equipment – Part 8: Low Voltage Electrical Installations*

TS 04978 (T MU HF 00001 ST) *Human Factors Integration – General Requirements*

TS 04992 *Surface Transport Fixed Infrastructure Physical Security Standard* (available on request from standards@transport.nsw.gov.au)

TS 04992:1.0 *Surface Transport Fixed Infrastructure Physical Security Standard* (available on request from standards@transport.nsw.gov.au)

TS 06178 (T MU MD 00005 GU) *Type Approval of Products*

TS 06210 (T MU TE 01001 ST) *Campus Backbone Telecommunication Routes and Cabling*

TS 06224 (T HR TE 21003 ST) *Telecommunications for Traction Substations and Sectioning Huts*

TS 10504 *AEO Guide to Engineering Management*

Transport for NSW drawings

EL0001999 *Mitsubishi 1500V DCCB – Arc Space Requirements*

EL0003147 *Electrolysis Isolating Joint for Underground Water Pipe*

TS 03689 (EL0065675) *General – Substations – 1500V DCCB Extended Palm – Drilling Details*

TS 03690 (EL0215513) *General – Substations – 1500V DCCB Cubicle (Non-imported frame) – Arrangement*

TS 03784 (EL0015238) *General – Substations – 415V Emergency Generator Fuse Box – Assembly Details*

TS 03893 (EL0204559) *General – Substations – Staff Access, Backup Lighting, A/C & HWU – Control Schematic Diagram*

TS 03944 (EL0023896) *Substations – Negative Bus Rail Termination – Arrangement Type No. 3*

TS 03945.1 (EL0099579) *General – Negative Bus Rail Termination – Type 4 (A, B, C) – Assembly and Drilling Details*

TS 03945.2 (EL0099580) *General – Negative Bus Rail Termination Type 4 (A, B, C) – Assembly and Drilling Details*

EL0024017 *Substations – HV Outdoor Equipment – Typical earthing Arrangements*

EL0227687 *General – Substations – 1500V DCCB Busbars and Insulating Plates – Details – Single Busbar (Non Imported Frame)*

EL0234193 *General – Substation – DCCB Frame Leakage Protection – Schematic Diagram*

EL0234194 *General – Substations – DCCB Frame Leakage Protection – Block Diagram*

EL0234195 *General – Substations – DCCB Frame Leakage Protection – Cable Schedule*

EL0435620 *General – Substation – Pole Mounted Substation – 11kV/433-250V & 11kV/250-120V Transformer*

EL0524980 *General – 11kV/415V Padmount Substation – Insulated Padmount Earthing System – Insulated Footing Arrangement*

TS 03691 (EL0234196) *General – Substations – DCCB Frame Leakage Protection – Arrangement*

TS 03693 (EL0237911) *General – Substations – Rectifier DCCB Cubicle Cable Termination – Bottom Cable Entry Arrangement*

TS 03696 (EL0383824) *General – Substation – 1500V Isolating/Rail Connecting Switch – General Arrangement*

TS 03697 (EL0383825) *General – Substation – 1500V Isolating/Rail Connecting Switch – General Arrangement*

TS 03698 (EL0446427) *General – Substations – 1500V DCCB Busbar Joints and Terminations – Technical Instructions*

TS 03712 (EL 0521637) *General – Substations – I & RCS Cable Isolation Bonding Hook*

TS 03720 (EL0283030) *General – Substations – 33kV Transformer Frame Leakage – Arrangement*

TS 03916.1 (EL0290965) *General – Substations – 415V Auxiliary Supply – Schematic Diagram*

TS 03916.2 (EL0290966) *General – Substation Generic – 415V Auxiliary Supply – Schematic Diagram*

TS 03938 (EL0494459) *General – Substations – 33kV Transformers & Swbds – HV Cable Screen Earthing Requirements – Arrangement*

Legislation

Disability Discrimination Act 1992 (Cth)

Environmental Planning and Assessment Act 1979 (NSW)

RailSafe documents

D2013/81208 *Electrical Practices for Construction Work*

PR D 78104 *Securing Systems for Electrical Equipment*

PR D 78700 *Working around Electrical Equipment*

RL D 79800 *Electrical Network Safety Rules*

Other referenced documents

Electricity Networks Association, 2015, ENA Doc 018-2015 – *Guideline for the Fire Protection of Electricity Substations*

Electricity Networks Association, 2022, ENA Doc 015-2022 – *National Guidelines for the Protective Security of Electricity Networks*

NSW Environment Protection Authority, 2017, *Noise Policy for Industry*

Safe Work Australia, 2019, *First Aid in the Workplace – Code of Practice*

The Australian Building Codes Board, *National Construction Code*, Volumes One, Two and Three

The Australian Building Codes Board, *The Plumbing Code of Australia*

4 Terms, definitions and abbreviations

The following terms, definitions and abbreviations apply in this document.

ac alternating current

ACCB alternating current circuit breaker

ARI average recurrence interval

CCTV closed circuit television

CEP common equipment panel

dc direct current

dc auxiliary the supply for the operation of electronic protection relays, energisation of multi-trip relay coils, energisation of HV ACCB trip and close coils and general control circuit operations. Nominally this is 125 V dc for new locations and some existing locations at a nominal 50 V dc.

DCCB direct current circuit breaker

EPA NSW Environment Protection Authority

ESO electrical system operator

flame trap a device to prevent the propagation of flame

FRL fire resistance level

GPO general purpose outlet

GWP global warming potential

HV high voltage

IRCS isolating and rail connecting switch

ITP inspection and test plan

LCC life cycle costing

MASD multi-point aspirated smoke detector

NATSPEC National Building Specification

NCC National Construction Code

non-preferred a configuration that should not be adopted unless the adoption of other configurations would necessitate disproportionate cost or result in a compromised outcome for some other aspect of the design

OHW overhead wiring

PAM Prioritisation and Asset Management

PCB polychlorinated biphenyls

preferred a configuration that should be adopted unless doing so would necessitate disproportionate cost or result in a compromised outcome for some other aspect of the design

RCD residual current device

REC rail earth contactor

RTU remote terminal unit

SCADA supervisory control and data acquisition

sectioning hut a location which contains 1500 V dc circuit breakers and associated links. There are no HV equipment and 1500 V rectifiers

TAO Technically Assured Organisation

TfNSW Transport for NSW

UV ultraviolet radiation

VPR Virtual Plan Room

VT voltage transformer

5 Construction and installation requirements and project life cycle responsibilities

The construction and installation phase of the system engineering life cycle model (V model) provided in TS 10504 requires specific verification activities to be completed to satisfy TS 01466.

These verification activities are the responsibility of the Construction or Installation TAO and Design TAO and are required throughout the installation phase.

5.1 Construction or Installation TAO responsibilities

The authorised Construction or Installation TAO is responsible for the construction or installation.

The Construction or Installation TAO or installer shall be responsible for the following:

- constructing and installing to the approved design documentation
- advising the Design TAO where the construction or installation cannot be produced to the approved design, and when this occurs, only construct and install to an approved revised design
- using a suitably qualified person or persons to develop, assess and implement the construction and installation inspection and test plans (ITPs) and associated documentation which have been developed in accordance with design requirements
- record information as required during the construction and installation phase.

5.2 Design TAO responsibilities

The authorised Design TAO is responsible for the design.

Design verification shall be obtained at each level of the life cycle. The Design TAO, during the installation life cycle, shall verify the installation has been installed according to the approved design.

Concessions to PAM standards shall be identified early in the design phase and submitted to PAM in accordance with TS 00003.1.

The Design TAO is also responsible for revising designs to address issues raised by the Construction or Installation TAO during the installation life cycle stage.

The Design TAO shall have the responsibilities outlined in TS 03881:1.0, section 6.2 in relation to the testing and commissioning phase.

6 Asset management requirements

Substation sectioning hut asset information requirements shall be in accordance with TS 01515.1. The asset information requirements in this standard cover the whole-of-life management of assets required to support and substantiate decisions made over the life cycle.

The development of substation design options shall have associated life cycle costings (LCCs) for each option in accordance with TS 01505 to optimise the total development and maintenance costs.

The design options developed shall satisfy the engineering requirements of this standard and optimising the LCC does not negate the Design TAO of any requirements of this standard.

As part of the LCC process, the Design TAO shall consider and document maintenance requirements for the design life (see Section 15.7) of the substation building and associated infrastructure. The maintenance requirements shall differentiate between recurrent maintenance and capital maintenance and shall be grouped into the appropriate engineering discipline, typically as follows:

- civil – retaining walls, service routes, pits and under track crossings, cable tunnels, vehicle parking area, pavements, access road and fences
- electrical – minor and major electrical equipment and associated systems installed with the substation and associated surrounding infrastructure
- building – building structure, fire and life safety systems, telecommunication, security system, lighting, ventilation and drainage pumping system.

The asset maintenance requirements of individual major electrical equipment that is installed within the substation is detailed in the specific PAM equipment standard and in accordance with

the PAM type approval process. To undertake any asset maintenance requirements, the TAO shall be authorised in the Plan Asset Maintenance asset life cycle activity.

7 Information required to be recorded during construction and installation phase

Specific information shall be recorded during the installation phase in accordance with TS 01515.1. The method of recording the information includes detailed survey, photos and other forms of recording as detailed by the Design TAO.

The naming and coding of engineering documents provided throughout the asset life cycle shall be in accordance with TS 01515.1. Typical examples of information that shall be recorded are as follows:

- location and depth of earthing grid
- location and depth of buried cable routes and cables
- location and depth of all undertrack crossings
- location and depth of non-electrical services (water, sewerage, stormwater, communications, insulating liquid bunding pipes and so on).

Refer to TS 03755 for the requirements for HV and 1500 V dc cables.

The Construction or Installation TAO shall record this information. The Design TAO shall specify the information to be recorded in accordance with TfNSW requirements.

8 Inspection and testing requirements during construction and installation phase

During the construction and installation phase, there will be specific inspection and testing requirements to be completed prior to the next stage of construction commencing, to ensure the integrity of the construction or installation of equipment is satisfactory. Typical examples are the following:

- inspection of electrical conduits to ensure quantity, size, bending radius and location complies with design
- inspection of earth grid and connections for correct depth, location and integrity of connections
- inspection of the earth grid connection to the building reinforcement and foundations
- checking the level of floors to ensure compliance with equipment requirements
- inspection and testing of civil aspects associated with the installation
- testing of insulating liquid bunding pipework to ensure correct flow and integrity of joints

- testing of specific electrical insulation that is installed.

The Design TAO shall be responsible for detailing the inspection and testing requirements. This includes the following detail:

- testing methodology
- verification and validation of acceptance criteria
- acceptance of the test implementation and record sheets prior to tests being undertaken.

The development of the ITPs should be in conjunction with the applicable TAO at the appropriate life cycle stage.

The Design TAO shall nominate inspection and hold points that are required to be present.

A final walkthrough by the Design TAO shall be undertaken before commissioning can commence.

Specific inspection and testing requirements related to the civil aspects of the building are detailed in PAM standards.

9 Disposal of equipment

Where a project involves decommissioning equipment or removing already decommissioned equipment, it is the responsibility of the project to do the following:

- liaise with stakeholders to determine if decommissioned equipment is required to be retained for system spares
- remove and dispose of equipment not required for system spares
- complete civil infrastructure works such as sealing of openings in floors, removal of brackets, removal of redundant footings and related works after the equipment has been removed
- remove and dispose of redundant cabling
- remove old labelling and install new labels on equipment to reflect they are spare (typically this includes ac and dc distribution boards, HV ACCB panels and direct current circuit breaker (DCCB) cubicles)
- revise the location drawings (internal and external arrangement drawings), equipment drawings (arrangement, schematic, interconnection diagram and so on), cable schedules, distribution board schematics, SCADA input and output schedules, cable layouts and other relevant drawings to reflect that the equipment has been decommissioned and removed
- amend electrical operating diagrams accordingly
- amend the local instructions where applicable
- update the appropriate asset databases
- complete any civil or electrical remedial works to ensure there are no residual hazards or operational restrictions as a result of the disposal of equipment.

The TAO shall determine the safety requirements to be assessed for the disposal and removal of equipment (such as HV cables, capacitors, equipment with PCB, and any earthing, bonding and electrolysis issues caused by removing earthing points). Refer to RL D 79800 for requirements for work on abandoned equipment such as HV cables.

10 TfNSW standard drawings

TfNSW has a set of standard drawings that detail general equipment requirements, specific configuration and installation requirements. Contact PAM for further details. The standard drawings for the electrical discipline generally have "GENERAL" or "PAM STANDARD DRAWING" in the first line in the title block.

Certain standard drawings have been specified in this standard usually related to equipment installation or standard design solutions and configurations.

Copies of the drawings are available from the Virtual Plan Room (VPR).

11 Design documentation

The approved design shall be comprehensive and appropriately detailed to enable the installer to construct the substation or sectioning hut and install equipment. This includes the following as a minimum:

- A design report. The contents are detailed in the TfNSW tender documents as certain requirements are tailored for the individual project.
- Complete set of approved 'for construction' drawings and associated design documentation produced in accordance with TS 01547.1. The typical electrical drawing set that is required for a substation is detailed in TS 01547.1. This drawing set is the minimum requirement for electrical drawings and the Design TAO is responsible for ensuring that there is a complete set as required for the entire installation.
- Specific ITPs to support activities during the life cycle as detailed in Section 8.
- Specific design calculations and supporting files including modelling data and associated files.

The approved 'for construction' drawings shall be submitted to the VPR prior to commencement of construction.

The Design TAO shall update all drawings to 'as built' to reflect any approved amendments and changes that occurred during the installation and testing and commissioning phase.

A marked–up copy of the 'for construction' drawings shall be left at the substation until the approved 'as built' drawings have been issued. When the 'as built' drawings have been issued, a full-size copy of all drawings shall be placed at the substation.

12 Statutory approvals and reports

The following statutory approval documentation and compliance reports are required:

- environmental consents and approvals in accordance with the *Environmental Planning and Assessment Act 1979*
- *National Construction Code* (NCC), *Volume One* and *NCC Volume Two* assessment and report
- fire engineering report.

13 Commissioning

The commissioning of substations and sectioning huts shall be undertaken in accordance with TS 03881.

14 Human factors

14.1 General

The design of substations and sectioning huts shall incorporate the principles of human factors integration as described in TS 04978. The generic human factors requirements within that standard shall be taken into account to determine their relevance to a specific project.

Human factors aspects that shall be taken into account for all substations and sectioning huts include position of equipment, location of signage, information content, alarms and alerts.

