Master Specification Part TUN-ME-DC2

Tunnel Power Systems

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Government of South Australia
Department for Infrastructure and Transport

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Document Management

Contents

TUN-ME-DC2 Tunnel Power Systems

1 General

a) This Master Specification Part sets out the requirements for the design, supply, installation and testing of Tunnel power systems including:

i) the documentation requirements, as set out in section 2;

ii) the technical requirements, as set out in section 3;

iii) the control and monitoring requirements, as set out in section 4;

iv) the reliability, Design Life, and functionality safety requirements, as set out in section 5;

v) the maintainability requirements, as set up in section 6;

vi) the Hold Point and Witness Point requirements, as set out in section 7; and

vii) the verification and testing requirements, as set out in section 7.

b) For the purposes of this Master Specification Part, Tunnel power systems includes the following subsystems:

i) Tunnel high voltage (HV) power systems;

ii) Tunnel low voltage (LV) power systems;

iii) substation automation systems;

iv) Tunnel uninterruptible power supply (UPS) and battery back-up systems;

v) Tunnel earthing system and lightning protection; and

vi) Tunnel cable containment systems.

c) The objective of this Master Specification Part is the delivery of a Tunnel power system that is a safe, highly reliable, easily maintainable and low whole-of-life cost system, that implements a substation automation system to provide fast and remote monitoring and control.

d) This Master Specification Part does not apply to LV power systems outside of the Tunnel, and which are not connected to the Tunnel LV power system.

e) The design, supply, installation and testing of Tunnel power systems must comply with the Reference Documents, including:

i) AS 1055 Acoustics - Description and measurement of environmental noise;

ii) AS/NZS 1429.1 Electrical cables - Polymeric insulated, Part 1: for working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV;

iii) AS/NZS 1660 Test methods for electric cables, cords and conductors;

iv) AS 1657 Fixed platforms, walkways, stairways and ladders - Design, construction and installation;

v) AS/NZS 1768 Lightning protection;

vi) AS/NZS 1891.4 Industrial fall-arrest systems and devices, Part 4: Selection, use and maintenance;

vii) AS 1931 High voltage testing techniques;

viii) AS/NZS 2053 Conduits and fittings for electrical installations;

ix) AS 2067 Substations and high voltage installations exceeding 1 kV a.c;

x) AS 2676 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings;

xi) AS 2700 Colour standards for general purposes;

xii) AS 2832 Cathodic protection of metals;

xiii) AS 2865 Confined spaces;

xiv) AS 3000 Electrical installations (known as the Australian/New Zealand Wiring Rules);

xv) AS/NZS 3008.1.1 Electrical installations - Selection of cables, Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions;

xvi) AS 3011 Electrical installations - Secondary batteries installed in buildings;

xvii) AS/NZS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements;

xviii) AS/NZS 3017 Electrical installations - Verification by inspection and testing;

xix) AS/NZS 3100 Approval and test specification - General requirements for electrical equipment;

xx) AS/NZS 3111 Approval and test specification - Miniature overcurrent circuit-breakers;

xxi) AS/NZS 3112 Approval and test specification - Plugs and socket-outlets;

xxii) AS/NZS 3190 Approval and test specification - Residual current devices (current operated earth-leakage devices);

xxiii) AS/NZS 3808 Insulating and sheathing materials for electric cables;

xxiv) AS 3851 The calculation of short-circuit currents in three-phase a.c. systems;

xxv) AS 3996 Access covers and grates;

xxvi) AS 4070 Recommended practices for protection of low-voltage electrical installations and equipment in MEN systems from transient overvoltages;

xxvii) AS 4072 Components for the protection of openings in fire-resistant separating elements;

xxviii) AS 4296 Cable trunking systems;

xxix) AS/NZS 4507 Cables - Classification of characteristics when exposed to fire;

xxx) AS 4825 Tunnel fire safety;

xxxi) AS/NZS 4853 Electrical hazards on metallic pipelines;

xxxii) AS/NZS 5000 Electrical cables - Polymeric insulated;

xxxiii) AS 7722 EMC Management;

xxxiv) AS 2832 Cathodic protection of metals;

xxxv) AS 60038 Standard voltages;

xxxvi) AS 60076 Power transformers;

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

xxxviii) AS/NZS IEC 60754.1 Test on gases evolved during combustion of materials from cables, Part 1: Determination of the halogen acid gas content;

xxxix) AS/NZS 60947 Low-voltage switchgear and control gear;

xl) AS/NZS 61000 Electromagnetic compatibility (EMC);

xli) AS/NZS 61439 Low-voltage switchgear and control gear assemblies;

xlii) AS/NZS 61558 Safety of transformers, reactors, power supply units and combinations thereof;

xliii) AS 61800.3 Adjustable speed electrical power drive systems, Part 3: EMC requirements and specific test methods;

xliv) AS 61818 Application guide for low-voltage fuses;

xlv) AS 61869 Instrument transformers;

xlvi) AS 62040 Uninterruptible power systems (UPS);

xlvii) AS 62053.22 Electricity metering equipment - Particular requirements, Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S);

xlviii) AS 62271 High-voltage switchgear and controlgear;

xlix) AS IEC 62619 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications;

l) Department Engineering Guideline AR-EL-STD-0102 Guidelines for the Protective Provisions Relating to Electrical Earthing and Bonding for the Adelaide Metro Electrified Rail Network;

li) Department Engineering Guideline TP2-DOC-002020 Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network;

lii) IEC 60255 Measuring relays and protection equipment;

liii) IEC 60287 Electric cables - Calculation of the current rating;

liv) IEC 60834-1 Teleprotection equipment of power systems - Performance and testing - Part 1: Command systems;

lv) IEC 61243-5 Live working - Voltage detectors - Part 5: Voltage detecting systems (VDS);

lvi) IEC 61557-12 - Electrical safety in low voltage distribution systems up to 1000 V ac and 1500 V dc - Equipment for testing, measuring or monitoring protective measures - Part 12: Power metering and monitoring devices (PMD);

lvii) IEC 61850 Communication networks and systems for power utility automation;

lviii) IEC 61914 Cable cleats for electrical installations;

lix) IEC 62128-2 Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by d.c. traction systems;

lx) IEC 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;

lxi) IEEE-80 Guide for safety in AC substation grounding;

lxii) ISO 9001 Quality management systems - Requirements;

lxiii) National Electricity Network Safety Code (ENA Doc 001);

lxiv) NCC: National Construction Code;

lxv) SAPN Service & Installation Rules Manual No. 32;

lxvi) SAPN Technical Standard TS085 - Trenching and Installation of Underground Conduits and Cables (up to and including 33kV); and

lxvii) SAPN Technical Standard - TS100 Electrical Design Standard for Underground Distribution Networks (up to and including 33kV).

f) Without limiting the obligation to comply with the document to the extent they form Reference Documents in other Master Specification Parts, the following guidance documents must be considered and applied to the extent required by Law and to meet the Contractor's Best Industry Practice obligations:

   i) Energy Networks Australia ENA DOC 025-2010 (EG-0) Power System Earthing Guide; and

   ii) Energy Networks Australia ENA DOC 045-2022 (EG1) Substation earthing guide.

2 Documentation

2.1 Design Documentation

In addition to the requirements of PC-EDM1 "Design Management", the Design Documentation must include:

a) calculations to demonstrate that conductors will be operated in accordance with the Reference Documents and the requirements of section 3 taking into account:

   i) current loading (or short circuit) variations;

   ii) ambient temperature;

   iii) thermal resistivity; and

   iv) specific cable routing (e.g. cable grouping, installation within ducts and on cable ladders with appropriate spacing etc);

b) calculations to demonstrate the maximum demand of the Tunnel network under various operating modes and failure scenarios, including future provision and the effects of climate change;

c) documentation required by section 3.2.4d) resulting from the current carrying capacity studies undertaken in accordance with the requirements of IEC 60287 Electric cables - Calculation of the current rating, for all HV circuits;

d) calculations to demonstrate the sizing of battery charger systems in accordance with section 3.6;

e) the lightning risk assessment outcomes as required by section 3.7.2c);

f) details of the voltage transformers as required by section 3.2.2v);

g) details of the current transformers as required by section 3.2.2y);

h) technical studies to demonstrate the design and selection of Tunnel power system equipment:

   i) load flow study;

   ii) fault level study;

   iii) details of soil resistivity testing as required by section 3.7.1b);

   iv) earthing strategy report demonstrating compliance with the requirements of section 3.7.1c);

   v) earthing strategy report as required by section 3.7.1e);

   vi) electrolysis study, where applicable, in accordance with section 3.7.1f);

   vii) insulation coordination study;

   viii) arc flash study;

   ix) Tunnel ventilation axial fan variable speed drive (VSD) analysis in accordance with 3.3.7b);

x) power quality study in accordance with sections 3.3.6f), 3.3.10a) and 3.3.11d)ii); and

xi) details regarding the design of power circuits in association with all VSDs as required by section 3.3.6h);

i) documentation of the HV protection system including:

i) evidence of SAPN's agreement regarding the HV protection system requirements, together with the interface schedule documentation, as required by section 3.2.5c);

ii) HV protection philosophy as required by section 3.2.5f);

iii) HV protection relay datasheets as required by section 3.2.5w);

iv) HV protection logic diagrams for each intelligent electronic device (IED) as required by section 3.2.5x); and

v) HV protection study report as required by section 3.2.5y);

j) documentation of the LV protection system in accordance with 3.3.11c);

k) Design Drawings of Tunnel power system equipment:

i) single line diagram drawings of all switchboards and distribution boards;

ii) schematic diagrams of all switchboards, distribution boards and electrical panels;

iii) site equipment layout and detail drawings;

iv) switchroom equipment layout and detail drawings;

v) cable routing layout and detail drawings, including pits and conduits;

vi) earthing schematics, layout drawings and connection detail drawings; and

vii) lightning protection layout drawings and connection detail drawings;

l) documentation of in-service operation history as required by section 3.2.7a)i) and section 3.3.1c)i); and

m) environmental impact report as required by section 5.2d).

2.2 Construction Documentation

In addition to the requirements of PC-CN3 "Construction Management", the Construction Documentation must include:

a) evidence of the licences of the electrical workers as required by section 3.1a);

b) supplier Shop Drawings of all transformers, switchboards, distribution boards and electrical panels forming part of the Tunnel power systems;

c) earthing residual risks; and

d) comprehensive equipment type test certification for all HV switchgear, LV switchgear and transformers forming part of the Tunnel power systems, as required by section 8a).

