Asset Management Plan

EHV Current Transformer

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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.*

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1 Purpose

The purpose of this asset management plan is to define the management strategy relating specifically to EHV Current Transformers. The plan provides:

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

2 Scope

This document is TasNetworks' networks asset management plan for its population of extra high voltage current transformers (EHV CT) 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.

This asset management plan covers only the post-type current transformers. It is TasNetworks strategy to replace aging post-type CTs with current transformers integral to a dead tank circuit breaker. Those CTs will be covered by the Circuit Breaker Asset Management Plan.

The strategies included in this plan have been developed using sound asset management principles, taking into account past asset performance, good electricity industry practice and the need for prudent investment to optimise the asset life-cycle costs and optimise EHV CT performance.

TasNetworks currently have 418 EHV CTs in service comprising of 352 Oil-filled, 60 SF6 gas-filled and 6 epoxy insulated EHV CTs. There are an additional 56 EHV CT spares located in TasNetworks' primary store.

The successful implementation of the strategies detailed in this plan will minimise TasNetworks' business risk by enhancing EHV CT performance. The defined preventive maintenance practices are designed to ensure optimal asset availability and service levels to customers while minimise expenditure and managing risk and duty-of-care obligation.

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 current transformers assets, with the aim of achieving these objectives.

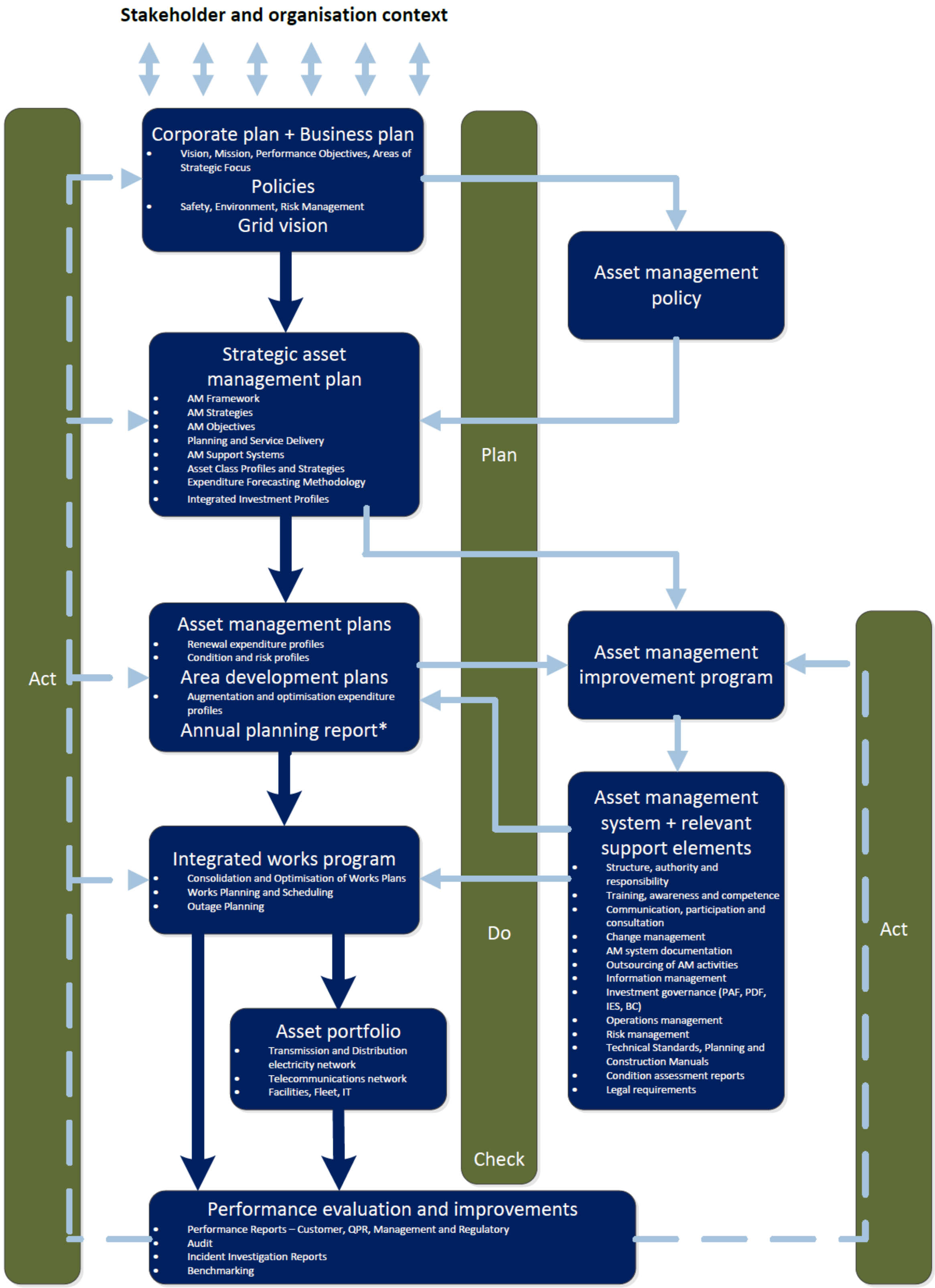
For these assets the management strategy focuses on the following objectives:

- 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 utilises Asset Management Information Systems to manage asset records for its network. The systems are maintained to contain up to date, detailed information for the GIS installations.

AMIS is a combination of processes, technology, and people applied to provide the essential outputs for effective asset management, such as:

- Reduced risk;
- Enhanced transmission system performance;
- Enhanced compliance, effective knowledge management;
- Effective resources 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 current transformers:

- R16971 WASP Asset Register – Data Integrity Standard – Current Transformer; and
- R16965 WASP Asset Register – Data Integrity Standard – 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.

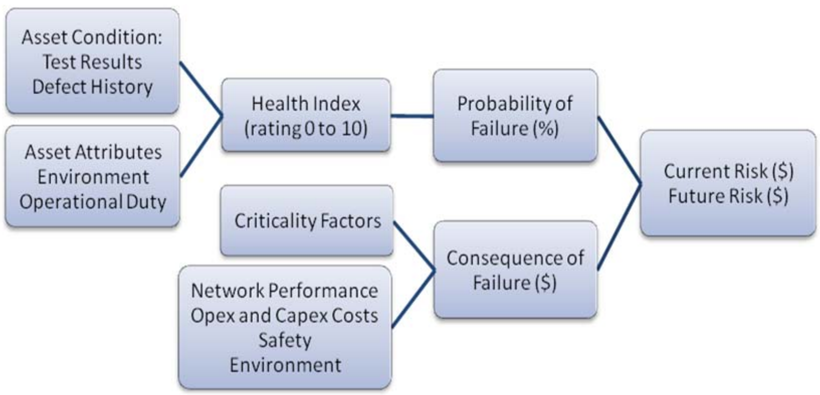
A number of observations were concluded as part of the review including the need to obtain condition data consistently across all asset types and in electronic form. The need for storage and collection would align with other business initiatives such as the AJILIS project.

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.

