TS 03818:1.0

EP 02 10 00 01 SP

Specification

Power Transformer 33/11kV

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Document information

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Document history

Revision	Effective date	Summary of changes
1.0	04/04/2024	First issue

Preface

First issue as TS 03818 superseding EP 02 10 00 01 SP *Power Transformer – 33/11 kV,* Version 2.1.

This document specifies the requirements for 33/11 kV transformers that are used on the TfNSW metropolitan heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area.

Appendix A is the technical schedule which is required to be completed by the manufacturer.

Appendix B details the data set requirements associated with transformer.

Appendix C details integrated support requirements.

Appendix D details the whole of life cost requirements.

Appendix E sets out information for the request for tender.

Appendix F details options that are required to be priced at time of tender.

The changes to previous content in EP 02 10 00 01 SP are as follows:

- incorporated technical note TN 046:2016
- addition of requirements for dry type transformers
- included details on the use of ester fluid
- updated to make it applicable to 1500 V dc metro lines.

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1 Scope

This document provides specifications for outdoor type 33/11 kV transformers that are type and routine tested and fitted with all auxiliary equipment for use in the TfNSW heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area electrical networks.

This document provides the specification for the following two configurations of transformers:

- 33 kV connected via cable with separable connectors
- 33 kV connected via busbar with bushings.

All information required to ensure that the transformers are electrically suitable for use within the TfNSW heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area electrical networks is contained in this document or referenced by this document.

2 Application

This requirements of this document apply to the purchase of 33/11 kV transformers to be installed in the TfNSW metropolitan heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area.

The requirements of this document are not applicable to existing 33/11 kV transformers currently in service.

For clarification of any requirements in this document contact the AMB.

Note: Contact the TfNSW AMB by email to standards@transport.nsw.gov.au

3 Referenced documents

International standards

EN 50180 (all parts) *Bushings above 1 kV up to 52 kV and from 250 A to 31.5 kA for liquid filled transformers*

IEC 62535 *Insulating liquids – Test method for detection of potentially corrosive sulphur in used and unused insulating oil*

Australian standards

AS 1627.4 *Metal finishing – Preparation and pretreatment of surfaces Part 4: Abrasive blast cleaning of steel*

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

AS 2700 *Colour standards for general purposes*

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

AS/NZS 3000 *Electrical Installations "Wiring Rules"*

AS/NZS 60076.1 *Power transformers Part 1: General (IEC 60076-1, Ed.3.0 (2011) MOD)*

AS/NZS 60076.3 *Power transformers Part 3: Insulation levels, dielectric tests and external clearances in air (IEC 60076-3:2013 (ED.3.0) MOD)*

AS/NZS 60076.10 *Power transformers, Part 10: Determination of sound levels (IEC 60076-10:2016 (ED.2.0) MOD)*

AS 60076.11 *Power transformers, Part 11: Dry-type transformers*

AS 60270 *High-voltage test techniques – Partial discharge measurements*

AS 60296 *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear (IEC 60296, Ed. 4.0 (2012), MOD)*

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

AS/NZS 60214.1 *Tap-changers Part 1: Performance requirements and test methods (IEC 60214-1:2014 (ED.2.0) MOD)*

Transport for NSW standards

TS 00011 *Common Requirements for Electrical Power Equipment*

TS 01517 (T MU AM 01002 MA) *Maintenance Requirements Analysis Manual*

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

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

TS 03742 (T HR EL 00002 PR) *Electrical Power Equipment – Integrated Support Requirements*

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

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

TS 03817 (EP 02 00 00 01 SP) *Transformer Loss Evaluation*

TS 03865 (T HR EL 11004 ST) *Electrical SCADA Interface Requirements*

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

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

Other reference documents

TS 03820 (EL 0416250) *Substations – 33/11 kV Power Transformer Basic Configuration Requirements*

TS 03938 (EL 0494459) *General, Substations – 33 kV Transformers & SWBDS, HV Cable Screen Earthing Requirements*

4 Terms, definitions and abbreviations

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

ac alternating current – an electric current that reverses its direction many times a second at regular intervals

AMB Asset Management Branch

AVR automatic voltage regulator

CSV comma-separated values, is a table structured format file

CT current transformer

DIN Deutsches Institut für Normung (German institute for standardisation)

HV winding the winding having the highest rated voltage

IP ingress protection

ISO International Organization for Standardization

ITP Installation Test Plan

LV low voltage: exceeding 50 V ac or 120 V ripple-free dc but not exceeding 1000 V ac or 1500 V dc

LV winding the winding having the lowest rated voltage

metro an urban railway transportation system that is associated with high capacity and high frequency (typically turn-up-and-go, rather than timetabled) and greater automation

MS Microsoft

NATA National Association of Testing Authorities, Australia

OLTC on load tap changer

ONAF oil natural air forced

ONAN oil natural air natural

PCB polychlorinated biphenyl

RCD residual current device

RFT request for tender

RTU remote terminal unit

SCADA supervisory control and data acquisition

TAO Technically Assured Organisation

TfNSW Transport for New South Wales

5 TfNSW type approval

All 33/11 kV transformers procured in accordance with this specification shall be type approved by TfNSW prior to being connected to the electrical network.

The type approval process is contained in TS 06178.

6 Functional requirements of transformer

The transformer shall provide the following:

- transformation of nominal system voltage of 33 kV to 11 kV
- automatic on load voltage adjustment
- connection of 33 kV and 11 kV cables to the associated high voltage switchgear or connection of 33 kV to busbar and 11 kV cables to high voltage switchgear
- measurement of the transformer temperature
- provision of transformer protective devices
- connection of SCADA system, protection, and auxiliary cabling
- suitability for operation in an environment with conditions as prescribed in this specification.

7 Transformer configurations

This specification provides detail on two transformer configurations as summarised in Table 1.

Table 1 – Transformer configurations

Configuration	Type of 33 kV connection	Type of 11 kV connection
1	Bushing	Separable connector
2	Separable connector	Separable connector

The 11 kV is connected to indoor switchgear via cable with separable connectors for both configurations. The exact configuration will be specified at the time of order.

The transformer shall be designed for one configuration or the other, not for both.

8 Performance characteristics

Where not specifically detailed in this document the functional characteristics of the transformer shall be in accordance with the following standards:

- AS/NZS 60076 (all parts)
- AS/NZS 60214.1.

Table 2 Provides general requirements for dry type transformer.

Table 2 – Dry type transformer general requirements

Parameter	Designation
General	Outdoor or indoor
Construction type	Encapsulated vacuum cast resin for both 33 kV and 11 kV windings.
Cooling method	AN
IP rating (indoor)	IP22 (See Note 1)
IP rating (outdoor)	IP43
Environment class	E0 for above ground installations E1 for below ground installations (in accordance with AS 60076.11)
Climatic class	C1 in accordance with AS 60076.11
Fire behaviour class	F0 for above ground installations F1 for below ground installations (in accordance with AS 60076.11)

Note 1: This IP rating does not apply to indoor transformers without enclosures that are located in dedicated transformer rooms.

