Asset Management Plan

Power Transformers

Record Number: R32667

Version Number: 3.0

Date: October 2017

Authorisations

Action	Name and title	Date
Prepared by	Michael Verrier - Senior Asset Strategy Engineer	28/10/2107
Reviewed by	Greg Hall - Senior Asset Strategy Engineer Santosh Dhakal –Asset Engineer	31/10/2107
Authorised by	Darryl Munro - Asset Strategy Team Leader	1/11/2017
Review cycle	2.5 Years	

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").

The approval of this document is the responsibility of the General Manager, Strategic Asset Management.

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

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

Record of revisions

Section number	Details
All sections	*Re-write from Transend format into TasNetworks format and update of data.*

Table of Contents

1 Purpose

The purpose of this asset management plan is to define the management strategy relating specifically to power transformers. The plan provides:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans;
- The key projects and programs underpinning its activities; and
- Forecast CAPEX and OPEX, including the basis upon which these forecasts are derived.

2 Scope

This document is TasNetworks' asset management plan for its population of all power transformers, being both supply and network transformers, for a ten year rolling planning period. The objective of this plan is to maintain business risk to within acceptable limits by achieving reliable asset performance at minimal life-cycle cost.

3 Strategic Alignment and Objectives

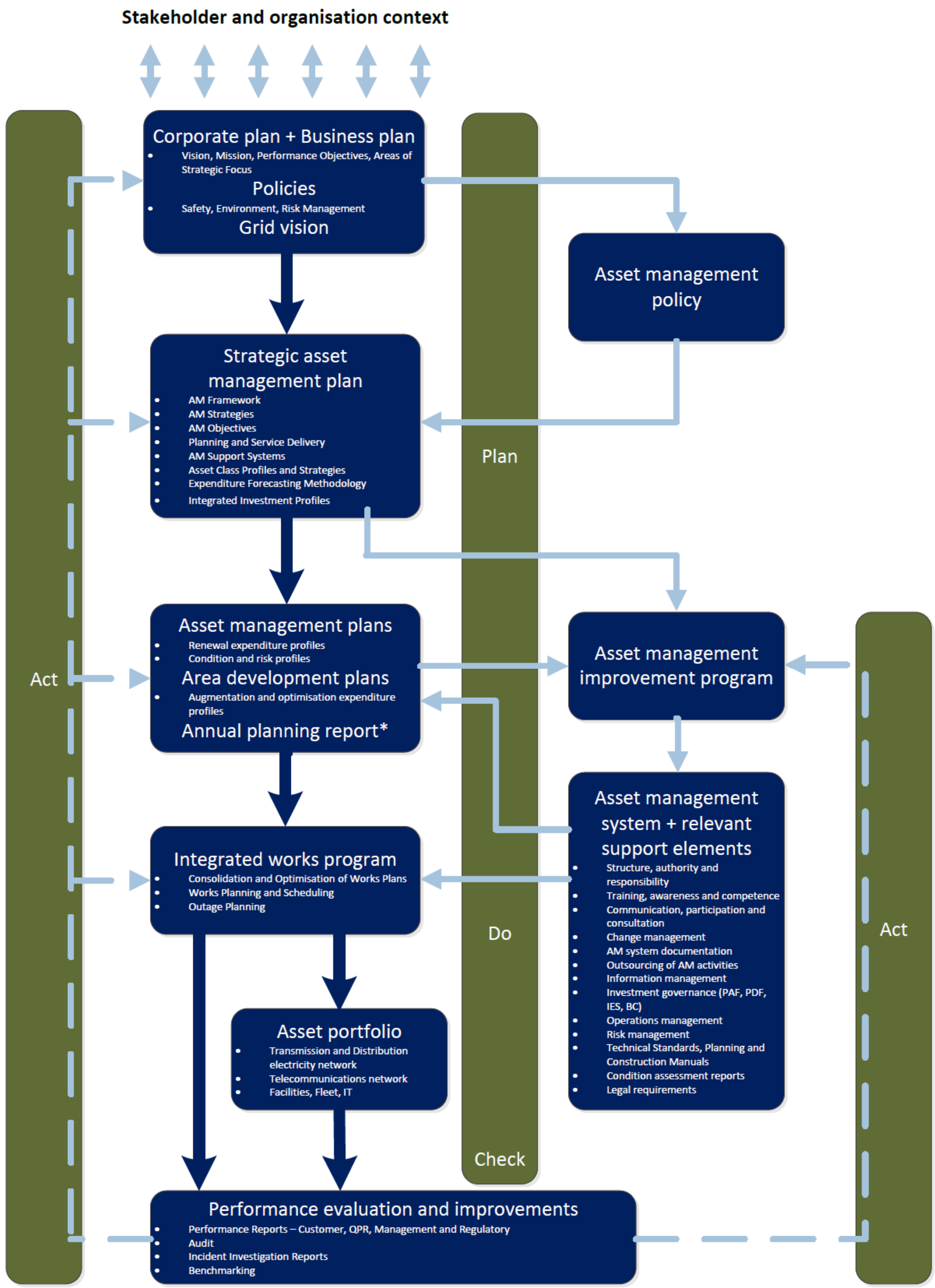
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives. This management plan describes the asset management strategies and programs developed to manage the Power Transformer assets, with the aim of achieving these objectives.

For these assets the management strategy focuses on the following objectives:

- Safety will continue to be our top priority and we will continue to ensure that our safety performance continues to improve
- Service performance will be maintained at current overall network service levels, whilst service to poorly performing reliability communities will be improved to meet regulatory requirements
- Cost performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers
- Customer engagement will be improved to ensure that we understand customer needs, and incorporate these into our decision making to maximise value to them
- Our program of work will be developed and delivered on time and within budget

The asset management policy and strategic objectives are outlined within the Strategic Asset Management Plan. Figure 1, from the Strategic Asset Management Plan, represents TasNetworks documents that support the asset management framework. The diagram highlights the existence of, and interdependence between the Plan, Do, Check, Act components of good asset management practice.

Figure 1: TasNetworks asset management documentation framework



* The Annual Planning Report (APR) is a requirement of sections 5.12.2 and 5.13.2 of the National Electricity Rules (NER) and also satisfies a licence obligation to publish a Tasmanian Annual Planning Statement (TAPS). The APR is a compilation of information from the Area Development Plans and the Asset Management Plans.

4 Asset Information Systems

4.1 Systems

TasNetworks maintains an asset management information system (AMIS) that contains detailed information relating to the power transformer population. AMIS is a combination people, processes and technology applied to provide the essential outputs for effective asset management, such as:

- Reduced risk;
- Enhanced transmission system performance;
- Enhanced compliance, effective knowledge management;
- Effective resource management; and
- Optimum infrastructure investment.

AMIS is a tool that interlinks asset management processes through the entire asset life-cycle and provides a robust platform for extraction of relevant asset information.

Asset defects are recorded directly against the asset registered in the asset management information system (WASP).

The defect information is readily accessible through TasNetworks' business intelligence reporting system and the results for power transformers feed directly into the development of probability of failure and consequences in the Condition Based Risk Management tool.

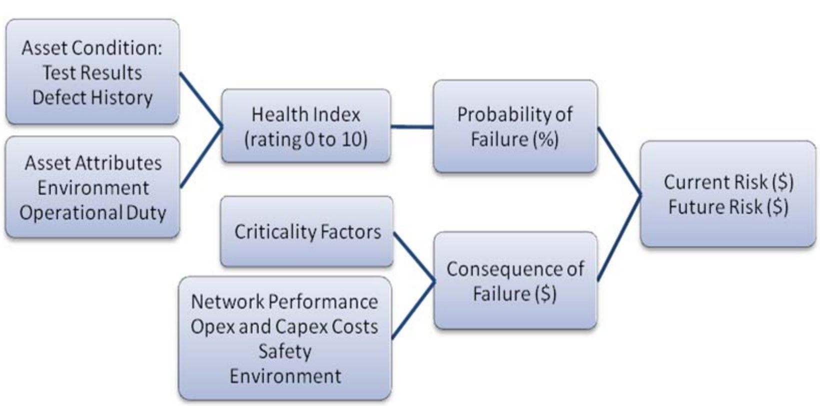
It is noted that a new Asset Management system (SAP) will be commissioned early in 2018 to replace WASP.

4.2 Condition Base Risk Management

In 2010 TasNetworks engaged EA Technologies to implement a condition based risk methodology tool known as CBRM. EA Technologies is a UK based consultancy company with decades of asset management experience within the electricity industry.

TasNetworks uses a Condition Based Risk Management (CBRM) tool to analyse a fleet of assets and determine the effects of risk and cost trade-offs when considering asset replace and refurbish type decisions. Most of the final analysis is based on asset health index and cost.

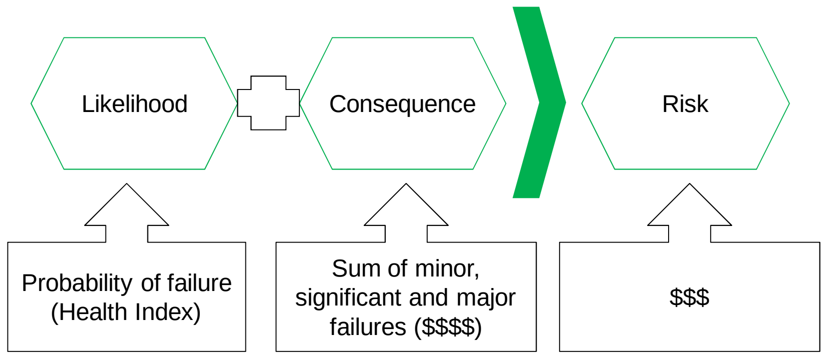
Figure 2: Asset risk framework



As with every risk decision, there are two main inputs, being likelihood and consequence.

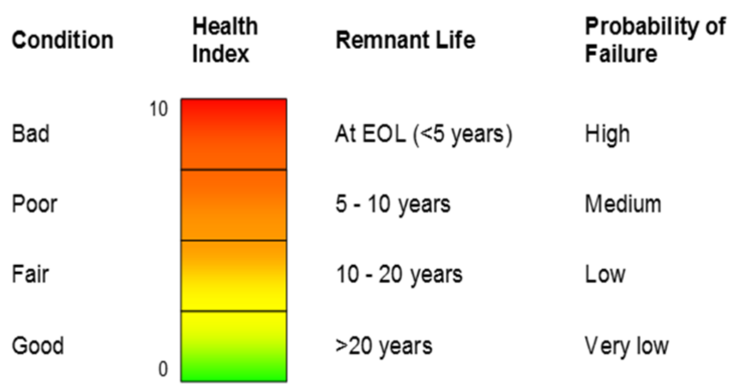
Figure **3**3 shows what CBRM considers as the two risk inputs.

Figure 3: Risk derivation for CBRM



CBRM calculates the likelihood, or the probability, of failure of an asset by deriving a health index (HI). The health index of an asset is a means of combining information that relates to its age, environment and duty, as well as specific condition and performance information to give a comparable measure of condition for individual assets in terms of proximity to end of life (EOL) and probability of failure (POF).

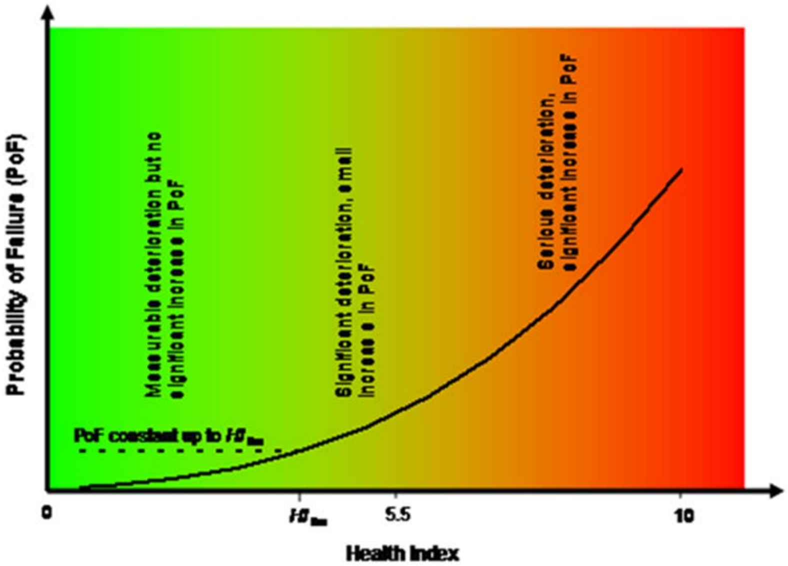
Figure 4: Health index interpretation



Notionally, any asset that has a HI of above 7 is expected reach end of life in less than five years. Any asset with a HI above five is expected to reach end of life in the coming ten years.

Once a health index for an asset is derived, a probability of failure can be found. Notionally, the POF is an exponential function as shown in Figure **5**5.

Figure 5: Deriving a probability of failure



It can be seen that assets with a low HI, even up to five, have quite a low probability of failure, but that increases dramatically at higher HIs. The equation and steepness of this curve is calculated independently for each asset based on input data.

The consequences of a failure for each asset are calculated by considering the effects of safety, environment, repairs effort, replacement difficulty and potential loss of load. The consequences are all evaluated in dollar terms which allow the consequences to be summed together.

The combination of the probability of failure and the consequences provides the calculated risk, in dollar terms, for each asset.

In addition, the health index and probability of failure can be predicted for future years. Consequently, risk can also be recalculated for future years.

The analysis of present versus future health and risk is the real power of the CBRM tool.

Appendix B – Transformer Health indices shows the health index as at September 2017 for each power transformer.

4.3 Asset Information

The following AMIS standards provide additional information relevant to Power Transformers:

- R17003 WASP Asset Register – Data Integrity Standard – Power Transformer

4.3.1 AM8 Condition data

An initiative within the Asset Performance and Strategy team was completed in 2016 to review key asset condition and maintenance regimes to assess their capability for asset condition being the basis for setting spending priorities. This initiative was referred to as AM8.

Condition based assessments provide a quantitative means to assess asset condition, their risk and failure probabilities and a basis to justify mitigation measures. Condition assessments are used to produce risk indices for assets and / or asset classes and provide a basis for asset expenditures.

Condition data is gathered through asset inspection and maintenance activities and is used along with defect, failure and performance data to formulate asset management strategies. Condition assessment relies on asset knowledge capable of being modelled using numerical analysis.

A number of observations were concluded as part of the review including the need to obtain condition data consistently across all asset types and in electronic form. The need for storage and collection would align with other business initiatives such as the AJILIS project.

5 Description of the Assets

Power transformers play a vital role within the transmission network. Their prime function is to transform voltage from one level to another to facilitate the efficient delivery of electrical energy. In addition, they serve to supply voltage to the distribution network within the limits prescribed by the National Electricity Rules (NER) and local jurisdictional requirements under terms of its licence issued by the Tasmanian Energy Regulator under the Tasmanian Electricity Supply Industry Act 1995 (ESI Act).

Power transformers are divided into two main categories, those being supply and network transformers.

The network transformers transform voltage from 220 kV to 110 kV and range from 150 to 260 MVA.

The supply transformers transform voltages from 220 kV or 110 kV to 44 kV, 33 kV, 22 kV, 11 kV and 6.6 kV. They range in nameplate transformation capacity from 4 MVA to 90 MVA. Only three phase transformers are used, there are no single phase units.

5.1 Power Transformer Types

5.1.1 Network Transformers

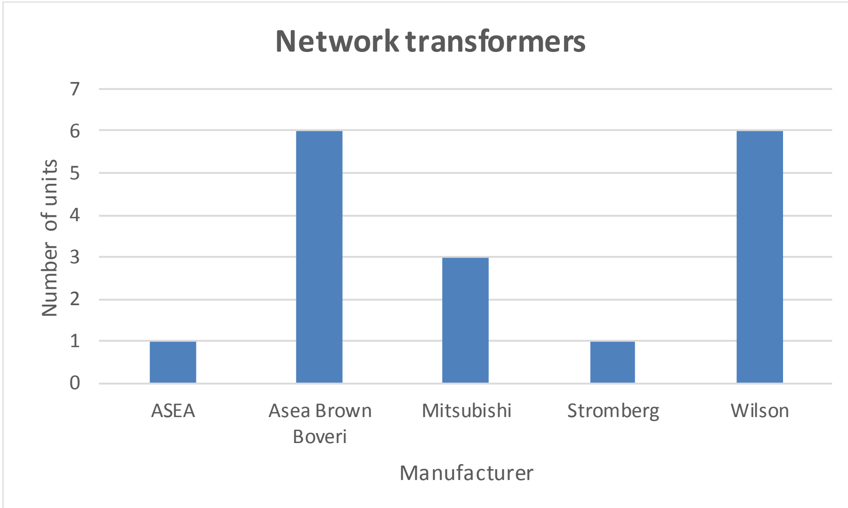
TasNetworks' network transformer population can be differentiated from one another by location, make, date of manufacture and power transfer capacity.

Network transformers are described in this manner for ease of identification and system operational requirements. Table 1 gives an overview of TasNetworks' network transformer population. It highlights that the fleet of 17 network transformers comprises 5 manufacturers, with varying ratings of different design eras.

Table 1: Network transformer population (as at October 2017)

Serial Number	Location	Manufacturer	Rating (MVA)	Year of manufacturer	Year commissioned
140146	Burnie T2	ABB	150/200	2010	2010
8033930101	Chapel Street T1	Mitsubishi	120/150/200	1980	1981
P0401A	Chapel Street T2	Wilson	150/200/260	2005	2005
P0401B	Chapel Street T3	Wilson	150/200/260	2005	2005
P0401C	Chapel Street T4	Wilson	150/200/260	2005	2005
8437300101	Farrell T1	Mitsubishi	90/120/150	1983	1984
8335270101	Farrell T2	Mitsubishi	90/120/150	1983	1984
P0401D	George Town T1	Wilson	150/200/260	2005	2008
140143	George Town T2	ABB	150/200	2008	2008
140144	George Town T3	ABB	150/200	2008	2008
P9714/B	Hadspen T1	Wilson	150/200	1998	1999
P9714A	Hadspen T2	Wilson	150/200	1998	1999
509014	Lindisfarne T4	ABB	150/200	2010	2011
140145	Lindisfarne T5	ABB	150/200	2010	2011
140375	Palmerston T1	ABB	150/200	1993	1994
5977487	Sheffield T1	ASEA	90/150	1967	1968
5800325	Sheffield T2	Stromberg	90/150	1985	1985

Figure 6: Network transformers by manufacturer type



5.1.2 Supply Transformers

TasNetworks currently has 100 supply transformers installed and commissioned in the transmission system. Within the population there are units from 11 different manufacturers. In addition, TasNetworks' supply transformer asset management is further complicated by the wide variations of supply transformers deployed in the network. They vary by:

- voltage transformation ratio;
- transfer capacity;
- transformer configuration and connections;
- make and physical design;
- design and manufacture vintage; and
- level of redundancy at a particular substation.

A summary of TasNetworks' supply transformers by voltage ratio and rated transformation capacity is provided in Table 2.

Table 2: Supply transformer population breakdown (as at October 2017)

	Rated MVA																			
Voltage Ratio	**5**	**6**	**10**	**15**	**17**	**20**	**22.5**	**24**	**25**	**30**	**31.5**	**35**	**36**	**40**	**45**	**50**	**60**	**63**	**90**	**Grand Total**
110/11/11															2		2		3	7
110/22	1						4		2	2		2				9	4			24
110/22-11		1	3	1	1	2	1		13		2	6		2	2	4	2			40
110/33															2	1	7			10
110/33-22-11																3				3
110/44-22										1			2							3
110/6.6							1		1											2
110/6.6/6.6																		2		2
110-88/22											2									2
110-88/22-11			2																	2
110-88/6.6								1												1
22/6.6				1																1
220/22			1																	1
44/22			2																	2
Grand Total	**1**	**1**	**8**	**2**	**1**	**2**	**6**	**1**	**16**	**3**	**4**	**8**	**2**	**2**	**6**	**17**	**15**	**2**	**3**	**100**

For the purposes of analysis the population has been categorised into smaller groupings based on capacity. In order to simplify the analysis the following groupings has been defined in Table 3.

Table 3: Supply transformer groupings

Group	Rated capacity (MVA)	Number of transformers
Small	≤15	12
Medium	16-30	29
Large	31-60	54
Extra Large	>61	5
	Total	100

The rating used for the grouping is the highest continuous operating capacity of the supply transformer under normal conditions, with any and all forced cooling equipment in operation. Within each of these groups the supply transformers can be segregated by manufacturer (refer to appendices for condition assessment by group and manufacturer). By grouping under manufacturer, it becomes possible to identify design differences by family types in addition to providing a useful examination of the differences within the entire supply transformer population.

