Asset Management Plan

Conductors and Hardware – Distribution

Info Zone Record Number: R260427

Version Number: 3.0

Date: October 2017

Authorisations

Action	Name and title	Date
Prepared by	David Eccles – Asset Strategies Engineer, Asset Strategy	15/09/2016
Reviewed by	Murray James Consultant	13/08/2017
Reviewed by	Guy Debney GHD Consultant	20/09/2017
Authorised by	Darryl Munro – Asset Strategy Team Leader	31/10/2017
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").

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

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

Disclaimer

UNCONTROLLED WHEN PRINTED

This document has been prepared and made available solely for information purposes. Whist care was taken in the preparation of the information in this document, and it is provided in good faith, TasNetworks make no representation or warranty (express or implied) as to the accuracy, reliability, or completeness of the information contained in this document, or its suitability for any intended purpose.

TasNetworks (which for the purposes of this disclaimer, includes all their related bodies corporate, officers, employees, contractors, agents and consultants, and those of their bodies corporate) shall have no liability for any loss or damage (including without limitation, liability to any person by reason of negligence or negligent misstatement) for any statements, opinions, information or matter (expressed or implied) arising out of, contained in, or derived from, or for any omissions from, the information in this document, except to the extent that liability under any applicable statute cannot be excluded.

In all cases, anyone proposing to rely on or use the information in this document should independently verify and check the accuracy, completeness, reliability and suitability of that information and the reports and other information relied on by TasNetworks in preparing this document, and should obtain independent and specific advice from appropriate experts or other sources.

Record of revisions

Section number	Details
	New Document
All sections	Reviewed and revised in 2017, to include Bushfire Risk Mitigations Overlay and Performance Reporting. This includes aged non-metalllic screened HV ABC replacement need

Table of Contents

1 Purpose

The purpose of this document is to describe for Conductors and Pole-top Hardware Distribution 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; and
- Forecast CAPEX and OPEX volumes.

2 Scope

This document covers distribution conductors and associated pole-top hardware.

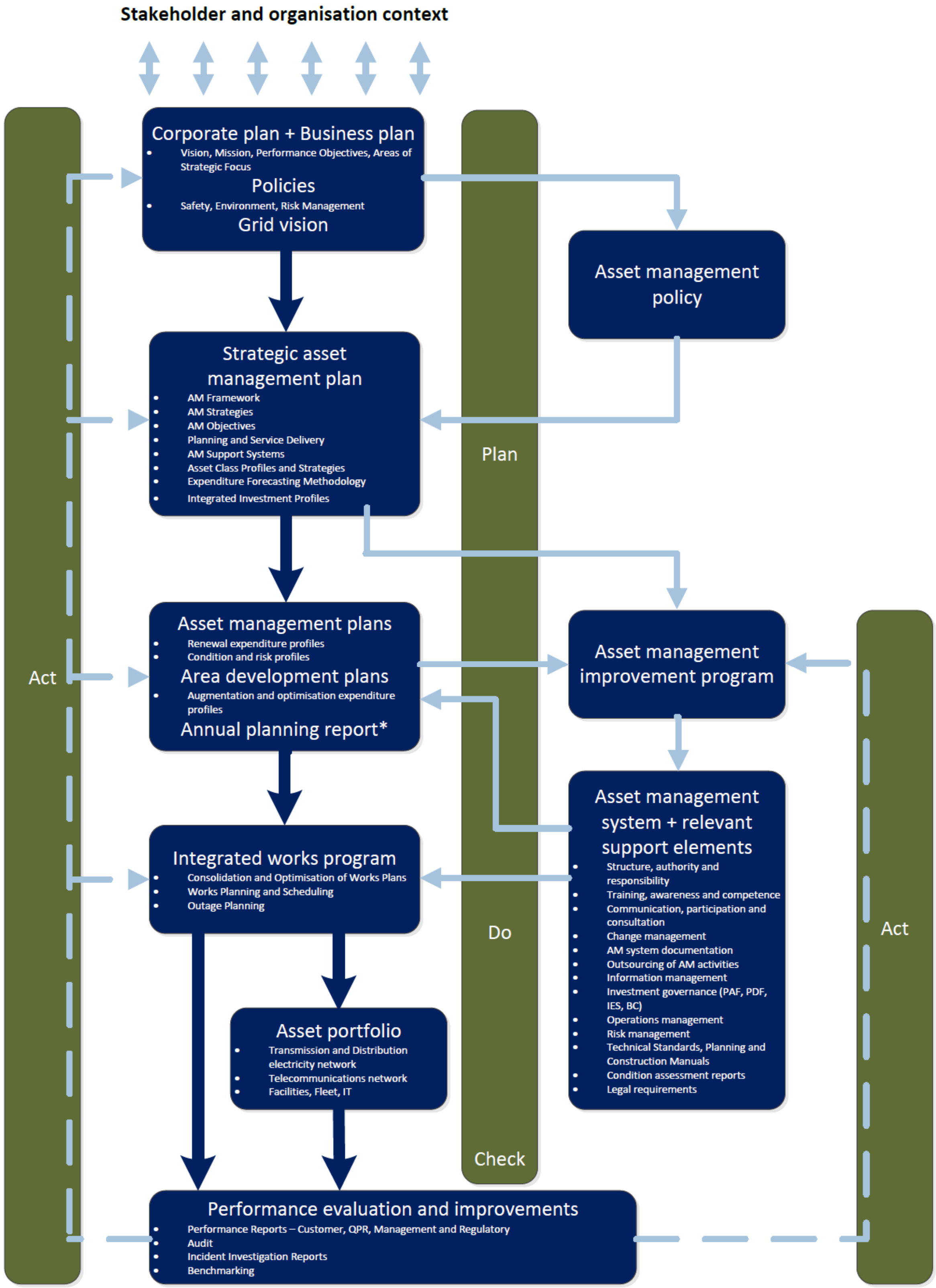
3 Strategic Alignment and Objectives

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 distribution overhead switchgear assets, with the aim of achieving these objectives.

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

- Safety will continue to be our top priority and we will continue to ensure that our safety performance continues to improve
- Service performance will be maintained at current overall network service levels, whilst service to poorly performing reliability communities will be improved to meet regulatory requirements
- Cost performance will be improved through prioritisation and efficiency improvements that enable us provide predictable and lowest sustainable pricing to our customers
- Customer engagement will be improved to ensure that we understand customer needs, and incorporate these into our decision making to maximise value to them
- Our program of work will be developed and delivered on time and within budget

The asset management policy and strategic objectives are outlined within the Strategic Asset Management Plan. Figure 1, from the Strategic Asset Management Plan, represents TasNetworks documents that support the asset management framework. The diagram highlights the existence of, and interdependence between, the Plan, Do, Check, Act components of good asset management practice.



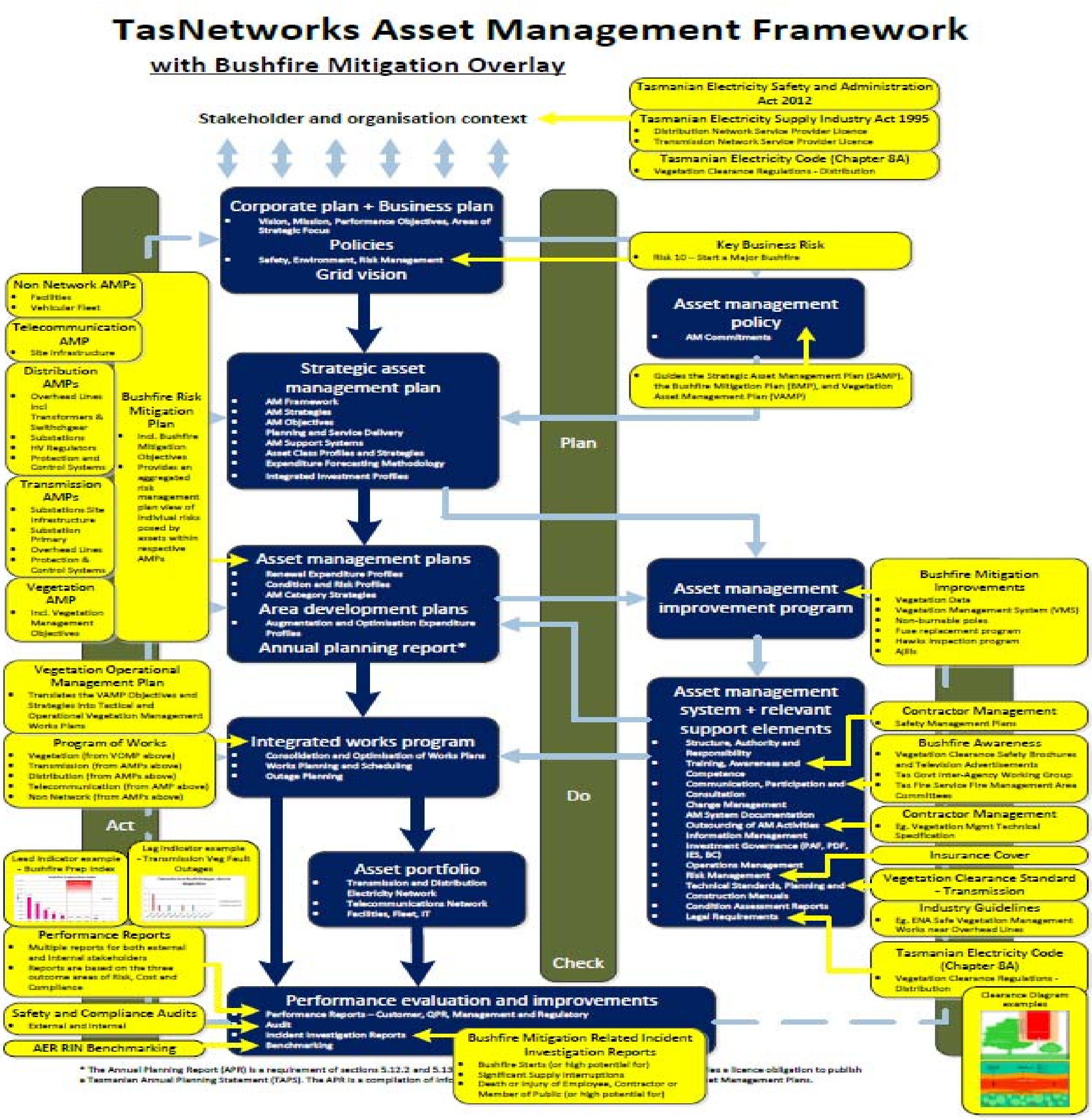
* The Annual Planning Report (APR) is a requirement of sections 5.12.2 and 5.13.2 of the National Electricity Rules (NER) and also satisfies a licence obligation to publish a Tasmanian Annual Planning Statement (TAPS). The APR is a compilation of information from the Area Development Plans and the Asset Management Plans.

Figure 1: TasNetworks Asset Management Documentation Framework

3.1 Bushfire Mitigation Framework

Many TasNetworks assets, including distribution conductors and poletop hardware are located within areas of the state affected by bushfire. TasNetworks' bushfire mitigation framework has been overlaid onto the TasNetworks Asset Management framework to show the direct relationship between the two, and is shown in Figure 2. The Bushfire Mitigation Asset Management Plan provides guidance to other stakeholders in the preparation of asset management plans, ensuring effective bushfire risk mitigation outcomes are achieved, while also summarising some key bushfire risk mitigation outcomes and commitments made within those asset management plans.

Figure 2: TasNetworks Asset Management Documentation Framework with Bushfire Mitigation Framework Overlay



3.2 Business objectives

Strategic and operational performance objectives relevant to this project are derived from TasNetworks 2017-18 Corporate Plan, approved by the board in 2017. This project is relevant to the following areas of the corporate plan:

- We understand our customers by making them central to all we do;
- We enable our people to deliver value; and
- We care for our assets, delivering safe and reliable networks services while transforming our business.

3.3 Business initiatives

The business initiatives reflected in TasNetworks' Transformation Roadmap 2025 publication (June 2017) for transition to the future that align this asset management plan are as follows:

- Voice of the customer: We anticipate and respond to your changing needs and market conditions.
- Network and operations productivity: We'll improve how we deliver the field works program, continue to seek cost savings and use productivity targets to drive our business.
- Electricity and telecoms network capability: To meet your energy needs and ensure power system security, we'll invest in the network to make sure it stays in good condition, even while the system grows more complex.
- Predictable and sustainable pricing: To deliver the lowest sustainable prices, we'll transition our pricing to better reflect the way you produce and use electricity.
- Enabling and harnessing new technologies and services: By investing in technology and customer service, we'll be better able to host the technologies you're embracing.

4 Asset information systems

4.1 Systems

TasNetworks maintains an asset management information system (AMIS) that contains detailed information relating to distribution overhead conductor and hardware assets. AMIS is a combination of people, processes, and technology applied to provide the essential outputs for effective asset management. AMIS data integrity standards provide additional information relevant to each asset class. Data integrity standards have been developed for transmission assets, however they have not yet been developed for distribution assets.

