Asset Management Plan

Transmission Line Insulator Assemblies Asset Management Plan

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Authorisations

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Responsibilities

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

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

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

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

Record of revisions

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

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1 Purpose

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

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

2 Scope

This document covers addresses all transmission line insulator assemblies owned and maintained by TasNetworks.

3 Strategic alignment and objectives

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

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

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

4 Asset information systems

4.1 Systems

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

- R17083 WASP Asset Register – Data Integrity Standard – String Insulators
- R17122 WASP Asset Register – Data Integrity Standard – Insulator and Damper Assemblies

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

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

4.2 Asset information

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

5 Description of the assets

Insulator assemblies mechanically support and electrically separate and insulate the energised conductors from their support structures in a safe and secure manner, compatible with the operating voltage and mechanical strength of the insulators.

The insulator assembly is one of the key components of the transmission line and failure can cause conductor drop and or a circuit outage.

TasNetworks has approximately 42,000 insulator assemblies in service, comprising predominantly glass or porcelain disc insulator assemblies. Since 1999 a small number of synthetic insulators have also been installed on the transmission network.

A summary of TasNetworks' disc insulator population is provided in Table 1.

Table 1 - Insulator population (August 2017)[1]

Insulator Material	Insulator Design	Size	Population	% of total
Glass	Disc	16mm	159,472	40%
		20mm	129,848	32%
Porcelain	Disc	16mm	45,436	11%
		20mm	64,553	16%
	Post		150	<1%
Synthetic			2,536	<1%
Total			**401,995**	**100%**

5.1 Transmission Line Insulator Assembly Types

Insulator assemblies are designed to withstand power frequency voltage and imposed overvoltages (switching surge or lightning voltages), mechanical load conditions, and varying environmental pollution levels.

On 110 kV transmission circuits TasNetworks utilises insulator assemblies with a minimum 70kN electromechanical failure rating, 16mm fitting and breakdown insulation level of 450 kV.

On 220 kV transmission circuits TasNetworks utilises insulator assemblies with a minimum 160kN electromechanical failure rating, 20mm fitting and breakdown insulation level of 950 kV.

5.1.1 Glass and porcelain disc insulators

Where disc insulators are utilised, an insulator assembly normally comprises seven insulator discs at 110 kV, or thirteen discs at 220 kV, with one extra disc utilised for insulator assemblies located within switchyards to ensure appropriate insulation coordination.

[1] An additional 744 synthetic insulators are installed on the Bluff Point–Smithton and Studland Bay Spur 110 kV transmission lines. These lines are owned by third parties, with asset management and maintenance activities contracted to TasNetworks.

Historically, TasNetworks has utilised either glass or porcelain insulator discs within its insulator assemblies. Porcelain and glass insulator discs are not mixed within a single insulator string, and in most locations a transmission circuit will consist wholly of either glass or porcelain insulator strings.

Metal fittings are cemented into the porcelain or glass discs to allow the units to be coupled together to form an insulator string or assembly. A ball is usually fitted to the underside of the disc and a socket to the top side. Each disc-to-disc joint is secured with a security clip to prevent mechanical separation. All of these components, including the cement, may deteriorate in service and result in electrical insulation breakdown (flashover), or mechanical failure (separation) resulting in the attached conductor falling.

Glass insulator discs, shown in Figure 1, are the preferred material for new transmission lines, as the glass is tempered and will shatter when they fail. This provides field personnel with a clear and visible indication of the failed insulator disc, facilitating swift identification and commencement of repair activities.

Figure 1: 220 kV glass disc insulator assembly

Porcelain insulator assemblies, shown in Figure 2, have been utilised extensively in the past, and upon failure would normally be replaced with a similar porcelain insulator assembly. These insulators are able to withstand attempts at vandalism more effectively than glass insulators. However, porcelain insulators are not preferred for new transmission lines, as failure often manifests itself in a small puncture of the insulator disc that is often visibly undetectable by field personnel, requiring costly condition monitoring.

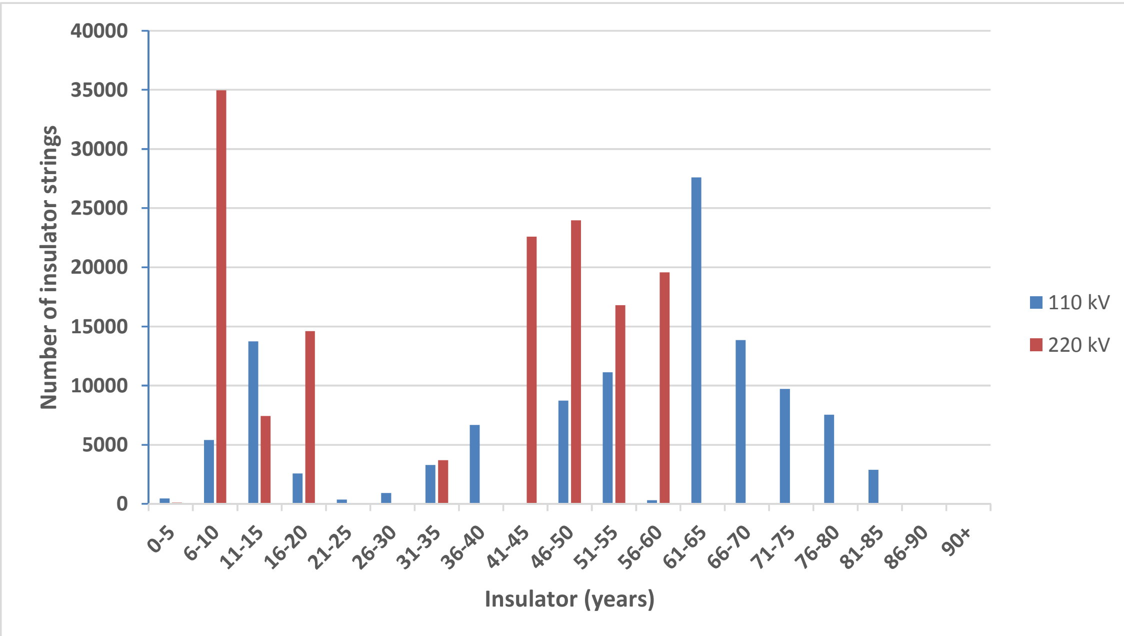
Figure 2: 220 kV porcelain disc insulator assembly

The design of TasNetworks' disc insulator assemblies is sufficiently robust to permit the failure of up to two discs before live line work activities are restricted.