Figure 7: Supply transformers by manufacturer type (Small ≤15 MVA)

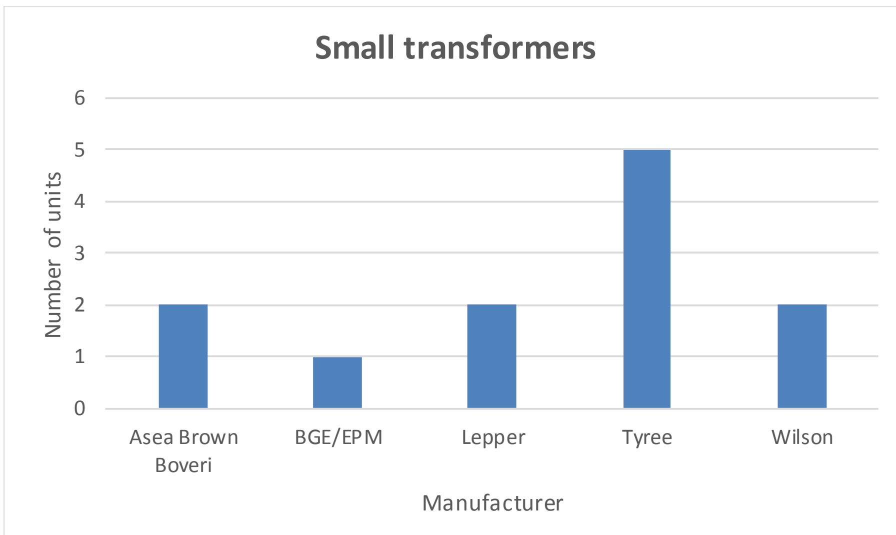


Figure 8: Supply transformers by manufacturer type (Medium 16 -30 MVA)

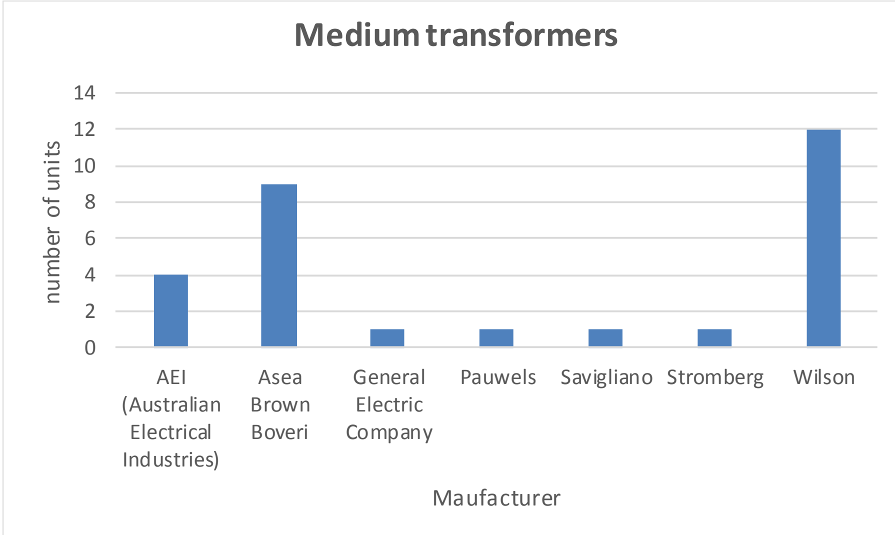


Figure 9: Supply transformers by manufacturer type (Large 31-60 MVA)

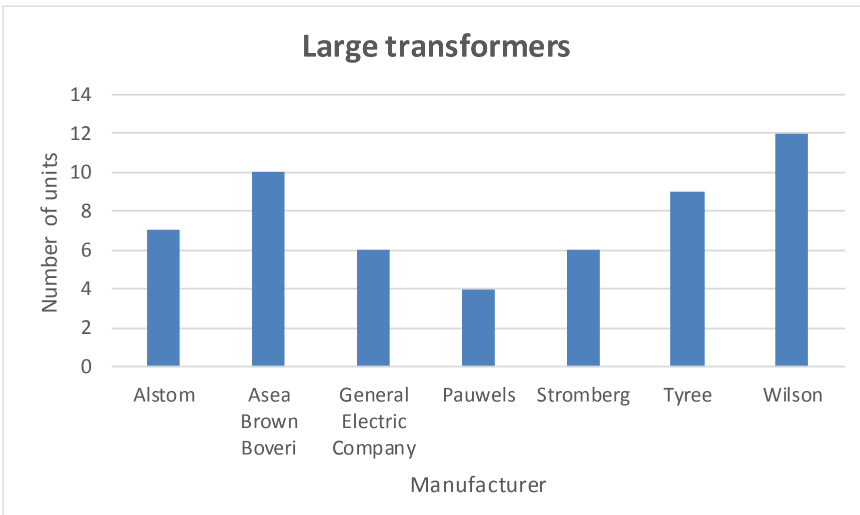
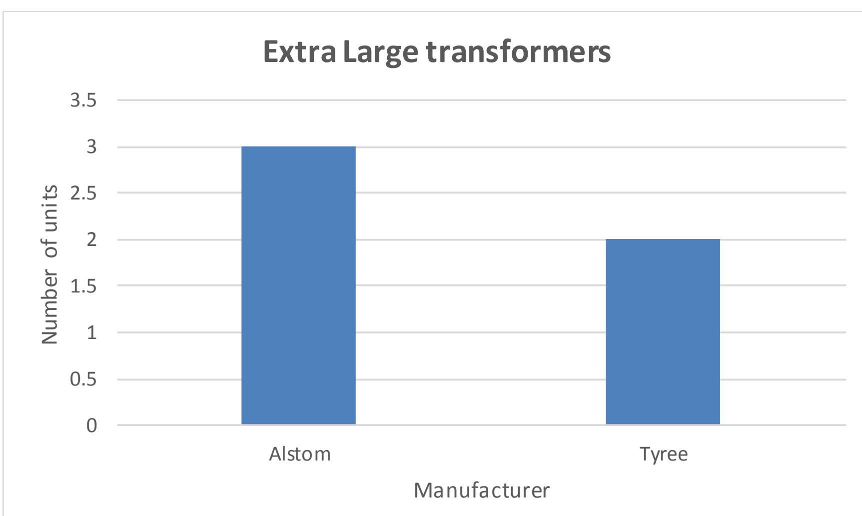


Figure 10: Supply transformers by manufacturer type (Extra-large >60 MVA)

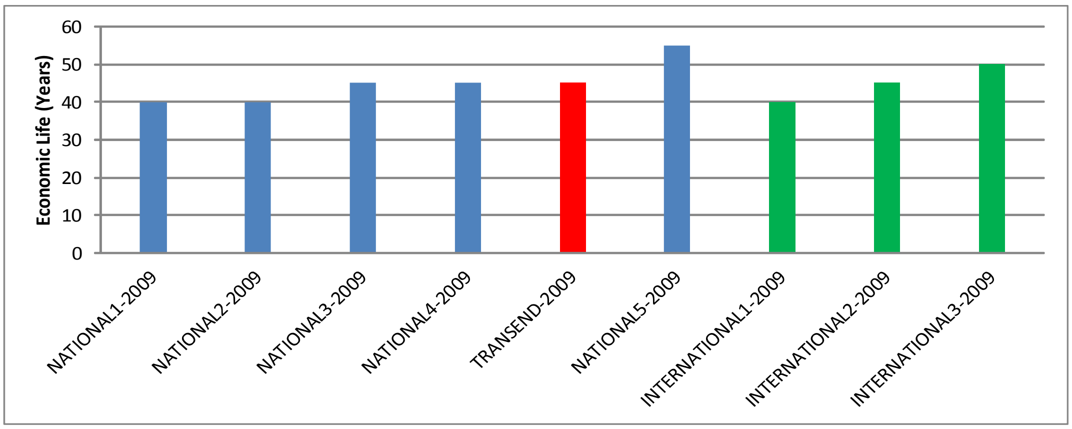


5.2 Age Profile

Various utilities have adopted an average asset life of 45 to 60 years for power transformers as detailed in *Assessment of Proposed Regulatory Asset Lives* report prepared by Sinclair Knight Mertz. An asset life for a transmission network asset is the period of time that an asset can be expected to reliably and efficiently provide the service capability for which it was designed. The asset life includes technical, strategic and economic considerations. TasNetworks references an economic life of 45 years for power transformers based on a medium life asset consistent with that of other utilities, however recognises that transformers often exceed this age in service. TasNetworks has adopted an expected asset life of approximately 60 years for power transformers which is comparable with similar utilities.

Figure **11**11 illustrates TasNetworks' alignment, based on 2009 data, with other national and international electrical utilities with regards to economic life expectancy of power transformers.

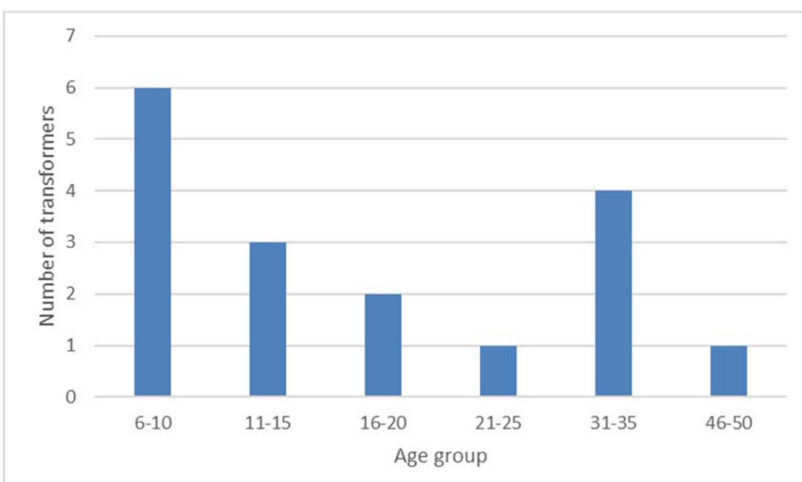
Figure 11: Utility economic life expectancy (as at 2009)



The average age of TasNetworks' power transformer population is 22.5 years.

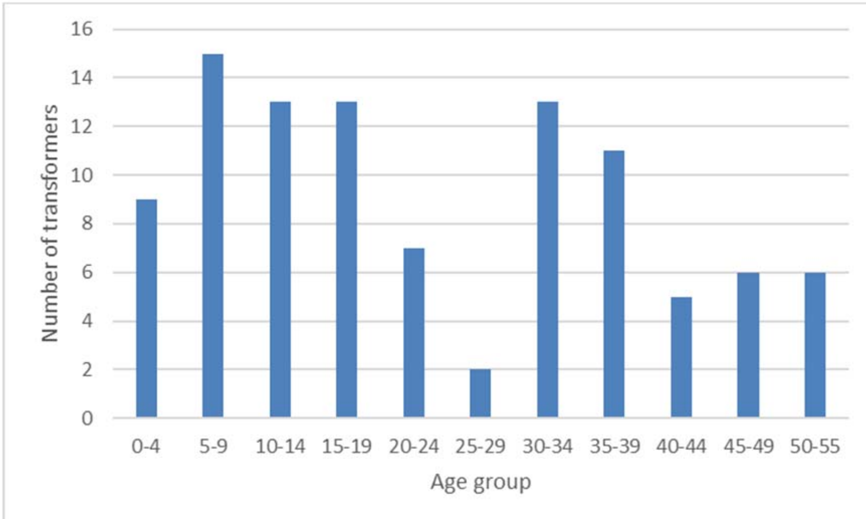
The average age of TasNetworks' network transformer population is 18.4 years. There is currently one network transformer that exceeds the economic life of 45 years, and one unit will reach it within the next ten years, as shown in Figure 122.

Figure 12: Network transformer age profile (as at October 2017)



The average age profile of TasNetworks' supply transformer population is 23.2 years. As shown in Figure 133, there is currently 12 supply transformers that exceed the economic life of 45 years, and a further 16 units will exceed it within the next ten years.

Figure 13: Supply transformer age profile (as at October 2017)



While economic and technical age is not the predominant driver for asset replacement decisions, it is important to recognise that the probability of failure for transformers increases significantly towards the end of their useful life. The primary contributing factors are:

- material degradation;
- design and manufacture deficiencies; and
- operational stresses.

5.3 Asset Specification

The design and installation requirements for new TasNetworks power transformers are described in detailed specifications. There are a number of key components to the design which can be points of difference when comparing modern versus older transformers.

The points of difference include:

- Tap changer type;
- Bushings;
- Tank design;
- Online monitoring systems;
- Low voltage terminations; and
- Cooling method.

The following sections describe these points of difference in detail.

5.3.1 Tap Changers

Older transformers use diverter switches in oil to switch currents in the tap changer whilst the transformer is on load. The resultant arcing of the diverter contacts results in contact wear and oil carbonisation. The oil carbonisation ultimately leads to insulation failure and can only be prevented by routine maintenance and changing of the insulating oil.

Tap changers can now be fitted with vacuum bottles on the diverter switch, which eliminates oil carbonisation in the chamber. Consequently, vacuum type tap changers require significantly less maintenance than oil filled type. TasNetworks now specifies vacuum type tap changers.

5.3.2 Bushings

Power transformers have historically been fitted with porcelain bushings to provide the electrical connection from outside to the internals of the unit. Porcelain bushings have a higher degree of mechanical strength than polymeric bushings; however polymers have a higher pollution performance. The main difference between the two is the behaviour during bushing failure.

A porcelain bushing is likely to fail catastrophically resulting in porcelain shrapnel which poses a risk to personnel and nearby equipment. Polymer bushings tend to split rather than shatter and are not likely to propel shrapnel. TasNetworks specifies polymer bushings for power transformers.

It is also noted that resin impregnated paper (RIP) bushings are being specified as standard requirement compared to previous specified oil impregnated paper (OIP) bushings.

5.3.3 Tanks

Modern power transformer tanks are all welded and minimise the use of oil gaskets that can leak fail over time.

Older units were fully gasketed, and some units even used a bell type tank design where the main lid cover was near ground level. TasNetworks specifies fully welded tanks.

5.3.4 Online Monitoring

TasNetworks specifies a transformer mounted monitoring device which acts as an intelligent communications hub for the transformer. The device connects to the station supervisory control and data acquisition (SCADA) system which provides remote control and monitoring of the transformer.

Typically online data such as oil, winding and ambient temperatures and the transformer guard device alarms and trips are collected, however other systems such as online oil analysis systems can be connected. Previous supplied devices could calculate loss of life rates for the transformer and may be used for calculating dynamic transformer ratings in the future. These have been superseded by implementing a single application in the NOCS system which can be customised to add transformers that may require more detailed rating analysis as needed.

5.3.5 Low Voltage Terminations

Older supply transformers that were connected to outdoor high voltage switchgear were fitted with external aerial bushings. The outdoor switchgear and associated terminations were prone to environmental interaction through debris and fauna which caused unplanned outages.

Modern switchgear is sited indoors and is connected via cable to the transformer.

Transformer cable boxes can be either oil or air filled, however the oil filled units often leak as the cable expands and contracts due to loading over time.

TasNetworks has standardised on the use of air filled cable boxes.

5.3.6 Cooling

TasNetworks has standardised on oil natural/air natural or forced (ONAN/ONAF) cooling for power transformers.

The use of pumps introduces an additional failure mechanism to the transformer where normal wear of the pump can result in the catastrophic failure of the transformer through metallic debris being forced into the main transformer tank and windings.

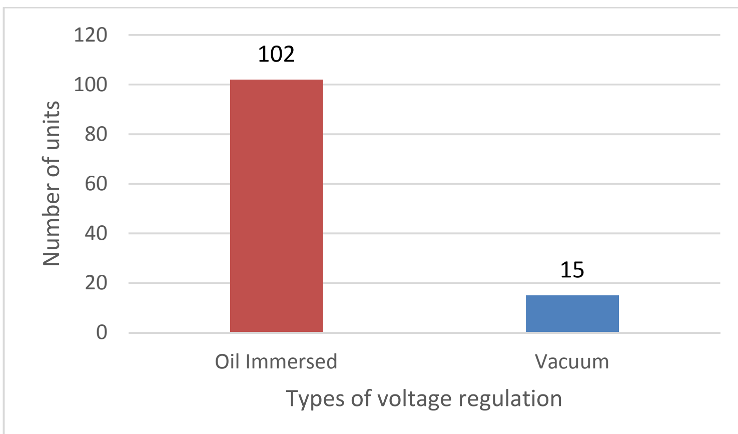
5.4 Technology types

The following sections identify which supply transformers are fitted with 'modern' equipment, including vacuum tap changers, polymer bushings, online monitoring and air filled cable boxes.

5.4.1 Transformer Tap Changer Types

Figure 144 shows the types of voltage regulation switching insulation medium applied to supply transformers. The present population is dominated by oil filled types. On load tap changers (OLTC) are applied to all supply transformers.

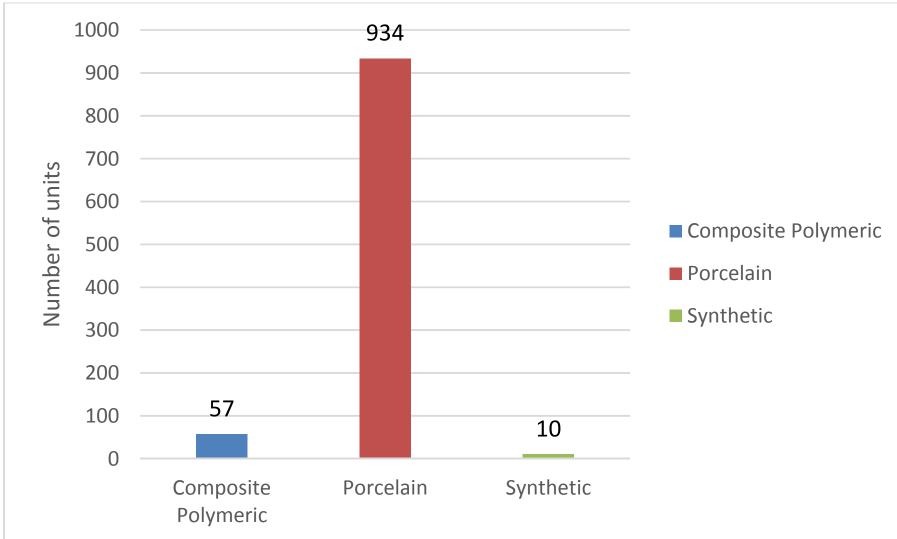
Figure 14: Power transformer voltage regulation types



5.4.2 Transformer Bushing Types

Figure 155 shows the types of bushings installed in power transformers. The present population is dominated by porcelain types; however this will slowly change as units are replaced with polymeric units as part of the natural transformer replacement regime.

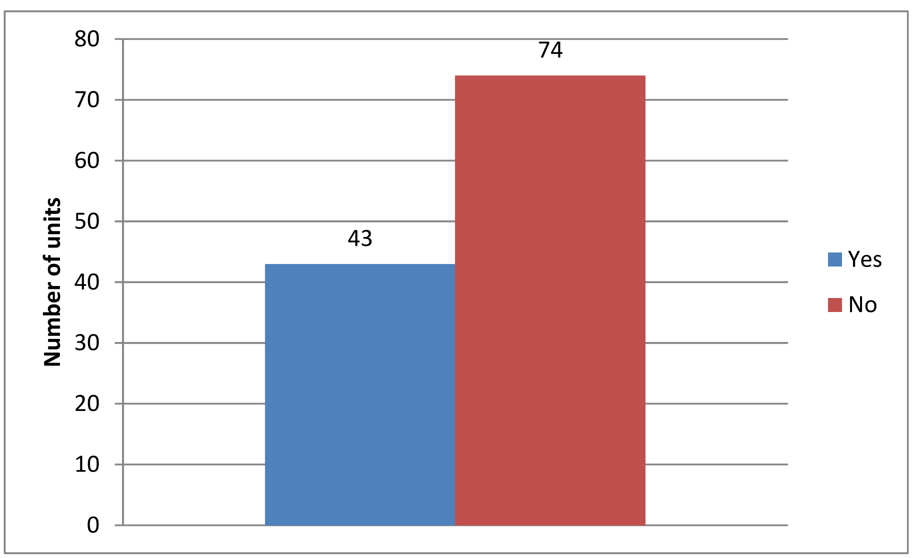
Figure 15: Power transformer bushing types



5.4.3 Online Monitoring

Figure 166 shows the number of power transformers that have an online monitoring system installed, typically a DRMMC unit. The program to install online monitoring systems has been in place since the early 2000s. The majority of online monitoring systems were factory installed as part of transformer replacement works. For future transformers online monitoring systems will be installed on an as-needed basis.

Figure 16: Power transformers with online monitoring system (DRMCC)



5.4.4 Supply transformer LV termination method

TasNetworks specifies for supply transformers to be supplied with an LV cable box installed. A program to retrofit a number of air filled cable boxes occurred in the early 2000s. There are still some supply transformers with external bushings which are in a satisfactory condition. All new transformers supplied since 2004 have been fitted with cable boxes.

6 Standard of Service

6.1 Technical Standards

To address potential design issues, TasNetworks has developed comprehensive, prescriptive standard specifications for the purchase of new power transformers. The specification requires new power transformers to be designed and type-tested to Australian and international standards. It is also a requirement that supply transformer suppliers have a history of proven service within Australia for at least three years.

6.2 Performance Objectives

To mitigate the risk of inadequate quality control during manufacturing, TasNetworks requires power transformer manufacturers to have AS/NZ ISO 9001 accreditation and conform to its requirements. TasNetworks also requires routine tests, as well as certain type tests, to be performed on each transformer unit to prove the quality of manufacture prior to dispatch from the manufacturer's works.

6.3 Key Performance Indicators

TasNetworks undertakes two broad classes of performance monitoring, namely internal and external performance monitoring.

6.3.1 Internal Performance Monitoring

TasNetworks monitors power transformers for major faults through its incident reporting process. The process involves the creation of a fault incident record in the event of a major power transformer failure that has an immediate impact on the transmission system. The fault is then subjected to a detailed investigation that establishes the root cause of the failure and recommends remedial strategies to reduce the likelihood of reoccurrence of the failure mode within the power transformer population. Reference to individual fault investigation reports can be found in TasNetworks' Governance Risk and Compliance incident management system (GRC).

For transformer failures that do not initiate a transmission system event, such as minor failure or defects, TasNetworks maintains a defects management system that enables internal performance monitoring of power transformer faults and/or defects.

Power transformer performance impacts directly on TasNetworks' overall network service obligations, which include specific performance requirements for both prescribed and non-prescribed transmission assets.

TasNetworks' service target and performance incentive (STPIs) scheme, which has been produced in accordance with the Australian Energy Regulator's (AER's) Service Standards Guideline, is based on plant and supply availability. The PI scheme includes the following specific measures:

- Plant availability:
  - Transmission line circuit availability (critical and non-critical); and
  - Transformer circuit availability.
- Supply availability:
  - Number of events in which loss of supply exceeds 0.1 system minute; and
  - Number of events in which loss of supply exceeds 1.0 system minute.

Details of the STPIS scheme and performance targets can be found in TasNetworks' SAMP (Strategic Asset Management Plan).

The availability of power transformers is a direct performance measure reported regularly to the AER and directly impacts on TasNetworks' performance incentive scheme.

TasNetworks has evaluated its transformer fleet performance against external benchmarks, such as ITOMS (International Transmission Operations & Maintenance Study), and the various performance incentive schemes which measure availability and loss of supply events.

6.3.2 External Performance Monitoring

TasNetworks participates in various formal benchmarking forums with the aim to benchmark asset management practices against international and national transmission companies. Key benchmarking forums include:

- International Transmission Operations & Maintenance Study (ITOMS); and
- Transmission survey, which provides information to the Electricity Supply Association of Australia (ESAA) for its annual Electricity Gas Australia report.

In addition, TasNetworks works closely with transmission companies in other key industry forums, such as CIGRE (International Council on Large Electric Systems), to compare asset management practices and performance.

6.3.2.1 ITOMS Benchmarking

ITOMS provides a means to benchmark Power Transformer averages (maintenance cost & service levels) between related utilities from around the world. The benchmarking exercise combines all 110 kV and 220 kV transformer assets into two distinct categories. Further details relating to the ITOMS studies are provided in appropriate ITOMS reports which are held by TasNetworks' Network Performance and Asset Strategy group.

The ITOMS results are typically presented in a scatter plot which enables comparison between participant utilities. The international benchmarked averages (cost & service) are shown as the centre crosshairs, with diamond shapes representative of surveyed participant utilities and regional averages shown as triangles marked NA (North America), EUR (Europe), ASP (Australia South Pacific), and SCAN (Scandinavia). The optimal performance location on the scatter plot is located in the upper right hand quadrant because, in this quadrant, service level is at its highest at the least cost. For both supply and network transformers assets, TasNetworks had previously been consistently in this upper right hand quadrant but for 2015 had dropped into the lower right quadrant indicating low service cost but with a low service level score as shown in Figure 17 and Figure 18.

Figure 17 illustrates TasNetworks' benchmarked supply transformer performance against all other ITOMS participants for the last five reporting periods. It shows that since 2007 TasNetworks has improved its service cost performance to be considerably better than the benchmarked average, while service performance has in the two latest reporting periods, 2009 and 2011, been above the benchmarked average. This trend improvement to strong service level score from 2007 to 2009 is largely contributed to the revised maintenance strategies implemented in 2008.

Whilst the results from 2011 to 2013 still remain in the targeted strong service with low maintenance costs region it does show a decline in service level score with a slight increase in maintenance spend as a result of several unplanned outage events. The latest results for 2015 show a large decline in service level score and an increase in maintenance spend as a result of several unplanned outage events

TasNetworks has slipped below the benchmarked average and there is a need to ensure maintenance processes and procedures are continually reviewed to ensure optimum financial and service benefits. The majority of forced outages where due to SF6 gas refills on related circuit breaker equipment and oil leaks. These could possibly have been avoided and continuous improvements of maintenance procedures and processes will be identified and implemented.

