

Equipment Technical Specification

15MVA 132/11kV power transformer

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EQUIPMENT TECHNICAL SPECIFICATION

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ETS 0030 – 15MVA 132/11kV power transformer

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1.0 PURPOSE

To set out in detail the minimum technical requirements for the fixed 132/11kV 15MVA power transformers used as part of Endeavour Energy's zone substations.

2.0 SCOPE

This specification covers the design, manufacture, quality assurance, testing at factory, delivery, erection and site testing of 132/11kV 15MVA power transformers. It is not the intention to specify all design and construction details of the power transformers. However the equipment supplied shall meet all the requirements specified in the referenced standards and this specification.

Details of the site specific installation requirements are not detailed in this specification but will be provided in the general requirements provided as part of any tender.

All supplied transformers and associated equipment shall be manufactured and tested to the standards with the year of publication listed in 3.0 below. In some circumstances based on local network conditions and experience, this specification is more stringent than that of the Australian and International standards; in this circumstance the requirements of this specification shall take precedence.

The tenderer shall state any non-compliance with the specification in the tender submission and any alternative offers should be submitted in full and separately from the main offer. Any proposed variations from this specification shall be referred to Network Substations Manager for approval prior to acceptance.

3.0 REFERENCES

- Company Policy (Governance) 2.0.3 – Compliance
- Company Policy (Governance) 2.0.5 – Risk Management
- Company Policy 9.2.5 – Network Asset Design
- Company Policy 9.7.1 – Network Construction
- Company Policy 9.1.8 – Network Configuration
- Company Policy 9.2.10 – Network Asset Ratings
- Company Policy 9.2.2 – Network Protection
- Company Procedure GRM 0003 – Risk Management
- Company Procedure GSY 0026 – Work Health and Safety Risk Assessment
- Company Form FSY 0138 – Risk Register
- Environmental Management Standards EMS 0001 – Environmental impact assessment and environmental management plans
- Equipment Technical Specification ETS 0010 – Insulating oil
- ETS 0014 – Protection and control panels
- Substation Design Instruction SDI 501 – Network configuration
- *Electricity Supply Act* 1995 (as amended)
- *Work Health and Safety Act* 2011 (NSW)
- *Work Health and Safety Regulation* 2011 (NSW)
- *Electricity (Consumer Safety) Act* 2004
- *Electricity (Consumer Safety) Regulation* 2006
- ENA National Electricity Network Safety Code (Doc 01-2008)
- Company Network Management Plan December – 2013 Review
- Service and Installation Rules for NSW
- AS 1000 -1998: The international system of units (SI)
- AS 60270 -2001 Recommendations for partial discharge measurements
- AS 1028 -1992 ; Power reactors and earthing transformers
- AS 1052 -2002 CISPR radio interference measuring apparatus
- AS 4392.2 -1996: Insulators, porcelain and glass

- AS 60137 -2008 High voltage bushings
- AS 1627.4 -2005: Abrasive blast cleaning of steel surfaces
- AS 1657-2013 : Fixed platforms, walkways, stairways and ladders – Design, construction and installation
- AS 60044.1 -2007: Instrument transformers Part 1: Current transformers
- AS 60529 – 2004: Degrees of protection provided by enclosures (IP Code)
- IEC 60567 – 2011: Sampling of gases and analysis of free and dissolved gases - Guidance
- IEC 60060 – 2006: High voltage test techniques definition and requirements for onsite testing
- IEC 60071 – 2011 :Insulation coordination – Definitions principles and rules
- AS 1768 – 2007 Lightning protection
- AS 1931.1 -1996: High voltage testing techniques
- AS 1939 -1990: Degrees of protection provided by enclosures
- AS 62271.100 -2008: High-voltage switchgear and control gear Part 1: High voltage alternating current circuit breakers
- AS 2067 -2010 Power Installations exceeding 1kV AC
- AS 60214 -2006: On-load tap-changers
- AS 60076 -2005-2013: Power transformers (all current parts)
- AS 62271.301-2005 - High voltage switchgear and controlgear Part 301: Dimensional standardization of terminals.
- AS 2650 -2005: HV AC switchgear and controlgear common requirements
- AS 2700 -2011: Colour standards for general purposes
- AS 4680:2006 - Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
- AS 4025.1 -1992: Full gloss enamel, oil and petrol resistant
- AS/NZS ISO 9001 -2008 Quality Management Systems
- AS 3000-2007 – Electrical installations (Australian/New Zealand wiring rules)
- IEC 60296 -2012 – Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear

4.0 DEFINITIONS AND ABBREVIATIONS

CT	current transformer
CTC	continuously transposed cables
DLA	dielectric loss angle (tangent) , also referred to as dielectric dissipation factor
DDF	dielectric dissipation factor, also referred to as dielectric loss angle (tangent)
Ellipse	Endeavour Energy asset database
EPA	Environment Protection Authority
ETS	Equipment Technical Specification
OLTC	on load tap changing equipment
OTI	oil temperature indicator
Redundant	One more than needed. A failure of one component will not result in the failure of the function, for example, if a fan is redundant it means that if one fan in the system fails, other fans will immediately take over its function. A component failure will not result in a functional failure.
SCADA	Supervisory Control and Data Acquisition
Ur	Nominal rated voltage

WTI winding temperature indicator

5.0 ACTIONS

5.1 General requirements

5.1.1 General

132/11kV 15MVA power transformers will be used throughout Endeavour Energy's network as part of a strategy to employ portable substations to cost effectively supply new load growth areas.

The transformer(s) supplied shall conform to all the current requirements of:

- AS 60076:2005-2013 for the transformer;
- AS 60137:2008 for high voltage bushings;
- AS 60214:2006 for the on-load tap-changer; and
- all relevant Australian and IEC Standards and this specification.

The equipment supplied shall meet the highest standards of engineering, design and manufacturing practices

The insulating medium shall generally be paper and mineral oil. For 11kV windings, enamel insulated conductor may be used. Where enamel insulated conductors are used, no direct turn-to-turn contact is allowed. This shall be facilitated by means of a radial spacer between each turn for complete axial separation. The new mineral insulating oil supplied shall be passivated and inhibited and meet the minimum requirements of Endeavour Energy specification ETS 0010 – Insulating oil.

Tap changers shall be supplied on the HV delta winding and suitable for high speed ($\leq 20\text{ms}$) on-load switching duty: the specific requirements are detailed in Annexure 1. Alternatively, tap changers may be offered on the LV side of this transformer for consideration but should be separate from the main offer and meet the suitability and voltage regulation requirements specified in Annexure 1.

The supplier shall provide everything necessary, including any special tools, usually supplied for the operation of the equipment, whether directly specified or not.

All equipment, except the outdoor primary and secondary bushing terminations, shall be effectively earthed and enclosed in earthed enclosures, to the extent that there is no safety hazard to operating personnel, to prevent accidental *shorts* by human error, flying objects or by rodents, and to prevent mechanical damage to the devices.

Primary and secondary bushings shall be of the configuration and type outlined in Annexure 1 and 5.4.11.

The design and construction shall be in accordance with the technical requirements stated. All materials shall be of a type and quality that will give a normal life expectancy of 50 years or more.

Equipment and components from third party suppliers, such as tap changer, bushings, control relays/devices and the like, shall not be modified without approval from the Network Substations Manager. Where a particular brand or model number is specified, these are Endeavour Energy's preferred options. Other makes and models may be submitted for approval by the Network Substations Manager. These will be evaluated on criteria such as quality, functionality, maintenance requirements and the need to keep additional spares and the overall lifecycle cost to Endeavour Energy.

Note: All values submitted to tender shall be guaranteed values and will be treated as such in the evaluation, and when assessing whether the delivered transformer meets the specification.

The supplier shall be responsible for all insurance relating to the transformer until the point of handover. The supplier to this specification and its subcontractors shall supply, deliver, offload, assemble and test all works to the nominated site at their own expense. The supplier shall pay all duty, GST, freight, cartage and all other charges in this process. All network access, business hours, insurances, traffic control, stakeholder management, site access and all duties required to safely meet these requirements are the responsibility of the supplier.

5.1.2 Work Health and Safety Requirements

Transformers shall be designed in accordance with the NSW Work Health and Safety Act 2011 and NSW Work Health and Safety Regulation 2011 as well as relevant Safe Work Australia and NSW WorkCover codes of practice and relevant safety standards. Compliance to the above shall require the designer and supplier to identify and consult and design to reduce risks associated with its equipment to a level that is as low as reasonably practicable for the lifetime of the transformer and its associated equipment. The lifetime shall include risk considerations for, but not be limited to the design, manufacture, delivery, installation, erection, commissioning, use, ongoing monitoring and repair, decommissioning, dismantling, storage and eventual disposal of the transformer and its associated equipment.

The supplier under this specification shall develop a risk assessment to meet the minimum requirements of Endeavour Energy Company Procedure GRM 0003 – Risk Management. The risk assessment for the power transformer and its associated equipment shall be submitted with the tender and will also be reviewed, discussed and agreed as part of the design review (refer 5.7.3). The supplier shall compile a risk assessment and risk register listing all the risks identified for its and all associated equipment and the control measures implemented to eliminate and where not practicable, minimise identified risks to a level as low as reasonably practicable. The risk register shall also form part of the supplied manual. Prior to the shipment of the power transformer, the supplier shall hand over a copy of the agreed risk register that also specifically outlines all remaining risks for the installation, operation, ongoing maintenance and eventual disposal of the power transformer.

If the designer of the transformer identifies reasonably practicable risk measures that differ from the minimum requirements stated in this specification, such measures shall be stated in writing for review by Endeavour Energy.

Additional specific health, safety and environmental requirements are detailed in 5.3.

5.1.3 Service conditions

The equipment shall be suitable for use on Endeavour Energy's 3-phase 50Hz system.

The system highest voltages, system earthing and fault levels are set out in Annexure 1.

The service conditions in which the transformer will operate shall be in accordance with AS 60076.1:2005 and as indicated in the table below.

Table 5-1: Service Conditions

Service condition	Criteria
Altitude	<1000m
Maximum ambient temperature	45 deg. C
Minimum ambient temperature	-10 deg. C

Service condition	Criteria
Annual keraunic days	30
Solar radiation- maximum	1.1 Kw/m ²
Average index of mean relative humidity: 9:00am	95%
Seismic acceleration coefficient (maximum)	0.09
Pollution level	Level IV
Ice coating	1mm
Wind speed	34m/s
Condensation/precipitation	Yes
Electromagnetic disturbance	AS 2650 cl.2.1 i
Duration for temperature drop by 20 deg. C	20 minutes

5.2 Network operating conditions

5.2.1 Site conditions

The transformers will generally be mounted outdoors on concrete slabs inside an oil containment bund. Transformers may also be installed within a sound enclosure having a height equal to or greater than that of the transformer.

5.2.2 Overload capacity and temperature rise limits

The transformer shall be capable of having its inherent cyclic and short term emergency overload capacity used in accordance with AS 60076.7:2013.

In particular, transformer components including tap-changers shall be rated such as not to limit this capability. Terminations and internal cables and busbars and all current carrying components, shall also be rated to suit this requirement. The bushings and tap-changer shall have a continuous current rating not less than 150% of the full load rating of the transformer at the maximum operating temperature.

Cyclic overload testing is to be proven with a temperature rise test stepping from 100% CMR (continuous maximum rating) in steady state to 110% CMR on the tapping position with the highest load loss for 8 hours. The winding hot spot rise of 90°C shall not be exceeded, that is a winding hot spot temperature of 130°C for an ambient of 40°C.

The transformer temperature rise limits shall not exceed those values set out in Annexure 1.

5.2.3 Short circuit withstand

The transformer together with all equipment and accessories, on any tapping, shall be capable of withstanding without deformation or damage the thermal and mechanical effects of external short circuits as may arise from any system fault with a capacity as set out in Annexure 1. External short circuits are not restricted to three-phase short circuits and therefore the thermal and dynamic stresses shall be suitable for all possible unbalanced external faults.

Short circuit design shall be as set out in AS 60076.5:2012 and shall be based on three (3) second duration. The manufacturer shall provide calculations and demonstrate at design reviews that the transformer will withstand both dynamic and thermal short circuit forces imposed during its whole life of operation.

The manufacturer shall supply details of a short circuit type test of a similar size and construction transformer. In the absence of a short circuit type test report of a similar transformer, the complete short circuit test shall be carried out on the transformer in accordance with AS60076.5:2012 if required by the Network Substations Manager. This requirement will be based on the ability of the manufacturer to provide evidence through test and/or calculation that their design and construction is suitable for the short circuit stresses applicable in Endeavour Energy's network.

The insulation and coil design shall be such that substantial coil clamping pressure is maintained throughout the life of the transformer, particularly in designs that do not allow for easy adjustment of coil pressure on site.

5.2.4 *Insulation coordination*

Suitable insulation levels and method of system earthing are as detailed in Annexure 1.

5.2.5 *Harmonics*

The transformer supplied shall be suitable for harmonic loads in addition to power frequency requirements. The transformer and its associated equipment supplied shall be suitable for harmonic loads of 7% total harmonic content inclusive of a maximum 1.5% even harmonic content. The load loss, excitation capability and temperature rise limits shall be guaranteed with this harmonic content.

5.2.6 *Core excitation*

The flux density in any part of the magnetic circuit including shunts should not attain a value that causes saturation. This applies to the specified voltage and frequency at any tap position and including transitory effects of combined system voltage, frequency fluctuations and harmonic load content.

Transformer shall have a minimum 30% constant flux over-excitation capability. The transformer supplied under this specification shall be proven suitable for operating continuously above rated voltage and below rated frequency at maximum continuous and allowance for cyclic rating (refer 5.2.2) for any tap position, without exceeding the limits of temperature rise detailed in Annexure 1 with the following additional conditions:

- With secondary voltage and volts per hertz at 105% of rating; and
- With load power factor at 0.86; and
- Frequency is at 47.5Hz

The transformer supplied shall also allow for continual operation above rated voltage and below rated frequency, on any tap at no load, without exceeding limits of temperature rise detailed in annexure 1 when the voltage and voltage per hertz are at 110% of rated values.

The maximum flux density shall be in accordance with the limits shown in annexure 1 and this is to be proven in the design review. At flux densities exceeding 1.9 Tesla, design justification and precautions to control saturation shall be explicitly detailed in the offer.

5.2.7 *Voltage regulation*

The transformer shall be able to regulate the voltage on-load within the tapping ranges indicated in Annexure 1. The specified voltage, ratio, impedance and timing requirements shall be met. Refer 5.4.10 for further detail.

5.2.8 *Interchangeability*

In order to manage network risks associated with transformer failures and spares management, the transformer and its parts including bushings, shall meet the mandatory dimension, technical and configuration requirement detailed in this specification and its

associated drawings referred in 5.9. Details of parts and accessories offered that are already in use by Endeavour Energy shall be provided by the supplier.

5.3 Health, Safety and Environmental requirements

5.3.1 Sound levels

The transformer may be installed in a residential area in close proximity to family residences. As a result of strict noise requirements, Endeavour Energy requires sound levels that are below the maximum sound levels detailed in Annexure 1.

Low noise performance shall be achieved by superior core and coil design (current and operating flux density). Sound level measurements for guaranteed performance shall be taken prior to adding any sand to sand pockets.

All main and auxiliary equipment, including the tap changer, tap changer motor box and linkages mounted on or near the transformer, shall be designed for operation within the specified noise limit, which includes both instantaneous and summated time noise levels.