14.2 Positioning of equipment

Human factors shall be taken into account in the positioning of equipment. In addition to the requirements of AS/NZS 3000, the NCC and AS 2067, equipment shall be located where possible to ensure the following:

- height of equipment is appropriate for operation (for example, 1500 V isolate and rail connecting switches (IRCSs), light switches, equipment control panels, instruments and protection relays)
- equipment is located in a logical and practical position in relation to operator and maintainer activities (for example, light switches, general purpose outlets (GPOs), equipment cabinets containing operating handles, cabinet doors open to allow maintenance access and workspace, emergency egress paths are not blocked and so on)
- the use of stepladders or work platforms is minimised to access equipment cabinets, particularly for frequently accessed elements.

14.3 Information content

The correct labelling of equipment is critical to reduce the likelihood of operator and maintainer error while switching.

Labels shall be specified and approved by the Design TAO. Refer to TS 03741 for details of safety and safety related signage applicable to substations and sectioning huts.

14.4 Location of signage

The location of signage is important to ensure it can be easily seen, read and comprehended by the personnel for whom it is intended. Aspects to consider include the following:

- appropriate location to equipment it references
- appropriate sizing given the distance from which it is viewed
- optimum height to ensure maximum visibility and readability
- lighting and shadowing.

14.5 Alarms and alerts

Alarms that are not specifically incorporated into the individual equipment shall be clearly identified as to their purpose and described in the local instructions. Such alarms would normally include the following:

- fire alarm (visual and audible)
- infrastructure control (ICON) contact alarm (audible)
- intruder alarm (audible)
- evacuation alarm (visual and audible).

The following are usually present only when the substation or sectioning hut is part of another building:

- SF6 gas alarm (visual and audible)
- closed circuit television (CCTV) where required by the substation security classification.

15 Building requirements

Section 15.1 to Section 15.31 detail the requirements associated with the building.

15.1 NCC classification

Substations are generally classified as 'Class 8 electricity network substations' for the purpose of the NCC. Smaller facilities that utilise modular, transportable and temporary structures may be classified as Class 10a.

15.2 Freestanding substations

15.2.1 General

Freestanding substations are those substations that are not attached or directly connected to another building structure.

The whole of Section 15 shall apply to freestanding substations.

15.2.2 Prefabricated substations

Prefabricated substations are those substations that are constructed offsite (including the installation of equipment) and are shipped to site and connected to the electrical network.

Prefabricated substations shall comply with both of the following:

- the whole of Section 15
- AS 62271.202:2019, excluding clause 2 where TS 03744 shall apply.

Where the prefabricated substation is elevated above the ground, then for the entire perimeter of the building, a vermin proof barrier shall be installed to prevent unauthorised access underneath the building. Lockable access gates are required for operator and maintainer access.

15.3 Sectioning huts

15.3.1 General

The requirements of Section 15 shall apply to sectioning huts with the following exceptions:

- provisions specific to equipment of a type not installed in a sectioning hut do not apply
- the following staff amenities are not required for a sectioning hut:
    - separate administration room
    - toilet
    - hot water
- sectioning huts require one ac auxiliary power supply, which is single phase.

15.3.2 Prefabricated sectioning huts

Prefabricated sectioning huts are those sectioning huts that are constructed offsite (including the installation of equipment) and are shipped to site and connected to the electrical network.

Prefabricated sectioning huts shall comply with both of the following:

- Section 15.3.1
- AS 62271.202:2019, excluding clause 2 where TS 03744 shall apply.

Where the prefabricated sectioning hut is elevated above the ground, then for the entire perimeter of the building, a barrier shall be installed to prevent unauthorised access underneath the building. Lockable access gates are required for operator and maintainer access.

15.4 Substations and sectioning huts integrated with other structures such as underground stations

The requirements of Section 15 apply to substations and sectioning huts (except requirements as detailed in Section 15.3) integrated with other structures such as underground stations with the following exceptions:

- The design life shall be in accordance with Section 15.7.
- The requirements of Section 15.11.11 do not apply. Graffiti management shall be as designed for the main structure.
- The fire resistance of the building envelope, otherwise nominated in Section 15.11.18, shall be as appropriate to the main structure. Appropriate fire segregation (both burn-in and burn-out) shall be provided between the spaces utilised for the substation function and other spaces within the building.
- The abatement of noise from the substation spaces shall be appropriate to the uses of the adjacent spaces.
- The requirements of Section 15.14.6 do not apply. Landscape and plantings shall be as designed for the main structure.
- It is not necessary to provide a toilet within the substation if there is a toilet available elsewhere in the building for use by substation maintenance personnel.
- Fire protection measures appropriate to the main building shall be provided for the substation spaces in addition to those stipulated in Section 17. Refer to the specific guidance regarding substations within host buildings provided in ENA Doc 018-2015.

Where the requirements applicable to the main structure require a higher standard than that required under Section 15, the requirements applicable to the main structure shall apply.

15.5 Sustainability

15.5.1 General

The design of substations and sectioning huts shall optimise sustainability for the life cycle of the asset.

Sustainability aspects to be considered relate to selection of materials, energy efficiency, resilience to climate change and environmental impacts.

15.5.2 Material selection

The sustainability of materials used for the installation shall be optimised as appropriate as follows:

- ensuring that materials are durable to last for the expected or planned operational life in accordance with the asset management cycle
- not using components and equipment which contain substances of high toxicity or global warming potential (GWP), if a substance with lower toxicity or GWP is available and suitable
- taking into account the use of recycled and recyclable materials
- planning for end of life disposal including options for disassembly, recycling and reuse.

15.5.3 Energy efficiency

Energy efficiency shall be optimised as appropriate as follows:

- taking into account building orientation and design to minimise heating, cooling and lighting requirements
- including insulation and energy efficient appliances where possible
- taking into account the use of photovoltaic panels and storage battery to supply lighting and heating, ventilation and air conditioning (HVAC) requirements of the installation.

15.5.4 Resilience to climate change

Significant risks posed by climate change shall be assessed and designs adjusted as necessary, to allow for the following:

- sea level rises and increased flood risks in coastal and flood prone areas
- changes to weather events such as heat waves and severe storms
- increases in bush fire risk in bush fire prone areas.

15.5.5 Environmental impacts

Appropriate planning and environmental approvals shall be obtained. Consideration and management of environmental impacts should include the following aspects:

- biodiversity (flora and fauna)
- water quality
- operational impacts on neighbours, such as noise and lighting
- heritage
- air quality
- waste management
- visual and aesthetics
- construction impacts such as noise and dust.

15.6 Site location considerations

The following shall be taken into account when determining the location of a substation:

- Site access – all weather heavy vehicle access is required for construction and future maintenance requirements.
- Space availability and site topography.
- Archaeological impacts and heritage significance.
- Easement requirements.
- Location from and orientation to track.
- Amenities – required stormwater and sewerage connections.
- Neighbouring land use and separation – current and future industrial and residential.
- Planned surrounding future infrastructure.
- Electrical sectioning, including the following:
    - location of 1500 V overhead sectioning point (the existing sectioning points may have to be changed to facilitate the location of sectioning points adjacent to substations)
    - location of electrical sectioning to support the normal and emergency operation of trains, including the facilitation of infrastructure maintenance work
- Proximity to signalling and communication locations.
- Availability of suitable auxiliary supply.
- HV cable or transmission line route.

- Security.
- Susceptibility of the site to adverse weather conditions.
- Site-specific environmental requirements.
- Flood immunity – the substation should not be subject to flooding (whether natural or due to surrounding infrastructure such as stormwater canals). If it is not possible to avoid such a location, then the switch room floor level shall be not less than 500 mm above the 100 year average recurrence interval (ARI) flood level. Taking into account environmental factors such as climate change as specified in TS 00026 shall be included.
- Bushfire susceptibility.
- Proximity to facilities that have hazardous areas.
- Potential risk of earth potential rises affecting neighbouring properties.

15.7 Design life of substation building

The design life of the building structure (substructure, slab, columns and roof structure) shall, as near as possible, match or be a multiple of the equipment life.

In determining the design life of the substation building the following factors shall also be taken into account:

- If it is feasible at the end of the economic life of the power equipment housed within, that a new substation can be constructed on adjacent land, cables can be transferred and the existing substation be decommissioned.
- Where there is limited availability of land and a new substation cannot be built adjacent, then at the end of the economic life of the power equipment housed within, it will be necessary to install the replacement power equipment within the existing substation. This requires that spatial provision shall be included in the substation to allow for the installation and pre-commissioning of replacement power equipment without undue disruption to the operation of the substation.

The design life of the substation or sectioning hut building fabric (external walls, roofs and openings), building internal divisions, fixtures and fittings and finishes, in turn shall be a multiple of the overall building life in order to optimise the maintenance requirements and associated cost.

See Section 6 for asset management requirements and LCC requirements.

15.8 Substation building design

15.8.1 General

The building fabric of a substation building shall perform a number of functions for the life of that equipment, subject to the following external environmental influences:

- provide necessary insulation in order to ensure the optimal operation of equipment housed therein
- provide appropriate ventilation, when necessary, to ensure the ambient temperature conditions required by TfNSW are met; see Section 15.12 for further details
- provide adequate openings for access and appropriate egress for technicians; see Section 15.9.4 for further details
- provide protection of the equipment from environmental forces such as flood or fire, which can originate externally, including adequate distances from existing buildings or boundaries
- provide protection of the external environment from the potential risks posed by the substation equipment and building
- provide appropriate security to protect the substation equipment and prevent unauthorised access; see Section 16 for further details.

15.8.2 Considerations for construction type

The majority of substations are located within the rail corridor which could impose restrictions on the type of construction that is feasible. Typical considerations are as follows:

- Restrictions of available land necessitating off-site manufacture.
- Limited accessibility for operation and maintenance vehicles.
- Environmental considerations.
- Type of construction required to meet an expedited timeframe required for operational reasons. This is typically due to unforeseen circumstances such as a fire in an existing substation.

15.9 General arrangement

Considerations for the building general arrangements (both plan and cross-section) are provided in Section 15.9.1 to Section 15.9.17.

15.9.1 Disability Discrimination Act compliance

Compliance with the *Disability Discrimination Act 1992* is not required in relation to the provision of means of access to premises or facilities which are, or form part of, a substation or sectioning hut.

15.9.2 Separate spaces required

The substation building shall be designed so that the following areas form separate rooms:

- HV and 1500 V dc equipment room
- HV switch room for ac switchgear with a rating of 66 kV and above
- bays for liquid immersed equipment as detailed in Section 15.15
- 1500 V isolating and rail connecting (IRCS) switch room as detailed in Section 15.9.13
- administration room as detailed in Section 15.20.1
- toilet as detailed in Section 15.20.2.

The requirement for a substation to have separate battery room or rooms is detailed in Section 15.18.

The interconnection of rooms and the access routes within the substation shall be consistent with the access control requirements detailed in Section 16.3 so that a person can reach an area that they are authorised to enter without having to pass through an area that they are not authorised to enter.

15.9.3 Spatial provision due to design life

Depending on the life cycle strategy as detailed in Section 15.7 spatial provision shall be included in the substation to allow for the installation and pre-commissioning of replacement power equipment without undue disruption to the operation of the substation.

15.9.4 Provision for access and egress

Provision for access and egress by personnel shall be in accordance with the requirements of AS 2067. The NCC contains provisions related to provision for access and egress by personnel. In addition to the requirements of AS 2067 and the NCC, the following may be egress routes:

- from the main part of the substation into a bay for liquid immersed equipment if there is an egress from that bay to a safe location
- from a bay for liquid immersed equipment into an adjacent bay for liquid immersed equipment, if there is an egress from that bay to a safe location
- from a bay with insulating liquid filled equipment into the main part of the substation.

See Section 15.9.13 in relation to provisions relating to egress from a 1500 V IRCS switch room.

Where operating handles protrude from switchboard panels, either normally or in the operating process, the required clearance for access and egress shall be provided from the operating handle at its greatest degree of protrusion.

15.9.5 Provision for moving equipment

Adequate spatial provision shall be made for moving equipment so that it is possible to replace an item of equipment without having to de-mount or remove another item of equipment. This applies to complete items of equipment such as transformers, switchboards, rectifiers, battery chargers and so on.

A degree of dismantling of an item of equipment may be done to replace that item of equipment or a component of that item of equipment. Reference should be made to the specific standards relevant to that class of equipment.

In the case of outdoor equipment that needs to be craned in any case, the item may be craned over other items of equipment, if this can be done safely and any electrical isolation of equipment does not affect the running of trains.

15.9.6 Provision for operation and withdrawal of switchgear

Clear space shall be provided in front of switchboards (ac and dc) that have withdrawable circuit breakers and shall extend not less than the length of the fully withdrawn circuit breaker truck plus an additional 1200 mm.

If there are equipment cabinets opposite the switchboard, the clearance shall be provided to the cabinets with the doors in the closed position. Likewise, if there is another switchboard opposite the same clearance applies with only one circuit breaker withdrawn, however the clearance between the two opposing withdrawn circuit breakers shall be the minimum clearance for egress in accordance with AS 2067. The NCC contains provisions related to the minimum clearance for egress.

15.9.7 Provision for operation of 1500 V negative link and IRCS

Where the 1500 V negative link is manually operated, adequate space shall be provided in front of the negative link for the operating stick and operator. Human factors analysis shall be used to determine the minimum distance required for operation of the link. The link is in its maximum protruding position when in the open position. The analysis shall be based on the type approved operating stick.

The current type approved rectifier requires a minimum distance of 1400 mm from the boundary of the negative link compartment.

If there are equipment cabinets opposite the rectifier negative link, the clearance shall be provided to the cabinets with the doors in the closed position.

The requirements for maintenance access and egress shall be provided in accordance with AS 2067. The NCC contains provisions related to maintenance access and egress.

A minimum of 2500 mm shall be provided in front of 1500 V IRCS switches to allow for the use of a stick type voltage tester.

15.9.8 Provision for 1500 V dc intertrip equipment

Provision shall be allowed for the future installation of dc intertrip equipment for all 1500 V overhead wiring (OHW) feeders. This is applicable to new locations where dc intertrip is not initially required to be installed or only partially installed. Provision shall be for the following:

- spatial allowance for the intertrip equipment panels which shall ensure egress compliance with AS 2067 is maintained if panels are installed

  Note: The NCC contains provisions related to this.
- spare capacity on the 125 V dc distribution board for additional circuits required to fully implement intertrip on all 1500 V OHW feeders
- allowance in telecommunication panels for additional fibre optic cables
- spare capacity in the SCADA remote terminal unit (RTU) and associated marshalling cubicle for additional alarms required to fully implement intertrip on all 1500 V OHW feeders
- installation of conduits where the conduits are penetrating the substation floor
- spare capacity of any cable ducts or cable ladders near the 1500 V dc switchgear and SCADA panels.

