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Equipment Technical Specification

11/22kV 20MVA Power auto-transformer

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EQUIPMENT TECHNICAL SPECIFICATION

ASSET STANDARDS & DESIGN

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ETS 0023 11/22KV 20MVA POWER AUTOTRANSFORMER

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1.0 PURPOSE

To set out in detail the minimum technical requirements for 11/22kV auto-transformer for use in zone substations in the Endeavour Energy network.

2.0 SCOPE

This specification covers the design, manufacture, testing at manufacturer's works, delivery, erection and site testing of 11/22kV auto-transformer.

It is not the intention to specify the manufacturing, testing and material requirements in detail. However, the equipment shall be manufactured to the highest quality standards. The scope includes all items that are necessary for the operation of the equipment, where specified.

All equipment shall be manufactured and tested to the standards with the year of publication listed in clause 3.0 below. Endeavour Energy will consider equipment manufactured to other recognised international standards provided the standards are at least equivalent to Australian/IEC standards. Where this document conflicts with a standard, this document will prevail.

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 Substation Assets Manager for approval prior to acceptance.

3.0 REFERENCES

Internal

Company Policy (Network) 9.2.1 – Network Planning
Company Policy (Network) 9.2.2 – Network Protection
Company Policy (Network) 9.2.5 – Network Asset Design
Company Policy (Network) 9.2.10 - Network Asset Ratings
Company Policy (Network) 9.7.1 – Network Asset Construction
Company Policy (Network) 9.9.1 – Network Asset Maintenance
Company Procedure GRM 0003 – Risk Management
Company Procedure GSY 0026 – Work Health and Safety Risk Assessment
Company Network Management Plan December - 2013 Review
Company Form FSY 0138 – Risk Register
Environmental Management Standard EMS 0001 – Environmental impact assessment and environmental management plans
Equipment Technical Specifications ETS 0010 - Mineral insulating oil
Equipment Technical Specifications ETS 0014 - Protection and control panels
Equipment Technical Specifications ETS 0020 - Portable earthing and short circuiting equipment

External

Work Health and Safety Act 2011 (NSW)
Work Health and Safety Regulation 2011 (NSW)
ENA National Electricity Network Safety Code (Doc. 01-2008)
EPA – Environmental Noise Management – Industrial Noise Policy: 2000.
Service and Installation Rules of NSW: August 2012
AS 1000 -1998: The international system of units (SI)
AS CISPR 16.1-2002 Specification for radio disturbance and immunity measuring apparatus and methods - Radio disturbance and immunity measuring apparatus
AS 1627.4 -2005: Abrasive blast cleaning of steel surfaces
AS 1657-2013: Fixed platforms, walkways, stairways and ladders – Design,
AS 1767 -1999: Insulating oil for Transformers and Switchgear
AS 1824.2 -1985: Insulation Co-ordination

AS 1931.1 -1996: High voltage testing techniques
 AS 2067 -2010: Substations and high voltage installations exceeding 1 kV a.c.
 AS 2344 - 1997: Limits of electromagnetic interference from overhead a.c. powerlines and high voltage equipment installations in the frequency range 0.15 to 1000 MHz
 AS 2700 -2011: Colour standards for general purposes
 AS 3750.22-2008: Paints for steel structures-Full gloss enamel-Solvent-borne
 AS 4398.1-1996: Insulators - Ceramic and Glass-Station post for indoor and outdoor use greater than 1000V ac- Characteristics
 AS 4398.2-1996: Insulators - Ceramic and Glass-Station post for indoor and outdoor use greater than 1000V ac- Tests
 AS 4436-1996 Guide for the selection of insulators in respect of polluted conditions
 AS 4680 -2006: Hot-dip galvanized (zinc) coatings on fabricated ferrous articles
 AS 60044.1 -2007: Instrument transformers Part 1: Current transformers
 AS 60076 -2006-2014: Power transformers - (All Parts)
 AS 60137 -2008: High voltage bushings
 AS 60270 -2001: Recommendations for partial discharge measurements
 AS 62271.301 -2005: High voltage switchgear and controlgear Part 301: Dimensional standardization of terminals.
 AS 60529-2004: Degrees of protection provided by enclosures
 IEC/TR 61850 2009-2013: Communication networks and systems for power utility automation - (All Parts)

4.0 DEFINITIONS AND ABBREVIATIONS

A.C.	alternating current
CT	Current Transformer
CTC	continuously transposed conductor
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 (Standard)
Fault level	three-phase balanced fault level
Hold point	A point where the works will not proceed without the verification and acceptance by Endeavour Energy
Inspection point	A point where the attendance or verification by Endeavour Energy shall be at Endeavour Energy's discretion
kA	kilo-Amps
kV	kilo-Volts
ONAN	oil natural air natural
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 pump is redundant it means that if one pump in the system fails, other pumps will immediately take over its

function. A component failure will not result in a functional failure.

RV	Regulating voltage winding
SCADA	Supervisory Control and Data Acquisition
TV	Tertiary voltage winding
Ur	nominal rated voltage
WTI	winding temperature indicator

5.0 ACTIONS

5.1 General requirements

5.1.1 General

The 11/22kV 20MVA auto-transformer is used in Endeavour Energy's network at Zone Substations in areas supplied by both 11kV and 22kV distribution networks.

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;
- all relevant Australian and IEC Standards and this specification.

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

The supplier shall provide everything necessary or that is 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 be 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.

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/components from third party suppliers, such as tap changer, bushings, control relays/devices and the like, shall not be modified without approval from the Substation Assets Manager.

Where a particular brand or model number is specified by Endeavour Energy, these are the preferred options. Other makes and models may be submitted for approval by the Substation Assets Manager. These will be evaluated on items such as quality, functionality, maintenance requirements and the need to keep additional spares.

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

5.1.2 Service conditions

All equipment shall be suitable for use on the Endeavour Energy's 11kV and 22kV 3-phase 50Hz systems.

The system highest voltages, system earthing and fault levels are set out in clause 5.4.

The service conditions in which the equipment will operate shall be in accordance with clause 2 of AS 62271.1 and as indicated in the table below.

Table 1 - Service condition

Description	Criteria
Normal service condition	Outdoor
Altitude	<1000m
Maximum ambient temperature	45 °C
Minimum ambient temperature	-10 °C
Annual Ground Flash Density- (No. of lightning strikes per km ²)	3
Solar radiation- maximum	1.0 Kw/m ²
Average index of mean relative humidity: 9:00am	95%
Pollution level (AS4436.1)	Level IV
Ice coating	1mm
Wind speed	34m/s
Condensation/precipitation	Yes
Seismic acceleration coefficient (maximum)	0.09

5.2 Network operating conditions

5.2.1 Site conditions

The equipment will be mounted outdoors on concrete footings inside an oil containment bund. They will be located at an appropriate location within the substation yard or essential spares storage location as directed by Endeavour Energy on a job by job basis. In some instances the equipment will be installed within a sound enclosure having a height equal to or greater than the equipment, which will be provided by Endeavour Energy. Preference will be given to equipment with smaller footprints. Dimensional restrictions are detailed in Appendix 4 and 5.2.8.

