Asset Management Plan

Power Cables

Record Number: R40527

Version Number: 2

Date: October 2017

Authorisations

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Review cycle	2.5 Years	

Responsibilities

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

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

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

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

Record of revisions

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

Table of Contents

1 Purpose

The purpose of this asset management plan is to define the management strategy relating specifically to EHV and HV power cables. 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) and high voltage (HV) power cable population for a ten year rolling planning period. The objective of this plan is to minimise business risk by achieving reliable asset performance at minimal life-cycle costs.

The plan does not include asset management aspects of power cables associated with TasNetworks distribution network.

3 Strategic Alignment and Objectives

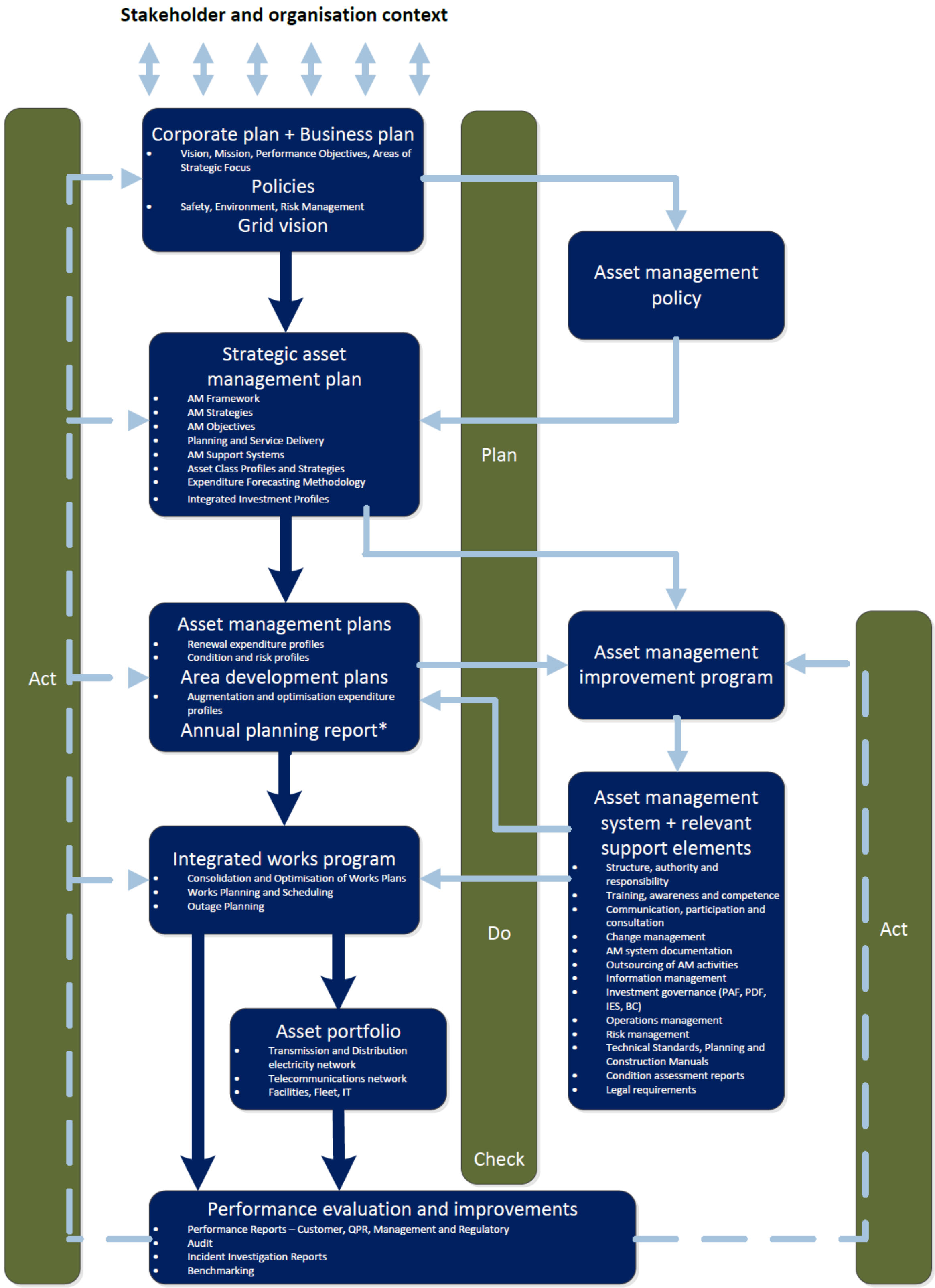
This asset management plan has been developed to align with both TasNetworks' Asset Management Policy and Strategic Objectives to maintain business risk to within acceptable limits by achieving reliable asset performance at minimal life-cycle cost. This management plan describes the asset management strategies and programs developed to manage power cables, 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 power cable 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 in future will 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 power cables:

- R17066 WASP Asset Register – Data Integrity Standard – Power Cable

4.2.1.1 AM8 Condition data

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

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

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

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

5 Description of the Assets

5.1 General

Power cables are insulated and protected conductors that allow transmission of electricity via underground or underwater routes. Power cables were first used in the early 1880s utilising gutta percha, rubber and vulcanized bitumen as the insulant.

Cables have since evolved using paper and oil insulation, cross linked polyethylene insulation and paper and polypropylene laminated insulation.

TasNetworks operates 220 power cable circuit sections at differing voltages. Table 1 shows the number of circuits operating at each voltage.

Table 1 – Power cables circuits by voltage

Operating voltage	Number of circuits
6.6 kV	10
11 kV	60
22 kV	103
33 kV	19
110 kV	28
Total	**220**

TasNetworks installed and commissioned two 110 kV transmission cables in late 2012 between its Norwood- St Leonards and St Leonards-Mowbray sections, increasing the total 110 kV cable circuit length by approximately 9.9 km. The Norwood-St Leonards and St Leonards-Mowbray circuits comprise approximately of 4.1 km and 5.8 km of XLPE 110 kV underground cables and these cable details have been summarised in Table 2.

Table 2 – Cable details for Norwood – St Leonards and St Leonards – Mowbray sections

Cable	Description	Rated Operating Voltage (kV)	Conductor material	Route length (km)	Insulant	Commissioned Date
SL-TC-488	110 kV St Leonards-Mowbray Transmission cable	110	Copper	5.788	XLPE	9/07/2012
NW-TC487	NW-SL Transmission cable	110	Copper	4.102	XLPE	9/07/2012

The predominant insulating medium is cross-linked-polyethylene (XLPE) (173 cable sections) covering HV and EHV installations.