Distribution asset information is recorded and stored in TasNetworks Geographic Information System (GIS) data systems. The location in which data is stored and maintained is dependent on the particular nature of the data, but systems are often configured to enable the flow of changes in one system to be reflected in the other. These systems will be replaced or updated in 2018 as part of the Ajilis Transformation program.

4.2 Asset management information improvement initiative

To realise this capability at TasNetworks, the AMIS improvement program is delivering a rigorous and methodical series of targeted initiatives designed to build capability. When implemented, this program will deliver trusted, timely and high quality asset information that supports the strategic and operational asset management processes required for best-practice asset management. This program is complimentary with the current upgrade data system project and will rely on and benefit from the integrated asset and works management system provided by that project.

The AMIS improvement program is currently delivering the foundations of a mature asset management system including the establishment of:

- asset hierarchies
- asset data integrity standards and
- asset nomenclature standards

The establishment of a contemporary asset condition inspection system for network assets (including, but not limited to distribution poles) has also been identified as a priority initiative within the scope of the AMIS improvement program. TasNetworks currently relies on an out dated and unsupported product for pole mounted transformer inspections. Whilst this tool captures rudimentary pole mounted transformer condition data, the application is no longer supported and cannot be enhanced to take account of altering asset management practices, changing work practices or varying asset configurations. Options for an enhanced, extensible and future-proofed solution are currently being investigated by TasNetworks.

4.3 Asset Information

The asset information contained on conductors is currently stored in the Spatial Data Warehouse (GIS data) and WASP asset management system. These databases will be replaced as part of the Ajilis program.

The following sections detail the information contained in each location.

4.3.1 Data Warehouse (G-Tech Data)

The information contained in the Data Warehouse (G-Tech Data) includes:

- G-Tech Conductor Type;
- Pole Install Date;
- Distance from Coastline;
- Fire Danger Area;
- Protection Zone;
- Substandard conductor (as per AS 7000);
- Conductor Failure;
- Protection Device Operations;
- Pole IDs;
- Owner; and
- Regional Area (South, North and North West).

4.3.2 WASP Asset Data

The data contained in WASP includes:

- WASP Conductor Type;
- WASP Asset ID;
- Owner; and
- Install date.

5 Description of the Assets

5.1 Overhead Conductors and Cables

Overhead conductors provide the means for electricity to be transported over medium to long distances in urban and rural areas across the distribution network system.

Table 1 details the types of overhead conductor and cable installed in the system.

Table 1: Distribution overhead conductors and cables in TasNetworks' distribution system (as at Jun 2017)

Description	Length (km)
HV Conductors – Copper	1,116
HV Conductors – Aluminium	8,908
HV Conductors – GI	5,791
HV Conductors – ACSR	732
HV ABC	18.5
LV Conductors (including bare and LV ABC)	4,973
Total	**21,539**

The size of the cross sectional area of each strand or group of strands determines the current carrying capacity of the conductor with the larger the cross sectional area the greater the current capacity flow. Although there are many varying sizes of bare conductor, standardised sizes have been introduced which satisfy the network management of voltage levels and current flow in conjunction with the electrical equipment employed in the distribution system.

The varying types and sizes of overhead conductor is a legacy of the changing customer supply requirements, cost constraints, improvements and efficiencies in technology, the refinement of planning tools/models and design standards of the day.

5.1.1 Bare Open Wire Conductors

The most commonly installed type of conductor in the overhead system is bare open wire type conductor. The support structures and pole top equipment are designed to maintain phase to phase separation and provide the required clearance to ground and to third party infrastructure.

HV bare open wire conductor is by far the easiest and most cost effective conductor to install, replace and augment of the conductor types presently in use within the industry.

The current standard materials used as bare open wire conductors are:

1. All Aluminium Conductor 19/3.25 AAC (Neptune);
2. All Aluminium Conductor 7/4.50 AAC (Mercury);
3. All Aluminium Alloy Conductor 7/3.00 AAAC (Fluorine); and
4. Steel Conductor 3/2.75 SC/GZ (GI).

There are a number of legacy materials found in the overhead system but are no longer installed including:

1. Aluminium Conductor Steel Reinforced (ACSR/GZ): multi-strand conductor with a strengthening galvanized steel core;
2. Copper (Cu): multi-strand conductor; and
3. Galvanised Iron (GI): both single strand (such as No.8 GI) and multi-strand (such as 3/12 GI).

Aluminium conductor came in to service in the 1960s. There are 3 types of Aluminium conductor in the system, All Aluminium Conductor (AAC) All Aluminium Alloy Conductors (AAAC) and Aluminium Conductor Steel Reinforced (ACSR/GZ): multi-strand conductor with a strengthening galvanized steel core. Aluminium Conductor Steel Reinforced (ACSR) conductor is no longer installed in the system.

Galvanised Iron (GI) conductor came into service in the 1940s. TasNetworks stopped installation of single strand No. 8 GI conductor in the 1970s and the imperial 3/12 GI conductor was replaced with the metric 3/2.75 GI conductor around 1976, which is the present day TasNetworks standard for rural conductors across private property.

5.1.2 Aerial Bundled Cable (ABC)

Aerial Bundled Cable (ABC) is an insulated overhead conductor of either two or three wires in a bundled or a twisted configuration. Both HV and LV ABC are installed within the distribution system.

ABC can reduce safety and bushfire risks, minimise the vegetation clearing around the overhead power lines and improve supply reliability through minimising the impacts of vegetation, birds, animals and windborne objects on the overhead power lines.

LV ABC is TasNetworks' standard conductor for any new LV networks and the replacement of existing LV networks unless LV ABC is unsuitable (such as for long single phase spans). In those situations bare overhead LV conductor is used.

The TasNetworks' standard HV ABC will in future be changed to a fully non-metallic semiconductive outer screen insulated cable consisting of three phases wrapped around a catenary wire.

Non-metallic screened (NMS) HV ABC was previously installed by TasNetworks in selective locations, such as heavily vegetated areas or areas prone to wind, bird and animal affected areas to reduce the impact of these on the overhead system. The TasNetworks HV network includes over 18 km of NMS HV ABC that is a similar material to Victorian utilities, such as United Energy and AusNet, which is at risk of developing 22 kV insulation failure of the catenary support bare wire rubbing on the semiconductive outer covering of covered phase conductors, initiating insulation stress leading to degradation failure.

In 2016, United Energy has undertaken age based cable replacement of HV ABC non-metallic screened conductors with an installed service life over 15 years. TasNetworks with has some older installed HV ABC assets and is observing the developments in Victoria.

United Energy has trialed but not found a suitable detection method so it adopted a plan to replace its HV ABC in 2016 in response to its accelerating annual rate of failure (see reference 10[1]). United Energy 22 kV HV ABC insulation failure defect details are shown in Appendix B of that document.

The oldest 22kV HV ABC still in service in the TasNetworks' system is located along forested main road at Port Arthur near the Fox & Hounds Inn and it was installed in 1995. This represents an in service age of 22 years for non-metallic screened HV ABC at 22kV system voltage.

As the fault current rating of the metallic screened HV ABC replacement options for 35 mm^2, 50 mm^2, 150 mm^2 and 180 mm^2 are less than that of equivalent phase cross section existing non-metallic screened HVABC a design review is needed for sites with a fault current higher than 4 kA.

United Energy also did not prefer HV spacer as replacemet for HV ABC because of its 'poor aesthetics' in open air skyline background.

For TasNetworks, the aesthetics and economical retention of most existing line structures positions favours a retrofit by Metallic Screened HV ABC replacement design for failed or at risk insulation failure risk in aged non-metallic screened HV ABC .

The alternative design for in longer spans is 22 kV HV Spacer Cable System, which can span span lengths of atleast up to 600 metres, and have relatively small air swing corridor width need.

A 22kV HV Spacer system trial in Yarra Valley, by AusNet, Victoria is noted. HV Spacer is also a routine 22 kV Network Standard overhead line design option used by Western Power in southwest Western Australia.

Also TasNetworks is reviewing new Victorian R&D innovation in progress by Ausnet Services, by Powercor and by United Energy to retrofit in high bushfire risk forest areas using "Hybrid undergrounding" which is metallic screened HV ABC lines but with ducted underground cable sections with ducts installed by the directional underboring method. This would be most favourable for optimally micromanaged sections of line under Tasmania's extremely tall tree species, reducing vegetation impact risks in areas of vegetation determined to be uneconomic to manage and maintain clearances to overhead line. (See Appendix P). Tasmania has locations similar to Victoria with overtopping category 5 risk forest(defined in Appendix Q). Tasmania has the tallest eucalypt species trees in the world, including extensive stringy bark drop risk types and out of corridor tall tree fall risks to manage. The Mountain Ash tree risk in Dandenongs, Victoria is called a Swamp Oak tree risk in Tasmania.

5.1.3 Covered Conductors (CC)

Covered Conductor (CC) differs from HV ABC in that CC is a single core unscreened self-supporting cable with an XLPE insulation thickness of 2 mm. If the insulation thickness is equivalent to that required for the rated voltage it is termed Covered Conductor Thick (CCT). Metallic Screened HV ABC is touch safe while, due to the lack of screen, non-metallic screened, CC and CCT covered conductors are not.

TasNetworks utilises 11kV and 22kV Covered Conductor for short length HV droppers and HV bridgings on a number of polemounted switchgear design kits such as RL27 Enclosed Switches and NOJA reclosers. These are predominantly HDPE insulating external cover.

PVC is the predominant material used as the insulating cover on LV service cables.

[1] NOTE all references in this document are listed in Section 11.

Covered conductors are primarily used for the overhead service cables connecting the customer's installation to the LV distribution network. There is a small amount of LV covered conductor used elsewhere in the system.

The use of covered conductor thick (CCT) HV conductors for overhead line spans is still being investigated.It could be a cost effective new line design or conductor replacement option as it has the potential to reduce bare conductor risk impacts from vegetation, extreme wind and wildlife impacts on the overhead system. However there are in CCT insulation & water blocking stripping, and unshielded conductor lightning strike insulation damage ringbarking risk in service failure mode risk issues to be overcome before it can be used in the TasNetworks network as in tension overhead span conductors.The new 22kV HV covered conductor made to standard EN50397-1 as used in 2017 Victorian-funded Victorian utility trial is showing pragmatic advantage over some older 22kV CCT for failure modes in service interstate.

5.1.4 Overhead Pilot Cables and Fibre Optic Cables

Overhead pilot cables are used to facilitate protection and control between various distribution substations within Hobart's central business district. These are mature aging metallic conductors and will be replaced by fibreoptic cables as and when opportunity arises.

Fibre optic cables are used for protection and control between TasNetworks' 110/33kV substations, urban zone substations, and regional distribution SCADA hub site connectivity.

OPGW used as a subtransmission or HV overhead line lightning shield wire retrofit with fibreoptics for pilot cable protection, IoT sensors ,and SCADA communications. OPGW in shield wire position can halve the line outage reliability risks from direct lightning strike.shield wire or underslung OPGW has a significantly longer service life expectation (60 years) over underslung ADSS (15 to 20 years) in high UV incidence, ice loadings locations, and/or bushfire risk locations.

ADSS as pilot cable was removed from Derwent River crossing service because of mechanical failure unreliability wearout (2015/16). ADSS with wetted surface pollution can become conductive for HV tracking and HV live Line worker voltage proximity risk precautions.

OPGW as underslung or as shield wire is preferred design choice for a TasNetwork owned asset on TasNetworks distribution lines.

Appendix L shows regions of higher lightning risk are mostly in the north /northwest of the state.

5.1.5 Earthing Conductors

Distribution overhead earthing conductors can be line support structure assets to local earth at base of line support structure, or as aerial conductor, spans of Overhead Earth Wire (OHEW) to shield line from lightning strike and/or connect from a line support structure to a remote earth. TasNetworks overhead subtransmission and HV feeders presently are not shielded by spans of overhead earth wires or OPGW. However, HV ABC has a catenary support conductor in the HV covered conductor bundle that is an overhead earthing conductor earthed at line support structures.

Overhead line support structure assets have attached earthing conductors used to connect non-current-carrying metallic parts of overhead system equipment, such as pole mounted transformer tanks and switchgear operating handles, to the HV earthing system. They provide a low impedance path for the flow of earth fault current into the ground for the reliable operation of protection devices, and they help to control voltage rises associated with faults.

Pole copper earth theft is persistent, but vandalism and theft risk is reduced by use of steel covers or using copper clad steel earthing conductors.

In the 64 SWER systems the HV SWER pole earth is also a load current carrying conductor, and any breakage or copper theft deliberate cut of the HV earth conductor can immediately impose 12.7kV ac open circuit voltage to earth on the break gap as a shock hazard risk and a gap current flow resitive heating wood risk of pole fire.

