Asset Management Plan

Transmission Line Conductor Assemblies Asset Management Plan

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Authorisations

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Review cycle	2.5 Years	

Responsibilities

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

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

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

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

Record of revisions

Section number	Details
Whole document	Revised document structure into new template Updated tables throughout document Updated risk assessment

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1 Purpose

The purpose of this document is to describe for transmission line conductor assemblies and related assets:

- TasNetworks' approach to asset management, as reflected through its legislative and regulatory obligations and strategic plans
- The key projects and programs underpinning its activities

2 Scope

This document covers all transmission line conductor assemblies, including conductors, optical ground wires (OPGW), all dielectric self-supporting (ADSS), earth wires, conductor fittings and dampers.

In this plan the term conductor will refer specifically to phase conductors. Auxiliary conductors are referred to by their construction or generic use e.g. OPGW and earth wire.

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 transmission line conductor assemblies, 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

4 Asset information systems

4.1 Systems

TasNetworks maintains an asset management information system (AMIS) that contains detailed information relating to transmission line support structure assets. AMIS is a combination of people, processes, and technology applied to provide the essential outputs for effective asset management. The following AMIS data integrity standards provides additional information relevant to transmission line conductor assemblies:

- R16948 WASP Asset Register – Data Integrity Standard – Conductor Assembly
- R17960 WASP Asset Register – Data Integrity Standard – Conductor Weight
- R17052 WASP Asset Register – Data Integrity Standard – In Span Fitting

- R17122 WASP Asset Register – Data Integrity Standard – Insulator and Damper Assembly
- R16984 WASP Asset Register – Data Integrity Standard – Fibre Junction Box

Currently individual conductor assembly asset information is located in the Works, Assets, Solutions and People (WASP) Asset management register. The WASP asset management register will be replaced in 2018 as part of the Ajilis Transformation program.

TasNetworks Geographic Information System (GIS) also captures asset data associated with transmission lines. This data is stored in a standalone database with links into WASP.

4.2 Asset information

Transmission conductor assembly asset information is recorded in the WASP asset register, which is used throughout TasNetworks for nameplate data, spares management, works scheduling and defect management.

5 Description of the assets

Conductor assemblies are defined to be all current carrying elements, conductors, overhead earth wires and fibre optic cables (OPGW and ADSS) including conductor clamps, spacers, vibration dampers and other line hardware attachments. Conductors constitute the medium of power transmission for TasNetworks.

5.1 Conductors

Conductors carry energy from the generation point to the terminal substation and between substations. Each conductor size has an optimal rating that determines the amount of energy that can be carried, and is directly related to the ambient temperature and other meteorological conditions.

TasNetworks has utilised numerous conductor types over time, with conductor selection based on numerous factors such as the required current carrying capability, terrain, environment and cost. The most common conductor type is ACSR/GZ, however over time this proportion will reduce as a result of conductor replacements and the construction of new lines, with AAAC becoming more common.

Table 1: Transmission line conductor details (August 2017)

Owner	Conductor material	Sizes	Circuit length (km)	% of total
TasNetworks	Aluminium conductor steel reinforced galvanised (ACSR/GZ)	9	1,988	56%
	All aluminium alloy conductor (AAAC)	7	851	24%
	Hard drawn copper (HD Cu)	5	652	18%
	Aluminium conductor alloy reinforced (ACAR)	2	55	2%
	All aluminium conductor (AAC)	2	6	<1%
	High temperature aluminium conductor invar reinforced (XTACIR)	1	7	<1%
Total	**6**	**26**	**3,559**	**100%**
Hydro Tasmania (maintained by TasNetworks)	All aluminium alloy conductor (AAAC)	2	47	-
Grand total		**28**	**3,606**	**-**

5.1.1 Aluminium conductor steel reinforced (ACSR/GZ)

ACSR/GZ conductors are strong, while still providing adequate current carrying capacity. However, the steel strands in the core of the conductor are susceptible to corrosion, causing loss of strength, degradation of the adjacent aluminium strands and eventual conductor failure. To reduce this risk TasNetworks has traditionally utilised greased ACSR/GZ. However, with time and particularly in environmentally corrosive areas, corrosion has been observed to occur, with eventual conductor replacement required.

5.1.2 All aluminium alloy conductor (AAAC)

AAAC conductors provide a good balance between strength, weight, cost and current carrying capacity. For these reasons AAAC is the preferred material utilised by TasNetworks when installing new conductors.

5.1.3 Hard drawn copper (HD Cu)

HD Cu conductors are highly conductive which minimises losses and provides very good performance over their lifespan. However, they are susceptible to annealing when overloaded or subjected to bushfires, causing a significant reduction in tensile strength, leading to conductor separation and/or significant reduction in conductor to ground clearance. As most of TasNetworks' HD Cu conductors were installed around the 1950s the maximum design temperatures of these transmission lines are generally low, thereby limiting transfer capacities. Subsequent load growth has resulted in TasNetworks' HD Cu conductors being operated very close to their maximum capability on hot days, risking possible annealing in the event that wind speeds drop or customer loads rapidly rise.

5.1.4 Aluminium conductor alloy reinforced (ACAR)

ACAR conductors are currently installed on only two transmission lines (Tarraleah–New Norfolk and Waddamana–Bridgewater 110 kV). These conductors were installed in the 1960s and at the time were considered to be the closest match to the copper conductors that were previously installed on these lines.

5.1.5 All aluminium conductor (AAC)

AAC conductors are currently installed on only two transmission lines (Bell Bay–George Town and Bell Bay Three Spur 110 kV). These conductors were selected as the most cost effective means of meeting TasNetworks' site specific requirement to transfer significant power across a short distance.

5.1.6 High temperature aluminium conductor invar reinforced (XTACIR)

XTACIR conductor is installed on the Creek Road–Risdon 110 kV transmission line. XTACIR was selected as it was the lowest cost option that both catered for existing and future power transfer requirements, while minimising the need for significant augmentation of transmission line support structures. This high temperature conductor is not common in Australia compared to other more traditional conductor types and hence there is not as much historical experience regarding XTACIR conductor performance over time. TasNetworks will continue to monitor the performance and condition of these conductors.

5.2 Earth wire, OPGW and ADSS

Similar to conductors, a number of different earth wires have been utilised in the past by TasNetworks, with earth wire selection based on factors such as fault current withstand, terrain, environment and cost. Since the early 1990s TasNetworks has installed optical fibre ground wire (OPGW) on all new transmission lines to provide earthing, lightning shielding, and communications between sites. Prior to this, TasNetworks did not utilise OPGW and only installed earth wires for the first 1.5km (110 kV) or 3km (220 kV) of a transmission line emanating from a substation, or in locations where lightning was prevalent.

To maintain similar earth potentials and to ensure reliable protection operation, overhead earth wires and OPGW are connected to the substation earthing grid.

All dielectric self-supporting (ADSS) has also been installed on a number of lines to provide a telecommunication path. ADSS is manufactured from a semiconducting material and is installed in proximity to 110 kV phase conductors within the body of the structure. This reduces any required structural augmentation and or strengthening.

Table 2: Transmission line earth wire, OPGW and ADSS summary

Owner	Conductor material	Sizes	Length (km)	% of total
TasNetworks	OPGW / ADSS	13	714	52%
	Aluminium conductor steel reinforced (ACSR/GZ)	5	370	27%
	Galvanised steel (SC/GZ)	6	219	16%
	Aluminium clad steel (SC/AC)	3	19	1%
	All aluminium alloy conductor aluminium clad steel reinforced (AAAC/ACS)	4	6	<1%
	Hard drawn copper (HD Cu)	3	4	<1%
	All aluminium alloy conductor (AAAC)	1	<1	<1%
Grand total	**7**	**35**	**1,333**	**100%**
Hydro Tasmania (maintained by TasNetworks)	OPGW	1	47	-
Grand total		**-**	**1,379**	**-**

5.3 Conductor fittings

Numerous fitting types are utilised on TasNetworks' conductors and earth wires. These include, but are not limited to:

- vibration dampers;
- mid-span joints;
- split bolt connectors;
- compression dead ends;
- suspension and strain clamps;
- armour grip suspension units (AGSUs); and
- weight carriers.

