Standard

Supply Transformer Standard

R527890

Version 3.0, June 2018

Authorisations

Action	Name and title	Date
Prepared by	Michael Verrier – Senior Asset Strategy Engineer	June 2018
Reviewed by	Santosh Dhakal –Asset Engineer	June 2018
Authorised by	Darryl Munro – Asset Strategy Team Leader	June 2018
Review cycle	30 months	

Responsibilities

This document is the responsibility of the Asset Strategy Team, Tasmanian Networks Pty Ltd, ABN 24 167 357 299 (hereafter referred to as "TasNetworks").

Please contact the Asset Strategy Leader with any queries or suggestions.

- Implementation All TasNetworks staff and contractors.
- Compliance All group managers.

Minimum Requirements

The requirements set out in TasNetworks' documents are minimum requirements that must be complied with by all TasNetworks team members, contractors, and other consultants.

The end user is expected to implement any practices which may not be stated but which can be reasonably regarded as good practices relevant to the objective of this document.

Record of revisions

Section number	Details
Authorisations	Review cycle changed from 60 months to 30 months.
13.1 (h)	Added option of use of LED light
13.1	In final sentence added (if fitted) to need for glass in doors.
17.5 (l)(ii)	To be the same as point (n) changed. 'the minimum turns ratio position 23' to 'the minimum tap, all turns out, position.'
17.5	Routine test sequence altered

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1 General

1.1 Purpose

The purpose of this standard is to define the requirements of supply transformers under the responsibility of Tasmanian Networks Pty Ltd (hereafter referred to as 'TasNetworks').

1.2 Scope

This standard applies to all supply transformers (hereafter referred to as 'power transformers') under the responsibility of TasNetworks.

This standard contains requirements for design, engineering, manufacture, construction, testing at manufacturer's works, secured packaging, supply, transportation, delivery to site, testing and commissioning with complete documentation of power transformers and is to be applied to new installations as well as redevelopment of part or all of existing installations.

1.3 Objective

TasNetworks requires design, construction, installation and commissioning of equipment and services as covered in this standard to ensure:

(a) that relevant Australian legal requirements are met;

(b) that the requirements of the National Electricity Rules are met;

(c) personnel and public safety;

(d) ease in operation and maintenance;

(e) reliability and continuity of the power supply;

(f) minimum disruptions to the power supply following a fault;

(g) that the requirements of TasNetworks business plan are met;

(h) that the exposure of TasNetworks' business to risk is minimised; and

(i) that TasNetworks' responsibilities under connection agreements are met.

1.1 Certificate of conformance

Before any new and/or modified power transformer is put into service in TasNetworks' system, certificate of conformance with this standard must be submitted to TasNetworks. The certificate of conformance must be duly supported with documents, drawings, test results, test reports, test certificates, completed checklists and other documents as applicable. Where TasNetworks has approved deviation to specific requirements of this standard, all such approvals must be included with the certificate of conformance.

(a) TasNetworks will supply blank forms for certificate of conformance, to be completed by the manufacturer.

(b) The power transformer will be put in service only after TasNetworks has accepted the certificate of conformance.

1.1 Precedence

The order of precedence for TasNetworks' requirements shall be:

(a) TasNetworks' project specification;

(b) TasNetworks standards;

(c) Other codes, specifications, drawings, rules, regulations and statutory requirements.

Any conflict between the requirements of these documents must be brought to the attention of TasNetworks for resolution.

1.1 Deviation

Special approval for a deviation to this standard may only be accorded if it does not reduce the quality of workmanship and does not deviate from the intent of the standard. A request for a deviation must follow a designated procedure that involves approval from TasNetworks. Deviations if any must be specifically requested, and approved in writing by TasNetworks.

1.2 References

As a component of the complete specification for a system, this standard is to be read in conjunction with other standards and documents as applicable. In particular this includes the project specifications and the following:

1.2.1 TasNetworks Standards

Surge Arrester Standard	R522696
Extra High Voltage System Standard	R565983
Supply Transformers information to be provided with Tender	R527892
Supply Transformers Deliverables	R527891
General Substation Requirements Standard	R522687
Testing, Commissioning and Training Standard	R246497
Insulating Oil for Transformers and Switchgear Standard	R517371
HV and LV Cable Systems Standard	R590630
High Voltage System Standard	R565983
Substation Lightning Protection and Earthing Standard	R522692
Asset Nomenclature Standard	R684808

1.2.2 Other Standards

Bushings for Alternating Voltages above 1000 V	AS/NZS 60137
Metal Finishing – Preparation and pre-treatment of surfaces	AS 1627
Degree of protection provided by enclosures for electrical equipment (IP Code)	AS 60529
Power Transformers	AS 2374.8
Hot-dipped galvanized (zinc) coatings on fabricated ferrous articles	AS 4680
Power Transformers	AS/NZS 60076
Instrument transformers – Current transformers	AS 60044.1
	AS 62271.301

High voltage switchgear and control gear, Part 301: Dimensional standardization of terminals

2 General requirements

Project specific requirements for the power transformers will be listed in the project specifications.

2.1 Service conditions

Service conditions will not exceed the limits stated in AS/NZS 60076.1, together with the particulars of the system stated in Table 1 of this standard.

Specific environmental conditions and any specific design, installation, operation or maintenance criteria for particular works will be stated in the project specifications, such as availability of space, arrangement of power cable connection terminals, protection CT requirements and if directly connected to gas insulated switchgear.

2.2 Performance

The following performance parameters must be met:

(a) the power transformers and their individual components must provide reliable performance;

(b) the performance of the power transformers must meet all specified electrical, mechanical and environmental criteria under both normal and abnormal system conditions;

(c) the selection of equipment, design and all works associated with the power transformers must conform to the requirements as specified in document R522687and meet or exceed the specified design criteria and performance stated within this standard; and

(d) the transformer must be rated for continuous operation at the specified ratings, on any tapping position, under service conditions as defined within this standard, without exceeding the specified temperature rise limits.

3 Power transformer design

3.1 General design requirements

Materials and components must be selected to ensure safe and reliable operation for at least 50 years, with minimum inspection and maintenance.

Power transformers must be designed to:

(a) withstand the forces and stresses associated with lifting, jacking, skating, transport and erection so that there must be no cracks in the welds, leakage from, or permanent deformation to any part of the transformer due to such forces and stresses;

(b) have adequate overfluxing (V/f) capabilities to withstand both continuous and temporary over-voltages. The transformer should be capable of continuous operation at full load with the system operating at minimum normal operating frequency while maintaining 105 per cent secondary voltage;

(c) demonstrate the incorporation of modern design, insulation processing, and control/monitoring technology;

(d) have forced air-cooling, ie be oil natural air natural (ONAN) /oil natural air forced (ONAF) cooled transformers; and

(e) all components constituting the power transformer must be capable of operation at their specified rating without assisted means, for example, forced oil cooling will not be permitted to achieve the rated capacity, or any overload criteria.

3.1 Specific design requirements

In order to ensure the flexibility to relocate power transformers and for reasons of rationalisation of requirements for the spare power transformer population, TasNetworks has standardised on specific types of power transformers.

The type of power transformer required for a specific project will be stated in the project specifications.

Specific performance requirements for the standard power transformer types are shown in Table 1 of this standard and any additional criteria specific to a project will be stated in the project specifications.

If the requirements of the power transformer differ significantly from the requirements stated in this standard, eg there is the requirement for a third winding or a non-standard secondary voltage; this shall also be defined in the project specification.

3.1.1 Standard power transformer types

Supply transformers comprise the power transformers within TasNetworks' transmission network at the connection points both to the distribution network and to the direct connect customers. Their function is to supply and regulate the voltage applied to the distribution network, and is of varying capacity.

TasNetworks' standard type designations are listed below:

(a) Type One – 110 / 22 – 11kV, 17* / 25 MVA rated power transformer;

(b) Type Two – 110 / 22 kV, 30* / 60 MVA rated power transformer;

(c) Type Three – 110 / 33 kV, 30* / 60 MVA rated power transformer; and

(d) Type Four – 110 / 33 – 22 – 11 kV, 30* / 60 MVA rated power transformer.

*NB: The ONAN ratings given above are the minimum required ONAN rating. If a more optimal transformer can be achieved with a higher rating then this will be generally acceptable.

3.1.1 Overload requirements

In addition to the transformer being capable of the loading defined in AS/NZS 60076, there exists the requirement for specific, verifiable, overload ratings. There are two separate overload requirements for supply transformers. The transformer shall:

(a) be capable of being loaded up to 120 per cent of the maximum continuous rating, as specified in Table 1 – 2.5c, for periods of up to eight hours (h=8 hours) in 24 hours following loading at full load (ONAF rating) (k1/k2 = 83 per cent) under a Weighted Ambient Temperature of 20◦C without exceeding a winding hotspot temperature of 120◦C and a top oil temperature of 105◦C. Refer to AS/NZS 60076.2; and

(b) be capable of being loaded up to the rating specified in Table 1, 2.5(d), for a period of four hours at a weighted ambient temperature of 20°C without exceeding a winding hot spot temperature of 130°C and a top oil temperature of 115°C following a 24 hour period being loaded at the continuous ONAN rating.

Specific attention should be given to the rating of the transformer accessories including, but not limited to, the bushings and tapchanger, to ensure that only the windings limit the overload capability of the transformer.

Table 1 Parameters for power transformers

Sr. No.	Parameter	Unit	Power Transformer type			
			One	Two	Three	Four
1	Particulars of the System					
1.1	Number of phases	-	3			
1.2	Frequency	Hz	50			
1.3	Normal operating frequency excursion band	Hz	48.8 to 52			
1.4	Power system frequency range	Hz	44.8 to 52			
1.5	Nominal Voltage					
1.5a	HV Winding	kV	110			
1.5b	LV Winding	kV	22-11	22	33	33 -22- 11
1.6	Highest Voltage for equipment					
1.6a	HV Winding	kV	123			
1.6b	LV Winding	kV	24-12	24	36	36-24-12
1.7	HV Winding Rated Withstand Voltages					
1.7a	Lightning impulse	kVp	550			
1.7b	Power frequency	kV	230			
1.8	LV Winding Rated Withstand Voltages					
1.8a	Lightning impulse	kVp	150		200	
1.8b	Power frequency	kV	50		70	
2	Particulars of Transformer					
2.1	Number of phases	-	3			
2.2	Kind of transformer	-	Two (2) winding, power transformer			
2.3	Kind of magnetic circuit	-	Three (3) limb, core form			
2.4	Method of cooling	-	Air cooled radiator			
2.5	Rated Power	-				
2.5a	ONAN cooling (minimum required rating)	MVA	17	30	30	30
2.5b	ONAF cooling	MVA	25	60	60	60
2.5c	8 Hour overload requirement (ONAF) – Refer to Section 3.2.2	MVA	30	72	72	72
2.5d		MVA	37.5	78	78	78

Sr. No.	Parameter	Unit	Power Transformer type			
	4 Hour overload requirement – refer to Section 3.2.2					
2.6	Winding connection					
2.6a	Vector group symbol	-	YNyn0			
2.7	System Earthing					
2.7a	HV Winding	-	Solidly earthed system, HV winding's neutral is unearthed			
2.7b	LV Winding's neutral	-	Solidly earthed			
2.8	Type of Insulation					
2.8a	HV Winding	-	Uniform			
2.8b	LV Winding	-	Uniform			
2.9	Minimum short circuit withstand					
2.9a	Rated short-time current, HV winding	kA	40			
2.9b	Rated short-time, HV winding	s	1			
2.9c	Rated short-time current, LV winding	kA	31.5			
2.9d	Rated short-time, LV winding	s	1			
3	Tappings					
3.1	Tapped winding	-	HV			
3.2	Category of voltage variation	-	CFVV			
3.2a	Continuous over-voltage on any tapping at continuous maximum rating	%	10	15	15	15
3.3	Mode of tap change	-	On load			
3.4	Number of tap positions	-	23			
3.5	Tapping range					
3.5a	Number of positive taps	-	6	6	6	6
3.5b	Number of negative taps	-	16	16	16	16
3.6	Step value	V	1270	1400	1375	1375
3.7	Principal tap number	-	7	7	7	7
4	Impedance					
4.1	Guaranteed Impedance voltage at continuous maximum rating:	Base MVA	25	60	60	60
4.1a	At principal tap	%	12.8[1]	30	23.4	23.4[2]
4.1b	At maximum ratio tap	%	13.0[1]	31.3	24	24[2]
4.1c	At minimum ratio tap	%	12.2[1]	28.2	22.8	22.8[2]