A sound level test report shall be provided and shall be as set out in AS60076.10:2005. The sound power level test report shall be submitted for approval by the Network Substations Manager. All sound power level tests must satisfy the relevant validity parameters/conditions. If the parameters/conditions are not met, the testing method and or testing environment shall be changed to provide legitimate test results.

Sound power levels exceeding the specified levels will not be accepted.

The low noise option(s) that is, option 2 or 3 from Annexure 1) shall only be used at sites identified to require low noise power transformers in accordance with EMS 0001 – Environmental impact assessment and environmental management plans.

5.3.2 Losses

In order to maintain minimal lifetime cost of any transformer as well as for environmental reasons, the no-load and load losses as well as cooling equipment losses shall be guaranteed and will be evaluated in the financial assessment at the rates indicated in Annexure 1.

5.3.3 Fall prevention and safe working at heights

As far as practicable, the design of the power transformer shall consider the requirement that all operational and maintenance work can be performed at ground level. Where it is necessary to perform work at heights exceeding two (2) metres, permanently fitted handrails shall be provided along with a Maypole base for fall restraint. The safety at heights requirement shall be in accordance with the NSW WorkCover Code of Practice: Managing the risk of falls at workplaces Dec 2011.

The permanently fitted handrail is required and shall meet the requirements of AS1657:2013, supplemented by a Maypole base to achieve the fall restraint systems for maintenance. It shall be possible to place all handrails into an upright position without disconnecting any busbars, conductors or cables. Electrical clearances are to be maintained while the transformer is energised.

The handrail may need to be folded down to obtain phase to earth clearances to any live parts, including busbars, conductors, cables, or bushings when the transformer is energised. The busbars typically come onto the top of the bushings horizontally. The handrail should fold down about a horizontal line 500mm from the transformer lid, in line with the bushing turrets, as shown in the drawing below.

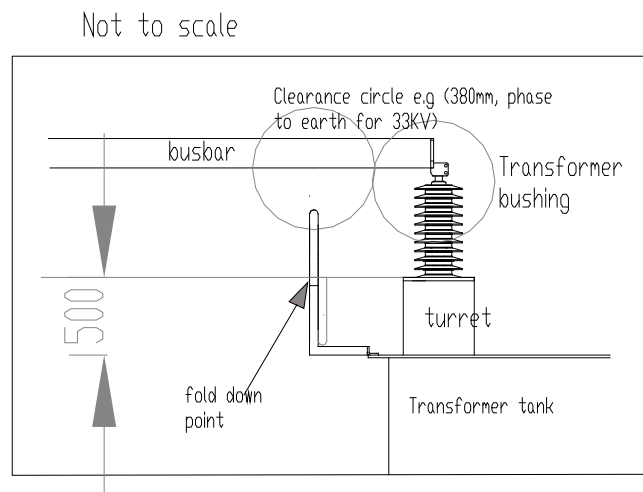


Figure 5-1: handrail and clearance requirements

The handrail may need to be folded down to obtain phase to earth clearances when the transformer is energised. It shall be possible to fold the handrail up or down without exposing the operator/technician to risk of a fall. Means shall be provided for locking the handrail when in the upright position.

Where a handrail is folded, it shall be to the inside of the transformer. The force required to lift the handrail shall not exceed 200N and the folding portion of handrail shall be fitted with stops to prevent it from folding outwards. Details of handrail are subject to approval in the design review prior to the manufacture of the transformer.

The risk of falls is increased by trip hazards particularly on the transformer lid and near where oil slips can occur. Trip hazards shall be clearly identified and eliminated as far as reasonably practicable in the design process. Oil handling equipment should be positioned so that any oil leaks do not impact on the lid of the transformer in particular.

Notwithstanding any of the above, employees will require access to the top of the transformer tank. Provision shall be made for a permanent ladder attachment and anchor points that will enable employees to have safe access to all elevated locations. Provisions for safe means of movement between different levels shall be provided.

5.3.4 Special environmental requirements: toxicology safety

The supplier shall provide with the offer, full details, including composition and toxicological information, regarding the health and safety aspects of the materials offered in their products.

Recommended procedures shall be provided for the safe handling, safe operation and maintenance of products supplied. The means of disposal of the materials shall be clearly stated.

Material safety data sheets (MSDS) shall be provided, with copies available on site, for materials that are supplied and subject to safety considerations in handling and use.

All equipment provided shall be asbestos free.

The above information is required as part of the offer and will be reviewed as part of the tender process.

5.3.5 Oil pollution

Joints between oil containing parts of the equipment shall be leak tight under all circumstances. Gasket joints shall be designed to avoid deterioration due to oil or excess strain.

Minimum gasket details are provided in 5.4.

5.3.6 Fire and blast hazards

The transformer and its components and in particular the tap changer, bushings and cable box shall be designed in a manner to reduce the risk of rupture and explosive failure and subsequent fire risk.

The appropriate sizing and locations of pressure relief devices, main tank, tap changer and cable box pressure withstand capability shall be key considerations in the design and be specifically addressed by the designer in the design review.

Suggested routine testing and maintenance regimes and limits (refer 5.4.15.3) shall be provided to manage ongoing risk of transformer and component failure.

5.3.7 Design for safe maintenance

Construction features shall be provided where necessary to enhance safe access to the tank lid, conservator, tap changer and gas accumulation relay for maintenance purposes. Suitable access points shall be provided for easy access to winding tails for collecting paper samples for tests. The exact location for proposed paper sampling should be provided by the supplier and additional paper placed at this point to assist with the safe removal.

5.3.8 Safe working systems

Prior to any site work, a comprehensive risk assessment of all hazards shall be carried out and mitigation measures identified and implemented. The work site hazard and risk assessment shall be provided to Endeavour Energy for approval seven (7) days prior to any commencement of work on site. Endeavour Energy reserves the right to specify additional mitigation measures, other than the mitigation methods specified by the supplier to maintain a level of safety whereby the work site hazards are controlled.

Works performed on or near Endeavour Energy's network shall be performed in accordance with Endeavour Energy's Electrical Safety Rules, Authorisations procedures and all relevant Safe Work Methods Statements (SWMS) and Safe Work Codes of Practice.

5.4 Technical requirements

5.4.1 General

The various technical components of the transformer supplied are specified in this section and in Annexure 1.

The key components in this technical sections and reference are provided in the table below:

Table 5-2: Technical requirement reference summary

Transformer Component	Reference
Core	5.4.2
Windings	5.4.3
Tank	5.4.4
Surface finish	5.4.15
Cooling system	5.4.6
Oil conservators	5.4.7
Insulating and cooling liquid	5.4.8
Fittings	5.4.9
On-load tap-changer	5.4.10
Bushings and terminations	5.4.11
Rating plate and labelling	5.4.12
Secondary wiring	5.4.14

All bolts, screws and nuts shall be ISO metric. All bolts shall be no longer than necessary. All bolts, nuts and washers used outside the tank shall be hot-dipped galvanised or grade 316 stainless steel. All connections shall be terminated using crimp lugs rated for maximum worst case fault duty. Clamps or u-bolt connections are not acceptable. All nuts within the tank shall be fitted with approved positive locking devices. Chemical locking is not permitted.

Bolts or studs of diameter less than 10mm shall not be used without the approval of the Network Substations Manager.

Sharp edges and corners shall be rounded off to avoid the risk of injury.

The general arrangement and configuration of all individual components shall allow for easy dismantling and removal without the need for dismantling of other components.

Welded surfaces shall be free of scale, dirt, grease, paint or heavy rust. The welding sequence to be adopted shall be such as to reduce distortion to a minimum. All slag shall be carefully removed after each run and all joints shall be seal welded.

All similar parts shall be accurately machined and set up by the aid of jigs, so that they can be interchangeable between transformers. All surfaces that will be connected together, or which have to be accurate for the purpose of sealing, levelling or setting up during erection, shall be accurately machined. Accurately set and machined dowels or holes shall be provided to allow correct and accurate fitting of all components.

5.4.2 Core

The core-form method of construction shall be used.

Cores shall be designed and constructed to withstand without deterioration the stresses imposed by service conditions, lifting, transport and handling.

The core shall be insulated from its supporting frame, clamps and tank. The core and its frame shall be individually earthed through a removable link, which is mounted on bushings external to the tank. The bushings and link shall be contained on the external side of the tank compartment in a protective housing to IP55. Links shall be readily accessible/ removable without the need to interfere with the oil system or ancillary equipment. The link and bushing shall be rated for core insulation testing.

The stray flux from windings must not cause the core surface temperature or that of steel limb stiffeners or tie-rods to become excessive under any operating condition, including overloading. Temperature rises of these components shall be in the general order of those of the windings.

The form of construction including core-bolts where applicable and core earthing method shall be fully described in the tender.

5.4.3 Windings

The windings shall be of the best modern design. Sufficient magnetic balance shall be maintained to satisfy the short circuit withstand requirements. Insulation materials shall be selected to provide stable clamping pressure that is maintained throughout the life of the transformer. The coil pressure ring at the top of the coils shall be constructed of a single piece per phase and be capable of supporting the forces applied during short circuits.

Conductors shall be free from scale and burrs and shall have suitably rounded corners. Individual strands shall not make inadvertent contact. This condition shall be verified after drying and with the winding clamped to full design clamping pressure by application of a 500V insulation test between paper insulated strands or 250V for strands within continuously transposed cables (CTC). No shorts between strands are permitted.

When using enamel insulated conductors, the conductors shall be separated by paper by means of a radial spacer to limit potential quality deficiencies in the enamel and particularly to prevent enamel to enamel contact in the axial direction (that is, direction of clamping pressure). Additional care is required for lead-outs when using enamel conductors and the design detail shall be fully described in the tender offer.

The type of windings used, including the conductor type, method of conductor jointing and the location and arrangement of winding end connections shall be fully described in the offer.

All packing materials at top and bottom of windings shall be positively and permanently held in position irrespective of winding or core movements. Radial spacers shall be lined up axially and vertical spacers/ribs shall be lined up radially.

5.4.4 Transformer tank

5.4.4.1 General

The tank design shall accept attached radiators.

All metallic surfaces including the tank lid shall be designed to prevent the accumulation of water.

Burrs and sharp edges on all steelwork shall be removed. All steel fasteners shall be either hot-dipped galvanised or grade 316 stainless steel.

All gasket joints shall be scarf joint.

The main tank shall have unpainted grade 316 stainless steel earthing terminals, welded to each corner of the transformer near the bottom of the tank.

A continuous fillet weld shall be used for stiffeners or attachments that are exposed to weather. Tack or intermittent welding shall not be used in any circumstances.

Gaskets shall be made of a high transformer grade neoprene impregnated cork material. Suitable alternatives to neoprene gaskets may be considered by the Network Substations Manager if their performance is superior to neoprene and full details are provided.

Suitable lugs shall be provided on the tank (or the underframe) for the attachment of handling tackle.

Construction features shall be provided where necessary to enhance safe access to the tank lid, conservator, tap changer and gas accumulation relay for maintenance purposes. Suitable access points shall be provided for easy access to winding tails for collecting paper samples for tests.

5.4.4.2 Handling facilities

Refer 5.4.5.

5.4.4.3 Jacking pads

Four (4) jacking pads shall be provided on the tank in locations to maximise the stability when lifting the transformer filled with oil.

The underside of each pad shall be:

- Free of gussets.
- At least 200 mm wide, project at least 280mm clear of the tank wall.
- Not less than 410 mm and not more than 500mm above the base of the tank.

Any other designs are subject to the approval of the Network Substations Manager.

5.4.4.4 Mounting plates

The base of the transformer shall have adequate strength to support the transformer when placed on the ground. The base or welded plates shall support the transformer through anti-vibration pads. The base or plate dimensions shall be fractionally larger than the anti-vibration pads.

5.4.4.5 Anti-vibration pads

Anti-vibration pads shall be provided. They shall be oil and weather resistant rubber or equivalent material. Their surface area and layered construction shall be such that vibration attenuation at 100Hz is achieved (assuming infinite ground impedance). Details of the attenuation and design for anti-vibration shall be provided by the supplier in the design review.

5.4.4.6 Lashing down/pulling lugs

Lugs shall be provided for:

- Lashing down the transformer securely when being carried on a road transporter.
- Enabling the transformer to be hauled in each direction along the lines of travel.

Pulling lugs shall be located on the centre line of each tank side, near the base of the transformer.

5.4.4.7 Cover

The tank lid shall be welded to the top of the tank. However, the core assembly shall not be supported by the lid. All metallic surfaces including the tank lid shall be designed to prevent the accumulation of water, that is, built with sufficient slope to shed water.

The tank and lid shall be designed so that all possible internally generated gases (including gases from spaces under access covers) will vent to the Buchholz relay.

Fixings shall be provided for attachments to provide a safe working environment when employees have to work on the top of the transformer. All pipes and equipment on top of the transformer shall be located in such a way as to maximise the safe movement of personnel.

5.4.4.8 Oil-tight joints

Oil leaks from the main tank-cover joint or other joints are unacceptable under any static oil-head or forced oil conditions or excess strain at any ambient and maximum operating temperatures. Only joints of proven design, capable of preventing deterioration of any seal or gasket materials shall be supplied and guaranteed.

5.4.4.9 Air release plugs

Air release plugs shall be provided at all points where air can be otherwise trapped during oil filling operations. This shall include, but not be limited to; each radiator cell, pipework between radiators and main tank, headers pipes, tap changer, main tank and pump.

5.4.4.10 Vacuum and pressure requirements

The tank shall be designed to withstand without leakage an overpressure of 50kPa absolute over the top of the oil filled transformer, in accordance with the test requirements and shall withstand full internal vacuum without oil.

5.4.4.11 Valves and oil facilities

All pipework is to be suitably braced and protected against being inadvertently stepped on and to allow safe unhindered access to employees.

Pipework and associated valves shall be extended to provide effective transformer and tap-changer filling, draining and filtering facilities at ground level. All pipework/valves are to be terminated 1200mm above ground level.

No valves shall be welded to the transformer main tank, and all valves should be easily accessible when all transformer auxiliaries are fitted.

Filtering/draining/sampling valves shall be provided on top and bottom headers of the separate radiator bank.

All terminating valves shall be of the gate type and have a 40mm nominal bore and fitted with a 100mm flange on the open side of the valve and have blanking plate fitted. All valves shall be fitted with a gasket between the valve flange and blanking plate. All blanking plates shall be secured to the valve by a chain welded to the plate and valve flange.

All terminating valves shall have permanent stainless steel labels adjacent to the valve clearly defining the valve function, for example, *Main conservator fill*, *Tap-changer drain*, *Main tank filter*, and so on.

An oil sampling valve, approximately 15mm nominal bore with 100mm flanges and blanking plates, shall be fitted in the bottom of the main tank and the radiator header pipe.

Oil draining valves shall be provided at all locations where oil can be trapped while disassembling pipe-work.

Details shall be supplied of an option of a suitable online oil drying system that may be fitted to the transformer.

5.4.4.12 Circulating and eddy currents

The tank shall be designed to minimise the losses caused by circulating and eddy-currents and avoid elevated temperatures at any part of the tank surface and at flanges between parts of the tank and its components including gasket sealed joints.

5.4.4.13 Inspection and access covers

Suitable access shall be provided for inspecting and servicing the tap switch selectors, internal bushing connections, CTs, winding tails, and earthing connections.