Figure 17: ITOMS supply transformers benchmarked performance chart

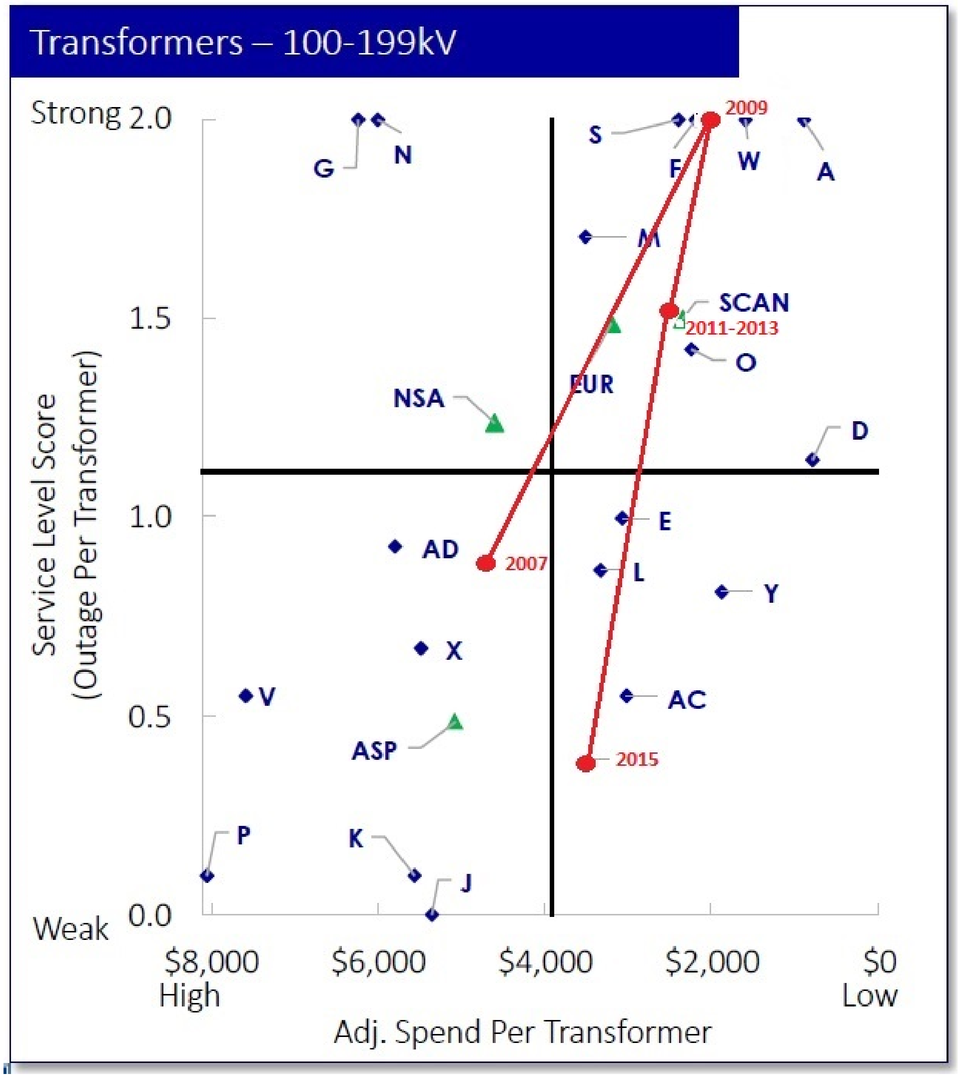
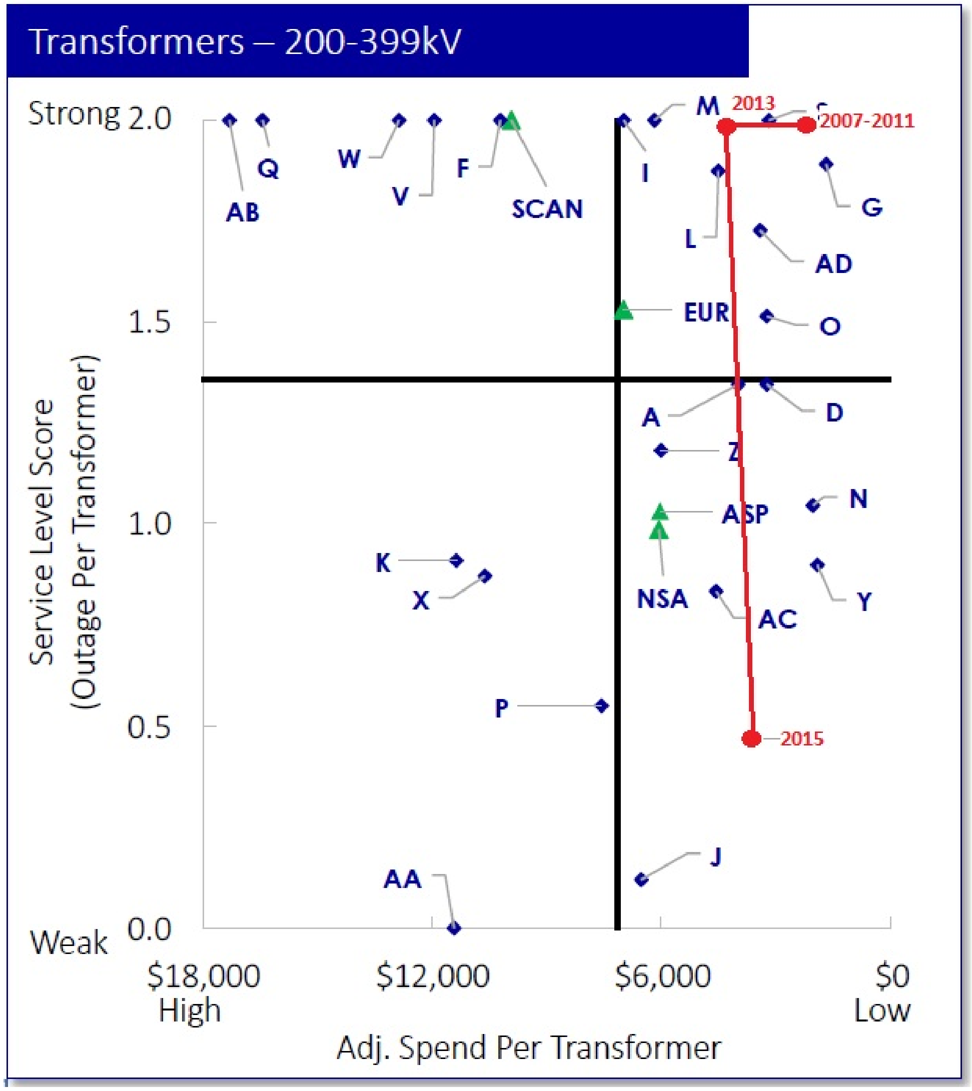


Figure 18 illustrates TasNetworks' benchmarked performance, in terms of maintenance expenditure and fault outages of TasNetworks' 220 kV Network transformers against all other ITOMS participants for the last four reporting periods. It shows that TasNetworks had consistently maintained a strong service level with low service costs prior to the 2015 results when compared to other transmission companies in the study.

The trend of consistent strong service level scores from 2005 to 2011 was largely contributed to the ongoing review and continuous improvements to maintenance strategies. TasNetworks will continue this practice to ensure minimum operating expenditure whilst maintaining strong service levels.

The maintenance strategies undergo regular review, and further opportunities for cost reduction and performance improvement is being considered.

Figure 18: ITOMS network transformers benchmarked performance chart



The latest result for 2015 show a large decline in service level score and an increase in maintenance spend for both 110 kV and 220 kV transformers as a result of several unplanned outage events as shown in figure 19

Figure 19: List of forced outages contributed to poor 2015 ITOMS results[1]

Circuit Name	Circuit Type	Circuit Voltage	Planned Open	Interruption Type	Notes
FA 220/110 kV T2 Transformer Circuit	Transformer	220/110	18/07/2014 03:45	Forced	Isolation Points:Open onlyWorkPlanned:
PL 110/22 kV T2 Transformer Circuit	Transformer	110/22	20/08/2014 09:00	Forced	Isolation Points:Open, isolate and earthWorkPlanned: Investigate voltage issue with VT B597
ST 110/22 kV T2 Transformer Circuit	Transformer	110/22	30/09/2014 08:30	Forced	Isolation Points:Open and isolateWorkPlanned:Forced replacement B599 relay Replace Transformer T2 B599 relay and test trips
KI 110/33 kV T4 Transformer Circuit	Transformer	110/33	09/10/2014 13:42	Forced	Isolation Points:Open, isolate and withdraw breakerWorkPlanned: Investigate issues associated with non availability of HMI or NOC's control of T4 low voltage breaker D552.
CS 220/110 kV T2 Transformer Circuit	Transformer	220/110	03/01/2015 08:30	Forced	Isolation Points:Open and isolateWorkPlanned:Remove 220/110kV T2 from service due to Stage 1 Low SF6 Alarm on 220kV CB B452. Remove 220/110kV T2 from service due to Stage 1 Low SF6 Alarm on 220kV CB B452.
KE 110/11 kV T2 Transformer Circuit	Transformer	110/11	08/01/2015 09:00	Forced	Isolation Points:Open and isolateWorkPlanned: Remove transformer T2 from service & test protection relay B499B ensuring trip LV & HV circuit breakers trip.
CR 110/33 kV T3 Transformer Circuit	Transformer	110/33	23/01/2015 11:36	Forced	Isolation Points:Open, isolate and earthWorkPlanned:Remove T3 from service at P&C request to investigate cause of tripping on 21/01/2015. Remove T3 from service at P&C request to investigate cause of tripping on 21/01/2015.
UL 110/22 kV T2 Transformer Circuit	Transformer	110/22	03/03/2015 15:00	Forced	Isolation Points:Open, isolate and earthWorkPlanned: Repair Oil Leak
WV 110/11 kV T3 Transformer Circuit	Transformer	110/11	20/04/2015 11:00	Forced	Isolation Points:Open and isolateWorkPlanned: Remove T3 from service to investigate T3 gas alarm.
PL 110/22 kV T1 Transformer Circuit	Transformer	110/22	04/05/2015 16:00	Forced	Isolation Points:Open, isolate and earthWorkPlanned:
CR 110/33 kV T3 Transformer Circuit	Transformer	110/33	24/06/2015 11:50	Forced	Isolation Points:Open, isolate and earthWorkPlanned: Repair fault in air box that caused trip on close of C452 on 24/6/2015.

6.3.2.2 ESAA Benchmarking

TasNetworks' reporting to the ESAA covers Transmission network data of system minutes unsupplied, energy delivered and transmission circuit availability. For ESAA benchmarking network data is limited to Transmission circuits. Performance monitoring of relevant asset classes is expanded in Section 6.3.1 of this AMP.

[1] Taken from 2015 ITOMS results presentation R0000538874

7 Associated Risk

7.1 Risk Management Framework

TasNetworks has developed a Risk Management Framework for the purposes of assessing and managing its business risks, and for ensuring a consistent and structured approach for the management of risk is applied.

The Risk Management Framework requires that each risk event is assessed against all of the following consequence categories:

- Safety and People
- Financial
- Customer
- Regulatory Compliance
- Network Performance
- Reputation
- Environment and Community

An assessment of the risks associated with the power transformers has been undertaken in accordance with the Risk Management Framework. For each asset in this class the assessments have been made based on:

- Condition of power transformers in service across the network
- Risk methodology tool-CBRM
- Consequence of failure
- Performance
- Safety risk
- Environmental risk
- Customer

The quantification of risk is supported by the Condition Based Risk Management (CBRM) framework. This approach allows the risks of individual assets to be quantified against the defined assessment.

Due to the level of risk identified in some of the assessment criteria a requirement to actively manage these risks has been identified.

7.1.1 Condition

The condition assessment and maintenance practices for power transformers have been revised where appropriate to sustain or improve reliability. Such maintenance practices, and industry benchmarking activities, are aimed at reinforcing and implementing a regime of continual improvement, innovation and learning.

The adoption of contemporary asset management techniques, including dissolved gas analysis (DGA) and online monitoring are the preferred methods of determining transformer health and improving life-cycle management practices and are aimed at reducing the power transformer average annual preventive maintenance expenditure.

TasNetworks has introduced online condition monitoring to supplement the preventive practices already employed typically targeted at transformers which are aged or exhibiting declining condition. Other online systems installed will also extend transformer service lives. The introduction of state-of-the-art online monitoring technologies targeted at specific units will enhance the knowledge required to effectively and efficiently manage these high capital investment and critical infrastructure assets.

The condition of power transformers is predominantly based on eight key areas, including:

- Electrical condition;
- Tap changer condition;
- Bushings condition;
- Physical condition;
- Technical and design issues;
- Performance;
- Maintenance requirements; and
- Safety and environment.

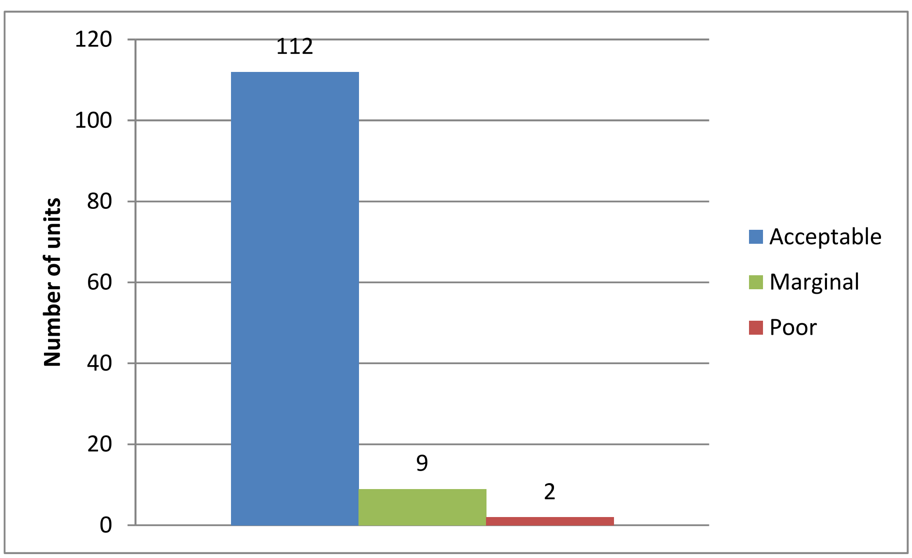
The overall condition of power transformers is categorised as either ‘acceptable’, ‘marginal’ or ‘poor’.

An overall condition assessment of the power transformer population (commissioned and spare) has identified that there is a total of two supply transformers which are classified as ‘poor’, and a further nine supply transformers as being of ‘marginal’ condition.

The remaining 112 transformers, including all network transformers, are in acceptable condition which infers that both their electrical and physical condition is satisfactory.

Figure 20 summaries the overall condition outcomes as reported in Appendix E Power transformer population condition.

Figure 20: Transformer condition summary



Refer to Appendix E for a summary of the condition assessment ranking for the power transformer population.

Appendices F, G, H, I and J provide a summary assessment of the transformer condition, based on a grouping by manufacturer type and recommends the appropriate management strategies to effectively manage the supply transformer population.

7.1.1.1 Electrical Condition Assessment Criteria

Assessment of the electrical condition is based primarily on the condition of the insulating oil. This practice is in line with that of other Transmission Network Service Providers (TNSPs) and is the approach recommended by SD Myers, a reputed organisation with over 40 years of experience in condition monitoring of transformers. The analysis of test data requires specialist knowledge, experience, and is, to some extent, subjective. For these reasons, a variety of different tests are performed on the insulating oil to ensure that analysis is not dependent on a single test result, but rather a collection of test results. The collective analysis approach provides a comprehensive and holistic view of the power transformer's condition. In addition to the insulating oil test results, electrical test results may be used to confirm the electrical condition.

Details of the condition assessment of insulating oil are included in Appendix D - Power Transformer Condition Assessment Criteria.

7.1.1.2 CBRM Fleet Analysis

The analysis of the transformer fleet results in four classes of assets being identified, being:

- High risk, poor condition units for which action must be taken as higher priority;
- Low risk, poor condition units for which action must be taken as lower priority;
- High risk, acceptable condition units for which action must be considered on a system needs basis, not just the individual asset;
- Low risk, acceptable condition for which no action is driven by TasNetworks.

Based upon the four classes, in 2012 CBRM modelled several capital regimes to identify the impact on risk and system performance. This information has been used to support the philosophy of future replacement projects, typically looking to replace a percentage of transformer fleet such that there is no 'tidal wave' of replacements required in future years.

The capital regimes considered in 2012were:

- Do nothing- no assets are replaced or refurbished;
- Replace all assets- the whole transformer fleet is replaced in the first year;
- Replace 1.6% of the fleet per year based on highest health index in present year;
- Replace 1.6% of the fleet per year based on predicted highest health index in future year;
- Replace 1.6% of the fleet per year based on highest delta risk;
- Replace in economically optimum year at 7.93% Rate of Return;
- Replace in economically optimum year at 5% Rate of Return; and
- TasNetworks' targeted capital program.

Regimes one and two provide the bounds for which the risk and performance can operate.

Regimes three and four are virtually identical in performance.

The targeted intervention regime is TasNetworks' proposed management plan. It includes several refurbishment and replacement activities with details of the actual plan included in Section 8.

The following charts show how the regimes perform over the next fifteen years from 2012 in terms of fault and defect performance and risk.

The charts are normalised, where 100% represents the fleet performance and risk as calculated at June 2012.

Figure 21: Normalised number of fleet faults

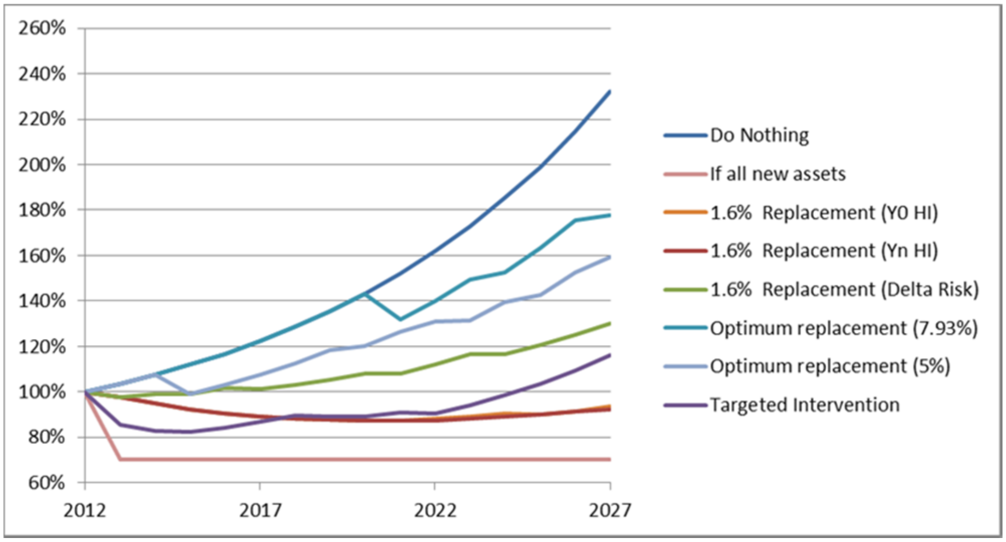


Figure 211 shows that any of the financial based regimes, being optimum replacement or delta risk see an increase in the number of faults across the fleet over time.

The replacement regimes based on health index show a definite improvement in terms of fault performance, which should be obvious, as replacing the units with high health index will reduce the associated probability of failure.

TasNetworks' targeted regime significantly improves the fleet fault performance until 2022, after which the performance begins to climb back to present levels.

Figure 22: Normalised fleet risk

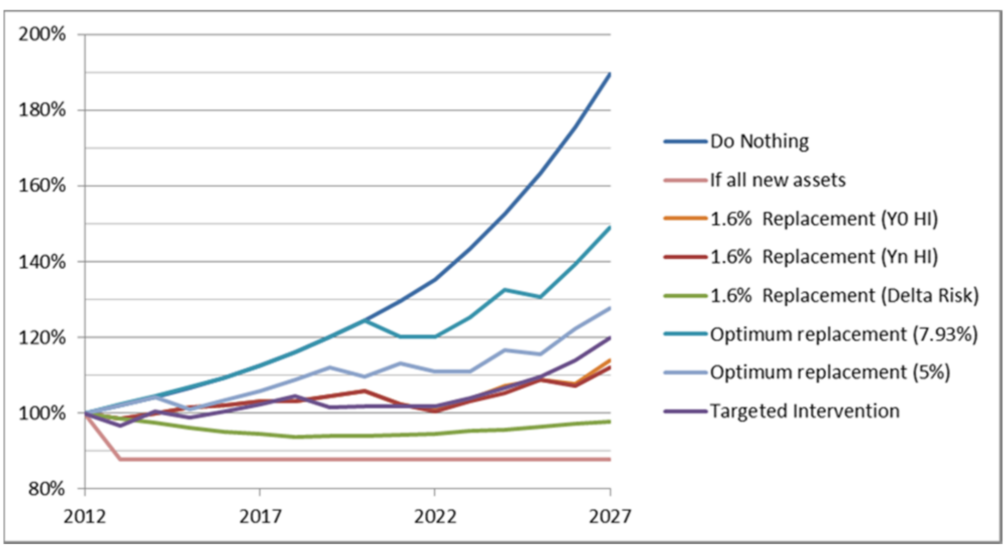


Figure 222 shows that the optimum replacement timing regimes see an increase in the risk across the fleet over time.

The replacement regimes based on health index show a slight increase in fleet risk over time. This indicates that the units that presently have a high health also coincidentally have high risk.

The delta risk regime shows a small decrease in fleet risk, however over the long term the fleet risk rises back to present levels.

TasNetworks' targeted regime maintains the present fleet risk levels until 2022, after which the risk begins to climb as no further capital works are considered beyond that date.

TasNetworks considers that present fleet performance in terms of both fault performance and risk is acceptable. Fleet fault performance should be maintained at present levels or improved to ensure reliability of supply to customers is maintained. The present levels of risk should also not be allowed to increase significantly.

Preferred operating envelopes for the next ten years have been developed for both fleet fault performance and risk, as shown in the following figures.

TasNetworks plans to keep the fleet fault performance within 80 to 100% of the presently calculated level for the period 2012 to 2022.

Similarly, TasNetworks plans to keep the fleet risk within 90 to 110% of the presently calculated level.