Table 3 provides general requirements for liquid immersed transformer.

Table 3 – Liquid immersed type transformer general requirements

Parameter	Designation
General	• outdoor • separate winding • three phase unit
Type of cooling	ONAN or ONAF
Type of liquid	Liquid immersed (mineral oil or ester fluid)

Table 4 provides details on the technical ratings for both dry type and liquid immersed transformers.

Table 4 Transformer technical ratings

Technical parameter	Rating
Rated voltage: • High voltage • Low voltage	 • 33 kV (rms) • 11 kV (rms)
System highest voltage: • High voltage • Low voltage	 • 36 kV (rms) • 12 kV (rms)
Connection symbol	Dyn1
Rated insulation level: • HV – lightning impulse • HV – power frequency • LV – lightning impulse • LV – power frequency	 • 200 kV (peak) • 70 kV (rms) • 95 kV (peak) • 28 kV (rms)
Rated frequency (f_r)	50 Hz
Rated power (see Note 1)	• 2.0/2.5 MVA, or • 5.0/6.25 MVA, or • 7.5/9.25 MVA • 20 MVA
Method of neutral earthing of the system	Both effectively earthed and non-effectively earthed
Impedance (See Note 2) at: • 2.0/2.5 MVA • 5.0/6.25 MVA • 7.5/9.25 MVA 20 MVA	 • 6% • 7.5% • 8% • 10%
Fault level (maximum): • High voltage • Low voltage	 • 1500 MVA for 3 phase symmetrical fault • Limited by transformer impedance
Sound power level	Refer to AS/NZS 60076.10
Overload requirements	Refer to AS 60076.7
Type of 33 kV termination (See Note 3)	Configuration 1: bushing Configuration 2: separable connector
Type of 11 kV termination	Separable connector
Ambient temperature range	TS 03744

Note 1: The rated power will be nominated in the RFT.

Note 2: These impedances are aligned with existing transformers within the respective networks. The required impedance will be nominated in the RFT.

Note 3: The type of connection will be nominated in the RFT.

Table 5 provides details on the general requirements of the OLTC.

Table 5 – OLTC requirements

Technical parameter	Rating
High voltage winding tapping range (heavy rail)	−15% to +5% of nominal voltage in increments of 1.25%
High voltage winding tapping range (1500 V dc metro rail)	−7.5% to +7.5% of nominal voltage in increments of 1.25%
Type of tap changer	On load
Tap changer control voltage	125 V dc (see note 1)
Tap changer motor drive voltage	415 V ac (see note 2)

Note 1: Standard supply voltage for auxiliary and control circuits used within TfNSW heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area is 125 V dc as specified in TS 00011. There are certain existing locations in the TfNSW heavy rail network where a 50 V dc supply voltage is used instead. This information shall be provided with the RFT in accordance with Appendix E.

Note 2: Standard auxiliary supply voltage for heaters and lights used within TfNSW heavy rail passenger network and 1500 V dc metro lines within the metropolitan rail area is 415 V ac as specified in TS 00011. At existing locations in the TfNSW heavy rail network where available supply differs from 415 V ac, information regarding available supply shall be provided with the RFT in accordance with Appendix E.

9 Technical characteristics

The ratings of bushings, tap changers, connecting leads, etc, shall be of sufficient capacity such that the transformer may be loaded in accordance with AS 60076.7.

All equipment supplied shall be suitable for normal handling during transport and installation, for continuous operation under the conditions specified in this document and is suitable for the required duty.

Bolts, screws and nuts shall be ISO metric. All bolts, nuts and washers used outside the tank shall be stainless steel, minimum grade of 314. All nuts within the tank shall be fitted with locking devices.

All valves, flanges and other equipment shall be easily accessible with the transformer installed on a foundation or a flat concrete slab.

9.1 Limiting dimensions – liquid immersed

Applicable to heavy rail, the transformer shall have dimensions in accordance with drawing TS 03820 with specific regard to the location and height of the HV and LV cable terminations and the transformer mounts. This facilitates the requirement for the transformer to be replaced with a similar transformer on the TfNSW heavy rail passenger network.

The 33 kV tank, radiators and associated equipment arrangement shall satisfy the limiting dimensions shown on drawing TS 03820.

9.2 Winding requirements

Windings and their connections shall be of robust design and construction, sufficient to withstand forces occurring during normal manufacture, transport, installation and service, and also to withstand external short circuits.

Independent of the tapping in use, the transformer shall be capable of withstanding, without deformation or injury, the thermal and mechanical effects of fault currents arising from any type of external short circuit with full voltage being maintained on the winding.

The following calculations shall be completed for three phase faults and earth faults including extreme tapping positions:

- short circuit current and current densities
- short circuit forces and stresses in windings
- end supports using finite element analysis.

9.3 Core requirements

The core shall be designed and constructed to withstand without deterioration the stresses imposed by service conditions, lifting, transport, handling and earthquakes in the TfNSW heavy rail passenger network and 1500 V dc metro geographical area.

There shall be one connection only between the core and the tank (earth). The core earth connection shall be inserted in the core lamination to such a depth that the core clamp brings sufficient pressure to bear upon it.

9.4 Main tank

The following sections provide detail on specific requirements to the transformer main tank.

9.4.1 Accumulation of water

The tank and accessories shall be designed to prevent accumulation of water.

9.4.2 Accumulation of gas

The main transformer tank and on load tap changer shall have separate oil systems. The internal surfaces of the tanks shall be such as to prevent the accumulation of gas. All gas generated within the tank shall find an easy route to the Buchholz relay.

9.4.3 Access to bushings and core connections

Where the transformer is HV bushing connected, hand-holes complete with covers shall be provided to allow all bushings to be replaced and the OLTC inspected without removing the main transformer cover.

The inspection covers and the tank lid shall be fitted with eyebolts for lifting.

Inspection covers shall be permanently labelled with details of the equipment that is accessible under the cover.

9.4.4 Earth terminals

Two earthing tabs (stainless steel 316) with 2 x 14 mm diameter holes suitable for connection of 2 x M12 bolt shall be located externally at opposite ends of the tank, near the bottom of the tank for connection to the substation earth grid.

9.4.5 Provision for temperature measurement devices – liquid immersed

Suitable oil tight pockets shall be provided for top oil temperature and winding temperature devices. The location of the pockets shall be carefully chosen to enable the measurements of the hottest top oil temperature.

The design of the transformer tank shall be such as to prevent the build-up of pockets of still hot oil. The thermometer pockets shall be provided with a sealing cap to prevent moisture ingress.

9.4.6 Cable cleats

Where the transformer is HV cable connected, a channel support system shall be provided below the HV and LV cable connection locations for attachment of cable cleats and the earth bar for the HV cable screen as detailed in TS 03938.

Cable support structures shall be designed such that transformer vibrations are managed, and not transferred to others substation structures or buildings (that is, suitable vibration damping is provided between the transformer, cable support structures, and other structures).