Access to these positions must be achieved without dropping the oil level below the core and winding and in particular the top of the winding clamping structure.

The openings shall have dimensions that allow unimpeded access to carry out the intended works.

All access covers shall be provided with lifting handles.

5.4.4.14 Conservator tanks

There shall be an oil conservator for the main tank and another one for the OLTC. Refer 5.4.7

5.4.4.15 Tank earthing

The tank shall have four (4) unpainted grade 316 stainless steel earthing terminals welded on each of the corners of the tank near the bottom of the tank.

The earthing terminal shall match a type 4 terminal palm as set out in AS 62271.301:2005, with the addition of a 50mm x 100mm extension shown at right. The earthing terminal shall be drilled with two (2) x 18mm diameter holes at 50mm spacing to accept two (2) x M16 bolts.

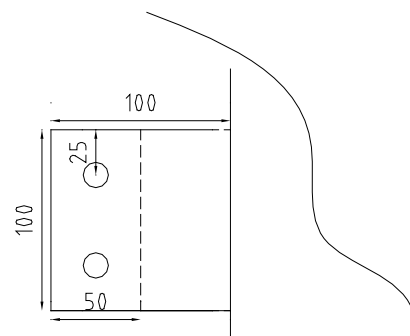


Figure 5-2: Tank Earth Tag

Welded studs shall be provided on the transformer tank to support the neutral leads/conductor from the transformer LV neutrals to the nearest earth terminals by a direct route. The studs shall be capable of fitting low voltage support bushings or brackets.

Additional studs shall be provided in the neutral/earth route for mounting of a toroidal neutral CT.

There shall be two (2) suitable earthing terminals on each cooler bank support structures for connecting directly to the earth grid.

Other internal and external metal parts of the transformer shall be earthed to the tank or separated to an earth bar installed at this site. Closed circulating current loops shall be avoided. All flanged joints and inspection covers etc. shall be electrically bridged.

5.4.4.16 Pressure relief for main tank

At least one (1) pressure relief device shall be fitted to the main tank and shall be of a self-sealing spring design. The pressure relief device shall preferably be located near the top of the tank and shall be located based on the pressure assessment performed by the designer. The pressure relief device shall have an approved oil deflection collar and piping or appropriate coverage shall be connected in order to direct oil down near the base of the transformer.

The device/device(s) shall incorporate a switch having one (1) normally open contact capable of making, carrying and breaking 0.5 Amps in a highly inductive circuit at 120V dc. The switch shall operate on activation of the pressure relief device.

5.4.5 Lifting facilities

The tank, tank cover, core, radiators, conservator and the housings/covers of all accessory items, including the pressure relief device, shall be provided with suitable lifting lugs or eyes. All lifting lugs or eyes shall be appropriately rated and identified with a suitable lifting symbol. The tank lifting lugs or eyes are to be suitable for lifting the complete transformer when filled with oil.

The height required from floor to crane hook (including slings) when the core and winding assembly is being removed from the tank shall not exceed nine (9) metres.

5.4.6 Cooling system

The 15MVA power transformer preferred cooling specification is ONAN only. However fans and pumps will be considered provided they meet the technical and layout requirements of this specification and will also be reviewed in terms of the lifecycle cost impact and maintenance.

5.4.6.1 Radiators

The tank design shall be for attached radiators.

The exterior of all radiators shall be hot dipped galvanised. The interior of all radiators shall be varnished. Radiators must be cleared of excess varnish and contaminants.

Extruded aluminium radiators are not acceptable.

Valves shall be provided on the inlet and outlet sides of each radiator to allow isolation of radiators. These valves are to be flanged butterfly valves with compatible proven seals. No valves are to be welded to the tank header pipes or radiators.

Valves are to be permanently fitted to the tank wall or header pipes to allow removal of the radiator while the transformer is filled with oil. The purchaser reserves the right to remove radiators and test the integrity of the butterfly valves. Valves found to be leaking will require replacement.

Oil drain and filling valves with 100mm flanges and blanking plates shall be provided on each radiator unit.

One (1) redundant radiator shall be provided. This radiator shall be isolated during temperature rise testing. The guaranteed performance shall be met with any one of the radiators isolated. The Endeavour Energy representative attending the factory acceptance tests will decide which radiator will be isolated during testing.

Radiator pipework and headers shall be fitted with drain valves with 100mm flanges and blanking plates that effectively drain each section of pipe to facilitate removal of the pipe work without loss of oil. All valves shall be fitted with a gasket between the valve flange and blanking plate. All blanking plates shall be secured to the valve by a chain welded to the plate and attached to the valve independently to the valve mounting bolts. Isolation of a bank of detached radiators shall be achieved by means of gate valves.

5.4.6.2 Cooler control and motor drive box cubicles

All 230V/400V terminals shall be shrouded and fitted with a warning label. The terminals for these devices shall be segregated from all other terminals, shrouded against direct contact and provided with red-white engraved laminated PVC 'live connections' warning labels. Warning labels shall state with red letters of **Warning 230V AC** on a white background.

Mechanical requirements

Cubicles including the motor drive box shall be arranged to accept bottom entry cabling and shall be provided with 4mm thick aluminium or brass gland plates, suitably sized to accept all the required cables and still have at least 50% spare capacity.

Enclosures shall be separated from each other so as to allow safe and ready access to electrical controls, be supplied complete with a weather hood, and shall be vermin proof.

Vertically hinged doors shall be provided to allow access to all equipment in the cubicle. Each door shall be of full height and not exceed 1000mm in width.

The doors shall open through 120°, shall be provided with a device to secure the door in an open position, and be secured closed by not more than two (2) hand-operated lockable handles suitable for *Lockwood* 234/45 (8mm shank) locks. All doors shall be provided with grade 316 stainless steel or other non-corroding lift off hinges.

Outdoor cubicles shall be provided with a low surface temperature thermostatically controlled anti-condensation heater, interior cubicle light and associated control switches.

All cubicles shall be protected to IP55 and shall be located in a position so that its gland plate is no lower than 800mm and its top no higher than 2000mm (1800mm preferred) from the floor level of the transformer installation.

Equipment in cubicles

All cubicles shall be mounted in such a position that there is clear unimpeded access to the cabinet and all equipment mounted in the cabinet.

Control cubicles must be provided to house terminal strips, CT test links, monitoring equipment and protection and control equipment of each transformer.

Isolating switches shall be provided in the cabinet to enable all control circuits in the cabinet to be isolated during maintenance.

These switches shall be *Kraus and Naimer* C26 or equivalent, as approved by the Network Substations Manager.

The control cubicle is to be fitted with a double 15 Amp single phase GPO protected and supplied in accordance with AS/NZS 3000-2007 from the substation distribution board.

The supplier is also required to supply a phase voltage supply monitor to connect to the *AC supply failure alarm* terminal. The device is to have an adjustable setting between 340 and 440V (phase-to-phase) and confirm phase to earth volts are healthy.

Secondary wiring and termination

All wiring (internal panel wiring and external control cables) shall be carried out in accordance with SDI 526 – Control cabling, panels and terminations. Alternative type tested connections can be utilised as approved by the Network Substations Manager.

The supplier shall make themselves aware of these requirements before submitting the tender.

Control wiring terminal blocks

The terminals shall be *Klippon*, *Entrelec* M series, *Phoenix* UT series or *Weidmuller* WDU series or equivalent, as approved by the Network Substations Manager.

Current transformer terminal blocks shall be of the stud type, minimum diameter 5mm, or tunnel connectors. Where tunnel connectors are used, they shall be of the spring pressure type, for example, WDU SL.

Protection circuit terminal blocks shall be tunnel connectors of the spring pressure type for example, WDU SL.

5.4.6.3 Directed oil and air auxiliaries (as applicable)**Oil pump**

Only one (1) pump is required and low oil flow rates are preferred. A non-return valve shall be provided on the outlet of the pump.

Valves shall be fitted on both sides of the pump so that the pump can be removed without the need to drain oil from the main transformer tank or radiator.

The operation of the oil pump (starting, stopping and running) shall not cause the *Buchholz* (oil surge component) relay to operate. This may be achieved by using soft starters. A pump fail alarm shall be raised in the instance where the pumps have failed to run as required by the control system.

Fans

Fans shall be low noise with non-ferrous metal blades and heavy gauge galvanised wire mesh guards for safety. Bearings shall be fully sealed.

The motors shall be corrosion resistant and totally enclosed to AS 1939:1990

One (1) redundant fan shall be installed. The redundant fan is to be isolated during temperature rise testing. The guaranteed performance shall be met with any one of the fans isolated.

Each fan shall have an isolating switch. The failure of a fan should initiate an alarm and the redundant fan should be made available.

The preferred location for fans is underneath the radiators.

Order of operation

Directed oil cooling is required to operate before forced air-cooling.

Fan and pump control

A multi-position switch - *Kraus and Naimer* C26 or equivalent, as approved by the Network Substations Manager - shall be provided to operate the fans and pumps in the following manner:

Position 1:	Auto - fans and pump
Position 2:	Off - fans and pump
Position 3:	Manual - pump
Position 4:	Manual - fans
Position 5:	Manual - fans and pumps

Where multiple service pumps are installed, progressive activation shall be provided.

Control and auxiliaries

A separate weatherproof control cubicle, protected to IP 55, complete with cooling control equipment as shown on the typical schematic drawing, shall be supplied. The cubicle shall be mounted on the transformer tank.

A contact for monitoring the status of the fans and pumps shall be provided. The contact shall be suitable for making, carrying and breaking one (1) Amp in a typically inductive (magnetic coil) circuit at 250V ac or 120V dc

The supplier shall take into account the starting and running currents of all pump and fan motors to be used in the cooling system when determining suitable motor protection requirements.

This auxiliary equipment shall be controlled from the winding temperature indicator or associated equipment which has provision for independently adjusting both the *cut-in* and *cut-out* of the fan motors and pump motors. Additionally, a facility shall be provided in the control system for SCADA control of the cooling system.

Hysteresis should be applied in the fan and pump control circuits to prevent the motors from hunting. To achieve this, the fans and pumps, shall be turned on by the WTI and turned off by the OTI.

For control and auxiliary wiring a maximum of two (2) wires on each terminal are allowed.

5.4.7 Oil conservators

There shall be an oil conservator for the main tank and another one for the OLTC.

5.4.7.1 Main tank and tap-changer conservator

The main tank and tap-changer conservator shall be designed for a temperature range of -5 deg. C to 120 deg. C.

The capacity is to be such that with the transformer operating at top oil temperature of 95 deg. C, the volume occupied by the oil shall not exceed 90% of the total capacity of the conservator.

The pipe to the gas relay shall finish 25mm above the bottom of the main conservator, providing a sump to retain any heavy contaminants.

The bottom oil level of conservator is to be not less than 75mm above the highest point of the gas and oil relay.

The bottom of the both the main conservator and the tap changer conservator should be level. The bleed pipe from the tap changer conservator should reach above the top of the main tank conservator. Both conservators should be mounted adjacent to each other on the same side of the transformer.

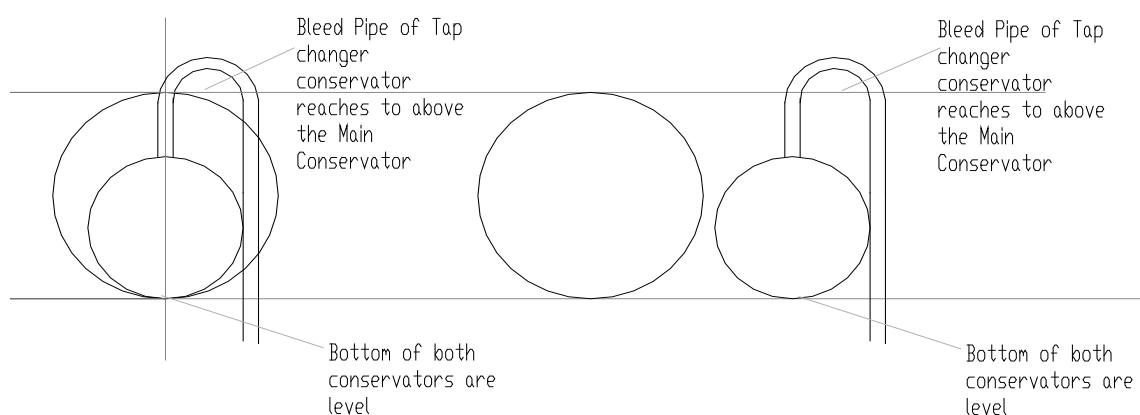


Figure 5-3: Conservators level and bleed pipe

5.4.7.2 Main tank and tap-changer oil level indicator

The oil level indicator is to be clearly visible from ground level without the aid of optical devices and be suitably marked to indicate the correct level at 20 deg. C, 60 deg. C and 90 deg. C.

Electromechanical oil level indicators shall be provided. The maximum and minimum oil level shall trigger alarms at the control panel; these will be wired to Endeavour Energy's SCADA system.

Each contact shall be suitable for making, carrying and breaking one (1) Amp in a typically inductive (magnet coil) circuit at 250V ac or 120V dc.

5.4.7.3 Main tank and tap-changer dehydrating breather

The main tank and tap-changer conservator shall be fitted with dehydrating breather(s). The capacity of the charge shall be at least equal to that recommended by the breather manufacturer for the respective oil volume. Alternative self-drying silica gel breather systems, in which the silica gel is continuously dried automatically, can also be offered and will be considered in the lifecycle cost assessment of the transformer.

5.4.7.4 Main tank and tap-changer conservator fill/drain/oil filtering

The main tank and tap changer, including conservators, shall be provided with oil filling/drainage/filtering pipe work and termination valves located 1200mm above ground level to allow for effective oil filling/drainage/filtering from ground level.

An equalising valve, connecting the main tank dehydrating breather pipe and main conservator filling/filtering pipe, shall be provided for equalising the pressures in the main conservator when pulling vacuum before oil filling. This valve shall also be located 1200mm above ground level.

All valves are to be appropriately labelled to describe their function,

5.4.7.5 Connection and removal

Bolted flanged joints on pipe work and bolted mounting on a horizontal surface shall be used so that the conservators can be readily removed with a minimum of disturbance to other equipment.

5.4.8 Insulating and cooling fluid

5.4.8.1 Mineral insulating oil requirements

The insulating oil used shall be new passivated inhibited mineral oil meeting the minimum requirements of ETS 0010 – Insulating oil, and shall not contain PCB or other contaminants or known or suspect carcinogens. The oil shall have no traces of chemicals having a corrosive sulphur tendency.

The supplier shall use new inhibited mineral oil during works testing. Details of the oil, including oil test results for the oil used during testing, shall be provided to the Network Substations Manager to verify the comparability of the test oil and the final installed oil.

Evidence shall be produced by the supplier, to show to Endeavour Energy's satisfaction, that oil added on the site is equal to or better in quality to that used in the factory to complete type and/or routine tests.

Under no circumstance shall any degree of forced-oil circulation create a static electrification hazard in any part of the transformer under any operating condition.

The main transformer tank as well as the tap changer shall each have a label affixed to their respective oil filling points. The label shall read as follows:

'Use inhibited and passivated oil only'

5.4.8.2 Oil filling

Oil filling of new approved mineral insulating oil shall be performed under vacuum. The vacuum held on the tank should not exceed the design strength capability of the transformer. Oil filling shall be performed with clean hoses and through an oil filtration unit. The temperature of the new oil in the filtration plant shall at no time exceed 60°C.