5.2 Cable types

TasNetworks power cables can be categorised based on the insulating medium used.

Table 3 – Cable types

Insulating medium	Number of power cables
Oil	4
Paper	43
XLPE	173
TOTAL	**220**

Definitions for the insulating media used can be found in Appendix F. TasNetworks' population of cables includes units constructed by eight manufacturers consisting of nine different manufacturer types.

Condition monitoring results for each of the types can vary substantially as different design and construction methods are used for each type. Of the eight types of power cables currently in-service, four have a population size of less than ten units, which restricts the ability to establish meaningful trends in condition monitoring data for each of the power cable types.

More importantly, in addition to condition monitoring issues, the difference in physical design and construction characteristics between installations presents contingency planning and spares management issues.

A summary of TasNetworks power cables by manufacturer is provided in Figure 2. Figure 3 and Figure 4 depict the design principle compared to the voltage used within the population.

Figure 2 – Route length installed by manufacturer excluding unknown route lengths

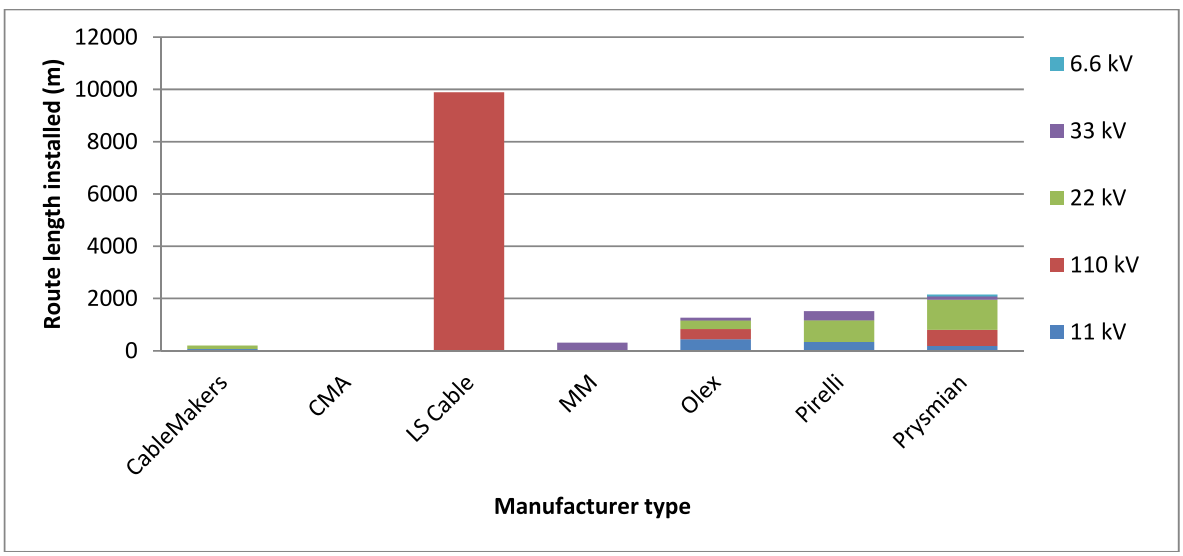


Figure 3 – Insulant category by manufacturer

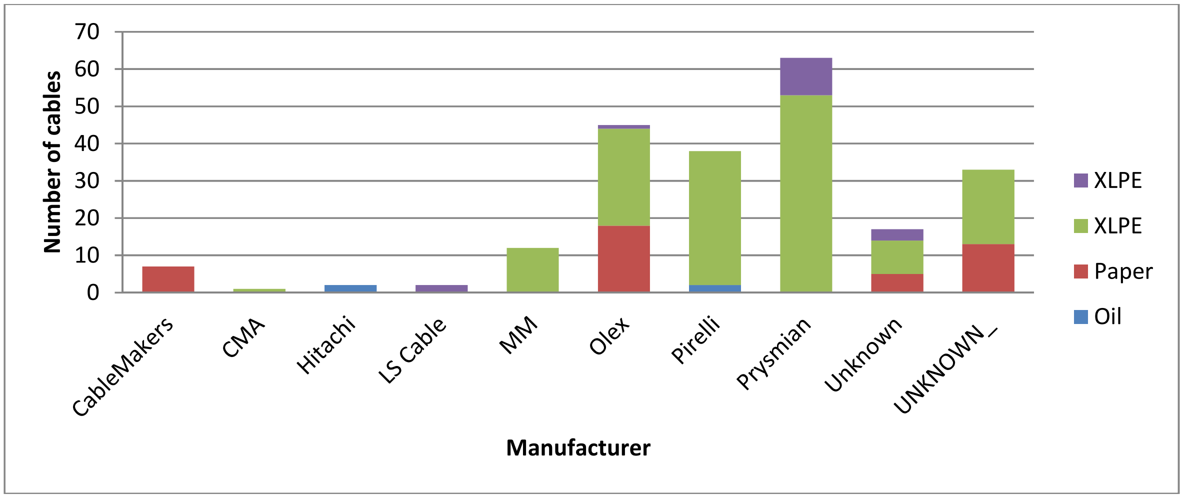
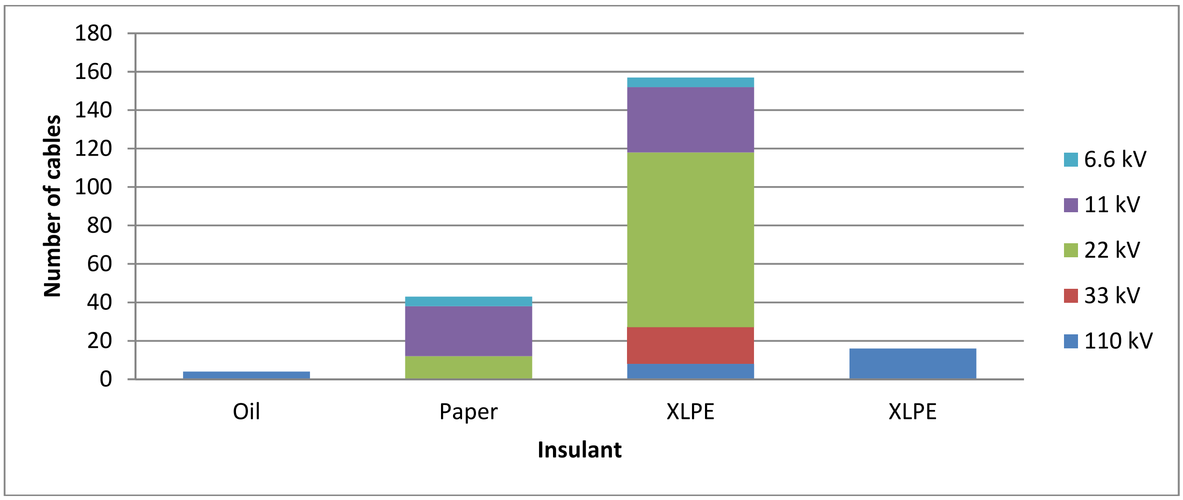


