Asset Management Plan

EHV Voltage Transformer (Including CVCT)

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Authorisations

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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 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.*
Multiple sections	Addition of CVCT assets

Table of Contents

1 Purpose

The purpose of this asset management plan is to define the management strategy relating specifically to EHV voltage transformers (VT) and combined voltage and current transformers (CVCT). 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 extra high voltage (EHV) post-type voltage transformers and combine voltage current 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.

TasNetworks existing population of extra high voltage post-type covers 110 kV and 220 kV VTs, CVCTs and coupling capacitors

3 Strategic Alignment and Objectives

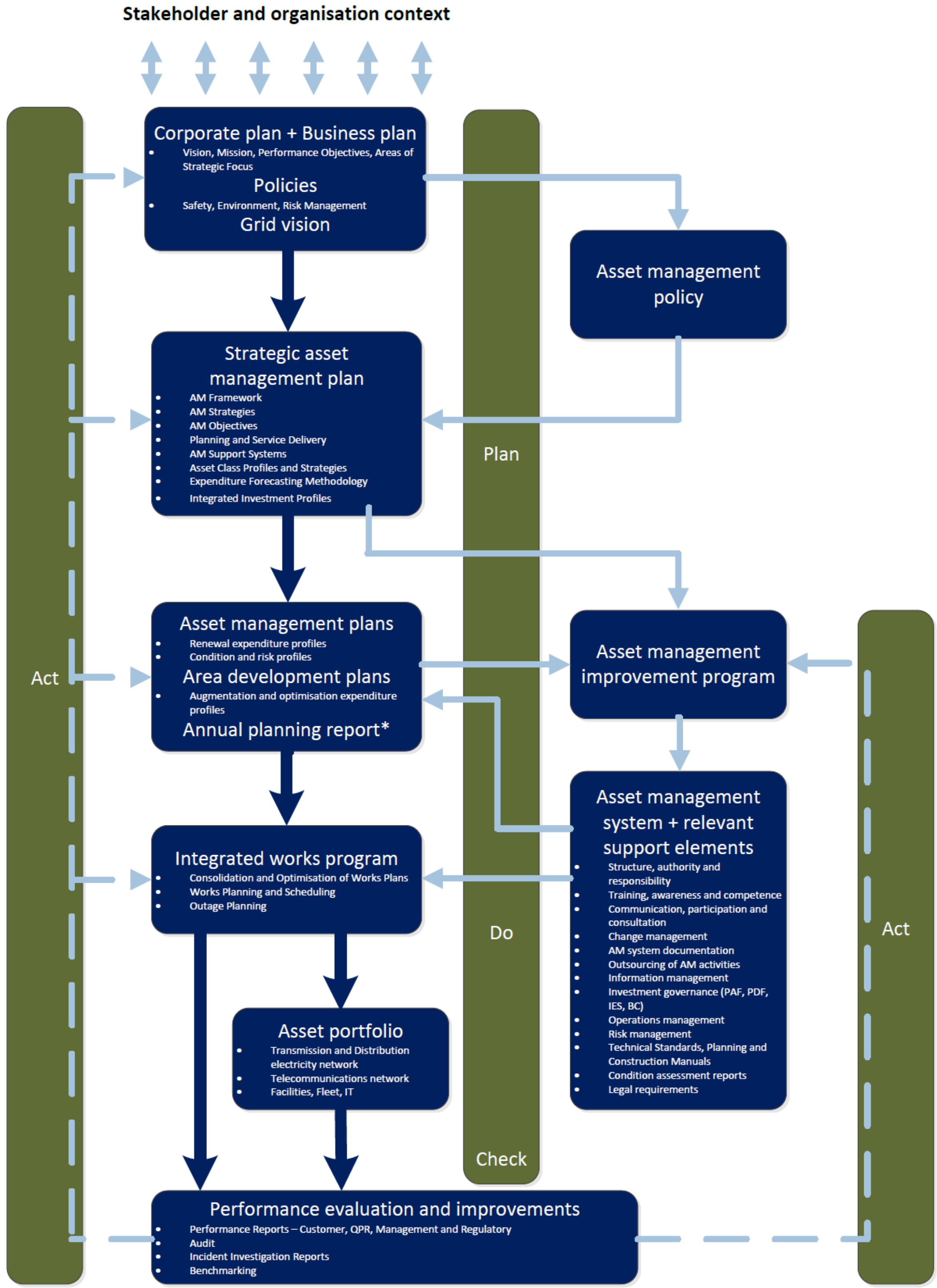
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives. This management plan describes the asset management strategies and programs developed to manage the circuit breaker assets, with the aim of achieving these objectives.

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 voltage 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.

It 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 in future may 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.

4.1.1 Asset Information

The following AMIS standards provide additional information relevant to circuit breakers:

R0000017100 WASP Asset Register – Data Integrity Standard – Voltage Transformer;

R0000017028 WASP Asset Register – Data Integrity Standard – Voltage Transformer Phase

R0000016967 WASP Asset Register – Data Integrity Standard – Combined Voltage Current Transformer; and

R0000016943 WASP Asset Register – Data Integrity Standard – Combined Voltage Current Transformer Phase

4.1.2 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.

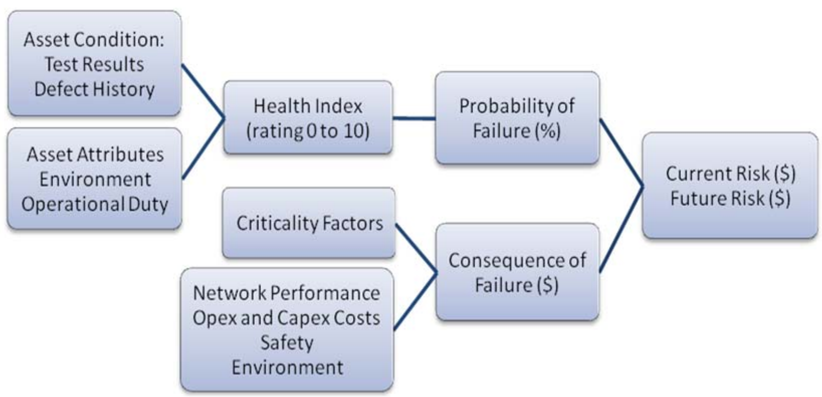
A number of observations were concluded as part of the review including the need to obtain condition data consistently across all asset types and in electronic form. The need for storage and collection would align with other business initiatives such as the AJILIS project.

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.

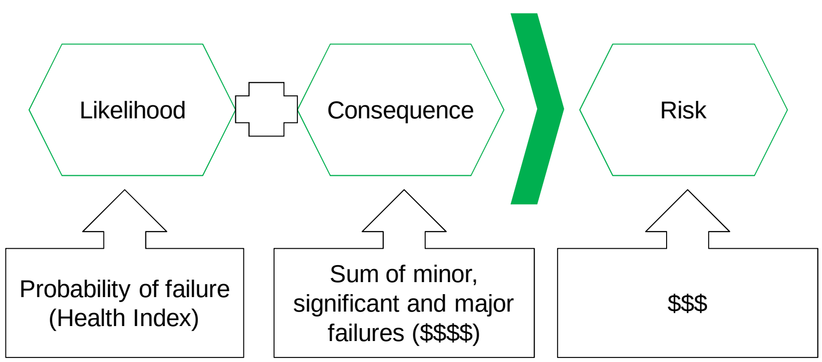
Figure 2: Asset risk framework



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

Figure 3 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).

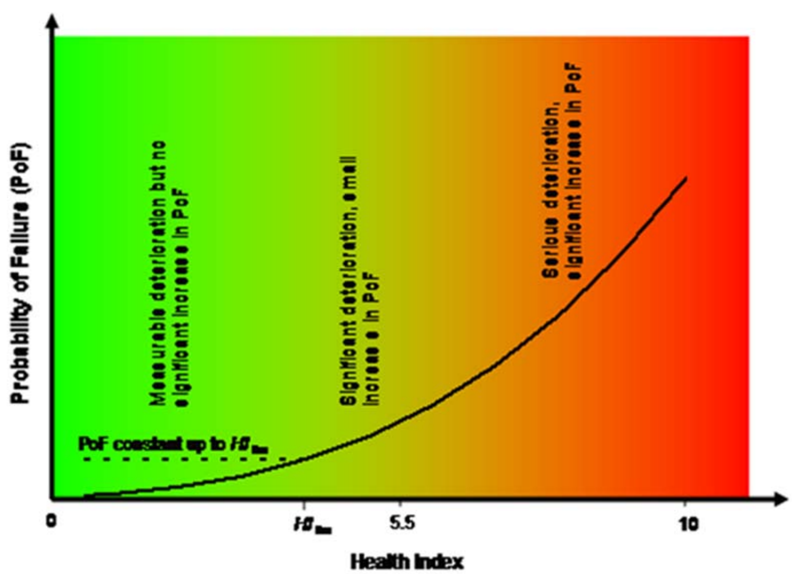
Figure 4: Health index interpretation

Condition	Health Index	Remnant Life	Probability of Failure
Bad	10	At EOL (<5 years)	High
Poor		5 - 10 years	Medium
Fair		10 - 20 years	Low
Good	0	>20 years	Very low

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.

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.

At present only power transformers have been integrated fully into the CBRM tool. Several other asset classes have been partially setup. It is expected that EHV VTs may be added into the CBRM tool in the near future.

5 Description of the Assets

5.1 General - VTs

Voltage transformers perform a critical function in the reliable operation of the transmission system, transforming extra high voltages to a suitable voltage level for protection and metering functions.