Due to the large number and relatively low cost of the conductor fittings installed on the transmission network, TasNetworks only includes dampers and mid-span joints in its asset register. A summary of the number of conductor dampers and mid-span joints is provided below.

Table 3: Transmission line vibration damper summary

Damper type	Total
Stockbridge (New)	33,065
Stockbridge (Old)	21,101
Spiral vibration damper	19,338
Dog bone	12,895
Torsion bar	5,043
Elgra	12
Total	**41,790**

Table 4: Transmission line mid-span joint summary

Mid-span joint type	Total
Compression	5,121
Macintyre Sleeve	2,290
Helical	258
Total	**7,669**

Transmission line dampers are designed to dynamically counteract Aeolian and other vibration within a conductor span. As such, over their lifetime they will experience mechanical wear and will deteriorate to the extent that they can no longer protect the conductor against the effects of vibration. At that point in time damper replacement is normally required.

The quality and integrity of a mid-span joint is largely dependent on the skill of the lineperson performing the installation. If the approved work methodology for the installation of a mid-span joint is not followed (e.g. poor material preparation) then it is likely that a hot joint will evolve, resulting in accelerated conductor deterioration and eventual failure if undetected.

5.4 Age profile

5.4.1 Conductors

TasNetworks' conductors have an average age of 45 years, with the average age of particular conductor types ranging between 3 and 81 years.

Table 5: Average age by conductor type

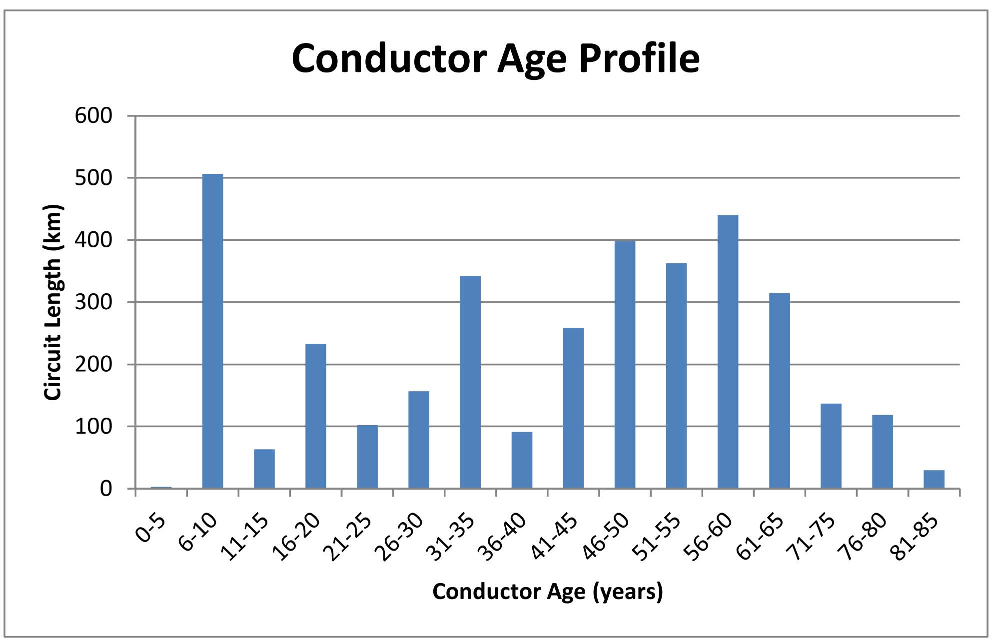
Conductor type	Average age (years)
AAAC	12
ACSR	47
HD Cu	69
XTACIR	11
ACAR	51
AAC	40
Total population	**45**

Although age is not a definitive indicator of remaining conductor life, it provides a fair and representative indication of the overall condition of TasNetworks' conductor population, as shown in Figure 1.

It should be noted that:

- 21 per cent of conductors are currently greater than 60 years of age;
- without an ongoing replacement program, 20 per cent of conductors will be greater than 60 years of age by the end of the 2014-19 regulatory control period; and
- without an ongoing replacement program, 35 per cent of conductors will be greater than 60 years of age by the end of the 2019-24 regulatory control period.

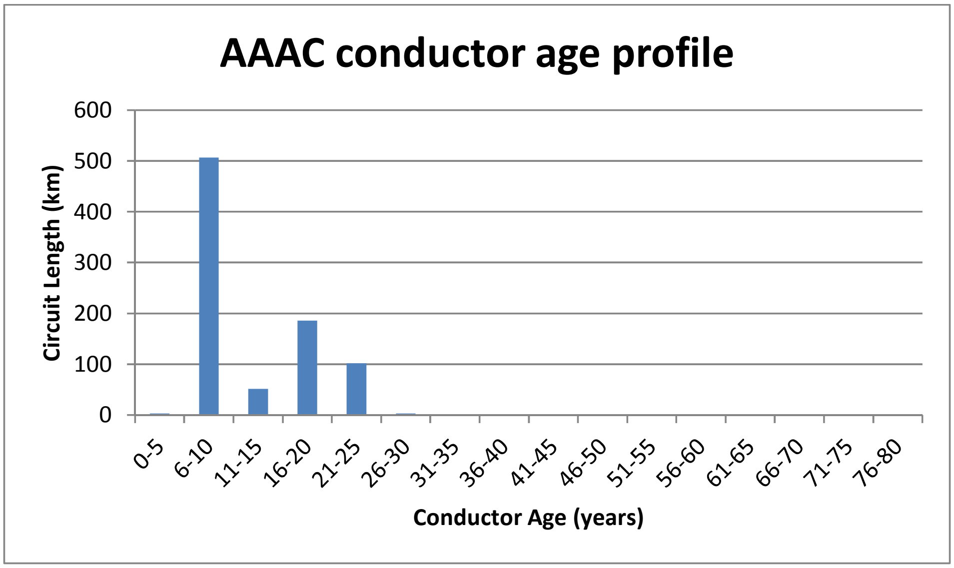
Figure 1: Conductor age profile



5.4.1.1 AAAC conductor

Over the last twenty years TasNetworks has moved towards making AAAC conductors its standard for new or upgraded transmission lines, and hence the age profile is relatively young.

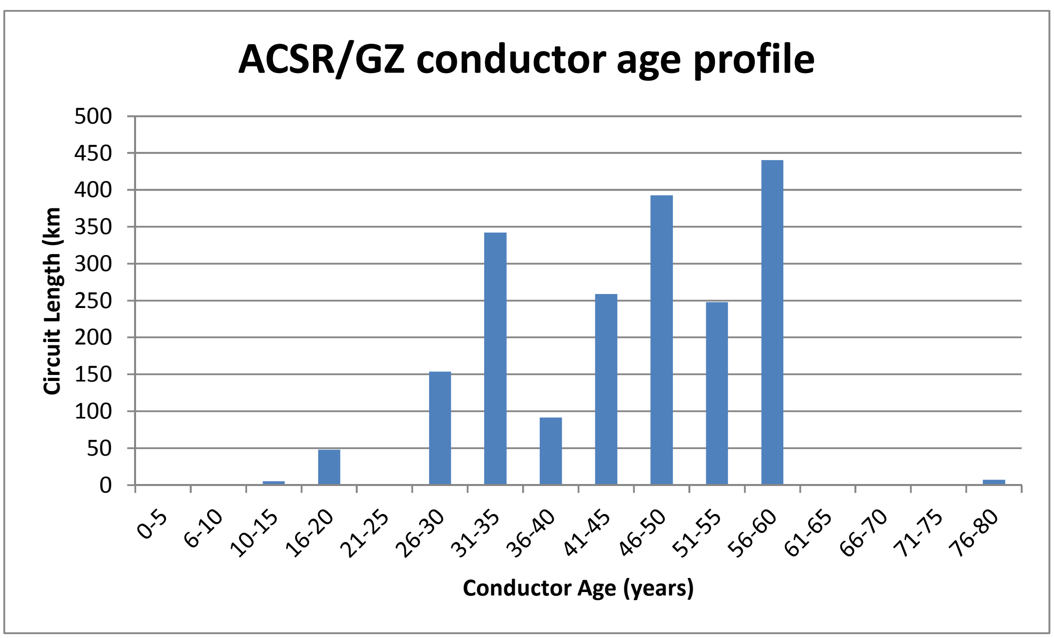
Figure 2: AAAC conductor age profile



5.4.1.2 ACSR/GZ conductor

During the 1950s, 60s and 70s TasNetworks typically utilised ACSR/GZ when constructing or upgrading transmission lines.