9.4.7 Pressure relief valve – liquid immersed

An extra high flow pressure relief device complete with directional discharge shield and highly visible semaphore shall be provided to minimise the build-up of pressure within the main tank in the event of an internal fault.

Vented oil shall have provisions made to direct its flow to ground level in the bunded area within a control gully or pipe. Vented oil shall not be directed over manual control points of the transformer.

Pressure relief valves shall be rated such that internal transformer faults do not cause structural damage to the tank.

Alarm and indication contacts shall be provided, integral with the pressure relief valve. The contacts shall be wired back to terminals in the transformer marshalling box in accordance with Section 9.8 and Section 9.9.

9.5 Surge arrester mounting

Where the transformer configuration is a 33 kV bushing type, mounting brackets shall be affixed to the tank for the mounting of suitable surge arresters adjacent to the 33 kV bushings.

9.6 Valves and pipework – liquid immersed

All valves shall be labelled to indicate their function and are readily operable with the transformer fully assembled. In this regard it may be necessary to provide extension handles on radiator valves so that inner radiators may be isolated while outer radiators are mounted.

All valves which are mounted near the base of the transformer shall have mechanical protection provided to prevent damage during transport and so on.

No valves shall exit the transformer tank under the high voltage cable bushings.

All radiator isolation valves shall have visual indications of ‘open’ and ‘shut’. The isolation valves shall be labelled as to their function. All other valves shall have clear indication of the direction to open and close the valve.

The Buchholz isolation valve shall be located on the conservator side of the relay. In case removal of the Buchholz relay is necessary; this isolation valve may be turned off and the main tank oil level lowered slightly to drain the Buchholz relay prior to its removal. The procedure shall be included in the operation and maintenance manual.

A drain valve 50 mm nominal bore pipe internal thread with flanged plug suitable for quick release fittings shall be fitted at the bottom of the transformer tank and the radiators to allow the oil and any moisture to be withdrawn.

An oil-sampling valve shall be provided at the bottom of the tank.

9.7 Lifting attachments or wheels

Lifting attachments of appropriate capacity shall be provided on all devices that have to be removed for inspection purposes. This includes the tank top lid if this is capable of removal from the tank.

Unless otherwise noted in the RFT, bi-directional wheels shall be provided for rolling the transformer full of oil into position. Wheels shall be of solid construction. Flanged wheels shall not be used.

Skid mounting facilities on the transformer in lieu of wheels may be required and will be included in the RFT. Unless stated otherwise in the RFT skids shall be placed in the alignment of the wheels given by EL0416250 for transformers intended to be used in heavy rail.

Lifting lugs shall be fitted to the transformer which allow the transformer to be lifted into or out of place while full of oil. Lifting lugs shall be located so that the transformer can be lifted without removal or fouling of any part.

Jacking plates shall be provided approximately 500 mm from the transformer foundation. The jacking plates shall be suitable for jacking the transformer when full of oil. The plates shall be accessible when the transformer is installed at site.

9.8 Marshalling box

A marshalling box with a suitable IP rating as detailed in TS 03744 shall be provided for connection of alarms and indications. All wiring shall be terminated on standard DIN rail terminals or equivalent and labelled with non-ferrous labels. The terminals shall also be clearly labelled as detailed in TS 00011.

The marshalling box shall contain the following:

- vertically hinged lockable doors, with a flexible earth bond to the main cabinet
- thermostatically controlled anti-condensation heater (appropriate warning label to be installed in the marshalling box)
- a door operated light
- double general purpose outlet (GPO) that can be locked and be protected by an RCD in accordance with AS/NZS 3000.

Wiring from the marshalling box to other substation equipment shall be installed by others (including supply of cable glands). A removable undrilled non-magnetic gland plate shall be supplied by the transformer manufacturer for the entry of cables. The gland plate shall be located to permit cable entry from below.

9.9 Control wiring

Control wiring shall be in accordance with the relevant sections of TS 00011.

9.10 Alarms and indication contacts

For each alarm or indication, one normally closed contact and one normally open contact shall be provided.

The contacts shall be suitable for making and breaking at least 100 mA in a 125 V dc circuit. Contacts shall be suitable for switching relay coils and similarly inductive loads.

9.11 Conservator – liquid immersed

An appropriately sized conservator shall be fitted to the main tank. The conservator shall be in accordance with the following requirements:

- Maintain positive oil pressure in the main tank.
- Appropriately sized for the rating of the transformer and be suitable for the ambient conditions specified in in TS 03744.
- Flanged pipes of 50 mm in diameter shall be fitted at each end of the conservator so that oil can be completely drained and all sludge and foreign matter can be extracted by filtering. The pipes shall be fitted with 50 mm valves.
- Internal surfaces shall be treated with an approved oil resistant coating sufficient to ensure that the conservator meets the specified design life.
- Where the chamber of the tap changer containing the load making and breaking contacts requires it, an additional conservator shall be provided. This may take the form of an extension to the main conservator. The oil shall not be allowed to mix with the main tank oil.
- Lifting eyes shall be fitted to the conservator of sufficient capacity to allow removal of a full conservator.
- A magnetic oil level gauge with alarm contacts shall be fitted (due to air bag conservator compatibility). The contacts shall be wired back to the marshalling box. When the transformer is in its installed position in the substation, the oil level shall be visible from ground level.
- A membrane (that is, air bag) between the oil and air to prevent moisture in the air from contaminating the oil in the conservator. Air bag shall be Fujikura type FNH8-045 or an equivalent to be approved by the person with the appropriate Engineering Authority Delegation, in the AMB.
- A bag rupture relay shall be provided with a set of contacts for an alarm to SCADA.

- The conservator base brackets shall be bolted to the main tank.
- Access shall be provided to all compartments of the conservator to facilitate cleaning.
- A stop valve on both sides of the Buchholz type relays.
- The conservator shall be arranged so that all air can be excluded from below the membrane at the time of filling.
- Oil Level indicators shall be provided as detailed Section 9.22.

9.12 Radiators – liquid immersed

The radiators shall be designed to adequately dispose of all heat generated inside and outside the transformer to maintain the top oil, winding and core temperature rises within the specified limits.

The main connection to the radiators shall be fitted with valves immediately adjacent to the tank to allow removal without lowering of the transformer oil level and without removal of other radiator sections.

A drain plug shall be fitted to the lowest point to allow removal of oil from individual radiators independent of the transformer tank oil and other radiator sections.

Valves shall not be welded to the tank or radiators.

The external surfaces of the radiators shall be hot dip galvanised to AS 4680.

The internal surfaces of the radiator shall be flushed to remove any contamination then dried and treated with an approved oil resistant coating.

Extruded aluminium type radiators shall not be used.

Radiators shall be fitted with lifting eyes capable of supporting the combined weight of the radiator and oil.

9.13 Fans – liquid immersed

Fan motors shall be mounted on anti-vibration dampers.

