TasNetworks
Delivering your power

Asset Management Plan

EHV Circuit Breakers

Record Number: R40413

Version Number: 2

Date: October 2017

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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 circuit breakers. 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) circuit breakers for a ten year rolling planning period. The objective of this plan is to maintain and minimise business risk to acceptable levels by achieving reliable asset performance at minimal life-cycle cost.

TasNetworks EHV circuit breakers covers 110 kV and 220 kV live-tank and dead-tank circuit breakers. The plan does not include asset management aspects of circuit breakers associated with EHV gas-insulated switchgear (GIS) installations.

TasNetworks has a population of 328 EHV circuit breakers in service, including 236 units operating at 110 kV and 92 units at 220 kV. This chapter provides high level information on the population.

3 Strategic Alignment and Objectives

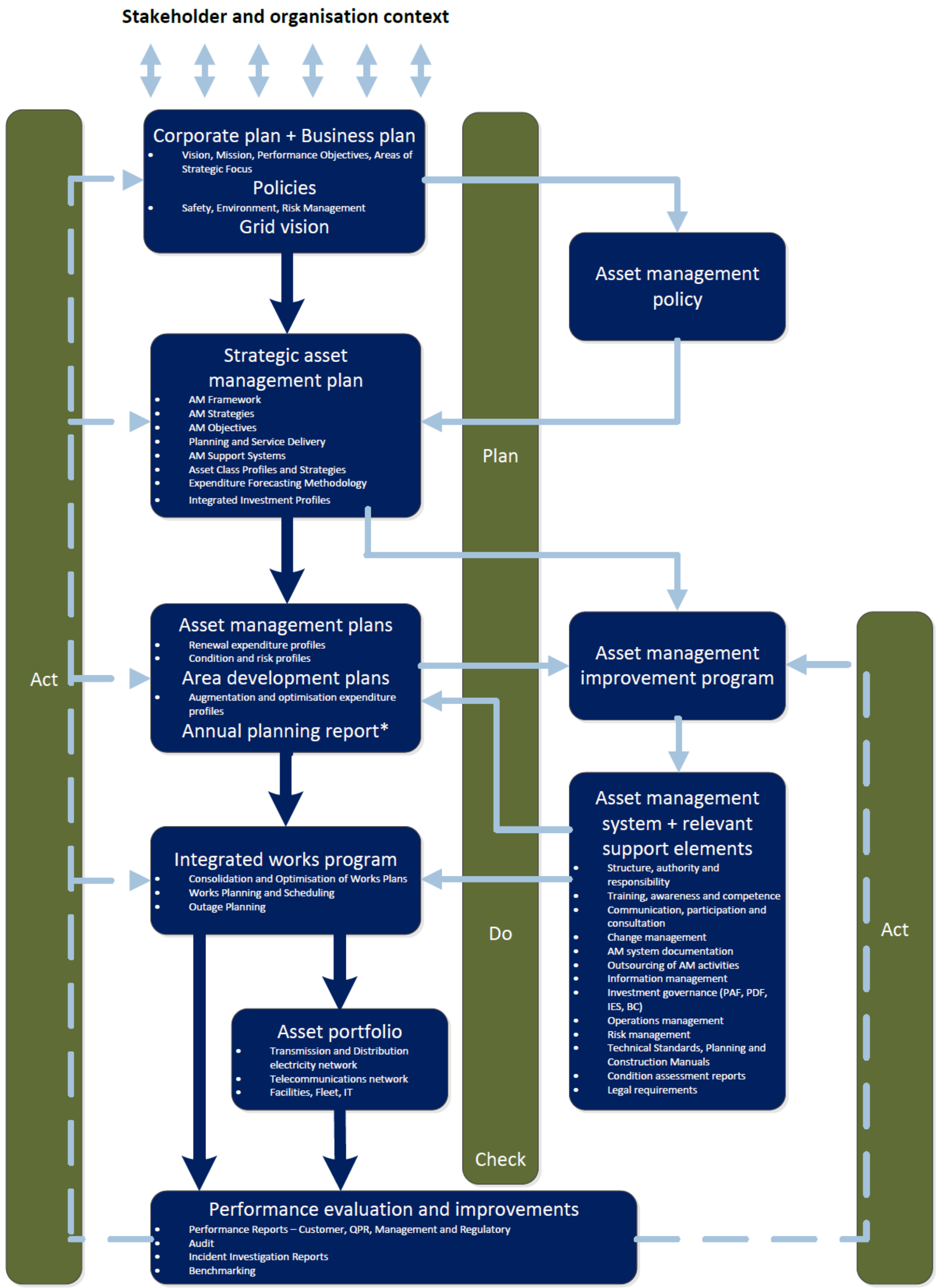
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives. This management plan describes the asset management strategies and programs developed to manage the circuit breaker assets, with the aim of achieving these objectives.

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) which contains detailed information relating to the circuit breaker population. AMIS is a combination of 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 the results for supply transformers feed directly into the development of probability of failure and consequences in the Condition Based Risk Management tool.

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

4.2 Asset Information

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

- R17042 WASP Asset Register – Data Integrity Standard – Circuit Breaker

4.2.1 AM8 Condition data

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

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

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

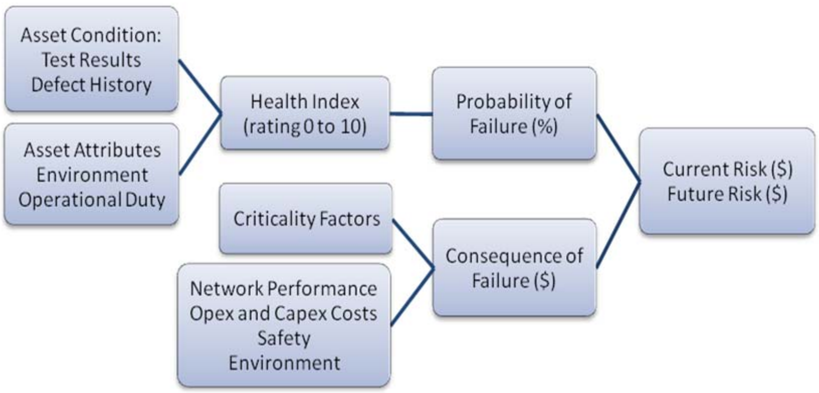
A number of observations were concluded as part of the review including the need to obtain condition data consistently across all asset types and in electronic form. The need for storage and collection would align with other business initiatives such as the AJILIS project.

4.3 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.

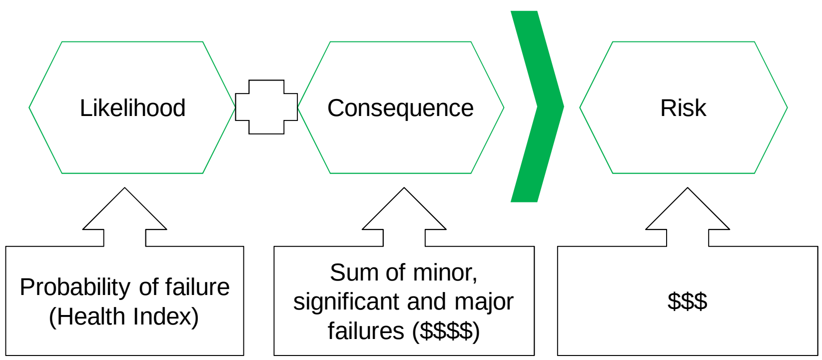
Figure 2: Asset risk framework



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

Figure 33 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).

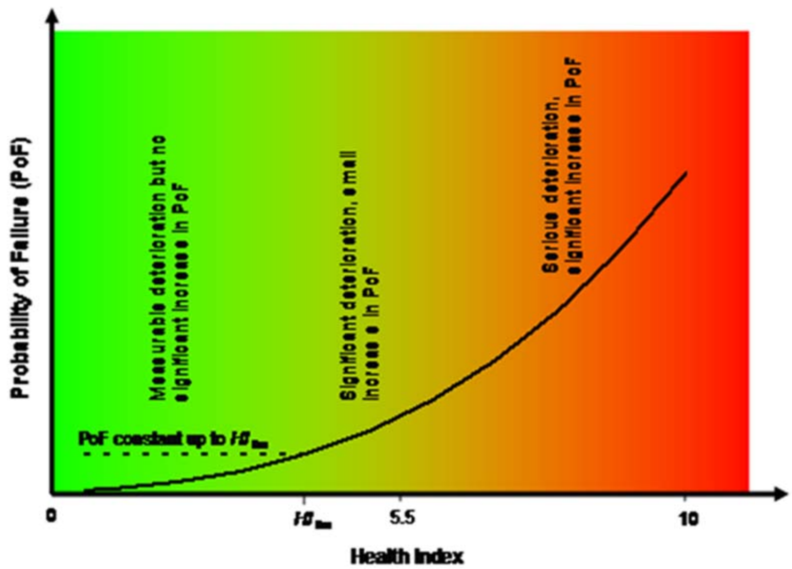
Figure 4: Health index interpretation

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

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 circuit breakers will be added into the CBRM tool in the near future. At present a spreadsheet has been devised which is a close CBRM equivalent. The results from this spreadsheet have been utilised in the preparation of the regulatory submission for 2019-2024 and out to 2029.

5 Description of the Assets

EHV circuit breakers are used to switch load currents, control power flows within the transmission network and interrupt fault currents when operation is initiated by electrical protection schemes. Fault clearance times must be in accordance with the National Electricity Rules (NER) requirements to enable containment of faults and reduce impacts on the power system.

TasNetworks' circuit breakers are categorised based on the construction and insulating medium used.

The categories include:

- Oil-filled live-tank circuit breakers (21 units in service);
- SF6 gas-filled live-tank circuit breakers (100 units in service); and
- SF6 gas-filled dead-tank breakers with integral current transformers (207 units in service).

TasNetworks' population of circuit breakers includes units constructed by nine manufacturers comprising 25 different types. Condition monitoring results for each of the types varies substantially because different design and construction methods are used for each type. Of the 25 types of circuit breakers currently in service, 16 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 circuit breaker 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 inventory management issues.