2.3 Quality Management Records

In addition to the requirements of PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable), the Quality Management Records must include:

a) supplier and manufacturer quality assurance system certification for all components of the Tunnel power system;

b) electrical certificate of compliance;

c) records of all test activities completed, including those listed in sections 8a) to 8q);

d) fire rated cable penetration records as required by section 8r); and

e) digital copies for all on-site test results for the entire Tunnel power systems HV and LV power distribution network.

2.4 Operation Manual

In addition to the requirements of PC-CN2 “Asset Handover”, the Operation Manual must include a user manual for the configuration and operation of the substation automation system as required by section 3.5.1c).

3 Technical requirements

3.1 General

a) The Contractor must ensure that all electrical works for Tunnel power systems are carried out by electrical workers who are licensed to perform electrical works in accordance with the *Electrical Safety Act 1996* (SA).

b) The Tunnel power systems must be designed in accordance with the following minimum parameters:

  i) all supplied HV and LV equipment must achieve a minimum Design Life in accordance with Contract Documents; and

  ii) all supplied HV and LV equipment must be manufactured under a quality system certified to ISO 9001 Quality management systems - Requirements.

3.2 HV power system requirements

3.2.1 General

a) The HV distribution network must comply with the requirements of AS 2067 Substation and high voltage installations exceeding 1 kV a.c..

b) The HV distribution network design must be such that there is no single point of failure.

c) The HV distribution network must be designed so that for all normal and abnormal switching, a single equipment failure scenario can be tolerated without degrading or interrupting the Tunnel power system’s operation.

d) Spare space and capacity must be provided in the HV power system to allow for future upgrades or replacement, with minimum requirements as follows:

  i) the HV switchboard for incoming substations and above ground substations must include spare space for 1 additional circuit breaker tier per bus;

  ii) the HV switchboard for below ground switchrooms does not require any additional spare space for additional circuit breaker tiers;

  iii) transformers must have spare capacity of 20%;

  iv) HV cabling must have spare capacity of 20%;

  v) cable tray and cable ladder within the Tunnel must have spare capacity of 25%;

  vi) cable conduits and ducts within the Tunnel must include spare capacity for 2 additional conduits per service within the trench (including HV, LV, communications and earthing); and

  vii) conduits outside of the Tunnel must include spare capacity of 1 additional conduit per service within the trench (including HV, LV, communications and earthing).

e) Where liaising with SAPN is required in the design, installation, and commissioning processes, correspondence with SAPN must be submitted via the Principal.

3.2.2 HV switchgear

a) The HV switchgear must be designed to ensure the safety of all working personnel associated with operation and maintenance of the Tunnel power system including:

i) safety padlocking;

ii) electrical or mechanical interlocking of primary circuit breakers for isolation;

iii) preventing inadvertent access to live parts; and

iv) remote operability.

b) The HV switchgear must:

i) be of the indoor, fixed, metal-clad type containing:

A. triple pole circuit breakers;

B. disconnectors and earth switches, or 3-position disconnector earth switches;

C. current transformers (CTs);

D. voltage transformers (VTs);

E. busbars;

F. surge arresters; and

G. auxiliary equipment,

for the operation, protection, control, isolation and earthing of the HV switchgear;

ii) comply with the requirements of AS 62271 High voltage switchgear and controlgear;

iii) be metallically partitioned and include separate compartments for:

A. the circuit breaker;

B. the busbar;

C. the power cable termination; and

D. LV control and protection;

iv) be capable of being operated manually by a single person;

v) have an Internal Arc Classification of A-FLR as defined in IEC 62217-200 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;

vi) be capable of withstanding the effects of short circuits and transient events; and

vii) be capable of withstanding the derived rated capacities without any damage.

c) The HV switchgear must comply with the ratings set out in Table TUN-ME-DC2 3-1.

d) SF6 based gas insulated switchgear or circuit breakers must not be used.

e) Substations and reticulation systems must be designed to minimise the risk of internal arcs in accordance with the requirements of AS 62271 High voltage switchgear and control gear.

f) All buildings or rooms that house HV switchgear must:

i) include means for managing overpressure;

ii) retain the nominated fire separation requirements set out in this Master Specification Part; and

iii) include corridor and door widths and heights, and access paths, which accommodate access for staff, equipment access and use of trolleys for removal of the HV switchgear, including spatial provision for turning.

g) All metalwork for the HV switchgear enclosure must be suitably prepared and painted to protect it against corrosion for the Design Life of the HV switchgear.

h) A lifting facility must be provided for each HV switchgear panel or tier.

i) A proprietary test block mounted to the front panel of the LV control compartment must be provided to facilitate:

i) energising the relay from the test kit when no other direct current (DC) supply is available;

ii) secondary injection testing of the protection relays; and

iii) testing the pickup and trip output contacts from the protection relay.

j) A detection system must be provided to detect the energised state of the cable terminals.

k) The detection system required by section 3.2.2j) must:

i) comply with the requirements of IEC 61243-5 Live working - Voltage detectors - Part 5: Voltage detecting systems (VDS); and

ii) be provided on each phase.

l) For the purposes of section 3.2.2j) the use of a complying voltage detector is acceptable.

m) The detection system required by section 3.2.2j) must provide an indication on the front of the control compartment of each tier of the HV switchgear.

n) Each tier of the HV switchgear which connects to a cable must be supplied with a surge arrester.

o) Each tier of the HV switchgear must have a compartment with interlock-controlled access for power cable termination which complies with the following requirements:

i) the compartment must contain the terminals for the connection of:

A. the external power cable;

B. the line earthing switch; and

C. a line alive detection system;

ii) the terminals required by section 3.2.2o)i) must only be accessible when the line earthing switch is closed;

iii) the compartment must be suitable for the power cable to enter from below and must allow power cable termination via the front of the assembly; and

iv) a padlock (together with 2 keys) must be provided to lock the earth switch into position and prevent the position from being changed.

p) The terminals for HV cables must be suitable for the connection of a terminated insulated cable and must otherwise comply with the following requirements:

i) appropriate brackets, clamps and gland plates must be provided to adequately support the cables in the compartment so that the weight of the conductor is not taken by the terminals;

ii) the height of the terminals must allow space for the HV cable termination within the compartment; and

iii) a means must be provided for insulation and phase rotation testing of the cables.

q) The HV circuit breaker and 3-position switch must:

i) be capable of making and breaking the calculated load currents and fault currents;

ii) be capable of making and breaking the magnetising current of transformers without sustaining damage or causing excessive over-voltage;

iii) be fitted with a non-resettable mechanical operations counter;

iv) each be supplied with adequate number of normally open and normally closed auxiliary contacts for control and indication purposes;

v) each be able to be closed and opened both:

A. locally via a manual push-button; and

B. remotely; and

vi) receive an auxiliary DC supply from a local dedicated DC battery system.

r) The front of each HV switchgear tier must include a mechanical indication of:

i) the status of the HV circuit breaker; and

ii) the state of the closing spring.

s) The HV 3-position earthing and disconnector switch must:

i) be interlocked with the circuit breaker so that it cannot be operated when the circuit breaker is closed; and

ii) be interlocked to prevent the closing of earth switches on live line.

t) A 3-phase voltage transformer must be provided and connected:

i) to the busbar for the purpose of providing a voltage reference to all meters and IEDs connected to that switchboard, for protection and metering purposes; and

ii) to the cable-side of the switch or circuit breaker, where required for the protection or functionality of that HV panel.

u) Each of the 3-phase voltage transformers required by section 3.2.2t) must:

i) comply with the requirements of AS 61869 Instrument transformers;

ii) be selected with the:

A. rating and characteristics to suit connected loads (burden); and

B. accuracy requirements for the duty;

iii) have a rating plate fitted to the transformer with an identical plate be affixed within the LV control compartment so that it is readily able to be read;

iv) include transformer fuse protection for each phase on the primary side to protect the switchgear and the voltage transformer against possible faults;

v) include a LV circuit breaker on the secondary side of the VT;

vi) include the neutral connected as per the requirement of the meters and protection relays; and

vii) be wired to IEDs and meters via a proprietary test block to facilitate VT testing and protection relay injection testing.

v) The Design Documentation must include details of the sizing of the Contractor’s proposed VTs, evidencing compliance with section 3.2.2u).

w) The compartment for HV power cable terminals must be capable of housing 2 sets of protection CTs on each phase.

x) The HV switchgear CTs must:

i) comply with the requirements of AS 61869 Instrument transformers;

ii) be selected with the:

A. rating and characteristics to suit connected loads (burden);

B. primary circuit load;

C. HV switchgear fault level; and

D. accuracy requirements for the duty;

iii) be capable of withstanding a short circuit current within the primary conductors at least equal to the short circuit rating and for the short withstand time of the associated switchgear;

iv) be capable of withstanding voltages induced by open circuiting the secondary windings when rated current is maintained in the primaries;

v) be ring type, epoxy resin moulded and labelled individually;

vi) be installed in locations easily accessible for maintenance and replacement;

vii) have a saturating characteristic such that the CTs and the equipment connected to the secondaries will not suffer damage when the switchboard rated short circuit current is passing through the CT;

viii) have the polarity of the primary and secondary windings of each transformer clearly indicated on each transformer and on the lead terminal connections;

ix) be wired to IEDs and meters via a proprietary test block to facilitate CT testing and protection relay injection testing; and

x) have rating plates fitted to the transformer with an identical plate affixed within the LV control compartment so that it is easily read.

y) The Design Documentation must include details of the Contractor's proposed CTs, evidencing compliance with section 3.2.2x).

z) A minimum of 2 separate 110 V DC control voltage supplies must be provided to each HV switchboard comprising:

i) a supply for:

A. the IEDs,

B. trip circuits; and

C. control circuits; and

ii) a supply for panel indications.

aa) An anti-condensation heater must be fitted in each LV control compartment which is controlled automatically based on an adjustable thermostat within the LV control compartment.

bb) The LV control compartment of HV switchgear must comply with the following requirements:

i) the LV control compartment must contain all the LV control and protection components, excluding those that are integral to the circuit breaker cubicle;

ii) the LV control compartment be accessible via a non-lockable hinged, dustproof, sealed door;

iii) a stay must be provided to enable the door to be held in the open position;

iv) the protection relays, indication lights, test block, control switches and indicating lights must be mounted on the door to the LV control compartment;

v) the control and auxiliary wiring terminations for connection to external circuits must be located in a position inside the LV control compartment with provision for field cabling that enables easy installation and modification;

vi) all terminals must be of the positively screw secured type, incorporating terminal identification numbers;

vii) push in terminals must not be used;

viii) the HV circuit breaker and 3-position switch must:

A. be locally electrically operated by a control switch; and

B. be operable from the PMCS;

ix) interposing relays for PMCS closing and opening functions must be provided in the LV control compartment; and

x) the protection relay associated with the HV circuit breaker may be mounted on the LV control compartment door.

cc) Wiring within the LV control compartment of HV switchgear must:

i) have a minimum cross-sectional area of 2.5 mm^2 for power supply wiring;

ii) have a minimum cross-sectional area of 1.0 mm^2 for control and indication wiring;

iii) comply with the requirements of AS/NZS 5000 Electrical cables - Polymeric insulated;

iv) be sized to suit the rated current of the particular circuit;

v) be de-rated in accordance with the requirements of AS/NZS 3008.1.1 Electrical installations - Selection of cables - Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions;

vi) be flexible (using stranded copper conductors) when wiring within the control compartment and across door hinge points or similar; and

vii) utilise low smoke zero halogen (LSZH) insulation throughout.

