Sub-transmission Towers, Insulators and Ground Wires

AMS – Electricity Distribution Network

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Disclaimer

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1 Executive Summary

This document defines the asset management strategies for sub-transmission towers, insulators and ground wires supported by steel lattice structures within AusNet Services' electricity distribution network.

Sub-transmission towers generally support either single-circuit or double-circuit lines composed of three phase conductors per circuit. The towers are insulated from the live conductors using insulators. In AusNet Services' distribution network, there are 465 sub-transmission towers, 2,625 sub-transmission insulators and approximately 146 km of ground wires. The majority of the assets, i.e. 46.2% are located on the Yallourn Power Station to Warragul/Moe #1 and #2 66-kV lines (YPS-WGL/MOE 66kV lines).

The service age of sub-transmission fleet spans over 95-years. During the last decade, the number of sub-transmission towers has remained unchanged, with 93.3% of the insulator fleet being of polymeric type, with a bare steel cable utilised as the ground wire.

Over half the population of the tower structures are in C4 condition or better (i.e. 45% in C3 and 55% in C4), while under 1% of the fleet is in C5 condition. Over the past ten years, there has been no major failures in the sub-transmission fleet.

The vast majority of the insulators are in C1 condition (93%), made from silicone rubber material that were installed in 2012 following the failure of a disc string due to excessive corrosion. The physical separation of the string resulted in a conductor drop, which triggered an insulator replacement program. Since its completion, there has been no failure in the fleet, with the rest of the cohort in C4 condition or better.

Currently 19% of ground wire spans are in C5 condition with the rest of the fleet evenly distributed in C2, C3 and C4 condition. Risk analysis, using quantified criticality, proposed that in the coming EDPR period, approximately 20.4 to 26.2km kilometres of steel ground wire along the YPS-WGL/MOE #2 66kV line should be replacement due to its corroded condition. This is one of two lines that play a strategic role in the Eastern region, during high demand days and/or during emergency situations.

Proactive management of subtransmission towers, insulators and ground wire inspection, condition monitoring and replacement practice is required to ensure that stakeholder expectations of cost, safety, reliability and environmental performance are met. The summary of proposed asset strategies is listed below.

1.1 Strategies

1.2 Steel Lattice Towers

1.2.1 Inspection

- Initiate intrusive inspection of tower legs outside zone substations by excavating and checking corrosion levels.
- Trial the use of Remotely Piloted Aerial Systems, e.g. UAVs to undertake condition assessment.
- Implement the use of SAP mobility solutions for the online recording of condition assessment data.

1.2.2 Maintenance

- Continue to include the testing of existing bitumen paint on tower legs into the ground level corrosion protection system works scope of works.
- Continue to replace corroded or damaged steel members, bolts and Anti-Climbing Devices as part of corrective and scheduled maintenance programs.
- Continue ground level corrosion protection system works at a rate of 4-towers per year.
- Continue implementing the tower safe access program, including installation of fall arrest systems on structures and maintain compliance with Occupational Health and Safety standards.

1.2.3 Replacement

- Install emergency restoration systems in place of a failed tower and
- Replace the emergency restoration systems with concrete or steel poles
- Perform structural modelling of existing structures to assist with the development of asset reinforcement/replacement programs.

1.3 Insulators

1.3.1 Inspection

- Inspect insulators in accordance with the criteria established in the Asset Inspection Manual 30-4111
- Trial non-intrusive inspections, i.e. Thermal and Corona surveys on polymeric strings to identify incipient failure modes.

1.3.2 Maintenance

- Replace insulators in accordance with the condition criteria established in the Asset Inspection Manual 30-4111
- Install polymeric insulators in place of damaged or corroded grey disc porcelain-type insulators

1.4 Ground Wires

1.4.1 Inspection

- Inspect ground wires in accordance with the criteria established in the Asset Inspection Manual 30-4111
- Trial non-intrusive inspection, i.e. use Smart Aerial Inspection and Processing (SAIP) to identify incipient failure modes.

1.4.2 Maintenance

- Replace ground wires in accordance with the condition criteria established in the Asset Inspection Manual 30-4111
- Replace like-for-like, i.e. steel ground wires for spans that are in need to replacement.

1.4.3 Replacements

- Replace “Very Poor” condition and “Poor” condition, high consequence, ground wire on the YPS-WGL/MOE #2 66kV line

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and performance of the sub-transmission assets supported by steel lattice towers in AusNet Service's electricity distribution network.

This document summarises the key strategies used to manage these assets in order to maintain the reliability, safety and security of the distribution network. This document informs the reader of AusNet Services' asset management decisions and the basis for these decisions.

In addition, this document forms part of the Asset Management System for compliance with relevant standards and regulatory requirements. This document demonstrates responsible asset management by outlining economically justified outcomes.

2.2 Scope

This asset management strategy applies to the steel lattice sub-transmission tower infrastructure, the associated insulators and bare steel ground wires that are owned by AusNet Services.

The sub-transmission fleet consists of steel lattice towers, the footings, steel legs and cross-arms; the insulator strings including the fittings and hardware; and finally the steel ground wires that provide lightning protection.

Assets relating to the phase conductors and their hardware, which are used in these towers are discussed in:

- AMS 20-52 Conductors

2.3 Asset Management Objectives

As stated in *AMS 01-01 Asset Management System Overview*, the high-level asset management objectives are:

- Comply with legal and contractual obligations;
- Maintain safety;
- Be future ready;
- Maintain network performance at the lowest sustainable cost; and
- Meet customer needs.

As stated in *AMS 20-01 Electricity Distribution Network Asset Management Strategy*, the electricity distribution network objectives are:

- Improve efficiency of network investments;
- Maintain long-term network reliability;
- Implement REFCL's within prescribed timeframes;
- Reduce risks in highest bushfire risk areas;
- Achieve top quartile operational efficiency; and
- Prepare for changing network usage.

3 Asset Description

3.1 Asset Function

Sub transmission towers provide the load bearing structural support for some of the sub transmission overhead conductors and equipment in the electricity distribution network. Their purpose is to establish safe electrical and physical clearances between conductors and the ground and other structures.

Insulators provide the mechanical connection between the live conductors and structure while providing safe electrical and physical clearances between conductors and tower structure.

The steel ground wires provide earthing to the sub-transmission fleet, which protects it against lighting and thus assure the reliable performance of the circuits during storm events.