Figure 4 – Insulant category by voltage



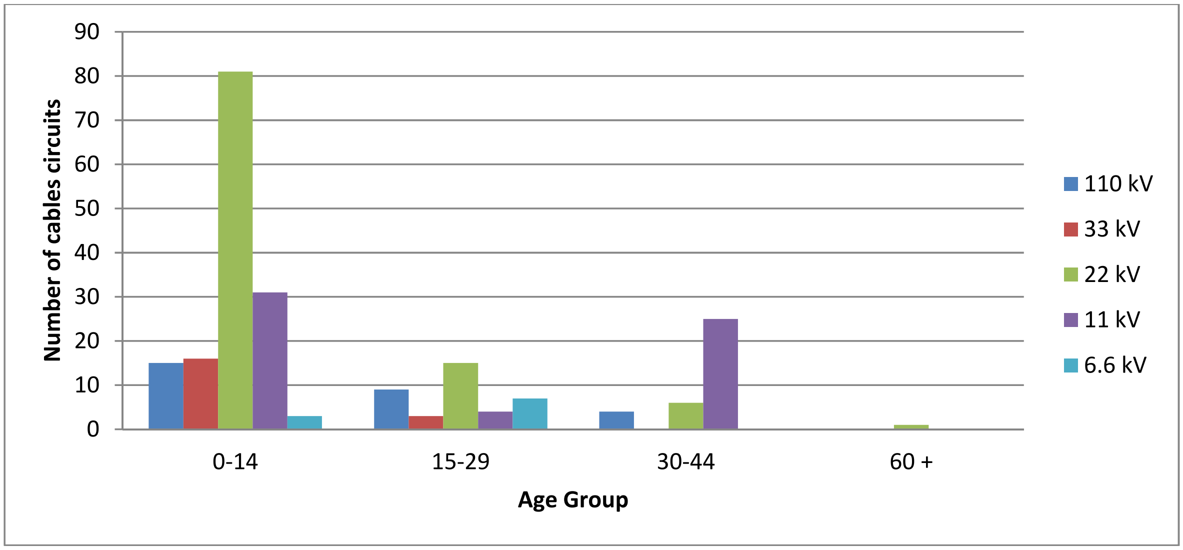
5.3 Age profile

On average, transmission cables are considered to have an average service life of 45 years. The average age of TasNetworks power cable population is 15.7 years as at October 2017. There is 1 22 kV installations that exceed the average service life for power cables.

Generally, the relatively low average age of TasNetworks' power cables should ensure overall performance levels of the population should not be adversely affected by age-related issues.

The age profile for TasNetworks' power cable population is shown in Figure 5.

Figure 5 – Power cable age profile (as at October 2017)



6 Standard of Service

6.1 Technical Standards

To address potential design issues, TasNetworks has developed a comprehensive, prescriptive standard specification for the design and procurement of power cables. The specification requires units to be XLPE insulated, and to be designed and type-tested to Australian and international standards. The prescriptive technical specification enables standardisation of cable design which also starts to address the population type issues.

6.2 Performance Objectives

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

In order to reduce cable faults that arise from poor quality of installation or assembly, TasNetworks ensures that adequate instruction is given to installation and repair crews. TasNetworks also ensures that cable installers and jointers have adequate training schemes in place, and have a well-documented history of good work practice in Australia.

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 cables for major faults through its incident reporting process. The process involves the creation of a fault incident record in the event of a major cable 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 cable population. Reference to individual fault investigation reports can be found in TasNetworks' reliability incident management system (RIMSys).

For cable 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 cable related faults or defects.

Power cable 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 (AERs) 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 Power Cables has an impact on the performance measures reported regularly to the AER and directly impacts on TasNetworks' performance incentive scheme.

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.

Of these, ITOMS does not directly involve benchmarking power cables. TasNetworks also works closely with transmission companies in other key industry forums, such as the International Council on Large Electric Systems (CIGRE), to compare asset management practices and performance

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 and HV power cables has been undertaken in accordance with the Risk Management Framework. For each asset in this class the assessments have been made based on:

- Condition of power cables in service across the network
- Criticality of power cables 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 power cables have been revised where appropriate to sustain or improve EHV and HV power cable reliability. The adoption of contemporary asset management techniques, including cable diagnostics (where possible) and defined condition monitoring techniques will aid in determining the health and improving life-cycle management practices of EHV and HV power cables, and are aimed at reducing the EHV and HV power cable average annual preventive maintenance expenditure. The revised maintenance practices will be aligned with current industry practice.

A variety of condition assessment methods are used to determine power cable electrical condition. The methods include:

- High voltage electrical testing;
- Oil sampling and dissolved gas analysis (DGA); and/or
- On-line distributed temperature sensing (DTS).

Power cable 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 cables. For example, oil-filled cables are constructed using a different design and construction principle than gas-filled or XLPE cables, resulting in different failure modes and the need for different condition assessment methods. The combination of test methods enables a collective and thorough approach to determine the condition of the power cable population.

The inclusion of a Health Index (HI) in future CBRM 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 power cables 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.

Third party damage due to a cable/s being inadvertently excavated or exposed is of concern, especially in an urban and peri-urban environment where other service utility excavation activities are high.

Purposeful damage as a result of vandalism, espionage, or cable theft activities is also a possibility, although remote at the present time.

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.

The Norwood- St Leonards and St Leonards-Mowbray cable circuit, although the length is short, their location and function, irrespective of voltage level, is such that a cable failure can potentially lead to major disruption to supply.

7.1.5 Environmental risk

TasNetworks' main environmental risks associated with power cables relate to the insulating medium used within the cables. As the power cables that TasNetworks has in service only use low volumes of insulating oil, the risk to the environment is minimal. The identified risks include:

- Management of polychlorinated biphenyls (PCBs) associated with oil-filled units; and
- Management of an oil spill in cable easements including public and private property

TasNetworks implemented a program to determine the PCB level within the oil filled cable population. All units tested have been proven to be PCB free and generally the management of PCB's and transport of chemicals is used during maintenance activities.