The arrangement drawings shall show the area which has been allowed for future installation of 1500 V dc intertrip equipment.

15.9.9 Arrangement of rectifier transformers and rectifiers

A rectifier and the corresponding rectifier transformer should be positioned as close as practical to each other with the corresponding rows of palms parallel. This is to minimise risk due to the rectifier 600 V windings being unearthed.

Where the transformer is of an outdoor type, appropriate penetrations shall be provided through the intervening wall for the ac cables between rectifier transformer and rectifier. The penetrations shall be sealed to provide the same fire rating as the external walls of the substation building in accordance with AS 2067 and TS 00008.4.

The transformer and rectifier may be mounted at different levels and the ac cables between rectifier transformer and rectifier may include a vertical portion.

See Section 15.15 for details on requirements on bays with insulating liquid filled equipment.

15.9.10 Cable basement

The preferred arrangement is for a suspended slab floor in the equipment room housing the HV ac switchgear, rectifiers and 1500 V dc switchgear.

This may be achieved by the provision of a below ground cable basement or by the elevation of the equipment room floor to provide an above ground cable space. The detailed requirements for such a space are set out in Section 15.19.

15.9.11 Provision for miscellaneous items

Provision shall be allowed for the location of the following items in the indoor substation area:

- emergency oil response spill kit
- ladders (stepladders and extension)
- large general waste bin (this should be adjacent to the administration room)
- flammable liquid storage cabinet (located adjacent to the spare parts cabinet)
- spare parts cabinet (1500 mm wide by 600 mm deep)
- key cabinet
- test equipment
- earthing and rail connection equipment.

The area allocated shall have signs or markings on the floor with its intended purpose. The area allocated shall not impede on areas designated for switchgear manoeuvring, AS 2067 and NCC requirements.

Appendix A contains further details of the ancillary items located in the substation. The operator and maintainer shall be consulted during the detailed design stage to determine the exact items required to be located within the substation.

15.9.12 High voltage enclosures

The majority of equipment used in substations is not required to be installed within a HV enclosure. However particular classes of equipment will require a HV enclosure (for example, HV ac harmonic filter) and the following apply:

- Design shall be in accordance with the requirements of AS 2067.

- Access points to the HV enclosure shall only be from within a substation space to which access is restricted to authorised persons.
- Access points shall be lockable to prevent entry. Access points should preferably be interlocked with the associated isolating equipment (HV circuit breakers) and egress should not be prevented by locking.
- Egress arrangements shall be in accordance with the requirements of AS 2067.

Prominent signage in accordance with Section 17.9 shall be provided near the access points of HV enclosures. In particular, the signage shall include a list of the relevant isolation points and “Entry under access permit only" signs.

Only equipment that is essential within the HV enclosure shall be mounted within the HV enclosure. The design shall minimise the requirement for maintenance of ancillary equipment such as luminaires within the HV enclosure.

See Section 20.15 for installation requirements associated with HV ac harmonic filters.

15.9.13 Accommodation of 1500 V IRCS switches

Locations that have 1500 V IRCS switches shall be accessible for operation by persons who are not authorised to enter other areas of the substation.

The 1500 V IRCS switches shall be readily accessible from the main part of the substation for the convenience of substation personnel. Where the IRCS are located as part of the substation building, they shall be undercover.

Adequate egress shall be provided in accordance with AS 2067. In the case of narrow space mounting where the 1500 V IRCS switches are installed along one or both sides, egress shall be provided at both ends. In this case, an emergency egress may be provided via a door from the 1500 V IRCS switch space into the main part of the substation where there is no alternative. Any such door shall be connected to the intruder alarm and be labelled appropriately including the words 'Door alarmed' and 'Substation personnel only except in emergency'.

15.9.14 Arrangement of control cable routes

Control cables may be run overhead on tray, or below floor level, in accordance with AS/NZS 3000.

Where control cables are run in a cable pit or trench also carrying HV or 1500 V dc power cables, a cable ladder shall be provided for the securing of the control cables clear of the power cables.

Cable entries or ducts shall be sealed to prevent the ingress of soil, water and vermin.

Control cables run to equipment outside the substation building shall be run in buried conduits in accordance with AS/NZS 3000. Where conduits are surface mounted on equipment plinths

(for example, transformers, reactors) they shall be protected from mechanical damage and be clear of the discharge ports of pressure relief valves.

Control cables for Mitsubishi style 1500 V DCCBs shall be run in a cable duct above the front of the DCCB cubicles. The cable ducts shall not impede normal switching operations. TS 03690 (EL0215513) shows a deemed-to-comply arrangement.

15.9.15 Arrangement of power cable routes

HV and 1500 V cables installed within the substation building shall generally be run below floor level with the following exceptions:

- 600 V ac cables between rectifier transformer and rectifier may be run overhead.
- 1500 V dc feeder cables may be run horizontally from the circuit breaker frame palm through the rear wall of the cubicle to an IRCS switch in the adjoining space. This is applicable to DCCBs not installed in a metal enclosed switchboard.

Cable entries, floor penetrations and ducts shall be sealed to prevent the ingress of soil, water and vermin.

HV and 1500 V cables installed outside the substation building may be run underground in ducts or direct buried, or in cable trenches with appropriate lids, in accordance with TS 03750. Where the cables transition from buried to above ground the requirements of TS 03753 shall apply.

The design of the substation shall include all necessary spatial and other provisions for the installation of large power cables where mechanical winching will be required. This shall include the following as a minimum:

- space for cable drums for the paying out of cable
- space for cable winches and other necessary mechanical equipment
- suitable anchor points for snatch blocks and other equipment where the winch rope or cable needs to change direction.

The positions for cable drums or winches need not be within the substation if the required equipment can be positioned appropriately for the installation of the cables, and the required space is protected to ensure that it is available for cable replacement in the future.

15.9.16 Provision for arc venting from indoor HV ac and 1500 V dc switchgear

Arc venting shall be provided where necessary in accordance with AS 2067 and the equipment manufacturers' requirements.

Where pressure relief openings are required as part of the substation building, they shall be arranged and situated such that when they operate, the danger to persons and damage to property is minimised.

Where indoor switchgear is provided with arc venting, the vents may be either directed upward, if the ceiling height is suitable, or ducted to outside the building.

If indoor switchgear vents are ducted to outside, the vents shall be arranged such as to not present a hazard to persons or property. Any such vents shall be configured to exclude rainwater.

15.9.17 Internal fire segregation

Fire segregation between rooms within the building is generally not required. However, if the substation is integrated within another structure the requirements of that structure take precedence.

External substation walls that form part of a transformer bay shall have a fire rating complying with AS 2067 and ENA Doc 018-2015.

15.10 Site access requirements

Considerations for site access requirements are provided in Section 15.10.1 to Section 15.10.4.

15.10.1 Sites located on sloping ground

Substations that are located on sloping ground shall have the following:

- a level area shall be provided in front of all equipment doors which shall be accessible by construction and maintenance vehicles
- suitable hand railing and guardrails shall be provided with walkways

  Note: The NCC contains additional requirements related to suitable hand railing and guardrails provided with walkways
- where the site is cut into a slope, provision shall be made for retention of the bank.

15.10.2 Light vehicle access

An all-weather access road shall be provided from a public road to the designated parking space for a light maintenance vehicle in accordance with TS 02391.

Adequate space shall be provided for light vehicles to turn around on the site or access road or both.

15.10.3 Heavy rigid vehicle access

Access for a heavy rigid vehicle suitable for transporting DCCB trucks, rectifiers, auxiliary transformers and the like shall be provided in accordance with TS 02391.

Adequate space shall be provided for heavy rigid vehicles to turn around on the site or access road or both.

15.10.4 Crane and float access

Suitable provision shall be made for access by cranes and floats as required for the transport, loading and unloading of large plant items such as transformers and for the manoeuvring and turning of such cranes and floats.

It shall be possible to lift the plant item between its position in the substation and the float in a single lift.

The areas required for the crane stabilisers shall be free of obstructions and services that would be incompatible with the loads imposed.

Pavements in areas designated for crane and float access shall be designed accordingly.

15.11 Building fabric and architectural features

15.11.1 General

The appearance of new substations and sectioning huts shall complement the streetscape and surroundings that they become part of. Building and landscape design shall respect and respond to the existing built and natural environment, including all local environmental elements in addition to functional constraints. This shall be reflected in the building orientation, height, bulk, scale, fenestration, exterior material, texture, finish and colour.

Substation buildings shall be designed to be recognisable, with access and circulation obvious to users. The design of substation buildings shall also clearly convey the need for restricted public access, expressed through architectural, urban, landscape design and signage.

Where functional design requirements may result in inappropriate unrelieved façades visible in the public domain, building elevations shall be designed with articulated façades to avoid plainness or blandness. Similarly, this may be complemented with landscape screening where appropriate, particularly so as not to impede natural surveillance of the building and its surrounds. Landscaping selections shall require minimal maintenance, be self-reliant and provide positive visual impact.

The construction of the substation building shall comply with all relevant clauses of AS 2067. The NCC contains provisions related to construction of substation buildings.

All structures, buildings and footings shall be designed in accordance with all parts of AS 1170 together with the following additional loadings:

- earthquake loads relevant to structures that serve post-disaster recovery functions in accordance with AS 1170.4
- short circuit forces
- operational loads
- manufacturer's specified loading data
- any other relevant loads.

15.11.2 Building perimeter

The perimeter of the building shall be designed to resist vandalism and forced entry such that the likelihood of the building perimeter being breached by such an attack would not be materially reduced by enclosing the building within a perimeter fence.

The perimeter of the building shall be designed to prevent intruders climbing onto the roof of the building or scaling any outdoor area fence.

Fencing requirements are detailed in Section 15.14.4.

15.11.3 Floor

An appropriate floor coating system shall be used to reduce dust within the building. The coating should have the following features:

- a pale colour (light grey)
- suitable for the surface stress imposed by the metal wheels of DCCBs
- low slip hazard.

The racked-out zone in front of withdrawable equipment (for example, 1500 V DCCBs, HV ACCBs) shall be finished to the tolerances specified by the manufacturer as Class A true plane in accordance with ASTM E1155M. The method for determining compliance is a straight-edge placed anywhere on the area in any direction. The finished level of the rack-out zone shall be flush with the finished floor level of the adjoining area.

Pathways for equipment between entry doors and equipment locations shall not include any steps, and be otherwise be suitable for rolling equipment into position.

15.11.4 Walls

External walls and roof shall be of colour and finish that is appropriate to the amenity of the area.

The internal surfaces of walls shall be suitable for the fastening of electrical conduits, electrical cables, switches and other equipment.

Painting of brick walls and other masonry shall not adversely affect the required fire rating.

Walls exposed to possible pressure wave loadings from deflagration events shall be designed in accordance with the relevant recommendations of ENA Doc 018-2015, having regard to the equipment and energy level present. This also applies to the connection of such walls to other elements of the structure.

15.11.5 Ceilings

A ceiling is not required but may be included in pursuance of specific functional or performance requirements.

Locations that do have a ceiling shall ensure that ceilings above equipment with exposed components (such as rectifier bushings, switchgear bus bar that is not enclosed, and so on) do not have any openings.

Locations that do not have a ceiling shall ensure the roof structure has the following:

- appropriate construction to prevent the ingress of dust into the building
- the roof insulation and associated means of securing it is designed for the life of the installation
- condensation is prevented as required by Section 15.11.6.

15.11.6 Roof

If the roof is of metal deck construction, it shall be ‘Colorbond’ or equivalent finish, together with all flashings, trims and rainwater pods.

The roof of the substation shall not include any box gutter. The roof shall be arranged so that if any gutter overflows, the water does not enter the building.

The roof shall not have any penetrations such as skylights or ventilation systems. This does not apply to transformer bays.

Thermal insulation shall be provided as appropriate to the conditions and waste heat management strategy adopted. Measures shall be included to prevent condensate forming and dripping onto equipment below.

The substation roof shall be bird proof, vermin proof and vandal proof.

The roof above exposed equipment (for example, DCCBs, rectifiers and 1500 V isolate and rail connect switches) shall be of materials and a form of construction that will not degrade in a way that results in particles or fragments falling on to the equipment below.

15.11.7 Doors

External doors and frames shall be in accordance with TS 04992:1.0. These doors shall be fitted with locking systems, which comply with PR D 78104, and the requirements of TS 04992:1.0. The NCC contains provisions related to door locking systems.

Only doors intended for entry shall be provided with external lock hardware.

External doors shall be either of the following:

- Heavy duty self-closing doors (fitted with pinned hinges inside of the building and a cover plate for locks).
- Heavy duty metal roller doors with lockable chains and motorised where required for human factors considerations. Where the doors are motorised, they shall also be able to operate manually and be able to be locked when the motor is disabled.

Where a heavy duty metal roller door is required to be open for maintenance access to equipment, then the external landing area shall be:

- the same height as the substation floor
- designed for the weight of equipment, tools and personnel
- there shall be a roof over the landing to enable access in all weather conditions.

The fire rating of external doors shall align with the fire rating of the building envelope.

Doors that restrict access to electrical equipment shall comply with PR D 78104 or as approved by Electrical Distribution Unit (EDU) within Sydney Trains.

All other doors shall be provided with locks in accordance with AS 4145.2.

Doors through which equipment needs to pass shall be of such a size and in such location(s) that the largest item of equipment can be removed without disassembly. Removable panels above doorways are acceptable to allow equipment through otherwise standard height doorways.

Double doors are non-preferred due to the likelihood of misalignment in time. Where a double door is required for occasional large equipment movements, a demountable centre mullion may be provided so that the doors do not close against each other.

External doors through which equipment needs to pass shall not include any steps. Prevention of water ingress shall be achieved utilising grated drains and other measures not requiring steps.

Substations located in bush fire prone areas shall have minimum of two-hour fire rated doors.

15.11.8 Equipment loading docks

Where a loading dock is provided to transfer equipment from a lorry to a substation equipment room with a floor level that is above the surrounding ground level, then any handrails shall be readily demountable to allow for the transfer of equipment.

The pavement of loading docks shall be designed for the heaviest equipment load and associated lorry weights.

15.11.9 Equipment access hatch and shaft

For underground substations where it is not practicable to install or remove equipment via equipment doors, an equipment access hatch and shaft may be provided.

The access hatch shall be designed to allow the removal of the largest piece of equipment for which the shaft is to be built. The access hatch shall not compromise the waterproofing of the substation building.