3.2 Asset Population

3.2.1 Steel Lattice Towers

AusNet Services has 481 steel lattice towers majority of which were originally designed for operation at 132 kV. Majority of these structures are currently operating at 66 kV, with a couple supporting 22kV feeders while some are currently Out-of-Service (OOS).

These towers were the first of their kind built by then State Electricity Commission of Victoria (SECV) as part of the electrification of the state of Victoria in the early 1920s.

There are 212 towers located on the Yallourn Power Station (YPS) to Warragul (WGL) to Moe (MOE) #1 66 kV line and YPS-WGL-MOE #2 66 kV line which are in service. There are 131 towers on the Warragul to Pakenham (WGL-PHM[1]) line, which are currently out of service. This OOS line is a contingency circuit to the Warragul zone substation and forms part of future network development in this area.

Significant work on the towers along the YPS-WGL-MOE lines were completed in the 2011 to 2013, replacing corroded members and bolts as well as assuring the footings and legs were in serviceable condition; while the insulators along the OOS WGL-PHM[1] line were replaced to assure failures are prevented which may result in a conductor drop. On the OOS YPS – ERTS line, 84 out of 89 towers are now energised to provide power to Gumbuya Park, said to be the largest Theme Park in Victoria, in Tynong North.

Tower locations are summarised below. Full circuit descriptions are found in Appendix 1.

[1] **WGL-PHM (OOS)** line is composed of 89-towers YPS-ERTS and 42-towers YPS-ERTS-PMMS

Table 1 – Tower locations and Service Status

LINE NAME	OOS	SERV	Grand Total
CBTS-BWN-ERTS	1	1	2
CLN ZONE SUBSTATION		2	2
HPS-WOTS		1	1
MBTS-MYT		33	33
MWTS-MFA		2	2
MWTS-YPS 1		1	1
MYT-BRT		1	1
RUB-KLK		14	14
TGN-MFA		1	1
TOWER Single Circuit	2	1	3
TTS-KLK		4	4
TTS-KLK & EPG2		1	1
WANG - MYT		3	3
WGI-PHI		2	2
WN-MYT		1	1
YALLOURN NORTH		1	1
YPS-ERTS OOS	89		89
YPS-ERTS-PMMS 2	42	64	106
YPS-WGL-MOE 1		97	97
YPS-WGL-MOE 2		115	115
YPS-YC 1		1	1
YPS-YC 2		1	1
Grand Total	**134**	**347**	**481**

These galvanised steel lattice towers support either single or double-circuit lines composed of three phase conductors per circuit. Ground wires located at the peaks of the structure protect the phase conductors from lightning strikes, while insulators electrically insulate the structure from the live conductors. The main components of the steel lattice tower are:

- The tower footing;
- Tower legs;
- Cross arms
- The main and redundant members;
- The nuts and bolts, and;
- Ancillary items such as anti-climbing devices (ACDs), fall arrest systems, ladders and signage

Figure 1 shows Tower 297 on the Narre Warren to Pakenham line. This tower is a double circuit structure with single conductor per phase.

Figure 1 – Tower 297 PHM-NRN.

3.2.2 Insulators

The AusNet Services' sub-transmission network supported by steel lattice towers has 2,445 composite insulator strings and 180 porcelain disc strings. Figure 2 below shows grey porcelain insulators account for 6.7% of the population and polymer type insulators account for 93.3% of the population.

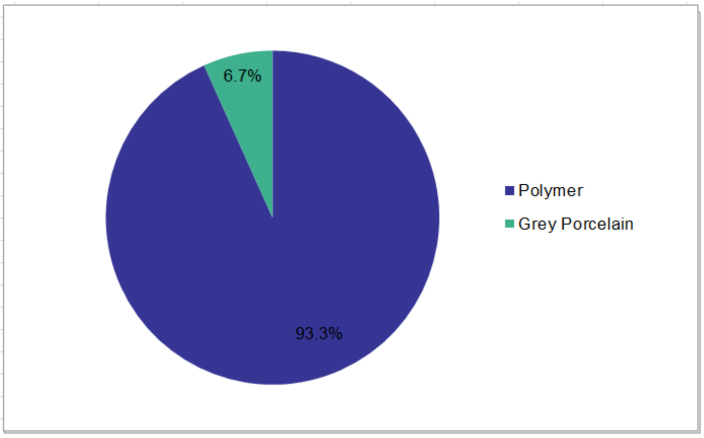

Figure 2 – Insulators by type.

AusNet Services' current policy is to install polymeric insulators due to their economic and operational advantages. The polymeric designs are cost effective relative to disc strings, lighter weight and do not require washing.

3.2.3 Ground wire

There are approximately 146 kilometres of steel ground wires strung on the sub-transmission fleet supported by steel lattice towers. The ground wires were installed when the line was originally built to protect the line against lightning strikes that may can cause an outage.

3.3 Asset Age Profile

3.3.1 Steel Lattice Towers

The oldest steel lattice towers in the sub-transmission network is 95 years old, significantly more than the original expected life of a tower. The main reason for the structures' longevity is the benign environment where the structures are located.

As can be seen in Figure 3, 57.4% of towers have an age of 95 years, 38.3% of towers have an age of 87 years, 1.0% of towers have a service age of 47 years, 1.9% are 21 years of age and 1.5% are 11 years of age.