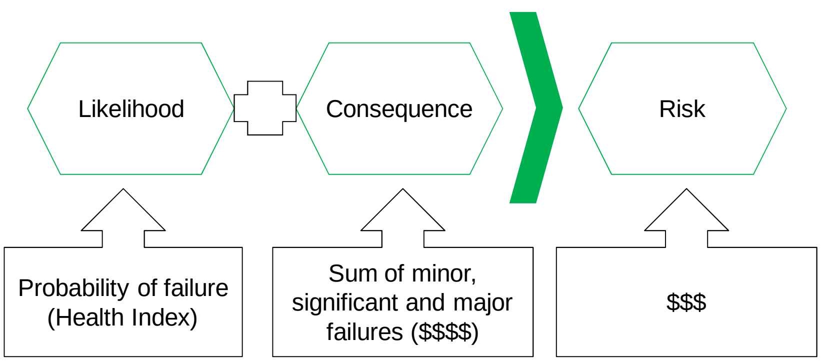
Figure 2: Asset risk framework



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

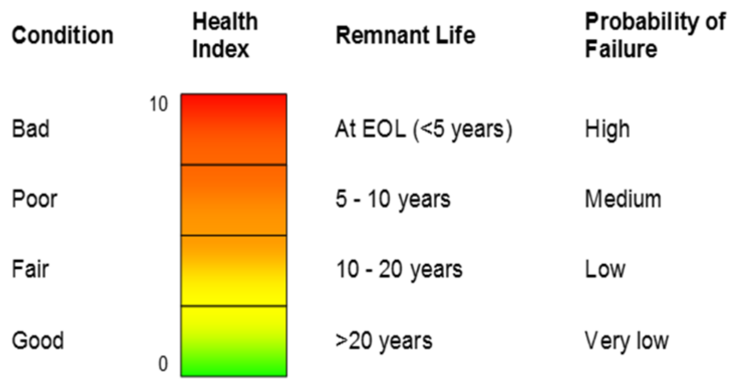
Figure 3 shows what CBRM considers as the two risk inputs.

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).

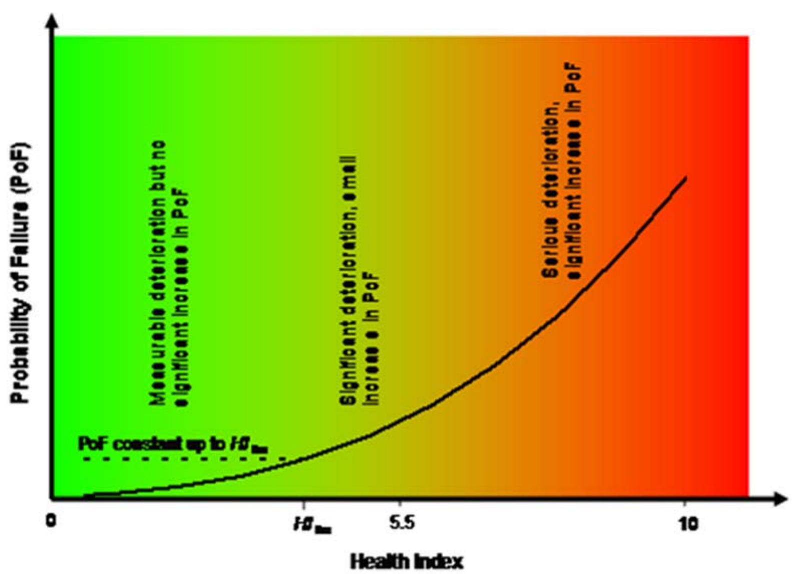
Figure 4: Health index interpretation



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 CTs may be added into the CBRM tool in the near future.

5 Description of the Assets

5.1 General

Current transformers perform a critical function in supporting the reliable operation of the transmission system and are used extensively to facilitate the safe measurement of large currents, often present at high voltages to safe levels of use in protective and metering relay functions.

A CT is a type of instrument transformer designed to provide a current in its secondary winding proportional to the current flowing in its primary.

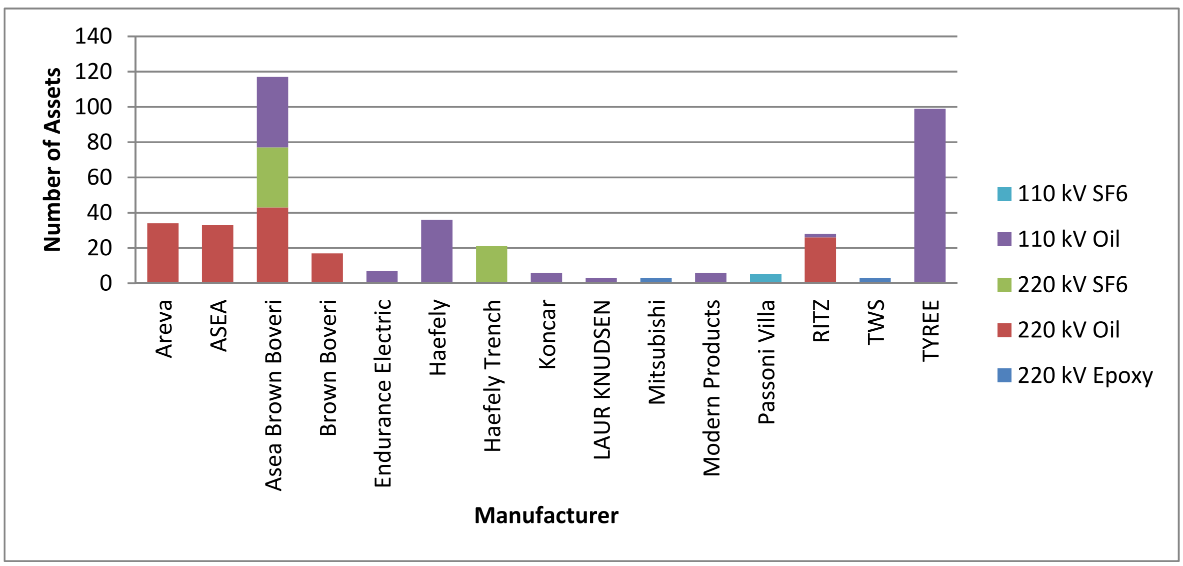
TasNetworks' current transformers are categorised based on the insulating medium. The categories are:

- Oil-filled current transformers;
- Sulphur hexafluoride (SF6) gas-filled current transformers; and
- Epoxy insulated current transformers.

5.1.1 Total Population by Manufacturer

TasNetworks' population consists of 38 different types of EHV CTs, constructed by 15 manufacturers. A summary of TasNetworks' EHV CTs by manufacturer is provided in Figure 6.

Figure 6: EHV CT by manufacturer and insulating medium



Of the 38 types of current transformers presently in service, 29 have a population size of less than 20 units. The resultant minimal population size per asset type considerably restricts the ability to establish meaningful trends in condition monitoring data for each of these current transformer types.

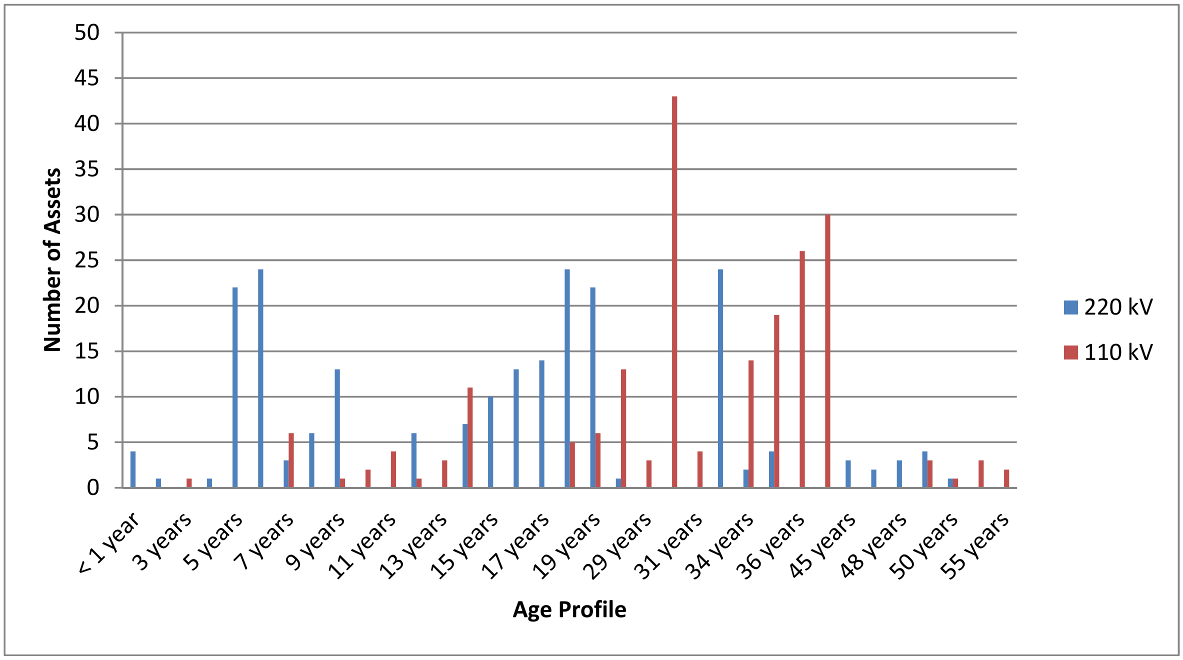
In addition to condition monitoring restrictions, the difference in physical design and construction characteristics between types presents contingency planning and spares management issues.