5.1 EHV Circuit Breaker types

5.1.1 Total Population by manufacturer

A summary of TasNetworks' circuit breakers by manufacturer is provided in Figure 66.

Figure 6 – Number of circuit breakers by manufacturer (as of August 2017)

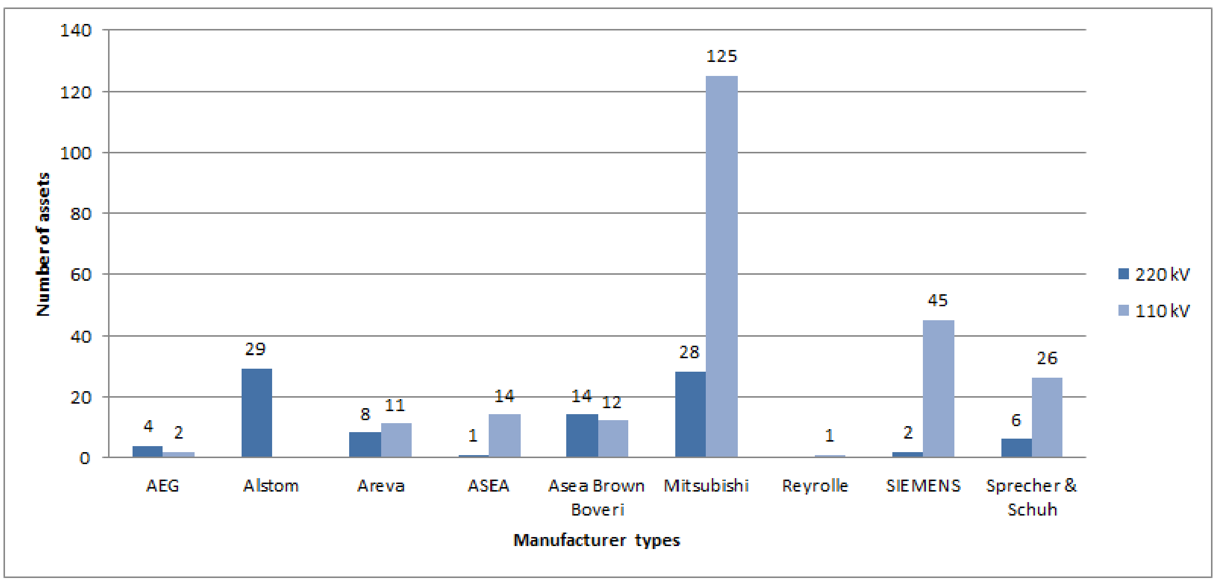


Figure 7 – 110 kV circuit breakers by manufacturer and design principle (as of August 2017)

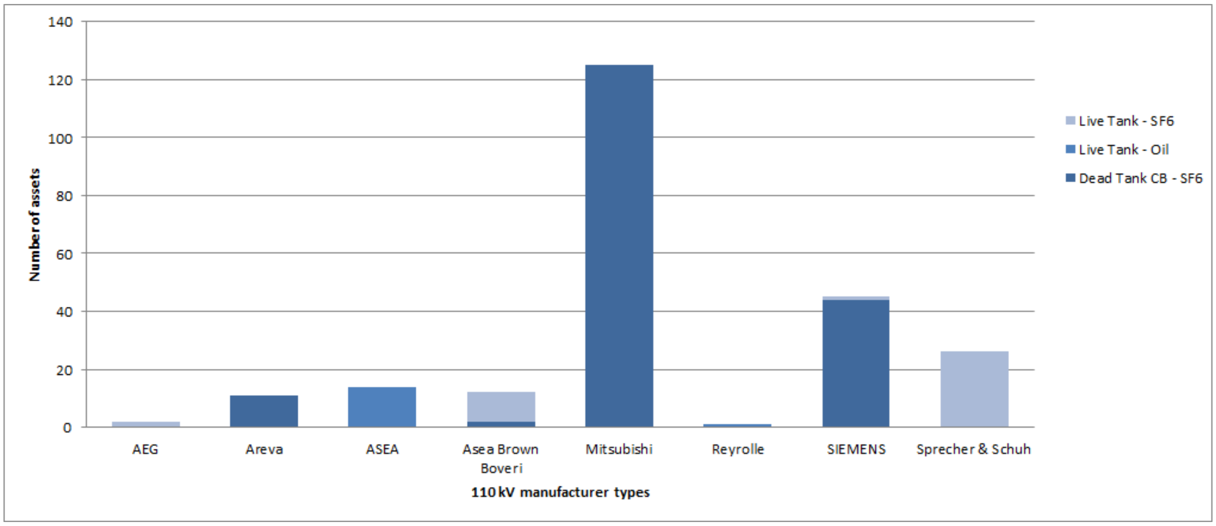
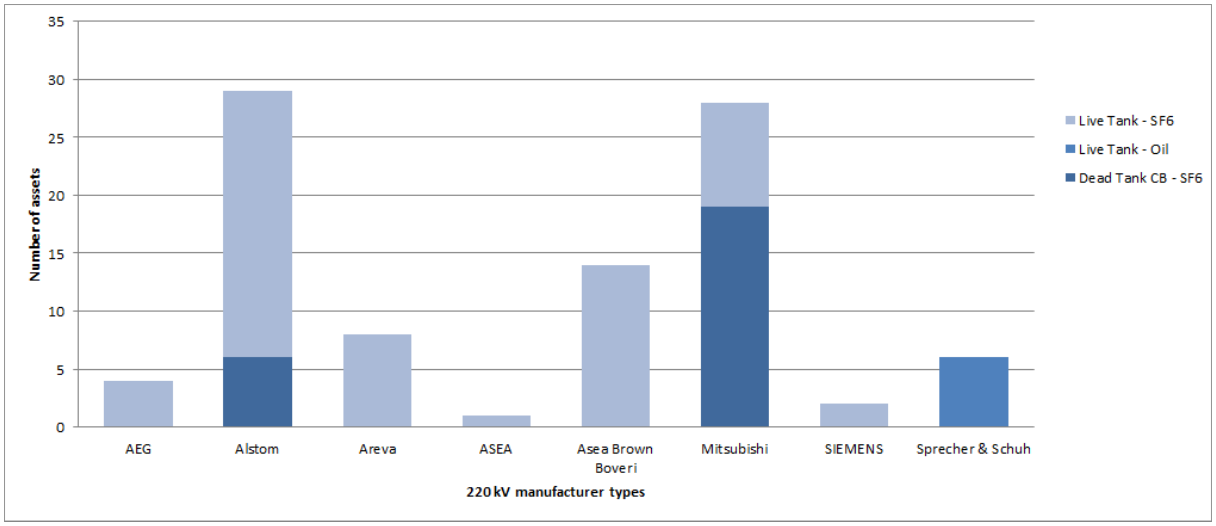


Figure 8 – 220 kV circuit breakers by manufacturer and design principle (as of August 2017)



5.1.2 Total Population by Age

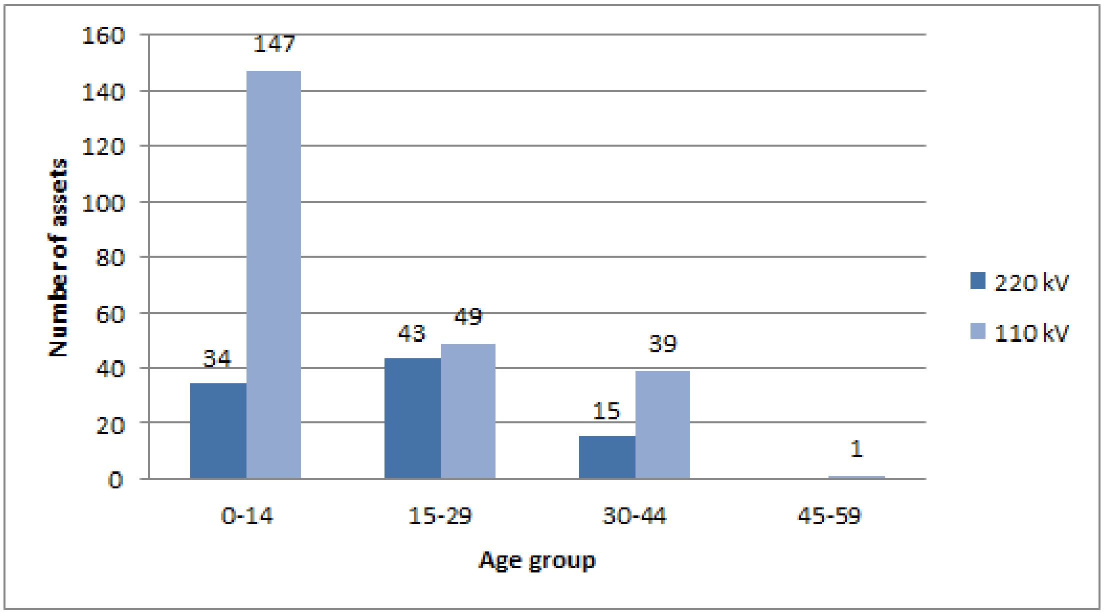
Circuit breakers have an assigned average service life of 45 years. The average age of TasNetworks' circuit breaker population is 15.3 years. The average age for 220 kV and 110 kV circuit breakers is 17.5 and 14.4 years respectively. There is 1 unit (110 kV) that has exceeded the average service life for circuit breakers, another 6 units (all 220 kV) that will exceed this average service life in the next 5 years and a further 12 units (all 110 kV) within the next 10 years.

TasNetworks' previous circuit breaker replacement program commenced in 1993 with completion targeted for 2014, with its primary objective being to address compliance, performance and life-cycle asset management issues. The program progressed well with several circuit breaker populations replaced prior to the completion of the program in 2014. These comprise the replacement of the remaining Sprecher and Schuh type HPF 110 kV, Reyrolle type 110/OS and Siemens type H800 small oil volume circuit breakers.