5.2.2 Rating/Overload capacity

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

In particular, transformer components such as bushings and tap-changers shall be rated such as not to limit this capability. Winding terminations and internal cables and busbars 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.

The hot spot temperature shall not be greater than 130°C at ambient temperature of 40°C, that is, a winding hot spot rise of 90 °C.

The transformer temperature rise limits shall not exceed those values set out in clause 5.4.

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 Table 2. 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 and shall be based on three (3) second duration. The manufacturer shall provide calculations and suitable experience to 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.

The insulation and coil design shall guarantee 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 clause 5.4.

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.

The transformer supplied under this specification shall be proven suitable for operating continuously above rated voltage and below rated frequency at maximum continuous rating (refer 5.2.2) for any tap position, without exceeding the limits of temperature rise detailed in Table 2 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 Table 2 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 Table 2 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 off-load within the tapping ranges indicated in Table 2. The specified voltage, ratio, impedance and timing requirements shall be met.

5.2.8 Interchangeability

In order to manage network risks associated with equipment failures and spares management, the equipment and its parts shall meet the mandatory dimension, technical and configuration requirement detailed in this specification and its associated drawings referred in 5.9 and Appendix 4. 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 Work Health and Safety Requirements

Equipment shall be designed in accordance with the Work Health and Safety Act 2011 (NSW) and Work Health and Safety Regulation 2011 (NSW) 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 equipment. The lifetime shall include risk considerations for, but not be limited to the design, manufacture, delivery, installation, erection, commissioning, use, ongoing monitoring, maintenance and repair, decommissioning, dismantling, storage and eventual disposal of the equipment.

The supplier under this specification shall develop a risk assessment. The risk assessment for the 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 equipment, 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 equipment .

If the designer of the equipment 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.

5.3.2 Fall prevention and safe working at heights

As far as practicable, the design of the equipment 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 Work Cover Code of Practice: Managing the risk of falls at workplaces Dec 2011.

Any permanently fitted handrail that is required shall meet the requirements of AS1657, 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 equipment is fitted and energised.

Handrails may need to be folded down to obtain phase to earth clearances to any live parts, including busbars, conductors, cables, or bushings when the equipment is energised. Details of handrail are subject to the Substation Assets Manager's agreement prior to their manufacture.

5.3.3 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 including packing materials shall be asbestos free.

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

5.3.4 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.

5.3.5 Fire and blast hazards

The equipment and its components 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 any pressure relief devices, main tank 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 5.7.3) shall be provided to manage ongoing risk of equipment or component failure.

5.3.6 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.

5.3.7 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.

5.3.8 Sound levels and Radio Interference Voltage (RIV)

The equipment, including auxiliary equipment and linkages mounted on or near the main equipment, may be installed in a residential area in close proximity to family residences. As a result of strict noise requirements, Endeavour Energy requires sound and radio interference voltage levels, which includes both instantaneous and summated time noise levels, that are below the maximum sound levels detailed in Table 2.

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.

Endeavour Energy requires sound levels lower than the reduced sound power level limit stipulated in AS60076.10. Guaranteed sound power levels and sound pressure levels shall be stated in the offer. Sound power levels exceeding the specified levels will not be accepted.

A sound level test report shall be provided, as set out in AS60076.10, and shall be submitted for approval by the Substation Assets 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.

The low noise option(s) that is, option 2 or 3 from Table 2 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.

Preference will be given to designs that offer minimal RIV in accordance with AS62271.1 and as indicated in Table 2.

5.3.9 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 Table 2.

5.4 Technical requirements

5.4.1 General

The equipment and its components shall have the following performance characteristics and ratings.

Table 2 - Technical requirements

Ref No.	Item description	Requirement
	General requirements – All Equipment to comply to the following:	
1	To comply with standard	AS60076
2	Type	Auto transformer
3	No of phases (system)	3

Ref No.	Item description	Requirement		
4	Rated frequency (Hz)	50		
5	Rated voltage (kV/kV)	11/22		
6	Vector connection	YNa0+d		
7	Insulation levels			
	HV - system highest voltage (U_M) / LI / AC (kV/kVp/kV)	24 / 145 / 50		
	LV - system highest voltage (U_M) / LI / AC (kV/kVp/kV)	12 / 95 / 28		
	HVN - --- / LI / AC (kV/kVp/kV)	12 / 95 / 28		
	LVN - --- / LI / AC (kV/kVp/kV)	12 / 95 / 28		
8	Rated output – ONAN (MVA)	20		
	– ODAF (MVA)	-		
9	System fault levels			
	HV rating all taps and conditions (kA-rms)	20		
	LV rating all taps and conditions (kA-rms)	20		
10	Rated short time current duration (sec)	3		
11	Installed location	Outdoor		
12	Altitude (m)	< 1000		
13	Pollution level (mm/kV ph-ph)	31		
14	System earthing arrangements	Solidly earthed		
15	Earthing arrangement of tertiary winding	One corner of winding earthed – tertiary suitable for short circuit duty		
16	Pressure relief device (Main tank)	Qualitrol or equivalent		
17	Tank withstand - overpressure (kPa)	30		
	- full internal vacuum (kPa)	< 0.2/hr after 30min		
	- Vacuum deflection (mm)	< 1		
	- Pressure deflection (mm)	< 1		
18	Max. overall height (mm)	5500		
19	Max. transport height, width length (mm)	To permit transport without special permits		
Temperature and overload details				
20	Cyclic and overload (MVA)	None specified directly		
21	Maximum temperature rises limitations for continuous loadings	ONAN	ODAN	ODAF
	Top oil by thermometer (°C)	60	-	-

