Insulators – High and Medium Voltage

AMS – Electricity Distribution Network

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Disclaimer

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1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity distribution network. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of high (HV) and medium voltage (MV) Insulators in AusNet Services' Victorian electricity distribution network.

This strategy is focused on all HV and MV insulators supporting conductors on approximately 370,000 pole top structures. The insulator fleet consists of porcelain insulators (66%), polymeric insulators (29%), cycloaliphatic epoxy insulators (5%) and glass type insulators (<0.5%).

Insulator tracking and cracking are the major root cause of insulator failure. Since 2008, the 10-year average failure rate of insulators is estimated as 0.02% per annum, which a customer might experience loss of supply due to unplanned interruptions caused by HV and MV insulators failure in an average of 0.09 minutes per event.

Condition assessment shows that about 53% of HV and MV insulators are in an above average condition (C1 or C2). Grey and brown pin type insulators are in "Very Poor" (C5) condition, which contribute to approximately 6% of the total insulators' population. These grey and brown pin type insulators may exhibit electrical leakage currents and thus contribute to cross-arm and/or pole fires, and their short physical length may contribute to bird and animal initiated flashovers on earthed structures.

Risk analysis of HV and MV insulators, using quantified consequence/criticality bands, shows that the condition 5 grey and brown pin type insulators, which are in high criticality locations, may be flagged for replacement due to their potential bushfire ignition risk. In order to manage the risk "as far as practicable" as per the Electricity Safety Act, it is recommended to proactively replace HV and MV insulators located in the high consequence effect and worst condition region.

Key asset management strategies for HV and MV insulators are listed below.

1.1 Asset Strategies

1.1.1 New Assets

- Install new assets as per EVX9/7020/91 and *Standard Maintenance Guideline* SOP 70-03.

1.1.2 Inspection

- Inspect insulators in conjunction with the inspection of other pole-mounted assets in accordance with the criteria established in the *Asset Inspection Manual* 30-4111.

1.1.3 Maintenance

- Upon line conductor re-tying, identify insulator condition and replace if required
- Install animal/bird proofing if requires as per the *Standard Maintenance Guideline* SOP 70-03.
- Re-fasten insulator attachments to cross-arms or poles in conjunction with maintenance works

1.1.4 Replacement

- Replace insulators in conjunction with the replacement of cross-arm and poles in accordance with the criteria established in the *Asset Inspection Manual 30-4111* and *Standard Maintenance Guideline SOP 70-03*.
- Proactively replace Condition 5 insulators in high consequence effect areas
- Reactively replace defective or faulty insulators

2 Introduction

2.1 Purpose

The purpose of this document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of high (HV) and medium voltage (MV) Insulators in AusNet Services' Victorian electricity distribution network. This document intends to be used to inform asset management decisions and communicate the basis for activities.

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

2.2 Scope

This Asset Management Strategy applies to all HV and MV insulators associated with the AusNet Services electricity distribution network that operate at 66kV, 22kV, 12.7kV, 11kV and 6.6kV.

2.3 Asset Management Objectives

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

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

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

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

3 Asset Description

3.1 Asset Function

HV and MV Insulators provide the following function:

- Provide a mechanical connection between live conductors and structures whilst insulating the structures from electrical current.

3.2 Asset Population

The distribution network has high and medium voltage line insulators supporting conductors on approximately 370,000 pole top structures.

3.2.1 Population by Insulator Type

Table 1 provides an overview of the line insulator population. The line insulators are specifically operated in HV and MV network, consisting of 66kV and 22kV insulators. The 22kV insulators are used on 22kV, 11kV and 6.6 circuits.

