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Technical Note - TN 046: 2016

Issued date: 22 June 2016

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Subject: Update to EP 02 10 00 01 SP *Power Transformer 33/11 kV*

This technical note is issued by the Asset Standards Authority (ASA) to notify the following updates to EP 02 10 00 01 SP *Power Transformer 33/11 kV,* version 2.1. It incorporates the requirements of the previously issued technical note TN 081: 2015. TN 081: 2015 is withdrawn with the publication of this technical note. This technical note provides the following:

- update of Australian and International standards
- ASA type approval requirements
- additional transformer rated power and associated impedance
- update of testing requirements
- update of transformer oil requirements
- inclusion of human factors requirements

All references to AS 2374 *Power transformers* shall be replaced with AS 60076 *Power transformers* unless otherwise stated.

The following sections in this technical note map to the corresponding sections in the specification. The following changes shall be applied.

2. Scope and application

Add the following new section after Section 2.

2.1 ASA type approval

Transformers procured in accordance with this specification require type approval by ASA prior to being connected to the RailCorp electrical network. The current ASA process for type approval at

the time of publication of this document is TN 050: 2014 *Electrical Type Approvals – Interim process*.

3 References

Replace Section 3 in its entirety with the following single section.

International standards

EN 50180 Bushings above 1 kV up to 52 kV and from 250 A to 31.5 kA for liquid filled transformers

EN 50181 Plug-in type bushings above 1 kV up to 52 kV and from 250 A to 31.5 kA for equipment other than liquid filled transformers

IEC 60296 Ed. 4.0 2012 Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear

IEC 60840 Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements

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 1627.5 Metal finishing – Preparation and pretreatment of surfaces Part 5:- Pickling

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

AS 2629 Separable insulated connectors for power distribution systems above 1 kV

AS 2700 Colour standards for general purposes

AS 60044.1 Instrument transformers Part 1: Current transformers (IEC 60044-1 Ed. 1.2 (2003) MOD)

AS 60076.4 Power transformers Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors

AS 60270 High voltage test techniques – Partial discharge measurements

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

AS/NZS 1891.4 Industrial fall-arrest systems and devices - Selection, use and maintenance

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

AS/NZS 4680 Hot-dip galvanized (zinc) coatings on fabricated ferrous articles

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

AS/NZS 60076.2 Power transformers Part 2: Temperature rise for liquid-immersed transformers (IEC 60076-2, 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, Ed. 2 (2000) MOD)

AS/NZS 60076.5 Power transformers Part 5: Ability to withstand short circuit (IEC 60076-5, Ed. 3.0 (2006) MOD)

AS/NZS 60076.10 Power transformers Part 10: Determination of sound levels (IEC 60076-10, Ed. 1 (2001) (MOD)

AS/NZS 60076.10.1 Power transformers Part 10.1: Determination of sound levels – Application guide

AS/NZS 60137 Insulated bushings for alternating voltages above 1000 V (IEC 60137, Ed. 5.0 (2003) MOD)

Transport for NSW standards

EP 00 00 00 15 SP Common Requirements for Electrical Power Equipment

EP 02 00 00 01 SP Transformer Loss Evaluation

T HR EL 00002 PR Electrical Power Equipment – Integrated Support Requirements

T HR EL 20001 ST High Voltage AC and 1500 V DC Traction Power Supply Cable Requirements

T MU AM 01002 MA Maintenance Requirements Analysis Manual

T MU HF 00001 ST Human Factors Integration – General Requirements

T MU MD 00006 ST Engineering Drawings and CAD Requirements

Other reference documents

EL0416250 Substations – 33/11 kV Power Transformer Basic Configuration Requirements drawing

5.1 General

Replace Section 5.1 with the following.

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
- monitoring of the transformer temperature oil, winding and hot spot
- provision of oil surge and gas detection

- connection of supervisory controlled and data acquisition (SCADA) system, protection and auxiliary cabling
- suitability for operation in an environment with conditions as prescribed in this specification

5.2 Interchangeability

Replace Section 5.2 with the following.

The transformer is to have dimensions in accordance with drawing EL0416250 *Substations – 33/11 kV Power Transformer Basic Configuration Requirements* with specific regard to the location and height of the HV and LV cable terminations and the transformer mounts. This is required to facilitate the requirement for the transformer to be replaced with a similar transformer on the RailCorp network.

6.1 General

Replace Section 6.1 with the following.

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

- AS/NZS 60076 *Power transformers*
- AS 602141.1 *Tap-changers Part 1: Performance requirements and test methods*

6.3 Electrical

Replace the existing rated power item shown in Table 1 with the following.

Rated power (continuous MVA)	2.0/2.5MVA or 5.0/6.25 MVA or 7.5/9.25 MVA (request for tender (RFT) will nominate size)

Replace the existing impedance voltage item shown in Table 1 with the following.

Impedance voltage	2.0/2.5 MVA 5.0/6.25 MVA 7.5/9.25 MVA	6% 7.5% 8%

Replace the sound pressure level item shown in Table 1 with the following.

Sound pressure level	Refer to AS/NZS 60076.10 *Power transformers, Part 10: Determination of sound levels (IEC 60076-10, Ed. 1 (2001) (MOD)*

7.12.2 33kV and 11kV separable connector terminals

Insert the following paragraph after the second paragraph.

Separable connectors shall comply with EN 50180 *Bushings above 1kV up to 52KV and from 250A to 31.5kA for liquid filled transformers*.

7.13.2 On load tap-changer

Insert the following paragraph after the first paragraph.

Tap-changers with vacuum interrupters are acceptable subject to life cycle costing analysis.

7.13.4 Tap-changer monitoring

Insert the following bullet point after the third bullet point.

- an auto/manual switch which also has an off position and auxiliary contacts for remote SCADA indication

Add the following new section after Section 7.13.4.

7.13.5 Tap-changer control for transformers in parallel

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

- both remote (SCADA) or local 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 principle method of the tap-changer control (master or slave or circulating current) is required to be evaluated by the Authorised Engineering Organisation (AEO) and both options 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.

7.15.1 Optical fibre type

Replace Section 7.15.1 with the following.

A minimum of four fibre optic temperature sensors shall be provided to monitor the winding hot spot, average winding, tap winding and top oil temperature. The manufacturer should recommend and justify recommended locations.

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

A logging device for monitoring fibre optic temperature sensors shall be provided including any patch leads. The unit will have the ability to interface to the SCADA remote terminal unit (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.

7.17 Oil

Replace Section 7.17 with the following.

The transformer oil shall be naphthenic, corrosive sulphur free, non-inhibited, unpassivated and compliant with IEC 60296 Ed 4.0 2012 *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*. Detection of sulphur shall be in accordance with IEC 62535 *Insulating liquids – Test method for detection of potentially corrosive sulphur in used and unused insulating oil*.

Oil shall be polychlorinated biphenyl (PCB) free and any deliveries (including the transformer) shall be accompanied by a National Association of Testing Authorities, Australia (NATA) certificate confirming this requirement.

The transformer shall contain all required oil when despatched from factory and on delivery to site.

8.2 Equipment supplier deliverable

Replace Section 8.2 with the following.

The integrated support requirements are a significant deliverable in the procurement of new switchgear. Manuals, training, documentation and other support deliverables shall be in accordance with T HR EL 00002 PR *Electrical Power Equipment – Integrated Support Requirements*.

9.2 Routine tests

Replace Section 9.2 with the following.

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

9.3 Type tests

Replace Section 9.3 with the following.

Type tests to AS/NZS 60076.1 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.

An additional requirement for the temperature rise test (AS/NZS 60076.3 *Power transformers Part 3: Insulation levels, dielectric tests and external clearances in air* (*IEC 60076-3, Ed. 2 (2000) MOD)*) is to record the temperature, time and current reading for each of the devices (top oil and winding) in a Microsoft Excel spreadsheet so that they can be compared with the results predicted by the virtual model generated from the Transport for NSW (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

A short circuit withstand test is not required; however, the designer is required to provide the short circuit design calculations.

9.4 Special test

Replace Section 9.4 with the following.

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 and shall be included in the determination of the sound power level as per AS 60076.10.

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

9.6 Tests after erection

Replace Section 9.6 with the following.

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

Inspection and test plans (ITP) and associated test sheets showing completion of all site test and test results shall be provided to TfNSW representative. The responsibility of the contractor is to ensure that the transformer is ready for service.

10 Data set associated with the equipment

Replace Section 10 with the following.

The following data shall be supplied by the manufacturer and maintained for the transformer.