7.2 Failure types

The main risks associated with the cable population include major asset failure, third party damage and environmental risks.

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

The predominant causes of a power cable failure or defect include:

- Inadequate quality control during manufacture (which can affect random units or batches of units of a proven design) including general quality, moisture ingress, poor welding, cable crushing and corrosion;
- Design faults, including electrical, mechanical, choice of materials used in construction and insulant failure; and
- Incorrect assembly or poor workmanship.

An international survey conducted by Cigre categorised power cable failures into three specific types:

- Category 1 – any occurrence on a cable system which causes the tripping of a switch automatically or necessitates the tripping of a switch manually in order to de-energise the circuit of which the cable forms a part;
- Category 2 – any defects in a cable system which causes a load reduction to be made; and
- Category 3 – any occasion on which the cable is switched out as a precautionary action and subsequently no defect or damage is found.

While TasNetworks does not currently have an accurate long term record of failure or defect rates for its population of power cables, an international survey of power cable failures undertaken by Cigre for the period 1982 to 1986 shows that failure rates for power cables are quite low. The combination of enhanced design capability, improved manufacturing quality and control processes, and comprehensive production testing usually ensures that power cable performance levels remain high throughout their service lives. Some results of the failure survey are shown in the following tables.

Table 4 – Distribution of failure for power cables

Cable system	Failures of internal origin			Failures of external origin		
	Category 1	Category 2	Category 3	Category 1	Category 2	Category 3
Oil filled	4	1	67	7	3	18
XLPE	60	-	7	30	1.5	1.5

Table 5 – Failure rates for power cables

Cable type	Component	Average outage time (hours per failure)	Failure rate (failures per 100 Cct km per year	
			Internal origin	External origin
Oil filled (22 kV to 500 kV)**	Cable	176	0.05	0.1
	Straight joint	420	0.08	-
	Stop joint	507	0.16	-
	Sealing end	76	0.07	0.06
	Auxiliary equipment	39	0.32	0.07
	Other	59	0.19	0.08
XLPE (60 kV to 220 kV)**	Cable	130	0.05 (0.07*)	0.08
	Site made straight joint	93	0.01	0.003
	Prefabricated sealing end	47	0.04	0.005

* For cables with provision against water penetration

** Other voltages were surveyed, but insufficient data was provided for a valid analysis.

7.3 Defects recorded

Analysis of TasNetworks AMIS defects recording system details that in the last ten years there have been 11 recorded major defects.

Table 6 – Condition monitoring and preventative maintenance practices

Site	Year	Power or transmission	count
Savage River	2007	Power cable	1
Derwent Bridge	2011	Power cable	1
Gordon	2013	Power cable	1
Creek Road Substation	2015	Transmission cable	1
Kingston	2015	Power cable (33kV)	1
Bridgewater	2016	Power cable	1
Kingston	2016	Power cable (33kV)	1
New Norfolk	2016	Power cable	1
Creek Road Substation	2017	Power cable	1
Hadspen	2017	Power cable	2
Total			11

7.4 EHV power cable issues

Overall, condition monitoring results for the population indicates that all installations are in serviceable condition.

In 2015 a trip of a Creek Road – North Hobart cable was a result of a faulty pressure gauge.

A detailed assessment of the condition of the EHV power cable population is provided in Appendix C.

7.5 HV power cable issues

TasNetworks has experienced a number of major failures in the past 15 years, including the failure of:

- 22 kV cable at Savage River due to external damage caused by drilling by a Contractor in 2007;
- 22 kV termination failure at Queenstown Substation due to poor and incorrect installation in 2006;
- 22 kV cable at Meadowbank Substation due to striking with a crowbar by a Contractor in 2006; and
- HV cable at Wesley Vale Substation struck by an excavator during site works in 2003.

- Several termination joints on transformer incomer cables, Creek Rd, Kingston and Hadspen Substation. Resultant cause has been linked to workmanship.

Overall, condition monitoring results for the population indicates that all units are in acceptable condition.

Further details on assessment of the condition of the HV power cable population is provided in Appendix D.

7.6 Special operation and design issues

7.6.1 Capacity

The capacity of power cables is typically measured and governed by the continuous current rating.

Capacity issues, both immediate and future, as they related to power cables are identified in the Regional Development Plans. The purpose of the development plans are to:

- Identify system performance issues in meeting future load growth with the existing transmission facility;
- Identify options to meet performance criteria if these are not met;
- Identify asset condition issues and consider them in developing options;
- Perform technical and economic analysis to identify the best development option; and
- Prepare a development plan for the period.

7.6.2 Design

Power cable design issues are key elements in developing an asset management strategy for the population. Power cable design is an important factor that can influence both asset and transmission system performance levels. In addition, design issues have a direct impact on maintenance practices and expenditure. Common design issues across TasNetworks' power cable population include:

- Construction of paper insulation and lead based sheaths;
- Poor termination; and
- Availability of spare parts.

Design considerations for specific power cables (grouped by manufacturer and type) are assessed in detail in Appendix C.

7.7 Summary of Risk

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

- Gas-filled power cables of obsolete design;
- Maintenance intensive oil insulating systems for which qualified resources are hard to acquire;
- Unknown manufacturers;
- Poor workmanship experienced with cable terminations especially at Kingston and Hadspen Substations; and
- Lack of standardisation throughout the power cable population.

8 Management Plan

8.1 Historical

Historically, management of power cables 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 6 – 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 power cables are monitored on an ongoing basis to ensure they are effective and relevant to achieving TasNetworks' risk management objectives. Practices are reviewed on a regular basis taking into account:

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

Failures within power cables 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 a power cable 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 power cables 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 power cables 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 power cables 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.

As the EHV oil insulated cables supplying Rokeby and North Hobart are at around half expected service life capital funds have been allocated into the 2019-24 regulatory period to allow expected refurbishment works on cable ancillary devices, such as oil monitoring and oil containment assets (pipe work/tanks) to ensure full service life is achieved from these cables. Condition assessment reports are planned to be prepared by the end of 2017 to identify and support required refurbishment works.

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. Power cables 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 power cables generally cannot be cost effectively substituted via upgrading other infrastructure on the network.

