SA Water

Engineering

Technical Standard

TS 0340 – Design, supply, installation and testing of high voltage equipment

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Documents superseded by this standard

a. TS 0340, Version 2.0.

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Updates in this version of the Technical Standard include:

- Updated in accordance with the SA Water Technical Standard Template Version 8.1 and the SA Water Style and Writing Standard Version 2.0.
- Internal references updated.
- Section 1.3.1 Update of Australian and international standards table.
- Section 1.3.2 Update of SA Water documents table.
- Section 3.2 Internal minimum temperature changed from 5°C to 0°C.
- Section 3.3 Changes to supply conditions around maximum fault levels.
- Section 6.1 Addition of requirement to obtain protection scheme approval.
- Section 6.2 Addition of minor clarification wording.
- Section 6.2.1 Addition of minor clarification wording.
- Section 6.2.4 New section on incoming distribution feeders.
- Section 6.2.5 Change to outgoing feeder protection requirements and the inclusion of arc flash detection.
- Section 6.7 New section on transformer differential protection.
- Section 6.8 New section on capacitor bank protection.
- Section 6.9 New section on circuit breaker failure protection.
- Section 6.10 New section on current limiting reactors.
- Section 6.11 New section on busbar differential protection.
- Section 6.12 New section on HV arc flash protection.
- Section 7.1 New requirement on Maximo hierarchy naming.
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- Section 8.3 Addition of minor clarification wording.
- Section 9.3 HV cable installation clarifications.
- Section 12.9.1 Addition of KNAN classification.
- Section 13.2 Addition of requirements for continuous vibration monitoring for HV motors.
- Section 13.5.6 New section for HV motor testing in-situ.
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- Section 17.2 Addition of insulation requirements for walls, ceilings and floors of buildings.
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1 Introduction

SA Water is responsible for the construction and commissioning of an extensive amount of engineering infrastructure such that it is safe and functional.

This technical standard covers the design, supply, installation and commissioning of High Voltage (HV) equipment along with associated control, protection, instrumentation equipment, HV cable testing and HV switch room requirements.

This technical standard shall be read in conjunction with the associated project specification, drawings and any documents annexed to the project specification. The provisions of this Technical Standard shall apply unless they are specifically deleted or amended in the project specification or drawings, which shall then take precedence; however, any requirement that does not comply with this Technical Standard shall be required to be approved by the SA Water Principal Electrical Engineer.

1.1 Purpose

The purpose of this standard is to detail minimum requirements to ensure that assets covered by the scope of this standard are constructed and maintained to consistent standards and attain the required asset life.

1.2 Glossary

Terms and Abbreviations utilised in this Standard are included in the following sections. The definitions presented below are to be used when interpreting this Standard and actions undertaken in relation to this Standard. Where a conflict exists, clarification is to be sought from SA Water.

1.2.1 Terms and Definitions

The following is a list of Terms applicable to this document:

Term	Description
Constructor	The organisation responsible for constructing and installing infrastructure for SA Water whether it be a third party under contract to SA Water or an in-house entity.
Contract	A set of documents supplied to Constructor as the basis for construction; these documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.
Designer	The organisation responsible for designing infrastructure for SA Water whether it be a third party under contract to SA Water or a Constructor, or an in-house entity. A Designer is a person who effects design, produces designs or undertakes design activities as defined in the *Work Health and Safety Act 2012 (SA)*.
Must	Indicates a requirement that is to be adopted in order to comply with the Standard.
Principal Engineer	The engineering discipline expert identified in the 'Approvers' table (via SA Water's Representative).
Provide	Means "supply and install".
SA Water	South Australian Water Corporation
SA Water Representative	The SA Water representative with delegated authority under a Contract or engagement, including (as applicable): Superintendent's Representative (e.g. AS 4300 and AS 2124 etc.) SA Water Project Manager SA Water nominated contact person

Term	Description
Should	Indicates practices which are advised or recommended, but is not required
Supply Authority	SA Power Networks or ElectraNet
Technical Dispensation Request Form	This form is part of SA Water's Technical Dispensation Request Procedure which details the process by which those required to comply, or ensure compliance, with SA Water's technical requirements may seek dispensation from those requirements.
Work	Elements of a project which require design and/or construction.

1.2.2 Abbreviations

The following is a list of Abbreviations, Acronyms and Initialisms used in this document:

Abbreviation	Description
BCA/NCC	Building code of Australia/National Construction Code
CB	Circuit Breaker
CT	Current Transformer
DOL	Direct on line
EI	Extreme Inverse
FIP	Fire Indication Panel
FLC	Full load current
FRL	Fire resistance level
FTB	Fluidised Thermal Backfill
HMI	Human Machine Interface
HRC	High Rupturing Capacity
HV	High Voltage
IAC	Internal arc classification
IDMT	Inverse Definite Minimum Time
IED	Intelligent Electronic Device
IP	International Protection (class)
LV	Low Voltage
MCB	Miniature circuit breaker
MFS/CFS	Metropolitan Fire Service/Country Fire Service
NER	Neutral Earthing Resistor
PCB	Polychlorinated Biphenyls
PF	Power Factor
PFC	Power Factor Correction
PLC	Programmable Logic Controller
RTD	Resistance Temperature Device
RTU	Remote Telemetry Unit
SCADA	Supervisory Control and Data Acquisition
SI	Standard Inverse
SLD	Single Line Diagram
TD	Tan Delta

Abbreviation	Description
TDRF	Technical Dispensation Request Form
TS	SA Water Technical Standard
TSB	Thermally stable backfill
VI	Very Inverse
VLF	Very Low Frequency
VSD	Variable Speed Drive
VT	Voltage Transformer
XLPE	Cross linked Polyethylene

1.3 References

1.3.1 Australian and international

The following table identifies Australian and International standards and other similar documents referenced in this document:

Reference	Title
AS 1170.4	Structural design actions — Earthquake actions in Australia
AS 1319	Safety signs for the occupational environment
AS 1530.4	Methods for fire tests on building materials, components and structures
AS 1768	Lightning protection
AS 2067	Substations and high voltage installations exceeding 1kV a.c.
AS 2374.1.2	Power Transformers Minimum energy performance standard (MEPS) requirements for distribution transformers
AS 2676.2	Guide to the installation, maintenance testing and replacement of secondary batteries in buildings – Sealed cells
AS 3011.2	Electrical installations - Secondary batteries installed in buildings - Sealed cells
AS 3600	Concrete Structures
AS 4044	Battery chargers for stationary batteries
AS 4100	Steel Structures
AS 4702	Polymeric cable protection covers
AS 60270	High voltage test techniques – Partial discharge measurements
AS 60470	High voltage alternating current contactors and contactor-based motor starters
AS 60529	Degrees of protection provided by enclosures (IPCode)
AS 60896.22	Stationary lead-acid batteries - Valve regulated types - Requirements (IEC 60896-22:2004 (ED 1.0) MOD)
AS 61869.2	Instrument transformers – Additional requirements for current transformers (IEC 61869-2:2012 (ED 1.0) MOD)
AS 62271.1	High-voltage switchgear and controlgear - Common specifications for alternating current switchgear and controlgear (IEC 62271-1:2017, MOD)
AS 62271.100	High voltage switchgear and control gear - Alternating-current circuit-breakers (IEC 62271-100:2008+AMD1:2012+AMD2:2017 CSV (ED. 2.2)/COR1:2018, MOD)

Reference	Title
AS 62271.102	High voltage switchgear and control gear – Alternating current disconnectors and earthing switches (IEC 62271-102:2018, MOD)
AS 62271.200	High voltage switchgear and control gear – AC metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV (IEC 62271-200:2011/COR1:2015, MOD)
AS/NZS 1429.1	Electric cables – Polymeric insulated Part 1 for working voltages 1.9/3.3 (3.6)kV up to and including 19/33 (36)kV
AS/NZS 1680.1	Interior and workplace lighting – General principles and recommendations
AS/NZS 2293.3	Emergency lighting and exit signs for buildings - Emergency luminaires and exit signs
AS/NZS 2648.1	Underground marking tape – Non-detectable tape
AS/NZS 3000	Wiring Rules
AS/NZS 3013	Electrical installation – Classification of the fire and mechanical performance of wiring system elements
AS/NZS 4029.2	Stationary batteries – Lead acid – Valve-regulated type
AS/NZS 5,000.1	Electric cables -– Polymeric insulated — For working voltages up to and including 0.6/1 (1.2)kV (Reconfirmed 2017)
AS/NZS 60076.1	Power Transformers – General (IEC 60076-1, ED 3.0 (2011) MOD)
AS/NZS 60076.10	Power Transformers – Determination of sound levels (IEC 60076-10:2016 (ED. 2.0) MOD)
AS/NZS 60076.10.1	Power Transformers – Determination of sound levels - Application guide (IEC 60076-10-1:2016 (ED. 2.1) MOD)
AS/NZS 60076.11	Power Transformers – Dry type transformers
AS/NZS 60076.2	Power Transformers – Temperature rise for liquid-immersed transformers (IEC 60076-2, Ed 3.0 (2001) MOD)
AS/NZS 60076.3	Power Transformers – Insulation levels, dielectric tests and external clearances in air (IEC 60076-3:2013, MOD)
AS/NZS 60076.5	Power Transformers – Ability to withstand short circuit (IEC 60076-5, Ed. 3.0 (2006) MOD)
AS/NZS 60076.7	Power transformers — Loading guide for oil-immersed power transformers (IEC 60076-7, Ed. 1.0 (2005) MOD)
AS/NZS 60137	Doc Title: Insulated bushings for alternating voltages above 1,000 V (IEC 60137:2017 (ED.7.0) MOD)
ENA EG-0	ENA DOC 025-2022 Power System Earthing Guide (EG-0) Part 1: Management Principles
ENA EG-1	ENA DOC 045-2022 Substation Earthing Guide
IEC 60034 Series	Rotating electrical machines
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60282-1	High Voltage fuses – Part 1: Current-limiting fuses
~~**IEC 60694**~~	~~Common specifications for High-Voltage Switchgear and controlgear standards~~
IEC 60871 Series	Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V
IEC 61039	Classification of insulating liquids
IEC 61850 Series	Communication networks and systems for power utility automation (all parts)
IEC 62271-106	High-voltage switchgear and controlgear - Part 106: Alternating current contactors, contactor-based controllers and motor-starters

Reference	Title
IEEE P400.2	IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)() (less than 1 Hz)
IEEE 43:2022	IEEE Recommended Practice for Insulation Testing of AC Electric Machinery with High Voltage Rating up to 30 kV at Very Low Frequency
ISO 9001	Quality management systems — Requirements
SAPN - TS105	SA Power Networks – Technical Standards (TS105)

1.3.2 SA Water documents

The following table identifies the SA Water standards and other similar documents referenced in this document:

Reference	Title
TS 0101	Safety in Design
TS 0245	Design requirements for ventilation and cooling systems
TS 0300	The supply and installation of low voltage electrical equipment
TS 0370	Fire detection and emergency evacuation systems
TS 0371	Arc flash hazard assessment and design aspects

2 Scope

2.1 Scope and application of this Technical Standard

This Technical Standard Specification covers the general requirements for the design, supply, installation and testing of high voltage electrical equipment.

This Technical Standard Specification shall be read in conjunction with the associated project specification, drawings and any documents annexed to the project specification. The provisions of this Technical Standard Specification shall apply unless they are specifically deleted or amended in the project specification or drawings, which shall then take precedence. The currency of these standards should be checked prior to use.

2.2 Works not in scope

N/A

2.3 Technical dispensation

Departure from any requirement of this Technical Standard shall require the submission of a Technical Dispensation Request Form (TDRF) for the review and approval (or otherwise) of the SA Water Principal Engineer listed in Page 5, on a case-by-case basis.

The Designer shall not proceed to document/incorporate the non-conforming Work before the Principal Engineer has approved of the proposed action in writing via the Technical Dispensation Request Form (TDRF).

SA Water requires sufficient information to assess dispensation requests and their potential impact. The onus is therefore on the proponent to justify dispensation request submissions and provide suitable evidence to support them.

Design works that are carried out without being appropriately sanctioned by SA Water shall be liable to rejection by SA Water and retrospective rectification by the Designer/Constructor.

2.4 Hazards

Hazards shall be identified and addressed in accordance with TS 0101.

2.5 Design criteria

The design criteria must be ascertained and agreed with SA Water or its representative during all stages of investigation, concept design and detailed design to achieve a value-for-money installation that is functional and with minimum or negligible risks to SA Water. The design criteria should consider the following aspects:

a. Safety considerations:

   The installations are to be designed with the safety and welfare of construction, operation and maintenance personnel and the general public in mind, complying with statutory regulations. Wherever possible, electrical equipment and wiring should not be located in areas classified as hazardous.

b. Environmental considerations:

   The installations are to be designed and suitable equipment selected to avoid or minimise unacceptable impact on the environment as far as possible.

c. Life cycle costs:

   Designs should be innovative and incorporate the appropriate techniques and technology, in conjunction with the selection of appropriate equipment, to minimise the life cycle costs while satisfying operation and maintenance requirements. Energy consumption must be given particular attention in this respect.

d. Security of operation:

   Designs should consider the failure of a single item of equipment or a fault in a particular area of an installation is confined to the associated part of the installation and does not affect the continuous operation of the remaining parts of the installation, where possible.

e. Reliability:

   The installations are to be designed to minimise the likelihood of a failure, taking into consideration the electricity supply characteristics, ambient conditions, load characteristics and operation and maintenance requirements.

f. Upgradability:

   The installations are to be designed to facilitate future upgrades where applicable.

g. Interchangeability:

   The installations are to be designed to maximise the interchangeability of components and assemblies as far as practical to improve flexibility and reduce the spare parts inventory.

h. Operation, maintenance and fault-finding facilities:

   The installations are to be provided with suitable and adequate facilities to allow ease of operation, maintenance and fault finding.

3 General

3.1 Design considerations

In relation to the design of new HV installations or design for the modification of existing HV installations, the minimum requirement would be to include items such as:

a. Load calculations.

b. Short circuit determination.

c. Arc flash assessment.

d. Protection coordination studies.

e. Motor acceleration studies.

f. Harmonic studies.

g. Power factor studies.

h. Earthing system studies.

i. Lightning protection studies.

j. Cable sizing studies.

k. Volt drop calculations.

l. Noise studies.

m. Heat loading studies.

n. Any other relevant studies highlighted by the project scope documents.

Design work should consider possible impacts to the site's upstream and downstream power systems and not just to new or upgraded HV equipment. A suitably qualified engineer shall conduct all design work.

All calculations performed in this respect need to be provided with a copy of the native file, especially for studies performed around protection settings, earthing calculations, load flow studies, arc flash determinations, harmonic calculations and pawer factor determination.