Ref No.	Item description	Requirement		
	• Windings by resistance (°C)	65	-	-
	• Winding hot spot by fibre optic (°C)	78	-	-
22	Localised heating of any metal part in contact with insulation or gasket (°C)	70		
23	Localised heating of any metal part in contact with oil only (°C)	80		
24	Core hot spot temperature rise at over excitation as in clause 5.2.6 (°C)	75		
25	Impedance @ 20 MVA, 75 °C ref temp (Refer to Fig 1 for allowable tolerance envelope)			
	• HV-LV, maximum tap (Position 1), max value including tolerances (%)	5.14		
	• HV-LV, maximum tap (Position 1), min including tolerances (%)	4.65		
	• HV- LV, principal tap (Position 3), tolerance +3, -3% (%)	4.31		
	• HV-LV, minimum tap (Position 5), max value including tolerances (%)	3.92		
	• HV-LV, minimum tap (Position 5), min value including tolerances (%)	3.55		
26	Impedance variation over the range	Suitable for parallel operation		
27	Category of voltage variation	CFVV		
Design details				
28	Insulating medium	Paper and Mineral oil		
29	Over-excitation at No-load, maximum continuous voltage any tapping (%Ur)	130 % Ur		
30	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 (Tesla)	Without saturation of the core		
	• 130% HV Ur @ full rating and load power factor of 0.86 (Tesla)	Without saturation of the core		
31	Maximum internal partial discharge @ 110% Um/√3 (pC)	< 50		
Tapchanger details				
32	Type of tap-changing	Off-circuit		

Ref No.	Item description	Requirement		
33	Location	HV		
34	Rated current (Amps)	≥ 790		
35	No of positions	5		
36	Off-circuit tapping range			
	• Winding	HV		
	• Range and step voltage	-5 to +5 at 2.5% step		
	• Tapping power	Full rating on all tap positions		
	• Max tap pos (Tap 1) - HV voltage (kV)	24.465		
	• Nom. tap pos (Tap 3) - HV voltage (kV)	23.300		
	• Min tap pos (Tap 5) - HV voltage (kV)	22.135		
	Insulating oil			
37	Oil to comply with standard	ETS 0010		
38	Type	Passivated inhibited		
39	PCB quantity (ppm)	< 0.1		
	Radiators and cooling			
40	Radiator mounting	Attached cooler bank		
41	Cooler location	In accordance with GA drawing in section 5.18		
42	Conservator type (Main Tank)	Sealed bag type with leak monitor		
43	Stand-by fan	-		
44	Stand-by radiator	Yes		
	Bushings, terminations and cable box	11kV	22kV	N
45	Bushings - To comply with AS60137			
	• Rated voltage (phase to phase) (kV)	12	24	12
	• Impulse voltage (kV peak)	95	145	95
	• Power frequency voltage (kV rms)	28	50	28
	• Continuous current rating (A)	≥ 1575	≥ 790	≥ 1575
	• One second current rating (kA)	20	20	20
	• Colour - To AS2700	Light Grey	Light Grey	Light Grey
	• Minimum creepage distance (mm)	372	744	372
	• Bushing type	Porcelain	Porcelain	Porcelain
	• Phase to phase clearance (mm)	200	350	-
	• Phase to earth clearance (mm)	160	280	160

Ref No.	Item description	Requirement		
	• Terminal palm size/type (Mains)	Type 8		
	• Terminal palm size/type (Earth)	Type 4		
46	Cable Box	11kV	22kV	
	• Termination type	Air insulated cable box		
	• No of cables	2 per Ø	1 per Ø	
	• Size of single core cables (Design must be able to accommodate all options)	630mm ² copper XLPE	800 mm ² copper XLPE	
	• Location of cable entry centres (Mandatory requirements)	Refer to attached typical transformer GA section 5.18		
	• Min. distance gland plate to centre of term. Palm	700 mm		
	• Location of termination centres (mm)	Refer to attached typical transformer GA in section 5.18		
	Current transformers	11kV	22kV	
47	CTs to comply with standard	AS 60044.1		
	CT mounting location	On bushing		
	Protection core 1 (close to bushing)	1 core/ bushing	1 core/ bushing	
	• Ratio	1200/0.577	600/0.577	
	• Class	0.05PL1000R7.0	0.05PL500R2.0	
	• Rated normal current, primary	1200	600	
	• Rated continuous thermal current, secondary (Multiple of secondary rating)	2	2	
	• Fault level	20kA/3s	20kA/3s	
48	Protection core 2	1 core/ bushing	1 core/ bushing	
	• Ratio	1200/1	600/1	
	• Class	10P300F20	10P600F20	
	• Rated normal current, primary	1200	600	
	• Rated continuous thermal current, secondary (Multiple of secondary rating)	2	2	
	• Fault level	20kA/3s	20kA/3s	
	Sound power and RIV			
49	Sound power Level (max acceptable-refer transf. cost assessment clause):	Opt 1 ¹⁾	Opt 2 ¹⁾	Opt 3 ²⁾
	• Tx @ 100% Ur no load with ONAN (dBA)	≤ 70	≤ 62	≤ 62
	• Tx @ 105% Ur no load with ONAN (dBA)	≤ 70	≤ 62	≤ 62
	• Sound power limitation during heat run test	≤ 70	≤ 62	≤ 62

Ref No.	Item description	Requirement		
	at TX full rating			
	Radio interference voltage (μV)	< 2500	< 2500	< 2500
	Auxiliaries / miscellaneous items			
50	Alarm and trip contact making, carrying and breaking capacity	1 A in typ. inductive (magnet coil) circuit at 250 V AC or 120 V DC		
51	Separate freestanding control cubicle for the temperature indicators	Not essential		
52	Local oil and winding temperature indicators with remote signal	Required		
53	Remote oil temperature signal	Required		
	Fibre-optic temperature sensors	Required as an option - Nortech		
54	• HV winding (A,B,C phases)	3		
	• LV winding (a,b,c phases)	3		
	• TV winding (b phases only)	Not required		
	• RV winding (b phases only)	1 (B phase only)		
55	Top oil temp. indicator and associated reed switch	Required		
56	Condition monitoring equipment	Optional		
	Delivery			
57	Delivery address	As nominated in the Works Section		
58	Delivery date			
	• Ex works	As nominated in the Works Section		
	• On site completed with all tests	As nominated in the Works Section		
	Capitalised cost assessment			
59	Ki = No load Loss (A\$/KW)	\$7,900		
60	Kc = Load loss on principal tap at CMR (A\$/KW)	\$830		

Note: 1) – Sound power level of no load, 2) – Sound power level at 66.7% rated load.

All bolts, screws and nuts shall be ISO metric. All bolts shall be no longer than necessary. All bolts nuts and washers used shall be hot-dipped galvanised or 316 stainless steel. All connections shall be terminated using crimp lugs rated for maximum worst case fault duty. All terminal palms used shall comply with AS62271.301. Clamps or u-bolt connections are not acceptable. All nuts shall be fitted with approved positive locking devices. Chemical locking is not permitted.

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 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. 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.

All metalwork shall be hot dipped galvanised in accordance with AS/NZS 4680 or 316 stainless steel unless specific approval to deviate is obtained from the Network Substation Manager.

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 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 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 accessible and 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 insulating medium shall be paper and mineral oil. Enamel insulated conductor may be used.