With consideration of the average expected life and condition assessment, there will be several 220 kV and 110 kV circuit breakers requiring replacement over the next 10 years.

Given the relatively low average age of TasNetworks' circuit breakers, overall performance levels of the population should not be adversely affected by age-related issues. Results from International Transmission Operations & Maintenance Study ITOMS show that TasNetworks significantly improved its circuit breaker performance since 2001 to around 2013, with service level performance for 220 kV and 110 kV circuit breakers being in the top quartile up until 2013. This trend could be attributed in part to the high levels of capital investment for the targeted replacement of TasNetworks' poor performing circuit breakers with new dead tank circuit breakers with integrated current transformers, which are far less maintenance intensive than the older circuit breakers that they replaced, and demonstrate improved performance characteristics. For the 2015 reporting period the service level has dropped for both 110 kV and 220 kV circuit breakers mainly due to unplanned outages resulting from SF6 gas top ups or equipment failures.

Figure 9 – Total Population by Age profile (as of August 2017)



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 circuit breakers. The specification requires new units to be SF6 insulated, and to be designed and type-tested to Australian and international standards. It is also a requirement that circuit breakers have a history of proven service within Australia for at least three years. The technical specification encourages some standardisation of design which also addresses population type issues identified in Section 5.

6.2 Performance Objectives

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

In order to ensure that circuit breaker 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 circuit breakers for major faults through its incident reporting process. The process involves the creation of a fault incident record in the event of a major circuit breaker failure that has an immediate impact on the transmission system (eg causes an immediate trip of a transmission circuit or element). The fault is then subjected to a detailed investigation that establishes the root cause of the failure and recommends remedial strategies to reduce the likelihood of reoccurrence of the failure mode within the circuit breaker population. Reference to individual fault investigation reports can be found in TasNetworks' Reliability Incident Management System (RIMSys).

For circuit breaker 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 and trending of all circuit breaker related faults or defects.

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

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

- Plant availability:
  - Transmission line circuit availability (critical and non-critical); and

  - Transformer circuit availability.
- Supply availability:
  - Number of events in which loss of supply exceeds 0.1 system minute; and
  - Number of events in which loss of supply exceeds 1.0 system minute.

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

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

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

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

Figure 9 and figure 10 illustrates TasNetworks' benchmarked circuit breaker performance against all other ITOMS participants for the last five reporting periods. It shows that since 2007 TasNetworks has improved its service cost performance to be considerably better than the benchmarked average, while service performance has in the two latest reporting periods, 2009 and 2011, been above the benchmarked average. This trend improvement to strong service level score from 2007 to 2009 is largely contributed to the revised maintenance strategies implemented in 2008.

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

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

Figure 10 – ITOMS circuit breakers benchmarked performance chart

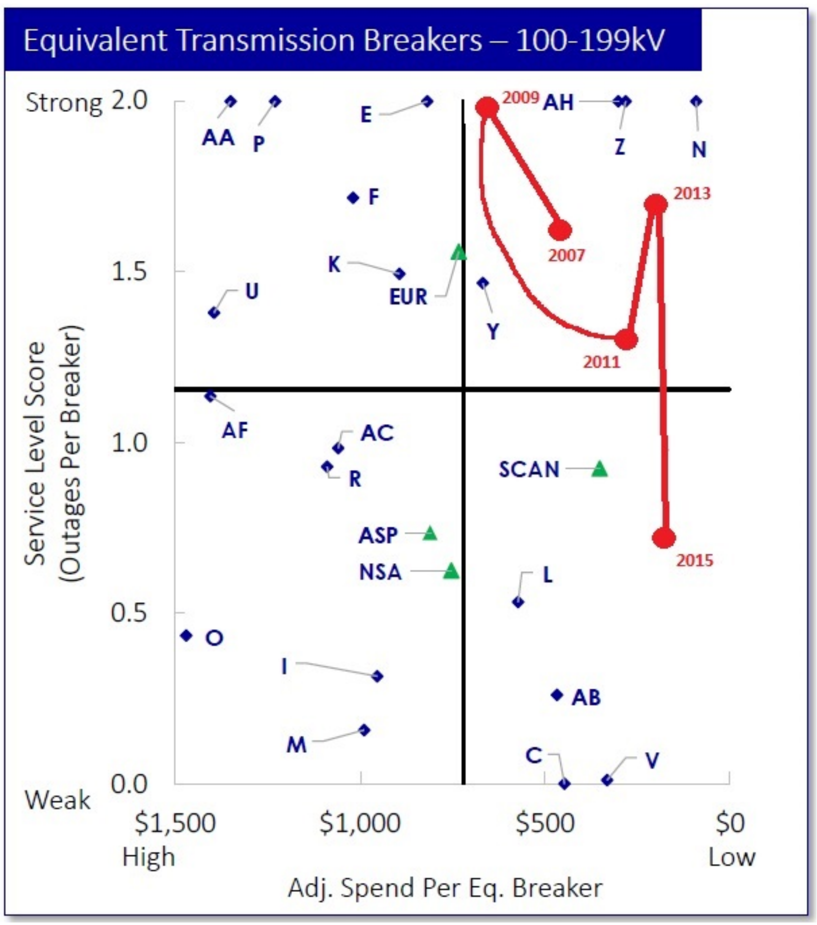
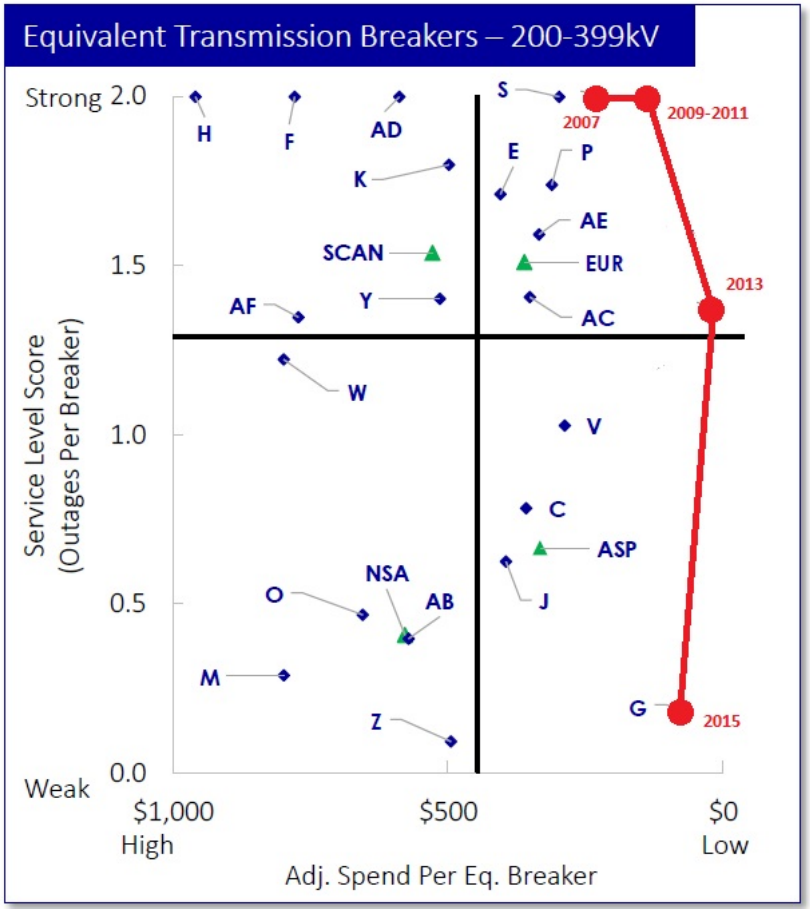


Figure 11 – ITOMS circuit breakers benchmarked performance chart



6.3.2.2 ESAA Benchmarking

TasNetworks' reporting to the ESAA covers Transmission network data of system minutes unsupplied, energy delivered and transmission circuit availability. For ESAA benchmarking network data is limited to Transmission circuits.

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 circuit breakers 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 circuit breakers in service across the network
- Criticality of EHV circuit breakers 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 EHV circuit breakers have been revised where appropriate to sustain or improve the reliability and optimise transmission system performance and to maintain TasNetworks' business risk to within acceptable levels. The adoption of contemporary asset management techniques, including Sulphur Hexafluoride (SF6) gas analysis and the implementation of on-line monitoring where practical, are aimed at reducing circuit breaker average annual preventive maintenance expenditure.

The improved preventive maintenance practices will also enhance transmission circuit availability, resulting in improved service levels to all customers.

A variety of condition assessment methods are used to determine circuit breaker electrical condition. The methods include:

- Operational duty analysis;
- High voltage electrical testing;
- Sulphur hexafluoride (SF6) gas monitoring, sampling and analysis; and
- Insulation oil monitoring, sampling and analysis.

Circuit breaker condition is determined using a combination of the condition monitoring methods, which are selected depending on the design and construction principle of specific types of units. For example, oil-filled circuit breakers are constructed using a different design and construction principle than SF6 gas-filled units, resulting in different failure modes and the need for different condition assessment methods.

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 EHV CB 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.

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

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 circuit breakers 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.

7.1.6 Failure types

The main risks associated with the circuit breaker population include major asset failure and environmental risks.

A major failure of a circuit breaker has been identified as a key risk for the circuit breaker class as it has the potential to impact on safety and transmission system performance.

The predominant causes of major circuit breaker failures include:

- 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;
- Design faults, including electrical, mechanical, choice of materials used in construction and oil or gas leaks; and
- Incorrect assembly or operation.

7.1.7 Failure analysis

An international survey conducted by Cigre categorised circuit breaker failures into two specific types:

- Major failures - sudden explosive events that cause an immediate emergency system outage or trip;

- Minor failures or defects - non-violent failures, but require an urgent system outage (eg within one hour); or incidents that require a non-urgent (planned) outage to repair or replace a unit.

