Technical Specification - Power Transformers

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Revision details

Version No.	Clause	Description of revision
1.0		General revision
2.0	21/9/2016	General revision
3.0	14/9/2018	General revision
4.0	20/02/2020	Format update, changing ‘shall’, ‘should’ and ‘may’ to must where relevant to Sydney Water, ‘approved’ replaced with ‘accepted’, minor editorial changes elsewhere.

Introduction

This Specification is for the design, supply and installation of Power Transformers for Sydney Water assets.

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Acronyms

Term	Definition
AC (ac)	Alternating Current
AI	Analogue Input
ANAF	Air (Natural convection) and Air (Forced convection)
ANSI	American National Standards Institute
AO	Analogue Output
AS	Australian Standard
AUD	Australian Dollars
CB	Circuit Breaker

Term	Definition
CT	Current Transformer
c/w	complete with
DC (dc)	Direct Current
DI	Digital Input
DO	Digital Output
ELV	Extra Low Voltage (i.e. ≤ 50 V AC or ≤ 120 V DC)
EN	European Normalised Standard
ESW	Earth Switch
FLC	Full Load Current
GA	General Arrangement (drawing)
HV	High Voltage (i.e. > 1000 V AC or > 1500 V DC)
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical & Electronic Engineers
I/O	Inputs/Outputs
ISO	International Standards Organisation
ITP	Inspection and Test Plan
KNAN	Cooling fluid with flash point > 300 (Natural convection) and Air (Natural convection)
LV	Low Voltage (i.e. greater than ELV but ≤ 1000 V AC or ≤ 1500 V DC)
MCR	Maximum Continuous Rating
MEPS	Minimum Energy Performance Standard (as defined in AS 2374.1.2 - 2003)
MSDS	Material Safety Data Sheet
MV	Medium Voltage (note this term is not used in this specification)
NEMA	National Electrical Manufacturers Association
ONAF	Oil (Natural convection) and Air (Forced convection)
ONAN	Oil (Natural convection) and Air (Natural convection)
OTI	Oil temperature Indicator

Term	Definition
PCB	Polychlorinated Biphenyl - chemical substance in which the biphenyl structure has chlorine substitutions (for hydrogen atoms) to varying degrees. They have the chemical formula C_{12} H_{10} - n Cl n where n ranges from 1 to 10.
PF	Power Factor
PLC	Programmable Logic Controller
pu	per unit
SAA	Standards Association of Australia
Sec.	second
SLD	Single Line Diagram
TBA	To Be Advised
TBC	To Be Confirmed
TCS	Trip Circuit Supervision
TCM	Transformer Conservator Membrane
TX	Transformer
WTI	Winding Temperature Indicator

1. General

1.1 Introduction

This specification defines the minimum technical requirements for the design, manufacture, supply and delivery of Power Transformers.

1.2 Scope

This specification ensures that Sydney Water will be delivered transformers to the minimum acceptable requirements.

Key stakeholders for this specification include the Sydney Water HV team, maintenance providers, and delivery partners

This specification does not apply to the installation / erection, commissioning or performance testing of the equipment

1.3 Proprietary items

Nomination of a proprietary item by Sydney Water does not imply preference or exclusivity for the item identified.

Alternatives that are equivalent to the nominated items can be submitted to Sydney Water for acceptance. The submission must include appropriate technical information, samples, calculations and the reasons for the proposed substitution, as appropriate.

2. Technical requirements - general

2.1 General

This Specification applies to Power Transformers that must be designed and constructed in accordance with the current issue of AS 2374, AS 60076 series, AS 60146 and any additional requirement indicated in the following sections.

The power transformers must be designed for continuous operation under environmental conditions as stated in section 2.2. The transformers must also be capable of standing de-energised for long periods without experiencing degradation of winding insulation or other components.

The power transformers must be capable of carrying rated load at rated frequency continuously without exceeding allowable design temperatures or experiencing excessive mechanical stress and undue deterioration of the winding insulation. The ratings and tolerances must comply with Australian Standards.

The power transformers must comply with the Minimum Energy Performance Standard (MEPS) requirements for Distribution Transformers as specified in AS 2374.1.2.

All performance data specified by the Contractor must be supported by type test certificates. Where the certificates are unavailable, the Contractor will be required to carry out the type tests. In those instances where it is not practical to carry out type tests, and with Sydney Water's approval, the Contractor must provide calculations proving the figures specified. The tolerances of calculated values must not exceed those specified in AS 2374 or AS 60076 series.

2.2 Environmental requirements

The Power Transformer must be designed to suit the environmental conditions as defined in AS 60076.

Environmental conditions	
Maximum ambient temperature	+45 ºC
Maximum ambient temperature (when installed in an outdoor enclosure)	+55 ºC
Monthly average temperature	+30 ºC
Yearly average temperature	+20 ºC
Minimum ambient temperature (corresponds to "minus 5 ºC indoor class")	-5 ºC
Minimum ambient temperature (corresponds to "minus 25 ºC outdoor class")	-25 ºC
Maximum relative humidity	95 %

The Power Transformer must be suitable for installation and service up to an elevation of 1000 m above sea level.

2.3 Key ratings and features

The key ratings and features of the Transformers must be as follows:

Ref	Rating or feature	Pad-mount TX	Pad-mount kiosk TX	Pole mount TX
1	Construction	1 x 3-phase transformer with 2 or 3 windings Hermetically sealed transformer	1 x 3-phase transformer with 2 or 3 windings Hermetically sealed transformer	1 x 3-phase transformer with 2 windings Hermetically sealed transformer
2	Vector Group	Dyn11 (2 winding) Dyn11yn11 (3 winding)	Dyn11 (2 winding) Dyn11yn11 (3 winding)	Dyn11
3	MCR	To be determined by Contractor	To be determined by Contractor	To be determined by Contractor
4	Mounting arrangement	Pad mounted	Pad mounted	Pole mounted
5	Kiosk enclosure	No	Yes	No
6	Impedance voltage at MCR at principal tap	To be determined by Contractor	To be determined by Contractor	To be determined by Contractor
7	X/R ratio at MCR	To be determined by Contractor	To be determined by Contractor	To be determined by Contractor
8	System fault level	Refer to Site Specific details	Refer to Site Specific details	Refer to Site Specific details
9	Neutral earthing system	Secondary star point solidly earthed – full size	Secondary star point solidly earthed – full size	Secondary star point solidly earthed – full size
10	Tappings	Five positions on primary winding +5.0%, +2.5%, 0%, -2.5%, -5.0%	Five positions on primary winding +5.0%, +2.5%, 0%, -2.5%, -5.0%	Five positions on primary winding +5.0%, +2.5%, 0%, -2.5%, -5.0%
11	Tap changer	Off load (padlockable) Links (dry type transformer)	Off load (padlockable) Links (dry type transformer)	Off load (padlockable)
12	Primary winding connections	Air insulated Cable box for bottom entry cables	Air insulated Cable box for bottom entry cables	Bushing
13	Secondary winding connections	Air insulated Cable box for bottom entry cables	Air insulated Cable box for bottom entry cables	Bushing
14	Winding temp. indicator (c/w	Yes	Yes	N/A

Ref	Rating or feature	Pad-mount TX	Pad-mount kiosk TX	Pole mount TX
	adjustable alarm & trip)			
15	Oil temperature indicator (c/w adjustable alarm & trip)	Yes (ONAN, KNAN) N/A (ANAF)	Yes (ONAN, KNAN) N/A (ANAF)	N/A
16	Sudden pressure relief valve (c/w trip)	Yes (ONAN, KNAN) N/A (ANAF)	Yes (ONAN, KNAN) N/A (ANAF)	N/A
17	HV and LV winding material	To be determined by Contractor	To be determined by Contractor	To be determined by Contractor
18	Sound power level at MCR	"Standard limit" Annex ZA of AS 60076.10	"Standard limit" Annex ZA of AS 60076.10	"Standard limit" Annex ZA of AS 60076.10

2.4 Power system condition

Transformers must be designed to suit the following system conditions for the voltages present at the respective sites.