TasNetworks' has utilised various different colours in both its glass and porcelain insulators. These colours have no bearing on the reliability and performance of the insulator, and have been chosen to ensure the insulator assemblies blend in with the surrounding vegetation and terrain.

The age profile of TasNetworks' 110 kV and 220 kV glass disc insulators is presented in Figure 3.

Figure 3: Glass disc insulator age profile (August 2017)[2]



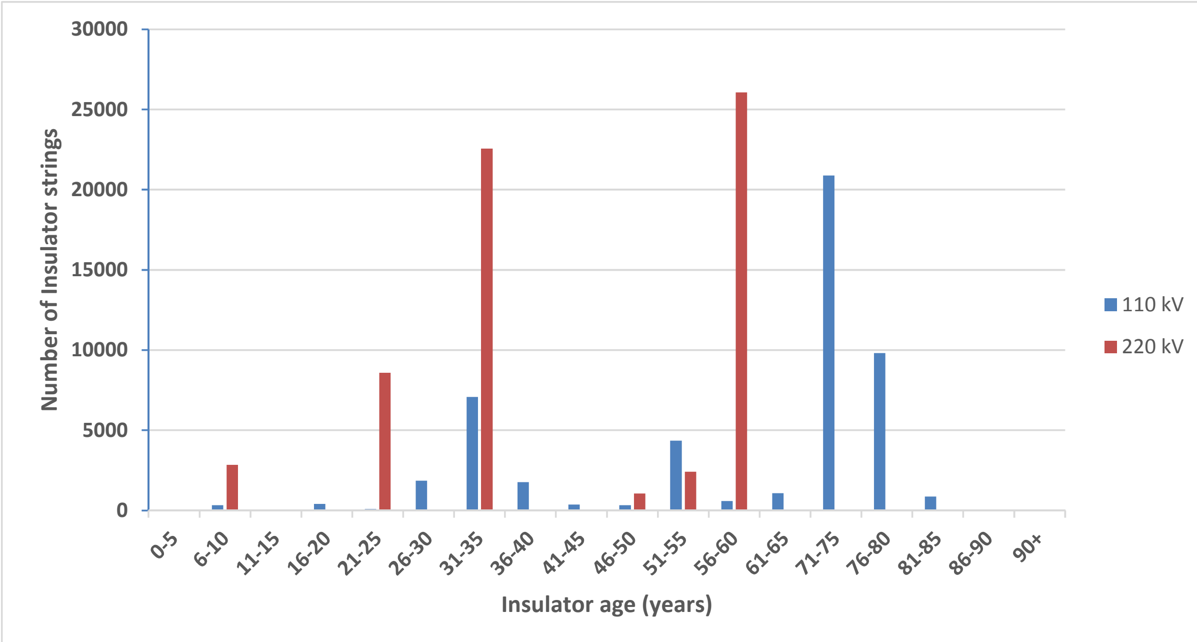
It can be seen that more than 53% of 110 kV glass disc insulators are greater than 60 years of age, and by the end of the next regulatory control period 14% of TasNetworks' 220 kV glass disc insulators will exceed 45 years of age.

The service life of TasNetworks' glass disc insulators has been good, however industry experience and good engineering practice suggests that increases in asset deterioration are likely to become evident, and that asset renewal activities should continue to ensure that the risk posed by TasNetworks' fleet of aged glass disc insulators is maintained at an acceptable level.

The age profile of TasNetworks' 110 kV and 220 kV porcelain disc insulators is presented in Figure 4.

[2] Where insulator data is unavailable for some older transmission lines, TasNetworks has relied on the transmission line structure age as a proxy for the insulator age.

Figure 4: Porcelain disc insulator age profile (August 2017)



It can be seen that more than 66% of 110 kV porcelain disc insulators are greater than 60 years of age, and by the end of the next regulatory control period 41% of TasNetworks' 220 kV glass disc insulators will exceed 60 years of age.

The service life of TasNetworks' porcelain disc insulators has been exceptional, however industry experience and good engineering practice suggests that increases in asset deterioration are likely to become evident, and that asset renewal activities should continue to ensure that the risk posed by TasNetworks' fleet of aged porcelain insulators is maintained at an acceptable level.

5.1.2 Synthetic insulators

The use of synthetic insulator assemblies by TasNetworks is not widespread, and has typically occurred where either there has been a specific requirement that could not be met through the use of disc insulators (e.g. high pollution area, or where greater ground clearance is required), or where TasNetworks has wanted to gain experience in the installation, operation and maintenance of synthetic insulator assemblies for the purposes of assessing their suitability in other applications.

Depending on the line design and associated insulator strength requirements, both long rod and standoff synthetic insulators have been used by TasNetworks.

Figure 5 shows typical synthetic post and suspension insulator assemblies.

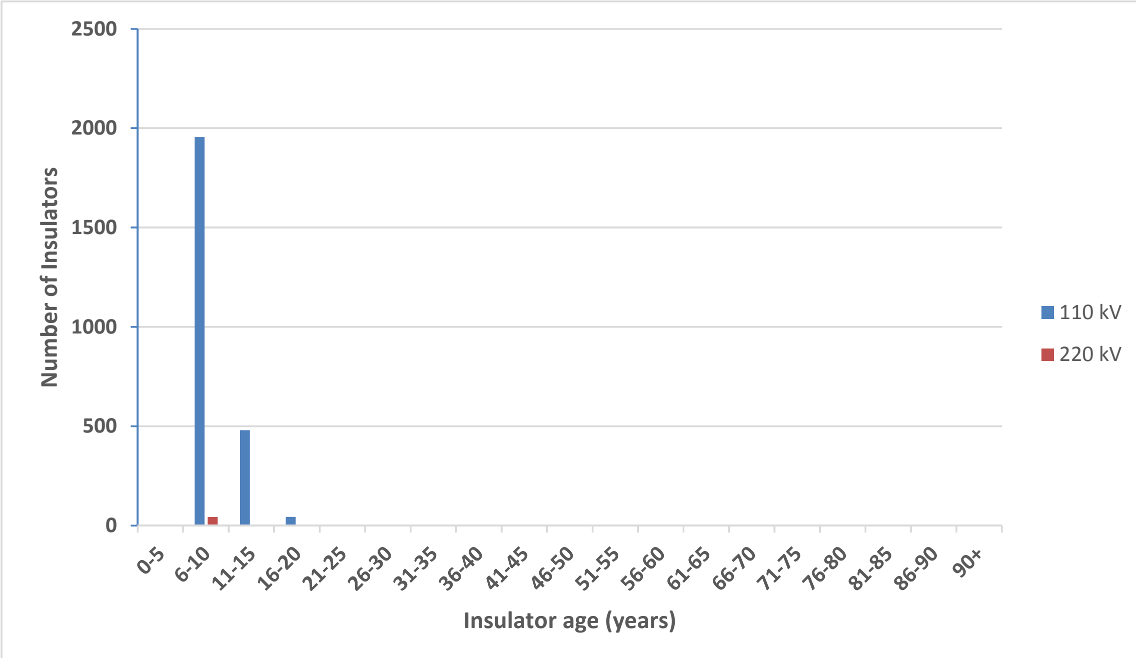
Figure 5: Post and long rod synthetic insulators