A recent incident associated with EHV CTs for other electrical utilities have shown porcelain bushing material to explode under failure. TasNetworks has 25 EHV CTs that are porcelain, oil filled and have exceeded their expected life.

5.1.2 Total Population by Age profile

Current transformers have an average service life of 45 years. The average age of TasNetworks' 110 kV EHV CT population is 30 years and for 220 kV EHV CT is 17.3 years as of October 2017. The population includes 25 units that exceed the expected service life, which consists of 12 units for 110 kV and 13 for 220 kV. The age profile of TasNetworks' current transformer population is shown in Figure 7.

Figure 7: Age Profile of Current Transformers (as of October 2017)



TasNetworks' condition assessment audits have not shown direct correlation between EHV CT age and poor performance.

5.2 Oil Filled Current Transformer

5.2.1 110 kV Current Transformer

TasNetworks have 199 110kV oil-filled current EHV CTs in service. Table 1 below summarises the population of transformers in service. More details about 110kV CTs can be found in Appendix B – 110 kV current transformer assessment.

Table 1: 110 kV Oil-filled Current Transformers

Description	Insulant	Location	Average Age (Years)	Number Installed
Asea Brown Boveri IMBM145SP1T4	Oil	New Norfolk	10	4
		Chapel Street	12	8
Asea Brown Boveri IMBD145T2T4	Oil	George Town	17	1
Asea Brown Boveri 236080	Oil	Rosebery	13	3
Asea Brown Boveri 913662	Oil	George Town	17	3
Asea Brown Boveri 389483	Oil	George Town	19	3
Asea Brown Boveri 309457	Oil	Lindisfarne	19	3
		Risdon	41	6
Asea Brown Boveri HPM123PIT4	Oil	Lindisfarne	19	1
		Risdon	19	2
Asea Brown Boveri 834348	Oil	Trevallyn	18	6
Endurance Electric Drg. 021533	Oil	Derwent Bridge	8	1
		Lindisfarne	51	3
Endurance Electric IC115	Oil	Ulverstone	48	3
		Chapel Street	33	6
		Farrell	33	24
		Sheffield	31	3
		Ulverstone	34	3
Koncar	Oil	Risdon	6	6
		Palmerston	52	3
Modern Products Drg. 043012	Oil	Boyer	31	6
Ritz OSKF123	Oil	Sheffield	9	1
	Oil	Burnie	11	1
Tyree 06/123/8	Oil	Norwood	36	6
Tyree 06/123/9	Oil	Norwood	36	6
Tyree 06/123/10	Oil	Rokeby	35	6
Tyree 06/123/11	Oil	Rokeby	35	6
Tyree 06/123/13	Oil	Bridgewater	36	12
		Kingston	36	6
		Lindisfarne	35	3
Tyree 06/123/14	Oil	Chapel Street	35	6
Tyree 06/123/22	Oil	Boyer	29	6
		New Norfolk	29	33
Tyree 06/123/23	Oil	Sheffield	29	6
Tyree 06/123/24	Oil	Knights Road	30	3
			Total	199

5.2.2 220 kV Current Transformer

TasNetworks have 153 220kV oil-filled EHV CTs in service. Table 2 summarizes the population of transformers in service. More details about 220kV CTs can be found in Appendix C – 220 kV current transformer assessment.

Table 2: 220 kV Oil-filled Current Transformers

Description	Insulant	Location	Average Age (Years)	Number Installed
Areva OSKF245	Oil	Burnie	5	3
		George Town	7	1
		Liapootah	4	3
		Lindisfarne	5	12
		Waddamana	5	12
		Wayatinah Tee	4	3
Asea IMBD245 A5	Oil	Farrell	32	24
		Sheffield	34	6
Asea IMDB245-ED2052	Oil	Sheffield	30	3
Asea Brown Boveri IMBD245L5T8-636198	Oil	Chapel Street	18	9
		Gordon	18	12
		Liapootah	14	6
Asea Brown Boveri IMBE245LST8	Oil	Hadspen	17	12
Asea Brown Boveri IMBD245L5T8-637139	Oil	Palmerston	18	3
Asea Brown Boveri IMBD245 A5	Oil	George Town	16	1
Brown Boveri TMBRI245	Oil	Sheffield	39	17
Ritz OSKF245	Oil	George Town	8	17
		Liapootah	8	3
		Palmerston	8	6
			Total	153

5.3 SF6 Gas Filled Current Transformer

5.3.1 110 kV Current Transformer

There are five 110kV SF6 gas-filled EHV CTs in service at TasNetworks. Table 3 below summarises the population of transformers in service. More details about 110kV CTs can be found in Appendix B – 110 kV current transformer assessment.

Table 3 - 110 kV SF6 Gas-filled Current Transformers

Description	Insulant	Location	Average Age (Years)	Number Installed
Passoni Villa CTS-166	SF6	Chapel Street	11	3
		Derwent Bridge	13	2
			Total	5

5.3.2 220 kV SF6 Gas-filled Current Transformer

TasNetworks have 55 220kV SF6 gas-filled EHV CTs in service. Table 4 below summarizes the population of transformers in service. More details about 220kV CTs can be found in Appendix C – 220 kV current transformer assessment.

Table 4 - 220 kV SF6 Gas-filled Current Transformers

Description	Insulant	Location	Average Age (Years)	Number Installed
Asea Brown Boveri TG245	SF6	Chapel Street	15	6
		George Town	5	9
		Liapootah	13	6
		Palmerston	15	9
		Sheffield	12	4
Haefely Trench SAS245/OG	SF6	Farrell	17	6
		George Town	16	3
		Liapootah	16	9
		Palmerston	17	3
			Total	55

5.4 Epoxy Insulated Current Transformer

5.4.1 220 kV Current Transformer

TasNetworks have six 220kV epoxy insulated EHV CTs in service. Table 5 below summarizes the population of transformers in service. More details about 220kV CTs can be found in Appendix C – 220 kV current transformer assessment.

Table 5 - 220 kV Epoxy Insulated Current Transformers

Description	Insulant	Location	Average Age (Years)	Number Installed
Mitsubishi SBW02L	Epoxy	George Town	4	3
TWS SBW02L	Epoxy	George Town	4	3
			Total	**6**

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 EHV CT units. The specification requires new units to be designed and type-tested to Australian and international standards. The specification requires composite insulation and pressure relief devices be fitted to reduce impacts of an explosive failure of the unit.

It is also a requirement for the manufacturer of EHV CTs 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 EHV CT manufacturers to have AS/NZ ISO 9001 accreditation and conform to its requirements. TasNetworks also requires routine tests to be performed on each EHV CT unit to prove the quality of manufacture prior to dispatch from the manufacturer's factory.

In order to ensure that EHV CT 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 CT 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 CT 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 CT population.