Figure 23: Fleet fault performance operating zone

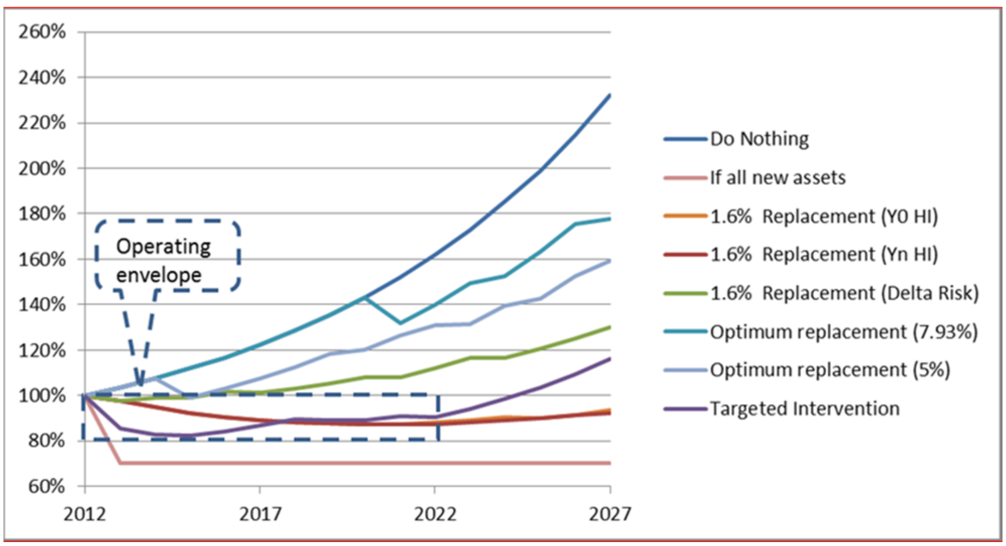
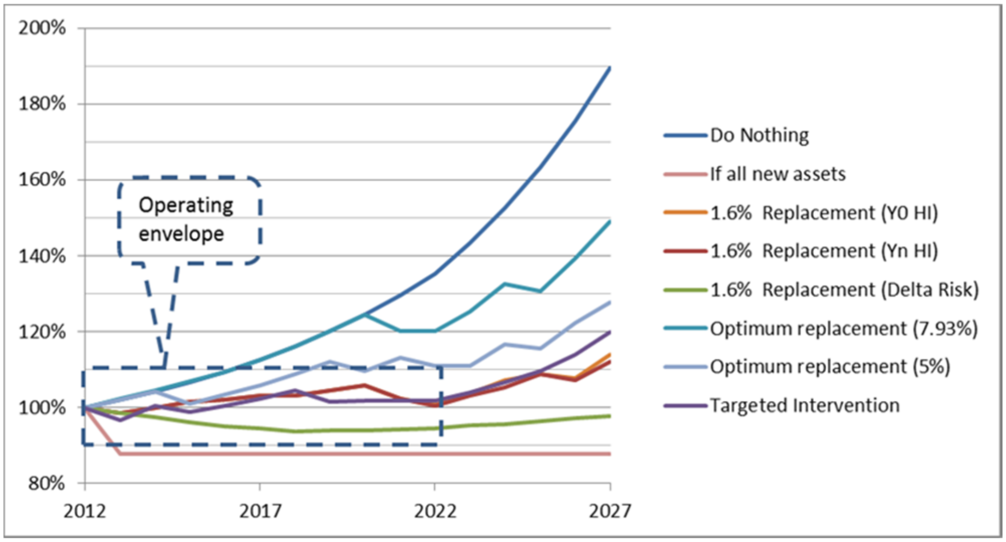


Figure 24: Fleet risk operating zone



The CBRM analysis performed shows that the only regime which maintains or improves present levels of risk and fault performance is the targeted intervention regime. The details of the actual works plan is provided in section 8.7.

7.1.2 Consequence of Failure

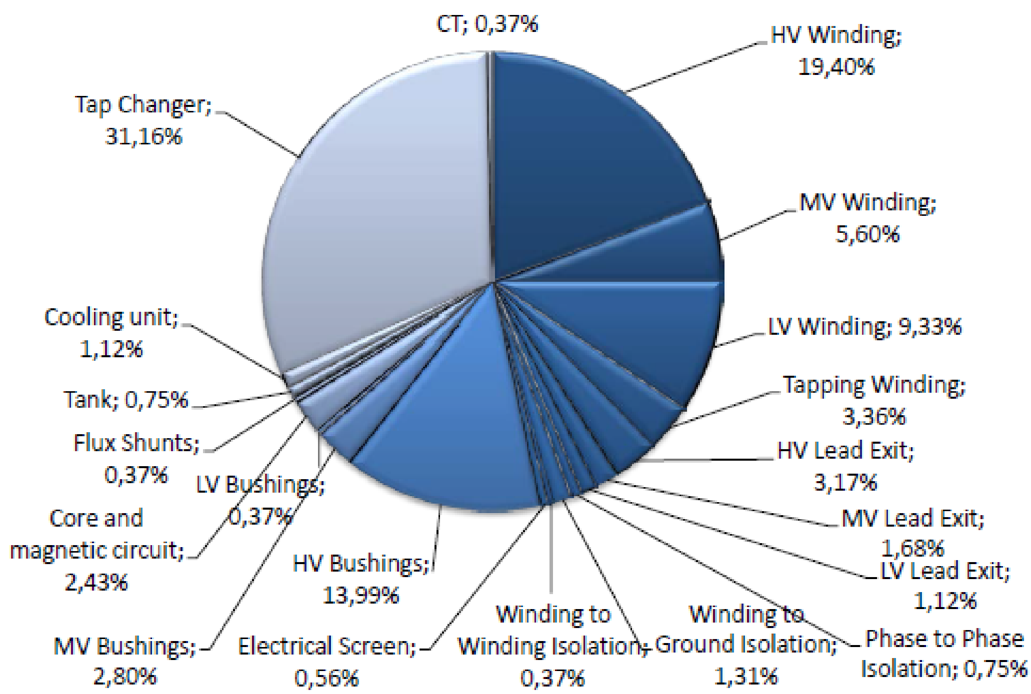
Transformer failures are divided into three main categories by TasNetworks' and CBRM tool. They are:

- Major asset failure – failure events that cause an immediate emergency system outage or trip;
- Minor asset failure – failure events that require an urgent system outage (eg within one hour); and
- Defects – incidents that require a non-urgent (planned) outage to repair the transformer.

7.1.3 Failure analysis

Studies have shown that there are a limited number of reasons which account for the majority of transformer failures. These include bushing failures, tap-changer failures, winding failures and failures of cable boxes and terminations. A percentage breakdown of these failure causes is also supported by CIGRE working group A2-37 technical bulletin TB-642 with a pie graph shown in figure 25.

Figure 25: Failure location analysis of substation transformers, U≥100KV, 536 FAILURES, Cigre.



Major failure

A major failure of a power transformer has the potential to impact on safety and transmission system performance. The predominant causes of a transformer major failure include:

- Design faults, including electrical, mechanical, choice of materials used in construction and oil or gas leaks;
- Dinding failures, whether due to design, manufacturing or material;
- OLTC failures attributed to design, moisture ingress, oil contamination or contact corrosion;
- Bushing failures due to degradation and obsolete design;
- Insulation deterioration due to adverse service conditions or aging;
- Inadequate quality control during manufacture, including general quality and transport damage; and
- In-service moisture ingress, oil leaks, and corrosion.

The combination of enhanced design capability, improved manufacturing quality and control processes, and comprehensive production testing usually ensures that power transformer performance levels remain high throughout their service lives.

Minor failure

A minor failure of a power transformer can pose a significant risk to the power system if not detected and actioned in time. For minor failure the emphasis is on early detection of the failure mechanism and remedial actions taken to rectify the problem before any further damage or forced power system interruption can occur. TasNetworks Supervisory Control and Data Acquisition (SCADA) system facilitates the remote monitoring of the power transformers. Online monitoring, scheduled site inspections and maintenance practices all contribute to the early detection of power transformer failures. Minor failures go undetected or are allowed to persist without being actioned are likely to develop into a major failure.

Defects

Asset defects are typically discovered by site inspections and do not require an immediate outage for rectification. A corrective works action will be generated by TasNetworks.

The defect information is readily accessible through TasNetworks business intelligence reporting system and the results for power transformers feed directly into the development of probability of failure and consequences in the Condition Based Risk Management tool.

Fire protection

In the event of an explosive transformer failure which results in a fire, there are a number of strategies in place to prevent its spread. These include the use of blast walls between neighbouring transformers as a means of direct protection and flame traps in the oil containment system to prevent the spread of burning oil.

In addition to these there are a number of active protective devices which are installed on transformers to assist in the prevention of an explosive failure in the first place. These are pressure relief valves which are fast acting, self-resealing valves which act to quickly reduce the pressure inside the transformer to prevent the tank rupturing; a gas pressure relay which detects a sudden pressure increase inside a tank and can be used to trigger transformer protection, and buchholz relays which are used to detect a build-up of gases inside the transformer and are used to operate protection schemes.

Noise

Transformers generate substantial amounts of noise as part of their normal operation. TasNetworks actively promotes the design of lower noise transformers through the design specifications. The specifications require that manufacturers meet specified noise levels, the "reduced" level according to the Australian standard AS60076, and directs the manufacturer to use certain types of materials which will inherently result in a quieter transformer. When a transformer is to be installed in a noise sensitive location the installation of walls to either absorb or deflect the noise may be appropriate. This is judged on a case-by-case basis.

Transformers are also installed on anti-vibration pads to achieve vibration attenuation.

Environmental Risk

TasNetworks' main environmental risk associated with power transformers relate to the insulating medium used within the units. As power transformers use high volumes of mineral-based insulating oil the consequences of a spill is potentially substantial. The risks include:

- Management of polychlorinated biphenyls (PCBs) associated with oil-filled units; and
- Management of minor and major leaks during both the life of the transformer and at times when oil is either drained from the tank or returned following draining.

In the event of an oil spill either from an in service or spare transformer, the transformer bunding and oil containment system is designed to contain all oil within the oil containment and separation system. This system includes fire traps to prevent the spread of fire and prevents the oil from escaping the confines of the substation in an uncontrolled fashion.

To mitigate the risks associated with PCB contamination, Transend implemented a program in about 2003 to determine the PCB levels within the power transformer population. This program has been completed and results recorded in WASP asset management system. TasNetworks insulating oil standard states that only oil with no-detectable PCB is acceptable.

7.1.4 Operational Issues

A review of the power transformer fleet has found that except for Rosebery Substation the units in the transmission system are presently sufficiently rated in terms of continuous and short-term capability rating. This situation will change in response to transmission system growth demands and requirements for new supply points. These factors are discussed in more detail under Section 8 of this document.

7.1.5 Design Issues

The most significant installation and design issue evident in the present power transformer population is the diverse nature of this population. This diversity makes the sourcing and availability of suitable spares challenging. This problem is predominantly being addressed through the standardisation of all newly purchased transformers.

Standardisation will address issues such as transformation ratio, impedance regimes and physical dimensions and design configuration, with the later of these issues generally the greater concern as this can significantly delay the replacement of an in-service unit with one from the population of spare transformers due to space and access constraints.

There are a number of issues with the existing population of power transformers which impact on the serviceability and longevity of these units. These issues include:

- Low voltage (LV) lid mounted bushings resulting in a number of forced outages due to wildlife interactions. TasNetworks has undertaken to convert many transformers with lid mounted LV bushings to installations physically protected by a cable box;
- The migration of contaminated tap-changer oil into the main tank of the transformer which is not conducive to the serviceability and longevity of the transformer;
- Obsolete synthetic resin-bonded paper transformer bushings that have been superseded by oil filled condenser and resin impregnated paper type;
- The use of porcelain insulated bushings;
- The presence of explosion vents instead of pressure relief valves that do not allow a controlled pressure release in the event of an explosion in the main tank of the transformer; and
- Inadequate methods of preventing moisture entering the transformer tank contributing to oil contamination, insulation degradation and inevitably premature failure.

TasNetworks’ transformer specifications will address these design issues over time. Most of these issues are sufficiently minor, or the modifications sufficiently large and expensive, that extensive works to remedy the identified issues is uneconomic.

7.1.6 Asset compliance

TasNetworks' Annual Planning Report 2017 (APR) describes the obligations for power transformers in regards to megawatt delivery capability and megawatt hours at risk in the event of a power transformer failure. The obligations are prescribed by the National Electricity Rules and the Electricity Supply Industry (Network Planning Requirements) Regulations, 2007.

The APR has identified several sites which currently or are likely to breach the ESI regulations in the 10 year planning period.

Table 4: APR identified sites with potential constraints

Substation	Transformer affected	Constraint	When
Meadowbank	T4	Above the 300 MWh unserved energy performance of the ESI regulations.	Now
Rosebery	T1 and T2	Firm capacity exceedance.	Now
Railton	T1 and t2	Firm capacity exceedance.	2022
North Hobart	T1 and T2	Firm capacity exceedance.	2025
Burnie	T6 and T7	Firm capacity exceedance.	2026

7.2 Summary of Risk

In the period from 1997 to 2012 there were three major supply transformer failures.

Queenstown T1 failed in 1997 and again in 2000 during an external short circuit and Hadspen T4 failed in 2006 during an external short circuit.

Since 2012 there have been no major power transformer failures. Several minor failures due to ancillary items or other causes have been recorded. These include:

- Several LV cable termination failures: Kingston 33 kV, Hadspen 22 kV.
- Insulation flash over due to moisture ingress into cable box - Creek Road 33 kV.
- Failure of PRD trip contact at Newton Substation – corrosion cause.

TasNetworks has established systems that ensure such details are recorded and maintained as part of normal business practices. Documented investigations into the root cause of failure are conducted by technical staff for every major failure. Defects are identified, and planned for repair, through a scheduled inspection regime.

The major issues identified in the review of the power transformer population include the following:

- Poor electrical condition of a number of supply transformers;
- Two units defined as being in 'poor' condition;
- Nine units defined as being in 'marginal' condition.
- The high number of supply transformers for which no suitable spare exists, including critical supply transformers such as Chapel Street T5 and T6, and North Hobart T1 and T2, which has now been addressed with the procurement of a strategic spare dual secondary winding supply transformer due for delivery mid 2018;
- The number of design issues identified;
- The migration of oil between the main tank and tap-changer;
- Obsolete bushings; and
- The high number of different physical supply transformer arrangements presently in operation, making replacement with a spare transformer more difficult.

8 Management Plan

8.1 Historical

Historically, management of substation power transformers has been undertaken based primarily on condition and condition assessments with time based maintenance. This will be continued into the future through inclusion of a Condition Based Risk Management (CBRM) program.

8.2 Strategy

The management strategies adopted to mitigate the risks associated with power transformers are monitored on an ongoing basis to ensure they are effective and relevant to achieving TasNetworks' risk management objectives. Practices are reviewed on a regular basis taking into account:

- Past performance;
- Manufacturer's recommendations;
- Industry practice (derived from participation in technical forums, benchmarking exercises and discussions with other transmission companies); and
- Availability of new technology.

Failures within power transformers may cause serious or catastrophic damage to the assets, so allowing failures to occur represents a real risk to the surrounding infrastructure.

To reduce the risk of power transformer failure, TasNetworks has adopted the following specific strategies to address the predominant causes and consequences of failure.

8.2.1 Routine Maintenance

There is a fundamental requirement for TasNetworks to periodically inspect the assets to ensure their physical state and condition does not represent a hazard to the public. Other than visiting the assets, there is no other economic solution to satisfy this requirement.

8.2.2 Routine Maintenance versus Non Routine Maintenance

Failures within power transformers may cause serious or catastrophic damage to the asset. These assets are sometimes located in close proximity to the public, so allowing failures to occur represents a real risk to the public and surrounding infrastructure. These assets also have a high unit value, so a preventative corrective maintenance program represents a cost effective alternative to a reactive corrective maintenance program.

8.2.3 Refurbishment

Where power transformers are removed from the network in good operating condition by activities such as capacity and power quality drivers, these assets are assessed for redeployment back into the network where such refurbishment is deemed to be an economic proposition.

8.2.4 Condition monitoring

In order to extend some transformer lives, or to more proactively identify any active internal faults, TasNetworks may install online monitoring systems to monitor oil and winding temperatures, or dissolved gas systems or moisture removal systems.

These are evaluated on a transformer by transformer basis.

The systems are typically portable and may be relocated from one transformer to another as needs change.

8.2.5 Planned Asset Replacement versus Reactive Asset Replacement

Replacement is generally only preferred when this is a more economic proposition compared to ongoing maintenance costs over the estimated remaining service life of the asset. These are identified from the maintenance and inspections activities and feed into the list of proposed capital expenditure projects for prioritisation. Reactive replacements are generally several times more expensive, incurring overtime, call out penalties and additional repair costs to cable terminations and nearby infrastructure.

The failure of any part of a transformer may be very difficult to predict and historical analysis along with industry statistics are often considered when predicting these events. At any one time there may be several minor repair projects including, e.g. the repair of leaks, the replacement of a bushing or the repair of a hot connection. Costs associated with such minor repairs can be catered for in-situ, however extensive transformer damage needs to be managed on an asset-by-asset basis when it occurs and the associated costs are expected to be extensive.

8.2.6 Non Network Solutions

The role of the power transformers generally cannot be cost effectively substituted via upgrading other infrastructure on the network.

8.2.7 Network Augmentation Impacts

8.2.7.1 Planned augmentation

TasNetworks' requirements for developing the power transmission system are principally driven by five elements:

1. Demand forecasts;
2. New customer connection requests;
3. New generation requests;
4. Network performance requirements; and
5. National electricity rules (NER) compliance.

Details of planned network argumentation works can be found in TasNetworks' Annual Planning Report and related Regional Development Plans, which are updated on a yearly basis.

8.2.7.2 Approved new augmentation

The installation of additional supply transformers within the network is based on customer request and load growth. Completed installations have recently included Mornington T1 and T2 Type 3 supply transformers, 60 MVA 110/33 kV; and St Leonards T1 and T2, Type 2 supply transformers, 60 MVA 110/22 kV.

8.2.7.3 Proposed new augmentation

TasNetworks' Annual Planning Report is referenced to identify possible augmentation scenarios that will require additional or upgraded transformers. This information is useful when considering the most appropriate driver for either a condition replacement or augmentation replacement of existing assets.

8.2.7.4 Capacity increase

There are a number of substations where the current transformation capacity is non-firm. These are possible locations for the installation of larger supply transformers which will not necessarily add to the population as in some cases the replaced supply transformers will be scrapped. Locations identified for possible upgrades include:

- Lindisfarne Substation – installation of two new larger, 60 MVA, supply transformers (this is a current approved project with completion targeted for 2019);
- Rosebery Substation – installation of two larger, 60 MVA, supply transformers; and
- St Marys Substation – installation of two larger, 25 MVA, supply transformers.

8.3 Routine Maintenance

Routine or preventive maintenance is, by its nature, a planned and scheduled maintenance activity that is completed to a predetermined scope, and can be broken down into two areas:

- Condition assessment. Condition assessment is routine inspection, testing and monitoring of assets to ascertain their condition.
- Maintenance (routine and condition based). With routine and condition based maintenance, assets are maintained either on pre-determined frequency basis (time-based) or require planned maintenance following condition assessments.

During the life of a power transformer a program of continuous monitoring is employed to detect any early signs of degradation beyond what would normally be expected. The use of oil analysis is now recognised as the most effective and least intrusive method of transformer condition monitoring. Refer to Appendix C for further detail regarding the condition assessment criteria as applied to power transformers.

When a problem is indicated by the oil analysis a higher level of testing is specified which usually includes electrical testing of the transformer in order to more fully define the nature of any fault.

8.3.1 Condition Monitoring

Condition monitoring and assessment criteria broadly fall into the following categories:

- Routine DGA sampling;
- Electrical testing (bushings);
- Tap-changer maintenance; and
- Auxiliary equipment testing.

8.3.1.1 DGA Sampling

Routine sampling of the complete transformer fleet is conducted on a two-yearly cycle.

A new sampling regime applicable for new and major refurbished transformers in being introduced from 2018. This includes installing a portable DGA unit to any new or major refurbished transformer for the first six months after its energisation. This is an innovative measure to provide real-time identification of any gassing issues which may occur during this initial life cycle phase. This aligns with strategic thinking based on the “bath tub” failure cycle for assets. A bathtub curve is a hazard function showing a decreasing failure rate in the early life and an increasing failure rate in later life I with the flat part of the bathtub curve being called useful life. The bathtub curve highlights that failures may occur early in an assets life cycle and if not then many years of satisfactory service is expected prior to end of life replacement/retirement.

8.3.1.2 Electrical Testing

Transformer electrical testing is performed on commissioning and acts as fingerprint tests for later comparison should more electrical tests be required.

Electrical tests are again required when DGA test results indicate the abnormally high generation or concentration of certain gases in the insulating oil.

Transformer bushings are subjected to electrical testing as a means of condition monitoring. Transformer bushings of an oil impregnated paper design, installed on transformers have provided reliable service with no instances of failure. Due to the reliability of oil impregnated paper bushings, electrical tests are not required for the first 18 years of service. This approach aligns with industry practice.

8.3.1.3 Tap-changer Maintenance

Tap-changer maintenance is carried out every six years on most transformers with a small number requiring maintenance on a three yearly cycle. Maintenance is based on either the number of operations of the switch mechanism or on a time-based frequency. Maintenance timings are also altered based on tap changer oil test results.

8.3.1.4 Auxiliary equipment testing

Routine test on auxiliaries such as Buchholz, OTI/WTI sensors and pressure relief device are carried out every six years in conjunction with other protection routine tests.

Table 5 presents the maintenance and monitoring of power transformers and their accessories throughout their lives.

Table 5: Defined power transformer maintenance regime

Task	Frequency
Visual inspections and routine condition monitoring (including oil level indicators)	Coordinated with substation quarterly inspections
Thermal imaging	Coordinated with substation annual thermal imaging program
Manual Insulating oil sampling and analysis (transformer) - in-service units	Prior to energisation for new units 24 hours after transformer has been put on soak 48 hours after transformer has been put on load Thereafter monthly for the first six months following commissioning (only if portable on-line DGA unit not available)
	Every two years or more frequently as determined by condition assessment
On-line Insulating oil sampling and analysis (transformer) - in-service units	Portable DGA unit is to be connected to each new transformer for the first six months following commissioning with alarm points and gas values telemetered back to NOCS.
	Online DGA unit can be connected to in-service units if age and condition assessment warrants real time monitoring.
	Online DGA monitoring devices, where fitted, are to be tested every six years in conjunction with protection routine testing (operational DC checks)
Insulating oil sampling and analysis (tap changer)	Every two years until the age of 35, then more frequently as determined by condition assessment
Tap-changer preventive maintenance a) resistor type load tap-changers b) reactor type load tap-changers c) vacuum type load tap changers	Every six years Every three years 18 years after commissioning and every six year thereafter Maintenance may also be determined by the number of tap operations and tapping range.
Degree of polymerisation (DP)	At midlife if determined necessary by oil analysis and condition assessment criteria As transformer approaches end of life if determined necessary by CBRM and verified by a detailed condition assessment Note: Undertaken only when practical Note: In transformers purchased after 2010 a paper samples has been placed on top of the core accessible from hand hole. If deemed necessary overtime then this paper sample could be taken and DP could be analysed.
Transformer and tap changer electrical testing (winding resistance, insulation resistance, ratio, DDF and DIRANA tests.)	At midlife if determined necessary by oil analysis and condition assessment criteria As transformer approaches end of life if determined necessary by CBRM and verified by a detailed condition assessment
Condenser bushings electrical testing (capacitive and power factor tests)	18 years after commissioning and every six years thereafter

Auxiliary equipment a) Buchholz gas detection relay operation check b) Pressure relief valve operation check (main tank and OLTC) c) Oil and winding temperature calibrations (mechanical indicators only) d) DRMCC or similar (where fitted)	Every six years in conjunction with protection routine testing (operational DC checks)
Cooling system (pumps and fans - functional tests)	Coordinated with substation quarterly inspections

8.3.1.5 Potential future maintenance practices

TasNetworks recognises that a proactive approach to life-cycle management of its assets is an established and accepted practice within the electrical industry. This is evident through TasNetworks' participation in various benchmarking and best practice activities, locally and internationally. As part of this participation, TasNetworks may make provision for, identify, develop, participate and or pilot various initiatives in the normal course of business. Initiatives are likely to be made and pursued in the areas as represented in table 6.