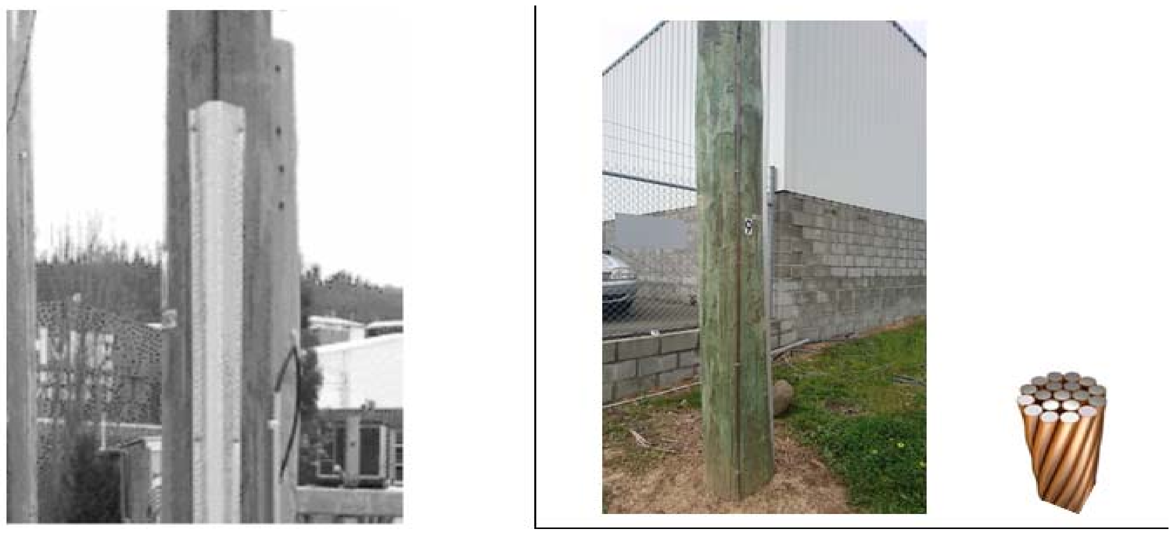


Figure 3: Pole earth copper theft is resisted by steel covers or using copper clad steel

5.2 Pole-top Hardware

TasNetworks' Pole-top Hardware comprises:

- Insulators;
- Cross-arms;
- Conductor fittings;
- Surge arrestors;
- Bird diverters;
- Aircraft warning markers;
- Live line clamps;
- Vibration Dampers; and
- LV Spreaders.

5.2.1 Insulators

Insulators provide an insulated means of attaching the conductors to the poles. The type of insulator, size and make used are dependent on the level of voltage of the conductors, the design requirements of the overhead line and various external influences such as pollution, weather conditions, and geographic location.

Generally HV and LV insulators are grey porcelain or glass and are bolted to the cross arm or pole by a steel pin or bolt. The remaining insulators are brown porcelain and so are a pre-1967 vintage, or over fifty years in service. Older porcelain insulators are at increasing risk to metal pin corrosion necking and thread swelling, for porcelain cracking or punch through risk.

A number of risks need to be addressed before polymeric insulators are selected to be installed extensively: weathershed native parrot chewing risks and the often high level of ultraviolet exposure in Tasmania. 22 kV polymeric post insulators were selected and installed on new air break switches from 2014/15.Shooter vandalism to porcelain and glass insulators is relatively low in Tasmania, but polymeric insulators can be used as needed.

Shortly after the establishment of Aurora Energy in 1998 a number of failures of porcelain insulators in the North-West (possibly due to the high pollution levels) led to a trial installation of polymeric insulators. These are valued long term in service NCI aging trial nearing 15 years (reference 18).

NCI bushings are now being used on polemounted switchgear, polemounted transformers, cable riser terminations, and cycloaliphatic insulators on new polemounted Air Break Switches.

TasNetworks currently uses:

- Pin (porcelain and polymeric)
- Strain (porcelain and polymeric)
- Guy strain (porcelain)

The historical practice of replacing a distribution pin insulator, shackle insulator or porcelain insulation mounting assembly only when its defective , ie one at a time meant the likelihood of repeated outage failures /fault repair works for adjacent similarly aged insulators. The replacement of all three phase set of aged insulators on first outage failure is outage time costly, but a full set replacementcan be done opportunely at times such as a planned condemned pole replacement or crossarm replacement (Figure 4 illustrates a multicircuit vintage poletop with brown porcelain ,grey porcelain and glass insulators in close proximity see Figure 4)..HV pin porcelain insulator punch through failure is hard to visually detect and can be risk minimised by prudent insulator replacement with condemned pole and /or crossarm. The need to replace EDO fuse mouting assemblies for longer Boric Acid fuse retrofit replacement in bushfire risk mitigation program , offers an opportunity to update the EDO fusemount insulation assemblies.

Pending trial of Corona Cameras, and sonic detectors can add to preventation by inspections.

5.2.2 Cross Arms

Insulators are mounted on cross arms attached to the structure to provide the required clearance between conductors.The mix of cross arms is show in Table 3.

Table 2: TasNetworks Crossarm population (2015/16)

Material	Distribution Network Crossarms	Private Crossarms	Crossarms replaced
Fibreglass	21	-	-
Steel	274,615	3,352	827
Timber (CCA)	209,150	58,439	1,707
Unknown	46,409	43,462	2
Total	530,195	105,253	2,536

Steel HV cross arms are used because they provide the structural integrity to withstand high conductor load tensions and associated loads imposed (see Figure 8).ENA industry feedback indicates these have the lowest failure rate of all crossarms at 1.6 per 100,000 crossarms installed.

LV cross arms are predominantly manufactured from sawn timber as this medium is cost effective and offers insulation qualities to allow live line activities to be performed safely. Sawn wood LV crosarms as are shown in Figure 9 and have a relatively short service life ≈20years) ENA industy feedback indicates the untreated wood cross arms mostly fail by fungal decay, and at rate of258 per 100,000 crossarms installed.

In 2016/17, a cross arm trial recommended in its Final Report (reference 17) replacing LV cross arms with more than 15 years service life with Fibreglass crossarms . An 18 months change period has been proposed and a further trial involving alternative HV cross arms was been recommended ,primarily for improved lighter weight lift ergonomics, increased insulation for reliability and endangered species flashover risk mitigation. The LV crossarm trial concluded that the fibreglass crossarms offered safer handling, an improved asset lifecycle cost and improved insulation for reliability (see references 12,17 and the summary in Appendix P) .

Figure 4: Steel HV cross arms and insulators on dual circuit 33kV and 33 kV and 11kV circuits on a stobie pole

Figure 5: Wooden LV cross arms

Figure 6: Fibreglass (FRP) LV cross arm in trial

5.2.3 Conductor Fittings

Conductor fittings are used to secure conductors to their supports and for connections between conductors both mechanical under tension and non-tension types. Various types of fittings are used depending on the size and type of conductors involved, their geographical and electrical location within the network for short circuit currents and the electrical loading on the conductors. Both replacement and new LV and HV conductor connections need to be matched for load current rating, load cycle and fault current in the circuit location (see Appendix K).

In SWER systems the HV earth conductor connections are also load current carrying conductor.

The general methods of connection include welds, compression, bolted, tension methods or AMPAC (wedge).

Bare overhead conductors are attached to insulators using conductor ties. These ties are generally the same material as the conductor.

Periodic aerial and thermal camera inspections find fitting defects for preventative repair action.

TasNetworks field requested trial evaluation of several brands of newer shearbolt bolted tension connectors for faster new jointing, and/or shunt repair jointing, for achieving timely and longer service performance jointing for weathered overhead bare conductor tension break repair jointing. SAA AS5804-2010 HV live line working friendlier design choices include ANSI C119.4 Class AA, extra heavy duty connectors like Classic Connectors ClampStar shunt kits or equivalent. Generally the conductor connectors to ANSI C119.4 Class AA, extra heavy have inbuilt spring-loading design and greases to help maintain grip and electrical connectivity on weathered conductors.

5.2.4 Surge Arresters

Surge arresters, alternatively called Surge Diverters, are installed to prevent damage to equipment in the event of a direct lightning strike on the overhead system.

Generally surge arresters are installed on specific higher replacement cost equipment, such as pole mounted cable risers or transformers. Figure 4 shows red weathershed metal oxide surge diverters also used as angled nearly horizontal support insulators for cable riser termination However, the surge arresters may also be placed in the overhead system at strategic locations prone to lightning strike.Appendix L illustrates lightning risk is higher in the north and northwest.

HV ABC installations and where underground cable risers connect to the bare conductor overhead system are examples of locations where surge arresters would be installed to minimise overvoltage doubling risk.

5.2.5 Animal barriers, bird diverters on conductors and poletop insulation

Wood poles are fitted with one or more flat metal sheet 'possum guards' to reduce arboreal animal climbing structures resulting in live bare conductor flashovers at the pole top (arboreal species include possums, rats, cats, young Tasmanian Devils, tree frogs , lizards, and snakes).

Nocturnal arboreal glider possums (see Figure 7) might glide/ jump onto urban overheadconductors to avoid ground crossing with urban dog/cat predator risk, to risk energised bare conductor flashover hazards at poletop (located above the pole possum guard). Trials are proposed with spin cover guards mounted on conductor such as critter guards, line guards, rat guards or equivalent, if tall tree/ gardens risk enable.

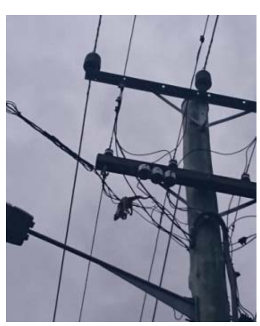


Figure 7: Proposed critter barrier trial for glider possum on pole top risk

Swans, geese, waterfowl and other large birds commonly collide with conductors. Bird diverters are installed in problematic locations to make conductors more visible to birds (Figure 17) but are not installed on substandard conductor that display red rust or have insufficient strength. Birds are the cause over 400 outages a year on TasNetworks' distribution system.

Figure 8: Bird diverters installed on conductor (but not on substandard conductors)

5.2.6 Aircraft Warning Markers

Aircraft warning markers are installed on selected overhead conductors and equipment to warn human aircraft pilots about the presence of aerial obstacles. AS/NZ 3891.1-2008 (reference 2) requires any conductor installed more than 90 metres above the ground or with a span length longer than 1,500 metres to be marked with Aircraft warning markers. This standard also requires any overhead line installed within specified limits of a CASA registered airport to be marked.

AS/NZ 3891.2-2008 (reference 2) specifies the responsibilities of pilots regarding line marking.

5.2.7 Live Line Clamps

In the past, live line clamps were used to connect new transformers directly to HV feeders without requiring an outage as in Figure 10. This connection was intended to be a temporary connection and to be changed to a 'D-loop' at the next planned outage. Records were poorly kept of installations connected using live line clamps and many were not changed to D-clamps. It is estimated that there are approximately 10,000 live line clamps still connected (by the WASP defect pool).

The connection of a live line clamp directly onto a live tensioned conductor can result in arcing, eroding individual strands of the conductor and greatly reducing its strength. The risk is greater for Galvanised Iron (GI) conductor as this arcing can remove the galvanising, which exposes the iron to moisture build up underneath the clamp. This results in corrosion of the conductor, which will lead to conductor failure or the fusing of the conductor to the clamp. Priority will be given to the HBCA for this program to remove live line clamps.

Figure 9: Live line clamp directly connected

Figure 10: Live line clamp connected via D-clamp

5.2.8 Vibration Dampers

Spiral vibration dampers are a relatively simple device used to minimise the effects of wind-induced vibration on HV power lines. Sustained vibration can lead to wearing and abrasion of a conductor and the ties near the connection point. It is for this reason that dampers are normally installed within a hand's width of where the conductor finishes at a pole. Dampers are helically wound around the outside of the conductor and clamped at one end. As the vibrating conductor hits the inside of the damper coil the coil disturbs the build-up of natural frequency, thereby reducing vibration. Figure 11 shows a series of three spiral dampers per phase in a long span.

For minimising conductor fatigue, spiral vibration dampers shall be designed to reduce the effects of wind-induced vibration on aluminium, ACSR, or galvanised steel overhead conductors strung at medium or full tension for a line service life of 50 years.

For longer span lengths more energy generally has to be absorbed by the damper. On longer spans use of two or more dampers might be needed on spans of 200-400m, 400- 500m, and greater than 500m span lengths. Terrain hills and tree shielding may reduce need for dampers.

Installation instructions for damper positioning design by designer and constructor should be supplied from successful tenderer. An application equation (for example only):

Supplier's installation guide should address designer design requirements , but historically empirically more efficient dampers were those placed in the middle of any half loop . Position modified if armour rods fitted .

$$\text{Spacing}= \frac{0.7 \times d}{2 \times 185 \times V} \sqrt{\frac{T}{m}}$$

Where :
d = conductor O.D. (mm)
V= wind speed (m/sec)
T* = horizontal tension (N)
M= conductor mass (Kg/m)

TasNetworks installs spiral vibration dampers in areas prone to heavy winds such as close to the coast and subject to aeolian vibration.

Figure 11: Three in series HV spiral dampers per conductor on a long span

Low Voltage SpreadersLow voltage spreaders are fitted to LV bare conductor spans to reduce LV bare conductor clashing risk. Low voltage fibreglass reinforced plastic spreaders also dampen span conductors relative movement.