3.2 Environmental conditions

All HV switchboards, transformers, motors, soft starters, variable speed drives and assemblies etc., shall be rated for operation at full load under the following conditions:

1. External
    a. Ambient Temperature:
        - Maximum +50°C
        - Minimum -5°C
    b. Humidity up to 90 per cent, non-condensing
2. Internal
    a. Ambient Temperature:
        - Maximum +40°C
        - Minimum ~~-5~~0°C
    b. Humidity up to 90 per cent, non-condensing.

All equipment shall be adequately de-rated, and/or ventilation shall be provided in accordance with the manufacturer's recommendations. Any low voltage equipment installed as part of the high voltage installation shall be de-rated and/or ventilated in accordance with the requirements of TS 0300. Cubicles and equipment located within buildings and switch rooms shall not be dependent upon the operation of any room or building air conditioning or mechanical ventilation system. Mechanical cooling of any apparatus shall be at the discretion of the Superintendent's representative.

Prior to the finalisation of the detailed design, the following calculations need to be supplied for items such as switchboards, transformers, drives, motors, capacitors, etc.:

a. All equipment, cubicle and room heat loads (must take account of all electrical, thermal and solar loads).

b. Predictions of the resulting equipment operating temperatures at full load.

c. Equipment manufacturer's temperature rating information and the de-rating factors proposed.

Temperature rise of the switchboards shall be in accordance with AS 62271.200.

3.3 Power supply conditions

The rated insulation level of equipment shall be suitable for the power supply characteristics in the following sections.

3.3.1 3.3kV supply conditions

Where 3.3kV is directly supplied or reduced/increased from another supply, it shall have the following characteristics:

a. Number of phases: 3

b. Nominal voltage: 3.3kV

c. Highest voltage: 3.6kV

d. Frequency: 50Hz

e. Impulse voltage: 40kV

f. System earthing: Site dependent

g. Maximum three-phase fault level: Site dependent[1]

For Supply Authority contribution at ElectraNet sites use 'Future Maximum' values. At SAPN sites use the SAPN nominated value plus an additional minimum of 20 per cent to cater for future increases in fault levels.

Any additional requirements that the Supply Authority mandates (harmonic limits, power factor, etc.) shall be accommodated.

3.3.2 11kV supply conditions

Where 11kV is directly supplied or reduced/increased from another supply, it shall have the following characteristics:

a. Number of phases: 3

b. Nominal voltage: 11kV

c. Highest voltage: 12kV

d. Frequency: 50Hz

[1] To be calculated with consideration of the contribution from:

a. Supply Authority
b. SA Water generation systems (PV and/or BESS)
c. SA Water motors.)

e. Impulse voltage: 75kV

f. System earthing: Site dependent

g. Maximum three-phase fault level: Site dependent[2]

For Supply Authority contribution at ElectraNet sites use 'Future Maximum' values. At SAPN sites use the SAPN nominated value plus an additional minimum of 20 per cent to cater for future increases in fault levels.

Any additional requirements that the Supply Authority mandates (harmonic limits, power factor, etc.) shall be accommodated.

[2] To be calculated with consideration of the contribution from:

d. Supply Authority

e. SA Water generation systems (PV and/or BESS)

f. SA Water motors.)

4 Primary HV switchboards

Primary switchboards house primary switchgear as the first stage in the process of conducting HV electrical power from the grid to the SA Water assets. The importance of positioning a primary switchboard within the SA Water asset means that the layout, design and operation must ensure maximum availability and reliability. As the system impedance is lower at the primary switchboard than further into the network, the fault level tends to be higher, usually between 25 kA and 50 kA.

4.1 Construction

Switchboards shall be modular, metal-clad, free-standing, air or cast resin insulated and constructed in accordance with AS 2067 and AS 62271.200. Supply conditions shall be in accordance with section 3.3 of this document and the project-specific specification. The switchboard modules shall each consist of three power compartments:

a. Feeder compartment

b. Busbar compartment

c. Apparatus compartment.

Secondary instruments such as meters, indicators, protection relays and associated wiring shall be housed in auxiliary compartments separated from high-voltage equipment.

All compartments containing high voltage conductors shall be of a design that has been type-tested in accordance with AS 62271.200 – internal arc fault testing requirements.

The switchgear construction shall also comply with the following:

a. All switchgear shall be of the withdrawable type.

b. The switchboard shall be supplied with all necessary mounting frames, plinths and rails for mounting on a concrete floor with open cable ducts below. Mounting structures shall not impede incoming or outgoing cable entry.

c. Switchboards shall be equipped with lifting facilities such as eye bolts.

d. Switchboards shall be constructed from a minimum 2mm thick zinc steel sheet and be painted to the manufacturer's specifications.

e. Doors shall be lockable.

f. Unless otherwise stated, switchboards shall facilitate extension to both right and left.

g. Cable entry shall be bottom-entry, where physically possible.

h. All panels and cubicles, compartments and doors shall be structurally stiff and braced to withstand twisting without distortion. There shall be no undue movement of panels or cubicles during normal operation, including withdrawing and replacing circuit breakers or other equipment.

i. All maintenance and service operations shall be capable of being carried out at grade from the front of the switchboard, VSD, etc.

j. The mounting height of switchboards and condition of the floor shall suit the use of trolleys for withdrawable switchgear.

k. The functional units (compartments) of the switchgear shall be arc proof in accordance with AS 62271.200, meeting Annex AA test criteria 1 to 5 for accessibility Type A enclosures (Restricted to authorised personnel only).

All switchboards shall be capable of remote operation via a dedicated control panel installed away from the location of the High Voltage switchboard. Unless otherwise specified, the remote control shall be accomplished through hard-wired control pushbuttons. The location of the remote-control panel shall be determined on a case-by-case basis.

Switchgear that can be remotely racked in/out should be considered on a case-by-case basis for the application being considered.

For switchgear that is required to be installed in a corrosive atmosphere, proposals shall be endorsed by the SA Water Principal Electrical Engineer.

4.2 Arc chutes

Switchboards required to be fitted with proprietary arc chutes shall be configured so that arcing exhaust gases are evacuated to the exterior of the switchboard/building in a way that does not present a hazard to personnel.

All exterior and interior (to the building) fittings, ductwork and couplings to vent the exhaust gases shall form part of the type-tested switchboard.

Arc chutes/external vents shall be fitted with insect/vermin-proof membranes, along with proprietary/approved weatherproof covers.

Arc vents shall be installed so they do not compromise the integrity of the building, or pose a safety or fire risk.

Asbestos materials shall not be used. Arc chutes shall be constructed from sheet steel with appropriate protective coatings.

4.3 Arc flash mitigation requirements

Switchboards for indoor installation in a switch room shall be provided with all-round clearance in accordance with AS/IEC 62271.200 and an accessibility rating of 'type A.'

Unless otherwise specified, the switchboard shall be type-tested to have an internal arc classification (IAC) rating of 'AFLR', that is, Restricted personnel access from Front, Lateral (sides) and Rear. The switchboard shall be rated to withstand an internal arc fault current equivalent to the rated short-time current unless a lower value is specified.

Switchboards with 'AFL' classification may be acceptable in installations where the rear side of the switchboard is inaccessible, subject to approval from SA Water's Principal Electrical Engineer. Where the manufacturer's proposal includes the detection of an arc and provision of a trip signal to the upstream or supplying circuit breaker, then the requirement and details shall be clearly stated.

4.4 Type testing

Supplied switchboards shall be fully type-tested in accordance with AS 62271.200 ~~and IEC 60694~~. Type-testing of switchboards shall include the testing of switchboards with the same degree of protection (IP rating) as specified. Verification of the protection shall be in accordance with AS 62271.200. Type-test reports, complete with details of the configuration of the switchboard which was type-tested shall be provided with any design.

4.5 Anti-condensation heaters

If the requirement for dehumidification is specified based on installation conditions, thermostatically controlled dehumidifying equipment such as anti-condensation heaters shall be provided on a per-compartment basis.

The heaters shall operate from a 230VAC supply, each heater being separately protected via an MCB in accordance with TS 0300.

The thermostat shall be adjustable between 5 and 25°C from within the compartment.

4.6 Busbars

The main high-voltage busbars shall be rated to carry the maximum load current plus a spare margin of 25 per cent. The busbar system shall be SF6, cast resin or air insulated. They shall be coloured to identify the phase colours – Red/White/Blue. Busbar maximum temperature shall be limited to 90°C (with an ambient of 40°C) for indoor switchboards.

Outdoor switchboard busbar temperatures shall be limited to 100°C, with an ambient of 50°C, and at the same time, absorbing a full solar load.

Busbar joints shall be bolted with high-tensile steel bolts, nuts and Belleville washers. Insulation integrity shall be maintained at joints, bends, etc.

Busbars shall be mounted on non-hygroscopic insulators and arranged such that under full short circuit conditions, they do not deform or that the insulation becomes compromised.

Busbar chambers shall be provided with an inter-panel barrier with epoxy cast seal-off bushings through which the busbars will pass through to prevent propagation of fire from one panel to another.

Busbars shall have a minimum fault rating of 20kA for 1 second at the rated voltage when the busbars are protected by a unit protection scheme and 3 seconds for all other protection schemes at the same fault level.

4.7 Degree of protection

For indoor switchboards installed in a dedicated high-voltage room, the degree of protection shall comply with AS 60529 and the following:

a. IP4X on the external housing.

b. IP2X inside the compartments.

For existing indoor switchboard installations only, not installed in a dedicated high voltage room but located in a pump hall where pressurised water presents a potential hazard, the degree of protection shall comply with AS 60529:

- Not less than IP54.

For all outdoor switchboards:

- Not less than IP56.

Clearances around switchboards shall be in accordance with AS 2067.

4.8 Switchgear

4.8.1 Circuit breakers

Circuit breakers shall be rated for a maximum symmetrical fault current +10 per cent at the breaker outgoing terminals. The circuit breakers shall conform to:

- AS 2067.
- AS 62271.100.
- AS 62271.200.
- AS 62271.1.

Circuit breakers shall be used for:

a. Incoming and outgoing distribution feeders

b. Incoming supplies (from a supply authority)

c. Neutral Earthing Resistors (NERs)

d. PFC equipment

e. VSDs

f. Capacitor banks

g. Transformer feeders

h. HV Motors with DOL starting.

Circuit breakers shall be three-pole devices with cast resin insulated spouts, truck mounted, and be either a horizontal or vertical motion type.

Tripping and closing control voltage shall be 48VDC.

The breaker shall be fitted with:

1. Anti-pumping circuitry.
2. Manual and motorised spring charging (48VDC motor).
3. Open/close push buttons.
4. Open/closed indicators.
5. Voltage presence indicators.
6. Spring charge status indicator.
7. Manual charging device and lever.
8. Operation counter.
9. Mechanical open/close push buttons from the front of the switchboard.
10. Mechanical flag-type indicators for open/closed status visible from the front of the switchboard.
11. Trip-free operation.
12. Mechanical interlocks between feeder compartment door and earthing switch position.
13. Automatic shutters (on the switchboard) to isolate both cable and busbar connections when the circuit breaker is withdrawn. Shutters shall be capable of being padlocked in the closed position.
14. Shunt releases for electric opening and closing.
15. Individual fuses for controls, indications, motor charging and remote signals.
16. Multiple auxiliary contacts (both NO and NC).
17. Have capability for connection to a remote panel, for additional controls and indications.

Tripping coils shall be duplicated if they are designed for momentary or non-continuous operation. Coils that are designed for continuous operation shall not require duplication. Where coils are duplicated, they shall operate in tandem. Failure of a coil (open or short circuit) shall not cause a failure of the second coil to operate or inhibit the tripping process.

The circuit breaker truck shall be provided with service, test and isolated positions, along with associated mechanical indications.

It shall be possible to rack the switchgear into the test position with the switchboard front door closed. Remote racking of switchgear is considered desirable but should be assessed on a project-by-project basis.

With the switchgear withdrawn from the service position, it shall be possible to maintain all control and indication connections to allow testing of circuit breaker functions.

A suitable lifting trolley shall be provided if the switchgear is not withdrawable directly onto the floor.

Withdrawable switchgear of the same type and rating shall be fully interchangeable within the switchboard.

4.8.2 Fused contactors

Fused contactors shall be fully type-tested withdrawable vacuum or SF6 (non-preferred) contactors that comply with AS 60470 and IEC 62271-106. They should be triple pole and protected by primary High Rupturing Capacity (HRC) fuses that comply with IEC 60282-1.

The fused contactor shall be mounted on a truck and be capable of making and breaking the prospective fault current. The contactor shall be rated at 400A (minimum). The HRC fuses shall be sized according to the load.

The contactor should be equipped as follows:

a. Solenoid type operating mechanism or magnetic operating mechanism.

b. Electrical holding or mechanical latching, as required.

c. Emergency manual operation for the mechanical latching contactor.

d. Mechanical indicators for switch position and mechanism position.

e. Mechanical operations counter.

f. Auxiliary signalling contacts.

g. Open/close push buttons.

h. Multiple auxiliary contacts (both NO and NC).

i. Open/closed/trip indicators.

j. Truck in test and truck in service indicators.

k. Mechanical open/close push buttons on the front of the switchboard.

l. Mechanical interlocks.

m. Automatic shutters to isolate both cable and busbar connections when contactor truck is withdrawn. Shutters shall be capable of being padlocked in the closed position.

n. Shunt releases for electric opening and closing.

o. Individual fuses for controls, indications, motor charging and remote signals.

p. Tripping indicators (strikers) on fuses to open contactors through protection relays.

q. Fuse carriage shall be capable of accepting two fuses per phase.

r. Contactors shall be rated for AC3 category of use. AC 4 shall be used where plugging or inching is required.

s. Rated for a minimum of 6,000A breaking capacity (without fuse).

t. Electrical and mechanical endurance shall be not less than 250,000 operations.

u. Have capability for connection to a remote panel, for additional controls and indications.

If used for transformer protection, then mechanically latched contactors with release coils are required.

The truck shall be provided with service, test and isolated positions, along with associated mechanical indications.

It shall be possible to rack the switchgear into the test position with the switchboard front door closed.

With the switchgear withdrawn from the service position, it shall be possible to maintain all control and indication connections to allow testing of the starter functions.

A suitable lifting trolley shall be provided if the switchgear is not withdrawable directly onto the floor.

Withdrawable switch gear of the same type and rating shall be fully interchangeable.

When requested by the specification, a separate (to the battery supply) closing supply shall be provided for all transformer feeder contactors. This shall be implemented by selecting a suitably sized VT to close the contactor (holding is not necessary as it will be mechanically latched).

The VT shall also be used for metering and instrumentation purposes as detailed in section 8.3.

Fuses shall be rated for full load operation and graded to protect the equipment against an electrical fault.

