Condition Assessment Report

Tailem Bend-Keith 132kV Transmission Line

F1836 - Built Section (1222)

October 2011

Revision: 1.03 A.

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guide as to what the functions are of the various components together with a narrative on "what to look for" and "why". Appendix B, Commentary Report: Framework describes the process undertaken in the development of these Condition Assessment reports.

These commentary reports, whilst generic in nature are intended to be "live" documents, capturing learning's to date as more condition assessment information is gathered and knowledge is learned.

This report has been developed at the desktop level utilising available desktop data with no complimentary field inspection. Findings have been provided as facts with modest narrative to avoid the impression of greater knowledge than historically available information is able to deliver.

All reference documents are listed at the end of this report.

2.1 Condition Coding.

The following tables are used to score the general condition of the line components, with the primary understanding that individual defects are managed adequately through routine maintenance.

Condition Code 5 (Good)	Impending failure will be detected within inspection cycle	Plant elements suit modern specification.
Condition Code 4	Impending failure will be detected within inspection cycle	Plant elements are in good condition and will maintain expected level of reliability.
Condition Code 3	Impending failure will be detected within inspection cycle	Plant elements are sound but show some minor deterioration. This however will not affect plant reliability.
Condition Code 2	Failure may occur within inspection cycle	Plant elements showing signs of deterioration and may cause plant to become unreliable.
Condition Code 1 (Bad)	Failure will occur well within inspection cycle	Plant elements are in poor condition and failure is impending. Plant will become unreliable*. Replacement required

Table 3. Condition Profile.

*Such unreliability will affect operating cost and plant availability targets.

2.2 Confidence Grade of Data.

In addition to the assessment of a condition code for each of the components, a Confidence Grade was also applied with respect to the quality of the information used to provide a condition score.

In absence of detailed quantitative assessments of condition required to make decisions, the confidence grade provides an understanding of the level of confidence in the available data, therefore under every condition code grading in this document, a Confidence Grade is applied as set out below;

Confidence Grade A	•Recently Built •Recent Complete Detailed Inspection •No information to suggest otherwise •100% Certain
Confidence Grade B	•Limited Sample of Representative Detailed Inspection. •Preliminary Inspection. •Decisive Non Destructive Testing, excellent quality results. •Mild Doubt on an "A" result
Confidence Grade C	•Inspection on small Sample •Preliminary testing - poor quality results. •Inspection Result on Similar Line (With B Class results) •Interpolation of SAP Notifications (Notis) •interpolation of Interviews / General knowledge
Confidence Grade D	•Old Inspection Data •Random Sample / Inspection •Extrapolation of SAP Notifications (Notis) •Extrapolation of Interviews / General knowledge
Confidence Grade E	•Environmental / Life Assessment -based on anticipated life span of component (for Environmental Zone) •Qualitative analysis •Interviews / General Knowledge. •"Gut Feel"

Table 4. Confidence Grade.

2.3 Component estimated life - Corrosion Zone

The following table provides a guideline of the estimated deterioration rate from new for various components within the environmental zones considered across the ElectraNet network (refer Appendix B);

Vibration Dampers added 1990.

Attachment Points Upgrade 2000.

Insulators Replaced 1990.

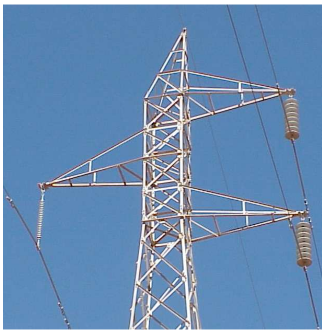
Foundations Upgraded (Every Second Tower) 1990.

Crossarms Strengthened 1990.

Further background information can be found in Appendix A, Commentary Report which has been provided as a guide to the "what to look for" and "how". This commentary report whilst generic in nature is intended to be a "live" document, capturing learning's to date as more condition assessment information is gathered.

4 Construction Overview

The Feeder construction type consists of Lattice Towers constructed by ETSA.



F1836 Tower Suspension Structure (311).

F1836 Tower Tension Structure (26).

Suspension Towers............311.

Tension Towers.................26.

Suspension Poles...............Nil.

Suspension Poles (Post)......Nil.

Tension Poles....................Nil.

TOTAL.............................337.

Transmission Line Condition Assessment Commentary

Appendix A: Components

September 2011

Version B

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Revision Record

Date	Version	Description	Author	Checked By	Approved By
22/09/2010	A1	Initial Draft	Ian Flatley ENGINEER		
30/10/2010	A	Document following internal and Client Review	Ian Flatley ENGINEER		
30/09/2011	B	Rewrite incorporating key learning's from desktop CA assessments	Ian Flatley ENGINEER		

Purpose

This commentary is provided as an addendum to various desktop based condition assessment reports developed to the date of this report. The intent of this document is to collect supporting information with respect to transmission line components on a generic, non-feeder specific basis.

This commentary provides information on the various degradation modes of the components that make up the transmission line as well as provide guidance on likely end of life criteria.

It provides an overview of component importance, modes of degradation and relevant performance on this line asset. Recommendations for future inspections are provided with particular focus on any known or potential areas of concern.

This commentary is not intended to provide a complete list of defects that may be evident on the line. Any future inspection or report write up should maintain a focus of impartiality to ensure that any additional problems that may eventuate are detected.

Assumptions are based on the transmission line being managed through a routine maintenance and inspection plan adequately addressing short term line security requirements.

Both the condition assessment report and this commentary do not cover compliance with relevant state regulations and acts, nor conformity to Australian Guidelines or Standards. Whilst design documentation was provided as part of the review, no verification as to suitability of the line asset to regulatory compliance and its components is implied.

Reference should also be made to Appendix B that provides a framework for the various inputs and discussions that make up this report;

- Environmental Study
- Maintainability
- Transmission Line Security
  - (Including effect of upgrading)
- Future Inspection Requirements

Appendix A Components

The ability of a line system to function reliably requires the constant operation of a number of sub-systems. With respect to reliability and potential consequence these can be further broken into;

- Conductor Systems
- Insulator Systems
- Structure Support Systems
- Sub Component Systems

The above are listed in order of criticality with conductor systems requiring a high level of reliability as failure of a component here will have a far greater effect and consequence than say other components such as suspension supports. Restoration time and other direct costs are usually far greater for the more critical components, hence these systems should have a higher degree of attention and potential increased redundancy or importance.

Consequence of failure of a component within a line system is dependent on redundancy of the connected network, duty of the component and the time taken to restore the line system to operation.

The functional duty of each component is discussed below together with common failure modes.

A.1.1 Conductor Systems

The conductor system in an overhead line is the most critical of all line systems. Failure of a conductor component will lead to increased mechanical loads on adjoining support structures and may cause a cascading collapse of adjacent structures. Included in the conductor system are the conductor and other hardware necessary to support or restrain the applied tension forces to the tension support structures.

A.1.1.1 Conductor

The primary purpose of the conductor is to provide a suitable path for electrical current to flow safely between source and load. As well as its primary electrical function, the conductor has to be self-supporting and therefore is required to have sufficient mechanical properties to maintain safe clearances for expected weather conditions.

Main degradation and failure modes of conductor are due to atmospheric conditions (corrosion), annealing (due to high thermal operating conditions) or fatigue (due to aeolian vibration) which causes fretting, abrasion and ultimately failure of the strands.

Corrosion Process (ACSR)

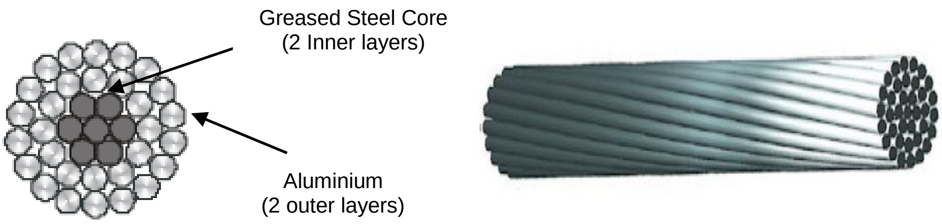

Figure 1. Typical ACSR Conductor

Chloride and pollutant deposition is deposited on the conductor and acts as an electrolyte between the zinc, steel and aluminium. The corrosion progresses as follows:

1. The grease degrades over time, dries out and becomes ineffective (where grease is applied, if not corrosion will start at step 2),
2. The zinc layer (galvanising) coating the steel strands begins to corrode as it is highest in the galvanic series (zinc 1st, aluminium 2nd, steel 3rd),
3. Once the zinc is lost, or the zinc is electrically isolated due to corrosion product, the aluminium starts to corrode,
4. Only once the aluminium is significantly corroded does the steel begin to corrode.

As the steel is the last part of the conductor to corrode there still remains a great amount of mechanical strength remaining in the conductor despite heavy loss of aluminium.

Vibration

Aeolian vibration is a result of laminar wind (usually at low velocities) blowing over the conductor generating vortices which alternately shed downstream of the conductor creating damaging vibration amplitudes.

Vibration occurs predominantly when the wind is perpendicular to the conductor and in open flat terrain. Prevailing wind and line directions together with the terrain in this case increase the probability and frequency of such vibration conditions occurring.

Higher conductor tensions reduce the self-damping capability of the conductor and thus increases the likelihood of conductor fretting. Conductor fretting is more likely at the conductor attachment points as a result of such vibration, but has been known to extend to entire spans. Aeolian Vibration may cause premature failure of the conductor after millions of such vibrations.

‘Grease Holidays’

> These are areas where there is no, or only partial, covering of the steel core with grease. These areas experience accelerated corrosion (greased portions of the line do not suffer from this issue). Where grease holidays exist there is rapid loss of cross sectional area of the aluminium once the onset of aluminium corrosion is reached. The corrosion of the aluminium causes significant bulging of the conductor as corrosion products form. MPT have reported that it takes two years for the aluminium corrosion to progress from onset to severe bulging, with a further two to three years before mechanical failure occurs.

Component Function		Provide an electrical path for current to flow along. Mechanically support itself so that clearances are maintained.
Functional Failure		Mechanical Failure Electrical resistance too high.
Failure Mechanisms		Corrosion / Fretting / Abrasion / Loss of section / Annealing / Fatigue / Bird caging / Bulging / Burn marks / Visible corrosion product / Loose, Unravelling, Broken strands or Pitting.
Routine Maintenance		Conductor damage is an aggregation of individual damaged strands at a single site on the conductor. Any damage, no matter how minor, is to be considered as a damage site. A damage site is defined as a length of conductor five times the conductor diameter. Multiple damage sites are considered individually. Conductor damage is classified into three categories (Minor, Intermediate and Major) refer Visual Coding Guide lines.
Gap (between Routine and CA requirements)		Whilst visual assessment of conductor can identify potential end of life evidence, many issues (such as internal fretting, degradation of grease) may be hidden in the case of ACSR. More invasive assessment is required to assess end of life.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of conductor bulging / white corrosion product along conductor. Pay particular attention to old ES2 damper and attachment damage. Consider much damage will be hidden from field inspections during normal routine maintenance.
	Inspect	ACSR: Visual Inspection (close) to assess extent of bulging, white corrosion products or other evidence of damage leading to identifiable trends. Non destructive testing may assist in identifying areas requiring sampling for end of life assessment.
	Sample	Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.
	Detailed Assessment	Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.

Table 1. Conductor Purpose and Recommendations Matrix

A.1.1.1.1 Notes on ES2 Damper Damage

In the early life of the line damage to the conductor from aoelian vibration occurred before ES2 dampers were fitted to absorb energy and to limit fatigue at the conductor attachment points. Dampers are discussed in more detail in below.

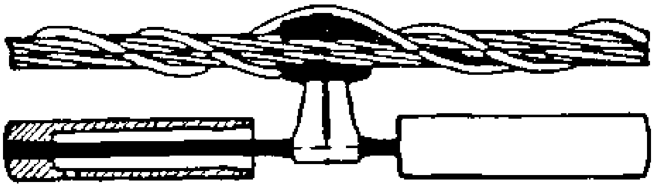

Figure 2. ES2 Damper

ES2 Dampers had specific issues with an elastomer insert that was designed to limit fatigue damage at the damper attachment point, however this insert had two negative effects. The first was to inhibit the transfer of energy from the vibrating conductor to the messenger wire that resulted in the damper unable to stifle reduce the vibration at the most damaging frequencies. The second effect was to hold moisture and contaminants that when combined with the semi conductive properties of the elastomer resulted in corrosion damage at the damper attachment point.

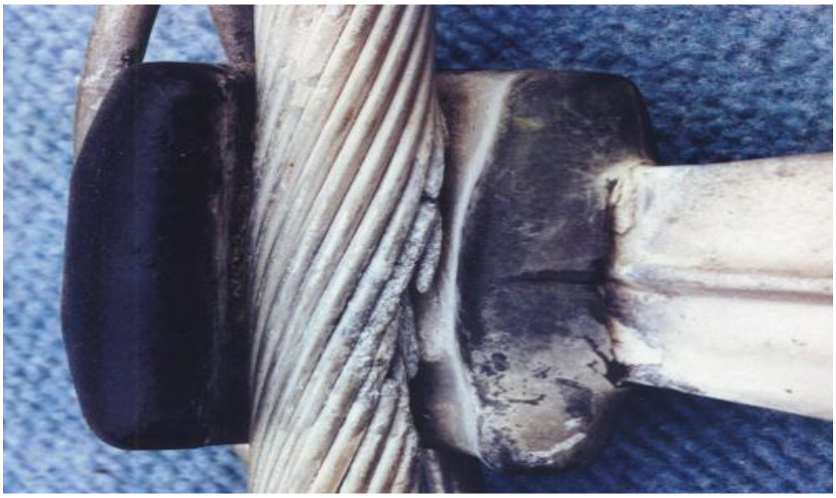

Image 1. Severe ES2 Damper Damage

ES2 dampers caused damage, grading from superficial to serious at a significant number of locations. All ES2 dampers were replaced in the period 1992 to 1994. Repairs to the corrosion damage were carried out using various repair rods in accordance with a prescribed regime which effectively reinstated the mechanical and electrical properties of the conductor.