Table 1- HV and MV Insulator Population

Insulator Type	% of Fleet Location
POST TYPE TIE TOP 9 SHED	25%
POST TYPE CLAMP TOP 9 SHED	13%
POST TYPE TIE TOP 5 SHED	12%
DISK TYPE EPDM LOW POLUTION	11%
DISK TYPE 255MM	11%
POST TIE TOP 1250MM 11 SHED	5%
POST TYPE TIE TOP CYCLO A	4%
PIN TYPE GREY	4%
DISK TYPE GREY	2%
POST TYPE CLAMP TOP 5 SHED	2%
PIN TYPE BROWN	2%
POST TYPE TIE TOP 4 SHED	2%
POST TYPE TIE TOP 16 SHED	1%
POST CLAMP TOP 1250MM 12 SHED	1%
POST TIE TOP 1250MM 17 SHED	1%
POST CLAMP TOP 1250MM 11 SHED	1%
POST CLAMP TOP 1250MM 17 SHED	1%
POST TIE TOP 1250MM 12 SHED	1%
POST TYPE CLAMP TOP 6 SHED	1%

POST TYPE TIE TOP 12 SHED	1%
DISK TYPE BROWN	1%
POST TYPE CLAMP TOP CYCLO A	<1%
WINE GLASS TYPE	<1%
POST TYPE TIE TOP 15 SHED	<1%
POST TYPE TIE TOP 6 SHED	<1%
POST TYPE CLAMP TOP 16 SHED	<1%
POST TYPE TIE TOP	<1%
POST CLAMP TOP 1250MM 13 SHED	<1%
UNKNOWN	<1%
STRAIN TYPE	<1%
PIN TYPE TIE TOP	<1%
POST TYPE TIE TOP 13 SHED	<1%

During the late 1970s, the pin type insulator was superseded by post type insulators.

The five-shed porcelain post insulator has been in service since the mid-1980s. There have been incidents reported on animal and bird flashovers on concrete poles due to the short lengths (arc distance) of the five-shed insulators. Therefore, the five-shed post insulators were discontinued in 2003.

The nine-shed porcelain post insulators are the current standard 22kV intermediate insulator across the distribution network on low pollution areas. They were first installed in the mid-1980s in portions of the network serving high population densities such as ‘Urban’ feeders.

The polymeric strain insulators were introduced around 1990 and are still in used in AusNet Services’ distribution network.

In 2004, AusNet Services introduced a polymer post insulator made of Cycloaliphatic resins. This was driven by health and safety concerns raised by field crews in respect to the weight of the porcelain insulators. In 2009, Cycloaliphatic insulators were discontinued in favour of light weight and competitively priced porcelain insulators.

The most up to date standard for insulators can be found in EVX9/7020/91.

3.2.2 Population by Material

Figure 1 shows approximately 66% of the insulator population is manufactured from porcelain, with the remaining fleet consisted of cycloaliphatic epoxy, glass and polymeric materials.

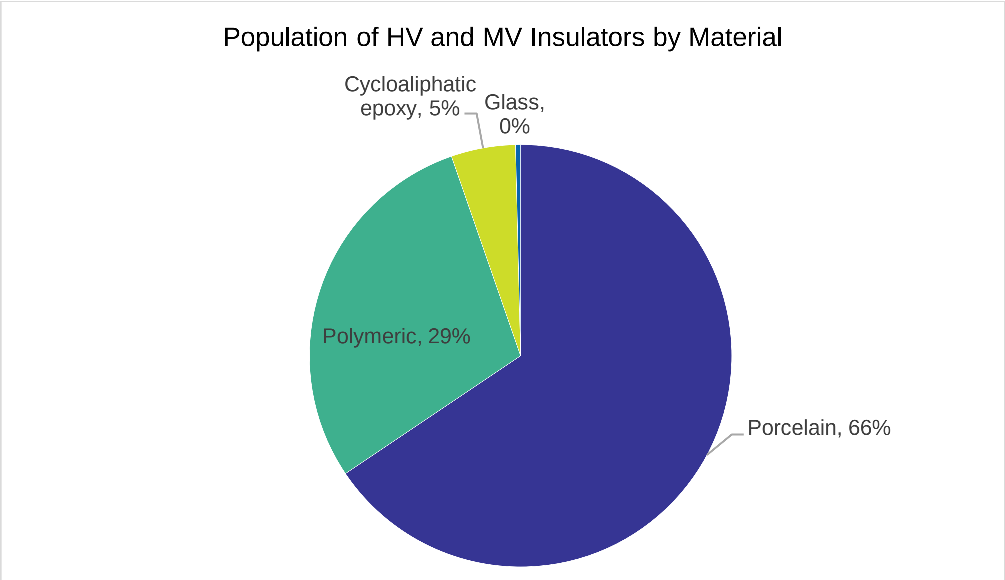

Figure 1 - Population by Material

3.3 Asset Age Profile

The average service age of the entire fleet of HV and MV insulators is 25 years with the standard deviation of 16 years. Figure 2 shows the age profile of HV and MV insulators.