Fan motor shall be three-phase rated at 415 Volts ±10% 3 phase, 50 hertz, suitable for direct online starting at an ambient temperature as specified in TS 03744, as specified for outdoor equipment.

In a limited number of locations, the supply available is 220 V, 3 phase, 50 Hz. The RFT will specify if the fan motors shall be operated at this voltage.

Fans motors shall have a local isolating switch. An alarm shall be generated with the isolating switch in the isolated position.

Motors shall be corrosion resistant squirrel cage induction motors. Bearings shall be of the fully sealed type. Any exposed metal part shall be corrosion free and treated to resist corrosion due to weather exposure and the transformer environment.

Fans shall have non-ferrous blades. The noise and vibration from fans shall be kept to a minimum.

Galvanised heavy wire mesh guards of not greater than 40 mm mesh and of not less than 3 mm diameter steel wire shall be provided over the fan blades.

Motor terminal box shall be permanently labelled to show the phasing for correct fan rotation for a phase rotation of ABC.

Fans shall be controlled via winding temperature indicators, with adjustable settings to turn on and turn off the fans.

9.14 33 kV and 11 kV terminal arrangements

Connection to the 33 kV terminals will be made by cables via separable connectors or busbar via bushings as indicated in the RFT. Connection to the 11 kV terminals shall be made by cables. The preferred cable quantities and sizes are detailed in TS 03748.

The design of the terminal arrangements shall minimise the mechanical loading of the connecting cables, including the allowance for the thermal expansion of the cables.

Minimum safety clearances in accordance with AS 2067 are required for the transformer configuration with 33 kV bushings. The minimum safety clearance is applicable for the transformer with wheels or when the wheels have been removed.

The manufacturers' scope includes the bushings or sockets, but not the external cable connection hardware. The manufacturer shall prove suitability of the arrangement during high voltage testing. For example, temporary test cables or temporary oil-to-air test bushings may be used; however, sockets shall be installed and fitted with dummy plugs.

9.14.1 33 kV aerial bushing

Where the transformer configuration is for the connection of 33 kV busbar, the bushings shall be in accordance with AS 60137. The bushings shall be suitable for a normally polluted atmosphere and fitted with flat connecting palms.

Oil filled bushings are not acceptable.

The clearance between the 33 kV bushing exposed metal caps and earth or between exposed metal caps to those of other phases shall be not less than 460 mm. This constraint exceeds the minimum requirements of AS 60076.3, however it is formulated with reference to AS 60076.3 and AS 2067 due to TfNSW heavy rail passenger network and 1500 V dc metro 33 kV bulk supply points being resistively earthed in many situations.

9.14.2 33 kV and 11 kV seperable connector terminals

Suitable mechanical and weather protection to the HV plug-in connector shall be incorporated in the design of the transformer.

The terminals shall be appropriately rated load break plug-in connectors comprising a separable bolted type connector attached to the high voltage cable and mating equipment bushings (such as Euromold).

If multiple parallel cables are required on the 11 kV side, a combination of an appropriately rated tee connector and an appropriately rated elbow can be used for paralleling two cables.

Separable connectors shall be in accordance with EN 50180.

9.14.3 11 kV star point (neutral)

The 11 kV star point (neutral) shall be brought out to a separable connector of the same type as the other 11 kV terminals.

9.15 On load tap changer

The transformer shall be provided with full output tap changing equipment suitable for regulating the three phases simultaneously under load. The OLTC shall be of the high-speed resistor type. Tap changers with vacuum interrupters are acceptable subject to life cycle costing analysis.

However, for metro rail the OLTC shall be provided with the vacuum type equipped with AVR.

The OLTC shall be in accordance with the requirements of AS 60214.1.

Only a single tap change shall be possible with each operation.

It shall be possible to determine the tap position safely from the ground without isolating the transformer.

All leads and connections to fixed and moving contact assemblies shall be supported and adequately braced to withstand short circuit currents for which the transformer is designed.

The oil in the diverter switch compartment shall be completely separated from the oil in the main tank by oil-tight barriers. Maintenance of the tap changer shall be possible without disturbing the main tank oil system.

The diverter switch shall be readily accessible and easily removable for maintenance.

Facilities shall be provided to permit ready inspection of the tapping connections and selector and diverter contacts without the necessity for removing the selector or diverter switches from their housing.

The design shall be such as to prevent the ingress of moisture into, or the leakage of oil from, the tank.

9.15.1 Tap changer control

The tap changer shall be fitted with the necessary controls and protective equipment for:

- completely automatic operation
- local manual push button operation
- local manual mechanical operation.

The time between changes of position of the tap change shall be adjustable in the range 0 – 300 seconds.

A supply from an 11 kV / 110 V three-phase voltage transformer will be provided at the substation for the operation of voltage sensing equipment. The voltage sensing equipment shall prevent operation of the tap changer if the reference voltage is lost.

The tap change control circuit shall operate at 125 V dc. This supply will be provided from the substation distribution board.

A 415 V, three-phase and neutral, 50 Hz supply will be provided for the operation of the tap changing equipment. In the event that the transformer will operate at a substation without such a supply, details of the alternative supply will be included in the RFT.

The tap changer mechanism shall be designed such that, following the initiation of a change of tap position, the change will be completed, even with a complete loss of supply to the drive motor.

The tap changer control cabinet shall be a suitable IP rating in accordance with TS 03744. The cabinet shall be bolted to the transformer main tank in a convenient position so that the operator standing at ground level can carry out maintenance on all equipment contained in the cabinet with the transformer energised.

The cubicle shall contain a thermostatically controlled anti-condensation heater, a door operated light, and a manual handle for emergency and maintenance operation.

9.15.2 Tap changer monitoring

Tap changers shall be fitted with the following:

- A mechanically operated tap position indicator which will provide a visible indication of the tapping in use. The tap position indicator shall also provide an indication into a SCADA system via a tap position encoder producing binary output or volt free contacts with shared common.
- A local cyclometer for recording the number of tap changing operations. Contacts for remote indication of either limit of travel.
- Local and remote 'tap change in progress' indication. A voltage free (normally closed) contact shall be provided for SCADA to indicate a tap change is in progress. The contact

shall be in the open state while a tap change is in progress. The actual tap change shall commence not less than one second after the indication signal goes to the 'changing position' state.

- A common ‘fault’ signal for remote indication which shall incorporate all fault conditions that can reasonably be monitored, together with loss of motor and control power supply. This signal shall be a contact that is normally closed but opens upon fault.
- Alarm equipment which shall operate if tap changing has not been completed within a predetermined time after being initiated. This equipment shall also operate if the ac control supply is lost. A set of changeover contacts capable of making and breaking 100 mA in a 125 V dc slightly inductive circuit shall be provided on this equipment for external alarm circuits.

9.15.3 Tap changer control for transformers in parallel

Where nominated in the RFT, the tap changer controls shall be suitable for operation of transformers in parallel. The tap changer control shall have the following functionality:

- both remote (SCADA), local electrical operation and manual operation
- operation of one transformer or multiple transformers (one off and two in service)
- variable operating settings and associated alarms limits
- failsafe operation due to control equipment or system failure
- local indication of all settings, status and alarms
- ability to monitor key parameters and alarms remotely
- serial communication interface.