This data will remain the property of TfNSW.

10.1 Drawings and information

Replace Section 10.1 with the following.

All drawings shall conform to the requirements of the T MU MD 00006 ST *Engineering Drawings and CAD Requirements*. The following drawings are required:

- Transformer arrangement drawings. Arrangement drawings shall be drawn to scale with the following details:
    - 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 is required to 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 is to 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 required in Section 7.22 Rating plate. 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 are included in the operations and maintenance manual.

All the above drawings shall bear the plant serial numbers of all units.

The calculation of inrush current is required.

10.4 Maintenance manuals

Replace Section 10.4 with the following.

An operation and maintenance manual shall be provided for the equipment in accordance with the requirements of T HR EL 00002 PR. The requirements for the scope of the operation and maintenance manual are as detailed in T HR EL 00002 PR with additional content and emphasis required as follows:

- photographs to be included from the manufacturing of transformer showing the winding and core
- detailed description including 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 that may be necessary to install, maintain, dismantle, reassemble or adjust the transformer and fittings and to repair or replace all parts liable to wear and failure.
  In particular, this will apply to fixed and moving contacts of the OLTC unit and auxiliary switches and 'special' gaskets (being those which cannot be hand cut from sheet materials for example; moulded gaskets, 'O' rings and so on).
- procedure to open the tank
- OLTC operation and maintenance manual

10.7 Technical schedule

Add the following new section after Section 10.7.

11 Human factors

The transformers are required to be designed in accordance with the human factors principles outlined in T MU HF 00001 ST *Human Factors Integration – General Requirements*.

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 and height of tap-changer control
- location and height of marshalling cubicle (AS 3000 *Electrical Installations (known as the Australian/New Zealand Wiring Rules)* 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

Replace Appendix A in its entirety with the following (including Section A.1).

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		
Rated HV voltage		V
Rated LV voltage		V
Rated power		MVA
Connection symbol		
No-load current with rated voltage applied to the principal tapping		%
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 brand and type		

Construction details:		
Type of core steel – hot or cold rolled		
Brand or trade name and grade of core steel		
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 HV winding		
Material used for LV winding		
Type and class of insulation on windings		
Type of gasket material		
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:	
Mass of transformer complete with oil	kg
Mass of transformer core and windings only	kg
Mass of windings only	kg
Volume of oil required to fill transformer, complete	Litres

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

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

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

The transformer reliability data is required to be submitted. Refer to T MU AM 01002 MA *Maintenance Requirements Analysis Manual* 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 should 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 7.23
- 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 C Request for tender checklist

Add the following rows to the table.

Item	Detail	Comment
Tap-changer supply voltage	Project team to confirm 415 V ac	
Rated power (MVA)	Project team to advise 2.0/2.5 or 5.0/6.25 or 7.5/9.25 MVA	
Neutral CT ratio and class	Project team to advise from concept protection design	

Appendix D Requirements for technical aspects of tender evaluation

Delete Appendix D.

Authorisation:

	Technical content prepared by	Checked and approved by	Interdisciplinary coordination checked by	Authorised for release
Signature				
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Name	Chris Lilly	Neal Hook	Andrea Parker	Graham Bradshaw
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Engineering Specification
Electrical

EP 02 10 00 01 SP

POWER TRANSFORMER – 33/11KV

Version 2.1

Issued May 2013

Reconfirmed 10 July 2019

Owner:	Chief Engineer, Electrical		
Approved by:	Neal Hook Chief Engineer Electrical	Authorised by:	Neal Hook Chief Engineer Electrical

Engineering Specification

Document control

Version	Date	Summary of change
	September 2008	Last Technical Review
2.0	May 2010	Application of TMA 400 format
2.1	May 2013	Template update

Contents

1 Introduction

This document details the whole-of-life performance requirements for outdoor ONAN / ONAF two winding, automatic on load tap changing transformers suitable for use in the RailCorp electrical network. It provides all necessary information to ensure that the transformers are electrically suitable for use with the RailCorp high voltage network. It covers a primary voltage of 33kV and a secondary voltage of 11kV.

The transformer is used to convert the 33kV supply voltage to 11kV for distribution to loads located at and between Substations.

In accordance with the philosophy of the RailCorp's system wide spares policy for major equipment some specific clauses have been included in this document to ensure that a new transformer will meet particular physical requirements necessary for the direct replacement of existing transformers.

2 Scope and Application

RailCorp is concerned to keep lifetime costs rather than purchase price to a minimum and features are specified that aim to achieve this. In that regard equipment that requires the minimum possible maintenance over its lifetime is preferred.

The release of this document will not affect the operation or maintenance of existing transformers currently in service in the RailCorp network.

3 References

The following documents are either referenced in this standard or can provide further information.

3.1 RailCorp Engineering Standards

AM 9955 PM Maintenance Requirements Analysis Manual

EP 00 00 00 12 SP Electrical Power Equipment – Integrated Support Requirements

EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions

EP 00 00 00 15 SP Common Requirements For Electrical Power Equipment

EP 02 00 00 01 SP Transformer Loss Evaluation

EP 12 10 00 10 SP System Substation Earthing

EP 20 10 00 02 SP High Voltage Cable Selection Guide

EP 19 00 00 02 SP Protection System Requirements for the High Voltage Network

EP 20 00 03 01 SP Requirements for Cable Polymetric Terminations and Joints

3.2 Australian Standards

AS/NZS 60137: 2008	*Insulated Bushings for alternating voltages above 1000 V*
AS 1627.4: 2005	*Metal Finishing – Preparation and pre-treatment of surfaces Part 4:Abrasive blast cleaning of steel*
AS1627.5: 2003	*Metal Finishing – Preparation and pretreatment of surfaces Part 5:Pickling*
AS 1767.1:1999	*Insulating Liquids Part 1:Specification for unused mineral insulating oils for transformers and switchgear*

AS/NZS 1891.4:2000	*Industrial fall-arrest systems and devices - Selection, use and maintenance*
AS 2374	*Series Power Transformers*
AS60076:2005	*Power Transformers Part 1 :General (IEC60076-1,Ed.2.1 (2000) MOD)*
AS2067:1984	*Switchgear Assemblies and Ancilliary Equipment for Alternating Voltages Above 1kV*
AS 2629:1983	*Separable insulated connectors for power distribution systems above 1kV*
AS 2700:1996	*Colour Standards for general purposes*
AS 3000:2007	*Electrical Installations*
AS/NZS 4680:2006	*Hot-dip galvanised (zinc) coatings on fabricated ferrous articles*
AS 60529:2004	*Degree of Protection provided by enclosures (IP Code)*
AS 60214.1:2005	*Tap Changers, Part 1: Performance requirements and test methods*

3.3 International Standards Organisation

ISO 8501.1:2007 Preparation of steel substrates before application of paint related products – visual assessment of surface cleanliness

3.4 American National Standards Institute

BSR/IEEE C57.12.90:2006 Standard Test Code for Liquid-Immersed Distribution, Power and Regulating Transformers

3.5 Drawings

EL0416250 - 33/11kV Transformer – Basic Requirements

4 Background

The 33kV/11kV transformers specified in this document are power transformers used to convert a 33kV AC supply to 11kV AC.

Generally the transformers are outdoor type connected to indoor 33kV switchgear via cable with separable connectors.

A limited number of transformers will be of the 33kV bushing type suitable for installation in locations with 33kV outdoor busbar systems.

The 11kV secondary winding is connected to the substation switchgear by cable.

5 Functional Characteristics

5.1 General

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

- *AS 2374* series – Power Transformers
- *AS 60076*. Power Transformers Part 1 :General (IEC60076-1,Ed.2.1 (2000) MOD)
- *AS 60214.1:2005* Tap Changers. Performance requirements and test methods.

Each transformer shall be of the three-phase, two winding, oil-immersed, outdoor type with a rated voltage ratio of 33,000 volts primary and 11,000 volts secondary, 50Hz. The transformers shall have continuous ratings based on 5.0MVA Natural Cooling and Forced Air Cooling of at least 6.25MVA.

The primary windings shall be connected in delta with the secondary windings connected in star. The star point of the secondary winding shall be connected to an external bushing.

An Automatic Tap Changer shall be provided with an on-load tap changing capability to correct a -15% to+5 % 33kV system voltage (in 1.25% steps) to nominal 11kV voltage.

The transformer will generally be protected as detailed in EP 19 00 00 02 SP. Paragraph 6.6 System Transformers.