TasNetworks has a defect management system that allows for accurate recording of failure or defect rates for its population of circuit breakers. An international survey of circuit breaker failures undertaken by Cigre for the period 1988 to 1991 shows that major failure rates for EHV circuit breakers. A more recent international survey by Cigre for the period 2004-2007 shows that the major failure rates remain quite low. The combination of enhanced design capability, improved manufacturing quality and control processes, and comprehensive production testing usually ensures that circuit breaker performance levels remain high throughout their service lives. Some results of the failure survey are shown in Table 1 with comparison to more recent 2007 results.

Table 1 – Failure rates for EHV circuit breakers

Circuit breaker operating voltage	**Failure rate (%) per 100 circuit breaker years**			
	Major		**Minor/ Defect**	
	1988-1991	**2004-2007**	**1988-1991**	**2004-2007**
100-200 kV	0.68	0.27	4.75	No detail
200-300 kV	0.81	0.35	6.97	No detail

Figures 12 and 13 shows a percent breakdown of primary cause of minor and major failures taken from the 2004-2007 Cigre survey. It can be seen that the most frequent cause of failure in both minor and major failures is due to wear/ageing.

Figure 12 – Primary cause of minor failure for EHV circuit breakers

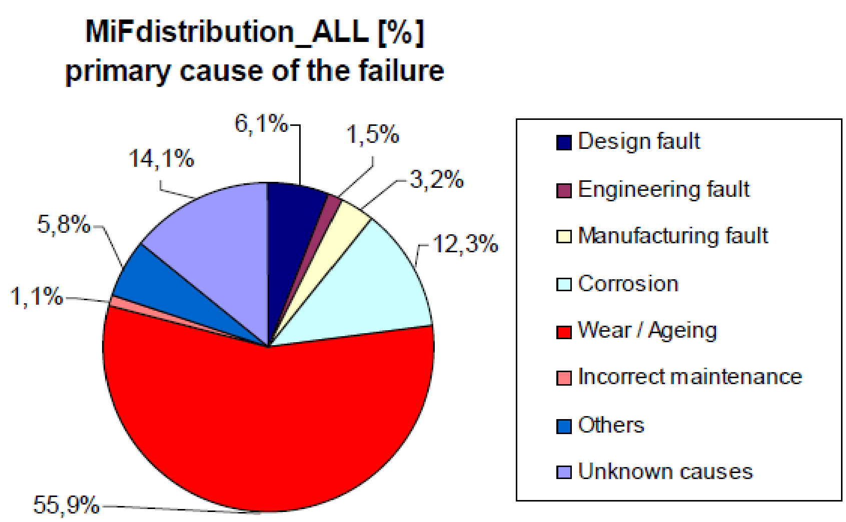
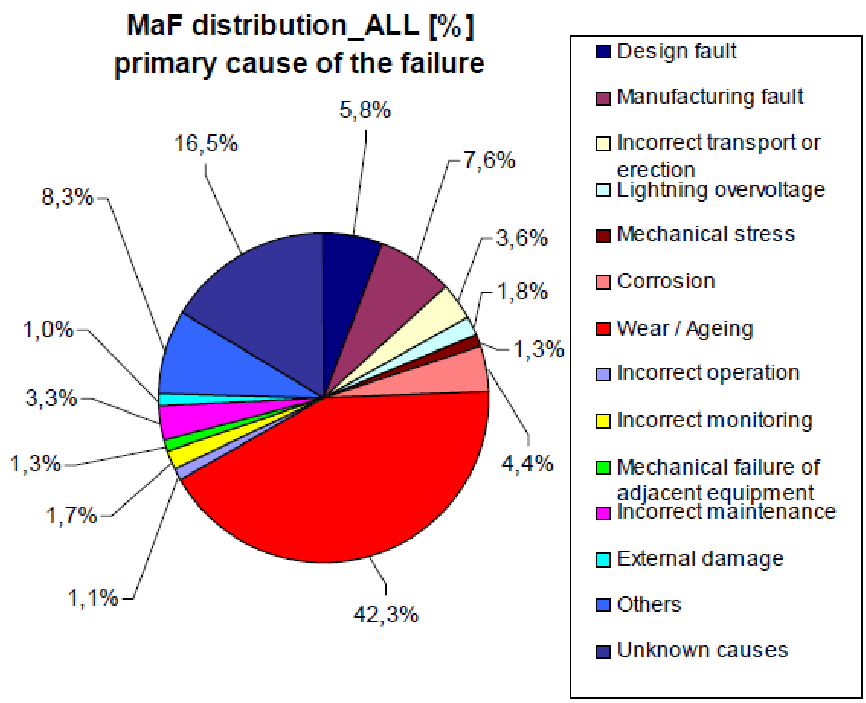


Figure 13 – Primary cause of major failure for EHV circuit breakers



7.2 110 kV circuit breaker issues

TasNetworks' has experienced a number of minor failures in the past 10 years. Such failures are considered significant in that they would generally have resulted in a forced outage, loss of supply or significant unplanned or prolonged outage to the system. Such failures include:

- ABB type LTB145D1 110 kV units at Risdon Substation failed in 2003 and 2007, and the unit at Lindisfarne Substation failed in 2005 and again in 2016, all of which involved the mechanical failure of the inter-phase linkage rod; and
- ASEA type HLD145/1250C 110 kV circuit breaker at Bridgewater Substation failed in 2003, as a result of the spring-wind motor failure. NW-B152 had latching issues with closing damper and replaced in Dec 2016.

Condition monitoring results for the circuit breaker population indicate that all units are in acceptable electrical condition, however a number of units are in poor physical condition, have design deficiencies and present an increased risk of major failure.

A detailed assessment of the condition of the 110 kV circuit breaker population is provided in Appendix C.

SF6 gas leakage has been an issue with gas top-ups being required on 12 separate occasions since 2012 (5 year period). Each top-up has required an outage which could, depending on circumstance, negatively affect TasNetworks STIPIS reporting.

7.3 220 kV circuit breaker condition issues

A detailed assessment of the condition of the 220 kV circuit breaker population is provided in Appendix D. Condition monitoring results for the population indicate that all units are in acceptable condition, however a number of units are in poor physical condition, have design deficiencies and present an increased risk of major failure. The population of 220 kV circuit breakers are not expected to present significant issues in the short to medium term. The six

Sprecher and Schuh HPF514P/4F breakers have been identified for replacement noting the similarity of the 110 kV units which were prone to failure and have already been replaced.

SF6 gas leakage has been an issue with gas top-ups being required on 10 separate occasions since 2012 (5 year period). Each top-up has required an outage which could, depending on circumstance, negatively affect TasNetworks STIPIS reporting.

7.4 Special operation and design issues

7.4.1 Operational issues

The capacity of circuit breakers is measured by two main components, the continuous current rating and the rated short circuit breaking capacity. A review of circuit breaker ratings has found that the EHV circuit breakers in the transmission system are sufficiently rated in terms of continuous current and short circuit capability ratings.

The NER places limits on the amount of time in which a transmission fault must be cleared. Whilst the operating speed of the circuit breaker population ranges from around 20 ms to 80 ms, all are within NER requirements.

7.4.2 Design issues

Circuit breaker design issues are key considerations in developing an asset management strategy for the population. Design considerations are separated into two areas, specific design issues and circuit breaker strategy.

7.4.3 Specific design issues

Circuit breaker design is an important factor that can influence both asset and transmission system performance, reliability and availability levels. In addition, design issues have a direct impact on maintenance practices and expenditure. Common technical and design deficiencies across TasNetworks' circuit breaker population include:

- Inadequate hermetic sealing resulting in moisture ingress and/or loss of the SF6 gas (for gas-filled circuit breakers);
- Rotating post insulator mechanical separation between the porcelain and metal mounting plates;
- Corrosion resulting in operating linkages to cease or facture;
- Use of pneumatic drive systems and the associated leaks (where installed);
- Motor limit switches susceptibility to failure;
- Adjustment and operation of moving assemblies; and
- Manufacturer support and the availability of spare parts.

Design considerations for specific circuit breakers (grouped by manufacturer and type) are assessed in detail in Appendices B and C.

8 Management Plan

8.1 Historical

Historically, management of EHV circuit breakers has been undertaken based primarily on condition and condition assessments. This will be continued into the future through inclusion of a Condition Based Risk Management (CBRM) program which aligns with direction provided in TasNetworks Strategic Asset management Plan (SAMP). Figure 14 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 14 – 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 circuit breakers 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 circuit breakers 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 circuit breaker 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 circuit breakers 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 circuit breakers 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 circuit breakers 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 circuit breakers 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 circuit breakers 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 Annual Planning Report (AMP), which is updated on an annual basis.

Proposed network augmentation projects identified in the AMP will have a minimal impact on the EHV circuit breakers population from an asset management perspective. Additional costs associated with new EHV circuit breakers 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

The performance of circuit breakers 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.

Condition assessment and maintenance practices for circuit breakers are presented in Appendix B. Based on condition monitoring data, the frequency of maintenance intervals may increase towards the end of a circuit breaker's life. In the event that increased maintenance levels are required, the decision to replace the unit may be justified depending on the impact on maintenance expenditure and the potential impact on transmission system performance.

Table 2 – Condition monitoring and preventative maintenance practices

Classification	**Frequency**
All units	
Visual inspections and routine condition monitoring	Quarterly
Thermal imaging	Coordinated with substation thermal imaging program
Operational checks (as per maintenance standards which typically aligns with a specific time and not number of operations) *Note: For breakers used for capacitor switching particular note of operations counter to be made to ascertain if maintenance period needs to be earlier than standard frequency.*	18 years after commissioning and every six years thereafter.
Timing tests – Performed on all units requiring Point on Wave (POW) switching and any non-mechanically ganged units. An indicative sample will be taken for units that are mechanically ganged.	Coordinated with operational checks on selected units
SF6-insulated CBs	
Monitoring of SF6 gas pressure	Continuous
SF6 dew point	As required
Electrical testing of bushings (porcelain only)	18 years after commissioning and every six years thereafter
Monitoring of air pressure (pneumatically driven)	Continuous
Small Oil Volume CBs	
Electrical testing of bushings (porcelain only)	Every six years
Oil maintenance	Every six years

Monitoring of air pressure (pneumatically driven)	Continuous
Electronic capturing of condition data#	In conjunction with thermal imaging

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

8.3.1 On-line monitoring

TasNetworks has separate programs for protection equipment upgrades and a rollout of a wide area network (WAN). The combination of these two projects and the associated increasing capability of supervisory control and data acquisition (SCADA) are providing the opportunity to implement a number of on-line monitoring schemes.