4.8.3 Earth switches

Earth switches shall be provided to earth the incoming supplies, outgoing feeders and switchboard busbars in accordance with ~~SAPN~~ the relevant electrical utility service and installation rules. The main contacts of the circuit breaker shall not be used for earthing purposes.

Earth switches shall be in accordance with AS 62271.102 and the following:

a. Fixed (non-withdrawable) and form an integral part of the high voltage panel.

b. Air-insulated three pole and be rated for fault making.

c. Manual only operation, pad-lockable in both the open and closed positions.

d. Mechanical switch position indicator on the panel facia operated by the position of the switch blades and not the operating handle.

e. It shall be possible to clearly view the switch blades by means of an inspection window in the front of the switchboard without the need to gain access to the compartments containing high voltage circuits.

f. Be uniquely labelled and documented on the single line diagram (SLD).

It should be noted that type-testing certification shall be unaffected by presence of an inspection window. The window shall be capable of withstanding the pressures caused by faults within the switchboard.

4.8.3.1 Earth switch interlocking

Earth switches associated with incoming and outgoing circuits shall only be operable when the switchgear is in the test position or removed from the switchboard. It should not be possible to insert the switchgear past the test position unless the earth switch is open. Mechanical interlocks shall be provided to prevent earth switches from closing onto live supplies.

4.8.3.2 Busbar earth switches

It should not be possible to close the busbar earth switch unless the main incomer circuit breaker(s) is removed or in the test position. It should not be possible to insert the main circuit breaker(s) past the test position unless the earth switch is open. Where multiple incomers exist, a key interlock system shall be used (trapped key type) to prevent any incoming circuit breaker from closing onto an earthed busbar.

4.8.3.3 Incoming supply(ies) earth switches

The incoming supply(ies) earth switch(es) shall be both mechanically and electrically interlocked.

The electrical interlocking shall prevent the earth switch from being closed if:

a. An interlock active signal is received from the Supply Authority; that is, their breaker is closed.

b. The supply cables are live.

The mechanical interlocking shall require a key (trapped key type system preferred) to be inserted into the earth switch locking mechanism before it can be operated. The same key shall be held captive by any upstream circuit breaker(s) (SA Water's only) and only be released when it is open and racked out into the 'Test' position (or the circuit breaker is removed completely). The same circuit breaker(s) shall not be capable of being inserted beyond the 'Test' position without the interlocking key being present.

4.9 Power factor correction

Switchboard motor starter sections that house Power Factor Correction (PFC) equipment shall be protected by the associated starter fuses.

The capacitors shall be housed in a separate stainless-steel case so that any internal fault with the capacitors will not cause them to rupture and contaminate the interior of the starter section. The cases shall be designed such that any internal fault (to the capacitor) shall be contained. The capacitors shall comply with the requirements of IEC 60871 and be capable of withstanding any voltage spikes on the system.

The capacitors shall be sized to meet the requirements of the Supply Authority's regulations in terms of power factor. In any case, the minimum power factor shall not be less than 0.95 lagging. The capacitors shall be fitted with inrush current limiting reactors to prevent the fuses from becoming stressed.

The capacitor dielectric shall be polypropylene film or similar non-hygroscopic material. All impregnating fluids shall be free of PCBs, environmentally safe and biodegradable.

Each capacitor shall be fitted with a discharge resistor such that the voltage across each capacitor will have discharged to less than 50V after 5 minutes of being switched off.

Capacitor cans shall be fitted with pressure switches or thermal monitoring devices to detect stress within the capacitor element. Contacts shall cause the relevant motor protection relay to operate, opening the contactor and displaying the reason why the relay tripped or logging in the relevant protective relay event log.

4.10 Cubicle door interlocking

Interlocking shall be provided in accordance with AS 62271.200.

It should not be possible to open the switchgear cubicle door unless the switchgear is racked into the 'Test' position. It shall also not be possible to rack the switchgear past the 'Test' position unless the switchgear cubicle door is closed.

4.11 Controls and indications

The switchboard front panel section shall be equipped with the following for each circuit breaker and motor starter truck:

a. Mechanical open pushbutton (red).
b. Electrical open pushbutton (red).
c. Mechanical close pushbutton (green).
d. Electrical close pushbutton (green).
e. Closed indicator light (red).
f. Open indicator light (green).
g. Tripped indicator light (yellow). When the protection relay is reset, this lamp should be extinguished.
h. Lamp test button (black).
i. Unit in test position light (blue).
j. Unit in service position light (blue).
k. Earth switch closed light (green).

Lamps shall be high-intensity LEDs (with lenses) supplied at 48VDC with integral step-down transformers.

Alternate means of indication, such as a single line mimic on the protection device HMI or front panel, etc., may be acceptable if it can be demonstrated that the indications will not cause confusion for the switchboard operator. Such alternate means, if proposed, shall be subject to approval.

The following signals shall be available for remote monitoring and control (per circuit contactor/breaker):

a. Open indication
b. Closed indication
c. Tripped indication
d. Earth switch closed
e. Open control
f. Close control.

Remote indication shall be in the form of C/O contacts for each signal rated at not less than 2A at 48VDC. Remote indication via alternate communications may be acceptable if specified otherwise.

Remote control circuits shall be suitable for interfacing with pushbuttons on a remote panel located out of the high-voltage designated room and area if the switchboard is not in a separate room.

4.12 Switchboard earthing

The earthing of the switchboard shall be in accordance with AS/NZS 3000, AS 2067, and AS 62271.200 and shall integrate with the site earthing system and comply with ENA EG-0 and ENA EG-1.

Careful consideration shall be given to the design of HV earthing systems. The earthing design basis and associated risk assessment shall be clearly documented as a part of the HV system design.

Earthing of withdrawable switchgear shall be by means of a sliding contact.

All metalwork associated with the high-voltage installation shall be connected to the site earthing system.

4.13 Vermin proofing

Switchboards shall be vermin-proofed to exclude vermin. Vermin plates shall be provided for cable entry chambers after the installation of cables.

4.14 Metering and indications

High-voltage switchboards shall be provided with dedicated metering equipment for both incoming and outgoing circuits. The equipment shall indicate the following parameters, as a minimum:

a. Current per phase.
b. Voltage per phase.
c. Real and reactive power.
d. Power factor.
e. Frequency.
f. Cumulative power (kWh).

The metering and indication equipment shall be microprocessor controlled, with digital displays.

Instruments and selector switches shall be mounted on the front of the switchboard unless otherwise stated.

Digital displays shall be front panel mounted, with only the display extending beyond the surface of the panel. They shall not compromise the IP rating or the type-testing certificate of the panel.

Electronic components shall be demonstrated to be reliable and maintain long-term operation in the environment in which the switchboard is located.

Numerical displays shall be clear and capable of being read without ambiguity. Displays shall use LEDs or backlit LCD. The numbers displayed shall not be less than 15mm in height.

Operation of the display selector switches shall not cause programs or stored data to be lost, for example, kWh etc.

Energy recordings shall be stored in non-volatile memory and be retained in the event of power loss.

All data (power, volts, amps, power factor, etc.) shall be capable of being retrieved by a PLC using the Modbus protocol, as preferred.

4.14.1 Voltage indicators

Voltage indicators shall be provided on the incoming supply cables (and all feeders) by means of capacitor bushings and neon indicator lamps.

The lamps shall be mounted on the front of the incoming cubicle and in phase sequence R-W-B.

Capacitive voltage indicators shall be equipped with suitable test sockets for banana-type cable plugs.

5 Secondary HV switchboards and RMUs

Future section – Refer to SA Water Principal Electrical Engineer for more information.

6 Protection relays

6.1 General

The protection system shall be designed to provide adequate levels of safety for personnel and for SA Water equipment and to meet requirements for clearance times and operations established by the relevant Supply Authority.

All protection schemes and their implementation must be thoroughly reviewed and discussed with the designated SA Water representative. Approval must be obtained from the Principal Engineer during the design stages to ensure compliance with site-specific requirements and operational standards. This collaborative approach guarantees that the protection strategy is tailored to the unique needs of each site while aligning with SA Water's technical specifications and safety protocols.

In general, relays should be IEC 61850 compatible. Relays shall be of the digital type unless otherwise stated. Relays shall include the following features:

a. Microprocessor-based.

b. Non-volatile memory.

c. Program and setting parameters shall be stored in non-volatile memory.

d. Data storage, for example, trip history, may be stored in volatile memory.

e. Event and fault log.

f. Self-diagnostic utility with alarm indications and output relay to indicate unit fault.

g. RS485/ethernet communications capability (Modbus preferred).

h. Commissioning port (RS485, RS232, USB, etc.)

i. Support password protection by setting parameters.

j. Backlit LCD display.

k. Status LEDs.

l. 48VDC powered.

m. Mounted in a withdrawable case.

n. Provide automatic shorting of CT contacts when removing the case.

o. Door mounted (flush).

p. Have auxiliary contacts for tripping, alarm and indication purposes; contacts shall be rated at 230VAC with a 1A inductive load.

q. Tripping contacts shall latch and be reset from the front of the relay via a button.

r. Testing facilities and connections to be included adjacent to key protection relays.

s. Circuit breaker fail protection to be included with trip signals to the Supply Authority equipment.

t. The protection scheme to provide the ability to accept trip signals from the Supply Authority (inter-tripping).

u. Trip circuit supervision is to be provided for all final trip circuits, with alarms available for remote monitoring.

All protective relays shall be supplied by the same manufacturer unless otherwise approved.

6.2 Switchboard protection

Switchboards and equipment shall be protected in accordance with the parameters laid down by the Supply Authority in terms of their supply rules.

It may not be possible to grade with the Supply Authority's protection equipment, and in such circumstances, unit protection schemes shall be used. Where high fault levels occur (within 25 per cent of the maximum circuit breaker capability) then unit protection schemes shall be used to ensure fast fault clearance times. However, in all projects, the Supply Authority should be contacted in the first instance to determine the grading with their protection equipment, and SA Water shall be notified if it is not possible to grade with the Supply Authority's protection.

Both SA Power Networks and ElectraNet require backup protection schemes (terms and conditions of supply at high voltage). This can be achieved by sending inter-trip signals to the Supply Authority. The inter-trip signal shall be allowed for, and implemented, to trip the Supply Authority's circuit breaker. The relevant Supply Authority shall be engaged to ensure their requirements are met in terms of protection schemes.

All high voltage alarm conditions shall be annunciated via both the site HMI/PLC/RTU and protection relay~~, unless otherwise stated~~ unless otherwise stated. The state of trip condition categorisations (i.e. the tripping conditions typically shown on the protection relay display) shall be made available to the RTU for display on SCADA.

The protection system shall be zoned and settings graded to ensure that only the circuit on which there is a fault is isolated.

Busbar faults shall trip the main incomer circuit breaker(s) or feeder (if fed from another switchboard). The relay shall provide short circuit, over-current, earth fault and circuit breaker failure monitoring. On detection of circuit breaker failure, the upstream breaker shall open (inter-trips to be provided). Protection relay features shall be as follows:

a. Three pole phase fault with instantaneous elements plus earth fault.
b. Selection of SI, VI or EI curves for phase and earth elements.
c. Selectable current and time setting ranges to allow discrimination with upstream and downstream protective devices.
d. Circuit breaker fail function with adjustable time delay, separate trip output for inter-trips.
e. Manual reset of fault at the relay. The associated breaker shall not be able to be closed until the relay is manually reset. The breaker shall be trip free if closed manually and the relay has not been reset.

CTs shall be located such that overlapping protection is achieved; that is, busbar CTs shall be located on the outgoing feeder section, and the feeder protection shall be located on the busbar circuit feeder. This will ensure that no unprotected or short zones exist.

Consideration shall be given to the inclusion of arc fault detection sensors in switchboards where an additional level of safety is being sought to minimise arc fault intensities. On detection of an arc fault in any busbar chamber, the result shall be disconnection of the incoming feeder(s). Where a split switchboard is used with bus ties, then only the switchboard with the arc fault shall be disconnected. The switchboard shall be equipped with a relay(s) to monitor the arc fault detectors and, on detection of an arc fault, the relay shall initiate the appropriate trips.

All incoming/outgoing cable boxes and CB/contactor cubicles shall, additionally, be equipped with arc fault monitoring devices. When an arc fault develops in the CB/contactor cubicle or cable box, only the breaker/fuse that feeds that section should trip.

The arc fault relay shall be microprocessor-controlled and be equipped with indicators to display the status and trip functions of the relay.

Trip functions may be connected to programmable inputs of the main protective relays such that a trip is initiated instantaneously.

6.2.1 Differential bus zone protection

Where discrimination cannot be achieved with other circuits or fault levels are high ~~(within 25% of the maximum incoming breaker rating)~~ or falls outside the clearance times required by the Supply Authority, then busbar differential protection shall be employed. The entire switchboard shall be protected using this protection scheme. Three-phase over current protection and circuit breaker fail function shall also be employed.

Split high-voltage switchboards with a bus-tie or sites with active dual high-voltage supplies shall always employ high impedance bus zone differential protection. This condition is only applicable with dual active supplies to the HV switchboard. Electronic relays shall be used for this purpose.

The protection system should be designed to be stable for 'through-faults' and not present a risk to operations for maintenance staff.

6.2.2 Over-voltage, under-voltage and phase imbalance

Over-voltage protection, relays shall be provided and shall trip the main incomer. Under voltage protection and phase imbalance, relays shall trip motor starter contactors. The relays shall detect any over-voltage and under-voltage for phase imbalance. Pickup values for over/under voltage protection are application-dependent and should be considered in HV design.

6.2.3 Phase imbalance, negative phase sequence voltage

Adjustable from 5-20 per cent, initially set to 10 per cent of the incoming Feeder Protection (From Supply Authority). Trip settings are application-dependent and should be considered in HV design.

If distances are short, extended CT cabling may be used, along with a single three-pole numerical differential relay. This arrangement shall only be employed on prior approval from SA Water. The relay shall be mounted on the associated incomer panel section.

All inter-trip and associated equipment shall meet the requirements of the Supply Authority.

6.2.4 Outgoing Distribution Feeders

An IDMT scheme may be used, but only if it can be demonstrated that it will safely grade with all other protection schemes (including the Supply Authority's). In either case, comprehensive calculations for all schemes shall be supplied and a grading margin of not less than 0.2 seconds shall be used. No equipment damage shall occur when using IDMT schemes; that is, all equipment shall be capable of supporting all fault currents without damage for the duration of any proposed IDMT settings.

Arc flash detection shall be incorporated as per TS 0371 and circuit breaker monitoring can be facilitated through the protection relay if the relay incorporates the necessary functionality.