TasNetworks has in service 659 EHV free-standing VTs, 205 at 220 kV and 454 at 110 kV. In addition, there are six coupling capacitors operating at 110 kV and two at 220 kV. TasNetworks' VTs can be categorised based on the insulating medium adopted. The categories include:

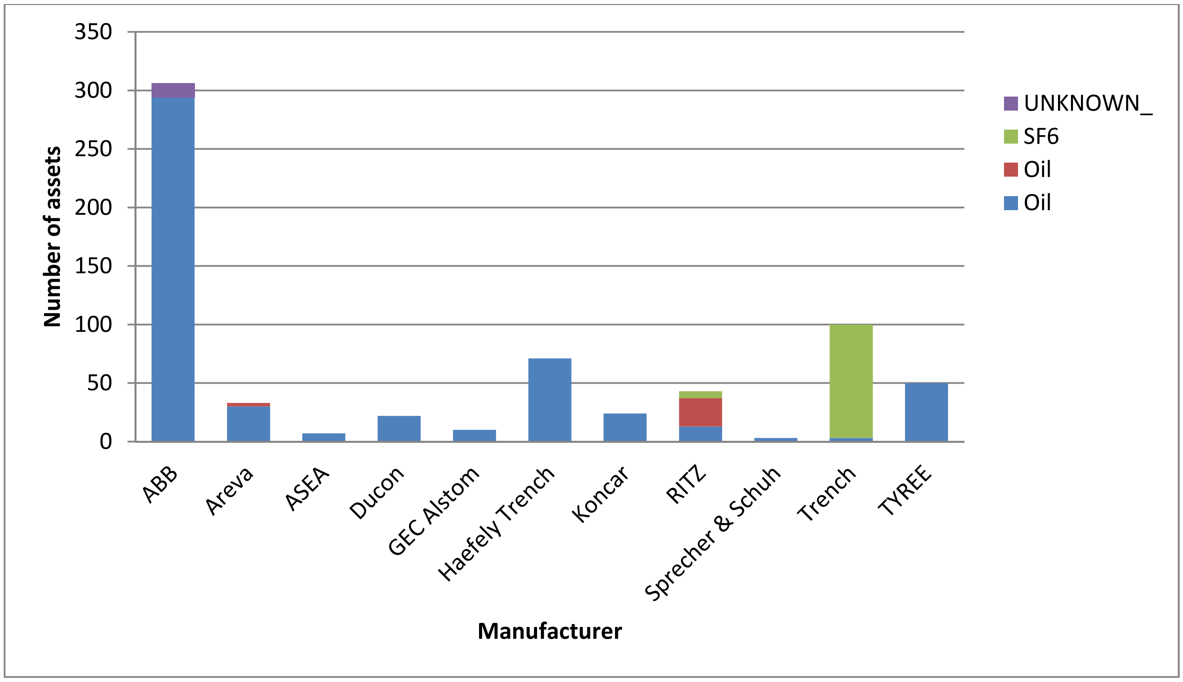
- Oil-filled VTs (526units); and
- SF6 gas-filled VTs (121 units).
- Unknown (12 units)

The population of voltage transformers includes units constructed by 11 manufacturers comprising 25 different types. Condition monitoring results for each of the types can vary substantially as different design and construction methods are used for each type. Of the 25 types of voltage transformers currently in-service, 9 have a population size of less than 10 units, which considerably restricts the ability to establish meaningful trends in condition monitoring data for each of the 25 voltage transformer types. In addition to condition monitoring issues, the difference in physical design and construction characteristics between types increases the complexity of contingency planning and spares management.

5.1.1 Total population by manufacturer

A summary of TasNetworks' voltage transformers by manufacturer is provided in Figure 6. The figure also depicts the insulating medium and design principle used within the population.

Figure 6 - Voltage transformer by manufacturer and design principle



5.1.2 Total population by insulating medium

TasNetworks voltage transformers can be categorised based on the insulating medium and design principle adopted. The categories are referred to in Table 1.

Table 1 -Voltage transformer categorisation (110kV & 220kV-commissioned)

Design principle	Insulation medium	Number of units
Capacitive voltage transformers (CVTs)	oil-filled	414
Inductive voltage transformers	oil-filled	112
Inductive voltage transformers	SF6 gas-filled	121
Total		**659**

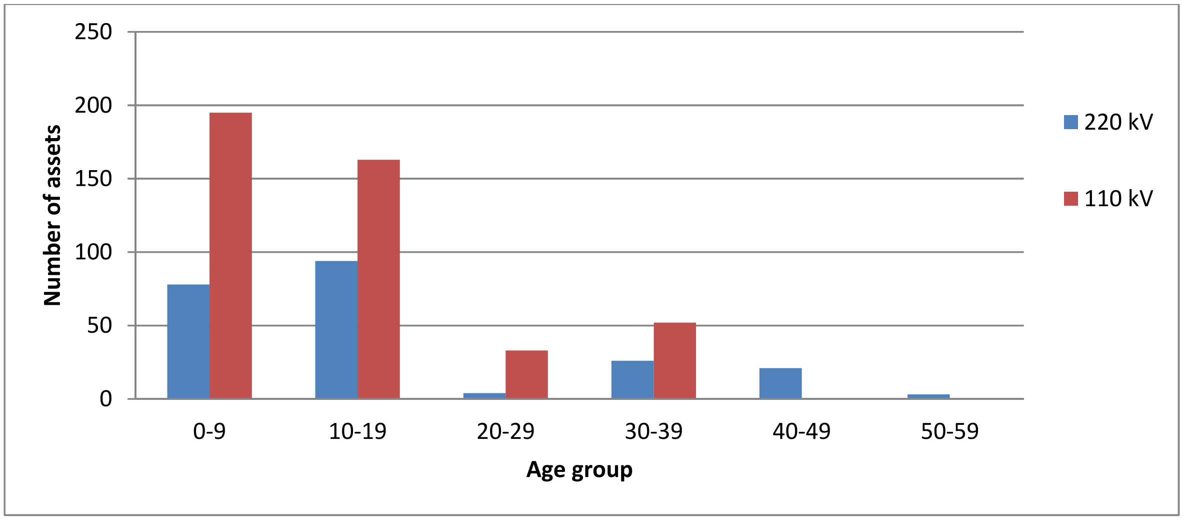
5.1.3 Total Population by Age

Voltage transformers are considered to have an average service life of 45 years. The average age of TasNetworks' 110kV voltage transformers population is 13.5 years and 220 kV is 18.

The population includes 24 units that exceed the average service life for voltage transformers. The relatively low average age profile is largely as a result of TasNetworks' transmission line voltage transformer installation program. Given the relatively low average age of TasNetworks' voltage transformers, overall performance levels of the population should not be adversely affected by age-related issues.

The age profile for TasNetworks' voltage transformer population is shown in Figure 7.

Figure 7 – Age profile of voltage transformers



5.2 General - CVCTs

Combined Voltage Current Transformers perform same function as VTs and CTs but in a single unit, ie. transforming EHV voltages and currents to a suitable level for protection and metering functions.

TasNetworks has in service 45 EHV free-standing CVCTs, 39 at 220 kV and 6 at 110 kV. All units use oil as the insulating medium,

5.2.1 Total population by manufacturer

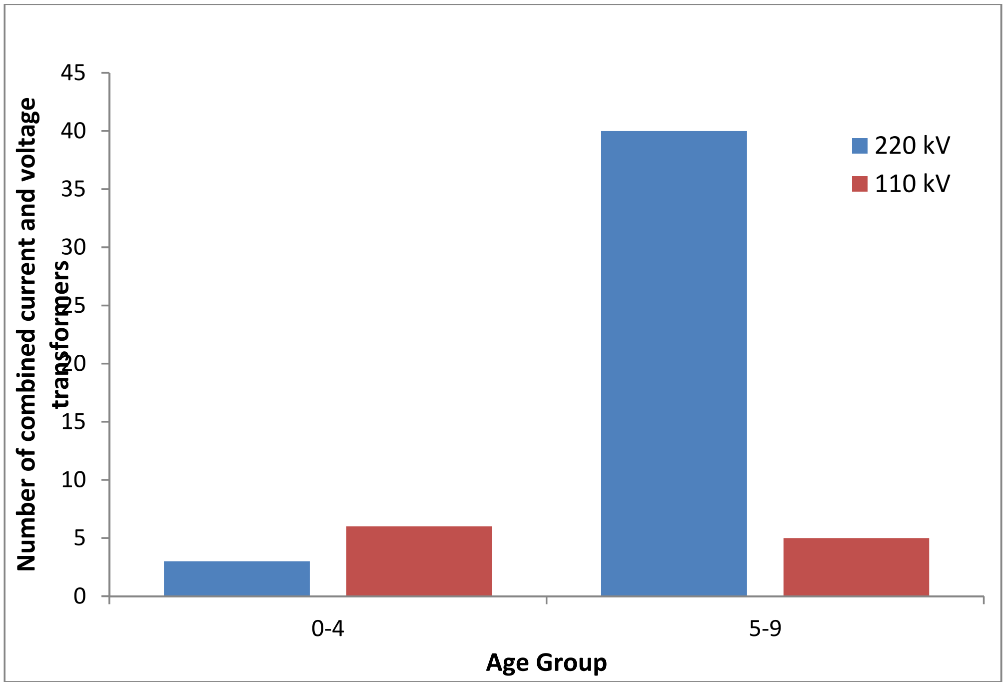
The population of CVCTs includes units constructed by 2 manufacturers, Areva (3 @ 220 kV and 3 @ 110 kV) and Ritz (36 @ 220 kV and 3 @ 110 kV).

5.2.2 Total Population by Age

CVCTs are considered to have an average service life of 45 years. The average age of TasNetworks' 110kV CVCT population is 6.3 years and 220 kV is 12 years.

The age profile for TasNetworks' voltage transformer population is shown in Figure 8.

Figure 8 – Age profile of CVCTs



6 Standard of Service

6.1 Technical Standards

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

It is also a requirement for the manufacturer of EHV VTs to have a proven history of service within Australia for at least three years.

6.2 Performance Objectives

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

In order to ensure that EHV VT faults do not arise from poor installation, assembly or repair of a unit, TasNetworks ensures that supplier and service providers are suitably qualified and experienced.

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 EHV VT performance for major faults through its incident reporting process. The process involves the creation of a fault incident record in the event of a major EHV VT failure that has an immediate impact on the transmission system. The fault incident 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 EHV VT population.

Reference to individual fault investigation reports can be found in TasNetworks' Reliability Incident Management System (RIMSys).

For EHV VT 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 all current transformer related faults or defects.

EHV Voltage Transformer performance impacts in-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' Strategic Asset Management Plan (SAMP).

The availability of EHV Voltage Transformers has an impact on the performance measures reported regularly to the AER and directly impacts on TasNetworks' performance incentive scheme.

TasNetworks has evaluated its EHV Voltage Transformer fleet performance against external benchmarks, such as International Transmission Operations & Maintenance Study (ITOMS), 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 to benchmark asset management practices against international and national transmission companies. Key benchmarking forums include:

- International Transmission Operations & Maintenance Study (ITOMS); and
- Australian and New Zealand chief executive officer's benchmarking forum, which provides information to the Energy Supply Association of Australia (ESAA) for its annual industry performance 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 EHV Voltage Transformer averages (maintenance cost & service levels) between related utilities from around the world.