5.4.9 Fittings

5.4.9.1 Buchholz relay

A double float relay of the Buchholz type, depending for its operation upon the formation of gas or an oil surge in the main tank of the transformer, shall be fitted. It shall also operate in the event of loss of oil from the relay. The surge sensitivity level of the relay shall be set by the supplier. The switch shall be of the reed type with contacts suitable for making, carrying and breaking one (1) Amp in a typically inductive (magnet coil) circuit at 250V ac or 120V dc.

It shall be located so that the relay mechanism may be readily removed without the need to disconnect the relay casing from the pipework.

Spindle gate valves shall be provided on the inlet and outlet side of the relay so that the relay can be removed without dropping oil level.

The Buchholz relay is to be positioned over the main tank in a convenient, safe access position for maintenance. Where it is not practical to mount the Buchholz relay over the tank, a maintenance platform and handrails shall be fitted allowing clear unimpeded access to the relay.

A ground level gas receiver shall be fitted.

5.4.9.2 Temperature control and indication

A winding temperature indicator and top oil temperature indicator are required. The temperature indicators shall be mounted in a separate glass fronted weatherproof enclosure, protected to IP 55, mounted on the transformer using vibration-dampening supports.

Winding temperature indicator (WTI)

The winding temperature indicator shall be provided. The measuring system shall consist of Bourdon tube, stainless steel capillary tube and pressure sensor such that the secondary outputs are driven via the pressure sensor attached to the capillary tube and are independent of the indication needle movement. A reset pointer for indicating maximum reading shall also be provided.

The measuring sensor / bulb shall generally be located over the B-phase winding on the radiator side of the transformer on in the oil flow to the top header pipe. Locating the sensing bulb at the end of the tank is not permitted.

The device shall be suitable for sensing through the range of 0 deg. C to 160 deg. C, and shall have a scale length not less than 150mm. The accuracy of the temperature measurements shall be +/- 2 deg. C.

Four (4) adjustable change-over microswitches, circuit closing, that can be separately adjusted to operate at any temperature setting, shall be provided on the winding temperature indicator.

Two (2) of these contacts shall be suitable for setting to a fixed value for alarm and trip, and two (2) shall be suitable for possible future fan control. Each contact shall be suitable for making, carrying and breaking one (1) Amp in a typically inductive (magnet coil) circuit at 250V ac or 120V dc.

The device shall be suitable for sensing temperatures between 0 deg. C to 160 deg. C and have a linear output signal of 4mA to 20mA corresponding to the above temperature range. The device shall be designed to operate correctly and without damage at up to 20% in excess of the above parameters. A digital communication interface shall also be tendered. The required mandatory communication link is RS485 and Ethernet link. Communication protocols requirement is for DNP3 with Modbus and IEC61850. The tender submission should clearly indicate exactly what is being offered as part of the tender for suitability review in the design review.

The output signal shall be electrically isolated from other signals, power supplies and earth.

A current transformer is necessary for operation of the winding temperature indicator and it shall be incorporated in the transformer and shall be of the bar primary or through type.

The sensing bulb for the indicator shall be housed in a pocket sealed from the main tank and located in the tank cover close to the oil outlet to the cooling equipment.

Facilities shall be provided to set the degree of boost on the winding temperature indicator to suit the CT or other device provided to sense transformer load current. Suitable control circuits shall be supplied to allow for the correct boost in the circuit for all modes of transformer operation.

The following information shall be provided for WTI setting verification for all operating conditions (i.e. ONAN, ODAN, ODAF):

- The winding hot spot temperature gradient shall be based on the higher value of the heat run measured or the calculated value using a hot spot factor of 1.3 in accordance with AS 60076.7-2013 (the temperature gradient is to be included on the nameplate).

- The current required to heat up the WTI heating element.
- The resistance of the heating element.
- The current available from CT to drive the heating element.
- Amount of current to be shunted.
- Ohmic value of the shunt resistor.
- The CT ratio.
- The total resistance connected to the CT (the parallel resistance of the heating element and its shunt resistor) - associated formula for the above calculation should be provided. The shunt resistance shall be set at the factory during the heat run test to provide the correct current passed to the heating element
- In order for Endeavour Energy to check the WTI at commissioning, the supplier shall indicate the amount of current to be injected and the corresponding °C temperature rise expected.

The WTI CT shall have links provided to allow for testing of the entire circuit and for insulation resistance tests to earth.

Top oil temperature indicator

A top oil temperature indicator shall be provided. The measuring system shall consist of Bourdon tube, stainless steel capillary tube and pressure sensor such that the secondary outputs are driven via the pressure sensor attached to the capillary tube and are independent of the indication needle movement. A reset pointer for indicating maximum reading shall also be provided.

The measuring sensor / bulb shall generally be located over the B-phase winding on the radiator side of the transformer on in the oil flow to the top header pipe. Locating the sensing bulb at the end of the tank is not permitted.

The device shall require no periodic readjustment or recalibration during the lifetime of the transformer.

The device shall be suitable for sensing through the range of 0 deg. C to 140 deg. C, and shall have a scale length not less than 150mm. The accuracy of the temperature measurements shall be +/- 2 deg. C.

Four (4) adjustable change-over microswitches, circuit closing that can be separately adjusted to operate at any temperature setting, shall be provided on the winding temperature indicator.

Two (2) of these contacts shall be suitable for setting to a fixed value for alarm and trip, and two (2) shall be suitable for fan and pump control. Each contact shall be suitable for making, carrying and breaking one (1) Amp in a typically inductive (magnet coil) circuit at 250V ac or 120V dc.

The device shall be suitable for sensing temperatures between 0 deg. C to 160 deg. C and have a linear output signal of 4mA to 20mA corresponding to the above temperature range. The device shall be designed to operate correctly and without damage at up to 20% in excess of the above parameters. A digital communication interface shall also be tendered. The required mandatory communication link is RS485 and Ethernet link. Communication protocols requirement is for DNP3 with Modbus and IEC61850. The tender submission should clearly indicate exactly what is being offered as part of the tender for suitability review in the design review.

Fibre optic temperature sensors (optional)

As an option, fibre optic probes shall be embedded in the transformer with a minimum of one probe on each of the phases of both the HV and LV windings. The option for fibre optic temperature sensors is subject to approval by the Network Substations Manager based on the expected benefit it could provide and the lifecycle cost impact.

The sensing end of the probes shall be positioned at calculated hot spots within the selected windings. The exact locations of the temperature sensing probes shall be agreed by the Network Substations Manager.

The probes shall be used for hot spot temperature measurement during the testing of the transformer, and may be subsequently used for hot spot measurement during service.

The contractor shall supply the thermometer for the fibre optic temperature measurement during the factory testing to monitor all temperature probes simultaneously. The temperature readings of all fibre optic probes shall be logged at a maximum of two (2) minute intervals for the first 30 minutes, and at a maximum of 10 minutes thereafter until the completion of the heat run tests.

Details of the fibre optic sensor, including brand and type, shall be supplied on the transformer nameplate. A diagrammatic representation of the external connection terminals of the fibre optic sensor shall be included on the transformer nameplate.

The oil to air interface of the fibre optic probes shall be mounted at a level above the top of the windings and terminated in a separate junction box mounted on the exterior of the tank. A user interface for the fibre optics shall be mounted in the control cubicle for the purposes of taking online temperature measurements. All fibres from the fibre optic probes should be brought down to the fibre optic interface.

Fibre optic temperature interface (optional)

Where fibre optic temperature sensing is offered, a fibre optic interface, as approved by the Network Substations Manager, shall be installed. The interface shall be capable of retransmitting temperature information to the SCADA system as well as providing local information and control. The interface shall be terminated onto a user interface or a separate plate that allows access from the front to connect the fibres to the user interface. The number of fibre optic patch leads supplied should match the number of channels of the measuring interface.

The controller shall be suitable for sensing temperatures between 0 deg. C and 160 deg. C and have a digital communication interface. The required mandatory communication link is RS485 and Ethernet link. In terms of communication protocols, preference is for DNP3 with Modbus and IEC61850 as optional protocols. The tender submission should clearly indicate as exactly what is being offered as part of the tender.

The device shall be designed to operate correctly and without damage at up to 20% in excess of the above parameters, and to operate in an environment where the ambient temperatures may exceed 50 deg. C. The output signal shall be electrically isolated from other signals, power supplies and earth.

Temperature and control settings

The specified differential in the cut in and cut out temperatures for Pumps and/or Fans controls can be implemented by using WTI/OTI control contacts with adjustable hysteresis. A control scheme based on Pumps and/or Fans' cut in by WTI contact and cut out by OTI is the preferred option. Alternatively, the winding temperature indicator (WTI) is can be the device to turn on the cooler controls. The operation method shall be of a hysteresis setting to prevent cycling based on the transformer cooling design. The supplier shall submit the proposed scheme in the tender process.

An alarm shall be wired to indicate if either or both the pumps and/or fans are not running.

The transformer shall have alarm and trip settings based on the design with an example outlined in the table below:

Table 5-3: Typical alarm and trip settings of WTI / OTI

WTI driven (°C)		OTI driven (°C)	
Alarm	Trip	Alarm	Trip
120	130	90	Non-auto

5.4.10 On-load tap-changing facility

5.4.10.1 General construction

The transformer shall be fitted with an external bolt-on, on-load tap-changer (OLTC) having the operation details as set out in Annexure 1. An internal tank on-load tap-changer is not acceptable unless it is of the vacuum diverter type.

Where the HV tap changer is used, the OLTC shall be generally be placed in the centre of the delta winding. Where alternative positions are offered by the supplier, additional impulse testing in excess of those detailed in 5.8.1 will be required which shall also measure output on the open tap windings to determine the whether the equipment can withstand the voltages imposed.

LV tap changers meeting the network requirement details specified in this specification will be considered but should be provided separately from the main offer.

The arc chamber shall be pressure proof, gas proof and fully isolated from the main tank oil. There shall not be any intermix of tap changer switch oil and cooling oil or possible contamination of the cooling oil with gases derived from the tap-changer.

Maintenance of the tap-changer shall be possible without disturbance of the main transformer oil system. Barriers shall be rated for full tank and conservator oil pressure and overpressure (50kPA over pressure) and withstand full internal vacuum.

Endeavour Energy prefers the ABB UZ tap changers: other types are subject to approval by the Network Substations Manager. The base offer should include the ABB UZ tap changer. Tap changers offered shall be of a type with non-proprietary support and have market accessible parts and servicing. Technical support of the tap-changer and its maintenance should be provided over the asset lifecycle.

Prices may also be provided for a vacuum tap changer with indications of the savings that may be experienced over the life cycle with this option.

A separate pricing schedule and technical details for an offer based on an alternative automatic on-load tap changing scheme may be submitted. The scheme shall be functionally similar to the scheme described above. Full details of the alternative scheme shall be supplied with the tender and acceptance of the alternative is subject to the approval of the Network Substations Manager

5.4.10.2 Tap changer pressure relief device

A pressure relief device/s shall be fitted to the tap changer tank.

The device/s shall be fitted with a cover designed to direct oil discharges towards the ground in the bund area and away from all manual control points. The device/s shall be self-sealing spring design.

5.4.10.3 Motor drive cabinet

The tap changer operation shall be designed for control by the following and shall be wired in accordance with the enclosed typical schematic drawings for 230V ac operation. The features shall include:

- Raise and lower control switch at the transformer. Each switching operation shall initiate only one tap-change such that the switch must be turned to the off-position and the tap-change completed before initiating a new tap-changing operation.
- Raise and lower operation from remote control equipment to be provided and installed by Endeavour Energy.
- Automatic voltage regulation apparatus to be provided and installed by Endeavour Energy.
- Manual handle for emergency and maintenance operation. Insertion of the handle shall lock out by automatic mechanical means, all electrical operation.
- Additional weatherproof labelling shall be permanently attached to the tap changer control cubicle to warn service personnel of the existence of AC control systems.

All control and auxiliary equipment associated with the tap changer shall be mounted in a separate weatherproof motor drive cabinet and is to be within the area designated on the typical arrangement drawing. All SCADA signal terminals in the cabinet shall be wired back to the transformer control cubicle.

5.4.10.4 Electrical operation and control

The general requirements for operation and control are indicated in the drawings in section 5.9

The transformer will be required to operate automatically, either individually or in parallel with other units.

The tap changing equipment shall be arranged for single step operation so that, once an operation is initiated, the completion of the operation is outside the control of the operator, who must first release the control switch before a further tap changing operation can be initiated.

A '*tap change in progress*' physical flag preferably or lamp shall be fitted to indicate the complete period of a tap changing operation and it shall remain flagged or alight if the tap changing operation is incomplete for any reason. The arrangements shall be such that immediately after the *tap change in progress* flag or light is switched off; the push button can be pressed for a further tap change.

A LOCAL/REMOTE changeover switch, *Kraus and Naimer* C26 or equivalent shall be provided in the transformer control cabinet so that the equipment may be placed under the control of either the local or remote operating switches. At the remote control point, a changeover switch will be installed (by others) to select manual or automatic control.

5.4.10.5 Ancillary equipment to be included in control cabinet

The weatherproof control cabinet shall house the following:

- A mechanical tap position indicator.
- A manually reset *Range of Operation* indicator to indicate the range of tapings over which the equipment has operated since the indicator was last set.
- An operation counter.
- Adequate auxiliary switches to carry out all functions necessary for the operation of the transformer tap changer and control and indication as set out in the attached drawings plus:

- Four (4) sets of contacts to close and remain closed whilst a tap changing operation is in progress.
- Four (4) sets of contacts to open and remain open whilst a tap changing operation is in progress.
- The auxiliary switches shall be capable of making, carrying and breaking one (1) Amp in a typically inductive (magnet coil) circuit at 250V ac or 120V dc.
- Limit switches to prevent over-travel of the tap changing gear, the switches being provided in the motor supply circuit and also in the motor control circuit.
- Facilities shall be provided to limit the tap range between any two (2) selected taps.
- Access shall be provided to carry out the necessary adjustments without the need to dismantle equipment. There shall be a minimum of 900mm unimpeded access in front of the motor box with the door opening 120° toward the transformer to allow access.
- One (1) multi-contact tap position indication switch, having at least as many contacts as tapping switch positions, and in which the contact corresponding to the actual tap position at any time is bridged to a common centre contact. The switch is to be *BREAK BEFORE MAKE*, and its contacts are to be wired to accessible terminals in the cabinet in accordance with the typical schematic drawing. The contacts shall be suitable for 230V ac or 120V dc and shall have a rating of one (1) Amp in a typically inductive (magnet coil) circuit at 120V dc.
- A tap position encoder shall be installed to convert the 21 (max) tap positions into a five (5) digit binary output. The five (5) outputs will represent the following values:

Output	Value	Description
1	1	least significant bit
2	2	
3	4	
4	8	
5	16	most significant bit

- Maintenance light - lighting shall be provided inside the cabinet to assist maintenance when required outside daylight hours.

5.4.11 Bushings and main terminals

The transformer shall have bushings on the 132kV side and a cable box on the 11kV side. Bushings shall comply with the requirements of AS 60137:2008.

The transformer terminations shall be in accordance with the requirements set out in Annexure 1. The internal termination on bushings shall be as set out in Table 1 and Table 2 in AS 62271.301:2005.