Table 2: Synthetic Insulator Population

Transmission line	Voltage (kV)	Insulators
TL400 Waddamana-Bridgewater Junction (West)	110	18
TL409 Waddamana-Parknook	110	2
TL414 Hadspen-Norwood	110	9
TL415 Burnie-Smithton	110	6
TL417 Tarraleah-New Norfolk (East)	110	3
TL429 Palmerston-Avoca	110	109
TL430 Chapel Street-Creek Road (East)	110	2
TL436 Knights Road-Kermandie	110	9
TL437 Sheffield-Devonport	110	66
TL440 Wesley Vale Spur	110	54
TL446 Waratah-Savage River	110	63
TL447 George Town-Temco	110	8
TL456 Triabunna Spur	110	81
TL463 New Norfolk-Creek Road	110	6
TL469 Electrona Spur	110	21
TL471 Hadspen-Trevallyn	110	24
TL472 Trevallyn-Mowbray	110	21
TL479 Norwood - Scottsdale	110	1,494
TL480 Derby Spur	110	360
TL481 Chapel St-Chapel St Junction	110	21
TL483 Bell Bay Three Spur	110	24
TL484 Huon River Spur	110	93
TL529 George Town-Longreach Junction	220	3
TL530 Tamar Valley Spur	220	39
Grand total		**2,536**

The age profile of TasNetworks' 110 kV and 220 kV synthetic insulators is presented in Figure 6. It can be seen that the majority of these assets are still very young, with only 10% of the insulators older than 20 years of age.

Figure 6: Synthetic insulator age profile



5.1.3 Porcelain post insulators

Only 56 porcelain post insulators have been installed on the transmission network. Porcelain post insulators are no longer installed by TasNetworks, but historically were typically used as an option to obtain additional ground clearance. A typical post installation is shown in Figure 7.

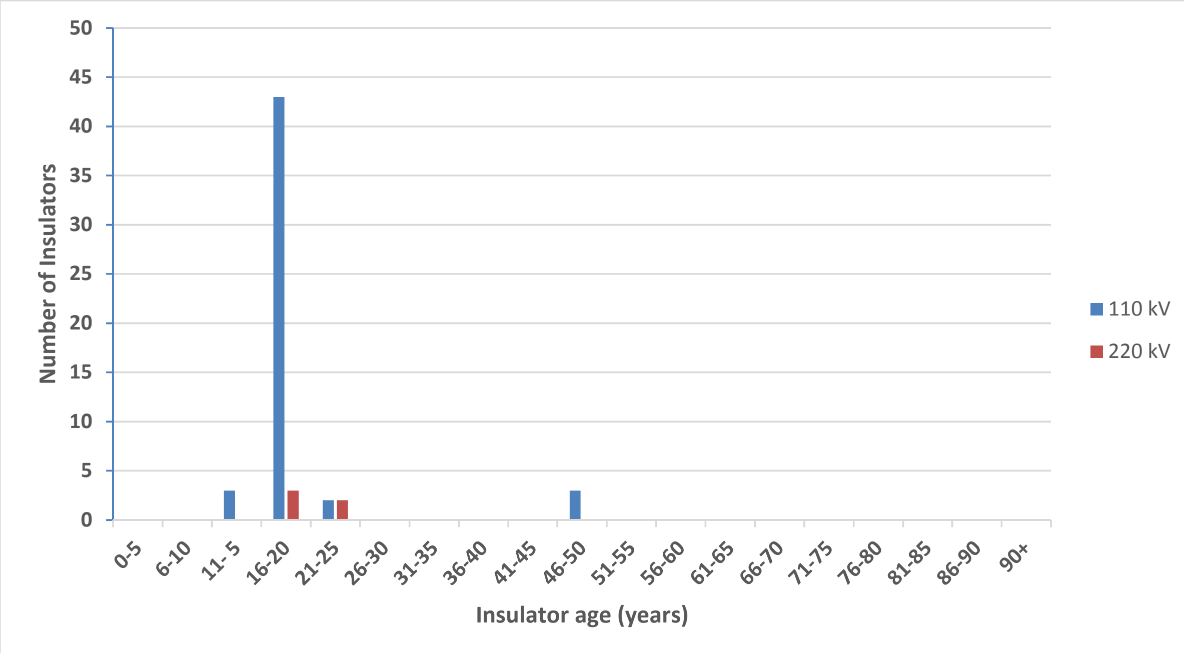
Table 3: Porcelain post insulator population

Transmission line	Voltage (kV)	Insulators
TL400 Waddamana-Bridgewater Junction (West)	110	2
TL404 Creek Road-Risdon	110	3
TL409 Waddamana-Parknook	110	16
TL413 Palmerston-Trevallyn	110	3
TL414 Hadspen-Norwood	110	12
TL425 Waddamana-Tungatinah (North)	110	12
TL445 Burnie-Waratah	110	3
TL502 Liapootah-Palmerston No. 1	220	3
TL524 Tribute Spur	220	2
TL456 Triabunna Spur	110	28
TL471 Hadspen-Trevallyn	110	6
TL484 Huon River Spur	110	60
Grand Total		**150**

Figure 7: Porcelain post insulators

The age profile of TasNetworks' 110 kV and 220 kV porcelain post-type insulators is presented in Figure 8. It can be seen that there are very few of these assets, with most being less than 20 years of age.

Figure 8: Porcelain post-type insulator age profile



5.2 Asset Condition Summary

5.2.1 Defect management practices

All insulator assemblies undergo periodic testing and or routine visual inspections, depending on the type, with any defective assets recorded and prioritised within TasNetworks' asset management system in accordance with the "Transmission Line Defect Priority Standard". These defects are then issued to TasNetworks' contractors for action within the specified time frames.