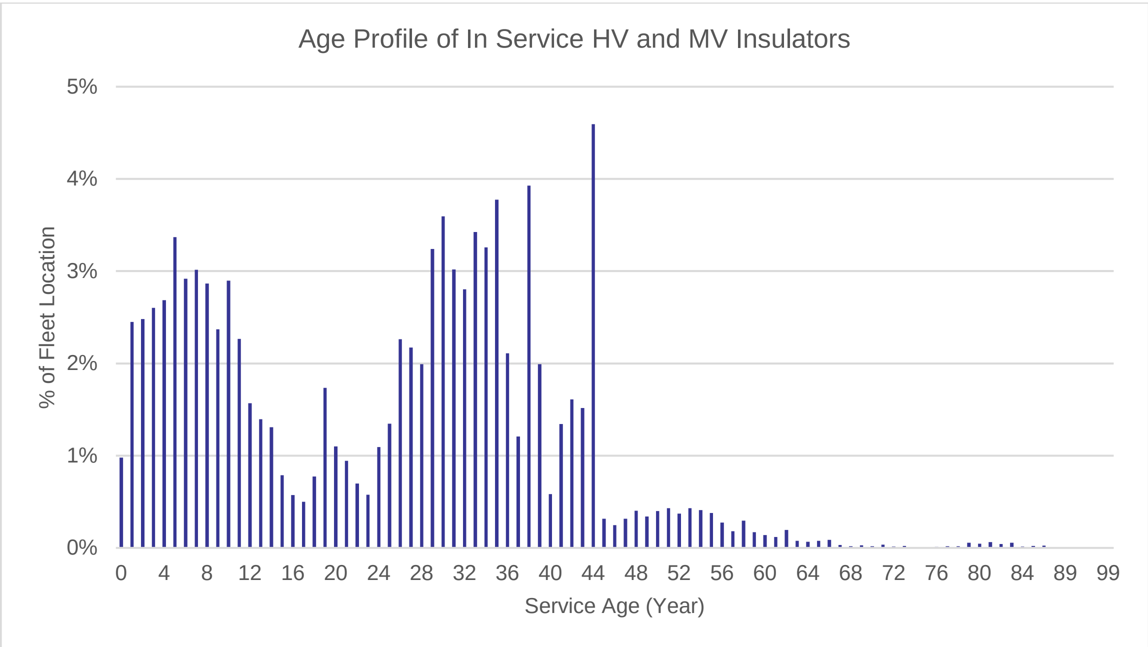

Figure 2 - Age Profile of HV and MV Insulators

3.4 Asset Condition

To provide a consistent assessment of the condition of the whole asset group, a common condition scoring methodology has been developed. This methodology uses the known condition details of each asset and grades that asset against common asset condition criteria.

There are five different condition scores that have been applied to MV and HV insulators, ranging from "Very Good" (C1) to "Very Poor" (C5). Table 2 describes the attributes, which determine the condition score rating.

Table 2 - Condition Scoring Methodology

Condition Scoring Methodology			
Condition Score	**Condition Description**	**Summary of Condition Score**	**Remaining Life**
C1	Very Good	• Good condition. No known issues identified	95%
C2	Good	• Relatively new. No known issues identified	70%
C3	Average	• Average condition. Some minor defects identified. Early signs of deterioration in condition or performance identified	60%
C4	Poor	• Approaching end of their economic life. Demonstrate declining performance and are prone to failure	45%
C5	Very Poor	• Assets with advanced deterioration, high failure rates and lower performance compared with other insulators	25%

For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussion of fails, refer to *AHR 20-66 – High and Medium Voltage Insulator.*

3.4.1 HV and MV Insulators Condition Summary

Condition summary for in-service HV and MV insulators is shown in Figure 3.