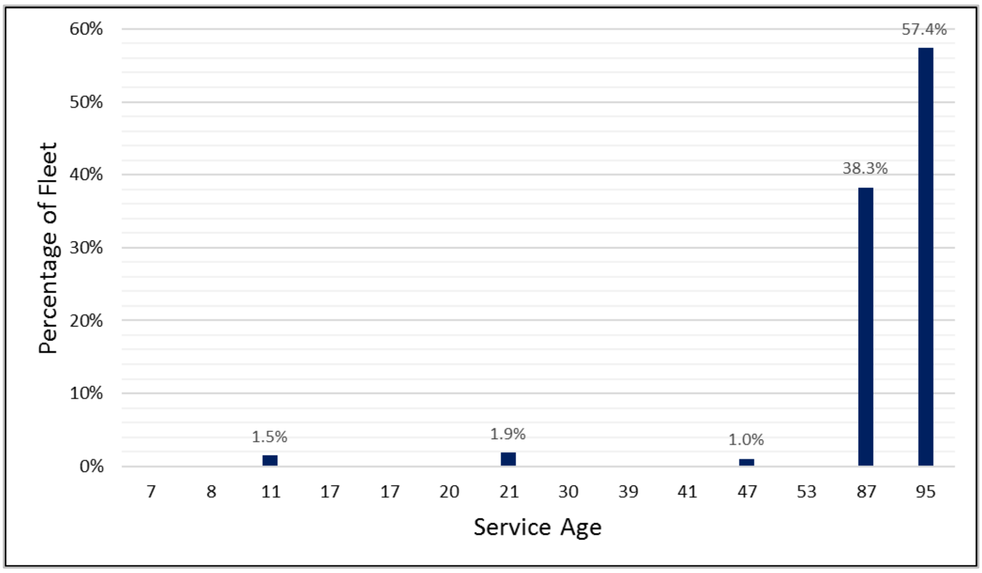

Figure 3 – Service age of the steel lattice towers.

The 87-year old towers and 95-year old towers were the first of their kind constructed in 1924 and 1932 respectively. Since that time, an additional 2-towers were installed in 1975 along the 22kV WGI31 feeder. These towers are the only steel lattice structures that support a 22kV feeder. The towers are used to cross the Bass Strait from San Remo, which is part of the Victorian mainland to New Haven, Phillip Island. No sub-transmission tower has been replaced since their original installation as the structures have continued to remain in a satisfactory condition.

Figure 4 – San Remo Tower

3.3.2 Insulators

The current age profile of the oldest insulator strings in the fleet span over 95 years - significantly more than the expected life of an insulator string, which is 60 years.

Figure 5 shows the age profile of AusNet Services' sub-transmission insulators on steel lattice towers.

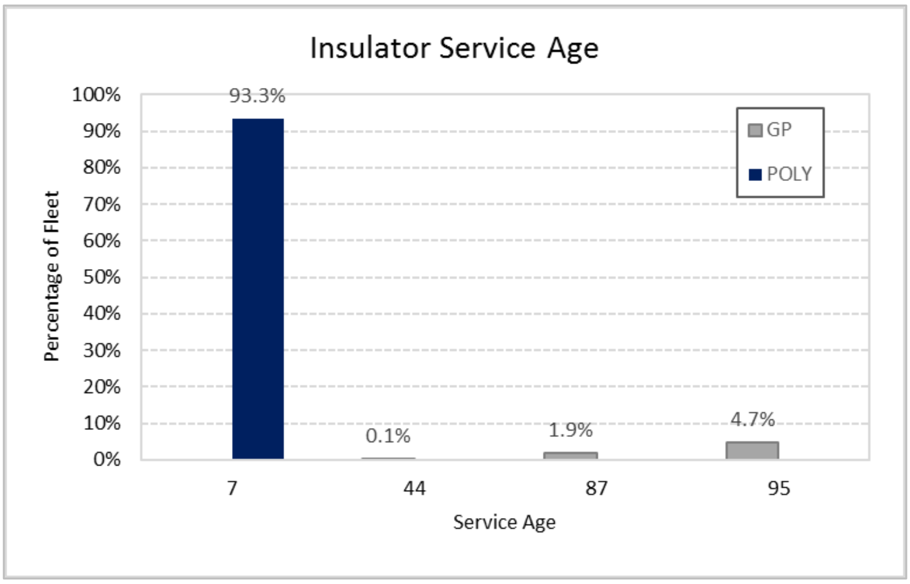

Figure 5 – Service age of tower insulators

As depicted in Figure 5, 4.7% of the insulator population have a service age of 95 years, 1.9% has a service age of 87 years and 0.1% has a service age of 44 years. These strings are the original grey porcelain discs used on the towers when they were constructed.

A recent project, *74316512: YPS-NRN* [2] *66 kV line upgrade* has replaced the majority of the older sub-transmission insulators on steel lattice towers. This project has seen the polymeric type insulators replace the grey porcelain disc type insulators in 2012. Currently 93.3% of the insulator fleet are polymer type insulators and have a service age of 7 years.

3.3.3 Ground Wire

The ground wires that were installed when the tower line was built are still in-service on the sub-transmission fleet and follow the age profile of the tower structures as shown in Figure 3 in section 3.3.1.

3.4 Asset Condition

3.4.1 Condition Summary

The key assessment tool used for the management of the tower fleet and insulator fleet is the Condition Assessment (CA) surveys, also known as Detailed Inspections that are undertaken on a regular basis. During the CA surveys, visual inspection of the tower components are carried-out following the procedures stipulated in the Asset Inspection Manual (30-4111) Section 3.14: Tower Lines.

The Asset Inspection Manual document contains photographs of the various components along with the various condition stages in relation to corrosion and/or wear, wherein each stage is assigned a numeric scale from C1 to C5 where C1 is “as new” condition while C5 is “worst condition”.

The CA surveys for insulators rate the condition of the disc insulators’ steel pins against corrosion while for the composite insulators the Asset Inspection Manual will be revised to follow the ratings used for transmission insulators.

The results of these inspections are recorded to track the rate of deterioration while components that are defective, i.e. loose nuts, plate wear/corroded, missing pins, extremely corroded members, bolts, insulators that

[2] **YPS-NRN 66kV** line is the in-service portion of YPS-ERTS-PMMS 2

require replacement, etc. are flagged for rectification by raising ZB Notifications (Condition-based Maintenance Activities) in SAP with appropriate priority ratings given in the same document.

If the process to replace a particular component is straight forward, the item is replaced following the priority ranking that is consistent with the asset's risk of failure. If however, the work requires some engineering analysis to assure the safety and security of the structure, or if it involves considerable expense, the work will be done as a project-based activity.

3.4.2 Steel Lattice Towers

To give a comprehensive condition rating for each tower, the criticality of each major component is given a weighting related to its contribution to the tower's structural integrity.

The condition rating for the legs and members are given equal weighting because these transmit the loads from the conductors and the structure's self-weight into the ground. Bolts and nuts are given lesser weighting due to the presence of multi-bolted joints on the structure which allows for some redundancy.

Although age is not a major contributor in the asset's strength compared to the amount of corrosion and wear the components has suffered, it is still considered in the analysis as the age also relates to the design standard and philosophy/methodology at the time the structure was built.