5.3 Conductor Age Profile

Condition based assessment is partly indicative by installed conductor service by age. However, SAA AS7000-2016 cites a risk based approach and provides informative on specific failure risk modes that include - conductor stress and fatigue assessment is referenced in SAA AS7000-2016 Appendix Y, Corrosion in Appendix X, and Creep in Appendix U, and annealing in Appendix AA, and short time and circuit current in Appendix Z.

Industry experience is also recognising the overhead conductor's tension joints and connections as points of risk by service age/condition assessment. For example in Appendix Y, it notes conductor fatigue will almost exclusively occur at a conductor fitting.).

LV conductors make up 23 per cent of overhead conductors by length

.There is no consolidated age profile information for LV conductors or for pole top hardware. These assets are risk managed on periodic maintenance inspection basis.

The optional opportunity to replace corroded aged bare conductors as condition based risk mitigation affords opportunity to replace it with LV ABC conductor. Urban load supplying LV ABC retrofit is often safer to perform and convert services, removes bare LV conductor clashing and bird impact risks, for reliability advantage. New LV bare conductor as condition based bare LV conductor replacement is still used for atleast the longer span length replacement works. (LV ABC conductor retrofit is limited by design maximum span length)

HV conductors are 77% of the overhead network by length.

The age profile of all HV overhead conductors is indicated in Figure12. Copper and galvanised iron conductors being the majority of the older conductors.

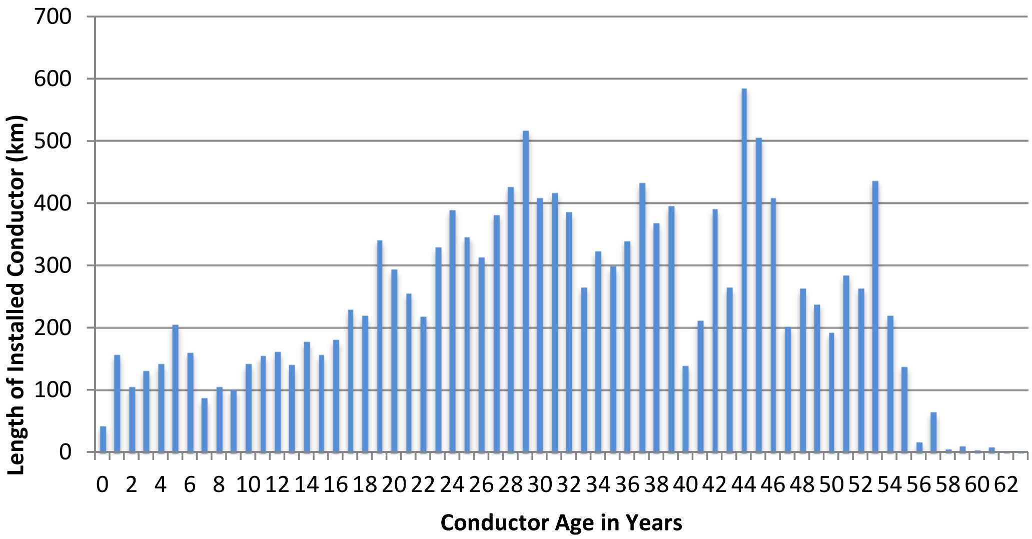


Figure 12: Estimated Age Profile for all HV Conductor in the Network

5.3.1 Copper Conductor Age Profile

Figure 13 gives the age profile of copper conductor. As the majority of copper conductor in the LV and HV system was installed prior to 1964 it will be in excess of 55 years old by the start of the current determination period in 2019.

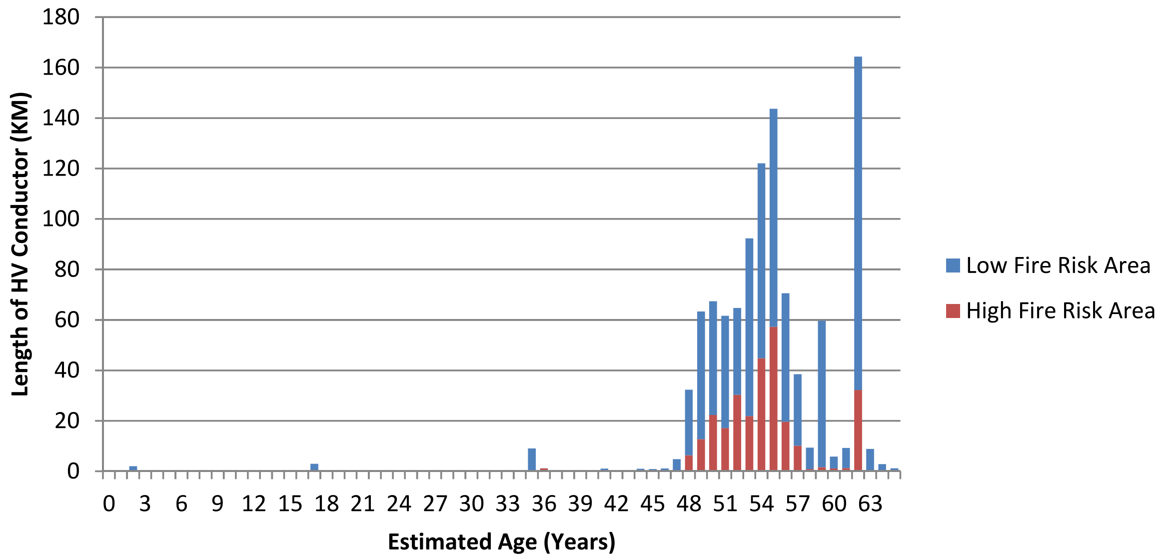


Figure 13 Copper HV Conductor Estimated Age Profile

5.4 GI Conductor Age Profile

Figure 14 shows the estimated age profile for GI HV overhead conductor.

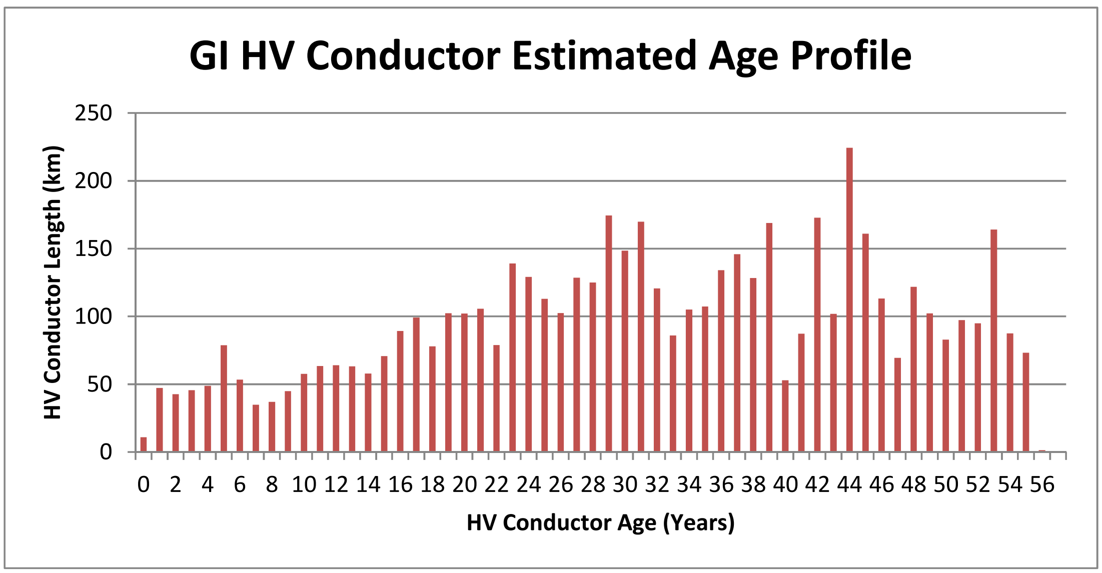


Figure 14: GI HV overhead conductor estimated age profile.

Figure 15 shows the age profile of the most at risk GI HV conductors, those within 2km of the coast. The large age spike of GI conductor currently at 51 years of age can be attributed to the work carried out in the aftermath of the 1967 bushfires and the older is mostly rural electrification not otherwise destroyed in bushfires.

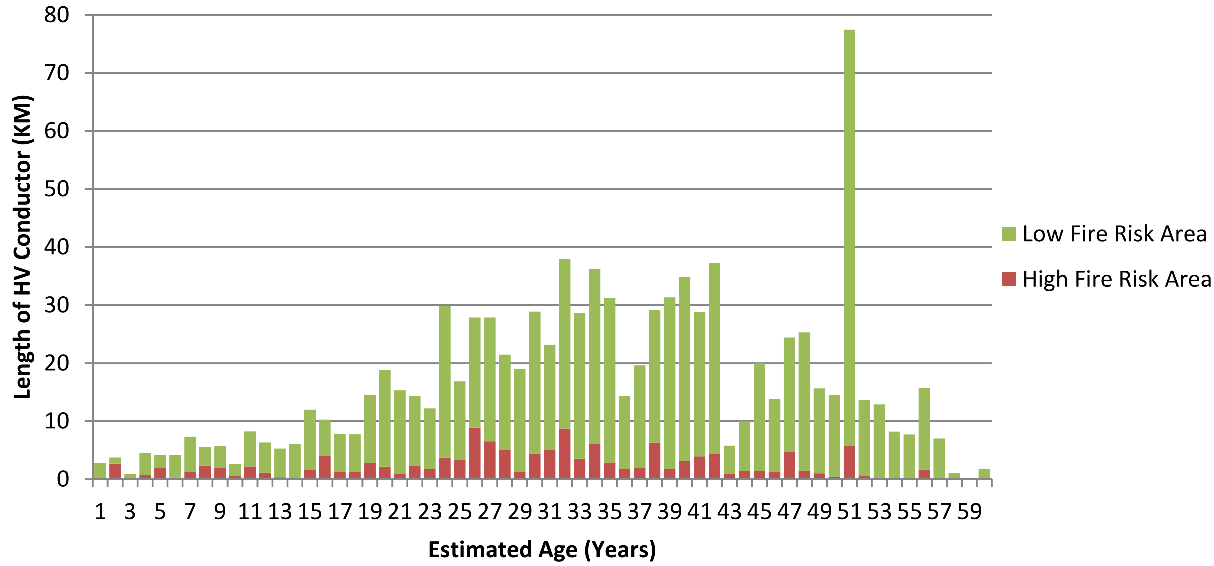


Figure 15: GI Conductor estimated age profile within 2km of the coast

5.5 Aluminium Conductor Age Profile

Figure 16 illustrates the age profile of aluminium conductors in TasNetworks distribution system. The majority of aluminium conductor in the LV and HV system was installed from 1963 and will average in age from new to 53 years by the end of the current determination period (2016/2017). Smaller cross section stranded AA conductor is more surface area to diameter prone to corrosion earlier, and to creep by fatigue if at high mechanical tensions likely in rural lines.

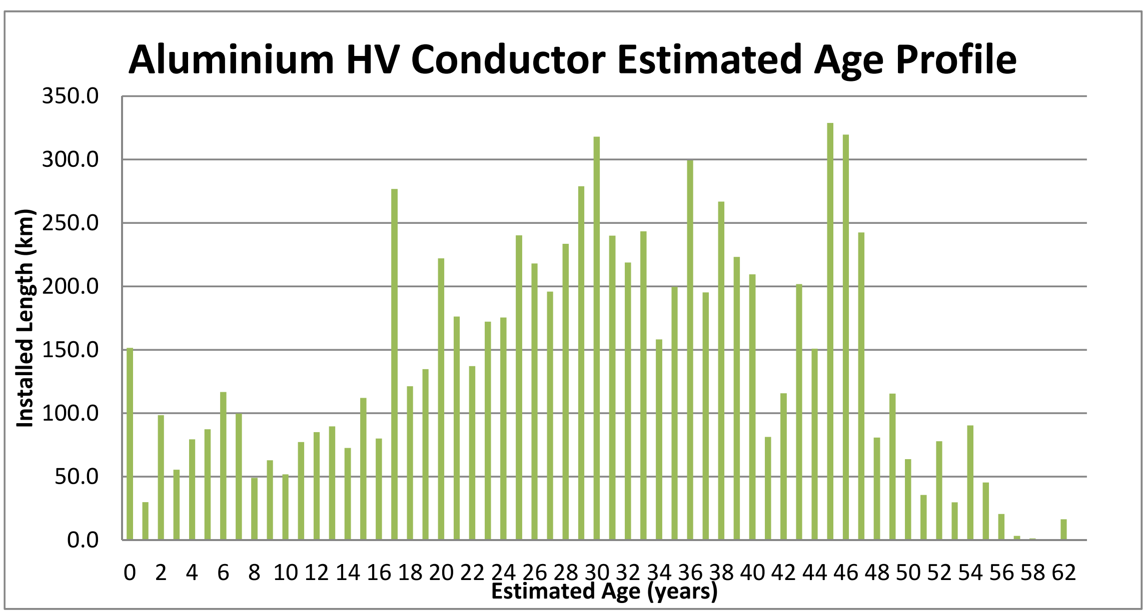


Figure 16: Aluminium HV conductor estimated age profile.