5.4.11.1 Bushings

All bushings shall be fitted on a turret not less than 500mm in height. The bushing locations shall be in accordance with the following sketch.

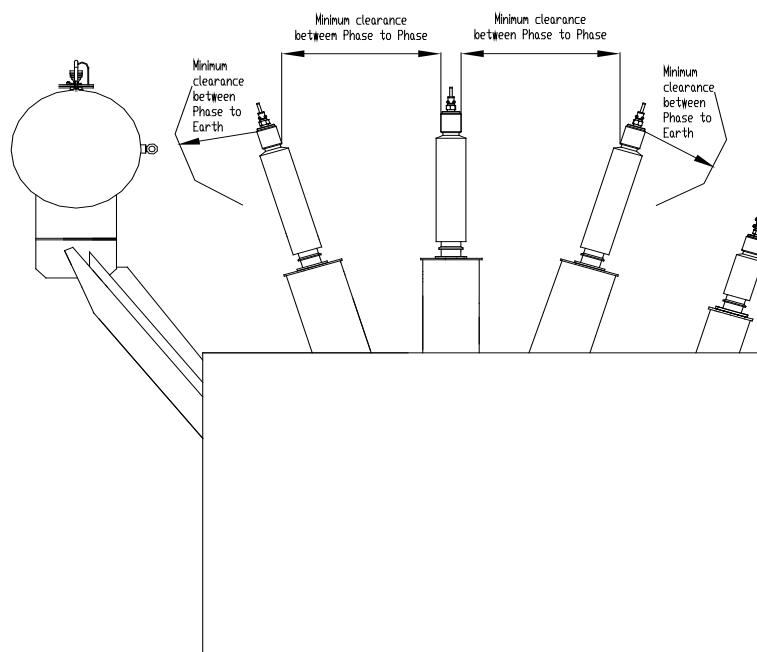


Figure 5-4: 132kV bushing locations

Bushings with rated voltage (U_m) equal to or exceeding 72.5kV shall be capacitance graded outdoor with resin impregnated paper (RIP) as the major insulation. The external insulation shall be porcelain. Silicone insulators may be used subject to approval by the Network Substations Manager provided they are of the high temperature vulcanised type and proven unsusceptible to animal caused breakdown and clearances can be maintained if porcelain bushings were to replace the silicone bushings. The insulator colour shall be light grey, similar to T33 Mist Blue, as in AS 2700-2011. A test point shall be available to measure the bushing dielectric dissipation factor. The HV bushings are to be partial discharge free and meet all the requirements of AS/NZS 60137:2008. As an option, resin impregnated synthetic (RIS) bushings can be offered but shall be separate to the main offer.

RIP bushing shall remain dry and shall be tested at site for variation of capacitance and dissipation factor prior to acceptance. A capacitance increase of 3% from nameplate will require the bushing to be dried using an approved method in agreement with the Network Substations Manager prior to acceptance by Endeavour Energy.

Bushings for insulation levels up to (U_m) up to 72.5kV shall be oil filled porcelain bushings, preferably of the ESAA standard type or a suitable complete ceramic type. Options should be provided for suitable alternatives including a cast or moulded resin-insulated bushing for consideration by the Network Substations Manager. All sealed oil-filled bushings shall have sight glasses to enable the oil level to be monitored.

Bushing minimum nominal creepage lengths shall be as provided in Annexure 1.

The primary bushings shall be arranged so that all three (3) bushings shall be on the vertical plane with reference to ground and not more than 13° off the vertical.

External clearances shall not be less than those specified in AS 60076.3-2005 or in Annexure 1, whichever is the greatest. Oil pipe to live metal clearances shall at least equal the appropriate phase-to-phase clearances. Where the specified clearances to oil pipes cannot be achieved conveniently, the oil pipes shall be protected with a metal shield of approved configuration, but the clearances under this condition shall not be less than the specified phase-to-earth clearances. The shields, if fitted, are required as protection against the possibility of a phase-to-earth arc puncturing an oil pipe.

The bushings shall have a continuous current rating not less than 150% of the full load rating of the transformer at the maximum operating temperature. They shall also be suitable for a through fault current equal to the standard ratings indicated in this Specification.

A flat termination palm shall be provided. The palm size shall be in accordance with details specified in the drawings in section 5.9 or as approved by the Network Substations Manager.

5.4.11.2 Air insulated cable box

An air insulated cable box shall be provided for connecting high voltage single or three phase cables to the transformers. The transformer shall be supplied with a cable box set out in Annexure 1 and the associated drawings to allow the cable terminations.

The 11kV cable box arrangements shall be designed so the transformer can still function as normal with the bushing terminations, should the cable box be removed.

The box shall be designed for air insulation with cross flow ventilation and be attached directly to the transformer tank. Oil filled cable boxes will not be accepted.

The box shall be sufficiently strong to be self-supporting and not sag with the maximum number of cables fitted, or should have appropriate bracing that does not interfere with the installation and clamping of cables.

The box shall allow connection as indicated in Annexure 1.

An un-drilled solid busbar is to be provided for the connection of the HV cables.

Removable flexible connections are to be provided between the solid busbars and the bushings.

A flag with a hole suitable for one (1) M16 bolt is to be provided internally in the base of the box for cable sheath earthing.

The cable box dimensions are to be adequate to allow cable AC test for five (5) minutes, with the highest phase to phase voltage of the system applied between the conductor and the metallic screen/sheath after cable jointing is complete.

The minimum phase to earth clearances and the phase to phase clearances shall be those set out in Annexure 1.

These clearances are to be achieved with the cable box fully assembled and cables fitted with associated lugs, nuts, lock nuts, bolts and washers.

The clearances shall also be maintained for back to back cable arrangement on each busbar.

The cable box shall have unrestricted access for cable jointing. A removable hinged front door shall be provided with full unimpeded access.

The door shall be provided with lifting lugs and should not exceed 20kg in mass. Adequate sealing via bolts shall be provided for the hinged covers to prevent ingress of moisture, dust and vermin and for the safety of personnel.

A multi-section gland plate constructed of non-magnetic material is to be provided. This plate shall be constructed of sections or slats whereby the cables can enter the box through holes drilled by Endeavour Energy (using glands) between the section or slats.

In this way, the back section can be installed, followed by the first set of three phase cables, followed by the next section of plate, the next cable set and so on until the final section of plate is installed.

The number of sections or slats can be determined from the technical schedules in Annexure 1.

Endeavour Energy shall supply the glands and cable lugs.

The box shall be constructed so that adequate space is provided for cable terminating and gland centre lines shall be on the same centre line as the cable lugs such that no setting of the cable core is necessary.

The cable box height from the gland plate to the centre of the terminal palm shall be at least as indicated in Annexure 1, section 33 (e). The cable box shall be located in the position indicated in the drawing in section 5.9.

Facilities shall be provided to support/clamp the cables within one (1) metre of the termination. The bracket shall be constructed so as to prevent sagging while supporting the cables.

Access to the cable terminations in the cable box shall only be possible through the bolted hinged doors and the whole cable box shall be vermin proof after all the cables are installed.

5.4.11.3 Cable terminations

Cables shall be supported in a manner that will limit undue mechanical stress applied to any cable termination. The weight of the cables shall be taken by cable clamps, and no pressure or tension shall be exerted on the termination.

5.4.12 Rating plate

A rating plate shall be installed and comply with AS 60076.1:2005, Clauses 7.1 and 7.2, with the following exceptions and additions:

- An indelibly etched, engraved or stamped grade 316 stainless steel nameplate.
- % impedance of the transformer at nominal tap.
- Top oil, average winding and hot spot temperature rises for each cooling mode.
- Sound power levels at 100% and 105% excitation levels.
- Current transformer ratios, class, thermal limit, polarity and diagrammatic location of the CTs..
- Customer number, contract number, and space for the customer number to be inserted.
- Oil quantity in tap changer.
- Transport mass (without conservator, top header, radiators) including oil in main tank and without oil in main tank.
- Mass of core and winding including all cables, busbar, insulation and supports.
- Permissible maximum tank pressure.
- A connection diagram, including a plan view of the transformer showing the correct physical relationship of the terminals, tap-changer, control panels and radiators.
- Primary and secondary voltages and tap changer terminal connections are to be shown for each tap.

5.4.13 Labelling

All equipment shall be clearly labelled to show its function. All labels shall indicate the device name and functionality, for example, *4R OLTC RAISE RELAY*.

Labels used inside the control cubicle(s) shall be of laminated plastic having black upper case letters on a white background and shall be affixed using double sided foam tape suitable for the lifetime of the equipment.

Lettering and numbering on labels shall be as large as practical and preferably not less than 5mm high. It is preferred that all labels are of the same size, or at least the number of sizes is kept to a minimum. Labels shall not be directly affixed to items that are readily removable or interchangeable.

All external labels shall be of laser etched stainless steel type and be affixed by nickel plated brass screws or sealed stainless steel rivets.

Drawings of labels shall be submitted for approval by the Network Substations Manager

5.4.14 Secondary wiring

5.4.14.1 Conduits for secondary wiring

All conduits and fittings on horizontal surfaces exposed to walking shall be weatherproof and fixed with galvanised screws, or equivalent. All external wiring on the transformer shall be installed in steel conduits. Flexible terminations to accessories (i.e. fans or pumps) may be made by flexible conduit that is UV rated and prevent water ingress.

Where steel wire armoured cable is used, adequate support shall be provided. Protection shall be given where any cable touches sharp corners. Support shall be given in areas where cables are exposed to walking.

5.4.14.2 Secondary wiring termination

All wiring (internal panel wiring and external control cables) shall be carried out in accordance with SDI 526 – Control cabling, panels and terminations. Alternative methods of secondary cable terminations can be approved by the Network Substations Manager, where type tests and mechanical calculations have suitably proven the termination type.

5.4.15 Surface finish

5.4.15.1 General

One (1) supplier shall supply all coatings. Notwithstanding this, equivalent proprietary coats may be used subject to the approval of the Network Substations Manager. Other systems will be considered only if complete details of the proposed paint system are provided to the Network Substations Manager. The supplier shall provide evidence to Endeavour Energy's satisfaction that H&S is not compromised for their employees when applying paint on the transformer and its components.

Paints shall be in accordance with AS/NZS 3750:2008-2013 and the painting and preparation requirements shall meet the requirements of AS/NZS 2312:2012. The painting shall meet long term durability requirements. Both internal and external surface preparation prior to the application of paints shall be in accordance with AS 1627.4 Class 2.5.

5.4.15.2 Radiators

The exterior of radiators shall be hot-dip galvanised and the interior shall be varnished. The galvanising shall comply with Australian Standards with no more than 40mm² of touch up/repair to be on each radiator bank.

5.4.15.3 Tank, accessories and external surfaces

The following table 5-5 and Table 5-6 indicate the preferred paint system to be used. However the supplier can propose a paint system that shall be evaluated by the Network Substations Manager based on the following as outlined in AS 3750:2008-2013

- Evaluation by means of statistical sampling
- The use of a product certification scheme
- Assurance using the acceptability of the supplier's quality system
- Other such means proposed by the supplier and acceptable to Endeavour Energy

Table 5-4: External surface painting recommendation

Surface preparation: abrasive blast clean to AS1627.4 class 2.5.

Paint coats	Paint description	Recommended Thickness (microns)
COAT 1 (full coat) Grey Colour	Interzinc 52 with polyimide cured epoxy binder (2 pack)	75
COAT 2 (stripe on all edges, sharp corners, lap joints etc.) Red Colour	Interfine 979 with polysiloxane binder (2 pack)	(100)
COAT 3 (full coat) N35 light grey colour	“Interfine 979 with polysiloxane binder (2 pack)	150
Total		225

*Thickness is in DFT (DRY FILM THICKNESS) in microns***Table 5-5: Internal surface painting recommendation**

Surface preparation: abrasive blast clean to AS1627.4 class 2.5.

Paint coats	Paint description	Recommended Thickness (microns)
COAT 1 (full coat) white colour	Interfine 399 with epoxy Novalac binder (2 pack)	75

*Thickness is in DFT (DRY FILM THICKNESS) in microns***5.4.15.4 Touch up work**

After erection all damaged paintwork shall be touched up with the coating system as detailed in the clause above.

If a total of more than eight (8) sections or an accumulative area of 0.5m² is found to have unsatisfactory surface paint finish, the Supplier will be required to steam clean and repaint the whole transformer according to the above specifications and full satisfaction of the Network Substations Manager.

5.4.15.5 Paint thickness test

The supplier shall carry out paint thickness test if required by Endeavour Energy.

All film thickness measurements shall be made with Tinsley gauge or Microtest gauge.

5.4.15.6 Yokes, clamps and other components internal to tank

Yokes shall not be painted clamps and other painted components within the tank shall utilise the same paint used for the internal of the transformer.

5.5 Maintenance requirements**5.5.1 Spare parts and maintenance**

The supplier shall supply a list of recommended spare parts, special tools and appliances required for the whole of life operation and maintenance of the transformer installation. The list, together with prices, shall be indicated in the appropriate schedule. The supplier must also provide details of the recommended maintenance and the frequency at which it must be carried out. Special tools are to be part of the main contract.

The items nominated must allow most common defects to be repaired and recommended maintenance to be carried out expeditiously over the whole life of the transformer.

Recommended tests to be carried out throughout the life of the transformer and its components, including the pass/caution/fail criteria for each test shall be included in the offer.

Predicted availability of ex-stock parts over the life of the transformer is to be considered. Lists shall be complete with part numbers and current prices for each item.

Where identical items have been supplied to Endeavour Energy as spares on previous contracts, details of the quantity and type supplied shall be provided.

The final quantities of spares to be supplied will be decided as part of contract negotiations.

5.5.2 *Failure mode analysis and preventative maintenance*

The supplier shall indicate and provide updates to Endeavour Energy the mean time between failures (MTBF) of the transformer and its components including the recommended maintenance regime and maintenance tasks and intervals. This regime shall be based on the mean time between failure (MTBF) and the critical failure modes identified by the failure mode, effects and criticality analysis (FMECA) of the equipment. Details substantiating the FMECA analysis shall be included in the offer.

5.6 **Transportation**

The supplier to this specification is responsible for the transportation between a manufacturer's works and the site nominated by Endeavour Energy within Endeavour Energy's franchise area.

The costs, risks and responsibilities for transportation are the responsibility of the supplier and shall be agreed prior to contract acceptance. This include the responsibility for the load profile for each transport mode, transport route, the means of transport, any necessary route alteration, statutory approval or licenses, shipping reservations and documentation or any other requirement concerning the delivery of the transformer to the nominated site.

5.6.1 *Design for transport*

The transformer with its active part (windings, core, framework, clamping arrangements and general structure) and tap changer shall be of a robust design and safeguarded for transportation, capable of withstanding any shock to which it may be subjected to during transport taking all planned transport modes into consideration. Necessary mechanical withstand capability shall be built into the design without any in-tank temporary bracings, supports or reinforcements.

All tubing, valves, cable connections and fittings attached to the load shall be adequately protected to minimise the risk of damage during loading, transport and unloading. All components that have oil flow inside them shall be transported air tight.