Table TUN-ME-DC2 3-1 Tunnel HV switchgear design parameters

HV switchgear design parameter	Design
Rated voltage	As set out in the Contract Documents
Rated frequency	50 Hz
Number of phases	3
Lightning impulse withstand voltage	In accordance with the requirements of Table 3.1 of AS 2067 Substation and high voltage installations exceeding 1 kV a.c.
1 minute power frequency withstand voltage	In accordance with the requirements of Table 3.1 of AS 2067 Substation and high voltage installations exceeding 1 kV a.c.
Rated normal current of busbar	As set out in the Contract Documents
Rated short time withstand current	As set out in the Contract Documents
Busbar insulation medium	Air or gas (Sulphur hexafluoride (SF6) based gas insulation must not be used)
Class of partitions	PM as defined by IEC 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
Internal Arc Classification	Type A-FLR as defined by IEC 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

3.2.3 HV transformers

a) The HV transformers must comply with the requirements of AS 60076 Power transformers.

b) The HV transformers must satisfy the design parameters set out in Table TUN-ME-DC2 3-2.

c) The HV transformers:

   i) must, subject to section 3.2.3c)ii), be dry type HV transformers with forced air cooling;

   ii) where comprising part of an above-ground installation, may be dry type or oil insulated HV transformers;

   iii) must be able to deliver power at 20% overload above the spare capacity for a period of 2 hours in each 24 hour period; and

   iv) must apply the service conditions as set out in AS 60076 Power transformers.

d) Where oil-natural-air-natural (ONAN) type HV transformers are proposed to be implemented by the Contractor pursuant to section 3.2.3c)ii), oil containment bunds and drainage capture and oil separation facilities must also be provided.

e) Supply to the primary winding of the HV transformer must be via an appropriately rated circuit breaker.

f) The secondary winding of the HV transformer must be connected to a switchboard via an appropriately rated circuit breaker.

g) The HV transformers must include 5 output taps on the primary windings for the following range:

   i) +5.0%;

   ii) +2.5%;

   iii) 0%;

   iv) -2.5%; and

   v) -5.0%.

h) The selection of the HV transformer output tapping may be on-load or off-load.

i) The HV transformer output tap changing device must have a continuous rating of 100% of the transformer full load current.

j) The HV transformer output tap position must be selected by a manually operated selector switch lockable with a padlock.

k) The HV transformer output tap switch positions must be labelled, and be readable from a distance of 1.2 m.

l) The HV transformers must include:

   i) accessible air insulated cable boxes supplied on the primary and secondary side, suitable for the connection of an insulated cable rising from below; and

   ii) appropriate cable supports within the HV transformer enclosure such that the weight of the input cable is not taken by the electrical connections.

m) The HV transformer terminals must be suitably located to accept cables entering the HV transformer enclosure from below the HV transformer, through an appropriate non-ferrous gland plate.

n) All HV transformer internal and control wiring must:

   i) comply with the requirements of AS/NZS 3000 Wiring rules; and

   ii) have flame-retardant LSZH insulation.

o) The HV transformer frame must be directly connected to the earthing system via 2 connections on opposite sides of the HV transformer.

p) The HV transformer enclosure must:

   i) have enclosure entries connected to the main enclosure by copper earth braids;

   ii) include lifting lugs capable of lifting the gross weight of the transformer;

   iii) have a final colour coat of “light grey” as defined by AS 2700 Colour standards for general purposes (N35); and

   iv) have 1 L of touch-up paint of the same colour supplied.

q) The HV transformer rating plate must:

   i) comply with the requirements of AS 60076 Power transformers;

   ii) have the tap link connections and positions or tap changer positions clearly shown on the rating plate;

   iii) be constructed of stainless steel and must be securely riveted to the body of the transformer; and

   iv) have recorded information physically etched, embossed or engraved clearly onto the surface of the rating plate and must be highlighted with black paint.

r) Oil insulated HV transformers must:

   i) utilise less combustible liquid-insulated type with a fire point greater than 300º C;

   ii) have the oil preservation system be freely breathing or sealed type;

   iii) be naturally cooled (KNAN);

   iv) have insulating oil in accordance with the requirements of AS 60076 Power transformers;

   v) not contain any polychlorinated biphenyl; and

   vi) subject to section 3.2.3s), be equipped with:

      A. oil level and temperature gauge;

      B. winding temperature gauge or display;

      C. oil level transmitter (for connection to PMCS);

      D. oil level alarm volt-free contacts (for connection to PMCS);

      E. oil level trip volt-free contacts (for connection to protection IED);

      F. oil temperature transmitter (for connection to PMCS);

      G. oil temperature alarm volt-free contacts (for connection to PMCS);

      H. oil temperature trip volt-free contacts (for connection to protection IED);

      I. winding temperature transmitter (for connection to PMCS);

      J. winding temperature alarm volt-free contacts (for connection to PMCS);

      K. winding temperature trip volt-free contacts (for connection to protection IED);

      L. drain valve 25 mm nominal bore pipe thread with flanged plug;

      M. oil filling hole and cap;

      N. breathing device of weatherproof type, which may also be used as a filling hole; and

O. thermometer pocket.

s) Fully sealed oil type HV transformers may exclude the following requirements of section 3.2.3r)vi):

i) the oil level gauge required by section 3.2.3r)vi)A; and

ii) the thermometer pocket required by section 3.2.3r)vi)O.

t) Dry type HV transformers must be equipped with:

i) forced air cooling fan thermostatic controller, including display and high-level interface to PMCS;

ii) winding temperature with analogue output (for connection to PMCS);

iii) winding temperature alarm volt-free contacts (for connection to PMCS); and

iv) winding temperature trip volt-free contacts (for connection to protection IED).

Table TUN-ME-DC2 3-2 HV transformer design parameters

HV transformer design parameter	Value
Transformer type (3 different types)	As set out in the Contract Documents
Number of phases	3
Rated primary voltage	As set out in the Contract Documents
Rated secondary voltage	400 V a.c. rms and/or 690 V a.c. rms as required
Rated power	As set out in the Contract Documents
Rated frequency	50 Hz
Primary winding highest voltage for equipment	As required by table 3.1 of AS 2067 Substation and high voltage installations exceeding 1kV a.c
Secondary winding highest voltage for equipment	<1.1 kV
Impedance	To be determined by the Contractor
Lightning impulse level - primary	In accordance with AS 2067 Substation and high voltage installations exceeding 1kV a.c.

3.2.4 HV cabling

a) HV cables must comply with the requirements of this section 3.2.4 and section 3.4.

b) The HV power system reticulation design must be optimised for the distribution within the Tunnel, and must take account of:

i) HV cable size;

ii) HV cable bending radius;

iii) segregation and fire separation requirements set out in this Master Specification Part; and

iv) HV cable rating requirements.

c) The HV power feeder reticulation within the public domain must:

i) be underground cables installed in conduits, in accordance with the requirements of section 3.4.1;

ii) comply with the design and installation requirements of SAPN Technical Standard TS085 - Trenching and Installation of Underground Conduits and Cables (up to and including 33kV);

iii) comply with the design and installation requirements of SAPN Technical Standard - TS100 Electrical Design Standard for Underground Distribution Networks (up to and including 33kV);

iv) be provided with marker tape and a mechanical protection system in accordance with the requirements of section 3.4.1e)iii); and

v) be provided with cable access pits in accordance with the requirements of section 3.8.

d) The Contractor must ensure that current carrying capacity studies are undertaken in accordance with the requirements of IEC 60287 Electric cables for all HV circuits and the resulting report submitted to the Principal as part of the Design Documentation.

e) HV cable routing systems must be designed to minimise the de-rating of cable systems.

f) Where redundant A and B HV circuits are utilised, the A and B circuits must:

i) comply with the fire resistance requirements of TUN-FIRE-DC3 "Tunnel Fire Engineering"; and

ii) be provided with a horizontal separation of no less than 2 m except for where they may enter a common switchboard.

g) HV cables in the Tunnel carriageways must be LSZH.