The TAO shall evaluate the principal method of the tap changer control (master or slave or circulating current). Both options shall be presented with a technical evaluation (advantages or disadvantages of either scheme, technical suitability for the installation and operational requirements), life cycle costing and determination of additional equipment and interface requirements.

9.16 Temperature monitoring and indication

The temperature of the transformer winding and oil shall be monitored with both local indication and remote indication to SCADA provided. The following temperature indications shall be provided:

- top oil temperature indication contact A and contact B
- top oil temperature local visual indicator
- top oil temperature remote analogue transducer

- winding hot spot temperature indication contact A and contact B
- winding hot spot temperature local visual indicator
- winding hot spot temperature remote analogue transducer.

The temperature at which each set of indication contacts operate shall be independently adjustable over the range of 70°C to 150°C in 10°C increments. It shall be possible to readily set the operating point within ±2°C without the need for additional set up instruments. The winding and oil instruments shall be capable of operating in ambient conditions as specified in TS 03744, for auxiliary equipment located near heat emitting equipment.

One set of indication contacts shall be used to provide remote alarms of abnormal temperatures. The second set of contacts shall be set to operate at a higher temperature and be used to trip the transformer ac circuit breaker.

Winding hot spot temperature local visual indicators shall be provided with a resettable maximum indicator. The indicator shall have an accuracy of ±2°C or better.

Winding hot spot and top oil temperature remote analogue transducers shall be provided in accordance with TS 03865 for connection to the SCADA system. Transducers shall have an accuracy of at least ±2°C. The transducers shall be capable of operation from the substation 125 V dc auxiliary supply.

The device shall be fixed on a flexible mounting to minimise the effects of transformer vibration. All set points shall be labelled as to their use (for example, 'alarm' or 'trip').

9.17 Gas and oil actuated relays – liquid immersed

The transformer and its tap changer shall be equipped with earthquake proof devices which are actuated by the generation of gas or pressure in the transformer unit and have similar characteristics to a float and flap type Buchholz relay. Relays, if of the reed switch type, shall not be affected by magnetic fields associated with the fault levels stated in Section 8.

Each device shall be fitted with two independent sets of contacts which, when actuated as described in the preceding text in this section shall perform the following functions:

- one set of normally open contacts to trip the HV circuit breaker controlling the transformer unit in the event of major faults
- one set of normally open contacts to operate an alarm system in the case of faults of a minor nature which are not sufficiently serious to warrant isolation of the transformer unit. All necessary wiring shall be installed in accordance with Section 9.8 and Section 9.9.

The Buchholz relay operating mechanism shall be removable without the need to disconnect the relay casing from the pipe work.

9.17.1 Test valve

The gas pressure relay shall be fitted with a test valve to facilitate the injection of air onto the relay vane to prove trip operation under simulated fault conditions.

9.17.2 Ground level gas receiver

Provision shall be made to enable gas from the relays to be sampled at ground level and for injection and subsequent release of air for testing and setting of the alarm float.

9.17.3 Location of relays

The gas protective relays shall be inserted in sections of the pipe between the conservator and the transformer and tap changer tanks.

The relays shall be mounted in such a manner that withdrawal of the relay mechanism is not impeded by the presence of any other pipework. The pipework shall be suitably braced so that pipeline vibration cannot operate the relay contacts.

9.18 Transformer liquid

Section 9.18.1 and 9.18.2 provide requirements for the use of mineral oil and synthetic ester.

9.18.1 Mineral oil

If mineral oil is used, then the transformer oil shall be naphthenic, corrosive sulphur free, non-inhibited, unpassivated, and be compliant with AS 60296.

Detection of sulphur shall be in accordance with IEC 62535.

Oil shall be PCB free. Any deliveries (including the transformer) shall be accompanied by a NATA certificate confirming this requirement.

9.18.2 Ester fluid

At the time of publishing this standard there are no 33/11 kV power transformers installed in the TfNSW heavy rail passenger network or 1500 V dc metro network with ester fluid. The appropriate person in the AMB shall be consulted if a transformer with ester fluid is proposed at the concept design stage of the project.

In addition to specific transformer technical requirements to determine suitability, other non-technical issues shall be addressed as follows:

- interchangeability
- identification of the transformer with ester fluid
- system spares

- operation and maintenance requirements (including specific maintenance equipment requirements).

9.19 Finish – liquid immersed

The main tank shall be shot blasted internally and externally to remove rust and scale in accordance with Class SA2½ 'near white' blast cleaning in accordance with the requirements of AS 1627.4.

The finished surface shall provide good adhesion properties for the primary coat.

The internal and external surfaces shall be prepared and coated strictly in accordance with the manufacturer's instructions. The preparation and method of application for the finish shall aim to ensure that the transformer is corrosion free for its design life.

Any surface that has the potential come into contact with oil shall not be galvanised.

9.19.1 Internal surfaces

The main tank, tap changer enclosure, conservators and pipework internal steel surfaces shall be painted with an oil resistant paint immediately after abrasive cleaning.

The internal surfaces of the control cubicle and marshalling cabinet shall be finished with an oil resistant full gloss white coating, colour N14. This requirement does not apply to stainless steel or aluminium marshalling cabinet with a natural finish.

9.19.2 External surfaces

The external steel surfaces shall be painted with an inorganic zinc rich paint immediately after abrasive cleaning. The preferred colour is storm grey, colour N42 in accordance with AS 2700.

9.20 Finish – dry type

The internal and external surfaces shall be prepared and coated strictly in accordance with the manufacturer's instructions. The preparation and method of application for the finish shall ensure that the transformer is corrosion-free for its design life.

The enclosure shall be constructed of Galvabond steel (G2 Z275) or equivalent with minimum thickness of 3 mm for base and lid, 2 mm for other panels. Alternative steel products require approval from the AMB.

The internal and external surfaces of the transformer enclosure shall be powder coated, colour N42 in accordance with AS 2700.

The internal surfaces of the control box and marshalling box shall be finished with an oil resistant full gloss white coating, colour N14 in accordance with AS 2700. This requirement does not apply to stainless steel or aluminium marshalling box with a natural finish.

9.21 Breathers – liquid immersed

Breathers shall be provided for the air space above the oil in the main tank and tap changer conservator. Dehydrating breathers shall be sized to allow for humid air conditions.

Breathers shall be provided with an effective oil seal and an inspection window so that the colour of the crystals can be observed. It shall be possible to replace the crystals in a simple and straightforward manner that does not require de-energisation of the transformer.

The breathers shall be arranged so that insects cannot enter the conservator air space. The breather shall be mounted in such a position that it can be serviced from ground level.

9.22 Oil level indicators – liquid immersed

Site glass type oil level indicators shall be provided for both the main conservator and the on load tap changer conservator. The indicators shall be clearly readable with the naked eye from ground level. The oil level indicators shall have a minimum visible range of −5°C up to 105°C with intermediate temperature calibration marks.