<table>
<tr><th>Sr. No.</th><th>Parameter</th><th>Unit</th><th colspan="4">Power Transformer type</th></tr>
<tr><td>4.2</td><td>Tolerance on impedance voltages for principal tap position</td><td>%</td><td colspan="4">- 3%, +7.5%</td></tr>
<tr><td>4.3</td><td>Tolerance on impedance voltages for all other tap positions</td><td>%</td><td colspan="4">-3%, +10%</td></tr>
<tr><td>5</td><td>Bushings</td><td></td><td colspan="4"></td></tr>
<tr><td>5.1</td><td>HV line and neutral bushings</td><td>-</td><td colspan="4">(Note: HV winding's neutral point connection unearthed, brought out to HV bushing)</td></tr>
<tr><td>5.1a</td><td>Arrangement</td><td>-</td><td colspan="4">N - A - B – C from left to right, viewed from HV side</td></tr>
<tr><td>5.1b</td><td>Manufacturer/Model</td><td>-</td><td colspan="4">ABB bushing type GSA 123 1600, LF130 123-BB</td></tr>
<tr><td>5.1c</td><td>Current rating, continuous</td><td>A</td><td colspan="4">1600, including conductor</td></tr>
<tr><td>5.1d</td><td>Installation</td><td>-</td><td colspan="4">Outdoor</td></tr>
<tr><td>5.1e</td><td>Voltage</td><td>kV</td><td colspan="4">123</td></tr>
<tr><td>5.1f</td><td>Pollution class</td><td>-</td><td colspan="4">Heavily polluted atmosphere</td></tr>
<tr><td>5.1g</td><td>Creepage distance</td><td>mm</td><td colspan="4">Greater than 3075 mm</td></tr>
<tr><td>5.1h</td><td>Palm Terminal HV Bushing</td><td></td><td colspan="4">Type 8 electro-tinned copper, AS 62271.301-2005</td></tr>
<tr><td>5.2</td><td>LV line and neutral bushings</td><td>-</td><td colspan="4">(Note: LV winding's neutral point connection solidly earthed to substation earth grid)</td></tr>
<tr><td>5.2a</td><td>Bushing arrangement, within cable box

(viewed from HV side, unless noted)</td><td>-</td><td>Horizontal bushings, right hand end.

c-b-a from left to right, view from right hand end.</td><td>Horizontal bushings, right hand end.

c-b-a from left to right, view from right hand end.</td><td colspan="2">Horizontal bushings, right hand end.

c-b-a from left to right, view from right hand end.</td></tr>
<tr><td>5.2b</td><td>Additional alternative bushing arrangement, without cable box (if specified by project specification)

(viewed from HV side, unless noted)</td><td>-</td><td>Provision for vertical, right hand end, top of transformer.

c-b-a from left to right, view from right hand end.</td><td>Provision for vertical, left hand end, top of transformer.

c-b-a from left to right, view from left hand end.</td><td colspan="2">Provision for vertical, right hand end, top of transformer.

c-b-a from left to right, view from right hand end.</td></tr>
<tr><td>5.2c</td><td>Voltage/Pollution class</td><td>-</td><td colspan="4">36 kV / Outdoor, heavily polluted atmosphere</td></tr>
<tr><td>5.2d</td><td>Current rating, continuous (min)</td><td>A</td><td>2500</td><td>2500</td><td>2500</td><td>3150</td></tr>
<tr><td>5.2e</td><td>Manufacturer/Model</td><td>-</td><td colspan="4">Webster Wilkinson</td></tr>
<tr><td>5.2f</td><td>Minimum creepage distance</td><td>mm</td><td colspan="2">600</td><td colspan="2">600</td></tr>
</table>

Sr. No.	Parameter	Unit	Power Transformer type			
5.2g	Palm terminal, LV bushings	-	Type 8 Tinned Copper, AS 62271.301-2005			
5.2h	Power cables per phase ($630mm^2$)	-	3	4	3	4
5.2i	Palm terminal, Power cable termination	-	Type 4, AS 62271.301-2005 (Type Utilux CG630LPMB or equivalent)			
5.3	Bushing colour	-	Silver-grey			
6	Surge Arrestors (Connected to HV line bushings)					
6.1	Manufacturer/Model	-	ABB/PEXLIM R096-YV123			
6.2	Bushing colour	-	Silver-grey			
7	Radiators					
7.1	Radiators/cooling equipment	-	Attached to transformer, on LV side			
8	Sound Power Level	-				
8.1	Method of measurement	-	Sound intensity measurements in accordance with AS/NZS 60076.6			
8.2	Maximum permissible value at both ONAN and ONAF ratings	-	Noise level at full load current, 105% excitation and all cooling equipment in operation			
8.3	Guaranteed Sound Level	dB(A)	85	90	90	90
9	Current Transformers					
9.1	HV side, metering & protection	-	Not required			
9.2	LV side, metering & protection	-	If required, CT quantity, ratio & performance to be specified in project specification			
9.2a	Winding Temperature, CT1, Internal	-	To be specified by manufacturer on winding with the highest temperature			
9.2b	Protection CT1 & CT2, External neutral CT: ratio; and performance designation	-	Restricted earth-fault and earth-fault 2000-1000-600/1 0.1 PX 100(R_S+2) R R_S @ 1000/1 (where Rs = secondary winding resistance in ohms at the maximum service temperature)			
9.2c	Protection CT3, External neutral CT: ratio; and performance designation burden		Sensitive earth-fault 100/1 5P20 5VA			
9.3	Rated secondary thermal limit current for each secondary core	A	2.0			

Sr. No.	Parameter	Unit	Power Transformer type	
10	Losses		Note: Losses will be used to assess the transformer life cycle costs during tender evaluation	
10.1	No-load losses at 100% excitation	$/kW	$4870	
10.2	Load losses on principal tap position and at continuous maximum rating	$/kW	$610	$560
10.3	Cooler losses	$/kW	$1,000	

Note 1 Impedances tabulated are for a Type One transformer configured as either 110/22 kV or 110/11 kV.

Note 2 Impedances tabulated are for a Type Four transformer configured as 110/33 kV. Refer to Type Two's tabulated impedances for transformer configured as 110/22 kV. Refer toType One's tabulated impedances for transformer configured as 110/11 kV.

4 Internal requirements

All materials used within the power transformer tank must be suitable for use in the specified service conditions and the environment in which they are to perform.

4.1 Current transformers

Where current transformers are specified that must meet the following requirements:

(a) Internally mounted current transformers must be removable without disturbing the main tank cover or lowering the oil in the main tank below the top of the windings.

(b) Where LV bushing current transformers are required, they must be provided external to the main tank, within an external CT box. The placement of any LV bushing current transformers should be as unobtrusive as possible and should require minimum dismantling for replacement.

(c) Externally mounted neutral current transformers will be multi-core cast-resin toroidal type, with a minimum of 100 mm internal diameter. A bracket suitable for mounting the neutral current transformer shall be provided, welded on the side of the transformer tank. If necessary the CT secondary cabling shall be routed to an intermediate marshalling box prior to connecting to the main control cabinet.

(d) The secondary cables of external CT's shall be terminated to an intermediate marshalling cubical when the length of those cables is insufficient to reach the main control cabinet. This intermediate marshalling cabinet shall have a degree of protection equivalent to IP55 and sufficient spare terminals to allow for the installation of one additional CT similar to those defined in.

(e) Current transformers must conform to AS 610044.1 and be rated for at least 1.5 times rated current capacity of the power transformer.

(f) Short circuit rating of the current transformers must be, as a minimum, the same as that specified for the high voltage system.

(g) The specified performance of the current transformer shall be obtained without recourse to compensating devices;

(h) Metering class current transformers shall be designed to withstand (without damage) the effects of an open circuit on the secondary winding when full load current is flowing in the primary.

(i) A fixed voltage-limiting device set to operate at no greater than 4.5 kV shall be fitted across the secondary terminals of protection class current transformers. The device shall be fitted with a protective cover and be mounted on the current transformer secondary output terminal strip within the transformer marshalling cubicle.

(j) Bushing, toroidal or bar type current transformers shall be indelibly marked with the serial number and shall be marked to clearly indicate the polarity of the virtual primary terminals.

(k) Primary terminal P1 shall be located adjacent to the transformer winding on internally mounted LV bushing current transformers. Primary terminal P1 shall be located remote from the transformer bushing for externally mounted neutral current transformers. In case of HV bushing current transformers primary terminal P1 shall be located remote from the transformer winding and towards HV bushing.

(l) Each tapping shall be connected to an individual terminal within the transformer marshalling cubicle. Multiple ratio current transformers shall be obtained only from tappings on the secondary winding; and

(m) Rating plates for externally mounted neutral current transformers shall be mounted adjacent to the main rating plate.

4.1 Core and coils assembly requirements

Core form transformers are required and must meet the following criteria:

(a) Under normal operation, the temperature of any part of the core, coils or their support structure in contact with oil must not exceed 105ºC.

(b) Under the most extreme operating conditions of full load, system maximum frequency excursions and 105 per cent rated voltage on the secondary, the temperature parts in direct contact with oil must not exceed 120ºC.

(c) The transformer core shall be suitable for continuous operation under the most severe of the following two conditions:

   (i) with the transformer under full load, the secondary voltage at 105 per cent of rated and at minimum normal operating frequency; or

   (ii) with 115 per cent of rated voltage applied to the primary and at full load with system normal frequency.

(d) Internal earthing connections from the core laminations and core frame must be brought out to separate bushings suitable for insulation test with 2.5 kV DC. The bushings must be housed in a secured air insulated weatherproof terminal box mounted on the tank surface. Each bushing must be earthed via a removable link and arranged such that this point is the only connection for earthing the core and frame. The connections from core laminations and core frame bushings must be extended to the HV side of the transformer tank to 1.2m from the base of the tank and terminated to bushings. A clearly marked warning label, as follows 'WARNING – DO NOT ENERGISE WITHOUT EARTHING LINK FITTED', must be installed adjacent the earthing link terminals.

(e) The core and structure insulating and earthing systems must be designed to avoid thermal deterioration and breakdown of insulated parts due to temperatures and voltages caused by circulating eddy currents.

(f) To reduce no-load loss and current and noise level, cores must have 45 degree mitred corners and must not have bolts passing through the legs or yokes. The steel used in the core must be grain-oriented cold-rolled silicon steel preferably domain-refined. Cores must be adequately clamped to withstand forces during lifting, transport and short circuits.

(g) The core and winding support structure must be of solid steel construction. Wood sections for the frame are not acceptable.

4.1.1 Windings

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

Where enamel covered conductors are used, either in the form of continuously transposed cable (CTC) or paper insulated multiple strand cable, its individual strands must not make inadvertent contact with each other. This condition must be verified through the application of 500V DC between all strands within a common covering. This test should be conducted with the windings under pressure, and prior to the completion of the winding ends. Proof of this test shall be included in the transformer test report. Where there is unintended electrical contact between an excessive number of strands, or strands which are physically distant, for example non-neighbouring strands in a CTC, this shall be brought to the attention of TasNetworks.

Where paper insulated conductors are used, the paper shall be of the thermally upgraded type.