The key issue affecting this repair is the potential for corrosion to continue to occur in the void under the repair rods due to the ingress of moisture and corrosive elements, resulting in reduced mechanical strength and current carrying capacity from the loss of cross-sectional area of the aluminium.

A.1.1.2 Conductor Joints

Conductor joints are required to perform not only the duty of the conductor, but also to provide both mechanical and electrical joint connections. Failure of a joint at high electrical loads can place additional strain on other normally redundant network systems.

Image 2. Sectioned ACSR MidSpan Joint Showing pressed Steel Inner Sleeve

Deterioration of the joint can occur as a consequence of various atmospheric degradation, thermo-mechanical stresses and/or vibration. Over time, joint resistance will increase and if left unchecked can lead to overheating and eventual failure. Accelerated degradation also occurs due to higher thermal operating temperatures. Poor construction practices increase the risk of joint failure.

Damage to the main conductor strands can occur near the joint due to aeolian vibration leading to hot spots or increased resistance.

Any thorough condition assessment of the line should include a joint resistance survey to evaluate joint performance. This should be undertaken as a minimum prior to any up-rating of the line to ensure the complete integrity and long term performance of the thermal chain.

The aim of joint resistance testing is to provide an indication of the current condition of the joints. Field measurements and more importantly analysis of the results is an expensive and specialised task. A methodical approach to scoping, collection of field data and analysis is required to determine remaining life and evaluate replacement criteria.

Image 3. Live Line Conductor Joint Testing

Termination joints are fitted to allow the conductor to connect to tension structures. These termination joints are considered as a half joint and together with the adjacent jumper palm and palm connection, shall be included in any resistance measurement survey to ensure the integrity of the circuit under evaluation. Particular attention to the bolted connection is required as this is the most likely area of high joint resistance. Experience shows that re-bolting and cleaning these joints at appropriate intervals (say 20 years) is a good preventative maintenance strategy.

During any conductor joint inspection, evidence of damage to outer strands of the conductor near the connector should also be noted.

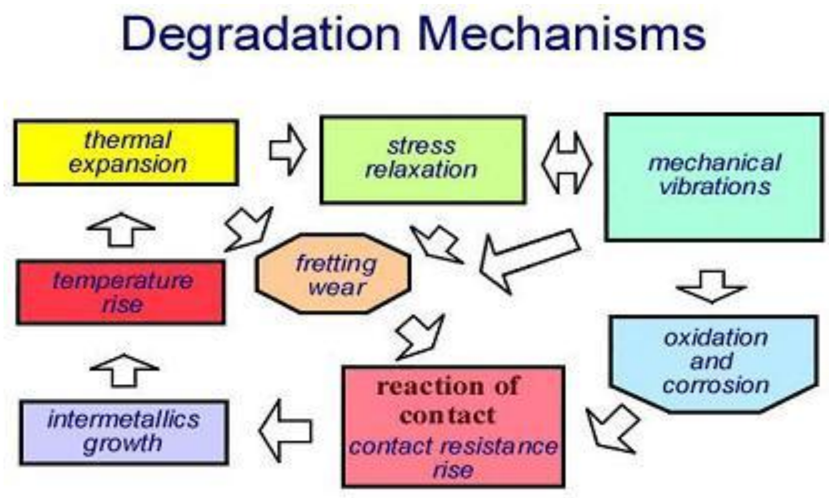

Figure 3. Schematic representation of the synergistic action of degradation mechanisms on electrical contacts.

From Workshop on the Performance and Reliability of Electrical Power Connections
26 - 27th February 2007, Fort Myers, FL, USA

The location of the joint should be recorded during any inspection.

Component Function	To mechanically join conductors. Allow a path for electrical current to flow.
Functional Failure	Electrical or Mechanical Failure.
Failure Mechanisms	Resistance is higher than that of Conductor / Corrosion / Loss of section / Annealing / Fatigue
Routine Maintenance	Routine Maintenance requires thermograhic inspection of 50% of bolted connections to be tested on a five yearly basis, effectively resulting in all connections being tested every 10 years. Resistance testing of 20% of joints on a five yearly cycle (commencing 10 years after initial commissioning) is required in each built section.
Gap (between Routine and CA requirements)	A well made conductor Joint should be maintance free for the life of the conductor. Good practice is towards the use of conductor resistance testing as a means of assessing the life position of the conductor joint. Resistance testing provides a much earlier indication of joint deteriation than thermography. The routine maintenance requirements provide a trade off between the cost effectiveness of thermograhy (for strain structures) and the accuracy of resistence testing.

Condition Assessment Recommendations	**Review**	Generally based around the requirements of CIGRE Brochure 216, a desktop review of available field joint testing information (of both thermographic and resistance testing) should be undertaken. The aim of joint resistance testing is to provide an indication of the current condition of the joints. Field measurements and more importantly analysis of the results is an expensive and specialised task. A methodical approach to scoping, collection of field data and analysis is required to determine remaining life and evaluate replacement criteria.
	Inspect	Review of available Joint Testing information (if none available then resistence testing should be undertaken). Further analysis (over and above resistance testing and review) may be required to establish the life cycle point of a reresentative sample of joints. May even warrant obtaining resistance measurements on strain towers to completely check and establish the integrity of the entire thermal chain.
	Sample	Review of available Joint Testing information (if none available then resistence testing should be undertaken). May even warrant obtaining resistance measurements on strain towers to completely check the integrity of the entire thermal chain. Further analysis (over and above resistance testing and review) may be required to establish the life cycle point of a reresentative sample of joints. This may include; o Heat Cycle Testing o Material Analysis o Destructive testing o Further Electrical / Mechanical Testing
	Detailed Assessment	Review of Available Joint Testing information (if none available then resistence testing should be undertaken). May even warrant obtaining resistance measurements on strain towers to completely check the integrity of the entire thermal chain. Further analysis (over and above resistance testing and review) may be required to establish the life cycle point of a reresentative sample of joints. This may include; o Heat Cycle Testing o Material Analysis o Destructive testing o Further Electrical / Mechanical Testing

Table 2. Termination / Mid span conductor Joints Purpose and Recommendations Matrix

Component Function	Electrical Connection at Termination / Angle / Dead End structures
Functional Failure	Electrical or Mechanical Failure.
Failure Mechanisms	Resistance is higher than that of Conductor / Corrosion / Loss of section / Annealing / Fatigue / Wear
Routine Maintenance	As with tension assemblies above, 50% of bolted connection are to be tested on a five yearly basis, effectively resulting in all connections being tested every 10 years.
Gap (between Routine and CA requirements)	At present jumper and palm connections are inspected with the termograhic survey and are not required to be resistence tested.

Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of abnormal jor advanced joint deteriation.
	Inspect	These jumper palm and palm connection, shall be included in any resistance measurement survey to ensure the integrity of the circuit under evaluation. Particular attention to the bolted connection is required as this is the most likely area of high joint resistance. Experience shows that re-bolting and cleaning these joints at appropriate intervals (say 20 years) is a good preventative maintenance strategy.
	Sample	These jumper palm and palm connection, shall be included in any resistance measurement survey to ensure the integrity of the circuit under evaluation. Particular attention to the bolted connection is required as this is the most likely area of high joint resistance. Experience shows that re-bolting and cleaning these joints at appropriate intervals (say 20 years) is a good preventative maintenance strategy.
	Detailed Assessment	These jumper palm and palm connection, shall be included in any resistance measurement survey to ensure the integrity of the circuit under evaluation. Particular attention to the bolted connection is required as this is the most likely area of high joint resistance. Experience shows that re-bolting and cleaning these joints at appropriate intervals (say 20 years) is a good preventative maintenance strategy.

Table 3. Jumper & Palm Connection Purpose and Recommendations Matrix

A.1.1.3 Conductor Hardware (Dampers)

Vibration Dampers assist in dissipating energy and reducing conductor amplitude created by aeolian vibration. Damper selection and installation is specialised and are designed to limit bending stress and strain along the conductor to permissible levels over a wide frequency range.

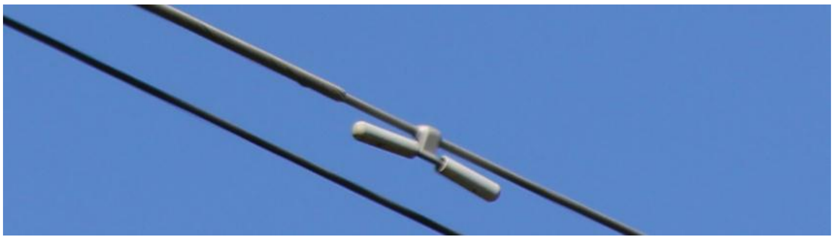

Image 4.Stockbridge Damper

Typical degradation modes are drooping messenger wires or dropped weights (not common).

Component Function	Mass spring damper system designed to absorb vibration from a conductor to prolong the life of other components
Functional Failure	Vibration dampening insufficient
Failure Mechanisms	Corrosion / Fatigue / Wear / Inadequate dampers installed / Drooping / Broken Strands on messenger wire / Brittleness in spiral dampers

Routine Maintenance		Vibration dampers are assessed and coded so that they will be replaced if any of the following is observed: o The messenger cable has yielded causing the weights to droop at an angle of 20° or more from their installed position (horizontal for most dampers). o The messenger cable has one or more broken strands. o The weights are loose on the messenger cable. o The messenger cable is corroded to the point where the loss of cross section of any individual strand is more than 50%. o Note that in most cases the damper will droop or the messenger cable will have broken strands before it requires replacement due to corrosion.
Gap (between Routine and CA requirements)		Visual assessment is sufficent to determine end of life criteria for vibration dampers. As the vibration damper droops, its effectiveness reduces and hence damage to the damper reduces as well.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of damper drooping or other defects. Program damper replacement with other (Insulator / Conductor) works where possible.
	Inspect	Review Notis for trends or evidence of damper drooping or other defects. Program damper replacement with other (Insulator / Conductor) works where possible.
	Sample	Review Notis for trends or evidence of damper drooping or other defects. Program damper replacement with other (Insulator / Conductor) works where possible.
	Detailed Assessment	Review Notis for trends or evidence of damper drooping or other defects. Program damper replacement with other (Insulator / Conductor) works where possible.

Table 4. Dampers Purpose and Recommendations Matrix

A.1.1.4 Conductor Hardware (Armour Rods)

Conductor Accessories refer to additional components fitted to the conductor to provide a range of functions. Conductor Accessories include dampers (for aeolian vibration), sub conductor spacers (where fitted) and Armour Rods (for additional conductor protection at the point of support).

Mid Span Repair Sleeves or Armour Rods also fit into this category. Whilst not considered a critical component, any such fittings observed during any inspection should be noted, along with type and description details. Repair Sleeves should be included in any joint resistance testing.

Component Function	Protect conductor in areas of high stress such as under clamps. Add strength to conductor where there is minor damage.
Functional Failure	Does not increase the remaining life of the conductor.
Failure Mechanisms	Corrosion / Damaged Members / Wear / Leaning / Missing Members
Routine Maintenance	Armour Rods are coded so that they will be replaced if any of the following is observed: o Burn marks from flash over or lightning o Corrosion Product o Evidence of conductor damage o Loose

<table>
<tr><td colspan="2">Gap
(between Routine and CA requirements)</td><td>Visual assessment is sufficent to determine end of life criteria for armour rods.

Damage to the conductor can be hidden underneath (ie fretting damage and broken strands) and it is considered good practice to undertake a "lifting inspection" when accessing the conductor for other works.</td></tr>
<tr><td rowspan="4">Condition Assessment Recommendations</td><td>Review</td><td>Review Notis for trends or evidence of loose armour rods or other defects.

Program "lifting inspection" with other (Insulator / Conductor) works where possible.</td></tr>
<tr><td>Inspect</td><td>Review Notis for trends or evidence of loose armour rods or other defects.

Program "lifting inspection" with other (Insulator / Conductor) works where possible.</td></tr>
<tr><td>Sample</td><td>Review Notis for trends or evidence of loose armour rods or other defects.

Program "lifting inspection" with other (Insulator / Conductor) works where possible.</td></tr>
<tr><td>Detailed Assessment</td><td>Review Notis for trends or evidence of loose armour rods or other defects.

Program "lifting inspection" with other (Insulator / Conductor) works where possible.</td></tr>
</table>

Table 5. Armour Rods Purpose and Recommendations Matrix

A.1.1.5 Earthwire / OPGW

An Earthwire and / or Optical Ground Wire (OPGW) are provided for lightning, earthing and communication purposes.

As with conductors, aeolian vibration may cause fatigue and/or fretting leading to early failure of the earthwire. The point at which damage is usually seen first is at the supports. Any visual inspection of the earthwire should include a sample examination of the outer (and inner strands if possible) under the clamps for evidence of fretting damage.

Other degradation modes of the overhead earthwire and OPGW are also similar to that of conductor being of similar helical construction.

Consideration should also be given for the possibility of further lightening damage to earthwire and any inspection in the span should look out for such damage from pitting to melting and breakage of the outer strands.

Note: conductors with strand diameters below 3mm are known to be susceptible to lightning stroke damage. Inspections should take note of this and ensure that the condition assessment technique used is capable of observing strand damage.

Further considerations for OPGW;

> As the OPGW carries optical fibres, care should be taken during any work on or near the OPGW system to avoid unnecessary compression, twisting or movement of the OPGW.