9.23 Rating plate

A rating plate made of pacified stainless steel in accordance with the requirements of AS 60076.1 shall be firmly attached by screws at each corner to a bracket, externally on the transformer enclosure. The plate shall not be attached to any removable cover.

In addition to the requirements of AS 60076.1, the rating plate shall also include the following:

- a diagram of connections
- type of insulating liquid (for liquid immersed transformers)
- the TfNSW specification number and version.

The rating plate shall be located so that it can be easily read from ground level with the naked eye.

9.24 Fall-arrest system

Anchorage points and other fixings suitable for an industrial fall-arrest system to permit a safe system of work for all maintenance actions identified in the equipment manual shall be fitted. The safe system of work shall meet the requirements of AS/NZS 1891.4. Further requirements and guidance on working safely from heights are available on the SafeWork NSW website.

9.25 Anti-vibration pads

Anti-vibration pads shall be installed on skid mounted units. The manufacturer shall provide details of pads if skids are specified.

9.26 Current transformers

The following sections provide detail on the CT to be fitted for the protection scheme and for the winding temperature indication.

9.26.1 Neutral earth protection

A CT shall be provided for neutral earth protection having the following characteristics:

- be an outdoor toroid type and mounted to the transformer tank that allows the fully rated neutral cable and separable connector to pass through the CT
- comply with AS 61869.2, with tests carried out and submitted in accordance with this standard
- have a ratio of 100/1 (class and ratio shall be confirmed at time of tender)
- secondary wiring shall be terminated in the marshalling box
- CT terminals and secondary wiring shall be in accordance with TS 03736.

9.26.2 Winding temperature indication

A CT shall be provided as part of the winding temperature indication equipment. The CT shall be located within the main tank and be accessible through the main tank cover without removing the core and coil assembly. The CT shall be wired to the marshalling box in accordance with Section 9.8 and Section 9.9.

10 Thermal model

A thermal model that uses the transformer HV current, thermal time constants (for example tank and winding time constants) and ambient air temperatures to predict the winding hot spot, top oil temperature and insulation aging shall be provided by the transformer manufacturer.

The electrical and thermal equation shall be provided in differential form suitable for solving by entry of time varying values of HV current and ambient temperature as inputs. The model shall be suitable for implementation in a table structured format such as CSV file or spreadsheet format (for example, MS Excel).

This electrical/thermal model shall facilitate the prediction of the expected winding hot spot and top oil temperatures for varying load conditions and compare to specified thermal limits. The input data sampling time interval shall be selectable.

The manufacturer shall validate the thermal model against results from the temperature rise testing requirements specified in Section 11.3.

11 Tests

All tests during final tightening and on completion shall be carried out in accordance with a test program prepared well ahead of the work. Such program shall also detail the sequence of tests.

The transformer shall be completely assembled in the factory with all protection devices, cubicles and so on. TfNSW reserves the right to witness any or all of the tests and at least four weeks' notice shall be given by the manufacturer.

All test results plus routine test results of bushings and the tap changer shall be included in the maintenance manuals.

11.1 Component tests

Certified results of type tests on all valves, relays, gauges, and other devices shall be available for inspection.

CTs shall be tested in accordance with their respective standard. The proper functioning of all protective, indicating and alarm devices shall be functionally tested.

The insulation between the built-up core laminations, the core clamping framework and the tank shall withstand a high voltage of 2.5 kV for one minute. The link between the core and core clamp shall be separable for testing. The link shall be accessible without removing the core assembly from the tank. The insulation between the built-up core laminations and through-bolts if any, the core-clamping framework and the tank shall withstand a high voltage of 2 kV for one minute.

11.2 Routine tests

Routine tests to AS/NZS 60076.1 shall be carried out on each transformer.

In addition to the routine tests as listed in AS/NZS 60076.1, a thermal image scan shall be completed on each transformer. This test, using thermal imaging equipment, shall record the temperature image at the rated current for the following:

- each face of the tank
- each face of the cooling radiator
- bushings, where fitted.

11.3 Type tests

Type tests to AS/NZS 60076.1 and AS/NZS 60076.11 shall be carried out on one transformer per batch. Type test certificates for each of these tests shall be accepted if it can be demonstrated that the transformer supplied is of a similar design to a previously type tested transformer.

The temperature rise test (refer to AS/NZS 60076.3) shall record the temperature, time and current reading for each of the devices (top oil and winding) in a table structured format such as CSV file or spreadsheet format (for example, MS Excel) so that they can be compared with the results predicted by the virtual model generated from the TfNSW transformer modelling software.

The following additional tests shall be carried out on each transformer as follows:

- full dissolved gas analysis of transformer oil both before and after the temperature rise test
- lightning impulse voltage withstand tests including chopped wave tests on maximum tap, mid tap and minimum tap positions for the three phases respectively and 11 kV secondary connections
- environment test (only for Class E1 in accordance with AS 60076.11)
- fire behaviour test (only for Class F1 in accordance with AS 60076.11).

A short circuit withstand test is not required; however, the designer shall demonstrate by the modelling and calculations that the transformer can withstand a short circuit.

11.4 Special test

Sound power level tests shall be conducted in accordance with AS 60076.10.

Sound pressure check readings shall be carried out at full rated output during load loss testing. The readings shall be included in the determination of the sound power level in accordance with AS 60076.10.

The hot insulation resistance shall be recorded on transformers subjected to a temperature rise test.

11.5 Optional test

Although the transformer covered by this specification has a 33 kV primary winding, the manufacturer shall provide an optional cost for partial discharge testing of the transformer in accordance with the test procedure given in AS 60076.3 for transformers with Um ≥ 300 kV.

The optional partial discharge test shall be deemed acceptable if the partial discharge levels remain below 50 Pico Coulombs (pC).

Where partial discharges are detected which exceed the noted limit, then TfNSW will at its discretion consult with the manufacturer to allow TfNSW to have final judgement. This is to determine whether the transformer design is rejected, accepted without modification, or required to undergo further testing at the manufacturers expense in order to allow further assessment on whether the transformer may be accepted.

11.6 Transport delivery and tests after erection

The transformer shall be equipped with a time stamped data logging impact recorder immediately after factory testing. This shall remain operational up until final installation of the unit on site. The data log shall be provided to TfNSW on delivery of the unit. On completion of delivery of the works, tests shall be carried out by the contractor to demonstrate readiness for service. These tests shall include, but not be limited to, the following:

- measurement of winding resistance on all taps and all windings
- measurement of voltage ratio and check of voltage vector relationship on all taps
- insulation resistance of all windings at 5 kV dc
- dielectric dissipation factor (DDF) tests of all winding configurations
- oil dielectric test and test for water content.

ITPs and associated test sheets showing completion of all site test and test results shall be provided to TfNSW representative. The contractor shall ensure that the transformer is ready for service.

12 Human factors

The transformers shall be designed in accordance with the human factors principles outlined in TS 04978.