4.1.2 Reconnection links

Where a requirement for reconfigurable windings is stated in the project specifications, off-circuit reconnection must be possible by easily accessible links within the power transformer tank. These links should be located in such a way to enable the connection to be changed without lowering the oil level below the top of the windings. Designs using an off-circuit tap switch to achieve this reconfiguration shall be considered. A clearly marked warning label, as follows 'WARNING – DO NOT ENERGISE WITHOUT LINKS FITTED', must be installed adjacent to the link terminals. Only captive links made of copper shall be used. The links should have identifying marks on them to minimise the risk of an incorrect connection.

The connection arrangements must be clearly shown on the power transformer rating plate, connection diagram plate and additional plates detailing procedure for access to power transformer link box.

4.1.3 Internal cable connections

Soft soldering must not be used for joining or connecting leads. Joints may be silver soldered, brazed or welded. The number of joints should be minimised to guard against the possibility of overheating. Bolted joints carrying current must use 'Belleville' or similar washers to maintain contact pressure. The use of crimp joints requires the approval of TasNetworks. Where these are used they shall not be of the 'negative space' type and should be properly insulated following the completion of the joint. When a joint is made within the body of the winding this shall be clearly identified by a mark on the outside of the conductor insulation. These joints should only be of the brazed type.

4.1.4 Paper sampling for loss of life monitoring

The manufacturer must provide three sets of paper samples for 'use of life' monitoring, degree of polymerisation (DP) testing. Each sample must be made up of a strip of transformer board covered by five layers of paper tape. The transformer board strip must be approximately 250 mm long and of the same make and type as used on spacer strips within the windings. The paper must be recovered from surplus conductors of the type used in the winding, re-taped onto the transformer board strip.

The paper samples must accompany the winding coils during the coil pre-dry out (sizing/stabilisation) and be fitted on the transformer prior to the dry-out procedure. On final tanking they must be mounted near the top of the tank, accessible from a suitably located access cover. The access cover must be indicated on the outline drawings and have a suitable label attached to it.

After test, while the transformer is dissembled for transportation, one sample must be taken for DP testing. The DP value after drying and testing should not normally be less than 1000. Measurements significantly below this figure must be brought to the attention of TasNetworks for resolution.

4.2 Winding short circuit requirements

The transformer when on any tapping must be capable of withstanding, without deformation or injury, the thermal and mechanical effects of external short circuits with fault currents as may arise from any type of fault and with full voltage maintained on all windings (zero source impedance).

Each of the transformer windings shall be capable of withstanding the effect of short circuit current without the aid of other windings. That is, all windings in the transformer shall be fully self-supporting under short circuit conditions.

Calculation of short circuit currents and current densities and finite element calculation of short circuit forces and stresses in windings and end supports, for all fault types, and for principal and extreme tapping positions, must be carried out and made available at the time specified within the Supply Transformer Deliverables document R527891.

5 Tank requirements

5.1 Tank design requirements

The tank must be designed to minimise the heating caused by circulating eddy currents. The tank design must prevent onerous temperatures arising at any part of the tank surface and at flanges between parts of the tank and its components especially at gasket-sealed joints.

5.2 Tank construction requirements

5.2.1 General

The tank must:

(a) be constructed of welded steel plate and must be suitably reinforced to withstand transport, handling or excess pressure during fault conditions, without distortion. The tank, conservator and large oil pipes must be fully welded internally. The main flange must be fully welded;

(b) be free of external pockets to prevent collection of water;

(c) have a lid designed with sufficient slope to properly shed water. It must also be designed and provided with a non-slip surface to facilitate the movement of personnel on top of the transformer;

(d) have on the cover of the tank a ladder attachment point. This shall be provided on the tank to position and tie off a ladder located on the HV side of the transformer;

(e) have personal fall arrest device attachment points located 2 meters apart on the tank lid. These attachment points should be located towards each end of the tank, and within reaching distance of the ladder attachment point. The attachment points for fall arrest devices must comprise eye-bolts or rings with minimum internal diameter 50 mm and a cross section of 16.6 mm, with a minimum load capability of 21 kN, and be designed for use with snap hooks associated with inertia-reel fall arrest devices;

(f) have hand rails of 1.5m high around the transformer top installed with 0.6m hinged lockable gate (opening inside) located next to the ladder attachment point. The hand rails shall be fabricated with galvanised mild steel pipes and plate. The hand rails shall be removable type to aid in transportation. The hand rails and hinged gate shall be effectively bonded to the tank.

(g) have labels which are to be securely fixed adjacent to the relevant attachment point, engraved with either 'LADDER ATTACHMENT POINT' or 'PERSONNEL ATTACHMENT POINT', together with additional information as detailed within AS 1891.4;

(h) consider placement of lifting points, stiffeners and under-bases to prevent distortion of the core under lifting stresses;

(i) be mounted on 'Embelton Shearflex' anti-vibration pads, or equivalent pads made from oil resistant synthetic rubber that achieve a minimum of 32 dB(A) vibration attenuation;

(j) ensure that the design of the magnetic circuit and tank and their individual members must be such that their natural frequencies of vibration do not coincide with, or approximate to, the frequency of the magnetic forces or their harmonics; and

(k) have studs which are used for mounting tank fittings on the power transformer tank made of stainless steel.

Bolts, screws and nuts must be ISO metric. All bolts, nuts and washers used outside the tank must be stainless steel. All nuts and bolts within the tank must be stainless steel and fitted with approved locking devices. Nuts and bolts which are specifically part of construction features and are not for the use of TasNetworks are excluded from this requirement. Spring washers and star washers must not be used. Belleville or similar washers are preferred. Double nuts are acceptable.

5.1.1 Tank surface preparation and coating

In order to ensure longevity of the transformer paint system any system used should be suitable for a coastal marine environment. The exterior coating system shall meet the following minimum requirements:

(a) surface preparation shall be fit for purpose and particular attention shall be given to the chamfering of corners and edges where a minimum 2 mm radius is required;

(b) surface preparation to a minimum of shot blast Grade 2.5 as per AS 1627.4 - 2005;

(c) initial coating with a zinc rich primer to a minimum DFT of 50 µm;

(d) intermediate coating shall be a white epoxy based paint with a minimum DFT of 125 µm in at least two coats;

(e) the final coat shall be an epoxy based paint equivalent in colour to Dulux N35 light grey, with a minimum DFT of 125 µm in at least two coats; and

(f) all internal surfaces shall be white.

Any deviation from the above requirements requires the written approval of TasNetworks.

5.1.1 Handling facilities

In order to enable the safe and efficient handling of the transformer, the transformer must:

(a) have adequate handling facilities provided to permit movement, assembly and dismantling of the complete, oil filled power transformer;

(b) have four adequately positioned jack pads designed to take the weight of the power transformer, complete with oil, provided on the tank. The jack pads must provide clear access for the jacks and must not be blocked by any accessories or control cabling;

(c) be provided with bollard type lifting lugs suitable for lifting the power transformer complete with oil. The lifting lugs and attachments must be designed to allow for possible unequal lifting forces, with an adequate allowance for a factor of safety;

(d) have lifting eyes provided for the cover of the power transformers main tank, conservator tanks, on load tap-changer, radiators and all other parts that require lifting for erection, inspection or repair; and

(e) have a base which is suitably reinforced to allow skidding of the power transformer in any direction and for hauling on skates. Hauling eyes must be provided on all sides of the tank and be free from obstruction.

5.1.1 Oil-tight joints

TasNetworks require that only joints of proven design capable of preventing deterioration of any seal or gasket materials are supplied. Joints must operate satisfactorily under static oil-head or forced oil conditions at maximum operating temperatures.

All openings into the main tank shall be through flanges raised a minimum of 40 mm off the tank surface. Blind holes or studs are not permissible where oil tight or load bearing joints are required. Nuts and bolts only should be used, unless approval is given by TasNetworks for another fixing method. Approval for other methods shall only be given on a case by case basis.

All bolted joints at the main flange, access-openings, and bushing openings must be provided with suitable gaskets made from oil resistant non-perishable material. The thermal performance of the material must exceed the maximum temperature attained by the metal parts in contact with the gaskets under all conditions. Screwed joints must not be used where oil tightness is required.

Where cantilever forces exist on the joint, gasket stops must be provided to prevent over-compression of gaskets.

5.1.2 Valves

Except where specifically stated, all valves must be metallic seating gate type or approved equivalent. Butterfly type valves are acceptable provided that they have been tested to withstand the head of oil pressure presented by a full conservator. Generally, globe or ball valves are not acceptable. All valves, which would require lowering of oil in the main tank for replacement, must be of the type that permits changing the valve spindle with the valve gate in the closed position, except where noted.

Valves must be positioned so that the clearance between the operating handle and adjacent fixtures is adequate for operation of the valve. All drain, filtering and filling valves must be of the female type, fitted with sealed flange plugs. Tapered screwed plugs are not acceptable.

When stripped for transport, all flanged valves must be provided with cover plates to prevent oil seepage and ingress of dirt.

Where a free-standing cooling system is employed, the main feed pipe valves may be of an approved butterfly type except for the lower feed pipe isolating valve adjacent to the main tank which must be a metallic seating gate type. The lower feed pipe must also have a valve at the cooler end. 25 NB drain valves and vent plugs must be provided on all headers and connecting pipes to permit individual draining of sections between valves where this is possible.

The power transformer tank must be equipped with the following valves:

(a) butterfly valve for the main isolating valves for the cooler bank and each individual detachable cooler element;

(b) valves made of bronze or a non-ferrous equivalent to cater for the following functions:

  (i) 50 mm fullway filter and drain valves at the top and bottom of the cooler bank;

  (ii) 50 mm fullway filter valve at the top of the main tank;

  (iii) 50 mm fullway drain valve at the lowest part of the main tank;

(iv) 25 mm fullway filter valve at the top part of the OLTC tank or compartment;

(v) 50 mm fullway filter valve at the top of the main conservator;

(vi) 50 mm fullway drain valve at the bottom of the main conservator;

(vii) 50 mm fullway filter valve at the top of the OLTC conservator;

(viii) 25 mm fullway drain valve at the bottom of the OLTC conservator;

(ix) 25 mm fullway sampling valve at the level of the bottom of windings;

(x) 12mm BSP ball valve (c/w screw cap) attached to the valve at the level of the bottom of windings to permit oil sampling;

(xi) 25 mm fullway drain / sampling valve at the bottom of the OLTC tank or compartment; and

(xii) 80 mm NB isolating gate valve on both side of the Buchholz relay.

Valve locations, functional names and normal status must be provided on an engraved valve plate, which must be located adjacent to the power transformer rating plate. The rating plate must be non-corrodible.

The plumbing pipe works of size less then 80mm shall be of stainless steel grade 316. The stainless steel pipe allows use of O-rings (rubber) on flanges instead of gaskets which prevents leaking from the shrinkage of gasket.

5.1.1 Valve locking requirements

All valves which can be accessed from ground level shall be capable of being locked in either the open or closed position.

5.1.2 Access openings

Power transformers must have at least two access openings on the tank cover for access to the interior without lowering the oil below the top of the core. If a separate tap-changer oil compartment is used, it must also be provided with at least one access opening on the cover.

Access openings must be provided (on the tank cover and for the tank walls) to permit access for:

(a) inspection and removal of current transformers, bushing connections, tap-changer connections;

(b) manipulation of bolted links for change of connection arrangements on reconfigurable windings; and

(c) visual check of alignment or engagement of locating pins, oil ducts, internal clearances, electrical connections during detanking and tanking operations.

In particular the access openings shall be:

(a) a minimum dimension of 660 mm diameter if circular or 660 mm x 660 mm is rectangular, to allow entry; and

(b) fitted with a label stating ‘ACCESS OPENING’.

All access openings and bushing openings on the cover must have a separate raised flange to ensure a quality gasket area and to prevent water from entering the openings when individual covers are removed, and must fulfil the requirements given in the section on oil-tight joints.

All covers must be designed to avoid entrapping gases generated within the transformer. If necessary, piping from the access opening to the conservator should be used to ensure that all gas generated inside the tank passes through the Buchholz relay. Covers shall be equipped with lifting lugs and prising-off bolts.