Fatigue damage at joint box/strain towers location is also a recognised failure mode. Inspection of the area at first attachment point to the tower is recommended. Fatigue failures can damage and crack the optic tube allowing moisture to penetrate (moisture inside the optic tube will seriously reduce the life of the fibres within). Fatigue failures at this location are generally preceded by evidence of severe fretting and black aluminium fretting product.

Component Function		Provide an electrical path for fault current to flow. Intercept lightning.
Functional Failure		Mechanical Failure / Electrical Resistance too high.
Failure Mechanisms		Corrosion / Fretting / Abrasion / Loss of section / Annealing / Fatigue / Bird caging / Bulging / Burn marks / Visible corrosion product / Loose, Unravelling, Broken strands or Pitting.
Routine Maintenance		Earthwires are coded so that they should be replaced when all the external galvanizing has been consumed but before significant loss of metal has occurred.
Gap (between Routine and CA requirements)		Whilst visual assessment of the earthwire can identify potential end of life evidence, internal fretting and loss of section leading to broken strands requires additional effort. More invasive assessment is required to assess end of life.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of earthwire (and earthwire joint) damage, loss of galvensing and evidence of broken strands. Consider much damage will be hidden from field inspections during normal routine maintenance.
	Inspect	Review Notis for trends or evidence of earthwire (and earthwire joint) damage, loss of galvensing and evidence of broken strands. Consider much damage will be hidden from field inspections during normal routine maintenance.
	Sample	Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.
	Detailed Assessment	Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.

Table 6. Earthwire / OPGW Purpose and Recommendations Matrix

A.1.1.6 Overhead Earthwire Joints

Degradation of overhead Earthwire Mid Span Joints is similar to that of the conductor joints, however as this type of joint does not carry electrical loads (except during fault events or lightning strikes) the joint runs cooler than the conductor and is not subjected to the same level of electrical stress. Corrosion is likely to be the main degradation mode, however when inspecting such joints, care should be taken to look for signs of previous overheating from lightning.

The location of the joint should be recorded during any inspection.

Component Function		To mechanically join earthwire, provide sheilding for conductors. Allow a path for electrical fault / lightening current to flow.
Functional Failure		Electrical or Mechanical Failure.
Failure Mechanisms		Resistance is higher than that of Conductor / Corrosion / Loss of section / Annealing / Fatigue.
Routine Maintenance		No specific routine maintenance requirement other than closer attention nearer substations.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of damage or localised heating of earthwire joints.
	Inspect	Review Notis for trends or evidence of damage or localised heating of earthwire joints. Specific inspect of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of damage or localised heating of earthwire joints. Specific inspect of a representative sample is recommended to assess likely remaining life.
	Detailed Assessment	Review Notis for trends or evidence of damage or localised heating of earthwire joints. Specific inspect of a representative sample is recommended to assess likely remaining life.

Table 7. Earthwire Joints Purpose and Recommendations Matrix

Component Function	To mechanically join conductors. Allow a path for electrical current and communications to flow (in the case of OPGW).
Functional Failure	Electrical or Mechanical Failure.
Failure Mechanisms	Corrosion / Wear / Missing.
Routine Maintenance	Closely inspected for any signs of vibration damage at support points. If conductor-to-tower bond cables are fitted then the security of the bond clamps, and for signs of fatigue failure on the bond cable are checked Earth wire fittings that are not directly bonded to the structure can suffer flash over damage and as such, items should be coded so that they are replaced if there is evidence of fusing of metal surfaces. Tower attachment points are also checked for excessive wear.
Gap (between Routine and CA requirements)	Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.

Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of frayed or worn bonds.
	Inspect	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Detailed Assessment	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.

Table 8. Earthwire / OPGW Joints (bonding to structure) Purpose and Recommendations Matrix

A.1.1.7 Overhead Earthwire Tension Hardware

The Overhead Earthwire Tension Hardware's purpose is to connect the earthwire to the structure. As with the conductor tension hardware, the earthwire tension hardware function is solely to perform mechanically. ie it should not carry any electrical current. Separate electrical bonding is provided to ensure fault and stray currents are not carried through the hardware.

The consequence of failure here is a dropped earthwire, damage to the bonding and increased longitudinal loads on adjacent structures. As with the conductor tension hardware, repairs are generally not as straight forward as for similar components on a suspension structure with a corresponding increase in restoration time.

Component Function		Mechanically connect earthwire and structures at tension / dead end structures.
Functional Failure		Mechanical Failure.
Failure Mechanisms		Corrosion / Split Pins / Wear / Loose bolts / Annealing.
Routine Maintenance		No specific routine maintenance requirement other than closer attention nearer substations.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware.
	Inspect	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.

	Detailed Assessment	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.

Table 9. Purpose and Recommendations Matrix

Further considerations for OPGW

OPGW Tension fittings are designed to accommodate the tension in the OPGW whilst allowing a continuous fibre link between joint boxes, thus tension assemblies to accommodate the OPGW may be fitted to suspension support structures.

A.1.2 Insulator Systems

A.1.2.1 Tension Insulators

Insulators are required to withstand both mechanical and electrical stresses. Mechanical stresses on standard suspension insulators are applied in tension. Electrical stresses include power frequency, switching and lightning over-voltages.

There are a fairly large number of degradation modes and these are also discussed in more detail in Appendix A.1.2.3 Suspension Insulators below.

Image 5. Tension Structure

A.1.2.2 Tension Hardware

The Tension Hardware connects the conductor to the tension insulators (hot end) and the tension insulators to the structure (cold end). The tension hardware function is solely to perform mechanically. i.e. it is not required to carry any electrical current.

The consequence of failure here is a dropped conductor, damage to the jumper flags and increased longitudinal loads on adjacent structures. Repairs are generally not as straight forward as for similar components on a suspension structure with a corresponding increase in restoration time should failure occur.

<table>
<tr><td colspan="2">Component Function</td><td>Mechanically connect conductors to insulators and structures at tension / dead end structures.</td></tr>
<tr><td colspan="2">Functional Failure</td><td>Mechanical Failure</td></tr>
<tr><td colspan="2">Failure Mechanisms</td><td>Corrosion / Split Pins / Wear / Loose bolts / Annealing</td></tr>
<tr><td colspan="2">Routine Maintenance</td><td>Prodominently looking for excessive corrosion and wear.

Other things such as the fitness for purpose of attachment hardware or burn marks are also checked.

Components may also deteriorate due to other processes such as fatigue, cracking across critically loaded sections, loss of security clips, internal melting/welding due to electrical flashover, loss of acceptable electrical performance etc.

Usually corrosion is tolerated provided that there is no significant loss of metal. Where ball and socket or tongue and clevis joints have become frozen due to severe corrosion these items are considered as requiring replacement.

In general fittings must not be allowed to deteriorate beyond the point where the mechanical safety factor is reduced unacceptably. While it may not be appropriate for all items, an approximate replacement guide is where there is a 25% reduction in the cross sectional area of load bearing metal, which is that part of any individual component through which the load is applied.</td></tr>
<tr><td colspan="2">Gap (between Routine and CA requirements)</td><td>Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.</td></tr>
<tr><td rowspan="4">Condition Assessment Recommendations</td><td>Review</td><td>Review Notis for trends or evidence of worn or corroded hardware</td></tr>
<tr><td>Inspect</td><td>Review Notis for trends or evidence of worn or corroded hardware

Specific inspection of a representative sample is recommended to assess likely remaining life.</td></tr>
<tr><td>Sample</td><td>Review Notis for trends or evidence of worn or corroded hardware

Specific inspection of a representative sample is recommended to assess likely remaining life.</td></tr>
<tr><td>Detailed Assessment</td><td>Review Notis for trends or evidence of worn or corroded hardware

Specific inspection of a representative sample is recommended to assess likely remaining life.</td></tr>
</table>

Table 10. Tension Hardware Purpose and Recommendations Matrix

A.1.2.3 Suspension Insulators

Insulators are required to withstand both mechanical and electrical stresses. Mechanical stresses on standard suspension insulators are applied in tension. Electrical stresses include power frequency, switching and lightning over voltages.

Some modes are easily detectable by visual inspection others need sophisticated methods. Degradation modes caused by easily detectable mechanisms like pin corrosion or surface erosion are considered to be reason for replacement of insulators and should be included in any visual inspection.

Consideration should also be made to obtaining samples for closer laboratory examination for life cycle analysis.

Cap and Pin Insulators

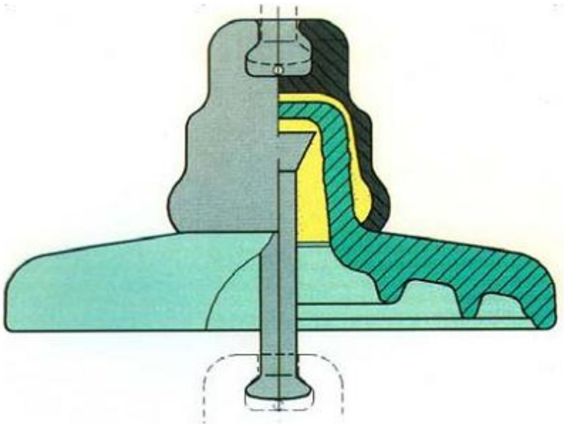

Figure 3. Cross-section Cap & Pin Insulator

Internal defects within the porcelain are not visible and can lead to failure both electrically and mechanically. Porcelain insulators should be electrically tested to identify units requiring replacement. Electrically defective insulators have an increased risk of failure mechanically and should be replaced as soon as practically possible to ensure adequate line security is maintained.

Electrical testing can be carried out by either;

- Potential Difference
- Electric Field (Field Probe)

Component Function	Electrically insulate live parts from mechanical structure. Mechanically connect conductor to structure.
Functional Failure	Insulation Failure / Mechanical failure.
Failure Mechanisms	Broken or Missing Discs / Cracks / missing W or R clips or split pins / Corrosion / Wear / Puncture / Flashed Over / Arc or Burn Marks / Tracking Marks (particularly on glass discs) / Pollution.

Routine Maintenance		Visual assesment to capture failed units or with evidence of limited life. For porcelain insulators live line voltage profiling is also required to identify hidden defects in porcelain insulators. An annual review of all maintenance records allows for: o Evaluation of trends or specific areas of concerns. o A determination of the expected end-of-life criteria for each insulator assembly type. o The production of a long term insulator assembly replacement plan and o Planning of additional investigations on insulator performance. Limited sampling of insulators have been carried out to confirm integirty concerns and provide a correlation betwen failed electrical porcelain discs and the remaining mechanical strength.
Gap (between Routine and CA requirements)		Glass Insulators require a visual inspection only, as a failed unit will have been "shattered" and easily identifiable. Shattered glass discs will normally maintain an adequate margin against failure due to the "interlock" of the shattered glass providing good mechanical shear resistance. Porcelain Insulators can have hidden defects undetectable unless electrically tested. An electrically failed porcelain disc can also suffer a reduced mechanical capacity as the failure planes offer little mechanical shear capacity. Both the visual assessment and the voltage drop testing for these disc insulators will record.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of degradation.
	Inspect	Review Notis for trends or evidence of degradation. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of degradation. Specific inspection of a representative sample including the obtaining of samples for further analysis is recommended to assess likely remaining life.
	Detailed Assessment	Review Notis for trends or evidence of degradation. Specific inspection of a representative sample including the obtaining of samples for further analysis is recommended to assess likely remaining life.

Table 11. Cap and Pin Purpose and Recommendations Matrix

Porcelain Long Rods

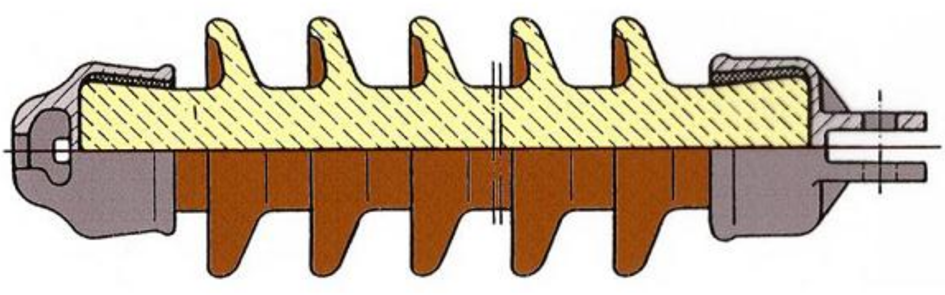

Figure 4. Cross-section Porcelain Long Rod Insulator

Porcelain Long Rods are constructed from a single piece of porcelain with metal caps either end and provide a high arc resistance with excellent self-cleaning characteristics.

These insulator types are simple in construction and have proven to be of good service life. Failure modes for these insulators are related primarily to the integrity of the porcelain insulating body.

Further work with respect to end of life criteria is required, however guidance can be sought from CIGRE Technical Brochure 306 (Guide for the Assessment of Old Cap & Pin and Long-Rod Transmission Line Insulators made of Porcelain or Glass: What to Check and When to Replace).

Polymeric Insulators

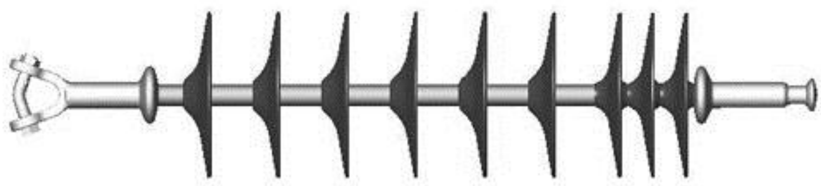

Figure 5.. Composite or Non-Ceramic (NCI) insulator

Polymeric insulators (also called Non-Ceramic Insulators) are constructed of a fibreglass core with weather sheds made from various polymer materials, compounded for electrical use. Metal fittings are normally pressed or glued to form the end attachments. The fibreglass core performs both the main electrical insulation and provides the tensile mechanical properties of the insulator. This core is made of mainly axially aligned fibreglass strands which can be damaged if exposed to UV, moisture or torsional loading.