Certain auxiliary equipment is required to be accessible from ground level with the transformer energised. The installed height of this equipment shall be approximately 1.2m height from the transformer base supports.

5.2 Interchange Ability

The transformer shall comply with drawings EL0416250 to ensure physical interchange ability with other power transformers of the same rating installed in substations in recent years.

5.3 Whole-of-Life Cost

The selection of the most suitable transformer design will be made on the basis of minimising the whole-of-life cost. The following factors must be considered in determining this: -

- Cost of changes to the Technical Maintenance Plan & Service Schedules or the creation of new manuals & 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 should be provided for consideration, if improved maintenance accessibility and performance could be achieved albeit at significant additional cost to the offered design.

6 Performance Characteristics

6.1 General

Where not specifically detailed in this document the performance characteristics of the transformer shall be in accordance with the *AS 2374* series – Power Transformers and *AS 60076*, Power Transformers Part 1 :General (*IEC60076-1,Ed.2.1 (2000) MOD*) and *AS60214.1:2005* Tap Changers. Performance requirements and test methods.

6.2 Sound Level

The average level of audible sound caused by the transformer when measured in accordance with as *AS 2374.6:1994* Power Transformers Part 6: Determination of Transformer and Reactor sound levels, shall be the Standard Limit as defined in Appendix AA. Figure AA1, of this standard, at the factory.

6.3 Electrical

Item			Requirements
Number of phases	Primary		3
	Secondary		3
Connection vector symbols			Dyn1
Rated Voltage	Primary		33kVrms
	Secondary		11kVrms
System Highest Voltage	Primary		36kVrms
	Secondary		12kVrms
Rated Insulation Level	Primary	Lightning Impulse	200kVpk
		Power Frequency	70kVrms
	Secondary	Lightning Impulse	95kVpk
		Power Frequency	28kVrms
Winding insulation			Uniform
Type			Outdoor, Oil Immersed, Ground type
Type of cooling			ONAN / ONAF
Rated Power (continuous MVA)			5.0/6.25 ONAF rating is minimum acceptable rating.
Rated Frequency			50Hz

Item	Requirements
Impedance voltage at rated current and 750C	5MVA
	7.5% Note: AS60076 Table 1 Tolerances apply.
Fault level	High Voltage (HV) -1500 MVA for 3 phase symmetrical fault LV – Limited by transformer impedance
Sound pressure level	Refer to AS 2374.6, Appendix AA. Figure AA1, Standard limit.
High voltage Winding Tappings	-15.0% to + 5.0% of nominal voltage in increments of 1.25%.
Type of tapchanger	Onload
Type of 33kV termination	Either bushing or HV cable. Refer RFT
Type of 11kV termination	Either bushing or HV cable. Refer RFT.
Overload requirements	Refer to AS 2374.7 Loading Guide for oil immersed power transformers.

Table 1 – Electrical requirements

6.4 Loss Capitalisation

The transformer loss capitalisation will be evaluated in accordance with RailCorp Standard EP 02 00 00 01 SP -Transformer Loss Evaluation. This will be evaluated at an energy rate of 12c/kwh.

6.5 Ambient Conditions

The power transformer shall be suitable for operation in the ambient conditions set out in EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions, as specified for outdoor equipment.

6.6 Fault Level and Protection

The transformer shall be suitable for a supply from a high voltage system with a 3 phase symmetrical fault level of up to 1500 MVA (26.3kA). The low voltage maximum through fault seen by the Power transformer will be limited by the transformer impedance in series with the 1500MVA 33kV fault level.

6.7 Electrical and Temperature Monitoring

6.7.1 Thermal Model

A thermal model shall be provided by the transformer manufacturer that uses the transformer primary current, thermal time constants, for example tank and winding time constants, and ambient air temperatures to predict Winding Hot Spot, Top Oil Temperature and Insulation Aging.

The electrical/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 of a form suitable for implementation in Microsoft Excel.

The input data sampling time interval shall be selectable, with the range of intervals providing at least 95% accuracy with factory temperature rise tests advised by the transformer manufacturer.

6.7.2 Thermal Model Validation

The manufacturer is to validate the thermal model against results from the temperature rise testing specified in Section 9 and results from fibre optic sensors.

The results should be used to calibrate the winding hot spot and top oil temperature gauges.

7 Technical Characteristics

7.1 General

The transformers shall be capable of continuous operation at 110% voltage and of rated output at power factors between unity and 0.85 lagging.

Ratings of bushings, tap-changers, connecting leads, etc, shall be of sufficient capacity such that the transformer may be loaded in accordance with *AS 2374.7:1997*, Loading Guide for Oil Immersed Power Transformers.

All materials used shall be new and of good quality. All equipment supplied shall be suitable for normal handling during transport and installation, for continuous operation under the conditions specified herein and for the required duty.

Bolts, screws and nuts shall be ISO metric. All bolts, nuts and washers used outside the tank shall be hot dip galvanised or stainless steel. All nuts within the tank shall be fitted with approved locking devices.

Where the substation is already established, the existing foundations may be used. All valves, flanges and other equipment shall be easily accessible with the transformer installed on such a foundation or a flat concrete slab. The transformers shall be simple to install and erect at site so as to minimise construction time.

7.2 Core

7.2.1 Core Material

Transformer cores shall be constructed of non-aging cold rolled grain oriented silicon steel.

7.2.2 Winding Material

HV & LV windings shall be manufactured from copper.

7.2.3 Winding Construction

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. It shall be possible to adjust the winding compression force in the field, using clamping bolts bearing on pressure pads, or other approved means, to compensate for any settling or shrinkage which may occur in service. The manufacturer shall provide the recommended torque settings for the clamping bolts in the transformer manual.

Where continuously transposed cable (CTC) is used, its individual strands shall not make inadvertent contact. This condition shall be verified before completing the winding ends and with the windings under pressure.

Soft soldering shall not be used for joining or connecting leads; joints may be silver soldered, brazed or welded. Bolted joints carrying current shall use "Belleville" or similar washers to maintain contact pressure.

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 calculation of short circuit current and current densities, short circuit forces and stresses in windings and end supports using finite element analysis shall be completed for three phase faults and earth faults for all tapping positions. The results shall be included in the transformer equipment manual.

All internal connections to bushings and the tap-changer shall be of sufficient size to permit continuous operation at 150% ONAF current rating.

7.2.4 Core Construction

The core shall be designed and constructed to withstand without deterioration the stresses imposed by service conditions, lifting, transport, handling and earthquakes in the RailCorp geographical area.

The interlamination and core bolt insulation shall not deteriorate from ageing, contact with transformer oil or service temperature.

In order to reduce no-load loss and current and noise level, cores shall be of three-leg core type design with 45° mitred corners, and shall not have bolts passing through the legs or yokes.

The core, especially the top yoke, shall be adequately clamped to withstand forces during lifting, transport and short circuits. The core and winding support structure shall be of solid steel construction. Timber sections for the frame are not acceptable. The edges of core plates shall be protected if necessary to prevent them from rusting during manufacture.

The core shall be electrically insulated from its supporting frames and clamps. The core insulation shall not be affected by core or frame heating under any specified operating condition, transformer oil or aging.

A core earth connection shall be assessable, refer Section 7.3.6. 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.

There shall be one connection only between the core and the earth bushing, the core connection of which shall be readily accessible during assembly. The purchaser intends to verify that the core to tank insulation is sound during the erection programme and accordingly the earth shall be designed to allow easy disconnection without risk of dropping loose components into the winding.

Split ring washers, star washers and other types of locking washer shall not be used inside the transformer tank.

7.3 Tank

7.3.1 Limiting Dimensions

The 33kV tank, radiators and associated equipment arrangement shall satisfy the limiting dimensions shown on Drawing No. EL0416250.

7.3.2 No structural failure

The tank and accessories shall be so constructed that under transport and service conditions no structural failure or leakage of oil shall occur. The tank lid shall not distort on lifting. The main tank, conservator, coolers, piping and fittings shall be capable of withstanding, without leakage or excessive permanent distortion:

- a full internal vacuum at sea level when empty or full of insulating oil, and
- an internal pressure 35kPa in excess of that required to operate the pressure relief vent.

7.3.3 Welds

The tank shall be welded by a submerged arc welding process and welded on both sides in order to provide a high degree of weld penetration and leak free construction. All permanent joints shall be welded and all external welds shall be continuous.

Caulking of defective welds is prohibited.

7.3.4 Accumulation of Water

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

7.3.5 Accumulation of Gas

The internal surfaces of the tank 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.