Site access to the access hatch shall be provided in accordance with Section 15.10.3.

15.11.10 Windows

Substation walls shall not have windows. Lighting shall be in accordance with Section 15.28. Ventilation shall be in accordance with Section 15.12.

Glass blocks may be used to allow natural light into the substation if they are vandal resistant and placed to reduce the risk of vandalism.

15.11.11 Graffiti management

The substation design shall be appropriate in relation to crime prevention through environmental design. In particular, the design shall do the following:

- minimise the attractiveness of substation walls as a canvas
- minimise access to walls using measures such as the placement of suitable choice of landscaping that deters access to walls and minimises risk of graffiti.

The design shall include surface finishes that allow graffiti to be readily removed.

15.11.12 Ventilation louvers

Ventilation louvers shall be designed and installed such that the substation security is not compromised. Fixings shall not be accessible from outside the substation.

The louvers shall be designed and installed such that water sprayed at an angle up to 60° on either side of the vertical shall not penetrate into the substation.

The ventilation louvres shall not compromise any fire rating requirement.

15.11.13 Indoor cable trenches and pits

Cable pits for HV and 1500 V cables shall comply with the requirements specified in TS 03754 in addition to the requirements in this document. Where there is a conflict between this standard and TS 03754, the requirements in this standard take precedence.

Cable pits and trenches shall not be located in the rack-out areas for withdrawable switchgear.

Lids shall be provided in accordance with AS 3996. The lids of indoor cable pits and trenches shall have the following characteristics:

- finish flush with the floor level
- be suitable to carry all reasonably foreseeable traffic, including the manoeuvring of any equipment for which the pit or trench might encroach on the path to be used for equipment replacement
- be provided with lifting points for attachment of a lifting handle; the matching handle (or pair of handles) shall be provided
- have the mass of all lid sections, including the infill, permanently marked and clearly indicated on the lid section
- be clearly marked for reference where a particular sequence of lid removal and replacement is required
- be designed so they are not classified as a confined space in accordance with AS 2865.

Pit and trench lids may be metallic or fibreglass reinforced and may be solid or mesh form.

A webbing cargo net shall be provided immediately below the lids of any cable pit or trench exceeding 500 mm across. The webbing shall be suitable to arrest the fall of a person and to prevent a dropped lid falling onto the cables. A fastening system shall be provided to allow the mesh to be readily attached and detached from the walls of the pit or trench as necessary.

Cable pits and trenches which a person might need to step into shall be provided with ladders or step irons in accordance with AS 1657 to allow persons to gain access without stepping on cables or cable trays.

The location of the access points to cable pits and trenches shall be clearly marked on the floor adjacent to the edge of the cable pit or trench.

Cable pits underneath equipment, where the operating diagram has identified future extension of the HV switchboard, shall allow for the expansion of the HV switchboard.

15.11.14 Exclusion zones around power equipment

Particular items of equipment due to exposed conductors or arc venting requirements have an exclusion zone where equipment cannot be installed. This is to avoid mal-operation or to enable

maintenance without the requirement for isolating the equipment. The following equipment shall not be installed in an exclusion zone:

- luminaires
- smoke detectors (except aspirating smoke detector tubes)
- heat detectors
- infrared motion detectors
- CCTV cameras
- water or wastewater plumbing
- cable ladders and conduits.

Note that the exclusion zone extends vertically upwards from the greatest extent of the horizontal clearance.

The exclusion zone around the rectifier extends from the edge of the rectifier enclosure to a horizontal distance at arm's reach as defined in AS/NZS 3000.

The exclusion zone around 1500 V DCCBs that are not installed in a metal enclosed switchboard extends from the edge of the DCCB enclosure to a horizontal distance at arm's reach as defined in AS/NZS 3000, plus the arc expulsion zone from the DCCBs. Refer to EL0001999 for more information.

For DCCBs that are not installed in a metal enclosed switchboard, the minimum ceiling height shall be 3870 mm. Where the ceiling above the cubicles for DCCBs that are not installed in a metal enclosed switchboard is FRL 120/120/120 in accordance with AS 1530.4 this may be reduced to 2900 mm. TS 03690 (EL0215513) shows a deemed-to-comply arrangement.

The exclusion zone around the 1500 V combined IRCS switch extends from the edge of the switch barriers to a horizontal distance at arm's reach as defined in AS/NZS 3000.

15.11.15 Waterproofing

The building shall be designed and constructed to prevent entry of water.

Conduits shall drain towards the outside of the building to prevent moisture ingress.

15.11.16 Termite control

Where indicated by risk assessment, the design documentation shall require that the whole of the area of the building and a strip 300 mm beyond the perimeter wall shall be treated against termites in accordance with AS 3660.1.

15.11.17 Vermin proofing

The building and penetrations or openings into the building, including ducts, shall be vermin-proofed to prevent the entry of rodents, snakes and other similarly sized animals. All penetrations and openings into the building, including louvers, shall have an equivalent IP rating of IP2X tested in accordance with AS 60529.

15.11.18 Fire resistance of building envelope

The building envelope shall have a minimum fire resistance level as specified in AS 2067. The fire resistance level may be higher than required in AS 2067 as determined by the fire risk assessment in TS 00008.4.

15.11.19 Lightning protection for building structure

Lightning protection for the substation building shall be in accordance with the highest protection level (class 1) in accordance with AS 1768.

15.12 Ventilation and waste heat management

15.12.1 General

Suitable ventilation shall be provided for the different substation areas in accordance with AS 1668.2.

External ventilation equipment shall be located in a secure, vandal proof and concealed position. Ventilation equipment shall not be located in dedicated equipment areas that have design requirements to address hazards such as the containment of oil or fire or such (for example, transformer equipment bays).

The design of the ventilation arrangements shall be in accordance with the relevant recommendations of ENA Doc 018-2015, having regard to the equipment and energy level present at specific locations within the substation.

15.12.2 Ambient conditions

The substation design shall be in accordance with TS 03744.

15.12.3 Permissible ventilation strategies

A suitable ventilation strategy shall be incorporated to keep the internal conditions within the requirements of Section 15.12.2. The ventilation system shall be designed such that it is readily maintainable and does not require maintenance at a frequency greater than other elements of the substation.

The preference for substation ventilation is natural ventilation or a forced ventilation system, in that order.

15.12.4 Special requirement for ventilation ducts

The strength and fire rating of the walls of ventilation ducts shall be the same as those specified for the relevant walls where fire dampers are not installed.

Normal air conditioning duct construction shall be used only where fire dampers are installed on wall penetrations where ventilation ducts enter or leave rooms.

15.12.5 Prevention of rain water ingress via ventilation system

There shall be no roof penetrating ventilation ducts or any other ducts located above any electrical equipment.

15.12.6 Requirements for forced ventilation systems

Where a forced ventilation system is used, at least two units shall be included in order that in the event of the failure of one unit some ventilation is available. A forced ventilation system shall be designed in accordance with AS 1668.2 such that the internal temperature does not exceed the maximum allowable indoor temperature at the maximum design external ambient temperature and with the equipment operating at 100% of rated load. The system shall include a filtered intake to keep the building reasonably dust free. Filters shall be located so that ladders are not required for maintenance access, or isolation of equipment is not required. Fans shall be arranged to provide positive pressure (blowing air into the building at low level) with exhaust air discharging at a high level.

Appropriate alarms shall be provided to SCADA RTU for the status of the ventilation system.

15.12.7 Administration room air conditioning

A split system air conditioner shall be provided for the administration room. The air conditioning system shall require minimum maintenance. The air conditioning shall be capable of regulating the room temperature from 22 °C to 28 °C at any time of the year with all substation loads running at 100%.

The air conditioner shall be arranged so that it is automatically shut down when the intruder alarm is armed and enabled when the intruder alarm is disarmed by the staff access switch in the main substation area. See Section 16.3 for details of the intruder detection system.

The condenser unit shall be positioned such that it is protected from vandalism and theft.

15.12.8 Toilet compartment vent

Appropriate forced ventilation shall be provided for the toilet compartment in accordance with AS 1668.2.

The vent fan shall be arranged so that it is automatically shut down when the intruder alarm is armed and enabled when the intruder alarm is disarmed.

15.12.9 Battery room vent

If there is a dedicated battery room, then appropriate forced ventilation in accordance with AS 2676.1 shall be provided for the battery room, suitable for the batteries to be used in the substation.

The battery type shall be in accordance with TS 03886.

Where a dedicated fan is used, an airflow sensor shall be installed and monitored by SCADA as required by AS 3011.

15.13 Noise mitigation

Considerations for noise mitigation are provided in Section 15.13.1 and Section 15.13.2.

15.13.1 Environmental

Noise at sensitive land uses (for example, residences) from the operation of substations and section huts shall comply with the NSW Environment Protection Authority's *Noise Policy for Industry*.

The noise from the operation of the substation shall not exceed 60 dB(A) at the nearest noise sensitive receiver.

15.13.2 Internal

All rooms associated with substations and section huts shall comply with the 'Satisfactory' level for the appropriate type of occupancy or activity as required by AS/NZS 2107.

15.14 Outdoor features

Considerations for outdoor features are provided in Section 15.14.1 to Section 15.14.6.

15.14.1 Outdoor HV switchyards

HV switchyards shall be as follows:

- designed in accordance with the requirements of AS 2067

- take into account transport routes for maintenance requirements to ensure minimal electrical isolations of equipment is required
- fencing shall be in accordance with Section 15.14.4 and with appropriate signage as detailed in Section 17.9.4
- egress arrangements shall be in accordance with the requirements of AS 2067
- lighting shall be in accordance with Section 15.28
- single phase and three phase GPOs shall be provided for maintenance purposes
- the operator and maintainer should be consulted for the required rating of GPOs
- geo-fabric shall be installed under a layer of blue metal as specified by the earthing Design TAO.

15.14.2 Access roads

Site access roads shall comply with the requirements specified in Section 15.10.

All internal roads and trafficable paved areas (within the substation fenced enclosure) shall be designed and constructed in accordance with TS 02391. The design shall be coordinated with earthing and bonding requirements as determined by the earthing design.

15.14.3 Parking areas

Sufficient parking for two light commercial vehicles (utility or van) near to the main entrance to the substation building shall be provided. Parking areas shall be sealed. A sealed pathway from the parking area to the substation building entry door shall be provided.

15.14.4 Fencing

Substation fencing shall be in accordance with the requirements of TS 03883. This standard provides detailed requirements for the design and construction of substation fences and has a list of deemed-to-comply fencing arrangement drawings.

The fencing and gate design shall be such that the largest item of plant in the substation can be transported out without the need to dismantle any part of the fence or gate.

15.14.5 Site (stormwater) drainage

Site grading and drainage shall be designed to ensure that all surface run-off from the site, including that from adjacent properties, is diverted into appropriate drainage system, away from the substation.

See Section 15.22 for details on the stormwater management.

15.14.6 Landscape and plantings

Any landscaping and plantings shall be low maintenance. In particular, lawns requiring mowing shall not be included.

Appropriate plantings of spikey plants may be used to deter graffiti and other vandalism.

Plants should be chosen to limit fire fuel load particularly in bushfire areas.

Plant species adjacent to the substation shall have a full-grown height less than 2 m.

15.15 Bays for liquid immersed equipment

Considerations for bays for liquid immersed equipment are provided in Section 15.15.1 to Section 15.15.3.

15.15.1 Clearance around equipment

The clearance around equipment in equipment bays shall be in accordance with AS 2067. This clearance shall be determined taking account of the specific maintenance tasks and access required.

Where the equipment is using a less combustible liquid for insulation, reduced clearances to surfaces may be used if enhanced protection is installed as per AS 2067.

15.15.2 Fire and explosion segregation

The fire and explosion segregation arrangements shall be in accordance with the relevant recommendations of ENA Doc 018-2015, having regards to the equipment and energy level present. The fire and explosion segregation arrangements shall address flame (burning vapour and gas), pressure waves, projectiles and radiation.

Where segregation is provided, the segregation shall comply with the requirements of AS 2067 and be sufficient to protect the other items of equipment from significant damage through the initiation, escalation and suppression phases of all credible fire and explosion incidents.

Fire and explosion segregation, appropriate to the fuel present, shall be provided between items which are redundant alternates and between other items where the provision of segregation is justified on the basis of the replacement cost of an item.

Fire and explosion segregation, appropriate to the fuel present, shall be provided between bays for liquid immersed equipment and other parts of the substation.

15.15.3 Liquid containment for liquid immersed equipment

Liquid containment for liquid immersed equipment shall generally be in accordance with AS 1940.

Spilled liquid shall be managed on the basis of capture and gravity drainage to a safe storage point away from the equipment.

Where the equipment is located outdoors, rainwater shall be drained via the same route.

Neither insulating liquid nor rainwater shall be held in a pool under or around the equipment.

The bund provided shall be of sufficient extent to capture insulating liquid leaking from the equipment in the event that the equipment tank or pipework is compromised in a credible manner at any point. It is not required that the bund be of sufficient extent to catch all insulating liquid that might be ejected from the equipment in the event of an explosive rupture of the tank.

The bund shall be sufficiently deep to capture the insulating liquid from such an event and allow it to drain via the intended route. Additional depth shall be added to allow for fire suppression agent applied at a reasonable rate. The depth of the bund shall be determined having consideration of the hydraulic capacity of the outflow.

To avoid introducing unnecessary hazards relating to safe access and egress, the bund shall not be appreciably deeper (threshold height) than the depth determined on the above basis.

A flame trap in accordance with AS 2067 shall be provided at, or close to, the point where the drain exits the bund. Where a common insulating liquid containment tank serves several equipment bunds, each bund shall be provided with a separate flame trap.

Flame traps are required for gravity drainage systems and should be located as close to the transformer as possible to do the following:

- facilitate the fast removal of insulating liquid and water
- reduce insulating liquid drainage paths across the bunded area
- reduce flame front size.

Flame traps shall be cast in-situ with a hydrophilic seal around the pipe. Joints are not permitted.

An insulating liquid containment tank shall be provided with sufficient capacity to retain the full volumetric insulating liquid capacity of the equipment item plus 10%, or 25% of the total capacity of all equipment when the containment tank serves more than one equipment item, whichever is larger. A containment tank shall not serve more than one equipment item if the insulating liquids of the equipment are not of the same type.

The insulating liquid containment tank shall be designed to provide for safe access for inspection and maintenance.

Any ground level conduits that are required for the connection of power and control cabling to the equipment located within the bunded area shall be located in the equipment concrete plinth. The conduit height shall be a minimum of 100 mm above the concrete plinth. The conduit shall be sealed to prevent the entry of insulating liquid.