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 EHV instrument Transformers (CT and VT) assets, TasNetworks had previously only been in this upper right hand quadrant in 2011 and since then has trended into the lower right quadrant indicating low service cost but with a low service level score.

For major EHV VT failures/forced outages (indicative of poor service level score), external benchmarking activities demonstrate that the performance of TasNetworks EHV VT population is below that of other transmission companies participating in the ITOMS study. TasNetworks' high maintenance costs incurred for associated poor service performance level is indicative of the failing condition of the EHV VT population. It is therefore prudent for TasNetworks to replace EHV VTs in poor condition and continue with the rationalisation of the EHV VT population in conjunction with the circuit breaker replacement program.

There needs to be follow up investigation into why this has occurred. Details shown in figure 10 show the outages attributed to instrument transformers in the 2014-15 period, which appear small (4) so why the poor service level score? Could be just that other TNSPs with strong service level score have no or very small percentage of outages in respect to their fleet size.

Figure 9: ITOMS CTs

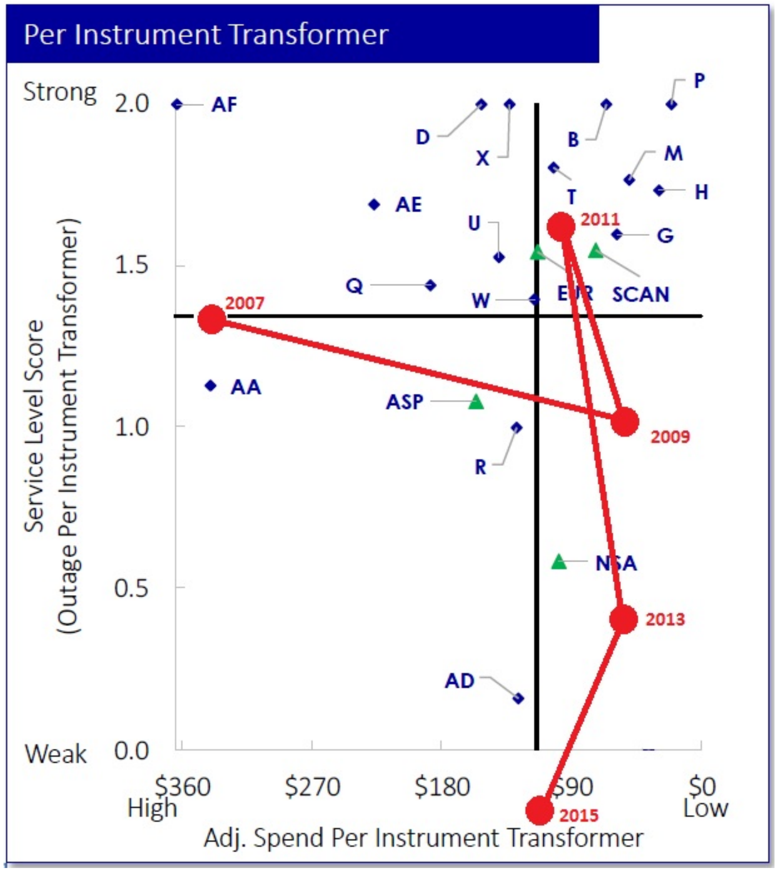
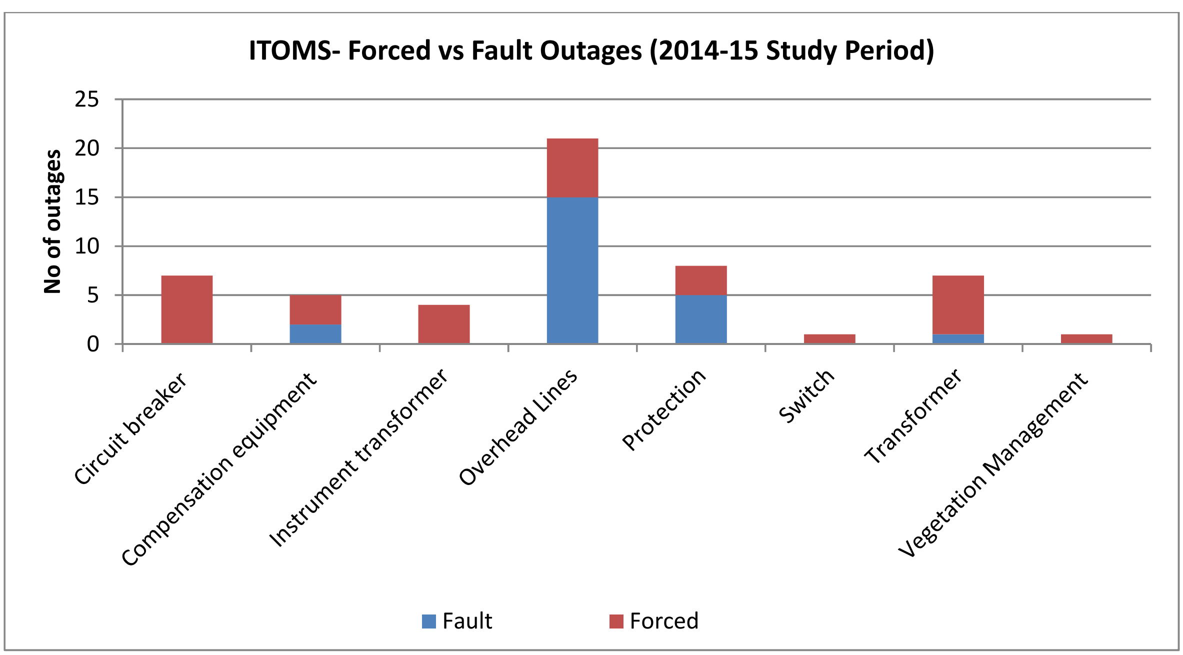


Figure 10: ITOMS reportable asset classes outage summary



6.3.2.2 Failure types

The main risks associated with the voltage transformer population include:

- Major asset failure; and
- Environmental risks

A major failure of a voltage transformer has been identified as a key risk for the voltage transformer asset class because it has the potential to impact on safety and transmission system performance. The predominant causes of a voltage transformer failure or defect include:

- Design faults, including electrical, mechanical, choice of materials used in construction and oil or gas leaks;
- Insulation deterioration due to adverse service conditions or aging; and
- Inadequate quality control during manufacture (which can affect random units or batches of units of a proven design) including general quality, moisture ingress, oil or gas leaks, and corrosion.
- An international survey conducted by Cigre categorised voltage transformer failures into three specific types:
- Major failures - sudden explosive events that cause an immediate emergency system outage or trip;
- Minor failures - non-violent failures, but require an urgent system outage (eg. within one hour); or
- Defects - incidents that require a non-urgent (planned) outage to repair or replace the voltage transformer.

While TasNetworks does not currently have an accurate record of failure or defect rates for its population of voltage transformers, an international survey of instrument transformer failures undertaken by Cigre for the period 1985 to 1995 shows that major failure rates for voltage transformers are extremely low. The combination of enhanced design capability, improved manufacturing quality and control processes, and comprehensive production testing usually ensures that voltage transformer performance levels remain high throughout their service lives. The results of the failure survey are shown in Table 2.

Table 2 - Failure rates for EHV voltage transformers

Voltage transformer construction	Failure rate (%) per 10 years		
	Major	Minor	Defects
Electromagnetic	0.44	0.20	2.16
Capacitive	0.26	0.66	1.82

6.3.2.3 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.

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 voltage 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 EHV voltage transformers in service across the network
- Criticality of EHV voltage transformers and associated assets
- Probability of failure (not meeting business requirement)
- 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 voltage transformers have been revised where appropriate to sustain or improve voltage transformer reliability. Contemporary asset management techniques, including dissolved gas analysis (DGA) and on-line monitoring of secondary phase voltages, have been adopted to determine voltage transformer condition and improve life-cycle management practices, and are aimed at reducing the voltage transformer average annual preventive maintenance expenditure.

A variety of condition assessment methods are used to determine voltage transformer electrical condition. The methods include:

- High voltage electrical testing;
- Oil sampling and DGA;
- Sulphur Hexafluoride (SF6) gas sampling and analysis; and/or
- On-line phase voltage measurement.

Details of the above condition assessment methods are included in Appendix B

The inclusion of a Health Index (HI) to monitor condition is based on asset condition data such as the average defect age, manufacturer support, spares availability, maintenance complexity and technology.

7.1.1.1 The average defect age

The average defect age for an asset category model is calculated from the defects recorded in the AMIS. The average defect age is compared to the asset age and as the asset approaches the average defect age it has an increased influence on the HI. The average defect age should indicate the upward trend of the 'bathtub curve' for the asset category model. In order to eliminate defects from the start of the bathtub curve, defects recorded within the asset warranty period are omitted. Where there are no defects recorded for a model, the average defect age is the manufacturers design life.

7.1.1.2 Manufacturer support

The factors affected by the manufacturer support are the supply of spares, provision of repair services, or availability of local support for the asset category model. These factors combine to determine the level of obsolescence and are used toward the HI calculation.

7.1.1.3 Spares availability

TasNetworks has set a policy of a minimum of one complete three phase set of spares for every voltage transformer category (110 and 220 kV) in service.

7.1.1.4 Maintenance complexity

The factors determining maintenance complexity include limited availability of knowledge and skills to maintain the asset category model. This maintenance complexity will increase the HI as human error can contribute to the failure of an asset category model.

7.1.1.5 Functionality

The lack of functionality of older asset category is deemed to be a contributor to poor condition. Improvements in technology lead to an increase in functionality and is generally regarded as an aid to decrease operating costs.

7.1.2 Criticality

The criticality factor is based on the primary circuit that the asset category asset is part of. These values are recorded within the AMIS and are used by both the secondary risk calculation and the CBRM tool.

7.1.3 Probability of Failure

The probability of failure is directly related to the HI. As with the CBRM tool, engineering experience is used to apply uniform weighting factors to the formula to ensure an accurate result is achieved in line with the current condition of the asset population.

7.1.4 Consequence of Failure

The consequence of failure takes in the circuit criticality and other cost factors associated with the circuit such as value of lost load, maintenance costs, equipment replacement costs etc. If these values are not able to be put into the risk method it needs to be included in capital expenditure analysis in the form of a net present value calculation.