The windings shall be of the best modern design. Sufficient magnetic balance shall be maintained to satisfy the short circuit strength requirements. Insulation materials shall be selected to guarantee that stable clamping pressure 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. To satisfy thermal and short circuit strength requirements, 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 gasket joints shall be scarf joint.

The main tank shall have unpainted stainless steel (grade 316) or galvanised 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 these circumstances.

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

Suitable lugs must 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.

Reasonable size hatches shall be provided for access to the off circuit selector switch for whole of life maintenance purposes. Suitable access points shall be provided for easy access to winding tails for collecting paper samples for tests.

5.4.4.2 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 Substation Assets Manager.

5.4.4.3 *Mounting plates*

The base of the transformer shall have adequate strength to support the transformer when placed on the ground. Plates shall be welded externally to the tank base at the designed load bearing areas to allow adequate support of the transformer through anti-vibration pads. The plate dimensions shall be fractionally larger than the anti-vibration pads.

5.4.4.4 *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.

5.4.4.5 *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.

5.4.4.6 *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.

5.4.4.7 *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.

5.4.4.8 *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, pipe work between radiators and main tank, headers pipes, tap changer, main tank and pump.

5.4.4.9 *Vacuum and pressure requirements*

The tank shall be designed to withstand without leakage an overpressure of 30kPa absolute over the top of the oil filled transformer, in accordance with the test requirements and shall withstand full internal vacuum without oil.

5.4.4.10 *Valves and oil facilities*

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

Pipe work and associated valves shall be extended to provide effective transformer filling, draining and filtering facilities at ground level. All pipe work/valves are to be terminated 1200mm above ground level.

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

Shut off valves shall be provided on the end of each pipe connecting the main tank and separate radiator bank of the transformer to allow the relocation of main tank and radiator bank separately. 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. The oil- sampling valve shall be fitted to the 100mm flanges.

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.

5.4.4.11 *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.

5.4.4.12 *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 windings and in particular the top of the winding clamping structure where possible.

The openings shall have dimensions that allow unimpeded access to carry out the intended works. All access covers shall be provided with lifting handles.

Inspection hatches shall be located above the level of the core and windings.

5.4.4.13 Conservator tanks

There shall be an oil conservator for the main tank. Refer 5.4.7

5.4.4.14 Tank earthing terminals

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

The earthing terminal shall match a type 4 Terminal Palm In accordance with AS 62271.301, with the addition of a 50mm x 100mm extension shown in Figure 1. The earthing terminal shall be drilled with two (2) x 18mm diameter holes at 50mm spacing to accept two (2) x M16 bolts.

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.

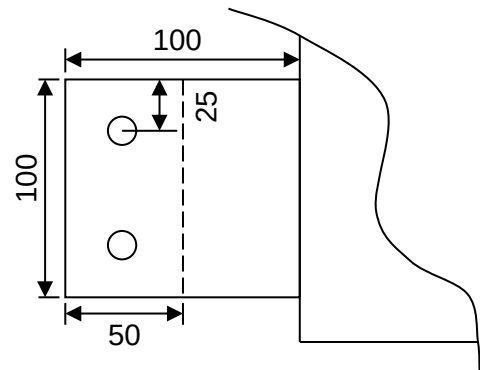


Figure 1 - Tank earthing

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.

5.4.4.15 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 into the oil bund.

The device/devices 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 20MVA auto-transformer preferred cooling specification is ONAN only.

5.4.6.1 Radiators

The tank design shall be for attached radiators.

The exterior of all radiators shall be hot dip galvanised. The interior of all radiators shall be varnished. Radiators must be cleared of excess varnish or 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 Viton seals. No valves are to be welded to the tank header pipes or radiators.

The valve is to be securely 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 pipe work 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 valve flange. Isolation of a bank of detached radiators shall be achieved by means of gate valves.

5.4.6.2 Cooler control 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 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. Cubicles shall be made of grade 316 stainless steel and shall not be painted.

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.

The terminals for these devices shall be segregated from all other terminals, shrouded against direct contact and provided with a red-white engraved Traffolyte live connections warning label.

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 Substation Assets Manager.

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

All 230V/400V terminals shall be shrouded and fitted with a warning label.

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 control cables, wiring and terminations shall be carried out in accordance with ETS0014. Alternative type tested connections can be utilised as approved by the Substation Assets 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 Substation Assets 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*

Not required on this transformer.

5.4.7 *Oil conservator*

There shall be an oil conservator for the main tank.

5.4.7.1 *Main tank conservator*

The main tank conservator shall be designed for a temperature range of -5°C to 120°C . The capacity is to be such that with the transformer operating at top oil temperature of 95°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.

5.4.7.2 *Main tank 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°C , 60°C and 90°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 dehydrating breather*

The main tank 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 be offered and will be considered in the lifecycle cost assessment of the transformer.

5.4.7.4 *Main tank conservator fill/drain/oil filtering*

The main tank, including conservator, shall be provided with oil filling/draining/filtering pipe work and termination valves located 1200mm above ground level to allow for effective oil filling/draining/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 Substation Assets 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 (if separate) shall each have a label affixed to their respective oil filling points. The label shall read as follows:

'Use inhibited 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 either 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.

Preference shall be given to ETI relays as Endeavour Energy already has them in wide use.

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 and oil temperature indicator (WTI and OTI)

The winding and oil temperature indicators shall be a Messko unit or equivalent. 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 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 devices shall require no periodic readjustment or recalibration during the lifetime of the transformer.

The devices shall be suitable for sensing through the range of 0 °C to 160 °C for the winding temperature and 0 °C to 140 °C for the oil temperature, and shall have a scale length not less than 150mm. The accuracy of the temperature measurements shall be +/- 2 °C.

Four (4) adjustable change-over micro switches, circuit closing, that can be separately adjusted to operate at any temperature setting, shall be provided on both the winding and oil temperature indicators.

On each unit two (2) of these contacts shall be suitable for setting to a fixed value for alarm and trip, and two (2) shall be spare. 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 °C to 160 °C for the winding temperature and 0 °C to 140 °C for the oil temperature and have a linear output signal of 4mA to 20mA corresponding to the above temperature ranges.

- The device shall be designed to operate correctly and without damage at up to 20% in excess of the above parameters. The option of a digital communication interface shall also be tendered. The required mandatory communication link is RS485 with Ethernet link as an added option. In terms of communication protocols, preference is for DNP3 with Modbus and IEC61850 as optional protocols. The tender submission should clearly indicate exactly what is being offered as part of the tender for suitable analysis in the design review.

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

Winding temperature indication CT and circuit

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 maintain the correct boost in the circuit for all modes of transformer operation.