All replacement disc insulators will generally be glass, except where other factors dictate that synthetic or porcelain insulators are preferred.

Where tests indicate that three or more insulators are defective, TasNetworks will restrict live-line work activities at that location until either the insulator string is replaced, or the individual defective insulator discs are replaced.

The analysis of historical defects for particular insulator types can be useful in identifying systemic or emerging failure modes, with the results of this analysis influencing operational or capital expenditure. This information is detailed within TasNetworks' condition assessment reports, with a summary of the outcomes of this analysis provided in section 5.2.2.

Some photos of typical insulator defects are presented in Figure 9.

Figure 9: Typical defective insulators

5.2.2 Insulator assembly defects

Since 2009–10 only one P1 insulator assembly defect has been identified on the network. Together with the reduction in P2 defects over the last three years, this is indicative of the effective and timely manner in which lower priority defects are identified and rectified, preventing P2 and P3 defects from developing into P1 defects. This also reflects the effectiveness of TasNetworks' targeted insulator replacement program.

Over the last three years there has been a reduction in most categories of insulator defect. The only exception to this is the number of insulator failures due to lightning flashover, with this slight increase corresponding to a rise in lightning storm activity.

As these assets age, it is expected that an insulator replacement program will continue to be required to ensure that TasNetworks' risk profile is sufficiently mitigated.

5.2.3 Porcelain insulator voltage gradient testing

TasNetworks undertakes annual voltage gradient testing on 10 per cent of all porcelain insulator strings that are greater than 20 years old. Based on the current age profile of TasNetworks' porcelain insulators, this results in approximately 10,000 insulator strings being tested per year.

These tests are useful in identifying insulator discs that have had their insulation properties compromised through lightning strikes or other causes.

Over the last three years approximately 4 per cent of the tested strings failed the gradient voltage assessment. It is reasonable to assume that similar failure rates will be experienced in the future, resulting in an ongoing replacement rate of at least 400 insulator strings per year as a result of the voltage gradient test program.

Where there are sufficient failed insulator strings, TasNetworks will package this work into a capital replacement program, and will also include adjacent insulators of the same type and vintage that are likely to exhibit similar poor performance in the future.

5.2.4 Insulator leakage current measurements

The measurement of insulator leakage current can provide an indication of insulation deterioration. Leakage counters have been installed in the Tamar Valley at the locations shown below. Any future infrastructure development in this or other areas of the state may require the installation of additional leakage counters.

Table 4: Surge counter locations

Box	Transmission Circuit	Tower	Phase	Thresholds (mA)
1	Palmerston–George Town No 2	T242	A	100 / 200 / 300
2	George Town–Comalco No 5	T1	B	100 / 200 / 300
3	George Town–Temco No 2	T3	A	100 / 150 / 200
4	George Town–Comalco No 4	T4	A	100 / 150 / 200
5	George Town–Temco No 1	T7	A	100 / 150 / 200
6	George Town–Temco No 2	T7	A	100 / 150 / 200

Analysis of data at each of these sites shows that some sites are experiencing a material number of leakage current events. This is not unexpected given the proximity of this site to both dust and sea mists, however this site will continue to be monitored closely. TasNetworks' insulator washing program is considered adequate to mitigate the risk of insulator flashover on this and other transmission circuits. Future industrial developments in the Tamar Valley may necessitate the expansion of TasNetworks’ leakage current measurement program.

5.2.5 Synthetic insulator condition monitoring

Other than visual inspection, there are no tests currently available for the assessment of synthetic insulator condition. While TasNetworks’ synthetic insulator population is still relatively young, to mitigate this risk TasNetworks will continue to keep abreast of global condition assessment practices and introduce any suitable testing regimes where appropriate.

Thermal imaging, recently undertaken after the failure of a synthetic post type insulator, may prove useful in the future in identifying defective synthetic insulators. TasNetworks will continue to evaluate the effectiveness of this form of condition monitoring and consider its inclusion in the broader suite of routine condition monitoring activities.

5.3 Special operational and design issues

5.3.1 Operational issues

There are no systemic operational issues associated with TasNetworks’ insulator assemblies. However there are a number of structures in the West Coast and North West regions of the network where insulator flash-overs, as a result of lightning strikes, are more frequent than in the general population. TasNetworks is currently trialling the augmenting structure earthing to mitigate double circuit transmission line outages due to back flash. This trail is due for completion in 2017/18 under the transmission line isokeraunic protection enhancement program.

5.3.2 Design issues

5.3.2.1 Synthetic horizontal post insulators

In September 2009 TasNetworks experienced a mechanical failure of a synthetic post type insulator on the Savage River Spur 110 kV transmission line. Following this unplanned outage, a thorough review of the transmission line design and insulator failure was conducted by engineering consultants and the manufacturer, respectively. The conclusion of these investigations was that no remedial actions were recommended.

A second failure of the same type of insulator occurred in June 2013 on the same transmission line, and in this instance the insulator was sent back to the manufacturer to facilitate an examination through dissection of the insulator. The manufacturer produced a report from this examination which found that mechanical failure of the insulator had resulted in a crack developing in the fibreglass centre of the insulator and that over time this crack had extended to the point where electrical failure occurred by means of flash-under. The report also concluded that complete mechanical failure would have eventually occurred, similar to that experienced in 2009.

Figure 10: Cracking of fibreglass rod of insulator on TL446T232 (2013 failure)[3]

Subsequent to the June 2013 failure, TasNetworks performed visual, infrared and corona scans of the remaining in-service insulators on the Savage River Spur 110 kV transmission line to determine their condition. The condition monitoring results highlighted a level of thermal hot-spots on insulators that are indicative of mechanical and electrical insulation breakdown.

These reviews have led TasNetworks to believe that the installed these insulators had deteriorated significantly since their installation, were in poor condition and now posed a significant security of supply risk to TasNetworks as well as a safety risk, where the failure of an insulator could cause a conductor to fall to the ground, the worst consequence being personal harm or bushfire.

As a result these post insulators installed on the Savage River Spur 110 kV transmission line were replaced and a review of other transmission lines that utilise this type of post insulators resulted in all others being replaced. A similar review of all composite insulators installed in a similar horizontal post insulator arrangement has taken place and all synthetic horizontal post insulators are currently being monitored for similar failures modes.