5.6.2 *Impact recorders*

A three dimensional impact recorder (3D with both plus and minus directions) shall be installed on top of the transformer tank immediately after the tanking process. The impact recorder shall remain installed and operational on the transformer until the installation of the transformer is complete. The impact recorder shall have the possibility to measure acceleration events with 3D curve in the range of 1024ms or more. The number of such stored events must be sufficient for the transport. The acceleration range shall be adjustable up to 10g with a frequency range of 1-100Hz. The impact recorder shall also be able to register both dynamic inclination curves and time-synchronous inclination events.

The supplier must indicate the maximum acceptable shock value of the transformer design in their tender in the form indicated below:

Table 5-6: Transformer g-shock design ratings

Axis	Max g-forces used for the design	Duration (cont. or msec)	Comments
Longitudinal			
Vertical			
Lateral			

In addition to the above, all transformers requiring shipping by sea will require an additional recorder to measure relative angle in pitch, roll and yaw which shall be recorded against the design rating in time-synchronous event logs.

The impact recorders shall be bolted rigidly to the transformer tank at or near the location where the transformer is supported by the transport vehicle and as close as possible to the corner of three intersecting surfaces. The mounting orientation shall align with the axis of the transformer.

A report indicating the above information and transportation events shall be provided to Endeavour Energy to monitor the suitability prior to acceptance for installation at the nominated site. The report shall contain a graph of the magnitude v's time and shall be provided within seven (7) days of delivery of the transformer.

5.6.3 Transportation with or without oil

If the transformer is transported without oil, provision shall be made to prevent the ingress of moisture. In addition, the transformer shall be filled with dry air and maintained at a continuous positive pressure (or nitrogen if it is safe to do so). The air pressure and dew point shall be monitored continuously through the period immediately after the oil is removed until the transformer is refilled with approved oil at site. At all times, alternative standby means should be provided to restore any loss of pressure immediately.

The dew point of the dry air should be measured and recorded to maintain a level below minus 40°C at all times. If the dew point readings indicate an average moisture level at the surface of the transformer insulation higher than 0.5%, the supplier must dry the transformer prior to Endeavour Energy acceptance.

One means of providing a dry environment is by having a dry air cylinder and regulator permanently attached and turned on to automatically replenish the dry air based on pressure. The transformer tank shall be fitted with a gauge that is clearly visible without climbing to show the dry air pressure within the tank. If the supplier chooses to transport the transformer with the dry air turned off or disconnected; the dry air pressure is to be recorded daily from the time oil is removed until oil is refilled into the transformer. A report of the dry air pressure is to be provided detailing this within seven (7) days of re-filling and prior to acceptance for installation.

Refer 5.6.6 for transformers that require storage for more than four (4) months without oil.

5.6.4 Loose equipment

Other transformer equipment such as bushings, cooling equipment, tap changers, power and control cabinets may be shipped disassembled and transported and secured in accordance with the manufacturer's shipment and storage guidelines and precautions. Where required, airtight seals or cover should be used.

Parts such as instruments, cabinets, terminal boxes etc. that are mounted on the main tank shall be attached by means of anti-vibration mountings and be protected with enclosures to prevent physical damage during transport.

5.6.5 Documentation

The supplier shall provide for approval, documentation which fully describes the transport arrangements and specifies all the instructions and requirements necessary to oversee that the transformer and all its equipment will be delivered to site properly and with any necessary and statutory approvals.

5.6.6 Storage

Transformers may require being stored for short or long periods of time. Transformer should not be stored for more than 4 months without oil unless alternative means of management is provided and agreed by the Network Substations Manager. All transformer parts and accessories (including bushings if installed) should be properly earthed.

All blanking plates used for long term storage and covers shall be designed for long-term outdoor storage and have surface treatment as required in this specification.

Heaters within all control cubicles where used shall remain energised during any storage period to prevent condensation.

5.7 Quality assurance

Quality assurance certification is required to establish the manufacturers ability to design and consistently manufacture transformers to this specification. The supplier and all its contractors shall have a quality system which complies with the requirements of AS/NZS ISO 9001 or other comparable Australian or International equivalent.

All nominated drawings and documents that have to be reviewed by Endeavour Energy are to be submitted as complete packages using document controls systems such that all the relevant information to enable the design to be reviewed is available. Design suitability approval will not relieve the supplier of its responsibilities for the correctness and appropriateness of the design of their design or their responsibility to conform to this specification.

5.7.1 Quality assurance plan

A quality assurance plan is a document subject to approval of Endeavour Energy and shall contain as a minimum the following information:

- The supplier's organisational structure for the works.
- A planned outline meeting the requirements and all stages of the scope and specification.
- An index showing all existing procedures, inspection and test plans and drawings.
- AS/NZS ISO 9001 certification for itself and subcontractors.
- A plan detailing the design, ordering of materials, manufacturing and test plans.

5.7.2 Quality Inspection and Test Plan (QITP)

A quality inspection and test plan shall be developed and agreed which contains sufficient details of the workflow so that Endeavour Energy can advise inspecting, witness and hold points. The test plan shall be prepared in accordance with AS/NZS ISO 9001. Where interstate or international inspections are required, a minimum of four (4) weeks' notice shall be given in writing.

As a minimum, Endeavour Energy nominates the inspection and hold points listed below:

Table 5-7: Inspection and hold points (QITP)

ID	Subject	Inspect / hold	Timeframe
	Design verification		(from order)
D1	Technical assessment and agreement on guaranteed performance	Hold	Prior to award of contract
D2	Quality assurance plan	Hold	< 2 weeks
D3	Quality inspection and test plan	Hold	< 2 weeks
D4	Initial drawings / information - Detail for the design of the concrete plinth and bund including final transformer dimensions - General arrangement showing location and weight of all accessories and interface details	Hold	< 4 weeks
D5	Production plan	Hold	< 4 weeks
D6	Design data	Hold	< 7 weeks
D7	Transformer risk assessment	Hold	< 7 weeks
D8	Design and risk assessment review	Hold	< 9 weeks
D9	Completed design data and drawings - General arrangement(s) - Control drawings	Hold	< 11 weeks
	Inspection and factory testing		
F1	Core strand insulation resistance	Inspect	As agreed
F2	Core and coil assembly; coils installed on limbs, upper insulation and pressure boards not installed so that Endeavour Energy can examine the oil ducts from the top of the winding assembly	Inspect	As agreed
F3	Pre-tanking	Hold	As agreed
F4	Oil acceptance prior to filling	Hold	As agreed
F5	Certified factory test certificates	Hold	Prior to dispatch from factory
	Transportation and delivery		
T1	Transport arrangement documentation / agreement	Hold	Prior to dispatch from factory
T2	Operation and Maintenance manuals	Hold	Prior to acceptance of delivery
T3	Dew point measurement and proof of moisture content less than 0.5%	Hold	Prior to acceptance of delivery to nominated site
T4	Impact and tilt recorder report and graphs	Hold	Prior to acceptance of delivery to nominated site
	Installation and commissioning		
C1	Worksite hazard and risk assessment provided	Hold	1 week prior to installation

ID	Subject	Inspect / hold	Timeframe
C2	Dew point / moisture indication test results Supply oil test results Site testing procedure and schedule	Hold	Prior to installation and filling
C3	Site test report	Hold	Within 21 days of commencement of installation
C4	Formal hand-over	Hold	As agreed

Important: Work shall not proceed past a hold or inspection point until formal written approval from Endeavour Energy has been provided to proceed.

It is the supplier's responsibility to arrange all inspections. Final inspection of the transformer is to be made by Endeavour Energy at the workshop of the supplier, or elsewhere as may be mutually arranged after Endeavour Energy has received notice that the transformer is ready for inspection.

The test plan shall as a minimum comprise the following information:

- A summary sheet listing the transformer being tested
- A summary of all the test activities including daily activities and order / duration of tests
- Details of each tests including but not limited to the following information:
 - i. Type of test
 - ii. Test procedure and test circuit diagram
 - iii. Applied specification of standard
 - iv. Criteria used to assess test results including the guaranteed values
 - v. List of instruments to be used including manufacturer's name, type, model number and accuracy
 - vi. Details of the current equipment accreditation

Routine, type and special tests will be carried out in the presence of the Endeavour Energy's inspecting officer, unless otherwise agreed by the Network Substations Manager.

Where possible, the supplier shall have use of a reliable video conferencing system to allow remote inspections for the transformers active part assembly and pre-tanking.

5.7.3 Design and risk assessment review

A design and risk assessment review meeting is required under this specification to be held at Endeavour Energy's office and shall be attended by the suppliers Design Engineer. Design and risk reviews for power transformers will be attended by the at least the Senior Engineer, Transmission Substation Equipment and Network Substations Manager from Endeavour Energy.

The design review shall cover mechanical, electrical, thermal and acoustic / sound level design and provide evidence of the short circuit performance. The risk assessment review will cover the risk register and design proposed by the supplier.

Prior to the design and risk review meeting, the following documented information is to be provided at least 10 business days prior to the design review in order for Endeavour Energy to be familiar with the detail to be discussed:

- General arrangement drawing
- Materials used for construction of the transformer
- Construction types, methods and procedures

- Final short circuit strength
- Calculated forces and locations, temperatures and locations, sound levels, losses, electrical stresses (power frequency and impulse), flux paths and flux control
- Electrical clearances
- Hot spot calculations and fibre optic locations
- Detailed drawings of core and coil construction
- Impedance curve for all tap positions
- Graph of the sound performance versus load (and no-load)
- Design risk assessment for lifecycle risk management
- Shock level design criteria and expected transportation mode
- Data sheets clearly marked for each component utilised to construct the transformer (including primary and secondary systems)

5.7.4 *Operations and maintenance manual*

The manufacturer/supplier shall submit the following documentation prior to delivery of the equipment to Endeavour Energy as follows:

Two (2) hard copies and one (1) electronic copy of the complete installation, operation and maintenance manual shall be provided for the complete transformer supplied for each contract. Each manual shall relate specifically to the equipment supplied and must not contain any material that is not applicable. The manual shall be A4 size and all drawings shall be suitably folded or reduced for filing within the manual. Each manual shall include:

- A hard cover to withstand normal handling.
- A comprehensive index.
- Installation instructions.
- Operating instructions.
- Instructions for the routine maintenance of the equipment and associated auxiliary equipment.
- Recommended maintenance schedules.
- Tests after maintenance work.
- Type test reports.
- A complete list of parts with serial numbers.
- Copies of detailed drawings.
- Drawings of auxiliary equipment.
- Routine factory tests.
- Data sheets for each piece of equipment used in the transformer clearly marking the components used.
- Design and ongoing risk assessment.

5.8 **Testing**

5.8.1 *Factory testing*

5.8.1.1 *General*

All routine, type and special tests shall be conducted with the transformer completely assembled in the factory with all protection devices, oil level gauges, control cubicles, handrails and cable boxes fully installed and operational. Gland plates may be removed for test cable access.

Reports written in any language other than English shall not be accepted by Endeavour Energy unless such reports are translated into English by a sworn translator.

Type tests shall be carried out on the first unit under the contract.

The tests to be carried out on the first unit, and the suggested sequence, are set out in the table below. Test items 13-21 immediately followed by 26-38 of the table shall be carried out in sequence.

Sound level tests shall be carried out without interfering with the sequence.

All test results shall be included in the maintenance manuals with a note indicating that the test results relate to the original unit.

One (1) copy of all test results shall be provided to the Network Substations Manager within one (1) week of the completion of the tests for approval, and shall include a cover page that lists all the tests and a statement indicating that all tests have passed including guaranteed values. The transformer shall only be delivered to site after the test reports have been approved by Endeavour Energy.

Should there be a discrepancy or a test failure, this should be noted on the cover sheet.

5.8.1.2 Tests to be performed on the transformer

Test items 13-21 shall be immediately sequentially followed by items 26-38.

Tests 26 to 29 (temperature rise tests) are only required on the first of type power transformer under this specification.

Table 5-8: Factory test requirements

Item no.	Description of test	Acceptable value	Test method reference.
1	Oil tests prior to filling of transformer – initial oil sample shall be taken from the bulk oil prior to filling. Results are to be approved by the Network Substations Manager prior to filling: The acceptable values and minimum oil and test requirements are set out in the attached Endeavour Energy's Insulating Oil Equipment Technical Specification (ETS 0010).	Refer ETS 0010	Endeavour Energy Specification. ETS 0010
2	Routine tests on winding temperature indicator current transformers, in accordance with AS 60044.1-2007.	As per standard's requirements	AS60044.1-2007 Cl 7.1 to 7.4, 11.4, 8.1 and 8.4
3	Perform insulation resistance test between conductor to conductor and conductor to earth on all control wiring, including tap changer control wirings and CT secondary wirings.	>5 MΩ using 1000volt megger @ 20C	AS60076.3-2007 Cl.10
4	Power frequency voltage withstand tests on secondary wiring installation at 2kV for one (1) minute.	No insulation breakdown	AS 60076.3-2008 Cl.10
5	The functional test of secondary wiring circuits.	Full functionality confirmed.	AS60076.1-2005 Cl.10.8.1
6	Measurement of the power taken by the fan and oil pump motors.	-	AS60076.1-2005 Cl.10.1.3
7	Gas and oil actuated relay stability where OFxx or ODxx cooling is utilised.	Non operation of Gas relay	AS60076.1-2005 Cl.10.1.3
8	Paint thickness test at points selected by the Endeavour Energy's representative.	<145 microns	AS2700-2011
9	Measurement of the winding resistance on each tap (tabular and graphical results in Excel required)	Differential resistance <0.02	AS60076.1-2005 Cl.10.2
10	Measurement of voltage ratio and check of phase displacement (tabular and graphical representation required).	Conforms to specification	AS60076.1-2005 Cl.10.3
11	Tests on on-load tap-changers (operational checks and auxiliary circuit insulation test).	No failure Correct operation for all range	AS60076.1-2005 Cl.10.8

Item no.	Description of test	Acceptable value	Test method reference.
12	Core to frame and core plus frame to tank insulation at 1kV for one (1) minute (reference IEEE 62:1995, page 44). Tests shall be carried out when the temperature of transformer including windings and cores is no more than 5 deg. C hotter than the ambient temperature.	>1 GΩ using 1000volt megger @ 20C	IEEE 62-1995.
13	tan δ and capacitance of bushings. Partial discharge of bushings ($U_m \mid 1.5U_m/\sqrt{3} \mid 1.05U_m/\sqrt{3}$) Capacitance	< 0.007 10 / 10 / 5 pC As per design and within 3% of nameplate	AS 60137:2008
14	Determination of capacitances winding-to-earth, and between windings	Based on design and recorded	AS60076.1-2005 Cl.10.1.3
15	Measurement of insulation resistance (5kV dc @ one [1] minute) and measurement of dissipation factor (tan δ) of the insulation system (10kV) and capacitances. Tests shall be carried out when the temperature of transformer including windings and cores is no more than 5 deg. C hotter than the ambient temperature. The insulation resistance test shall be carried out from: - Each winding to all other winding(s) plus earth/tank, - Each pair of windings to all other winding(s) plus earth/tank, - All windings to earth/tank. Refer to Annexure 2 for guaranteed values. Measurements of tan δ and capacitances as per design. Winding DLA:	>5 GΩ @ 20C >5 GΩ @ 20C >5 GΩ @ 20C < 0.0045	AS60076.1-2005 Cl.10.1.3
16	Prior to HV testing an oil sample shall be taken from the transformer bottom sample point just prior to the testing and tested for dissolved gas for the following gases: - Hydrogen - Methane - Ethane - Ethylene - Acetylene - Carbon monoxide - Carbon dioxide	Nil Nil Nil Nil Nil < 50 ppm < 500 ppm	AS60076.1-2005 Cl.10.1.3
17	Measurement of no-load loss and current at 100%, 110% and 120% of excitation.	Based on guaranteed values	AS60076.1-2005 Cl.10.5