6.2.5 Incoming distribution feeders

Incoming feeders shall be protected using transformer differential protection relays with fibre communications (or approved equivalent~~).~~) where applicable. An IDMT scheme may be used, but only if it can be demonstrated that it will safely grade with all other protection schemes (including the Supply Authority's). In either case, comprehensive calculations for all schemes shall be supplied and a grading margin of not less than 0.2 seconds shall be used. No equipment damage shall occur when using IDMT schemes; that is, all equipment shall be capable of supporting all fault currents without damage, for the duration of any proposed IDMT settings.

Arc flash detection shall be incorporated as per TS 0371 and circuit breaker monitoring can be facilitated through the protection relay if the relay incorporates the necessary functionality.

6.3 Trip circuit monitoring

Each circuit breaker tripping circuit shall include a relay or function in the protection relay to continuously monitor the integrity of the circuit, including the coil(s) and loss of tripping voltage. This functionality shall be capable of alarming through the PLC control system or to SCADA via an RTU (changeover volt free contacts to be provided) and be indicated on the circuit breaker cubicle.

The trip circuit shall be continuously monitored with the circuit breaker in the open as well as the closed state. Circuit breaker closing shall be inhibited if the trip circuit integrity is compromised.

6.4 Trip lockout relay

A trip lockout relay shall be provided for each circuit breaker/fused contactor. The trip lockout relay, once operated, shall require a manual reset. No circuit breaker/contactor shall be capable of being closed with the trip lockout relay being operated. Trip lockout relay shall require a push action by the finger to reset. Indication shall be an integral part of the relay and shall be manually reset when the relay is reset.

6.5 Protection for HV motors

HV motor sections shall be fitted with relay(s) to provide protection against:

a. Over current.

b. Over temperature (using embedded winding sensors, for example, thermistors, RTDs).

c. Over/under voltage.

d. Under/over frequency.

e. Phase-to-phase faults.

f. Phase to earth faults.

g. Phase to phase to earth faults.

h. Three phase faults.

i. Phase imbalance.

j. Bearing over temperature (load and non-load ends).

k. Cooling medium over temperature.

l. Locked rotor.

m. Excessive number of starts.

The alarm conditions shall be enunciated via both the site HMI/PLC/RTU and protection relay.

6.6 Protection for transformers

Transformer sections shall be fitted with relay(s) to provide protection against the following:

a. Sustained overloads.

b. Over temperature.

c. Phase-to-phase faults.

d. Phase to earth faults.

e. Three phase faults.

f. Temperature monitoring (transformers >1MVA).

Oil-filled transformers with conservators shall employ Buchholz protection Buchholz protection shall be implemented as a two-stage process:

- Stage 1 Alarm (gas build-up).
- Stage 2 Trip.

The alarm condition shall be available via both the site HMI/PLC/RTU and protection relay. The protection relay shall be capable of tripping the relevant circuit breaker on Buchholz operation (Stage 2).

For oil-filled transformers, over-temperature detection shall be provided locally with the transformer through auxiliary instruments. The instrument then provides dry contacts for a Stage 1-Alarm and a Stage 2 trip to the protection relay.

Dry-type transformers shall use PTC probes (or approved equivalent) to detect any over-temperature condition. The transformer protection relay shall, using PTC probes and associated controller, implement a two-stage process:

- Stage 1 Alarm.
- Stage 2 Trip.

The alarm condition shall be available via both the site HMI/PLC/RTU and protection relay. Alarm conditions shall be available at least 2 hours before tripping or 12 per cent below tripping temperature.

6.7 Transformer differential protection

For 11kV transformers with a capacity of 1MVA or higher, the primary protection shall be a transformer differential scheme. Depending on site requirements and the protection philosophy, conventional secondary protection such as overcurrent, earth fault, etc., can be applied. Additionally, oil-filled transformers may be equipped with a Buchholz oil and gas relay to enhance safety measures.

Transformers smaller than 1MVA primarily rely on overcurrent and earth leakage protection, however, transformer differential schemes may be employed if necessary to ensure that the transformer protection grades over the LV protection.

The transformer differential scheme shall be arranged to trip both the primary and secondary circuit breakers, and the function can be provided with up to six three-phase sets of current inputs depending on the site requirement, making the IED suitable for two- or three-winding transformers in multi-breaker station arrangements. The protection settings can be applied as per the manufacturer’s recommendation or the specific application and approved by SA Water.

The protection system should be designed such that it is stable for ‘through-faults’ and not present a risk to operations or maintenance staff. All inter-trip and associated equipment shall meet the requirements of the Supply Authority.

6.8 Capacitor bank protection

Capacitor banks shall implement an overcurrent and earth fault protection relay system. This system is essential for identifying and addressing potential internal short circuits within the filter bank, as well as instances of earth fault currents. Its function is to ensure the integrity and safety of the capacitor banks by promptly detecting and responding to electrical irregularities or faults that may arise. The protection settings shall be applied as per the manufacturer's recommendation and approved by SA Water.

6.9 Circuit breaker failure protection

The failure of a circuit breaker to open in response to a backup protection trip command shall be detected and the associated trip relay activated. A time delay of not more than 0.2 seconds shall be applied to avoid nuisance tripping.

6.10 Current limiting reactors (IS)

Application of current limiting reactors to manage the damage to switchboard assets created by short circuits is considered an acceptable solution. The perceived need for a short circuit current (IS) limiter should be evaluated in environments where downtime due to equipment damage will severely affect the operation of critical plant. Assessment of potential costs and benefits needs to be included in the evaluation.

6.11 Busbar differential protection

Busbar differential protection is well-suited for detecting high impedance faults, phase faults, and insulation leakage, particularly in SF6 switchboards.

A busbar differential protection scheme should be used to protect the busbar zone of a switchboard that, due to physical or operational constraints, cannot be protected using arc flash sensors. This is particularly useful for HV switchboards with complex configurations, where certain sections might have limited arc flash sensor coverage.

6.12 HV arc flash protection

Given the criticality of HV switchboards, implementing arc flash sensors (optionally with CTs) for all HV switchboards, regardless of arc flash category, is recommended to align with SA Water standards (TS 0371). This approach minimizes the need for multiple protection schemes and ensures comprehensive fault detection and operator safety.

Any design for arc flash sensors shall include detail of the strategic placement for effective coverage of all switchboard sections, including busbar tiers. Coordination between arc flash detection and CT protection schemes is essential, especially for SF6 switchboards and cases involving insulation leakage detection.

In scenarios where the line side of a switchboard operates at a higher arc flash category than the rest of the switchboard, and the zone is not covered by arc flash relays, transformer or line differential protection must be used to provide essential coverage.

7 Switchboard labelling

7.1 General

Labelling of HV apparatus shall follow the SA Water Maximo hierarchy of naming. The labels must match those depicted on the Single Line Diagrams (SLDs) and hence, those labels referred to on HV Switching programs.

Labels shall be made of engraved multi-layered Phenolic plastic sheet, such as Gravoply, Rowmark, or approved equivalent, giving white lettering on a red background for warning labels and black lettering on a white background for all other labels. Embossing tape shall not be used. Labels for outdoor equipment shall be resistant to corrosion and sunlight.

Labels shall be fixed by pins, screws or an approved adhesive. Labels that are fixed to the outside surfaces of outdoor Switchboards, control/telemetry panels and other equipment shall be fixed with corrosion-resistant (preferably stainless steel) pins or screws. Adhesives shall not be used for fixing outdoor labels.

Labels shall not be affixed to removable covers, such as cable ducting lids.

Where applicable, the location of the main switch room shall be clearly identified by a permanent sign at the entrance or at the fire indicator board, in accordance with AS/NZS 3000.

7.2 Rating plates

A switchboard rating plate shall be fitted and provide the relevant information specified in the standard used to manufacture the switchboard.

7.3 Main titles and subtitles

Switchboards, control panels and their sub-sections shall be labelled with the titles provided in the project specification and drawings or, where these are not specified, titles that adequately and accurately describe the units.

Minimum lettering height shall be as follows:

a. Main titles 20mm

b. Sub sections 10mm

7.4 Earth switch labelling

Earth switches shall be uniquely labelled and captured on the SLD. Earth switches shall be labelled as follows:

1. For the switch's flags:
    a. Earth switch open 'IN SERVICE'
    with white lettering on a red background.
    b. Earth switch closed 'EARTHED'
    in white lettering with a green background.
2. Adjacent to the operating handle:
    a. Earth switch open 'BUS BAR IN SERVICE' or 'CABLE IN SERVICE'
    as appropriate, in white lettering on a red background.
    b. Earth switch closed 'BUS BAR EARTHED' or 'CABLE EARTHED'
    as appropriate, in white lettering on a green background.
3. Danger notices shall be in accordance with AS/NZS 3000 and AS 2607.

8 Protection and measurement transformers

8.1 Metering current transformers

Metering current transformers (including all incoming and outgoing feeders) shall be in accordance with AS ~~60044.1~~61869.2 and the following:

a. Minimum accuracy class 0.5M or 0.5S.

b. Short circuit rating shall be the same as its switchboard (1 or 3 seconds).

c. Rated to suit total load (including cables, etc.).

d. Winding temperature rise shall be class F.

e. Rating plate information in accordance with the above standard.

f. CTs shall be rated at 120 per cent of maximum FLC (continuous).

g. Dual wound CTs are suitable for use; however, each secondary core shall be rated for the specific application.

h. The metering cores need to have the same continuous thermal rated current as the protection CT cores in the circuit they are associated with.

8.2 Protection current transformers

Protection current transformers shall be in accordance with AS ~~60044.1~~61869.2 and the following:

a. Class PX CTs to be used with circulating current protection schemes (differential), unless it can be proven by calculations that protection class (5P) CTs will suffice for the application.

b. Type-test certificates shall be submitted (for PX CTs).

c. Class 5P CTs are to be used with all other schemes unless otherwise recommended by the relay manufacturer.

d. Secondary current rating shall be 1A;

e. Winding temperature rise shall be class F.

f. Rating plate information in accordance with the above standard.

g. Shall not be oil immersed or be encapsulated with a bituminous compound.

h. VA rating shall be calculated in accordance with the relay manufacturer's recommendations, taking into consideration all burdens.

i. Outdoor CTs shall be of the ceramic type and be IP68 rated.

j. Review the CT knee point for the given maximum system fault level.

8.3 Voltage transformers

Voltage transformers (VT) shall be in accordance with AS ~~60044.2~~61869.2 and the following:

a. VTs shall have a secondary voltage of 110V.

b. Be withdrawable and the switchboard shall have automatic shutters to prevent contact with busbar terminals when removed from service.

c. Accuracy class 0.5 for metering core and accuracy class 3P for the protection core.

d. ~~Output rating~~Burden shall be sized to meet the required load (including provision of any contactor closing function).

e. Cast resin construction.

f. HV and LV fuses shall be mounted on the withdrawable unit.

g. Three single-phase units or a three-phase unit (with an accessible neutral point) shall be provided.

h. Be located in the metering section.

If the unit is not withdrawable directly onto the floor, then a suitable lifting trolley shall be provided. The white phase of the VT secondary shall be earthed and not fused. A bolted solid link shall be used in lieu of the fuse.

8.4 Rogowski coils or low-power current transformers

Rogowski Coils shall be in accordance with ~~IEC 60044-8AS~~AS 61869-9 and the following:

a. Supplied by the protective relay manufacturer.

b. Thermal short circuit rating shall be the same as the busbar rating (1 or 3 seconds.)

c. Insulation level shall be rated according to the highest voltage present within the switchboard.

d. Accuracy class 0.5 (for measurement purposes).

e. Rated primary current 100A.

f. Rated extended primary current 1,250A or higher depending on loading.

g. Secondary voltage 22.5mV or as per the protection relay manufacturer’s requirements.

h. Class 5P from 1,250A – 40,000A (for protection purposes), the minimum requirement may need to be increased, depending on-site loading.

8.5 Test sockets

Flush mounted test sockets shall be provided on each panel section for testing the operation of the protective relay(s).

9 Cables

9.1 Power cables

Insulated high-voltage power cables shall comply with the manufacturing and testing requirements of AS/NZS 1429.1 and be of the following type:

a. Multicore or single core are both suitable for use.

b. Copper conductors.

c. XLPE insulated.

d. Semiconductor layer.

e. Heavy duty copper wire or tape screen with a rating rated based on the situation specific earth fault current withstand requirement and the protection device settings.

f. PVC sleeved.

g. PVC sacrificial cover.

h. Water-blocking screen tape.

i. Nylon jackets or approved equivalent shall be used for termite-proofing for cables installed underground.

Aluminium conductor cables will be considered per application, subject to the approval of the SA Water Principal Electrical Engineer.

Full details of cable type, size and design calculations shall be submitted to the SA Water Engineering prior to the ordering of cables.

9.2 Secondary circuit cables

Secondary and control cables associated with the HV system shall comply with AS/NZS 5,000.1 and shall include the following features:

a. PVC insulated and sleeved.

b. Copper or brass tape screened.

c. PVC outer sleeve.

CT secondary conductor cross-sectional areas shall be determined with reference to the protective relay and any other burdens, operating voltages, prospective fault currents and CT characteristics. The minimum cross-sections shall be:

1. Tripping circuits: 2.5mm^2
2. VT secondary circuits: 2.5mm^2
3. CT secondary circuits (over current): 4mm^2
4. CT secondary circuits (differential protection): 6mm^2
5. Tripping supplies: 10mm^2
6. Rogowski coil cabling shall be as per the manufacturer's recommendations (usually co-axial/screened twisted pair with BNC or RJ45 connectors).

The overall circuit voltage drop for tripping circuits shall not exceed 2 per cent of the nominal voltage.

CT cables shall be screened and earthed at both ends.

All cables shall be provided with a minimum of one spare core or pair or 25 per cent spare cores or pairs, whichever is the greater.

Power and control/protection cabling shall be separated by at least 600mm.

9.3 Installation of HV cables

The design and design calculations for HV cables must include, but not be limited to:

a. Cable size and sheath size calculation

b. Cable sheath, single or double point-bonding system

c. Voltage rise under fault conditions for single-point bonding

d. Type of installation, for example, in-ground direct buried/conduit/cable trenches/cable ducts; above ground; cable tunnel.

e. Selection of cable route

f. Thermal performance of the cable installation.

Suitable segregation and separation of HV/LV/ELVAC and DC cabling shall be in line with good engineering practice.

Cable terminations shall be made using a disconnectable termination system. Cables shall be terminated with stress cones.

Cable joints will only be allowed at the discretion of the SA Water Principal Electrical Engineer. Only manufacturer-approved jointing techniques shall be used. Jointing shall only be executed by fully trained individuals with the appropriate tools and jointing kits.

Where cables enter or pass through a switchyard or at locations possibly subject to electromagnetic or electrostatic interference, they must be screened.

High voltage cables that are installed and running between floors/rooms shall be fitted in such a manner as to maintain the structure's fire rating.

Cable sheaths are to be earthed at the switchboard end only.