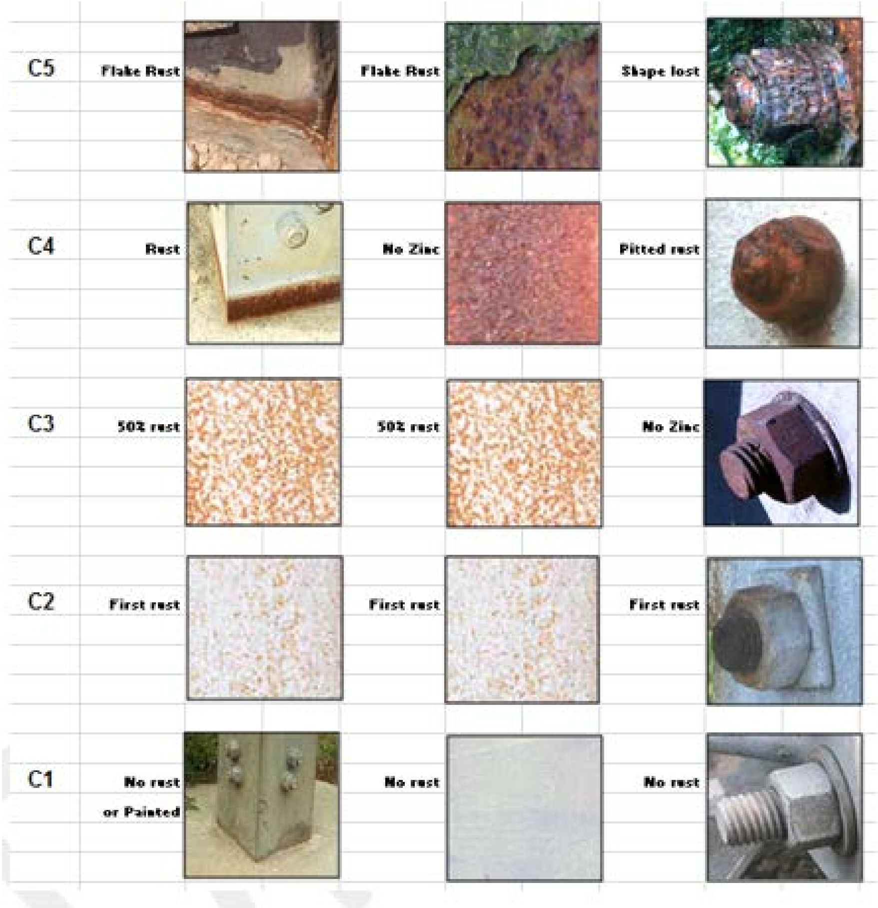

Figure 6 – Condition codes for legs, steel members and bolts

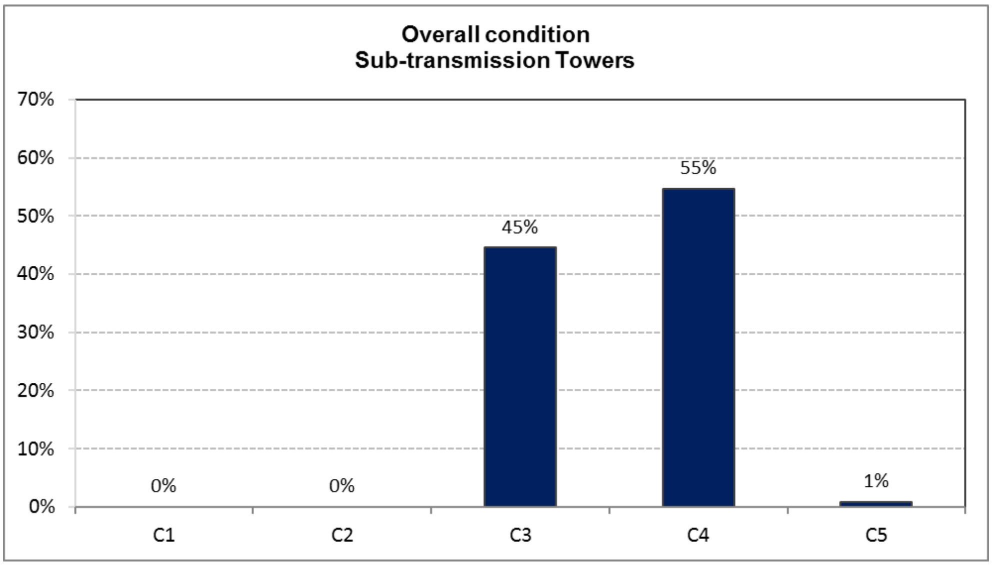

Figure 7 – Condition scores of the sub-transmission towers population

At present, approximately 45% of the tower fleet are at C3 condition, 55% at C4, and only 1% at C5 as shown in Figure 7. The towers at C5 are still structurally adequate to support the gravity loads coming from the conductors as well as the wind acting on the conductors and itself. However, these structures will have to be monitored on a regular basis with some level of refurbishment or replacement required on certain components, i.e. bolts and members which have started to lose sectional area to assure its reliability and public safety.

3.4.3 Insulators

The majority of the insulator strings along the sub-transmission fleet are polymeric strings with only a few towers still retaining the original disc strings.

Similar to the towers, the key assessment tool used for the management of the insulator fleet is the Condition Assessment (CA) surveys. The CA surveys rate the condition of the disc insulators' steel pins against corrosion.

The same process is followed for defect recording and management of insulator strings as with the steel lattice towers, with the rating scale as shown in Figure 8.

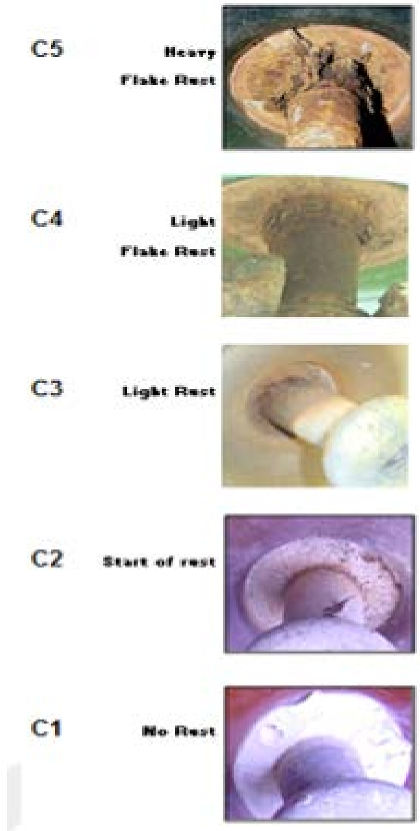

Figure 8 – Condition codes for the disc insulator pins and polymeric insulators.