A program will be developed to formalise the on-line condition monitoring requirements for the circuit breaker population. The likely items for monitoring will include circuit breaker operating times, actual fault and load current interrupted, counts of operations and SF6 gas pressure.

8.3.2 PCB testing

TasNetworks completed its program to determine the PCB levels within the circuit breaker population to mitigate the risks associated with PCB contamination. PCB details have been recorded against each asset in WASP.

All new oil purchased is certified as PCB free

8.3.3 Potential future maintenance practices

TasNetworks recognises that a proactive approach to life-cycle management of its assets is an established and accepted practice within the electrical industry. This is evident through TasNetworks' participation in various benchmarking and best practice activities, locally and internationally. As part of this participation, TasNetworks may make provision for, identify, develop, participate and or pilot various initiatives in the normal course of business. Initiatives are likely to be made and pursued in the areas as represented in **Error! Reference source not found.**6.

Table 3: Technology and innovation initiatives

Initiative	Rationale	Driver
Online condition monitoring	• The introduction of new measurement techniques and technologies • Increased utilisation of intelligent condition monitoring systems	• Improved assessment of asset condition. • Improved life-cycle management.
PD testing	• Early identification of insulation degradation. (Ultrasonic using PD Hawk or similar)	• Improved assessment of asset condition.
SF6 gas top with asset in service	• At present equipment is taken out of service (OOS) for SF6 gas top up. • There is possibility for dead tank circuit breakers to be safely topped up with asset remaining in service.	• Prevent negative impact on STIPIS due to un-availability of transline or transformer as a result of circuit breaker outage.

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

TasNetworks has standardised on the use of dead tank circuit breakers for new or replacement 110 kV installations as dead tank circuit breakers with integral current transformers offer reduced life-cycle cost and higher availability. The exception to this standardisation is for installations that require the use of single-pole auto-reclose functionality such as 220 kV transmission line application. Typically live tank circuit breakers are used where single-phase auto-reclose facilities are required. Manufacturer development of 110 kV and 220 kV dead tank circuit breakers suitable for single phase auto-recloser allows for TasNetworks to evaluate each installation on its merits and adopts the optimal engineering solution

For installations that require the application of point-on-wave switching, TasNetworks evaluates each installation on its merits and adopts the optimal engineering solution.

The standardisation of circuit breaker types addresses the population type issues identified in Section 5.

8.6 Regulatory Obligations

8.6.1 Service obligations for network assets

Circuit breaker performance impacts on TasNetworks' overall network service obligations, which includes specific performance requirements for both regulated and connection transmission assets

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

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

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

There are currently no specific service level obligations for circuit breakers 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

8.7.1 110 kV Circuit breaker replacement

The replacement strategy has been developed based on life-cycle cost analysis and is consistent with industry practice. Application of the circuit breaker strategy will result in the replacement of up to 39 110 kV live tank circuit breakers with units of a dead tank design fitted with integral current transformers by 2029.

The major issues identified in the review of the circuit breaker population are:

- Design, condition and performance issues along with Intensive maintenance requirements and resultant high OPEX cost for the population of ASEA HLD 110 kV oil insulated live tank circuit breakers.
- Design, condition, performance and reliability issues are expected for the population of Sprecher & Schuh type HGF 112/1 110 kV units due to them approaching and exceeding their expected service lives.

- Reyrolle type OS 110 kV unit is nearing or have exceeded the expected service lives; and lack of standardisation creating spares inventory and contingency planning difficulties throughout the circuit breaker population. The final unit in the Network is planned to be replaced in 2018 (PM-P152)

The 110 kV circuit breaker replacement program is presented in Table 44. Where practicable, circuit breaker replacements will be co-ordinated with other planned works.

Table 4 – 110 kV Circuit breaker replacement program

Circuit breaker type	Location	Proposed replacement numbers	Estimated replacement year
ASEA HLD live tank breakers	Lindisfarne LF-F152, LF-G152	2	2020
	Bridgewater BW-A752, BW-G152, BW-H152	3	2020
	Chapel St CS-A552, CS-F152, CS-G152	3	2020
	Kingston KI-A152, KI-B152	2	2020
	Norwood NW-A152, NW-A752, NW-B152	3	2020
Total: ASEA HLD live tank breakers		13	2020
Sprecher & Schuh HGF 112/1 breakers	Chapel St CS-E452, CS-F452	2	2027
	Farrell FA-A552, FA-B552,FA-B752,FA-N152,FA-P152,FA-S152,FA-T152,	7	2027
	Knights Rd KR-A452	1	2027
	New Norfolk NN-A452, NN-A752, NN-B452, NN-D152, NN-E152, NN-F152, NN-J152, NN-K152, NN-P152, NN-R152	10	2027
	Rosebery RB-B452	1	2027
	Sheffield SH-B552, SH-N152, SH-V152	3	2027

Circuit breaker type	Location	Proposed replacement numbers	Estimated replacement year
	Ulverstone UL-A752 & UL-B152.	2	2027
Total: Sprechur & Schuh HGF 112/1 breakers		26	2027
Total planned 110 kV circuit breaker replacements		**39**	

8.7.2 220 kV Circuit breaker replacement

The replacement strategy has been developed based on life-cycle cost analysis and is consistent with industry practice. Application of the circuit breaker strategy will result in the replacement of up to 15 220 kV live tank circuit breakers potentially with units of a dead tank design fitted with integral current transformers by 2025.

Circuit breaker B452 at Sheffield Substation was a Mitsubishi type 200-SFM-40A-GCB unit and was replaced in 2009 and held as an operational spare. A further two units of this type are installed at Sheffield Substation and seven units are installed at Farrell Substation. All of these circuit breakers are installed on critical transmission circuits. There are currently limited major spare components in stock for this type of circuit breaker. Replacing this circuit breaker will simplify contingency planning and enhance transmission circuit availability in the event of a circuit breaker failure.

The major issues identified in the review of the circuit breaker population are:

- Design, condition, performance and reliability issues are expected for the population of Sprecher & Schuh type HPF 514 P/4F oil insulated live tank circuit breakers units due to them approaching and exceeding their expected service lives. They are also the last of the oil insulated 220 kV circuit breakers and are the most expensive to maintain.
- Design, condition and performance issues along with Intensive maintenance requirements and resultant high OPEX cost for the population of Mitsubishi type 200-SFM-40A-GCB SF6 insulated live tank circuit breakers.

The 220 kV circuit breaker replacement program is presented in table 5. Where practicable, circuit breaker replacements will be co-ordinated with other planned works.

Table 5 – 220 kV Circuit breaker replacement program

Circuit breaker type	Location	Proposed replacement numbers	Estimated replacement year
Sprechur & Schuh HPF 514 P/4F live tank circuit breakers	Palmerston PM-A152	1	2020
	Gordon GO-A152, GO-B152, GO-A752, GO-C752, GO-S752	5	2020
Total: Sprechur & Schuh HPF live tank circuit breakers		6	2020
Mitsubishi 200-SFM-40A-	Farrell	7	2024

Circuit breaker type	Location	Proposed replacement numbers	Estimated replacement year
GCB	FA-A452, FA-A752, FA-B452, FA-D152, FA-E152, FA-H152, FA-J152.		
	Sheffield SH-Y152, SH-Z152	2	2024
Total: Mitsubishi 200-SFM-40A-GCB		9	2024
Total planned 220 kV circuit breaker replacements		**15**	

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, the investment program will rationalise the number of EHV circuit breaker types and designs through equipment standardisation, enabling improved use of condition monitoring data, a reduction in EHV circuit breaker spares inventory and simplified contingency planning and fault response processes.

This plan also recommends the purchase of three new circuit breakers to be kept as strategic system spares in line with TasNetworks' system spares policy, as the current spare circuit breakers held are not suitable for long term service.

8.10Technical 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.

8.11Disposal Plan

Prior to disposal of decommissioned circuit breakers, units will be reviewed to determine their suitability for retention as system spares or redeployment elsewhere in the transmission system.

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

8.12Summary of Programs

Tables 6 and 7 provide a summary of all of the programs/projects described in this management plan.

Table 6: Summary of EHV Circuit Breaker OPEX programs / projects

Work Program	Work Category	Work Category	Project/Program
Routine Maintenance	CMCBE	Corrective maintenance	S041-SUBS-Corrective-Circuit Breaker EHV
	PMCBE	Preventative maintenance	S429-Circuit Breaker Maintenance EHV

Table 7: Summary of EHV Circuit Breaker CAPEX programs / projects

Work Program	Work Category	Project title	Project/Program details
Capital	RENSB	Replace 220 kV Mitsubishi 200-SFM live tank circuit breakers	Replace 9x 220 kV Mitsubishi 200-SFM-40A-GCB live tank breakers at: FA-A452, FA-A752, FA-B452, FA-D152, FA-E152, FA-H152, FA-J152. SH-Y152, SH-Z152
	RENSB	Replace 220 kV Sprechur & Schuh HPF live tank circuit breakers	Replace 6x 220 kV Sprechur & Schuh HPF live tank circuit breakers at: PM-A152 GO-A152, GO-B152, GO-A752, GO-C752, GO-S752
	RENSB	Replace 110 kV ASEA HLD live tank breakers	Replace 13x 110 kV ASEA HLD live tank breakers at: LF-F152, LF-G152. BW-A752, BW-G152, BW-H152. CS-A552, CS-F152, CS-G152. KI-A152, KI-B152. NW-A152, NW-A752, NW-B152 Assume that DB-A452 remains and that DB as a transmission substation will be decommissioned by 2025.
	RENSB	Replace 110 kV Sprechur & Schuh HGF 112/1 live tank breakers	Replace 26x 110 kV Sprechur & Schuh HGF 112/1 live tank breakers at: CS-E452, CS-F452, FA-A552, FA-B552,FA-B752,FA-N152,FA-P152,FA-S152,FA-T152, KR-A452, NN-A452, NN-A752, NN-B452, NN-D152, NN-E152, NN-F152, NN-J152, NN-K152, NN-P152, NN-R152, RB-B452, SH-B552, SH-N152, SH-V152, UL-A752 & UL-B152.