Typical practice is to use double point bonding for new HV cable installations at distribution (3.3kV, 11kV and 33kV) voltage levels. Cable sizing must consider the additional derating caused by earth loop currents in the screen for double point bonded systems. Existing installations should be considered on a case-by-case basis.

9.3.1 Above-ground cable installation

Internal high voltage cables shall be installed in ducts or on heavy duty hot dipped galvanised steel cable ladder with covers. Proprietary cable clamps shall be used throughout. No cable ties shall be used. Clamps used outdoors shall utilise stainless steel nuts and bolts.

Cable trays that are constructed with conductive metal material shall be solidly earthed.

Cables shall be protected against impact in accordance with AS/NZS 3013. Cables installed externally shall be installed in wiring systems that meet the impact requirements of category WSX2.

The length of cables installed in air must be kept to a minimum. Where portions of cables are installed in air, ventilation and/or shading must be provided. All cable tails must have highly visible coloured phase identification markings on them. Any cables run between an RMU, transformer, etc, shall be installed in conduits. Where conduits are used, they must have an internal diameter not less than twice the cable overall outer diameter. Fire retardant foam or other solutions approved by SA Water shall be applied at the conduit ends.

Where an HV cable enters a switching station from a cable trough or chamber outside the installation, fire retardant foam or other solutions approved by SA Water shall be applied at the cable entries.

9.3.2 Below ground cable installation

Underground HV cables shall be direct buried, other than for short sections of ducted installation, unless otherwise specified.

Trenching for HV cables shall be of uniform depth. Depth to the top surface of the installed cables shall be a minimum of 750mm, as per AS/NZS 3000. Trenches shall be of sufficient width for chosen mechanical protection to be easily placed in accordance with AS/NZS 3000. Orange marker tape, in accordance with AS/NZS 2648.1, shall be laid on top of the mechanical protection. Where cables are installed beneath a road surface or vehicular accessway, then they shall be protected in accordance with category WSX3.

Prior to commencement of cable installation, the following cable installation design information shall be provided to SA Water for review and acceptance to ensure that cables are installed to achieve the specified cable current carrying capacity:

a. Thickness and compaction of thermally controlled bedding material on the base of the trench.

b. Thermal Resistivity (TR) test reports of native soil samples.

c. Trench dimensions, cable centre line and cable spacings.

Circuits located parallel to other circuit cables must maintain a separation of at least 3.0 m. Cable crossovers should be made at an angle of at least 70°. If such conditions are unable to be met, rating calculations incorporating the adjacent cable circuits shall be made to design an appropriate arrangement and/or increase cable conductor sizes.

Cables must be laid in trefoil formation for circuits with screens solidly bonded to earth at both ends, unless approved otherwise by the Principal.

Where cable screens are single-point bonded, a flat spaced arrangement may be required to achieve the necessary rating. Such design spacings shall be regarded as a minimum and shall be set out accurately in the cable trench during installation using spacers (templates).

A bedding layer consisting of Thermally Stable Backfill (TSB) shall be installed and compacted to 150mm minimum thickness in the base of the excavated trench to serve as a stable working floor prior to cable laying.

9.3.2.1 Backfilling

Test Reports showing full details of all proposed backfill materials, including material sources, descriptions, mix proportions, and results of Maximum Dry Density and Thermal Resistivity tests (including 'dry-out' curve) shall be submitted to SA Water for review prior to commencement of site work.

Thermally Stable Backfill (TSB) shall be used from the trench floor up to within 200mm from finished ground level or, in the case of a driveway, up to the boundary of the determined thickness of the road.

Traditionally, TSB is a 14:1 sand/cement mixture. Fluidised Thermal Backfill (FTB) is the preferred backfill due to its free-flowing quality and ability to fill voids beneath and around cables without the need for compaction.

The thermally controlled material shall be free of rock, shells, or other foreign matter that may impair the overall thermal resistivity of blended materials or cause damage to the cable's anti-corrosion jacket.

Polymeric cable protection covers (to AS 4702) and warning tapes (to AS/NZS 2648.1) shall be installed in the cable trench. The protective covers shall be placed 150mm above the cables.

9.3.2.2 Marking of underground cable routes

Underground HV cable routes shall be marked at each end and, at 25 metre intervals and at every change in direction. The markers shall be either the concrete block type or a dedicated post where it would otherwise be difficult to sight block-type markers. Special note should be made as to the type of block marker used in situations where traffic would be present or where undergrowth or soil erosion might be an issue.

Cable marker posts shall be commercially produced and preapproved by the SA Water representative. Concrete block markers shall be 300 x 300 x 300mm in size and buried to a minimum depth of 200mm. Stamped on the top surface shall be:

a. "HIGH VOLTAGE CABLE".

b. The cable depth.

c. Arrows indicating the approaching and departing cable direction.

9.3.3 Cable entry seals

All duct openings within High Voltage ducted networks (including unused/spare ducts) and openings into building structures provided explicitly for the passage of HV cables shall be sealed after cable installation to prevent the ingress of harmful, flammable and corrosive gases, liquids, smoke, fire and vermin.

The type of sealing systems should be selected that take into consideration environmental and hazardous area conditions.

Duct sealing systems must comply with the following performance requirements, as a minimum:

a. Gas and watertight to a minimum of 2-bar pressure.

b. Resistant to corrosion/degradation in the relevant operational environment.

c. Resistant to vermin.

d. Fire resistant for 2 hours, tested to Australian Standard, AS 1530.4.

In no circumstances shall expanding foam be used to seal any HV cable ducts.

9.3.4 Provision of cable route information

As-built single-line diagrams shall include cable information as such:

a. Voltage of circuit.

b. Cable manufacturer.

c. Conductor size and number of conductors per phase.

d. Laying/spacing configuration.

e. Cable bonding arrangement (solid or single point).

As-built information shall also include cable trench survey data. The survey drawings shall include all trench particulars such as position, depth, width, type and size of other services, distances to road kerbs/property boundaries and other significant landmarks.

9.4 High voltage cable testing

9.4.1 General

A high-voltage cable test plan must be supplied to SA Water Engineering department prior to the commencement of any high-voltage cable testing.

VLF tan delta cable testing shall comply with IEEE P400.2. It is noted that this is a tan delta test, which is powered with a VLF device, it is not a VLF performance test. Under no conditions shall a VLF performance test be completed.

Before any Very Low Frequency (VLF) Tan Delta (TD) testing is undertaken, a high voltage cable is required to have an 'Outer Sheath Insulation Resistance Test' and an 'Insulation Resistance Test' completed to indicate minimum acceptable results have been achieved.

The testing requirement for the Outer Sheath Insulation Resistance Test and the Insulation Resistance Test shall refer to SA Power Networks Standard TS105.

9.4.2 Outer sheath insulation resistance testing

The purpose of the high voltage cable outer sheath insulation resistance test is to determine the condition of the outer sheath of the cable and identify if there has been any damage to the sheath during/after cable installation. A sheath integrity test should be done after installation (prior to termination and trench backfilling) to verify that cable damage during installation has not occurred, and repeated when terminations are complete.

Some newer cables may have a semi-conductive outer sheath. This is used to provide improved lightning performance and a more reliable mechanism for detecting sheath faults. The semi-conductive HDPE does not require additional bonding to earth.

Each high-voltage cable outer sheath shall be tested, that is, each screen wire to an independent earth.

For 11kV cables, the test parameters are:

- 1,000VDC.
- Time of test: 1 minute.

For 3.3kV cables, the test parameters are:

- 500VDC.
- Time of test: 1 minute.

This test is required for the following situations:

- New cable installations.
- Existing cables ongoing monitoring.
- Where existing cables have been joined and repaired.

The reading for cable sheath resistance should be greater than the acceptance value set out below for HDPE and sheathed cables. The SA Water representative must be advised where the value remains low.

Table 1: Cable sheath resistance

Cable size (mm^2)	Distance (m)			
	250	500	1,000	2,000
≤ 11kV				
35	500MΩ	250MΩ	125MΩ	62MΩ
185 - 240	300MΩ	150MΩ	75MΩ	37MΩ
400	250MΩ	125MΩ	60MΩ	30MΩ
≥ 22kV				
35	400MΩ	200MΩ	100MΩ	50MΩ
185 - 630	500MΩ	250MΩ	125MΩ	62MΩ

Data is not presently available for cables larger than the cables specified above. However, the insulation resistance should not be significantly lower than the figures above.

For PVC sheathed cables, the acceptance value is 1MΩ.

9.4.3 Insulation resistance test

Prior to a VLF TD test, the high voltage cable's core insulation resistance for new or aged cables shall be tested, that is, each core to screen, with the following parameters:

a. For 3.3kV cables, the Core Insulation Testing shall be conducted with the following parameters:
    - Voltage: 1,000VDC phase to earth.
    - Duration: The insulation resistance shall be recorded 1 minute, 2 minutes, and 5 minutes after application of the voltage.

b. For 11kV cables, the Core Insulation Testing shall be conducted with the following parameters:
    - Voltage: 5,000VDC phase to earth
    - Duration: The insulation resistance shall be recorded 1 minute, 2 minutes and 5 minutes after application of the voltage.

The 2-minute and 5-minute readings may not be required for short cables if the reading has already stabilised after 1 minute.

The core insulation resistance is to be measured A to B+C+E, B to A+C+E, and C to A+B+E. The cable screen should be earthed during the above measurement.

This test is required for the following situations:

a. New cable installations.
b. Existing cables ongoing monitoring.
c. Where existing cables have been joined and repaired.

The minimum acceptable result for a new XLPE cable shall be 4,000MΩ. The minimum acceptable result for an aged XLPE cable shall be 1,000MΩ. The SA Water representative must be advised where the value remains low.

9.4.4 VLF tan delta testing

The VLF tan delta test shall only commence once 'Outer Sheath Insulation Resistance Tests' and 'Insulation Resistance Tests' have been completed and the minimum acceptable results achieved.

The VLF TD test shall be performed using the following parameters:

a. 0.1Hz AC frequency.
b. Voltage steps of the following:
    - 0.5 x Uo.
    - 0.7 x Uo.
    - 1.0 x Uo.
    - 1.2 x Uo.
    - 1.5 x Uo.
c. Each voltage step should be tested for a minimum of 2 minutes. It is suggested that an inspection of the tan delta versus voltage curve is made after the 1.0 x Uo measurement is taken. If the curve is flat, continue the test.
d. Uo (phase to earth voltage) for:
    - 3.3kV Uo = 1.9kV.
    - 11kV Uo = 6.4kV.
    - 22kV Uo = 12.7kV.

10 High voltage earthing

Any earthing report will need to include details of compliance with the relevant Australian Standards, and any risk considerations should be detailed. Earthing designs are required to comply with ENA EG-0 and ENA EG-1.

All metal objects located in HV switch rooms (and substations) shall be bonded to the high-voltage earthing system and comply with the requirements of AS 2067 and AS/NZS 3000.

Individual earthing conductors shall be run for motors, transformers, drives, switchboards, etc.

Each switchboard shall be provided with a separate earth bar on which earthing to the individual pieces of equipment shall terminate. The earth bar shall be mounted on insulated bushings and shall have a cross-sectional area of not less than 50mm x 10mm. All earthing bars and conductors shall be made from copper.

Cables shall be terminated on the earth bar by means of compression lugs and be bolted to the earth bar. Cables on the earth bar shall be identified by engraved labels attached to the earth bar.

All ladder and other wiring systems used to support HV cables shall be electrically continuous and bonded to the station earth bar.

The minimum bonding conductor size shall be 70mm^2.

All earthing cable sizes shall be determined through calculation in accordance with standards such as AS2067 and ENA EG-1~~ and IEEE 80~~. Installed earthing conductor sizes shall not be less than the following minimum requirements:

a.	Interconnection to Supply Authority	2x 120mm^2
b.	Interconnection between earth bars	2 x 120mm^2
c.	Main earth conductors	120mm^2
d.	Switchboard earthing conductors	120mm^2
e.	Motor earthing conductors	70mm^2
f.	Capacitor earthing conductors	70mm^2
g.	Cable ladders/conduit for feeders	70mm^2
h.	Transformers	120mm^2

11 DC auxiliary supplies

11.1 General

DC power systems shall comply with AS 3011.2, AS 2676.2 and AS 4044.

The requirements include:

a. Battery Bank.

b. DC distribution system.

c. DC Battery charger.

d. Rack mount design with adequate segregation and key components replaceable.

e. Earth fault monitoring.

f. Cell or block voltage/condition monitoring.

g. AC input breakers.

h. Battery isolation switches to facilitate battery testing.

i. Alarm wiring compatible with station indication requirements.

j. Housing to prevent ingress of vermin.

11.2 Battery bank

The battery system shall be unearthed, however, earth leakage current shall be monitored such that leakage currents of greater than 10mA shall be detected as an alarm condition. The alarm condition shall be visibly enunciated on the battery charger panel and shall cause a volt-free contact to open. This shall be used for remote monitoring purposes.

The battery bank shall comprise a series connection of single-cell battery units.

The batteries shall be of the valve-regulated lead acid type, complying with the requirements of AS ~~4029.2~~60896.22 and have flame retardant cases.

The enclosure shall be sheet steel painted with an acid-resistant coating and compliant with the requirements of AS 3011.2 and AS 2676.2. Enclosures shall surround the batteries on all sides.

The battery bank shall be required to supply the tripping supply and protection system control supply for a minimum of 24 hours in the event of the AC mains power failure.

Sizing calculations for all battery banks shall be provided to SA Water.

Batteries with a minimum warranty of two years shall only be used.

11.3 Battery charger

The battery charger shall comply with AS 4044 and be of the automatic constant potential, current-limited type. It shall be compatible with the battery, and only charger systems that have components that are considered 'hot-swappable' should be used.

The charger shall be rated to maintain the standing load and to fully charge a discharged battery in 20 hours.

The charger shall be short-circuit protected and be fitted with a thermal overload device to prevent damage with a sustained overload.

The charger shall maintain the output voltage and current when the input voltage deviates from +10 per cent to -15 per cent of nominal voltage.

The charger shall be housed in a separate compartment from the batteries. The charger shall be fitted with the following alarm indications:

a. Battery over voltage
b. Battery under voltage
c. Supply failure
d. Subcircuit breaker trip
e. Charger failure
f. Earth fault on the battery system.

Alarm conditions shall be indicated on the charger facia. Volt-free change over contacts shall be provided to indicate the above conditions for annunciation of the above conditions to the SCADA system and/or site monitoring system, for example, local HMI and PLCs.

Alarm conditions shall latch and shall be reset through local Operator action.

11.4 Charger distribution

The battery enclosure shall include a DC distribution board to control the sub-circuits. Sub-circuit protection shall be provided by MCBs for DC distribution purposes. The circuit breaker shall disconnect both positive and negative supplies and be fitted with auxiliary contacts for monitoring purposes.