7.1.5 Environmental risk

TasNetworks' main environmental risks associated with voltage transformers relate to the insulating medium used within the units. As the circuit breakers that TasNetworks has in service only use low volumes of insulating oil or SF6 gas, the risk to the environment is minimal. The identified risks include:

- Management of polychlorinated biphenyls (PCBs) associated with oil-filled units; and
- Management of SF6 gas associated with gas-filled units

7.2 Voltage transformer issues

TasNetworks has experienced two major failures in the past, including the failure of:

- One Tyree 05/123/5 type 110 kV voltage transformer installed at Port Latta Substation in 1997, which was attributed to moisture ingress through a corroded oil-level indicator;
- One Ducon PD AS 11AB type 110 kV unit installed at Palmerston Substation in 2001, where the cause of failure is unknown; and
- One Ducon capacitive voltage transformer (CVT) A197 manufactured in 1963 and commissioned the same year, catastrophically failed at Avoca Substation in March 2008, resulting in a significant transmission circuit interruption.

7.3 Special operation and design issues

7.3.1 Operational issues

There are currently no specific capacity issues with the voltage transformer population.

7.3.2 Design issues

Voltage transformer design issues are key inputs in developing an asset management strategy for the population. Design considerations are separated into two areas; specific design issues and substation design philosophy

Voltage transformer design is an important factor that can influence both asset and transmission system performance levels. In addition, design issues have a direct impact on maintenance practices and expenditure. Common design issues across TasNetworks voltage transformer population include:

- Inadequate hermetic sealing resulting in moisture ingress; and
- Inability to obtain oil samples for condition monitoring.

Design considerations for specific voltage transformers (grouped by manufacturer and type) are assessed in detail in Appendices D and E

7.3.3 Specific design issues

Many substations of a double bus bar design did not have voltage transformers installed on each transmission line but had voltage transformers installed on the bus bars only. In this arrangement, the transmission line distance protection systems rely on the voltage transformers installed on the bus bars to provide a voltage source. When bus bar voltage transformers only are used, a voltage selection scheme is required to enable the voltage source for the distance protection systems to be transferred to the bus bar to which the transmission line is connected. The voltage selection operation can be performed either by a manual switch or automated by using relays. Both methods have inherent deficiencies and have resulted in unplanned interruptions to electricity supply. Modern substation designs include the provision of voltage transformers on each transmission line to provide the voltage source for the transmission line distance protection systems, as well as voltage transformers on each bus bar. The inclusion of voltage transformers on transmission line circuits has the additional benefit of enabling and checking of voltage synchronisation between bus bars and transmission lines.

Six operating incidents directly relating to mal-operation of voltage selection schemes associated with transmission line protection systems have occurred since 1998, four of which have resulted in the interruption of electricity supply. A number of similar incidents have also occurred that, if not detected by diligent Field Operators, would have also resulted in the interruption of electricity supply. To enhance the reliability of electricity supply and substantially reduce operational risk, a program has been initiated to install voltage transformers on transmission lines at substations that only have voltage transformers installed on the bus bars

7.4 Summary of Risk

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

- Poor electrical condition of a number of 110 kV voltage transformers, including:
  - Asea EMFA 120; and
  - Balteau UEV 110 voltage transformers.
- Design issues associated with specific voltage transformers, including:
  - Inadequate hermetic sealing resulting in moisture ingress; and
  - Inability to obtain oil samples for condition monitoring.
- Design and operational issues associated with voltage selection schemes at substations that do not utilise voltage transformers on transmission line circuits; and
- Lack of standardisation throughout the voltage transformer population, which includes units constructed by 16 manufacturers comprising 31 different types

8 Management Plan

8.1 Historical

Historically, high voltage electrical testing has been the prime method for condition assessment of EHV VTs.

The high voltage testing process involves measurement of the percentage power factor and insulation resistance to provide an indication of the quality of the insulation material. The electrical testing process is, however, sensitive to the prevailing ambient conditions at the time of test. Conditions such as temperature, humidity, cleanliness of insulation and quality of connections, test equipment and testing procedures all influence test results.

In addition, results and test methods will vary depending on the design and construction of EHV VTs making comparisons between different manufacturers and types difficult. The analysis of electrical test data requires specialist knowledge, experience, and is, to some extent, subjective.

This method will be continued into the future when appropriate. Condition Based Risk Management (CBRM) program will also be applied to assess asset condition and which aligns with direction provided in TasNetworks Strategic Asset management Plan (SAMP). Figure 11 provides an overview as to which management techniques are applied by TasNetworks in managing the risks of each asset category in our asset base as detailed in the SAMP.

Figure 11 – TasNetworks asset category management overview

How are assets managed?																		
Assets	Past						Present						Future					
	Run to failure	Subject Matter Expert (SME)	Time based (Age)	Reliability centered maintenance (RCM)	Condition based	CBRM	Run to failure	Subject Matter Expert (SME)	Time based (Age)	Reliability centered maintenance (RCM)	Condition based	CBRM	Run to failure	Subject Matter Expert (SME)	Time based (Age)	Reliability centered maintenance (RCM)	Condition based	CBRM
Substations																		
Transformers (power)			✓						✓ (maintenance)		✓	✓ (renewed)			✓			✓
EHV circuit breakers			✓						✓ (maintenance)			✓ (renewed)			✓			✓
HV circuit breakers			✓						✓ (maintenance)			✓ (renewed)			✓			✓
EHV Disconnectors & Earth switches			✓						✓ (maintenance)			✓ (renewed)			✓			✓
EHV CT's			✓						✓ (maintenance)			✓ (renewed)					✓	✓
EHV VT's			✓						✓ (maintenance)			✓ (renewed)					✓	✓
Power cables			✓						✓ (maintenance)		✓	✓ (renewed)					✓	✓
Site infrastructure					✓						✓						✓	✓

8.2 Strategy

The management strategies adopted to mitigate the risks associated with voltage 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 voltage 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 an EHV voltage transformer failure, TasNetworks has adopted the following specific strategies to address the predominant causes and consequences of failure.

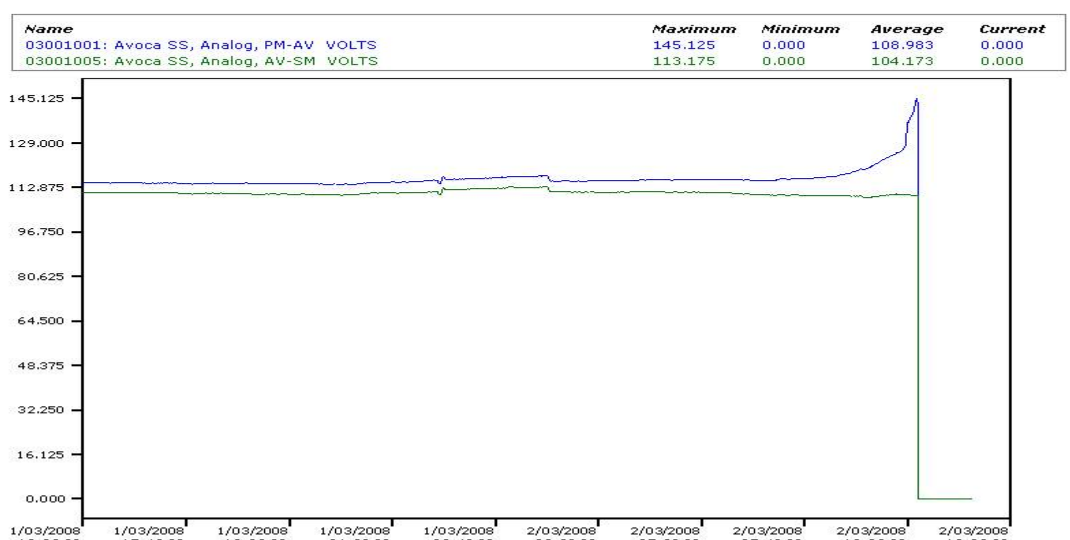
8.2.1 Routine Maintenance

There is a fundamental requirement for TasNetworks to periodically inspect its assets to ensure their physical state and condition does not represent a hazard to the public and to the electricity supply. The voltage transformer have a high unit value, so a preventative corrective maintenance program represents a cost effective alternative to a reactive corrective maintenance program.

With certain types of HV apparatus, TasNetworks experience is that maintenance does not have any material effect on preventing the occurrence of failures, in particular those that are explosive in nature. For example, Figure 12 presents a chart of the voltage output of two post type 110 kV capacitive voltage transformers. The output voltage for asset 03001001 can be seen to increase dramatically within a very short period of time (within hours). This capacitive voltage transformer failed explosively, even though the condition monitoring results for this capacitive voltage transformer were satisfactory when it was last maintained. This event clearly illustrates the rapid deterioration that leads to explosive failures and highlights the minimal impact that maintenance activities can have on preventing such failures, even with minimal time intervals between maintenance activities.

A forum conducted by CIGRE (International Council on Large Electric Systems) panel APB3 - Substations, in October 2005 identified that a number of HV switchgear installations had failed catastrophically, even though the condition monitoring results obtained during planned maintenance were acceptable. This outcome is consistent with TasNetworks' experience. In addition to the above failures, other Australian transmission companies have reported explosive failures of Balteau voltage transformers, of which TasNetworks has a number of units in service of identical design.

Figure 12 - Avoca substation CVT voltage trace



8.2.2 Routine Maintenance versus Non Routine Maintenance

Failures within voltage transformers may cause serious or catastrophic damage to the asset. These assets are located in critical network points, so allowing failures to occur represents a real risk to the stability of the electrical system. 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 voltage 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. These assets can also be included in the pool of spare management.

8.2.4 Planned Asset Replacement versus Reactive Asset Replacement

Similarly to Section 8.2.2, a reactive replacement does not represent an attractive alternative to a planned renewal activity. Voltage transformers are critical for the correct operation of the network, with a high service level expectation in the Tasmanian Electricity Code. Also reactive replacements are generally several times more expensive, incurring overtime, call out penalties and additional repair costs and potential damage to nearby infrastructure.

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.

8.2.5 Non Network Solutions

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

8.2.6 Network Augmentation Impacts

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 augmentation works can be found in TasNetworks Regional Development Plan, which is updated on an annual basis.

Proposed network augmentation projects identified in the Regional Development Plan will have a minimal impact on the voltage transformer population from an asset management perspective.

8.3 Routine Maintenance

The performance of voltage transformers is sustained by the implementation of regular condition monitoring and preventive maintenance activities. Maintenance 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
- The availability of new technology.