8.2.6 Network Augmentation Impacts

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

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

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

Proposed network augmentation projects identified in the Regional Development Plan will have a minimal impact on the power cable population from an asset management perspective. Additional costs associated with new power cables installed as part of network augmentation projects will not materially impact on the ten-year projected operational expenditure.

8.3 Routine Maintenance

8.3.1 TasNetworks owned assets

The performance of power cables 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.

Previous preventive maintenance practices of power cables included bi-annual DGA testing of oil-filled cables and visual inspection of the sealing ends, with no planned condition monitoring of EHV or HV XLPE cables.

The revised condition assessment and maintenance practices for power cables are shown in Table 7. Based on condition monitoring data, the frequency of maintenance intervals may increase. In the event that increased maintenance levels are required, the decision to replace the unit may be justified depending on the impact on preventive maintenance expenditure and transmission system performance.

Table 7 – Condition monitoring and preventative maintenance practices

Task	Frequency
All units	
Visual inspections and routine condition monitoring	Quarterly
Thermal imaging	Coordinated with substation thermal imaging program Annually
Electronic capturing of condition data[#]	In conjunction with thermal imaging
Oil-filled	
Oil pressure monitoring	Continuous
Sheath and Pressure sensor test	Annually
Oil impregnation test	Every four years
Dissolved gas analysis	As required by impregnation test
EHV XLPE	
Temperature monitoring (F/o probes)	Continuous
Sheath test (per section)	At year one and two, every six years thereafter

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

8.3.2 Skilled resources

TasNetworks has identified a shortage of EHV qualified, oil filled cable jointers. It is not practical, given the small population of oil filled cables, to maintain a permanent human resource to maintain, or be available for emergency response for the oil filled cables. Also, TasNetworks does not own any test or fault finding equipment that would be used in a breakdown situation.

TasNetworks has approached a number of mainland Australian companies to ascertain if a collaborative approach to pooling resources or contracting emergency response crews is viable. To date, whilst discussions have been useful, a preferred approach has not been identified. TasNetworks will continue to investigate the merits of a multi company approach.

8.3.3 Partial discharge

Utilise partial discharge (PD) testing and other fingerprinting technologies as the need arises. The successful implementation could facilitate condition monitoring and act as early warning indicator of latent or impending failures.

8.3.4 Real time rating

Implementation of real time rating system for power cables will enable more efficient operation, utilisation and management of the cable networks. Renewal of cables will be able to be postponed, and life extension becomes a reality, if the power transfer capabilities of cables are maximised.

8.3.5 Third party assets

TasNetworks is also contracted to perform the ongoing maintenance on a third party EHV cable connected to Smithton Substation, which is owned by Roaring Forties Pty Ltd.

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 size and type of cable to be used for new or replacement high voltage and extra high voltage installations. The standardisation of cable size and design reduces spares requirements and starts to address the population type issues.

8.5.2 Third party damage mitigation

There are a number of mitigation strategies aimed at reducing the risk of accidental damage to cable installations both within the boundaries of TasNetworks substation sites and those that transverse third party property. Such strategies are incorporated in and addressed in the Cable Systems Standard and covers such issues as:

- Cable segregation, routes, excavations, protection, marking, identification, warning;
- Reliability, security and redundancy performance requirements; and
- Protection of cables rising from ground level.

8.6 Regulatory Obligations

8.6.1 Service obligations for network assets

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

TasNetworks' Service Target 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 incentive 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 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 power cables, however it is noted that predominantly cables are associated with transmission line and transformer circuits and that any outage of the cable is reflected in transmission performance.

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

The capital plan and future power cable replacements are predominantly aimed at replacing the units that are older than 40 years of age because of their obsolete design. The nominated replacements will be performed in conjunction with other capital works.

The assessment of the power cable population detailed in Appendix C recommends the replacement of 10 HV cables should be replaced. Table 8 provides a summary of the units to be replaced and a proposed replacement schedule.

Table 8 – Proposed power cable replacement program

Power cable type	Location	Replacement schedule / number of units Align with other capital work
Unknown manufacturer (PILC)	Rosebery T4 and T5	4
Olex PLY PVC	Chapel Street T5 and T6	4
	Knights Road T1 and T2	2
Total		**12**

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

As per TasNetworks' Networks System spares policy.

8.10 Disposal Plan

Prior to disposing of decommissioned cables and their associated components, they will be reviewed to determine their suitability for system spares in accordance with TasNetworks System Spares Policy document.

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

8.11 Summary of Programs

Tables 9 and 10 provide a summary of all of the programs/projects described in this management plan.

Table 9: Summary of EHV Circuit Breaker OPEX programs / projects

Work Program	Work Category	Work Category	Project/Program
Routine Maintenance	CMPCE	Corrective maintenance	S025-SUBS-Corrective-Cable EHV
	PMPCE	Preventative maintenance	S173-SUBS -Cable Sheath Tests EHV

Table 10: Summary of EHV Circuit Breaker CAPEX programs / projects

Work Program	Work Category	Project title	Project/Program details
Capital	RENSB	EHV cable RKtransition-RK	To refurbish or replace insulating oil containment assets and cable ancillary assets, eg. Gauges, pipe work, etc associated with each of the two EHV cables. Oil pressure meters to be replaced with analog telemetered units c/w alarm points.
	RENSB	EHV cable CR-NH	To refurbish or replace insulating oil containment assets and cable ancillary assets, eg. Gauges, pipe work, etc associated with each of the two EHV cables. Oil pressure meters to be replaced with analog telemetered units c/w alarm points.

9 Financial Summary

9.1 Proposed OPEX Expenditure Plan

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

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

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

9.2 Proposed CAPEX Expenditure Plan

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

A comprehensive capital investment plan has been developed to address the design and performance issues associated with power cables population and to improve transmission system performance. The plan recommends that the oil insulated EHV power cables have relevant refurbishment work undertaken to ensure they provide reliable service for their prospective life. The refurbishment program will mitigate the business risks presented by the existing EHV and HV power cables population and reduce future preventive maintenance costs.