The following information shall be provided for WTI setting at transformer maximum load rating:

- The winding hot spot temperature gradient shall be based on the higher value of the heat run measured with the embedded fibre optic temperature sensors, or the calculated value using a hot spot factor of 1.3 in accordance with AS 60076.7.
- Temperature gradient to be included in 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 check that the correct current is passed to the heating element.
- In order for Endeavour Energy to set the WTI at commissioning, the supplier shall indicate the amount of current to be injected and the corresponding oC temperature rise expected.

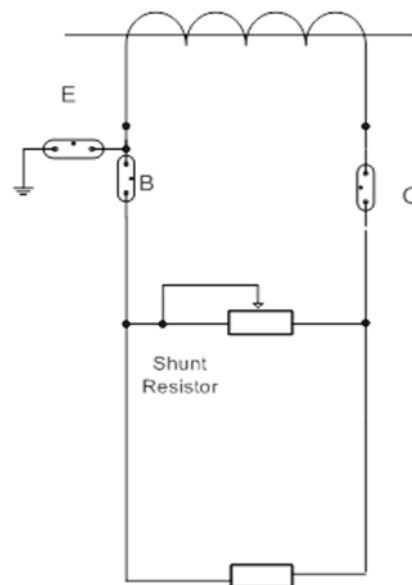


Figure 2 - WTI heater

The WTI CT shall have links provided as shown in Figure 2:

- Links B and C are for testing the entire circuit.
- Link E for meggering.

Fibre optic temperature sensors

Fibre optic sensors/probes shall be embedded in the transformer windings as follows:

Table 3 - Fibre optic sensor/probes

	HV winding			LV winding			TV winding			RV winding		
	A	B	C	a	b	c	a	b	c	a	b	c
No of probes	1	1	1	1	1	1	-	-	-	0	1	0

The sensing end of the probes shall be positioned at calculated hot spots within the selected windings.

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. A thermometer may or may not be required as part of the supply of the transformer. 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

Where fibre optic temperature sensing is offered, a fibre optic interface 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 °C and 160 °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 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 °C. The output signal shall be electrically isolated from other signals, power supplies and earth.

Temperature and control settings

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

Table 4 - 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 Off-load tap changing equipment

5.4.10.1 General construction

The transformer shall be fitted with an off-load tap-changer having the operation details as set out in Table 2.

The off-circuit tap changer shall also meet the minimum operational requirements as follows:

- The tap changer shall be capable of carrying the specified short-circuit current without damage or contact separation;
- The tap changer shall be gang operated from a single externally mounted operating mechanism;
- The tap changer shall be fitted with a mechanical tap position indicator;
- The tap changer neutral tap position shall be marked;
- The tap changer shall have provisions for pad locking in each position.

5.4.11 Bushings and main terminals

5.4.11.1 General

The specific requirements for transformer bushings and terminations shall be in accordance with the details set out in Table 2. Both 22kV and 11kV terminals shall be bushing installed within an air insulated box.

5.4.11.2 Bushings

All bushings shall be outdoor type oil-air bushings as detailed in Table 2.

The bushings shall be partial discharge free.

Bushings for insulation levels (U_m) up to 72.5kV shall be oil filled porcelain bushings, preferably of the ESAA standard type or a suitable complete ceramic type.

Clearances shall not be less than those specified in Table 2.

Both primary and secondary bushings shall be arranged side by side so that all bushings shall be on the horizontal plane with reference to ground to accept cable as indicated in the General arrangement drawing 390854. The neutral bushing shall also be located as indicated on this drawing.

The bushings shall be suitable for a through fault current equal as indicated in Table 2.

5.4.11.3 Bushing-type current transformers

The specific requirements for the current transformers shall be in accordance with the details set out in Table 2.

The secondary windings of the current transformers shall be capable of carrying continuously a current not less than 2 times the rated secondary current.

A rating plate shall be fitted to each current transformer.

A second identical plate is to be fixed within the control cubicle in such a position that facilitates ease of access to read the information. The CT details shall be stamped on a stainless steel plate and the nameplate shall be easily readable in all lighting conditions.

Each set of current transformers shall have all secondary leads brought out to an accessible terminal block.

The terminals and leads shall be clearly marked with current transformer secondary terminal markings to AS 60044.1, and show the current transformer group number in which the current transformer is mounted (for example, 3S2 - terminal number S2 of the third group).

Wiring shall be arranged so as to enable the changing of ratios.

The current transformer shall be tested in accordance with AS 60044.1.

The induced high voltage test on secondary winding insulation as specified in AS60044.1 is to equally apply to all current transformer secondary wiring and terminals between the current transformer secondary terminals and terminals provided for ratio change.

For one current transformer of each type, a temperature rise test shall be made in accordance with AS 60044.1. Rated burden in ohms shall be connected to each secondary winding during the tests. The test shall demonstrate that the specified temperature rise limits in AS 60044.1 will not be exceeded under any combination or ratio, primary current and secondary current up to their respective thermal ratings.

All routine test reports In accordance with AS 60044.1 including resistance measurements, accuracy checks, CT saturation curve, etc. shall be provided.

5.4.11.4 *Air insulated cable box*

Air insulated cable boxes shall be provided for connecting high voltage single or three phase cables to the transformers. The transformer shall be supplied with a cable box arrangement set out in Table 2 and the associated drawings to allow the cable terminations.

All 22kV and 11kV cable box arrangements shall be designed so the transformer can still function as normal and meet minimum clearance requirements 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.

An un-drilled solid busbar is to be provided for the connection of any 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 Table 2.

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 cover to the whole front of the box shall be provided with full unimpeded access.

Removable covers shall be provided with lifting lugs and handles. Where the cover weighs more than 20kg, it is to be slit horizontally into portions weighing not more than 20kg each, with each portion being fitted with lifting lugs and handles.

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 Table 2.

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 Table 2.

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 removable covers and the whole cable box shall be vermin proof after all the cables are installed.

5.4.11.5 Cable terminations

Cables shall be supported in a manner that will guarantee that no undue mechanical stress is 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

The rating plate shall comply with AS60076.1, Clauses 7.1 and 7.2, with the following 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 the cooling mode.
- Sound power levels at 100% and 105% excitation levels.
- Current transformer ratios, class, thermal limit, polarity and diagrammatic location of the CTs.

- Radiator quantity.
- A notation that one (1) radiator is standby (if applicable).
- Customer number, contract number, and space for the customer number to be inserted.
- Transport mass (without conservator, top header, radiators) including oil in main 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.
- Details of the fibre optic sensor and diagrammatic representation of the fibre optic locations and external connection terminals.

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, WINDING TEMPERATURE INDICATOR.

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 on one side of the devices by mechanical means.

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 nickle plated brass screws or sealed stainless steel rivets.