Requirements for operating expenditure are a function of the defined periodic condition monitoring regimes, defined preventive maintenance requirements and corrective works.

The revised condition assessment and maintenance practices for capacitive and inductive voltage transformers are presented in Table 3. Based on condition monitoring data, the frequency of maintenance intervals may increase. In the event that increased maintenance is required, the decision to replace a voltage transformer may be justified depending on the impact on preventive maintenance expenditure and transmission system performance.

Table 3 – Condition monitoring and preventative maintenance practices

Task	**Frequency**
All units	
Visual inspections and routine condition monitoring	Quarterly - coordinated with substation inspections
Thermal imaging	Coordinated with substation thermal imaging program
Electronic capturing of condition data#	In conjunction with thermal imaging
Oil-filled capacitive voltage transformers	
Monitoring of secondary phase voltage balances (to be installed on all new installations)	Continuous
Electrical testing (insulation resistance and power factor)	18 years after commissioning and every six years thereafter
Oil-filled inductive voltage transformers (same for CVCTs)	
Insulating oil sampling and DGA (where practicable)	18 years after commissioning and every six years thereafter
Electrical testing (insulation resistance and power factor) where insulating oil sampling facilities are not available	18 years after commissioning and every six years thereafter
SF6-filled inductive voltage transformers	
Monitoring of SF6 gas pressure	Continuous

The proposed additional line item is to be released post the AJILIS project.

8.3.1 DGA program

DGA provides a more accurate means of assessing asset condition and is substantially lower in cost compared with electrical testing. In addition, the duration of a transmission circuit outage to take an oil sample is considerably lower than the electrical testing method.

During the development stage of the DGA program, a detailed investigation into the practicalities of obtaining insulating-oil samples from the oil-filled inductive voltage transformer population will be undertaken. Where practicable, the DGA method will be used in lieu of the current practice of electrical testing.

8.3.2 PCB testing program

TasNetworks completed a program to determine the PCB levels within the circuit breaker population to mitigate the risks associated with PCB contamination. Specific PCB details have been updated in the WASP registry.

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 voltage transformer, TasNetworks has standardised on the use of capacitive type voltage transformers for new or replacement installations. While the failure rates for both electromagnetic (inductive) and capacitive voltage transformers are relatively low, the Cigre instrument transformer failure survey found that capacitive units are less susceptible to a major failure. In addition, the on-line phase voltage measurement method can be applied to CVTs for continuous condition monitoring, enabling early detection of deterioration in the condition of a CVT. In addition, the standardisation of voltage transformer types also addresses population type issues.

8.6 Regulatory Obligations

Voltage transformer performance impacts on TasNetworks’ overall network service obligations, which include specific performance requirements for both regulated and connection transmission assets.

There are currently no specific service level obligations for voltage transformers

8.6.1 Service obligations for network assets

EHV voltage transformer performance impacts on TasNetworks’ overall network service obligations, which include 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.

There are currently no specific service level obligations for current transformers but they do have an impact on transmission lines and transformer circuit availability.

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 have a number of direct connections to major industrial customers through EHV and HV substations. The following sites have asset category 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

To address design, condition and performance risks associated with the voltage transformer population, continuation of the voltage transformer replacement program is recommended.

The following sections provide details of the recommended replacement program for the 110 kV and 220 kV voltage transformer populations.

8.7.1 110 kV voltage transformer replacement

The assessment of the 110 kV voltage transformer populations recommends the replacement of 21 units over the 2019-24 regulatory period. Table 4 presents a summary of the units proposed to be replaced. Proposed replacement of connection assets are subject to customer consultation and agreement. Where practicable, voltage transformer replacements will be co-ordinated with other substation capital works.

Table 4 – 110 kV Voltage transformers planned replacements

Manufacturer	Type	Station	Units
Ducon CVT	PD-BE-22H	Sheffield	21
Total			21

8.7.2 220 kV voltage transformer replacement

There are no proposed 220 kV voltage transformer projects identified at this time.

8.7.3 On-line CVT monitoring program

For CVTs, on-line measurement of the secondary phase voltages can be used to determine the likelihood of failure of the capacitive element. The use of on-line monitoring eliminates the need for regular off-line condition monitoring tests, such as electrical testing, that require a transmission circuit outage. As the costs associated with the method are negligible, the potential preventive maintenance expenditure savings are significant. In addition, the improvement in transmission circuit availability will improve TasNetworks' overall level of service and performance levels.

Operating expenditure had been included previously to implement the on-line phase voltage monitoring method for condition assessment of TasNetworks' existing CVT units currently in service. The implementation of the on-line condition monitoring program for CVTs will involve an initial investigation to determine which of the existing CVT installations already have modern relays capable of performing secondary voltage comparison. The program will also investigate the possibility of retrofitting external voltage comparison relays to existing CVT units for condition monitoring purposes. In addition, future protection and control upgrades that involve new or existing CVT installations will incorporate on-line condition monitoring functionality.

8.8 Program Delivery

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

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

8.9 Spares Management

In addition to spares availability policy referred in section 7.1.1.3, TasNetworks has developed a contingency plan to mitigate the risk of inadequate response in the event of a voltage transformer failure.

TasNetworks' System Spares Policy details the minimum requirements for maintaining spare voltage transformer units, which include:

- One three-phase set of 110 kV capacitive voltage transformers;
- One three-phase set of 220 kV capacitive voltage transformers (fitted with power line carrier (PLC) equipment); and
- For 110 kV or 220 kV voltage transformers with unique characteristics, a minimum of one spare unit for each type.

A list of TasNetworks' spare 110 kV and 220 kV voltage transformer units is provided in Appendix G.

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 the service providers;
- Training;
- Group management; and
- General technical advice.

8.11 Disposal Plan

Prior to disposing of decommissioned voltage transformers, units will be reviewed to determine their suitability as system spare units (in accordance with TasNetworks' System Spares Policy, document) or redeployment elsewhere in the transmission system.

Disposal of voltage transformers that use insulating oil or SF6 gas will be done so in accordance with relevant standards and procedures.

8.12 Summary of Programs

Tables 5 and 6 provide a summary of all of the programs/projects described in this management plan.

Table 5: Summary of EHV VT OPEX programs / projects

Work Program	Work Category	Work Category	Project/Program
Routine Maintenance	CMVTE	Corrective maintenance	S145-SUBS-Corrective-Voltage Transformer EHV
	PMVTE	Preventative maintenance	S377-Voltage Transformer Oil Samples EHV
	PMVTE	Preventative maintenance	S361-Voltage Transformer Electrical Tests EHV

Table 6: Summary of EHV VT CAPEX programs / projects

Work Program	Work Category	Project title	Project/Program details
Capital	RENSB	Replace Ducon CVT's	Replace remaining fleet of Ducon 220 kV CVT's (21 in total) at Sheffield Substation which comprise the following designations: SH-B197, SH-C197, SH-D197, SH-E197, SH-F197, SH-J197, SH-K197.

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 site infrastructure works.

In the event that increased maintenance levels are required, the decision to replace equipment may be justified depending on the impact on preventive maintenance expenditure and transmission system performance.

The developed works plan is held and maintained in the works planning tool in AMIS. It contains details such as planning dates, task types, specific assets and planned costs.

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.

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 to either in the development of this management plan, or provide supporting information to it:

TasNetworks documents:

1. System Spares Policy R517373
2. Strategic Asset Management Plan R248812
3. Annual Planning Report 2017 R689487
4. Sulphur Hexafluoride Gas Management Procedure, Transend Networks, 2005 D04/10176
5. Management of Insulating Oil, Transend Networks 2006 TNM-PC-809-0091
6. System Spares Policy R517373
7. Engineering and Asset Services operational expenditure planning methodology D11/102320
8. AM8 Asset Condition Review – project report June16 FINAL R503361

Technical requirements for the supply and installation of new current transformers are detailed in the following TasNetworks standards:

9. EHV voltage transformers standard R586391
10. Extra High Voltage System Standard R586386
11. EHV Combined Voltage and Current Transformer Standard R586371

Other standards and documents:

12. Australian Standard AS 1883 'Guide to maintenance and supervision of insulating oils in service', Standards Australia, 1993
13. Australian Standard AS 4360 'Risk Management', Standards Australia, 2004
14. Australian Standard AS 2067-2008 : Substations and high voltage installations exceeding 1 kV ac
15. IEC standard 60599 'Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved and free gases analysis', IEC, 1999
16. Sinclair Knight Merz, 'Assessment of Economic Lives for Transend Regulatory Asset Classes', 2013. R192773
17. Cigre Publication, WG12.16 Report - Survey of Instrument Transformer Design and Performance, Cigre 1997

11 Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S145-SUBS-Corrective-Voltage Transformer EHV	CMCTE	Medium	Customer Financial Network performance Regulatory Compliance Safety	Opex	Low
S377-Voltage Transformer Oil Samples EHV	PMCTE	Medium	Customer Financial Network performance Regulatory Compliance Safety	Opex	Low
S361-Voltage Transformer Electrical Tests EHV	PMCTE	Medium	Customer Financial Network performance Regulatory Compliance Safety	Opex	Low
Replace Ducon CVT's	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Safety	Capex	Low

12 Appendix B – Condition assessment methodologies

A variety of condition assessment methods are available to determine voltage transformer condition. The methods include:

- High voltage electrical testing;
- Oil-sampling and analysis;
- Sulphur Hexafluoride (SF6) gas sampling and analysis; and/or
- On-line phase voltage measurement.

12.1 Electrical testing

Historically, high voltage electrical testing has been the prime method for condition assessment of voltage transformers. The high voltage testing process involves measurement of the percentage power factor and insulation resistance to provide an indication of the quality of the insulation material. The electrical testing process is, however, sensitive to the prevailing ambient conditions at the time of test. Conditions such as temperature, humidity, cleanliness of insulation and quality of connections, test equipment and testing procedures all influence test results. In addition, results and test methods will vary depending on the design and construction of voltage transformers making comparisons between different manufacturers and types difficult. The analysis of electrical test data requires specialist knowledge, experience, and is, to some extent, subjective.

12.2 Power factor testing

The power factor test provides an indication of the dielectric losses present within the voltage transformer insulation. Dielectric losses will develop heat within the insulation and, along with moisture, can cause deterioration of the insulation. Cigre 'WG12.16 Report - Survey of Instrument Transformer Design and Performance' states the percentage power factor of the high voltage insulation should generally be less than the following values:

- Electromagnetic voltage transformers 0.4 per cent
- Capacitive voltage transformers (CVT)
    - Capacitor unit 0.3 per cent
    - Electromagnetic (intermediate) unit 1.0 per cent
    - Complete unit 1.0 per cent

As a general rule, the Cigre report suggests paper-oil instrument transformers should be removed from service when the percentage power factor exceeds twice the new value.