All unavoidable pockets in the lid such as bushing turrets shall have pipes fitted to their highest point to direct any gas collected into the main oil feed pipe from the conservator. All such gases shall collect in the Buchholz relay.

7.3.6 Access to Bushing and Core Connections

Hand-holes complete with covers shall be provided to enable removal and fitting of bushings and current transformers, inspection of the OLTC selector switch, access to the HV and LV sides of the windings and access to the core earth connection without removing the main lid. All hand holes shall be kerbed with flanges raised above the transformer tank lid.

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

Construction features shall be provided where necessary to enhance safe access to the Buchholz relay for maintenance purposes.

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

7.3.7 Joints

All joints that may have to be broken shall be rendered oil-tight either by the use of nitrile rubber bonded non-porous cork gaskets without the use of adhesives or other sealing components or by O-rings within appropriately designed grooves. The main lid shall be electrically bonded to the tank.

7.3.8 Tank Earth

A 50 x M12 diameter Stainless Steel (grade 316) earthing stud shall be welded externally on each side, and as near as possible to the base of the tank, for connection to the substation earth grid.

A tab with two 14mm diameter holes shall be welded to both sides of the tank. This tab is for the connection of earth cables.

7.3.9 Burrs

External surfaces shall have welds made smooth, rough edges rounded and weld spatter removed.

7.3.10 Provision for Temperature Measurement Devices

A suitable oil tight pocket shall be provided in the lid 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 cover of the 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 and shall be of the external hexagonal head type with a gasket seal.

7.3.11 Cable Cleats (HV Cable entry type only)

Brackets shall be provided below cable boxes for attachment of cable cleats.

7.3.12 Pressure Relief Valve

Self sealing pressure relief valves shall be provided to minimise the build up of pressure within the main tank and in the tap changer compartment 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 and shall be wired back to terminals in the Transformer Marshalling Box in accordance with Section 7.6 and Section 7.7.

7.3.13 Surge Arrester Mounting Plate (HV Bushing Type only)

Standard fittings shall be affixed to the tank for the mounting of suitable surge arresters adjacent to the HV bushings.

7.4 Valves and Pipework

The following valves and plugs shall be provided:

Item	Location	Description
1	Conservator – Main	Filler Pipe with cap 50mm
2	Conservator – OLTC	Filler Pipe with cap 50mm
3	Conservator – Main	Drain Valve 25mm Internal thread with flanged plug. One each end.
4	Conservator – OLTC	Drain Valve 25mm internal thread with flanged plug.
5	Main Tank	Filter Valve 50mm
6	Main Tank	Drain Valve 50mm internal thread with flanged plug.
7	Main Tank	Sampling Valve 15mm
8	OLTC	Filter Valve 50mm
9	OLTC	Drain Valve 32mm
10	Radiator	Isolation Valve 1 per Radiator
11	Radiator	Air Bleed Plug 25mm
12	Radiator	Drain Plug 15mm. 1 per Radiator
13	Conservator – Main	Isolation Valve 50mm
14	Conservator – OLTC	Isolation Valve 27mm
15	Buchholz relay	Isolation Valve

Valves shall be copper alloy, of an approved type, suitable for a maximum working pressure of 350 kPA (50 psi) and a maximum working temperature of 100°C

All valves which have one side open to the atmosphere during transport or service shall be provided with either a blanking plate or a BSP screwed flanged plug with sealing washers.

All valves shall have visual indications of “open’ and “shut” and shall be labelled as to their function.

All valves shall be 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 etc.

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

Buchholz isolation valve shall be located on the conservator side of the relay. In case of necessary removal of the Buchholz relay, 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 main connections to the cooling equipment shall be fitted with valves immediately adjacent to the tank. These valves shall be fitted to the transformer for transport so that the first oil filling can be carried out on site without losing control of the gas pressure inside the tank.

All joints which may have to be broken shall incorporate oil tight gaskets and shall be to a high standard of design and construction such that with normal erection techniques no oil leaks or weeps shall occur.

7.5 Lifting Attachments/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, as indicated on drawing EL0416250, for rolling the transformer full of oil into position. Wheels shall be of solid construction, flanged wheels are not acceptable.

Skid mounting facilities on the transformer in lieu of wheels may be required and will be included in the RFT if necessary. Unless stated otherwise in the RFT skids shall be placed in the alignment of the wheels given by EL0416250.

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 500mm from the transformer foundation. The jacking plates shall be suitable for jacking the transformer when full of oil.

The method and equipment required for lifting/rolling/skidding shall be included in the Equipment Manual however a design that necessitates slide rails being placed in discrete positions is not acceptable.

7.6 Marshalling Box

All internal wiring operating on the 125 Volt DC supply shall have a rated insulation level of 0.6/1kV.

A marshalling box(s), with a suitable Ingress Protection (IP) rating as detailed in EP 00 00 00 13 SP Electrical Power Equipment–Design Ranges of Ambient Conditions, shall be provided for connection of alarms and indications. All wiring shall be terminated on standard DIN rail terminals and labelled with non-ferrous labels. The terminals shall also be clearly labelled as detailed in EP 00 00 00 15 SP Common Requirements for Electrical Power Equipment.

The marshalling box(s) shall contain vertically hinged doors, a thermostatically controlled anti-condensation heater, a door operated light and a double General Purpose Outlet (GPO) protected by RCD in accordance with AS3000 and shall be able to be locked.

For wiring to the transformers equipment out of the Marshalling Box, others will supply cable glands, however a removable undrilled gland plate of an approved size shall be supplied by the transformer manufacturer, located to permit cable entry from below.

7.7 Control Wiring

Shall comply with the relevant sections of EP 00 00 00 15 SP Common Requirements for Electric Power Equipment

7.8 Alarm and Indication Contacts

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

The contacts shall be suitable for making and breaking at least 100mA in a 125V dc circuit or 250mA in a 50V dc circuit. The contacts shall be suitable for switching relay coils and similarly inductive loads.

7.9 Cable Tray

100mm stainless steel cable tray or “J” hooks shall be provided attached to the top cover and side walls for the purpose of routing small wiring between equipment items.

The manufacturer may recommend an alternative system for routing of cables between equipment.

7.10 Conservator

An appropriately sized conservator shall be fitted, conforming to the following :

- The conservator shall maintain positive oil pressure in the main tank
- With an average oil temperature of 0 °C the oil in the conservator shall occupy not less than 10% of its volume. With an average oil temperature of 100 °C the oil in the conservator shall occupy not more than 90% of its volume.
- A main oil feed pipe to the tank shall project through the bottom of the conservator by an amount sufficient to provide a sump with a volume of approximately 5% of the conservator volume.
- Flanged pipes of 50mm diameter shall be fitted at each end of the conservator. The pipes shall not project into the conservator so that oil may be completely drained and all sludge and foreign matter may be extracted by filtering. The pipes shall be fitted with 50mm valves.

- 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 but under no circumstances shall the oil be allowed to mix with the main tank oil.
- Internal surfaces shall be treated with an approved oil resistant coating sufficient to ensure that the conservator meets the specified design life criteria.
- A membrane (air bag) between the oil and air to prevent moisture in the air from contaminating the oil in the conservator. Air bag is to be Fujikura type FNH8-045 or an equivalent to be approved by Railcorp.
- The conservator shall be arranged so that all air can be excluded from below the membrane at the time of filling.
- Conservators equipped with an air bag shall also be provided with a gas collection relay.
- The conservator base brackets shall be bolted to the main tank.
- Access shall be provided to all compartments of the conservator to facilitate cleaning.
- The conservators shall withstand an internal pressure of 35kPa in excess of that required to operate the pressure relief vent and full vacuum without leakage or permanent distortion.
- Lifting eyes shall be fitted to the conservator of sufficient capacity to allow removal of a full conservator.
- Oil Level indicators shall be provided as detailed in 7.20 Oil Level Indicators.

7.11 Cooling Plant

7.11.1 Radiators

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. No allowance shall be made for cooling provided by the external surface of the main tank.

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. Drain cocks 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.

The radiators and the valves on the transformer tank shall be capable of withstanding the full vacuum that can be held on the transformer.

Valves shall not be welded to the tank or radiators.

The external surfaces of the radiators shall be hot dip galvanised to *AS 4680*. Minimum thickness of galvanising shall not be less than 84 micrometres.

Extruded aluminium type radiators shall not be accepted.

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

The radiators shall have all apertures sealed against ingress of moisture and dust during transport of the transformer to site. Details of such sealing shall be agreed with RailCorp.