11.5 Tripping supply configuration

The tripping supply system shall be duplicated such that any one failure (charger, battery bank, tripping supply) shall not cause the high voltage system to become inoperative.

12 Transformers

12.1 Construction

The transformer core shall be constructed using cold rolled grain-orientated magnetic silicon steel (HiB type). The core design shall be of the 3-limb type; each limb shall have a fully rounded shape (stepped construction).

Transformers that are constructed using Amorphous Metal to achieve lower no-load loss will be considered.

12.2 Ratings

Transformers shall be rated for the given load with at least 30 per cent spare capacity for transformers rated at less than or equal to 100kVA. Transformers whose ratings are between 101 and 200kVA shall have at least 25 per cent spare capacity. Transformers whose ratings are between 201kVA and 2.5MVA shall have at least 20 per cent spare capacity. Transformers over 2.5MVA shall have their spare capacity defined in the specification requirements.

Transformers shall be capable of being loaded to 110 per cent of rating for 2 hours, every 24-hour period, indefinitely (cyclic conditions) at worst-case environmental conditions. The initial loading of the transformer shall be assumed to have been 90 per cent of rating for the 22 hours prior to the overload.

Transformers shall comply with the requirements of the following standards:

a. AS 2374.1.2 Power Transformers: Minimum energy performance standard (MEPS) requirements for distribution transformers.

b. AS/NZS 60076.1 Power transformers – General.

c. AS/NZS 60076.2 Power transformers – Temperature rise.

d. AS/NZS 60076.3 Power transformers – Insulation levels dielectric tests and external clearances in air.

e. AS/NZS 60076.5 Power transformers – Ability to withstand short circuit.

f. AS/NZS 60076.7 Power transformers – Loading guide for oil immersed power transformers.

g. AS/NZS 60076.10 Power transformers – Determination of sound levels.

h. AS/NZS 60076.11 Power Transformers – Dry type.

i. IEC 60085 Thermal evaluation and classification of electrical insulation.

j. AS/NZS 60137 Insulated bushings for alternating voltages above 1,000V.

k. AS 60270 High Voltage Test Techniques – Partial discharge measurement.

l. IEC 61100 – Classification of insulating liquids according to fire-point and net calorific value.

12.3 Requirements

12.3.1 General

Transformers shall be 50Hz, three-phase units with electrically separate primary and secondary windings.

Transformers shall meet the minimum requirements of efficiency as detailed in AS 2374.1.2.

Winding temperature probes for temperature control when using forced ventilation shall be installed in any supplied transformer for future or current use. Terminals shall be located in the auxiliary terminal box.

The windings shall be able to withstand without damage the thermal and dynamic effects of an external short circuit at fault levels that may be encountered at the point of installation.

Transformers shall be designed such that leakage flux does not cause overheating in any part of the transformer. Avoidance of over-fluxing at the most onerous operating conditions, especially on cyclic overloading condition, is essential.

The transformer and all associated components shall be designed to be suitable for use at the defined cycle rating (see above) without exceeding any specified parameters, as noted in section 3.2 of this document.

The transformer and all the ancillary equipment, for example, CTs, instruments etc. forming part of the transformer shall have been type-tested by a recognised manufacturer or testing authority in accordance with the relevant AS and IEC standards before delivery. The relevant type-test certificates shall be included with any submitted offer.

All rating plates (metal) and labels shall be clearly visible from the normal operating position. The cyclic rating is to be included on the nameplate.

Manuals shall be provided that clearly indicate any special considerations, along with procedures for installation, commissioning, use, maintenance, and disposal in respect of Health and Safety issues, environmental requirements and other statutory obligations.

Tap changing shall preferably be by means of an easily accessible rotary switch on the HV side. The links shall be arranged such that the LV nominal voltage can be changed by +/- 5 per cent in 2.5 per cent increments.

12.4 Transformer sound levels

As there are several options available for defining sound levels for transformers means that the supplier must consider how to set a guarantee level when specifying new equipment, to avoid conflict when the unit is subjected to its final acceptance tests.

The following items should be agreed with SA Water before the purchase of a transformer is undertaken (as per AS/NZS 60076.10.1):

a. The guaranteed sound pressure or power level.

b. The choice of test method.

c. The load conditions (such as test voltage and power factor).

d. Presence of auxiliary equipment, such as coolers.

e. On-site operating conditions (optional).

f. Any relevant legal requirements.

12.5 Vector group

The transformer vector group shall be Dyn11 (11/0.415KV), Dyn11 (3.3/0.415KV) and Dyn11 (11/3.3KV) for greenfield installations. Any vector group employed at an existing installation shall remain.

12.6 Cable box requirements

High voltage feeders shall terminate on the transformer high voltage cable box. All high voltage cable boxes shall be capable of accepting stackable cable connectors to suit 630mm² XLPE single core armoured high voltage cables (two cables per phase and Neutral).

12.6.1 Cable box

Low voltage transformer cable boxes shall be capable of accepting and terminating both busbar (when necessary) and cable terminations (not simultaneously). The cable boxes shall be suitably sized to accommodate the number of perspective cables that are necessary for the size of the transformer, given the specific site conditions in terms of volt drop, current carrying capacity and fault levels/clearance times.

Multiple low voltage cable boxes may be required, depending on specific design requirements, for example, transformers with tertiary windings.

Adequate means shall be provided to support all cables underneath/above the cable boxes.

12.7 Flux densities

For the purposes of determining the maximum flux density in the core and other magnetic components, it may be assumed that the system's highest voltage at 47 Hz represents the worst combination of voltage and frequency for continuous operation. Where a maximum peak flux density exceeding 1.9T will be induced in the core or any other magnetic component under the above condition at any tap position, then this shall be clearly stated in the tender and evidence provided to show that the transformer shall be capable of continuous service without damage under this condition.

12.8 Earthing connection

The transformer shall be provided with an earthing bolt. The bolt shall be capable of accepting 2 x 120mm^2 copper earth conductors.

12.9 Transformer options

12.9.1 Oil filled transformers

Oil-filled transformers shall utilise natural cooling and be of the type KNAN or ONAN. Transformers (above 1MVA) shall be capable of being simply converted to forced cooling of the KNAF/ONAF type with a subsequent increase in rating of 20 per cent.

It is preferable that oil-filled transformers utilise a biodegradable product, for example, natural Ester-based dielectric fluid, which meets the requirements of IEC 61100 K2 fire hazard class. It should be noted that SA Water encourages the proposal of less flammable liquid insulated transformers in accordance with AS 2067. Where this specification cannot be met, the SA Water Principal Electrical Engineer shall be consulted.

Oil Transformers shall be fitted with the following:

a. Oil drain valve.

b. Thermometer.

c. Auxiliary cable box (for auxiliary circuits, for example, Buchholz Relay).

d. Silica gel breather with a five-year service interval (relevant to non-hermetically sealed units only).

e. Oil filling plug (relevant to non-hermetically sealed units, only).

f. Relief vent valve.

Oil-filled transformers shall be filled on-site.

Oil-filled transformers shall be rated for indoor and outdoor use and have a rating of not less than IP56.

12.9.2 Dry-type transformers

All dry-type transformers shall be capable of being retrofitted with cooling fans, without changing the enclosure.

Dry-type transformers may employ tap changing by means of bolted links.

Dry-type transformers shall be fitted with the following:

a. PTC probes (probes shall terminate in the transformer auxiliary box).
b. Bi-directional rollers.
c. Auxiliary terminal box.
d. Forced cooling temperature probes.
e. Temperature display (derived from PTC probes).

Dry-type transformers shall be rated for indoor use, be fitted with the manufacturers proprietary steel enclosure and have a rating of not less than IP31.

Dry-type transformers shall be installed in a dedicated HV room.

13 High voltage motors

13.1 Construction

High voltage motors shall be constructed from cast iron and be of the high-efficiency type. Motors shall be totally enclosed, and cooling shall be via an integral fan blowing over the stator heat sinks (ribs), which shall form part of the cast iron frame or be water cooled.

Water coolers and associated components shall be constructed from 316 stainless steel or approved equivalent. The cooling system shall be supplied by the motor manufacturer. All flexible coolant connections in the vicinity of the motor shall be to marine certified standards (Australian Standards and Lloyds). Cathodic protection, where applicable, shall be fitted to the liquid cooling circuit.

Additional protection circuitry shall be incorporated into the motor starter to detect and prevent the motor from starting/running should the water-cooling system have the following faults:

a. Low coolant flow (water).

b. Coolant over temperature.

c. Coolant leak.

Motors shall be suitable for either vertical or horizontal mounting and be of the induction type (squirrel cage).

The rotor shall utilise swaged high-conductivity copper rotor bars and be dynamically balanced.

The rotor shall be supported using ball bearings for horizontal machines and angular contact bearings for the vertical machine. In both machines, labyrinth bearing seals shall be used to prevent airborne particles from contaminating the bearings. The non-drive end bearing assembly shall be insulated and a shaft grounding ring assembly fitted to prevent circulating shaft currents when operating with a variable speed drive. Bearings shall be protected to IP56.

Motor windings are to be fitted with RTDs for temperature monitoring and alarms. Motor specifications shall include information on motor windings normal operating temperature range and temperature alarm set points.

Motors shall be suitable for both internal and external use.

13.1.1 Finish

Motors shall be painted to the manufacturer's specifications. However, the environment in which these motors are installed shall be taken into consideration. If the environment is highly corrosive, then the manufacturer should be consulted as to the final finish for the motor.

13.1.2 Motor IP rating

Motors shall be rated as follows:

a. Where pressurised water presents a potential hazard within the vicinity of the motor – IP56. This will generally be the rating required in pump halls.

b. IP55 In all other cases.

13.2 Vibration

Motors shall be designed to produce a low vibration level. Motors shall produce no more than 0.8mm/s when running at rated speed over the full operating temperature range. Continuous vibration monitoring ~~is required for all new high voltage motors~~compatible with SA Water's existing vibration monitoring platform shall be provided for all new high voltage motors. The

Technical Specification covering the mandatory requirements for any continuous vibration monitoring installation is available on request to SA Water's Representative.

13.3 Noise

Motor noise shall be less than 80db (A) at 1m.

13.4 Terminal boxes

13.4.1 Auxiliary terminal box

Two terminal boxes shall be provided, one for power cables and the other for auxiliary circuits. Terminal boxes shall have the same IP rating as the motor or be IP54 as a minimum.

13.4.2 HV terminal boxes

The HV terminal box shall be capable of accepting two 240mm^2, XLPE, single core, copper, heavy-duty screened cables per phase (as a minimum). It shall also be capable of accepting two 240mm^2 copper earth conductors. Terminal boxes shall be air-insulated.

13.5 Electrical characteristics

Motors shall be suitable for operation at the rated nominal voltage of 3.3kV or 11kV.

13.5.1 Efficiency

Motors shall be of the high-efficiency type and not be less than 96.5 per cent at full load. The power factor shall not be less than 0.88 lagging at full load.

13.5.2 Operation and starting duty

HV motors shall be suitable for the supply voltage and be rated for continuous use at FLC with a maximum of 4 starts per hour (two in rapid succession).

Motors shall be capable of being operated and started by the following methods:

a. Variable frequency drive.

b. Soft Starter.

c. DOL.

13.5.3 Auxiliaries

The motor shall be fitted with, and have wired to the auxiliary terminal box:

a. PTC sensors embedded within the stator windings (6 probes minimum).

b. Anti-condensation heaters.

c. Bearing over temperature sensors (at both drive and non-drive ends).

PTC sensors and anti-condensation heaters shall be terminated in a separate terminal box.

13.5.4 Standards and type testing

Motors shall comply with the requirements of:

- IEC 60034 series of standards relating to Rotating Electrical Machines.

The motor(s) and all ancillary equipment, for example, bearing monitoring, etc. forming part of the motor shall have been type-tested by a recognised manufacturer or testing authority in accordance with the relevant AS and IEC standards, before delivery. The relevant type-test certificates shall be included with any submitted offer.

13.5.5 Insulation

Stator winding shall meet the requirements of Class F insulation, but the motor shall meet Temperature Rise Class B. This shall ensure a reasonable overload margin whilst providing for a long stator lifetime.

Motors shall be manufactured under an ISO 9001 quality system.

13.5.6 High Voltage Motor Testing (in-situ)

Performing in-situ periodic testing on high voltage (HV) motors is crucial to ensuring their proper functioning and reliability.

Table 2 lists the range of recommended tests for HV motors. The age and configuration of the motor will determine the required tests. The motor testing specialist must present justification for the set of tests chosen or for any additional suggested tests. Any deviations or clarifications on the listed tests shall be vetted by the SA Water Principal Electrical Engineer.

These tests are recommended to be conducted in the order listed. Machines to be tested must be clean and dry.

Table 2: Recommended tests for HV motors

	Test Description	**Suggested actions/Standards/Notes**
1	Winding Impedance/Inductance/Phase Angle Measurement	
1.1	DC Winding Resistance	Record winding temperature during DC resistance test and correct to 75°C
1.2	Tan Delta test (DLA or DDF)	IEC 60034-27-3:2015 – Rotating Electrical Machines – Part 27-3: Dielectric Dissipation Factor Measurement on Stator (and the AS 60034 series of standards) Winding Insulation of Rotating Electrical Machines.
2	Visual Inspections	
2.1	Inspect the motor and terminal box for any signs of wear, corrosion, overheating, moisture or damage.	
2.2	Check for damaged insulation, and any unusual noise or vibration.	
3	Insulation Resistance (IR) Testing	
3.1	Perform insulation resistance tests using a megohmmeter to ensure the insulation system is intact.	IEEE 43-20~~13~~22 – Recommended Practice for Insulation Testing of AC Electric Machinery with High Voltage Rating up to 30 kV at Very Low Frequency~~Recommended Practice for Testing Insulation Resistance of Electric Machinery~~. Machines with windings not reconditioned should have an insulation resistance test instead of a high potential test. High-potential tests for reconditioned windings should be performed at 65% of the new winding test value. Compare the results with the motor's baseline values and investigate any significant deviations.
4	Dielectric Absorption Ratio (DAR) /Polarization Index (PI) Testing	

	Test Description	Suggested actions/Standards/Notes
4.1	Conduct a DAR/PI test to assess the insulation resistance over a specific time interval.	As per IEEE 43-201~~13~~22 Recommended Practice for Insulation Testing of AC Electric Machinery with High Voltage Rating up to 30 kV at Very Low Frequency, ~~"Recommended Practice for Testing Insulation Resistance of Electric Machinery"~~ a high DAR/PI indicates good insulation condition, while a decreasing PI/DAR might signal insulation degradation.
5	Surge Comparison Testing	
5.1	Analyse the waveforms to identify any issues with the insulation system.	A surge test is the only test that finds weak turn-to-turn insulation. This is due to higher voltages used in a surge test. This test also detects loose connections in the windings.
6	Partial Discharge (PD) Testing	
6.1	Perform PD testing to detect localized insulation breakdown.	(on motors in 6.6kV and 11kV ranges) Refer IEC 60034-27-1:2017 for test connections and setup. Evaluate the PD levels and take corrective action if abnormal readings are observed.
7	Power Factor Testing	
7.1	Perform the power factor test to assess the efficiency of motor operation and ensure optimal energy use.	Deviations from the standard power factor may indicate insulation issues.
8	Current Signature Analysis	
8.1	Look for irregularities in the current waveform that could indicate problems with the motor or load.	Use current signature analysis to monitor the motor's operating condition and identify abnormalities. This test is conducted to understand the condition of the bar winding of the cage rotor of the motor. This test also provides information on rotor eccentricity.
9	Temperature Monitoring	
9.1	Monitor the operating temperature of the motor using infrared thermography, where possible.	Identify any hotspots that may indicate issues with the motor's components.
9.2	Review RTD temperatures from SCADA trends (winding, bearing, heat exchanger, etc).	
9.3	Check RTD and heater resistance values	To confirm the health of these devices.
10	Condition of Relevant Monitoring Instruments	
10.1	Check the condition of instruments relevant to the operation of the motor, such as air flow, water flow, water leakage.	To confirm the health of these devices.
11	Tightness of Cable Connections	
11.1	Ensure tightness of cables before returning assets back to SA Water for re energising and record the torque of each phase.	
12	Vibration Analysis	
12.1	Utilise vibration analysis to detect mechanical issues within the motor.	Abnormal vibration patterns may indicate misalignment, imbalance, or other mechanical problems.