An oil-water separator shall be provided in conjunction with the insulating liquid containment tank to allow water entering the system to pass while retaining the insulating liquid.

The oil-water separator shall be designed to ensure that under the nominated operation and maintenance regime, the water discharged is suitable for discharge to the stormwater system.

The drainage shall be provided in accordance with AS/NZS 3500 and the requirements of the governing authority including but not limited to the following:

- Sydney Water
- local council
- Hunter Water
- EPA.

The hydraulic capacity of the separator shall be provided to cater for a 100-year ARI event, taking into account both direct and windblown rain.

The separator is to be provided with a level monitoring device to signal to the SCADA that insulating liquid is present to a volume no greater than 5 % of the transformer capacity.

A manually operated sluice valve shall be provided in the outlet line from the oil-water separator to allow the discharge to be closed as may be appropriate during the application of certain fire supersession agents. The valve actuating handle and operation shall be clearly marked.

A disposable fabric filter may be included in the discharge line from the oil-water separator if this is necessary to achieve the required discharge water quality. If such a filter is included, the filter shall be readily accessible for inspection and replacement without requiring entry to any confined space.

Note that the inclusion of a disposable fabric filter is a non-preferred solution due to the requirement for maintenance and the on-going supply of consumables.

The system capacity for rainwater shall be not less than that required for the 0.5-year ARI event. For larger rain events, the bund may overflow on the basis of the 'first-flush' principle provided that insulating liquid cannot return from the insulating liquid containment tank to the bund.

If a bund is located in a flood prone area, the design shall be developed on the basis of taking into account the particular conditions.

15.16 Security segregation of equipment bays

There is no requirement for equipment bays to be segregated from each other in a security sense (that is, restricting personnel access between the consecutive bays).

15.17 Roofing of equipment bays

If bays for insulating liquid filled equipment are roofed for acoustic or other reasons, the roof shall be readily demountable to facilitate the replacement of the equipment. The roof shall not cause a derating of the insulating liquid filled equipment.

It shall be possible to demount the roof without damage to either the demountable or fixed sections. The demountable portions shall be clearly identified to facilitate correct reassembly. The design drawings shall clearly identify infrastructure and describe the methodology for removing and reinstating the roof including specialised equipment required.

15.18 Battery room

15.18.1 General

The requirement for a dedicated battery room depends on several factors as follows:

- thermal environment suitable for the battery type
- fire and life safety requirements
- network criticality
- a requirement as determined from a specific risk analysis.

If any battery rooms are to be installed, then they shall comply with AS 3011.1 regardless of the type of cell to be installed. See Section 20.5 for specific battery, charger and associated equipment installation requirements.

See Section 17.8 for details on emergency shower and eyewash.

Considerations for battery rooms are provided in Section 15.18.2 to Section 15.18.8.

15.18.2 Thermal segregation

To prevent accelerated degradation of batteries, battery rooms shall be thermally segregated from spaces where the temperature will be significantly elevated above the general ambient temperature due to waste heat from power equipment.

15.18.3 Ventilation

Appropriate ventilation shall be provided in accordance with Section 15.12.9.

15.18.4 Pressure relief

Appropriate pressure relief shall be provided to limit damage to the structure in the event of a hydrogen explosion.

15.18.5 Lighting

Task lighting shall be provided to facilitate the checking of electrolyte levels. Refer to TS 04955.7 for specific requirements.

15.18.6 Exclusive use

Any battery room shall not house any equipment other than the battery and luminaires for room and task lighting.

15.18.7 Dual batteries

Where two separate batteries are required for independent protection supplies, a separate battery room shall be provided for each battery.

15.18.8 Floor finish and drainage

Battery room floors shall be finished with a durable, non-slip coating resistant to electrolyte damage.

Appropriate provision shall be made for floor drainage in the event of any spill and the subsequent clean-up operations. The floor shall be arranged such that any spilled electrolyte does not flow into other areas of the substation.

15.19 Cable basement

The requirements for sub-floor cable ways such as cable basements are provided in Section 15.19.1 to Section 15.19.5.

15.19.1 Access and egress

Access and egress paths shall be such that the style of access and egress provided does not result in the cable basement being classified as a confined space in accordance with AS 2865.

It shall be reasonably practicable to extract a stretcher casualty from the cable basement via a stairway without the use of a hauling system.

15.19.2 Headroom

The headroom over the main access walkways within the cable basement shall not be less than 2000 mm.

15.19.3 Walkways

Clear walkways shall be provided to provide general access within the cable basement. The designated walkway area shall be painted with lines.

15.19.4 Ventilation

Adequate ventilation shall be provided so that the lack of ventilation does not result in the cable basement being classified as a confined space in accordance with AS 2865.

15.19.5 Drainage

The cable basement shall be drained either by a gravity or pump system. The floor of the basement shall be sloped to ensure that any water flows to a collection point at one of the basement walls.

Where a pump is required, this shall be installed and configured for automatic operation with alarms connected to the RTU.

The water discharged shall meet the requirements of the EPA and local council.

15.20 Staff amenities

The primary exterior door intended as the normal means of entry to the substation should provide convenient access to the amenities area.

15.20.1 Administration room

An administration room with minimum unrestricted floor area of 3 m x 3 m shall be provided for all traction substations.

The building layout shall be designed so that the administration room does not become a hallway and staff using the administration room are not disturbed by passing foot traffic.

A sink with hot and cold water shall be provided in the administration room.

The following furniture shall be provided in the administration room:

- a desk suitable for report writing, updating maintenance records, the completion of procedural documentation and meals
- four chairs
- a wall mounted bookcase suitable for equipment manuals
- a suitable storage unit for copies of all as-built drawings of the substation
- a key locker for storing equipment cabinet keys.

There shall be provision for the display of electrical system, reticulation and operating diagrams on the wall of the administration room.

A phone and data port shall be provided.

Ancillary substation equipment shall not be located in the administration room.

15.20.2 Toilet

A toilet shall be provided and shall be connected to the sewer where available at traction substations. This should be adjacent to the administration room.

A hand wash facility with hot and cold water shall also be provided in the toilet compartment.

15.20.3 Facilities for cleaning

A cold water tap at a height suitable for filling a bucket shall be provided in an area with adequate drainage.

15.21 Building services

Section 15.21.1 to Section 15.21.3 provide building services details.

15.21.1 Water supply

Traction substations shall have a mains connected water supply where available. If mains water supply is not available, a rainwater tank shall be provided.

An insulated joint shall be used in the water mains in accordance with EL0003147.

The water meter shall be located in a position that can be accessed by the meter reader without requiring access to rail corridor or substation.

The water supply system shall be provided in accordance with AS/NZS 3500. The *NCC Volume Three* contains provisions related to water supply systems.

15.21.2 Rainwater tank

Where a rainwater tank is required, it shall have a capacity of 1500 litres or more. Where a tank stand is required, it shall be galvanized steel. The rainwater tank shall be positioned such that it can be supplied from the substation building gutters.

A suitable pump shall be provided with the rainwater tank. The pump shall be located in a secure vandal proof metal enclosure, in a concealed position. Any discharge of water from failure of the pump shall be adequately drained.

The pump shall be located so that it can be easily replaced. The pump shall be arranged so that it is automatically shut down when the intruder alarm is armed and automatically activated when the intruder alarm is disarmed.

The rainwater tank shall be provided with a vermin proof stainless steel fine mesh screen with galvanized finish over top openings and overflow outlets. The overflow outlets shall be connected to the stormwater drainage system.

A water treatment system (such as filtration and UV steriliser) shall be provided to ensure that the water is treated to safe drinking water standards.

15.21.3 Hot water heater

A suitable instantaneous hot water heater shall be provided for traction substations.

The hot water heater shall be arranged so that it is automatically shut down when the intruder alarm is armed and automatically activated when the intruder alarm is disarmed. See Section 16.3 for details of the intruder detection system.

The primary purpose of the hot water heater is for hand washing.

15.22 Rainwater management

15.22.1 General

Drainage shall be provided in accordance with AS/NZS 3500 and *The Plumbing Code of Australia*. The drainage system shall be designed for a minimum return period of 100 years for the local area.

The drainage system shall be sufficient to collect and discharge water that is trapped by site features such as footings, cable trenches, buildings and fences.

All stormwater shall be collected and discharged beyond the substation site in accordance the relevant local council standard as appropriate to the location. Site stormwater drainage arrangements shall not be contrary to the requirements of TS 01638. The design shall also comply with Section 15.15.3 relating to insulating liquid containment.

15.22.2 Stormwater detention system

Stormwater detention shall be provided in accordance with the requirements of the local council.

15.23 Ground water seepage management

Considerations for ground water seepage management are provided Section 15.23.1 to Section 15.23.3.

15.23.1 Consideration of normal water table level

The normal water table level shall be determined prior to the detailed design of the substation. The design shall be appropriate to the normal water table level.

15.23.2 Indoor cable pits, trenches and cable basements

Cable pits, trenches and cable basements shall be sealed by an approved method to prevent the ingress of soil, water and dangerous gases via cable ducts.

The floor of cable pits and trenches shall grade to a blind sump no less than 300 mm depth suitable for a submersible pump in accordance with TS 03754.

In the case of cable basements and large and interconnected pit systems, suitable pipework shall be provided for the discharge from a portable submersible pump to allow pumping to continue with the substation secured. A GPO shall also be provided at a suitable location for supply to the pump.

Cable basements shall be provided with an appropriate pump. Associated alarms shall be connected to the SCADA RTU.

15.23.3 Sealing or interception of seepage via cable ducts

Appropriate measures shall be made to seal cable pits, cable trenches and cable basements from ingress of water seeping via cable ducts or to intercept such seepage water to prevent it entering cable pits, cable trenches and cable basements within the substation. Cable ducts entering the substation should slope away from the substation to assist with preventing water entering the substation.

15.24 Sewer

Sewerage installation shall be provided in accordance with AS/NZS 3500. The *NCC Volume Three* contains provisions related to sewerage installation.

The substation sewerage shall be connected to the local sewer network and be carried out to the satisfaction of the sewerage authority where possible. Where a sewer network connection is not available, the substation sewerage shall be connected to a properly designed septic tank or pump-out system. A composting toilet, with the toilet compartment external to substation, shall be provided where a sewer connection is not reasonably practicable. Incinerating toilets shall not be used.

15.25 Low voltage ac switchboards

15.25.1 General

The ac low voltage supply shall be designed and constructed in accordance with AS/NZS 3000, AS/NZS 61439 (all parts) and TS 04955.8:1.0.

15.25.2 Allowance for future additions

Each switchboard shall have sufficient space and electrical capacity to allow for 25% extra capacity for future additions (that is, only 75% of the total capacity shall be used for new substations). The 25% spare capacity is in addition to the spare capacity required for 1500 V dc intertripping (see Section 15.9.8). This requirement applies only to new substations or where the low voltage system is to be substantially upgraded or replaced.

15.25.3 Protective devices

Protective devices on each switchboard shall comply with AS/NZS 3000 and generally be miniature circuit breakers (MCBs) or moulded case circuit breakers (MCCBs) where prospective fault currents are greater than the MCB fault rating.

15.25.4 Labelling of devices

Each fuse, link, MCCB, relay, switch, indication and so on, shall be identified by its correct label in accordance with TS 00011.

15.25.5 Generator changeover switch

The 415/240 V switchboard shall have a manually operated changeover switch to provide supply from a temporary three-phase motor generator set during an outage of the auxiliary transformer or upstream ac supply.

The manual changeover switch shall have three stable contact positions (auxiliary transformer, off, and generator) and full circuit indications.

15.26 Electrical circuits

Separate sub-circuits shall be provided for lighting, GPOs and equipment. Mixed circuits shall only be used in battery rooms which are fitted with an exhaust fan.

Refer to TS 04955.7 for specific requirements of lighting circuits.

15.27 AC auxiliary power supplies

15.27.1 General

The ac auxiliary power supply is the general supply for equipment associated with the building services and specific items of the substation equipment. Alternating current auxiliary power supplies normally includes lights, general power outlets (GPOs), hot water heaters, air-conditioning, basement pumps, battery chargers, transformer tap-changer motors and equipment heaters.

Alternating current auxiliary power supplies are nominally 240/415 V ac. There are a limited number of existing substations that have a 220 V ac auxiliary supply, which is an unearthed supply.

Due to the hazards associated with a HV substation, electrolysis issues and potential effect on reliability, substation ac auxiliary supplies are not allowed to be reticulated outside the substation. The approval of the Director Energy Networks and Systems, PAM shall be required if an ac auxiliary supply is required to be reticulated outside the substation.

Considerations for ac power supplies are provided in Section 15.27.2 and Section 15.27.3.

15.27.2 Dual ac auxiliary supplies

Traction substations shall have dual ac auxiliary supplies. These supplies are normally taken from the secondary of the rectifier transformer in a substation with two or more rectifiers.

Where the substation has two or more 11 kV/415 V auxiliary transformers then the ac auxiliary supply shall be sourced from these transformers.

A single ac auxiliary supply is acceptable for sectioning huts and HV switching stations.

15.27.3 Emergency generator connection point

All traction substations shall have the provision for connection of a generator to the 415 V distribution board.

A three-phase cable termination point shall be provided in a convenient place near the location nominated for the generator.

The generator connection point shall supply the substation 415 V distribution board through a manual changeover switch. The changeover shall be configured such that when the distribution board is supplied from the generator, the main earth-neutral (MEN) link will be disconnected from the system. This ensures that only one MEN (the one in the generator) is connected.

TS 03916.1 (EL0290965), TS 03916.2 (EL0290966) and TS 03784 (EL0015238) show deemed to comply arrangements.

15.28 Lighting

Lighting shall be provided in accordance with TS 04955.7.

It is particularly important that internal lighting is located to minimise shadowing on equipment and shall be located outside exclusion zones as detailed in Section 15.11.14. Similarly, external lighting in HV yards shall be installed so that the working clearance to live parts can be maintained during maintenance of the light fittings.

15.29 General power and power outlets

GPOs of sufficient quantity shall be located to supply ancillary equipment and to allow ease of construction and maintenance works. GPOs shall be installed in accordance with AS/NZS 3000.

Substations with outdoor yards shall have single phase and three phase outlets which would normally be located on the external wall of the substation at both extremes of the substation building.

Transformer bays shall have a single phase GPO and a three phase GPO in each bay. The three phase GPO and associated circuit shall be rated for maintenance equipment such as

insulating liquid pumping equipment. The operator and maintainer shall be consulted for the required rating of GPOs.

15.30 Communications

Communications systems in substation areas shall be provided in accordance with TS 06224 and TS 06210.