9.3 CAPEX – OPEX trade offs

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

10 Related Standards and Documentation

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

TasNetworks documents:

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

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

8. Extra High Voltage System Standard R586386
9. EHV Cable Systems Standard, R565986
10. HV and LV Cable Systems Standard R590630

Other standards and documents:

11. Australian Standard AS 1883 ‘Guide to maintenance and supervision of insulating oils in service’, Standards Australia, 1993
12. Australian Standard AS 4360 ‘Risk Management’, Standards Australia, 2004
13. IEC standard 60599 ‘Mineral oil-impregnated electrical equipment in service - Guide to the interpretation of dissolved and free gases analysis’, IEC, 1999
14. Sinclair Knight Merz, ‘Assessment of Economic Lives for Transend Regulatory Asset Classes’, 2013. R192773
15. British Standard BS480 ‘Lead or lead alloy sheathed cables for working voltages up to and including 33 kV’
16. Cigre Publication, ‘WG21.10 Report – Survey on the service performance on HV AC cable systems’, Cigre, 1987
17. Mike Loring ‘Tricor Cable Manual’, plus updates 2007

11 Appendix A – Summary of Programs and Risk

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
S025-SUBS-Corrective-Cable EHV	CMPCE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
S173-SUBS -Cable Sheath Tests EHV	PMPCE	Medium	Customer Financial Network performance Regulatory Compliance Reputation Safety	Opex	Low
EHV cable RKtransition-RK	RENSB	Medium	Financial Safety	Capex	Low
EHV cable CR-NH	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 cable condition. The methods include:

- Visual inspection;
- Electrical testing; and/or
- Insulating oil monitoring, sampling and analysis.

12.1 Electrical testing

12.1.1 Sheath insulation test

The sheath insulation test is performed on all cables with a metallic sheath to measure the sheath integrity; thereby ensuring corrosion of the metallic sheath does not occur. It is a simple two step test that involves applying a 2.5 kV meggar ohm-meter between the sheath and earth to determine the insulation resistance. Low resistance is an indication of poor insulation which may lead to moisture ingress into the cable in turn causing corrosion of the metallic sheath.

The second phase of the test is to prove the integrity of the sheath insulation by applying a HVDC test. Typically 5 kV is applied for a minute for new cables and 4 kV is applied to older (nearing average service life) cables, 2.5 kV will be applied to cables older than 50 years.

Acceptable sheath insulation resistance values are dependent on the cable type, soil conditions and ambient conditions and differ greatly. Values of hundreds of megaohms may be acceptable for cables but it is important to monitor and trend the results over time to ensure the sheath resistance is not rapidly decaying, potentially indicating a sheath to earth fault.

12.2 Insulating oil testing

12.2.1 Oil impregnation coefficient test

The oil impregnation test is performed to calculate the compressibility of the oil. The test is performed on each individual closed oil system. Higher values from the test indicate higher levels of dissolved gas in the oil. As with any insulating oil, high levels of gas reduce the electrical integrity of the oil and the impregnation coefficient test is used as a trigger for either dissolved gas analysis (DGA) to determine the constituent gasses as described below, or ultimately oil treatment to remove the gas.

TasNetworks has a formally documented procedure, document TNM-MP-809-0523, for carrying out the test which involves drawing off a known quantity of oil and measuring the change in the pressure with a manometer. Once the field testing is completed, simple calculations are performed to ascertain the compressibility. The following table shows the acceptable limits for the impregnation coefficient.

Table 11 – Impregnation coefficient limits

Voltage	Acceptable limits
33 kV	$< 6 \times 10^{-6}$
110kV	$< 4.5 \times 10^{-6}$

12.2.2 Dissolved gas analysis

The DGA method can be used to identify past, present or evolving faults within a power cable. As the oil-paper insulating systems deteriorate, gases are produced. Analysis of the types and quantities of the gases dissolved in the insulating oil can be used to determine the type and severity of the fault causing the production of gas.

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

Table 12 - Key DGA levels for sealed oil-insulated power cables

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

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

13 Appendix C – EHV cable assessment

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

13.1 Hitachi.

Table 13 - Hitachi EHV cables are in service as follows:

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
Oil filled	Three core, Aluminium conductor	Creek Road	Creek Road-North Hobart No.1 Transmission cable Creek Road-North Hobart No.2 Transmission cable	41	2
Total number of units in service					**2**

13.1.1 Condition

Condition monitoring results through DGA and visual inspections shows the Hitachi cables are in acceptable condition.

13.1.2 Design considerations

The Hitachi cables are three core, oil insulated design; comprising aluminium conductor, paper insulation, and a corrugated aluminium sheath. The cable is rated at 566 Amps.

TasNetworks owns a spare run of cable with straight joints and accessories. The consumables, consisting of paper tapes and the like, have passed their useful shelf life and are not suitable for use.

A significant consideration for the Hitachi cables is the lack of qualified and available resources for any jointing and repair work. Whilst oil qualified cable jointers exist in Australia, few are qualified for both oil and extra high voltage work.

13.1.2.1 Future management strategy

The recommended maintenance practices will be continued for the Hitachi power cables.

TasNetworks' response to the lack of qualified oil cable jointers is described in Section 0. Contingency plans to be used in the event of a major failure of the Hitachi cables are being developed.

An in-depth conditional assessment report is to be prepared in 2017 to confirm condition of cables and that they are at about half serviceable life. Capital funds have been allocated into the 2019-24 regulatory period to allow expected refurbishment works on cable ancillary devices, such as oil monitoring and oil containment assets (pipe work/tanks) to ensure full service life is achieved from these cables.

13.2 LS Cable

Table 14 – LS EHV cable is in service as follows

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
XLPE	Single core, copper conductor	Norwood	NW-SL Transmission cable	5	1
XLPE	Single core, copper conductor	St Leonards	110 kV St Leonards-Mowbray Transmission cable	5	1
Total number of units in service					**2**

13.2.1 Condition

Condition monitoring results for the LS power cables indicate the units are in acceptable condition.

13.2.2 Design considerations

The Olex XLPE cable at George Town Substation is single core, XLPE insulated; comprising copper conductor, and a lead alloy sheath. The cable is rated at 420 Amps. The lead alloy sheath of the cable is particularly susceptible to corrosion when placed in a galvanic cell with elements like a copper earth mat as is present at George Town Substation. Sheath tests performed in 2006 and 2007 returned unacceptable test results on all three phases and subsequent investigations found that supporting post insulators used on the cable terminations had failed. The insulators were replaced and no further issues found.

The Olex cables installed at Trevallyn and Mowbray substations are single core, XLPE insulated; comprising copper conductor, and a corrugated stainless steel sheath. The cable is rated at 880 Amps (summer) and 965 Amps (winter).

Two spare straight joints for cross bonded installations of XLPE cable are held in store.

The cables at Risdon Substation are used to connect the transformers and capacitor banks to the indoor gas insulated switchgear (GIS). They are single core, copper conductor, XLPE insulated with a corrugated stainless steel sheath. There are no design issues evident with the cables installed at Risdon Substation.