7.11.2 Fans

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 DOL starting, at an ambient temperature as specified in EP 00 00 00 13 SP Electrical Power Equipment – Design Ranges of Ambient Conditions, as specified for outdoor equipment.

In a limited number of locations the supply available is 220V, 3 phase, 50Hz. The RFT will specify if the fan motors are required to 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 TEFC corrosion resistant squirrel cage induction motors in accordance with AS 60529 – designation IP56D. 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, noise and vibration from fans shall be kept to a minimum.

Galvanised heavy wire mesh guards of not greater than 40mm 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, to turn on at 65°C and turn off at 55°C.

7.12 Terminal Arrangements

Connection to the primary terminals will be made by cables or bare conductor as indicated in the RFT.

Connection to the secondary terminals will be made by cables.

RailCorp Standard *EP 20 10 00 02 SP* High Voltage Cable provides guidance on the preferred cable quantities and sizes. The design of the terminal arrangements shall be such as to minimise the mechanical loading of the connecting cables, including allowance for thermal expansion of the cables.

Minimum safety clearances of 2615mm and 2860 mm respectively for 11kV and 33kV terminals are required between the base of the transformer (with Wheels or Skids removed) and the uninsulated section of any bushing in accordance with *AS 2067*.

7.12.1 33kV Aerial Conductor Bushing Terminals

Where 33kV bushings are specified in the RFT as the 33kV connection method, the transformer shall be fitted with open 33kV bushings of a continuous current rating greater than 125% of the ONAF transformer rating.

All the terminal bushings shall be fitted with flat connecting palms, comply with *AS 60137* for a normally polluted atmosphere and shall be solidly insulated.

The clearance between the 33kV 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 60076.3:2008*, however it is formulated with reference to *AS 60076.3* and *AS 2067:1984* due to RailCorp 33kV bulk supply points being resistively earthed in many situations.

7.12.2 33kV & 11kV Separable Connector Terminals

Where a HV cable termination is specified as the HV connection method in the RFT, the cable connections shall be protected from ultra violet radiation by a fabricated steel shroud fitted with a suitable lifting handle. The terminals shall be appropriately rated Euromold or similar load break plug-in connectors comprising a separable bolted type connector attached to the high voltage cable and mating equipment bushings.

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

7.12.3 11kV Star Point (Neutral)

The 11kV star point (neutral) shall be brought out to a touch safe separable connector or other appropriate touch safe method. The proposed method of connection is to be approved by RailCorp.

7.13 Tappings and Tap-Changer

7.13.1 Tappings

High Voltage winding tappings at increments of 1.25% over the range –15.0 % to +5.0% of the nominal voltage shall be provided.

7.13.2 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 on-load tap-changer shall be of the high-speed resistor type.

The on-load tap-changer shall comply with the requirements of *AS 60214.1:2005*. Tap Changers, Part 1: Performance requirements and test methods.

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.

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 tapping switch shall be capable of withstanding the overload characteristic specified in Section 7.1 test certificates proving continuous current, 3 second short circuit withstand current, and BIL shall be provided.

All contacts shall be of the self-wiping and snap action type. Only a single tap change shall be possible with each operation.

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

Tapping switches shall be provided with mechanical end stops that prevent movement beyond an end position.

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

7.13.3 Tap-Changer Control

The tap-changer shall be fitted with the necessary control and protective equipment for completely automatic, manual push button and 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 11kV/110V three-phase voltage transformer will be provided by RailCorp for the operation of voltage sensing equipment.

The voltage sensing equipment shall prevent operation of the tap-changer if the reference voltage is lost. A set of changeover contacts capable of making and breaking 100mA in a 125V dc slightly inductive circuit shall be provided on this equipment for external alarm circuits.

A 415V, three-phase and neutral, 50Hz supply of the required capacity will be provided by RailCorp for the operation of the tap-changing equipment. In the event that the transformer is required to operate at a substation without such a supply, details of the alternative arrangement will be included in the RFT. This may result in a star/delta winding configuration to enable 220V ac supplies to be used.

The tap change control circuit shall operate at 125V dc, supplied from the Substation 125V dc Distribution Board. All wiring supplied from the 125V dc Distribution Board shall have an insulation withstand capability of at least 0.6/1kV rms.

The relays, switches and push buttons shall be enclosed in a weatherproof cubicle and be readily accessible for maintenance at ground level with the transformer energised.

All equipment shall be so rated that no damage will result should the controller stop between tappings. In addition 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.

Space shall be provided in the tap changer control cabinet for installing two additional relays at a later date. The cubicle shall contain a thermostatically controlled anti-condensation heater, a door operated light and a manual handle for emergency and maintenance operation.

The tap changer control cabinet shall be weatherproof and dustproof (IP55) and shall be bolted to the transformer main tank in a convenient position such that the operator standing at ground level can carry out maintenance on all equipment contained in the cabinet with the transformer energised.

The location of the tap changer control cabinet shall be arranged such that the overall size of the transformer complies with Section 5.2Interchange Ability.

7.13.4 Tap Changer monitoring.

The tap-changers shall be fitted with:

- A mechanically operated tap-position indicator which will provide a visible indication of the tapping in use. In addition the tap-position indicator shall 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. Provision shall be made for remote indication that the tap change sequence is in progress when the tap changer is changing position. This signal shall comprise a relay contact that is normally closed and which opens whilst 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 may reasonably be monitored, together with loss of motor and control power supply. This signal shall be a contact that is normally closed and which opens upon fault.
- Alarm equipment which will 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 100mA in a 125 V DC slightly inductive circuit shall be provided on this equipment for external alarm circuits.

7.14 System Earthing

The RailCorp 33kV supply may be solidly earthed or resistively earthed.

RailCorp may operate 11kV systems as resistively earth or solidly earthed.

All accessible exposed metal parts of the transformer, cable sheaths, etc shall be connected to the substation earth mat.

7.15 Winding and Oil Temperature Indicators

All alarm and trip set-points shall be labelled as to their use.

7.15.1 Optical fibre Type

RailCorp 11kV supplies may be characterised with small two phase signalling systems utilising A and C phase only, single phase lighting and ancillary systems plus larger three phase systems. With the exception of signalling supplies it is expected that the 11kV system could be reasonably balanced. In this case it is considered that monitoring of only one winding temperature should be acceptable.

Unless the transformer windings are not thermally balanced, then “A” phase shall be monitored with fibre optic systems. In the case where the transformer design is not significantly thermally balanced, then the manufacturer shall recommend which phase to monitor based on the proposed design.

A minimum of four optical fibre temperature sensing probes shall be placed in the transformer such that winding hot-spot, average winding, tap winding and top oil temperatures may be monitored. The transformer designer shall recommend the most suitable locations for the probes and provide justification for the recommendations. Marshalling of the fibres shall be completed inside an appropriately designed box attached to the outside of the transformer tank in a position where it can be safely accessed from the ground, without the use of ladders or steps, with the transformer energised.

When specified in the RFT, a suitable data analyser shall be provided into which the output from the optical fibre sensors may be stored. The equipment shall have an appropriate IP rating, have the ability to interface to the SCADA RTU for remote monitoring and be capable of having the data downloaded via a portable computer.

7.15.2 Thermometer Type

The following shall be provided:

- Top Oil Temperature indication contacts A.
- Top Oil Temperature indication contacts B.
- Top Oil Temperature local visual indicator.
- Top Oil Temperature remote analogue transducer.
- Winding Hot-spot Temperature indication contacts A.
- Winding Hot-spot Temperature indication contacts 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 70°C to 150°C in 10°C increments and it shall be possible to readily set the operating point within +/- 2O°C without the need for additional set up instruments. The instrument shall be capable of operating in ambient conditions as specified in EP 00 00 00 13 SP Design Ranges of Ambient Conditions, for auxiliary equipment located near heat emitting equipment.

It is intended that one set of indication contacts will be used to provide remote alarms of abnormal temperatures and that the second set of contacts will be set to operate at a higher temperature and will be used to trip the transformer AC circuit breaker.

Winding Hot-spot Temperature local visual indicator shall be provided with a re-settable maximum indicator and shall have an accuracy of +/- 2O°C or better

Winding Hot-spot and Top Oil Temperature remote analogue transducers shall provide a 0-20mA output and shall have accuracy of +/- 2O°C or better. The transducers shall be capable of operation from the substation auxiliary supply voltage as nominated in the RFT. It is intended that the output of the transducer will be connected to the SCADA system.