Common Data

Ref	Power system condition	Requirement
1	Power Frequency	50 Hz
2	Power Factor	0.8 lag to 0.8 lead (over the entire tapping range)
3	Load profile	Continuously variable across 0-100% of MCR

Transformer Data

Ref	Power system condition	Transformer Primary				
		415 V	3.3 kV	11 kV	22 kV	33 kV
		Requirement				
1	Nominal system voltage	415 V AC	3.3kV AC	11 kV AC	22 kV AC	33 kV AC
2	Maximum system voltage (steady state) U_{max}	457 V AC	3.6kV AC	12 kV AC	24 kV AC	36 kV AC
3	Lightning impulse withstand voltage (1.2 / 50 µs wave)	N/A	40 kVp	95 kVp	145 kVp	200 kVp

Ref	Power system condition	Transformer Primary				
		415 V	3.3 kV	11 kV	22 kV	33 kV
		Requirement				
4	Power Frequency Withstand Voltage	2 kV AC	10 kV AC	28 kV AC	50 kV AC	70 kV AC

2.5 Power system conditions

Transformers must be designed, constructed and installed to meet the requirements outlined in AS 2067.

2.6 Standardisation

Equipment must be designed with standard parts and components readily available within Australia. Parts and components must be standardised as much as possible. All replaceable and consumable equipment must be standard supply equipment. The use of “one off” special designs is not permitted.

3. Technical requirements - construction

3.1 General

All transformers and associated equipment must be designed and manufactured in accordance with the latest industry practice and technology and must comply with the requirements of AS 2374 and AS 60076.

The transformers must be designed and constructed to withstand all shipping, lifting, installation and operating loads without deformation, damage or oil leakage.

The use of aluminium for external mounted components must be avoided and any aluminium components that are externally must be coated with an epoxy resin and rubber isolation pads installed between dissimilar metals

Oil immersed transformer

Unless otherwise specified the transformer cooling must be designated as ONAN. In water sensitive sites, KNAN is preferred.

Dry type/converter transformer

Unless otherwise specified the transformer cooling must be designated as ANAF.

3.2 Windings

The transformer must have separate three-phase primary and secondary windings suitable for connection to a three phase 50 Hz supply system. Fully rated taps must be provided in the primary windings.

The neutral conductor between the star point and the neutral bushing must be dimensioned to carry the rated phase current of the transformer and the worst-case earth-fault current. The neutral point of star connection winding must be brought out to a neutral terminal.

The windings must be adequately braced against all possible mechanical forces arising under short-circuit conditions.

The winding assembly must be pre-shrunk during construction to minimise shrinkage during the service life of the transformer.

The Contractor must select either aluminium or copper materials for the primary and secondary windings based on design optimisation of the transformer losses, short-circuit performance, etc.

Soldered joints in winding conductors must not be accepted.

Windings and associated equipment must be designed and sized for a potential increase in rating achievable by fitting of additional cooling to the transformer in accordance with Australian Standards.

Temperature rise limits

When continuously loaded at rated power the winding temperature rise must be less than the limits specified in the following Australian Standards

a) For Oil Immersed Transformers: AS 60076.2

b) For Dry Type Transformers: AS 60076.11

c) For Semiconductor converter Transformers: AS 60146.1.3

Type test certificate must be provided for the temperature rise limits. Detailed in section 7.

Attention is to be drawn to the fact that the heat transfer must be such as not to cause temperature rise above thermal limits of the equipment not forming part of the transformer, such as 60 °C for high voltage paper insulated cables within the termination box or 75 °C for low voltage PVC insulated cable attached to the transformer tank.

The manufacturer must submit a statement of temperature rises and types of insulating material used in the construction.

Dry type/converter transformer

The transformer windings must be one of the following types:

a) Resin encapsulated

b) Varnished

c) Resin rich coating.

The transformer winding insulation should be as flame resistant as possible and should be self-extinguishing.

Winding terminations and busbar connections must be arranged to ensure that build-up of dust material does not compromise the insulation integrity of the winding connection or provide a discharge path between the winding conductors or to earthed components.

3.3 Insulation

Unless otherwise specified, all windings must have uniform insulation and fully insulated to ground. Winding insulation must be as defined in AS 2768:

a) Oil immersed Transformer - Class 105 (Class A) or higher

b) Dry Type Transformer - Class 155 (Class F) or higher.

Transformers must be designed to withstand an impulse voltage as set out in the current issue of AS 2374 and as specified in section 2.4.

3.4 Tank and core

The transformer tank must be constructed to withstand, without damage, the mechanical stresses and internal pressures which may occur in normal service as well as those during short-circuit conditions, transport or handling during manufacture, testing, installation, inspection, maintenance and repair.

The tank must be fabricated from welded mild steel plate.

All external welding (including that for external bracing) must be continuously welded along the upper line to prevent moisture from lodging behind the weld.

Gaskets must be of an oil resistant synthetic rubber or synthetic rubber and cork composition without textile backing, formed and cut to suit the application. Any joints must be scarf-type.

The vacuum-withstand capability of the tank, cooling tubes and radiators must be tested prior to installation of the core and windings.

Each transformer tank must be provided with lifting lugs, a minimum of four jacking pads and four anchor points; all of which must be designed with ample dimensions and strength so that standard shackles or hydraulic jacks can be readily fitted and safely utilised.

The tank lid must be provided with lifting points and must be sufficiently rigid to resist distortion during lifting. The lid must be designed so as not to trap air during oil filling process

To minimize dust accumulation and subsequent corrosion the transformer tank must be so designed that no flat horizontal surface is exposed to atmosphere. All inspection holes on the transformer must have raised flanges with holding down bolts passing through the flanges and covers. Welded studs will not be accepted.

The design of the magnetic core must take into account heat dissipation and must be such that excessive core temperatures do not occur under any operating conditions. The core must be manufactured from non-ageing, high grade, cold rolled, grain orientated, low loss, silicon steel laminations coated on both sides with an insulating material. Laminations must be produced with accurate dies and be free of irregularities.

The core must be secured from movement inside the tank during normal handling and transport, and fully supported when installed within the tank.