5.1 Air insulated cable box requirements

In all circumstances the interior of the cable box shall be considered to be an outdoor installation. This has particular reference to the cable terminations and fittings. The cable box shall:

(a) have a double flange arrangement where the cable box is attached to the main tank with through bolts. Attachment using welded studs is not acceptable;

(b) be weatherproof and fitted with a vermin proof vent of the multi-pass type, with a degree of protection for the cable box of IP44;

(c) be fitted with a threaded removable drain plug;

(d) have vents placed at diagonally opposite corners of the box which are constructed of a steel plate welded into the cable box which is at least 150 mm high and 300 mm long with at least four rows of ten suitably sized holes drilled into it. These vents shall be protected by a cover to prevent rain from entering the box and shall be backed by stainless steel wire mesh to prevent the entry of insects and vermin;

(e) have a 6 mm thick aluminium gland plate;

(f) be mechanically sturdy and sufficiently braced to withstand a phase-to-phase and phase-to-earth faults with the fault levels specified on either the primary or secondary lines; and

(g) on one side of the cable box (preferably on the LV side of the transformer), in addition to the cable box cover on the front of the box, there shall be a lockable, hinged inspection opening.

The LV bushings shall be suitable for horizontal or vertical mounting and shall be mounted such that any bleed holes are installed in the correct location, generally on the upper or top side, of the bushing. There should be sufficient room between the bushing and the top of the cable box to allow free access to this location.

The bushings are to be connected to a solid, tinned, copper bar, correctly sized and rated for the full load current, including overloads or the rated short circuit current, whichever is the more onerous. The connection between the bushings and this bar shall be via a flexible copper connection to ensure that no torque force is applied to the bushing by the weight of the LV cables. The bar shall be firmly fixed to the interior of the cable box through the use stand-off insulators of an appropriate rating.

The bar shall be sized to accept the number of cables, as specified in Table 1, located on 200 mm centres. Pilot holes shall be drilled at these locations. Corresponding pilot holes shall be drilled in the cable box gland plate.

The weight of the cable box should be supported back to the main tank wall by the use of support structures.

5.1 Pressure and vacuum requirements

The oil containment and circulation system, consisting of main tanks, cooling banks, conservators, valves, vital pipe-work parts and all other associated fittings and components, must be capable of withstanding, without distortion, an internal pressure of 50 kPa in excess of that required to operate the pressure relief valve.

The oil containment and circulation system must be capable of withstanding a vacuum test with a leak rate less than 10 Torr-litres per second. A continuous vacuum of 1 Torr must be maintained for 48 hours duration without any resultant permanent deflection or deformation of the tank or parts.

6 Earthing

Earthing must comply with requirements as in document R522692. In addition to the requirements of the document R522692, each of the following requirements will be met:

(a) On each of the four corners of the transformer, at ground level, and one below the surge counter, there shall be an earth connection point. These shall be 90 x 50 x 6 mm in size with 2 x M14 holes on 44 mm centres.

(b) The main tank cover, the bushing turrets, cable boxes, attached cooler banks and any other components of the transformer containing items connected to the power system must be effectively bonded to the tank.

(c) All metal work both internal and external to the tank must be effectively earthed.

(d) Circulating current loops within the earth system are not permitted so as to avoid localised heating of the tank.

(e) There shall be an insulated conductor, rated for the maximum fault level and duration, bolted to the neutral bushing and passing through the toroidal current transformers for connection to the substation earth grid with a minimum of bends and deviations. If stranded cable is used it shall have a minimum cross-sectional area of 120 mm^2 or if solid copper bar is used then this shall have minimum dimensions of 40 mm x 3 mm. There should be break points in the bar to facilitate the removal or replacement of the neutral CT's; and

(f) The earth points of the three surge arresters shall be connected together with a single solid copper bar of minimum dimension of 40mmx 3mm. The copper bar shall be supported with insulators as required and shall not come in contact with the metallic part of the bracket. There shall be a 120mm^2 insulated copper cable bolted on to the copper bar and brought straight with minimum bends to the top of the surge counter. The surge counter shall be earthed directly to its dedicated connection point using 120mm^2 insulated copper cable.

7 Bushings

The bushings shall be of the type given in Table 1 of this document for the high and low voltage sides respectively. The bushings must be capable of withstanding the maximum cantilever load stated in AS/NZS 60137. The bushings including conductor must have a current rating at least 50 per cent higher than the maximum current on any tap-position. The neutral bushings shall be of the same type and current rating as the line bushings.

The low voltage bushings shall be suitable for mounting in either the vertical or horizontal planes, either in open air or contained in a cable box, without requiring a reduction in the current rating of the bushing. The bushings shall generally be suitable for the overload rating of the transformer.

Where the bushings are mounted on turrets, the turrets must not be fixed by studs screwed and welded into the tank cover. Blind holes with studs welded in are likewise unacceptable if the bushing is to be directly mounted on the transformer lid.

The minimum electrical clearance, phase-to-phase, between primary and secondary terminals, phase to neutral and phase to earth of all terminals in air must be at least as required by AS/NZS 60076.3 for equipment with insulation levels as specified in Table 1.

8 Surge diverters

The transformers must be supplied with 110 kV surge diverters mounted on brackets attached to the transformer tank. Surge diverters must be of the metal oxide type and must comply with requirements as in document R522696. One surge counter must be provided for each set of three phase surge diverters and shall be located no more than 1.1 metres above the base of the tank and directly below the 'B'-phase surge diverter. Insulating bases are required. The earthing of the surge diverters shall be as described in Section 6(f).

9 Cooling and Insulation system

Power transformers must be of the mineral oil-immersed type to provide insulation and cooling.

9.1 General requirements

Any degree of oil circulation must not create a static electrification hazard in any part of the transformer or trip the transformer.

Oil pipelines and flexible couplings are to be adequately secured to prevent excessive vibration.

9.2 Transformer oil

Transformer oil must comply with the requirements of document R517371and must be supplied to fill the transformer to the correct oil level.

9.3 Conservator requirements

Oil expansion in any oil-filled chamber in the power transformer tank (eg. main tank, OLTC compartment, oil-filled disconnect chamber and alike) must be accommodated by the use of conservators. Conservators must be constructed such that:

(a) there is a separate conservator for the OLTC with both oil and air side separated from the main conservator of the power transformer;

(b) each conservator must have sufficient capacity to accommodate the change in oil volume expected in the corresponding power transformer chambers that will occur for extremes of loading conditions (range of service to the most severe overload condition specified in AS/NZS 60076.7) within the specified ambient temperature range;

(c) the volume of each conservator compartment must in no case be less than 10 per cent of the total oil volume of the corresponding tank chamber;

(d) each conservator must be fitted with its own oil level indicator, breather, filter/filling and drain/sampling valves, and removable end plates for inspection and maintenance. The valves must be brought down to permit safe connection of filling and sampling devices while standing at ground level with the power transformer energised; and

(e) the conservators must contain a minimum oil depth of 20 mm above the inlet point with the oil at its minimum temperature.

The oil level indicators must:

(f) be unaffected by the condition of oil within the conservators;

(g) have a sensing mechanism that is electrically and mechanically isolated from the indicating device; magnetic type oil level devices are acceptable;

(h) have a visible range of oil levels for oil temperatures from 5°C to 105°C, with calibration from 15°C to 90°C in steps of 15°C;

(i) have a set of normally open contacts for low oil level alarm;

(j) include 4-20 mA analogue output connected to separate terminals within the power transformer control cubicle and to the current loop input of the power transformer monitoring and control unit for remote level indication

(k) be mounted on the conservator tank at a position easily readable with the naked eye from ground level; and

(l) have a minimum diameter of 250 mm and be mounted at an angle of approximately 20 degrees to the vertical.

9.1.1 Oil – air exchange

The main oil conservator must be fitted with an air cell to prevent direct contact of the oil with the air and labelled accordingly. It must have a sump and the sump protected to cause no damage to the air cell. A relay must be fitted to detect leakage of the cell, and initiation of the relay must raise an alarm. The alarm must be connected to the station SCADA system.

In addition to this, the conservator must meet the following requirements:

(a) access to the conservator air cell for inspection must be made via a removable end and inspection opening cover situated at the ends of the conservator;

(b) air exchange for each conservator must be via silica gel or other equivalent breathers, suitably sized for the particular compartment. The breathers must be mounted such that the breather can be easily maintained or inspected while standing in a safe position at ground level;

(c) all silica gel breathers must be fitted with oil cup seals;

(d) blue silica gel has been identified as an occupational health and safety hazard and must not be utilised. All silica gel provided must be orange or other suitable silica gel with properties similar to the blue silica gel.; and

(e) all silica gel within any breather must be identical. Mixing of two different types of silica gel is not acceptable.

9.1 Radiators

The radiators must be of robust, compact, maintenance-free design. They must be demountable with machined flanges and arranged as stated in Table 1. If panel radiators are offered they must be hot-dip galvanised with an average coating mass of at least 350 g/m^2, in accordance with AS 4680:1999, and are not required to be painted.

Radiators manufactured by 'MENK' are preferred. The internal surfaces of the radiators should be suitably coated to resist corrosion.

9.2 Radiator fans

In order to meet the ONAF rating of the transformer, the transformer must also be provided with a bank of cooling fans located at one end of the radiators.

Typically it is preferred that fans shall not be mounted so as to blow air in the vertical direction, nor shall fans be mounted at either end of the radiator bank and arranged to blow air towards each other without a suitable separating gap in the middle of the radiator bank. Any deviations from this mounting arrangement for fans will be specified in technical specifications.

The bank of cooling fans must be suitably sized to permit one fan to be out of circuit during normal operation while maintaining the full rating of the transformer. Under normal operating conditions all fans shall be in use.

Factory testing is to be done with all fans in service to provide maximum load potential. To confirm ratings with one fan out of service, and save on undertaking additional heat run test, the hot spot temperatures and gradients are to be confirmed against design calculations.

The fan motors must be of the industrial weatherproof and maintenance free type with sealed long-life bearings. Fan blades must be enclosed with a guard to prevent inadvertent contact with the fan blades. This may necessitate fan guards on both the inlet and outlet side of the fans. The guard must provide a minimum degree of protection to AS 60529 of IP20. The entire fan assemblies must be resistant to corrosion either by the material used or by the protective covering.

10 On load tap changer and control

10.1 On load tap changer design

Supply transformers are to be provided with an on-load tap changer (OLTC) with the tapping range as described in Table 1. Tap changers manufactured by ABB or Reinhausen only, are acceptable. Both in-tank and bolt-on types are acceptable. The tapchanger should be of the high-speed resistive type, and must meet the following requirements:

(a) OLTC's must match the overload and short circuit capabilities of the power transformer;

(b) all switches that make, break, or divert current must be contained in a separate compartment that will permanently withstand 30 kPa pressure difference to the main tank. This is so that the oil is completely isolated from that in the main power transformer tank and that any decomposition products from these switching operations must not contaminate the insulating oil of the power transformer windings. The switches must be so mounted that they can be inspected, maintained and, if necessary, removed without disturbing the main tank oil;

(c) the diverter switch compartment must be provided with separate oil drainage, filling and filtering valves, together with drainage suction tube and flanged pipe connection to enable pressure equalisation with the main tank if required during vacuuming;

(d) the design of the tapping winding and the selection of the tap-changer must be such that non-linear devices are not necessary;

(e) the variation of voltage between taps must be smooth and without disturbance of line conditions. The equipment must not cause radio interference in any position of the tap-changer, whether stationary or in motion. Operation of the selector switch(es) in the main tank space must not contribute to the generation of combustible gases in the main tank oil;

(f) the OLTC must be controllable both locally and remotely. When the LOCAL/REMOTE switch at the power transformer is switched to the LOCAL mode the tap position can only be controlled locally at the tap changer control panel of the power transformer. With the REMOTE mode selected, the tap position may be controlled remotely by the substation SCADA system or by the voltage-regulating relay (voltage regulating relay requirements listed in R565983). The tap changer raise and lower control relays must be designed to accept dry clean contact outputs from either the SCADA or voltage regulation relay;

(g) the OLTC system must include a dc operated tap position transducer with 4-20 mA analogue output connected to separate terminals within the power transformer control cubicle and to the current loop input of the power transformer monitoring and control unit for remote tap position indication. The transducer must function properly and indicate correctly the tap position even under substation blackout conditions;

(h) tap changer voltage control scheme must use 230 V ac power supply, with a 110 V ac operating voltage with centre tap earthed, that is, two by 55 V with respect to earth;

(i) the tap-changer motor and brake must be rated for a 3-phase 400 V ac 50 Hz supply; and

(j) a tap-changer surge relay or over-pressure switch (if that is the tap-changer manufacturer's standard form of protection) must be provided for every tap-changer diverter compartment in accordance with the tap-changer manufacturer's recommendations. The device must be fitted with two sets of normally open, voltage free (trip) contacts. These contacts should be separately wired back to the transformer control cabinet.