To obtain the condition rating for a disc insulator, the steel pin is rated against corrosion and the amount of pollution on the disc is assessed during the time of inspection. The worse score is taken as the over-all condition for the string as it is the limiting item in its performance.

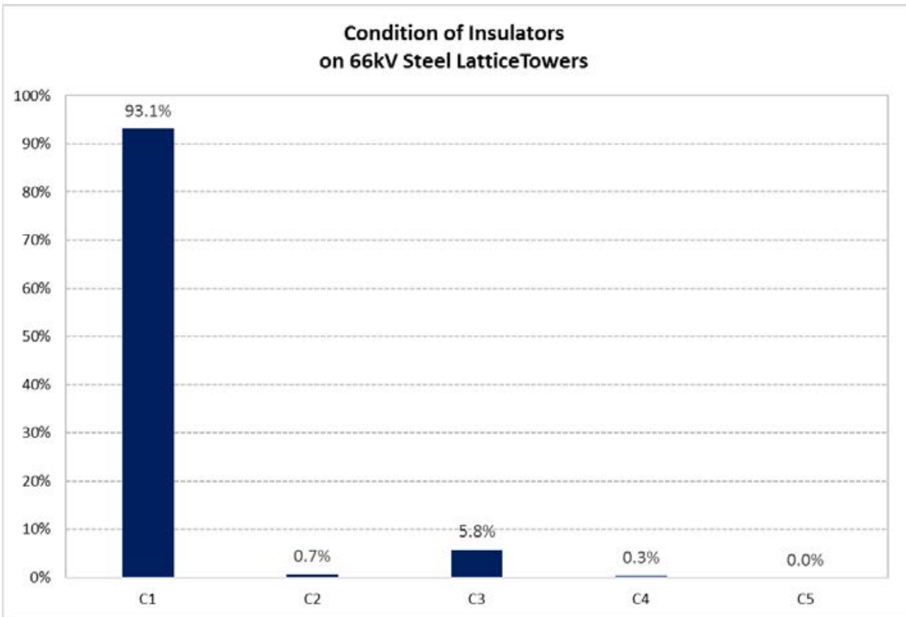

Figure 9 – Insulator condition on 66kV lattice towers

As most of the insulators on the YPS to NRN[3] 66kV line have been recently replaced, 93.1% of the fleet are in C1 condition, with 0.7% at C2, 5.8% at C3, and 0.3% at C4. The reliability and safety of the lines have improved with the added benefit of cost savings. This is due to less maintenance due to the self-cleaning properties of the polymeric insulators, which do not require regular washing.

3.4.4 Ground wire

The steel ground wires along the line has seen an average service life of more than eighty years. As such, 25% are in C2 condition, 25% in C3, 31% in C4 and 19% of the fleet have become C5, which is the worst condition.

These spans will require regular inspections with some sections to be replaced in the coming EDPR period to mitigate the risk of failure.

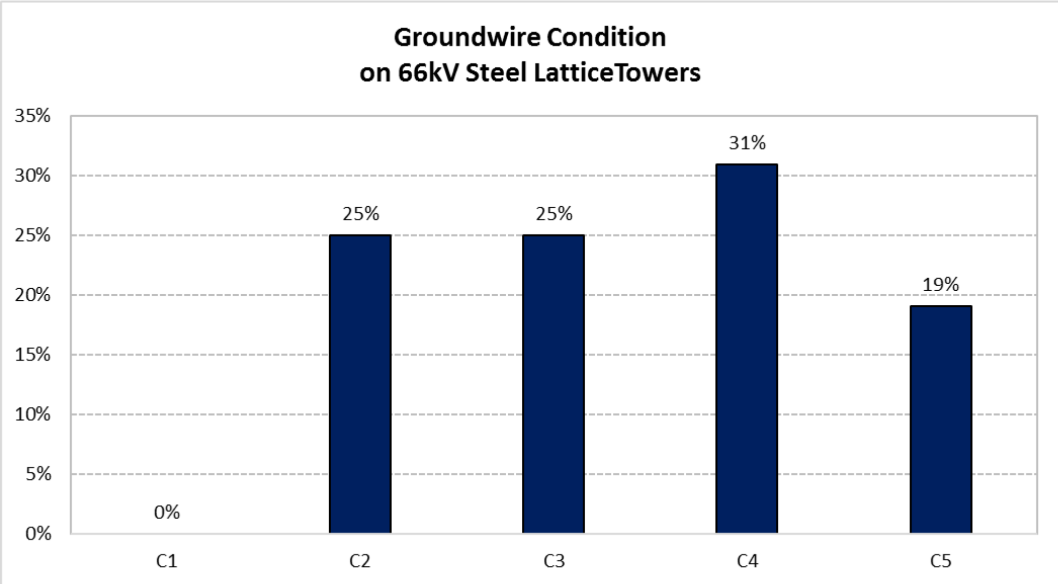

Figure 10 – Steel ground wire condition

3.5 Asset Criticality

Functional failures of transmission line structures can result in structures and live conductors falling to the ground and so can have significant effects or consequences. Major structure failures can lead to four different effect types including third party damage, health and safety, bushfire ignition and unserved energy.

3.5.1 Health and Safety

Line easements traverse both public and private land where public access to the easement is not restricted. In many instances, easements are shared or located next to other infrastructure such as roads, railway lines, pipes and fences. Functional failures of structures can present health and safety risks to members of the public, AusNet Services employees and/or AusNet Services contractors accessing the line easements.

Line workers performing structure climbing activities are exposed to risks associated with working at heights and electrical clearances which are heightened under failure conditions. Tower functional failures may also present risks to members of the public, particularly with towers adjacent to roadways, railway lines and public areas such as car parks or parks and gardens.

There have been no instances of major insulator failures adjacent to roads or railways.