Clamping arrangements must be provided so that when the core, windings and supporting framework are assembled, the general structure forms a rigid assembly unaffected by short-circuit conditions, transport or handling during manufacture, testing, installation, inspection, maintenance and repair.

The core must be electrically bonded to the transformer tank cover.

Attachments must be provided for lifting so that the core is readily removable from the tank for inspection.

Specific Requirements for Cast Resin or Encapsulated Dry Type Transformers

Unless otherwise specified cast resin or encapsulated dry type transformers must be supplied with a suitable enclosure to class IP23 using sheet mild steel with a surface finish in accordance with Sydney Water specifications WSA 201 and PCS 100.

Every enclosure must be fitted with removable front and rear panels for easy connection of HV tappings and assembly of connecting cables. However, the panels which can be removed from outside the transformer enclosure must be fitted with suitable stainless steel padlocking facilities for Sydney Water's 10 mm HV locks.

Cut-outs for cable entry must be provided in the enclosure floor or/and ceiling with a suitable 6 mm Aluminium cable gland plates.

3.5 Cooling

The transformers' cooling system must be designed to dissipate sufficient heat such that temperature rise at maximum rated load is within allowable limits.

Provision must be made on transformers for the future upgrading and attachment of supplementary cooling.

Transformers with supplementary cooling must be fitted with cooling fans must be driven by direct coupled, 415 volt, 3 phase 50 Hz, totally enclosed fan cooled motors to AS 1359. Fan blades must be of corrosion resistant metal and suitably guarded.

Manual and automatic control of supplementary cooling equipment must be provided. Automatic operation must be controlled from a transformer winding temperature supervisory device, which may be the Winding Temperature indicator.

Provision must be made for cooling equipment to switch on and off at prescribed temperature and for an alarm to be initiated at a third prescribed temperature. Normally open contacts will be required to perform these functions.

Where duplicate or multi drives are provided, these must be sectionalised into a minimum of two groups with separate group control and isolation.

Control must comprise of a main isolator, main and control fuses, control relays and line contactors. Individual thermal cut-outs must be provided for each motor drive.

All equipment necessary for control of the supplementary cooling must be mounted on the transformer in a stainless steel control cabinet rated at IP65 to AS 1939. Cable entries to this cabinet must be from below via compression glands. The cabinet must be fitted at a height not greater than 1.5 mm above ground level. Supply to the auxiliary panel must be separate from the transformer connections.

Oil immersed transformer

Whenever separate or detachable radiators are used, flanged isolating valves must be provided. Air release plugs must be fitted at top of each radiator bank and oil drain plug at bottom of each radiator bank. Non-aluminium radiators must be hot dipped galvanised, before painting.

No equipment must be mounted on or from the transformers radiators unless directly necessary by the radiator to perform its intended function.

A gate valve must be fitted to the top of the transformer tank for connection to an external oil filter. To minimise oil leakage, all drain and filling gate valves must be fitted with flanged brass plugs.

Dry type/converter transformer

The transformer must be enclosed and must be one of the following:

a) Air ventilated dry type transformer

b) Cast resin or encapsulated dry type transformer.

Cubicles must be fitted with ventilating openings which permits a natural flow of air into the windings.

Provision must be made for cooling fans to be fitted to the transformer assembly permitting uprating of the transformer's apparent power rating when specified.

3.6 Cooling and insulating medium

Oil immersed transformer

The insulating oil used in the transformers must be of a manufacture and type that is readily available in Australia.

The use of insulating oil containing polychlorobiphenols (PCBs) is strictly prohibited.

In its maintenance instructions, the Contractor must include procedures for periodic sampling of insulating oil for laboratory analysis. Allowable ranges of dielectric strength, oil impurities and any other indications of oil and/or winding breakdown must be provided. Corrective procedures for each type of problem that can be identified by periodic oil analysis must be provided

Mineral based

The insulating oil used in pad mount and kiosk transformers must be unused mineral insulating oil complying with AS 1767 Type Nynas Gemini X.

Organic based

The insulating oil used in pole mounted transformers must be unused environmentally friendly organic based insulating oil complying with IEC 61099. Type FR3 only.

Dry type transformer

For the air insulated and cast resin/encapsulated type transformers the cooling medium must be air.

For sealed dry type transformer the Contractor must indicate the cooling medium being offered.

3.7 Terminations and terminal boxes

HV windings must be terminated on suitable high voltage terminal located in air insulated, steel terminal boxes or on bushings according to the application. Terminal boxes earthing requirements have been specified in Section 3.14.

The terminal boxes must be of adequate size to accommodate the cables and lugs and must be equipped with suitable terminals for the rated voltage. The winding star point must be bought out onto an insulated neutral terminal. The minimum clearances between phases or between phase and earth must be in accordance with Table 3.1 of AS 2067.

Primary and secondary terminal boxes must be located on opposite sides of the transformer and must be suitable for bottom cable entry through undrilled, removable 6 mm aluminium gland plates of adequate size for the cables to meet the FLC capacity of the transformer.

Access for termination, testing and inspection must be through the front face of the cable boxes. Suitable gaskets must be provided to maintain a minimum IP rating of IP56 for the primary and secondary terminal boxes.

The location of both terminal boxes must provide sufficient clearance above ground with the transformer mounted at ground level that the radius at which incoming cables must bend is not less than the cable manufactures recommendation.

The design of the terminal boxes must be such that:

a) With front cover and bottom plate removed, cables can be loosely glanded, after which the bottom plate together with the cables can be fixed into position. Any steelwork at the front bottom edge of the box which would impede this installation method must therefore be removable.

b) The conductors, including single-core type, can be connected straight onto the terminals without introducing harmful bends inside the box

c) Uncluttered straight connections of two or more parallel conductors are made possible by copper bards or flags of adequate dimensions and rating

d) Electrical clearances in accordance with the standards are maintained under all operating conditions

e) Ample space is provided for installation of ‘Raychem’ or similar heat shrink type stress-relieving devices.

All main power terminal boxes must be provided with a suitably sized and rated tinned copper earth bar. The earth bar must be provided with sufficient drilled and tapped holes for termination of all earth conductors, e.g. HV cable screens (1 per phase/cable), cable armour and gland plate. Terminations must be suitable for compression type M12 cable lugs.

The porcelain bushings must protrude horizontally through the walls of the tanks into the cable boxes. The palms of the bushings must be pre-drilled to suit the respective number and size of cables nominated by the Contractor. Only one cable termination lug must be bolted per pre-drilled hole. If necessary, extension palms must be provided.

Cable supports must be provided to ensure that, under no circumstance, any weight attributed to the cables is imposed on the transformer bushings. The gland plate must not be included in the design of the cable supports. The cable clamping supports must be welded or mounted onto the tank wall, without obstructing the cooling system, to provide an effective strain relief on the actual conductor connection. The centre line of a clamped cable must match the centre line of its gland and the extension of this line to the ground must be clear of any part of the transformer or its skid.

3.8 Disconnecting boxes

Disconnecting boxes provided with bolted links between the bushings insulators and cable connections must be installed at HV sides on transformers above 3 MVA.

3.9 Bushings and insulators

Bushing insulators must be outdoor porcelain type mounted, fixed, sealed and leak-proof, into the tank wall in accordance with the manufacturer’s instructions.