Additional details for the staff access and phone silencing switch are detailed on TS 03893 (EL0204559).

15.31 Conduits and pipes

15.31.1 General

Electrical conduits and pipes shall be installed in accordance with AS/NZS 3000. Water, drainage and sewerage pipes shall be installed in accordance with AS/NZS 3500. The NCC contains provisions related to installation of water, drainage and sewerage pipes.

The design and installation of metallic pipes shall be coordinated with the earthing and bonding design.

15.31.2 Surface mounting

Conduits and pipes may be surface mounted within the substation building.

Conduits and pipes shall not be surface mounted on the exterior walls of substation buildings where the substation wall is not fenced from the rail corridor or publicly accessible lands.

The requirements of Section 15.11.14 regarding exclusion zones also apply.

15.31.3 Floor penetrations

Floor penetrations for conduits and pipes shall be located adjacent to walls or equipment, or under equipment with provision for bottom entry.

Floor penetrations for conduits and pipes shall be positioned to minimise the risk of impact by persons or equipment and the conduits and pipes shall be provided with appropriate mechanical protection.

16 Security

16.1 General

Security arrangements for substations and sectioning huts shall be designed to minimise the risk of the following:

- injury to persons who might gain unauthorised access by limiting such access
- vandalism or interference with equipment
- theft of equipment or material.

The safety of workers and the public shall take precedence over operational convenience and asset protection.

The security arrangements shall comply with ENA Doc 015-2022 and with security requirements of TS 04992.

The design of prefabricated substations and prefabricated sectioning huts shall inhibit unauthorised access to the interior of the substation. This not only includes the entry via doors, but also consideration of the building's external wall construction, materials used and associated attachment of external panels.

The security treatment requirement for a specific location depends on the security category in accordance with TS 04992.

Section 16.3 details the requirements for the general intruder system which is required for all locations.

16.2 Access control (locks)

The lock system installed after the commissioning of the substation shall allow only authorised personnel to access each of the different rooms within the substation. The access authorisation is as shown in Table 1.

Table 1 – Access control matrix

Room or area	Authorised traction line worker	Authorised substation operator
HV and traction room	No	Yes
HV outdoor areas and transformer bays	No	Yes
1500 V switch area	Yes	Yes

In the case of a substation or sectioning hut within another secure building, such as a passenger station, the access to the substation may be controlled by means of staff identifying

themselves to an appropriate control room via CCTV and the control room releasing the door by means of an electric striker release.

The locking system shall comply with PR D 78104 or as approved by Electrical Distribution Unit (EDU) within Sydney Trains.

16.3 Intruder detection system

The level of intruder detection will depend on the security classification of the substation. TS 04992 provides the factors for determining the security classification of substations. The classification shall be confirmed with the Director Energy Networks and Systems, PAM.

All substations shall have the basic intruder detection system which provides an alert to the electrical system operator (ESO) when persons enter the substation.

The following items shall be provided as part of the intruder detection system:

- reed switches for all doors to each of the following areas (one loop of reed switches for each area):
    - main substation area, including doors to 1500 V switch areas
    - 1500 V switch areas, excluding doors to the main substation area
- a staff access switch for the main substation and 1500 V switch areas which shall be located in the corresponding area and positioned in a convenient location near the entry point
- audible alarms for the main substation and 1500 V switch areas.

The reed switches shall be of the enclosed type. The reed switches shall be connected in a series loop. Each loop of reed switches covering one of the areas identified above shall be individually connected to the SCADA system.

Staff access switches shall be a conventional rocker type light switch with the toggle and the mounting plate coloured red. The staff access switches shall be integrated with the control systems for power and lighting as specified in Section 15.12.8 and Section 15.21.3.

The intruder alarm is said to be disarmed when either of the staff access switches' contacts to SCADA are in the open position.

The staff access switches and audible alarms shall be individually connected to the SCADA system. The audible alarms shall be energised from the SCADA system.

All contacts to SCADA shall be rated for the dc auxiliary voltage.

All cabling for the intruder detection system shall be protected from mechanical damage.

TS 03893 (EL0204559) shows an acceptable (deemed to comply) configuration.

17 Fire detection and protection requirements

17.1 General

The fire protection and detection arrangements shall comply with TS 00008.4. The approved system is a very early warning aspirating smoke detection (XTRAILS - VESDA – laser plus) system.

17.2 Smoke detection

Smoke detection complying with AS 1670.6 shall be provided in all rooms and in other equipment and cable spaces. Detectors shall be provided in accordance with the spacing stipulated in AS 1670.6.

In rooms where ionised gas is likely to be generated by DCCBs, smoke detectors shall be of a type that will minimise the likelihood of false triggering by the ionised gas emitted by the opening of DCCBs that are not enclosed. These DCCBs are air type with expulsion arc chutes, and all detection systems shall be configured to be compatible with these.

Smoke detectors shall be positioned in accordance with AS 1670.6. With the exception of sampling tubes for MASD systems, smoke detectors shall not be positioned in the exclusion zones set out in Section 15.11.14. With the exception of sampling tubes for MASD systems, smoke detectors should not be positioned within HV enclosures.

Detection systems shall be MASD systems in accordance with the TS 00008.4. The smoke sampling systems shall be provided with the control and sampling box in a readily accessible location close to the preferred entry door. The smoke sampling tubes shall be distributed within the substation to ensure coverage to all areas.

An outdoor smoke sampling point shall be provided to provide comparison to prevent air pollution or external fire triggering a nuisance alarm.

The design shall take account of the normal heat output of the power equipment, in particular the traction rectifiers.

17.3 Fire indication panel and SCADA interface

The fire detection MASD system shall connect to the SCADA system to provide the alarm signals as required in TS 00008.4. A separate fire indication panel is not required.

17.4 Fire suppression

Requirements for fire suppression are provided in Section 17.4.1 to Section 17.4.4.

17.4.1 Portable fire extinguishers

CO2 type portable fire extinguishers compliant with AS 2444 shall be provided.

As a minimum, portable fire extinguishers shall be provided at the following locations:

- near the staff alarm switch
- at the preferred entry door (no need to duplicate if this is also near the staff alarm switch)
- at the nominated second exit
- outside the battery room
- adjacent to the door to any external transformer compound.

External fire extinguishers are to be wall hung and housed in weather protection boxes.

17.4.2 Fire hydrants

Fire hydrants are to be provided in accordance with AS 2419.1 and TS 00008.4. The *NCC Volume One* contains provisions related to the providing of fire hydrants.

17.4.3 Hose reels

Fire hose reels shall not be provided in substations and electrical rooms.

17.4.4 Injection facilities for fire suppression agents

ENA Doc 018-2015 provides guidance regarding enclosed transformers.

Where bays for insulating liquid filled equipment are enclosed above and on the sides such that fire suppression agents cannot readily be applied to the fire from external hose streams and where the attending fire fighters have the capability to generate foam, injection facilities shall be provided in the form of a dry pipe and nozzle system. Nozzles positioned within the enclosure and at appropriate positions around the insulating liquid filled equipment shall be provided. The pipework and nozzles in the equipment bays shall be designed to survive exposure to fire for a period prior to the arrival of fire fighters. The foam inlet shall be positioned in a safe place in accordance with AS 2419.1.

Separate foam injection systems shall be provided for each such bay for insulating liquid filled equipment. All foam injection inlet points shall be in the same location with clear concise signage indicating the part of the substation served. The inlet assemblies shall be provided adjacent to any hydrant inlet boosters and be included on the hydrant block plan.

17.5 Passive fire protection of cables

Section 17.5.1 and Section 17.5.2 contain requirements for passive fire protection of cables.

17.5.1 Intumescent coatings for cables

Cables that represent a significant fuel load or flame propagation risk shall be coated with a suitable intumescent coating to minimise damage and prevent spread of fire via the cable routes.

17.5.2 Fire sealing of wall penetrations

For cables that penetrate fire segregation walls, appropriate fire sealing shall be provided in accordance with the specific recommendations of ENA Doc 018-2015. The NCC contains provisions related to appropriate fire sealing for fire segregation walls penetrated by cables.

17.6 Emergency equipment

17.6.1 General

Emergency equipment as detailed in Section 17.6.2 to Section 17.6.6 shall be supplied and installed.

17.6.2 First-aid kit

First-aid kits shall be provided as required in the Safe Work Australia *First Aid in the Workplace – Code of Practice*.

First-aid kits shall be portable types suitable for a workplace with four persons. In addition to the standard provisions, water-gel burns dressings to treat a single casualty with extensive burns shall be included.

The first aid kit shall be located in the administration room on a dedicated shelf or suitable wall mount bracket.

In a sectioning hut, the first aid kit shall be located near the main entry door generally grouped with the light switches, staff access switch and emergency push button.

A first aid kit location marker in accordance with Section 17.9 shall be provided on the administration room door.

No first aid kit marker is required in a sectioning hut where the first aid kit is in full view from within the switch room.

17.6.3 Electric shock treatment poster

Electric shock treatment posters and resuscitation instructions shall be provided. These posters and instructions shall be located next to the entry and exit doors within each HV area and in clear view from the front of the main space in each HV area.

17.6.4 Emergency push button configuration

Emergency push buttons shall be provided for medical emergency use.

The emergency push button shall be:

- mushroom head type push button
- red in colour
- mechanically latching type with turn or rotate to release mechanism
- of at least 20 mm diameter at the head of the button
- installed on white plate of at least 75 cm^2
- mounted approximately 1.4 m above finished floor level.

When the emergency push button is pressed:

- An indication to SCADA shall be sent.
- The SCADA master station shall energise indication lights associated with all emergency push buttons as confirmation that the push button signal has been received and alarmed to the ESO. Indication light for illumination shall be a separate light installed directly above the button. The indication light shall be orange in colour.
- Where installed, all strobe lights at the substation shall also be activated.
- Strobe lights and emergency push button lights shall only be deactivated when the push button is released.

A traffolyte label with red background and white text which reads ‘Emergency Help Point’ shall be located above the push button.

For existing substations being upgraded, emergency push button scheme throughout the substation should be implemented where it is reasonably practical. The final decision to implement emergency push button scheme remains with the Professional Head Electrical Engineering, Engineering and System Integrity, Sydney Trains.

17.6.5 Emergency push button location

Emergency push buttons shall be located as follows:

- In each substation indoor area or room except for the toilet and the battery room. For clarity, this requirement also applies to the cable basement areas of the substation.
- In each segregated equipment bay in the outdoor area.
- Distance between the emergency push button and any point in the area or room being served shall be no more than 10 m. Additional buttons shall be provided as required to comply with this requirement.

- This requirement does not apply to areas of substations such as walkways where no equipment is located.

Wherever possible, the emergency push buttons should be located adjacent to exit doors and generally grouped with light switches or staff access switch.

The emergency push button in the administration room shall be located near the first aid kit.

The Design TAO shall determine the exact number and location of emergency push buttons required with consultation with the region's respective Regional Electrical Engineer, Network Maintenance, Sydney Trains.

The location of the emergency push button shall be documented in the substation local instructions.

17.6.6 Emergency push button SCADA connection

Activation of an emergency push button will result in an indication at ICON with details of which substation area the pushbutton is located in. If multiple emergency push buttons are located in the same room or area, they may be wired to the same digital SCADA point.

Individual rooms shall be connected to separate digital inputs to SCADA.

A single SCADA point shall be used to control the illumination of all emergency push buttons' lights.

17.7 Sound and intercom systems for emergency purposes

A sound system and intercom system for emergency purposes (SSISEP) is not required by the *NCC Volume One* unless the substation is integrated with another building for which such a system is required.

17.8 Emergency shower and eyewash

An emergency shower shall be provided at all traction substations. Other types of substations do not generally require an emergency shower unless as a result of hazard and risk assessment.

The emergency shower shall be provided inside the substation. Measures shall be taken to ensure that water does not spray or flow onto electrical equipment while the emergency shower is in use. Adequate drainage shall be provided. The emergency shower may be combined with the toilet compartment.

If the emergency shower is not provided immediately adjacent to the battery room, an eye-wash station shall be provided adjacent to the battery room (near the battery room door).

Eyewash stations shall be provided in accordance with AS 2067. The eyewash station and emergency shower shall be installed and manufactured in accordance with AS 4775.

17.9 Identification and marking

Specific identification and marking requirements are in Section 17.9.1 to Section 17.9.4.

17.9.1 Information plates and warning plates

Information plates and warning plates shall be provided in accordance with AS 2067.

17.9.2 Electrical hazard warning

Electrical hazard warning signs shall be provided for doors leading to the HV areas in accordance with AS 2067 and AS 1319.

17.9.3 Cable identification marks

Cable identification marks shall be provided in accordance with AS 2067.

17.9.4 Substation signage requirements

Signage shall be provided in accordance with TS 03741.

18 Inter discipline responsibility

The responsibility for the installation of certain infrastructure, particularly with equipment associated with the traction system, involves multiple engineering disciplines.

It is critical that all relevant disciplines are involved throughout the life cycle to ensure respective requirements are met.

19 Construction within an existing substation

19.1 General

Construction works within an existing substation or sectioning hut pose unique risks and hazards which need to be assessed, and appropriate planning and controls put in place.

There are also operational impacts which need to be considered and agreement from stakeholders sought.

Prior to the start of the detailed design the TAO shall perform the following:

- document the non-compliances with the existing location
- identify the particular non-compliances that are relevant to the project scope
- complete hazard and risk register in relation to the non-compliances and seek a concession from the PAM as required by TS 00003.1.

19.2 Operational considerations

Where the works will require equipment not being available for service or a reduced functionality, the operational and safety consequences shall be taken into account and affected stakeholders consulted. The following are typical factors that need to be taken into account:

- fire and life safety requirements applicable to underground locations
- impact on the reliability of the 1500 V traction power supply
- impact on the reliability of the HV network
- impact on critical systems such as train communication systems, signalling supplies, tunnel pump supplies, emergency evacuation systems and fire systems
- impact on passengers such as lifts, escalators, lighting and passenger information displays.

Sydney Trains shall be consulted and notified of the following:

- consultation and agreement from Sydney Trains prior to commencing of work on isolation of electrical equipment
- notification to Sydney Trains prior to actual works commencing
- provision of temporary amenities for Sydney Trains maintenance staff where the works will affect availability of existing amenities
- ensure access is available at all times for Sydney Trains operations and maintenance staff.

19.3 Working around energised equipment

Where construction works are within an existing energised substation or a new substation which has commissioned HV or 1500 V equipment, the following shall be complied with at all times:

- AS 2067
- RL D 79800
- PR D 78700
- D2013/81208.