Table 6: Technology and innovation initiatives

Initiative	Rationale	Driver
Online condition monitoring	• The introduction of new measurement techniques and technologies • Increased utilisation of intelligent condition monitoring systems	• Improved assessment of asset condition. • Improved life-cycle management.
PD testing	• Early identification of insulation degradation. (Ultrasonic using PD Hawk or similar)	• Improved assessment of asset condition (bushings).

8.4 Non Routine Maintenance

Minor and major asset defects that are specifically identified during asset inspections and routine maintenance or through other ad-hoc site visits are prioritised and rectified as per the recommendations set out in TasNetworks' condition assessment report and general asset defects management process.

The methodology used to develop and manage non routine maintenance is adjusted to meet the option analysis completed specific for the defect to meet the performance criteria set out in TasNetworks' risk framework, with the objective to return to service and prevent asset failure.

8.5 Reliability and Quality Maintained

8.5.1 Standardisation

To mitigate the risk of a major failure of a power transformer, TasNetworks has standardised on the use of four types of supply transformer and two types of network transformer for new or replacement installations.

While the failure rates for power transformers are relatively low, the consequences of such a failure are relatively high. Through the introduction of standardised transformer types and firm capacity at most substations, the consequences of a failure are minimised.

8.6 Regulatory Obligations

Service Obligations for Network Assets power transformers performance impacts on TasNetworks' overall network service obligations, which includes specific performance requirements for both regulated and connection transmission assets

TasNetworks' performance incentive (STIPIS) scheme has been produced in accordance with the Australian Energy Regulator's Service Standards Guideline is based on plant and supply availability. The STIPIS scheme includes the following specific measures:

- Plant availability:
    - Transmission line circuit availability; and
    - Transformer circuit availability.
- Supply availability:
    - Loss-of-supply event frequency index
    - Number of events in which loss of supply exceeds 0.1 system minute; and
    - Number of events in which loss of supply exceeds 2.0 system minutes.

Details of the STIPIS scheme and performance targets are managed by TasNetworks Asset Performance group and are listed in TasNetworks Corporate and Business plans.

8.6.1 Service Obligations for Network Assets

8.6.1.1 Power Transformer In-service Redundancy

To mitigate the risk of unserved energy, in accordance with the Electricity Supply Industry (ESI Act) - Network Performance Requirements Regulations, any replacement or repair undertaken must not exceed eight days for a supply transformer, or eighteen days for a network transformer. Contingency planning obligations specific to substation primary plant is presently detailed in Substation fault response guideline document D06/29656. In support of this there are several site specific contingency plans developed to suit specific locations which present more complex issues.

In order to meet such criteria, TasNetworks maintains a population of spare transformers which includes those that are dedicated to a specific site, and those which are for general use within the transmission system, also refer to TasNetworks' Power Transformer Movements.

8.6.1.2 Power Transformer Recovery Procedure

TasNetworks' power transformer recovery procedures are detailed in TasNetworks' System Spares Policy, R517373. This policy states that transformers which are decommissioned from the system for reasons other than failure or retirement are added to the pool of system spare transformers. This policy also states that new transformer installations should make use of excess spare transformers to avoid additional, unwarranted, capital expenditure where practicable.

Where a new transformer is to be purchased, an analysis should first be undertaken to determine whether a more appropriate solution is the purchase of a system spare transformer as opposed to a site specific unit.

8.6.1.3 Accelerated Transformer Replacements

There are presently a number of substations in the network which do not meet the requirements of the Electricity Supply Industry (Network Performance Requirements) Regulations, specifically the need to limit load loss to 300 MWh.

If a supply transformer replacement time of eight days is required, as under the regulations, then the transformer load must not exceed 1.6 MW to ensure limiting energy at risk to 300 MWh.

TasNetworks has identified three substations, being Derby, Avoca and Meadowbank, which have a single transformer but exceed 1.6 MW in load. The load at these substations is significantly below the rating of the smallest standard transformer size of 25 MVA. As a result, it is not cost effective to install dual 25 MVA transformers at these sites.

One way to meet the 300 MWh requirement is to reduce the replacement time from eight days.

By reducing this replacement time to 24 hours then a single 25 MVA supply transformer could now serve 12.5 MW of load without violating this criteria.

A possible solution is for a mobile trailer mounted transformer could be utilised, which when paired with both 110 kV and 22 kV circuit breakers, would allow for a ‘drive-in’ quick connect solution to a transformer failure. This unit could also be used during transformer replacements or maintenance periods to secure supply to the distribution network.

Alternatively, suitably sized cold spare units could be already located onsite, such that the failed unit could be quickly replaced by another onsite unit.

TasNetworks has recently evaluating options at specific sites to determine a preferred solution. The current way forward is that holding a trailer mounted spare transformer is not warranted which can be reviewed if need drivers change.

8.6.2 Service Obligations for Non-regulated Assets

8.6.2.1 Hydro Tasmania

TasNetworks has a Performance Incentive (PI) scheme in place with Hydro Tasmania under its Connection and Network Service Agreement (CANS 2) for connection assets between the two companies. The PI scheme includes the connection asset availability measure.

An overview of Hydro Tasmania PI scheme and performance targets can be found in the associated connection agreement.

8.6.2.2 Tamar Valley Power Station (TVPS)

TasNetworks has a PI scheme in place with TVPS under its Generator Connection Agreement for connection assets between the two companies. The PI scheme includes the connection asset availability measure. An overview of TVPS PI scheme and performance targets can be found in the associated Connection Agreement.

8.6.2.3 Major Industrial Direct Customer Connections

TasNetworks has a number of direct connections to major industrial customers through EHV and HV substations. The following sites have supply transformer assets providing these direct connections:

- Boyer Substation (6.6 kV);
- George Town Substation (220 kV & 110 kV);

- Huon River Substation (11 kV);
- Newton Substation (22 kV);
- Port Latta Substation (22 kV);
- Que Substation (22 kV);
- Queenstown Substation (11 kV);
- Risdon Substation (11 kV);
- Rosebery Substation (44 kV); and
- Savage River Substation (22 kV)

The individual connection agreements describe the level of service and performance obligations required from the associated connection assets.

8.7 Replacement and Refurbishment

Extensive analysis including using CBRM to aid with the decision on whether to maintain, refurbish or replace identified units, and the optimal timing of the appropriate actions.

TasNetworks' transformer capital program is developed taking into consideration the power transformer condition, performance and reliability issues, and aims to achieve cost-effective integration with other capital works.

As well as the dedicated projects listed below reference is made to TasNetworks' Power Transformer Movements document which provided guidance to proposed relocations and spares handling details.

Power transformers capital works for specific planning periods is presented in 7.

Table 7: Power transformers CAPEX replacements

Period	Transformer	Scope	Status
2009/14	AL-T1	Replace	Completed
	DE-T1	Replace	Completed
	NT-T1	Replace with ex Sorell unit (PS-1)	Completed
	NT-T2	Replace with ex Sorell unit (PS-2)	Completed
	TU-T8	Replace	Completed
	BW-T1	Repair Tapchanger	Completed
	UL-T2	Replace Bushings	Completed
	PL-T2	Replace Bushings	Completed
	RA-T1	Replace Bushings	Completed
	RA-T2	Replace Bushings	Completed
	PS-T1x	Refurbish and relocate to Newton	Completed
	PS-T2x	Refurbish and relocate to Newton	Completed
	QT-T1	Replace	Completed
	WA-T1	Repaint and corrosion control	Not yet commenced
	LF-T2	Replace	Underway – approved project
	LF-T3	Replace	Underway – approved project
	KE-T1	Dryout	Completed
	KE-T2	Dryout	Completed

Period	Transformer	Scope	Status
	SH-T1	Repaint and corrosion control	Completed
	GO-T6	Refurbish	Completed
2014/19	SM-T1	Refurbish	Completed
	GT-T5	Refurbish and Repair	Completed
	FA-T1	Refurbish	No longer required
	FA-T2	Refurbish	No longer required
	BY-T1	Replace	Underway – approved project
	BU-T6	Replace	Not undertaken transferred into R19
	BU-T7	Replace	Not undertaken transferred into R19
	System Spare	Procure three winding 60 MVA	Underway – approved project
	System Spare	Procure two winding 25 MVA	Underway – approved project
	RB-T1	Refurbish	May be replaced/relocated in R19 and if not supported move into R24
	RB-T2	Refurbish	May be replaced / relocated in R19 and if not supported move into R24
2019/24	PL-T1	Replace	Included into R19
	PL-T2	Replace	Included into R19
	BU-T6	Replace	Included into R19 (moved from R14)
	BU-T7	Replace	Included into R19 (moved from R14)
	SR-T2	Replace (potential to re-use Rosebery units)	Included into R19
	SR-T3	Replace (potential to re-use Rosebery units)	Included into R19
	SM-T1	Replace (potential relocate to Waddamana)	Included into R19 (potentially replaced by relocating Derwent Bridge DB-T1 as part of Derwent Bridge 22 kV supply project)
	SM-T2	Replace (look to relocate/hold as spare)	Included into R19
	RB-T1	Replace (potential relocate to Savage River)	Included into R19
	RB-T2	Replace (potential relocate to Savage River)	Included into R19
	BY-T13	Replace	Included into R19
	BY-T14	Replace	Included into R19
	KE-T1	Replace	Included into R19
	KE-T2	Replace	Included into R19
	WA-T1	Replace (potential to re-use St Marys unit)	Included into R19
2024/2029	BY-T2	Replace	Included into R24
	RB-T1	Replace	Included into R24 if not completed in R19
	RB-T2	Replace	Included into R24 if not completed in R19

Period	Transformer	Scope	Status
	SH-T1	Replace	Included into R24

8.8 Program Delivery

The needs assessment and options analysis for undertaking an asset management activity is documented in the Investment Evaluation Summary for project work.

The delivery of these activities follows TasNetworks' end to end (E2E) works delivery process.

8.9 Spares Management

To mitigate the risk of inadequate response levels, in the event of a power transformer failure, TasNetworks has developed a set of contingency plans to minimise the impact on the reliability and availability of electricity supply. Contingency plans are maintained by the Works and Service Delivery Asset Engineering group.

In addition, TasNetworks System Spares Policy, document R517373, details the minimum requirements for maintaining spare power transformer units, which include:

- One off 17/25 MVA, 110/22 – 11 kV ONAN/ONAF supply transformer;
- One off 30/60 MVA, 110/33 – 22 – 11 kV ONAN/ONAF supply transformer; and
- One off 150/200 MVA, 220/110 kV ONAN/ONAF network transformer.

TasNetworks has identified other sites for which the standard spare units will not suffice. TasNetworks will procure a further three winding spare unit to cover these sites.

A list of TasNetworks spare power transformer units is provided in Appendix C – Designated Spare Transformer Listing.

TasNetworks currently has a total of six spare transformers available for use at locations in the transmission network.

These six system spare transformers are available for use anywhere in the system as required based upon their suitability, including at the sites of major industrial connections. Any of these transformers is also available for installation, at a newly created or expanded site, on a permanent basis should the need arise as covered by the system spares policy.

Table 8: System spare power transformers

Substation	Manufacturer	Rating (MVA)	Voltage Ratio (kV)	Year	Comment	Condition
Burnie	ABB	150/200	220/110	2010	Network transformer	Acceptable
Creek Road	Siemens Westinghouse	30/40/50	110/22	1999	Noisy unit Had seen three years' service.	Acceptable
Emu Bay	AEI	15/22.5	110/22	1967	Identical rating to Port Latta and Savage River units	Marginal
Palmerston	Wilson	30/50	110/33-22-11	2005	Only 33kV spare unit	Acceptable
Risdon	Wilson	17/25	110/22-11-6.6	2014	Standard type 1 unit with 6.6 kV delta suitable for Arthurs Lake Substation.	Acceptable

Table 9: Dedicated spare supply transformers

Substation	Manufacturer	Rating (MVA)	Voltage Ratio (kV)	Year	Comment	Condition
Boyer T5	Savigliano	15/22.5	110/6.6	1968	Dedicated major industrial customer – unique voltage	Poor

Table 10: In-service spare transformers

Substation	Manufacturer	Rating (MVA)	Voltage Ratio (kV)	Year	Comment	Condition
Devonport T3	Stromberg	31.5	110/44 – 22	1983	Dedicated spare for Rosebery 44 kV injection point	Acceptable

8.10 Technical Support

Other operational costs which are not able to be classified under the above categories are allocated to technical support. These tasks include:

- System fault analysis and investigation;
- Preparation of asset management plans;
- Standards management;
- Management of service providers;

- Training;
- Group management; and
- General technical advice.

8.11 Disposal Plan

A disposal plan may be considered when a transformer either:

- Fails prematurely during service and repair is not economically feasible, or
- The electrical and mechanical condition of the power transformer deteriorates to such an extent, due to age and environmental factors, that it is considered appropriate to retire.

Power transformers are disposed of in accordance with the environmental policy and the relevant TasNetworks standards and procedures. Transformers which are decommissioned, but are determined to still be in a serviceable condition, are either redeployed elsewhere in the system or retained as system spares where they are subject to the requirements of the System Spares Policy.

The following is a list of transformers expected to be decommissioned and scrapped over the next ten year period.

- Boyer T13 and T14
- Burnie T6 and T7;
- Kermandie T1 and T2
- Lindisfarne T2 and T3;
- Savage River T2 and T3; and
- Waddamana T1.

8.12 Summary of Programs

Table 11 provides a summary of all of the OPEX programs described in this management plan. CAPEX projects are detailed in section 8.7 table 7.

Table 11: Summary of power transformer programs / projects

Work Program	**Work Category**	**Project/Program**
Routine Maintenance	Conditioning monitoring	S261-Network Transformer Main Tank Oil Samples
		S349-Transformer Bushing Electrical Tests
		S269-Network Transformer Tap Changer Oil Samples
		S321-Supply Transformer Main Tank Oil Samples
		S329-Supply Transformer Tap Changer Oil Samples
	Preventative maintenance	S593-Supply Transformer Clean Oil Bunds
		S501-Network Transformer Tap Changer Maintenance
		S601-Supply Transformer Tap Changer Maintenance
		S133-SUBS-Corrective-Supply Transformer

9 Financial Summary

9.1 Proposed OPEX Expenditure Plan

Requirements for operating expenditure are a function of the defined periodic condition monitoring regimes, defined maintenance requirements and expected minor and major transformer works.

9.2 Proposed CAPEX Expenditure Plan

The capital programs and expenditure identified in this management plan are necessary to manage operational and safety risks and maintain network reliably at an acceptable level. All capital expenditure is prioritised expenditure based on current condition data, field failure rates and prudent risk management.

A comprehensive capital investment plan has been developed to address the identified design and performance issues associated with the power transformer population and to improve transmission system performance. This plan recommends that several transformers require specific management interventions due to failing condition and response to customer demand.

To support this program it is recommended that some transformers are replaced and some units undergo a form of refurbishment. The program will mitigate the business risks presented by the existing power transformer population and reduce future preventive maintenance costs.

9.3 CAPEX – OPEX trade offs

The operating expenditure programs are essential for identifying assets that require replacement for condition-based reasons. There is a positive relationship between these two categories in that regular inspection programs gather continuous condition information of the assets to better target asset replacements and identify any asset trends. Maintenance and repair activities also defer the requirement for capital expenditure and increase the likelihood of the asset operating for as long as possible within the network.

10 Related Standards and Documentation

The following documents have been used either in the development of this management plan, or provide supporting information to it:

TasNetworks documents:

1. Strategic Asset Management Plan R248812
2. Annual Planning Report 2017 R689487
3. Insulating Oil for Transformers and Switchgear Standard R517371
4. System Spares Policy R517373
5. Data Integrity Standard – Power Transformer R17003
6. Data Integrity Standard – bushing electrical test results R17094
7. Data Integrity Standard – main tank oil test results D11/7082
8. Data Integrity Standard – Tapchanger oil test results D11/7084
9. Data Integrity Standard – Transformer electrical test results D11/100553
10. AM8 Asset Condition Review – project report June16 FINAL R503361
11. Power Transformer Movements R279578

Technical requirements for new power transformers are detailed in the following standard/specifications:

12. Supply Transformer Standard TNM-DS-806-0833 R527890
13. Network Transformer Standard TNM-DS-806-0240 R527893

Other related standards and documents:

14. Guide to Maintenance and Supervision of Insulating Oils in Service AS1883 - 1992
15. Risk Management AS 4360
16. Guide on Economics of Transformer Management CIGRE, Working Group A2.20
17. Management Techniques for Power Transformers CIGRE, Working Group A2.18
18. Transformer Maintenance Guide, Transformer Maintenance Institute, 2nd edition, 2001 Horning M, Kelly J, Myers S
19. Mineral Oil-impregnated Electrical Equipment in Service – Guide to the Interpretation of Dissolved and Free Gases Analysis IEC Standard 60599
20. IEEE Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers IEEE Publication C57.104 – 1991
21. Sinclair Knight Mertz report, Asset Valuation for Financial Reporting Purposes, August 2013 R192773
22. Peterson, A. and Austin, P., “Impact of recent transformer failures and fires – Australian and New Zealand experience”
23. CIGRE TB642 TRANSFORMER RELIABILITY SURVEY, Working Group A2-37, December 2015.

11 Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S593-Supply Transformer Clean Oil Bunds	PMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S501-Network Transformer Tap Changer Maintenance	PMNTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S261-Network Transformer Main Tank Oil Samples	PMNTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S349-Transformer Bushing Electrical Tests	PMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S601-Supply Transformer Tap Changer Maintenance	PMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S133-SUBS-Corrective-Supply Transformer	CMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S269-Network Transformer Tap Changer Oil Samples	PMNTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S321-Supply Transformer Main Tank Oil Samples	PMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
S329-Supply Transformer Tap Changer Oil Samples	PMSTX	Medium	Customer Financial Compliance Reputation Safety Reliability	Opex	Low
Waddamana T1 supply transformer - replacement	RENSB	Medium	Safety Reliability	Capex	Low
Sheffield SH-T1 Network transformer - replacement	RENSB	Medium	Customer Financial Compliance Reputation Safety Reliability	Capex	Low
Boyer T2 supply transformer - replacement	RENSB	Medium	Customer Financial Compliance Safety Reliability	Capex	Low
Boyer T13 & T14 supply transformers - replacement	RENSB	Medium	Customer Financial Compliance Safety Reliability	Capex	Low

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
Rosebery Substation supply transformers - replacement	RENSB	Medium	Customer Financial Safety Reliability	Capex	Low
St Marys supply transformers - replacement	RENSB	Medium	Customer Financial Safety Reliability	Capex	Low
Kermandie supply transformers - replacement	RENSB	Medium	Financial Safety Reliability	Capex	Low
Savage River supply transformers - replacement	RENSB	Medium	Customer Financial Safety Reliability	Capex	Low
Port Latta supply transformers - replacement	RENSB	Medium	Customer Financial Safety Reliability	Capex	Low
Burnie supply transformers - replacement	RENSB	Medium	Customer Financial Safety Reliability	Capex	Low

12 Appendix B – Transformer Health indices

Transformer	Age (Ys)	HI 1	DGA HI(2a)	Oil Condition HI(2b)	FFA HI(2c)	Transformer HI	Tap changer HI	Final Asset HI Y0	Years to Reach EOL
AL-T1	5	0.6	0.5	0.19	0.08	0.36	0.61	0.61	67.7
AV-T1	21	1.05	0.5	0	0.09	0.66	1.14	1.14	45.35
BU-T2	8	0.68	0.91	0	0.14	0.91	0.74	0.95	50.36
BU-T3	8	0.7	0.5	0	0.12	0.42	0.7	0.7	52.35
BU-T6	48	3.3	2.45	0	0.23	4.54	4.47	5	6.98
BU-T7	48	3.3	0.5	0	0.54	2.77	4.07	4.07	12.35
BW-T1	38	2.08	1.09	0	0.16	2.38	2.63	2.89	18.96
BW-T2	38	2.08	2.18	0	0.2	2.46	2.89	3.18	16.04
BY-S-50719	50	4.98	0.5	0.61	3.41	7.1	5.5	7.45	0
BY-T1	50	4.98	0.5	1.65	3.79	6.86	4.63	6.86	0.38
BY-T13	30	1.97	2	1.49	1.27	2.1	2.36	2.6	17.84
BY-T14	30	1.74	0.73	1.49	2.44	2.68	2.48	2.95	14.48
BY-T2	31	1.93	0.5	3	1.5	3.09	2.37	3.24	12.62
BY-T7	47	2.92	0.5	1.08	0.62	3.1	5.32	5.32	5.4
CR-T2	17	0.97	1	0	0.02	0.9	1.18	1.24	32
CR-T3	17	0.97	0.5	0	0.02	0.75	1.18	1.18	34.78
CR-T4	17	0.97	1.64	0.12	0.03	1.64	1.18	1.72	18.98
CS-T1	38	2.22	0.5	0.91	0.19	1.8	2.62	2.62	22.35
CS-T2	13	0.83	0.5	0	0.02	0.5	0.87	0.87	47.35
CS-T3	13	0.83	0.5	0.7	0.02	0.5	0.92	0.92	42.52
CS-T4	13	0.83	0.5	0	0.02	0.57	0.87	0.87	47.35
CS-T5	35	1.97	1	0.47	0.13	1.84	2.73	2.73	19.28
CS-T6	35	1.97	2.27	0.35	0.04	2.27	2.6	2.86	17.77
DB-T1	10	0.71	0.5	0.58	0.06	0.43	0.74	0.74	62.61
DE-T1A	5	0.6	0.5	0	0.09	0.36	0.61	0.61	67.7
DP-T1	22	1.18	0.5	0	0.03	0.88	1.43	1.43	32.77
DP-T2	22	1.26	0.5	0.23	0.03	0.95	1.43	1.43	32.77
DP-T3	35	1.97	0.5	3	0.63	3	2.69	3.3	13.82
EB-T2	45	2.93	0.5	0.12	0.11	2.28	3.56	3.56	15.35
EB-T3	45	2.93	0.5	0.58	0.1	2.28	3.56	3.56	15.35
EB-T-50765	51	4.64	0.5	0.35	0.13	2.92	4.64	4.64	9.35
EL-T1	9	0.72	0.5	0	0.15	0.47	0.78	0.78	55.44
EL-T2	20	1.11	0.5	0.12	0.02	0.67	1.33	1.33	34.25
FA-T1	35	1.74	0.91	0.7	0.53	1.25	2.14	2.14	28.21
FA-T2	35	1.74	1.18	0.23	0.17	2.07	2.25	2.48	22.54
GO-T6	43	2.75	0.5	0.17	0.12	2.23	2.75	2.89	21.51
GT-T1	13	0.83	0.5	0.12	0.02	0.57	0.95	0.95	39.29