13.2.3 Future management strategy

The recommended maintenance strategies will be implemented for the cables at George Town, Trevallyn and Mowbray substations.

For the cables at Risdon Substation, sheath tests will be performed in conjunction with associated primary plant maintenance, being either transformer or capacitor bank works. The reduced condition monitoring regime is appropriate due to the cable installations being internal to the substation, the young age of the cables and the criticality of the elements supplied by the cables.

13.3 Olex

Table 15 - Olex EHV power cables are in service as follows

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
XLPE	Single core, copper conductor	Risdon	Transformers T1, T3, T4, T5 and T6 Capacitor banks C1 and C2 power cable	16	7
XLPE	Single core, copper conductor	Risdon	Transformer T2	17	1
XLPE	Single core, copper conductor	Mowbray	Trevallyn–Mowbray transmission cable (Mowbray End)	12	1
Total number of units in service					**9**

13.3.1 Condition

Condition monitoring results for the Olex power cables indicate the units are in acceptable condition.

13.3.2 Design considerations

The Olex XLPE cable at George Town Substation is single core, XLPE insulated; comprising copper conductor, and a lead alloy sheath. The cable is rated at 420 Amps. The lead alloy sheath of the cable is particularly susceptible to corrosion when placed in a galvanic cell with elements like a copper earth mat as is present at George Town Substation. Sheath tests performed in 2006 and 2007 returned unacceptable test results on all three phases and subsequent investigations found that supporting post insulators used on the cable terminations had failed. The insulators were replaced and no further issues found.

The Olex cables installed at Trevallyn and Mowbray substations are single core, XLPE insulated; comprising copper conductor, and a corrugated stainless steel sheath. The cable is rated at 880 Amps (summer) and 965 Amps (winter).

Two spare straight joints for cross bonded installations of XLPE cable are held in store.

The cables at Risdon Substation are used to connect the transformers and capacitor banks to the indoor gas insulated switchgear (GIS). They are single core, copper conductor, XLPE insulated with a corrugated stainless steel sheath. There are no design issues evident with the cables installed at Risdon Substation.

13.3.3 Future management strategy

The recommended maintenance strategies will be implemented for the cables at George Town, Trevallyn and Mowbray substations.

For the cables at Risdon Substation, sheath tests will be performed in conjunction with associated primary plant maintenance, being either transformer or capacitor bank works. The reduced condition monitoring regime is appropriate due to the cable installations being internal to the substation, the young age of the cables and the criticality of the elements supplied by the cables.

13.4 Pirelli

Table 16 - Pirelli EHV cables are in service as follows

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
Oil filled	Three core, copper conductor	Rokeby	Rokeby Transition Station-Rokeby No.1 Circuit Transmission cable Rokeby Transition Station-Rokeby No.2 Circuit Transmission cable	35	2
Total number of units in service					**2**

13.4.1 Condition

Condition monitoring results for the Pirelli cables indicate the units are in acceptable condition.

13.4.2 Design considerations

The Pirelli oil filled cables are three core, oil insulated design; comprising copper conductor, paper insulation, and a corrugated aluminium sheath. The cable is rated at 405 Amps continuous.

TasNetworks owns spare cable straight joints, stop joints and accessories. The consumables, consisting of paper tapes and the like, have past their useful shelf life and are not suitable for use. Also, the joint coffins are in poor physical condition.

A significant consideration for the oil filled cables is the lack of qualified and available resources for any jointing and repair work. Whilst oil qualified cable jointers exist in Australia, few are qualified for both oil and extra high voltage work.

13.4.3 Future management strategy

The recommended maintenance practices will be continued for the Pirelli power cables.

TasNetworks' response to the lack of qualified oil cable jointers is described in Section 8.3.2.

An in-depth conditional assessment report is to be prepared in 2017 to confirm condition of cables and that they are at about half serviceable life. Capital funds have been allocated into the 2019-24 regulatory period to allow expected refurbishment works on cable ancillary devices, such as oil monitoring and oil containment assets (pipe work/tanks) to ensure full service life is achieved from these cables.

13.5 Prysmian

Table 17 – Prysmian EHV cables are in service as follows

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
XLPE	Single core, copper conductor	Creek Road	Chapel ST-Creek Road No1 Transmission cable Chapel ST-Creek Road No2 Transmission cable Chapel ST-Creek Road No3 Transmission cable Creek Road-North Hobart No1 Transmission cable Creek Road-North Hobart No2 Transmission cable Creek Road-Risdon No1 Transmission cable New Norfolk-Creek Road Transmission cable T2 Transmission cable T3 Transmission cable T4 Transmission cable	4	10
Total number of units in service					**10**

13.6 Unknown

Table 18 – Unknown cables in service

Insulant	Design principle	Location	Circuit Name	Average age	Number of units
XLPE	Single core, copper conductor	Smithton	Smithton-Woolnorth Transmission cable	10	1
XLPE	Single core, copper conductor	Trevallyn	Trevallyn-Mowbray Transmission cable (Trevallyn End)	12	1
XLPE	Single core, copper conductor	George Town	George Town-George Town Transition Station Transmission cable	19	1
Total number of units in service					**3**

14 Appendix D – High Voltage power cable assessment

TasNetworks’ population of high voltage power cables have not been subjected to regular condition monitoring in the past. Rather, exception based reporting and maintenance was performed, triggered by visual inspections or unplanned means such as post fault testing.

The revised maintenance regime, which includes sheath or screen testing of high voltage cables in conjunction with connected plant maintenance, will provide appropriate condition monitoring data so that electrical and physical condition, design issues and future management strategies for each cable type can be determined.

Off-line PD testing of the 11 kV power cables between the supply transformer and incomer circuit breaker was performed at Rokeby Substation in 2016 as a result of perceived need to replace these paper/lead insulated cables for XLPE cables with other associated capital works, namely the HV switchgear replacement. This was applicable for not only Rokeby Substation but also Bridgewater and Kingston.

The testing confirmed that there were no PD detected and that the cables were in a good condition and suitable for 20+ years more life. As such no paper/lead cables have been replaced with XLPE as was originally proposed.