12.3 Insulation resistance measurements

Insulation resistance values are compared with previous test results to identify any damage or contamination to the voltage transformer insulation. The method involves measuring the leakage current that flows either through the volume of insulation or over the external surface of the insulation. Any tendency for the leakage current to steadily increase with time at a constant voltage is an indication that the insulation may be deteriorated.

As the insulation resistance measurement is largely dependent on prevailing conditions at the time of test, there is no set limit for resistance values. As a general rule, the insulation resistance value should be greater than 1 GΩ.

12.4 Oil sampling and analysis

For oil-filled voltage transformer units with oil-sampling facilities, analysis of the insulating oil can be used to determine the condition of the voltage transformer. In particular, the DGA method can be used to identify evolving faults within a voltage transformer unit. As the oil-paper insulating systems deteriorate, gases are produced. Analysis of the types and quantities of the gases dissolved in the insulating oil can be used to determine the type and severity of the fault causing the production of gas. The DGA method is typically not applied to CVTs due to the relatively low oil volume of CVT units and the separation of the capacitor divider and intermediate voltage transformer sections.

The following table outlines key dissolved gas concentration limits for sealed, oil-insulated instrument transformers, which are based on limits as defined in IEC standard 60599 ‘Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved gases’.

Table 7 - Key DGA levels for sealed oil-insulated instrument transformers[1]

Gas	Unit	Limits		
		Acceptable	**Marginal**	**Poor**
Acetylene, C_2H_2	ppm	< 1	1 - 5	> 5
Carbon monoxide, CO	ppm	< 200	200 - 300	> 300
Ethane, C_2H_6	ppm	< 50	50 - 500	> 500
Ethylene, C_2H_4	ppm	< 5	5 - 10	> 10
Hydrogen, H_2	ppm	< 300	300 - 1000	> 1000
Methane, CH_4	ppm	< 30	30 - 200	> 200

In addition to the DGA method, measuring the water content within the insulating oil of a voltage transformer unit can be used as an indicator of electrical condition. The amount of water present in the insulating oil can indicate the ingress of moisture from the atmosphere or deterioration of the paper insulation within a voltage transformer unit. High water content also accelerates the chemical deterioration of the paper insulation. The following table outlines the limits of moisture in insulating oil for instrument transformers, which is based on the limits defined in Table 8 of Australian Standard AS 1883 - 1993 ‘Guide to maintenance and supervision of insulating oils in service’.

[1] based on IEC 60599 - 1999, p.55 and Cigre’s ‘WG12.16 Report - Survey of Instrument Transformer Design and Performance’

Table 8 - Moisture content limits for oil-insulated instrument transformers[2]

Instrument transformer category	Moisture content		
	Acceptable	Marginal	Poor
> 170 kV (Category D in AS 1883)	< 20	20 - 25	> 25
< 170 kV (Category E in AS 1883)	< 30	30 - 35	> 35

12.5 SF6 gas sampling and analysis

For SF6 gas-insulated voltage transformers, gas sampling and analysis can be used to determine voltage transformer condition. In particular, measurement of the water present within the gas can provide an indication of the likelihood of moisture ingress or internal deterioration of the insulation in the event of gas loss. The presence of water within SF6 gas hampers the natural recombination process of decomposition products back to SF6. Instead, decomposition products combine with water to form hydrogen fluoride, which is a highly corrosive electrolyte. The water content within SF6 gas can be obtained via a dew-point measurement. Dew-point limits for in-service voltage transformers are typically specified by the manufacturer.

SF6 analysis can also be used as a diagnostic tool in the event of a voltage transformer failure. Internal problems within SF6 insulated equipment such as sparking, arcing or overheating generate specific by-products, which can be identified through SF6 gas analysis.

12.6 On-line phase voltage measurement

For CVTs, on-line monitoring and comparison of secondary voltages of each phase can be used to determine the likelihood of failure of the capacitive element. Deterioration of a capacitor causes the secondary voltage to progressively decrease as it approaches failure. By continually monitoring the difference in secondary voltages between each phase in a three-phase set, a likely failure can be detected. If the secondary voltage of a CVT deviates by more than five per cent from the other two phases for an extended period, it is likely that the capacitive element is deteriorated or damaged.

The continuous monitoring of CVT secondary voltages can be performed by using modern protection relays, which can be configured to generate a voltage imbalance alarm both locally via the substation supervisory control and data acquisition (SCADA) system and remotely via the Network Operations Control System (NOCS).

[2] based on AS 1883 - 1993, p.26

13 Appendix C – Coupling capacitor

TasNetworks currently has 13 coupling capacitors in service within the transmission system network, all operating at a voltage of 110 kV. The following table lists the coupling capacitors currently in service.

Table 9 - Coupling capacitors listing

Manufacturer	Location	Device Number	Average age	Number of units
Ducon	Sheffield	Q1CC (red, blue), S1CC (red , blue)	41	4
	Ulverstone	A1CC (red, blue)	40	2
Haefely Trench	Farrell	T1CC (red, white)	20	2
		Total number of units in service		**8**

13.1 Electrical condition

Condition monitoring results for Ducon and Haefely Trench coupling capacitors indicate the units are in acceptable electrical condition.

13.2 Design considerations

There are no design issues evident with Ducon and Haefely Trench coupling capacitors.

13.3 Future management strategy

Ducon units installed at Sheffield and Ulverstone substations will be replaced in conjunction with associated 110 kV Ducon voltage transformer replacements, as detailed in Appendix D.

Units installed at Farrell Substation will become redundant as part of planned optical ground wire (OPGW) installation to the west coast region. Redundant coupling capacitors will be retained as system spare units.

14 Appendix D – 110 kV voltage transformer assessment

110 kV voltage transformers have been grouped by manufacturer and assessed on two key criteria: electrical condition and design considerations. Based on electrical condition and design issues, future management strategies for each type are determined.

ABB

ABB 110 kV voltage transformers are in service as follows

Electrical condition

ABB voltage transformers are in acceptable electrical condition.

Design considerations

Type (ABB)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CPA 123	Oil	Burnie	D197	4	3
		Chapel Street	L197	10	3
		Emu Bay	B197, C197	4	6
		Electrona	A197, B197	7	6
		George Town	H197, I197	7	6
		Hadspen	C797, D797, E197, G197, H197, J197, K197, N197	16	23
		Lindisfarne	H197	4	3
		Mornington	A197, A797, B197, B797	4	8
		Sheffield	C797, D797, Q197, R197, S197, T197, U197	7	21
		Sorell	A497, B497	4	2
		Trevallyn	A197, A797, B197, B797	16	12
			C197	14	3
			C797	15	1
CPB 123	?	Burnie	E197, H197, J197, K197	2	12
	Oil	Chapel Street	G197, H197	3	6
		Derby	A797	4	3
		Kingston	A797, B797	3	6
		Knights Road	A197, C197, J197,	3	9
		New Norfolk	A797, B797	2	6
		Norwood	A797, B797, C197	3	5
		Palmerston	C797, D797, M197, N197, O197, R197, Y197, Z197	3	24
		Rosebery	A197, C197	2	6
		St Leonards	A197, A797, B197, B797	3	8
		Tungatinah	A197, D197, E197	1	9
Total units in service					**191**

There are no design issues evident with ABB CPA-123 voltage transformers. Type 540846 units installed at Temco Substation have a metering accuracy class of 0.2M. They do not have oil-sampling facilities.

Future management strategy

Electrical testing should be continued for CPA-123 units installed at Hadspen and Trevallyn substations. An investigation should be undertaken to determine if the existing relays associated with the CVT installations at Hadspen and Trevallyn substations are capable of performing on-line secondary phase voltage comparison, which would eliminate the need for regular off-line electrical testing. Voltage transformer L196 installed at Chapel Street Substation utilises on-line secondary phase voltage comparison for condition assessment.

Electrical testing should be continued for condition assessment of type 540846 units installed at Temco Substation.

Asea

Asea 110 kV voltage transformers are in service as follows:

Type (ASEA)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CPA 123	Oil	Hadspen	D797	14	1
Total units in service					**1**

Electrical condition

Electrical test data for EMFA 120 type voltage transformers show high percentage power factor and low insulation resistance readings on units installed at Knights Road and Temco substations. Past failures have been experienced on previously installed units due to moisture ingress issues which have resulted in explosive failure.

Design considerations

EMFA 120 type voltage transformers have a number of design issues, including:

- Poor quality of insulating medium - the units are filled with poor quality oil and sand, which has resulted in poor percentage power factor test results;
- Oil leaks resulting in low oil-levels on previously installed units;
- A poorly designed oil-level sight glass, which deteriorates due to exposure to ultra-violet (UV) light; and
- Units do not have oil-sampling facilities.

Future management strategy

Asea EMFA 120 voltage transformers are in poor electrical condition, have inherent design deficiencies and are susceptible to major failure. The units are planned to be replaced.

Balteau

Balteau 110 kV voltage transformers are in service as follows:

Type (Balteau)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
UEV 110	Oil	Meadowbank	797	33	3
Total units in service					**3**

Electrical condition

Electrical tests show that the Balteau UEV 110 voltage transformers are in poor electrical condition. Units installed at Emu Bay, Tarraleah and Creek Road substations have high percentage power factor readings, which indicate excessive moisture in the voltage transformer insulating oil and likely degradation of the winding insulation. While TasNetworks has not experienced any major failures of Balteau voltage transformers, other Australian transmission companies have reported explosive failures of Balteau voltage transformers of a similar design.

Design considerations

Balteau UEV110 voltage transformers are an obsolete design. They have a number of design issues, including:

- The design is susceptible to moisture ingress. Instances of moisture ingress through the diaphragm have occurred, which has resulted in the high percentage power factor readings;
- A poorly designed oil-level sight glass. The sight glass is susceptible to mechanical failure and vandalism. The failure of a sight glass will allow moisture to enter the expansion chamber and pool on the rubber diaphragm. It is extremely difficult to assess the integrity of the sight glass with the voltage transformer in service; and
- Units do not have oil-sampling facilities.

Future management strategy

Balteau UEV110 voltage transformers are in poor electrical condition and are an obsolete design. The units should be progressively replaced.