(k) Copper tube of 6 to 7.5 mm diameter needs to be connected between tap changer plumbing pipe connecting to oil surge relay and run down front of transformer on HV side. An oil sampling valve must be installed at the end of the copper tube 1.2 m from the base of the tank.

10.1 On load tap changer control cubicle

The OLTC shall have its own control cubical, weatherproof to IP55, attached to the transformer main tank and house as a minimum the equipment listed below:

(a) a counter, visible at ground level without opening the cubicle door, to register the number of tap changes made;

(b) tap position indicator, visible at ground level without opening the cubicle door;

(c) position range indicators on the local tap position indicator showing the maximum and minimum positions reached during operation, with reset facility;

(d) a detachable, manual handle for operation of the tap changer. While manual tap change is being undertaken it must disable electrical operation. Location of the handle is to allow its operation to be 0.9m above base of tank;

(e) 'Raise' and 'Lower' push buttons for manual electrical operation, which, once being pressed, must seal in the motor supply until one step is completed;

(f) limit switches and mechanical stop or other approved device to prevent over-running of the tap change mechanism;

(g) 'REMOTE'/ 'LOCAL' control changeover switch;

(h) door actuated internal fluorescent light;

(i) anti condensation heater complete with control thermostat and MCB;

(j) 230/400 Vac auxiliary supply and connections must be shrouded against accidental contact using clear polycarbonate and fitted with a danger notice;

(k) terminal blocks and other associated accessories to facilitate full testing and monitoring; and

(l) additional terminal blocks to achieve at least 30 per cent spare capacity for future use.

11 Power transformer mechanical protection devices

Power transformers must be fitted with Buchholz relays and pressure release valves.

11.1 Buchholz relay requirements

A Buchholz relay must be provided between the main tank and its conservator compartment. The installation of the Buchholz relay shall meet the following:

(a) the Buchholz and surge relays must not operate inadvertently under any combination of pump start-up and running or in the event of loss or restoration of the auxiliary supply;

(b) there shall be one set of normally open contacts provided for the gas-actuated element for alarm, and two sets of normally open contacts for the surge-actuated element for indication and tripping of incoming and outgoing circuit breakers that connect the power transformer to the power system;

(c) any bushing turrets or pockets where gas may collect must have bleed pipe-work to ensure all gas reports to the Buchholz relay. Such pipe-work must rise all the way to the relay. Horizontal or downward slope will not be acceptable. The strength of the pipe work must be such that a point load of 1000 N may be supported without permanent deformation. Any pipe work should be routed in such a way as to minimise any impediment to movement for personnel working on the top of the transformer tank;

(d) there shall be isolating gate valves fitted between the Buchholz relay and the tank and the Buchholz relay and the conservator to facilitate maintenance on and replacement of the relay without the need to drain significant quantities of oil. The Buchholz relay should be able to be removed without removal of either of these valves;

(e) a pipe must be brought down from the Buchholz relay to a gas receiver chamber accessible at ground level and fitted with an inspection window and gas sampling cock. An isolating valve must be fitted immediately above the receiver for isolation; and

(f) a mechanical testing facility must be incorporated. Air injection facility will not be acceptable for the Buchholz relay, as a gas detection relay is fitted to the conservator.

11.1 Pressure relief requirements

An approved self resetting spring operated pressure relief valve must be located directly on the power transformer tank main compartment. A pressure relief valve shall also be fitted to the tap changer compartment unless a surge relay is provided. The operating pressure of the pressure relief valve must suit the designed pressure withstand requirements. The following requirements must also be met:

(a) the device for the main tank must be fitted on the tank wall complete with a baffle to deflect the oil downward with provision of a pipe bringing oil down to 0.6m from the base of the tank for discharge within the bunded area.

(b) a pin or flag indicator must be provided at the device clearly visible at ground level to indicate operation of the device; and

(c) two sets of normally-open contacts must be provided for indication and for tripping of incoming and outgoing circuit breakers that connect the power transformer to the power system.

(d) The number of pressure relief devices fitted to any one transformer shall depend on the overall size of the transformer tank and the volume of oil contained in each compartment. The recommendations of the device manufacturer must be followed.

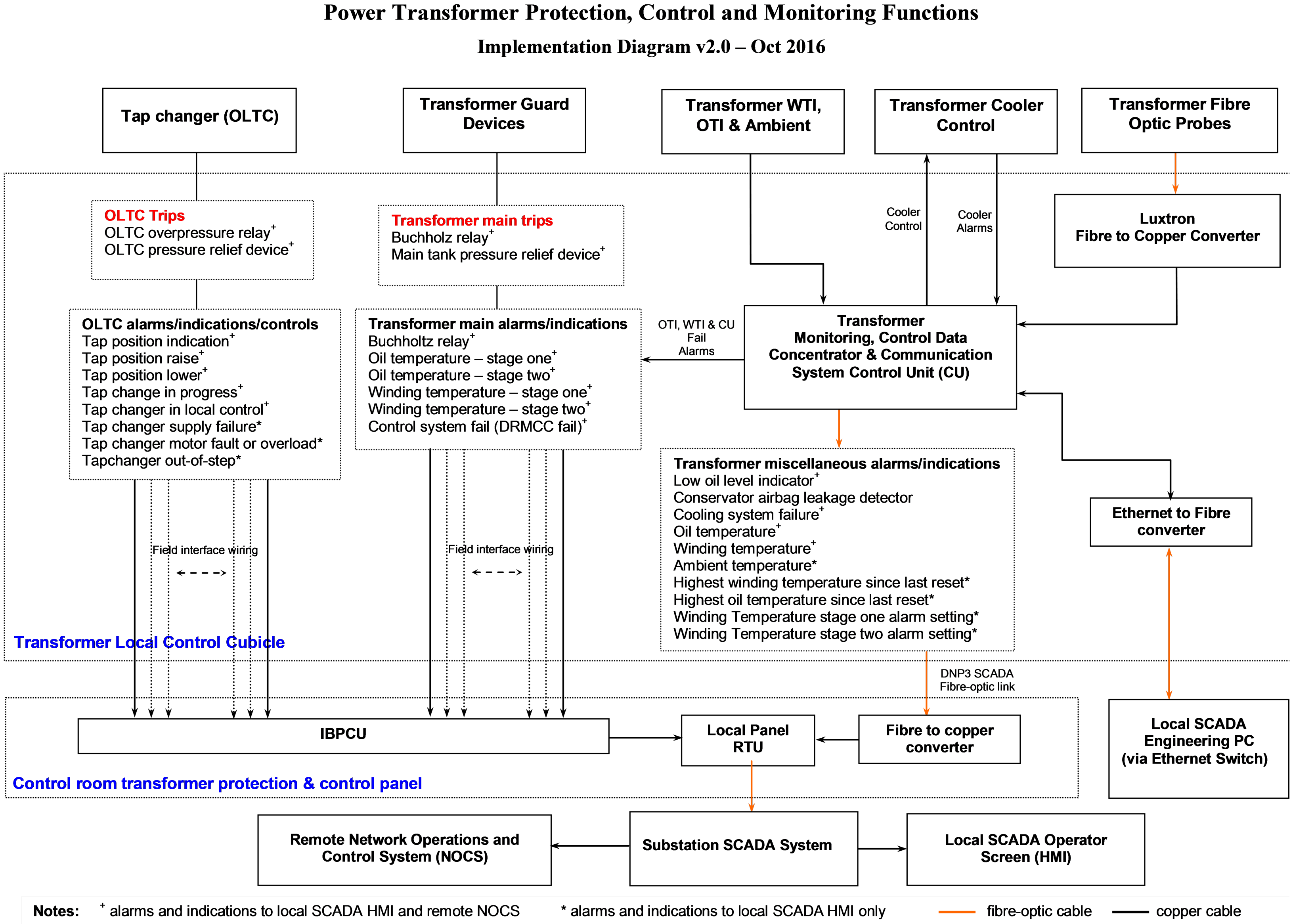
12 Control, monitoring and alarms

12.1 Control and monitoring requirements

12.1.1 General requirements

The complete monitoring and control scheme shall generally be as shown in the 'Power Transformer Protection, Control and Monitoring Functions – Implementation diagram v2.0'

Figure 1 Power Transformer Protection, Control and Monitoring Functions – Implementation diagram v2.0



12.1.2 Intelligent control and monitoring system

A condition monitoring and control data concentrator unit approved by TasNetworks, shall be provided with each power transformer.

The data concentrator unit must be capable of being connected to the substation SCADA system communications bus over Ethernet for alarms and monitoring.

Information required from the transformer data concentrator unit is typically:

- Winding temperature;
- Oil temperature;
- Ambient temperature;
- Hot spot measurement (fibre optic based);
- Oil level indication
- Winding and oil temperature alarms in stages;
- Cooling fan operation;
- Online dissolved gas analysis (if fitted);
- Online bushing monitoring (if fitted).

All oil and winding temperature parameters, related trends, alarms for power transformer and condition of the cooling system must be available for display on the station SCADA HMI and the Network Operations Control System (NOCS).

If the data concentrator unit has a user interface panel it shall be mounted inside the transformer control cubicle and shall be visible without needing to open the cabinet door. The data concentrator must be capable of potential future connection of on-line condition monitoring device/s for example, dynamic ratings, bushing monitoring and insulating oil DGA.

12.1.1 Optical fibre probes

Optical fibre probes shall be fitted to all units to permit direct measurement of hot-spot temperatures and also to calibrate the current transformer based winding temperature indicator. The probes must be Luxtron or an equivalent type.

The number of optical fibre probes and their location will be dependent on the design of the power transformer and will be based on the recommendations of the manufacturer. The suggested location of the probes will be provided at the design review meeting and will be subject to the agreement of TasNetworks. As a minimum, one probe must be provided per winding and located at the expected hottest spot of that winding. A minimum of six fibre optic probes is required.

The optical fibre probes will be used for temperature measurement during temperature rise test and results evaluated within the test report.

The tank penetration for the fibre optic probes shall be above the level of the top of the windings such that any maintenance on this penetration can be conducted without the need to lower the oil below the level of the windings. The penetration shall be protected by weatherproof cabinet.

The optical fibre probes must be terminated in the power transformer marshalling cabinet for future connection to a local and/or remote temperature indicator. A four channel fibre optic transducer, Luxtron type M600 series, shall be provided and interfaced with the transformer monitoring system. The four hottest probes, as identified during the temperature rise test, shall be connected to this device.

The fibre optic probes shall be tested for calibration prior to insertion in the windings. A calibration report shall be available at the time of the factory acceptance testing and shall be included in the transformers operation and maintenance manual.