3.2.5 HV protection systems

a) The Contractor must develop a comprehensive HV protection system in compliance with:

i) Appendix F of AS 2067 Substation and high voltage installations exceeding 1kV a.c.; and

ii) the technical requirements of IEC 61850 Communication networks and systems for power utility automation,

to provide for the safety of operations personnel, Tunnel users and equipment.

b) The Contractor must coordinate and interface with SAPN to:

i) agree and implement the required HV protection functions, interfaces and equipment;

ii) agree and implement any interlocking and inter-tripping required;

iii) agree and implement any switchgear status, CT and VT signal interfaces required; and

iv) agree and document the interface schedule for the matters required by this section 3.2.5b).

c) Evidence of SAPN's agreement as required by section 3.2.5b), together with the interface schedule documented pursuant to section 3.2.5b)iv), must form part of the Design Documentation.

d) Redundant communication paths must be provided for the interfaces between the Tunnel HV distribution network protection devices and the SAPN substation and integration with PMCS.

e) Signage in accordance with relevant electricity supply Laws must be provided along the HV cable route and termination points at both ends and throughout all HV switchrooms.

f) An HV protection philosophy must be submitted to the Principal as part of the Design Documentation which addresses:

i) protection functions implemented;

ii) protection coverage;

iii) protection scheme operating times;

iv) protection coordination and sensitivity;

v) trip circuit and trip supply monitoring;

vi) interlocking and inter-trips;

vii) network and communications;

viii) disturbance recording;

ix) CT and VT monitoring; and

x) CT and VT sizing.

g) HV cables that form part of the HV (open) ring or twin radial feeder network for the Tunnel, including the interconnectors between Tunnels, must be protected via a differential current protection scheme.

h) HV switchboards must be protected via a busbar differential current protection scheme, which overlaps with the cable differential protection.

i) The HV cable and busbar differential protection zones must trip only the equipment within the faulted zone.

j) Incoming HV feeders from SAPN network must include:

i) overcurrent and short circuit protection;

ii) earth fault protection; and

iii) any additional protection functions required by SAPN as part of the connection agreement.

k) HV interconnectors and outgoing HV feeders from the intake substation must include:

i) overcurrent and short circuit protection;

ii) earth fault protection; and

iii) cable differential protection.

l) Feeders to HV transformers must include the following protection functions:

i) overcurrent and short circuit protection;

ii) earth fault protection; and

iii) transformer trip inputs.

m) The HV protection system design must include IEDs:

i) which satisfy the requirements of IEC 61850 Communication networks and systems for power utility automation;

ii) which are fully configured, including event recording, LED mapping, alarm and event messaging, labelling and circuit breaker condition monitoring; and

iii) that are interoperable with other IEDs.

n) The Contractor must undertake testing to demonstrate the interoperability of the IEDs as required by section 3.2.5m).

o) The HV protection system design must include a high-speed dedicate data communications network which:

i) complies with the requirements of IEC 61850 Communication networks and systems for power utility automation; and

ii) links all IED’s across all substations forming part of the Tunnel power systems.

p) The HV protection system must detect fault conditions including:

i) 3-phase symmetrical faults;

ii) phase to phase faults;

iii) phase to phase to earth faults; and

iv) single phase to earth faults.

q) The protection for the HV and LV equipment forming part of the Tunnel power systems must be designed to grade and in the event of a fault, to isolate the minimum possible connected electrical equipment. Where possible, the protection system must disconnect only the failed or faulted equipment.

r) The HV protection system's fault clearance time must be as short as possible and be short enough to ensure:

  i) the safety of personnel and Tunnel users;

  ii) the rest of the Tunnel HV power supply network continues to operate without interruption or supply dip, so that the remaining connected electrical equipment continues to function as required by the Contract Documents; and

  iii) energy released as a result of the fault is minimised, protecting personnel, plant and equipment so far as is reasonably practicable and in accordance with the Reference Documents.

s) The HV protection system must communicate fault information to recording, monitoring and control systems both locally at the IED and remotely to the PMCS to facilitate either automatic or manual restoration of power in a timely manner.

t) IEDs must be used for HV protection relays with a watchdog contact provided.

u) For the purposes of section 3.2.5t):

  i) electromechanical and solid-state protection relays must not be used;

  ii) electromechanical auxiliary relays are acceptable; and

  iii) microprocessor-based protection relays with programmable software-based protection algorithms and with network capability in accordance with section 3.2.5m) must be used.

v) Facilities to permit maintenance to be carried out safely must be provided for all HV protection schemes.

w) HV protection relay datasheets must be submitted to the Principal as part of the Design Documentation and must include:

  i) relay make and model and part number;

  ii) communications configuration;

  iii) manufacturing message specification (MMS) analogue and digital signals;

  iv) generic object oriented substation event (GOOSE) mapping between IEDs; and

  v) evidence of compliance with the requirements of this Master Specification Part on a section-by-section basis.

x) HV protection logic diagrams for each IED must be submitted to the Principal as part of the Design Documentation and must include:

  i) IED inputs;

  ii) IED outputs; and

  iii) IED internal logic.

y) An HV protection study report must be submitted to the Principal as part of the Design Documentation and must include:

  i) input data, equipment ratings;

  ii) earthing arrangements;

  iii) model details;

  iv) short circuit calculations;

v) overcurrent and earth fault grading margins;

vi) protection setting calculations; and

vii) relay settings and configuration specific to the relay make and model.

z) The Testing and Commissioning Management Plan developed in accordance with PC-CN1 “Testing and Commissioning” must include the following HV protection tests:

i) off-site and on-site works;

ii) CT analyser tests;

iii) CT primary injection;

iv) VT primary injection testing;

v) relay secondary injection testing;

vi) relay logic and input/output testing;

vii) primary injection for current differential in-zone and out-of-zone stability testing;

viii) metering testing; and

ix) inter-trip and interlock testing.

3.2.6 HV power metering

a) HV power metering must be provided and integrated with the PMCS, providing the following functionality:

i) power consumption and instantaneous load for each HV switchboard tier of a main incomer substation including:

A. energy consumption (totalised);

B. peak or maximum power demand; and

C. real-time power, voltage, current, power factor, and frequency; and

ii) power quality monitoring with following data at each high voltage substation:

A. harmonic distortion;

B. voltage sag and swell; and

C. voltage and current waveform capture.

b) Power metering accuracy for the main HV incomer from the SAPN network must conform to the following requirements:

i) active energy metering must comply with the requirements of class 0.2 S of AS 62053.22 Electricity metering equipment - Particular requirements, Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S);

ii) active power metering must comply with the requirements of class 0.2 of IEC 61557-12 Electrical safety in low voltage distribution systems up to 1000 V ac and 1500 V dc - Equipment for testing, measuring or monitoring protective measures - Part 12: Power metering and monitoring devices (PMD);

iii) voltage, current, and power factor metering must comply with the requirements of class 0.2 of IEC 61557-12 Electrical safety in low voltage distribution systems up to 1000 V ac and 1500 V dc - Equipment for testing, measuring or monitoring protective measures - Part 12: Power metering and monitoring devices (PMD); and

iv) power quality metering must comply with the requirements of class A of AS 61000.4.30 Electromagnetic compatibility (EMC) Testing and measurement techniques - Power quality measurement methods.

c) Power metering accuracy for all HV energy meters other than those required by section 3.2.6b) must comply with the requirements of class 0.5 S of AS 62053.22 Electricity metering equipment - Particular requirements, Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S).

3.2.7 HV equipment supply and installation

a) All HV power equipment proposed for inclusion as part of the Tunnel power system must:

   i) have a proven satisfactory in-service operation of similar equipment in road Tunnels or similar environments for a minimum period of 10 years (evidence of which must be included as part of the Design Documentation); and

   ii) be capable of operating at full power, without any limitation or restriction of performance or functionality across the full range of ambient conditions.

b) All HV cables must be installed in accordance with manufacturer recommendations, including for:

   i) bending radius;

   ii) pulling tension; and

   iii) environmental conditions.

c) HV cables must be provided with fire separation that complies with TUN-FIRE-DC3 “Tunnel Fire Engineering”.

d) HV cable screens must be solidly bonded to earth at both ends.

e) HV route markers must be provided for underground installations at regular intervals, and at each change of direction, and either side of each road crossing.

f) HV cable joints and HV terminations must be performed by a certified cable jointer and be undertaken in accordance with the instructions of both the cable manufacturer and the relevant equipment manufacturer.

g) HV cable lengths must be maximised to minimise the amount of intermediate cable joints.

h) Where HV cable joints are utilised, they must be:

   i) installed so as to be readily accessible for maintenance;

   ii) installed in a location that will achieve a dry condition; and

   iii) available for inspection or replacement as required.

i) Oil filled HV transformers must be installed in self-bunded kiosks enclosures, or within concrete bunds in accordance with AS 2067 Substation and high voltage installations exceeding 1kV a.c.

3.3 LV power system requirements

3.3.1 General

a) The Tunnel LV reticulation system must be designed to ensure the safety of Tunnel users and all personnel associated with the operation and maintenance of electrical equipment.

b) The Tunnel LV power system design must be optimised for efficient energy distribution within the Tunnels and must take account of:

   i) current carrying capacity;

   ii) fault and earth loop impedance levels;

   iii) specified fire rating and survivability; and

   iv) limitation of functional loss should a failure event occur.

c) All LV equipment proposed to be implemented by the Contractor must:

i) have a proven satisfactory in-service operation of similar equipment in road Tunnels or similar environments for a minimum period of 10 years (evidence of which must be included as part of the Design Documentation); and

ii) be capable of operating at full power, including spare capacity provision, without any limitation or restriction of performance or functionality across the full range of ambient conditions.

d) Spare space and capacity must be provided to allow for future upgrades or replacement as follows:

i) LV switchboards and distribution boards must have spare capacity of 20%, noting that the spare capacity must not be accumulated in the calculation of upstream equipment spare capacity;

ii) LV switchboard and distribution board: spare space of 20%;

iii) submains cabling must have spare capacity of 20%, noting that this spare capacity must not be carried into the calculation for upstream equipment to avoid accumulation of the additional capacity;

iv) cable trays within Tunnels must have spare space of 25%;

v) trunk cable routes must have a minimum of one spare LV conduit and one spare communications conduit in accordance with RD-EL-D3 “Conduit Design for Road Lighting, Traffic Signals and ITS” along the entire length of the cable route;

vi) conduits outside of the Tunnel must have a minimum of one spare conduit for HV cables within each conduit trench in addition to the spare LV and communications conduit requirements of RD-EL-D3 “Conduit Design for Road Lighting, Traffic Signals and ITS”; and

vii) UPS must have spare capacity of 20%.

e) The Tunnel LV power system must be designed in accordance with the parameters listed in Table TUN-ME-DC2 3-3.

Table TUN-ME-DC2 3-3 Tunnel LV system design parameters

LV system design parameter	Value
Nominal system voltage	a) 3-Phase: 400 V +10% / -6% b) 3-Phase: 690 V +10% / -6% optional voltage for Tunnel ventilation plant c) Single-Phase: 230 V +10% / -6%
Standard system frequency	50 Hz
Earthing system	M.E.N System (TN-C-S)
Power factor limit	PF ≥0.9
Total voltage harmonic distortion limit	THD ≤6.5%

3.3.2 LV network structure

a) LV equipment or switchrooms supplying separate Tunnel bores must be provided with fire separation in accordance with TUN-FIRE-DC3 “Tunnel Fire Engineering”.

b) Final subcircuits for lighting, ventilation, ITS, CCTV, and automatic incident detection (AID) cameras and other similar Tunnel electrical equipment must be interleaved such that the failure of one distribution board or one main switchboard does not result in the complete loss of the services within a LV distribution section.