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

7.16 Gas and Oil Actuated Relays

For protection purposes, 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 fault levels stated in Section 6.6.

Each device shall be fitted with two independent sets of contacts which, when actuated as above, will 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 installed in accordance with Section 7.6.

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

7.16.1 Test Cock

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

7.16.2 Ground Level Gas Receiver

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

7.16.3 Positioning

The gas protective relays shall be inserted in sections of the pipe between the conservator and the transformer and tap changer tanks. The pipes shall slope upwards to the conservator at an angle of between 3 and 5 degrees to the horizontal.

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

7.17 Oil

Corrosive sulphur free Nynas Transformer oil - Nytro Libra compliant with *AS 1767.1:1999* shall be used.

In order to comply with NSW Environment Protection Agency guidelines for PCB free materials the transformer oil must contain less than 2 milligrams per kilogram of PCB. Should the PCB content exceed 2 mg/kg then the oil shall be treated as necessary to reduce the PCB level below 2 mg/kg. A tag indicating that the oil contained within the transformer and tap changer is PCB free shall be attached permanently to the transformer.

Should a transformer be delivered without oil and arrive on site without gas pressure, then it shall be dried out on site at the Contractors expense. Oil delivered separately to site shall be in dedicated isotanks, not drums.

7.18 Finish

The main tank shall be shot blasted internally and externally to remove rust and scale in accordance with Class SA2½ “Near White” Blast Cleaning to *AS1627 4:2005* Preparation and pre-treatment of surfaces-Part 4:Abrasive Blast Cleaning of Steel.

The finished surface shall be in a suitable condition to provide good adhesion properties for the primary coat.

The internal and external surfaces shall be prepared and the coating applied strictly in accordance with the manufacturer's instructions. Galvanising of surfaces in contact with oil is not permitted.

7.18.1 Internal Surfaces

The main tank, tap changer enclosure, conservators and pipework internal steel surfaces are to 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.

Internal surfaces of the main tank core clamping steel etc. shall be treated with an approved oil resistant insulating varnish.

7.18.2 Tank External Surfaces

The following system shall be used to protect all external steel surfaces. Manufacturers wishing to offer an alternative shall provide evidence such as accelerated life test results proving that their proposed system has the same or better life expectancy. Sheared or cropped edges of all steelwork shall be dressed before the application of the specified protective finishes.

- Preparation: Abrasive grit blast clean to remove scale, rust, grease, to *AS 1627.4* class 2½.
- Primer: Dulux "Zinc Rich Primer WP", abrasion resistant, 50-70 µm Dry Film Thickness (DFT) single pack zinc rich phenoxy primer.
- Intermediate: Dulux "Durepon P14" anti-corrosive, chemical resistant, 45-65 mm DFT, two pack epoxy, zinc phosphate primer.
- Top Coat: Dulux "Luxathane" full gloss two pack acrylic polyurethane 50-70 µm DFT. Preferred colour: Storm Grey, N42 - *AS 2700*.
- Total DFT: 140 to 210 µm.
- The transformer tank, Tap Changer enclosure, conservators, pipework and covers shall remain corrosion free for the life of the transformer.

7.19 Breather

Breathers shall be provided for the air space above the membrane in the main tank and tap changer conservators. If these air spaces have not been designed to be unaffected by moisture a de-hydrating breathers shall be provided, 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 for replacement.

If de-hydrating breathers are not required, the breathers shall be arranged to exclude insects from the conservator air space. The breather shall be mounted in such a position that it can be serviced from ground level.

7.20 Oil Level Indicators

Magnetic type oil level indicators shall be provided for both the main conservator and the on-load tap-changer conservator. The indicators shall be in a position clearly readable with the naked eye from ground level. The indicator for the main oil shall have a minimum diameter of 200 mm and be mounted at an angle of 20 degrees to the vertical. The oil level indicator for the main transformer oil shall have a visible range up to 105 °C. It shall have calibration marks including 0°C, 10°C, 30°C, 50°C, 70°C, 100°C whereas that for the tap-changer conservator requires only two temperature marks.

The two oil level indicators shall each have normally open low oil level alarm contacts.

7.21 Gas Collection Relay

Where conservators are equipped with an air bag, a gas collection relay shall be fitted at the highest place of the conservator. The relay shall be supplied with alarm contacts which close if gas is collected. The contacts shall be wired to alarm terminals in the marshalling cubicle.

7.22 Rating Plate

A rating plate conforming to the requirements *AS 60076:2005* Power Transformers Section 7, Rating plates, made of brass, pacified stainless steel or other approved material shall be firmly attached by means of screws at each corner to a bracket (the size of the rating plate) externally on the transformer enclosure. The plate shall not be attached to any removable cover.

The rating plate shall include, in addition to the requirements of *AS 60076*:

- a diagram of connections,
- RailCorp specification number,
- month and year of manufacture,
- Top oil, Average Winding, Winding Hot Spot maximum temperatures achieved in heat run tests for each cooling mode

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

7.23 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 must meet the requirements of *AS/NZS 1891.4* and WorkCover NSW Regulations.

7.24 Anti-vibration pads

The transformer shall be mounted on anti-vibration pads such as Embelton Shearflex or similar. The loading of the pads shall be appropriate for providing adequate noise isolation to the foundations.

The pads shall be of a non-conductive type of material.

7.25 Current Transformers

7.25.1 Neutral Earth Protection

A Current Transformer (CT) shall be provided on the LV Neutral for neutral earth protection having the following characteristics:

- Comply with *AS 1675*, with tests carried out and submitted in accordance with this standard.
- Have a ratio of 150/1 (class and ratio to be confirmed by RailCorp at time of tender)
- Secondary wiring shall be terminated in the marshalling box.
- The primary shall comprise the copper earthing bar which shall be attached to the transformer tank on stand off insulators and routed to ground level for connection to the earthing stud. Links shall be provided for primary injection testing.
- Comply with *EP 19 00 00 02 SP* Protection System Requirements for the HV Network, Table B2.

7.25.2 Winding Temperature Indication

A Current Transformer shall be provided as part of the Winding Temperature Indication equipment. The CT shall be located within the main tank and be accessible through covers on the top of the tank. The CT shall be wired to the Marshalling box in accordance with Section 7.7 of this standard.

8 Integrated System Support Requirements

8.1 Integrated Support Objectives

The tenderer must 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:

- Specifying Maintenance Requirements
- Spares Support
- Operations and Maintenance Manuals
- Training, and
- Support Equipment and Tooling

8.2 Equipment Supplier Deliverable

Manuals, training, documentation and other support deliverable's shall be in accordance with EP 00 00 00 12 SP Electrical Power Equipment – Integrated Support Requirements.

9 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 etc. RailCorp reserves the right to witness any or all of the tests and at least four week's 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.

9.1 Component Tests

All radiators shall withstand a test at pressure of 100kPa or twice normal working pressure whichever is the greater. Certified results of type tests on all valves, relays, gauges and other devices shall be available for inspection.

Current transformers shall be tested in accordance with their respective standard. The proper functioning of all protective, indicating and alarm devices shall be tested and all external equipment and wiring shall be subject to an applied voltage test of 5kV for one minute.

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 2kV for one minute.

9.2 Routine Tests

The following tests shall be carried out on each transformer in addition to the Routine Tests as listed in *AS 60076* Section 10.1.1.

- Full Dissolved Gas Analysis of transformer oil both before and after the temperature rise test.
- An extended No-Load Loss and Current Test in which the transformer shall be energised continuously at rated no-load voltage for at least six hours after which time the no-load watts and current shall be measured. If these losses are greater than those measured in the routine test specified in AS60076, they shall be used in the evaluation of losses.
- No-load losses and currents at 100%, 110% and 120% of rated excitation.
- Temperature Rise Test as detailed in AS 2374.2. The test shall be carried out using the top oil temperature and winding thermometers and the optical fibre temperature sensors specified in 7.15 Winding and Oil Temperature Indicators. The temperature/time/current records for each of the devices shall be recorded on a MS Excel spreadsheet in order that they may be compared with the results predicted by the virtual model generated from the RailCorp transformer modelling software as specified in 6.7.2 Thermal Model Validation.
- Thermal Image Scan. This test, using thermal imaging equipment, shall record the temperature image at rated current for the following:
  - Each face of the tank
  - Each face of the cooling radiator
  - Bushings, where fitted.
- Harmonic content at 100% of rated excitation.
- Load losses and impedance on maximum, minimum and principal tap positions.
- Zero sequence impedance in all configurations of open- and short-circuited windings and at currents as close as possible to 1 p.u.
- Oil pressure leak test of 35kPa in excess of that required operating the pressure relief vent with the completely assembled and oil filled transformer for 24 hours.
- After the transformer has been delivered to site and any oil added as may be necessary, the suppliers shall arrange for the oil to be tested for PCB content and a certificate issued to the Purchaser showing the PCB content.
- Inrush Current Peak and Envelope recording

9.3 Type Tests

The following tests shall be carried out on each transformer in addition to the Type Tests as listed in *AS 60076* Section 10.1.1.Type tests shall be carried out on one transformer of a batch as follows-:

- A sound level test in accordance with *AS 2374.6*
- A short-circuit test in accordance with *AS 2374.5* . This shall be carried out at the end of the temperature rise test when the transformer is hot.
- Lightning impulse voltage withstand tests including chopped wave tests on maximum tap, mid tap and minimum tap positions for the three phases respectively and 11kV secondary connections. For the purpose of interpretation of test results, evidence shall be produced confirming that supplementary measurements are adequate for the detection of any likely fault of disruptive discharge, which could be present during the tests.