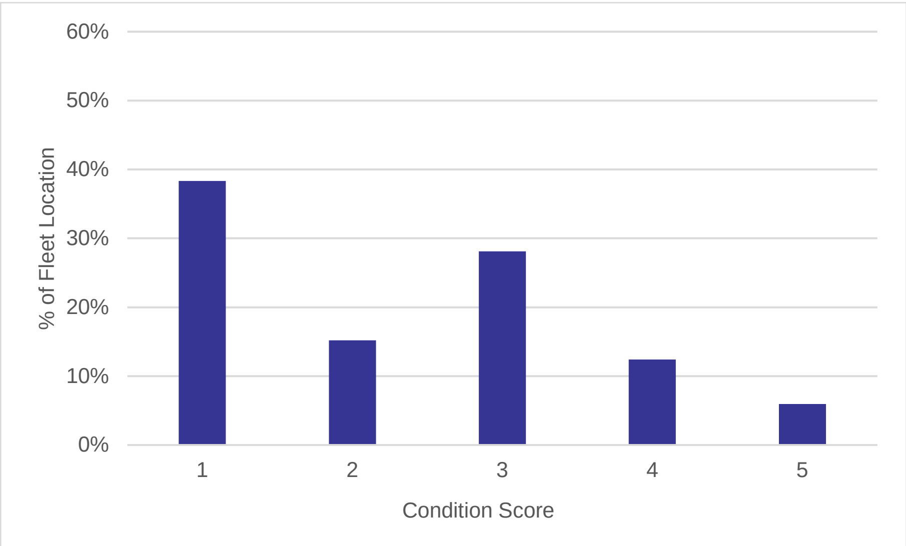

Figure 3 - Condition Assessment for HV and MV Insulators

Grey and brown pin type insulators contribute to approximately 6% of the insulators in Condition 5. They frequently exhibit:

- Electrical leakage currents and thus contribute to cross-arm and/or pole fires; and
- Their short physical length contributes to bird and animal initiated flashovers on earthed structures.

3.5 Asset Criticality

The consequences of insulator failure are allocated into five criticality bands based on their economic impact as the result of the failure. These asset criticality or consequence impacts are independent of the likelihood of the actual failure.

The economic impact consists of the below three components:

1. Bushfire start impact
2. Health and safety impact
3. Value of unserved energy

The five criticality bands are tabulated in Table 3:

Table 3 - Criticality Band for HV and MV Insulators

Criticality Band	Definition
1 – Very Low	Potential consequence of asset failure in case of a network fault event is less than or equal to 0.3 times unit replacement cost (URC)
2 - Low	Potential consequence of asset failure in case of a network fault event is between 0.3 to 1 times URC
3 - Medium	Potential consequence of asset failure in case of a network fault event is between 1 to 3 times URC
4 - High	Potential consequence of asset failure in case of a network fault event is between 3 to 10 times URC
5 – Very High	Potential consequence of asset failure in case of a network fault event is greater than 10 times URC

The result of the criticality analysis is shown in Figure 4. The condition 5 grey and brown pin type insulators with high criticality will be flagged for replacement due to its potential bushfire ignition risk.