3.3.3 LV electrical panel general requirements

a) Wiring within switchboards, distribution boards and electrical panels must:

i) have a minimum cross-sectional area of 2.5 mm² for power supply wiring;

ii) have a minimum cross-sectional area of 1.0 mm² for control and indication wiring;

iii) utilise insulation throughout;

iv) be sized to suit the rated current of the particular circuit;

v) be de-rated in accordance with AS/NZS 3008.1.1 Electrical installations - Selection of cables - Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions;

vi) have only one wire connected to each terminal; and

vii) use proprietary bonding links for parallel connections between adjacent terminals.

b) Push in terminals must not be used.

c) All terminals must:

i) be of the positively screw secured type; and

ii) incorporate terminal identification numbers.

d) The maximum height of functional units in switchboards and distribution boards must be no greater than 1.8 m from the floor.

e) Switchboards and distribution boards must have external colour “X15 orange” in accordance with AS 2700 Colour standard for general purposes.

f) Switchboard and distribution board mounting plates and escutcheons must be coloured “RAL9003 signal white” in accordance with AS 2700 Colour standard for general purposes.

g) Electrical control panels must have external colour “RAL7035 light grey” in accordance with AS 2700 Colour standard for general purposes.

h) Electrical control panel mounting plates must be coloured “RAL9003 signal white” in accordance with AS 2700 Colour standard for general purposes.

3.3.4 LV main switchboards and motor control centres

a) LV main switchboards and MCCs must:

i) be Form 3B modular fully type-tested switchboards compliant with the requirements of:

A. AS/NZS 61439 Low-voltage switchgear and control gear assemblies; and

B. AS/NZS 3000 Wiring Rules for internal arc containment;

ii) have an internal ingress protection rating of IP2X, in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code);

iii) be floor standing assemblies;

iv) include a control section within the panel for PMCS equipment to allow for controls wiring and testing to be completed prior to installation on site;

v) be extendable with drilled holes in busbar to facilitate any possible extension;

vi) be provided with a steel plinth suitable for lifting either by:

A. slinging around lifting bars inserted through the plinth; or

B. forklift pockets integral to the base;

vii) be provided with arc detection incorporated into the line-side and load side of incomer circuit breakers as well as bus-zones;

viii) be constructed such that it is possible to close and lock the panel door when the air circuit breaker (ACB) is in the fully racked out position;

ix) be constructed such that LV functional unit doors are interlocked and cannot be opened unless the moulded case circuit breaker (MCCB) is open;

x) be constructed such that all doors are lockable with padlock;

xi) have PMCS equipment installed within the LV main switchboard, where practical, to allow for off-site assembly and testing and the minimisation of on-site termination and testing works; and

xii) have gland plates sized to accommodate the total number of installed cables and spare circuits.

b) A break-before-make automatic transfer switch (ATS) must be provided for each of the LV main switchboards to provide changeover of upstream supply between the A circuit and B circuit in the event of the failure of either.

c) The ATS required by section 3.3.4b) must be able to be monitored and controlled via the PMCS.

d) All outgoing circuits of LV main switchboards must be protected by MCCBs.

e) Where fans or motors are required to operate in both forward and reverse, and are not supplied via a VSD, the motor starting circuit must incorporate a phase-inversion contactor and control.

f) The main switchboard and MCC gland plates required by section 3.3.4a)xii) must:

i) be non-ferrous metal material with thickness not less than 6 mm;

ii) be bonded to the main switchboard or motor control centre earth bar with a copper conductor of cross-sectional area not less than 6 mm^2;

iii) be fitted with glands suitably sized for the holes; and

iv) have any unused holes to be plugged with suitably sized and secured blanking plugs.

3.3.5 LV distribution boards

a) The LV distribution boards must:

i) be Form 2B modular switchboards compliant with the requirements of:

A. AS/NZS 61439 Low-voltage switchgear and control gear assemblies;

B. AS/NZS 61439.1 Low-voltage switchgear and control gear assemblies - General rules (Appendix ZC & ZD); and

C. AS/NZS 3000 Wiring Rules for internal arc containment;

ii) achieve an IP2X internal ingress protection rating, in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code);

iii) be constructed with bottom cable entry and exit. Top exit for final subcircuits is permitted if the LV distribution board is within a switchroom with a structural adequacy, separating integrity and insulation rating for a time period of no less than 120 minutes (120/120/120) when tested against the standard time vs temperature curve defined in AS1530.4 Methods for fire tests on building materials, components and structures, Part 4: Fire-resistance tests for elements of construction;

iv) have gland plates and cable connections sized to accommodate the installed cables;

v) have a main switch which can be locked in the open position using a padlock; and

vi) have doors that can be locked with a padlock.

b) The LV distribution board doors required by section 3.3.5a)vi) must:

i) be fitted with 316 stainless steel hardware;

ii) for doors less than 900 mm high, be provided with provided with 2-point locking at the door top and door bottom;

iii) for doors of a height equal to or greater than 900 mm, be provided with provided with 3-point locking at the door top, door centre and door bottom;

iv) be mechanically secured when in the open position at 90^{o} degrees and 140^{o} degrees from their closed position via a captive non-sliding mechanism; and

v) be bonded to the LV distribution board panel enclosure with a copper conductor of cross-sectional area not less than 6 mm².

c) The LV distribution board gland plates required by section 3.3.5a)iv) must:

i) be at least 3 mm aluminium;

ii) be bonded to the LV distribution board panel enclosure earth bar with a copper conductor of cross-sectional area not less than 6 mm²; and

iii) be fitted with glands suitably sized for the holes, with any unused hols to be plugged with suitably sized and secured blanking plugs.

3.3.6 Soft starters and variable speed drives

a) VSDs or soft-starters must be provided for the following electrical equipment to limit electro-mechanical stress during start-up:

i) ventilation jet fans;

ii) motors greater than 20 kW; and

iii) sump pumps.

b) Thermistors providing overload detection must be provided for all motors greater than 20 kW.

c) VSDs and soft starters must be integrated with the PMCS for control and monitoring.

d) VSDs must be provided with reverse direction operation where required.

e) Vitiated Tunnel air must not be used for cooling of VSDs or soft starters.

f) The design associated with all VSD circuits must address the following factors, unambiguously demonstrating that the power system as an integrated whole will function for the Design Life duration with no detriment to motor reliability or availability, including:

i) the specification of the type of low harmonic technology being used for the proposed variable speed drives;

ii) installation instructions and technical advice from the VSD manufacturer;

iii) harmonic effects on the motor and reflected into the LV network;

iv) analysis of any residual VSD generated resonance and coupled cable inductance, and capacitance, confirming no risk to motor reliability and availability for the Design Life duration;

v) electrical insulation level, current carrying capacity, fault withstand rating and thermal capacity; and

vi) limitation of electromagnetic interference emissions.

g) Screened VSD cabling must be used for VSD circuits.

h) The Design Documentation must include details of the VSD circuit design as required by section 3.3.6f).

i) The VSDs must be of dedicated low harmonic type using either an active front end or shunt active filter technology.

j) Low harmonic VSDs utilising passive filters in series must not be used.

k) VSDs and soft starters must be fully configured for the specific equipment that they are connected to, including input of the specific motor parameters, automatic tuning of motor control and equipment condition monitoring.

l) All VSDs must be from the same series, type and manufacturer with a common operator keypad and display mounted on the front panels of the VSD enclosure or where installed within a MCC, on the front panel of that motor control centre.

m) Where installed within an MCC the VSD human machine interface (HMI) must be mounted on the MCC door ensuring the MCC enclosure retains the specified ingress protection rating set out in section 3.9.2.

n) The VSD cabling zones must be dimensioned to ensure that the selected submain cabling terminations and bending radii can be readily accommodated.

3.3.7 Variable speed drives for Tunnel ventilation axial fans

a) VSDs must be provided for the Tunnel ventilation axial fans.

b) The design of the power system associated the Tunnel ventilation axial fans VSD must be subject to extensive design analysis and modelling to ensure that no condition may occur that could potentially lead to the premature failure of the motor under control.

3.3.8 LV power metering

a) LV power metering must be integrated with the PMCS for monitoring and analysis.

b) LV power metering must include the following functionality:

  i) power consumption and instantaneous load for each main LV switchboard, distribution boards and MCCs, including:

    A. energy consumption (totalised);

    B. peak or maximum power demand; and

    C. real-time power, voltage, current, power factor, and frequency; and

  ii) power quality monitoring with following data at each low voltage main switchboard:

    A. harmonic distortion;

    B. voltage sag and swell; and

    C. voltage and current waveform capture.

c) Metering accuracy for a main LV switchboard must comply with the following requirements:

  i) active energy metering must comply with the requirements of class 0.2s of AS 62053.22 Electricity metering equipment - Particular requirements, Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S);

  ii) active power metering must comply with the requirements of class 0.2 of IEC 61557-12 Electrical safety in low voltage distribution systems up to 1000 V ac and 1500 V dc - Equipment for testing, measuring or monitoring protective measures - Part 12: Power metering and monitoring devices (PMD);

  iii) voltage, current, and power factor metering must comply with the requirements of class 0.2 of IEC 61557-12 Electrical safety in low voltage distribution systems up to 1000 V ac and 1500 V dc - Equipment for testing, measuring or monitoring protective measures - Part 12: Power metering and monitoring devices (PMD); and

  iv) power quality metering must comply with the requirements of class A of AS 61000.4.30 Electromagnetic compatibility (EMC) Testing and measurement techniques - Power quality measurement methods.

d) Metering accuracy for all LV energy meters other than those required by section 3.3.8c), must be a minimum of class 0.5 S of AS 62053.22 Electricity metering equipment - Particular requirements, Part 22: Static meters for AC active energy (classes 0.1S, 0.2S and 0.5S).