GT-T2	10	0.73	0.5	0.29	0.27	0.55	0.82	0.82	54.27
GT-T3	10	0.73	0.5	0.12	0.33	0.55	0.82	0.82	54.27
GT-T4	18	1.01	0.5	0.12	0.02	0.75	1.09	1.09	42.35
GT-T5	15	0.89	0.5	0	0.16	0.62	0.95	0.95	45.35
HA-T1	20	1.01	0.5	0	0.05	0.85	1.35	1.35	32.52
HA-T2	20	1.01	0.5	0.15	0.02	0.85	1.35	1.35	32.52
HA-T3	13	0.79	0.5	0	0.02	0.47	0.85	0.85	50.21
HA-T4	13	0.79	0.5	0	0.13	0.64	0.85	0.89	44.93
HR-T1	11	0.73	0.5	0.12	0.02	0.57	0.78	0.82	46.08
KE-T1	57	4.25	0.5	0.26	0.23	3.57	5.5	5.5	5.7
KE-T2	57	4.25	1.18	2	0.19	5.66	5.5	6.22	2.65
KI-T1	39	2.31	0.5	0.15	0.2	1.8	2.98	2.98	18.49
KI-T2	39	2.31	0.5	0	0.15	1.87	2.98	2.98	18.49
KI-T3	6	0.66	0.5	0	0.09	0.4	0.66	0.66	53.76
KI-T4	6	0.66	0.5	0	0.09	0.4	0.66	0.66	53.76
KR-T1	31	1.59	0.5	0	0.07	1.19	1.81	1.81	32.21
KR-T2	31	1.93	0.5	0	0.02	1.39	1.81	1.9	29.91
LF-T2	54	4.18	0.5	0.26	0.21	3.51	5.5	5.5	5.4
LF-T3	54	4.18	0.73	0.26	0.14	3.14	5.5	5.5	5.4
LF-T4	8	0.67	0.5	0	0.1	0.4	0.71	0.71	57.93
LF-T5	7	0.67	0.5	0	0.1	0.46	0.69	0.69	58.64
MB-T4	21	1.09	0.5	0	0.02	0.82	1.14	1.2	41.67
MT-T1	8	0.68	0.5	0	0.05	0.41	0.71	0.71	57.74
MT-T2	8	0.68	0.5	0	0.05	0.41	0.71	0.71	57.74
MY-T1	10	0.71	0.5	0.58	0.19	0.43	0.77	0.77	61.51
MY-T2	14	0.82	0.5	0	0.02	0.56	0.91	0.91	46.21
NH-T1	42	2.6	0.5	0.91	0.48	2.03	3.44	3.44	15.38
NH-T2	42	2.6	0.5	0.91	0.52	2.19	3.12	3.12	18.35
NN-T1	31	1.59	0.5	0	0.04	0.96	2.06	2.06	26.49
NN-T2	31	1.59	0.5	0	0.02	0.96	2.06	2.06	26.49
NT-T1	48	2.78	0.5	0	0.2	2.33	3.36	3.36	18.35
NT-T2	48	2.78	0.5	0	0.09	2	3.36	3.36	18.35
NW-T1	23	1.13	0.73	0	0.02	0.88	1.36	1.36	37.14
NW-T2	39	2.01	1.09	0.35	0.37	2.48	2.53	2.79	20.72
PL-T1	51	4.11	0.5	0.19	0.17	3.33	5.5	5.5	5.1
PL-T2	51	4.11	0.5	0.12	0.17	3.57	5.5	5.5	5.1
PM-Spare1	13	0.83	0.5	0	0.02	0.5	0.83	0.83	53.35
PM-T1	25	1.21	1.45	0	0.09	1.5	1.55	1.71	28.31
PM-T3	20	1.01	0.5	0.12	0.04	0.79	1.1	1.15	42.49
PM-T4	12	0.76	0.5	0.1	0.02	0.62	0.82	0.86	45.51
PS-Spare2	4	0.58	0.5	0	0.08	0.35	0.58	0.58	62.35
PS-T1 40073	19	0.98	0.5	0.58	0.02	0.59	1.05	1.05	47.35

QT-T1	4	0.57	0.5	0	0.09	0.34	0.58	0.58	69.43
QT-T2	15	0.85	0.5	0.12	0.27	0.64	0.95	0.95	45.21
QT-T3	9	0.7	0.5	0.07	0.09	0.52	0.75	0.75	62.14
QT-T4	9	0.7	0.5	0	0.06	0.42	0.75	0.75	62.14
QU-T1	39	2.01	0.5	0	0.11	1.21	2.35	2.35	27.35
RA-T1	36	2.14	0.5	0	0.51	1.86	2.61	2.74	19.72
RA-T2	36	1.92	0.5	0.91	0.73	1.67	2.61	2.61	21.36
RB-T1	49	2.9	0.5	1.16	0.55	3.45	3.52	3.87	14.13
RB-T2	49	4.31	0.91	0.48	0.16	3.62	3.53	3.98	13.3
RB-T4	36	2.08	0.5	0.08	0.09	1.62	2.08	2.19	28.17
RB-T5	36	1.8	0.5	0.48	0.15	1.08	2.5	2.5	22.87
RI-T1	17	0.97	0.5	0	0.04	0.81	1.15	1.2	33.49
RI-T2	17	1.04	0.73	0	0.05	0.81	1.09	1.15	36.3
RI-T3	17	1.04	0.5	0.58	2.33	2.33	1.15	2.33	11.92
RI-T4	18	1.01	0.5	0	0.05	0.79	1.13	1.13	39.49
RI-T5	23	1.23	0.73	0	0.03	0.88	1.42	1.42	34.49
RI-T6	13	0.83	0.5	0	0.02	0.57	0.9	0.9	44.49
RK-T1	37	2.13	0.5	0	0.15	1.73	2.95	2.95	17.89
RK-T2	37	2.13	0.5	0.48	0.12	1.66	2.95	2.95	17.89
SD-T1	35	2.06	0.5	0	0.12	1.6	2.3	2.3	25.21
SD-T2	35	1.85	0.5	0.23	0.09	1.45	2.3	2.3	25.21
SH-T1	51	3.39	0.5	1.01	0.43	3.31	4.66	4.9	7.93
SH-T2	33	1.72	0.73	0	0.03	1.03	2.11	2.11	27.21
SL-T1	6	0.63	0.5	0	0.04	0.38	0.63	0.63	60.35
SL-T2	6	0.63	0.5	0.39	0.05	0.38	0.63	0.63	60.35
SM-T1	52	3.88	0.5	0.08	0.12	3.14	4.87	4.87	8.21
SM-T2	52	4.12	0.5	0	0.12	3.46	4.87	5.12	6.96
SO-T1	8	0.68	0.5	0.58	0.05	0.41	0.71	0.71	57.74
SO-T2	8	0.68	0.5	0	0.05	0.45	0.71	0.71	57.74
SR-T2	51	3.58	0.5	0.19	0.19	3.01	4.66	4.66	9.21
SR-T3	51	3.39	0.5	0.19	0.21	2.95	4.66	4.66	9.21
ST-T1	15	0.89	0.5	0	0.02	0.67	1.02	1.02	39.77
ST-T2	15	0.95	0.5	0	0.02	0.72	0.95	1	41.13
TB-T1	12	0.79	0.5	2.33	0.04	2.33	0.92	2.33	8.37
TB-T2	12	0.79	0.5	1.26	0.06	1.3	0.92	1.36	19.05
TR-T1	20	1.01	1.45	3	0.07	3.09	1.3	3.09	8.84
TR-T2	20	1.01	0.73	0	0.06	0.76	1.14	1.14	43.21
TR-T3	19	0.98	4.73	0	0.07	4.73	1.15	4.73	3.26
TU-T8	8	0.66	0.5	0	0.02	0.4	0.68	0.68	64.83
UL-T1	43	2.71	0.5	0	0.38	2.27	4.33	4.33	9.48
UL-T2	35	1.97	0.5	0.58	0.06	1.54	2.68	2.68	19.89
WA-T1	68	5.5	0.91	1.49	0.63	6.31	5.5	6.94	0.21

WV-T3	48	3.3	0.5	0.91	0.22	2.87	5.04	5.04	6.77
WV-T4	48	3.3	0.5	0.91	0.22	2.67	5.02	5.02	6.89

13 Appendix C – Designated Spare Transformer Listing

All the network transformers in the system can be interchanged with the spare unit stored at Burnie Substation.

The following tables define the designated spare supply transformer for each unit currently installed in the transmission network. Where a specific transformer has no designated spare this is indicated and explained in the table below.

The selections below are based mainly on electrical characteristics. Where an obvious physical limitation exists this has been considered.

As well as the details listed below reference is made to TasNetworks' Power Transformer Movements document which provided further guidance to overall spares management.

Table 12: Supply transformer population spare assignment (as at August 2017)

Substation	Unit	Designate Spare	Substation	Unit	Designate Spare
Arthurs Lake	T1	Risdon Spare	Newton	T1	Risdon Spare
Avoca	T1	Risdon Spare	Newton	T2	Risdon Spare
Burnie	T6	Creek Road T1	Norwood	T1	Creek Road T1
Burnie	T7	Creek Road T1	Norwood	T2	Creek Road T1
Bridgewater	T1	Palmerston Spare	Port Latta	T1	Emu Bay
Bridgewater	T2	Palmerston Spare	Port Latta	T2	Emu Bay
Boyer	T1	Boyer T5	Palmerston	T3	Creek Road T1
Boyer	T13	Boyer T5	Palmerston	T4	Creek Road T1
Boyer	T14	Boyer T5	Queenstown	T1	Risdon Spare
Boyer	T2	Boyer T5	Queenstown	T2	Risdon Spare
Boyer	T7	None available	Queenstown	T3	Risdon Spare
Creek Road Substation	T2	Palmerston Spare	Queenstown	T4	Risdon Spare
Creek Road Substation	T3	Palmerston Spare	Que	T1	Creek Road T1
Creek Road Substation	T4	Palmerston Spare	Railton	T1	Creek Road T1
Chapel Street	T5	Palmerston Spare	Railton	T2	Creek Road T1
Chapel Street	T6	Palmerston Spare	Rosebery	T1	Devonport T3
Derwent Bridge	T1	Risdon Spare	Rosebery	T2	Devonport T3
Derby	T1A	Risdon Spare	Rosebery	T4	None available
Devonport	T1	Creek Road T1	Rosebery	T5	None available
Devonport	T2	Creek Road T1	Risdon	T1	Palmerston Spare

Devonport	T3	Creek Road T1	Risdon	T2	Palmerston Spare
Emu Bay	T2	Palmerston Spare	Risdon	T3	Palmerston Spare
Emu Bay	T3	Palmerston Spare	Risdon	T4	Palmerston Spare
Electrona	T1	Risdon Spare	Risdon	T5	Palmerston Spare
Electrona	T2	Risdon Spare	Risdon	T6	Palmerston Spare
Gordon	T6	None available	Rokeby	T1	Palmerston Spare
George Town	T4	Creek Road T1	Rokeby	T2	Palmerston Spare
George Town	T5	Creek Road T1	Scottsdale	T1	Palmerston Spare
Hadspen	T3	Creek Road T1	Scottsdale	T2	Palmerston Spare
Hadspen	T4	Creek Road T1	St Leonards	T1	Palmerston Spare
Huon River	T1	Risdon Spare	St Leonards	T2	Palmerston Spare
Kermandie	T1	Risdon Spare	St Marys	T1	Emu Bay
Kermandie	T2	Risdon Spare	St Marys	T2	Emu Bay
Kingston	T1	Palmerston Spare	Sorell	T1	Palmerston Spare
Kingston	T2	Palmerston Spare	Sorell	T2	Palmerston Spare
Kingston	T3	Palmerston Spare	Savage River	T2	Emu Bay
Kingston	T4	Palmerston Spare	Savage River	T3	Emu Bay
Knights Road	T1	Risdon Spare	Smithton	T1	Creek Road T1
Knights Road	T2	Risdon Spare	Smithton	T2	Creek Road T1
Lindisfarne	T2	Palmerston Spare	Triabunna	T1	Risdon Spare
Lindisfarne	T3	Palmerston Spare	Triabunna	T2	Risdon Spare
Meadowbank	T4	Risdon Spare	Trevallyn Substation	T1	Creek Road T1
Mornington	T1	Palmerston Spare	Trevallyn Substation	T2	Creek Road T1
Mornington	T2	Palmerston Spare	Trevallyn Substation	T3	Creek Road T1
Mowbray	T1	Creek Road T1	Tungatinah	T8	Risdon Spare
Mowbray	T2	Creek Road T1	Ulverstone	T1	Creek Road T1
North Hobart	T1	Palmerston Spare	Ulverstone	T2	Creek Road T1
North Hobart	T2	Palmerston Spare	Waddamana	T1	Emu Bay
New Norfolk	T1	Creek Road T1	Wesley Vale	T3	Risdon Spare

New Norfolk	T2	Creek Road T1	Wesley Vale	T4	Risdon Spare

The following table lists the units in the supply transformer population for which there is no designated spare available. The risk is managed by appropriate asset management practices.

Table 13: Supply transformers with no designated spare (as at August 2017)

Substation	Comment
Boyer T7	Voltage ratio (22/6.6). Only used on an ad-hoc basis as emergency supply point to Norske Skog. Normally de-energised.
Gordon T6	Voltage ratio (220/22). Recently refurbished including with new 220 kV bushings.
Rosebery T4 & T5	Voltage ratio (44/22).Lightly loaded assets with no indication of deteriorating condition.

14 Appendix D – Power Transformer Condition Assessment Criteria

The condition assessment of power transformers is based on an overall analysis of the electrical condition of the transformer along with any design peculiarities of the individual units. The physical external condition of the transformer is not specifically excluded from this assessment, but carries only little weight, as it has little impact on the satisfactory operation of the transformer, and most physical external issues can be overcome with minor remedial works.

Electrical condition assessment criteria

Assessment of the electrical condition is based primarily on the condition of the insulating oil. This practice is in line with that of other Transmission Network Service Providers (TNSPs) and is the approach recommended by SD Myers, a reputed organisation with over 40 years of experience in condition monitoring of transformers. The analysis of test data requires specialist knowledge, experience, and is, to some extent, subjective. For these reasons, a variety of different tests are performed on the insulating oil to ensure that analysis is not dependant on a single test result, but rather a collection of test results. The collective analysis approach provides a comprehensive and holistic view of the power transformer's condition. In addition to the insulating oil test results, electrical test results may be used to confirm the electrical condition.

The following criteria are used to assess the condition of insulating oil:

Acidity - measure of the amount of oxidation in the insulating oil. It provides an indication of the extent of deterioration of the insulating oil.

Dielectric dissipation factor (DDF) – measurement of the percentage of leakage current in the insulating oil. The presence of contaminants increases the leakage current.

Dielectric strength – measurement of the ability of the insulating oil to withstand electrical stress. The presence of contaminants, such as moisture, reduces the dielectric strength of the insulating oil.

Dissolved gas analysis (DGA– analysis of the gases that are produced during the service life of the transformer. The presence of key gases provides information about the condition of the transformer's insulation system.

Furans – measurement of the furanic compounds, in particular the 2 furfaldehyde (2FAL) compound, which indicates the extent of paper insulation degradation.

Interfacial tension (IFT) – measurement of the tension at the interface between the insulating oil and moisture that may be present. The presence of contaminants reduces the value of interfacial tension.

Oil quality index (OQI) – ratio of the interfacial tension and acidity value. It provides an overall indication of the condition of the insulating oil.

Moisture content – measurement of the amount of water in the insulating oil. The level of moisture in the insulating oil provides an indication of the extent of deterioration of the transformer insulation.

Insulating oil parameters and key gas concentration limits used to assess the condition of power transformers are shown in tables 16 to 19. It should be noted that the limits are provided as a general guideline only. As mentioned previously, accurate and reliable assessment of a power transformer's electrical condition requires the holistic analysis of all test data. Insulating oil test data is included in the following appendices. The rate of change of values is also an important consideration and should be considered as part of condition monitoring.

Table 14: Network transformer insulating oil condition limits

Parameter	Unit	Limits		
		Acceptable	**Marginal**	**Poor**
Acidity	mg KOH/g	< 0.1	0.1 – 0.15	> 0.15
DDF (at 25 �C)	-	< 0.07	0.07 - 0.15	> 0.15
Dielectric strength	kV	> 50	50 - 45	< 45
Furans - 2FAL	ppb	< 100	100 - 250	>250
Interfacial Tension	mN/m	> 35	35 - 25	< 25
Moisture	ppm	< 20	20 - 25	> 25
Oil Quality Index	-	> 1200	500 - 1200	< 500

Table 15: Network transformer insulating oil DGA limits

Parameter	Unit	Limits		
		Acceptable	**Marginal**	**Poor**
Acetylene, C_2H_2	ppm	< 35	35 - 50	> 50
Carbon monoxide, CO	ppm	< 300	300 - 1400	> 1400
Carbon Dioxide, CO2	ppm	< 5100	5100 - 13000	> 13000
Ethane, C_2H_6	ppm	< 65	65 -100	> 100
Ethylene, C_2H_4	ppm	< 50	50 -100	> 100
Hydrogen, H_2	ppm	< 100	100 - 700	> 700
Methane, CH_4	ppm	< 120	120 - 400	> 400
Total Combustible Gases	ppm	< 720	720 - 1900	> 1900

Table 16: Supply transformer insulating oil condition limits

Parameter	Unit	Limits		
		Acceptable	**Marginal**	**Poor**
Acidity	mg KOH/g	< 0.1	0.1 – 0.15	> 0.15
DDF (at 25 degC)	-	< 0.15	0.15 - 0.3	> 0.3
Dielectric strength	kV	> 40	40 - 35	< 35
Furans - 2FAL	ppb	< 100	100 - 250	>250
Interfacial Tension	mN/m	> 35	35 - 25	< 25
Moisture	ppm	< 30	30 - 35	> 35
Oil Quality Index	-	> 1200	500 - 1200	< 500

Table 17: Supply transformer insulating oil DGA limits

Parameter	Unit	Limits		
		Acceptable	Marginal	Poor
Acetylene, C_2H_2	ppm	< 10	10 - 50	> 50
Carbon monoxide, CO	ppm	< 350	350 - 1400	> 1400
Carbon Dioxide, CO2	ppm	< 5100	5100 - 13000	> 13000
Ethane, C_2H_6	ppm	< 65	65 -100	> 100
Ethylene, C_2H_4	ppm	< 50	50 -100	> 100
Hydrogen, H_2	ppm	< 100	100 - 700	> 700
Methane, CH_4	ppm	< 120	120 - 400	> 400
Total Combustible Gases	ppm	< 720	720 - 1900	> 1900

Where the limits in key gas concentration levels detailed in tables 17 and 19 have been exceeded, analysis of the key gas ratios can be used to diagnose the likely fault condition for a supply transformer. A ratio analysis based on IEC Publication 60599 'Interpretation of the analysis of gases in transformers and other oil-filled electrical equipment in service' has been performed for units that exceed the above key gas concentration limits. The outcome of the analysis is included in appendices F, G, H, I and J.

Table 18: Fault diagnosis using key gas ratio analysis

Suggested fault diagnosis	Key gas ratio		
	Ratio 1 Acetylene/Ethylene (C_2H_2/C_2H_4)	Ratio 2 Ethylene/Hydrogen (C_2H_4/H_2)	Ratio 3 Ethylene/Ethane (C_2H_4/C_2H_6)
Normal aging	< 0.1	> 0.1 and < 1.0	< 1.0
Partial discharge of low energy	< 0.1	< 0.1	< 1.0
Partial discharge of high energy	> 0.1 and < 3.0	< 0.1	< 1.0
Discharge of low energy	> 0.1	> 0.1 and < 1.0	> 1.0
Discharge of high energy	> 0.1 and < 3.0	> 0.1 and < 1.0	> 3.0
Thermal - low temperature < 150 °C	< 0.1	> 0.1 and < 1.0	> 1.0 and < 3.0
Thermal - low temperature 150 °C – 300 °C	< 0.1	> 1.0	< 1.0
Thermal - medium temperature 300°C – 700 °C	< 0.1	> 1.0	> 1.0 and < 3.0
Thermal - high temperature > 700 °C	< 0.1	> 1.0	> 3.0

Design consideration

Specific design aspects of the power transformers, and their associated accessories, can influence both asset and transmission system performance. For example, the absence of an OLTC on a supply transformer restricts the ability to meet customer expectations in terms of regulating voltage levels to appropriate and acceptable levels. The physical location of low voltage terminals may restrict the interchangeability of specific transformers, thus reducing the flexibility of the population. This document assesses the design of each power transformer make and its specific application, and identifies any issues that effect, or are likely to effect, asset and transmission system performance levels.

Insulating paper

The analysis of the degree of polymerization (DP) of the paper insulation is not a routine preventive test used to assess the health of a transformer in service because it is necessary to obtain a sample of the paper insulation, which at a minimum requires that the transformer be opened to gain access to the insulation paper and is never performed while a unit is in service. DP tests make a determination of the degradation of cellulose chains of the paper and extrapolate such results as the retention of the tensile strength of the paper and thus the remaining service life of the transformer paper insulation.

Furan derivatives are a measure of the degradation of cellulose paper. As a normal part of a power transformers operation it is exposed to insulation thermal degradation due to cyclical loading and high fault and short-circuit currents. Exposure to high temperatures and various mechanical stresses the transformer insulating paper ages, its degree of polymerization reduces, its mechanical strength decreases, and inevitably leads to transformer insulation failure. There is some collation between the degree of polymerization of the paper and the concentration of furan derivatives in the oil.

Furan derivatives are formed as a direct result of the breakdown of the polymeric structure of cellulose paper. The content of furan derivatives is relatively easy to measure in the oil, and is thus an alternative non-intrusive method of measuring the aging of the paper.

TasNetworks views DP analysis as a supplementary test method, to that of DGA analysis, for the assessment of power transformer health. Such tests will only be considered should the opportunity arise for a paper sample to be taken.

15 Appendix E – Power Transformer Condition Summary

Each of the power transformers in the population has been assessed against the criteria described in the following sections. The table below lists all of the transformers installed and gives a high level condition assessment of each transformer. The assessment has been based on key asset management considerations, including technical, design, reliability, condition, maintenance history and requirements, safety and environment issues.

It is important to recognise that it is mainly the electrical condition of the transformer that drives whether or not the unit is suitable for service. For the electrical condition assessment the terms poor, marginal and acceptable can be related to probability of failure under through fault conditions, where poor represents a high probability that the transformer would not survive such as event. Additionally, the presence of an active fault, as determined by DGA sampling or evidence of advanced deterioration of the insulation structures will also equate to a poor or marginal assessment.

When assessing the physical condition of the transformer factors such as corrosion and oil leaks were considered.

Other factors such as environment, safety and design relate more to the consequences of a failure, rather than the actual condition and have little impact on the overall assessment.

Whilst a transformer may not be in the best physical condition this is not necessarily the best indicator as to the serviceability of the transformer. It is also significantly easier to rectify physical as opposed to electrical condition issues.

The following table presents a summary of the condition assessment ranking for the power transformer population.