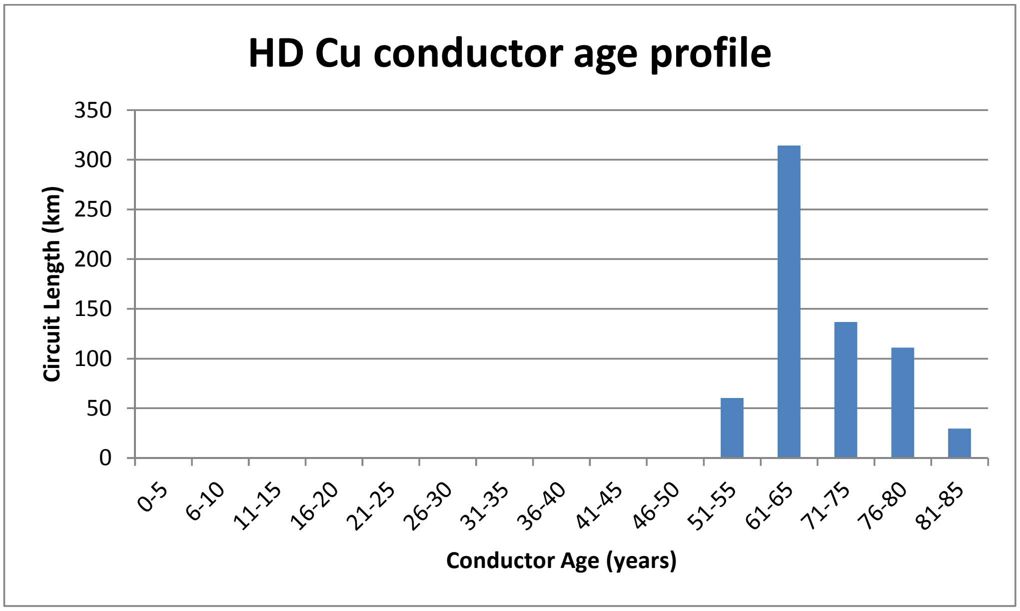
Figure 3: ACSR/GZ conductor age profile



5.4.1.3 HD Cu conductor

The earliest transmission lines constructed in Tasmania utilised hard drawn copper (HD Cu) conductors.

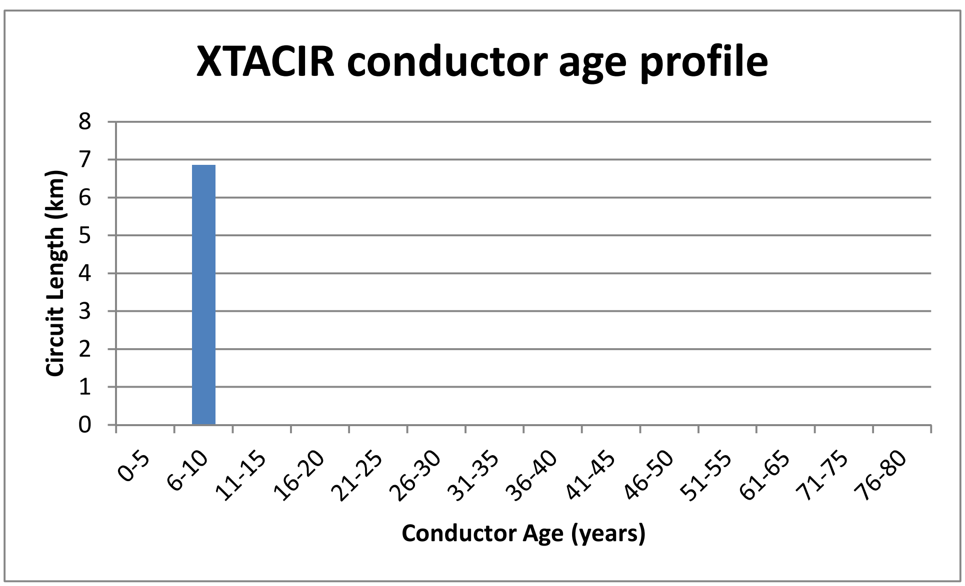
Figure 4: HD Cu conductor age profile



5.4.1.4 XTACIR conductor

The Creek Road–Risdon 110 kV transmission line is the only line in the TasNetworks network to utilise XTACIR conductor, and was installed in 2006.

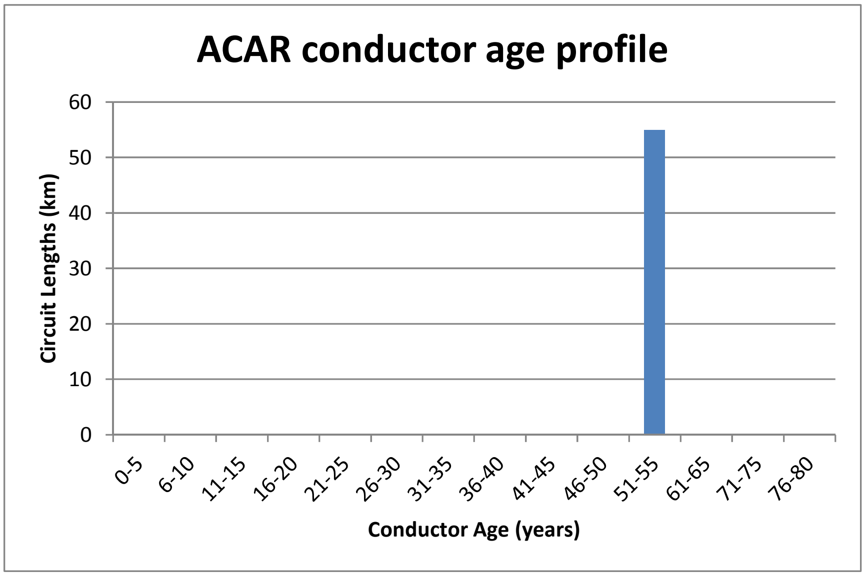
Figure 5: XTACIR conductor age profile



5.4.1.5 ACAR conductor

The age profile of TasNetworks' ACAR conductor is shown below.

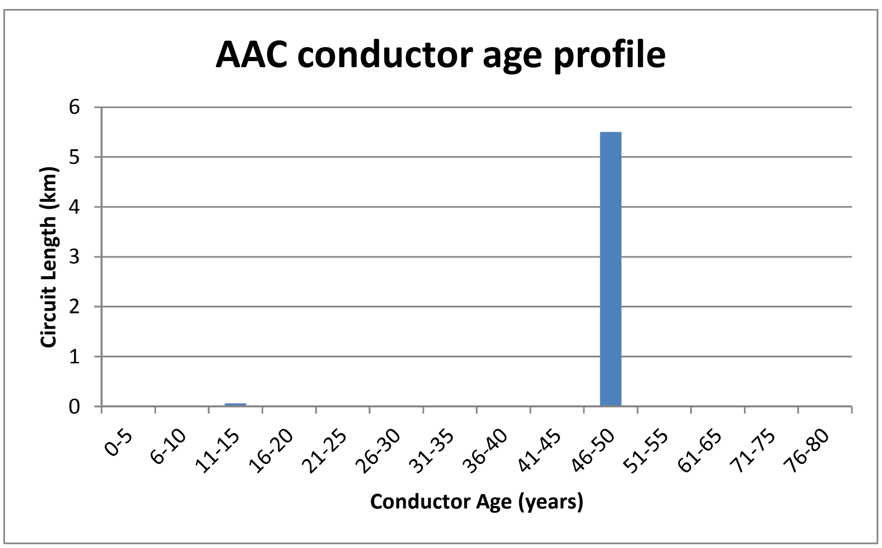
Figure 6: ACAR conductor age profile



5.4.1.6 AAC conductor

The age profile of TasNetworks' AAC conductor is shown below.