3.3.9 LV cabling

a) LV cables must comply with the requirements of this sections 3.3.9 and section 3.4.

b) LV cables must not be jointed.

c) All LV cables must comply with the requirements of:

   i) AS/NZS 3000 Wiring Rules; and

   ii) AS3008.1.1 Electrical installations - Selection of cables - Cables for alternating voltages up to and including 0.6/1 kV - Typical Australian installation conditions.

d) LV cabling between VSDs and motors must:

   i) be screened; and

   ii) low capacitance type intended for VSD applications.

e) For fire exposed locations within the Tunnel:

   i) LV cables must be WS52W fire rated in accordance with the requirements of AS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements; and

   ii) multi-core controls, communications and proprietary cabling must be LSZH.

f) LV cables which are fire separated in accordance with Master Specification Part TUN-FIRE-DC3 “Tunnel Fire Engineering” from the Tunnel carriageways throughout their entire length must be LSZH.

3.3.10 LV power quality treatment

a) Harmonic filters and power factor correction equipment must be provided as determined in the power quality study required by this Master Specification Part to meet:

   i) AS 61000 Electromagnetic compatibility (EMC);

   ii) equipment requirements; and

   iii) the requirements of SAPN at the point of connection.

b) Active harmonic filtering must be provided to manage harmonic distortion.

c) Power quality systems must integrate with the PMCS via high level interface.

3.3.11 LV electrical protection

a) LV overcurrent protection must be provided for all circuits, in accordance with the requirements of AS/NZS 3000 Wiring Rules.

b) LV overcurrent and earth fault protection must be provided on the incoming submain cable to main LV switchboards This may be achieved either via a protection device integral to the ACB, or via an IED connected to the IEC 61850 Communication networks and systems for power utility automation network and PMCS.

c) Grading and discrimination between devices must be achieved in accordance with the requirements of AS/NZS 3000 Wiring Rules and evidence included as part of the Design Documentation.

d) Surge protection devices (SPDs) must be provided:

   i) on LV switchboards;

   ii) on LV distribution boards as determined by the Contractor’s design; and

iii) with filters provided as determined by the Contractor's design.

e) Overcurrent protection must be provided to the SPDs in accordance with the manufacturer's requirements.

f) The overcurrent protection for SPDs required by section 3.3.11e) must be provided with a fault withstand rating not less than the maximum surge current rating of the protected SPD.

g) SPDs must integrate with the PMCS for monitoring.

h) Arc-fault detection and protection devices must be provided:

i) on main LV switchboards; and

ii) where necessary to limit the requirement for arc-rated clothing and personal protective equipment to category II or lower as required by the National Electricity Network Safety Code (ENA Doc 001).

i) Residual current device (RCD) protection must be provided in accordance with the requirements of AS/NZS 3000 Wiring Rules except on circuits where failure is considered to pose a more significant risk than electrocution, including:

i) Tunnel ventilation plant and equipment (including egress passageway pressurisation fans and dampers);

ii) Tunnel carriageway and egress lighting;

iii) building heating, ventilation and air-conditioning;

iv) electrical supplies related to fire detection and suppression systems and capabilities;

v) Tunnel security and access control system;

vi) PMCS equipment;

vii) Traffic Monitoring and Control System (TMCS) equipment;

viii) CCTV and AID cameras; and

ix) control and communication equipment associated with the systems and items of equipment as listed in 3.3.11i)i) to 3.3.11i)viii).

j) RCD protection must not be shared across multiple circuits.

k) ACBs must:

i) be equipped with an integral electronic trip unit;

ii) be withdrawable whilst the panels doors are closed;

iii) provide access to the ACB local open push-button, close push-button and integral protection device, whilst in the service position, test position and racked out position;

iv) provide positive indication of isolation status;

v) be lockable in the OFF/OPEN position;

vi) be lockable in the fully racked out position. In this position it must be possible for the switchboard door to be closed and locked; and

vii) controlled and monitored on PMCS.

l) MCCBs must:

i) be equipped with an integral electronic trip unit;

ii) provide positive indication of isolation status;

iii) be lockable in the OFF/OPEN position; and

iv) controlled and monitored on PMCS.

3.4 Cables

3.4.1 General

a) Cable routes must facilitate ease of maintenance and replacement.

b) Electrical assets and cabling must be designed and placed strategically to ensure volt drop limitations are not exceeded.

c) Cables must be installed in containment and not direct buried in ground.

d) Polyvinyl chloride (PVC) insulation, cabling or cable containment must not be used within the Tunnel.

e) Power cables must be:

  i) copper material;

  ii) continuously supported over their entire length by a cable containment and support system;

  iii) labelled at:

    A. terminations;

    B. joints;

    C. entry and exit from equipment; and

    D. in all pits; and

  iv) labelled at regular intervals along the cable route, where un-enclosed.

3.4.2 Cable installation

a) Cables must be installed in accordance with cable manufacturer’s specifications.

b) The minimum cable bending radii must not be exceeded during:

  i) storage prior to and during installation; and

  ii) all stages of installation.

c) Cables must:

  i) be laid and fixed in such a way to avoid any damage to their insulation and or sheathing;

  ii) not be laid over protruding edges, bent or twisted in such a way to cause damage to the cables; and

  iii) be appropriately secured to prevent their movement.

d) Cable pulling tensions must not exceed the cable manufacturer’s limit during installation including:

  i) all cable installation works must be planned with prior estimation of maximum anticipated tension; and

  ii) monitoring the tension during the pull.

e) Cable penetrations into or through fire-rated walls and surfaces must comply with the requirements of TUN-FIRE-DC3 “Tunnel Fire Engineering”.

f) Cable installation roller locations must be:

  i) subject to prior pre-planning; and

  ii) secured to ensure that detachment or movement whilst under load cannot occur.

g) Cable installation lubricants to be used when installing cables in conduits must be:

i) environmentally inert;

ii) water soluble; and

iii) unable to result in the long-term deterioration of either the cable or the cable containment system.

3.5 Substation automation system

3.5.1 Functional requirements

a) The substation automation system must:

i) provide an IEC 61850 Communications Network and Systems compliant network for the power utility automation system that:

A. utilises optical fibre and structured copper cabling between IEDs;

B. provides physically separate dedicated network devices and fibre cores; and

C. provides fully coordinated substation automation when integrated with the over-arching PMCS;

ii) enable the coordinated (automatic and manual) switching of the fault tolerant HV distribution network to recover supply under all foreseeable fault conditions;

iii) include provision for the future stages or expansion of the Tunnel HV distribution network;

iv) monitor the operational condition of the substation equipment;

v) include a detailed interface definition to the PMCS, providing fault alarms and operator interface via the SCADA system;

vi) include equipment monitoring to record and report following parameters:

A. monitoring the operational condition of transformers, switchgear, and control equipment;

B. transformer thermal monitoring;

C. trending and monitoring of power quality, instantaneous and maximum power demand and energy consumption; and

D. equipment failure and distribution network faults;

vii) include automatic fault recovery switching;

viii) include inter-tripping between IEDs for current differential and circuit-breaker fail trips;

ix) include inter-locking between IEDs to prevent paralleling any of the HV supplies; and

x) include an operator button on or adjacent the IED to inhibit inter-trips during testing.

b) The substation automation system components must be connected and synchronised to a master global positioning system (GPS), to allow sequence of events analysis.

c) A user manual must be provided to detail the configuration and operation of the substation automation system as part of the Operation Manual.

3.5.2 Performance requirements

a) The substation automation network message transfer time between IEDs must not exceed the limits described in IEC 61850-5 Communication networks and systems for power utility automation - Part 5: Communication requirements for functions and device models.

b) The fault clearance time of the substation automation protection system must not exceed the limits set out in IEC 60834-1 Teleprotection equipment of power systems - Performance and testing - Part 1: Command systems.

c) The substation automation system communication network must be a high-availability seamless redundancy or parallel redundancy protocol arrangement as set out in IEC 61850-3 Communication networks and systems for power utility automation - Part 3: General requirements.

3.6 Uninterruptible power supply and battery systems

a) A 110 V DC battery and battery charger system must be provided in each HV switchroom and supply the following loads:

   i) HV switchgear trip, control and indication circuits;

   ii) protection IEDs;

   iii) IEC 61850 Communication networks and systems for power utility automation network switches; and

   iv) PMCS control circuits and PLC/Remote IO equipment via local DC conversion to 24 V DC within the respective PMCS panel.

b) Each 110 V DC battery system required by section 3.6a) must comprise:

   i) a battery charger;

   ii) a battery bank; and

   iii) a distribution board.

c) Each 110 V DC battery bank and battery charger required by section 3.6b) must be sized to supply both switchroom A and switchroom B DC loads in the event of one being unavailable.

d) Each 110 V DC distribution board required by section 3.6b) must be able to be supplied from either switchroom A or switchroom B battery charger via switch that provides bump-less transfer.

e) Each 110 V DC system battery size and duty must be rated for 10 hrs operation following the loss of mains power supply.

f) 230V AC and 400V AC UPS must comply with the requirement of AS/IEC 62040 Uninterruptible power systems (UPS).

g) A 230 V AC or 400 V AC UPS must be provided in each LV switchroom and supply loads, including:

   i) PMCS equipment, other than the HV and protection equipment noted in section 3.6a) as being supplied by the 110 V DC system;

   ii) ITS equipment;

   iii) Tunnel closure system;

   iv) Tunnel ITS, CCTV and AID equipment;

   v) RRB system;

   vi) PA system;

   vii) Tunnel data communications systems;

   viii) Tunnel emergency telephone system;

   ix) Tunnel maintenance telephone system;

   x) Tunnel carriageway lighting at emergency lighting level;

   xi) egress passageway lighting at normal operation lighting level;

   xii) building services lighting in electrical equipment rooms at emergency lighting level;

   xiii) egress directional signage and associated lighting control; and

xiv) lighting control equipment.

h) Each UPS system must include:

i) a static bypass;

ii) an external maintenance bypass switch;

iii) a UPS enclosure;

iv) a battery bank; and

v) a distribution board.

i) Each UPS system battery size and duty must be rated for 4 hrs operation following the loss of mains power supply.

j) A dedicated mechanical external maintenance bypass switch must be provided to each UPS system to provide no load-break bypass and safe isolation for maintenance or replacement purposes.

k) The static bypass within the UPS system required by section 3.6h)i) must not be relied upon for maintenance isolation purposes required by section 3.6j).

l) The UPS system must have high efficiency mode that utilises the internal static bypass to reduce energy consumption and cooling demand when the mains power supply parameters are within the range of LV distribution design criteria.

m) The UPS system must be capable of automatically switching back to double conversion mode when the mains power quality deteriorates.