Figure 4 shows the criticality for all in service HV and MV Insulators

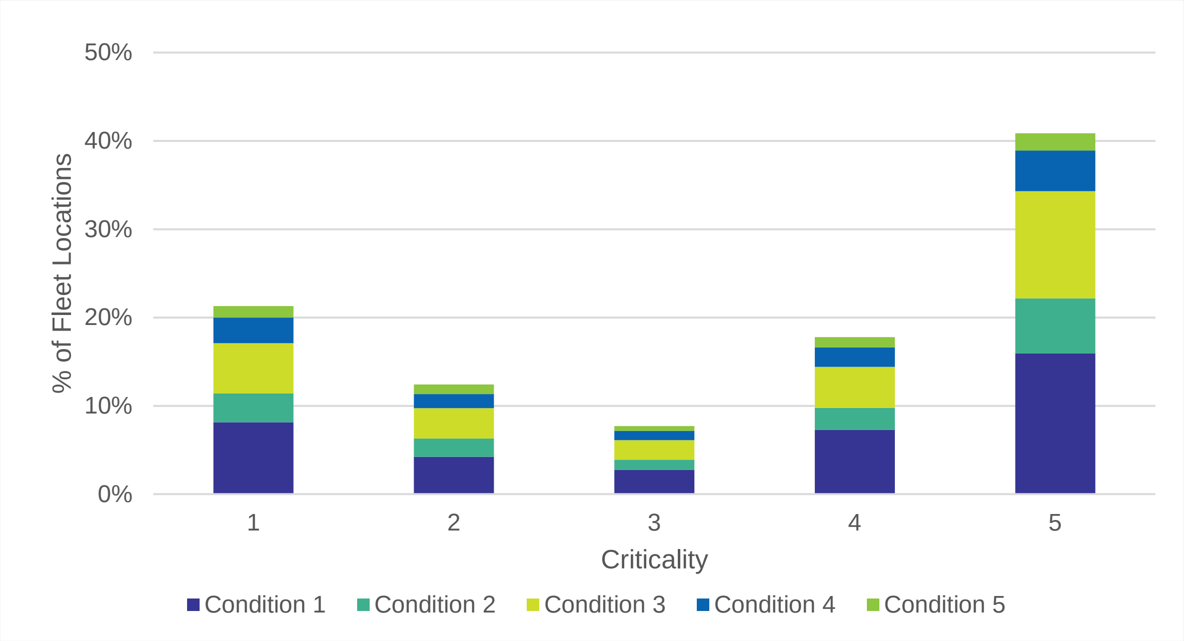

Figure 4 - Criticality for HV and MV Insulators

Details for each impact are discussed below.

3.5.1 Unserved Energy

Failure of distribution line assets can result in system outages and unserved energy effect.

Values of expected unserved energy were calculated by using the value of customer reliability (VCR) and the expected outage time. Mean time to restore (MTTR) is used to estimate the expected outage time. The approach taken is consistent with AEMO's energy forecasting approach as detailed in paper by AEMO and in AusNet Services Distribution Annual Planning Report (DARP)[1]

3.5.2 Bushfire Starts

The risk resulting from a bushfire start is calculated from the product of probability of fire ignition, probability of unfavourable weather conditions, expected house loss consequence and house loss value. Data has been sourced from the Victorian Bushfires Royal Commission findings, Government departments, Bureau of Meteorology and CSIRO.

If the insulator is located in the REFCL regions, it is assumed that the bushfire risk will be reduced by 30%.

Since 2006, there have been an average of 13 HV and MV insulator related failures reported per annum that have led to fire ignitions. 8% of these failures caused ground fires.

3.5.3 Health and Safety Risk

Health and Safety risk related, such as catastrophic failure risk, to the possibility that a safety consequence may occur as a result of HV and MV insulators failure.

[1] Distribution Annual Planning Report – AusNet Services 2018-2022

3.6 Asset Performance

3.6.1 Asset Failure

The root causes of HV and MV insulators related power failures are recorded in the Distribution Outage Management System (DOMS).

3.6.1.1. Failure by Year

Figure 5 shows HV and MV insulators related power failures per year since 2008. The failure rate of insulators is estimated as 0.02% per annum on a 10 years' average.