They must be of a high quality, high strength, non-hygroscopic and non-tracking material, capable of withstanding handling conditions during transport, erection and maintenance and be in accordance with AS/NZS 60137.

Terminal stems through the bushing insulator must be effectively sealed and locked in such a way that rotating/turning of the stem inside the bushing is completely impossible under any circumstances. The internal winding ends connected to the bushings must always remain submerged under the oil level.

All bushings must be clearly marked to identify the phase connections in accordance with the connection diagram on the rating plate

The connections to all bushings must be inside the cable boxes as defined in Section 3.7.

If required, insulators must be air insulated indoor or outdoor porcelain type and must comply with AS 4398.

Air clearances for all live parts must comply with the relevant Australian Standards.

All types of bushings and insulators must satisfactorily withstand the service conditions. Porcelain and metal fittings must remain unaffected by atmospheric conditions producing weathering, acids, alkalis, dust or rapid changes in temperature.

The strength of bushings and insulators as given by the electro-mechanical test load must be such that the factor of safety when supporting their maximum working loads must be not less than 2.5.

Designs must be such that stresses due to expansion or contraction in any part of the bushings, insulators or associated fittings do not lead to the development of defects.

All porcelains must be manufactured in one piece. Jointing of solid or hollow porcelains is not permitted except by use of metal fittings. Porcelain must be sound, free from defects and thoroughly vitrified and the glaze must not be depended upon for insulation. Glaze must be smooth, hard, of a uniform shade of grey and must completely cover all exposed parts of the insulators.

Each bushing and insulator must be clearly marked with the manufacturer’s name or trademark, the year of manufacture and the insulator type. Marks must be visible after assembly of fittings and must be imprinted before firing.

3.10 Off load tap changers

The primary windings of the transformer must be fitted with a manually operated, off load tap changers with five positions as specified in section 2.3, unless an on-load tap changer is specified.

The tap changer must comply with the following requirements:

a) Positive snap-action contact changing

b) The construction must be such that it is not possible for the contacts to be set in a position whereby the HV winding remain open-circuited or partly shot-circuited, substantial mechanical stops must be provided to prevent over-running.

c) The driving rod through cover or tank must be permanently sealed against air/liquid leakage under all operating conditions

d) The off load tap changer switches must be accessible from the outside of the tank

e) The handle must be adequately sized to allow operation without the need of tools and be located in an accessible position such that operation cannot cause injuries to the operator

f) Tap positions must be clearly marked to show each tap position and provided with a padlock facility for Sydney Water 10 mm high voltage locks to lock the tap changer in the required position

g) A label warning against changing taps with the high voltage energised must be located adjacent to the handle.

Dry type transformers must use internal tapping links in lieu of tapping switches.

3.11 Surface preparation and finish

All exposed stationary metal surfaces must be prepared and painted to provide adequate protection against the adverse effects of the site conditions specified in Section 2.2.

For SPS and STPs, transformers must be painted for corrosive sewage gas environment as per WSA 201 - Manual for selection and Application of Protective Coatings and WSA 201 - Sydney Water Supplement.

Surface preparation and paint systems must be selected to give a life of not less than 15 years to first maintenance.

All metal finishing, the preparation, pre-treatment of surfaces and painting must be carried out strictly in accordance with Sydney Water Standard specification WSA 201 - Manual for selection and Application of Protective Coatings and WSA 201 - Sydney Water Supplement and PCS 100 - Protective coating standard.

Preferred paint colours	
Transformers	Manufacturers standard colour
Electrical Kiosk	N35 (light Grey)

3.12 Mounting

Transformers must have bi-directional skids suitable for skidding the transformer in longitudinal or transverse direction on platforms or concrete foundations. The skids must not interfere with the main electrical cables and their termination. Provisions for anchor bolts must be provided.

Transformer tanks must be mounted on supports to ensure the bottom of the transformer tank is raised of the ground.

3.13 Fastenings

All nuts, bolts and washers used on the exterior of the transformer must be galvanised, zinc electroplated or cadmium plated.

Bolts must be selected to give the shortest possible length protruding beyond the nut with a minimum of two threads. Spring and flat washers must be fitted under all nuts and flat washers under bolt heads.

3.14 Earthing

All metal parts of each transformer must be electrically bonded. Bonding of gland plates, terminal box covers and other removable parts of the transformer must be achieved by installing a suitably sized PVC insulated copper conductor or bare copper strip. The terminal boxes, auxiliary marshalling box and other auxiliary equipment wiring enclosures must be equipped with an earth terminal suitable for the termination of earth conductors of outgoing cables.

Cable termination boxes must be provided with an earth terminal predrilled with two holes suitable for M12 bolts located on outside of box.

For connection to an external earthing grid each transformer must be provided with two earth terminals each predrilled with two holes suitable for M12 bolts located on the lower part of the tank wall on the two opposite sides not containing the main primary and secondary cable boxes.

4. Technical requirements - fittings and accessories

4.1 General

The transformer must be provided with:

a) Lifting lugs

b) Bi-directional wheels or; six wheels with the centre pair larger to facilitate slewing

c) Jacking lugs on all units larger than 2 MVA.

4.2 Marshall control box

A Marshalling box must be provided on each transformer for marshalling with all the transformer protection, control and instrumentation devices including CTs installed pre-wired to terminals in the marshalling box.

The Marshalling box must be located any side of the transformer other than the primary side and must be readily accessible from ground level no higher than 1.5 m above ground level.

The Marshalling box must be of stainless steel construction with stainless steel padlock facilities for Sydney Water's 10 mm locks. The marshalling box must be suitable for bottom cable entry via compression glands through undrilled, removable 3 mm aluminium gland plates.

All terminals must be uniquely numbered in accordance with the respective schematic diagrams.

4.3 Rating plates

Each transformer must be fitted with a stainless steel rating plate with all information engraved/etched onto the rating plate. Printed rating plates will not be acceptable.

The rating plate must be placed in a position that it is clearly visible from the front of the transformer (and inside the kiosk enclosure).

Rating plates must include the connection diagram and vector diagram showing the general phase relations of the transformer in addition to other information as required by AS 60067.1.

Each tap position expressed both as an actual no-load volt ratio and as a percentage of the normal no-load voltage must be indicated on one plate.

4.4 For oil immersed transformers

Oil filling/filtering valve

All oil immersed transformers must be fitted with one oil filling/filter connection point, located in the tank cover and provided with sealing plug or cap. Access to the filling point must be with no aids or restrictions.

Oil drain valve

All oil immersed transformers must be fitted with one oil drain connection valve of 32 mm BSP with a screwed outlet, located in the lowest part of the tank and provided with sealing plug or cap and padlock facilities.

For self-bunded oil transformer, the containment bund must be fitted with a separate oil drain valve of 32 mm BSP with a screwed outlet located in the lowest part of the bund and provided with sealing plug or cap and padlock facility.

A detachable metal surround to protect the valve from accidental damage must be fitted.