Brown Boveri

Brown Boveri 110 kV voltage transformers are in service as follows:

Type (Brown Boveri)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
TMZF	Oil	Tarraleah	B797	77	3
Total units in service					**3**

Electrical condition

The electrical condition of TMZF type voltage transformers cannot be assessed by electrical testing as the primary winding of the units is earthed internally.

Design considerations

Brown Boveri TMZF voltage transformers are an obsolete design. They have a number of design issues, including:

- The use of a free-to-air vent, which exposes the insulating oil to moisture ingress;
- The units are installed at ground level, which presents safety issues associated with safety fences and substandard electrical clearances; and
- Units do not have oil-sampling facilities.

Future management strategy

Brown Boveri TMZF voltage transformers are an obsolete. Units installed at Tarraleah Substation B797 should be replaced in conjunction with the planned 110 kV upgrade of the substation.

Ducon

Ducon 110 kV voltage transformers are in service as follows:

<table>
<tr><th>Type (Ducon)</th><th>Design Principle</th><th>Location</th><th>Asset ID</th><th>Average Age (years)</th><th>Number of units</th></tr>
<tr><td>?</td><td rowspan="5">Oil</td><td>Avoca</td><td>A197</td><td rowspan="4">51</td><td>1</td></tr>
<tr><td rowspan="2">PD-AS-11AB</td><td>Meadowbank</td><td>A197</td><td>1</td></tr>
<tr><td>St Marys</td><td>197</td><td>1</td></tr>
<tr><td>CHU-221</td><td>St Marys</td><td>197</td><td>1</td></tr>
<tr><td>PD-BE-11E</td><td>Ulverstone</td><td>A197B</td><td>46</td><td>1</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="5">Total units in service</td><td>5</td></tr>
<tr><td colspan="6"></td></tr>
</table>

Electrical condition

Condition monitoring results for each of the Ducon type voltage transformers indicate the units are in acceptable electrical condition. An explosive failure of a PD-AS-11AB unit was experienced at Palmerston Substation in 2001 on the previously installed P197 (white phase). Also, in March 2008 the A197 unit failed explosively resulting in interruption to customers supplied from Avoca and St Marys Substations. Electrical tests performed in March 2007, and thermographic inspection completed in February 2008 did not indicate any evidence of imminent failure.

Design considerations

Wave traps are installed on a number of Ducon voltage transformers for communication purposes. Wave trap installations include:

- Avoca A197 and St Marys 197 (CHU-221);
- Palmerston R197 and St Marys 197 (PD-AS-11AB); and
- Paloona A197 and B197, Sheffield Q197 and S197 and Ulverstone A197B (PD-BE-11E).

Wave traps have a thermal current rating limit of 600 Amps.

Future management strategy

The majority of Ducon 110 kV voltage transformers are installed on radial transmission circuits, which imposes additional outage constraints for maintenance and condition monitoring purposes. Ducon voltage transformers should be progressively replaced in conjunction with other planned capital works. Electrical testing should be continued for condition assessment until these units are replaced.

Endurance electric

Endurance Electric 110 kV voltage transformers are in service as follows:

Type (Endurance Electric)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
05/110/4	Oil	George Town	K197A, L197A	36	6
Total units in service					**6**

Electrical condition

Condition monitoring results for the 05/110/04 type voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

Endurance electric type 05/110/4 type voltage transformers are an identical sand-filled design to the Tyree 05/110/4 units. The voltage transformers have an oil drain valve, which enables oil sampling.

Future management strategy

DGA should be adopted for condition assessment of Endurance Electric voltage transformers.

Haefely Trench

Haefely Trench 110 kV voltage transformers are in service as follows

Type (Haefely Trench)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
		Avoca	B197	19	1
			B197	29	2

Type (Haefely Trench)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CVE 123	Oil	Chapel Street	D197	27	3
		New Norfolk	E197, R197	27	5
VEOT 123	Oil	Boyer	C497N, D497N	27	2
		Chapel Street	F197	28	3
		Farrell	C797, D797, N197, P197, S197, T197	32	18
		New Norfolk	D197	32	3
			F197, J197, K197, P197, R197	27	13
		Sheffield	N197, V197	28	6
		Tungatinah	C797	17	3
		Ulverstone	A197, B197	32	6
Total units in service					**65**

Electrical condition

Condition monitoring results for the Haefely Trench voltage transformers indicate the units are in acceptable electrical condition. CVE 123 type units installed at Chapel Street Substation show high percentage power factor measurements, but the readings are consistent with factory test results. Type VEOT 123 type voltage transformers also show high percentage power factor readings on the HV to LV (all else guarded) measurement across the population. The high power factor can be attributed to the design of the units.

Design considerations

Specific design considerations for Haefely Trench voltage transformers include:

- Wave traps are installed on CVE 123 type voltage transformers for communication purposes at Avoca Substation B197; and
- All units have oil drain plugs or valves fitted.

Future management strategy

Electrical testing should be continued for condition assessment of CVE 123 type voltage transformers. However, an investigation should be undertaken to determine the feasibility of retrofitting relays capable of performing on-line secondary phase voltage comparison for condition assessment of the CVE 123 units, which would eliminate the need for regular off-line electrical testing. For VEOT 123 type units, the DGA method should be adopted for condition assessment purposes.

Koncar

Koncar 110 kV voltage transformers are in service as follows:

Type (Koncar)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
VPU-123	Oil	Chapel Street	J197, K197	9	6
		Lindisfarne	A197, B197, C197, E197, F197, G197	10	18
Total units in service					**24**

Electrical condition

Koncar voltage transformers are in acceptable electrical condition.

Design considerations

There are no known design issues associated with Koncar voltage transformers. Units are fitted with oil drain valves.

Future management strategy

DGA should be adopted for condition assessment of Koncar voltage transformers.

Ritz

Ritz 110 kV voltage transformers are in service as follows:

Type (RITZ)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
STEF 123	SF6	Mowbray	A197	6	3
			B197	10	3
OTEF 123	Oil	Port Latta	A197, B197	18	2
		Risdon	J697-T, K697-T	18	2
		Tarraleah	C197	15	3
		Tungatinah	A797, B797	18	6

Type (RITZ)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
Total units in service					**19**

Electrical condition

Condition monitoring results for the Ritz voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with Ritz voltage transformers. OTEF 123 units are fitted with oil drain valves and STEF 123 units are equipped with a gas pressure gauge.

Future management strategy

DGA should be adopted for condition assessment of OTEF 123 voltage transformers. The unit installed at Lindisfarne Substation will be retained as a system spare when the Waddamana-Lindisfarne 110 kV transmission line is decommissioned as part of the planned southern 220 kV system development. Units installed at Tarraleah and Tungatinah substations will become redundant as part of the planned upgrades at the substations. The redundant units will be re-used elsewhere in the transmission system.

On-line monitoring of SF6 gas pressure should continue for condition assessment of STEF 123 type voltage transformers.

Trench

Trench 110 kV voltage transformers are in service as follows:

Type (Trench)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
SVS 123/3	SF6	Burnie	C797, D797	14	6
		Chapel Street	C797, D797	14	6
		Devonport	A197	14	3
			B197	9	3
		George Town	C797, D797	14	6
		Lindisfarne	A797, B797	14	6
		Norwood	D197, E197	8	6
		Queenstown	A797	15	3
		Railton	C197, D197	14	6
		Scottsdale	A197, B197	11	6
		Smithton	A197, B197, D197	12	9

Type (Trench)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
		Tungatinah	E197, H197	14	6
		Waddamana	A797, B797, C797	11	9
			D797	14	3
		Wesley Vale	A197, B197	14	6
TEMF 115C	Oil	Huon River	A197	8	3
Total units in service					**87**

Electrical condition

Condition monitoring results for the Trench voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with Trench voltage transformers. The SVS 123/3 units can operate with SF6 gas at atmospheric pressure.

Future management strategy

On-line monitoring of SF6 gas pressure should continue for condition assessment of SVS 123/3 voltage transformers. An investigation should be undertaken to determine if the existing relays associated with the CVT installation at Huon River Substation are capable of performing on-line secondary phase voltage comparison, which would eliminate the need for regular off-line electrical testing.

Tyree

Tyree 110 kV voltage transformers are in service as follows:

Type (TYREE)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
05/123/5	Oil	Bridgewater	G197, H197	34	6
		Kingston	A197, B197	34	6
		Meadowbank	B197	35	1
		Norwood	A197, B197	35	6
		Port Latta	A797, B797	35	6
		Rokeby	A497N, B497N	33	2
		Tarraleah	B197, D197	35	6

Type (TYREE)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
05/110/4	Oil	Tarraleah	A797	38	3
Total units in service					**36**

Electrical condition

Condition monitoring results for the Tyree voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

One major failure of a Tyree type 05/123/5 occurred at Port Latta Substation in 1997. The failure was attributed to possible moisture ingress through the oil-level indicator assembly, which was showing signs of advanced corrosion as a consequence of the harsh service environment at Port Latta Substation. The condition of the oil-level indicator assembly on Tyree voltage transformers is regularly monitored in conjunction with routine substation inspections.

Tyree voltage transformers are a sand-filled design and have oil drain valves fitted.

Future management strategy

DGA should be adopted for condition assessment of Tyree voltage transformers. Units installed at Tarraleah Substation will become redundant as part of the planned upgrade at the substation. The units will be retained as system spares.

15 Appendix E – 220 kV voltage transformer assessment

220 kV voltage transformers have been grouped by manufacturer and assessed on two key criteria: electrical condition and design considerations. Based on electrical condition and design issues, future management strategies for each type are determined.

ABB

ABB 220 kV voltage transformers are in service as follows:

Type (ABB)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CPA 245	Oil	Burnie	A197	4	3
		Chapel Street	B197A, C197A, T197, U197	10	12
			A797, B797	9	6
		Gordon	A797, B797, C797	9	9
		George Town	B197, D197	10	6
		Hadspen	A797, B797, P197, Q197, T197, V197	16	16
			V197	10	2
		Liapootah	B797	4	3
			C197, E197A, F197, G197	10	12
		Palmerston	A797, B797, F197, K197, L197	7	15
		Primary Store	B797	10	1
		Sheffield	B797, E797	6	6
CPB245	Oil	George Town	A197, C197, F797	3	9
		Liapootah	A797	4	3
Total units in service					**103**

Electrical condition

ABB voltage transformers are in acceptable electrical condition.

Design considerations

There are no design issues evident with ABB CPA-245 voltage transformers.