Non-ceramic Insulators can be easily damaged through “rough handling” and special precautions are required during installation. The integrity of the inner core is of most importance when considering the effect of any damage the insulator may have suffered or when assessing the insulator.

Failure and degradation modes of suspension polymeric insulators (as fitted to this line) include;

Brittle Facture of the inner fibreglass core.

The following can lead to moisture/acid ingress into the rod potentially leading to Brittle Fracture;

- Punctures
- Corona Cutting of Sheath
- Erosion of Sheath – Exposed Core
- End Seal Damage

Flashover Potential;

- o Tracking
- o Excessive UV degradation

Corona Rings can be installed at the hot and cold end to reduce the electric field gradient experienced by the insulator. Composite insulators do not have internal capacitance like cap and pin insulators which results in a higher electric field gradient at the hot and cold ends and increased likelihood of corona occurring which can damage the insulators

Suspension Insulators are also fitted to Tension structures to provide additional support of the conductor jumper assembly and maintain electrical integrity to the support structure.

During any inspection the hot end and cold end of polymer insulators should be closely inspected to ensure there is no corona damage, especially where corona rings are found to be missing, damaged or installed incorrectly.

Any visual damage to the sheath shall be recorded and a picture taken to assess the potential implications. Any exposure of the rod or signs of tracking during inspection warrants immediate attention.

<table>
<tr><td colspan="2">Component Function</td><td>Electrically insulate live parts from mechanical structure. Mechanically connect conductor to structure.</td></tr>
<tr><td colspan="2">Functional Failure</td><td>Insulation Failure / Mechanical failure.</td></tr>
<tr><td colspan="2">Failure Mechanisms</td><td>Corrosion or wear of end caps or attachment points / Damaged Sheds / Damage to sheath / Punctured Sheath or Sheds / Damaged Sheds / bullets / oxidation / H20 ingress to rod / Chalking / Pollution / Flashed Over /arc or Burn Marks</td></tr>
<tr><td colspan="2">Routine Maintenance</td><td>Polymer (NCI) Insulators are notified as defective if they have evidence of the following;
o Exposed rod
o Rod / shed interface damage
o Evidence of sheath tracking
o Erosion of sheath (away from terminals)
o Excessive mould growth
o Extensive chalking / alligatoring

Owing to the absence of recognised test standards for aged polymer insulators, it is recommended the insulator be sent for analysis to a laboratory for end of life analysis. Particular attention is to be made to the integrity of the polymer sheath and evidence of damage or degradation of the inner fibreglass core.</td></tr>
<tr><td colspan="2">Gap (between Routine and CA requirements)</td><td>CA Criteria for Composite or NCI Insulators are not fully established as yet.

Routine Maintenance requirements focus on damage which can lead to failure in the short term rather than life cycle assessment.</td></tr>
<tr><td rowspan="3">Condition Assessment Recommendations</td><td>Review</td><td>Review Notis for trends or evidence of degradation</td></tr>
<tr><td>Inspect</td><td>Review Notis for trends or evidence of degradation.

Specific inspection of a representative sample is recommended to assess likely remaining life.</td></tr>
<tr><td>Sample</td><td>Review Notis for trends or evidence of degradation.

Specific inspection of a representative sample including the obtaining of samples for further analysis is recommended to assess likely remaining life.</td></tr>
</table>

	Detailed Assessment	Review Notis for trends or evidence of degradation. Specific inspection of a representative sample including the obtaining of samples for further analysis is recommended to assess likely remaining life.

Table 12. Composite Purpose and Recommendations Matrix

A.1.2.4 Suspension Hardware

Suspension Hardware refers to the non-insulating components of the suspension assembly. They are normally classed as either “hot end” or “cold end” depending on contact to live components.

Degradation modes of these components include wear, corrosion, fatigue, cracking, loss of security clips, internal melting/welding due to electrical flashover, loss of acceptable electrical performance etc. Any degradation of these components can lead to a loss of the components functional duty and ultimately conductor dropping to the ground.

AGS Suspension clamps use a helically formed armour grip with an elastomer insert which provide protection of the conductor resulting from mechanical vibration. These clamps have no special inspection requirements however consideration should be given to inspecting the conductor under these clamps to assess any damage to the conductor as a result of aoelian vibration.

Component Function	Mechanically connect conductors to insulators at suspension structures.
Functional Failure	Mechanical Failure.
Failure Mechanisms	Corrosion / Split Pins / Wear / Loose bolts / Annealing.
Routine Maintenance	Prodominently looking for excessive corrosion and wear. Other things such as the fitness for purpose of attachment hardware or burn marks are also checked. Components may also deteriorate due to other processes such as fatigue, cracking across critically loaded sections, loss of security clips, internal melting/welding due to electrical flashover, loss of acceptable electrical performance etc. Usually corrosion is tolerated provided that there is no significant loss of metal. Where ball and socket or tongue and clevis joints have become frozen due to severe corrosion these items are considered as requiring replacement. In general fittings must not be allowed to deteriorate beyond the point where the mechanical safety factor is reduced unacceptably. While it may not be appropriate for all items, an approximate replacement guide is where there is a 25% reduction in the cross sectional area of load bearing metal, which is that part of any individual component through which the load is applied.
Gap (between Routine and CA requirements)	Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.

Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware.
	Inspect	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Detailed Assessment	Review Notis for trends or evidence of worn or corroded hardware. Specific inspection of a representative sample is recommended to assess likely remaining life.

Table 13. Suspension Hardware Purpose and Recommendations Matrix

A.1.3 Support Systems

Providing support to the Conductor System, Strain or Tension Structures require a higher level of reliability than general suspension support structures as this system is required to withstand tension or termination mechanical loads.

The installation of strain or dead end structures provides additional security in the event of cascade type failures. They have a higher structural capacity and are generally heavier than conventional suspension type supports.

A.1.3.1 Foundations

The foundations of structures support the structure. They are usually required to work in compression, uplift and shear. A problem with the foundations could lead to a tower collapse resulting in adjacent towers collapsing and lead to a cascade failure until the next strain structure in either direction is reached.

In addition to carrying compressive loads the concrete in the foundation also protects the steel reinforcing (important for tensile and shear capacity) from corrosive attack. To ensure that the concrete can carry out both of these functions it is essential that the concrete is of suitable durability.

The external interface between the steel and concrete is likely to be the first area to show signs of corrosion. This is due to the water (from rain and dew) that runs down the tower and collects at this point. Any detritus material at the interface can retain moisture and contribute to corrosion.

Image 6. Stobie Pole – Ground Line Corrosion

As the corrosion process requires water it is essential that the foundation tops are shaped or angled to allow water to flow freely from their surfaces. It is also important that the surrounding soil is free draining and does not allow water to pool around a foundation.

As only a small portion of the foundation is visible above ground it is important that the inspection that can be carried out is thorough.

Consideration should be made to a concrete durability survey, to be included in any maintenance plan, of the sub grade concrete to assess condition and provide end of life criteria.

Integrity testing of tower foundations can indicate foundations requiring further invasive investigation.

Reinforced / Unreinforced Foundations


Image 7. Unreinforced and (Exposed) Foundation

Circa 1965, an ETSA internal memo recommended the installation of a single ring of reinforcing steel to be placed near the top of concrete foundations to constrain radial movement of the foundation.

Foundations poured without this ring are susceptible to subsequent cracking where the stub leg enters the foundation due to normal shear stresses of the leg member. Such cracking if left unchecked can lead to accelerated corrosion of the buried steel and potential for foundation failure.

The installation of a small steel reinforcement ring within the concrete at the top of the foundation assists in the transfer of shear loads from the steel stub to the concrete and the surrounding soil without placing undue tensile stresses into the concrete foundation.

Component Function	Support the structure
Functional Failure	Structure loads not supported.
Failure Mechanisms	Corrosion / Loss of Section / Soil Erosion / Subsidence / Structure Movement.
Routine Maintenance	Routine maintenance allows for a cursory look at the top of the foundation for ground line corrosion and contributing influences.

		Ground line corrosion refers to both corrosion at the steel / soil interface (eg – for grillage type foundations) and corrosion at the steel / concrete interface (eg – for cast in-situ stubs in pile foundations). To help prevent ground line corrosion it is essential the area surrounding the foundation be considered as well as the foundation itself. Things looked for include: o Vegetation / moss covering foundations o Water pooling (or potential to pool), o Material covering foundations, o Foundation shaped to allow water to flow off freely. The level of sand and soil build-up against the footing shall be maintained at least 150mm below the top of the concrete excluding the 'dome'. Any foundation movement, or signs of foundation movement, should also be noted and coded appropriately. The main consideration for steel poles is loss of section due to corrosion, particularly at the ground line interface. Particular attention is paid to this area.
Gap (between Routine and CA requirements)		Routine Maintenance through patrols and inspections allows for a coursory visual inspection of the steel/concrete interface and an assessment of erosion / aggredation (exposure or burial of the concrete foundations). Hidden defects can exist under the ground interface, however for ElectraNet grillage installations, cathodic protection is installed and hence replacement and monitoring of sacrifical protective anodes is required to ensure protection is maintained.
Condition Assessment Recommendations	**Review**	Review monitoring of sacrifical protective anodes and aligned reports for evidence of rapid degredation or other issues.
	Inspect	Review monitoring of sacrifical protective anodes and aligned reports for evidence of rapid degredation or other issues.
	Sample	Review monitoring of sacrifical protective anodes and aligned reports for evidence of rapid degredation or other issues. Invasive inspection of a number of grillages should be undertaken to ensure grillages are protected.
	Detailed Assessment	Review monitoring of sacrifical protective anodes and aligned reports for evidence of rapid degredation or other issues. Invasive inspection of a number of grillages should be undertaken to ensure grillages are protected.

Table 14. Grillage Purpose and Recommendations Matrix

Component Function	Support the structure
Functional Failure	Structure loads not supported.
Failure Mechanisms	Corrosion / Soil Erosion / Cracking / Spalling / Subsidence / Structure movement / Foundation top covered / In-adequate drainage
Routine Maintenance	Routine maintenance allows for a cursory look at the top of the foundation for ground line corrosion and contributing influences. Ground line corrosion refers to both corrosion at the steel / soil interface (eg – for grillage type foundations) and corrosion at the steel / concrete interface (eg – for cast in-situ stubs in pile foundations).

		To help prevent ground line corrosion it is essential the area surrounding the foundation be considered as well as the foundation itself. Things looked for include: ○ Vegetation / moss covering foundations ○ Water pooling (or potential to pool), ○ Material covering foundations, ○ Foundation shaped to allow water to flow off freely. The level of sand and soil build-up against the footing shall be maintained at least 150mm below the top of the concrete excluding the 'dome'. Any foundation movement, or signs of foundation movement, should also be noted and coded appropriately.
Gap (between Routine and CA requirements)		Routine Maintenance through patrols and inspections allows for a coursory visual inspection of the steel/concrete interface and an assessment of erosion / aggredation (exposure or burial of the concrete foundations). Hidden defects can exist under the ground interface and non destructive testing is required to provide an assessment of foundation integrity and identify foundations of concern.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware
	Inspect	Non destructive testing of a sample of foundations to identify foundations of concern with invasive inspection to collaborate findings. Pay particular attention to non cohesive and / or aggressive soils.
	Sample	Non destructive testing of a sample of foundations to identify foundations of concern with invasive inspection to collaborate findings. Pay particular attention to non cohesive and / or aggressive soils.
	Detailed Assessment	Non destructive testing of all foundations to identify foundations of concern with invasive inspection to collaborate findings. Pay particular attention to non cohesive and / or aggressive soils.

Table 15. Piled footing Purpose and Recommendations Matrix

Component Function	Support the structure
Functional Failure	Structure loads not supported
Failure Mechanisms	Corrosion / Vandalism / Wear / Vibration
Routine Maintenance	Routine maintenance allows for a cursory look at the top of the foundation for ground line corrosion and contributing influences. Ground line corrosion refers to both corrosion at the steel / soil interface (eg – for grillage type foundations) and corrosion at the steel / concrete interface (eg – for cast in-situ stubs in pile foundations). To help prevent ground line corrosion it is essential the area surrounding the foundation be considered as well as the foundation itself. Things looked for include: ○ Vegetation / moss covering foundations ○ Water pooling (or potential to pool), ○ Material covering foundations, ○ Foundation shaped to allow water to flow off freely. The level of sand and soil build-up against the footing shall be maintained at least 150mm below the top of the concrete excluding the 'dome'.

		Any foundation movement, or signs of foundation movement, should also be noted and coded appropriately.
Gap (between Routine and CA requirements)		Routine Maintenance through patrols and inspections allows for a coursory visual inspection of the steel/concrete interface and an assessment of erosion / aggredation (exposure or burial of the concrete foundations). Hidden defects can exist under the ground interface and non destructive testing or invasive testing is required to provide an assessment of foundation integrity and identify foundations of concern.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware
	Inspect	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Sample	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Detailed Assessment	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.

Table 16. Pole Foundations Purpose and Recommendations Matrix

Component Function	Support the structure
Functional Failure	Structure loads not supported
Failure Mechanisms	Corrosion / Wear
Routine Maintenance	Routine maintenance allows for a cursory look at the top of the foundation for ground line corrosion and contributing influences. Ground line corrosion refers to both corrosion at the steel / soil interface (eg – for grillage type foundations) and corrosion at the steel / concrete interface (eg – for cast in-situ stubs in pile foundations). To help prevent ground line corrosion it is essential the area surrounding the foundation be considered as well as the foundation itself. Things looked for include: o Vegetation / moss covering foundations o Water pooling (or potential to pool), o Material covering foundations, o Foundation shaped to allow water to flow off freely. The level of sand and soil build-up against the footing shall be maintained at least 150mm below the top of the concrete excluding the 'dome'. Any foundation movement, or signs of foundation movement, should also be noted and coded appropriately.