Figure 7: AAC conductor age profile (August 2017)



5.4.2 Earth wires, OPGW, ADSS and other conductor assemblies

TasNetworks does not currently record the age of its earth wires, OPGW/ADSS, dampers or other conductor assemblies. This is a deficiency that TasNetworks is currently assessing, to determine how this information can be captured in the future within TasNetworks' asset register, at the most appropriate asset level.

5.5 Asset Condition Summary

5.5.1 Conductors

TasNetwork's conductors are considered to be in good condition. In 2008-09 TasNetworks identified severe corrosion on the Wesley Vale Spur 110 kV transmission line and subsequently removed a conductor sample for testing purposes. In response to these findings, in 2010 TasNetworks replaced conductors between tower T21 and Wesley Vale Substation on the Wesley Vale Spur 110 kV transmission line. The remaining conductor on this transmission line was programmed for replacement in the 2014–19 regulatory control period.

5.5.2 Earth wires and OPGW/ADSS

TasNetworks' inspection regimes have identified that the condition of SC/GZ earth wires on the 220kV transmission lines is poor due to corrosion and is at a point where it warrants the programmed replacement over the next regulatory period.

5.5.3 Vibration dampers

TasNetworks' inspection regimes have identified that a small number of dampers are in poor condition on a number of transmission lines, and that replacement is warranted to mitigate the risk of damper failure resulting in conductor damage.

5.6 Operational and design issues

5.6.1 Conductors

In operating its transmission lines, TasNetworks must ensure that conductors do not breach Australian standards [17] requiring minimum conductor-to-ground clearances of 6.7m and 7.5m for 110 kV and 220 kV transmissions line respectively. This is achieved through the selection of an appropriate conductor type, together with a line design that permits the conductor to transfer the required energy, while not exceeding its design temperature and breaching conductor-to-ground clearances.

In general TasNetworks chooses to operate hard drawn copper (HDCu) and all aluminium alloy conductors (AAAC) at a maximum operating temperature of 75°C and Aluminium Conductor Steel Reinforced (ACSR/GZ) at 90°C. High Temperature Aluminium Conductor Invar Reinforced (XTACIR) is operated at a thermal limit of 230°C.

Assessment of the transmission system 2016/17 using LiDAR has identified substandard clearances on a number of transmission lines and a program should be undertaken to bring these lines up to their maximum operating temperatures.

5.6.2 Earth wires and OPGW/ADSS

An assessment of TasNetworks' telecommunications requirements has identified that there is a significant opportunity to improve telecommunications diversity and achieve whole of life cost savings through the replacement of one earth wire with optical fibre ground wire (OPGW) on the following transmission lines/circuits:

- Liapootah–Wayatinah–Catagunya 220 kV.
- Repulse-Cluny Spur 220 kV.

These assets have started exhibiting signs of corrosion. Therefore, in addition to these benefits, the replacement of one out of two earth wires on each transmission line will also assist in the mitigation of risk due to asset failure.

With time, asset augmentation and other activities result in fault levels gradually rising across the network. It is important that TasNetworks ensures that fault levels do not exceed the short circuit capacity of its earth wires; however such a study had not been undertaken for some years. It is recommended that TasNetworks undertake a review of earth wire short circuit ratings across the network, with insufficiently rated earth wires assessed for replacement.

5.6.3 Conductor fittings

Mid span joints

In July 2016 two separate conductor joint failures were experience on the Sheffield – George Town 220 kV transmission circuits. The conductor failure at the end of a conductor joint is considered to be as a result of a number of contributing factors rather than a single predominant failure mechanism. This type of failure is considered extremely rare with no similar failures recorded by Australian TNSPs. The remaining conductor joints on this transmission line were assessed with no indication of further failures evident and new methods for assessing conductor joints for this failure mode are being investigated.

Figure 8: Broken conductor just inside the mid-span joint

Dead end assemblies

Conductor dead end assemblies installed on eleven 220 kV transmission circuits were identified as having a rating lower than both the conductors to which the fittings are attached and the substation terminal to which the transmission circuit is connected [9].

The lower rating is due to the small surface area at the point of connection between the conductor palm of the main dead end fitting and the conductor palm of the jumper fitting, hence limiting current flow. To operate beyond this rating may result in excessive heating, thermal run away, and eventual joint failure. Joint failure typically would result in the connected conductor falling to the ground, posing a safety risk to the public, while the presence of molten metal significantly increases the risk of fire start to the environment. The subsequent circuit outage would also impact on system security, reduce system capacity and disrupt electricity supply to TasNetworks' customers.

Figure 9: Dead end assembly with inadequate rating

A program of work to augment or replace these dead end assemblies to maximise the capacity of the transmission lines has recently been completed.

Trunnion clamps

As part of TasNetworks' substandard clearance rectification project in the 2000s a number of synthetic horizontal line post insulators were fitted with trunnion clamps that did not incorporate a rubber shoe or other means of energy dissipation. At these locations TasNetworks is starting to observe signs of conductor fatigue (including strand breakage) on small diameter conductors, as well as damage to the trunnion clamp itself for large diameter conductors. It is TasNetworks' preference to install armour grip supports (AGSs) in this situation, and to retrofit defective trunnion clamps with AGSs where required.

Hooks

Hooks are often used to support insulators from support structures, and conductors from insulators. However, hooks can pose a number of issues where live line maintenance or construction activities are required. This is due to conductor suspension clamps sometimes 'jamming' onto hooks and being difficult to unhook. In addition, the cold end hook may dislodge when lifting the conductor causing the insulator string to fall. This exposes personnel to risk and increases the likelihood of a circuit outage during these activities. Where a transmission line will be upgraded, or where a number of conductor clamps are to be changed on a transmission line, consideration is given to removing hooks from service. Other factors impacting on this decision include the criticality of the transmission line and history of in-service hook failure or dislodgement.

6 Standard of service

6.1 Technical Standards

In general, conductors and earth wires have been designed and installed to various British, American and Australian standards over the last 85 years. OPGW and ADSS have been installed in accordance with manufacturer's requirements to meet contractual guarantee conditions.

Conductor clamps and other line hardware have also been designed and installed to various British, American and Australian standards over the last 85 years. The more contemporary line fittings comply with the current or previous versions of AS 1154.

6.2 Performance objectives

6.2.1 Service obligations for network assets

TasNetworks' performance incentive (PI) 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; and
- transformer circuit availability.

supply availability:

- number of events in which loss of supply exceeds 0.1 system minutes; and
- number of events in which loss of supply exceeds 1.0 system minutes.

Details of the PI scheme and performance targets can be found in TasNetworks' SAMP.

6.2.2 Service obligations for non-regulated assets

6.2.2.1 Hydro Tasmania

TasNetworks has a 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 connection asset availability which can be impacted by TasNetworks asset category assets. An overview of Hydro Tasmania PI scheme and performance targets can be found in the SAMP.

6.2.2.2 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.

6.2.2.3 Major Industrial Direct Customer Connections

TasNetworks has a number of direct connections to major industrial customers through EHV and Transmission Lines. The following transmission line assets provide these direct connections:

- George Town – Colmalco 220 kV;

- George Town – Temco 110 kV;
- George town – Starwood 110 kV); and
- Burnie Hampshire 110 kV (via Hampshire switching station).

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

6.3 Key Performance Indicators

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

For asset category 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 asset category related faults or defects.

6.3.1 Conductor assembly KPIs

The following Key Performance Indicators (KPIs) are used to monitor the conductor assembly asset base:

- Conductor assembly defect volumes are maintained at a consistent level over a 5 year period; and
- Transmission line outages due to conductor assembly failures are maintained.

6.3.2 Performance summary

Since 1990 there have been 20 conductor assembly failures which resulted in an interruption to electricity supply. Statistics suggest that the failure rate has increased slightly since 2005; however this can also be partly explained by improvements in the storage and analysis of fault event information initiated by TasNetworks in the mid-2000s, resulting in more effective and visible linkages between asset information and fault data.

Lightning is a common trigger for conductor failure but is difficult to mitigate due to its unpredictable nature and the significant energy discharged by each strike. TasNetworks has targeted the installation of OPGW on a number of 110 kV and 220 kV transmission circuits in the West, North and North West of the state to provide additional lightning protection in lightning prone regions. TasNetworks has also planned to trial the use of surge diverters on lightning prone transmission lines in the west and north west of the state.