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

For EHV CT 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 Current 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 Current 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 Current 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 Current 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 CT failures/forced outages (indicative of poor service level score), external benchmarking activities demonstrate that the performance of TasNetworks EHV CT population is below that of other transmission companies participating in the ITOMS study. TasNetworks' average maintenance costs incurred for associated poor service performance level is indicative of the failing condition of the EHV CT population. It is therefore prudent for TasNetworks to replace EHV CTs in poor condition and continue with the rationalisation of the EHV CT 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 9 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 8: ITOMS CTs

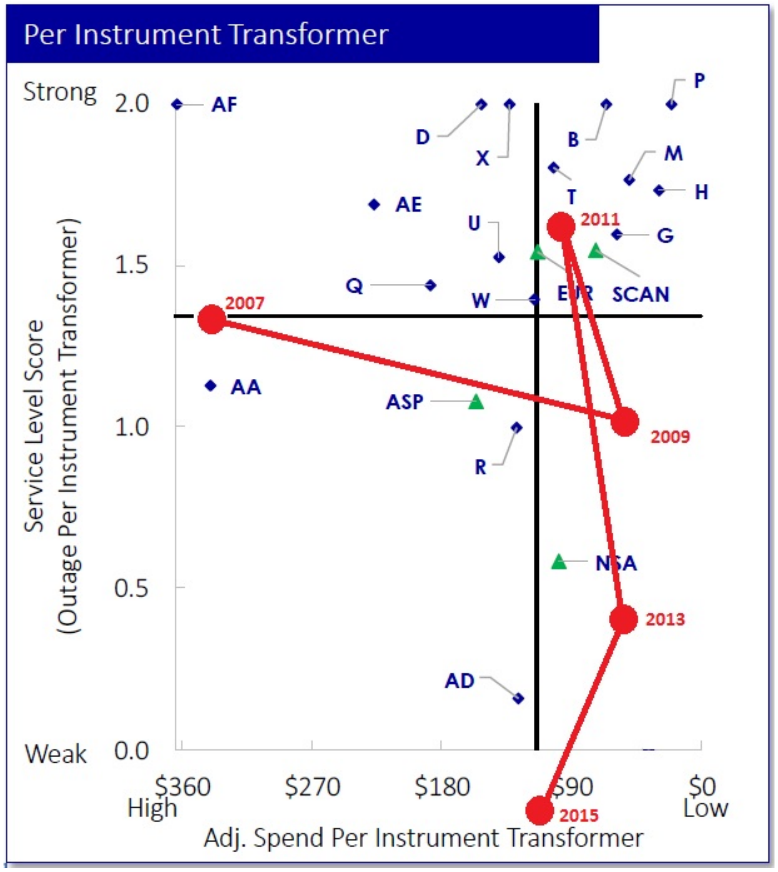
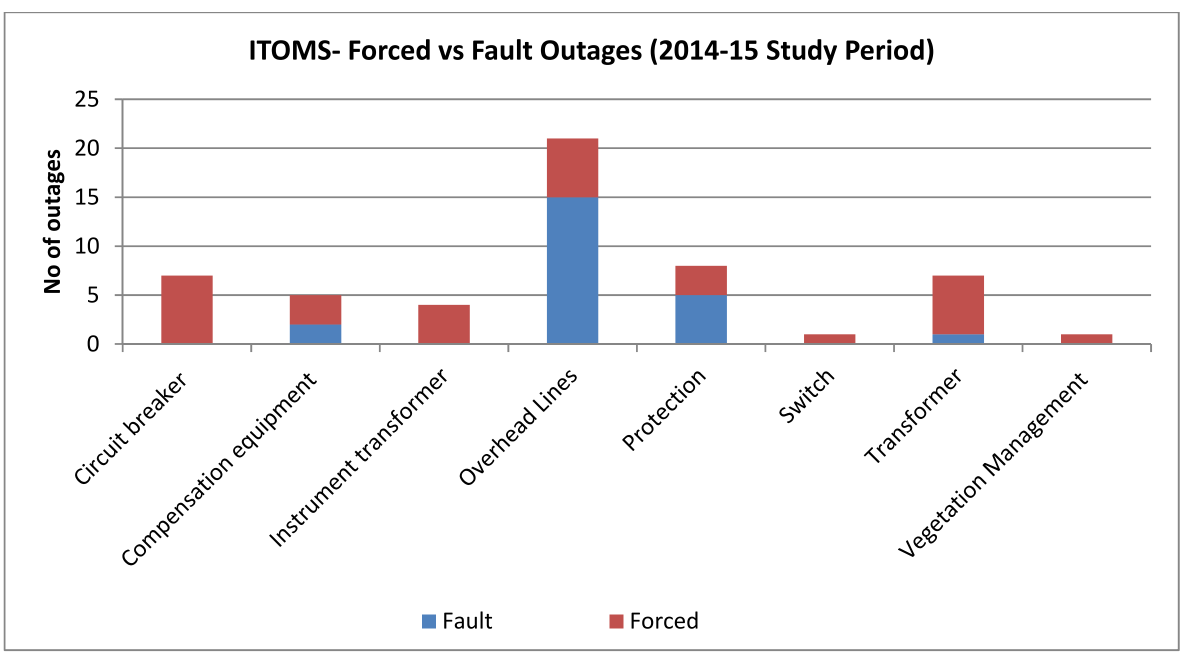


Figure 9: ITOMS reportable asset classes outage summary



6.3.2.2 Failure Types

An international survey conducted by Cigre categorised current 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 current transformer.

6.3.2.3 Failure Rates

While TasNetworks does not currently have an accurate record of failure or defect rates for its EHV CT population, an international survey of instrument transformer failures undertaken by Cigre for the period 1985 to 1995 shows that major failure rates for EHV CTs are extremely low.

While the failure rates for EHV CT are relatively low, the Cigre instrument transformer failure survey found that EHV CTs are less susceptible to minor failures and defects than other instrument transformers but are still relatively high in terms of major failures.

A significant conclusion from the survey was that existing condition monitoring techniques used by industry and TasNetworks are not effective in predicting a failure.

The combination of enhanced design capability, improved manufacturing quality and control processes, and comprehensive production testing usually ensures that EHV CT performance levels remain high throughout their service lives. The results of the failure survey are presented in the following table.

Table 6 – Failure rates for EHV current transformers

Type of instrument transformer	Failure rate (%) per 10 years		
	Major	Minor	Defects
Current transformer	0.40	0.19	0.98

6.3.2.4 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 EHV CT 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 CT in service across the network
- Criticality of EHV CT 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

EHV CT condition assessment is based on its electrical integrity. A variety of condition assessment methods are used to determine EHV CT electrical condition. The HI 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 EHV CT voltage 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 Risks

TasNetworks’ main environmental risks associated with EHV CTs relate to the insulating medium used within the units. As EHV CTs use low volumes of insulating oil or SF6 gas, the risk to the environment is minimal. The risks include:

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

7.2 Oil filled EHV CTs issues

TasNetworks has experienced a failure of an oil-filled EHV CT associated with an English Electric air-blast circuit breaker at Waddamana Substation, which failed explosively in 2000 likely due to moisture ingress. All current transformers of this type have since been decommissioned.

Some minor failures such as oil leaks and primary terminal damage due to mechanical stresses have also occurred.

- An ABB IMBE245L5T8 oil filled unit experienced an oil leak from the secondary terminal box in 2017. Un-planned outage was taken to enable repair.

7.3 SF6 EHV CT issues

TasNetworks has experienced failures in the past ten years, including:

- An Passoni Villa CTS-1GG SF6 gas-filled unit failed in 2007 due to suspected moisture ingress due to ongoing gas leaks; and
- An ABB TG245, SF6 gas-filled unit installed at Liapootah Switching Station failed in 2004, where an internal flash over occurred.

Some minor failures such as gas leaks and primary terminal damage due to mechanical stresses have also occurred.

7.4 Epoxy EHV CT issues

There has been no performance issues recorded with epoxy insulated EHV CTs since their installation.

7.5 Special Operation and Design issues

7.5.1 Operational Issues

A review of the EHV CT population has found that there are currently no significant operational capacity issues associated with the EHV CT population. There are a small number of EHV CTs in service that limit the maximum current rating on some transmission circuits, which yield operational constraints; however, the constraints are not considered to have a material impact on the operation of the transmission system and will only be considered for replacement based on a holistic condition assessment in conjunction with system augmentation projects.