Gap (between Routine and CA requirements)		Routine Maintenance through patrols and inspections allows for a coursory visual inspection of the steel/concrete interface Hidden defects can exist under the ground interface and non destructive testing or invasive testing is required to provide an assessment of foundation integrity and identify foundations of concern.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware
	Inspect	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Sample	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Detailed Assessment	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.

Table 17. Stay Anchors Purpose and Recommendations Matrix

A.1.3.2 Structure above K Point

The Structure above the k point refers to the members and components that make up the structure from just above the ground line interface and includes tower legs, body, superstructure, cross arms and earthpeaks.

Component Function		A mechanical structure used to keep live components off the ground
Functional Failure		Unable to support mechanical load.
Failure Mechanisms		Corrosion / Damaged Members / Wear / Spalling (concrete) Cracking / Leaning.
Routine Maintenance		A comprehensive Tower member classification table is provided with patrollers carrying out routine patrols and inspections which provide guidance on allowable deviations from straightness for a variity of towers. During patrols any leaning poles should be noted, whether the lean is due to everyday conductor loads or movement of the foundation. It is up to the patroller to decide on the seriousness of any lean. An engineering assessment may be required.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance (particually climbing inspections) should be sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degredation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate
	Sample	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate

	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate

Table 18. Structure Purpose and Recommendations Matrix

A.1.3.3 Primary Members (Including Plates)

The primary members of a transmission tower carry the main mechanical loads and generally consist of much heavier steel than the secondary members. A failure of a main member causes a serious structural deficiency in the structure that could cause it to collapse under everyday operating conditions.

Primary members can be damaged in a number of ways including vehicle impacts, overloading and damage during or prior to construction. The members are also subject to corrosion.

During inspection, any bent or deformed primary members should be noted, including the member number which should be stamped in to it. An engineering assessment should be carried out to determine if the member needs to be repaired or replaced. Any members with corrosion should be reported along with the extent of the corrosion.

Primary Members
Any members on a critical load path that carry everyday loads whereby the loss of capacity of those members would have a serious and immediate consequence on the structural integrity of the structure.

Main Members include;
- Structure Leg Members
- Crossarm Top & Bottom Chords
- Earthpeak Leg Members
- Leg Diagonals
- K Bracing
- Structure Diagonal Members
- Cross Bracing (Horizontal Plan Bracing)

Secondary Members
Any members other than main members that carry nominal everyday static loads providing support to the main members or allow transverse loads down through the truss structure to the foundation.

Redundant Members
Redundant Members are generally limited to those members providing buckling support to secondary members or perform duties of a minor nature such as ladder attachments. These members are at best only required during critical loading events and are provided to effectively stiffen the structure rather than carry significant loads

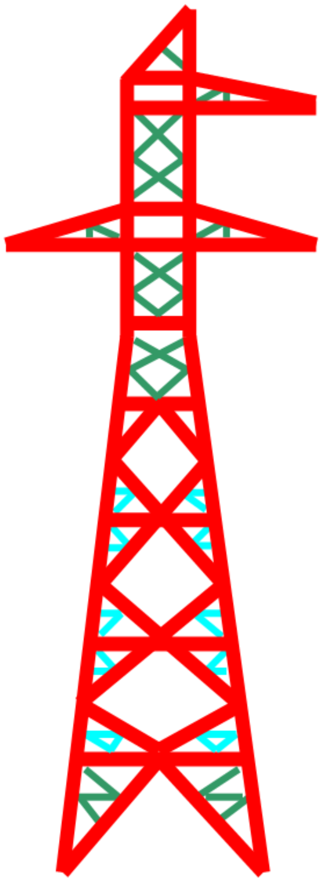

Figure 6. Schematic showing Member Importance and Duty (with Narrative)

A.1.3.4 Secondary Members

Duty forces of secondary members are not as great as on primary members. These members therefore usually only become critical components when the structure is loaded beyond every day conditions or when unusual out of plane forces act upon the structure.

Failure of a secondary member under everyday conditions should be able to be contained. However conditions may be such that the failure of the secondary member results in additional load being applied to other members. If unchecked, this could lead to a tower collapse in the extreme case and consideration should be given to appropriate engineering input for damaged secondary members.

Secondary members can be damaged in a number of ways including vehicle impacts, overloading and damage during or prior to construction. The members are also subject to corrosion.

During the inspection any bent or deformed secondary members shall be noted, including the member number (which should be stamped into it). An engineering assessment is recommended to determine if the member is suitable in its current state or if repairs or replacement are required.

Any members with corrosion shall be reported along with the extent of the corrosion.

A.1.3.5 Bolts

Bolts are used to join the members of transmission structures. Bolts used on transmission structures have special characteristics and are commonly referred to as tower bolts. Bolts that come loose or fail in any way can ultimately cause a structure to collapse.

Tower bolts usually have a thinner layer of galvanic coating than the main tower members so are typically the first component to show signs of corrosion. Some rusting is acceptable but not to the extent that the tensile or shear strength of the nut or bolt assembly is significantly affected.

Special attention should be paid to any corrosion of bolts as it is useful for determining the rate of degradation of a particular built section.

Nuts and bolts coming undone are not uncommon usually caused by vibration and a lack of initial tightening at the time of construction.

Component Function	Used to join structure parts together
Functional Failure	Joints not securely held.
Failure Mechanisms	Corrosion / Wear / Fatigue / Vibration / Missing / Loose / Double nut missing where it is required / Wrong type /

Routine Maintenance		Tower bolts usually have a thinner layer of galvanic coating than the main tower members so are typically the first component to show signs of corrosion. Some rusting is acceptable but not to the extent that the tensile or shear strength of the nut or bolt assembly is significantly affected. Special attention is paid to any corrosion of bolts as it is useful for determining the rate of degradation of a particular built section. Galvanised flat washers (not spring washers) should be fitted under the nut of all bolts, No threads should be in the shear plane, Bolts must be as a minimum at least flush with the nut (ideally 1.5 threads should protrude above the nut), Nuts should be tight to due to compression of the jointed members, not because the thread has bottomed out. Bolts and nuts, including step bolts, are to be replaced before corrosion has advanced to the stage that the assembly is becoming significantly weakened by rust (ie when any part of the bolt or the nut is corroded to the extent that it can no longer take its design load). In practice, if corrosion has occurred to the extent that a normal socket or ring spanner cannot be securely fitted to the bolt head or nut, then replacement is required.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance (particually climbing inspections) should be sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degredation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate
	Sample	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate
	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degredation. Undertake specific assessment on remaining galv and in some cases abnormal wear. Limited sampling may also be appropriate

Table 19. Bolts Purpose and Recommendations Matrix

A.1.3.6 Stays

Stays are used to economically provide additional support to pole or mast structures. Failure of a stay can cause a mast or pole to collapse.

Stay wires are subject to aeolian vibration in the same way that conductors are. Due to this vibration and residual strand settlement (most of the strand settlement will have occurred during installation and construction) the stays may lose tension over time. This can cause masts or poles to deflect and move unacceptably increasing the chance of a buckling failure of the structure. The tension of each guy on a structure should be uniform to prevent this.

Stay wires are of similar construction to conductors being a helical laid cable. The outer strands (and inner if possible) should be checked for signs of fretting, abrasion and corrosion. Samples may also be taken for further analysis by a specialist.

In addition the tensions of the stays need to be checked and adjusted to ensure stays at each structure are of sufficient and uniform tension. The helical grip shall also be closely inspected at the point of contact with the thimble, for signs of fatigue, broken or flattened strands.

Component Function		Support the structure
Functional Failure		Structure loads not supported.
Failure Mechanisms		Corrosion / Wear.
Routine Maintenance		Routine maintenance allows for a cursory look at the top of the foundation for ground line corrosion and contributing influences. Ground line corrosion refers to both corrosion at the steel / soil interface (eg – for grillage type foundations) and corrosion at the steel / concrete interface (eg – for cast in-situ stubs in pile foundations). To help prevent ground line corrosion it is essential the area surrounding the foundation be considered as well as the foundation itself. Things looked for include: o Vegetation / moss covering foundations o Water pooling (or potential to pool), o Material covering foundations, o Foundation shaped to allow water to flow off freely. o The level of sand and soil build-up against the footing shall be maintained at least 150mm below the top of the concrete excluding the 'dome'. Any foundation movement, or signs of foundation movement, should also be noted and coded appropriately.
Gap (between Routine and CA requirements)		Routine Maintenance through patrols and inspections allows for a coursory visual inspection of the steel/concrete interface. Hidden defects can exist under the ground interface and non destructive testing or invasive testing is required to provide an assessment of foundation integrity and identify foundations of concern.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of worn or corroded hardware
	Inspect	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Sample	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.
	Detailed Assessment	Invasive Inspection or non destructive testing of a sample of pole foundations to identify foundations of concern. Pay particular attention to non cohesive and / or aggressive soils.

Table 20. Stay Anchors Purpose and Recommendations Matrix

A.1.3.7 OHEW Hardware / Bonding

Bonding of the earthwire and OPGW is required to allow lightning surges to pass as efficiently as possible to the tower and allows for the efficient passage of stray or fault currents (rather than through the bolted components). If no bonding existed, such currents would have to pass through other connected components leading to increased wear and degradation of the mechanical connections.

Broken bonds can exist on the earthwire assembly due to a combination of aeolian vibration and a relatively stiff bonding conductor. The earthwire attachment hardware should allow for conductor swing due to wind resulting in movement of the earthwire assembly and this will also contribute to wear.

Broken bonds vary from broken lug connections at the cable end through to loose/missing bolts or disconnection at the tower end.

Component Function		To mechanically join conductors. Allow a path for electrical current and communications to flow (in the case of OPGW).
Functional Failure		Electrical or Mechanical Failure.
Failure Mechanisms		Corrosion / Wear / Missing.
Routine Maintenance		Closely inspected for any signs of vibration damage at support points. If conductor-to-tower bond cables are fitted then the security of the bond clamps, and for signs of fatigue failure on the bond cable are checked. Earth wire fittings that are not directly bonded to the structure can suffer flash over damage and as such, items should be coded so that they are replaced if there is evidence of fusing of metal surfaces. Tower attachment points are also checked for excessive wear.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of frayed or worn bonds.
	Inspect	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Sample	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.
	Detailed Assessment	Review Notis for trends or evidence of frayed or worn bonds. Specific inspection of a representative sample is recommended to assess likely remaining life.

Table 21. Earthwire / OPGW Joints (bonding to structure) Purpose and Recommendations Matrix

A.1.4 Sub Component Systems

Whilst not central to the immediate functionality of the asset, failure of the following sub-components may lead to safety, maintainability or if left unchecked operational issues.

A.1.4.1 Climbing Aids

Climbing aids are fitted to a structure to make climbing easier and safer. Climbing aids on this line are a combination of step bolts and ladders. Missing or damaged climbing aids can make climbing more difficult and dangerous.

Climbing aids can come loose or are sometime not fitted during construction. Climbing aids are also subject to corrosion.

Attachments of climbing aids to towers are generally made from lighter steel members than the main tower members including bolts. As such they are likely to corrode first and inspection of these items should not be neglected.

Check to see that the appropriate climbing aids are fitted and assess their condition.

Component Function		Make structures easier and safer to climb.
Functional Failure		Structures are not easier or safer to climb.
Failure Mechanisms		Corrosion / Wear
Routine Maintenance		Not considerd specifically, other than assessed during climbing inspections.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degredation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degredation
	Sample	Review Notis for trends or evidence of accelerated or unexpected degredation
	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degredation

Table 22. Climbing Aids Purpose and Recommendations Matrix

A.1.4.2 Earthing

Earthing is a system of conductive material buried in the ground to reduce the electrical resistance between a structure and the earth. The earthing system is installed to allow current to flow to earth during an earth fault or lighting strike. A good earth (low resistance) reduces the probability of insulator back flashover during overvoltage events such as lightening or switching surge.

The control of step and touch voltages at transmission structures is recognised as being primarily a risk management process as improvements in impedance and resistance can have an adverse effect on safety at the structure.

The South Australia Electricity (General) Regulations (section 5) require:

Earthing systems must be inspected and tested from time to time to ensure that the design requirements of:

(a) resistance to the general mass of earth; and
(b) electrical capacity; and
(c) step, touch and transfer potentials; and
(d) corrosion resistance,

are being maintained.

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<table>
<tr><td colspan="2">Component Function</td><td>Reduce the step and touch potential of structures. Reduce the likelihood of insulator flashovers.</td></tr>
<tr><td colspan="2">Functional Failure</td><td>Step and touch potential are not sufficiently reduced. TFR too high, increasing chances of back flashover.</td></tr>
<tr><td colspan="2">Failure Mechanisms</td><td>Corrosion / Erosion / Wear / Fatigue / Theft / Not bonded to structure / Earth bond undersize.</td></tr>
<tr><td colspan="2">Routine Maintenance</td><td>Earthing systems form an integral part of transmission line protection and Patrollers / Inspectors check the condition of the earthing system;

Steel Lattice Structures
The earthwire installed on lattice structures are checked that they are effectively bonded to the steel frame work of the tower and to the installed earth electrodes adjacent to the footings.

Stobie Poles
The earthwires on double “Pi” pole construction are checked that they are bonded to the steel of the poles. As various earthing arrangements have been installed, the integrity of the earthing system is typically maintained as constructed.

Spun Concrete Poles
Spun concrete poles have been installed at various locations on the transmission line network. Each pole has earthing ferrules incorporated in the manufacture of the pole.