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.

9.2 Proposed CAPEX Expenditure Plan

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

A comprehensive capital investment plan has been developed to address the identified design and performance issues associated with the EHV circuit breaker population and to improve transmission system performance. This plan recommends that 15 220 kV circuit breakers and 39 110 kV circuit breakers be replaced.

9.3 CAPEX – OPEX trade offs

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

10 Related Standards and Documentation

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

TasNetworks documents:

1. System Spares Policy R517373
2. Strategic Asset Management Plan R248812
3. Annual Planning Report 2017 R689487
4. WASP Asset Register – Data Integrity Standard – Circuit breaker, Transend Networks, 2006 TNM-GS-809-0512-007 R17042
5. Sulphur Hexafluoride Gas Management Procedure, Transend Networks, 2005 D04/10176
6. Strategy for PCB Management, Transend Networks, 2004 TNM-SY-806-0114
7. Management of Insulating Oil, Transend Networks 2006 TNM-PC-809-0091
8. System Spares Policy R517373
9. Engineering and Asset Services operational expenditure planning methodology D11/102320
10. AM8 Asset Condition Review – project report June16 FINAL R503361
11. TasNetworks document, Risk Analysis tool (EHV – CB module) R108052
12. EHV Circuit Breaker replacement program 2011 R743337

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

13. Extra High Voltage Dead Tank and Live Tank Circuit Breaker Standard, 2013 R586376
14. Extra High Voltage System Standard, 2013 R586386

Other standards and documents:

15. Australian Standard AS 1883 ‘Guide to maintenance and supervision of insulating oils in service’, Standards Australia, 1993
16. Australian Standard AS 4360 ‘Risk Management’, Standards Australia, 2004
17. Cigre Publication, ‘Final Report of the second International Enquiry on High Voltage Circuit Breaker Failures and Defects in Service’, Cigre, 1994
18. IEC standard 60599 ‘Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved and free gases analysis’, IEC, 1999
19. Sinclair Knight Merz, ‘Assessment of Economic Lives for Transend Regulatory Asset Classes’, 2013. R192773
20. Cigre Publication, ‘Final Report of the 2004-2007 International Enquiry on reliability of High Voltage equipment, Cigre, 2012

11 Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S041-SUBS-Corrective-Circuit Breaker EHV	CMCBE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
S429-Circuit Breaker Maintenance EHV	PMCBE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
Replace 220 kV Mitsubishi 200-SFM live tank circuit breakers	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Capex	Low
Replace 220 kV Sprechur & Schuh HPF live tank circuit breakers	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Capex	Low
Replace 110 kV ASEA HLD live tank breakers	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Capex	Low

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
Replace 110kV Sprechur & Schuh HGF 112/1 live tank breakers	RENSB	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Capex	Low

12 Appendix B – Condition assessment methodologies

A variety of condition assessment methods are available to determine circuit breaker condition. The methods include:

(a) Operational analysis;

(b) Electrical testing; and

(c) SF6 gas monitoring, sampling and analysis.

For pneumatically operated units, annual pressure vessel inspections and certification and compressor maintenance also aids in ascertaining the physical condition of the units.

12.1 Operational analysis

Circuit breakers are mechanical devices that act to break a current path in the event of a fault in the transmission system. By detecting an over current/voltage or under current/voltage, a circuit breaker, via relays, opens contacts to physically break the current path in the affected transmission circuit. Circuit breakers can also be manually operated to disconnect a transmission circuit. Operational analysis includes a check of the number of operations of individual units, and operational timing tests.

12.1.1 Number of operations

The number of operations performed by a circuit breaker is a measure of the amount of work done by the unit and can be used to indicate the mechanical and electrical condition. TasNetworks' circuit breakers rarely approach the operational limits set out by the manufacturer (apart from those circuit breakers used for switching capacitor banks), and so other methods of condition assessment are important.

The actual number of operations can be difficult to obtain as mechanical counters often do not exist on older units, and where they do exist, they are often unreliable. The introduction of on-line monitoring techniques will aid the accurate record keeping of operation counts.

12.1.2 Operational timing tests

Operational timing tests provide an indication of the operating condition of a circuit breaker. The tests are performed on all types of circuit breaker main contacts, resistor switches and auxiliary contacts. The purpose of these operational tests is to check that a circuit breaker responds in the correct time-frame to an open or close command. If a breaker takes too long to open, critical equipment may be exposed to high fault currents for substantial periods of time and power system security may be compromised.

12.1.3 Contact travel

Contact travel is measured to ensure that contacts open far enough to ensure complete current isolation occurs during the opening operation. Travel can be affected by the contacts being subjected to significant mechanical forces during opening and closing operations irrespective of the MVA interrupted. The measured travel provides evidence of loose linkages or mechanical failure.

12.2Electrical testing

12.2.1Insulation and contact resistance

Insulation resistance is an indicator of the physical condition of the insulation of a circuit breaker. As insulation condition deteriorates, resistance of the insulation decreases indicating a future potential failure. The test is performed by applying a DC potential and measuring the resulting current using a mega-ohmmeter. Results are compared with previous test results to identify any trend which may indicate a decline in the physical integrity of the insulating material.

Measurement of contact resistance can be performed on all types of circuit breakers and is a similar test to the insulation resistance except that a known current is applied and the voltage difference is measured across the circuit breaker terminals. More than 100 amps are normally applied. The result is measured in micro-Ohms.

The electrical testing process, particularly the insulation resistance, is sensitive to the prevailing ambient conditions at the time of the test. Conditions such as temperature, humidity, test equipment and test procedures can all influence the results. Analysis of the electrical testing results is subjective and is always done in comparison with previous test results, similar unit results and in consideration of all other available condition monitoring data.

Generally acceptable insulation and contact resistance values are outlined in the Table 88.

Table 8 - Insulation and contact resistance

Acceptable limits	Insulation Resistance (MΩ)	Contact Resistance (μΩ)
Limits	> 1000	< 300

12.2.2SF6 Gas sampling and analysis

For SF6 gas-insulated circuit breakers, gas sampling and analysis is used to determine the condition of a circuit breaker. In particular, measurement of the water present within the gas can provide evidence of moisture ingress or internal deterioration of the insulation. The presence of water within SF6 gas impedes 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 circuit breakers are typically specified by the manufacturer.

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

The assessment of SF6 gas is important in the prevention of failures in SF6 insulated circuit breakers. SF6 is widely used as an insulating material for EHV equipment due to its arc quenching and self-regenerative properties. Under ideal conditions, when a SF6 circuit breaker operates, a discharge occurs, causing each fluorine atom to disassociate from the sulphur by capturing an electron. Once the discharge is complete, the fluorine atoms release the extra electrons, and re-join with the sulphur atoms, reforming SF6. However under less than ideal circumstances, contamination can occur (eg oxygen and moisture from the atmosphere) and this regeneration process is impaired, causing the SF6 to deteriorate. Periodic analysis of the SF6 gas can detect the presence of such contaminants prior to a failure, enabling the circuit breaker to be refurbished rather than replaced, and potentially extending its operational life.

13 Appendix C – 110 kV circuit breaker assessments

110 kV circuit breakers have been grouped by manufacturer and assessed on two key criteria; being condition and design considerations. Based on the condition and design issues, future management strategies for each type are determined. Assessment validity is applicable as at August 2017.

13.1AEG

Table 9 - AEG 110 kV circuit breakers

Type (AEG)	Design Principle	Location	Device Number	Average Age (years)	Number of units
S1-145-F1	Live Tank/SF6	Hampshire	A152, B152	23	2
Total number of units in service					**2**

Condition

The condition of these circuit breakers indicates the units are in acceptable electrical and physical condition.

Design considerations

Circuit breaker B152 presented a low gas alarm in 2006. An O-ring was replaced and the unit refilled with gas. The alarm has not recurred. There are no other significant design issues evident with AEG circuit breakers.

Future management strategy

Recommended maintenance practices will be continued for AEG circuit breakers.

13.2Areva

Table 10 - Areva 110 kV circuit breakers

Type (Areva)	Design Principle	Location	Device Number	Average Age (years)	Number of units
DT1-145 F3	Dead Tank CB/SF6	Burnie	F652	13	1
		Sheffield	A652	11	1
DT1-145 F1	Dead Tank CB/SF6	Devonport	A152, A452, A752, B152, B452, B752, C452	12	7
		Savage River	B452, C452	12	2
Total number of units in service					**11**

Condition

Condition monitoring results for the Areva circuit breakers indicate the units are in acceptable electrical and physical condition.

Design considerations

The DT1-145-F3 units are dead tank circuit breaker capable of a single pole operation hence used in capacitor banks required for point-on-wave switching.

Burnie Substation F652 was refurbished at site in 2016 due to very high contact resistance found during the routine maintenance. The breaker was degassed, bushings and interrupters removed and carried out the inspection and refurbishment work by the technician from OEM.

There are no other known design issues associated with Areva DT1-145-F3 circuit breakers.

Devonport and Savage River units (DT1-145-F1) are three pole operated dead tank circuit breakers with no known design issues.

Future management strategy

There is a new spare dead tank circuit breaker capable of single pole operation suitable for Burnie and Sheffield substations capacitor bank units.

Recommended maintenance practices will be continued for these circuit breakers. For breakers used for capacitor switching particular note of operations counter to be made to ascertain if maintenance period needs to be earlier than standard frequency.