The design of the transformer should allow for good access and visibility to items that require access for operation and maintenance. The following are the typical items this applies to:

- height of Buchholz gas sampling device
- location and height of breathers
- location of valves
- location and height of tap changer control
- location and height of marshalling cubicle (AS/NZS 3000 requirements also apply)
- location, visibility and legibility of signage
- location and visibility of temperature indicators (should be visible from ground level).

Appendix A Technical schedule (normative)

The tenderer shall supply the information listed in this technical schedule with the tender, for each transformer.

Transformer details:		
Name of manufacturer		
Country of manufacture		
Design life of transformer		
Type of transformer (dry/mineral oil/ ester)		
IP Rating of transformer		
IP rating of marshalling cubicle		
Rated HV voltage		V
Rated LV voltage		V
Rated power		MVA
Connection symbol		
Tapping range		
No-load current with rated voltage applied to the principal tapping		A
No-load current with 110% rated voltage applied to the principal tapping		A
No-load loss		W
Load loss at 75 °C		W
Thermal time constant – Tank		Hrs
Thermal time constant – Winding		Mins
Impedance voltage at rated current and 75°C based on ONAN MVA Rating		%
Sound power level		dB(A)

Oil details	
Manufacturer	
Type of oil	
Model	

Construction details:	
Type of core steel – hot or cold rolled	
Brand or trade name and grade of core steel	

Construction details:	
Maximum flux density on net cross-section of steel with rated volts at rated frequency applied to the centre tapping	
Limbs	T
Yoke	T
Material used for 33 kV winding	
Material used for 11 kV winding	
Construction of windings for dry type transformer	
Type and class of insulation on windings	
Type of gasket material	
Material and grade of bolts	
Locking mechanism applied to all internal bolts	Yes/No
Type of Locking mechanism used on internal bolts	

Protective treatment applied to tank:	
Internal surfaces	
External surfaces	

Tap changer details:	
Manufacturer	
Manufacturer model	
Type	
Motor supply voltage	V
Power requirement of motor	W
Continuous rating of tap changer	A
Overload rating of tap changer and information to show that it is capable of carrying the overload specified:	

Transformer dimensions:	
Overall dimensions	mm x mm
Extreme height from foundation level	mm
Extreme height from foundation level when stripped for transport	mm
Projected floor area	mm x mm

Transformer mass (oil immersed):	
Mass of transformer complete with oil	kg

Transformer mass (oil immersed):	
Mass of transformer core and windings only	kg
Mass of windings only	kg
Volume of oil required to fill transformer, complete	Litres

Transformer mass (dry type):	
Mass of complete transformer	kg
Mass of transformer core and windings only	kg
Mass of transformer without enclosure	kg

33 kV bushing details (where applicable):	
Manufacturer	
Manufacturer's type number	
Insulator material	
Continuous current rating	A
Lightning impulse flashover	kVp
Creepage distance	mm
Minimum air clearance between phases	mm
Minimum air clearance phase to earth	mm
Palm dimensions	mm x mm

11 kV separable connectors:	
Manufacturer	
Manufacturers model number	
Continuous current rating	A

33 kV separable connectors (where applicable):	
Manufacturer	
Manufacturers model number	
Continuous current rating	A

Miscellaneous equipment:	Manufacturer	Model number
Voltage regulator		
Buchholz relay		
Temperature indicators		

Miscellaneous equipment:	Manufacturer	Model number
Overpressure relay		
Type of conservator bag		
Conservator bag rupture relay		

The transformer reliability data shall be submitted with the tender. Refer to TS 01517 for further details of TfNSW requirements. This manual supports the TfNSW Asset Management Policy with detailed processes for undertaking a maintenance requirement analysis.

Transformer reliability data (use separate sheet if necessary):		
Design life		Years
Failure modes (for early, normal life and wear out periods):	a)	
	b)	
	c)	
Mean operating hours between failures:	a)	
	b)	
	c)	
Time to repair:	a)	
	b)	
	c)	

A.1 Drawings and information to be submitted with the tender

In addition to the technical schedule, the following information shall also be submitted with the tender:

- Outline drawings: Fully dimensioned outline drawings showing all fittings, terminal arrangements, radiator equipment, tap changer equipment, and marshalling cubicle. The general arrangements and layouts shall be adhered to in the final design unless written approval is obtained from TfNSW.
- Foundation drawings: Foundation drawings showing detail of the base for the main tank and radiators (if these are separately mounted) including dimensions.
- Core material characteristics: Typical curves of flux density versus ampere turns per metre for the core material.
- Core information: Detailed description of the core type, methods of making joints, insulation between laminations, treatment of edges, core bolt insulation and method for minimising

hot spots in limbs. Include details of the proposed method for verifying core hot spot temperature and method for how the core is earthed.

- Temperature indicators: A full description of temperature indicators and transducers including detailed design information of the type of pocket to be used.
- Tap changer details: A full description of the tap changer proposed including type test certificates.
- Other information: Any other information considered necessary by the manufacturer.
- Features of the transformer design: Provide details of the transformer design. This shall include a description of:
    - the overall transformer design
    - the method for electrically, thermally, and structurally modelling the design
    - lessons learnt from previous similar designs and how this has been addressed in this design
    - quality processes during design and manufacture to ensure the design will meet the TfNSW and appropriate Australian and international standards and how the manufacture of the transformer will be in accordance with the design
- Conservator sizing: Provide detailed calculations for the sizing of the conservator.
- Fall Arrest system: Provide details of the proposal for the industrial fall arrest system as required in Section 9.24.
- Departures from standard: Are there any departures from the requirements of this standard? If there are departures, include details on a separate sheet.
- Special delivery requirements: Any special requirements that are envisaged for the safe delivery of the transformer to the specified site shall be stated at tender stage. For example, removal of the conservator could be necessary due to a low bridge on the delivery route. These costs shall be provided separately at the tender stage.

Appendix B Data set associated with the equipment (normative)

The following data shall be supplied by the manufacturer and maintained for the transformer. This data shall remain the property of TfNSW.

B.1 Drawings and information

All drawings shall conform to the requirements of TS 01547.1. The following drawings are required:

- Transformer arrangement drawings. Arrangement drawings shall be drawn to scale with the following detail:
  - complete detail of the transformer with views of all sides of the transformer and detailed sections as required
  - dimensions, including overall size, position of HV connectors relative to the centre lines of the tank and the level of the foundations, marshalling cubicle height from base
  - position of the centre of gravity
  - mass of the transformer complete both with and without oil
  - mass of main tank (including tank fitted with accessories) and filled with oil
  - quantity of insulating oil required in each oil-holding compartment
  - jacking points to be identified
  - complete listing of all fittings, accessories and parts with the associated manufacturer, part or model number and relevant ratings
- Where the transformer will be shipped in a dismantled state, a separate outline drawing shall be produced detailing the dimensions and weight of the separated components.
- Drawings of any special slinging arrangement required for handling the transformer during shipment or erection.
- Foundation drawings showing detail of base for the main tank.
- Schematic and wiring diagrams. Schematic diagrams shall include the following:
  - schematic diagrams of the transformer windings showing connections, tappings and tabulations of current and voltage rating of all windings
  - schematic and wiring diagram of the tap changer control
  - schematic diagram of alarm and trip circuits
  - schematic diagrams of control of auxiliary systems

  - wiring diagrams including cable block diagram, cable schedule and cable termination schedule

- Marshalling cabinet arrangement drawing showing details of all components. This shall include an item list detailing the components, the manufacturer, part/serial number and rating (where applicable).
- Marshalling cabinet terminal layout.
- Drawings of the rating plate as specified in Section 9.23. Details shown on these drawings shall not vary from that shown on the plates fixed to the transformer.