	Test Description	Suggested actions/Standards/Notes
13	Documentation and Trend Analysis	
13.1	Keep detailed records of all test results and observations.	Record nameplate details (a photo is required)
14	Report any anomalies with suggested remedies	
14.1	Analyse trends over time to predict potential issues and schedule preventive maintenance.	
14.2	Write and submit the inspection report with asset health condition information.	'Before' and 'after' photos are always helpful.

14 Soft starters

Soft starters shall be suitable for controlled starting of induction motors (squirrel cage).

Soft starters shall be either stand-alone devices (replacements or retrofits) or, when part of a new panel installation, shall form an integral part of the new switchboard and be supplied by the panel manufacturer. The soft starter, in this instance, shall comprise a motor starter section (vacuum contactors controlled by the soft starter module), as detailed in section 4.8. The soft starter section shall comply with the switchboard's physical, earthing and interlocking requirements, as per section 4.

Soft Starters and motors purchased as a package from one vendor shall be preferred. In all cases, the soft starter vendor shall ensure that the soft starter, motor and cabling are properly coordinated. Precautions shall be taken to ensure that the vibration levels over the speed range does not excite natural frequencies that can create resonance or other similar effects.

14.1 General

All soft starters shall be equipped with the following:

a. Electrically held vacuum bypass contactor (same rating as that provisioned in the motor starter cubicle).

b. SCR power module, SCR modules protected by snubber circuits, preferably the energy recovery types.

c. Soft starter protection relay.

d. Motor protection as per section 6.5.

e. Soft starter control module with HMI for fault, performance monitoring and user programming of soft-starter parameters, including ramp up (0-120 secs) and ramp down times (0-120 secs), kick-start settings, pre-set ramps and user-configurable ramp/curve parameters. Control module to use in-built PID algorithms for control purposes.

f. Input for tachometer feedback signal from the motor to control SCR firing.

g. Communications module supporting Modbus for control and monitoring purposes.

h. Programmable analogue and digital I/O modules.

i. SCR circuit shall meet the Supply Authority's specifications in terms of their harmonic requirements at the point of common coupling (PCC).

j. Emergency stop push button, reset button and lamp. The emergency stop circuit shall be hard-wired into the contactor circuit (minimum of a category 1 circuit). When activated, the motor will not start unless the emergency stop circuitry has been reset at the starter.

k. Capable of at least four (4) starts per hour, with two in rapid succession.

14.2 Stand-alone soft starters

The soft starter cubicle(s) shall be complete with all required base frames and plinths, which are suitable for mounting on concrete floors with open-top cable ducts below. All structural work shall be done in accordance with AS 1170.4 regarding stability under earthquake loads.

The mounting height of soft starters and the condition of the floor shall suit the use of trolleys for any withdrawable components.

All maintenance and service operations shall be capable of being carried out from the front of the soft starter.

Voltage indicators shall be provided on the incoming supply cables by means of capacitor bushings and neon indicator lamps.

The lamps shall be mounted on the front of the incoming cubicle and in phase sequence R-W-B.

14.2.1 Degree of protection

For soft starters installed in a dedicated high-voltage room, the degree of protection shall comply with AS 60529 and the following:

a. IP4X on the external housing.

b. IP2X inside the compartments.

For soft start units not installed in a dedicated high voltage room but located in a pump hall where pressurised water presents a potential hazard, for example, should a pipe flange fail, etc.

- Not less than IP54.

Soft starters shall not be installed outdoors.

14.2.2 Construction

Starters shall be constructed from a minimum 2mm thick zinc steel sheet and be painted to manufacturers' specifications.

The soft starter shall satisfy the same requirements in 4.1 of this document.

There shall be no undue movement of panels or cubicles during normal operation, including times when withdrawing and replacing equipment.

Soft starters shall be equipped with four distinct compartments:

a. Incoming section.

b. Power electronics section.

c. Low Voltage control section.

d. Outgoing section.

The incoming section shall terminate incoming feeder cable(s) and be capable of accepting both multi-core and single-core, heavy-duty screened XLPE cables for the required motor load. Both top and bottom cable entry shall be possible. The incoming section shall be interlocked with the associated main switchboard section, and it shall not be possible to open this section unless the upstream truck-mounted fused contactor has been racked into either the test position or withdrawn and the earth switch is closed.

The soft starter incoming section shall be equipped with a load break/fault make/earth switch. The switch, when in the earth position, shall earth the soft-starter busbars. The switch shall have mechanical flag-type indicators for open/closed/earth position status, visible from the front of the starter section. The switch shall be capable of being padlocked in the open and earth positions. It shall not be possible to move the switch directly to the earth position from the open position or closed position. It shall not be possible to move the switch to the earth position unless the upstream contactor/switching device is racked out, in the test position or, in the case of a switch, in the open position. Mechanical interlocks shall be provided (trapped key type is preferred) with any upstream devices.

14.2.3 Power electronics section

The power electronics section door shall be mechanically interlocked with the incoming section's load break switch. It shall not be possible to open the cubicle door unless the load break switch is in the earth position.

The power electronics section shall be fitted with an incoming vacuum contactor. The contactor shall be coordinated (AS 60470) with the fuses located in the motor starter section (fuses may have to be replaced to ensure this requirement is met). Should the soft starter be fed from an upstream switch, the soft starter shall be equipped with high voltage HRC fuses in the incoming section.

Should any components, for example, capacitors, carry a lethal voltage after the power has been removed, then the doors of this section shall be electrically interlocked until the voltage decays to a safe level.

All power capacitors shall have discharge resistors fitted such that the voltage shall not be more than 50V after five (5) minutes.

14.2.4 Low voltage control section

LV control section shall contain all protective and control interfaces. This section shall be provided with a lockable door complete with an inspection window. No access to HV sections shall be possible from the LV control section. Access to all signalling, control and communications cables/terminals/interfaces shall be via this section.

14.2.5 Outgoing section

The outgoing section shall terminate the motor feeder cable(s) and be capable of accepting both multi-core and single-core, heavy-duty screened XLPE cables sized for the required motor load. Both top and bottom cable entry shall be possible. The outgoing section shall be mechanically interlocked with the incomer section load break/earth switch, and it shall not be possible to open this section unless the switch is in the earth position.

It shall be possible to earth the outgoing cables using portable earthing equipment. The outgoing cable termination system shall facilitate safe and easy connection of such equipment. All necessary earthing equipment shall be supplied with the installation.

14.2.6 Lifting accessories

Soft starter shall be equipped with lifting eye bolts.

14.2.7 Earthing lugs

Soft starters shall be equipped with an earthing bar (6mm x 50mm x 300mm) which shall be capable of accepting 2 x 240mm^2 earthing cables.

14.2.8 Painting

The paint finish shall be as per the manufacturer’s specifications.

However, the environment in which these soft starters are installed shall be taken into consideration. If the environment is highly corrosive, then the manufacturer should be consulted as to the final finish for the soft starter.

15 High voltage variable speed drives

15.1 General

The drive shall operate within the terms and conditions of supply as required by the Supply Authority (SA Power Networks or ElectraNet). Liaison with the Supply Authority will be required to determine the suitability of any proposed drive in terms of induced harmonics at the PCC. This information shall be conveyed to the SA Water representative prior to ordering any equipment. All drives shall be supplied with a motor starter section (with a fused contactor or circuit breaker, depending on the drive manufacturer's recommendations). The motor starter section shall fully comply with the requirements of section 4. The starter section shall be controlled by the drive and may be located on an existing or new switchboard or adjacent to the drive. The location shall be determined in consultation with the SA Water representative.

15.2 Incoming/outgoing supply conditions

15.2.1 Incoming voltage

The drive shall operate from either a 3.3kV or 11kV (site dependent), 50Hz, three-phase supply. The drive shall be capable of operating continuously with a supply voltage deviation of ±10 per cent.

15.2.2 Auxiliary voltage

The drive's electronics and auxiliary systems shall be capable of being supplied and operate from a 400V, three-phase, 50Hz source.

15.2.3 Output voltage and frequency

The output Voltage shall nominally be 3.3kV or 11kV with an adjustable output frequency of 0–50Hz.

15.2.4 Output current

The drive shall be capable of supplying the motor full load current at any set frequency indefinitely (provided the motor can operate in a similar manner).

15.2.5 Output filter

The three-phase output shall employ a three-phase L-C filter (sine filter). This shall ensure a smooth sine wave output is available to drive the motor.

15.3 Input rectifier

The input rectifier shall utilise an 18 or 24-pulse bridge (using IGBTs or approved equivalent). This is a minimum requirement. If a 36-pulse (or higher) device is required to meet the Supply Authority's requirements in terms of harmonic control, then this shall be provided. The existing harmonic distortion of the installation shall be considered when selecting the required drive (in terms of harmonics). All harmonic calculations shall be submitted to the SA Water Superintendent's representative for review.

15.4 Earthing switch

The drive shall be equipped with an integral earthing switch~~.~~ that can be locked in the closed position. This arrangement shall ground the internal busbars and smoothing capacitors.

15.5 Efficiency and power factor

The overall efficiency of the drive (including input transformer) shall be greater than 95 per cent at a power factor of greater or equal to 0.97.

15.6 Input transformer

The input transformer shall be of the dry type. Transformer cooling shall be provided by the drive system cooling mechanism and shall not use an independent forced ventilation system. The transformer shall be an integral part of the drive and be contained within the same enclosure. The input transformer's sole function shall be the provision of 3 or 4 three-phase supplies to the 18 or 24-pulse-controlled rectifier and be used for harmonic control. The input transformer shall be fed at either 3.3kV, 6.6kV or 11kV (dependent on-site supply).

15.7 Drive features

15.7.1 Overload capacity

The drive system shall be capable of a 10 per cent overload above the rated output current for one minute without damage or shutting down due to overtemperature.

15.7.2 Inverter

The inverter shall utilise single-power electronic devices. Devices shall not be connected in series or parallel (unless approved by the SA Water Principal Electrical Engineer). Power components shall be readily accessible for maintenance purposes (replacement). Power electronic devices shall not require reverse biasing to switch off. GTO thyristors shall be employed for shorting purposes to protect the power electronic devices from motor-induced voltages, should motor self-excitation occur.

15.7.3 Protective functions

The drive system (including input transformer) shall provide the following protective functions and be protected against:

a. Short circuit (inverter).

b. Earth fault.

c. Over current (with adjustable current pickup and tripping time).

d. Input and output phase loss.

e. Over voltage and under voltage.

f. Over temperature (drive electronics and transformer winding temp).

g. Cooling fan failure.

h. Motor overload (electronic).

i. Motor stall.

j. Motor overload (thermistors).

k. DC link voltage (under voltage).

l. Air inlet over temperature.

m. Transformer winding earth fault (primary and secondary winding faults).

n. Transformer winding phase-phase fault (primary and secondary winding faults).

Should any of the above fault conditions exist, the drive shall shut down, and no damage to the power electronics or any other part of the drive (semiconductor fuses excepted) shall occur. The drive shall also selectively trip the external contactor or circuit breaker (fault dependent); for example, cooling fan failure shall cause the drive to gracefully shut down, whereas detection of a short circuit shall cause the drive's contactor or circuit breaker to instantaneously open.

The drive shall also be capable of accepting signals from the following other fault monitoring devices:

a. Motor bearing over temperature (drive and non-drive ends).
b. Pump bearing over temperature (drive and non-drive ends).
c. Pump low suction.
d. Pump high suction.
e. Pump low flow.
f. Vibration monitoring.
g. Water cooling monitoring (if used).

15.7.4 Drive enclosure

The drive system enclosure shall be of modular construction so it can be disassembled, transported and re-assembled on-site. The drive's functional blocks shall be constructed in a logical format with dedicated cubicles for each of the functional blocks, such as the drive control system, rectifier, transformer, inverter, and output filter systems.

The drive system enclosure shall be rated to a minimum of IP42 and be suitable for indoor use.

The enclosure and doors shall be of galvanised, fabricated sheet steel construction with hinged doors. The enclosure shall be fully painted as per section 4.1 of this document.

Enclosure compartments shall be fitted with lifting lugs.

Busbars shall be fully insulated and marked for identification. Exposed live parts within the enclosure, which are accessible during normal operation of the VSD for measuring, adjusting or resetting, shall be protected against accidental contact when the door is open. Shrouding shall be provided to IP2X.

Earthing facilities shall be provided for the connection of cable screens and earth conductors.

15.7.5 Cooling

The enclosure shall utilise forced air cooling. The air intake system shall be fitted with filters to prevent dust and fine particles from entering the drive.

Water cooling systems for drives may be proposed; however, approval will need to be sought from the SA Water Principal Electrical Engineer.

15.7.6 Access for maintenance

All maintenance shall be capable of being undertaken from the front of the drive cubicle.

15.7.7 Enclosure interlocking

All doors that provide access to high-voltage equipment shall be mechanically and electrically interlocked with the main external contactor/circuit breaker for the drive.

Drive doors shall not be capable of being opened unless:

a. The drive/motor feeder contactor is racked out or in the isolated/test position and the cable earth switch (to the drive) is in the earth position.
b. The drive earthing switch is closed.