Drawings of labels shall be submitted for approval by the Substation Assets 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 ETS0014. Alternative methods of secondary cable terminations can be approved by the Substation Assets 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. Endeavour Energy uses standard International products supplied as indicated below. Notwithstanding this, equivalent proprietary coats may be used subject to the approval of the Substation Assets Manager. Other systems will be considered only if complete details of the proposed paint system are provided to the Substation Assets 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 and the painting and preparation requirements shall meet the requirements of AS/NZS 2312. 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 and Table 6 indicate the preferred paint system to be used. However the supplier can propose a paint system that shall be evaluated by the Substation Assets Manager based on the following as outlined in AS 3750:

- 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 - External surface painting recommendation

Paint coats	Paint description	Req. thickness (microns)
Surface preparation	Abrasive blast clean to AS1627.4 class 2.5	
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 6 - Internal surface painting recommendation

Paint coats	Paint description	Req. thickness (microns)
Surface preparation	Abrasive blast clean to AS1627.4 class 2.5	
COAT 1 (full coat) White colour	Interfine 399 with epoxy Novalac binder (2 pack)	75
	Total	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 this 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 Substation Assets 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 equipment 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 equipment.

Recommended tests to be carried out throughout the life of the equipment 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 equipment 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 for the mean time between failures (MTBF) of the equipment 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 equipment to the nominated site.

5.6.1 Design for transport

The equipment with its active parts (any internal windings, core, framework, clamping arrangements and general structure) and associated components 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 internal 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 7 - Transformer g-shock design rating

Axis	Max g-force used for the design	Duration (cont. or msec)	Comment
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 shall be in accordance with clause 5.8.1.2.

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 equipment and all its components equipment will be delivered to site properly and with any necessary and statutory approvals.

5.6.6 Storage

Equipment may require being stored for short or long periods of time.

Transformer should not be stored for more than four (4) months without oil unless alternative means of management is provided and agreed by the Substation Assets 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.

Where equipment condition becomes affected by storage, any damage or degradation shall be noted and brought to the attention of Endeavour Energy prior to delivery. Equipment with damage or degradation may not be accepted.

5.7 Quality assurance

Quality assurance certification is required to establish the manufacturers' ability to design and consistently manufacture equipment 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 8 - Inspection and hold points (QITP)

ID	Subject	Inspect / hold	Timeframe
	Design verification		
D1	Technical assessment and agreement on guaranteed performance	Hold	Prior to award of contract
D2	Quality assurance plan	Hold	< 2 weeks from award of contract
D3	Quality inspection and test plan	Hold	< 2 weeks from award of contract
D4	Initial drawings / information - Detail for the design of the concrete plinth and final equipment dimensions - General arrangement showing location and weight of all accessories and interface details	Hold	< 4 weeks from award of contract
D5	Production plan	Hold	< 4 weeks from award of contract
D6	Design data	Hold	< 7 weeks from award of contract
D7	Equipment risk assessment	Hold	< 7 weeks from award of contract
D8	Completed design data and drawings - General arrangement(s) - Control drawings	Hold	< 9 weeks from award of contract
D9	Design and risk assessment review	Hold	< 11 weeks from award of contract
	Inspection and factory testing		
F1	Complete equipment assembly	Inspect	As agreed
F2	Core strand insulation resistance	Inspect	As agreed
F3	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	Hold	As agreed
F4	Pre-tanking	Hold	As agreed
F5	Oil acceptance prior to filling	Hold	As agreed
F6	Certified factory test certificates	Hold	Prior to dispatch from factory
	Transportation and delivery		
T1	Transport arrangement documentation / agreement	Hold	Prior to dispatch from factory

ID	Subject	Inspect / hold	Timeframe
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 plus SWMS and MSDS documentation	Hold	1 week prior to installation
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 equipment 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 equipment is ready for inspection.

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

- A summary sheet listing the equipment 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 Substation Assets Manager.

Where possible, the supplier shall have use of a reliable video conferencing system to allow remote inspections for the equipment 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.

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 equipment
- Construction types, methods and procedures
- Calculated harmonic distortion levels, temperatures and locations, sound levels, losses, electrical stresses (power frequency and impulse)
- Electrical clearances
- Detailed drawings of all components including frames
- 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 equipment (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 equipment 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 clearly marking the components used.
- Design and ongoing risk assessment

5.7.5 *Equipment performance history*

The following information shall also be submitted;

- Details of technical back-up facilities available.
- Details of equipment operating history, including how many in service, where, and for what period, plus reference contact names and numbers.

5.8 **Testing**

5.8.1 *Factory testing*

5.8.1.1 *General*

The supplier shall be responsible for carrying out tests to demonstrate the equipment and its components supplied, complies with the technical requirements in this specification.

All routine, type and special tests shall be conducted with the equipment completely assembled in the factory with all protection devices, oil level gauges, control cubicles, handrails, support structures 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 Table 9 below. Test items 13-21 and 27-39 of the table shall be carried out in sequence.

Tests on all subsequent units and the suggested sequence are set out in Table 9 below. The test items 27 through to item 36 of the table shall be carried out in sequence.

Sound level tests may be carried out in conjunction with other tests but shall not interfere with the sequence for first or subsequent transformers.

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 Substation Assets 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.

Table 9 - 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 Substation Assets Manager prior to filling. The acceptable values of the above tests are set out in the attached Endeavour Energy insulating oil Engineering Technical Specification, ETS 0010.	ETS 0010	ETS 0010
2	Routine tests on winding temperature indicator current transformers, in accordance with AS 60044.1. The supplier shall indicate the amount of current to be injected and the corresponding °C temperature rise expected.	In accordance with standard's requirements	AS60044.1, 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 and CT secondary wirings.	> 5 MΩ using 1000V megger @ 20°C	AS60076.3, Cl.10
	Check of the ratio and polarity of built-in current transformers	Conforms to specification	AS60076.1, Cl.11.1.2.1
4	Power frequency voltage withstand tests on secondary wiring installation at 2kV for one (1) minute.	No insulation breakdown	AS 60076.3, Cl.10
5	The functional test of secondary wiring circuits.	Not applicable	AS60076.1, Cl.11.7
6	Measurement of the power taken by the fan and oil pump motors.	Not applicable	-
7	Gas and oil actuated relay stability where OFxx or ODxx cooling.	Not applicable	-
8	Paint thickness test at points selected by the Endeavour Energy's representative.	< 145 microns	AS2700
9	Measurement of the winding resistance on each tap (tabular and graphical results in Excel required)	Differential resistance < 0.02	AS60076.1, Cl.11.2
10	Measurement of voltage ratio and check of phase displacement (tabular and graphical results in Excel required).	Conforms to specification	AS60076.1, Cl.11.3
11	Tests on off-load tap-changers (operational checks and auxiliary circuit insulation test).	No failure Correct operation for full range	AS60076.1, Cl.11.7 a) and c)
12	Core to frame and core plus frame to tank insulation at 2.5kV for one (1) minute. Tests shall be carried out when the temperature of transformer including windings and cores is no more than 5°C hotter than the ambient temperature.	> 1 GΩ using 2500volt megger @ 20°C	AS60076.1, Cl.11.12
13	DDF (tan δ) and capacitance of bushings (where applicable)	< 0.007rad	AS60137