[3] **YPS-NRN 66kV** line is the in-service portion of YPS-ERTS-PMMS 2

3.5.2 Bushfire Ignition

The majority of towers are located in high bushfire risk areas; however the towers are in cleared easements that separate them from immediate proximity to vegetation. This is addressed by the Bushfire Mitigation Plan – Electricity Distribution Network, BFM 10-01. Less than 1% of AusNet Services towers are located in low bushfire risk areas. Whilst failures of electricity distribution lines may cause a fire ignition; historically the circuits supported by these towers have not been involved in any bush or grass fire ignitions. Relative to other distribution lines assets, this fleet presents a significantly lower bushfire risk.

3.5.3 Reliability

The Service Target Performance Incentive Scheme (STPIS) provides financial incentives for Distribution Network Service Providers (DNSP) to maintain and improve the reliability of service performance. Performance targets are set based on historical performances of individual DNSP; thus, providing financial rewards for DNSPs beating their targets and financial penalties for failing to meet targets.

Due to the looped nature of sub-transmission lines, this fleet of sub-transmission towers and insulators don't attract any STPIS penalties.

3.5.4 Criticality Bands

Using the criticality factors described above, the criticality is quantified for each asset. This has been performed and can be grouped into bands based on the ratio between the *Consequence of Failure* divided the *Cost of Proactive Replacement*. The applied interpretation of relative base criticality is shown in Table 2.

Criticality Bands	Definition
5	Total Effect Cost exceeds 10 times of replacement cost
4	Total Effect Cost is between 3 -10 times of replacement cost
3	Total Effect Cost is between 1.0 - 3 times of replacement cost
2	Total Effect Cost is between 0.3 – 1.0 times of replacement cost
1	Total failure effect cost < 0.3 times Replacement Cost

Table 2- Interpretation of Relative Base Criticality

3.6 Asset Performance

3.6.1 Work Order Analysis

The following ZA (Condition-Based Maintenance) and Work Order analysis takes into account all work created from 2011 to 2019. It excludes any work orders related to conductors and focuses on sub-transmission towers and insulators only. A total 3,111 NOTIs and work orders were analysed, the breakup of the work orders shown in Figure 11.

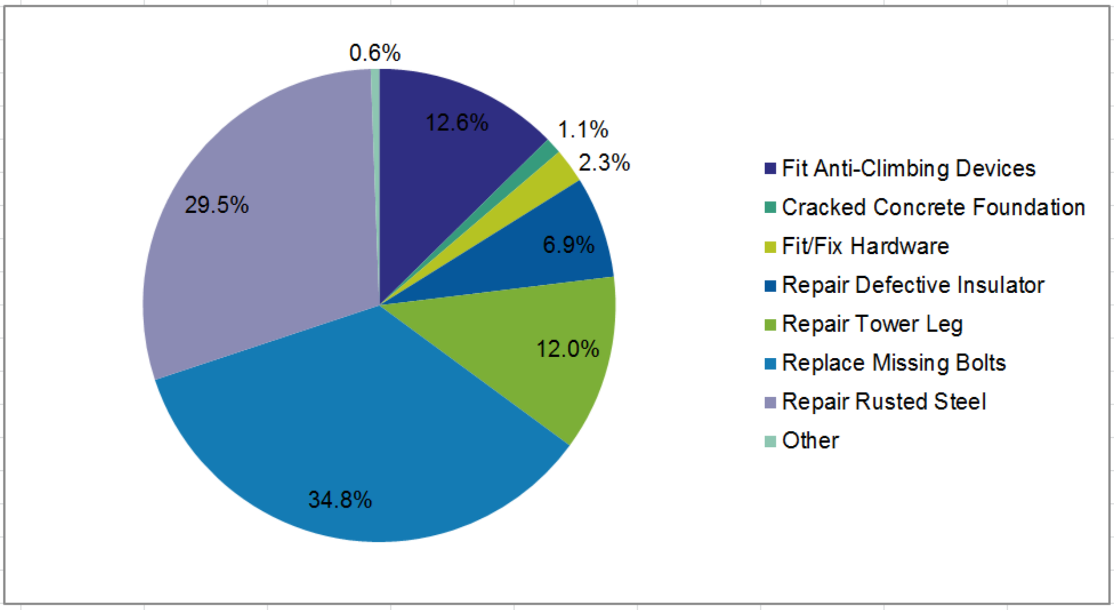

Figure 11– Work orders by percentage of total.

Figure 11 shows that the majority of the ZA Notifications over the last nine years have been based around replacing missing bolts, repairing rusted steel, fitting anti-climbing devices and repairing tower legs. The 'Other' description includes painting tower legs as part of the ground level corrosion protection system program, repairing damaged steel, repairing hot spots, washing insulators and installing/replacing sub transmission cross arms.

3.6.2 Major Failures

No major failures have been experienced in the tower fleet. However, during the past couple of years, some of the direct-buried steel legs which were excavated to assess their condition against corrosion have been found to require refurbishment.

In relation to insulators, there have been eight separate steel insulator pin failures over the last eleven years due to decreased strength caused by corrosion that resulted in the conductor span dropping to the ground. Although these incidents didn't result in any third party injury or property damage, the risks associated with these events warranted the replacement of the original insulators with more reliable and corrosion resistant polymeric insulators in project *74316512: YPS-NRN 66 kV line upgrade*. Since the major insulator replacement project has been completed, no insulator failures have occurred.

There have been no major failures attributed to the steel ground wires used in the sub-transmission fleet, although a couple of maintenance works have been completed recently to assure the physical integrity of the spans.

4 Other Issues

The following section provides a summary of specific issues that can present defects and potential failures in similar towers.

4.1 Tower Safe Access

The original design of the sub-transmission towers did not consider the provision of adequate electrical clearance for tower access. This lack of electrical clearance exposes the line worker to the risk of a flashover event once he has reached the conductor level while climbing along the tower leg.

The presence of this hazard will require administrative controls such as having a safety observer to prevent inadvertent movement while on the tower leg. As per the hierarchy of risk mitigation, this solution is not preferable and a program to address this risk has been initiated in 2016.

This program complies with the Occupational Health and Safety laws, which have been introduced for employers to provide a safe working environment for workers climbing up to a level greater than 2 metres above ground. The program includes providing a central ladder on the tower body and installing fall arrest systems.