n) The reliability value of the UPS system in high efficiency mode must be not less than that in double conversion mode.

o) The UPS system must include:

i) modular construction with capability to accept future installation of additional battery capacity;

ii) double conversion topology that satisfy VFI-SS-111 performance class in accordance with AS/IEC 62040 Uninterruptible power systems (UPS) with energy efficient mode;

iii) double conversion mode efficiency not less than 96% at full load;

iv) energy efficient mode efficiency not less than 98% at full load; and

v) energy efficient mode transfer time not more than 2 ms.

p) Battery enclosures must be ventilated in accordance with the requirements of AS 2676 Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings.

q) DC battery system chargers and UPS systems must provide:

i) fault detection and alarms;

ii) a high-level interface to the PMCS; and

iii) system management software which enables remote trouble shooting and diagnostics.

r) The battery system DC chargers, UPS and battery enclosures must allow for maintenance and battery replacement to be undertaken without power interruption to the load.

s) Commonality in UPS and DC battery system charger supplier and manufacturer must be ensured as far as reasonably practicable.

t) The battery system DC chargers, UPS and battery enclosures must be housed in air-conditioned rooms at temperatures to meet the requirements of the relevant supplier and manufacturer for the Design Life of that equipment.

u) Vitiate Tunnel air must not be used for cooling the battery system chargers, UPS or battery enclosures.

v) UPS and DC battery systems must be installed in rooms provided with multi-point aspirated smoke detection and inert gas fire suppression systems.

w) Batteries for UPS and DC battery systems must:

   i) comply with AS IEC 62619 Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications;

   ii) not release any gas during charging and discharging; and

   iii) have a design lifespan not less than 15 years.

3.7 Earthing system and lightning protection

3.7.1 General

a) A consolidated earth and bonding system must be provided which ensures the below outcomes in the following priority order:

   i) protection of persons;

   ii) protection of infrastructure;

   iii) assurance of asset operability and functioning of electrical equipment;

   iv) ease of maintenance; and

   v) ease of construction.

b) The Contractor must develop and undertake a soil resistivity testing process in accordance with the requirements of IEEE-80 Guide for safety in AC substation grounding. The Design Documentation must include details of the soil resistivity testing process.

c) The Contractor must develop an earthing strategy report which must include design rationale, compliance statements, assumptions, interfaces and hazard mitigations. The Design Documentation must include the earthing strategy report.

d) An earthing study must be developed based upon the following design criteria:

   i) the earthing systems must be specified in accordance with the electrical safety limits defined in AS 2067 Substation and high voltage installations exceeding 1kV a.c.;

   ii) the earthing systems must follow the process outlined in AS 2067 Substation and high voltage installations exceeding 1kV a.c.;

   iii) the fault duration used to calculate electrical safety limits must be specified to be equal to the operation of the back-up protection applicable to the point of the fault;

   iv) direct probabilistic calculations must be used in the determination of safety limits;

   v) HV supply arrangements and associated fault scenarios must be considered as part of the earthing system design, ensuring that the earthing system performs within the electrical safety limits for all applicable fault scenarios;

   vi) earth potential rise due to earth faults on third party HV earths in the vicinity of earth systems must be considered as part of the earthing system design to ensure that the earthing system performs within the electrical safety limits for all applicable fault scenarios;

   vii) earthing system design must be based on a soil model which has been developed using computer software (CDEGS or equivalent), with input from soil resistivity test measurements undertaken onsite; and

viii) the transfer of earth potential to metallic pipelines and services, and the effects of low frequency induction emitted by HV cables must be assessed in accordance with the requirements of AS/NZS 4853 Electrical hazards on metallic pipelines.

e) The Contractor must prepare an earthing study report, based on the earthing study required by section 3.7.1d), which must include:

i) evidence of validation and verification of compliance criteria;

ii) design information such as calculations and drawings;

iii) test plans, installation methodology and schedules; and

iv) as built records and residual hazards.

f) Where any part of Tunnel electrical system or bonded conductive objects crosses or is within the vicinity of electrified railway corridor or tram lines, the potential electrolysis effect from stray current must be assessed in accordance with:

i) AS 2832 Cathodic protection of metals; and

ii) IEC 62128-2 Railway applications - fixed installations - electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by d.c. traction systems.

g) The Contractor must implement electrolysis mitigation measures which must comply with the requirements of:

i) Department Engineering Guideline AR-EL-STD-0102 Guidelines for the Protective Provisions Relating to Electrical Earthing and Bonding for the Adelaide Metro Electrified Rail Network; and

ii) Department Engineering Guideline TP2-DOC-002020 Guideline for Low Voltage Electrical Earthing and Bonding for the Adelaide Metro Tram Network.

h) A common multiple earthed neutral (MEN) system must be provided for the Tunnel HV distribution network in accordance with the requirements of AS 2067 Substation and high voltage installations exceeding 1kV a.c..

i) Connections between the HV and LV earth systems must be made at the HV main earth bar located within each substation.

j) An earthing system, consisting of electrodes or earth mats, must be provided at each of the Tunnel surface distribution substations and switch rooms.

k) Underground substations must be earthed via longitudinal earthing conductors, solidly connected to each surface substation’s earthing system.

l) Earthing of the LV electrical distribution network must be provided in accordance with the requirements of AS/NZS 3000 Wiring rules.

m) All earth electrodes must be copper or copper bonded steel.

n) All earthing conductors must:

i) be sized for the worst-case earth fault current, in accordance with the earthing study undertaken pursuant to section 3.7.1d);

ii) be provided in a redundant arrangement to each bore of the Tunnel; and

iii) be provided for the low impedance earth bonding of all extraneous metalwork.

o) A minimum of 2 fault-rated connections must be provided between the main earth bar and the earth grid.

p) All earth bars must:

i) be tinned copper;

ii) be provided in switchrooms to facilitate the connection to:

A. equipment;

B. cable containment; and

C. exposed metallic parts;

iii) be provided with 20% spare, pre-drilled earthing conductor connection points; and

iv) be indelibly labelled.

3.7.2 Structural lightning protection

a) The Contractor must ensure that a lightning protection system is provided to the Tunnel ventilation station outlet (VSO) buildings.

b) The Contractor must undertake a lightning risk assessment in accordance with the requirements of AS 1768 Lightning protection for all external buildings and facilities other than the ventilation station outlet buildings the subject of section 3.7.2a).

c) The Design Documentation must include details of the lighting risk assessment required by section 3.7.2b), including outcomes and recommendations resulting from that assessment.

d) Where the lightning risk assessment required by section 3.7.2b) determines that a lightning protection system should be provided to a particular external building or facility, the Contractor must ensure that a lighting protection system is so provided.

e) The lightning protection system required by section 3.7.2a) and section 3.7.2d) must be provided in accordance with the requirements of AS 1768 Lightning protection.

f) Fall-restraint systems must be provided to allow for access to install, inspect and maintain finials mounted on buildings as part of the lighting protection system.

g) Lightning strike counters must be provided.

h) The lightning strike counters required by section 3.7.2g) must ingrate with the PMCS for monitoring.

3.7.3 Installation of earthing system and lightning protection

a) The earthing system must be installed in accordance with the requirements of:

i) AS/NZS 3000 Wiring rules; and

ii) AS 2067 Substation and high voltage installations exceeding 1kV a.c.

b) All earthing conductors must be:

i) installed at locations and in a manner that ensures that the earthing conductors are accessible for testing; and

ii) able to be easily maintained and replaced without degradation of Tunnel operations.

c) The earthing electrode installation must consider soil condition and annual variation in moisture in the use of ground enhancing material.

d) The lightning protection system must be installed in accordance with the requirements of AS 1768 Lightning protection.

3.8 Cable containment

a) Conduits used for HV cables outside of the Tunnel or in the open section of a motorway must:

i) be rigid heavy duty unplasticised poly vinyl chloride (UPVC); and

ii) comply with the requirements of AS 2053 Conduits and fittings for electrical installations.

b) The HV and LV conduit and pit system must be proof against water ingress and designed to freely drain should any water (regardless of source) enter.

c) Conduits must:

  i) be bedded on compacted sand above and below, in accordance with RD-EL-C3 “Supply and Installation of Conduits and Pits”;

  ii) use select backfill material which meets the requirements of the cable current ratings; and

  iii) be proven cleared of any obstructions or debris prior to installation of any cables.

d) All spare conduits must have draw cords installed in accordance with the draw cord requirements of RD-EL-C3 “Supply and Installation of Conduits and Pits”.

e) All cable pits for HV and LV power systems must be:

  i) sized to suit the minimum bend radius of the cable;

  ii) in accordance with the pit requirements of:

    A. RD-EL-D3 “Conduit Design for Road Lighting, Traffic Signals and ITS”; and

    B. RD-EL-C3 “Supply and Installation of Conduits and Pits”; and

  iii) fitted with a metallic lid that allows for access to the pit.

f) In addition to the requirements of section 3.8e), cable pits for HV power systems must be:

  i) precast concrete pits;

  ii) provided to allow change of direction for HV cable routes;

  iii) provided at an interval to suit the pulling tension of HV cables; and

  iv) provided at an interval to suit the cable lengths on cable reels.

g) Cable containment and supports (including junction boxes, fixtures and anchoring systems) within fire exposed locations within the Tunnel carriageways must meet the WS52W wiring system rating in accordance with the requirements of AS/NZS 3013 Electrical installations - Classification of the fire and mechanical performance of wiring system elements.

h) All cable containment systems must:

  i) be designed to withstand the arduous Tunnel environment in terms of their Design Life;

  ii) be corrosion and fire-resistant; and

  iii) where installed within or above the Tunnel carriageways, be non-flammable and LSZH.

i) HV and LV cables must not share the same pit or wiring enclosure, in accordance with AS/NZS 3000 Wiring Rules.

j) HV and LV power cables must be restrained whenever they are not contained within a conduit.

k) HV power cables must be mechanically protected whenever they are not contained within a conduit.

l) HV and LV power cable restraints must retain and support the cables during normal and multiple short-circuit events.

m) PVC cable containment must not be used within the Tunnel.

3.9 Environmental requirements

3.9.1 LV power system environmental requirements

The LV power system must be designed to operate without derating under the operating parameters listed in Table TUN-ME-DC2 3-4.