5.3.2.2 Zinc collars

To reduce the rate of corrosion and improve the performance of TasNetworks' porcelain and glass insulators, TasNetworks specifies the use of a zinc collar on all new insulator discs. This collar acts as a sacrificial anode, preventing premature asset degradation. This practice should be continued.

5.3.2.3 Hooks

Hooks are often used to support insulators from support structures, and conductors from insulators. However, hooks can pose a number of issues where live line maintenance or construction activities are required. This is due to conductor suspension clamps sometimes 'jamming' onto hooks and being difficult to unhook. Also, the cold end hook may dislodge when lifting the conductor causing the insulator string to fall. This exposes personnel to risk and increases the likelihood of a circuit outage during these activities. Where a transmission line will

[3] Viewed from the base of the insulator

be upgraded, consideration is given to removing hooks from service. This decision will be based on importance of the transmission line, risk of the conductor falling in a number of spans and history of hook failure or dislodgement.

6 Standard of service

6.1 Technical Standards

In general, insulators have been designed and installed to a range of standards over the last 90 years. Insulators have been designed according to Australian Standards to mitigate the risk of flashover under normal conditions (power frequency), overvoltage conditions (switching surge and lightning impulse) and environmental pollution.

6.2 Performance objectives

6.2.1 Service obligations for network assets

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

- plant availability:
  - transmission line circuit availability; and
  - transformer circuit availability.
- supply availability:
  - number of events in which loss of supply exceeds 0.1 system minutes; and
  - number of events in which loss of supply exceeds 1.0 system minutes.

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

6.2.2 Service obligations for non-regulated assets

6.2.2.1 Hydro Tasmania

TasNetworks has a PI scheme in place with Hydro Tasmania under its Connection and Network Service Agreement (CANS 2) for connection assets between the two companies. The PI scheme includes connection asset availability which can be impacted by TasNetworks asset category assets. An overview of Hydro Tasmania PI scheme and performance targets can be found in the SAMP.

6.2.2.2 Tamar Valley Power Station (TVPS)

TasNetworks has a PI scheme in place with TVPS under its Generator Connection Agreement for connection assets between the two companies. The PI scheme includes the connection asset availability measure. An overview of TVPS PI scheme and performance targets can be found in the associated Connection Agreement.

6.2.2.3 Major Industrial Direct Customer Connections

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

- George Town – Colmalco 220 kV;
- George Town – Temco 110 kV;
- George town – Starwood 110 kV; and
- Burnie Hampshire 110 kV (via Hampshire switching station).

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

6.3 Key Performance Indicators

TasNetworks monitors insulator performance for major faults through its incident reporting process. The process involves the creation of a fault incident record in the event of a major asset category failure that has an immediate impact on the transmission system. The fault is then subjected to a detailed investigation that establishes the root cause of the failure and recommends remedial strategies to reduce the likelihood of reoccurrence of the failure mode within the asset category population.

For insulator failures that do not initiate a transmission system event, such as minor failure or defects, TasNetworks maintains a defects management system that enables internal performance monitoring and trending of all asset category related faults or defects.

6.3.1 Insulator KPIs

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

- Insulator defect volumes are maintained at a consistent level over a 5 year period; and
- Failures due to voltage gradient test results are maintained at a consistent level over a 5 year period.

6.4 Benchmarking

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

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

In addition, TasNetworks works closely with transmission companies in other key industry forums, such as CIGRE (International Council on Large Electric Systems), to compare asset management practices and performance.

6.4.1 External benchmarking

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

6.4.1.1 Service Performance

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

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

Figure 11: ITOMS Overall transmission line composite performance trend

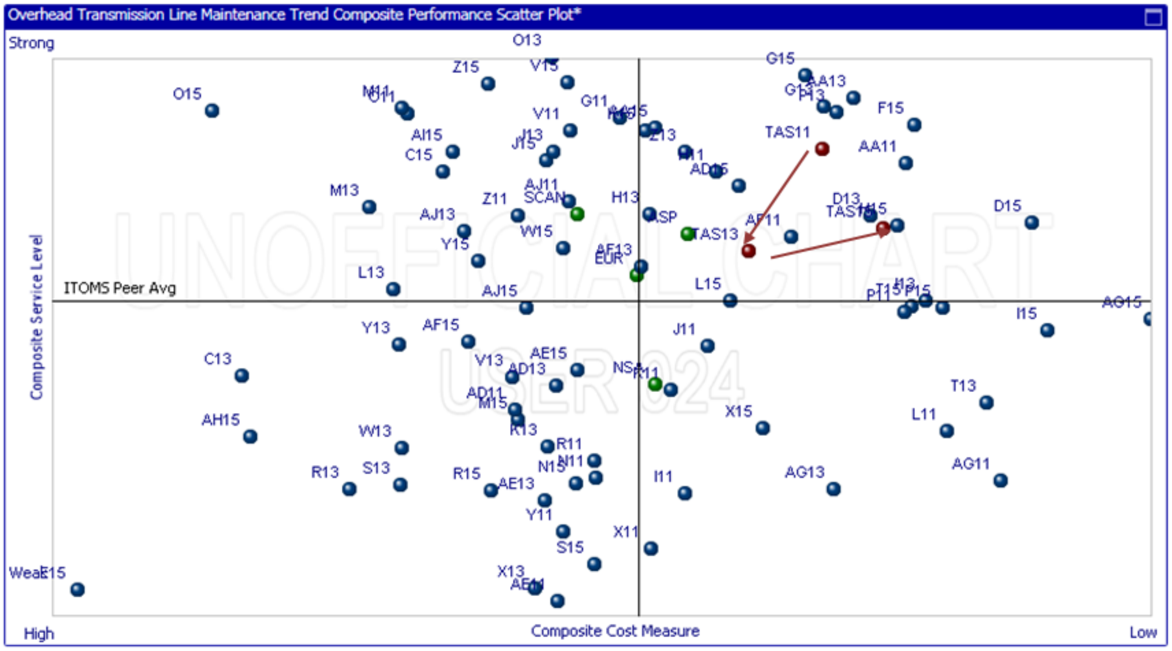
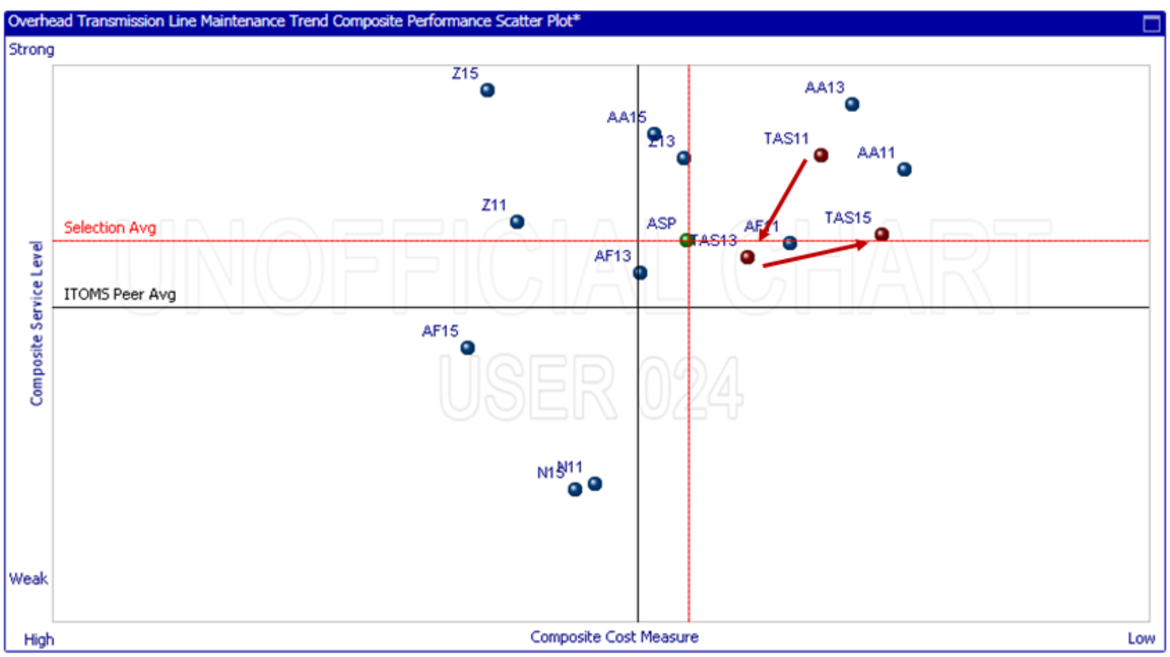