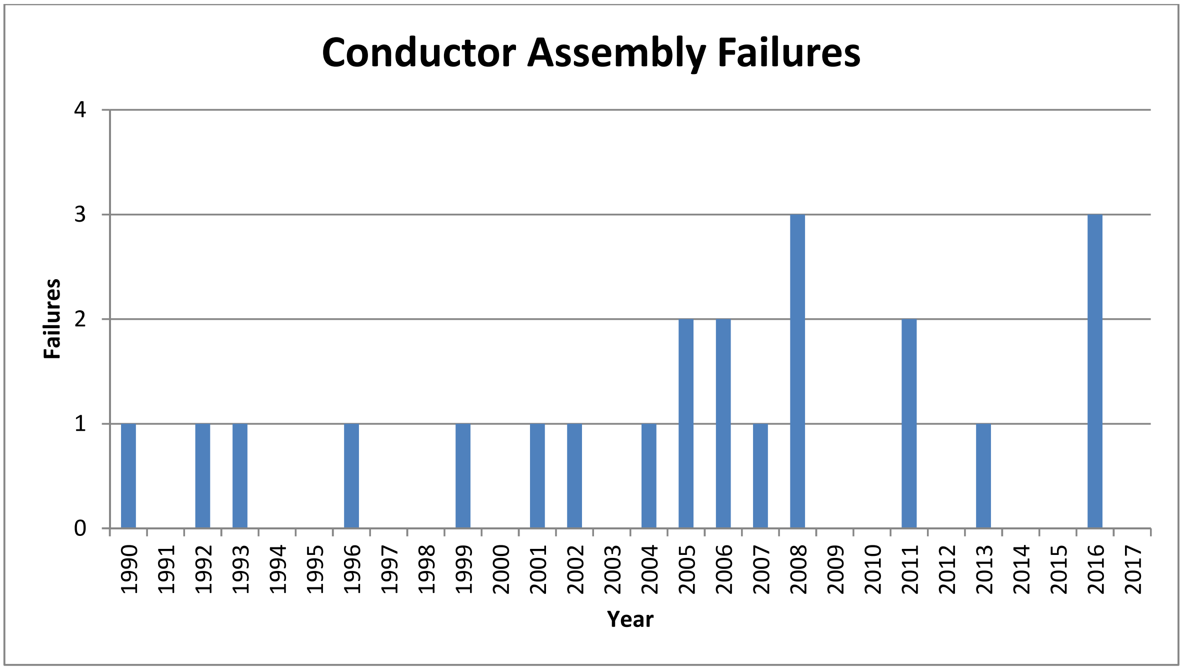
Analysis of these fault events also shows that fatigue and corrosion have caused conductor assembly failures in the past. The risk of this reoccurring is high on transmission lines:

- located in highly corrosive regions (e.g. coastal, industrial and/or moist environments);
- constructed utilising galvanised steel strands, particularly SC/GZ earth wires and ACSR/GZ conductors) and
- approaching end of technical life.

To maintain and improve asset reliability, all conductor assembly replacement programs should target these particular assets and regions.

TasNetworks should also continue to implement thermo graphic and corona inspections on critical transmission lines to assist in identifying defective assets prior to failure.

Figure 10: Conductor assembly failure history



6.4 Benchmarking

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

- International Transmission Operations & Maintenance Study (ITOMS); and
- Australian Energy Regulator (AER) Regulatory Information Notices (RIN).

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.

6.4.1 External benchmarking

ITOMS provides a means to benchmark performance (maintenance cost & service levels) between related utilities from around the world. For transmission line assets, the benchmarking exercise combines patrol and inspection costs into one category, and maintenance costs in another.

6.4.1.1 Service Performance

Figure 11 and Figure 12 on the following page shows that TasNetworks' service performance has been better than the ITOMS study participant's average for 220 kV transmission line assets. Similarly, 110 kV transmission line assets have shown a path of continual and significant improvement as benchmarked against ITOMS study participants.

The low number of fault outages attributable to transmission line assets is confirmation of the effectiveness of TasNetworks' inspection and defect management regime. Under this regime, assets in poor condition are identified, prioritised and replaced in a timely and planned manner. TasNetworks' whole-of-life risk based approach to asset management results in effective fleet management of transmission line assets, ensuring that assets are systematically replaced as they approach end of life.

Figure 11: ITOMS Overall transmission line composite performance trend

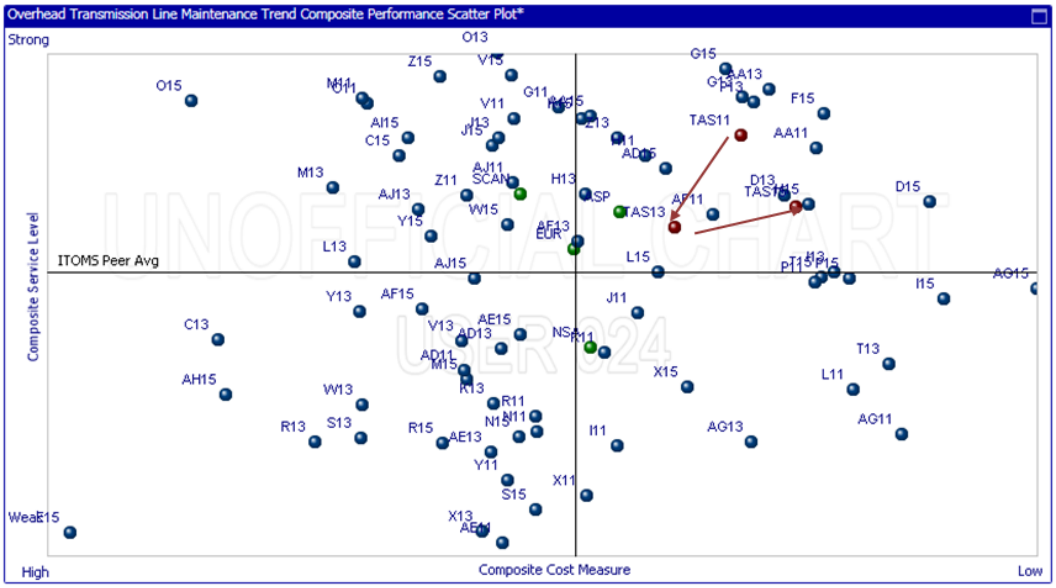
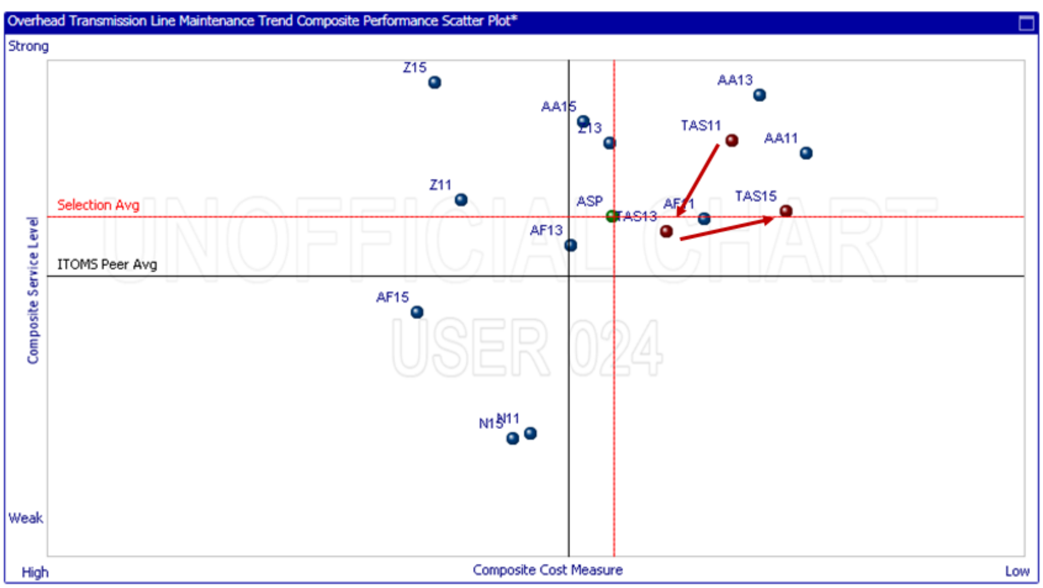


Figure 12: ITOMS Overall transmission line composite regional performance trend



7 Associated risk

TasNetworks has adopted the risk management principles detailed in Australian Standard AS/NZS ISO 31000:2009 'Risk management – principles and guidelines' in managing risks associated with its transmission line conductor assemblies. The primary goals of the risk management strategy are to:

- ensure the safety of personnel and the public as far as practicable;
- manage the impact of defective conductors on transmission system performance; and
- reduce the risk of fire starts due to conductor failure to an acceptable level.