The circuits include:

- Sheffield–Wesley Vale and Devonport–Wesley Vale 110 kV circuits are limited to 600 Amps (115 MVA) by the EHV CTs at Wesley Vale;
- Gordon–Chapel Street 220 kV transmission lines are limited to 1200 Amps (457 MVA) by the EHV CTs at Chapel Street Substation;
- Sheffield–Burnie No. 1, Sheffield–Cethana, Sheffield–Fisher, Sheffield–Lemonthyme, Sheffield–Wilmot transmission circuits are limited to 600 Amps (229 MVA) by the EHV CTs at Sheffield Substation;
- Sheffield–Burnie No. 2, Sheffield–Devonport, Sheffield–Paloona, Sheffield–Wesley Vale transmission circuits are limited to 600 Amps (115 MVA) by the EHV CTs at Sheffield Substation; and
- George Town–Starwood and George Town–Temco 110 kV transmission circuits are limited to 800 Amps (152 MVA) by the EHV CTs at George Town Substation.

7.5.2 Substation Design Issues

Design considerations are separated into three areas, specific design issues, compliance with National Electricity Rules (NER) and circuit breaker strategy (e.g. whether the EHV CTs are to be integral with the circuit breakers).

EHV CT 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' EHV CT population include:

- Use of porcelain insulation presenting a serious threat to personnel and equipment under explosive failure situations;
- Use of silica gel breathers;

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

The strategic design considerations for specific current transformers (grouped by manufacturer and type) are assessed in detail in Appendix B – 110 kV current transformer assessment and Appendix C – 220 kV current transformer assessment.

7.6 EHV CT Risk Factors

An event that involves a major failure of an EHV CT, has been identified as a key risk factor for this asset class. A major failure has the potential to impact on safety and transmission system performance due to the EHV CT's explosive nature under catastrophic conditions.

The main risks associated with TasNetworks' EHV CT assets are:

- Major asset failure; and
- Environmental risks.

The predominant causes of a EHV CT asset 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.

The environmental risk associated with EHV CTs relate to the insulation medium as outlined in section 7.1.5, however the overall risk is low due to the relative low quantities.

8 Management Plan

8.1 Historical

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

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 CTs 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 10 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 10 – 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 EHV CTs 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 EHV CTs 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 CT 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 EHV CTs have a high unit value, so a preventative corrective maintenance program represents a cost effective alternative to a reactive corrective maintenance program.

8.2.2 Routine Maintenance versus Non Routine Maintenance

Failures within EHV CTs 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 EHV CTs 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. EHV CT 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 EHV CTs 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 EHV CT population from an asset management perspective. Additional costs associated with new EHV CTs installed as part of network augmentation projects will not materially impact on the ten-year projected operational expenditure, since no testing is performed until the unit is 18 years of age.

8.3 Routine Maintenance

In the period 2000 to 2005, TasNetworks had a major focus on beginning to understand the condition of the EHV CT population. Preventive maintenance practices included electrical testing of EHV CTs on a six yearly basis. As the electrical testing process is sensitive to the prevailing ambient conditions at the time of test, other condition assessment methods are preferred to determine EHV CT electrical condition.

The revised condition assessment and maintenance practices for EHV CTs are presented in Table 7. Based on condition monitoring data, the frequency of maintenance intervals may increase towards the end of an EHV CTs life.

Table 7 – Condition monitoring and preventative maintenance practices

Classification	Frequency
All units	
Visual inspections and routine condition monitoring	Coordinated with substation inspections
Thermal imaging	Coordinated with substation thermal imaging program
Oil-filled current transformers	
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 current transformers	
Remote monitoring of SF6 gas pressure	Continuous
Electronic capturing of condition data[#]	In conjunction with thermal imaging

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

8.3.1 Insulating Oil Gas Sampling and Analysis

For oil-filled EHV CT units with oil-sampling facilities, analysis of the insulating oil can be used to determine the condition of the EHV CT. In particular, the Dissolved Gas Analysis (DGA) method can be used to identify evolving faults within an EHV CT 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 following table outlines key dissolved gas concentration limits for sealed, oil-insulated instrument transformers, which are based on limits as defined in standard IEC 60599.

Table 8 – Key DGA levels for sealed oil-insulated instrument transformers

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

There are a number of older EHV CTs that do not avail themselves to oil sampling and DGA testing. In addition, some units have unique design issues such as being fitted with silica gel breathers which compound and increases maintenance frequencies and practices.

The provision of oil sampling facilities as standard on new units allows the use of the more successful dissolved gas analysis technique for condition assessment and trending of EHV CT condition.

8.3.2 Insulating Oil Moisture Sampling and Analysis

In addition to the DGA method, measuring the water content within the insulating oil of a CT 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 current 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 2 of Australian Standard AS 1883.

Table 9 – Moisture content limits for oil-insulated transformers

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

TasNetworks has a procedure in place to ensure contractors take the oil sample correctly whilst maintaining the electrical integrity of the remaining insulating oil in the unit. The procedure also covers maintenance, cleaning, storage and handling of all sampling equipment.

8.3.3 PCB Testing Program

To mitigate the risks associated with PCB contamination, TasNetworks has implemented a program to determine the PCB levels within the EHV CT population where practicable. Of the units that have been tested to date, 12 units have PCB levels deemed to be ‘scheduled’.

All of the ‘scheduled’ units have been identified for replacement based on condition or planned decommissioning as part of recent circuit breaker replacement program.

8.3.4 SF6 Gas Management

To mitigate the risk of loss of SF6 gas to the atmosphere, TasNetworks has developed a comprehensive procedure for the management of SF6 gas, which is detailed in document TNM-PC-809-0094 D04/10176 ‘Sulphur Hexafluoride Gas Management Procedure’

8.3.5 Power Factor Testing

The power factor test provides an indication of the dielectric losses within the EHV CT 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 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.

8.3.6 Insulation Resistance Measurements

Insulation resistance values are compared with previous test results to identify any damage or contamination to the EHV CT 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, or that moisture is present.

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.

8.3.7 SF6 Gas Sampling and Analysis

For SF6 gas-insulated EHV CTs, gas sampling and analysis can be used to determine EHV CT condition. In particular, measurement of the moisture present within the gas provides 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 EHV CTs are typically specified by the manufacturer.

SF6 analysis can also be used as a diagnostic tool in the event of a EHV CT 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.

TasNetworks has a procedure in place to ensure contractors take the gas sample correctly whilst maintaining the electrical integrity of the remaining insulating gas in the unit. The procedure also covers maintenance, cleaning, storage and handling of all sampling equipment.

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 an EHV CT resulting in extended network outages, TasNetworks has standardised on the use of oil-filled EHV CTs for new or replacement installations. By standardising equipment through the use of period supply contracts greater reliability can be achieved. Subjective condition monitoring data is also standardised, making interpretation of condition monitoring results more successful.

8.6 Regulatory Obligations

8.6.1 Asset Compliance

The Rules and Metrology Procedure require that metering providers maintain Metering Installations

All metering EHV CTs installed on TasNetworks electricity network need to be provided, installed and maintained in accordance with the NER, or by an alternative process that is acceptable to AEMO.

The NER imposes strict guidelines in relation to outages caused by transmission circuit protection. The NER implies that if a complete and fully functional protection scheme (including EHV CT cores) is not in place, then the primary circuit must also be out of service. TasNetworks has taken the view that duplicated protection schemes are required for all transmission circuits.

An audit of TasNetworks' protection schemes undertaken in 2005 identified that some installations, where four core EHV CTs are used, did not comply with the NER because the 'A' and 'B' protection schemes were both supplied via the same core in the EHV CT. TasNetworks has initiated a program to replace the identified four core EHV CTs with five core units to remove the reliance of both protection schemes on one EHV CT core. EHV CTs that do not comply with the NER requirements include:

- 220 kV CTs at Sheffield Substation (ABB typeTMBRI245) 17 units, SH-B196, SH-C196, SH-D196, SH-E196, SH-F196, SH-J196.