Item no.	Description of test	Acceptable value	Test method reference
	Partial discharge of bushings (where applicable) (Um 1.5Um/√3 1.05Um/√3)	10 / 10 / 5 pC	
	Capacitance	Manufacturer to provide	
14	Determination of capacitances winding-to-earth, and between windings	Based on design and recorded	AS60076.1, Cl.11.1.4
15	Measurement of insulation resistance (5kV dc @ one [1] minute) and measurement of dissipation factor (tan δ) of the insulation system (10kV), capacitances and polarisation index. Tests shall be carried out when the temperature of transformer including windings and cores is no more than 5°C hotter than the ambient temperature. The insulation resistance test shall be carried out from:		AS60076.1, Cl.11.1.4
	Each winding to all other winding(s) plus earth/tank	> 5 GΩ @ 20 °C	
	Each pair of windings to all other winding(s) plus earth/tank	> 5 GΩ @ 20 °C	
	All windings to earth/tank	> 5 GΩ @ 20 °C	
	Measurement of dissipation factor (tan δ) and capacitances as per design. Winding DLA:	< 0.0045rad	
	Polarisation Index 10/1 minute ratio	> 1.2	
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:		AS60076.1, Cl.11.1.4
	Hydrogen	Nil	
	Methane	Nil	
	Ethane	Nil	
	Ethylene	Nil	
	Acetylene	Nil	
	Carbon monoxide	Nil	
	Carbon dioxide	Nil	
	Nitrogen	<50 ppm	
	Oxygen	<50 ppm	
17	Measurement of no-load loss and current at 90%, 100% and 110% of excitation.	Based on guaranteed values	AS60076.1, Cl.11.5
18	Measurements of the harmonics of the no-load current.	Not applicable	-
19	Measurement of zero - sequence impedances on three-phase transformers (to be measured at 3 varying current levels to be agreed in tender response) .	< positive sequence impedance in Table 2	AS60076.1, Cl.11.6

Item no.	Description of test	Acceptable value	Test method reference
20	Item 20A - Measurement of short-circuit impedance and load loss. The Supplier is required to prove the impedance curve submitted in Annexure 1. As a minimum, the Supplier is required to plot impedance values at maximum, nominal and minimum taps. Other taps may be identified during design review. The minimum and maximum short circuit impedance values of the impedance curve are required.	In accordance with Table 2 envelope for each transformer.	AS60076.1, Cl.11.4
	Item 20B - 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 20A above.	AS60076.1, Cl.11.4
21	Oil sample to be taken from the transformer sample valve and temperature recorded.	-	AS60076.1, Cl.11.1.3
22	Sound level tests shall be conducted on the transformers at 100% and 105% core excitation with all cooling equipment de-energised (ONAN).	In accordance with Table 2 limits for each transformer	AS60076.10
23	Sound level tests shall be conducted on the transformers at 100% and 105% core excitation with pumps and fans (if any) energized (ODAF).	Test not required	Test not required
24	Sound level test shall be conducted on the transformers for measurement of noise due to 2/3 rated load currents.	In accordance with Table 2 limits for each transformer	AS60076.10
25	A transformer sound spectrum measurement shall be carried out at 100% core excitation on ONAN	In accordance with Table 2 limits for each transformer	AS60076.10
26	Short circuit test (Provide calculated design data or actual test, to be stipulated at tender time, refer to Cl 5.2.3 of this ETS)	The manuf. to provide evidence through test and/or calculation that their design and construction is suitable	AS60076.5
27	A temperature rise test shall be carried out under all implemented cooling conditions and to the criteria specified in Table 2. Temperature rise tests may be conducted only with the radiators that belong to the finished unit. Sharing radiator banks is not permitted.	In accordance with Table 2 limits for each transformer	AS60076.2
28	Oil sample to be taken from the transformer sample valve.	-	AS60076.1, Cl.11.1.3
29	Not applicable for this specification		

Item no.	Description of test	Acceptable value	Test method reference
30	Not applicable for this specification		
31	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°C with the transformer fully assembled.	No disruptive discharge.	AS60076.3, Cl 13.1
32	Lightning impulse voltage withstand tests for neutral on maximum tap position with the transformer fully assembled.	No disruptive discharge	AS60076.3, Cl 13.3.2
33	Oil sample to be taken from the transformer sample valve	-	AS60076.1, Cl.11.1.3
34	The separate source voltage withstand test to be carried out.	No voltage collapse	AS60076.3, Cl. 11
35	Oil sample to be taken from the transformer sample valve.	-	AS60076.1, Cl.11.1.3
36	Induced over voltage short duration withstand test	No voltage collapse	AS60076.3, Cl. 12
37	Oil sample to be taken from the transformer sample valve.	-	AS60076.1, Cl.11.1.3
38	Partial discharge tests shall be carried out on all terminals with the transformer fully assembled. The maximum apparent charge (q) shall not be greater than 50 pC at 110% 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, Cl. Annex A.
39	Oil sample to be taken from the transformer sample valve.	-	AS60076.1, Cl.11.1.3
40	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, Cl.11.1.4
41	Oil pressure test of 30kPa over the top of the oil filled transformer for 24 hours.	Tank withstands pressure.	AS60076.1, Cl.11.8
	Vacuum deflection test on liquid immersed transformers	< 1mm	AS60076.1, Cl.11.9
	Pressure deflection test on liquid immersed transformers	< 1mm	AS60076.1, Cl.11.10
	Vacuum tightness test on site on liquid immersed transformers	< 0.2kPa/hr	AS60076.1, Cl.11.11

Item no.	Description of test	Acceptable value	Test method reference
42	Dew Point measurement for moisture determination of cellulose insulation of transformer (in main tank and TC 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.	-40 °C and < 0.5%	IEEE. C57.93 and CI 5.8.1.2 of this specification
43	RIV test	Does not exceed 2500 μV @ $1.1 \times U_r / \sqrt{3}$	AS 62271-1 clause 6.9.1

Note: The handrails shall be fitted but lowered 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 Table 9. The final sample after testing shall be analysed for dissolved gas.

If any out of limit results are found from this sample then the sample taken at the completion of the previous test shall also be analysed. If this also has out of limit results then the previous sample shall be tested. This process shall be continued until the source of any out of limits has been identified.

5.8.1.2 Dew point measurement

When required, a dew point measurement according to IEEE C57.93 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 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.