7.1 Risk Management Framework

TasNetworks has developed a Risk Management Framework for the purposes of

- Demonstrating the commitment and approach to the management of risk – how it is integrated with existing business practices and processes and ensure risk management is not viewed or practiced as an isolated activity;
- Setting a consistent and structured approach for the management of all types of risk; and
- Providing an overview on how to apply the risk management process.

Assessment of the risks associated with the transmission line conductor assemblies has been undertaken in accordance with the Risk Management Framework. The risk assessment involves:

- Identification of the individual risks including how and when they might occur
- Risk analysis of the effectiveness of the existing controls, the potential consequences from the risk event and the likelihood of these consequences occurring to arrive at the overall level of risk.
- Risk evaluation where risks are prioritised based on their ratings and whether the risk can be treated) or managed at the current level.
- The likelihood and consequence of risk events occurred are assessed using the following risk rating matrix in Figure 7.

Figure 6: Risk Ranking Matrix

		CONSEQUENCE				
LIKELIHOOD		**1 NEGLIGIBLE**	**2 MINOR**	**3 MODERATE**	**4 MAJOR**	**5 SEVERE**
• ≥ 99% probability • Impact occurring now • Could occur within "days to weeks"	**5 ALMOST CERTAIN**	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH
• 50% - 98% probability • Balance of probability will occur • Could occur within "weeks to months"	**4 LIKELY**	LOW	MEDIUM	HIGH	HIGH	VERY HIGH
• 20% - 49% probability • May occur shortly but a distinct probability it won't • Could occur within "months to years"	**3 POSSIBLE**	LOW	LOW	MEDIUM	HIGH	HIGH
• 1% - 19% probability • May occur but not anticipated • Could occur in "years to decades"	**2 UNLIKELY**	LOW	LOW	MEDIUM	MEDIUM	HIGH
• ≤1% probability • Occurrence requires exceptional circumstances • Only occur as a "100 year event"	**1 RARE**	LOW	LOW	LOW	MEDIUM	MEDIUM

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

This asset management plan describes the major risks associated with transmission line conductor assemblies and the current or proposed treatment plans.

7.2 Risk identification

The following areas have been identified as risk areas in the management of conductor assemblies and are discussed below and summarised in Table 7.

7.2.1 Conductor Assemblies Degradation

Conductor breaks (including earth wires, ADSS and OPGW) are rare and are normally initiated by either a single, high-energy event (e.g. lightning or bushfire), or through long term fatigue at a conductor joint, or the point of suspension.

Over time, the condition of conductor fittings such as dampers, connector clamps and hooks will degrade due to the environmental factors to which they are subjected (e.g. wind, corrosion), ultimately resulting in asset failure.

Damper degradation in particular has an associated risk with potentially damaging vibration frequencies induced in the conductor resulting in mechanical failure.

Condition monitoring, both routine and post fault, can detect these defects. Aerial inspections are the most cost-effective way to inspect these assets to reduce loss of supply events and prevent vegetation fires. In no-fly zones, ground inspections must be undertaken to complete the condition assessments every 3 years. Other opportunities also present for ground inspection on an occasional basis.

7.2.2 Accelerated corrosion causes premature conductor assembly failure

Transmission lines close to aggressive atmospheres (industrial and/or marine) are susceptible to premature component failure and should be closely monitored and maintained. For transmission line assets identified in such environments inspection frequencies should be such that any defects can be identified and remediated prior to a failure.

7.2.3 Aged conductor assemblies will fail due to deterioration

Some aged conductors assembly types have an increased risk of failure. These assets must be closely monitored and maintained so that transmission line safety and reliability is maintained.

7.2.4 Non-compliance Risks

Non-compliance resulting from a change in use or augmentation of the transmission line under the National design standards require TNSPs to ensure that conductors do not encroach upon minimum clearances to ground.

7.3 Mitigating strategies

Risk mitigation takes the form of identifiable actions in the form of operations and maintenance or capital expenditure which seek to either manage or remove the risk. Risk mitigation activities to either remove or lower the risk will normally consist of either inspections and maintenance, or capital expenditure for asset replacement or refurbishment.

The assumption is that if the mitigation action is taken, the likelihood of the risk occurring is reduced to a lower risk profile. Table 7 contains the mitigation actions.

Table 7: Transmission line conductor assembly risk analysis

RISK IDENTIFICATION		RISK ANALYSIS				RISK MITIGATION	
Risk	**Detailed Risk**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Mitigating Action(s)**	**Residual Risk Rating**
Conductor Degradation	Degraded conductor breaks (including earth wires and OPGW) resulting in conductor falling to the ground and a serious injury/death, bushfire event and/or network constraint or outage.	Safety and People	Rare	Severe	Medium	Perform full condition assessment of conductor assemblies every three years and ground inspection annually. Inspect conductors (electrically, visually and thermally) seeking any visual evidence of weakness. Test any location of concern. Inspect (electrically, visually and thermally) fittings seeking any visual evidence of weakness. Test any location of concern. Replace as required.	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium
Inspection methods and frequency	Infrequent and over reliance on one assessment for conductor assemblies results in defects not being identified which may lead to conductor failure.	Safety and People	Rare	Severe	Medium	Ensure access conductor assemblies are assessed and defects reported as part of: • 3 yearly detailed assessment of transmission overhead transmission assets (aerial for 97% and ground based for 3% which can't be flown); and • Annual aerial inspection for vegetation (for easily observable defects).	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Minor	Low		Low
Non-compliant clearances	Non-compliance resulting from a change in land use in the vicinity of the transmission line conductors or augmentation of the transmission line. Increased risk on contact with conductors resulting severe injury/death, bushfire event and/or network constraint or outage.	Safety and People	Rare	Severe	Medium	Assess for compliance against AS7000 during routine inspections and LiDAR. Non-compliant spans to be rectified as a matter of priority.	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Severe	Medium		Low

8 Management plan

8.1 Maintenance strategy

The good performance of transmission line conductor assemblies is partially achieved through the implementation of a programmed condition assessment regime and resulting asset management activities such as asset refurbishment or replacement. Preventive and corrective maintenance practices are reviewed on a regular basis taking into account:

- past performance;
- industry practice (derived from participation in technical forums, benchmarking exercises and discussions with other transmission companies); and
- the availability of new technologies.

As transmission line conductor assemblies age different life cycle issues and failure modes arise which must be captured in the preventative and corrective practices. Table 8 provides a summary of the life cycle issues applicable to conductor assemblies.

8.1.1 Routine maintenance

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

8.1.2 Routine maintenance versus non routine maintenance

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

8.1.3 Refurbishment

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

8.1.4 Planned asset replacement versus reactive asset replacement

Replacement is generally only preferred when this is a more economic proposition compared to ongoing maintenance costs over the estimated remaining service life of the asset. These are identified from the maintenance and inspections activities and feed into the list of proposed capital expenditure projects for prioritisation.

8.1.5 Non network solutions

Non network solutions are not a viable option for transmission line conductor assemblies.