It is a requirement of the Electricty Act / Regulations to maintain earthing systems in South Australia. Typically poles and towers within 2.5km of a substation are inspected more frequently than the rest of the network</td></tr>
<tr><td colspan="2">Gap (between Routine and CA requirements)</td><td>Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.</td></tr>
<tr><td rowspan="4">Condition Assessment Recommendations</td><td>Review</td><td>Review Notis for trends or evidence of accelerated or unexpected degredation</td></tr>
<tr><td>Inspect</td><td>Review Notis for trends or evidence of accelerated or unexpected degredation</td></tr>
<tr><td>Sample</td><td>Review Notis for trends or evidence of accelerated or unexpected degredation</td></tr>
<tr><td>Detailed Assessment</td><td>Review Notis for trends or evidence of accelerated or unexpected degredation</td></tr>
</table>

Table 23. Earthing Purpose and Recommendations Matrix

A.1.4.3 Anti Climbs

Anti climbs are attached to structures to deter people from climbing the structure. They are usually fitted in urban areas and near roads or other places that people are likely to be.

Anti climbs often suffer from broken strands of barbed wire, corrosion. And can also be the target of vandals.

A defect report provides locations where anti climbs are reported as missing or have broken strands.

Any future inspection should confirm structures where anti climbs are fitted and the condition of barbed wire and supports. Proximity to roads other hazards should be recorded to assist in the identification of any towers required to have anti climbs fitted.

Component Function		Prevent unauthorised persons climbing structures
Functional Failure		Person is not restricted from climbing.
Failure Mechanisms		Corrosion / Vandalism / Wear / Vibration
Routine Maintenance		Anti-climbing barriers identified during patrols or inspections as defective are coded so that they will be repaired in a timeframe appropriate for the area. Things checked for during patrols and inspections include: o Broken strands of barbed wire, o Prongs loose or missing on crown of thorns type anti climbs, o Severe corrosion affecting ability to work effectively or cause damage to host structure, o No anti climb fitted on a structure that should have one, o No lock / bolt fitted where required, o Lock not an ElectraNet standard lock. Generally, neither barriers nor notices will be fitted on transmission pole lines. Note: Prior to the early '70's, "crown of thorns" anti-climbing devices were fitted to tower structures. These devices are non standard thus any structures where these are fitted and meet the above locations criteria should be up-graded to the standard required. The remainder of the structures falling outside these determinations shall remain as installed.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degredation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degredation
	Sample	Review Notis for trends or evidence of accelerated or unexpected degredation
	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degredation

Table 24. Anti Climbs Purpose and Recommendations Matrix

A.1.4.4 Signage

Each structure should have a danger and identification / number plate located on the step bolt side.

Aerial and Phase plates are fitted on terminal structures as well as every tenth structure.

Inspections of the line should note any degradation or damage to signage. Special attention should be given to any missing signs with particular attention to expected aerial and phase plates on every tenth structure.

Component Function		Provide information on tower number, feeder number, phasing etc.
Functional Failure		Signs are missing or do not provide required information.
Failure Mechanisms		Corrosion / Bullet holes / Illegible signs / Information incorrect.
Routine Maintenance		Patrollers / Inspectors check that signs: o Are legible o Are installed as required o Display accurate information o Are located correctly o Signs used on transmission structures include circuit identification, warning signs and stickers, structure number plate and aerial number plate.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degredation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degredation
	Sample	Review Notis for trends or evidence of accelerated or unexpected degredation
	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degredation

Table 25. Signage Purpose and Recommendations Matrix

A.1.4.5 Communications

Where the line carries an OPGW communications link, reference should also be made to communications requirements. Historical information taken over time such as OTDR traces may provide evidence of abnormal degradation to vibration.

A.1.4.6 Easements

Access

Access tracks are maintained to allow quick and efficient access to transmission structures. These are required so that routine patrols and inspections can be carried out and where necessary to allow maintenance to be performed quickly. A poorly maintained access track can prevent the required equipment from reaching a site resulting in repair or restoration work being delayed and incurring additional costs.

Tracks may be owned or maintained by various parties.

Tracks can be damaged by wind and water erosion and other events such as slips and washouts. Some tracks have items such as bridges and culverts that need to be maintained to allow the track to maintain its function.

Other obstacles such as gates are also common. These can be in a poor state or can be locked by a third party.

Any areas of the track that are impassable or impassable by equipment likely to be needed after a failure, eg crane should be noted. Any gates that are locked with by non-standard locks should be noted.

Where tracks are impassable any alternative routes should be described.

Component Function		Provide access to transmission structures for routine maintenance, refurbishment projects or emergency repairs.
Functional Failure		Access to Transmission Structure not available.
Failure Mechanisms		Erosion
Routine Maintenance		It is crucial to maintain access to transmission assets so that regular patrols can be carried out and emergency work can be completed without hindrance. While some areas may have poor vehicular access, ElectraNet may not necessarily require the ground access to be improved as other forms of access may be considered acceptable. Access to structures and other sites is normally to be by 4WD vehicle, unless such access is impractical, uneconomic, or is prevented by environmental or other constraints.
Gap (between Routine and CA requirements)		Visual Assessment as per routine maintenance is sufficent to satisfy condition assessment requirements.
Condition Assessment Recommendations	**Review**	Review Notis for trends or evidence of accelerated or unexpected degradation
	Inspect	Review Notis for trends or evidence of accelerated or unexpected degradation
	Sample	Review Notis for trends or evidence of accelerated or unexpected degradation
	Detailed Assessment	Review Notis for trends or evidence of accelerated or unexpected degradation

Table 26. Purpose and Recommendations Matrix

Vegetation

There are several aspects that need to be considered for vegetation within the easement.

Vegetation can cause line outages and in extreme events have the potential for a fire start. Vegetation that touches or gets too close to live components on the transmission line can cause an earth fault that trips the line out of service. Depending on the nature of the fault the outage may only be temporary, or it may last until crews are able to remove the offending vegetation.

Vegetation also has beneficial qualities and can be used to help reduce the effects of erosion.

Vegetation is currently managed on a three yearly cycle under the existing ElectraNet management processes. During trimming, a three year re-growth buffer is provided for to allow the vegetation to the mandatory clearance zone.

Weeds

Weeds and noxious plants may be found in the easement of transmission lines. Some of these will have only nuisance value while others may be declared plants that need to be managed according to the requirements of the Department of Water, Land and Biodiversity Conservation.

Transmission Line Condition Assessment Commentary

Appendix B: Framework

September 2011

Version B

Copyright and Disclaimer

Revision Record

Date	Version	Description	Author	Checked By	Approved By
22/9/10	A	Initial Draft	Ian Flatley ENGINEER		
30/09/2011	B	Rewrite incorporating key learning's from desktop CA assessments	Ian Flatley ENGINEER		

B.1 Purpose

The aim of condition assessment is to establish where on the curve the various components that make up a transmission line fit, to provide an estimate as to both the general condition and the expected remaining life of components that make up the asset. Identification of any special inspection or detailed assessments that are required to make such decisions should also be provided.

The following graph provides a high level view of the interrelationship between the condition assessment results and asset management decisions with respect to proposed actions.

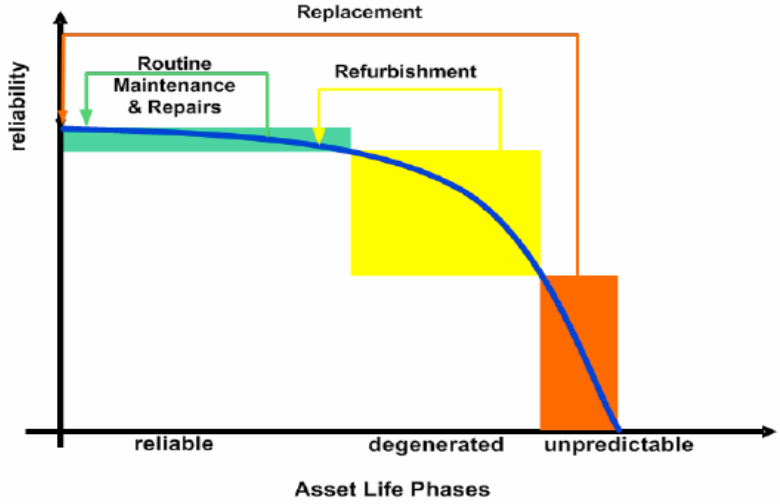

Table 1. States of Aging Concept and Possible Asset Management Actions

(Cigre TB309 Asset Management of Transmission Systems and Associated CIGRE Activites)

The new AS/NZS 7000:2010 Overhead Line Design Standard defines the Design working and Service life of an overhead line (Clause 2.3) as;

> *2.3 Design Life of Overhead Lines*
>
> *The design life, or targeted nominal service life expectancy, of a structure is dependent on its exposure to a number of variable factors such as solar radiation, temperature, precipitation, wind, ice and seismic effects.*
>
> *The service life of an overhead line is the period over which it will continue to serve its intended purpose safely, without excessive maintenance or repair disproportionate to its cost of replacement and without exceeding any specified serviceability criteria. This recognises that cumulative deterioration of the overhead line will occur over time. Therefore, due maintenance and possible repairs will be required from time to time to maintain the structure in a safe and useable condition over its service life.*

Expectations of Transmission Line performance and safety have changed over time. Condition Assessment acknowledges that the Transmission Line will perform as intended at commissioning. No specific inference should be made that the components or lines constructed years ago, comply with modern expectations and standards.

Appendix B Condition Assessment Framework

The framework below discusses the how various pieces of available line data are pieced together

The role of the various components, how they fit into the line system together with their degradation and failure mechanisms is discussed in Appendix A.

B.2 Component Coding

In order to provide both a snapshot of the components condition and likely remaining life, quality data should be available identifying the component type. Ideally component coding should be taken to the component level indicating, type, make and date of installation of each component.

The current level of available Transmission Line schedule information falls short of that required to enable a bottom up assessment, therefore for the purposes of the condition assessment reports undertaken April – October 2011 a top down assessment of available lines information was undertaken.

Component coding is discussed in more detail in B.9 Future Inspection Requirements (Discussion) below.

B.3 Condition Coding

The following tables are used to score the general condition of the line elements with the understanding that individual defects are managed adequately through routine maintenance.

Condition Code 5 (Good)	Impending failure will be detected within inspection cycle.	Plant elements suit modern specification.
Condition Code 4	Impending failure will be detected within inspection cycle.	Plant elements are in good condition and will maintain expected level of reliability.
Condition Code 3	Impending failure will be detected within inspection cycle.	Plant elements are sound but show some minor deterioration. This however will not affect plant reliability.
Condition Code 2	Failure may occur within inspection cycle.	Plant elements showing signs of deterioration and may cause plant to become unreliable.
Condition Code 1 (Bad)	Failure will occur well within inspection cycle.	Plant elements are in poor condition and failure is impending. Plant will become unreliable*. Replacement required

Table 2. Condition Profile.

*Such unreliability will affect operating cost and plant availability targets.

B.4 Confidence Grade of Data

In addition to the assessment of a condition code for each of the components, a Confidence Grade was also applied with respect to the quality of the information.

Confidence Grade A	•Recently Built. •Recent Complete Detailed Inspection. •No information to suggest otherwise. •100% Certain.
Confidence Grade B	•Limited Sample of Representative Detailed Inspection. •Preliminary Inspection. •Decisive Non Destructive Testing, excellent quality results. •Mild Doubt on an "A" result
Confidence Grade C	•Inspection on small Sample. •Preliminary testing - poor quality results. •Inspection Result on Similar Line (With B Class results). •Interpolation of Notis. •interpolation of Interviews / General knowledge.
Confidence Grade D	•Old Inspection Data. •Random Sample / Inspection. •Extrapolation of Notis. •Extrapolation of Interviews / General knowledge.
Confidence Grade E	•Environmental / Life Assessment. -based on anticipated life span of component (for Environmental Zone) •Qualitative analysis. •Interviews / General Knowledge. •"Gut Feel".

Table 3. Confidence Grade

B.5 Indicative Remaining Life

An estimate of where a component is on its environmental life cycle will require the input of any three of the following four parameters;

- Environmental Aggressiveness
- Age of Component
- Current Condition
- Replacement Criteria

The following graph shows the interdependency of each parameter;

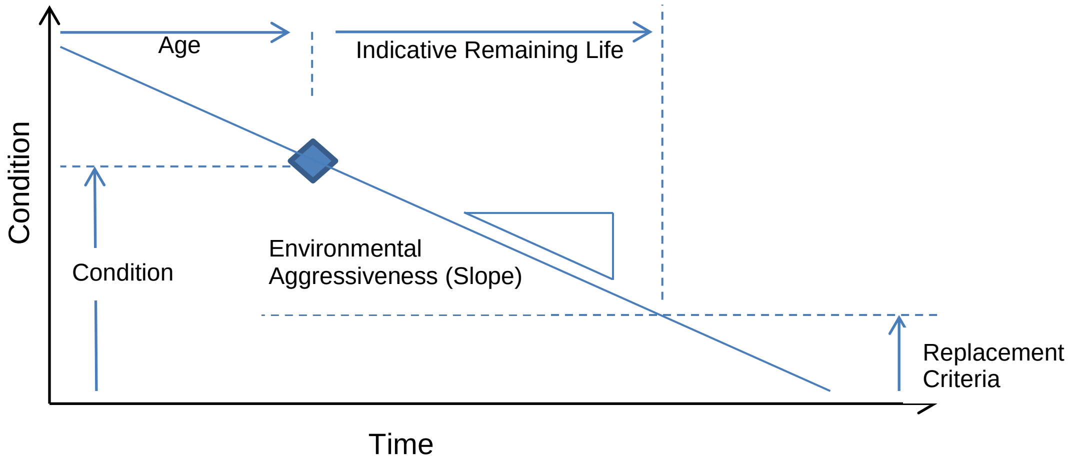

Figure 1. Simple (Linear Degradation) Condition Assessment Model

For example, without going into the field or knowing precisely the components condition, an assessment could be made utilising the other three parameters. Actual Field Inspections undertaken with the appropriate support and coding information will further improve this assessment.