Table TUN-ME-DC2 3-4 Tunnel LV system operating environment parameters

LV system operating environment	Value
Minimum operating temperature range	a) Outdoor and non airconditioned space: -15°C to +50°C b) Indoor airconditioned space: -5°C to +40°C
Minimum storage temperature range	-15°C to +50°C
Altitude	H <1000 m ASL

3.9.2 Ingress protection

All Tunnel power system equipment enclosures must satisfy the following ingress protection (IP) ratings in accordance with AS 60529 Degrees of protection provided by enclosures (IP Code):

a) IP42 for electrical equipment enclosures within switchrooms;

b) IP65 for outdoor electrical equipment enclosures or equipment enclosures within the Tunnel; and

c) IP66 for any electrical equipment enclosures which may be subject to high pressure washing during Tunnel wall cleaning or within the zone of the deluge system.

3.10 Equipment enclosures

The surface of all Tunnel power systems equipment enclosures must satisfy the following finish and surface protection requirements:

a) the exterior and interior of all Tunnel power systems equipment enclosures must be free from burrs, protrusions, and sharp projections; and

b) bends and folds must have an external bend radius not less than 3 mm.

4 Control and monitoring requirements

a) The Tunnel power systems must be provided with local and remote operation and indication.

b) The Tunnel power systems must be controlled and monitored by the PMCS in accordance with the requirements of TUN-PMCS-DC1 “Tunnel Plant Monitoring and Control Systems”.

c) Remote monitoring and control of the Tunnel power systems via the PMCS must be provided for the following equipment:

   i) HV switchboard components including:

      A. circuit breakers;

      B. switches and disconnectors; and

      C. earth switches;

   ii) transformer auto tap changer (if installed);

   iii) protection relay IEDs including:

      A. relay remote interrogation for input/output status, metering, event record extraction and programming interface;

      B. relay inter-trip inhibited status (for testing);

      C. relay protection tripped status; and

      D. relay watchdog status;

   iv) VSDs and soft starters including:

A. remote interrogation for status, event records extraction and programming interface;

B. motor condition monitoring including overload alarm; and

C. fault or tripped status; and

v) LV main switchboards including:

A. incomer circuit breaker open/close command;

B. incomer circuit breaker open/closed status;

C. incomer circuit breaker racked in/out/test status;

D. incomer circuit breaker spring motor charged status;

E. incomer circuit breaker ready to close status;

F. ATS close to normal/replacement source command; and

G. ATS closed to normal/replacement source status.

d) Remote monitoring of the Tunnel power system via the PMCS must be provided for the following equipment:

i) transformers including:

A. oil temperature for oil filled transformers;

B. winding temperature (both oil and dry type transformers);

C. tap changer status/position;

D. oil level indications for oil filled transformers. Note that this must also be provided as a local indication at the transformer;

E. alarm and trip events. Note that transformer trip contacts must be wired directly to the input of the respective protection relay IED, and must not be wired via the PMCS;

F. oil condition monitoring instrumentation (online dissolved gas analysis) feedback; and

G. forced ventilation fan status and thermostatic control set points (dry type transformers);

ii) LV main switchboard equipment including:

A. MCCB status;

B. contactor status;

C. phase failure status;

D. arc-fault detection status;

E. local/remote selector switch status;

F. surge protection devices status;

G. soft starters status;

H. motor starter circuit status; and

I. fan isolator status;

iii) metering devices including:

A. individual AC feeder currents;

B. busbar voltages;

C. energy consumption and metering on a per board basis;

D. negative phase sequence voltage;

E. harmonic voltages and currents;

F. total harmonic distortion; and

G. power factor;

iv) UPS systems including:

A. UPS external maintenance bypass switch status;

B. mains fail status;

C. UPS fault/fail status (including batteries);

D. UPS common alarm;

E. UPS low volts alarm; and

F. UPS high volts alarm;

v) DC battery chargers including:

A. mains fail status;

B. DC charger fault/fail status;

C. DC charger common alarm;

D. DC charger low volts alarm;

E. DC charger high volts alarm; and

F. DC charger earth leakage alarm;

vi) UPS and DC distribution board circuit breaker statuses;

vii) DC distribution board supply source selection switch (A or B system) status;

viii) battery enclosure temperatures;

ix) electrical room temperatures;

x) electrical room air-conditioner fault status;

xi) power quality systems equipment (if installed);

xii) power factor correction equipment (if installed); and

xiii) remote terminal units and any telecommunication or data communications network related equipment.

5 Reliability, Design Life, and functional safety requirements

5.1 General

The Tunnel power system equipment, and any associated enclosures, must be designed and supplied in accordance with the systems engineering requirements and the analysis for reliability, availability, maintainability and safety (RAMS) in accordance with PC-EDM6 “Systems Engineering Management”.

5.2 Sustainability requirements

a) The Tunnel power system must integrate sustainable design and construction practices including:

i) maximisation of overall system efficiency;

ii) the use of recyclable / low environmental impact materials wherever possible; and

iii) exclusion of toxic materials (and gases) wherever possible.

b) Polyethylene (PE) must be used in lieu of PVC where practical.

c) Low-loss and energy-efficient plant must be used where practical.

d) An environmental impact report must be provided as part of the Design Documentation for major electrical equipment to support applicable infrastructure sustainability assessment and rating including:

i) power transformers;

ii) motor control and driving devices;

iii) HV and LV switchgear; and

iv) power quality treatment and filtration devices.

6 Maintainability

The Contractor must ensure that all Tunnel power system equipment is supported locally in Australia by the relevant equipment manufacturer, or its local agent, who will provide full technical support and troubleshooting capability from their local facility.

7 Hold Points and Witness Points

a) Table TUN-ME-DC2 7-1 details the review period or notification period, and type (documentation or construction quality) for each Hold Point referred to in this Master Specification Part.

b) Table TUN-ME-DC2 7-2 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referred to in this Master Specification Part.

Table TUN-ME-DC2 7-1 Hold Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
8c)	Routine test results	Documentation	10 Business Days review
8e)	NATA accredited laboratory test results for oil insulated HV transformers	Documentation	10 Business Days review

Table TUN-ME-DC2 7-2 Witness Points

Section reference	Witness Point	Documentation or construction quality	Review period or notification period
8b)	Routine testing	Construction quality	20 days notification
8g)	Pre-energisation tests	Construction quality	20 days notification

8 Verification requirements and records

Testing and commissioning procedures and documentation for the Tunnel power systems must be undertaken in compliance with PC-CN1 “Testing and Commissioning” and in compliance with the following verification and testing requirements:

a) the Contractor must submit type test certificates for HV switchgear, LV switchgear and transformers as part of the Construction Documentation;

b) the Contractor must conduct routine tests on the following equipment. The Principal must be invited to attend, which will constitute a **Witness Point**:

    i) transformers in accordance with the requirements of AS 60076 Power transformers;

    ii) HV switchgear in accordance with the requirements of AS 62271 High-voltage switchgear and controlgear; and

    iii) LV switchgear in accordance with the requirements of AS/NZS 61439 Low-voltage switchgear and control gear assemblies;

c) the results of routine tests required by section 8b) must be submitted to the Principal for approval prior to delivery, which will constitute a **Hold Point**;

d) oil insulated HV transformers must have the oil tested for polychlorinated biphenyl in accordance with the requirements of AS 60076 Power transformers by a NATA accredited laboratory to ensure that the polychlorinated biphenyl concentration is less than one part per million;

e) the NATA accredited laboratory oil polychlorinated biphenyl certification must be submitted to the Principal prior to delivery of the oil insulated HV transformers, which constitutes a **Hold Point**;

f) immediately following the installation of oil filled transformers, the following tests must be conducted:

    i) inspection for oil leaks and damage;

    ii) 1k V Megger test between:

        A. HV and earth;

        B. LV and earth; and

        C. between HV and LV windings; and

    iii) oil sample tests;

g) HV switchgear, LV switchgear and transformers must be tested prior to energisation, in accordance with the manufacturer’s requirements to unambiguously confirm that the system is safe to energise and the Principal must be invited to attend, which constitutes a **Witness Point**;

h) the following HV cable tests must be conducted:

    i) HV tests in accordance with AS/NZS 1429.1 Electrical cables - Polymeric insulated, Part 1: for working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV;

    ii) sheath integrity test;

    iii) point to point test;

    iv) insulation resistance; and

    v) very low frequency test;

i) the HV cable insulation resistance test required by section 8h)iv) and the very low frequency test required by section 8h)v) must be conducted less than 4 hours prior to first energisation;

j) representative load testing of HV equipment anchors, fixings and fasteners must be undertaken following the completion of the installation, ensuring that no movement can occur under any fault conditions;

k) busbars and busducts must be tested so far as is reasonably practicable using infra-red thermography to confirm that all joints and connections are tight under high load conditions;

l) circuit breaker enclosures and arc chutes must be inspected at the completion of the SAT to ensure that all covers and access hatches have been replaced and that all fixings and fasteners have been torqued back to the manufacturer’s requirements;

m) LV switchboards must:

   i) be checked for deflection post-installation, with all panel doors able to be opened, closed and locked easily;

   ii) have all circuit breaker settings checked and adjusted to match nominated settings;

   iii) have all busbars checked for alignment, assembly and bolt tightness to the manufacturer’s torque settings; and

   iv) be subjected to insulation resistance tests in compliance with the requirements of AS/NZS 3017 Electrical installations - Verification by inspection and testing as part of:

      A. Site Acceptance Testing; and

      B. immediately prior to energisation;

n) distribution boards must:

   i) be insulation resistance tested in compliance with the requirements of AS/NZS 3017 Electrical installations - Verification by inspection and testing immediately prior to energisation;

   ii) have phase rotation of the incoming supply checked;

   iii) have all protection devices checked for correctness of type, rating and installation; and

   iv) have circuit schedules checked for correctness;

o) LV power and control cables must be tested in accordance with the requirements of:

   i) AS/NZS 3017 Electrical installations - Verification by inspection and testing; and

   ii) AS/NZS 3000 Wiring Rules;

p) correct phase rotation and sequence must be tested for all equipment and be ensured for consistency across all supply and switching combinations;

q) the following tests must be conducted on all electric motors:

   i) winding insulation tests;

   ii) correct direction of rotation;

   iii) load current measured and recorded; and

   iv) overload devices set;

r) fire rated cable penetration records; and

s) the Contractor must submit to the Principal records of all test activities and inspections completed, including those listed in sections 8a) to 8r), as part of the Quality Management Records.