15 Appendix E – Spare cable and fittings

Table 19 - TasNetworks currently has the following operational spares for power cable

Manufacturer	Insulant	Design principle	Location	Circuit Name	Average age	Number of units
LS Cable	XLPE		Primary Store	Spare Transmission cable	2	1
	Total number of operational spares					**1**

Table 20 – TasNetworks currently has the following strategic spares for power cables

Manufacturer	Insulant	Design principle	Location	Circuit Name	Average age	Number of units
Hitachi	Oil		Primary Store	Spare for Creek Road-North Hobart Transmission cable - Length 1 Spare for Creek Road-North Hobart Transmission cable - Length 2 Spare for Creek Road-North Hobart Transmission cable - Length 3	38	3
Olex	XLPE		Primary Store	Transmission cable drum 1 Transmission cable drum 2 Transmission cable drum G Transmission cable drum O Transmission cable drum Q	6	7
Pirelli	Oil		Primary Store	Spare for Rokeby Transition Station-Rokeby Transmission cable D83 Spare for Rokeby Transition Station-Rokeby Transmission cable D84 Spare for Rokeby Transition Station-Rokeby Transmission	33	4

				cable drum 89 Spare for Rokeby Transition Station-Rokeby Transmission cable drum W		
Unknown	Oil		Primary Store	Spare for Creek Road-North Hobart Transmission cable Yellow drum	Unknown	1
	Total number of strategic spares					**15**

Presently, TasNetworks owns two new straight joints suitable for EHV XLPE cables housed at the Moonah store.

Whilst TasNetworks has a number of joints and accessories for the EHV oil filled cables, all the consumables in the kits have passed their shelf life. Also, the joint coffins themselves are in poor physical condition due to numerous handling and movements plus poor physical protection in store. None of the units are considered suitable for service.

There are no spare high voltage joint kits kept as all high voltage cables are installed as straight runs without joints.

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16 Appendix F – Cable type definition code

The Code originated with one set out in BS480[*] and has been expanded to cover all types of underground cable used in Tasmania. It provides a convenient shorthand method for the identification of a cable on construction plans, records and other documents.

The identification of a cable commences with the conductor and proceeds outwards across the cable cross section.

16.1 Definitions

16.1.1 Group 1

Table 21 – Group1 cable code

Conductor Size	Square inch	Square mm
	Omit unit eg 0.1, 0.25 etc	Omit unit eg 120, 300 etc

The use of terminology such as 'Aluminium equivalent' and the like is unnecessary and is preferably avoided.

16.1.2 Group 2

Table 22 – Group 2 code

Conductor material	Symbol
Stranded copper	c
Stranded aluminium	a
Solid aluminium	sa

16.1.3 Group 3

Table 23 – Group 3 code

Number of core conductors	Symbol
Single core	1/c
Two cores	2/c
Three cores	3/c
Three and a half cores[1]	3½/c
Four cores	4/c

[*] BS480 Lead or lead alloy sheathed cables for working voltages up to and including 33 kV.
[1] The half sized core is the neutral conductor in larger low voltage paper insulated cables.

16.1.4 Group 4

Table 24 – Group 4 code

Cable Construction	Symbol
Paper insulation	p
Lead alloy sheath[2]	ly
Smooth aluminium sheath	A
Corrugated aluminium sheath	AZ
Corrugated copper sheath	CZ
Corrugated stainless steel sheath	SSZ
Serving and bedding	s
Single wire armour	w
Double wire armour[3]	d
Double steel tape armour[4]	t
Screened (paper insulated cable only)	H
Screened, separately leaded[5]	sl
Belted paper insulation	b
PVC (insulation and sheath)	pvc
Copper neutral screen (LV cables XLPE insulated)[6]	hc
Individual core copper screen (HV XLPE cables only) [7]	shc
Cross linked polyethylene insulation	x
Polyethylene insulation and sheath	pe
High density polyethylene sheath	HDPE
Cross bonded EHV installation	CB

[2] Some cables prior to 1956 were plain lead sheathed. They are subject to fatigue of the lead if they are moved. They are identified by the symbol l instead of ly. There are very few low voltage cables and probably even fewer HV cables of this type left in service.
[3] Double wire armour is used on submarine cables.
[4] Double steel tape armour is in most cases on LV cables. There are very few HV cables with double steel tape armour and caution is needed.
[5] Each core of a three core paper insulated cable has its own lead sheath. 22 and 33 kV cables only.
[6] These copper screens are helically wound.
[7] These copper screens are helically wound.

16.1.5 Group 5

Table 25 – Group 5 code

Voltage Designation	Symbol
600/1000 & 660/1100v	LV
6350/11000 & 11000/11000v	11 kV
12700/22000v	22 kV
19000/33000v	33 kV
63500/110000v	110 kV
127000/220000v	220 kV

16.1.6 Unique group code

In addition to the above groups, the following cables have been assigned their own codes.

Table 26 – unique cable code

Cable	Symbol
Aluminium conductor, paper insulated, extruded aluminium neutral sheath, pvc oversheath, LV	consac
Stranded copper conductor, pvc insulated, copper neutral screen, pvc insulating sheath, LV	dins

16.1.7 Example of the codes

Table 27 – Example of the codes

Cable	Symbol
0.25 in^2 copper, 3½ core, paper insulated, lead alloy sheath, bedding, double steel tape armour, hessian serving, 660/1 100v.	0.25c 3½/c pblysts LV
185 mm^2 stranded aluminium, 3 core, cross linked polyethylene insulated, helically wound individual copper wire screen, pvc sheath, high density polyethylene outer sheath 12 700/22 000v.	185a 3/c xshcpvc/HDPE 22 kV
240 mm^2 stranded aluminium, 3 core, paper insulated, belted construction, corrugated aluminium sheath, pvc oversheath, 6 350/11 000v.	240a 3/c pbZpvc 11 kV
185 mm^2 solid aluminium conductor, 3 core, cross linked polyethylene insulated, overall helically wound copper neutral screen, pvc insulating sheath 600/1 000v	185sa 3/c xhcpvc LV
120 mm^2 solid aluminium conductor, 4 core, cross linked polyethylene insulated, pvc sheath, 600/1 000v	120sa 4/c xpvc LV
185 mm^2 copper conductor, 1 core, cross linked polyethylene insulated, lead alloy sheath, copper wire screened, pvc sheathed, high density polyethylene outer sheath, 63500/110000v.	185c 1/c x ly hc pvc/HDPE 110 kV (eg George Town)
800 mm^2 copper conductor, 1 core, cross linked polyethylene insulated, stainless steel sheath, copper wire screened, pvc sheathed, high density polyethylene outer sheath, 63500/110000v, cross bonded installation.	800c 1/c x SSZ hc pvc/HDPE 110 kV CB (eg Mowbray).