6 Standard of service

6.1 Technical Standards

Standards applying to distribution overhead conductors and hardware include:

- AS/NZS 7000:2010 – Overhead line design – Detailed procedures
- AS/NZS 2067:2016 – Substations and High Voltage Installations
- AS/NZS 5804-2010 –High Voltage Live Working

6.2 Key performance indicators

TasNetworks monitors distribution asset faults through its outage and incident reporting processes.

Asset failures resulting in unplanned outages are recorded in the In-service outage management tool by field staff, with cause and consequence information being available to staff for reporting and analysis. Those outages with a significant enough consequence are also recorded in RMSS and are investigated by the business to establish the root cause of the failure and to recommend remedial strategies to reduce the likelihood of reoccurrence of the failure mode. Reference to individual fault investigation reports can be found in RMSS.

TasNetworks also maintains a defect management system that enables internal performance monitoring and statistical analysis of asset faults and/or defects that either may not result in unplanned outages, or whose failure may only result in a minor consequence not requiring full investigation.

Examples of distribution performance impacts are seen in:

- Appendix L illustrates a 10 year lightning history contour with network asset locations. It identifies a higher lightning frequency risk to asset location concentration in the north of the state.
- Appendix M shows an example of regular report on Asset Performance by Asset Thread Category (12 month rolling average). Localised OHEW /OPGW shielding of higher exposure risk subtransmission and HV line sections might improve reliability.
- Appendix N shows locations of mostly unshielded low profile 33kV lines in Hobart area, which reliability benefits from urban shielding and low thunderday locality.

TasNetworks' Service Target Performance Incentive Scheme (STPIS), which meets the requirements of the Australian Energy Regulator's (AER's) Service Standards Guideline, imposes service performance measures and targets on TasNetworks with a focus on outage duration and frequency. While the STPIS does not target specific asset classes, good asset performance will have a significant impact on TasNetworks' ability to meet the STPIS targets.

STPIS parameters include:

- System Average Interruption Duration Index (SAIDI); and
- System Average Interruption Frequency Index (SAIFI).

Details of the STPIS scheme and performance targets can be found in the *"Electricity distribution network service providers - Service target performance incentive scheme - November 2009"*.

Figure 17 identifies conductor and hardware asset failure contribution to SAIFI 2015/2016 and 2016/2017

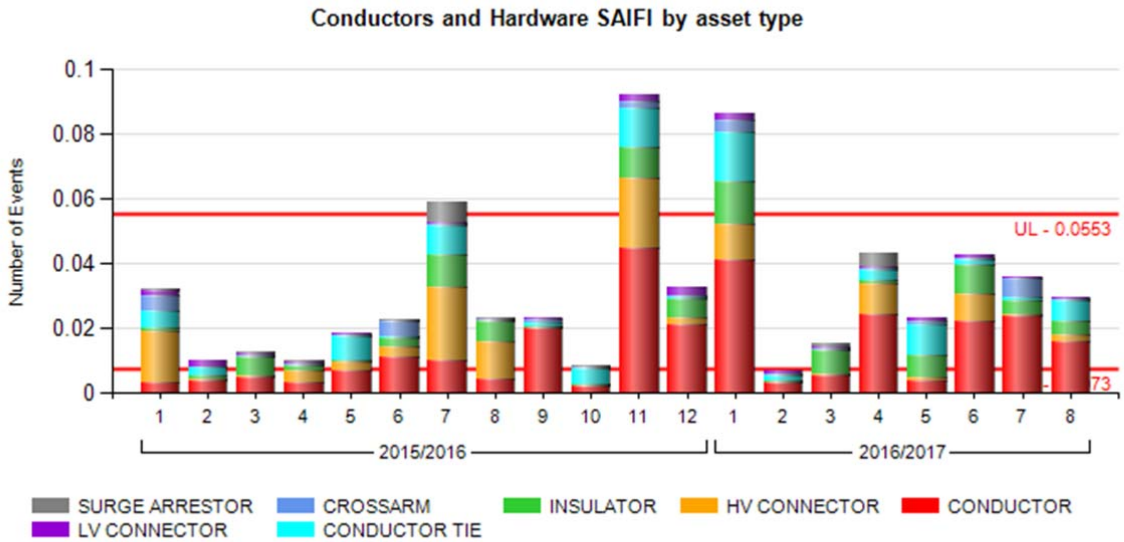


Figure 13: Asset Failure SAIFI contribution – Conductors and Hardware

Figure 18 identifies conductor and hardware asset events as a proportion of all overhead asset events.

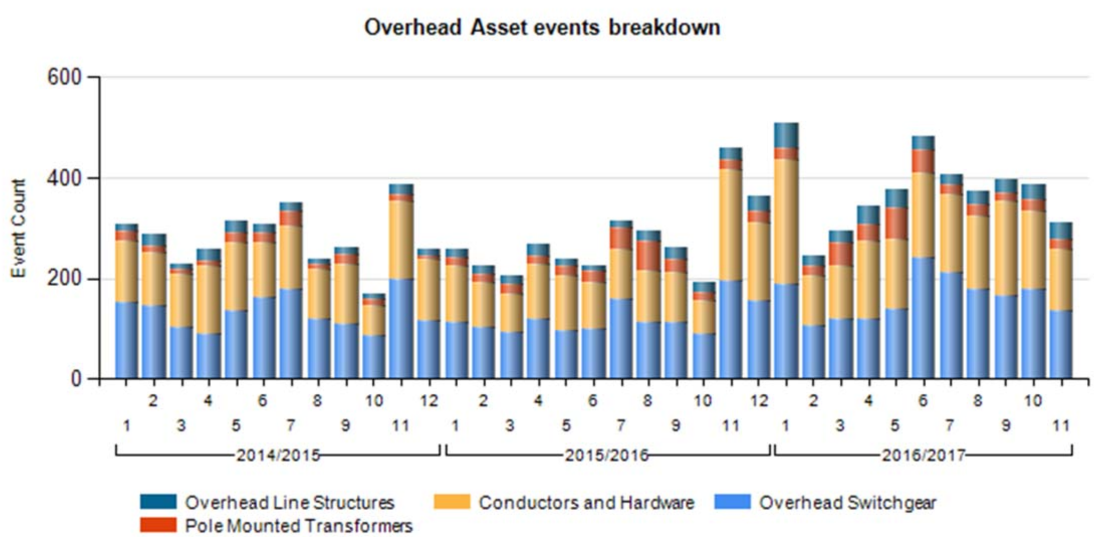


Figure 18: Conductor and hardware as a proportion of all overall Overhead Asset events breakdown (June 2017)

6.3 Benchmarking

TasNetworks' service performance is benchmarked against other DNSPs through the AER's RIN framework.

In addition, TasNetworks also works closely with its other distribution networks, to compare asset management practices and performance.

TasNetworks is also internally benchmarking its Bushfire Risk Mitigation Management. It is updated periodically as Year To Date Performance Report in TasNetworks (refer to Appendices C, D, E, and F). Most of the highest bushfire risk asset types are addressed in this Asset Management Plan and a long lived service life asset types. Strategy actions in condition based replacement including benchmarked technology innovation where practicable.

The definition of the High Bushfire Consequence Area is flexible, and can change between years. TasNetworks has the option of extending the consequence area covered by its pre-summer inspection and cutting program if conditions leading into the bushfire season pose sufficient risk to warrant additional work being undertaken. Such risks and additions to the program are developed in consultation with the Tasmania Fire Service and the Bureau of Meteorology. Map of the current High Bushfire Risk Consequence Area is shown in Figure 19.

About 16% of TasNetworks distribution network assets are located in the current HBCA as in May 2017.

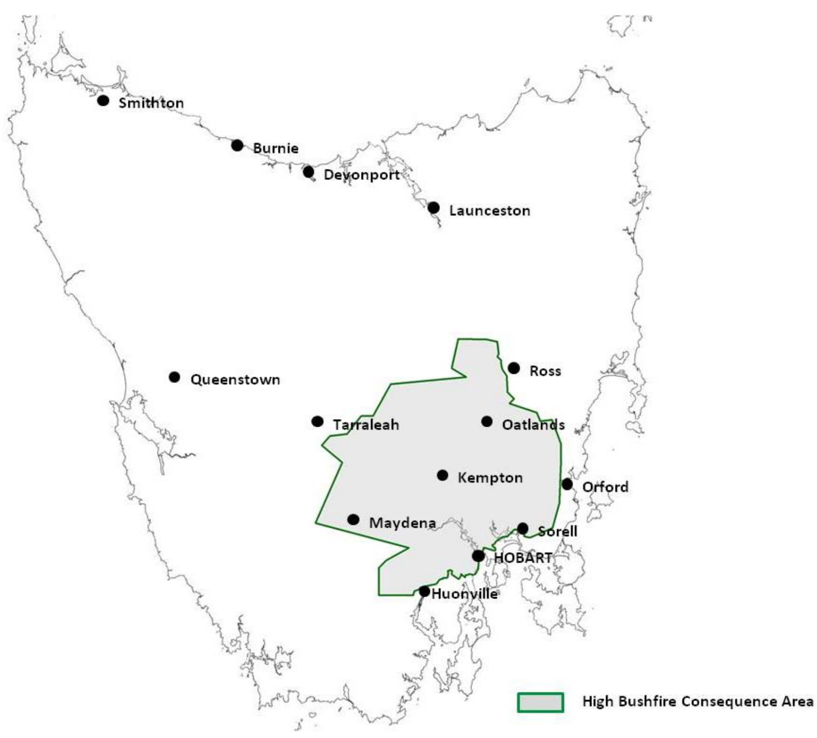


Figure 19: Current High Bushfire Consequence Area

7 Associated Risks

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 distribution overhead switchgear 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 20:

Figure 20 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 distribution overhead conductors and hardware assets and the current or proposed treatment plans.

7.1 Overhead Conductors and Cable Risks

7.1.1 Low Conductor Clearances

TasNetworks is required to maintain minimum clearances to ground for its overhead conductors to ensure that pedestrians or vehicles do not come in contact with conductors. Low conductor clearance may be the result of a number of issues; change in the ground level after installation, inadequate design or installation, higher than anticipated load on the conductors or insufficient tension on the conductor.

TasNetworks experiences approximately 30 incidents every year where third party vehicles contact and / or pull down overhead services or conductor. The risks from these events include: damage to third parties' and TasNetworks' assets, electric shocks or electrocution and fire starts.

7.1.2 Vegetation coming in contact with conductors

TasNetworks is required to maintain minimum clearances to vegetation for its overhead conductors to ensure that vegetation does not come in contact with conductors. Venation may come in contact with vegetation for a number of reasons: vegetation near the conductor grows till it comes in contact, a nearby branch sways when windy and hits a conductor or a branch or tree falls onto conductors. The risks from these events include: damage to TasNetworks assets, outages and fire starts.

Mitigation measures that manage the vegetation growth are addressed by the Vegetation Asset Management Plan whilst this plan includes measures that eliminate the risk such as undergrounding sections of a line or relocation of a line or replacing bar conductor with insulated conductor.

7.1.3 Substandard Conductor

Substandard overhead conductor may result in broken wires, presenting fire and safety risks as well as interrupting supply to customers. Copper and Galvanised Iron Conductor have been identified as representing the highest proportion of conductor failures.

TasNetworks records on average approximately 200 outages caused by conductor failures every year. In 2016/17, conductor failures contributed 8.95 minutes SAIDI (or 19% of the total asset related failure contribution to SAIDI of 48.02 minutes) and 0.04 interruptions SAIFI (or 11% if the total asset related failure contribution to SAIFI of 0.37 interruptions).

Table 3 shows the results of analysis of conductor failures by distance from the coast. These results show that over 36% of all conductor failures occur within 5 km of the coast (with 21% of all conductor located within 5 km of the coast). Conductors installed close to the coast more susceptible to salt spray from the prevailing winds and therefore is more likely to fail due to corrosion.

Table 3: Conductor failure statistics by distance from coast (as at June 2015 – from WASP Outage Data)

	Distance to Coastline (km)						
Conductor Type	**0 - 5**	**5 - 10**	**10 - 20**	**20 - 30**	**>30**	**Total Failures**	**% of Total Failures**
Number of AAC failures	57	11	4	13	24	109	25%
% of all AAC failures	52%	10%	4%	12%	22%		
Number of AAAC failures	30	14	6	3	24	77	18%
% of all AAAC failures	39%	18%	8%	4%	31%		
Number of ACSR Failures	5	4	6	2	12	29	7%
% of all ACSR failures	17%	14%	21%	7%	41%		
Number of Copper failures	15	5	2	4	42	68	15%
% of all Copper failures	22%	7%	3%	6%	62%		
Number of GI failures	53	31	12	18	43	157	36%
% of all GI failures	34%	20%	8%	11%	27%		
Total Number of Failures	160	65	30	40	145	440	100%
% of All Failures	36%	15%	7%	9%	33%		

7.1.3.1 Overhead Copper (Cu) Conductor

Analysis of conductor failures has shown that the percentage of copper conductor failures in the network is higher than any other conductor type. Copper conductors make up 15% of the total failures while only representing 7.8% of total installed conductors.