Type test certificates for each of these tests will be accepted where it can be demonstrated that the transformer supplied is of a similar design to a previously type tested transformer.

9.4 Special Test

Sound power level tests shall be conducted at 100% core excitation with all cooling equipment de-energised (ONAN) and again with fans energised for the continuous maximum rating condition (ONAF) in accordance with *AS 2374.6*.

Sound pressure check readings on all four sides (or if the manufacturer prefers, full tests) and at full rated output during load loss testing shall be included in the determination of the sound power level as per the above standard.

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

9.5 Optional Test

Although the transformer covered by this specification is to have a 33kV 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 2374.3:1982* for transformers with Um ≥ 300kV.

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

In the case that partial discharges are detected which exceed the noted limit, then RailCorp will at its discretion consult with the manufacturer to allow RailCorp to have final judgement on 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.

9.6 Tests After Erection

On completion of delivery and erection 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 2.5kV DC.
- Dielectric Dissipation Factor (DDF) tests of all winding configurations.
- Operation of the fans in automatic and manual mode.
- Overpressure test at 35kPa for 24 hours before setting to work the pressure relief device.
- Oil dielectric test and test for water content.

Check sheets showing completion of all site test and test results shall be provided to the Engineer. It is the responsibility of the Contractor to ensure that the transformer is ready for service.

10 Data Set Associated with the Equipment

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

10.1 Drawings and Information

All drawings shall conform to the requirements of the RailCorp CAD Manual.

The following drawings are required.

- Final Outline Drawing

  Final outline drawings with full details and locations of all items. The outline drawings shall include the mass of individual items in the erected condition such as main tank and radiator bank.

- Foundation Drawings

  Foundation drawings showing detail of base for the main tank.

- Schematic and Wiring Diagrams

  Schematic diagrams of the transformer windings showing connections, tappings and tabulations of current and voltage rating of all windings.

  Schematic diagrams of control of auxiliary systems.

  Wiring diagrams: including Cable Block Diagram, Cable Schedule and Cable Termination Schedule.

- Cabinet Layout

  Layout drawing of marshalling cabinet showing details of all components.

- Rating Plate

  Drawings of the rating plate required in 7.22. Rating Plate. Details shown on these drawings must not vary from that shown on the plates fixed to the transformer.

- Internal Construction

  Detailed construction drawings of internal arrangements of the transformer.

- Bushings and Cable Box Drawings

  Full details of all bushings including profile drawings and full details of the cable box where supplied.

- Winding Details

10.2 Contract Drawings

Preliminary rating and diagram (R&D) plate and, if applicable, preliminary general arrangement (GA) drawings, with sufficient confirmed dimensions and masses to allow civil design to proceed, shall be provided within six weeks after contract award.

The final GA drawing shall be provided within ten weeks after contract award, showing:

- The location and identification of fittings and accessories.
- Mass and overall dimensions of main unit including tank fitted with accessories and filled with oil.
- Mass and overall dimensions of any equipment mounted separately from the main tank.
- Quantity of insulating oil required in each oil-holding compartment.
- Shipping mass and dimensions of main unit including tank and fittings not removed for transport. Transport dimensions shall be shown encircled.
- Position of terminals relative to the centre lines of the tank and the level of the foundations.
- The position of the centre of gravity under the following conditions:
  - the main unit in its tank when stripped for transport and,
  - completely assembled and filled with oil.
- Pipe-work and flange details for erection purposes.

Other drawings to be provided at that time are:

- Proposed foundations for the plant and detail drawings of gland plates and lugs to be furnished. The position of control cable entries is to be shown.
- The rating and diagram plate drawing(s).
- Schematic and wiring diagrams of tap-changer control.
- Schematic and wiring diagram of cooling control.
- Schematic diagram of alarm and trip circuits.
- Any other drawings and information required for the design of the transformer installation and related substation facilities.

All the above drawings shall bear the plant serial numbers of all units.

10.3 Final Contract Drawings

The final drawings as listed above shall be provided prior to arrival of the transformers on site. Other drawings required at that time:

- Cross section drawings of core and windings showing clearly the construction and assembly of all parts.
- Cross section drawings of the tap changer showing clearly the construction and assembly of all parts.
- Arrangement of all equipment in the panels including the tap changer control panel.
- Drawings showing outline of and section through each bushing.
- Outline drawings and material list giving manufacturer's part numbers for all main and arcing current carrying contacts associated with the tap-changer.
- Drawings of any special slinging arrangement required for handling the transformer during shipment or erection.
- Drawings and/or schedule showing full details of all gaskets.
- Drawings of all valves, breathers, relays and oil- and winding temperature indicators.

Final drawings shall be provided on CD/DVD in a format compatible with the Principal's drawing format, which is Microstation V8, in addition to the paper copies specified in the RFT.

10.4 Maintenance manuals

A draft installation, operation and maintenance manual (text only), excluding pamphlets, brochures and the like for accessories, shall be submitted for approval four weeks prior to dispatch of transformers.

Three sets of final installation, operation and maintenance manuals for each transformer rating shall be provided one week after dispatch ex -works. The manuals shall be international A4 size and all drawings shall be suitably folded or reduced for convenient filing within the manual.

Each manual shall include:

- A cover suitable to withstand normal handling.
- A comprehensive index of all materials in the manual.
- Instructions for the routine maintenance of the equipment and associated auxiliary equipment including data for the calibration of winding temperature indicators.
- Detailed description including required plant for the vacuum / oil filling procedure.
- A detailed evacuation procedure of the conservator where an air bag or diaphragm is provided.
- One copy of each drawing listed under final contract drawings above.
- Pamphlets, booklets and drawings describing each item of auxiliary equipment fitted.
- A photograph from each side and end of the associated core and windings and of the fully erected unit. The photographs should be about 200 mm x 150 mm in size.
- A test certificate for type, routine and special tests. The manuals may be dispatched without this certificate, but it should follow as soon as possible.
- Drawings that may be 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 will apply to fixed and moving contacts of the OLTC unit and auxiliary switches and "special" gaskets (being those which cannot be hand cut from sheet materials eg; moulded gaskets, "O" rings etc).
- Procedure to open the tank in the case of a welded lid.

10.5 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.

10.6 Life Cycle Costing

All the data and assumptions pertaining to the determination of the whole-of-life cost calculations shall be recorded, including transformer loss calculations as detailed in EP 02 00 00 02 SP Transformer Loss Evaluation.

10.7 Technical Schedule

The information listed in the technical schedule of Appendix A, from the successful Tenderer, shall be maintained for each transformer.

Appendix A Technical Schedule

The Tenderer shall supply the information listed in this Technical Schedule at tender stage, for each transformer.

Transformer Details:

Rated primary voltage	…….....	V
Rated secondary voltage	…….....	V
Rated power of primary winding	…….....	MVA
Rated power of secondary winding	…….....	MVA
Connection symbol	…….....	
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	…….....	
Thermal Time Constant – Tank	…….....	Hrs
Thermal Time Constant – Winding	…….....	Min/s
Impedance voltage at rated current and 75°C based on ONAN MVA Rating	…….....	%
Type of core steel - hot or cold rolled	…….....	
Brand or trade name and grade of core steel	…….....	
Maximum flux density on net cross-section of steel with rated volts at rated frequency applied to the centre tapping		
– Limbs	…….....	T
– Yoke	…….....	T
Mean sound level	…….....	dB(A)
Continuous rating of tap-changer	…….....	A
Overload rating of tap-changer and information to show that it is capable of carrying the overload specified:	…….....	
Type of material used for windings		
– HV	…….....	
– LV	…….....	
Type & class of insulation on windings	…….....	
Maximum dielectric stress on winding insulation	…….....	V/mm
Type of gasket material	…….....	
Type of Conservator Air/Oil separator – Diaphragm or Airbag	…….....	
Membrane/Airbag Material	…….....	