Item no.	Description of test	Acceptable value	Test method reference.
18	Measurements of the harmonics of the no-load current.	Based on guaranteed values	AS60076.1-2005 Cl.10.6
19	Measurement of zero - sequence impedances on three-phase transformer (to be measured at 3 varying current levels to be agreed in tender response)	< positive sequence impedance in Annexure1	AS60076.1-2005 Cl.10.7
20	Measurement of short-circuit impedance and load loss. The supplier is required to prove the impedance curve submitted in Annexure 2 by testing impedance at each tap position.	As set out in Annexure 1 envelope for each transformer.	AS60076.1-2005 Cl.10.4
20A	Measurement of leakage / short circuit impedance using a low current device (2 to 40A) which can be repeated at site test in accordance with 5.8.2.3 (min, nominal and maximum tap).	Compared to test 20 above.	AS60076.1-2005 Cl.10.4
21	Oil sample to be taken from the transformer sample valve and temperature recorded.	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3
22	Sound power level tests shall be conducted on the transformers at 100% and 105% core excitation with all cooling equipment de-energised (ONAN).	As set out in Annexure 1 limits for each transformer	AS60076.10-2009
23	Sound power level tests shall be conducted on the transformers at 100% and 105% core excitation with pumps and fans (if any) energised (ODAF).	As set out in Annexure 1 limits for the transformer	AS60076.10-2009
24	Sound level test shall be conducted on the transformers for measurement of noise due to 2/3 rated load currents.	As set out in Annexure 1 limits for each transformer	AS60076.10-2005
25	A transformer sound spectrum measurement shall be carried out at 100% core excitation on ODAF.	As set out in Annexure 1 limits for each transformer	AS60076.10-2005
26	A temperature rise test shall be carried out under all implemented cooling conditions and to the criteria specified in Annexure 1. Temperature rise tests may be conducted only with the radiators that belong to the finished unit. Sharing radiator banks is not permitted and redundant fans and pumps are not to be utilised.	As set out in Annexure 1 limits for each transformer	AS60076.2-2013
27	Oil sample to be taken from the transformer sample valve.	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3

Item no.	Description of test	Acceptable value	Test method reference.
28	A temperature rise test shall be performed starting from 100% CMR (continuous maximum rating) with stable temperature and followed by a step to 110% CMR on the same (maximum current) tapping position as the other temperature rise tests.	As set out in Annexure 1 limits for each transformer	AS60076.2-2013
29	Oil sample to be taken from the transformer sample valve.	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3
30	Lightning impulse voltage withstand tests including chopped wave tests for the three phases of the transformer and each phase (HV, LV and /or TV windings) to be tested once on one different tap position of maximum tap, principal tap and minimum tap with average oil rise greater than 40 deg. C with the transformer fully assembled.	No disruptive discharge.	AS60076.3-2008 Cl 13.1
31	Lightning impulse voltage withstand tests for neutral on maximum tap position with the transformer fully assembled.	No disruptive discharge	AS60076.3-2008 Cl 13.3.2
32	Oil sample to be taken from the transformer sample valve	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3
33	The separate source voltage withstand test to be carried out.	No voltage collapse	AS60076.3-2008 Cl. 11
34	Oil sample to be taken from the transformer sample valve.	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3
35	Induced over voltage withstand test in accordance with AS 60076, Part 3 short duration	No voltage collapse	AS60076.3-2008 Cl. 12
36	Oil sample to be taken from the transformer sample valve.	Analysed for acceptability	AS60076.1-2005 Cl.10.1.3
37	Partial discharge tests shall be carried out to AS 60076, Part 3 on all terminals with the transformer fully assembled. The maximum apparent charge (q) shall not be greater than 50 pC at 130% rated voltage on bottom tap, with 30 minute evaluation time. Sources of discharge if any shall be located and rectified if greater than 50pC.	<50pC	AS60076.3-2008 Cl. Annex A.
38	Oil sample to be taken from the transformer sample valve.	-	AS60076.1-2005 Cl.10.1.3
39	Frequency Response Analysis (FRA) of the transformer at factory. After the dielectric tests, the transformer shall not be subject to any movement prior to FRA analysis,	Tracing to be compared with site test tracing	AS60076.1-2005 Cl.10.1.3

Item no.	Description of test	Acceptable value	Test method reference.
40	Oil pressure test of 50 kPa over the top of the oil filled transformer for 24 hours.	Tank withstands pressure.	AS60076.1-2005 Cl.10.1.3
41	Dew Point measurement as in IEEE C57.93:1995 for moisture determination of cellulose insulation of transformer (in main tank and OLTC tank) prior to shipping and continuously throughout if the transformer is shipped under gas (dew point measurement also required prior to filling at site). Otherwise determined by approved PDC and/ or FDS response. The measurement shall be carried out after a state of moisture equilibrium between insulation surface and the surrounding gas is achieved and insulation temperature to be accurately determined.	-40 deg. Celsius	IEEE. C57.93-1995

Note: The handrails shall be in place for sound level test and all dielectric tests, including lightning impulse test, separate source test, induced voltage test and partial discharge test.

Oil samples are to be taken from the transformer bottom sample point after completion of tests as shown in Tables 1

The final sample after testing shall be analysed for dissolved gas.

If the final oil sample is outside any of the limits, the oil sample will require analysis to determine the cause.

5.8.2 Site testing

5.8.2.1 Dew point measurement

If the transformer is shipped under gas, a Dew point measurement according to IEEE C57.93:1995 shall be carried out for determining the surface moisture level of cellulose insulation of transformer immediately prior to degassing of the transformer.

The measurement shall be carried out after a state of moisture equilibrium between insulation surface and the surrounding gas has been achieved and insulation temperature can be accurately determined.

The test result shall be submitted to the Network Substations Manager, for approval prior to oil filling. Filling shall be performed in accordance with 5.4.8.2.

5.8.2.2 Oil

Oil samples shall be taken on site:

- From the bulk oil tank on arrival at site immediately prior to filling, this is to be tested in accordance with the complete requirements of ETS 0010 – Insulating oil.

The test result shall be submitted to the Network Substations Manager for approval prior to oil filling. The acceptable values of the above tests are set out in the attached Endeavour Energy's Insulating oil Equipment Technical Specification (ETS 0010 – Insulating oil) and are also summarised (incompletely) for ease of reference below.

- After degassing on site, DGA test shall be carried out for main tank oil and OLTC oil for:
 - Hydrogen: Nil detectable
 - Methane: Nil detectable
 - Ethane: Nil detectable
 - Ethylene: Nil detectable
 - Acetylene: Nil detectable
 - Carbon monoxide: < 50 ppm
 - Carbon dioxide: < 500 ppm

The test results shall be submitted to the Network Substations Manager for approval.

- After oil impregnation period (typically 24 hours after refill), the main tank oil and OLTC oil shall be tested for:
 - Moisture ≤ 20 mg/kg (ppm)
 - Breakdown voltage (12mm diameter electrodes, stirred) > 60kV
 - Acidity < 0.01 mg KOH/g
 - Interfacial tension > 40mN/m
 - DDF: Max. 0.005
 - Furans: Nil detectable
 - Conductivity: < 0.9pS/m
 - Colour: 1.0

The acceptable values of the above test are set out in the attached Endeavour Energy's Insulating oil Equipment Technical Specification (ETS 0010 – Insulating oil). The values if stated above are in some circumstances less stringent than the requirements of ETS 0010 – Insulating oil. This takes into consideration the expectation after oil impregnation with good oil filling practice.

The test results shall be submitted to the Network Substations Manager for approval prior to commissioning.

5.8.2.3 Tests after erection by supplier

On completion of delivery and erection of the works, the following tests shall be carried out by the supplier and witnessed by Endeavour Energy's representative to demonstrate readiness for service. The supplier's tests shall include the following:

- Measurement of voltage ratio (within $\pm 0.5\%$ of the design nameplate values).
- Confirmation of vector group.
- Measure excitation current.
- Measure single phase and three phase impedance (maximum **3%** difference for single phase impedance and between phases and **1%** variation from nameplate for three phase equivalent). To be tested at maximum, nominal and minimum tap position.
- Measurement of winding resistance on all taps and all windings (differential resistance maximum **0.02 Ω**).
- Insulation resistance between all windings and to earth at **5kV dc**. The insulation resistance temperature correction formula shall be submitted with the tender offer (test results shall not be less than the value obtained in the factory test results).
- Measure core to core frame insulation resistance and core frame to tank insulation resistance with the guaranteed values of minimum **1G Ω** @ 20 deg. C for one (1) minute, tested using 1kVdc test voltage (reference IEEE 62:1995, page 44).

- Perform insulation resistance test between conductor to conductor and conductor to earth on all control wiring, including tap changer control wirings and CT secondary wirings with the guaranteed value of minimum **1M Ω** @ 20 deg. C for one (1) minute, tested using 500Vdc test voltage.
- Frequency Response Analysis (FRA) and comparison report
- Polarisation and depolarisation current variation (time domain - PDC) and/or capacitance and dissipation factor variation (frequency domain – FDS) for determination of moisture content and other by-products (approach to be agreed in the tender process).

All site test results shall be forwarded to the Network Substations Manager for approval within seven (7) days of tests being completed on site.

The test result of the on-site FRA compared with the factory results on a phase by phase basis shall be submitted for approval by the Network Substations Manager before commissioning. It is the supplier's responsibility to compare the test results both at factory and on-site to demonstrate that the transformer was not subject to any core and winding movement/deformation arising from transportation. Endeavour Energy will also carry out a separate evaluation of the SFRA results from the electronic data and applicable software submitted by the supplier.

It is the supplier's responsibility to inform Endeavour Energy that the transformer is in a state fit for service. This shall be confirmed by the supplier in writing.

5.8.2.4 Tests after erection by Endeavour Energy

Endeavour Energy shall also carry out the following tests.

- Perform separate source AC withstand voltage test. The test shall satisfy no disruptive discharge at 100% of factory test voltage (IEC 60076-3, clause 9).
- Perform PD test on the complete transformer, including bushings, with the guaranteed values of maximum 50pC at 1.2 p.u. rated voltage.
- Perform DDF test on all windings, including bushings with the following guaranteed values.

Winding DDF / DLA	Criteria
$\leq 4.5\text{mrad @ } 20 \text{ deg. C}$	Acceptable
Between 4.5mrad - 5 mrad @ 20 deg. C	Extend transformer warranty by five (5) years during which the DDF shall be $< 5\text{mrad @ } 20 \text{ deg. C}$.
$\geq 5\text{mrad @ } 20 \text{ deg. C}$	Unacceptable (supplier to rectify and/or replace)

- Perform DDF test on bushings with DDF test point with the guaranteed value of maximum $< 0.007 @ 20 \text{ deg. C}$ and capacitance variation less than 3% from nameplate.
- Measure the winding to earth and inter-winding capacitances. Test results shall be consistent with the values obtained in the factory test results.
- Measure the capacitance of bushings with DDF test point. Test results shall be consistent with the values obtained in the factory test results.

Endeavour Energy will provide all labour, material and equipment necessary for these tests. The supplier may witness these tests at the supplier's cost.

Should the plant or any portion thereof fail under the supplier's or Endeavour Energy's tests, the cost of replacements, repairs and any further tests shall be borne by the supplier.

Any expense by the supplier in having representatives present during tests shall be borne by the supplier.

5.9 Tender drawings

Drawings appropriate to this specification are listed below:

No.	Drawing no.	Admt no.	Title
1	355770	A	General arrangement – 132/11kV 15MVA 132/11kV (HV bushings / LV cable box)
2	355768	A	Transformer control typical circuit diagram.
3	355769	A	Power Transformer interface connection

6.0 AUTHORITIES AND RESPONSIBILITIES

The **Chief Engineer** has the authority and responsibility for:

- approving technical specifications, including any variations;
- making all decisions concerning compliance in respect to this specification;
- approving nominations of Endeavour Energy's representatives; and
- delegating any of these authorities and responsibilities to the Network Substations Manager.

The **Manager Primary Systems** has the authority and responsibility for:

- reviewing this specification and making recommendations to the Chief Engineer;
- making recommendations concerning compliance in respect to this specification; and
- making nominations of Endeavour Energy's representatives.

The **Manager Project Development** has the authority and responsibility for:

- determining the equipment procured complies with the requirements of this specification; and.
- checking factory and site test reports and seeking dispensation from Primary Systems as necessary for marginal non-compliances.

The **Network Substations Manager** has the authority and responsibility for

- reviewing all test reports and alternative proposals submitted, and making recommendations to the Manager Primary Systems;
- clarifying all the technical aspects of this specification to the stakeholders; and
- approving the relevant actions required and outlined in this specification

The **Project Manager** has authority and responsibility to maintain that all equipment installed complies with the requirements of this specification.

The **Strategic Category Manager** has the authority and responsibility to certify that the transformer purchased through the tender process complies with the requirements of this specification.

Manufacturers/suppliers have the authority and responsibility for:

- maintaining awareness of their responsibilities under this specification;
- certifying that the supplier/s under their control have provided suitable training for their employees;
- managing that an effective safety, environmental and quality auditing system is in place; and

- implementing this specification and keeping Endeavour Energy or other responsible equivalent officers informed of any factors that may prevent them from accepting responsibility for its full implementation.