12.1.2 Oil and winding temperature indicators and cooler control

The transformer shall be fitted with indicators to display the top oil temperature and the winding hotspot temperature. The oil and winding hot spot temperature indicators must:

(a) be fitted to provide direct reading for local indication of the actual and maximum temperature over a range of 0°C - 150°C;

(b) be driven independently of the monitoring and control system such that a failure of the monitoring and control system does not disable or impair these indicators;

(c) be provided with a minimum of two sets of normally open contacts (in addition to those required for automatic control of the coolers). The contacts must be independently adjustable for closure between 50°C and 120°C, with a close/open differential to prevent hunting under any continuous operation condition; and

(d) include 4-20 mA analogue output connected to separate terminals within the power transformer control cubicle and to the current loop input of the power transformer monitoring and control unit for remote temperature indication.

Selection of the actual set points shall be by consultation between TasNetworks and the manufacturer.

Fan controls must be initiated from the winding hotspot temperature indicator, and failure of any or all fans must initiate an alarm.

To obtain optimum utilisation of any forced cooling equipment provided, the fan controls should be designed to select only that amount of forced cooling equipment needed to match the transformer thermal time constant and the appropriate design transformer operating temperatures consistent with the load.

To accommodate overload requirements, the cooler control system must incorporate means to initiate fans immediately upon sudden increases of load (current sensing required) or when the winding temperature rises above the set point.

Cooling fan operation control equipment must be housed in the main control cubicle or in an adjacent weatherproof stainless steel cabinet with a degree of protection of at least IP55.

12.1.1 Thermometer pockets

Thermometer pockets must be provided in the power transformer tank to permit measurement of oil temperatures during temperature rise tests and for installation of oil and winding temperature indicators. Thermometer pockets must fulfil the following requirements:

(a) the temperature bulbs must be removable without having to drain oil from the tank;

(b) the pockets should be located such that they are exposed to continuous oil flow;

(c) the pockets must include screwed plugs to prevent accumulation of moisture within the pockets; and

(d) the pockets and plugs must be manufactured from non-corrosive metal.

12.1.1 Tapchanger alarm requirements

The alarms from the OLTC, as listed in Table 2, must be available to report back to the station SCADA system and to the NOCS.

Table 2 Alarm indications required from on load tap changer

Sr. No.	Alarm Description
1	Tap change in progress
2	Tap changer on local control

Sr. No.	Alarm Description
3	Tap changer drive supply failure
4	Tap changer control supply failure
5	Tap changer motor fault or overloaded
6	Tap changer out-of –step
7	OLTC overpressure relay

12.2 Other fittings and monitoring provisions

Provision must be included for retrofitting on line condition monitoring equipment, such as a 50 NB valve, on the bottom oil line (between main tank and radiator bank) to permit potential future fitment of on-line oil DGA sampling units.

13 Other requirements

Equipment such as instruments, cabinets, terminal boxes that are mounted on the main tank must be attached by means of anti-vibration mountings to prevent the effects of vibration during normal operation.

13.1 Main control cubicle

A cabinet must be provided for housing the relays, temperature indicators, cooler supply control contactors, miniature circuit breakers (MCB) and small wiring and accessories. The equipment is to be supplied and arranged as per R522687. It is preferred that the number of individual cabinets required be minimised whenever possible, and as such two door cabinets, where appropriate, will generally be acceptable. Care should be taken to ensure that any sharp edges are suitably removed and any welding is effectively coated to avoid any formation of corrosion.

As a minimum the cabinet must be:

(a) stainless steel, minimum grade 316 and 1.6 mm thick, weather-proof with a degree of protection of IP55;

(b) equipped with door stays that lock doors into open position at 120 degrees;

(c) fitted with lockable doors no wider than 750 mm;

(d) fitted with identification labels mounted externally on doors;

(e) arranged for terminal strips to be no less than 200 mm above the gland plate to provide adequate access for TasNetworks' cable terminations below the terminal strips;

(f) fitted with terminals installed on DIN 'C' rail and comprised of slide-disconnect terminals, with the exception of 230/400 Vac terminals. The slide disconnect terminals must be Weidmuller type WTL 6/1, Phoenix type URTK/S or equivalent;

(g) mounted on the HV side of the transformer such that the bottom gland plate is no less than 600 mm above the tank base;

(h) contains a thermostatically controlled heater, a door-operated fluorescent or LED cubicle light and a general purpose outlet (GPO). The GPO is to be situated outside the control cubicle and should have a point of electrical isolation inside the control cabinet. In case of two cubicles, location of GPO must be on the outer end of one of the cubicles; and

(i) 230/400 Vac auxiliary supply and connections must be shrouded against accidental contact using clear polycarbonate and fitted with a danger notice.

The doors of cabinets must have glass windows to enable an observer to clearly view the temperature indicators and intelligent control systems (if fitted) without the need to open the cubical door.

13.1 Interconnection cables

In addition to other requirements for cable screening, all externally mounted interconnecting cables must be PVC insulated with PVC oversheath. Fixing of the cables to the transformer tank must be such that damage to the cable does not occur as a result of the vibration of the transformer.

All external cables and fixings must be suitable for outdoor environments and hardened against the effects of UV light.

13.1.1 Fibre optic extension cables

Extension cables for the fibre optic temperature probes shall be run in a separate conduit and marked as containing fibre optics. Where possible this conduit should not be run in locations where it can be used as a stepping point.

13.2 Labels

All marshalling and control cubicles are to be labelled externally and all equipment and devices inside the control cubicle must be labelled as per R522687. All labels must be engraved on Traffolyte labels. All other identification labels affixed externally to the transformer such as warning, valve, inspection, access, jacking, attachment point labels etc. must be stainless steel, have all lettering engraved, etched or formed in relief and be affixed by means of stainless steel screws.

13.3 Power transformer rating plate information

Stainless steel name and rating plate along with a valve diagram plate as described below must be affixed in a suitable position and display on it the particulars given in the following clauses. Other required name and rating plates are described in the clauses below.

13.3.1 Power transformer rating plate

The transformer shall have a rating plate affixed showing the particulars of the power transformer as listed in Table 3 as a minimum. In addition to these requirements;

(a) the layout of the plate must be in accordance with the relevant applicable Australian Standard; and

(b) the information listed in Table 3 must be indelibly and legibly marked on the power transformer on one or more plates securely attached to the power transformer and should be located so that it is clearly and safely visible with the transformer in service and without any obstructions. It should generally be located such that it is visible from the tapchanger control cubicle.

Table 3 Details of power transformer rating plate information

Sr. No.	Description
1	The name or registered trade name or mark of the manufacturer
2	Description: (Type of Transformer)
3	Number of the Applicable Standard(s)

Sr. No.	Description
4	Manufacturer's serial number, relating Power Transformer to the test certificate(s)
5	Manufacturer's drawing number
6	Year of Manufacture
7	Number of phases
8	Rated power in MVA
9	Rated frequency (in Hz)
10	Rated primary voltage in kV
11	Rated secondary voltage(s) in kV
12	Connection symbol (Vector group)
13	Connection diagram
14	Tapping Range and steps
15	Tapping voltage and current at all taps
16	Principal tap
17	Rated Primary Current in A and kA
18	Rated Secondary Current(s) in A and kA
19	Short circuit impedance value (measured in percentage) at all tap positions
20	Zero sequence impedance value at the principal tap (expressed in ohms/phase, referred to the LV winding with the HV winding open circuited)
21	X/R ratio of transformer
22	Type of cooling methods
23	Power values at different cooling methods in MVA
24	Top oil temperature rise
25	Average winding temperature rise
26	Current Transformer designations and details (as per AS1675)
27	Total Mass
28	Transportation Mass (without oil)
29	Mass of Core and Windings
30	Mass of Oil (Volume of Oil)
31	Type of insulating oil (inhibited or un-inhibited)
32	Oil quantity in OLTC (if not shown on OLTC name plate)
33	Oil quantity to cover core and windings
34	Oil quantity in one radiator
35	Oil Flow
36	Vacuum withstand capability of the transformer and the conservator
37	Number of Fans

Sr. No.	Description
38	Air Flow and power consumption of fans
39	Contract Number
40	Plant number
41	Owner (marked as 'Property of Tasmanian Networks Pty Ltd')

13.1.1 Power transformers with reconnected windings

In cases where the transformer has a reconnectable secondary winding, an additional nameplate is required to be affixed directly above the main nameplate indicating the connected voltage. Plates must be available for each possible voltage connection.

13.1.2 Valve name plate

A nameplate showing the location, purpose, and normal operating condition of all valves shall be attached near the transformer rating plate.

13.1.3 Fibre optic probe nameplate

There shall be a nameplate which defines the location and the tank penetration sequence of the fibre optic probes. This nameplate shall be located in a suitable location either close to the transformer rating plate or close to the main control cabinet.

13.1.4 Access openings

All access openings shall have a nameplate affixed to the cover indicating it is an 'Access Opening'.

14 Cable systems

All internal cubicle wiring, cables and cable systems associated with power transformers must be in accordance with document D02/521.

All cables used inside the transformer tank should be suitable for immersion in hot transformer oil and should have Teflon sheathing.

15 Data for Asset Management Information System

TasNetworks maintains a comprehensive 'Asset Management Information System' (AMIS) that contains all design, test results and the condition of all TasNetworks assets. The AMIS also contains maintenance regimes for all assets.

The supplier must provide the information required to maintain the currency of AMIS for each asset on standard forms. TasNetworks will provide the forms to the selected supplier. Forms are required to be completed for new assets and for decommissioned assets.

The completed forms must be submitted to TasNetworks as below:

(a) design information and maintenance regime information for all assets commencing installation on site; and

(b) information on test results for all assets must be submitted prior to commissioning.

16 Assessment of damages for performance parameters

Power transformer parameters must meet the tolerances specified in AS/NZS 60076.1, unless otherwise stated in TasNetworks specifications.

The following loss information must be specified by the supplier for evaluation and subsequent selection of equipment:

(a) no-load losses at 100 per cent, 105 per cent and 110 per cent of rated voltage;

(b) load losses at 75◦C for principal, extreme plus and minus tap positions, and for maximum loss tapping in case it is not one of these tappings, with rated current flowing in each winding; and

(c) cooling equipment losses in kW with all cooling equipment in operation.

The no load loss at 100 per cent and 110 per cent rated voltage and the load losses at principal tapping, extreme plus and minus tapping, and at the maximum loss tapping if different to any of these tappings, must be have zero positive tolerance.

The impedances and the tolerances stated in Table 1 must be met. The transformer will be rejected if any other guaranteed parameters without specified tolerances exceed the tolerances as permitted by AS/NZS 60076.1.

Where a measured loss exceeds the value stated at the time of selection it is a minor defect, provided that the losses are still within the tolerances allowed by AS/NZS 60076. Where the measured losses are within this range, damages shall be assessed according to the following formula:

Cost Reduction = (ΔNLL * NLLe) + (ΔLL * LLe)

Where;

ΔNLL = the difference between the measured no-load losses and the stated losses, where the no-load losses exceed the stated figure

NLLe = the value of no-load losses as given in Table 1

ΔLL = the difference between the measured load losses and the stated figure, where the measured losses exceed the guaranteed

LLe = the value of load losses as given in Table 1

This evaluation shall be applied to any and all transformers of an order which fail to meet the stated losses. Where the measured losses exceed the stated figure by an amount greater than that allowed by the Australian standard this shall be considered a test failure and the transformer shall be rejected.

In cases where the measured losses are lower than the stated figure, credit towards a reduction of any damages will not be accepted under any conditions. Likewise, requests for an increase in purchase price should the measured losses be below the stated figures will not be considered.

In the event of a failure of one or more of the fibre optic probes inserted in the transformer this shall also be considered a minor defect. In this case the damages will be imposed at the rate of $5000 per non-functional probe. In the event that half or more of the probes are damaged, all the damage probes must be replaced.

Prior to the award of any contract the zero sequence impedances, the testing configuration and the testing currents under which the impedances are obtained must be defined by the supplier and agreed to by TasNetworks.

Transformers must have a defects liability period after delivery and assembly of not less than 5 years.

16.1 Factory acceptance testing failures

In the event that a power transformer fails factory acceptance testing, all costs incurred by TasNetworks in witnessing the retesting of the failed transformer, or a failed component, shall be at the cost of the supplier.