Table 20: Power transformer population condition (as at May 2017)

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
AL-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
AV-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
BU-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
BU-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
BU-T6	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable
BU-T7	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable
BW-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
BW-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
BY-T1	Poor	Marginal	Acceptable	Marginal	Marginal	Marginal	Marginal	Marginal	Poor
BY-T13	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Marginal	Acceptable
BY-T14	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Marginal	Acceptable
BY-T2	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Acceptable	Acceptable
BY-T-50718	Poor	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Marginal	Poor
BY-T7	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable
CR-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
CR-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable
CR-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable
CR-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable
CS-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
CS-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
CS-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
CS-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
CS-T5	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
CS-T6	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
DB-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
DE-T1A	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
DP-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
DP-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
DP-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
EB-T2	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
EB-T3	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
EB-T-50765	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
EL-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
EL-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
FA-T1	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
FA-T2	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
GO-T6	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
GT-T1	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
GT-T2	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
GT-T3	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
GT-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
GT-T5	Marginal	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
HA-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable
HA-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable
HA-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
HA-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable
HR-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KE-T1	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Marginal	Marginal
KE-T2	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Marginal	Marginal
KI-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KI-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KI-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KI-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KR-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
KR-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
LF-T2	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Marginal
LF-T3	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Marginal
LF-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
LF-T5	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
MB-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
MT-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
MT-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
MY-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
MY-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
NH-T1	Acceptable	Marginal	Marginal	Marginal	Marginal	Acceptable	Acceptable	Marginal	Acceptable
NH-T2	Acceptable	Marginal	Marginal	Marginal	Marginal	Acceptable	Acceptable	Marginal	Acceptable
NN-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
NN-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
NT-T1	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
NT-T2	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
NW-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
NW-T2	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Marginal	Marginal	Acceptable
PL-T1	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
PL-T2	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
PM-Spare1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
PM-T1	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable
PM-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
PM-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QT-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QT-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QT-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QT-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
QU-T1	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
RA-T1	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
RA-T2	Marginal	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
RB-T1	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Marginal	Marginal	Acceptable
RB-T2	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Marginal	Marginal	Acceptable
RB-T4	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable
RB-T5	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Marginal	Acceptable
RI-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
RI-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable
RI-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable
RI-T4	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RI-T5	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RI-T6	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RI-Tspare-25717	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RK-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RK-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SD-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SD-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SH-T1	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
SH-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SL-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SL-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SM-T1	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
SM-T2	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
SO-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SO-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
SR-T2	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Marginal	Marginal
SR-T3	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Marginal	Marginal
ST-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

Unit	Main Tank (electrical) Condition	Tap changer Condition	Bushings Condition	Physical Condition	Technical and Design	Performance	Maintenance	Safety and environment	Overall condition assessment
ST-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TB-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TB-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TR-T1	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TR-T2	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TR-T3	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
TU-T8	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
UL-T1	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
UL-T2	Acceptable	Acceptable	Acceptable	Acceptable	Marginal	Acceptable	Acceptable	Acceptable	Acceptable
WA-T1	Marginal	Acceptable	Acceptable	Marginal	Marginal	Acceptable	Marginal	Acceptable	Marginal
WV-T3	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Acceptable	Marginal	Acceptable
WV-T4	Acceptable	Acceptable	Acceptable	Marginal	Marginal	Marginal	Acceptable	Marginal	Acceptable

16 Appendix F – Condition Assessment – Network Transformers

ABB

Table 21: ABB network transformers are in service as follows:

Location	Year of manufacture	Nominal capacity(MVA)
Burnie T2	2010	150/200
George Town T2	2008	150/200
George Town T3	2008	150/200
Lindisfarne T4	2010	150/200
Lindisfarne T5	2010	150/200
Palmerston T1	1993	150/200

Figure 26: Network transformer T1 at Palmerston Substation

Condition

The ABB network transformers are in acceptable condition.

George Town T2 and T3 transformers OLTC transformer oil have been generating high levels of DGA gases and evident of large amount carbonisation in the OLTC. The tap changers were running in an average of 50 taps per 24 hours period working like ‘industrial transformer’. This could have resulted in large formation of carbonisation in oil. The AVR bandwidth has been increased to reduce the number of tap changer operations. The OLTC maintenance frequency also has been increased from six yearly to three yearly.

Design Consideration

There is no known design issues associated with ABB network transformers.

Future management strategy

Recommended condition monitoring and increased frequency of tap changer maintenance practices will be continued for these units.

ASEA

Table 22: ASEA network transformer is in service as follows:

Location	Year of manufacture	Nominal capacity(MVA)
Sheffield T1	1967	90/150

Figure 27: Network transformer T1 at Sheffield Substation

Condition

The ASEA network transformer is in an acceptable condition. The condition assessment report has identified that the unit:

- is in generally acceptable physical condition, due to refurbishments carried out in 1997 and painting of transformer in Feb 2017;
- has corrosion in some areas which have been rectified in Feb 2017; and
- is generally in acceptable electrical condition.

Design Consideration

Apart from Bell type design of tank, there is no known design issues associated with the ASEA network transformer.

Future management strategy

Given the present system conditions, this report expects that Sheffield T1 will be suitable for at least another ten years of service.

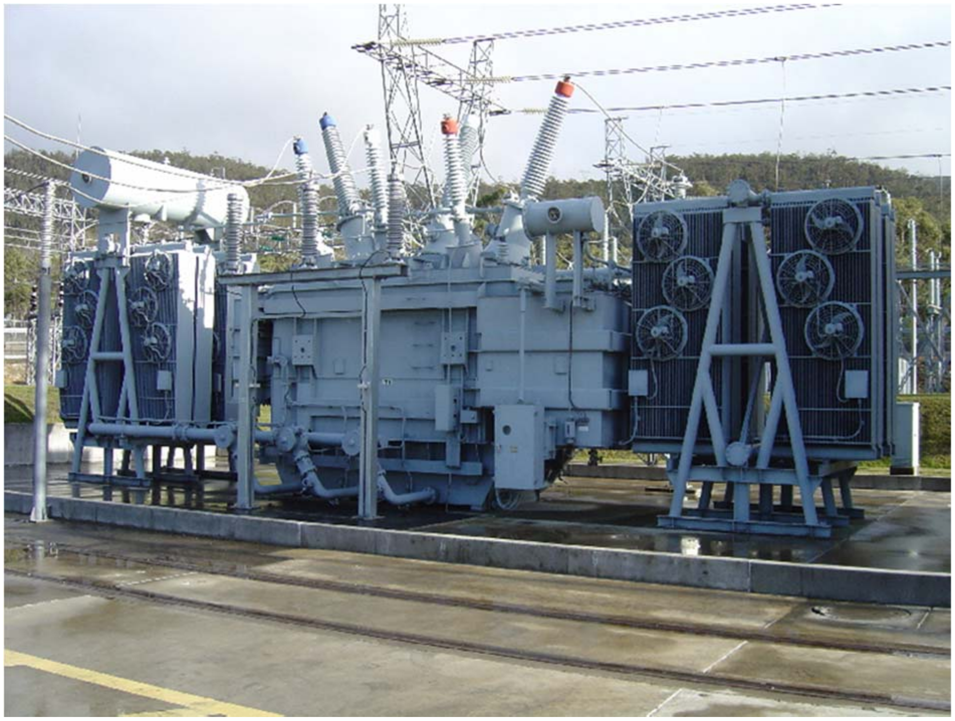
It is also recommended that insulating oil testing frequency to be increased.

Mitsubishi

Figure 28: Mitsubishi network transformers are in service as follows:

Location	Year of manufacture	Nominal capacity(MVA)
Chapel Street T1	1980	120/150/200
Farrell T1	1983	90/120/150
Farrell T2	1983	90/120/150

Figure 29: Network transformer T1 at Chapel Street Substation



Condition

The Mitsubishi network transformers are in acceptable condition.

The units in service at Farrell Substation:

- have degraded bushing gaskets;
- are in an acceptable physical condition; and
- are in an acceptable electrical condition.

Design Consideration

All three Mitsubishi units have Shell Form cores. There are no other major technical or design deficiencies with Mitsubishi network transformers except Farrell Substation units which have only one access point to access the internals of the transformer.

Future management strategy

No additional works are required for these three units.

Recommended condition monitoring and maintenance practices will be continued for these units.

Stromberg

Table 23: Stromberg network transformer is in service as follows:

Location	Year of manufacture	Nominal capacity(MVA)
Sheffield T2	1985	90/150

Figure 30: Network transformer T2 at Sheffield Substation

Condition

The Stromberg network transformer is in an acceptable condition.

Design Consideration

The transformer has Bell tank design. There are no other technical or design deficiencies evident with the Stromberg network transformer.

Future management strategy

Recommended condition monitoring and maintenance practices should be continued for this unit.

Wilson

Table 24: Wilson units are in service as follows:

Location	Year of manufacture	Nominal capacity(MVA)
Chapel T2	2005	150/200/260
Chapel T3	2005	150/200/260
Chapel T4	2005	150/200/260
George Town T1	2005	150/200/260
Hadspen T1	1998	150/200
Hadspen T2	1998	150/200

Figure 31: Network transformers T1 and T2 at Hadspen Substation

Condition

The Wilson network transformers are in acceptable condition.

Design Consideration

There are no known technical or design deficiencies with Wilson network transformers.

Future management strategy

Recommended condition monitoring and maintenance practices should be continued for all units.

17 Appendix G – Condition Assessment – Small Supply Transformers

BGE/EPM 5 MVA Unit

Table 25: BGE/EPM 5 MVA supply transformer is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Waddamana T1	1950	110/20	5	10725

Figure 32: BGE/EPM 5 MVA (old photo having gooseneck and SRBP bushings which have been replaced)

Condition

The condition assessment report has identified that Waddamana T1:

- is critical to the security of electricity supply to customers in the Waddamana area;
- has been in service for over 67 years;
- tap changer in the low voltage (22 kV) side;
- has inherent technical and design deficiencies that increases the transformer's susceptibility to failure if subjected to fault current or over-voltage conditions;
- is in poor physical condition; and
- is nearing end of life, and is expected to be suitable for service for up to five years.

Design Consideration

This family of transformers have a significant design deficiency, where the LV regulating leads are inadequately supported between the winding and the tap-changer. One of this family of transformers suffered an in-service failure when installed in Queenstown Substation and was repaired by the addition of extra insulation to these leads. A second unit of identical design, Derwent Bridge T1, failed in what was suspected to be a similar area.

Future management strategy

Waddamana T1 should be replaced by a suitable system unit that may become available from another replacement project and which could be suitable for re-use in a lightly loaded area. A potential is the St. Marys Substation T1 transformer. The replacement should occur within the next five to seven years.

The load on this transformer is such that a new unit of standard design is difficult to justify.

Lepper 10 MVA Units

Table 26: Lepper 10 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number

St Marys T1	1966	110-88/22	10	653720
St Marys T2	1966	110-88/22	10	653719

Figure 33: Lepper 10MVA (note that since this photo SM-T1 has received new RIP bushings)

Condition

The condition assessment report for St Marys T1 and T2 has identified the units are in acceptable physical and electrical condition.

Design Consideration

St Marys T1 and T2 have bolted lead cover on top of the tanks which are susceptible to leaks.

Future management strategy

St Marys Substation may be subjected to a capacity increase in this planning period. If the capacity increase is required, then St Marys T1 which has new 110 kV polymeric bushings including separate OLTC conservator and good electrical condition could be suitable to be relocated to Waddamana T1.

Tyree 10/15 MVA Units

Table 27: Tyree 10/15 MVA unit is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Boyer T7	1971	22/6.6	10/15	70567

Figure 34: Tyree 10/15 MVA

Condition

This unit is in an acceptable condition. The transformer oil contains PCB.

Design Consideration

The OLTC and main tank of this transformer share a common conservator. As such the use of DGA to evaluate the condition of the active part may not be accurate. There is also no self-resetting pressure relief device fitted to this transformer and has ‘gooseneck’ pressure vent which are susceptible to moisture ingress as well as limit to apply vacuum in the transformer if oil needs to be drained and filtered. This transformer is unique to the transmission system.

Future management strategy

This transformer is unique to the transmission system, but is specifically associated with an industrial customer. In this capacity it is only used under emergency conditions when other transformers at the substation are out of service. While this increases it relative importance, the lack of load on this transformer on a continuous basis, it is energised but unloaded, makes the probably of fault development or failure extremely unlikely. There is no requirement for an enhanced monitoring or maintenance regime for this transformer.

Tyree 10MVA Units

Table 28: Tyree 10 MVA units are in service as follows:

Location	**Year of manufacture**	**Voltage transformation**	**Nominal capacity(MVA)**	**Serial Number**
Kermandie T1	1961	110/22-11	10	17112
Kermandie T1	1961	110/22-11	10	15324

Figure 35: Tyree 10MVA

Condition

The condition assessment report has identified that both transformers:

- are critical to the security of electricity supply to customers in the Kermandie area;
- are in an acceptable physical condition with minor oil leaks;
- had a high moisture in oil content and online moisture removal system was connected for few months; and
- have oil results which indicate that the transformer paper insulation is in a good condition.

Design Consideration

The transformer has Bell type tank. The type of tap changer used in this design is known to share oil with the main tank. As a result of this oil sample taken for the purpose of DGA to evaluate the condition of the transformer are more difficult to interpret.

Kermandie T1 and T2 are slightly noisy units which could pose nuisance to neighbours.

Future management strategy

Due to age and deteriorating physical condition, it is recommended for the replacement with Type 1 standard transformer.

Tyree 6/10 MVA Units

Table 29: Tyree 6/10 MVA supply transformers are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Rosebery T4	1982	44/22	6/10	112342
Rosebery T5	1982	44/22	6/10	112343

Figure 36: Tyree 6/10 MVA

Condition

These units are in acceptable condition.

Design Consideration

These transformers are without a self-resetting pressure relief device and have ‘gooseneck’ pressure vents The ATL tapchanger which is used on these transformers is no longer supported as the manufacturer has been dissolved. As a result of this, the sourcing of spares and the maintenance of these tap changers have been difficult.

These transformers have voltage transformers for the metering purpose connected directly to the LV winding which is unique to the system.

Future management strategy

Routine maintenance and condition monitoring activities will continue for these units.

Wilson 10 MVA Unit

Table 30: Wilson 10 MVA supply transformer is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Gordon T6	1975	220/22	10	57104

Figure 37: Wilson 10 MVA (before and after bushing replacement)

Condition

The condition assessment report has identified that the transformer:

- is critical to the security of electricity supply to customers in the Strathgordon area and auxiliary power supply to Gordon Power Station;
- is overall in acceptable condition; and
- should continue to be fit for service for at least 20 years.

Design Consideration

This transformer is unique to the transmission system and performs an important function being the main supply of power to the Gordon Power Station and Strathgordon village.

There is currently no designated spare for this transformer.

Future management strategy

Recommended condition monitoring and maintenance practices should be continued.

ABB 6/10 MVA

Table 31: ABB 6/10 MVA supply transformers are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Derwent Bridge T1	2008	110/22-11	6 (potential for 17/25)	VN00255
Meadowbank T4	1997	110/22-11	10 (potential for 17/25)	140512

Condition

The ABB units are in acceptable condition.

Design Consideration

These transformers were purchased as a series of units with three ratings. The electrical design is suitable for an ONAF rating of up to 25 MVA. With a full complement of radiators (ONAN) the transformers are rated for 17 MVA. With only a single large radiator installed the Meadowbank transformers has been rated at 10 MVA and with two smaller radiators the Derwent Bridge transformer has been rated 6MVA.

There are no known design issues with these transformers.

Future management strategy

These transformers are all relatively new and directly interchangeable with the system spare transformer. As such there is no need for an elevated monitoring and maintenance regime.

18 Appendix H – Condition Assessment – Medium Transformers

ABB 17/25 MVA Units

Table 32: ABB 17/25 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Avoca T1	1997	110/22-11	17	140513
Electrona T2	1997	110/22-11	17/25	140511
Palmerston T3	1998	110/22-11	17/25	140522
Huon River T1	2007	110/22-11	17/25	VN00197
Electrona T1	2008	110/22-11	17/25	VN00254
Queenstown T4	2008	110/22-11	17/25	VN00315
Queenstown T3	2008	110/22-11	17/25	VN00316

Figure 38: 25/17 MVA Meadowbank Transformer MB-T4

Condition

The ABB units are in acceptable condition.

Design Consideration

In 1997-1998 four transformers were purchased as a series of units with three ratings. With one radiator no fans a transformer is rated to 10 MVA. With four sets of radiator no fans a transformer is rated to 17 MVA. With four sets of radiator and fans transformer is rated to 25 MVA. Avoca T1 originally purchased with one radiator (sister unit to MB T4) and in 2013 four new radiators were added to achieve 17 MVA rating.

In 2007-2008 five transformers were purchased from ABB, Vietnam. All five units are designed with an ONAF rating of up to 25 MVA. With a full complement of radiators the transformers are rated for 17 MVA. With two radiators installed the transformers are capable of 10 MVA. Derwent Bridge Substation T1 is fitted with two radiators with no fans and is rated to 6 MVA. Other four units are rated to 17/25 MVA.

There are no known design issues with these transformers.

Future management strategy

These transformers are all relatively new and directly interchangeable with the system spare transformer. As such there is no need for an elevated monitoring and maintenance regime.

ABB 20/30 MVA Units

Table 33: ABB 20/30 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Devonport T1	1996	110/22	20/30	140471
Devonport T2	1996	110/22	20/30	140464

Figure 39: ABB 20/30 MVA

Condition

Devonport T1 and T2 are in acceptable condition.

Design Consideration

These transformers are rebuilt Elin units (original made in 1956) and were replaced in 1996. The tanks of the original transformers were reused with new active parts supplied.

There are no known design issues with these transformers.

Future management strategy

Routine condition monitoring and maintenance will continue for these units.

AEI 15/22.5 MVA Units

Table 34: AEI 15/22.5 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Port Latta T1	1967	110/22	15/22.5	64101
Port Latta T2	1967	110/22	15/22.5	64098
Savage River T2	1967	110/22	15/22.5	64100
Savage River T3	1967	110/22	15/22.5	64097

Figure 40: AEI 15/22.5 MVA

Condition

All four transformers are in deteriorating condition with oil leaks from cable boxes, main tank lid and also have deteriorating transformer marshalling boxes.

Design Consideration

All the reports summarise that the units:

- are 50 years old;
- have no major inherent design deficiencies except the bolted tank lids;
- are in marginal physical condition (oil leaks);
- are in acceptable electrical condition; and
- are expected to be fit for service for at least 5 years.

Future management strategy

Due to age and deteriorating physical condition, it is recommended for the replacement with modified Type 1 standard transformer as the impedance of these transformers are lower compared to standard Type 1.

GEC 17/24 MVA Unit

Table 35: GEC 17/24 MVA unit is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Boyer T2	1987	110-88/6.6	17/24	31U3759/1

Condition

The transformer is fitted with new WTI and OTI with 4-20 mA output for the remote monitoring of transformer temperatures.

The insulating paper condition is degrading.

The unit is presently in acceptable condition.

Design Consideration

The high voltage winding on this transformer is re-connectable to 88 kV. The highest tapping voltage available on the HV side is 110 kV and there is not sufficient taps towards maximum tap to correct the secondary voltage.

There are no other known design issues with this transformer.

Future management strategy

Routine condition monitoring and maintenance practices will continue for this unit.

Pauwels 17/25 MVA Unit

Table 36: Pauwels 17/25 MVA unit is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Queenstown T2	2003	110/22-11	17/25	02P0029

Figure 41: Pauwels 17/25 MVA

Condition

This unit is in an acceptable condition.

Design Consideration

Modifications were made to the cable box on this transformer in 2005 to address an issue with moisture ingress into the chamber. At the same time a hot oil circulation was undertaken to reduce the moisture level in the transformer oil and paint work was touched up.

Future management strategy

It is currently in good condition and is directly replaceable by the system spare transformer. As such an increased monitoring and maintenance regime is not necessary.

Savigliano 15/22.5 MVA Units

Table 37: Savigliano 15/22.5 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Boyer T1	1968	110/6.6	15/22.5	59735
Boyer Spare (T5)	1968	110/6.6	15/22.5	59735

Figure 42: Savigliano 15/22.5 MVA

Condition

The condition assessment report has identified that:

- the units are critical to the security of electricity supply to the Norske Skog customer connected at Boyer Substation;
- the units have bolted main flanges which are susceptible to leaks;

- T1 fitted with new WTI and OTI with 4-20 mA output for the remote monitoring of transformer temperatures;
- T1 paper insulation is significantly degraded and nearing end-of-life;
- T1 has evidence of oil leaks;
- the units are 49 years of age.

For transformer T1, the insulating oil quality and DGA analysis has identified the windings to be nearing end-of-life.

These units are considered to be at the end of their economic lives.

Design Consideration

These transformers have a 6.6 kV secondary voltage which severely limits their usefulness at other locations within the system. The tapchanger used in these transformers has a history of leakage leading to cross-contamination with the main tank oil.

Future management strategy

These transformers form part of the supply to a major industrial customer, and as such are of increased importance.

TasNetworks is replacing Boyer T1 with a new modified Type 1 transformer in mid-2018 in adjacent location to spare T5 transformer. The existing in-service T1 will be retained at site for few years as a ‘cold spare’. TasNetworks is purchasing another new modified Type 1 which will be a suitable spare for Boyer Substation.

Stromberg 20/30 MVA Unit

Table 38: Stromberg 20/30 MVA unit is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Devonport T3	1983	110/44-22	20/30	580035

Figure 43: Stromberg 20/30 MVA

Condition

This unit is in an acceptable condition.

Design Consideration

The LV winding on this transformer is re-connectable at either 44 or 22 kV, as this unit was originally commissioned at Rosebery Substation.

The high voltage bushings on this transformer have a non-standard 650 kV BIL rated bushings instead of the standard 550 kV BIL.

This transformer is the designated system spare for the 44 kV connections at Rosebery Substation.

Future management strategy

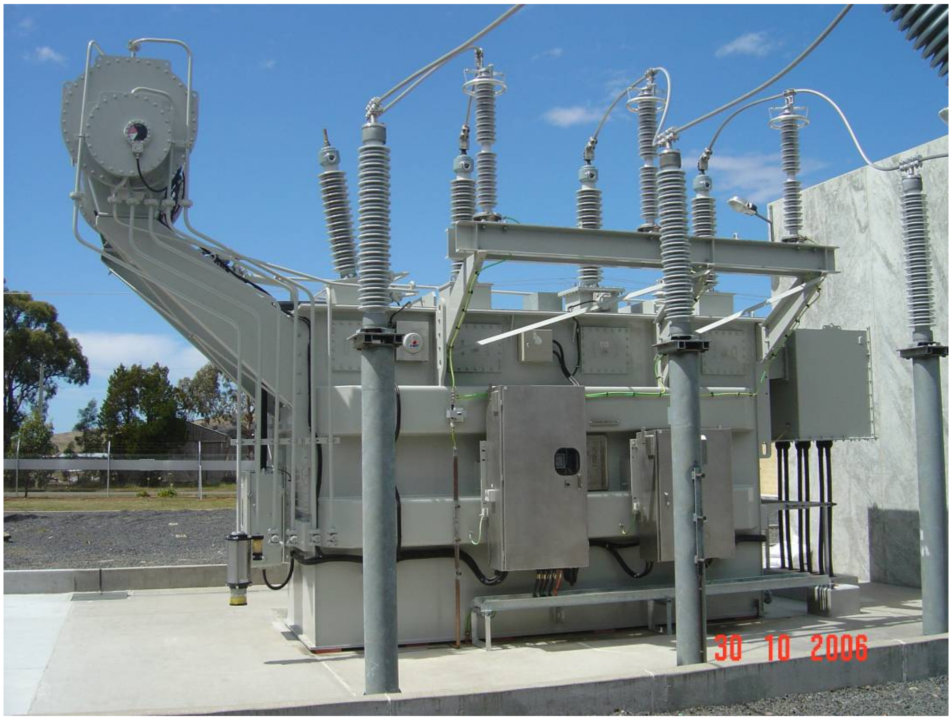
Routine condition monitoring and maintenance practices will continue for this unit.