Table 4 shows there have been an increasing trend of copper conductor failures over the past few years.

Table 4: Copper conductor failure statistics by year

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Number of failures	5	7	7	8	4	5	1	11	13

During their life these conductors are exposed to significant fault currents that could cause the copper to anneal (reduction in tensile strength) and scale (reduction in diameter). This deterioration, which is easily identified by its orange and scaling appearance, affects the tensile strength. Small size copper conductor is particularly susceptible to corrosion and failure in marine type environments.

The risks from copper conductor failure include: damage to third parties' and TasNetworks' assets, electric shocks or electrocution and fire starts.

7.1.3.2 Overhead Galvanised Iron (GI) Conductor

Galvanised conductor is a poor conductor in marine environments. When subjected to wind borne salt spray and sea fogs containing salt contaminants, salt crystals are deposited on to the steel conductors. A galvanic cell is formed and removal of the zinc coating results over time. Once the zinc coating has been removed, severe corrosion of the steel leads to loss of mechanical strength and eventual conductor failure.

The risk of public safety as a result of conductor failure in marine environments is exacerbated by the fact that most of these conductors are at the end of long feeders and the ground is sand, having a high resistance, making it highly probable that the protection will not see the event as a fault and isolate the line.

Table 5 shows the number of galvanised iron conductor failures by year.

Table 5: Galvanised iron conductor failure statistics by year

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Number of failures	7	20	13	15	4	14	9	17	28

Though the conductor failure rate is lower than other conductors, the fire start risk is much greater due to an increased likliness of ground fire ignition from clashing steel conductors compared to copper or aluminum. This is compounded by the fact that a primary benefit of using steel conductors is increased span lengths however, increased span lengths increase the likliness of clashing conductors.

Table 6 shows the results of geospatial analysis of galvanised iron conductor failures from 2010-2014. These results indicate that conductor closer to the coast is more susceptible to salt spray from the prevailing winds and therefore are more likely to fail due to rusting. It can also be seen that galvanised iron conductor represents an average of 36% of all failures.

Table 6: Conductor failure statistics by distance from coast (2010-2014)

	Distance to Coastline (km)				
Row Labels	**0 - 5**	**5 - 10**	**10 - 20**	**20 - 30**	**>30**
AA	57	11	4	13	24
AAA	30	14	6	3	24
ACSR	5	4	6	2	12
Cu	15	5	2	4	42
GI	53	31	12	18	43
Grand Total	160	65	30	40	145

7.1.3.3 Overhead Aluminium (AA) Conductor (REMAC)

The following conductors with a smaller diameter are identified to be at a higher risk of failure:

- AAC 7/2.50 Leo
- ACSR 6/1/2.50 Almond conductor

The only type of Aluminium conductor currently used in TasNetworks distribution system are 19/3.25 AAC (Naptune0, and 7/3.00 AAAC (fluorine) as standard conductors. These are used when higher load carrying capacity is required, such as when the line is a feeder trunk or the future load forecast is high.

As displayed in Table 6, 43% of conductor failures are from aluminium conductor either AAC or AAAC. The causes may be locality specific or a result of generic wearout based on fatigue or corrosion.

Another cause of conductor failure may be a lightning direct strike on an unshielded conductor which results in arc melt those progresses to a broken conductor. Inspections such as by mast camera, EWP, helicopter or unmanned aerial vehicle camera from above and /or by corona camera can assist detection of in span arc melts from lightning strike to unshielded distribution conductors or conductor clashing.

Figure 20 shows one of two adjacent conductor arc melt defects (from another network) that arose from midspan clashing and conductor galloping that could progress to a broken conductor. Figure 21 is an example of midspan set of two 33kV interphase spacers and conductor melt retrofit repair kit (Adapt Australia).

Figure 20 shows one of two adjacent AAC midspan conductor arc melts from galloping

Figure 21 shows a HV mid span spacer set for AAC damping galloping solution

Figure 22 shows fretting fatigue failure that can become a cause of strand failures in both outer and inner strands. Interstrand microslip amplitude increases, small cracks are generated, and some propagate to strand failures (reference 11)

Figure 22 shows example of fretting conductor fatigue failure risk in AA or ACSR conductor

7.2 Other Risks

7.2.1 Cross Arm Failures

Timber cross arms are subject to failure due to decay or loose or fatigued steelwork. The risks from cross arm failure include: damage to TasNetworks assets (falling conductor or equipment such as pole top transformers), injury to the general public, outages and fire starts.

TasNetworks mitigation measures are to inspect and replace damaged or weak cross arms and to tighten any loose bolts or replace fatigued steelwork.

7.2.2 Access Tracks

The majority of TasNetworks' overhead assets are located adjacent to existing roads where there is suitable access to the assets for operations, maintenance and replacement works. However in some locations overhead assets travel through private and public owned land where access tracks adjacent to the overhead lines are required. There is the potential for access to be prevented to TasNetworks lines and equipment for routine maintenance and emergency fault repairs if the vegetation is not periodically removed. The risks from these event includes: damage to TasNetworks vehicles and a delay in access means delay in addressing emergency situations (e.g. making safe on site, larger, longer unplanned outages) or planned works.

7.2.3 Weed Management

Tasmania has specifically designated clean and unclean sites, farms and areas with respect to weed and disease around the state. TasNetworks has strict weed and disease management procedures in place when travelling between these areas. However there is a risk that TasNetworks' activities when travelling on access tracks whilst carrying out overhead works may contribute to the spread of weeds, such as gorse outbreaks in gorse-free areas within TasNetworks' easements. The risks from this event includes: damage to native vegetation or loss of agricultural production due to the spread of weeds or diseases. TasNetworks has approximately 25,000km of easements for transmission and distribution lines, and it is anticipated that additional annual expenditure will be required for weeds management and biosecurity to changing legislative requirements on distribution line easements.

7.2.4 Contact with bird and animal species

It is common for bird and animal species including protected species such as Tasmanian wedge tail eagles to come in contact with poles, conductors and pole top hardware. The separation distances between conductors and pole top hardware are generally adequate to prevent current tracking down the pole to the ground. However, birds and animals occasionally bridge this gap, resulting in phase-to-phase contact of the conductors and the electrocution and potential combustion of the animal.

TasNetworks records approximately 500 outages caused birds and animals every year (including mid-span collisions). The risks from these events include: unplanned outages, damage to TasNetworks' assets, damage to the wildlife involved and the potential for fire starts.

7.3 Summary of Risks

Appendix A has list of the programs for distribution overhead conductor and pole top hardware risks, risk drivers, and residual risk. Each program specific risk is detailed in matching Investment Evaluation Summary.

8 Management Plan

8.1 Historical

TasNetworks' asset management practices on the overhead and structures asset classes have been consistent for a number of years; however current practices are under review, with the approach changing to Reliability Centred Maintenance (RCM).

Although there is a robust condition based replacement process for structures, condition based replacements of overhead assets can be improved. Better understanding of the condition of the overhead assets is required; hence the historic inspection process will have to change to support this.

Operational expenditure on the overhead system is increasing. This is due to an increase in the volume of defects reported along with a growing pool of existing defects carried over from previous years where tasks have been put on hold due to resource and budget constraints. This has prompted a review of TasNetworks' defect management process and has resulted in some restructuring of programs.

8.2 Strategy

8.2.1 Routine Maintenance

There is a fundamental requirement for TasNetworks to periodically inspect its overhead conductors and hardware 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. The Strategy for inspection of overhead lines (reference 16) outlines the roles of ground line inspection, aerial visual inspection photography, thermal inspection and LiDAR survey inspection.

8.3 Planned Asset Replacement versus Reactive Asset Replacement

Failure of overhead conductor and hardware assets have the potential to cause a bushfire or a serious injury or fatality to a member of the public. It is therefore seen as prudent to inspect the condition of assets on a regular basis and to replace or reinforce assets in poor condition before they fail. Poor condition assets are identified in maintenance and inspections activities and feed into the list of proposed capital expenditure projects for prioritisation.

While poor condition assets are primarily replaced for safety reasons, there is also an economic advantage as reactive replacements are generally several times more expensive, incurring overtime, call out penalties and additional repair costs to cables and nearby infrastructure. By identifying weak spots and defects prior to any asset failure, reactive maintenance can be undertaken with less disruption to customers at lower cost and potential fire starts can be avoided.

8.4 Non Network Solutions

Non Networks Solutions are generally not applicable for conductors and hardware asset class. Other options do exist to minimise customer disruption, including temporary mobile generation substitution while an asset is out of service. TasNetworks currently has mobile generators and has leasing arrangements in place to source additional units as required.

Remote Area Power Schemes (RAPS) are used to replace some SWER spurs where cost justified and the end customer agrees to grid disconnection.

8.5 Routine Maintenance

8.5.1 Overhead System Aerial Inspections (AIOFD)

The business objectives driving this program are:

1. Managing Business Operating Risk (through identifying defects before they impact on safety or fire risks – primary driver); and
2. Maintaining Network Performance (through identifying defects before they impact on reliability – secondary driver).

The overhead system contributes over 60 percent of total asset failures impacting TasNetworks' SAIDI and SAIFI (reference 3). The aim of this program is to effectively target maintenance and replacement activities.

In early 2012 a Reliability Centred Maintenance (RCM) review of the overhead system identified that the best method to manage the inspections was to separate the overhead asset inspection from the ground-line pole inspection.

This RCM review resulted on the ground-line inspection of poles moving to a five year cycle.

These are the added programs also implemented from this review e:

1. Aerial inspection program for pole top assets (5 year cycle);
2. Thermal imaging program (2 year cycle); and
3. OH transformers earthing inspection (10 year cycle)[2]

Recently another program was trialled in 2016/17, and now added to a 5 year cycle-

4. Aerial LiDAR survey program for overhead line conductor span clearances

A visual inspection from the ground limits the Asset Inspector undertaking a full assessment of the pole top assets making the identification of critical asset failures such as broken tie wires and faulty cross-arms difficult. The RCM review identified that TasNetworks should visually inspect pole tops from above every five years as part of its new overhead system maintenance strategy.

The use of high definition imagery and remote sensing technologies for asset inspection is becoming commonplace throughout the utility sector across the world, and is gaining acceptance as standard industry best practice. A detailed trial in 2013 of various available technologies (including unmanned aerial vehicles and hi-mast) found that helicopters provided the most cost effective solution. Helicopters also have an added advantage of being able to assist with vegetation inspections due to their ability to efficiently patrol long stretches of feeders.

The program which commenced in 2014/15 consists of using a helicopter to inspect feeders from the air. The inspections will run on a rolling five year program and cover approximately 44,000 poles per year. In the years 2017/18 to 2019/20 additional funds have been allocated to also

[2] *OH transformers earthing inspection program is included in the Distribution Pole Mounted Transformers Asset Management Plan*

inspect TasNetworks' poor performing feeders. TasNetworks has previously only used aerial inspections in the past on an ad-hoc basis, for example for fault finding.

8.3.1.1 Helicopter aerial LiDAR Survey (AIOFD)

TasNetworks commenced LiDAR surveying of transmission lines in 2012 to evaluate the benefits to operational and strategic management of transmission line assets (reference 16). In 2016/17 a trial distribution LiDAR surveys were carried out in conjunction with helicopter aerial patrol of overhead 33kV subtransmission lines near Hobart, and of the overhead line distribution HV feeders from Sorell into the Tasman Peninsula. This trial facilitated improved checks on overhead conductor clearances, line corridor encroachments, line profile data for reviewing overhead line ratings and for use in future simplified redesign.

Aerial LiDAR Survey data can become the basis for future overhead line augmentation redesign because it provides the following benefits;

- improved clearances auditability including for vegetation and from newly built structures
- greater line design productivity,
- enhanced easement management for overhead line corridor encroachments detection, recording changes and in landowner safety communication co-operation such as the positioning of new large travelling irrigators.

A period of five years for aerial LiDAR surveys is proposed to match aging conductors.

In summary, the current progress in LiDAR surveying of distribution overhead lines is:

- A trial of alternative inspection methods to compliment ground based assessment of pole top assets to aerial inspection has resulted in more effective identification and prioritisation of defects lowering overall risk,
- Aerial inspections of pole top assets and spans are now done on a 5 year cycle,
- The LiDAR trials of Tasman Peninsula feeders in early 2017 has proven the effectiveness in assessing all clearances and allowed refinement of scope for roll out to the entire distribution network, and
- Risk priority based LiDAR surveys are planned on the entire network focusing on vegetation, conductor clearances and asset condition (e.g. leaning poles) and are to be completed in 3 years (80% by end year 2).

The longer term distribution LiDAR strategy includes:

- Annual Inspection of highly vegetated HBLCA areas,
- Inspection of less vegetated HBLCA areas on a 3 year cycle, and
- Non HBLCA areas on a 5 year cycle.

A combination of LiDAR, aerial and ground based inspections allows best use of available technologies to better risk assess the network and manage risks associated with potential failures.