Future management strategy

Electrical testing should be continued for CPA-245 units that do not use on-line monitoring of secondary phase voltages for condition assessment (refer to Appendix G for a listing). An investigation should be undertaken to determine if the existing relays associated with the CVT installations at Chapel Street, George Town, Gordon and Hadspen substations are capable of performing on-line secondary phase voltage comparison, which would eliminate the need for regular off-line electrical testing.

Areva

Type (Areva)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
OTCF 245.1M	Oil	Lindisfarne	C797, D797, Y197, Z197	4	12
		Waddamana	F797, G797, J197, M197, N197, Q197	4	18
Total units in service					**30**

Asea

Asea 220 kV voltage transformers are in service as follows:

Type (ASEA)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CPEE 245 N-6	Oil	Sheffield	L197	27	3
Total units in service					**3**

Electrical condition

Condition monitoring results for CPEE 245 type voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with Asea CPEE 245 type voltage transformers.

Future management strategy

Electrical testing should be continued for condition assessment of Asea 220 kV voltage transformers. An investigation should be undertaken to determine the feasibility of retrofitting relays capable of performing on-line secondary phase voltage comparison for condition assessment of the Asea units, which would eliminate the need for regular off-line electrical testing.

Ducon

Ducon 220 kV voltage transformers are in service as follows:

Type (Ducon)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
PD-BE-22H	Oil	Sheffield	B197, C197, D197, E197, F197, J197, K197	46	21
Total units in service					**21**

Electrical condition

Condition monitoring results for each of the Ducon type voltage transformers indicate the units are in acceptable electrical condition. The design principles for both 220 kV and 110 kV units are similar and the recent failure at Avoca Substation where despite various preventative maintenance practices being followed, evidence of failure was not possible and the unit failed catastrophically.

Design considerations

Wave traps are installed on Sheffield B197, C197, D197 and E197 voltage transformers for communication purposes. Wave traps have a thermal current rating limit of 600 Amps.

Future management strategy

Ducon 220 kV voltage transformers are installed on critical transmission circuits, including a number of radial transmission lines. The voltage transformers should be progressively replaced. Units installed at Palmerston Substation will be replaced as part of the Palmerston Substation 220 kV upgrade project. Units at George Town and Sheffield substations should be replaced in conjunction with other planned capital works. Electrical testing should be continued for condition assessment until units are replaced. A three-phase set of decommissioned units will be retained as system spares until the remainder of the population has been replaced.

GEC Alstom

GEC Alstom 220 kV voltage transformers are in service as follows:

Type (GEC Alstom)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CCV 245	Oil	Liapootah	D197	16	3
		Palmerston	E797	15	1
			G197, J197	16	6
Total units in service					**10**

Electrical condition

Condition monitoring results for the CCV 245 type voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with GEC Alstom CCV 245 type voltage transformers.

Future management strategy

GEC Alstom voltage transformers use on-line secondary phase voltage comparison for condition assessment with the exception of E797 (white phase) installed at Palmerston Substation. Electrical testing should be continued for condition assessment of this unit.

Haefely Trench

Haefely Trench 220 kV voltage transformers are in service as follows:

Type (Haefely Trench)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
CVE 245/950	Oil	Farrell	A197	28	2
				29	1
230 H			B197	15	3
Total units in service					**6**

Electrical condition

Condition monitoring results for the Haefely Trench voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with Haefely Trench voltage transformers

Future management strategy

Electrical testing should be continued for condition assessment of Haefely Trench voltage transformers. An investigation should be undertaken to determine the feasibility of retrofitting relays capable of performing on-line secondary phase voltage comparison for condition assessment of the Haefely Trench units, which would eliminate the need for regular off-line electrical testing.

Ritz

Ritz 220 kV voltage transformers are in service as follows:

Type (RITZ)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
OTCF 245.1M	Oil	George Town	Z197	10	3
Total units in service					**3**

Electrical condition

Ritz voltage transformers are in acceptable electrical condition.

Design considerations

There are no known design issues associated with Ritz voltage transformers.

Future management strategy

Electrical testing should be continued for Ritz units. An investigation should be undertaken to determine if the existing relays associated with the CVT installation at George Town Substation are capable of performing on-line secondary phase voltage comparison, which would eliminate the need for regular off-line electrical testing.

Sprecher and Schuh

Sprecher and Schuh 220 kV voltage transformers are in service as follows:

Type (Sprecher & Schuh)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
WUF 214	Oil	George Town	GTz - B797	51	3
Total units in service					**3**

Electrical condition

Condition monitoring results for the Sprecher and Schuh voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no known design issues associated with Sprecher and Schuh voltage transformers. Units are fitted with oil drain valves.

Future management strategy

Sprecher and Schuh voltage transformers should be replaced as part of planned capital works at the George Town and Palmerston substations as units have reach end of life. Electrical testing should be continued until units are replaced.

Tyree

Tyree 220 kV voltage transformers are in service as follows:

Type (TYREE)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
04/245/7	Oil	Farrell	A797, B797, D197, H197, J197	30	13
			B797, E197	31	5
		Sheffield	Y197	30	2
			Y197, Z197	31	4
Total units in service					**24**

Electrical condition

Condition monitoring results for the Tyree voltage transformers indicate the units are in acceptable electrical condition.

Design considerations

There are no known design issues associated with Tyree 220 kV voltage transformers. Units are a sand-filled design and have oil drain valves fitted.

Future management strategy

Electrical testing should be continued for Tyree voltage transformers. The units installed at Burnie Substation B797 (white phase) should be replaced in conjunction with the replacement of the Micafil units installed on red and blue phases. The decommissioned unit should be retained as a system spare for the remainder of the Tyree voltage transformer population. An investigation should also be undertaken to determine the feasibility of retrofitting relays capable of performing on-line secondary phase voltage comparison for condition assessment of the Tyree units, which would eliminate the need for regular off-line electrical testing.

16 Appendix G – spare voltage transformer units

The following tables details TasNetworks spare 110 kV and 220 kV voltage transformer units that are deemed suitable for service.

Table 10 110 kV Operational spare voltage transformer listing

Manufacturer	Type	Design Principle	Location	Number of units
ABB	CPB 123	Oil	Primary Store	7
	Unknown	?	Primary Store	1
Haefely Trench	VEOT 123	Oil	Primary Store	1
Koncar	VPU-123	Oil	Primary Store	2
	VPT-123	Oil	Primary Store	1
Ritz	OTEF 123		Primary Store	3
Trench	SVS 123/3		Primary Store	1
TYREE	05/123/5	Oil	Primary Store	7
Total	23			

Table 11 220 kV Operational spare voltage transformer listing

Manufacturer	Type	Design Principle	Location	Number of units
ABB	CPA 245	Oil	Primary Store	5
	CPBA 245	?	Primary Store	2
Sprecher & Schuh	WUF 214	Oil	Primary Store	2
Total	9			

17 Appendix H – 110 kV CVCT assessment

110 kV CVCTs have been grouped by manufacturer and assessed on two key criteria: electrical condition and design considerations. Based on electrical condition and design issues, future management strategies for each type are determined.

Areva

Areva 110 kV CVCTs are in service as follows:

Type (Areva)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
Kotef	Oil	Derby	D196B/97-B D196B/97-R D196B/97-W	4	3
Total units in service					**3**

Electrical condition

Areva CVCTs are in acceptable electrical condition.

Design considerations

There are no design issues evident with Areva 110 kV CVCTs.

Future management strategy

Electrical testing should be continued for condition assessment of this unit.

Ritz

Ritz 110 kV CVCTs are in service as follows:

Type (Ritz)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
Kotef	Oil	Sheffield	Q196/97-W	2	1
			Q196/97-B Q196/97-R	12	2
Total units in service					**3**

Electrical condition

Ritz CVCTs are in acceptable electrical condition.

Design considerations

There are no design issues evident with Ritz 110 kV CVCTs.

Future management strategy

Electrical testing should be continued for condition assessment of this unit.

18 Appendix I – 220 kV CVCT assessment

220 kV CVCTs have been grouped by manufacturer and assessed on two key criteria: electrical condition and design considerations. Based on electrical condition and design issues, future management strategies for each type are determined.

Areva

Areva 110 kV CVCTs are in service as follows:

Type (Areva)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
Kotef	Oil	George Town	X196/97-B X196/97-R X196/97-W	8	3
Total units in service					**3**

Electrical condition

Areva CVCTs are in acceptable electrical condition.

Design considerations

There are no design issues evident with Areva 110 kV CVCTs.

Future management strategy

Electrical testing should be continued for condition assessment of this unit.

Ritz

Ritz 110 kV CVCTs are in service as follows:

Type (Ritz)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
Kotef	Oil	George Town	F196/97-B F196/97-R F196/97-W G196/97-B G196/97-R G196/97-W	10	6
Kotef	Oil	Farrell	D196/97-B D196/97-R D196/97-W	12	6

Type (Ritz)	Design Principle	Location	Asset ID	Average Age (years)	Number of units
			E196/97-B E196/97-R E196/97-W		
Kotef	Oil	Chapel St	B196/97-B B196/97-R B196/97-W C196/97-B C196/97-R C196/97-W	13	6
Kotef	Oil	Cluny	B196/97B-B B196/97B-R B196/97B-W	13	3
Kotef	Oil	Liapootah	E196/97-B E196/97-R E196/97-W	13	3
Kotef	Oil	Sheffield	B196/97-B B196/97-R B196/97-W C196/97-B C196/97-R C196/97-W D196/97-B D196/97-R D196/97-W E196/97-B E196/97-R E196/97-W	13	12
Total units in service					**36**

Electrical condition

Ritz CVCTs are in acceptable electrical condition.

Design considerations

There are no design issues evident with Ritz 110 kV CVCTs.

Future management strategy

Electrical testing should be continued for condition assessment of this unit.

19 Appendix J – spare CVCT units

The following tables details TasNetworks spare 110 kV and 220 kV CVCT units that are deemed suitable for service.

Table 12 110 kV Operational spare CVCT listing

Manufacturer	Type	Design Principle	Location	Number of units
Areva	Kotef	Oil	Primary Store	1
Ritz	Kotef	Oil	Primary Store	1
Total				2

Table 13 220 kV Operational spare CVCT listing

Manufacturer	Type	Design Principle	Location	Number of units
Areva	Kotef	Oil	Primary Store	3
Ritz	Kotef	Oil	Primary Store	1
Total				4