The test result shall be submitted to the Substation Assets Manager, for approval prior to oil filling.

5.8.2 Site tests

5.8.2.1 Dew point measurement

If the transformer is shipped under gas, a dew point measurement according to clause 5.8.1.2 shall be carried out for determining the surface moisture level of cellulose insulation of the transformer. Filling shall be performed in accordance with 5.4.8.2.

5.8.2.2 Oil test

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 Substation Assets 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: 0 ppm
 - Methane: 0 ppm
 - Ethane: 0 ppm
 - Ethylene: 0 ppm
 - Acetylene: 0 ppm
 - Carbon monoxide: 50 ppm

The test results shall be submitted to the Substation Assets Manager for approval.

- After oil impregnation period (typically 24 hours after refill), the main tank oil and TC oil shall be tested for:
 - Moisture ≤ 20 mg/kg (ppm)
 - Breakdown voltage (12mm diameter electrodes, stirred) > 60 kv
 - Acidity < 0.1 mgKOH/g
 - Interfacial tension > 40 mN/m
 - DDF < 5 mRad
 - Furans: Nil
 - Colour : 1.0

The acceptable values of the above test are set out in the attached Endeavour Energy's insulating oil specification, ETS 0010. The values if stated above are in some circumstances less stringent than the requirements of ETS 0010. This takes into consideration the expectation after oil impregnation with good oil filling practice.

The test results shall be submitted to the Substation Assets 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 be 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 **1GΩ** @ 20 °C for one (1) minute, tested using 1kVdc test voltage (reference IEEE 62, 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 **5MΩ** @ 20 °C for one (1) minute, tested using 1000Vdc 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 Substation Assets 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 Substation Assets 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 1.1 p.u. rated voltage.
- Perform DDF test on all windings, including bushings with the following guaranteed values.

Table 10 - DDF/DLA guaranteed values

Winding DDF / DLA	Criteria
≤ 4.5mrad @ 20 °C	Acceptable
Between 4.5mrad - 5mrad @ 20 °C	Extend transformer warranty to a total of five (5) years during which the DDF shall be < 5mrad @ 20 °C.
≥ 5mrad @20 °C	Unacceptable

- Perform DDF test on bushings with DDF test point with the guaranteed value of maximum < 0.007 rad @ 20 °C.
- 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 Drawings

The following drawings form part of this specification:

Table 11 - Drawings

No.	Drawing no.	Amnd no.	Title
1	Refer Appendix 4	-	Mandatory Transformer General arrangement –11/22 kV 20MVA, Auto-Transformer(HV cable/ LV cable)
2	355766	A	Typical transformer circuit diagram
3	355769	A	Transformer block rail connection diagram

5.10 Product approval

5.10.1 Product approval process

The equipment shall be evaluated under the product approval process set out in PAE1004. The Network Substation Manager will approve the equipment for use on the network.

5.10.2 Product approval and audit form

Complete information on the equipment shall be provided on Branch Form FAE 3175.

6.0 AUTHORITIES AND RESPONSIBILITIES

General Manager Asset Management has the authority and responsibility for:

- approving this specification, including any variations;
- making all decisions concerning compliance in respect to this specification;
- nominating Endeavour Energy's representative(s) for either the manufacturing facility inspection and/or witness testing; and
- delegating any of these authorities and responsibilities to the Manager Asset Standards & Design.

Manager Asset Standards & Design has the authority and responsibility for:

- reviewing this specification and making recommendations to the General Manager Asset Management; and
- making recommendations concerning compliance in respect of this specification; and
- making nominations of Endeavour Energy's representatives.

Substation Assets Manager has authority and responsibility for:

- reviewing all type and routine test reports and alternative proposals submitted for evaluation, and making recommendations to the Manager Asset Standards & Design;
- clarifying all the technical aspects of this specification to the stakeholders; and
- approving the relevant actions required and outlined in this specification.

Project Manager shall have authority and responsibility to check that:

- All equipment installed complies with the requirements of this specification.

Commercial Manager has the authority and responsibility to certify that the equipment purchased through the tender process complies with the requirements of this specification.

Manufacturers/suppliers have the authority and responsibility for:

- establishing awareness of their responsibilities under this specification;
- determining the contractor/s under their control have provided suitable training for their staff;
- implementing 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	: Substation Assets Manager
Documentation process coordinator	: Branch Process Coordinator

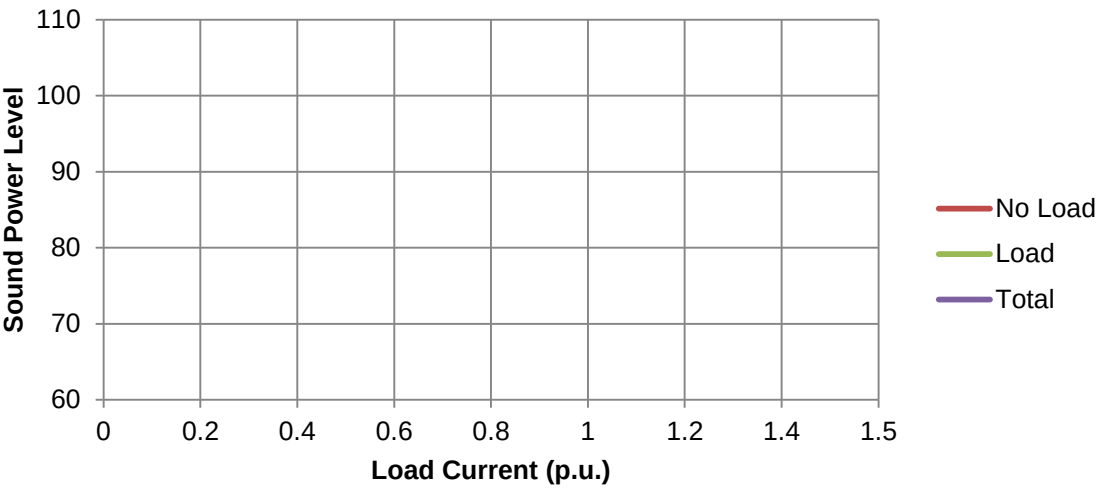
Appendix 1 - Graphical representation of offered impedance

Tenderer impedance must fit within the upper and lower limits in the envelope shown.

Appendix 2 - Tabular representation of offered impedance – one table for all transformer types

Transformer			
Impedance curve %			
Tap no.	Upper tolerance	Nominal	Lower tolerance
1			
2			
3			
4			
5			

Appendix 3 - Offered sound power levels – one graph for all transformer types



Appendix 4 – General arrangement drawing

Transformer drawing notes:

1. All dimensions indicated are mandatory.
2. Bushings to be 2130mm from ground level to centre line of bushings