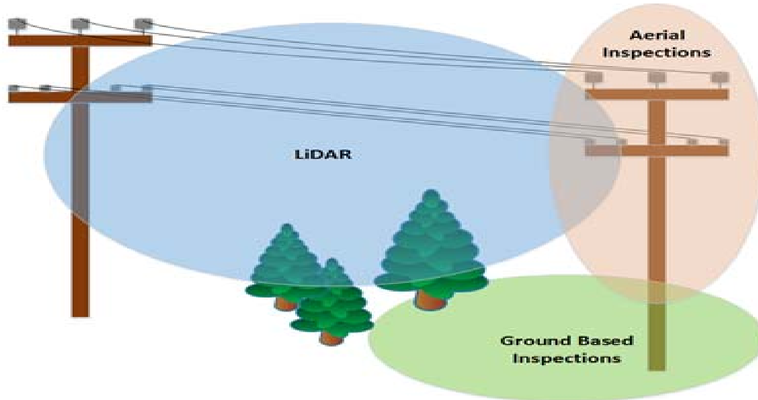


Figure 14: Synergy between Distribution Inspections

Figure 24: The same pole as seen from the ground and from the air

Figure 15: 3D image example of a LiDAR survey identified a line span conductor clearance risk.

Figure 26: shared corridor for a distribution line in this Transmission line for LiDAR survey

8.5.2 Thermal Inspections – Overhead Feeders (AIOTI)

The driver for this program is managing business operating risks (safety) through preventing fire starts. Network reliability improvement is considered as a secondary benefit of the implementation of this program. From 01 July 2012 to 27 April 2015, TasNetworks experienced 2,311 outages as a result of asset failure that may have been identified in a thermal inspection program.

This program entails the use of a thermal imaging camera to identify joints or connections that are displaying signs of high resistance within the network. The results of a recent RCM analysis identified this work as critical to the overhead strategy of no failures that matter. By identifying weak spots and defects prior to asset failure, reactive maintenance can be undertaken with less disruption to customers at lower cost, and potential fire starts can be avoided. Measuring in situ three phase set for asset temperature differences of 5 degrees Centigrade or more can by comparison help identify potential assets at risk, for example a failing surge diverter.

This program commenced in 2013/2014 and was expanded in 2014/2015 to include systematic inspections of all poles containing joints/connections and mid-span connections with greater than 1,000 kVA connected downstream over a three year inspection cycle.

In April 2015 a review of this program was undertaken (see AIOTI Strategy Review, reference 6) which identified a number of opportunities for improving the program's effectiveness and efficiency. This resulted in a more targeted approach and co-ordinating the inspection so feeders are inspected at times when they are more heavily loaded. From 2015/2016 onwards in particular areas of the network such as the high bushfire consequence area and on the seven worst performing feeders, the 1,000 kVA threshold will be maintained. For all other areas of the network it is the inspection threshold will be raised to 4,000 kVA to maximise the likelihood of finding asset defects.

Figure 27: A Live Line Clamp through a thermal imaging camera and a normal camera

8.6 Non Routine Maintenance

8.6.1 OH System Asset Repairs (Defects) (AROCO)

The drivers for this program are managing business operating risks and maintaining network reliability.

This program covers minor asset repairs that have been identified and have the potential to cause asset failure in the future or shorten the expected life of the asset.

The majority of these defects are reported through the Pole inspection program (AIOHS) and the Overhead System Aerial Inspections program (AIOFD). Defects identified include minor work involving asset repair such as refixing loose material, replacing possum guards, replacing loose ties, etc.

A review of the defect pool has resulted in changes to priorities. Some defects, such as missing pole caps will no longer be rectified as time priority, but as opportunity. Replacement of decayed wood LV cross arms has been separated into a new targeted capital program (Refer to RELSA Replace Cross Arms (Safety)).

In 2014/15 TasNetworks began inspecting its assets from the air. This provided a previously hidden view of the network that showed many assets were in a worse condition than previously thought. The first aerial inspection which focused on the High Bushfire Loss Consequence Area, found a total of 1,700 defects (5 per 100 poles), all of which were considered to be potential fire start risks. This resulted in expenditure much higher than forecast. As aerial inspections are done on a five year cycle there is expected to be an increase in overhead maintenance over the next five years, following the first round of aerial inspections as these identify defects that have gone undetected for many years. The following round of aerial inspections is expected to yield a much lower volume of maintenance work.

From January 2015 to March 2016, ten conductor clashing conductor (AROCO) events occurred – one on HV conductor, and nine on LV conductor, with the latter requiring LV spreaders or conversion to LV ABC. In 2016/17, 2017/18, targeted capital programs in bushfire mitigation (SIFIC) were/are installing LV spreaders and HV dampers.

8.6.2 OH System Low Conductor Clearance (AROLC)

The driver for this program is managing business operating risks.

This program covers simple repair tasks such as the re-tensioning of slack spans of LV and HV conductor to address conductor clearance issues. Where a more complex solution is required (such as the installation of a pole) that work is undertaken as an asset replacement task.

Approximately 1,100 LV and LV service conductor clearance defects are identified every year.

The introduction of aerial LIDAR surveys of all overhead assets is expected to bring a sharp increase in the number of under clearance defects identified within the 2019 Regulatory period. Previously TasNetworks underclearance defects have only been identified by visual inspection from the ground level which leaves the possibility that many under clearance defects have gone unnoticed.

8.6.3 Maintain Access Track and Weed Management (RMOTC)

The budget for this program has historically been managed by the Vegetation Management team. Therefore the budget in the 2014/2015 POW and on, has been substantially reduced to reflect the low level of spend by the Overhead Structures team in this program.

There are two components to this program:

1. Access track maintenance; and
2. Weed management.

8.6.3.1 Access Track Maintenance

The aim of this program is to maintain access tracks to a level and condition where safe all-weather access to TasNetworks lines and equipment is possible for the purposes of routine maintenance and emergency fault repairs.

Experience within TasNetworks has shown existing access tracks need to be maintained approximately every four years for optimum cost versus benefit and to stop them degrading to the stage where they require extensive works.

Figure 28 Examples of high slope access tracks & track washout near pole footing

8.6.3.2 Weed Management

There are specifically designated clean and unclean sites, farms and areas with respect to weed and disease around the state. Although TasNetworks has strict weed and disease management procedures in place when travelling between these areas, the aim of this program is to reactively address situations where TasNetworks' activities have contributed to the spread of weeds, such as gorse outbreaks in gorse-free areas within TasNetworks' easements.

8.7 Reliability and Quality Maintenance

8.7.1 Low HV Conductors (REHCR)

The driver for this project is managing business operating risks.

This program covers the relocation or replacement of HV overhead conductor to address low clearances associated with road crossings and plant contact that cannot be repaired under the reactive maintenance program such as the installation of a pole to fix the clearance issue.

Low HV conductors also pose a significant public safety risk and are addressed as soon as possible.

The introduction of aerial LIDAR surveys of all overhead assets is expected to bring a large increase in the number of under clearance defects identified within the 2019-24 regulatory period. Previously TasNetworks underclearance defects have only been identified by visual inspection from the ground level which leaves the possibility that many under clearance defects have gone unnoticed. The forecasted spending for this program is expected to oscillate following the 3 yearly cycle of the LIDAR survey program.

8.7.2 Rectify Low LV Clearances Public Safety (RELCR)

This program covers the relocation or replacement of LV overhead conductor to address low clearances associated with road crossings and plant contact that require more complex solutions, for example new pole installations, than available under the reactive maintenance program (AROLC).

Approximately 1,100 LV and service conductor clearance defects are identified every year.

8.7.3 Replace/Relocate HV due to Vegetation Issues (REHVE)

The driver for this program is minimising costs to customers and managing business operating risks (fire).

The aim of this program is to address the issue of high vegetation maintenance costs in certain areas. Historically, there have been cases where it is more efficient to relocate hybrid underground or insulate bare overhead assets around vegetation rather than managing the vegetation near the assets such as areas where vegetation is protected (national parks) or where there are community or environmental considerations or there are onerous vegetation management requirements due to bushfire risk management.

This program has been in place for a number of years but as part of the Replace HV Feeders (Safety) and Fire Mitigation asset replacements. This program is being increased in the 2019 Regulatory period due to TasNetworks' increased focus on mitigating bushfire risk.

8.7.4 Replace Cross Arms (RELSA)

The drivers for this program are managing business operating risks. This program commenced midway through 2013/2014 and will continue on throughout the next regulatory period. This is a targeted asset rectification program which focuses mainly on decayed timber cross arms, but also includes other cross arm related defects (such as loose/missing steelwork and transformers hung directly on timber cross arms). This work was previously done under AROCO OH System Asset Repairs Defects, but has been separated into a dedicated program in order to drive efficiencies.

8.7.5 Replace Substandard Overhead Conductor (REMCU/REMGI/REMAC)

Substandard overhead conductor may result in broken wires, presenting fire and safety risks as well as interrupting supply to customers. Copper and Galvanised Iron Conductor have been identified as representing the highest proportion of conductor failures and so have been targeted for prioritised replacement programs. There are three programs for replacing substandard overhead conductor:

1. Replace Substandard Overhead Copper Conductor (REMCU)
2. Replace Substandard Overhead Galvanised Iron (GI) Conductor (REMGI)
3. Replace substandard Overhead Aluminium AAC/AAAC (REMAC)

TasNetworks records on average approximately 200 outages caused by conductor failures every year. In 2016/2017, conductor failures contributed 8.95 minutes SAIDI (or 19% of the total asset related failure contribution to SAIDI of 48.02 minutes) and 0.04 interruptions SAIFI (or 11% if the total asset related failure contribution to SAIFI of 0.37 interruptions).

8.7.5.1 Replace Substandard Overhead Copper Conductor (REMCU)

The drivers for this program are maintaining network performance, and compliance with regulatory responsibilities. The aim of this program is to remove substandard condition copper conductor from the overhead system.

During their life these conductors are exposed to significant fault currents that could cause the copper to anneal (reduction in tensile strength) and scale (reduction in diameter). This deterioration, which is easily identified by its orange and scaling appearance, affects the tensile strength.

Smaller stranded conductor (7/.044 and 7/.048) does not comply with AS 7000, which requires conductors to have an ultimate breaking strength of at least 5 kN. Small size copper conductor is particularly susceptible to corrosion and failure in marine type environments.

The number of joints in a span can be used as an indication of the condition of the conductor.

Initial inspections have shown that approximately 35% of all inspected conductor will require replacement in the near future however, conductor failure rates will be monitored and conductor inspections undertaken.

This program has been in place for a number of years but as part of Replace HV Feeders (Safety) (REHSA). A new work category was created at the beginning of the 2012-2017 Determination Period for this work.

8.7.5.2 Replace Substandard Overhead Galvanised Iron (GI) Conductor (REMGI)

The drivers for this program are maintaining network performance and managing business operating risks (safety). The aim of this program is to remove substandard condition GI conductor from the overhead system and to replace sections of overhead GI conductor around coastal areas.

Galvanised Iron (GI) conductor came into service in the 1940s. TasNetworks stopped installation of single strand No. 8 GI conductor in the 1970s and the imperial 3/12 GI conductor was replaced with the metric 3/2.75 GI conductor around 1976, which is the present day TasNetworks standard for rural conductors across private property. By the end of the current determination period), the minimum age of any 3/12 GI conductor will be 46 years with the majority greater than 55 years.

AS 7000 (Reference 8) rates GI conductor as a very poor conductor in marine environments. When subjected to wind borne salt spray and sea fogs containing salt contaminants, salt crystals are deposited on to the steel conductors. A galvanic cell is formed and removal of the zinc coating results over time. Once the zinc coating has been removed, severe corrosion of the steel leads to loss of mechanical strength and eventual conductor failure.

The risk of public safety as a result of conductor failure in marine environments is exacerbated by the fact that most of these conductors are at the end of long feeders and the ground is sand, having a high resistance, making it highly probable that the protection will not see the event as a fault and isolate the line.

8.7.5.3 Replace or repair Overhead Aluminium (AA) Conductor (REMAC)

The drivers for this program are maintaining network performance and managing business operating risks (safety). The aim of this program is to remove substandard condition AA conductor from the overhead system and to replace sections of overhead AA conductor around coastal areas.

Inspections such as by mast camera, EWP, helicopter or unmanned aerial vehicle camera from above and /or by corona camera can assist detection of in span arc melts from lightning strike to unshielded distribution conductors or conductor clashing.

An unshielded conductor arc melt defect could be from lightning direct strike that could progress to a broken conductor. While Figure 29 shows one of two adjacent conductor arc melt defects that in another network arose from midspan clashing, from conductor galloping could progress to a broken conductor Periodic inspection detection reduces expense in repair, risk mitigation and avoids outage and mitigation options include spiral dampers, HV interphase spacers or increased phase separation redressing. Figure 30 is an example of midspan set of two 33kV interphase spacers and conductor melt retrofit repair kit (Adapt Australia).