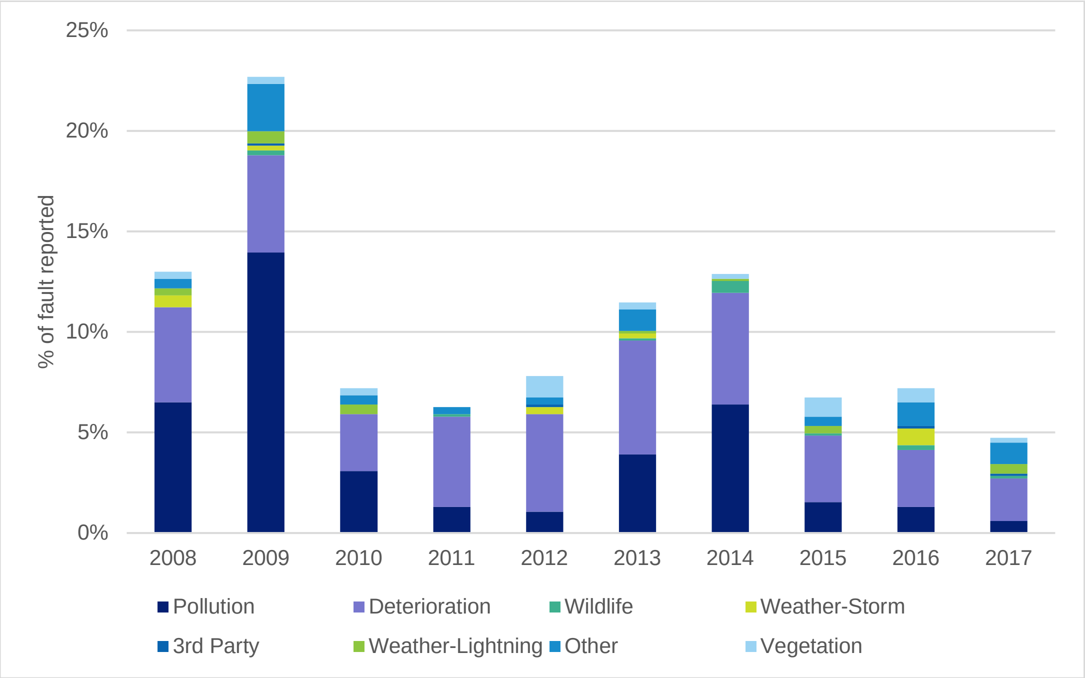

Figure 5 - HV and MV Insulator related fault per year

3.6.1.2. Failure by Cause

Figure 6 shows that insulator pollution is the major cause of insulator failure followed by deterioration.

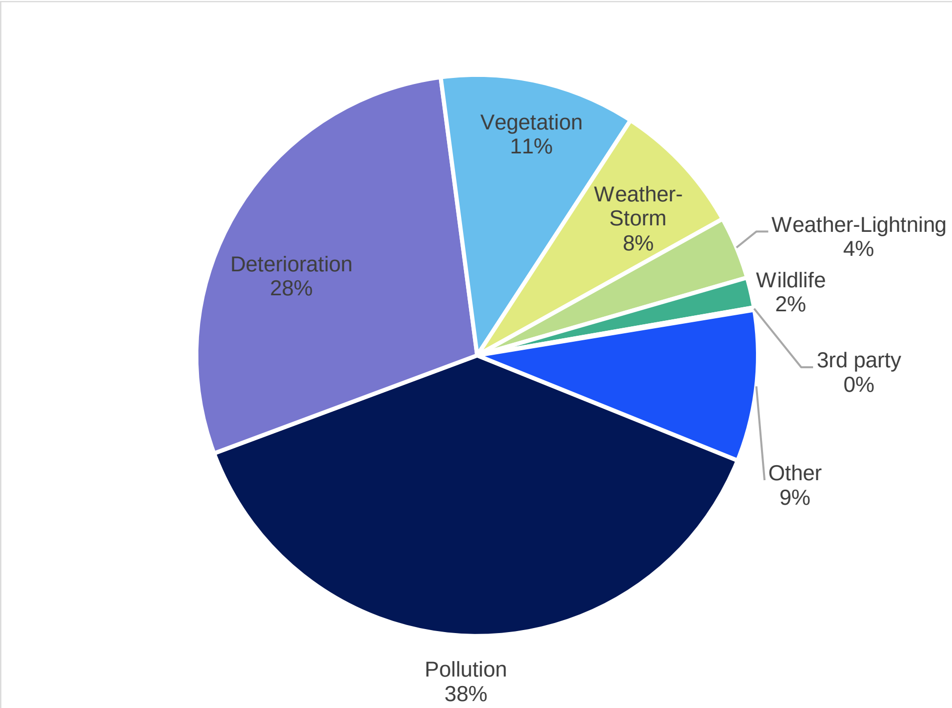

Figure 6 - Insulator Failure by Cause

3.6.2 Sustain Outages

There are about 85 HV and MV insulator related sustain outages reported each year. Since 2008, a customer might experience loss of supply due to unplanned interruptions caused by HV and MV insulators failure in an average of 0.09 minutes per event. This has resulted in an average of Service Targe Performance Incentive Scheme (STPIS) penalty of $2.9M per year.