19.4 Risks and hazards

19.4.1 General

Section 19.4.2 to Section 19.4.4 identify typical hazards in an existing substation. Individual locations shall be assessed and appropriate hazard and risk analysis completed.

The staging of works shall take into account all the hazards and risks identified.

19.4.2 Safety

Typical safety hazards and risks include the following:

- electrical hazards such as buried cables, working around equipment with exposed terminals
- cable pits and basements (some basements are confined spaces)
- trip hazards due to uneven ground, old equipment footings and so on
- noise hazards due to 1500 V DCCB operation
- exposure to polychlorinated biphenyls (PCBs), asbestos, lead paint, acid and so on
- absence of protective devices (such as RCDs) at existing locations.

19.4.3 Operational

Whilst the following is a list of typical risks which will have an operational impact, individual sites shall be assessed to determine the specific risks at the site:

- loss of electrical supply to in-service equipment
- damage to control cabling
- operation of fire systems
- contamination of exposed equipment (rectifiers, DCCBs and so on) with dust resulting in a flashover.

19.4.4 Environmental

Whilst typical environmental hazards in existing substations include the following, individual sites shall be assessed to determine the specific hazards:

- contaminated soil
- equipment which contains oil, PCB, asbestos, acid and lead.

20 Equipment installation

Section 20.1 to Section 20.16 provides information about the installation of specific items of equipment. Not all items of equipment that would be installed in a substation are listed, only items that have specific requirements due to the unique rail environment or where specific design solutions have been developed.

The requirements of Section 20.1 to Section 20.16 do not take precedence over the specific manufacturers' installation requirements.

20.1 Type approved equipment

All major equipment requires type approval by the TfNSW Prioritisation and Asset Management branch prior to being connected to the TfNSW metropolitan heavy rail network. Typically for substation and sectioning huts this includes, but is not limited to, the following:

- battery and charger
- RTU
- 1500 V equipment – dc switchgear, rectifier, negative reactor, links and switches, dc arresters, harmonic filter, 1500 V cables and terminations and dc protection relays
- transformers – rectifier, power, distribution, auxiliary and isolation
- HV ac equipment – switchgear (indoor and outdoor), air-break switches, harmonic filters, ac arresters, post type current transformer, external VTs, outdoor exposed busbars, HV cables and terminations, ac protection relays and revenue metering relays.

TS 06178 provides further information on the type approval process.

20.2 Civil building requirements prior to installation of equipment

Prior to the installation of electrical equipment in a building, certain civil aspects of the construction shall be completed prior to the equipment installation. The following general building requirements shall be met prior to the installation of all equipment:

- Waterproof and indoor equipment shall be protected from meteorological events (that is, the structure of building shall be complete with roofing and associated stormwater systems complete to ensure no water ingress into the building due to stormwater).
- Free of dust with all construction activities that would create dust once completed. This is particularly important as the majority of equipment to be installed is sensitive to dust. (for example, 1500 V rectifier, HV ac switchgear, 1500 V dc metal enclosed switchgear, 1500 V DCCBs and auxiliary transformers).

The following additional specific requirements for the dc auxiliary battery system shall be met:

- The battery bank shall not be installed unless the battery room is complete and eyewash facilities are installed and commissioned.
- The battery charger and associated battery bank shall be commissioned within the manufacturers recommended timeframe. This shall not happen until a permanent ac auxiliary supply is available.

The insulating liquid containment system shall be installed and commissioned prior to the installation of insulating liquid filled equipment (for example, rectifier transformers, power transformers and reactors).

TS 03881 contains additional requirements which shall be met prior to the energisation and commissioning of equipment.

20.3 General equipment requirements

The general requirements for electrical equipment are specified in TS 00011.

20.4 Telecommunication equipment

Depending on the location there are a variety of interfaces with the TfNSW fibre optic network. These connections are typically for the following:

- telephone services using voice over internet protocol (VoIP) technology
- SCADA services
- data port for TfNSW ICT desktop services
- CCTV camera
- HV feeder protection (line differential protection)
- 1500 V dc intertripping.

The minimum requirements for facilities installed in substations and sectioning huts is specified in TS 06224.

Where practical, telecommunication equipment shall be located together in one location of the substation and in close proximity of the SCADA RTU.

The data port shall be located adjacent to the desk in the administration room.

20.5 Battery and battery charger

20.5.1 General

All substations and sectioning huts shall have a dc auxiliary system installed, which for new locations is nominally 125 V dc.

Refer to TS 03886 for specific charger and battery requirements.

Section 20.5.2 to Section 20.5.7 provides specific requirements for the installation of the dc cabling, battery isolation board or panel and general connection arrangements.

20.5.2 Battery stand (installed in battery room)

Cells are to be mounted on a stand which shall not be earthed. The stand shall be mounted on insulators with a 1.5 kV insulation level to earth.

The stand shall be arranged to facilitate removal, replacement, inspection and maintenance of any individual cell without the need to remove or disconnect other cells.

Where flooded cells are used, trays shall be provided under each cell to contain any electrolyte spillage. Stands, shelves and trays shall be made of corrosion resistant material or be protected against corrosion.

20.5.3 Battery cabinets

Where a battery room is not required then the battery shall be accommodated in a battery cabinet that complies with AS 2676.2 and AS 3011.2. Refer to TS 03886 for specific requirements of the charger, batteries and battery cabinet.

Where battery cabinets use forced ventilation, the vented gas shall be expelled outside the substation.

20.5.4 Battery location

Where the battery is located in the same room as 1500 V DCCBs associated with an exposed 1500 V positive busbar it shall not be located directly adjacent to or directly opposite the 1500 V dc busbar as the 1500 V busbar and associated DCCBs are not enclosed.

The battery shall be located so that the natural air flow of the location directs any gas from the battery away from the 1500 V busbar.

20.5.5 DC cabling

As the battery system is not earthed, the dc cabling shall be installed in a manner to ensure this is maintained.

The following circuits shall be single double insulated (SDI) cables:

- battery to battery isolation board
- battery isolation board to respective dc distribution board
- paralleling cables between dc distribution boards in a dual battery location.

All cables originating from the distribution board to equipment shall be two core (no earth wire).

The following cables shall be installed in separate rigid conduit, with respective positive and negative adjacent to each other:

- the dc cables from the battery to the battery isolation board

- the dc cables from the battery isolation board to the dc distribution board
- the dc paralleling cables between dc distribution boards in a dual battery location.

The conduit for the positive and negative circuits shall be located adjacent to each other to minimise electromagnetic compatibility (EMC) effects.

20.5.6 DC connection

The 125 V dc connection arrangement shall be in accordance with Figure 1. Where dc circuit breakers have been used in Figure 1, they may be substituted by fuses. The direction of fault current shall be taken into account when using uni-directional dc circuit breakers and whether fault current can flow in both directions. (such as battery charger, multiple 125 V dc distribution boards connected in parallel, and so on).

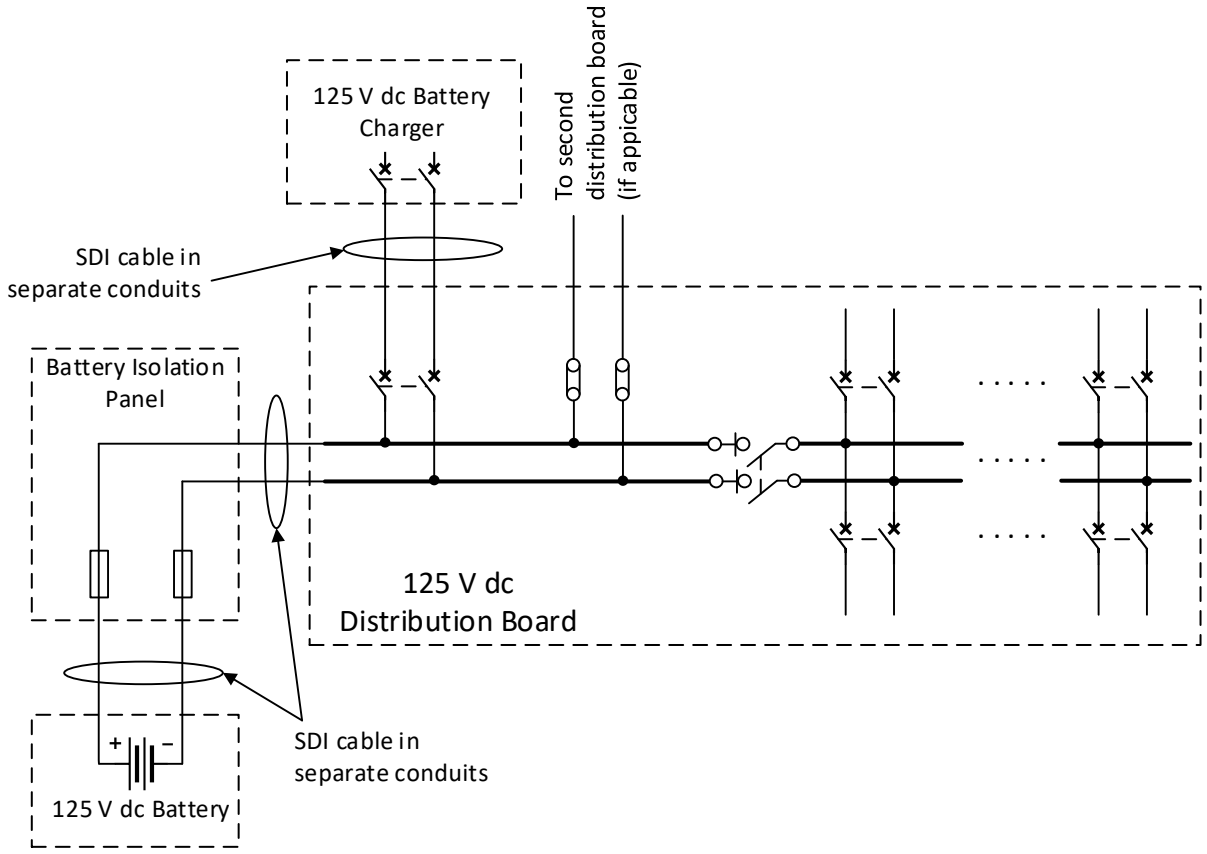

Figure 1 – 125 V dc connection arrangement

20.5.7 Dual battery requirements

Where a location has dual batteries, the batteries, charger and associated cabling shall be arranged to avoid common mode failures. In principle this means, but is not limited to, the following:

- The battery and charger of one system shall not be located adjacent to the other battery system.
- The ac supply to the chargers shall be from separate dedicated low voltage circuit breakers and the submain cables be run via separate routes.
- Each system shall have its own battery isolation board or panel.
- The dc cabling from the battery isolation board or panel to the respective distribution board shall be run in dedicated independent conduit.

Paralleling links shall be installed on both 125 V dc distribution boards where a location has dual batteries.

20.6 Voltage limiting devices

For requirements of voltage limiting devices including RECs for traction substations and sectioning huts, refer to TS 03726.

20.7 Rectification and transformers

Considerations for rectification and transformers are provided in Section 20.7.1 to Section 20.7.5.

20.7.1 Power transformers

Power transformers shall be installed in accordance with manufacturers' requirements. See Section 15.15 for details on the transformer bay enclosure requirements.

The cable screens of HV cables connected to power transformers, with the exclusion of the electrostatic screens of the cable terminations, shall be single point bonded to prevent circulating currents. The electrostatic screens of the cable terminations shall be earthed at both ends as applicable. Cable screens shall be terminated as follows:

- Switchboard end – cable screens shall be earthed at the switchboard end and connected to the switchboard earth bar.
- Transformer end – cable screens shall be left floating at the transformer end and terminated onto a low voltage insulator.

Earthing of a power transformer tank shall be in accordance with Section 13 of TS 03726:1.0, specifically the requirement for redundancy of N-1 for the earthing connection between the main earth grid and the transformer tank.

The transformer tank shall have two earth connections at opposite sides, both connected to the same transformer earth bar on the primary side.

For wye (Y) connected windings of transformers with direct earthing of the star point (neutral), the connection to earth shall be made directly to the substation main earth bar.

Typical details of the transformer and HV cable screen earthing requirements are shown in drawing TS 03938 (EL0494459).

20.7.2 Rectifier transformers

The following shall apply regarding locations of rectifier transformers:

- see Section 15.15 for details on the transformer bay enclosure requirements
- rectifier transformer shall be located to minimise the length of 600 V ac cables to the rectifier.

The rectifier transformer is usually located adjacent to a substation wall with the rectifier located directly on the other side of the wall.

The following shall apply regarding 600 V ac cables:

- Cable size and type as required by TS 03749 and TS 03748.
- The 600 V ac cables shall be installed to ensure grouping of the phases is maintained, the cables are supported to ensure there is no load on the 600 V bushings and the connection to the transformer palms are perpendicular to the palm to minimise forces on the 600 V bushings. It is preferred that multi-stranded flexible cables should be used for this application as required by TS 03749.
- The 600 V ac cable palms shall be fitted with a proprietary insulated cover.
- TS 03698 (EL0446427) provides details of the approved connection method of 600 V cables.

The following shall apply regarding 33 kV and 66 kV cables:

- The approved cable size and type shall be as required by TS 03748.
- The screen of the cable at the transformer termination shall be connected together and insulated from earth. Refer to TS 03938 (EL0494459) for further information.

The rectifier transformer shall be fitted with a frame leakage protection scheme if the transformer bay has a roof enclosure. Refer to TS 03720 (EL0283030) for the arrangement of this scheme.

20.7.3 1500 V rectifiers

When the traction substation has multiple rectifiers, the type of rectifier shall be the same (that is, both are type A or both type B) to ensure the rectifier auxiliary voltages are in phase.

Auxiliary transformers shall be connected to the 600 V winding of the transformer associated with the negative of the rectifier.

The fuses protecting the auxiliary transformer are located in the bottom of the rectifier cubicle.

The following shall apply regarding 600 V ac cables:

- The cable size and type shall be as required by TS 03749 and TS 03748.
- The height of the 600 V ac cables shall align with the height of the connection palms and be adequately supported to ensure minimal force on the rectifier palm.
- As the 600 V cables are not screened they shall be at a minimum height of 2.44 m for the entire route which is the ground safety clearance as required by AS 2067.
- Connection of the 600 V ac cables to the aluminium rectifier palms shall be as shown in TS 03698 (EL0446427).

The following shall apply regarding 1500 V dc cables (positive and negative):

- Cable size and type as required by TS 03749 and TS 03748.
- The 1500 V positive cables shall have their screens terminated onto a busbar within the rectifier cubicle. This busbar shall be connected to the rectifier frame leakage system. At the 1500 V positive busbar associated with the DCCBs, the positive cables shall have the screens connected together and left floating.