  Note: This list does not include component drawings which are required as part of the integrated support requirements and inclusion in the operations and maintenance manual.

All the drawings identified in this section shall bear the transformer serial numbers of all units.

The calculation of inrush current is also required.

B.2 Technical schedule

The information listed in the technical schedule in Appendix A, shall be supplied by the manufacturer and maintained for each transformer.

B.3 Life cycle costing

All the data and assumptions pertaining to the determination of the whole-of-life cost calculations of the transformer shall be recorded including the transformer loss calculations as detailed in TS 03817.

B.4 Test results

The results of all tests, including routine, type, special, acceptance, periodic and corrective maintenance tests shall be recorded and maintained.

Routine tests certificates showing the results of each test performed shall be supplied in duplicate and electronically, in English, and maintained for the life of the transformer.

Type tests certificates showing the results of each test shall be supplied in duplicate and electronically, in English, and maintained for the life of the equipment.

Appendix C Integrated system support requirements (normative)

The transformer manufacturer shall establish and provide the information required to operate and maintain the equipment throughout its operational life, in a cost-effective manner and to a level that is consistent with the planned operational performance and usage of the transformer.

This includes the following:

- specifying maintenance requirements
- spares support
- operations and maintenance manuals
- training
- support equipment and tooling.

C.1 Equipment supplier deliverable

The integrated support requirements are a significant deliverable in the procurement of new transformer. Manuals, training, documentation, and other support deliverables shall be in accordance with TS 03742.

C.2 Operation and maintenance manual

An operation and maintenance manual shall be provided for the equipment in accordance with the requirements of TS 03742. The requirements for the scope of the operation and maintenance manual are as detailed in TS 03742. The following additional content is also required:

- Photographs showing the winding and core taken during manufacturing of the transformer and the complete finished transformer from all sides
- Detailed description and overall transformer oil system diagram (with valves identified) including the required plant for the vacuum and oil filling procedure.
- Detailed step by step instruction for sampling gas from the Buchholz relay.
- Detailed step by step instruction for obtaining oil samples.
- Drawings necessary to install, maintain, dismantle, re-assemble or adjust the transformer and fittings and to repair or replace all parts liable to wear and failure. In particular this applies to fixed and moving contacts of the OLTC unit and auxiliary switches and special gaskets (being those that cannot be hand cut from sheet materials such as moulded gaskets and 'O' rings).

- Procedure to open the tank.
- OLTC operation and maintenance manual.

All operation instructions and associated descriptions of equipment shall be accompanied by colour photos of the actual equipment installed on the transformer that is being described.

Appendix D Whole-of-life cost (normative)

This appendix is provided for use by the TAO in assessing the whole-of-life cost.

The selection of the most suitable transformer design will be made based on minimising the whole-of-life cost. The following factors shall be taken into account in determining this:

- cost of changes to the technical maintenance plan and service schedules or the creation of new manuals and schedules
- cost of decommissioning and disposal
- cost of installation
- cost of inventory spares
- cost of maintenance
- cost of modifications to other parts of the installation
- cost of replacement parts
- cost of special tools
- cost of staff training
- discount rate
- electrical losses
- environmental costs
- initial purchase price
- lifetime of equipment
- reliability and cost of consequential damage after failure
- cost of optional tests.

Preference will be given to tap changers that require minimum maintenance. The contact life of diverter contacts will be of particular interest in this regard. Alternative offers shall be provided for consideration if improved maintenance accessibility and performance can be achieved even if it will be at significant additional cost to the offered design.

If this transformer has not previously been type approved by AMB in accordance with TS 06178, the costs for this process shall be included in the whole-of-life cost.

Appendix E Information for the request for tender (informative)

This appendix provides a summary of the information that should be included in the RFT. The information includes both technical details in Table 6 and site-specific information in Table 7.

Table 6 – Technical details to include in the RFT

Transformer item	Technical details to include in the RFT
Transformer HV configuration	Indicate whether the configuration is bushing or separable connection
Transformer type	Indicate whether the transformer is a liquid immersed or dry type. In addition, specify the type of fluid (mineral oil or ester fluid) if a liquid immersed transformer
Transformer impedance	Where the transformer is intended to be a replacement for an existing transformer or network spare then the impedance should match the existing transformers in the network
Tap changer ac motor supply	Indicate whether 415 V ac or 220 V ac (unearthed)
Substation auxiliary supply	Indicate the substation dc auxiliary supply
Transformer mounting	Wheels or mounting plates with anti-vibration pads
Physical dimensions of transformer & configuration	Where the transformer is intended to be a replacement for an existing transformer or network spare then the configuration of the transformer and the dimensions shall be provided

Table 7 – Site specific information to consider including in the RFT

Site specific information	Information to include in the RFT
Site specific limitations on size or arrangement	Indicate whether there are size limitations imposed by surrounding infrastructure
Foundation	Type of foundation (plinth or slab)
Access and transportation limits	Access road weight limit Maximum road width Maximum standard height above road
Access road alongside operating railway	Provide details of whether or not the access road to the site is within the rail corridor and adjacent to an operating railway track

Appendix F Options to be priced at tender (normative)

The following items shall be priced at the time of tender and based on life cycle assessment and functional requirements recommended to TfNSW for inclusion.

F.1 Winding and oil fibre optic temperature indicators

The provision of a minimum of four fibre optic temperature sensors to monitor the winding hot spot, average winding, tap winding and top oil temperature. The manufacturer is responsible for the recommendation and justification of the proposed locations.

The fibre optic sensors shall be brought out to the marshalling cubicle where a data logger can be placed while the unit is in service.

The provision of a logging device for monitoring fibre optic temperature sensors above, including any patch leads. The unit will have the ability to interface to the SCADA RTU for remote monitoring and be capable of having the data downloaded via a portable computer. The make and type of unit shall be clearly specified.

F.2 Hermetically sealed tank with no conservator

Provide detailed calculations for the sizing of the tank for this option, in particular how the required operating temperature range is met, with associated minimum and maximum allowed deflection in the tank and margins.

F.3 Conservator membrane

Provision of conservator fitted with a membrane or bag for sealing of oil to air interface. The membrane shall be vented through a breather pipe fitted with a silica gel breather.