7.0 DOCUMENT CONTROL

Documentation content coordinator: Network Substations Manager

Documentation process coordinator: Standards Process Coordinator

Annexure 1 – Technical requirements*Annexure 1.1 132/11kV 15MVA transformer*

Ref no.	Item description	Unit	Requirement		
1.	Standard		60076-2005-2013		
2.	Type		Outdoor Mineral Oil Immersed		
3.	No of phases		3		
4.	Rated frequency	Hz	50		
5.	Nominal voltage ratio		132/11		
6.	Vector connection (vector selection switch)		Dyn1		
7.	Nominal voltage (Ur)				
	a. HV	kV	132		
	b. LV	kV	11		
	c. TV	kV	-		
8.	System Highest Voltage (Um)				
	a) HV	kV	145		
	b) LV	kV	12		
	c) TV	kV	-		
9.	Rated power (15 MVA mandatory requirement)				
	a) ONAN - HV/LV	MVA	e.g. 10/10 or 15/15		
	b) ODAN – HV/LV (optional)	MVA	e.g. 12.5/12.5 or 15/15		
	c) ODAF - HV/LV (optional)	MVA	e.g. 15/15		
10.	System fault levels (3 sec)				
	a) HV	kA	40		
	b) LV	kA	20		
	c) TV	kA	-		
11.	Cyclic and overload rating	MVA	16.5MVA (8 hours) in accordance with 5.2.2.		
12.	Maximum temperature rises limitations for continuous loadings		ONAN	ODAN	ODAF
	a) Top oil by thermometer	deg. C	52	49	49
	b) Windings by resistance	deg. C	63	68	68
	c) Winding hot spot by fibre optic	deg. C	78	78	78
	d) Localised heating of any metal part in contact with insulation or gasket	deg. C	70		
	e) Localised heating of any metal part in contact with oil only	deg. C	80		
	f) Core surface temperature rise at over excitation in accordance with 5.2.6	deg. C	75		
13.	Impedance @ full rating, 75 deg. C ref temp (refer to Figure 1 for allowable tolerance envelope)				

Ref no.	Item description	Unit	Requirement		
	a) HV - LV, maximum tap (Position 1), maximum value including tolerances	%	9.32		
	b) HV - LV, maximum tap (Position 1), minimum including tolerances	%	8.0		
	c) HV - LV, Principal Tap (Position 4), within the specified impedance envelope	%	8.95		
	d) HV - LV, minimum tap (Position 21), maximum value including tolerances	%	8.4		
	e) HV - LV, minimum tap (Position 21), minimum value including tolerances	%	8.0		
14.	Impedance variation over the range		Suitable for parallel operation		
15.	Category of voltage variation		CFVV		
16.	Type of tap-changing		On-load and bolt-on		
17.	On-load tapping range				
	a) Winding		HV		
	b) Range and step voltage		+3 x 1.5%, -17 x 1.5%		
	c) Tapping power		Full rating on all tap positions		
	d) Maximum tap position (Tap 1) - HV voltage	kV	137.94		
	e) Nominal tap position (Tap 4) - HV voltage	kV	132		
	f) Minimum tap position (Tap 21) - HV voltage	kV	98.34		
18.	System earthing				
	g) HV neutral		-		
	h) LV neutral		Solidly Earthed (generally)		
	i) TV		-		
19.	Sound power level (max acceptable - refer transformer cost assessment clause):		Opt 1	Opt 2	Opt 3
	a) Sound power limitation @ 100% Ur no-load with ONAN cooling	dBA	≤70	≤62	≤62
	b) Sound power limitation @ 100% Ur no-load with ODAN cooling	dBA	≤70	≤62	≤62
	c) Sound power limitation @ 100% Ur no-load with ODAF cooling	dBA	≤70	≤62	≤62
	d) Sound power limitation @ 105% Ur no-load with ONAN cooling	dBA	≤71	≤63	≤63
	e) Sound power limitation @ 105% Ur no-load with ODAN cooling	dBA	≤71	≤63	≤63
	f) Sound power limitation @ 105% Ur no-load with ODAF cooling	dBA	≤71	≤63	≤63
	g) Sound power limitation @100% Ur no-load with ODAF cooling and 2/3 rated load	dBA	-	-	≤62

Ref no.	Item description	Unit	Requirement
	h) Sound power limitation @105% Ur no-load with ODAF cooling and 2/3 rated load	dBA	- - ≤63
20.	Radio interference voltage levels		Comply with AS2344-1997
21.	Insulation level		
	• HV - system highest voltage (UM) / LI / U _d	kV/kVp/kV	145 / 650 / 275
	• LV - system highest voltage (UM) / LI / U _d	kV/kVp/kV	12 / 95 / 28
	• TV - system highest voltage (UM) / LI / U _d	kV/kVp/kV	-
	• HVN - --- / LI / U _d	kV/kVp/kV	-
	• LVN – (UM) / LI / U _d	kV/kVp/kV	12 / 95 / 28
22.	Over-excitation at full load with a load power factor of 0.86, maximum continuous voltage for any tap	%Ur	130 % Ur
23.	Maximum flux density		
	• 100 % Ur @ no load	Tesla	1.7
	• 110% Ur @ no load	Tesla	1.7
	• 105% LV Ur @full rating and load power factor of 0.86 and frequency 47.5Hz	Tesla	Without saturation of the core Refer 5.2.6
	• 130% HV Ur @ full rating and load power factor of 0.86	Tesla	Without saturation of the core Refer 5.2.6
24.	Maximum internal partial discharge @ 120% U _M /√3	pC	50
25.	On-load tap changer - high speed resistor type		
	a) Type		ABB UZ or UC preferred
	b) Location		HV (or alternative detailed offer will be considered)
	c) Rated current	Amp	≥100
	d) Power supply	V (rms)	400/230 ± 10%
	e) Control supply	V (dc)	96 - 125 or AC as above
26.	Cooling		
	a) Radiator mounting		Attached cooler bank
	b) Cooler location		Refer to typical transformer GA drawing listed in section 5.9
	c) Conservator type		Refer 5.4.7
	d) Stand-by pump required		No
	e) Stand-by fan required		Yes (if fans fitted)
	f) Stand-by radiator required		Yes
27.	Primary line terminations		
	a) Rated voltage (phase to phase)	kV	145
	b) Termination type		Bushing
	c) No of conductors		Refer to typical transformer

Ref no.	Item description	Unit	Requirement
			GA drawing listed in section 5.9
	d) Location of termination centres	mm	Refer to typical transformer GA drawing listed in section 5.9
28.	Secondary line terminations		
	a) Rated voltage (phase to phase)	kV	12
	b) Termination type		Air insulated cable box
	c) No of conductors		Refer to typical transformer GA drawing listed in section 5.9
	d) Location of termination centres	mm	Refer to typical transformer GA drawing listed in section 5.9
29.	Bushings HV		
	a) Rated voltage (phase to phase)	kV	145
	b) Continuous current rating	Amps	≥100
	c) Current rating of stem/rod	Amps	≥100
	d) Three (3) second current rating	kA	40
	e) Insulation levels:		
	• Impulse	kVp	650
	• Power frequency	kV	275
	f) Bushing type		Resin impregnated paper, insulated capacitor porcelain or silicone.
	g) Colour		Light grey
	h) Minimum creepage distance	mm	4495
	i) Minimum phase to phase clearance ¹⁾	mm	1495(between live parts)
	j) Minimum phase to earth clearance ¹⁾	mm	1300 (live parts to earth)
	k) Terminal palm to AS62271.301-2005, Table 1, Figure 1		No 5 copper, pre-drilled
30.	a) Bushings LV		
	b) Rated voltage (phase to phase)	kV	12
	c) Continuous current rating	Amps	≥1300
	d) Current rating of stem/rod	Amps	≥1300
	e) Three (3) second current rating	kA	20
	f) Insulation levels:		
	• Impulse	kVp	95
	• Power frequency	kV	28
	g) Bushing type		Oil filled porcelain/silicone

Ref no.	Item description	Unit	Requirement
	h) Colour		Light grey
	i) Minimum creepage distance	mm	372
	j) Minimum phase to phase clearance ¹⁾	mm	184 (between live part)
	k) Minimum phase to earth clearance ¹⁾	mm	160 (live parts to earth)
	l) Terminal palm to AS62271.301-2005, Table 1, Figure 1		No 8 copper, pre-drilled
31.	Bushings LV-N		
	a) Rated voltage (phase to phase)	kV	12
	b) Continuous current rating	Amps	≥1300
	c) Current rating of stem/rod	Amps	≥1300
	d) Three (3) second current rating	kA	20
	e) Insulation levels:		
	• Impulse	kVp	95
	• Power frequency	kV	28
	f) Bushing type		Oil filled porcelain
	g) Colour		Light grey
	h) Minimum creepage distance	mm	372
	i) Minimum phase to earth clearance ¹⁾	mm	160 (between live part)
	j) Terminal palm to AS62271.301-2005, Table 1, Figure 1		No 8 copper, pre-drilled
32.	Cable box LV(11kV)		
	a) Termination type		Air insulated
	b) No of cables		Refer to typical transformer GA drawing listed in section 5.9
	c) Size of single core cables (design must be able to accommodate all options)		Suitable for copper XLPE up to 1200 mm ²
	d) Location of cable entry centres (mandatory requirements)		Refer to typical transformer GA drawing listed in section 5.9
	e) Min. distance gland plate to centre of term. Palm		700
	f) Bushing details		as per ref 30
33.	Alarm and trip contact making, carrying and breaking capacity		1A in typically inductive (magnet coil) circuit at 250V AC or 120V DC
34.	Insulating medium		Paper and oil
35.	Pressure relief device (main tank)		Qualitrol or equivalent
36.	Separate freestanding control cubicle for the temperature indicators		Not essential

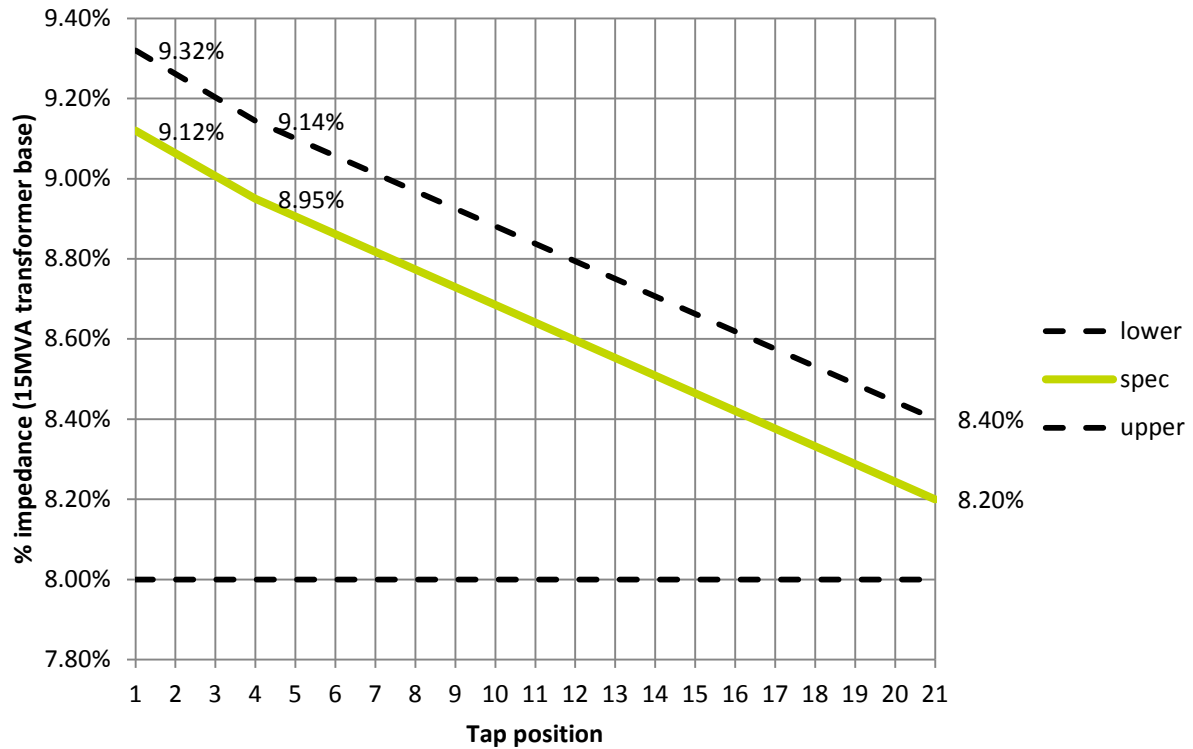
Ref no.	Item description	Unit	Requirement
37.	Local oil and winding temperature indicators with remote signal		Required
38.	Remote oil temperature signal		Required
39.	Fibre-optic temperature sensors		Required as an option
	• HV winding (A, B, C phases)		3
	• LV winding (a, b, c phases)		3
	• TV winding (b phases only)		-
	• RV winding (b phases only)		-
40.	Top oil temperature indicator and associated micro switches		Required
41.	Condition monitoring equipment		Optional
42.	Maximum overall height	mm	6100
	Max. transport height		To permit transport without special permits
43.	Delivery address		As nominated in the Works Section.
	Delivery date		
	a) Ex works		As nominated in the Works Section.
	b) On site completed with all tests		Within 21 days of commencement of installation
44.	Capitalised cost assessment		
	a) Ki = No load loss	A\$/KW	\$7,900
	b) Kc = Load loss on principal tap at CMR	A\$/KW	\$830

Note:

Refer to the requirements outlined in air insulated cable box section and refer to GA drawing listed in section 5.9.

Annexure 1.2 Graphical representation of required impedance**Annexure 1.2.1 132/11kV 15MVA transformer**

The transformer impedance can be designed to vary within the bounds determined below:



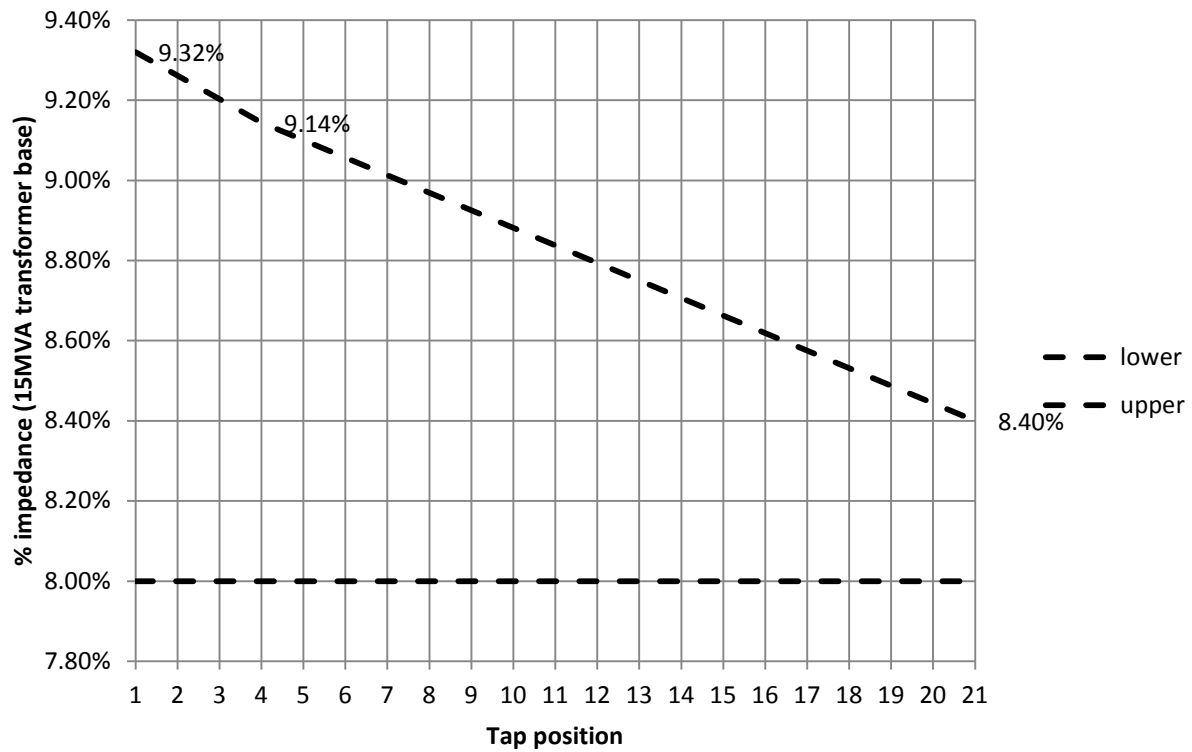
Annexure 2 - Technical schedule

Annexure 2.1 – Technical data

Excel spreadsheet attached to this specification sets out the requirements for confirmation of compliance with this specification - *Endeavour Energy technical schedules ETS0030a0 - spreadsheet for 132/11 15MVA power transformer.*

Annexure 2.2 Graphical representation of offered impedance

Annexure 2.2.1 -132/11kV 15MVA transformer



Annexure 2.3 *Tabular representation of offered impedance – one table for all transformer types*

Transformer _____ kV _____ MVA			
Impedance curve %			
Tap no.	Upper tolerance	Nominal	Lower tolerance
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			

Annexure 2.4 Offered sound power levels – one graph for all transformer types