Figure 12: ITOMS Overall transmission line composite regional performance trend



7 Associated risk

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

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

7.1 Risk Management Framework

TasNetworks has developed a Risk Management Framework for the purposes of

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

Assessment of the risks associated with the transmission line support structure foundations 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 13:

Figure 13: Risk Ranking Matrix

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

The Risk Management Framework requires that each risk event is assessed against all of the following consequence categories:

- Safety and People
- Financial
- Customer
- Regulatory Compliance
- Network Performance
- Reputation
- Environment and Community

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

7.2 Risk identification

The following areas have been identified as risk areas in the management of insulator assemblies and are discussed below and summarised in Table 5.

7.2.1 Defective insulator resulting in conductor to drop

Insulators are subject to damage by natural causes (e.g. lightning), corrosion and occasionally vandalism (shooting). Failure to identify defective insulators can result in a live conductor dropping to the ground adversely impacting safety to the public and TasNetworks personnel, increasing the risk of a fire start and adversely impacting customer supply and network reliability.

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

7.2.2 Synthetic insulators failure

Some insulators are considered more likely to exhibit accelerated degradation and subsequent failure. These insulators must be monitored more intensively to ensure reliability of the transmission network.

7.2.3 Accelerated corrosion causes premature insulator failure

Transmission lines close to aggressive atmospheres (industrial and/or marine) are susceptible to premature failure and should be closely monitored and maintained.

7.2.4 Aged insulators will fail due to deterioration

Aged porcelain insulators have an increased risk of failure. These assets must be closely monitored and maintained so that transmission line safety and reliability is maintained.

7.2.5 Insulator contamination

Air born containments from industrial emissions, salt laden environments can build up on transmission line insulators and result in insulator flashover from increased conductivity and leakage current. Similarly acidic ash build up post bushfire can result in insulators being exposed to surface damage and tracking if there is insufficient rain to clean insulators. Failure to assess and maintain insulator in a contamination free state decreases insulator life and transmission line reliability.

Washing of insulators on transmission lines sections exposed to industrial emissions and salt laden environments has proven to be effective in mitigating the risk of build-up of contaminants. Post bushfire assessment of transmission lines can also identify line sections at risk to ash build up so that mitigation measures can be implemented.

7.3 Failure Rates

TasNetworks experiences a very low incidence of insulator failure, with eight failures experienced since 1990 due to poor condition. Of these, five were due to pollution and two due to mechanical failure.

Pollution has resulted in three fault outages in the George Town region in the late 1990s and two fault outages near Risdon Substation in 2008 and 2017. TasNetworks' insulator washing program has proven to be sufficient to mitigate the future risk of failure at George Town, while TasNetworks' inspection regime is deemed to be sufficient to mitigate the risk at Risdon Substation. The pollution performance at these sites will be monitored on a continuous basis.

In 2001 TasNetworks experienced an insulator failure on the Lindisfarne–Rokeby No. 2–Sorell 110 kV transmission circuit during strong winds. Subsequent investigation found that over time the ball joint on the bottom disc had worn away causing the bottom disc and connected conductor to fall and flashover to ground. As this is the only insulator defect in more than twenty years to have escaped detection and resulted in a fault outage, TasNetworks considers that this is a rare occurrence and that its inspection regimes are adequate in the detection of such defects.

In January 2004 TasNetworks experienced an insulator string failure on the Sheffield–Paloona 110kV transmission circuit during severe weather conditions. Subsequent investigation found that a lightning flashover had led to a mechanical failure of several discs resulting in a conductor drop. To prevent a reoccurrence of such an incident, TasNetworks' subsequent assessment of the failure mode recommended that the aging porcelain insulators on the Sheffield–Burnie 110kV transmission line, which supports the Sheffield–Paloona 110 kV circuit, should be replaced with glass disc insulators. This insulator replacement was subsequently undertaken in 2005.

Section 5.3.2.1 discusses two recent synthetic horizontal post insulator failures experienced on the Savage River Spur 110 kV transmission line.

7.4 Mitigating strategies

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

The assumption is that if the mitigation action is taken, the likelihood of the risk occurring is reduced to a lower risk profile. Table 5 contains the mitigation actions.

7.5 Monitoring and Review

The management strategies adopted to mitigate the risks associated with transmission line insulators are monitored on an ongoing basis to ensure that they are effective and relevant to achieving TasNetworks' risk management objectives.