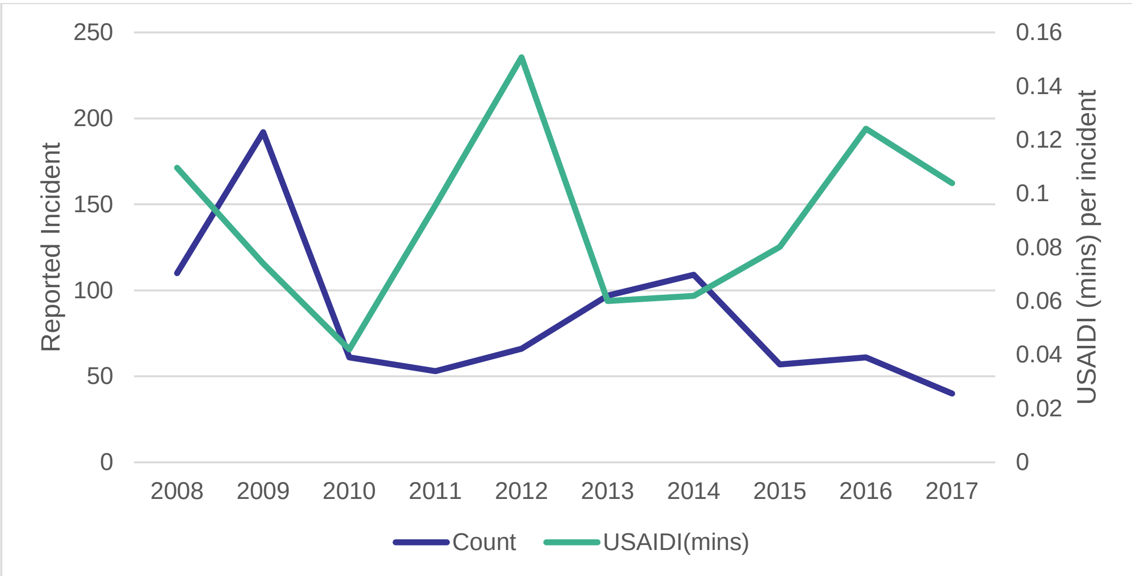

Figure 7 - Network Performance

3.6.3 Fire Ignition

Since 2006, there have been 154 HV and MV insulator failures, which are the root cause of fire ignitions. 8% of these failure caused ground fires. Figure 8 shows the historical trend of fires related to HV and MV insulators. From 2009, a downward trend is observed in the fire ignitions caused by insulator failures.