Other contributing factors such as wear or fatigue should be considered and may reveal a shorter life. A good example of this is fatigue of ACSR or Steel conductor when installed under higher tension.

Such assessment on a component basis at each structure or along the line as the asset crosses different environmental classifications can be undertaken by either;

- Desktop Survey

Obtaining historic information such as fault history, known refurbishment or replacement works, asset information from line schedules “F files” can be combined with environmental data and historical information such as fault and Notification data.

- Field Inspection

Establishing the actual life cycle location will require a focus on actual condition at the structure, or focus on a likely representative sample combined with adequate environmental and performance criteria.

This commentary focuses on the derivation of a number of Condition Assessment Reports developed April – October 2011 by Groundline.

B.6 Component Life Cycle analysis

How Components age / wear

Specific knowledge on the various degradation and aging mechanisms as they apply to the various components that make up a Transmission line are discussed in depth in Appendix A: Components.

Additional end of life criterion and assessment during routine maintenance can also be sourced from ElectraNet document 1-03-G01 Guideline A&O Transmission Line Maintainance Inspection Coding.

B.6.1 Environmental Study

An Environmental consultant was engaged to determine geographically, through his knowledge and from commercially available environmental overlay maps, the environmental conditions for each structure / feeder and assist in the development of a holistic state-wide corrosion map.

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B.7 Derivation of Indicative Remaining Life

In the absence of high order deterioration and failure data for the majority of the ElectraNet network reviewed, general probabilistic formulae have been utilised to generate indicative remaining life timeframes.

Specifically a skew-normal distribution has been utilised to generate expected remaining life of components using a swap table of probability distribution properties vs. condition and quality of data properties, and the expected remaining life as calculated elsewhere.

Given the standard normal probability density function:

$$\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$$

the cumulative distribution function:

$$\emptyset(x) = \int_{-\infty}^{x} \varphi(x)dt = \frac{1}{2}\left(1 + erf\left(\frac{x}{\sqrt{2}}\right)\right)$$

and given the probability density function modification parameters:

$$f(x) = \frac{2}{\omega}\varphi\left(\frac{x-\varepsilon}{\omega}\right)\emptyset\left(\alpha\left(\frac{x-\varepsilon}{\omega}\right)\right)$$

The skew-normal probability density function becomes:

$$f(x) = \left(\frac{2}{\omega}\left(\frac{1}{\sqrt{2\pi\omega^2}}\right)e^{-\frac{(x-\varepsilon)^2}{2\omega^2}}\right)\left(\frac{1}{2}\left(1 + erf\left(\frac{(x-\varepsilon)\alpha}{\sqrt{2\omega^2}}\right)\right)\right)$$

Where ω is the scale or 'statistical dispersion', α is the shape or 'skewness', and ξ is the location or 'shift' of the distribution.

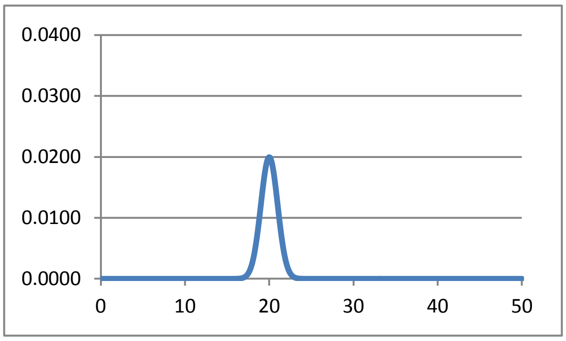
Using the above function and the following swap table of properties generated based on 'rule of thumb' estimates and assuming ξ is equal to the average predicted remaining life calculated elsewhere:

		Quality of Data					
		A	**B**	**C**	**D**	**E**	
Condition Code	**1**	4	4	4	4	4	α
		1	2	3	4	5	ω
	2	2	2	2	2	2	α
		1	2	3	4	5	ω
	3	0	0	0	0	0	α
		1	2	3	4	5	ω
	4	-2	-2	-2	-2	-2	α
		1	2	3	4	5	ω
	5	-4	-4	-4	-4	-4	α
		1	2	3	4	5	ω

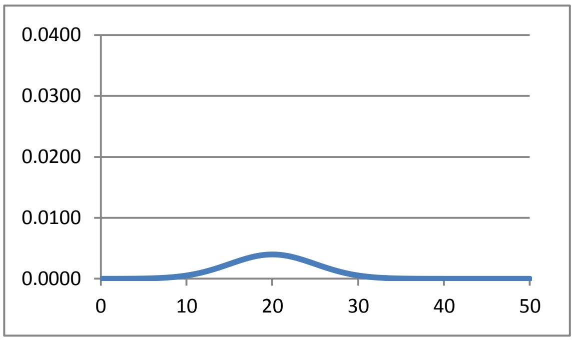
A prediction of expected maximum and minimum remaining life is generated based on the 90^{th} percentile of the skew-normal probability density function spread.

Below are examples of the effect of the properties on the distribution function:

ω 1	α 0	ξ 20	ω 5	α 0	ξ 20

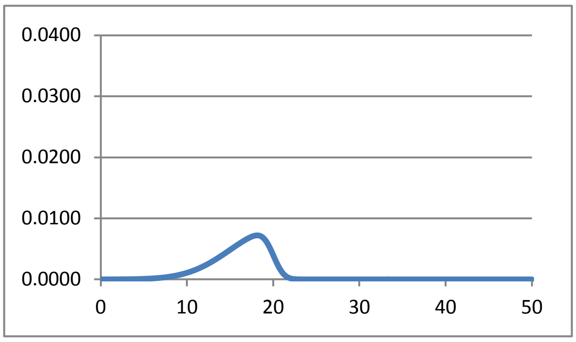


Curve A: 20 year Indicative Remaining Life
High Confidence Grade of Measurements (Grade A)
Good Condition (Code 3)

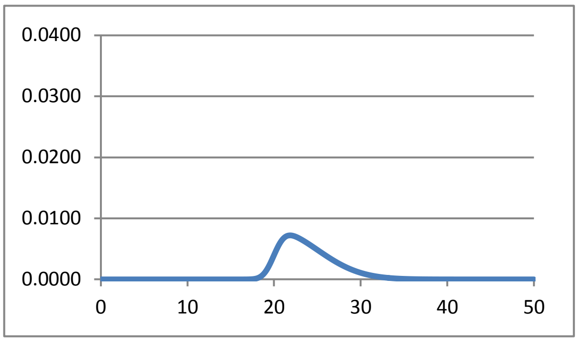


Curve B: 20 year Indicative Remaining Life:
Low Confidence Grade of Measurements(Grade A)
Good Condition (Code 3)

ω 5	α -5	ξ 20	ω 5	α 5	ξ 20

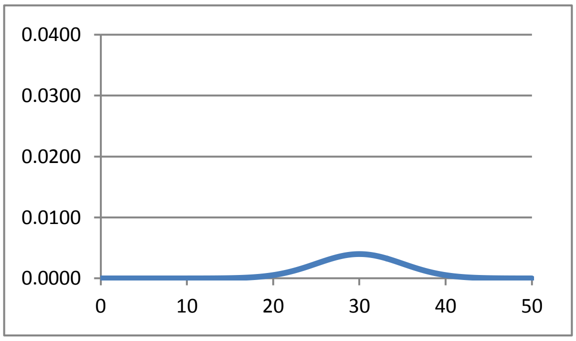


Curve C: 20 year Indicative Remaining Life:
Low Confidence Grade of Measurements (Grade E)
Poor Condition (Code 1)

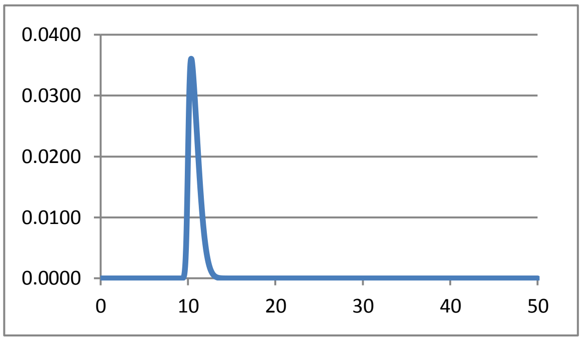


Curve D: 20 year Indicative Remaining Life:
Low Confidence Grade of Measurements (Grade E)
Excellent Condition (Code 5)

ω 5	α 0	ξ 30	ω 1	α 5	ξ 10



Curve E: 30 year Indicative Remaining Life:
Low Confidence Grade of Measurements(Grade E)
Good Condition (Code 3)



Curve F: 10 year Indicative Remaining Life:
High Confidence Grade of Measurements(Grade A)
Poor Condition (Code 1)

Where there are two or more groups of similar component on a line, i.e. two sections of the same line built at different times, multiple distributions are generated and summed together. The resultant curve is then scaled to ensure the cumulative total of the combined distributions is one. This scaling is also performed on single distribution curves to on a reduced scale to ensure the cumulative total is always one.

Example:

[redacted]

Findings from "F" files and SAP Noti's reported the conductor had signs of degradation indicating limited life in isolated areas of the conductor. Reports of "grease holidays" indicate localised degradation. Whilst not indicative of the wider of the conductor system, this nonetheless provides evidence that the conductor is aging, has issues and will require additional attention, including possible replacement.

This feeder runs for much of its southern section in a "C4" corrosion zone. Reported instances of corroded bolts on the structures also provide evidence that this section of the line is in a higher corrosive environment.

Whilst this feeder runs for most of its length in the more aggressive C4 environmental zone, 80% of the conductor on this feeder was assessed as being Condition Code 3 (Impending failure will be detected within inspection cycle Plant elements are sound but show some minor deterioration), with the remaining 20% as Condition Code 2. (Failure may occur within inspection cycle. Plant elements showing signs of deterioration and may cause plant to become unreliable).

The Grade of Confidence in the data was classed as Confidence Grade D (Old Inspection Data, Random Sample / Inspection, Extrapolation of Noties, Extrapolation of Interviews / General knowledge).

From the above Component Life under Different Environmental Conditions table we can see that a typical ACSR (greased) conductor is expected to provide a life of 50 – 80 years in a corrosion zone C3 with 40 – 60 years in a corrosion zone C4.

[redacted]

[redacted]

Figure 2. Indicative Remaining Life: Conductor Feeder 1837

[redacted]

Table 6. Conclusions Table (as per Condition Assessment Reports)

The algorithm discussed above provides an indicative remaining life whilst also assisting the derivation of recommendations in line with the matrix established above.

In this case the following recommendations are made for the conductor on this feeder;

[redacted]

A generic recommendations matrix was also developed to assist scoping of further inspection or detailed assessment works. As can be seen from the table below, higher confidence of data flows through to a reduction in the effort required in terms of reviews and inspection requirements.

[redacted]

Table 7. Recommendations Matrix

Specific engineering input is avoided and reference should be made to the commentary section of this report (Appendix A) in cognisance with the lines duty, importance and consequence of an event occurring with respect to what, where and how such inspections, sampling and detailed assessment should be carried out.

Condition Assessment Recommendations	***Review***	*Review Notis for trends or evidence of conductor bulging / white corrosion product along conductor. Pay particualr attention to old ES2 damper and attachment damage. Consider much damage will be hidden from field inspections during normal routine maintenance.*
	Inspect	*ACSR: Visual Inspection (close) to assess extent of bulging, white corrosion products or other evidence of damage leading to identifiable trends. Non destructive testing may assist in identifying areas requiring sampling for end of life assessment.*
	Sample	*Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.*
	Detailed Assessment	*Obtain samples of conductor for life cycle assessment by competant personal and seek material science input.*

Table 8 Conductor Purpose and Recommendations Matrix (Excerpt from Appendix A):

B.8 Additional Source Material

In addition to the above review, additional information was sourced from multiple sources to provide a history of the line with the intent of identifying trends or areas of specific concern.

This information was tabulated into the findings section of the report as facts with little narrative other than the source of the information normally provided in brackets.

These findings together with the environmental, age and condition scores enabled a derivation of a condition code and confidence grade score. Where applicable, a brief narrative was provided in the conclusions section to support and validate

B.8.1 Interview Process

Interviews were held with five senior ElectraNet personnel as to their experiences and general knowledge of the assets. These Engineers held extensive Transmission Line experience within the South Australian system. These interviews were held in June / July 2011 and provided valuable information which was utilised to confirm many of the findings and draw the appropriate conclusions from.

A matrix of interview results was subsequently assembled. This was used in identifying trends and a general “feel” for an assets condition that may not have been evident from the other sources of information.

This interview information was not used in isolation of other information, but rather as an indication that further investigation into a particular identified component was warranted, or in support of the other information gathering on components.

B.8.2 Review of Available Information

B.8.2.1 F Files

These files contain archival information such as procurement, construction and maintenance issues of feeders and circuits up to the mid 1990’s. The F files were recently scanned, however the information was not in a readily retrievable format and required a re-indexing process.

It was found that much of the useful information was split and shuffled within various “F” files and required processing to retrieve in a functional format. Indexing was carried out on both feeders being assessed and other more generic information.

To date, over eight hundred files were suitably indexed for the feeders analysed. These files are provided as a functional historical maintenance and operational archive.

The F Files were researched for any information that would give an indication as to the present condition of the Asset. For example if conductor was discovered as being supplied with defects, then this was noted for all conductors from that approximate era. This information was then used as an input to assess the present conductor condition (along with the other factors).

B.8.2.2 SAP Notifications

The SAP notifications were assembled into look-up tables in Excel, and interrogated using various pivot tables and queries. This data was then further analysed to report on the number, type, and trends of work that was has occurred over recent years.