Oil level gauge

An oil level gauge must be provided on all transformers. For transformers up to 500 kVA this must be a sight glass type. Above this rating a magnetic type level gauge the oil level gauge must be a dial type complete with two adjustable contacts (change-over type). Dial type oil level gauges must be marked in degrees Celsius to indicate the correct oil level for the temperature. Taps for draining a quantity of oil must not be fitted to the oil gauge.

Pressure relief device

A pressure relief device must be fitted to all oil immersed transformers. The device must be sized to allow rapid release of over pressure to prevent damage to the tank and must be self re-sealing. Two auxiliary changeover contacts to signal operation of the device must be fitted.

Oil sampling valve

An oil sampling valve must be provided for oil immersed transformers and be readily accessible from ground level. The sampling valve must be a screwed outlet type and clearly labelled.

Oil temperature indicator

An oil temperature indicator (OTI) must be provided for all oil immersed transformers to measure top oil temperature. The OTI must have a dial type face to show temperature, with instantaneous pointer (black) and maximum temperature pointer (red). The indicator must be accessible at ground level and must include capillary tubing between the indicator and the temperature measurement device. Two sets of Volt-free adjustable alarm and trip contacts must be provided integral to the indicator and wired to a terminal box for connection to external cables. The OTI enclosure must be minimum IP66 for outdoor installed transformers. Vibration isolation mounting must be used to mount the OTI to the transformer.

Winding temperature indicator

A winding temperature indicator (WTI) must be fitted to all oil immersed transformers. The WTI must have a dial type face to show temperature, with instantaneous pointer (black) and maximum temperature pointer (red). The indicator must be accessible at ground level. The winding temperature sensor must be located to measure the worst-case winding temperature rise. Two sets of Volt-free adjustable alarm and trip contacts must be provided integral to the indicator and wired to a terminal box for connection to external cables. The WTI enclosure must be minimum IP66 for outdoor installed transformers. Vibration isolation mounting must be used to mount the WTI to the transformer.

Maximum temperature indicator

All temperature gauges must have a maximum temperature indicating needle coloured in red. This will store the maximum temperature recorded.

Conservator/breather

Where Oil immersed transformers are fitted with a conservator it must be fitted with a Transformer Conservator Membrane (TCM) air-cell that floats in oil inside the conservator and expands/contracts by breathing through a flange placed the top of the conservator.

All conservators must be fitted with a Silica Gel Breather bottle type ‘Easy Dry Breather’. The breather must be fitted at a height not greater than 1.5m above ground level and piped to the air-cell in the conservator. The size and quantity of breather(s) being provided must be specified by the Contractor.

All conservators must be fitted with a temperature calibrated float type oil level indicator which must have a dial gauge of not less than 100 mm diameter.

Provisions must be made for the collection of water and sludge. A drain valve must be provided in the lowest part of the conservator.

All conservators must be fitted with one oil filling point, located in the top of the conservator and provided with sealing plug or cap. Access to the filling point must be with no aids or restrictions.

All conservators must be fitted with one oil drain connection valve, located in the lowest part of the conservator tank and provided with sealing plug or cap. Access to the valve must be with no aids or restrictions.

Buchholz relay

A Buchholz relay must be fitted on all oil immersed transformers with a conservator tank. The relay must be installed in the pipe connected between the main tank and the conservator. The transformer tank must be design such that all gas rising from the transformer must pass into the relay pipe and not collect in stray pockets, in order to ensure no delay in the operation of the alarm float.

The buchholz relay must have ground level gas receiver and must be of the double float type for gas and surge, alarm and tripping duty respectively and be wired to a terminal box accessible from ground level. The relay contacts (N/O contacts required) must not be of the mercury type. The relays must be seismic proof to avoid spurious tripping due to earth tremors. Gate valves are to be fitted either side of the Gas Pressure relay. For testing purposes, a gas injection block accessible from ground level also must be provided, the outlet of which should be capped against dirt ingress.

4.5 For sealed oil immersed transformers

A gas pressure gauge must be provided on all sealed transformers.

The pressure gauge must have a dial type face to show pressure, with instantaneous pointer. Two sets of Volt-free adjustable alarm and trip contacts must be provided integral to the indicator and wired to a terminal box for connection to external cables.

4.6 For dry type transformers

Over temperature protection

An over temperature protection relay unit must be fitted to all dry type transformers with suitable sensors in each phase. The sensors must provide two signals at appropriate temperatures, one for a warning and one for automatic switch-off.

The relay unit must be mounted on the all dry type transformer enclosures accessible from outside the enclosure no higher than 1.5 m above ground level and be connected to the winding temperature detectors.

The relay unit must have two sets of output contacts and be arranged to operate its temperature warning relays in the event of its own failure or due to loss of its power supply. The alarm and switch-off contacts must be inhibited for a short period to allow energisation of the transformer. In any case, the relay must operate in fail-safe mode.

The power supply for the relay unit must be able to be supplied from 48 V DC. If requested, the AC voltage must suit the secondary voltage of the transformer.

A temperature indicator must be mounted on the transformer enclosure and connected to the winding temperature detectors. This indicator must be mounted no higher than 1.5 m above ground level to allow for easy reading.

4.7 Wiring

All LV and ELV wiring is to be installed in a neat and logical manner following standard industry practices.

All LV and ELV wiring must fully comply with the requirements of AS 3000 Wiring Rules.

All conductors must be FLEXIBLE stranded tinned copper wire.

Minimum conductor sizes must be:

Item	Wire type	Wiring and/or conductors	Colours
Extra Low Voltage (AC or DC)	1.5 mm^2 Cu, 0.6 / 1 kV PVC insulated type V75 to AS 3147	Active/Positive Neutral/Negative	Light Grey (LtG)
24 0V AC control when supplied from same compartment or SCA In all other cases	2.5 mm^2 Cu, 0.6 / 1 kV PVC insulated type V75 to AS 3147	Active Neutral Active Neutral	Brown (BN) Black (BK) Orange (O) Black (BK)
CT and VT secondaries	4 mm^2 Cu, 0.6 / 1 kV PVC insulated type V105 to AS 3147	Red Phase White Phase Blue Phase Neutral	Red (R) White (W) Blue (B) Black (BK)
Core Balance toroids	4 mm^2 Cu, 0.6 / 1 kV PVC insulated type V105 to AS 3147	S1 S2	Black (BK) Black (BK)
Earth conductors	Minimum 4 mm^2 Cu, 0.6 / 1 kV PVC insulated type V75 to AS 3147		Green-Yellow (G-Y)
Instrumentation twisted pair conductors		Positive Negative	White (w) Black (BK)
Ethernet	CAT 6		Blue
Conductors connecting voltage free relay contacts where the voltage is undefined	1.5 mm^2 Cu, 0.6 / 1 kV PVC insulated type V75 to AS 3147	Active/Positive Neutral/Negative	Violet (V)

All LV and ELV wiring is to be installed in plastic cable duct with clip-on covers, strapped looms or flexible conduit is to be provided from panel to door. Cable ducts are to have 30% spare capacity. Panel to door wiring must include a loop to relieve stress and must be anchored at the panel and the door.

No joints in runs of wiring (i.e. at locations other than at terminals) must be permitted.