The NER also has guidelines in relation to accuracy and testing of the installation, as well as communications interfaces for devices with capability for remote acquisition of metering data.

8.6.2 Service Obligations for network assets

Current 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.

8.6.3 Service obligations for non-regulated assets

8.6.3.1 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.

8.6.3.2 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.

8.6.3.3 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

In the event that increased maintenance levels are required, the decision to replace an EHV CT may be justified.

The decision to replace or decommission EHV CTs is not driven by age alone but considers a combination of other criteria in the decision process, such as obsolete designs, spares availability, and manufacturer support. These factors together with other condition monitoring techniques are aligned with capital works programs which determine when the EHV CTs should be replaced.

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

8.7.1 110 kV Current Transformers

There are 3 110 kV EHV CTs that have reached, or are approaching, the end of their service lives. The probability of failure for an EHV CT increases significantly towards the end of its service life.

The following 110 kV EHV CT units will require replacement. The replacement of these units will be undertaken in conjunction with other planned capital works as appropriate.

Table 10 – 110 kV current transformers planned replacements

Manufacturer	Type	Station	Units
Endurance Electric	IC-115	Ulverstone	3
Total			3

The circuit breaker replacement strategy includes the use of dead tank circuit breakers with integral EHV CTs where appropriate.

An EHV CT replacement program is in place to address design, reliability, performance and standardisation issues and high maintenance and repair costs associated with the EHV CT population.

The number of EHV CT replacements is expected to increase as asset replacement and augmentation projects are identified in future revenue reset periods.

8.7.2 220 kV Current Transformers

The replacement of 17 220 kV EHV CTs that are approaching, or are at the end of their service lives will be coordinated with other planned capital works. As well these CT's (ABB typeTMBRI245) only have 4 cores whilst the current TasNetworks standard is minimum 5 cores. This in effect has removed one protection class core.

A condition assessment determination of the design, compliance and physical parameters indicates that there are a number of EHV CTs where, as a result of their vintage, certain unique design issues pose constraints on new condition monitoring techniques and complicate and increase maintenance frequencies.

The following table identifies the 220 kV EHV CTs that are planned to be replaced:

Table 11 – 220 kV current transformers identified for replacement

Manufacturer	Type	Units
Brown Boveri	TMBRI245	17
Total		17

8.8 Program Delivery

The assessment requirements 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

To implement the spares availability policy referred to in section 7.1.1, TasNetworks has both 110 kV and 220 kV EHV CT spares located in TasNetworks' primary store in Bridgewater. The EHV CTs spare parts cover a wide range of manufacturers and equipment ages.

The practice to use standard EHV CTs for any new installations on the TasNetworks' system, as well as the adoption of oil as the preferred insulation medium will assist in the logistics and management of spares.

Details of the available spares are provided in Appendix D – Spare Current transformer units.

8.10 Disposal Plan

TasNetworks' current strategy is to utilise dead tank circuit breakers with integral EHV CTs in its circuit breaker replacement program, which will result in the decommissioning of a number of 110 kV post-type current transformers. Prior to disposing of decommissioned EHV CTs, units will be reviewed to determine their suitability as system spare units (in accordance with TasNetworks' System Spares Policy, document or redeployed elsewhere in the transmission system.

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

8.11 Summary of Programs

Tables 12 and 13 provide a summary of all of the programs/projects described in this management plan.

Table 12: Summary of EHV CT OPEX programs / projects

Work Program	Work Category	Work Category	Project/Program
Routine Maintenance	CMCTE	Corrective maintenance	S057-SUBS-Corrective-Current Transformer EHV
	PMCTE	Preventative maintenance	S213-Current Transformer Electrical Tests EHV
	PMCTE	Preventative maintenance	S229-Current Transformer Oil Samples EHV

Table 13: Summary of EHV CT CAPEX programs / projects

Work Program	Work Category	Project title	Project/Program details
Capital	RENSB	Replace Current Transformers (ABB TMBRI245)	Replace remaining fleet of ABB TMBRI245 220 kV CT's (17 in total) at Sheffield Substation which comprise the following designations: SH-B196, SH-C196, SH-D196, SH-E196, SH-F196, SH-J196.
	RENSB	Replace Ulverstone 110 kV CTs A796	Replace Ulverstone 110 kV CT A796 (3 units)

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 EHV CT 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. Extra High Voltage Current Transformer Standard R522690
10. Extra High Voltage System Standard, 2013 R586386

Other standards and documents:

11. Australian Standard AS 1883 ‘Guide to maintenance and supervision of insulating oils in service’, Standards Australia, 1993
12. Australian Standard AS 4360 ‘Risk Management’, Standards Australia, 2004
13. Australian Standard AS 60044.1-2007 Instrument transformers Part 1: Current transformers
14. Australian Standard AS 2067-2008 : Substations and high voltage installations exceeding 1 kV a.c
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

Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S057-SUBS-Corrective-Current Transformer EHV	CMCTE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
S213-Current Transformer Electrical Tests EHV	PMCTE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
S229-Current Transformer Oil Samples EHV	PMCTE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
Replace Current Transformers (ABB TMBRI245)	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Capex	Low
Replace Ulverstone 110 kV CTs A796	RENSB	Medium	Customer Regulatory Compliance Safety	Capex	Low

Appendix B – 110 kV current transformer assessment

110 kV EHV CTs 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.

Asea Brown Boveri

Asea Brown Boveri 110 kV current transformers are in service as follows:

Table 14 – 110 kV Asea Brown Boveri EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
IMBM145SP1T4	Oil	New Norfolk	G696 G696N	11	4
		Chapel Street	A696 B696	13	8
236080	Oil	Rosebery	B496A	14	3
913662	Oil	George Town	A696	18	3
389483	Oil	George Town	T196	20	3
309457	Oil	Lindisfarne	A696	20	3
		Risdon	J696	20	3
			K696	64	3
HPM123PIT4	Oil	Lindisfarne	A696N	20	1
		Risdon	J696	20	1
			K696N	20	1
834348	Oil	Trevallyn	C196 H496	19	6
Total number of units in service					**39**

Electrical condition

Condition monitoring results for each of the Asea Brown Boveri type EHV CTs indicates the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident for Asea Brown Boveri EHV CTs that will impact on the ongoing management of the units. Where DGA sampling is used for condition assessment, it should be noted that most of these units are filled with an oil/sand mixture.

For types 309457, 389483, HPM123 and 834348 a drain valve is present and DGA sampling is possible.

Future management strategy

Oil sampling and analysis will be trialled on units fitted with oil drain valves. The remainder will be examined closely to determine if DGA testing is possible without risking the integrity of the units. Where oil sampling is not practicable, electrical testing will be continued.

Decommissioned Asea Brown Boveri EHV CTs will be used elsewhere in the transmission system where possible or retained as spares in accordance with spares policy.

Endurance Electric

Endurance Electric 110 kV EHV CTs are in service as follows:

Table 15 – 110 kV Endurance Electric EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
Drg. 021533	Oil	Derwent Bridge	A496	9	1
		Lindisfarne	G196	52	3
IC-115	Oil	Ulverstone	A796	49	3
Total number of units in service					**7**

Electrical condition

Condition monitoring results for each of the Endurance Electric type EHV CTs indicate the units are in acceptable electrical condition.

Design considerations

There are no design issues evident with Endurance Electric EHV CTs. The units are not fitted with oil sampling facilities.

Future management strategy

Type Drg. 021533 and IC-115 EHV CTs are of an obsolete design and are no longer supported by manufacturers. The remainder of units should be progressively decommissioned in conjunction with other planned capital works.

Electrical testing should be continued for condition assessment purposes until Endurance Electric units are decommissioned.