The drive earthing switch shall be mechanically interlocked with the drive feeder contactor/circuit breaker such that it shall not close unless the contactor is racked out or in the isolated/test position and the cable earth switch (to the drive) is in the earth position. The drive shall not be capable of being energised if any of the enclosure doors are open and/or the drive earthing switch is closed.

Mechanical interlocking shall be provided by using a trapped key system.

15.7.8 Cabling

The drive shall be capable of accepting cables from either top or bottom.

15.8 Environment

The drive shall be capable of operating in environments of up to 45°C without de-rating.

15.9 User interface, communications and control

The drive shall incorporate a user interface mounted on the front of the drive. The interface shall display at least four lines of drive information in plain text. It shall be possible to input the following parameters from the interface panel:

a. Enter start-up data, such as start-up torque, speed, current, etc.

b. Set reference signals to stop, start and control the direction of the motor.

c. Adjust all other required drive parameters.

d. Select control mode, such as manual, auto, or off.

e. Stop and start the drive when in manual mode.

The drive shall be fitted with the following I/O for control purposes:

1. 8 analogue outputs (4-20mA);
2. 4 analogue inputs (4-20mA);
3. 24 digital inputs (opto-isolated 22-150VDC).
4. 12 digital outputs (switch-over contact rated for 2A @ 230VAC).

All I/O shall be capable of being expanded by a further 20 per cent.

15.9.1 Communications

The drive shall be equipped with an Ethernet port for communications and support Ethernet TCP/IP and other protocols (proprietary) used by PLC manufacturers. A second Ethernet port shall be installed to support Modbus over IP.

The following signals shall be capable of being remotely monitored via the specified communications protocol and via the VSDs display:

a. Status, including Start, Stop, Fault, etc.

b. Duty/Standby mode selection.

c. Speed/flow set-point feedback.

d. Speed Feedback.

e. Torque Feedback.

f. Current Phase A.

g. Current Phase B.

h. Current Phase C.

i. Voltage Vab.

j. Voltage Vbc.
k. Voltage Vca.
l. Real Power (kW).
m. Apparent Power (kVA).
n. Reactive Power (kVAr).
o. Power factor (PF).
p. Motor and Bearing RTDs.
q. I/O status.
r. Alarm status.
s. VSD Fault.

15.9.2 Control

The variable speed drive shall incorporate a control system which shall be pre-programmed at the factory. The control system shall be selectable (from the user interface) and shall consist of programs written explicitly for the task at hand. The control system shall use factory assigned I/O to implement the required control functionality.

The drive shall incorporate the following controls:

a. Pump control.
b. Speed control.
c. PID control.
d. Sequential Control.
e. Auto–control is implemented by another process control device, for example, PLC.

It shall be possible to select certain parameters within the control system and shall include:

1. Flux optimisation, whereby the drive can operate the motor at the optimum efficiency to help reduce power consumption.
2. Supply loss ride-through.
3. Acceleration and deceleration ramps (ramps shall be selectable from 0 – 1600 seconds).
4. Speed control feedback.

15.9.3 Pulse encoder

The drive system shall be capable of being equipped with a pulse encoder to allow accurate speed measurement.

16 Neutral earthing systems

Neutral Earthing systems shall be based on packaged units and be suitable for outdoor use. The systems shall comprise:

a. Low impedance dry-type earthing transformer (zig-zag)[3].
b. Neutral Earthing Resistor (NER) modules (stainless steel, edge-wound).
c. Three-position, three-phase switch (open-closed-earth). Rated for fault make/load break fault current (20kA max). The switch position shall also be displayed on any site SCADA or HMI. A switch in the earth position shall earth the NER system.
d. IP55 painted mild steel enclosure (meeting the requirements of SA Water's painting requirements) with three-point lockable doors.
e. No live accessible parts when the door(s) is opened.
f. Hot-dipped galvanised steel (I or H beam) mounting plinth (minimum 100mm high).
g. Two earth lugs.
h. Top-mounted eye bolts at each corner for ease of installation/removal.
i. Single pole electrically latched 300A vacuum contactor at rated voltage (and associated control circuitry). 6kA breaking capacity, 110V control and 100,000 operation rating.
j. Anti-condensation heaters with thermostat and switch.
k. Protection equipment (CTs).
l. Suitable earthing points for portable earthing leads.
m. Side cable box (IP55) capable of accepting 3 x 300mm^2 single core XLPE cables and protection CTs via an undrilled non-ferrous gland plate.
n. Separate IP55 cable box for auxiliaries.
o. BIL level 95kV;
p. Direct thermal element protection and controller.
q. The roof is to be angled to prevent water pooling.

The earthing arrangement shall limit the system earth fault current to 200A for a duration of not less than 10 seconds. The arrangement shall have a continuous rating of 10A.

The three-position switch shall be interlocked such that main doors (to the NER and earthing transformer) cannot be opened unless the switch is in the open or earth position.

When the doors are open, there shall be no exposed live parts. All live parts shall be enclosed behind partitions (IP4X). Equipment on the dead side of the switch shall be fully shrouded (test points shall be provided). It shall not be possible to energise the system with the doors open and unlocked.

The switch shall have clearly visible mechanical indicators showing its relative position, such as open or closed when all doors are closed.

Large (400mm x 400mm) enamelled metallic signs shall be fitted to each side (4) of the NER enclosure, warning of the high temperatures that can occur after the unit has operated.

[3] Constructed using aluminium windings with F1/F2 fire class. F0 may be considered but requires the approval of SA Water. The transformer shall be hermetically sealed.

17 General building and switch room requirements for high voltage installations

In general, HV equipment should be housed separately from LV switchboards and battery supplies. Depending on the type of installation, HV switch rooms may be constructed either as a conventional concrete structure or as a suitably rated 'transportable' type building.

The following subsections highlight SA Water preferences and prompts in support of the building codes and Australian Standards, and are not written as complete requirements.

17.1 Structural provisions

All works associated with the substation/building construction and associated installations shall comply with the following standards:

Building Code of Australia (where relevant), AS 2067, AS/NZS 3000, AS/NZS 1170.4, AS 3600, AS 4100 and relevant local government regulations.

17.2 General construction requirements

Installations and equipment shall be capable of withstanding electrical, mechanical, climatic and environmental influences anticipated on the site.

Load-carrying structural members and partition walls shall be selected to achieve the appropriate fire rating.

Electrical operating areas shall be designed to prevent ingress of water and to minimise condensation.

Materials used for walls, ceilings and floors shall not be damaged by water penetration or leakage.

The building design or modifications to an existing building shall consider the expected mechanical loading and internal pressure caused by an arc fault.

Pipelines, ducts, etc. and other equipment required to be in the vicinity of HV switch rooms shall be designed so that the electrical installation is not affected, even in the event of damage.

High voltage installations shall be separated from all parts of a building by an enclosure constructed to an FRL (Fire Resistance Level) not less than 120/120/120.

Building security should also be considered for any high voltage switch room, in accordance with SA Water operational and security standards. Designs should take into account that only authorised persons may enter these areas.

17.2.1 Specifications for walls

~~The external walls of the building shall have sufficient mechanical strength for the environmental conditions.~~

The mechanical strength of the buildings shall be sufficient to withstand all static and dynamic loads due to environmental conditions and normal operation of the high voltage installation, per AS 2067, which includes arc faults.

The passage of pipes or wiring systems shall not affect the structural integrity of the walls.

Pipes, conduits and cabling passing through the walls shall not reduce the fire rating of the walls they pass through.

External walls shall maintain a fire resistance level (FRL) of 120/120/120 in accordance with the Building Code of Australia.

Wall insulation for new transportable type HV switchrooms shall meet the equivalent of R2.5 batts (Earthwool®/Rockwool®/fibreglass).

Walls shall be white in colour.

17.2.2 Specifications for windows

Typically, windows for high-voltage switch rooms are not to be installed. However, if switchgear is to be installed within a high-voltage switch room with windows, then the following shall be provided:

a. Windows shall be designed so that entry is difficult. This requirement is considered fulfilled if one or more of the following measures are applied:

   i. Window is made of unbreakable material.

   ii. The window is screened (metal screen).

   iii. The lower edges of the window are at least 1.8m above access level.

   iv. Windows have the same fire rating as the switch room and building.

   v. The mechanical strength of the window shall be sufficient to withstand all static and dynamic loads due to normal operation of the high voltage installation, per AS 2067, which include arc faults.

17.2.3 Specifications for roofs

The roof of the building (and any extension) shall have sufficient mechanical strength to withstand the environmental conditions.

If the ceiling of the high voltage room is also the roof of the building, the anchoring of the roof to the walls shall be adequate in terms of pressure build-up during an arcing fault. Minimum height clearance to switchboards shall be taken into consideration to ensure arc fault separation distance and venting requirements are suitably met.

Ceiling insulation for new transportable type HV switchrooms shall meet the equivalent of R5.0 batts (Earthwool®/Rockwool®/fibreglass).

The ceilings shall be white in colour.

17.2.4 Specifications for floors

Floors shall be prepared level for switchboard installation (this may involve cutting and re-laying the concrete floor). The area in front of the switchboard may also require preparation to allow any supplied trolleys to be safely and smoothly removed during normal operation. All structural work shall be in accordance with AS 1170.4 regarding stability under earthquake loads.

The floors shall be flat and stable and shall be able to support the static and dynamic loads of the high-voltage equipment.

Raised floors shall be arranged so that the spread of fire is prevented.

Underfloor insulation for new transportable type HV switchrooms shall meet the equivalent of R2.0 (polyester).

Floors shall be clean and free from flaking paint. If necessary, floors shall be sealed with a suitable commercial grade floor paint prior to high voltage equipment being installed. Colour to be approved by SA Water.

17.2.5 Specifications for doors

Access doors shall be equipped with security locks.

Access doors shall open outwards and shall be provided with safety signs that comply with AS 1319. The safety signs shall consist of bold letters not less than 40mm high and contain the words "DANGER – HIGH VOLTAGE" and "AUTHORISED PERSONS ONLY." The signs shall comply with national regulations.

The appropriate safety warning signs shall indicate emergency exits. The signs and exit locations shall comply with national regulations.

Doors must be positioned such that they do not create a personnel hazard or can be blocked by parked vehicles.

Doors that lead outside shall be of low-flammability material. External doors shall require a fire resistance level (FRL) of -/120/30 in accordance with the Building Code of Australia.

It shall be possible to open emergency doors from the inside without a key by using a latch or other simple means, even when they are locked from the outside.

Panic bars shall be fitted on all outward opening doors used for emergency egress in rooms containing high-voltage switchgear.

The minimum dimensions of the opening for an emergency door shall be 1980 high and 750mm wide.

Sliding and roller doors are not permitted as escape doors.

17.3 Rooms for high voltage equipment

The dimensions of the room and of any required pressure relief openings depend on the type of equipment and the short-circuit current. Relief openings shall be in accordance with high voltage equipment manufacturer recommendations for the given fault level and room dimensions.

If pressure relief openings are necessary, they shall be arranged in such a way that when they operate (blow out due to an arc fault), the danger to persons and damage to property is minimised.

17.4 Service areas

Service areas comprise aisles, access areas, handling passages and escape routes.

Aisles and access areas shall be adequately dimensioned for carrying out work, operating switchgear, transporting equipment and enabling work to be carried out safely.

~~Aisles shall be at least 1m wide to comply with NCC section D1.6.~~

The width of aisles shall not be reduced, even when equipment projects into the aisles, for example, open doors, installed operating mechanisms or switchgear trucks in the isolated position.

~~Space for evacuation shall be at least 1m wide, even when removable parts or open doors, which are blocked in the direction of escape, intrude into the escape routes.~~

~~Clear and safe access for personnel shall be provided at all times.~~

Exits shall be arranged so that the maximum length of the escape route complies with the requirements of section D of the Building Code of Australia (NCC).

17.5 Air conditioning

Indoor climatic conditions shall be established by adequate cooling, heating, dehumidifying, and ventilation or by adequate building design. Adequate ventilation must be provided to dissipate heat and explosive gases (Hydrogen) generated by electrical equipment.

High voltage room temperatures shall not exceed 30°C at full high voltage loadings with an external building ambient temperature of 40°C.

Mechanical ventilation systems shall be so arranged and placed such that inspection and maintenance can be carried out when the switch gear is in operation.

Specification and installation guidelines for air conditioning systems shall be as per TS 0300 and TS 0245.

17.6 Protection against fire

The minimum requirements for the protection of buildings against fire are contained within the Building Code of Australia. Refer to TS 0370 Fire detection and evacuation systems.

The minimum requirements for high-voltage installations are:

a. A fire detection system shall be provided on a per-building basis. The system shall utilise both thermal rise detection and smoke detection units in every HV/Switch/Transformer room and shall also include associated cable chambers and plenums. Audible alarms in HV rooms shall sound on a sensor activating. Visual indication may also be necessary. Call points shall be installed in every high-voltage room at every egress point. Each individual HV room shall be assigned a separate zone within the fire detection system.

b. All fire detection equipment shall be installed to comply with the relevant Australian Standard.

c. All fire detection and extinguishing equipment, when activated, shall raise a remote alarm on SCADA. The status of such systems shall also be monitored – healthy, fault, power fail, etc.

d. Hand-held fire extinguishers shall be installed in HV switch rooms. They shall be installed in compliance with the BCA and suitable for electrical fires and personal safety.

e. Fire Indication Panels (FIPs) at some high voltage installations will be required to be connected directly to fire alarm interface equipment of the fire brigade. The commissioning of this type of fire alarm system will need endorsement from MFS/CFS.

17.7 Lighting

High-voltage rooms shall have adequate lighting to allow authorised personnel to perform inspections. The recommendations set out in AS/NZS 1680.1 shall be followed. Table 3.1, in the standard details, recommends maintaining illuminance levels against the task to be performed. The task designation shall be 'moderately difficult' for inspection work in the high-voltage rooms and, as such, shall require a luminance of 400 lux.

Lighting shall utilise LED type or fluorescent light fittings (with dual tubes), with non-diffused luminaires and be rated to IP44.

Emergency exit lighting (and illuminated signs) shall comply with AS/NZS 2293.3. Such systems shall be installed as per requirements of both local and national legislation, that is, BCA/NCC. Emergency lighting shall be of the non-maintained fluorescent type.

17.8 Lightning protection

Buildings and structures relating to HV equipment shall follow the requirements of AS 1768 for protection against lightning.

17.9 EMF and safety

The building designer (new buildings) must ensure that the installation is, so far as is reasonable and practicable, carried out in such a way as to provide for the safety of persons in respect of exposure to electric and magnetic field effects.

The National Health and Medical Research Council Interim Guidelines shall be followed in terms of 50/60Hz electric and magnetic field exposure.