Table 8: Life cycle issues

Type of conductor assembly	Issue
All	A significant proportion of TasNetworks' transmission line conductor assemblies are either at, or have exceeded, their economic life of 60 years, and it is likely that these assets will exhibit an increase in condition deterioration. To support TasNetworks' medium and long term vision, it may be necessary for transmission lines to be either augmented or decommissioned. Where this occurs it is important that TasNetworks consider the requirements of new and more onerous design standards to ensure that compliance is maintained. New conductor design technologies are providing greater electrical energy transfer capacity and/or reduced structural loading. Re-conductoring options are increasingly likely to be utilised as part of augmentation activities, ultimately resulting in an extension of the useful life of transmission line support structures.
AAAC conductor	AAAC conductor is relatively new within TasNetworks' transmission system and has not exhibited any systemic condition deterioration. Typical weathering can be expected to occur over time, with eventual increased degradation and resulting replacement likely as the conductor approaches 60 years of age.
ACSR conductor	Steel strands in the core of ACSR conductor are susceptible to corrosion, causing loss of strength, degradation of the adjacent aluminium strands and eventual conductor failure. To minimise this risk TasNetworks has traditionally utilised greased ACSR/GZ. However, with time and particularly in environmentally corrosive areas, corrosion has been observed to occur, with eventual conductor replacement required.
HD Cu conductor	HD Cu conductors are highly conductive, minimising losses. However, they are susceptible to annealing when overloaded or subjected to bushfires. As most of TasNetworks' HD Cu conductors were installed around the 1950s the design temperatures of these transmission lines are generally low. Subsequent load growth has resulted in TasNetworks' HD Cu conductors being operated very close to their design capability on hot days, increasing the risk of constraining generation and/or load shedding.
XTACIR conductor	XTACIR conductor has only been in use by TasNetworks since 2006. This high temperature conductor is not common compared to other more traditional conductor types and hence there is not as much historical experience regarding XTACIR conductor performance over time. TasNetworks will continue to monitor the performance and condition of these conductors.
OPGW	OPGW is the most common form of overhead earthing utilised on the transmission network, and has not exhibited any signs of premature degradation or design deficiency. Typical weathering can be expected to occur over time, with eventual increased degradation and resulting replacement likely as the OPGW approaches 60 years of age.
Galvanised steel earth wire	Galvanised steel earth wires have been utilised by TasNetworks since the 1950s and are common. Over time, the galvanising layer has been observed by TasNetworks to degrade, resulting in steel corrosion and increasing the likelihood of earth wire failure. With time, earth wire replacement will eventually be required, particularly in those locations where atmospheric corrosion has been observed to be higher than in other locations across the network
Dampers	TasNetworks has not identified any significant design issues with its dampers, however due to their requirement to absorb energy generated by conductor vibration, they are susceptible to wear, particularly in windy regions and where aeolian vibration is more prevalent. Damper replacement is necessary where dampers are assessed as being at end of life and are unable to perform their protective duty.

8.1.6 Preventative maintenance

Preventive maintenance is, by its nature, a planned and scheduled maintenance activity that is completed to a predetermined scope, and consists of:

- Condition assessment - the routine inspection, testing and monitoring of assets to ascertain their condition.
- Maintenance (routine and condition based) - assets are maintained either on predetermined frequency basis (time-based) or in response to findings arising from condition assessment activities.

TasNetworks has adopted internationally recognised procedures for the maintenance of its transmission line conductor assemblies. After consideration of the many factors applying to Tasmania's geography, climatic conditions and the history of known deterioration of transmission line conductor assemblies in this environment, TasNetworks has adopted the preventive maintenance strategies summarised in Table 11.

Table 9: Preventive maintenance strategies

Strategy	Frequency	Description
'Detailed methodical' aerial condition assessment	3 year cycle	• A detailed condition assessment is conducted utilising a helicopter (approximately 33 per cent of total structures per year). • Effective for approximately 97 per cent of the transmission line population over the 3 year period. The remainder is subject to a climbing condition assessment.
'Detailed methodical' climbing condition assessment	3 year cycle	• A detailed condition assessment is conducted by climbing individual structures. • Applies to approximately 3 per cent of total structures over the 3 year period. • Only applicable where 'no-fly' areas prevent the use of a helicopter.
Ground-based inspections (non-climbing)	Annually	• A visual inspection aimed at identifying obvious defects that could impair the electrical or structural integrity of the transmission line. • Any defects are reported. • Applies to the structures that did not receive a 'detailed methodical' inspection (i.e. 67 per cent of total structures).
Thermographic inspection	5 year cycle	• Perform thermo graphic surveys on 17 circuits critical to the operation of Basslink every five years (funded externally).
	As required	• Ad hoc thermo graphic inspections are undertaken where identified (through routine inspections) as being necessary. TasNetworks is currently reviewing whether there is value in establishing a cyclic thermo graphic program for all transmission circuits.
Specialised inspection and test regimes	As required	• If TasNetworks identifies a new or unusual failure mode, then targeted inspection or test regimes may be employed.

8.1.7 Corrective maintenance

In the event of a fault condition TasNetworks will arrange for corrective maintenance to occur to either replace the asset, or undertake other activities such as ground profiling in the case of substandard clearances to restore the asset to an appropriate level of service.

8.1.8 Defect management practices

All conductor assemblies undergo routine visual inspections, with any defective assets recorded and prioritised within TasNetworks' asset management system in accordance with the 'Transmission Line Defect Priority Standard [6]. These defects are then issued to TasNetworks' contractors for action within the specified timeframes.

Factors such as the remaining transmission line life, support structure strength or geographic environment may dictate a specific type of asset to be used when replacing a defective conductor assembly, or installing a new conductor assembly. However, to assist in achieving greater standardisation across the network, TasNetworks' preferred asset replacement strategy, whether in response to defects or augmentation requirements, is summarised in Table 10 below.

Table 10: Conductor assembly replacement strategy

Conductor assembly category	Preferred new or replacement asset
Conductors	AAAC
Earth wire	SC/AC or OPGW
OPGW	OPGW
ADSS	ADSS
Dampers	Stockbridge damper (large diameter conductor) Spiral vibration damper (small diameter conductor)

8.1.9 Network augmentation impacts

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

- Demand forecasts
- New customer connection requests
- New generation requests
- Network performance requirements
- National electricity rules (NER) compliance

Installation of transmission line conductor assemblies would be required as part of any transmission line development as a result of a network augmentation requirement.

Proposed network augmentation projects identified in the Area Development Plans and Annual Planning Report will have a minimal impact on the transmission line conductor assemblies from an asset management perspective.

Despite this, TasNetworks is aware that new conductor design technologies are becoming available, providing greater load transfer capacity and/or reduced structural loading. Re-conductoring options are increasingly likely to provide a solution for system augmentation.

The power system is meeting the current requirements of the market but there are future drivers that will impact on the implementation of TasNetworks' ongoing conductor assemblies maintenance and operational works program. These drivers include:

- the requirement of additional transmission capacity aided by the availability of new conductor technologies with increased capacity and/or reduced tower loading effect;
- requirements to operate conductor assemblies closer to their thermal limits;
- the need for improved transmission line performance regarding their tolerance and response to lightning strikes; and
- the desire to create telecommunication diversity, facilitate improved protection and control functionality, and provide improved high speed data networks through the increased utilisation of OPGW.

8.2 Replacement

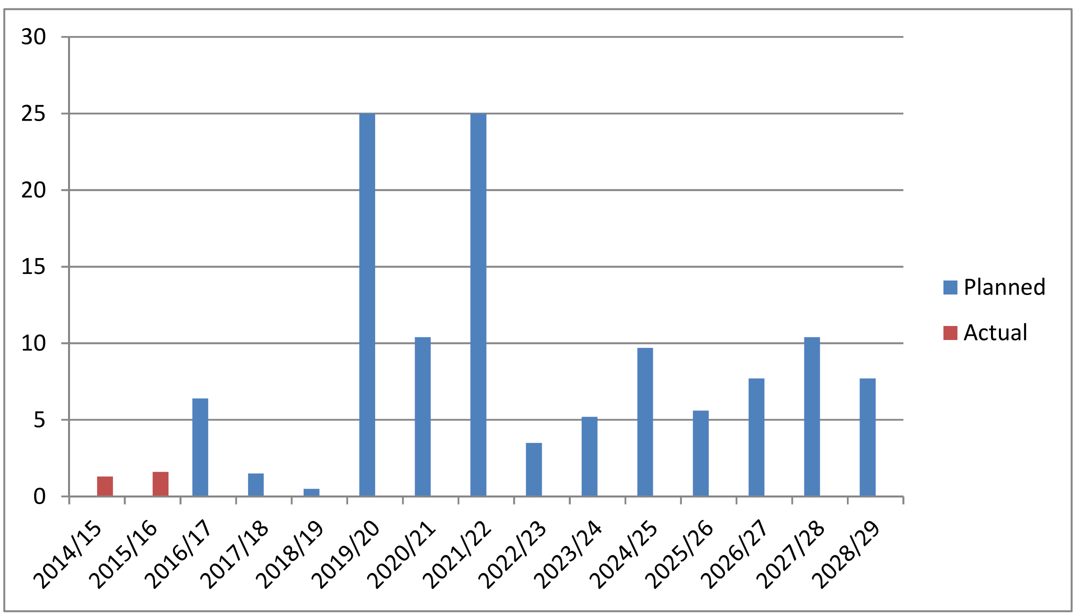
The cost of asset replacement activities that meet the capitalisation requirements outlined within TasNetworks' Asset Accounting Standard can be capitalised. These capital projects are detailed below. Asset replacement activities not meeting these requirements will be undertaken as operational expenditure.