Haefely

Haefely 110 kV current transformers are in service as follows:

Table 16 – 110 kV Haefely EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
IOSK123/230/550	Oil	Chapel Street	E496 F496	34	6
		Farrell	N196	14	1
		Farrell Sheffield	B596 A596	34	6
			B796 N196 P196 S196 T196	35	17
			B596	32	3
		Ulverstone	B196	35	3
Total number of units in service					**36**

Electrical condition

Condition monitoring results for each of the Haefely type EHV CT indicates the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Haefely 110 kV EHV CTs. A drain plug and oil filling plug is available to enable oil sampling and DGA testing.

Future management strategy

DGA should be adopted for the condition assessment of Haefely EHV CTs.

Koncar

Koncar 110 kV EHV CTs are in service as follows:

Table 17 – 110 kV Koncar EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
AGU123	Oil	Risdon	C696	7	3
			D696	7	3
Total number of units in service					**6**

Electrical condition

Condition monitoring results for each of the Koncar type EHV CT indicates the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Koncar 110 kV EHV CTs.

Future management strategy

Electrical testing should be continued for condition assessment purposes.

Laur Knudsen

Laur Knudsen 110 kV EHV CTs are currently in service as follows:

Table 18 – 110 kV Laur Knudsen EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
A8Z X	Oil	Palmerston	P196	53	3
Total number of units in service					**3**

Electrical condition

Condition monitoring results for each of the Laur Knudsen type EHV CTs indicate the units are in an acceptable electrical condition. Some units at Palmerston Substation have revealed low insulation resistance values.

Design considerations

Laur Knudsen EHV CTs are fitted with silica gel breathers which require ongoing maintenance.

Future management strategy

Laur Knudsen units have been superseded or are of an obsolete design and are no longer supported by the industry manufacturers. All EHV CTs are associated with circuit breakers that are scheduled to be replaced with dead tank circuit breakers with integral EHV CTs. Decommissioning of the units should occur in conjunction with other planned capital works at the respective sites.

Electrical testing should be continued for Laur Knudsen EHV CTs until the units are decommissioned. P Bay at Palmerston is expected to be refurbished in 2018 with the removal of these CTs and replaced with integral units in a new dead tank circuit breaker.

Modern Products

Modern Products 110 kV EHV CTs are in service as follows:

Table 19 – 110 kV Modern Products EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
Drg. 043012	Oil	Boyer	A496A B496	32	6
Total number of units in service					**6**

Electrical condition

Condition monitoring results for each of the Modern Products type EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no significant design issues evident in these units. A unit installed as part of Boyer B496 had shown oil leaks and was replaced by a unit of the same design in 2007. Repairs will be carried as required on the removed unit in order to retain it as a spare.

Modern Products EHV CTs are fitted with a drain valve and are suitable for oil sampling.

Future management strategy

DGA sampling will be conducted on these units as the primary condition monitoring method.

Passoni Villa

Passoni Villa 110 kV EHV CTs are in service as follows:

Table 20 – 110 kV Passoni Villa EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
CTS-166	SF6	Chapel Street	G196	12	3
		Derwent Bridge	A496	14	2
Total number of units in service					**5**

Electrical condition

Condition monitoring results for each of the Passoni Villa type EHV CTs indicate the units are in acceptable electrical condition.

Design considerations

Two Passoni Villa type EHV CTs have had gas leaks which have been detected by low gas alarms. Both units were repaired but the blue phase unit at Derwent Bridge Substation failed in December 2007 through suspected moisture ingress. TasNetworks suspects poor construction through the fitting of incorrect or poorly manufactured gaskets as the cause of the gas leak.

Future management strategy

Consideration should be given to replacing the leaking unit at Derwent Bridge Substation in conjunction with other planned capital works. The replacement will be justified by the relatively high repair cost when compared with the cost of replacement.

On-line monitoring of SF6 gas pressure will be used to monitor the condition of Passoni Villa EHV CTs.

Ritz

Ritz 110 kV EHV CTs are in service as follows:

Table 21 – 110 kV Ritz EHV CTs in service

Type (RITZ)	Insulant	Location	Device number	Average age (years)	Number of units
OSKF123	Oil	Sheffield	A696N	10	1
		Burnie	F696N	12	1
Total number of units in service					**2**

Electrical condition

Condition monitoring results for the Ritz type EHV CTs indicates that the unit is in an acceptable electrical condition.

Design considerations

This unit is installed on the neutral point in the 110 kV capacitor bank at Burnie Substation. There are no design issues evident with the unit.

Future management strategy

DGA should be adopted for condition assessment of Ritz EHV CTs.

Tyree

Tyree 110 kV EHV CTs are in service as follows:

Table 22 – 110 kV Tyree EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
06/123/8	Oil	Norwood	A196 B196	37	6
06/123/9	Oil	Norwood	A796A	37	6
06/123/10	Oil	Rokeby	A496 B496	36	6
06/123/11	Oil	Rokeby	A196 B196	36	6
06/123/13	Oil	Bridgewater	A796 G196 H196	37	12
		Kingston	A196 B196	37	6
		Lindisfarne	F196	36	3
06/123/14	Oil	Chapel Street	A596 F196	36	6
06/123/22	Oil	Boyer	D496 C496	30	6
		New Norfolk	A496 A796 B496 D196 E196 F196 J196 K196 P196 R196	30	33
06/123/23	Oil	Sheffield	N196 V196	30	6
06/123/24	Oil	Knights Road	A496	30	3
Total number of units in service					**99**

Electrical condition

Condition monitoring results for each of the Tyree type EHV CTs indicates the units are in an acceptable electrical condition.

Design considerations

Tyree EHV CTs are fitted with interchangeable primary links. The links have been a source of minor oil leaks in the past. As such, they have also been identified as a potential source of moisture ingress.

Tyree EHV CTs are fitted with a nitrogen gas cushion.

Future management strategy

DGA should be adopted for condition assessment of Tyree EHV CTs. In particular, levels of moisture should be closely monitored.

Summary of 110 kV EHV CTs

Table 23 – 110 kV EHV CTs in service

Manufacturer	Number of units
Asea Brown Boveri	40
Endurance Electric	7
Haefely	36
Koncar	6
Laur Knudsen	3
Modern Products	6
Passoni Villa	5
Ritz	2
Tyree	99
Grand total number of units in service	**204**

Appendix C – 220 kV current transformer assessment

220 kV EHV CTs 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 220 kV EHV CTs are in service as follows:

Table 24 – 220 kV Areva EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
245	Oil	Burnie	B496	6	3
		George Town	X196	8	1
		Liapootah	E196	5	3
		Lindisfarne	D496 D796 E496 E796	6	12
		Waddamana	M196 M796 N196 N796	6	12
		Wayatinah Tee	A196 A196	5	3
Total number of units in service					**34**

Electrical condition

Condition monitoring results for each of the Areva 220 kV EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Areva 220 kV EHV CTs.

Future management strategy

Electrical testing should be continued for condition assessment until the units are replaced.

Asea

Asea 220 kV EHV CTs are in service as follows:

Table 25 – 220 kV Asea EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
IMBD245 A5	Oil	Farrell	A496 A796 B496 D196 E196 H196 J196	33	24

Type	Insulant	Location	Device number	Average age (years)	Number of units
		Sheffield	Y196 Z196	35	6
IMBD245 - ED2052	Oil	Sheffield	L196	31	3
Total number of units in service					**33**

Electrical condition

Condition monitoring results for each of the Asea type EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

Asea EHV CTs are oil/sand filled and are not fitted with an oil drain valve. It is unlikely that obtaining oil samples for condition monitoring purposes will be practicable.

Future management strategy

Electrical testing should be continued for condition assessment until the units are replaced.