13.3ASEA

Table 11 - ASEA 110 kV circuit breakers

Type (ASEA)	Design Principle	Location	Device Number	Average Age (years)	Number of units
HLD145/1250C	Live Tank/Oil	Bridgewater	A752, G152, H152	39	3
		Chapel Street	A552, F152, G152	39	3
		Derwent Bridge	A452	39	1
		Kingston	A152, B152	39	2
		Lindisfarne	F152, G152	39	2
		Norwood	A152, A752, B152	39	3
				Total number of units in service	**14**

Condition

Condition monitoring results for the ASEA circuit breakers indicate the units are in marginal condition.

Design considerations

These breakers are minimum oil circuit breakers where arc quenching is done in oil. ASEA circuit breakers are costly to maintain compared with units of dead tank design.

The following units have required repairs for:

(a) Unit H152 at Bridgewater Substation suffered a failure of the spring-wind motor;

(b) Replacement of the blue phase pole of NW-A752 due to ongoing oil leaks;

(c) Replacement of the blue phase pole of LF-G152 due to ongoing oil leaks;

(d) Unit A552 at Chapel Street Substation suffered seizing of the outer operating arm;

(e) Unit A752 at Kingston Substation had moisture in the red phase interrupter chamber; and

(f) In Dec 2016 unit B152 at Norwood Substation had latching issues in closed position and closing damper was replaced.

Future management strategy

ASEA circuit breakers have been experiencing some minor failures; all which are complicated by the lack of manufacturer support and spares availability. The circuit breakers also utilise oil as an insulating and arc extinguishing medium which requires more frequent maintenance intervals compared to modern equivalent assets. These circuit breakers are closely monitored and assessed to determine their continued maintainability, serviceability and performance.

It is recommended to replace 13 units in network except Derwent Bridge A452 as the future of Derwent Bridge Substation is unknown.

13.4Asea Brown Boveri

Table 12 – Asea Brown Boveri 110 kV circuit breakers

Type (Asea Brown Boveri)	Design Principle	Location	Device Number	Average Age (years)	Number of units
123 PMC 40-25	Dead Tank CB/SF6	Hadspen	C452, D452	12	2
LTB145D1/BUS	Live Tank/SF6	New Norfolk	G652	12	1
		Chapel Street	A652, B652	14	2
		George Town	A652	18	1
		Risdon	J652, K652	21	2
		Risdon	C652, D652	7	2
LTB145D1/B	Live Tank/SF6	Lindisfarne	A652	21	1
		George Town	T152	21	1
Total number of units in service					**12**

Condition

The condition of the 123 PMC 40-25 dead tank units at Hadspen Substation C452 and D452 circuit breakers are in acceptable electrical and physical condition.

The condition of LTB 145D1/BUS and LTB145D1/B types were marginal and are currently undergoing refurbishment work. The condition of the breakers is detailed in the condition assessment report.

Design considerations

123 PMC 40-25 is a dead type design. LTB145D1/B is the live tank design with no mechanical staggering between phases use for line or transformer switching as ganged operated. However LTB145D1/BUS is the live tank design with mechanical staggering between phases for the capacitor bank switching for point-on-wave.

Lindisfarne Substation live tank A652 circuit breaker is currently connected for switching a capacitor bank, after the refurbishment in Feb 2016, will be utilised as a transmission line switching breaker from July 2019. The current capacitor bank will be relocated within Lindisfarne Substation and will have a new single pole operated dead tank circuit breaker for a cap bank switching.

Future management strategy

Existing Risdon Substation K652 circuit breaker has been sent to manufacturer's workshop for refurbishment and on return will be retained as a spare breaker at Primary Store.

Recommended maintenance practices will be continued for ABB live and dead tank circuit breakers. For breakers used for capacitor switching particular note of operations counter to be made to ascertain if maintenance period needs to be earlier than standard frequency.

13.5Mitsubishi

Table 13 – Mitsubishi 110 kV circuit breakers

Type (Mitsubishi)	Design Principle	Location	Device Number	Average Age (years)	Number of units
120-SFMT-40E	Dead Tank CB/SF6	Tungatinah	A152, A452, B152, F152	4	4
		George Town	D452, E452, M152, N152, R752,	4	5
		Meadowbank	A452, A152, B152	4	3
		Arthurs Lake	A152	5	1
		Norwood	C152	5	1
		Rosebery	A152, A752	5	2
		St Leonards	A152, A452, A752, B152, B452	5	5
		Mornington	A152, A752, B152	6	3

Type (Mitsubishi)	Design Principle	Location	Device Number	Average Age (years)	Number of units
		Palmerston	P152[1]	1	1
				Total number of units in service	**25**
100-SFMT-40E	Dead Tank CB/SF6	Kingston	A452, A752, B452, C452, D452	6	5
		Lindisfarne	H152, D552, E552	6	3
		Burnie	B552, D152	7	2
		Emu Bay	A752, B152, C152	7	3
		Knights Road	A152, B452, C152, J152, JD752	7	5
		Palmerston	C452, M152, N152, R152, Y152, Z152	7	6
		Port Latta	A152, A752, B152	7	3
		Railton	A752, C152, D152	7	3
		Wesley Vale	A152, A752, B152	7	3
		Derby	D152	8	1
		Avoca	A152	8	1
		George Town	H152, I152	8	2
		Palmerston	A552, B752, O152, D452	9	4
		Sheffield	R152, S152, T152, U152	9	4
		George Town	A552	9	1
		Ulverstone	A152	9	1
		Lindisfarne	B452, C452, A152, A752,	12	7

[1] Targeted to be commissioned in 2018, currently held in store.

Type (Mitsubishi)	Design Principle	Location	Device Number	Average Age (years)	Number of units
			B152, C152, E152		
		Chapel Street	L152	13	1
		Norwood	A452, B452	13	2
		Scottsdale	A152, A752, B152	13	3
		Sheffield	Q152, A552, B752	13	3
		George Town	B552, C552	14	2
		Que	A152	14	1
		Electrona	B452	19	1
		Triabunna	A452, B452	18	2
		Tungatinah	A752, B752, C752, C152, G152, H152	19	6
		Avoca	B152	19	1
		Chapel Street	D152, H152, B552, B752, D552, C552, J152, K152	19	8
		Derby	A152	19	1
		Hadspen	A752, B552, D752, E152, G152, H152, J152, K152, N152	19	9
		Newton	B152	19	1
		Norwood	D152, E152	19	2
		Sorell	A452, B452	19	2
		St Marys	A452, B452	19	2
Total number of units in service					**101**

Condition

Condition monitoring results for the Mitsubishi circuit breakers indicate the units are in acceptable electrical and physical condition.

Design considerations

Some manufacturing issues resulted in pin-hole SF6 leaks from the metal end cover plates in two units at Tungatinah Substation and another at Triabunna Substation. It is likely that the end plates were porous allowing escape of SF6 gas. The end plates have been replaced and no other significant design issues are evident.

The breakers installed after 2014 have been fitted with transducers having 4-20 mA are mapped to NOCS for the remote monitoring of SF6. These transducers are in addition to the SF6 mechanical gauge installed locally in the CB cabinet.

Future management strategy

Each unit of 100-SFMT-40E and 120-SFMT-40E are in Primary Store holding as spares.

Recommended maintenance practices should be continued for Mitsubishi circuit breakers.

13.6Reyrolle

Table 14 - Reyrolle 110 kV circuit breaker

Type (Reyrolle)	Design Principle	Location	Device Number	Average Age (years)	Number of units
110/OS/14/X4/PO	Live Tank/Oil	Palmerston	P152	55	1

Condition and design summary

The Reyrolle 110 kV Circuit Breaker Condition Assessment Report quantifies the condition of Reyrolle type 110/OS circuit breaker in detail. This report has identified that Reyrolle type 110/OS circuit breakers:

(a) Have a number of inherent technical and major design deficiencies that have adversely impacted transmission circuit reliability and availability;

(b) Are unreliable, in particular the air and insulation oil systems;

(c) Are maintenance intensive and costly to maintain when compared with modern equivalent units;

(d) Spare parts are no longer available;

(e) Require skilled personnel to maintain; and

(f) Are approaching the end of their useful lives.

Future management strategy

21 Reyrolle type 110/OS have been replaced over the last 10 years at Meadowbank, Creek Road, Burnie and Tarraleah substations. The last Reyrolle type 110/OS unit is in operation in P1 bay at Palmerston Substation and is scheduled to be replaced by June 2018 with Mitsubishi type 120-SFMT-40E.

13.7Siemens

Table 15 - Siemens 110 kV circuit breakers

Type (Siemens)	Design Principle	Location	Device Number	Average Age (years)	Number of units

Type (Siemens)	Design Principle	Location	Device Number	Average Age (years)	Number of units
3AP1DT	Dead Tank CB/SF6	Burnie	B752, E152, F452, G452, H152, J152, K152	5	7
		Newton	A452, B452	5	2
		Mowbray	A152	9	1
		Electrona	A152, A452, A752, B152	9	4
		Huon River	A452	11	1
		Kermandie	A452, B452	12	2
		Mowbray	A752, B152	13	2
		Waddamana	D752, E752, F752, G752, H752	13	5
		Smithton	A152, D152, A752, B152	14	4
		Tungatinah	D152, E152	17	2
SPS2	Dead Tank CB/SF6	Queenstown	A152, B152, A452, B452, C452, D452	18	6
		Trevallyn	A152, B152, B752, C752, D752, J452, K452, L452, M452	19	9
				Total number of units in service	**45**

Condition

Condition monitoring results for the Siemens circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

Units installed at Queenstown and Waddamana substations had initial issues where the weight of the integral current transformers caused cracking of the support housing. The units were strengthened and this issue is no longer a problem.

Future management strategy

The recommended maintenance practices will be continued for Siemens circuit breakers.