Costs may include the labour and expenses of TasNetworks in the provision of up to two staff to the manufacturer's works or site for the duration of any retesting. A full detailed report on the likely cause of failure and actions contemplated must be prepared and provided to TasNetworks before oil is drained below the top of the windings or other significant corrective action undertaken, and before any request to attend further testing. Any failure under test must constitute an additional Hold Point in terms of Clause 20.

17 Inspection and testing

Testing, installation and commissioning must comply with the requirements of the document R246497.

All testing shall be at the suppliers cost.

To prove compliance with the specification and the stated performance, routine tests must be carried out on the transformers as listed in AS/NZS 60076.1, except for the additions, amendments and modifications listed below.

All components of power transformers must be duly tested in accordance with relevant applicable Australian and International standards. Where tests are optional in the standards, it will be taken that these tests are required by TasNetworks, unless otherwise stated in writing by TasNetworks.

Where the power transformer has more than two windings, or where windings can be reconfigured, all appropriate tests must be performed for each combination of winding pairs and configurations on every transformer supplied to TasNetworks unless otherwise agreed to in writing by TasNetworks.

All auxiliary items such as the transformer monitoring and control unit, fibre-optic equipment, oil gauges, Buchholz and surge relays etc. must be fitted and functional for the tests. This includes the complete cooling and oil expansion systems. TasNetworks reserves the right to defer the commencement of any specified tests if this requirement is not met.

The Supplier must prepare a detailed testing program not less than two months prior to the start of testing, listing all routine tests to be carried out in the chronological order of testing.

On each transformer oil samples must be obtained before the start of each dielectric test, before the start of each stage of the heat run tests (on the type-tested unit), and after all tests are completed. If Dissolved Gas Analysis (DGA) of the final sample indicates the presence of a fault, then DGA will be performed on each interim sample as an aid to diagnosis of the fault.

All test reports must be forwarded to TasNetworks for approval and acceptance prior to the delivery of the transformer. The tests will be considered as completed only after approval and acceptance of test results by TasNetworks in writing. A list of the tests to be conducted on the power transformers is given in the following clauses.

17.1 Type tests

Type tests are intended to prove the soundness of design of the equipment and their suitability for operation under the conditions detailed in the specifications. Type tests must be carried out before the delivery of the equipment.

All type tests defined in AS/NZS 60076 shall be performed on the first unit of any order, subject to the constraints below.

17.2 Type tests on repeated units

Where it is intended to provide a duplicate of equipment which has been previously manufactured a certified test report, detailing the results of such tests along with the procedures followed, must be provided to TasNetworks. These tests must have been applied to equipment of identical design with that offered, or on equipment of a similar design, which does not differ from that offered in a way that might influence the properties to be checked by the type tests.

Where such tests have already been performed, copies of type test reports that qualify for the exemption from conducting these tests must be supplied with the tender along with a request for approval. Written approval is required, and may be given after consideration by TasNetworks.

Exemption from repeating the type tests based on the conditions above may be given by TasNetworks but should in no case be taken as being automatically.

17.3 Type tests on previously failed transformers

Where a transformer has suffered a dielectric failure during factory acceptance testing, it is required that all tests, including type tests, are conducted on the failed unit following its repair.

In the event that a failed transformer is one of a larger series of identical units, and not the last of that series, then all subsequent units of the same design shall have all tests, including type tests, conducted on them.

Where a transformer fails due to a minor defect, as defined in Section 16, subsequent transformers of that design are not required to undergo all type tests. If it is the case that transformers of identical design repeatedly fail the same test the design shall be rejected and any remaining transformer of the series must be redesigned.

17.4 Power transformer type test requirements

The tests listed below must be performed on the first power transformer of each design being supplied, subject to the conditions of the clauses covering transformer failures.

17.4.1 Temperature rise tests

Generally a temperature rise test performed on the maximum loss tapping at the corresponding tapping current in all implemented cooling conditions, unless agreed otherwise at the design review, with the tests to include direct measurement of hot-spot temperatures with optical fibre temperature probes.

(a) TasNetworks require the following temperature rise tests to be performed, generally in the order listed:

  (i) a test with total losses at the ONAF, 100 per cent nameplate rating, of the transformer to winding temperature stability. This test shall be at least eight hours in duration

  (ii) the ONAF heat run test shall be followed by a test at 8-hour overload rating, subject to the constraints of Section 3.1 of this standard;

  (iii) following the 8-hour overload test the transformer shall be subjected to a test at the ONAN rating until stability is reached;

  (iv) following the completion of the ONAN heat run the transformer shall be loaded at the 4-hour overload rating. If, during this 4-hour overload test, the top oil temperature approaches 115°C or the winding hotspot temperature approaches 130°C by fibre optic measurement, the test current shall be reduced to a level to maintain these temperatures for the remainder of the 4 hour test period. This reduced current shall be as agreed between TasNetworks and the Supplier at the time of the design review;

  (v) the measurement of winding gradients by the resistance method shall be performed on the main windings of each phase;

  (vi) oil samples shall be taken immediately prior to the commencement of each of these tests. At no time during the conducting of any of these tests should any part of the transformer be exposed to potentially damaging conditions;

(vii) following the completion of the 4-hour overload an oil sample shall be taken and DGA analysis performed immediately before the continuation of the testing program. Evolution of high temperature gases during this test shall not be taken as evidence of a test failure. However, the presence of acetylene (> 2ppm) or significant amounts of ethylene ($C_2H_4 > CH_4 + C_2H_6$, or C_2H_4 > 20 ppm) in the sample shall indicate a test failure and investigation shall then proceed to determine the source of this gas; and

(viii) during all of these tests the tank shall be thermographically monitored and recorded, and the test shall be discontinued if dangerous hotspots appear on the tank surface.

(b) the time between the switching of current and recording of the winding temperature should be as short as possible. Attempts should be made to take the first recording within 120 seconds. Delays significantly longer than this require the approval of TasNetworks.

17.1 Routine tests

Routine tests must be conducted on the completely assembled transformer to prove the quality of manufacture and conformance with the relevant performance requirements.

Splitting of routine tests into separate phases for individual components is not normally acceptable. Routine testing must be performed at the manufacturer's works prior to delivery.

Procedures for routine tests with supporting documentation must be submitted to TasNetworks for approval and acceptance. Routine tests must not be conducted unless the routine test procedures have been accepted and approved by TasNetworks.

Routine test results and certificates must be submitted to TasNetworks for approval and acceptance. Routine tests will be considered as completed only after TasNetworks approves and accepts the test results.

Routine factory test results must be approved and accepted by TasNetworks prior to dispatch of equipment to site.

A gradient check for each winding of each transformer to ensure that adequate oil flow is reaching the winding is required. This may be in the form of a short duration temperature rise test (two hours) or an extended duration load loss test, or other method as agreed between TasNetworks and the manufacturer. This test is also used to verify the correct operation of the fibre optic probes.

As a minimum, the tests stated below must be conducted generally in the order listed:

(a) vacuum withstand and over-pressure withstand and oil leakage test (using chalk or whitewash to check) on the completed assembly or sub-assembly as appropriate;

(b) oil dielectric strength and dissolved gas analysis (DGA);

(c) measurement of insulation resistances: windings to earth, between windings, core to earth, core to frame and frame to earth, at 1 minute and 10 minutes after application of the dc voltage;

(d) 2.5 kV applied voltage test to the core, the frame and the tank, in each case with the other components earthed;

(e) measurement of the dissipation factor (loss tangent) and the capacitance of the windings to earth and between windings;

(f) measurement of dissipation factor (loss tangent) and the capacitance of HV condenser bushings;

(g) functional, calibration and performance tests on all accessories and cooling equipment including without limitation:

(i) Buchholz relay,

(ii) pressure relief device,

(iii) Oil level indicators,

(iv) temperature indicators

(v) control and monitoring equipment, etc;

(h) pressure test of pressure relief device to prove its operating pressure and reseal / reseat properly after operation;

(i) tests on instrument transformers including knee point voltage determination;

(j) measurement of the power and current taken by the fans;

(k) applied high voltage test;

(l) impulse withstand tests including chopped wave tests on all phase terminals in the following sequence (note that for the HV winding the following sequence satisfies the requirements as given in AS/NZS 60076.3);

(i) the test for each phase of the HV winding shall be

- Maximum tap impulse on Red phase – RFW, FW, RCW, CW, CW, CW, FW, RFW.
- Nominal tap impulse on White phase – RFW, FW, RCW, CW, CW, CW, FW, RFW.
- Minimum tap impulse on Blue phase – RFW, FW, RCW, CW, CW, CW, FW, RFW.

(ii) impulse testing of the LV windings (with the sequence as per that given in AS/NZS 60076.3) shall be performed with the HV winding connected in the minimum tap, all turns out, position;

(m) testing shall also include fault sensitivity measurements;

(n) impulse testing on both the HV and LV neutral terminals by direct application. The HVN impulse shall be made with the tapping winding in the maximum tap, all turns in, position. The LVN impulse shall be made in the minimum tap, all turns out, position;

(o) measurement of no-load losses, no-load currents, harmonic content and oscillograph of no-load voltage waveform at 90 per cent, 100 per cent, 105 per cent, and 110 per cent rated voltage, required for each phase;

(p) sound power levels, by the sound intensity method to determine the total sound power level of the transformer. Tests shall be conducted as follows:

(i) with only the core excited at 100 per cent of nominal rating;

(ii) with only the core excited at 110 per cent of nominal rating;

(iii) with full load, 100 per cent ONAF, current following in the windings; and

(iv) with all cooling equipment active.

(q) on load tap changer operation at full voltage and full rated current;

(r) measurement of impedance voltages and load losses at >75 per cent load currents on all tappings, except that nominal, maximum and minimum tap positions must be tested at >95 per cent load current – preferably rated current – (winding temperature, determined by DC resistance, to be measured at the start and end of this test series AND after each guaranteed tap position is tested);

(s) a gradient check for each winding of the transformer to ensure that adequate oil flow is available to each winding. This test may take the form of an extended load loss test, or another method as agreed between TasNetworks and the manufacturer. This test shall also be used to verify the operation of the fibre optic probes;

(t) measurements of zero phase sequence impedances at nominal, maximum and minimum tap. The zero sequence impedance is required to be measure with a series of test current of 5 per cent, 10 per cent, 15 per cent, 20 per cent, 25 per cent, 30 per cent and 40 per cent of rated current. The manufacturer should attempt to measure the zero sequence impedance with as high a test current as possible subject to the limitations of the test equipment and the safety of the transformer. Zero sequence impedance measurements are required for the following test conditions;

(i) HV winding supplied with the LV winding short circuited;

(ii) HV winding supplied with the LV winding open circuit;

(iii) LV winding supplied with the HV winding short circuited; and

(iv) LV winding supplied with the HV winding open circuit. (This is required only for maximum tap ratio as there is no difference in reading if tap is altered as HV winding is open circuited);

(u) induced voltage test;

(v) partial discharge measurement (see Note 1), which should generally following the completion of all other high voltage and high power tests. The measured discharge must be no greater than 100pC at 1.3Um;

(w) measurement of insulation resistance of auxiliary wiring;

(x) frequency response analysis (FRA) for each phase of each winding, and with:

(i) HV supply with LV open for maximum, nominal and minimum tap ratio;

(ii) HV supply with LV shorted for maximum, nominal and minimum tap ratio;

(iii) LV supply with HV open for maximum tap ratio.; and

(y) pressure and vacuum test to prove compliance with this specification.

Evidence of strand to strand test performed as per Section 4.2.1.

Note 1: On condenser-type bushings, the only permissible measure to reduce airborne corona discharge on bushings during partial discharge tests must be electrode spheres on the HV and LV terminals. Temporary modifications to the bushing mounting flanges are not acceptable.

17.1 Testing of transformers with reconnectable windings

Where a transformer has a reconnectable primary or secondary winding there are a number of tests which must be performed on all possible connections.