Risk assessment is reviewed and where the risk level has been evaluated to have changed, a review based on a monitoring and evaluation program may initiate changes to the asset management plan strategies.

Table 5: Transmission line insulator assembly risk analysis

RISK IDENTIFICATION		RISK ANALYSIS				RISK MITIGATION	
Risk	**Detailed Risk**	**Category**	**Likelihood**	**Consequence**	**Risk Rank**	**Mitigating Action(s)**	**Residual Risk Rating**
Defective insulator fails, causing a conductor to drop	Insulators are subject to damage by natural causes (eg lightning), corrosion and occasionally vandalism (shooting). Condition monitoring, both routine and post fault, can detect these defects. Aerial inspections are the most cost-effective way to inspect these assets to reduce loss of supply events and prevent vegetation fires.	Safety and People	Rare	Severe	Medium	Perform full condition assessment of insulator assemblies every three years and ground inspection annually. Perform ground based inspection annually. Perform voltage gradient testing on porcelain disc insulators to identify pinhole failures not visible to the naked eye.	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium
		Financial	Possible	Negligible	Low		Low
Synthetic insulators	Some insulators are considered more likely to exhibit accelerated degradation and subsequent failure. These insulators must be monitored more intensively.	Safety and People	Rare	Severe	Medium	Detailed inspection and mechanical testing of suspect insulators where appropriate. Replacement of K-Line synthetic horizontal post insulators installed on Savage River Spur 110 kV transmission line. Condition assessment of remaining synthetic insulators.	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Minor	Low		Low
Accelerated corrosion causes premature insulator failure	Transmission lines close to aggressive atmospheres (industrial and/or marine) are susceptible to premature failure and should be closely monitored and maintained.	Safety and People	Rare	Severe	Medium	Increased surveillance and targeted maintenance of insulator assemblies. Utilisation of disc insulators that incorporate a zinc collar	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low

Aged insulators will fail due to deterioration.	Aged porcelain insulators have an increased risk of failure. These assets must be closely monitored and maintained.	Safety and People	Rare	Severe	Medium	Increased surveillance and targeted maintenance of insulator assemblies	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium
		Financial	Possible	Negligible	Low		Low
Insulator contamination	Insulator contamination results line flashover and outage	Safety and People	Rare	Severe	Medium	Wash insulators in contamination prone areas on a periodic basis. Inspect insulators post bushfire event and implement appropriate cleaning or replacement measures.	Medium
		Customer	Unlikely	Minor	Low		Low
		Financial	Unlikely	Minor	Low		Low
		Regulatory Compliance	Unlikely	Minor	Low		Low
		Network Performance	Unlikely	Moderate	Medium		Medium
		Reputation	Unlikely	Minor	Low		Low
		Environment & Community	Rare	Severe	Medium		Medium
		Financial	Possible	Negligible	Low		Low

8 Management plan

8.1 Maintenance Strategy

The good performance of transmission line insulator assemblies is achieved through the implementation of regular preventive and corrective maintenance activities. These preventive and corrective maintenance practices are reviewed on a regular basis taking into account:

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

As insulators assemblies age different life cycle issues and failure modes arise which must be captured in the preventative and corrective practices. Table 6 provides a summary of the life cycle issues applicable to insulator assemblies.

Table 6: Life cycle issues

Type of insulator assembly	Issue
All	All insulator assemblies are susceptible to flashover due to an accumulation of pollution, but particularly in industrial and marine environments. All insulators are subject to fatigue and vibration resulting from wind and conductor tensions. This can result in excessive wear and eventual fitting failure.
Porcelain and glass	TasNetworks' porcelain and glass transmission line insulator assemblies are very old, with almost 50 per cent already exceeding their design life. It is likely that porcelain and glass insulator assembly condition will exhibit an increase in deterioration. Porcelain and glass disc insulators are susceptible to failure due to corrosion of the steel insulator pin. Without intervention, the pin will eventually fail, causing the insulator and energised conductor to fall. Porcelain and glass insulators are also susceptible to failure due to degradation of the cement compound used to connect the insulator disc with the steel pin or socket.
Porcelain	Porcelain insulators are susceptible to flashover due to pinholes that are not visible to the naked eye. Voltage gradient testing is one technique by which these defective insulators can be identified.
Synthetic	The condition of synthetic insulators can only be determined through visual inspection, however the design of these insulators is such that it is difficult to determine whether the insulator is defective or not. Thermal imaging, recently undertaken after the failure of a synthetic post type insulator, may prove useful in the future in identifying defective synthetic insulators. TasNetworks will continue to evaluate the effectiveness of this form of condition monitoring and consider its inclusion in the broader suite of routine condition monitoring activities.

8.1.1 Preventative maintenance

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

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

TasNetworks has adopted internationally recognised procedures for the assessment and maintenance of its transmission line insulator assemblies. Condition assessments by air and by ground each have their merits which must be balanced to achieve an optimum level of cost effectiveness and overall outcomes efficiency.

After consideration of the many factors applying to Tasmania’s geography, climatic conditions and the history of known deterioration of transmission line insulator assemblies in this environment, TasNetworks’ has adopted the preventive maintenance strategies summarised in Table 7.

Table 7: Transmission line insulator assemblies’ inspection and test strategies

Strategy	Frequency	Description
‘Detailed methodical’ aerial condition assessment	3 year cycle	A detailed condition assessment is conducted utilising a helicopter (approximately 33 per cent of total assemblies per year). Effective for approximately 97 per cent of the transmission line population over the 3 year period. The remainder are subject to a climbing condition assessment. Where damaged or corroded insulator assemblies are observed, a defect will be recorded for remedial action.
‘Detailed methodical’ climbing condition assessment	3 year cycle	A detailed condition assessment is conducted by climbing individual structures. Only applicable where ‘no-fly’ areas prevent the usage of a helicopter and applies to approximately 3 per cent of total structures over the 3 year period. Where damaged or corroded insulator assemblies are observed, a defect will be recorded for remedial action.
Ground-based inspections (non-climbing)	Annually	Applies to the 66 per cent of total assemblies that did not receive a ‘detailed methodical’ inspection. A visual inspection aimed at identifying obvious defects that could impair the electrical or structural integrity of the transmission line. Where damaged or corroded insulator assemblies are observed, a defect will be recorded for remedial action.
Porcelain insulator testing	10 year cycle	Testing of porcelain insulators is required once the insulator reaches 20 years of age and then every 10 years thereafter (focusing on critical transmission lines, or insulators known to pose a higher risk to TasNetworks).
Other inspections/tests	As required	Porcelain insulators known to have incurred a lightning strike(s) will be inspected and/or tested to determine if they require replacement. In corrosive atmospheres, leakage tests will be conducted where condition deterioration is forecast or observed to be rapid. Polluted insulators will be washed to prolong life, and defective units will be replaced on an “as required” basis. Where there is a lack of condition information, TasNetworks will remove one or more insulator assemblies from service and perform stress tests to determine the remaining strength in the unit(s).