13.8Sprecher & Schuh

Table 16 - Sprecher & Schuh 110 kV circuit breakers

Type (Sprecher & Schuh)	Design Principle	Location	Device Number	Average Age (years)	Number of units
HGF 112/1	Live Tank/SF6	New Norfolk	A452, A752, B452, D152, E152, F152, J152, K152, P152, R152	31	10
		Sheffield	N152, V152	31	2
		Sheffield	B552	32	1
		Chapel Street	E452, F452	35	2
		Farrell	A552, B552, B752, N152, P152, S152, T152	35	7
		Knights Road	A452	35	1
		Rosebery	B452	35	1
		Ulverstone	A752, B152	35	2
				Total number of units in service	**26**

Condition and design summary

Condition monitoring results for the Sprecher & Schuh HGF 112/1circuit breakers indicate the units are in acceptable condition.

Future management strategy

The recommended maintenance practices will be continued for Sprecher & Schuh circuit breakers. These units are being targeted for replacement in the 2024-29 regulatory period and will require a condition assessment report to be prepared.

14 Appendix C – 220 kV circuit breaker assessments

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

14.1AEG

Table 17 - AEG 220 kV circuit breakers

Type (AEG)	Design Principle	Location	Device Number	Average Age (years)	Number of units
S1-245F3	Live Tank/SF6	Hadspen	P152, Q152, T152, V152	17	4
				Total number of units in service	**4**

Condition

Condition monitoring results for the AEG circuit breakers indicate the units are in acceptable condition.

Design considerations

There is no known design issues associated with AEG circuit breakers.

Future management strategy

Recommended maintenance practices will be continued for the AEG circuit breakers.

14.2Alstom

Table 18 - Alstom 220 kV circuit breakers

Type (Alstom)	Design Principle	Location	Device Number	Average Age (years)	Number of units
FXT14F	Live Tank/SF6	Burnie	B452	17	1
		Chapel Street	B152, C152	14	2
			S752, T152, U152	16	3
		Farrell	FA-B452	18	1
		Liapootah	752, E152	15	2
			F152, G152	17	2
			D152, H152	18	2
		George Town	B752, C752, D752	17	3
		Sheffield	B152, C152, D152, E152	14	4

Type (Alstom)	Design Principle	Location	Device Number	Average Age (years)	Number of units
		Sheffield	F152, J152, K152	17	3
		Wayatinah Tee	A152	14	1
HGF 1014 DTCB	Dead Tank CB/SF6	Chapel Street	A452, A752, B452, C452, D452	16	5
		Sheffield	E752	14	1
				Total number of units in service	**30**

Condition

Condition monitoring results for the Alstom circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

A number of auxiliary relays on FXT14 units failed shortly after commissioning. These have subsequently been replaced and have shown no further signs of failure.

Future management strategy

The recommended maintenance practices will be continued for Alstom circuit breakers.

14.3Areva

Table 19 – Areva 220 kV circuit breakers

Type (Areva)	Design Principle	Location	Device Number	Average Age (years)	Number of units
GL314	Live Tank/SF6	Lindisfarne	D452, D752, E452, E752	7	4
		Waddamana	M152, M752, N152, N752	7	4
				Total number of units in service	**8**

Condition

Condition monitoring results for the Areva circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

No design issues are seen with these breakers.

Future management strategy

The recommended maintenance practices will be continued for Areva circuit breakers.

14.4Asea Brown Boveri

Table 20 - Asea Brown Boveri 220 kV circuit breakers

Type (Asea Brown Boveri)	Design Principle	Location	Device Number	Average Age (years)	Number of units
LTB245E1	Live Tank/SF6	George Town	A752, X152	9	2
			B452, C452	14	2
HPL245/25B1	Live Tank/SF6	Farrell	A152, B152	25	2
		George Town	B652	17	1
		Liapootah	C152	19	1
		Palmerston	F152, G152, J152	20	3
			K152, L152	18	2
			A452	24	1
		Sheffield	L152	29	1
Total number of units in service					**15**

Condition

Condition monitoring results for the ABB circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

There is no known design issues associated with Asea Brown Boveri circuit breaker

Future management strategy

The recommended maintenance practices will be continued for ABB circuit breakers. For breakers used for capacitor switching particular note of operations counter to be made to ascertain if maintenance period needs to be altered

14.5Mitsubishi

Table 21 - Mitsubishi 220 kV circuit breakers

Type (Mitsubishi)	Design Principle	Location	Device Number	Average Age (years)	Number of units
200-SFMT-40GE IPO	Dead Tank CB/SF6	George Town	A152, B152, C152, D152	5	4
200-SFMT-40E	Dead Tank CB/SF6	George Town	A452	9	1
			F152, G152	17	2
		Hadspen	A452, B752, BW752	17	3

Type (Mitsubishi)	Design Principle	Location	Device Number	Average Age (years)	Number of units
		Palmerston	B152, C152, D152, A752, E752	17	5
		Sheffield	F752, G752	9	2
			A452, B452	18	2
200-SFM-40A-GCB	Live Tank/SF6	Farrell	A452, A752B, D152, E152, J152, B452, H152	33	7
		Sheffield	Y152, Z152	33	2
				Total number of units in service	**28**

Condition

Condition monitoring results for the Mitsubishi circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

Type 200-SFMT-40GE IPO is a single pole operated dead tank circuit breaker.

Type 200-SFM-40A-GCB circuit breakers utilises compressed air systems for mechanical operation which are maintenance intensive. Failure of compressor and the leak in the air system has resulted in Farrell Substation B452 being non-functional in September 2017. The gaskets with the rescue kit were sourced from the OEM however have a lead time of 6 months plus. This resulted in installing temporary protection for Farrell T2 transformer and tripping bus coupler A752B. It is intended to replace this breaker with a spare unit from Burnie Substation decommissioned BU-C452 by November 2017.

A gas leak occurred in unit BW752 at Hadspen Substation in 1999. A bushing was replaced and no subsequent leaks have occurred.

Future management strategy

Type 200-SFM-40A-GCB circuit breaker B452 at Sheffield Substation was replaced with a unit of dead tank design in 2008. The removed unit is retained for spares for the remaining 200-SFM-40A-GCB units.

It is recommended to replace type 200-SFM-40A-GCB with the dead tank design as the in-service units are maintenance intensive, unreliable (FA-B452) and utilises compressor and air compressed system which tends to fail overtime and outsourcing the spare parts are difficult and time consuming. The type 200-SFM-40A-GCB are to have increased maintenance practice applied to monitor their air compressor systems until their replacement.

The recommended maintenance practices will be continued for other Mitsubishi circuit breakers.

14.6Siemens

Table 22 - Siemens 220 kV circuit breakers are in service as follows:

Type (SIEMENS)	Design Principle	Location	Device Number	Average Age (years)	Number of units
3AP2FI	Live Tank/SF6	George Town	H752, Z152	12	2
				Total number of units in service	**2**

Condition

Condition monitoring results for the Siemens circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

There is no known design issues associated with Siemens circuit breakers.

Future management strategy

The recommended maintenance practices will be continued for the Siemens circuit breakers.

14.7Sprecher & Schuh

Table 23 - Sprecher & Schuh 220 kV

Type (Sprecher & Schuh)	Design Principle	Location	Device Number	Average Age (years)	Number of units
HPF 514 P/4F	Live Tank/Oil	Gordon	A152, A752, B152, C752, S752	41	5
		Palmerston	A152	41	1
				Total number of units in service	**6**

Condition

Condition monitoring results for the Sprecher & Schuh circuit breakers indicate the units are in acceptable electrical condition.

Design considerations

These HPF 514 P/4F are the last fleet of oil filled circuit breakers operating at 220 kV system of TasNetworks.

The breaker utilises oil as an arc quenching which is not reliable as compared to SF6. The moisture ingress in oil diminishes the dielectric strength of oil.

The breaker maintenance regime is every six years and is very expensive due to being labour intensive. These breakers are the most expensive assets to maintain in the TasNetworks fleets.

The external operating linkages and rotating post insulators on this type of circuit breaker are poorly designed, and units of similar design operating at 110 kV are prone to failure. Although there has been no significant failures have occurred in the small population of 220 kV units, a review of maintenance practices is deemed to be a proactive and anticipatory maintenance approach.

Future management strategy

The recommended maintenance practices should be continued for the Sprecher & Schuh circuit breakers. Special attention will be given during substation visual inspections to identify any possible signs of linkage failure.

It is recommended to replace Sprecher & Schuh oil filled circuit breaker with the dead tank design as the in-service units are maintenance intensive and costly to maintain when compared with modern equivalent units. The spare parts are no longer supported by manufacturer’s agents.

15 Appendix C – Spare circuit breaker units

Table 24 – 110 kV Operational Spares

Manufacturer	Type	Design Principle	Location	Device Number	Average Age (years)	Number of units
Alstom	DT1-145 F3	Single pole operated dead tank/SF6	Primary Store	PS-152-280721	1	1
Mitsubishi	100-SFMT-40E	Dead tank/SF6	Primary Store	PS-A152 60706 (Ex-Avoca A152	19	1
Mitsubishi	120-SFMT-40E	Dead tank/SF6	Primary Store	PS-B452-250546	5	1
ASEA	HLD145/1250C	Live Tank/Oil	Primary Store	PS-A752X	39	1
Asea Brown Boveri	LTB145D1/BUS	Live Tank/SF6	Primary Store[2]	Ex-RI-K652	18	1
Total number of Operational spares						**5**

[2] Currently spare is being used in the network whilst related LTBs are being refurbished. Once refurbishment works are complete unit will be returned to store as system spare.

Table 25 – 220 kV Operational Spares

Manufacturer	Type	Design Principle	Location	Device Number	Average Age (years)	Number of units
Alstom	HGF 1014 DTCB	Dead Tank CB/SF6	George Town	PS-A752 50110	17	1
ASEA	HPL245/25B1	Live Tank/SF6	Primary Store	PS-B152x	30	1
Asea Brown Boveri	LTB245E1	Live Tank/SF6	Primary Store	PS-152-245257	9	1
Mitsubishi	200-SFMT-40GE	Dead Tank CB/SF6	Primary Store	PS-152-247193	9	1
	200-SFM-40A-GCB	Live Tank/SF6	Primary Store	PS-B452X	32	1
Total number of Operational spares						**5**