All LV and ELV wiring is to be arranged so that the line side is connected to the top of the respective device.

Adhesive wiring supports are unacceptable.

Where wiring is to pass through cut-outs in panelling, the hole must be bushed.

All terminal strips and individual terminal blocks must be labelled using proprietary labelling/numbering systems.

All conductors must be terminated at both ends with pre-insulated crimp terminations. They must be of the correct size for the conductor and must be applied with the terminations manufacturer’s tool.

- Ring type termination lugs must be used for terminating to stud-type terminals
- Lip blade termination lugs must be used for terminating to rail-type terminals
- U shaped termination lugs must be used on selector switches and similar small equipment.

Solder connections are not acceptable.

All conductors must be uniquely numbered at both ends in accordance with the respective schematic diagrams.

All field wiring must be marshalled at terminal strips.

Terminals must comply with the following requirements:

a) Tunnel type connectors

b) Only one conductor must be terminated on each side of each terminal

c) All terminal strips must maintain a degree of protection of IP2X

d) All field cabling must be terminated on one side of each terminal strip and all panel wiring must be terminated on the other side of the terminal strip

e) For clarity, provide barriers between groups of terminals having different functions (e.g. between terminals for 240 V AC supply, DC output and signal terminals)

f) Provide a separate earth terminal for each field cable

g) All terminal blocks must be uniquely numbered in accordance with the respective schematic diagrams

h) All terminals must be uniquely numbered in accordance with the respective schematic diagrams.

MCBs must be provided for isolating all auxiliary power supplies.

5. Technical requirements - transformers

5.1 Losses

The transformers must be designed in accordance with modern low loss practices incorporating standard features commensurate with distribution transformers in the range of 1 - 5 MVA.

5.2 Pad mount and kiosk transformers - hermetically sealed

The following minimum fittings and protection devices must be provided on each transformer:

a) Porcelain cable bushings
b) Air insulated Cable termination boxes
c) Oil filling valve
d) Oil sampling valve suitable to also facilitate in-service oil filtering
e) Oil drain valve
f) Oil level indicator
g) A dial type oil temperature indicator
h) A dial type winding temperature indicator
i) A sudden pressure relief valve with integral volt-free limit switches
j) Marshalling box for auxiliary circuits
k) Lifting lugs capable of lifting the transformer complete with oil
l) Tie down lugs
m) Hauling and jacking lug
n) Earthing points on transformer tank and cable termination boxes
o) Stainless steel rating plate
p) Stainless steel name plate.

Note: To facilitate inspections, the oil level indicator, oil temperature indicator and winding temperature indicator must all be visible from the front of the transformers.

5.3 Pad mount and kiosk transformers - conservator

The following minimum fittings and protection devices must be provided on each transformer:

a) Porcelain cable bushings
b) Air insulated Cable termination boxes
c) Oil filling valve
d) Oil sampling valve suitable to also facilitate in-service oil filtering
e) Oil drain valve
f) Oil level indicator
g) A dial type oil temperature indicator
h) A dial type winding temperature indicator
i) A sudden pressure relief valve with integral volt-free limit switches

j) Oil Conservator
k) Buchholz Relay
l) Marshalling box for auxiliary circuits
m) Lifting lugs capable of lifting the transformer complete with oil
n) Tie down lugs
o) Hauling and jacking lug
p) Earthing points on transformer tank and cable termination boxes
q) Stainless steel rating plate
r) Stainless steel name plate.

Note: To facilitate inspections, the oil level indicator, oil temperature indicator and winding temperature indicator must all be visible from the front of the transformers.

5.4 Pole mounted transformers

The following minimum fittings and protection devices must be provided on each pole mounted transformer:

a) Porcelain cable bushings
b) Oil filling valve
c) Oil sampling valve suitable to also facilitate in-service oil filtering
d) Drain valve
e) Oil level indicator
f) A sudden pressure relief valve with integral volt-free limit switch
g) Lifting lugs capable of lifting the transformer complete with oil
h) Tie down lugs
i) Earthing points on transformer tank and cable termination boxes
j) Stainless steel rating plate
k) Stainless steel name plate.

5.5 Pad mount and kiosk transformers - dry type

The following minimum fittings and protection devices must be provided on each transformer:

a) Cable termination busbar flags
b) Winding temperature indicator and relay
c) IP23 enclosure (for indoor applications only)
d) IP54 enclosure (for outdoor applications)
e) Galvanized mild steel sheet, fully welded construction
f) Hot dipped galvanized mild steel, fully welded skid base complete with lifting facilities
g) Peaked roof to shed rainwater
h) Ventilation louvres (same material as the kiosk)

i) Hinged lockable doors (three point locking mechanism) at each end and side access point(s) - providing access to off load tapping connections, all protection and indication devices, all valves, CTs etc

j) The lockable doors must be fitted with standard lock barrels to Sydney Water's keying standards

k) Stainless steel door handles with padlock facilities suitable for Sydney Water's 10 mm pack locks

l) Transformer marshalling box located inside the secondary end of the enclosure

m) Cable gland plates for all cable entry

n) Cable clamps and adjustable cable support frames (e.g. "unistrut") for primary and secondary power cables

o) Tinned copper earth bar (40 mm x 6 mm minimum size) inside the secondary end of the enclosure, complete with stand-off stud insulators, predrilled with not less than 12 14mm diameter holes to suit M12 bolts

p) Earth bonds (i.e. green/yellow PVC insulated cable) to the earth bar for kiosk, transformer, all doors, etc as required by AS/NZS 3000 Wiring Rules

q) Surface preparation and paint system as specified for transformers in Section 3.11 - Surface Treatment and Painting

r) Stainless Steel rating plate located on the outside and inside of the kiosk enclosure

s) Stainless steel name plates located outside on opposite sides the kiosk enclosure

t) Tie down lugs

u) Hauling and jacking lug.

Note: To facilitate inspections, the oil level indicator, oil temperature indicator and winding temperature indicator must all be visible from the front of the transformers.

5.6 Kiosk enclosures for transformers

Kiosk enclosures for transformer must comply with Sydney Water Prefabricated Substation specification DOC0020.

The Contractor must confirm that the kiosk enclosure does not invalidate the transformer temperature rise requirements.

6. Identification and labelling

All electrical equipment forming part of the transformer must be readily identified in the English language by a label in accordance with the relevant standard and this Specification.

All labelling and nameplates must be in accordance with nomenclature used on the relevant electrical Drawings and Schedules provided by Sydney Water.

All labels must be engraved/etched stainless steel secured with stainless steel screws into tapped holes. Departures from these requirements must require the written pre-approval of Sydney Water.

All external and internal labels must be attached to the mounting surface with a minimum of two screws with holes drilled and tapped. Double sided adhesive tape is not acceptable.

All equipment labels must be mounted on a fixed portion of the enclosure directly adjacent to the device.

Terminal block group labels must be manufactured of the material and mounted in accordance with the standard procedures adopted by the terminal strip manufacturer. Terminals must not be made of brittle material.