Asea Brown Boveri

Asea Brown Boveri 220 kV EHV CTs are in service as follows:

Table 26 – 220 kV Asea Brown Boveri EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
TG245	SF6	Chapel Street	T196 U196	16	6
		George Town	B796 C796 D796	6	9
		Liapootah	F196 G196	14	6
		Palmerston	G196 K196 L196	14	9
		Sheffield	K196 J196	13	4
IMBD245L5T8 - 636198	Oil	Chapel Street	B196 C196 S796	19	9
		Gordon	B196 A196 A796 C796	19	12
		Liapootah	796	15	6
IMBE245LST8	Oil	Hadspen	P196 Q196 T196 V196	18	12
IMBD245L5T8 - 637139	Oil	Palmerston	A196	19	3
IMBD245 A5	Oil	George Town	B696N	17	1
Total number of units in service					**77**

Electrical condition

Condition monitoring results for each of the Asea Brown Boveri type EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

Asea Brown Boveri IMBD and IMBE245 type EHV CTs are a sand-filled design and are not fitted with an oil drain valve. It is unlikely that taking oil samples for DGA will be practicable. At the time these units were purchased, flaws in the manufacturing process resulted in large numbers of EHV CTs being filled with a wet sand mix. The wet sand introduces moisture into the insulating, thereby degrading the insulating performance. TasNetworks suspects the Asea Brown Boveri oil filled units are filled with wet sand.

TG245 units are filled with SF6 gas as an insulating medium. A TG245 EHV CT installed as C196 at Liapootah Switching Station failed in 2004 during recommissioning of secondary equipment. The failure involved an internal flashover within the EHV CT. The manufacturers report found the cause of the failure as unknown.

Future management strategy

Electrical testing should be continued for condition assessment of type IMBD245 and IMBE245 EHV CTs and the possibility of DGA testing will be seriously investigated because it provides an ideal means of ascertaining the moisture content of the oil. These units will be closely monitored because they are not expected to reach their nominated service life of 45 years.

On-line monitoring of SF6 gas pressure will be used to monitor the condition of TG245 type EHV CT.

Brown Boveri

Brown Boveri 220 kV EHV CTs are in service as follows:

Table 27 – 220 kV Brown Boveri EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
TMBRI245	Oil	Sheffield	C196 -B F196 -B/R/W	15	4
			E196 – B/R/W	45	3
			C196- -R/W	47	2
			B196 -B/R/W	48	3
			D196-B/R/W J196 -R	49	4
			J196-B	50	1
Total number of units in service					**17**

Electrical condition

Condition monitoring results for each of the Brown Boveri type EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

Brown Boveri EHV CTs have a 600/1 tap which constrain the primary transmission circuit ratings.

Future management strategy

DGA should be adopted for condition assessment of Brown Boveri EHV CTs. In particular, levels of moisture should be closely monitored.

All these 220 kV CTs at Sheffield Substation (17 units, SH-B196, SH-C196, SH-D196, SH-E196, SH-F196, SH-J196) are targeted for replacement in the next regulatory period (2019-24) due to age and that they do not comply to current TasNetworks standard which specifies minimum 5 cores and these units only have 4.

Haefely Trench

Haefely Trench 220 kV EHV CTs are in service as follows:

Table 28 – 220 kV Haefely Trench EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
SAS 245/OG	SF6	Farrell	A196 B196	18	6
		George Town	B696	17	3
		Liapootah	D196 H196	17	9
		Palmerston	J196	18	3
Total number of units in service					**21**

Electrical condition

Condition monitoring results for each of the Haefely Trench type EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Haefely Trench EHV CTs.

Future management strategy

On-line monitoring of SF6 gas pressure will be used to monitor the condition of Haefely Trench current transformers.

Mitsubishi

Mitsubishi 220 kV EHV CTs are in service as follows:

Table 29 – 220 kV Mitsubishi EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
SBW02L	Epoxy	George Town	C196	4	3
Total number of units in service					**3**

Electrical condition

Condition monitoring results for each of the Mitsubishi 220 kV EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Mitsubishi 220 kV EHV CTs.

Future management strategy

Electrical testing should be continued for condition assessment.

Ritz

Ritz 220 kV EHV CTs are in service as follows:

Table 30 – 220 kV Ritz EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
OSKF245	Oil	George Town	A796 B496 C496 X196 H796 Z196	10	17
		Liapootah	C196	10	3
		Palmerston	A496 F196	10	6
Total number of units in service					**26**

Electrical condition

Condition monitoring results for each of the Ritz EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with Ritz EHV CTs.

Future management strategy

DGA should be adopted for condition assessment of Ritz EHV CTs.

TWS

Table 31 – 220 kV TWS EHV CTs in service

Type	Insulant	Location	Device number	Average age (years)	Number of units
SBW02L	Epoxy	George Town	D196	4	3
Total number of units in service					**3**

Electrical condition

Condition monitoring results for each of the TWS 220 kV EHV CTs indicate the units are in an acceptable electrical condition.

Design considerations

There are no design issues evident with TWS 220 kV EHV CTs.

Future management strategy

Electrical testing should be continued for condition assessment.

Summary of 220 kV EHV CTs

Table 32 – 220 kV EHV CTs in service

Manufacturer	Number of units
Areva	34
Asea	33
Asea Brown Boveri	77
Brown Boveri	17
Haefely Trench	21
Mitsubishi	3
Ritz	26
TWS	3
Grand total number of units in service	**214**

Appendix D – Spare current transformer units

The following tables detail TasNetworks' spare 110 kV and 220 kV current transformer units that are deemed suitable for service. The units are located at TasNetworks' store in Bridgewater.

Table 33 - 110 kV operational spare current transformer listing

Manufacturer	Type	Insulant	Location	Device number	Average age (years)	Number of units
Asea Brown Boveri	236080	Oil	Primary Store	A496A	15	3
				B496A		
			Tungatinah	A496	15	3
			Primary Store	F796A-B40038	18	6
				F796A-R40036		
				F796A-W40037		
				F796B-B40050		
				F796B-R40048		
				F796B-W40049		
				B596	28	1
	HPM123 PIT4			96-60790	0	0
	138185			96-61220	28	4
	451844			I196	28	3
	Drg. 043012			96-243378	23	3
				96-243380		
				96-243381		
Dickson Primer	Dickson Primer	Oil	Primary Store	96-61290	0	0
Endurance Electric	Drg. 021533	Oil	Primary Store	D196	51	1
Haefely	IOSK123/23/550	Oil	Primary Store	96-52618	32	4
				96-52640		
				96-52643		
				96-61209		
Koncar	AGU123	Oil	Primary Store	196-252769 196-252770 196-252771	3	3
Laur Knudsen	A8ZX	Oil	Primary Store	A496	0	0
Modern Products	Drg. 043012	Oil	Primary Store	A196-40121	34	2
				A196-40122		
				B496-60583		
Tyree	06/123/9	Oil	Primary Store	96-61213	35	1
	06/123/10			96-52828	33	1
	06/123/13			96-61201	0	0
	06/123/14			96-52796	35	3
				96-52797		
				96-52798		
	06/123/22			96-61210	28	3

Manufacturer	Type	Insulant	Location	Device number	Average age (years)	Number of units
				96-61211		
				96-61212		
	06/110			96-52576	36	3
				96-52582		
				96-52583		
				96-61219	44	4
Total number of operational spares						**48**

Table 34 - 220 kV operational spare current transformer listing

Manufacturer	Type	Insulant	Location	Device number	Average age (years)	Number of units
Areva	OSKF245	Oil	Primary Store	196-255694	10	3
		Oil	Primary Store		5	1
ASEA	IMBD245 A5	Oil	Primary Store	96-60262	35	1
	IMBD245 A6			B196	37	3
Asea Brown Boveri	TG245	SF6	Primary Store	B796-R61234	17	1
				A196	15	1
	IMBE245LST8	Oil		96-67314	16	1
	IMBD245L5T8 - 636198			96-67422	20	1
RITZ	OSKF245	Oil	Primary Store	96-244160	13	1
Total number of Strategic spares						**13**