As a result of defect and other condition information it is recommended that the following transmission line conductor assembly replacement and refurbishment activities should be programmed for the 2014–19 and 2024-29 regulatory control periods.

8.2.1 Conductor replacement

Steel earth wire corrosion has emerged as a problem on a number of 220 kV transmission lines in the North and North West region of the state and a program to replace all SC/GZ earth wires with modern earth wire or OPGW where telecommunications diversity has been identified as being required. This program will result in 110 km of earth wire[1] being replaced between 2019 and 2029 as detailed in Figure 13.

Figure 13: Conductor replacement program (km)

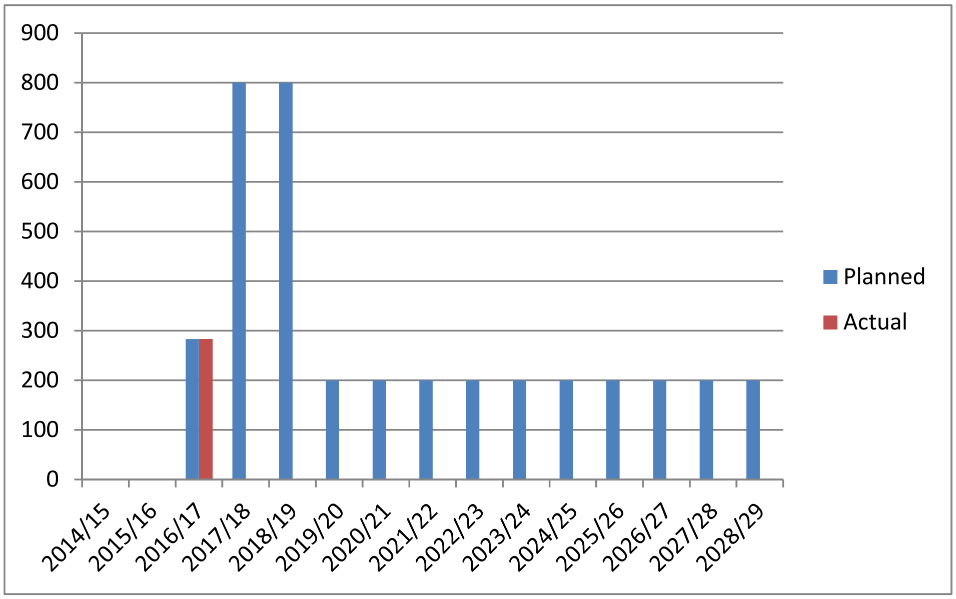


[1] Total conductor length

8.2.2 Damper replacement program

Condition monitoring and long term trends show that 200 degraded Stockbridge dampers will require renewal annually and this is best performed as a coordinated program. This is shown graphically in Figure 14 below.

Figure 14: Damper replacement program (volume)



8.3 Technology and Innovation

TasNetworks recognises that a proactive approach to the 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 such, TasNetworks has identified various initiatives for assessing conductor assemblies for consideration in the future.

Table 11: Transmission line conductor assemblies performance improvement initiatives

Initiative	Project description	Driver
Emerging inspection technologies	Maintain awareness of industry developments regarding inspection tools and practices for the identification and prioritisation of defective conductor assemblies. Where appropriate, new tools and processes will be implemented within TasNetworks.	Improved condition monitoring tools and processes resulting in more effective asset management decision making.
Risk management	Develop conductor assemblies condition assessment models This will facilitate more effective risk assessment and strategic decision making.	Risk management, cost efficiencies, work program development.

8.4 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.

8.5 Spares management

TasNetworks' maintains appropriate levels of asset spares for emergency response and other activities as defined within the System Spares Policy R517373.

8.6 Disposal plan

Due to the need to preserve TasNetworks Networks' easements there are some transmission line structures held on-site in vertical storage even though the line is out-of-service. Maintenance must continue on the conductors attached to these structures until easement arrangements are finalised and the structures can be dismantled and recovered or disposed.

9 Financial summary

9.1 Operational expenditure

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

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

The planned costs for each differing task type are derived from either unit rates from Contractors or averaged historical costs.

9.2 Capital expenditure

Transmission line conductor assemblies capital works are typically combined with other works to optimise system performance and mitigate network and business risk.

The projected capital expenditure required to implement the support structure foundation capital program is subject to change and optimisation as the integrated works plan is refined and further developed.

Each project within the program is then subjected to a detailed investment evaluation.

9.3 Investment evaluation

For each program or project to be included within the upcoming revenue proposal, an Investment Evaluation Summary (IES) is prepared describing the condition, performance and risk issues identified within this and other asset management plans.

The IES then identifies a preferred option using cost estimates that have been developed in line with TasNetworks' estimation process. Each option is evaluated on both technical and financial merits and the preferred option is submitted for regulatory approval.

The Investment Evaluation Summaries associated with the current 2014–2019 capital program and proposed 2019-2024 capital program for transmission line conductor assemblies are listed in Appendix B.

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. R16948 WASP Asset Register – Data Integrity Standard – Conductor Assembly
2. R17960 WASP Asset Register – Data Integrity Standard – Conductor Weight
3. R17052 WASP Asset Register – Data Integrity Standard – In Span Fitting
4. R17122 WASP Asset Register – Data Integrity Standard – Insulator and Damper Assembly
5. R16984 WASP Asset Register – Data Integrity Standard – Fibre Junction Box
6. TNM-GS-809-510-05 - Transmission line defect prioritisation standard (draft)
7. D08/74976 – Transmission Lines Conductor Assemblies Condition Assessment Report
8. Asset Condition Review – project report June16 FINAL – R503361
9. Transmission line dead end assembly rating upgrade business case, 15 June 2012
10. R517373 System Spares Policy

Technical requirements for new conductor assemblies are detailed in the following standards/specifications:

11. D08/93590 OPGW Procurement standard TNM-IS-809-0017
12. D03/6112 Transmission Circuit Name Abbreviations standard TNM-GS-809-0032
13. D05/10286 Transmission Line Design standard TNM-GS-809-0058
14. D05/18680 Temporary Earthing of Overhead Transmission Circuits standard TNM-GS-808-0501
15. D07/67177 Transmission Line Construction standard TNM-GS-809-0524
16. D10/90107 Fibre Optic Overhead Ground Wire (OPGW) Standard

Other standards and documents:

17. AS7000:2010 – Overhead line design – Detailed procedures
18. AS1154.1-2009 - Insulator and conductor fittings for overhead power lines - Performance, material, general requirements and dimensions

Appendix A Conductor assemblies renewals profile

Year	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29
Conductor (volume)	1.5	0.5	25	10.4	25	3.5	5.2	9.7	5.6	7.7	10.4	7.7
Conductor (Transmission Line)	TL440	TL509	TL507/508	TL501	TL500	TL510	TL504	TL514 TL515	TL502	TL503	TL512 TL513	TL509
Dampers (volume)	1600	0	200	200	200	200	200	200	200	200	200	200
Dampers (Transmission Line)	TL429	-	-	-	-	-	-	-	-	-	-	-

Appendix B Investment Evaluation Summaries

The following Investment Evaluation Summary (IES) documents relate to transmission line conductor assemblies.

Reference	Name	Expenditure Type	Regulatory Period
R433966	Transmission Line Conductor Assembly Refurbishment Program Investment Evaluation Summary	CAPEX	2014-2019
01423	Transmission Line Conductor Assembly Refurbishment Program Investment Evaluation Summary	CAPEX	2019-2024