Protective treatment applied to tank:		
– Internal surfaces	…….....	
– External surfaces	…….....	
Locking mechansim applied to ALL internal bolts		Yes/No
Type of Locking mechanism used on internal bolts	…….....	
Gland Plate Dimensions of Marshalling Box	…….....	
Overall Dimensions		
Extreme height from floor level	…….....	mm
Extreme height from floor level when stripped for transport	…….....	mm
Projected floor area	…….....	mm x mm
Mass		
Mass of transformer complete with oil	…….....	kg
Mass of transformer core and windings only	…….....	kg
Mass of windings only	…….....	kg
Volume of oil required to fill transformer, complete	…….....	Litres

Bushings

	33kV	**11kV**	**LV Neutral**	
Maker	…….....	…….....	…….....	
Maker's type number	…….....	…….....	…….....	
Material	…….....	…….....	…….....	
Continuous current rating	…….....	…….....	…….....	A
Number per transformer	…….....	…….....	…….....	
Lightning impulse flashover	…….....	…….....	…….....	kVp
Creepage distance	…….....	…….....	…….....	mm
Minimum air clearance between phases	…….....	…….....	…….....	mm
Phase to earth	…….....	…….....	…….....	mm
Palm dimensions	…….....	…….....	…….....	mm x mm

Other particulars

……..……..……..……..……..……..
……..……..……..……..……..……..…
……..……..……..……..……..……..……..
……..……..……..……..……..……..……..

Separable Connectors

	33kV	11kV	LV Star Point	
Maker	…….....	…….....	…….....	
Maker's type number	…….....	…….....	…….....	
Continuous current rating	…….....	…….....	…….....	A

Reliability Data (use separate sheet if necessary)

Design Life		…….....	Years
Failure Modes (for Early, Normal Life, & Wear Out periods)	a)	…….....	
	b)	…….....	
	c)	…….....	
Mean Operating Hours Between Failures:	a)	…….....	
	b)	…….....	
	c)	…….....	
Time to Repair:	a)	…….....	
	b)	…….....	
	c)	…….....	

Drawings and Information to be submitted with the Tender

- Outline Drawings

  Fully dimensioned outline drawings showing all fittings, terminal arrangements, radiator equipment, tap changer equipment, marshalling cubicle, required maintenance access. The general arrangements and layouts are to be adhered to in the final design unless written approval is obtained from RailCorp.

- Foundation Drawings

  Foundation drawings showing detail of base for the main tank and radiators if these are separately mounted.

- Core Material Characteristics

  Typical Curves Of Flux Density Versus Ampere Turns Per Metre For The Core Material.

- Core Information

  Drawing and detailed description of core type, methods of making joints, insulation between laminations, treatment of edges, core bolt insulation and method of minimising hot spots in limbs. Details of the proposed method of verifying core hot spot temperature. Method of how the core is earthed.

- Schematic and wiring Diagrams

  Schematic diagrams of the transformer windings showing connections, tappings, and tabulations of current and voltage rating of all windings.

Schematic diagrams of control of auxiliary systems.

Wiring diagrams: including Cable block diagram, Cable schedule and Cable termination schedule.

- Temperature Indicators

  A full description of temperature indicators and transducers including detailed design information of the type of pocket to be used. Full details of the proposed optical fibre temperature measurement installation, including the method of ensuring that the fibre tip is securely located.

- 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 should include a description of:

- the overall transformer design
- the method of electrically, thermally and structurally modelling of the design
- lessons learnt from previous similar designs and how this was addressed in the design
- quality processes during design and manufacture to ensure the design will meet the RailCorp 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 7.14.

Departure from Standard

Are there any departures from the requirements of this Standard?

* YES / NO

* If ‘YES’ Include details on separate sheet.

Special Delivery Requirements

Any special requirements that are envisaged for the safe delivery of the transformer to the specified site must be stated at Tender stage, for example, removal of bushings due to low bridge on delivery route. These costs shall be provided separately at Tender stage.

Appendix B Options to be Priced at Tender

Winding and Oil Temperature Indicators

Provision of logging device for monitoring fibre optic temperature sensors.

Hermetically sealed tank with no conservator.

Equipment for the detection of arcing faults within the windings shall be included.

Provide detailed calculations for the sizing of the tank for this option.

Non-Fitting of Fans

Provide the take-out cost of not providing fans.

Stainless Steel Conservator

Conservator fabricated from Stainless Steel, Grade 316 if required to make the conservator air space above the membrane unaffected by moisture.

Transformer Short Circuit Test

Details of an appropriate short circuit test involving the on load tap changer shall be nominated by the transformer manufacturer.

Transformer Partial Discharge Test

Details of an appropriate partial discharge test involving the on load tap changer shall be nominated by the transformer manufacturer in accordance with Section 9.5.

Tap Changing Monitoring

Details of proposal for monitoring the operation of the tap changer

Tap Changer Operation Log

The manufacturer shall offer an option for remote signalling of the number of tap change operations as cumulative indicator of tap change operations. Alternative options with respect to monitoring tap change performance may be offered as an option.

Integrated Support Information

Tenders to complete and submit Integrated Support information as per Railcorp Standard EP 00 00 00 12 SP Electrical Power systems – Integrated Support Requirements.

Appendix C Request for Tender Checklist

Where this standard is used as the basis for procurement of automatic tap changing transformers for a particular location, in addition to the general requirement in this standard the following information will need to be supplied related to the particular site:

ITEM	DETAIL	COMMENT
Substation location		
Transformer Earthing	The transformer shall be suitable for operation as secondary solidly earth or resistively earthed.	
Primary Connection	HV Cable HV Bushing	
Secondary Connection	Separable Connector	
Number, size and type of secondary conductors / phase		
Bushing	Type Preference	
Separable Connector	Type Preference	
EP 00 00 00 12 SP Electrical Power Systems - Integrated Support Requirements	Document included with RFT	
Any site specific limitations on size or arrangement	Headroom Available	
Foundation	Base/Footing prepared	
Limitations due to access or transport	Access road weight limit	
	Access times	
	Maximum road width (2.5 metres)	
	Maximum standard height above road (4.3 metres)	
	Access road alongside/across operating railway	
	Safe-working considerations	
Supply of Additional Oil required to make the transformer ready for service	Include in RFT	
Delivery	Include in RFT	
Tests	Include in RFT	
Neutral Bushings		

Appendix D Requirements for Technical Aspects of Tender Evaluation

Evaluation of tenders

Tender submissions will be evaluated based on a number of criteria. One constant criterion is compliance with this specification. The Chief Engineer Electrical requires that persons evaluating the technical aspects of this tender have sufficient technical competence for the task.

Tender evaluation committees shall forward details of persons evaluating the technical aspects of the tender to the Chief Engineer Electrical for concurrence. This will normally be in the form of an email and is to include sufficient detail of the tender and the person to enable the Chief Engineer Electrical to satisfy themself of the merits of the evaluating person. A minimum of 4 weeks notice is required prior to the evaluation of the Tenders.

The Chief Engineer Electrical will advise within 5 working days only if the person is considered technically unsuitable for the technical evaluation.

Acceptance of product

A number of the specifications require acceptance of product at both the factory and at site. The purchaser is to advise the Chief Engineer Electrical the details of the person carrying out the acceptance testing for the concurrence of the Chief Engineer Electrical. A minimum of 4 weeks notice is required prior to the evaluation of the acceptance testing.

The Chief Engineer Electrical will advise only if the person is considered unsuitable for the acceptance testing.

The Chief Engineer Electrical reserves the right to nominate a representative to review and/or attend such acceptance.

Record Keeping

Where product is purchased against this specification, the Chief Engineer Electrical requires that relevant detail be provided so that it can be logged against this specification.

For RailCorp purchases, all records are recorded in Ariba.

Where this specification is utilised by parties external to RailCorp (Alliance parties, etc) then copies of all relevant technical information and evaluation shall be forwarded to the Chief Engineer Electrical for filing against the specification. In addition copies of selected commercial information pertaining to the ongoing support of the product as follows is also required.

- Warranty details
- Spare parts and associated availability
- Product support information