This information was used as an input to assess the components current condition and provided an important historic performance of the transmission line, indicating areas of concern or trends. Particularly useful in absence of any specific inspections, the number of defects recorded in notifications as well as the nature of the defect was reported within the findings section of each report.

B.8.2.3 Line Schedule Information

ElectraNet sourced line schedule information such as age, number and type of structures, length of line was obtained utilising Grazer. The line schedule information was also used as a pointer towards more detailed information, such as the drawings advising insulator and hardware type. Field notes such as construction contractors, and information on some recent upgraded also contained within Grazer assisted with identifying potential for similar issues on other lines.

B.8.2.4 Various Defect and Condition Assessment Reports

Other available reports were reviewed and summarised as an additional input to assess the current condition. The information contained within these other reports was also given various grades depending on items such as age of information, and relevance to the feeder being assessed.

B.9 Future Inspection Requirements (Discussion)

During the condition assessment process undertaken on thirty five feeders in May - September 2011, it became evident that a lack of current, verifiable condition assessment information is readily available system wide for such an exercise.

The current patrol inspections concentrate on defects and exception recording primarily for the identification and prioritisation of short term rectifications.

A condition assessment program is required to make effective long term strategic asset maintenance decisions. In fact, many of the recommendations arrived at from the condition assessment project are for targeted inspections and sampling such that remaining life assessments can be made.

Below are discussion points on what could be utilised to collect such data.

B.9.1 Field Inspection

Condition Assessment should be undertaken by experienced technical personnel with respect to identifying and assessing the components condition to the agreed detail. Whilst visual methods are qualitative and generally do not provide quantitative assessments of either material loss or residual strength, visual methods can provide justification for further investigative sampling work to provide quantitative assessment and effectively "audit" the remaining life score. Such end of life analysis and investigation provide a valuable tool with respect to the prioritisation of future maintenance, repairs and optimise the allocation of finances.

In all of the cases pre-defined parameters of the component conditions are helpful for future management decisions, therefore prior to any field inspection, a scoping exercise should be carried out and agreed to between the asset management team and inspection service provider.

B.9.2 Component Coding

Component coding (as distinct from condition coding) provides the asset owner / management / engineering team with sufficient information to determine what components are fitted to the line and where.

Coding allows for rapid identification of the type of component or assembly installed and can vary in complexity from say 25 x Cap and Pin insulators to 25 x NGK 125kN CA-525BR Porcelain Ceramic Insulators. Standardisation and reference to applicable drawings can greatly reduce the level of detail required.

Further development of the maintenance planning lines systems could see a component coding scoping exercise be carried out and agreed to between the asset management team and inspection service provider. This should be undertaken prior to any field inspections such that sufficient recording of component attributes, type and condition is satisfactorily captured in the field.

The purpose of Asset Data is to define what is fitted to each structure down to component level (or level of replacement). For example, insulator type including date of manufacture / installation date (as much as is available) could be identified separately to Cold and Hot End Hardware as these will likely have different lifetime and degradation rate of decay / wear.

Also important is obtaining consistency between the number of components coded.

Is it practical to go down to number of insulators strings / discs or set (three phases)? Similarly for the use of units ie km of conductor or number of spans.

The list should be as short but as detailed as possible with little option to use other as identification.

One option is to utilise the existing object code breakdown as a starting point and build as appropriate.

B.9.3 Establishment of Replacement or End of Life Criteria

ElectraNet document 1-03-G01 Guideline A&O Transmission Line Maintenance Inspection Coding provides a life cycle assessment of transmission line elements with what and how to code. Various replacement and performance criteria are provided which can provide a degradation rate and likely time to failure.

B.10 Predictive Spend / Asset Cost Profile

The cost to replace various components, on a single replacement level, allows for the production of a forward costing database. ie if the time of replacement is known (refer life cycle assessment) then a cost can be applied at that date.

Unit assumptions such as per disc / phase or set (all phases) are required to be consistently applied between asset data information and as such, at the time of writing this report, development of high level / rough order costing data is continuing

Splitting replacement into Labour, Non Labour and Material costs is proposed to allow for variation over time. Given the present accuracy of this rough order costing information, Escalation or Net Present Value costing has not been allowed for.

It is expected that ultimately this costing information will enable the production of an accurate, auditable and proactive forward costing model which can be inputted into future Asset Management Plans.

Forecasting can be costed annually and detailed line by line, into the various component groups (structures, insulators, foundations etc)

				132kV Pole		132kV Tower	
Component		**Unit**	**Notes**	Labour	Materials	Labour	Materials
Insulators	Cap and Pin	per Circuit	Undertaken at same time as Circuit Replacement on Structure (de-energised and part of wider insulator changeout project)				
	Composite	per Circuit	Undertaken at same time as Circuit Replacement on Structure (de-energised and part of wider insulator changeout project)				
	Akimbo Arms	per Circuit	Undertaken at same time as Circuit Replacement on Structure (de-energised and part of wider insulator changeout project)				

Insulator hardware	Suspension Hardware	per Circuit	Replacement of all Hardware (Hot & Cold ends) on Circuit Replacement @ same time as Insulator Changeout				
	Tension Hardware	per Circuit	Replacement of all Hardware (Hot & Cold ends) on Circuit Replacement @ same time as Insulator Changeout				
Insulator hardware	Suspension Hardware	per Circuit	Stand Alone Replacement of all Hardware (Hot & Cold ends) on circuit Replacement - Denergised				
	Tension Hardware	per Circuit	Stand Alone Replacement of all Hardware (Hot & Cold ends) on circuit Replacement - Denergised				
Compression Joints	Mid span conductor Joints	per Joint	Undertaken Denergised as part of wider replacement project				
	Earthwire Joints	per Joint	Undertaken Denergised as part of wider replacement project				
	Jumper & palm connection	per Joint	Undertaken Denergised as part of wider replacement project (All phases on Tower)				
	Jumper Flags	per Joint	Undertaken Denergised as part of wider replacement project (All phases on Tower)				
	Termination Joints	per Joint	Undertaken Denergised as part of wider replacement project				
	Earthwire Attachment (bonding to structure)	per Tower	Remaking of Attachment Bond				
Conductor hardware	Dampers	per Circuit (assume 1 each side)	Replacement of all Dampers at tower on one circuit				
	Armour Rods	per Circuit	Replacement of all armour rods at tower on one circuit				
	Spacers (including spacer dampers)	per Circuit Span	replacement of all spacer (or spacer dampers on complete circuit span) as part of wider replacement project				
Structures	Lattice towers	per Structure	Assume single circuit suspension for voltage				
	Guyed Masts	per Structure	Assume single circuit suspension for voltage				
	Stobie Poles	per Structure	Assume single circuit suspension for voltage				
	Steel Poles	per Structure	Assume single circuit suspension for voltage				
	Concrete Poles	per Structure	Assume single circuit suspension for voltage				
	Crossarm Replacement	per Pole Structure	Assume replacement of single circuit wishbone crossarm assembly (de-energised and as part of wider crossarm replacement project)				
	Bolts	per Tower Structure	Replacement of 1000 bolts on single structure as part of wider bolt refurbishment structure (assume existing bolts can be removed with spanner)				
Foundations	Grillage	per Structure	Replacement / refurbishment of all grillage foundations on single foundations				

	Piled footing	per Structure	Installation of two piled footings per foundation x four legs				
	Pole Foundations	per Structure	Installation of new foundation				
Sub components	Stay Anchors	per Stay Anchors	Replacement of single stay and anchor as part of wider stay anchor refurbishment project				
	Anti Climbs	per Structure	Installation of Anti Climb barrier at single structure as part of wider installation project				
	Climbing Aids	per Structure	Replacement of step bolts at Structure (including appropriate fall restraint system)				
	Signage	per Structure	Replacement of signage - as part of wider signage replacement project				
	Aircraft markers	per Structure	Installation of Aircraft makers at structure (Stand alone)				
	Earthing	per Structure	Earthing refurbishment at structure as part of wider refurbishment project				
Other	Refurbishment	per Structure	Blast and zinc spray foundation connection (complete tower as part of wider refurbishment project)				
	Refurbishment	per Structure	Blast tower (assume 20% of tower surface area), patch prime & two full coats (whole tower)				

Table 9. Structure Component Costing Table

				Earthwire 19/2.0 SC/AC		Conductor Hen ACSR	
				Labour	Materials	Labour	Materials
Conductor	Conductor	per circuit km	undertaken as part of wider conductor replacment (assume existing conductor can be utilised as pull wire)				
	Earthwire	per km	undertaken as part of wider earthwire replacment (assume existing earthwire can be utilised as pull wire)				
	OPGW	per km	undertaken as part of wider earthwire replacment (assume existing earthwire can be utilised as pull wire)				

Table 10. Span (per km) Costing Table

B.11 Line Security and Maintainability (Discussion)

B.11.1 Maintainability

Maintainability is the probability that a system can be returned to full capability in a given time (usually after a failure). High maintainability is required where long periods of interruption are unacceptable. The factors considered in providing a measure of maintainability of a transmission line are:

Spares availability
Access to plant
Resources

The measure of maintainability cannot be given in terms of condition and remaining life. Therefore, maintainability is assessed as a statement in terms of the three measures.

Spares

Can spares be sourced in a timely manner and are the stock holdings appropriate?

Access to plant

Is there suitable contingency in the system to allow maintenance to be performed? Can maintenance be performed without interruption to the plant function (i.e. live line work capability)?

Resources

Are there skilled people available to perform maintenance and will they respond in an appropriate time frame? As plant ages it is likely that the skills to maintain it will become unavailable.

B.11.2 Line Security

Wind Return

Consideration of a line and structural loading review of the line should be undertaken to assess the capability of the line system to adequately resist design wind return periods along with other suitable load scenarios.

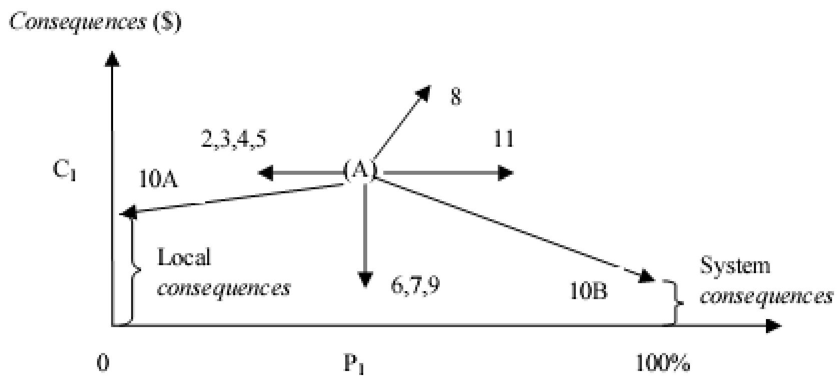
Failure Containment

Mechanical loads from a component failure on an adjacent structure are complex due to the unpredictability of other loads acting on the actual structure under consideration at the time of the event. Various methods however do exist to prevent cascade and avoid the situation where failure of a single component has a domino effect on adjacent structures. An independent analysis of failure containment could be carried out and assessed with cognisance of required reliability levels.

B.11.3 Line Upgrade – Effect on Security

A review of the line design together with close inspection of the various components will provide a snapshot of the lines capability to adequately perform its intended function.

Below is an excerpt form CIGRE technical Brochure 309 (Asset Management of Transmission Systems and Associated CIGRE Activities) which provides the effect of various management actions from the present day. Of relevant note here is the effect of upgrading on increased consequence and probability of failure. Various options exist to mitigate and reduce the effect of upgrading and these should be considered during any proposed increase of operational load requirements.



(Cigre TB309 Asset Management of Transmission Systems and Associated CIGRE Activities)

1	Risk Acceptance	Remain @ A
2	Maintenance	Movement to the left
3	Refurbishment	Movement to the left
4	Life Extension	Movement to the left
5	Upgrading	Movement to the left
6	Insurance	Movement down
7	Fast Restoration	Movement down
8	Uprating	Movement up and to the right
9	System Development	Movement down
10a	Decommissioning	OHTL operation consequences have 0% probability (a decommissioned line can not fail)
10b	Decommissioning	System operations consequences have 100% probability (a decommissioned line is continually missing)
11	Reduce	Movement to the right

	Maintenance	

B.12 Other Notes / References (Discussion)

B.12.1 Asset Strategies / Life Extension

Mid Life extension projects

Other strategies or policy decisions may determine likely asset refurbishment dates and hence time to replacement for various components.

For example a decision to reinsulate midway through the life of an asset can see improved performance both in terms of safety and reliability of the asset over its life. When making the decision to reinuslate it would be appropriate to consider refurbishment or replacement of cold and hot end hardware, conductor lifting inspectons etc which all contribute to life cycle asset of other componentry.

B.12.2 Replacement / Repair Costing Information

How much to refurbish / Repair or Replace

By understanding the cost to replace various components on a single replacement level allows for the production of a forward costing database. ie if the time of replacement is known (refer life cycle assessment) then a cost can be applied at that date.

Assumptions such as per disc / phase or set (all phases) will need to be consistently applied between asset data information.

Other variability such as weather the component will be replaced with other items (such as the hardware / insulator discussion above) or if replacement is to be replaced live line or de-energised.

Development of high level / rough order costing data

Splitting replacement into Labour, Non Labour and Material costs will allow for variation over time.

B.12.3 Condition Based Risk Management (CBRM)

Refer separate CBRM papers by David Hughes of EA Technology.

B.12.4 Forecasting

Collection of such data described above will enable the production of an accurate, auditable and proactive forward costing model which can be inputted into the Asset Management Plan

Forecasting can be costed annually and detailed line by line, into the various component groups (structures, insulators, foundations etc)