Generally, labels must be manufactured to the following specification:

Label function and location	Typical label size (mm)	Text colour / background colour	Label description	Text height (mm)
Transformer Rating Plate - Mounted on bracket attached to transformer tank		Black / Stainless Steel	Refer to section 4.3	
Transformer Main Label - Mounted so visible from front of transformer	400 L x 250 H	Black / Stainless Steel	Transformer Number Voltage rating primary / secondary winding Transformer MVA Rating	80 50 50
Sampling Valve label - Mounted adjacent to sampling valve point	80 L x 50 H	Black / Stainless Steel	Sampling Valve	15
Terminal box voltage Label - Mounted on front of Terminal box cover	200 L x 50 H	Black / Stainless Steel	Voltage rating	40
Marshalling box label - Mounted on front door of marshalling box	100 L x 50 H	Black / Stainless Steel	Marshalling Box	20 20
All other removable cover labels that		White / Red / Black	DANGER HIGH VOLTAGE (to AS 1319)	

Label function and location	Typical label size (mm)	Text colour / background colour	Label description	Text height (mm)
provide access to high voltage equipment - Mounted on all covers that provide access to HV				
All marshalling box internally mounted equipment labels (e.g. control relays, control MCBs, Terminals etc) - Mounted below equipment.		Black / White		3
All compartment internally mounted equipment labels (e.g. control relays, control MCBs, Terminals etc) - Mounted below equipment		Black / White		3

6.1 Label schedule

A label schedule showing details of each label must be submitted for approval prior to manufacture of the relevant labels.

7. Testing requirements

7.1 Type testing

Impulse test (type test)

The Contractor must provide an impulse test (type test) report in accordance with AS 2374.3 (or IEC 60076-3) for each type of transformer.

Previous impulse type test reports may be presented if the equipment previously tested is identical or similar to the designs for the Site. All differences between the type tested designs and the designs for the Site must be supported by calculations and/or explanations to demonstrate that the equipment complies with the specified requirements.

Alternatively, new impulse type tests may be performed on one of each type of transformer.

Temperature rise test (type test)

The Contractor must provide a temperature rise test (type test) report in accordance with AS 60076-2 for each type of transformer.

It is preferred to have the type test carried out at the ambient temperature prescribed in section 2.2 of this specification. However, type test certificate carried out at 45 °C maximum ambient temperature can also be accepted with prior approval from Sydney Water, and manufacture will also need to provide written confirmation the temperature rise corrections in AS 60076.2 - section 6.3.2-Table 2 can be achieved at the ambient temperature prescribed in section 2.2 of this Specification.

Previous temperature rise test reports may be presented if the equipment previously tested is identical or similar to the designs for Sydney Water. All differences between the type tested designs and the designs must be supported by calculations and/or explanations to demonstrate that the equipment complies with the specified requirements.

Alternatively, new temperature rise type tests may be performed on one of each type of the transformers.

The Contractor must provide evidence that the kiosk enclosure described in Section 5.6 - Kiosk Enclosure for Transformers does not invalidate the temperature rise type test.

Sound pressure test (special test)

The Contractor must provide a sound pressure test (special test) report in accordance with AS 60076.10 (or IEC 60076-10) for each type of Transformer.

Previous sound level test reports may be presented if the equipment previously tested is identical or similar to the designs for the project. All differences between the type tested designs and the designs must be supported by calculations and/or explanations to demonstrate that the equipment complies with the specified requirements.

Alternatively, new sound level tests may be performed on one of each type of the transformers.

Short circuit test for transformers

The Contractor must provide a short circuit test report in accordance with AS 2374.5 (or IEC 60076-5) for the transformers.

Previous short circuit test reports may be presented if the equipment previously tested is identical or similar to the designs. All differences between the type tested designs and the designs must be supported by calculations and/or explanations to demonstrate that the equipment complies with the specified requirements.

Alternatively, new short circuit tests may be performed on one of each of the transformers.

Alternatively, if short circuit strength is demonstrated by calculation, then such calculations must consider relevant factors such as:

a) Peak asymmetrical short circuit current

b) Peak asymmetrical ampere turns

c) Ability to withstand thermal effects of short circuits

d) Ability to withstand peak hoop stresses on the HV windings

e) Ability to withstand peak hoop stresses on the LV windings

f) Ability to withstand peak internal axial compression

g) Ability to withstand peak unbalanced axial forces

h) Ability to withstand peak tensile stress on tie rods.

All such calculations must take into consideration the specified requirements for Sydney Water and must be fully documented in a written report.

General

If a new type or special tests are performed, representatives from Sydney Water must be given the opportunity to witness the tests. 14 calendar days' notice must be given for tests in Australia and 21 calendar days' notice must be given for tests outside Australia.

Copies of all type test reports (whether previous or new) must be submitted to Sydney Water for approval.

7.2 Factory inspection

Sydney Water must be given the option of witnessing all inspections and tests including type tests, (routine) factory tests and site tests. Sufficient notice (14 calendar days for tests on site, 42 calendar days for test elsewhere in Australia, 42 calendar days for tests outside Australia) must be given to enable the necessary travel arrangements to be made.

7.3 Routine (factory) testing

All routine tests listed by AS 2374-1997 Parts 1-6 must be performed on each transformer at the transformer factory prior to shipment to site, including:

a) Measurement of voltage ratio and vector group relationship

b) Measurement of winding resistance (primary and secondary windings)

c) Measurement of impedance voltage

d) Measurement of load losses

e) Measurement of no-load losses

f) Insulation resistance tests

g) Dielectric tests

h) Separate source power frequency test

i) Separate source power frequency test (secondary to Primary and earth for one minute)

j) Induced over-voltage withstand test

k) Calculated load losses at 25%, 50%, 75% and 100% of MCR with correction to T_{ref} = 75 °C.

Factory tests must also include:

l) Thermal image scans of all four sides and top of transformer after it has been energised for 24 hrs with no load

m) Detailed mechanical inspection

n) Detailed electrical inspection

o) Functional testing of all protective devices (where possible)

p) Review of routine test certificates for protection devices (from place of manufacture)

q) Review of routine test certificates and magnetisation curves for CTs (from place of manufacture)

r) Review of manufacturing inspection and test documentation and records

s) Review of manufacturing defect lists / punch lists.

The results of all factory tests must be available for review during the tests.

A comprehensive Factory Test Report must be submitted for review within five working days of completion of the tests (or prior to shipment, whichever is the earlier). The Factory Test Report must include:

t) Results of all tests

u) Copies of any test oscillograms, graphs, printouts, etc

v) Copies of all routine test certificates (from place of manufacture) for protection devices, CTs, etc

w) Copies of magnetisation curves for all CTs

x) Copies of manufacturing inspection and test documentation and records, follower cards, etc

y) Copies of factory defect lists / punch lists

z) Copy of the completed Factory ITP

aa) Statement confirming compliance with the specified requirements.

Unless agreed otherwise by the Superintendent, all defects arising prior to or during the factory tests must be rectified to the satisfaction of the Superintendent prior to the respective transformer being shipped to site.

7.4 Site testing

The Contractor must provide a detailed procedure (for review by Sydney Water) for site testing and commissioning of the transformers. The procedure must fully comply with the requirements of AS 2374-1997 and AS/NZS 3000:2007.