Type tests on reconnectable transformers shall be performed as routine tests unless otherwise agreed with TasNetworks. Refer AS/NZS 60076.3.

As a minimum the following shall be performed:

(a) impulse tests – all connections unless the manufacturer can show, to the satisfaction of TasNetworks, that the winding/s are sufficiently tested in full by a reduced testing regime;

(b) induced tests – all connections unless the manufacturer can show, to the satisfaction of TasNetworks, that the winding/s are sufficiently test in full by a reduced testing regime;

(c) separate source (applied high voltage) test – where there are windings which are switched completely in or completely out to achieve the correct voltage ratio a separate test shall be conducted for each condition. Where windings are rearranged in series or parallel conditions a single test may be sufficient provided that it can be adequately shown that a single test fully tests the windings;

(d) for transformers which have reconnectable windings, where entire windings are not switched completely in or completely out, a single temperature rise test in the worst loss position is acceptable. Where this is not the case, additional tests must be performed to verify the gradient of those windings which are switched in or out;

(e) additional load sound measurements are required to be performed when the arrangement of the transformer is such that complete windings are switched in or out. The ONAF sound level test should be conducted in the connection in which the transformer will be delivered. Measurements should be made using the sound intensity method as per the relevant section of the Australian and TasNetworks standards; and

(f) the following routine tests shall be conducted on all connections regardless of physical arrangement;

(i) winding resistance, all taps;

(ii) impedance, all taps;

(iii) load loss for nominal, minimum and maximum taps;

(iv) no-load loss and excitation; and

(v) zero sequence impedance for nominal, minimum and maximum taps similar to 17.5.o.

17.1 Site tests on power transformers

Site installation and commissioning tests must be conducted on the installed system after erection on site and before it is put into service to prove that it has not been damaged during transportation or erection. The site test procedures must be submitted to TasNetworks for approval.

Site test reports must be approved and accepted by TasNetworks prior to placing equipment in service.

As a minimum the tests listed in subsections 17.7.1 and 17.7.2 must be conducted.

17.1.1 Pre-commissioning tests

After the assembly of the transformer at site the following tests must be performed to verify the unit has not been damaged during transport and that it has been erected correctly:

(a) Frequency Response Analysis (FRA);

(b) Recovery Voltage Method (RVM);

(c) voltage ratio on all tappings;

(d) vector group phase displacement;

(e) measurement of winding resistance on all tappings;

(f) measurement of magnetising currents on all tappings;

(g) measurement of power factor and capacitance between all windings and between all windings to earth;

(h) measurement of dissipation factor (loss tangent) and the capacitance of HV condenser bushings;

(i) insulation resistance measurement (the type of instrument and measurement voltage must be recorded);

(i) all windings to earth;

(ii) between windings;

(iii) between core to frame;

(iv) between core to earth;

(v) between frame to earth;

(vi) current transformer windings to earth;

(vii) between current transformer windings;

(viii) control cabling

(ix) auxiliary power cabling;

(x) fan motors; and

(xi) tapchanger motor;

(j) check of protective earthing connections;

(k) bushing turrets;

(l) on load tap changer and motor drive;

(m) cubicles;

(n) control cabling;

(o) auxiliary power cabling;

(p) current transformer ratios, magnetisation characteristics, DC resistances and polarity check;

(q) calibration and functional checks of all control, monitoring and protection equipment, instruments, gauges, temperature and oil level indicators;

(r) oil tests;

(s) oil level check;

(t) dielectric breakdown strength test on each separate container before filling and from the transformer tank after filling;

(u) oil samples for DGA;

(v) operation of intelligent control and monitoring system;

(w) operation test of supervisory equipment;

(x) operation test of cooling equipment;

(y) operation test of on-load tap-changer;

(z) pressure test to confirm oil tightness; and

(aa) functional test of fibre-optic thermometer and probes.

The Contractor must provide TasNetworks with a copy of these test results and compare the results of the above to the results obtained during the factory acceptance testing, and advise of any abnormality.

17.1.1 Commissioning tests

The following tests and inspection must be made before commissioning a transformer:

(a) visual inspection;

(b) verify and adjust if required:

(i) conservator oil level;

(ii) air drier;

(iii) valves;

(iv) cubicles and their cleanliness;

(v) touch up painting;

(vi) cubicle heaters;

(vii) de-aeration of the Buchholz relay and gas detection relay;

(viii) oil leaks;

(ix) tank protective earthing;

(x) neutral earthing;

(xi) line and bus connections; and

(xii) air clearances.

17.1.1 Energisation

The transformer must be left unloaded for at least 24 hours after energisation.

The transformer must be carefully inspected, especially the Buchholz relay for accumulation of gas, temperature indicators and monitoring equipment, and any sign of oil leaks.

Any sign of abnormality must be reported to and witnessed by TasNetworks.

Oil samples for main tank need to be carried out after 24 hours of soaking and 48 hours of loading.

18 Delivery and Installation requirements

18.1 Transport

All necessary measures must be taken to comply with the relevant legislation in relation to transport of the transformer and the oil, including preparation of a comprehensive emergency plan to deal with an oil spill.

18.1.1 Transportation of transformers without oil

The following requirements must be met prior to the transformer being shipped:

(a) as the transformer is delivered without oil, then provisions must be made to prevent the ingress of moisture and to maintain the internal insulation in a dry, contaminant-free condition;

(b) as the transformer is drained of oil at the factory, the transformer must be filled with an inert dry gas such as nitrogen. Dew-point measurement must be taken before the transformer is dispatched from the manufacturer's works. This will confirm the insulation moisture level and provides a reference in the event that a leakage occurs during transport to evaluate the dryness upon arrival at site;

(c) during transport, the gas must be maintained at a continuous positive pressure. The gas pressure must be monitored and logged continuously throughout the period immediately after the oil is removed until the transformer is refilled with oil at site. The ability to immediately restore any loss of gas pressure must be maintained at all times;

(d) integrity of the dryness of the cellulose insulation whilst under gas pressure must be checked by a Dewpoint test of the gas after offloading at site. The test results must be submitted to TasNetworks for acceptance; and

(e) all tubing, valves, cable connections, and fittings attached to the payload are to be adequately protected to minimise risk of damage during transport, loading, and unloading.

18.1.1 Loose equipment

Where other parts such as bushings, cooling equipment, power / control and regulation cabinets, need to be shipped in a disassembled state and where the surfaces of which will be in contact with the transformer oil, they must be properly sealed by gas tight covers to prevent ingress of moisture.

Parts that are vulnerable to damage during transit must be attached by means of anti-vibration mountings or must be otherwise appropriately protected.

18.1.2 Inventory

Each individual component or part is to be properly prepared for dispatch, itemised and labelled. Each item must be named, coded and identified by make or manufacture, size, type, drawing number or part number and recorded in a transport inventory that must form part of the contract documentation.

18.1.3 Impact recorder

To provide a partial record of transport conditions, each transformer must be fitted with an impact recorder on its main tank prior to dispatch from the factory. Electronic recorders are preferred to paper loggers, although in either case the device should have sufficient capacity to cover the entire expected period of delivery, unloading, and placement on the plinth.

After the transformers are off-loaded onto the final positions, the Contractor, in the presence of a TasNetworks representative, must inspect the impact recorder to determine whether or not the transformers have received rough handling that may lead to internal damage.

The Contractor must notify TasNetworks a minimum of 7 days prior to the arrival of the transformer on site to arrange inspection.

18.1.4 Handling and markings

To facilitate the handling and installation of the transformer and accessories, the following requirements must be met:

(a) to facilitate handling and accurate positioning of the transformers onto the foundation pads, the longitudinal and transverse axes and centre of gravity of the main indivisible unit and any other parts as may be required to conform with regulations, must be clearly and indelibly marked. Specifically the transformer base will be marked permanently on the four sides with the longitudinal axes defined by the centre line of the core and winding, and the transverse axes by the position of the HV B-phase bushing. The centre of gravity of the transformer in the transport condition and, if substantially different, that of the transformer when in-service, must be marked at least on one side and one end;

(b) the oil level to just cover the top of the windings must be marked and labelled on the outside of the tank;

(c) all items arranged for transport must have their lifting, jacking and haulage points and safe working load (SWL) clearly marked at all stages of the delivery and the erection period. These markings must be permanent; and

(d) the general arrangement drawing must also note and dimension the above markings.

18.1 Erection

The transformer must be filled on site with degassed oil, conforming to document R517371under vacuum condition in order to minimise the oxygen content of the insulation system.

19 Information to be provided with the tender

Requirements for information to be submitted as part of the tender are outlined in document R527892.

20 Deliverables

Requirements for project deliverables are outlined in document R527891.

21 Hold points

The requirement of documentation is listed in the deliverable schedule in document R527891.

The hold points for power transformers are:

(a) 'Critical design information documentation' must be submitted four weeks after letter of acceptance for TasNetworks' review, comments and approval prior to procurement of equipment;

(b) 'Detailed design documentation' must be submitted prior to manufacturing of equipment, for TasNetworks' review, comments and approval. This shall include the completed schedule R527892. A face-to-face design review(s) shall be held no later than 12 weeks after acceptance of the order. This design review shall cover the complete electrical and mechanical design of the transformer, including the construction and capabilities of the transformer, with the primary purpose being to confirm compliance with TasNetworks requirements. It may be more appropriate to conduct the mechanical design review following the completion of the electrical design review. As a minimum, all information relevant to these reviews should be provided to TasNetworks a minimum of two weeks prior to the date of the review, and this shall comprise any amendments to the schedule of information, the short circuit information required in the 'Information to be provided with Tender, Table 2' schedule and the draft outline drawing. Drawings showing the internal design of the transformer, including lead routines should be available at this time;

(c) 'Inspection and Test Plan' must be submitted one month prior to 'Factory Acceptance Testing (FAT)', for TasNetworks' review, comments and approval;

(d) draft 'Operations and Maintenance manuals (O&M manuals)' must be provided at least three months prior to FAT, for TasNetworks' review, comments and approval;

(e) during the manufacturing process, prior to the drying of the active part, TasNetworks may choose to perform an inspection of the completed active part. Notice should be given to TasNetworks at least one week prior to this date to allow TasNetworks Personnel to attend this inspection;

(f) 'Invitation to witness testing' must be submitted prior to any testing of equipment, for TasNetworks' arrangements to witness. A minimum of two weeks notice must be given;

(g) complete updated O&M manuals must be submitted one week prior to FAT for TasNetworks' preparation to attend FAT;

(h) 'FAT' must have been witnessed by TasNetworks and FAT results approved by TasNetworks, prior to 'pre-commissioning tests';

(i) all non-conformances as identified during FAT or other inspections must have been completed before commencing any pre-commissioning tests;

(j) information required for AMIS pertaining to design information and maintenance regimes must be submitted to TasNetworks prior to commencing installation;

(k) 'Pre-commissioning tests' must have been witnessed by TasNetworks and test results approved by TasNetworks, prior to 'commissioning tests';

(l) all non-conformances as identified during pre-commissioning tests must have been completed before commencing any commissioning tests;

(m) results of commissioning tests must be approved by the 'System Controller', other code participants and relevant testing authorities as per the requirements of the Code, prior to commissioning;

(n) 'Commissioning tests' must be witnessed by TasNetworks and test results approved by TasNetworks, prior to 'energisation';

(o) all defects as identified during commissioning tests must be rectified before commencing any energisation;

(p) 'Training' must be completed prior to energisation;

(q) information for AMIS pertaining to test results must have been submitted to TasNetworks prior to energisation;

(r) Certificate of conformance with contract specifications, standard specifications, codes and standards with associated documents, drawings, test results, test reports, test certificates, completed check lists and other documents must be submitted and must be accepted and approved by TasNetworks prior to acceptance, but in any case prior to energisation;

(s) TasNetworks must have completed the inspection of each asset prior to its energisation; and

(t) all as-built documentation, software licences, O&M manuals, test results and test certificates must be supplied.