4.2 Tower Corrosion – above and under ground

As with all steel structures exposed to the environment, towers are susceptible to corrosion over their service life. Issues with above ground corrosion are not wide spread but can be attributed to localised pollution sources such as power stations and specific industries.

In New Zealand during 2001, a tower of similar design and foundation arrangements to that of this fleet of sub-transmission towers suffered a footing failure. On investigation this failure was attributed to the below ground metal fatigue and corrosion of the legs where they were joined to the footing stubs at a nominal depth of 2 metres. AusNet Services commenced a program in 2010 to check the direct buried steel leg condition for 19 towers. This program included towers along the YPS-WGL-MOE #1 and #2 lines. The remainder of the towers along these lines are targeted for buried steel inspection over the coming years. If required, corrosion issues will be rectified to prevent further section loss by the application of an ultra-high built epoxy coating system.

Circulating currents may also pose a risk to tower legs closely located to zone substations. Intrusive inspection of the tower legs is recommended to ensure the tower legs in these critical locations are not deteriorating/losing their cross sectional area.

4.3 Asbestos in the Corrosion Protection System

In 2011 it was identified that, the existing corrosion protection system that was used by the State Electricity Commission of Victoria (SECV) contained asbestos. Tests conducted on hundreds of towers forming the Victorian electricity transmission network confirmed that coatings used pre-1965 have a high probability of containing asbestos.

Consistent with the AusNet Services' asbestos management strategy, all existing coatings for the tower legs will be tested for the presence of asbestos prior to removal as part of the on-going corrosion protection program for tower legs. If the existing coating is found to contain asbestos, it will be removed, handled and disposed-off appropriately.

4.4 Extreme Winds

The frequency of exposure to extreme winds is regional and depends on the geographic location of the structures. Additionally, the potential of a tower failure due to extreme winds would identify the towers as having inadequate strength to withstand the downdraft winds. No spares are held for this fleet of sub-transmission towers. The plan for management of a tower failure is to utilise the transmission network emergency restoration system as illustrated in Figure 12. The emergency restoration system will then be replaced by a concrete pole.

Figure 12 – An emergency restoration system stayed tower.

4.5 Insulator Corrosion

Although most of the original disc insulators have been replaced by polymeric strings, there are still some of the original disc-type insulators in service. These strings are monitored during condition assessment inspections so the risks associated with a failure due to decreasing strength are managed.
Figure 13 below shows a steel pin which failed due to corrosion that has resulted in a conductor drop. These disc string insulators had been progressively replaced with polymeric strings, which do not get affected by the aggressive environment due to corrosivity.

Figure 13 – Failed insulator string due to pin corrosion

4.6 Pollution on Disc Insulators

Unlike polymeric insulators which have the capacity to self-clean pollution, disc insulator strings must be washed when pollution levels are too high to reduce electrical tracking and potentially a flashover event. This is especially true for suspension strings as the underside of the sheds aren't washed so the steel pins can have residual moisture in the pollution that could lead to oxidation.

4.7 Ground Wire Corrosion

The steel ground-wires of the sub-transmission line have been in service for more than 90 years old and 19% of the fleet had degraded to C5 condition. One span along the YPS-WGL-MOE #2 line had suffered several strand breakages that were repaired in 2019 by installing patch rods.

Samples of ground wires along high-risk areas, i.e. road and rail crossings will be collected, analysed for corrosion damage and tested mechanically to determine its residual life and understand the urgency for replacement. The optimal time to replace the steel ground-wire is when the cable still has enough tensile strength to be used as a “draw wire” for the new ground wire.

4.8 Environmental Factors

The sub-transmission line network is exposed to varying levels of corrosivity depending on environmental factors. The two factors which have the greatest impact on levels of corrosivity include salt deposition experienced in coastal regions and air pollution caused by emissions from heavy industry. In order to manage the effects of corrosion in a prudent manner corrosivity classifications are assigned to line assets. There are a total of three corrosivity zones including severe, moderate and low. Figure 11 shows the proportion of towers in each of these zones.

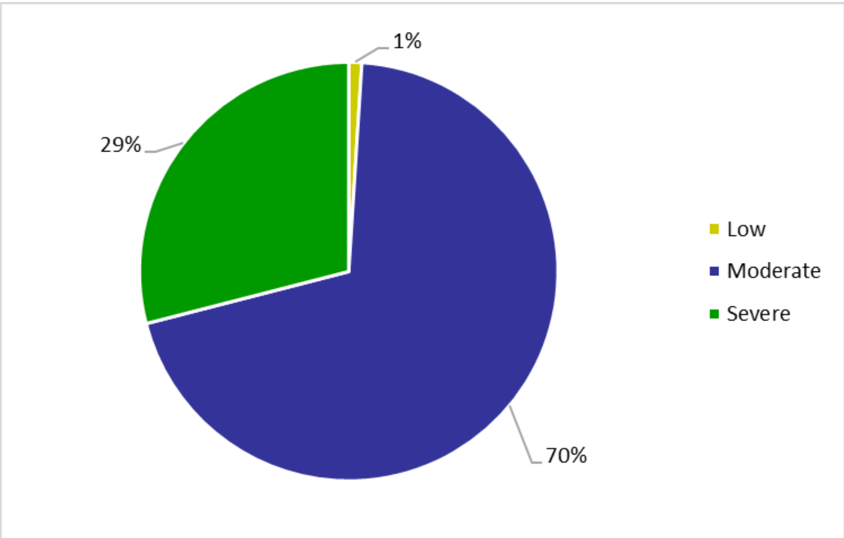

Figure 11 – Proportion of towers in each Corrosivity zone

5 Risks and Options Analysis

The criticality of the sub-transmission network are attributed to three major factors: the Cost of Unserved Energy, Public Safety along road crossings and Urban/Rural areas; and Bushfire risks.

Over the past ten years, numerous replacement and maintenance projects have been undertaken on the sub-transmission network to assure its safe and reliable operation. Some of the projects that have been done are outlined below.

5.1 Insulator Fleet

In 2012, after the failure of a disc insulator string that resulted in a conductor drop, over 93% of the insulator fleet were replaced with polymeric strings. This project increased the reliability and safety of the sub-transmission network, as well as enabled the cancellation of the washing program while assuring that the strings perform well against pollution.