In addition, the Contractor must complete thermal image scan of all four sides and top of the transformer after the transformer has been energised for a minimum of 24 hrs with no load.

A thermal image scan of all four sides and top of the transformer must be completed after the transformer has been loaded for a minimum of 24 hours.

The site test will be performed by the Contractor, in accordance with the procedure provided by the Contractor.

8. Quality assurance and inspection and test plans

The Contractor must implement a quality system that complies with the requirements of ISO 9001 for all work on the transformers.

The Contractor must submit to Sydney Water for review two project-specific Inspection and Test Plans (ITPs) for the Transformers:

a) Transformer ITP covering all activities i.e. engineering, design, supply, manufacture, factory assembly, factory testing, type testing, resolution of factory defects/punch lists, release for delivery, preparation for transport, etc for the transformers

b) Kiosk ITP covering all activities i.e. engineering, design, supply, manufacture, factory assembly, factory inspection, resolution of factory defects/punch lists, release for delivery, preparation for transport, etc for the kiosk enclosure for the transformer.

The ITPs must identify the standards and/or procedures as well as the acceptance criteria that must apply for each stage in the ITPs.

Unless approved otherwise by the Superintendent, all standards, procedures and acceptance criteria included in the ITPs must comply with the requirements defined in this specification.

Perform all work on the Transformers in accordance with the approved ITPs.

Sydney Water may apply witness points and/or hold points on various stages of the ITPs.

Sydney Water must be given the option of witnessing all inspections and tests including type tests, (routine) factory tests and site tests. Sufficient notice (14 calendar days for tests on site, 42 calendar days for test elsewhere in Australia, 42 calendar days for tests outside Australia) must be given to enable the necessary travel arrangements to be made.

Sydney Water may elect to appoint third party inspector(s) to witness inspections and tests.

All costs associated with attendance by representatives of Sydney Water at inspections and tests must be borne by Sydney Water.

9. Spare parts

9.1 Consumable spare parts

The Contractor must provide all consumable spare parts (including fluids) required for the transformers up to the end of the defects liability period.

All consumable spares must be provided in advance and held in storage at site.

9.2 Routine maintenance spare parts (for defects liability period)

The Contractor must provide all consumables and spare parts for routine and scheduled maintenance up to end of the defects liability period.

All routine maintenance spares must be provided in advance and held in storage at site.

9.3 Long-term maintenance / strategic spare parts and special tools

The Contractor must provide a priced list of optional recommended spare parts for long-term maintenance activities and strategic planning, as well as any special tools required to perform long-term maintenance activities.

Sydney Water will confirm if it wishes to purchase some (or all) of these recommended spare parts and tools.

10. Manuals and drawings

Two paper copies of erection, maintenance and operating manuals must be supplied. One electronic copy of all manuals, drawings and test results must be provided on suitable electronic media in PDF file format as a minimum. Equipment manuals provided must contain details of all aspects of the operation and maintenance of the supplied equipment, a detailed parts list of all major components and copies of all factory test results.

Electrical circuit diagrams must be supplied either with the manuals or as separate A3 size drawings. All drawings must be supplied electronically in an AUTOCAD compatible format.

Equipment manuals and drawings must not contain descriptions or details of alternative equipment not specifically used in the supplied equipment.

Maintenance manuals and regimes must be specific for each site installation, with respect to the maintenance timeframes required for the environmental conditions of the specific site.

11. Related documents

The Power Transformers and all associated equipment and materials must be designed, manufactured and tested in accordance with the latest revisions of the Federal and State statutory requirements, applicable Australian and IEC Standards, as well as the Sydney Water standard specifications.

Document type	Title
Legislation	- Latest edition of the Work Health and Safety Act - Latest edition of the Service and Installation Rules of New South Wales
Policies and procedures	- WSA201 - Manual for Selection and application of protective coatings - Supplement to WSA201 - Manual for Selection and application of protective coatings - PCS100 - Protective Coatings
Other documents	CPDMS0022 – Technical Specification Electrical
Standards	- AS ISO 1000: The International System of Units (SI) and its application (ISO 1000) - AS 1170: Minimum design loads on structures (known as the SAA Loading Code). (Parts 2 and 4) - AS 1214 (ISO 1460/61): Hot-dip galvanized coatings on threaded fasteners (ISO metric coarse thread series) - AS 1627: Metal finishing - Preparation and pre-treatment of surfaces - AS 1767 (IEC 60296): Insulation liquid - Specification for unused mineral insulating oils transformers and switchgear (IEC296) - AS 1824 (IEC 60071): Insulation coordination (phase-to-earth and phase-to-phase, above 1 kV) (Parts 1 and 2) - AS 1931 (IEC 60060): High voltage testing techniques (Parts 1 and 2) - AS1939: Classification of Degrees of Protection for Enclosures for Electrical Equipment - AS1940: The storage and handling of flammable and combustible liquids - AS 2067: Switchgear assemblies and ancillary equipment for alternating voltages above 1 kV - AS2374 (IEC 60076): Power transformers (Parts 1, 2, 5, 7 and 8) - AS 2700: Colour standards for general purposes - AS 2768: Electrical Insulating Materials - AS/NZS 3000: Electrical installations (known as the Australian/New Zealand Wiring Rules) - AS 4398.1 (IEC 60237): Insulators - Ceramic or glass - Station post for indoor and outdoor use - Voltages greater than 1000 V AC (parts 1, 2) - AS 60038: Standard voltages - AS 60044.1 (IEC 60044-1): Instrument transformer - Current transformers - AS 60076 (IEC 60076): Power transformers (parts 1, 3, 4, 10 and 11).

Document type	Title
	- AS 60137 (IEC 60137): Bushings for alternating voltages above 1000 V - AS 60146: Semiconductor Convertors - AS 60214 (IEC 60214): Tap-changers (Parts 1 and 2) IEC214. - AS 60529 (IEC 60529): Degrees of protection provided by enclosures (IP Code) - AS/NZS 6100: Electromagnetic Compatibility (EMC) - IEC 60085: Electrical insulation - Thermal evaluation and designation - IEC 61099: Specification for unused synthetic organic esters for electrical purposes - BS2562: Specification for Cable-Boxes For Transformers and Reactors

11.1 Conflicts between specification, standards and/or codes

Review the above standards and make use of them where they are applicable. Identify any conflicts between the above standards and recommend which criteria to use. The Contractor must refer any conflicts in the information to Sydney Water for clarification.

Ownership

Ownership

Role	Title
Group	Integrated Systems Planning - Liveable City Solutions
Owner	Manager of Urban Design and Engineering
Author	Lead Engineer Electrical

Change history

Version No.	Prepared by	Date	Approved by	Issue date
1	Robert Lau / Andrew Manganas / Paul Zhou	05/12/2014	Norbert Schaeper	05/12/2014
2	Robert Lau / Andrew Manganas / Paul Zhou	21/09/2016	Norbert Schaeper	21/09/2017
3	Robert Lau / Paul Zhou	14/09/2018	Ken Wiggins	14/09/2018
4	Paul Zhou	20/02/2020	Steve-Keevil Jones	20/02/2020