8.1.2 Corrective maintenance

In the event of a fault condition TasNetworks will arrange for corrective maintenance to occur to either replace the asset, or undertake other activities such as insulator washing to restore the asset to an appropriate level of service.

8.1.3 Spares management

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

8.2 Replacement

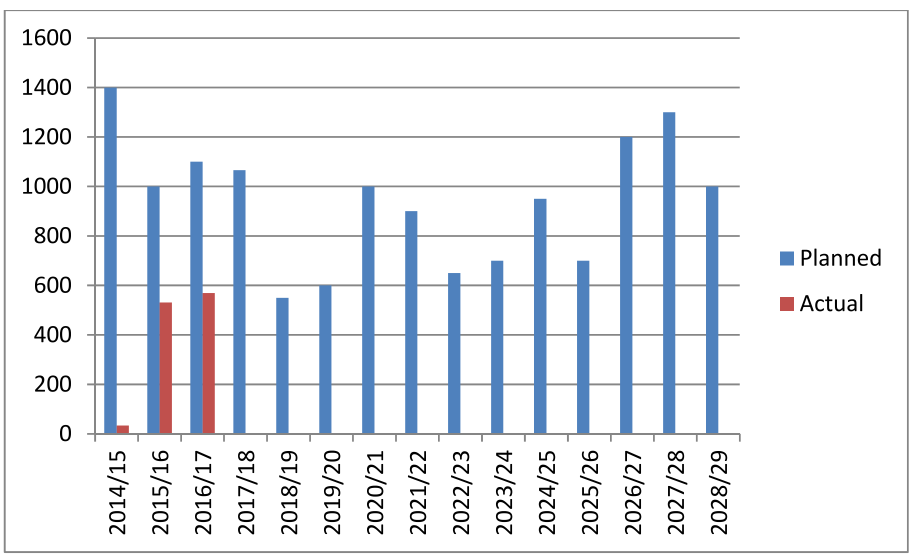
The cost of asset replacement activities meeting the capitalisation requirements outlined within TasNetworks' Asset Accounting Standard can be capitalised. These capital projects are detailed below. Asset replacement activities not meeting these requirements will be undertaken as operational expenditure.

8.2.1 Insulator replacement program

As a result of test results, defects and other condition information, and bearing in mind fleet management considerations, the transmission line insulator assembly replacement program detailed in Appendix A should be implemented over the next twelve years. This is shown graphically in Figure 14 below noting that the difference between the planned and actuals is due to the assumption that all insulators on a line may be require replacement but insulators are replaced on a condition basis.

Those insulators selected for replacement in the 2019-24 regulatory control period have an average age of approximately 65 years.

Figure 14 – Insulator replacement profile (volume)



8.3 Disposal plan

When defective insulator string assemblies are removed from service the individual insulator discs are inspected and retained as spare holdings if found to be in good condition. Defective insulators are recycled or suitably disposed of in registered disposal areas.

9 Financial Summary

9.1 Operational expenditure

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

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

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

9.2 Capital expenditure

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

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

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

9.3 Investment evaluation

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

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

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

10 Related standards and documentation

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

TasNetworks documents:

1. R17083 WASP Asset Register – Data Integrity Standard – String Insulators
2. R17122 WASP Asset Register – Data Integrity Standard – Insulator and Damper Assemblies
3. TNM-GS-809-510-05 - Transmission line defect prioritisation standard (draft)
4. Asset Condition Review – project report June16 FINAL – R503361
5. Memorandum, Waratah-Savage River 110 kV TL446, HLPI Failure, TD Consulting Engineers, 28th October 2009 (D10/5390).
6. R517373 System Spares Policy

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

7. D04/25966 High Voltage Disc Insulator Standard
8. D05/10286 Transmission Line Design Standard
9. D07/67177 Transmission Construction Standard
10. D03/6112 Transmission Circuit Abbreviations
11. D11/33093 Live Line Work Standard
12. D08/81931 Temporary Earthing of Overhead Transmission Circuits
13. D05/9256 Site Names, Numbers and Abbreviation Standard
14. D05/2191 Access Control FormD07/67177 Transmission Line Construction standard TNM-GS-809-0524
15. D10/90107 Fibre Optic Overhead Ground Wire (OPGW) Standard

Other standards and documents:

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

Appendix A Insulator Replacement Profile

Year	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29
Insulator Strings	900	450	600	1000	893	654	708	933	686	1200	1331	1000
Circuit(s)	TL425 Tungatinah-Lake Echo-Waddamana (north) TL426 Tungatinah-Lake Echo-Waddamana (south)	TL503 Sheffield - Palmerston	Tl463 New Norfolk–Creek Road	TL413 Palmerston-Trevallyn		TL428 Lake Echo Supr (west) TL450 Sheffield–Devils Gate	TL411 Arthurs Lake Spur TL419 Meadowbank Spur	TL430 Chapel Street–Creek Road (east) TL431 Chapel Street–Creek Road (west) TL432 Chapel Street–Knights Road	TL404 Creek Road–Risdon	TL500 Liapootah–Chapel Street		
	TL449 Bell Bay – George Town				TL429 Palmerston-Avoca		TL436 Knights Road–Kermandie TL469 Electrona Spur		TL409 Waddamana–Parknook		TL509 Palmerston–George Town	
						TL501 Repulse–Cluny Spur TL507 Liapootah–Wayatinah TL508 Wayatinah–Catagunya	TL444 Emu Bay Spur				TL516 Gordon–Chapel Street	

Appendix B Investment Evaluation Summaries

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

Reference	Name	Expenditure Type	Regulatory Period
R419682	Transmission Line Insulator Assembly Replacement Program Investment Evaluation Summary	CAPEX	2014-2019
01281	Transmission Line Insulator Assembly Replacement Program Investment Evaluation Summary	CAPEX	2019-2024