5.2 Corroded tower members and bolts

As part of the Bushfire Regulations, detailed inspection aka Condition Assessment of the tower line is conducted every 3 years as the fleet is located within the High Bushfire Risk Area (HBRA). As part of the inspections, ZA notifications[4] are raised by linesmen for items that have deteriorated to a state where failure may occur over time.

In the past couple of years, a major project was undertaken to replace the corroded members and bolts of the towers that support the conductors from San Remo to Newhaven in Philip Island. A selection of degraded members, including members with completely corroded sections were tested to determine their residual strength in tension, compression and flexure.

5.3 Corroded steel ground wire

The Corporate Risk Management System is followed to understand the risk exposure of the business with regards to the ground wire assets and determine the most appropriate method to manage the fleet. The criticality of an asset is the ratio between the *Consequence of Failure* divided the *Cost of Proactive Replacement* and is grouped into bands as described in section 3.5.

Table 3 shows the risk matrix for the steel ground wire fleet.

		CONDITION				
		C1	C2	C3	C4	C5
CRITICALITY	5	0	5	18	12	2
	4	0	0	5	56	43
	3	0	0	0	13	7
	2	0	14	27	66	18
	1	0	80	109	59	8

From Table 3, the 64- spans indicated in the red boxes pose the highest risk to the business (Risk Level 5) and are planned to be replacement in the EDPR period. This represents 15% of the total ground wire fleet and is 20.4 kilometres in length.

[4] ZA NOTIs are condition-based maintenance work

The 18-spans in Criticality 2 and 8 spans in criticality 1 will also be considered in the replacement program as these belong to the same line, i.e. YPS-WGL/MOE # 2 66kV line. This represents a further 5.8km in length.

5.4 Tower safe access

AusNet Services is mandated by the Occupational Health and Safety Regulations to provide a safe work environment to its employees both staff and contractors. As the towers in the sub-transmission fleet were constructed using old design standards, towers along certain lines lack the appropriate safety clearance between the line worker and the live conductors.

To address this hazard, the tower safe access program was initiated during the last EDPR period wherein a ladder was installed along the centre of the tower body and a cable fall arrest system was installed along the access path of 210- steel lattice towers.

A major driver for the installation of the fall arrest system is to provide safety to lineworkers during tower inspections and maintenance/replacement works. With the advent of unmanned aerial vehicles or drones for doing inspections, the urgency for completing the program has waned and so installation on an “as-needs” basis can be undertaken. Examples would be towers scheduled for project work such as insulator replacement, ground wire replacement or conductor replacement.

6 Strategies

6.1 Steel Lattice Towers

6.1.1 Inspection

- Initiate intrusive inspection of tower leg conditions of towers outside of zone substations
- Trial the use of Remotely Piloted Aerial Systems, e.g. UAVs to undertake condition assessment
- Implement the use of SAP mobility solutions for the online recording of condition assessment data.

6.1.2 Maintenance

- Continue to include the testing of existing bitumen paint on tower legs into the ground level corrosion protection system works scope of works.
- Continue to replace corroded or damage steel members, bolts and Anti-Climbing Devices as part of corrective and scheduled maintenance programs.
- Continue ground level corrosion protection system works at a rate of 4-towers per year.
- Continue implementing fall arrest systems on tower structures and maintain compliance with Occupational Health and Safety standards

6.1.3 Replacement

- Install emergency restoration systems in place of a failed tower and
- Replace the emergency restoration systems with concrete or steel poles
- Perform structural modelling of existing structures to assist with the development of asset reinforcement/replacement programs.

6.2 Insulators

6.2.1 Inspection

- Inspect insulators in accordance with the criteria established in the Asset Inspection Manual 30-4111
- Trial non-intrusive inspections, i.e. Thermal and Corona surveys on polymeric strings to identify incipient failure modes.

6.2.2 Maintenance

- Replace insulators in accordance with the condition criteria established in the Asset Inspection Manual 30-4111
- Install polymeric insulators in place of damaged or corroded grey disc porcelain-type insulators

6.3 Ground Wire

6.3.1 Inspection

- Inspect ground wires in accordance with the criteria established in the Asset Inspection Manual 30-4111

- Trial the use of Smart Aerial Inspection and Processing (SAIP) on the ground wires to identify defective sections and determine the condition of the fleet.

6.3.2 Maintenance

- Replace corroded ground wires in accordance with the condition criteria established in the Asset Inspection Manual 30-4111
- Install steel ground wires where sections are to be replaced

6.3.1 Replacements

- Replace “Very Poor” condition and “Poor” condition, high consequence, steel ground wire on the YPS-WGL/MOE #2 66kV line

7 Appendix

Full circuit descriptions are summarised in Table 3 below.

Circuit Acronyms	Full Circuit Descriptions
CBTS-BWN-ERTS	Cranburne Terminal Station to Berwick North to East Rowville Terminal Station 66kV line
CLN ZONE SUBSTATION	Clyde North Zonesubstation
HPS-WOTS	HPS to Wodonga 66kV line
MBTS-MYT	Mount Beauty to Myrtleford 66kV line
MWTS-MFA	Morwell Terminal Station to Maffra 66kV line
MWTS-YPS 1	Morwell Terminal Station to Yallourn Power Station #1 66 kV line
MYT-BRT	Myrtleford to Bright 66kV line
RUB-KLK	Rubicon to Kinglake 66kV line
TGN-MFA	Traralgon to Maffra 66kV line
TTS-KLK	Thomastown to Kinglake 66kV line
TTS-KLK & EPG2	Thomastown to Kinglake & Epping 66kV line
WANG - MYT	Wangaratta to Myrtleford 66kV line
WGI-PHI	Wonthaggi to Phillip Island 22kV/ 66kV line
WN-MYT	Wangaratta to Myrtleford 66kV line
YPS-ERTS	Yallourn Power Station to East Rowville Terminal Station 66kV line
YPS-ERTS-PMMS 2	Yallourn Power Station to East Rowville Terminal Station to PMMS #2 66kV line
YPS-WGL-MOE 1	Yallourn Power Station to Warragul to Moe #1 66 kV line
YPS-WGL-MOE 2	Yallourn Power Station to Warragul to Moe #2 66 kV line
YPS-YC 1	Yallourn Power Station to Yallourn C #1 66kV line
YPS-YC 2	Yallourn Power Station to Yallourn C #2 66kV line

Table 3 – Full circuit descriptions of sub-transmission towers