The following shall apply regarding rectifier frame leakage:

- The rectifier shall have a frame leakage protection scheme installed on 3 mm thick Delrin sheeting (or equivalent) to ensure isolation from the substation earth.
- Requirements for the rectifier auxiliary transformer are detailed in Section 20.7.4.
- The substation earth connection point shall be the rectifier frame leakage relay which is located inside the rectifier marshalling cubicle.

20.7.4 Rectifier auxiliary transformer

The rectifier auxiliary transformer primary shall be supplied from the unearthed 600 V winding of the rectifier with cables in accordance with TS 03748.

The preferred arrangement is that the rectifier auxiliary transformer should be located adjacent to the rectifier. The transformer enclosure shall be connected to the frame leakage earth of the rectifier frame leakage scheme. The transformer enclosure shall be installed on Delrin sheet (or equivalent) to isolate the transformer enclosure from the substation earth.

If the rectifier auxiliary transformer is not adjacent to the rectifier, then the associated rectifier frame leakage scheme shall be extended by a dedicated earth cable enclosed in conduit. The auxiliary transformer shall be as follows:

- installed on 3 mm thick Delrin sheet (or equivalent) to isolate the transformer enclosure from the substation earth
- have a minimum of 600 mm clearance on all sides
- have signs installed that read 'WARNING - TRANSFORMER ENCLOSURE CONNECTED TO EARTH VIA RECTIFIER FRAME LEAKAGE SCHEME'.

20.7.5 1500 V negative reactor

A 1500 V negative reactor shall be installed at traction substations. The number of reactors required and the minimal current rating of the reactor for a new location shall be in accordance with the associated power study. These requirements are to be documented on the approved proposed dc operating diagram.

Where the reactor is a replacement for an existing location it shall have a minimum 1 pu current rating of 3200 A (suitable for 5 MW rectifiers) and overload ratings in accordance with TS 03873.

The following shall apply regarding 1500 V dc cables (negative) that connect to the reactor:

- cable size and type as required by TS 03749 and TS 03748
- the 1500 V negative cables shall be terminated onto a busbar arrangement adjacent to the reactor
- the connection from the busbar to the reactor terminals shall be with flexible cables or braid to ensure there is no mechanical force placed on the bushings of the reactor
- a mesh cover is required over the exposed busbar and terminals to prevent touching and bridging to the substation earth.

20.8 Lightning protection and insulation coordination

TS 03869 contains requirements in relation to lightning protection and insulation coordination.

20.8.1 HV ac arresters

HV ac surge arresters shall be installed in the following locations:

- all transformers connected to aerial lines, including pole top transformers
- all transformers within a substation that are connected to an outdoor busbar
- all cables to aerial junctions which includes aerial bunded conductors

- at the termination structure where the transmission lines interface with an outdoor substation busbar.

Indoor 33 kV and 66 kV ac switchgear shall have surge arresters on the feeder panel or panels for short cable lengths. Where surge arrestors are proposed not to be installed, this shall be supported by an engineering study prepared by a TAO and submitted to the Director Energy Networks and Systems, PAM for approval.

Indoor 11 kV ac switchgear may have surge arrestors installed on the feeder panels as determined by a site-specific insulation coordination study.

20.8.2 1500 V dc arresters

The requirements for 1500 V dc arresters are specified in TS 03869.

20.9 Earthing

The requirements of the following standards and drawings related to earthing shall be applied:

- TS 00006
- TS 03726
- TS 03677
- EL0024017
- EL0524980
- EL0435620.

20.10 Protection

Considerations for protection are provided in Section 20.10.1 to Section 20.10.3.

20.10.1 1500 V dc protection

The requirements for the protection of the 1500 V dc network are specified in TS 03735.

20.10.2 1500 V DCCB frame leakage protection

All traction substations and sectioning huts shall have a DCCB frame leakage scheme installed. There shall be a DCCB frame leakage scheme for each section of the busbar where the 1500 V positive busbar is sectionalised.

The detection of a fault shall result in the opening of all 1500 V feeder and rectifier DCCBs on the associated section.

It is critical that the 1500 V DCCB frames of the exposed 1500 V busbar system (Mitsubishi type DCCB) and the 1500 V metal enclosed switchboard shall be installed correctly to ensure they are not directly connected to earth.

The DCCB frame leakage relay or relays shall be installed as follows:

- in the common equipment panel (CEP) for a new location with an exposed 1500 V dc positive busbar
- in the 1500 V dc metal enclosed switchboard or in a separate frame leakage panel adjacent to the associated switchboard for a location with metal enclosed switchboard.

The following drawings are applicable to a location installed with an exposed 1500 V busbar and no CEP:

- EL0234193
- EL0234194
- EL0234195
- TS 03691 (EL0234196).

Substations with dual batteries require a special DCCB frame leakage design which is not detailed in these drawings.

20.10.3 HV ac protection

The requirements for the protection of the HV network including associated equipment is detailed in TS 03736.

The type of HV protection to be installed at a location is documented on the approved proposed ac operating diagram in accordance with TS 03736.

The detailed protection scheme requirements such as protection relay, current transformer details, VT details, metering requirements, trip coils and SCADA alarms are documented on the associated protection concept design.

20.11 Cables and busbars

20.11.1 General

See Section 9 for the requirements for the removal and disposal of cables.

Considerations for cables and busbars are provided in Section 20.11.2.

20.11.2 HV ac, 1500 V dc cables and terminations

The requirements for joints and terminations of HV and 1500 V dc cables are specified in TS 03748. Type approved cable terminations for 1500 V dc and HV cables are published on the PAM website.

The approved configuration and type of 1500 V dc and HV ac cables are specified in TS 03748.

Cables located in basements shall be installed as follows:

- on a proprietary cable ladder system
- secured to the cable ladder at spacing suitable for the mechanical forces determined from the maximum fault levels
- floor penetrations shall align with the switchgear opening and cable termination points
- where the cable is terminated into switchgear it shall be secured to ensure that the cable termination is not supporting the weight of the cable
- cable ladder located at floor level shall be at a height above the basement drainage outlet
- all HV ac and 1500 V dc cables shall be labelled with corrosion-resistant labels securely attached to the cable with a corrosion-resistant securing system showing the feeder number and voltage
- cable ladders that have HV cables installed shall have corrosion-resistant 'Danger – high voltage' labels attached to the cable ladder.

The arrangement of cables in basements shall ensure that redundancy is not reduced and the segregation is maintained between HV, 1500 V dc and control cabling.

20.11.3 HV ac busbar (exposed)

New locations that have an outdoor yard with exposed HV busbar shall have a busbar system installed where parts and fittings are readily available from multiple suppliers. The main busbar shall be of the tubed aluminium type with electrical ratings suitable for the substation and future network requirements.

20.12 1500 V DCCB positive busbar

Section 20.12.1 to Section 20.12.5 detail applicable drawings and information for the exposed 1500 V dc busbar system associated with 1500 V DCCBs that are not installed in a metal enclosed switchboard. The drawings listed are applicable to Mitsubishi DCCBs.

20.12.1 1500 V dc cubicles

The TfNSW preferred 1500 V DCCB cubicle should be of double brick wall construction. Correct construction of 1500 V DCCB cubicles is critical to ensure the associated 1500 V busbar, 1500 V DCCB frames and the 1500 V DCCB can be installed.

Refer to drawing TS 03690 (EL0215513) for details on the arrangement.

This arrangement is standard for TfNSW and the use of Mitsubishi DCCBs. The design has been developed to ensure inter-changeability of the DCCBs within the majority of the TfNSW metropolitan heavy rail network.

20.12.2 1500 V dc busbar

The 1500 V busbar consists of copper bar mounted on the DCCB frame and bridging copper bar that connects adjacent DCCB frames. The bridging busbar has insulating plates installed either side of the DCCB cubicle wall.

Refer to EL0227687 for details on the copper busbar components that form the 1500 V dc busbar and the associated insulating plates.

Refer to TS 03689 (EL0065675) for details on the copper palms required for termination of the 1500 V positive cables in both the feeder and rectifier cubicles.

Refer to TS 03693 (EL0237911) for details on the 1500 V positive cable screen termination for the rectifier 1500 V positive cables.

20.12.3 1500 V DCCB frame

The location of the 1500 V DCCB frame is critical and shall ensure the 1500 V DCCB has the required clearance from the brick cubicle walls and when the DCCB is racked in it does not hit the front face of the brick walls.

The DCCB frame shall be insulated from earth for correct operation of the DCCB frame leakage system. TS 03691 (EL0234196) provides detail on the insulating requirements and method of securing the DCCB frames.

20.12.4 Arc exclusion zone

The Mitsubishi DCCBs have an arc exclusion zone where no metallic components are allowed to be installed. This zone is detailed in EL0001999.

20.12.5 Trackside negative bar

Trackside negative busbars shall be installed to form the interface between the substation 1500 V negative cables and the connection to rail. Standard arrangement of trackside negative busbars is detailed in TS 03749 and TS 03943.

The cable between the trackside negative busbar and the substation or sectioning hut shall comply with TS 03749.

The following drawings are applicable:

- TS 03944 (EL0023896)
- TS 03945.1 (EL0099579)
- TS 03945.2 (EL0099580).

20.13 Stand-alone 1500 V isolating and rail connecting switches

1500 V isolating and rail connecting switches (IRCSs) which are not integral to 1500 V dc switchgear are normally installed as follows:

- in a separate dedicated room within the substation building or on an external wall of the substation building (usually directly behind the DCCBs)
- as a group located close to the OHW feeding structure where the substation is supplying a junction which is a significant distance from the OHW feeding structure
- as single or pairs for the primary purpose of providing rail connection to sections of OHW to facilitate safe and expedient OHW isolations.

The following drawings provide details where the IRCSs are installed as part of the substation:

- TS 03696 (EL0383824)
- TS 03697 (EL0383825).

Where 1500 V IRCSs are located outside of the substation, signs with the wording 'TWO PERMITS, A SUBSTATION ACCESS PERMIT AND AN ELECTRICAL PERMIT TO WORK, ARE REQUIRED TO WORK ON 1500 V SWITCH' shall be installed on all access gates.

Where 1500 V IRCSs are outside the substation boundary, then rail connecting hooks shall be installed on each IRCS. See drawing TS 03712 (EL 0521637) for more details.

20.14 1500 V dc harmonic filters

1500 V dc harmonic filters shall be installed and connected to the 1500 V positive busbar.

The filter shall be truck mounted and withdrawable. The 1500 V positive busbar surge arrester may be mounted on the same truck.

20.15 HV ac harmonic filters

HV ac harmonic filters shall be located outdoors. HV ac harmonic filters shall have the following characteristics:

- be enclosed in their own HV enclosure
- have access gates which are key interlocked with the HV switchgear ACCB to ensure access only when the harmonic filter has been earthed and relevant capacitor discharge time exceeded
- have appropriate signage for HV enclosure in accordance with AS 2067, TS 03741 and signs on the access gates regarding the key interlocking
- have an interlocking system where the HV switchgear ACCB is required to be type approved, normally as part of the type approval of the HV switchgear.

20.16 HV ac indoor switchgear

HV ac indoor switchgear shall be installed to ensure the following:

- Compliance with manufacturers' recommendations for minimum clearances required for maintenance. Where distances required by AS 2067 and the NCC are greater they shall be used. See Section 15.9 for further detail on spatial requirements.
- Where the switchboard does not have an internal arc classification of AFLR in accordance with AS 62271.200, appropriate physical restrictions, signage and the floor shall be painted to ensure the hazardous zone is clearly identified. This zone shall not be a designated walkway. This zone shall not have serviceable equipment (such as distribution boards, SCADA panels) within it. The electrical design drawings shall clearly identify the hazard zone with associated notes.
- Switchboards with a voltage of 66 kV and greater which are insulated with high pressure sulphur hexafluoride (SF6) shall have dedicated SF6 warning alarms placed at the entry doors to the switch room.
- Where HV ac switchgear vents arc faults below the HV ac switchgear, the safety of any personnel working in the cable basement below the HV ac switchgear shall be taken into account (such as restricted access and appropriate signage in the cable basement).

21 Electromagnetic compatibility

Substations and sectioning huts shall be designed to manage the risks associated with the generation, propagation and reception of electromagnetic energy, as specified in Section 7.9 of TS 01471:0.0. The limits of any magnetic fields shall comply with TS 00049.

Appendix A Substation ancillary equipment (normative)

A.1 General

Appendix A contains details of typical items that are located within substations that shall be provided as part of the project. Consultation shall be undertaken with the operator and maintainer to determine the exact requirements as not all locations will require all of the equipment.

Major electrical equipment (HV ac switchgear, dc switchgear, rectifier, harmonic filter and so on) have specialised operating tools supplied with the equipment. Strategic spares are purchased after a spares analysis and agreement with the operator and maintainer and located in the store system or held at the substation location.

A.2 Test equipment

The following typical current type approved test equipment shall be provided:

- 1500 V dc substation tester
- HV ac tester
- test equipment and meters associated with non-standard equipment (for example, capacitor meters for harmonic filters).

A.3 Equipment operating tools

Specialised tools for operating equipment are provided with the purchase of equipment. The following is intended as a checklist and will depend on the type of equipment installed:

- rectifier 1500 V dc negative link stick
- Mitsubishi 1500 V DCCB – withdrawing tool and manual operating handle
- 1500 V dc metal enclosed switchgear – circuit breaker test panel, emergency closing device, direct acting overload (DAOL) test device
- HV ac switchgear operating handles
- phase checking meters (required for certain HV switchboards).

A.4 Earthing and rail connecting equipment

The following current approved earthing and rail connecting equipment shall be provided:

- 1500 V dc OHW rail connection equipment
- HV ac earthing equipment (locations with outdoor yards).

A.5 Miscellaneous maintenance items

The following maintenance items shall be provided:

- safe work barrier tape, including storage cabinet
- magnetic danger tag holders and danger tape
- spring loaded insulated rod for hanging danger sign at DCCB cubicle entry (Mitsubishi 1500 V DCCBs)
- flammable liquid storage cabinet
- emergency oil spill kit
- fibreglass step ladder and extension ladders
- discrete consumables such as fuses, MCBs, lights and so on
- confined space equipment including storage cabinet.

A.6 Administration and general items

The following administration and general items shall be provided:

- desk and chairs
- drawing cabinet or A1 drawing rack
- cupboard for storing equipment operation and maintenance manuals
- wall mounted electrical operating diagram frames
- wall mounted key cabinet
- refrigerator and kettle (only required at traction substation)
- mop and bucket; broom; dust pan and brush, large garbage bin with lid.