Figure 29 shows one of two adjacent AAC midspan conductor arc melts from galloping

Figure 30 shows a HV mid span spacer set for AAC damping galloping solution

Figure 31 shows fretting fatigue failure that can become a cause of strand failures in both outer and inner strands. Interstrand microslip amplitude increases, small cracks are generated, and some propagate to strand failures (reference 11)

Figure 31 shows example of fretting conductor fatigue failure risk in AA or ACSR conductor

Methods for inspecting topside of conductors for arc melts are by use of mirrors on insulated sticks or Go-Pro Cameras. The use of helicopter aerial patrol inspection or UAV rotorcraft camera inspection can be alternatives.

For spans with three or more tension joints in series from conductor or conductor connector break failures, the span should be replaced or sample cut lengths of suspect fretting fatigue conductor can be sent for testing at a NATA Mechanical accredited facility, such as Victoria University Testing Station, Melbourne, One Steel Wire Rope NATA Testing Laboratory, Newcastle or equivalent for assessment of remaining service life estimation. AS7000-2016 includes overhead conductor assessment criteria for creep, annealing, corrosion, stress and fatigue. Improved tension repair joints for use on aged conductors are in industry review.

8.8 Regulatory Obligations

8.8.1 Replace HV Feeders – Safety (REHSA)

This category is for miscellaneous small scale capex jobs that are scoped in response to specific one off situations to do with the HV overhead system. Jobs under this category will be raised throughout the year as they arise with urgent jobs to be processed in the current financial year, and non-urgent jobs to be deferred till the following year.

8.8.2 Replace/Relocate LV OH (Building Clearances) (RELCL and RELCU)

The drivers for this project are compliance with regulatory requirements and managing business operating risks (safety). This program covers relocation or replacement LV overhead conductor because of issues with building clearances e.g. when new buildings are erected that infringe on TasNetworks' clearance, that cannot be repaired under the reactive maintenance program (AROLC).

This program has two components:

1. Relocating or replacing with LV ABC (RELCL); and
2. Replacing with underground cable (RELCU).

Approximately 1,100 low voltage and LV service conductor clearance defects are identified every year.

8.8.3 Endangered Species (SIWES)

The drivers for this project are compliance with regulatory requirements and maintaining network reliability.

This aim of this program is to proactively mitigate pole top assets to ensure that protected species (such as Tasmanian wedge tail eagles) are not harmed when interacting with poles or wires. The secondary and complementary aim is to protect overhead assets from damage due to wildlife contact. This program is based on asset failures and outage information. TasNetworks records approximately 500 outages caused birds and animals every year (including mid-span collisions). The separation distances between conductors and pole top hardware are generally adequate to prevent current tracking down the pole to the ground. However, birds and animals occasionally bridge this gap, resulting in phase-to-phase contact of the conductors and the electrocution and potential combustion of the animal. This project involves insulating live components and parts on pole tops in high wildlife trafficked areas.

This program is coordinated with the Environment Officer in collaboration with the relevant authorities. Specific detail on the 2017/18 program is included in Appendix K.

8.8.4 Fire Mitigation Projects (SIFIC)

TasNetworks has a number of fire mitigation programs in place to address the risk of fire start posed by the assets. These programs are pritorised by assets in the HBCA (High Bushfire Consequence Area). Over this period the Fire Mitigation Projects program is focusing on 3 main components:

- Replace EDO fuses with Boric Acid fuses in HBCA
- Install Vibration Dampers
- Install LV Spreaders

8.6.4.1 Replace EDO fuses with Boric Acid fuses

This program is detailed in Overhead Switchgear Asset Management Plan, but is actioned as an integral part of the Bushfire Risk mitigation on overhead line conductors and poletops.

8.6.4.2 Install Vibration Dampers

This program is to install vibration dampers and armour rods on long spans greater than 300m. A desk top audit and prioritisation will be performed to get volumes.

8.6.4.3 Install LV Spreaders

This program is to retrofit LV Spreaders within all rural areas. Priority will first be within HBCA. A desktop audit is still required to be performed to get exact volumes.

8.7 Removed/obsolete programs

The following programs have been removed as deemed no longer required.

8.7.1 High Load Route Inspection (AIOHL)

The high load route inspection program is used to ensure TasNetworks' infrastructure is not damaged by transportation of high load, which is triggered by requests from the public.

This task is generally undertaken by a TasNetworks preferred contractor under the request of the customer; however, TasNetworks previously retained this program to address the infrequent situations when customers bypass this process. The costs involved are now usually recovered from the customer; this category was used for when costs were not able to be recovered. Historically this category has been underutilised so is deemed no longer required.

8.7.2 Replace Live Line Clamps Fitted on Tensioned Conductors

In the 2013/2014 POW the approach to this issue was to replace all live line clamps attached directly to a conductor with a live line clamp and dee-loop configuration (the dee-loop provides a more secure double attachment to the conductor so is less likely to wiggle loose. The live line clamp may still become loose but will only burn through the dee-loop and not the conductor so consequences are much lower). The area targeted was the High Bushfire Consequence Loss Zone.

The strategy to deal with this risk has been changed since the 2014/2015 POW. Now, live line clamps attached directly to the conductor are replaced with D-Loops with a priority put on sites within the High Bushfire Loss Consequence Area.

8.7.3 Replace Worn Insulation HV ABC Conductor

The 2017/2018 POW approach is to risk review the insulation wear on 27 km of non-metallic screened (NMS) HV ABC based on in service life and condition assessment for planned replacement based on risk, noting reference 32 illustrates findings of a Victorian Utility.

Figure 32 existing non-metallic screened (NMS) HV ABC conductor

8.8 Investment Evaluation

Investment evaluation is undertaken using TasNetworks' investment evaluation tool, see Gated Investment Framework (reference 7). Investment Evaluation Summaries (IES) are used to provide information in support of a project for inclusion in the Capital Works Program. This information provides a record of the project as it progresses from initiation to finalisation and is required to support a request for funding approval. This IES aims to improve the efficiency and delivery of the capital investment justification and approval process and is a requirement for regulatory and governance purposes.

8.9 Summary of Programs

Table 9 provides a summary of all of the programs described in this management plan.

Table 9: Summary of Conductors & Hardware Programs

Work Program	Work Category	Category Code	Project/Program
Routine Maintenance	OH Feeder Ground Auditing and Inspection	AIOFD	OH System Feeder Inspections by Helicopter LIDAR Survey OH System Feeder Inspections by Helicopter
	OH Feeder High Vehicle Load Auditing and Inspection	AIOHL (Obsolete)	High Load Route Inspection
	OH System thermal inspections	AIOTI	Thermal Inspection – O/H Feeders (Defined)
Non-Routine Maintenance	OH System Asset Repair	AROCO	OH System Asset Repair (Defects)
	OH System Low Conductor Clearance	AROLC	OH System Low Conductor Clearance
	Access Track Clearing	RMOTC	Maintain access tracks and weed management
Reliability and Quality Maintained	Replace/relocate HV OH (Low Clearance)	REHCR	Low HV Conductors
	Replace/relocate HV (Vegetation)	REHVE	Replace/relocate HV due to vegetation issues
	Replace/relocate LV OH (Low Clearance)	RELCR	Rectify low LV clearances public safety
	Replace/relocate LV OH (Low Clearance)	RELSA	Replace Cross arms
Regulatory Obligations	Replace HV Feeders Safety	REHSA	HV Feeders (Safety)
	Replace/relocate LV OH (Building Clearances)	RELCL	Replace/relocate LV OH (Building Clearances)
	Replace/relocate LV OH (Building Clearances) with UG	RELCU	Replace/relocate LV OH (Building Clearances) with UG
	Wildlife Endangered Species Protection	SIWES	Endangered species

9 Responsibilities

Maintenance and implementation of this management plan is the responsibility of Overhead and Structures Asset Strategy Engineer.

Approval of this management plan is the responsibility of the Asset Strategy Team Leader.

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:

1. Asset Management Strategic Plan (R94876)
2. Air navigation - Cables and their supporting structures - Marking and safety requirements AS/NZ 3891.1-2008
3. Overhead and Structures Asset Reporting 2012-2013 (R295196)
4. REMGI & REMCU Investment Evaluation Summary (R150772)
5. Overhead Conductor Replacement Programs Prioritisation Guideline (R208597 and R603335)
6. AIOTI Program Strategy Review April 2015 (R159945)
7. Gated Investment Process – Investment Evaluation Summary (R150791)
8. Standard for Design and Maintenance of Overhead Distribution and Transmission Lines AS/NZS 7000 – 2016
9. Bushfire Risk Mitigation Plan (R303735)
10. United Energy HV Bundled Conductor Strategic Direction Plan Document No UEPL 2053
11. Peter Dulhunty,CIGRE B2 WG49, EESA Webinar combining TB 273 and TB653 ,Sydney 11th October 2016
12. Fibreglass reinforced plastic crossarm trial (R 370233)
13. Monthly Asset Performance Report
14. https://blogs.scientificamerican.com/guest-blog/why-do-trees-topple-in-a-storm/
15. https://www.researchgate.net/publication/266260400_Tree_Stability_in_Wind_Storms-_Open_grown_trees_in_Urban_areas
16. Inspections of Overhead Lines Strategy (R210959)
17. Fibreglass Crossarm Trial –Review and Request for Endorsement (R 712219)
    Tasmanian Fire Service Website
18. Polymeric Versus Porcelain, (R 759983)
19. TasNetworks Transformation Roadmap 2025 https://www.tasnetworks.com.au/customer-engagement/submissions/
20. TasNetworks Corporate Plan – Planning period: 2017-18 http://reclink/R0000745475
21. Conductors for the uprating of overhead lines ,CIGRE 244, April 2004
22. AD Stokes ,Fire Ignition by Electrically Produced Incandescent Particles, Journal of Electrical & Electronic Engineering ,10,pp175 to187, Sept 1990.

11 Appendix A - Summary of expenditure programs, main drivers and risks

Description	Work Category	Risk Level	Driver	Expenditure Type	Residual Risk
OH System Feeder Inspections by Helicopter	AIOFD	High	Safety	OPEX	Medium
Thermal Inspection – O/H Feeders (Defined)	AIOTI	High	Safety	OPEX	Medium
OH System Asset Repair (Defects)	AROCO	High	Safety	OPEX	Medium
OH System Low Conductor Clearance	AROLC	High	Safety	OPEX	Medium
Maintain access tracks and weed management	RMOTC	High	Safety	OPEX	Medium
Low HV Conductors	REHCR	High	Safety	CAPEX	Medium
Replace/relocate HV due to vegetation issues	REHVE	High	Safety	CAPEX	Medium
Rectify low LV clearances public safety	RELCR	High	Safety	CAPEX	Medium
Replace Cross arms	RELSA	High	Safety	CAPEX	Medium
HV Feeders (Safety)	REHSA	High	Safety	CAPEX	Medium
Replace/relocate LV OH (Building Clearances)	RELCL	High	Safety	CAPEX	Medium
Replace/relocate LV OH (Building Clearances) with UG	RELCU	High	Safety	CAPEX	Medium
Endangered species	SIWES	High	Environment	CAPEX	Medium

12 Appendix B - Summary of CAPEX Projects for Replacement of Substandard Conductor

REMGI Replacement of aged/deteriorated HV galvanised Iron Conductors

Year	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Unit (km) Volume												
in BFM	14	22	36	36	36	14	14	14	14	14	14	14
other			13	13	13	13	13	13	13	13	13	13
Total	14	22	49	49	49	27	27	27	27	27	27	27

REMCU Replacement of aged/deteriorated HV Copper Conductors

Year	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Unit (km) Volume												
in BFM	19	29	48	48	48	19	19	19	19	19	19	19
other	8.4	0	33	33	33	33	33	33	33	33	33	33
Total	27.4	29	61	61	61	52	52	52	52	52	52	52

REMAC Replacement of aged/deteriorated HV Aluminium Conductors

Year	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Unit (km) Volume												
in BFM	5	7	12	12	12	5	5	5	5	5	5	5
other	0	0	15	15	15	15	15	15	15	15	15	15
Total	5	7	27	27	27	20	20	20	20	20	20	20

REMAC Replacement of aged/deteriorated NMS HV ABC with MS HV ABC

Year	17/18	18/19	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Unit =spans Volume												
in BFM	20	20	20	20	20	20	20	2	2	2	2	2
other	0	0	20	20	20	20	20	20	20	20	20	20
Total	20	20	40	40	40	40	40	22	22	22	22	22

These projects are part of ongoing programs that is risk priority based addressing aging Copper and Galvanised steel conductor wearout including substandard conductors. Another program (REMAC) is for aluminium conductors based on similar risk assessment data including supply reliability.

Condition based decisionmaking can be enhanced using conductor sample testing for risk review evaluation for remaining service life (AS7000-2016 Appendices). High tension small sized Aluminium conductor can be prone to subtle corrosion and metal fatigue risk and the current risk- based decision for aluminium is presently that after more than three full tension joint repairs in just one span, it precipitates the need to replace that span of conductor. Multiple failure rates on 7/3.00 AAC for some now at 50 years in service, has already warranted trial conductor replacement. New innovations in faster tension jointing, and potentially longer connector service life tension joint connector fittings for emergency broken conductor repairs are under review for field trial.

A new program is added for NMS HV ABC risk management replacement