Wilson 17/25 MVA Units

Table 39: Wilson 17/25 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Arthurs Lake T1	2012	110/11.43-6.6	17/25	P1113A
Derby T1A	2012	110/22-11	17/25	P0924B
Palmerston T4	2006	110/22-11	17/25	P0427A
Queenstown T1	2014	110/22-11	17/25	P0924C
Triabunna T1	2006	110/22	17/25	P0927B
Triabunna T2	2006	110/22	17/25	P0427C
Tungatinah T8	2010	110/22-11	17/25	P0924A

Figure 44: Wilson 17/25 MVA



Condition

These transformers were purchased as Type 1 standard transformers. There are no known issues with these transformers.

Design Consideration

There are no known design issues with these units.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

Wilson 15/25 MVA Units

Table 40: Wilson 15/25 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Wesley Vale T3	1970	110/22-11	15/25	50378
Wesley Vale T4	1970	110/22-11	15/25	50381

Condition

The condition assessment report has identified that these transformers:

- are in an acceptable condition;
- have their insulating paper in good condition;
- are fitted with LV cable boxes that may be limited to 11 kV;
- transformer oil is PCB contaminated; and
- should continue to be fit for service for at least 15 years.

Design Consideration

Originally these units were rated to 15/22.5 MVA with new radiators added and increase the ONAF rating to 25 MVA. These are the sister units to currently in-service Newton T1 and T2 transformers.

During the LV cable box conversion from oil to air filled in 2005, the spacing between phases was not increased.

These units will be fitted with new air insulated cable box suitable to be operated at 22 kV. The transformers will be converted to 110/22 kV in early 2018 as part of the Wesley Vale Substation 11 kV to 22 kV conversion project as a part of the new 22 kV injection point.

Future management strategy

The substation will be upgraded to 22 kV in early 2018 and the following actions will be conducted:

- modify the cable box to confirm operation at 22 kV; and
- installation of new digital temperature devices and routine condition monitoring and maintenance practices will continue for these units.

Wilson 15/22.5 MVA Unit

Table 41: Wilson 15/22.5 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Newton T1	1970	110/22-11	15/22.5	50380
Newton T2	1970	110/22-11	15	50379

Figure 45: Wilson 22.5/15 MVA

Condition

These transformers were in service at Sorell Substation till 2011 and were removed and underwent minor refurbishment in 2012 that included new air insulated cable box, new WTI and OTI and painting of transformers.

Currently Newton T1 is operating as 110/22 kV and Newton T2 as 110/11 kV. NT-T2 cooling fans have been disconnected and it is rated as 15 MVA ONAN only.

These units are in acceptable condition.

Design Consideration

Except bolted lid which are prone to leaks, there are no other significant design considerations for these units.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

Wilson 12/20 MVA Units

Table 42: Wilson 12/20 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Knights Road T1	1987	110/22-11	12/20	83142
Knights Road T2	1987	110/22-11	12/20	83143

Figure 46: Wilson 12/20 MVA

Condition

The transformers are fitted with new WTIs and OTIs with 4-20 mA output for the remote monitoring of transformer temperatures. These units are in an acceptable condition.

Design Consideration

Except bolted lid which are prone to leaks, there are no other significant design considerations for these units.

Future management strategy

Routine condition monitoring and maintenance practices will continue for this unit.

19 Appendix I – Condition Assessment – Large Transformers

ABB 42/60 MVA Units

Table 43: ABB 42/60 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Kingston T3	2011	110/33	42/60	510024
Kingston T4	2011	110/33	42/60	510025
Mornington T1	2010	110/33	42/60	509017
Mornington T2	2010	110/33	42/60	509018

Figure 47: ABB 42/60 MVA

Condition

These units are in an acceptable condition.

Design Consideration

There are no known design issues with these transformers.

Future management strategy

Routine condition monitoring practices will continue for these units.

ABB 30/50 MVA Units

Table 44: ABB 30/50 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Mowbray T1	2008	110/22	30/50	507054
Norwood T1	1995	110/33-22-11	30/50	140440
Risdon T4	2000	110/33-22-11	30/50	140578
Risdon T5	1995	110/33-22-11	30/50	140441

Figure 48: ABB 30/50 MVA

Condition

These transformers are in acceptable condition age.

Design Consideration

There are no known technical or design deficiencies with these supply transformers.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

ABB 20/36 MVA Units

Table 45: ABB (Tyree) 20/36 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Rosebery T1	1969	110/44-22	20//30/36	65512
Rosebery T2	1969 (1994 full factory refurb)	110/44-22	20/30/36	65511

Figure 49: ABB (Tyree) 20/36 MVA RB-T1

Figure 50: ABB (Tyree) 20/36 MVA RB-T2

Condition

In 2000, transformer T1 underwent mid-life refurbishment. This included installation of new radiators, bushings and LV conductor terminations, as well as replacement of transformer oil.

In 1994 transformer T2 underwent a full refurbishment in the ABB factory, including winding and insulating oil replacement, core and coil assembly redesigned and replaced and radiators cooling system replacement. As such, transformer T2 is considered to be manufactured in 1994, reducing the age of the transformer to 23 years old. The tank of the transformer however was not changed.

Transformers:

- Are 48 years old
- have persistent oil leaks; and
- have inherent design deficiencies i.e. bolted lids.

Design Consideration

Transformers originally design for 20/30 MVA rating without any fans. Four fans on each transformer were added to achieve the continuous rating of 36 MVA each. New WTIs/OTIs with 4-20 mA output replaced old temperature devices. The transformer and ambient temperatures are mapped to NOCS which in future could be used for dynamic rating as well as loss of life calculation of the paper insulation.

Future management strategy

Devonport T3 which was previously in-service at Rosebery Substation is the dedicated spare that could be deployed in case of contingency. Depending upon the load demand in future at Rosebery Substation these transformers could be replaced with the larger rating transformer.

RB-T1 and RB-T2 are actively being reviewed for replacement in the 2019-24 regulatory period due to operational limitations in their current location. It has been identified that they could be relocated to another substation to maximise their useful service life. Savage River Substation would be a priority location as the replacement of the supply transformers at that site have been targeted for condition based replacement. There is an additional benefit as there is potential load increase at this location which would exceed the rating of the existing units but relocated Rosebery RB-T1 and RB-T2 would suit well.

Routine condition monitoring and maintenance practices will continue for these units.

Alstom 30/50 MVA Units

Table 46: Alstom 30/50 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
George Town T4	2000	110/22	30/50	31N4055/01
Trevallyn T1	1998	110/22	30/50	31K3986/1
Trevallyn T2	1998	110/22	30/50	31K3986/2
Trevallyn T3	1998	110/22	30/50	31K3986/3

Condition

There were moisture ingress issues in Trevallyn T1 and T2 air insulated cable boxes which lead to the PD on the cable termination. Suitable air vents were added on Trevallyn units to rectify the moisture ingress. These units are in an acceptable condition.

Design Consideration

There are no known design deficiencies with these transformers.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

Alstom 30/60 MVA Units

Table 47: Alstom 30/60 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Creek Road T2	2001	110/33	30/60	31R4083/2
Creek Road T3	2001	110/33-22	30/60	31R4082/1
Creek Road T4	2001	110/33	30/60	31R4083/1

Figure 51: Alstom 30/60 MVA

Condition

There was moisture ingress issues in an air insulated cable boxes of all three units which lead to flashover on the cable termination resulting in forced outages. Wooden supports between phases within the cable box were soaking with moisture. Wooden supports were removed and suitable air vents were added to rectify the moisture ingress issues.

These supply transformers are in an acceptable condition.

Design Consideration

There are no known design issues with these transformers.

Future management strategy

These transformers are performing as expected. Routine condition monitoring and maintenance practices will continue for these units.

GEC 21/35 MVA Units

Table 48: GEC 21/35 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Bridgewater T1	1980	110/22-11	21/35	A31L3114/2
Bridgewater T2	1980	110/22-11	21/35	A31L3114/1
Kingston T1	1980	110/22-11	21/35	A31K3026/1
Kingston T2	1980	110/22-11	21/35	A31K3026/2
Rokeby T1	1982	110/22-11	21/35	A31L3115/1
Rokeby T2	1982	110/22-11	21/35	A31L3115/2

Figure 52: GEC 21/35MVA

Condition

Bridgewater T1 had a significant leak between the tapchanger and main tank barrier board causing overflow of the OLTC conservator which was rectified in 2012 by replacing the bolt-on tap changer.

Rokeby T2 has minor oil leaks between the tapchanger and main tank however leak does not appear to have impact on the OLTC conservator level.

All other units are presently in acceptable condition.

Design Consideration

Apart from the bolted lids on the tank there are no significant design issues with these units.

Future management strategy

Rokeby T2 OLTC conservator level will be monitored for any change.

All units will undergo routine monitoring and maintenance regimes.

Pauwels 30/50 MVA Units

Table 49: Pauwels 30/50 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
George Town T5	2003	110/22	30/50	02P0028
Hadspen T3	2005	110/22	30/50	05P0003
Hadspen T4	2005	110/22	30/50	05P0002
Mowbray T2	2004	110/22	30/50	04P0035

Figure 53: Pauwels 30/50 MVA

Condition

Major work was carried out on the cable boxes of both the George Town and Mowbray units due to design deficiencies allowing moisture inside the cable box. Repairs were carried out on the George Town transformer following a cable box explosion.

Hadspen T4 failed under short circuit conditions in service in August 2006 and was returned to the manufacturer and reinstalled in 2007. Hadspen T4 had two cable termination failures towards transformer end in early 2017 and was due to PD which might have resulted due to poor workmanship on cable terminations. Due to the fault one of the 22 kV bushing is leaking.

George Town T5 has had elevated dissolved gas levels for some time. TasNetworks has installed an online dissolved gas analysis monitor to ensure that any sudden change in the internal condition of the transformer is captured. T5 was internally inspected in Feb 2017 to see any evident of internal heating which could have elevated Ethane and Ethylene however no obvious heating or discolouration on the tap changer leads or 22 kV bushing connections were seen.

These units are in acceptable condition.

Design Consideration

The design of these transformers locates the cable box on the opposite end of the transformer with respect to the arrangement of the ‘Type 4’ system spare transformer. This has implications for the turnaround time should one of these transformers need to be replaced as extensive modifications are required to bring the LV phasing back to the correct orientation.

Future management strategy

Hadspen T4 transformer power cables as well as one leaking bushing are targeted to be replaced.

Routine condition monitoring and maintenance practices will continue for these units.

Stromberg 18.9/31.5 MVA Units

Table 50: Stromberg 18.9/31.5 MVA unis are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
New Norfolk T1	1987	110/22-11	18.9/31.5	5800407
New Norfolk T2	1987	110/22-11	18.9/31.5	5800406

Figure 54: Stromberg 18.9/31.5 MVA

Condition

The insulation oil test indicates that these units are in acceptable condition.

Design Consideration

Apart from Bell type design of tank, there is no known design issues with these transformers.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

Stromberg 36/60 MVA Units

Table 51: Stromberg 36/60 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Chapel Street T5	1983	110/11-11	36/60	5800077
Chapel Street T6	1983	110/11-11	36/60	5800078

Figure 55: Stromberg 36/60 MVA

Condition

These units are in acceptable condition.

Design Consideration

These transformers have dual secondary windings. Apart from the Bell tank design there are no known other issues associated with the Stromberg 60 MVA units.

Future management strategy

Due to the unique nature of these transformers (dual secondary windings) there is a project to purchase a designated spare transformer which will be delivered by the end of June 2018.

Routine condition monitoring practices will continue for these units.

Stromberg 19/31.5 MVA Units

Table 52: Stromberg 31.5/19 MVA units are in service as follows:

Location	Year of manufacture	Voltage	Nominal	Serial Number

		transformation	capacity(MVA)	
Scottsdale T1	1983	110-88/22	19/31.5	5800153
Scottsdale T1	1983	110-88/22	19/31.5	5800152

Figure 56: Stromberg 19/31.5 MVA (old photo showing previous outdoor 22kV bushings)

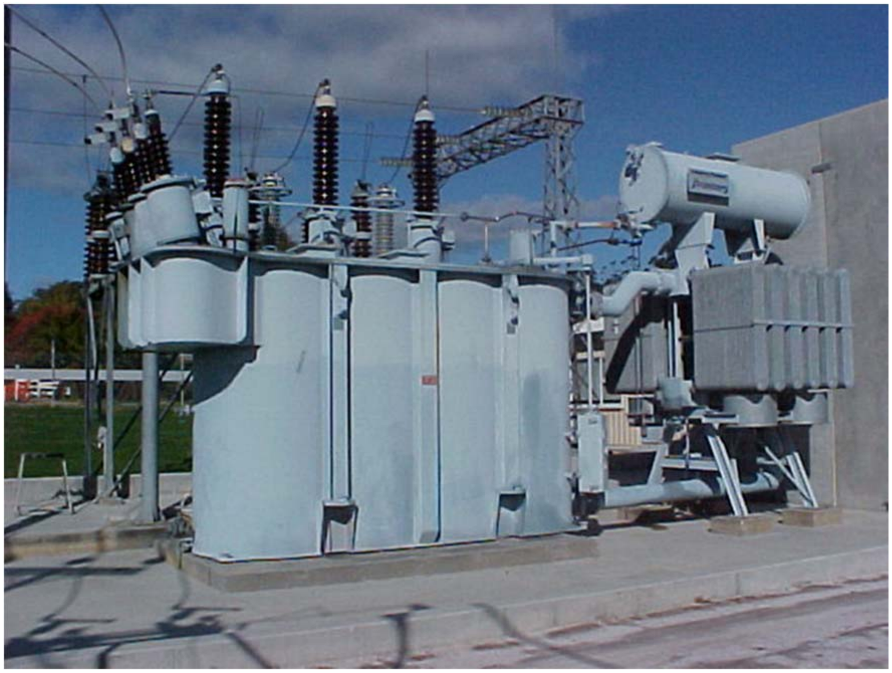


Figure 57: Stromberg 19/31.5 MVA (with new cable box)

Condition

Transformers are in an acceptable condition.

Design Consideration

There are no significant design issues with these transformers. The vertical lid mounted outdoor connected 22 kV bushings were replaced with an air insulated cable box when the 22 kV switchgear was replaced.

Future management strategy

Routine condition monitoring and maintenance practices will continue for these units.

Tyree 30/45 MVA Units

Table 53: Tyree 30/45MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Lindisfarne T2	1964	110/33	30/45	18651
Lindisfarne T3	1964	110/33	30/45	18652
Ulverstone T2	1983	110/22	30/45	70992

Figure 58: Tyree 30/45 MVA

Condition

The condition assessment report for Lindisfarne T2 and T3 has identified that both transformers are in a declining electrical and physical condition and are likely to be fit for service for up to 5 years.

The Ulverstone T2 unit 110 kV bushings were replaced with new polymeric housing bushings and transformer is in an acceptable condition.

Design Consideration

Lindisfarne T2 and T3 transformers have Bell tank type design. The transformers have highest tapping voltage of 110 kV hence there are insufficient taps to reduce the voltage on the secondary side to the nominal 33 kV, when their primary side is higher than 110 kV. No significant design issues with Ulverstone T2 transformer.

Future management strategy

There is an approved business case to have the Lindisfarne units replaced by 2019.

Ulverstone T2 has no requirement for an increased monitoring and maintenance regime.

Tyree 30/50 MVA Units

Table 54: Tyree 30/50 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Norwood T2	1979	110/22-11	30/50	70856
Que T1	1979	110/22-11	30/50	70855
Railton T1	1982	110/22	30/50	70990
Railton T2	1982	110/22	30/50	70991

Figure 59: Tyree 30/50MVA (old photo with SRBP bushings)

Condition

These units are in acceptable condition.

Design Consideration

Norwood T2 and Que T1 are fitted detached radiators and lid mounted LV terminals. All of these factors influence maintenance practises and limit the interchangeability of these units.

The mixing of the oil between the conservator and the main tank is a concern as this makes analysis of DGA results more complicated. The LV bushings are mounted on top of the tank and not enclosed by a cable box.

New fans were installed on QU-T1 in 2016.

Future management strategy

Routine condition monitoring and maintenance practices will be continued.

Tyree 30/60 MVA Units

Table 55: Tyree 30/60 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Burnie T6	1970	110/22-11	30/60	70058
Burnie T7	1970	110/22-11	30/60	70059

Figure 60: Tyree 30/60 MVA (old photo insert new photo)

Condition

The condition assessment report for T6 and T7 has highlighted that these units are presently in acceptable condition.

Burnie transformers T6 and T7 underwent a significant refurbishment in 2000 which removed the vast majority of design and condition issues associated with these units.

New fans were installed on separate stands. New WTI/OTs installed and fan control circuits have been upgraded.

These units are expected to be fit for service for another 7 years for T6 and 12 years for T7 according to CBRM results.

Design Consideration

These units have inherent design deficiencies and are subject to cross contamination of the transformer main tank and tap changer, resulting in key dissolved gas analysis results being masked. The transformers have Bell tank type design.

Future management strategy

Routine condition monitoring practices will be continued.

Wilson 20/40 MVA Units

Table 56: Wilson 20/40 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Emu Bay T2	1973	110/22-11	20/40	54605
Emu Bay T3	1973	110/22-11	20/40	54604

Figure 61: Wilson 40/20 MVA

Condition

The insulating oil test results indicate that these units are in acceptable condition.

Design Consideration

Apart from the Bell tank type there are no other known issues with the design of these transformers.

Future management strategy

The transformers have reconnectable secondaries and currently connected to 11 kV. However these transformers in future are being considered to be converted to 110/22 kV connection.

These transformers are performing as expected. Routine condition monitoring and maintenance practices will be continued.

Wilson 30/45 MVA Units

Table 57: Wilson 30/45 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
North Hobart T1	1976	110/11-11	30/45	58887
North Hobart T2	1976	110/11-11	30/45	58888
Ulverstone T1	1975	110/22-11	30/45	57172

Figure 62: Wilson 30/45 MVA

Condition

North Hobart T1 and T2 units supply the Hobart CBD and are critical to the supply network. Whilst they are in acceptable condition, TasNetworks has installed online dissolved gas analysis monitors to ensure that any sudden change in the internal condition of the transformer is captured.

In late 2016, 'blue' phase 110 kV bushing on T2 was replaced with a spare bushing as high test tap to earth resistance and complete corroded test tap was found as this was concerning instead of being shorted.

The pump and fan control system consists of aged technology.

Transformers have oil leaks from the HV bushing turret and LV bushing gaskets.

Design Consideration

NH T1 and T2 tapchanger utilises a filtering cloth (felt casing) between the diverter-switch and the main tank and this material can allow oil to pass between the tapchanger diverter switch and the main tank. The direct result of this is contamination of the main tank oil with tapchanger arcing products. These products distort the DGA analysis of the main tank oil and make accurate assessment of the condition of the active part more complicated.

NH T1 and T2 and Ulverstone T1 all have a bolted tank lids which are prone to leaks. NH T1 and T2 bushings are in horizontal orientations which are unique to the system.

Due to the unique nature of these transformers and the North Hobart Substation load importance, a designated spare transformer will be delivered to TasNetworks in June 2018.

Future management strategy

NH T1 and T2 110 kV transformer bushings will be replaced with polymeric housing RIP bushings including the upgradation of fan and pump control and minor leak repairs early 2018.

Routine condition monitoring, as well as the ongoing use of online monitoring, and regular maintenance activities will continue for these units.

Wilson 21/35 MVA Units

Table 58: Wilson 21/35 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Smithton T1	2003	110/22	21/35	P0227A
Smithton T2	2003	110/22	21/35	P0227B

Figure 63: Wilson 21/35 MVA

Condition

The insulating oil test results indicate that these units are in acceptable condition.

The LV bushings were leaking as the power cables were directly pulling and stressing the bushings. The air insulated cable box was modified on both units by inserting flexible connections between the bushings and the cable termination and also suitable stand-off insulators were added to support the cable termination. Air vents were also installed in the cable box to minimise the moisture ingress.

Design Consideration

There are no known design issues with these transformers.

Future management strategy

Routine condition monitoring and maintenance practices will be continued.

Wilson 30/50 MVA Unit

Table 59: Wilson 30/50 MVA unit is in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number

Risdon T6	2005	110/33	30/50	P0407A
Palmerston Spare	2005	110/33-22-11	30/50	P0408A

Figure 64: Wilson 30/50 MVA

Condition

These transformers are in acceptable condition.

Design Consideration

The Palmerston spare unit is the strategic system spare transformer and is reconnectable at either 11 kV, 22 kV or 33 kV. This spare was installed briefly at Hadspen T4 location in 2005-2006 when in-service T4 failed and was sent to OEM for the repair.

There are no other design issues with these units.

Future management strategy

Routine condition monitoring and maintenance practices will be continued.

Wilson 36/60 MVA Unit

Table 60: Wilson 36/60 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
St Leonards T1	2012	110/22	36/60	P0934C
St Leonards T2	2012	110/22	36/60	P0934D
Sorell T1	2010	110/22	36/60	P0934B
Sorell T2	2010	110/22	36/60	P0934A

Figure 65: Wilson 36/60 MVA

Condition

These units are in an acceptable condition.

Design Consideration

There are no known design issues with these transformers. They are manufactured as per the current Type 2 standard transformer.

Future management strategy

Routine condition monitoring and maintenance practices will be continued.

20 Appendix J – Condition Assessment – Extra-large Transformers

Alstom 65/90 MVA Units

Table 61: Alstom 65/90 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Risdon T1	2001	110/11-11	65/90	31P4057/02
Risdon T2	2001	110/11-11	65/90	31P4057/03
Risdon T3	2001	110/11-11	65/90	31P4057/01

Figure 66: Alstom 65/90 MVA

Condition

The insulating oil test results indicate that the units are in acceptable condition.

These units are connected to a major industrial customer and are required to perform greater numbers of tap operations.

Design Consideration

These transformers have a double secondary winding arrangement. There are no known design issues associated with these transformers. At this time there is no direct replacement for this transformer should a replacement be required however a suitable spare has been purchased which will be available by June 2018.

Future management strategy

These units require increased tap changer maintenance. Tap changer maintenance is required every three years on these units due to greater number of operations.

Oil sampling will continue as routine.

Tyree 31.5/63 MVA Units

Table 62: Tyree 31.5/63 MVA units are in service as follows:

Location	Year of manufacture	Voltage transformation	Nominal capacity(MVA)	Serial Number
Boyer T13	1988	110/6.6-6.6	31.5/63	140192
Boyer T14	1988	110/6.6-6.6	31.5/63	140193

Figure 67: Tyree 31.5/63 MVA

Condition

The condition assessment report of Boyer T13 and T14 identifies that these units are in acceptable condition. There is a slight elevated Ethylene which indicates heating at higher temperatures however both units are showing similar trends which could be related due to design. However due to their high duty factor, they are ageing faster than any other units in the system.

There are minor oil leaks on T13 transformer.

TasNetworks has installed online dissolved gas analysis monitors to ensure that any sudden change in the internal condition of the transformer is captured.

Design Consideration

These transformers have a double secondary winding arrangement, and its unusual secondary voltage makes them unique in the system. At this time there is no direct replacement for this transformer should a replacement be required however a suitable spare has been purchased which will be available by June 2018.

The type of tank used for these transformers is known as a bell type tank.

Future management strategy

Routine condition monitoring, as well as the ongoing use of online monitoring, and regular maintenance activities will continue for these units.