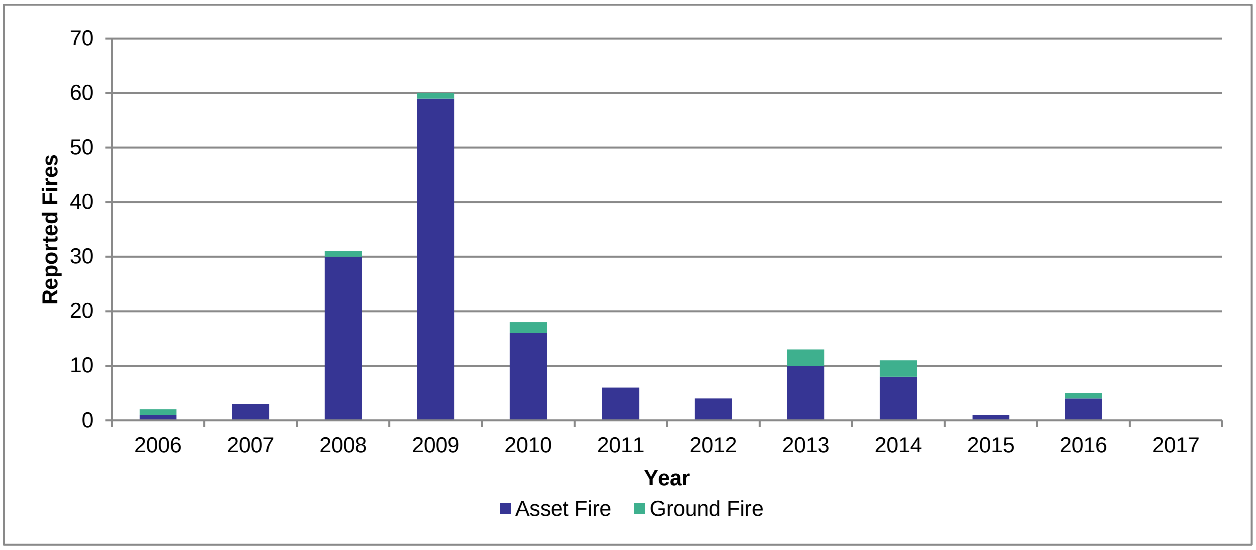

Figure 8 – HV and MV insulator related fires

4 Other Issues

4.1 Inspection

HV and MV insulators are being inspected as part of the routine line inspection as per the *Asset Inspection Manual* *30-4111* and supported by the *Insulator Identification Manual* *30-4166*. Insulators are inspected visually by trained asset inspectors using image stabilised binoculars from two position, with the purpose to detect cracking, damage, alignment pollution, tracking, missing insulators and/or metal stains from conductors.

If insulators show signs of deterioration indicating that the units may fail prior to the next scheduled inspection, a notification for rectification will be raised in the Enterprise Asset Management System – SAP.

The standard maintenance guideline for insulators is detailed in the *SOP 70-03*.

4.2 Maintenance

HV and MV insulators are essentially maintenance-free device. If it is correctly installed, there is no maintenance during the life of an insulator, except for targeted retro-fitting of bird and animal insulating covers.

4.3 Installation & Replacement

Replacement criteria are documented in the *Asset Inspection Manual* *30-4111*.The selection guideline for insulators can be found in *EVX9/7020/91.*

In general, if one fog type insulator requires replacement, all fog type insulators on the same structure should be replaced at the same time. If any insulator on a wooden cross-arm requires replacement, replace the wooden cross-arm at the same time.

Animal proofing such as bird covers shall be installed according to the standard maintenance guideline *SOP 70-03.*

4.4 Failure Modes

Two major failure modes of HV and MV insulators are discussed below.

4.4.1 Electrical Failure

Electrical failure causes electrical current to track across or through the insulator often resulting in pole or cross-arm fires.

The fog pin type insulators form the oldest cohort of the MV insulator fleet. They frequently exhibit electrical tracking, when:

- airborne dust or salt pollution build up on the insulator surface following dry weather spell
- subjected to light mist or rain, results in conductive paths across the insulator surface allowing electrical currents to pass to earth.

The passage of electrical currents can ignite timber cross-arms at the insulator attachment point or timber poles at the attachment point of the timber cross-arm.

The physical design of the pin type insulators sheds inhibits self-cleaning of the insulator surface on the underside of the sheds during normal rainfall. Service age and the degree of degradation of the insulating medium surface are the two major factors contribute to the failure of pin type insulator, as the faster and higher levels of pollution build up will lead to electrical tracking.

4.4.2 Mechanical Failure

Mechanical failure of an insulator usually results in the attached electrical conductor falling from the supporting cross-arm which will lead to:

- High voltage injections into subsidiary low voltage circuits or fire ignition due to the live conductor making contact with other assets or ground

The most common pin fog type insulator used on the distribution network is the multi-piece design. It may exhibit mechanical failure due to

- moisture ingress,
- subsequent swelling of the cement jointing compound which used to join the sheds and the pin assembly

Cracking of the insulators may result in tracking and subsequent pole or cross-arm fire. The failure of the cement joint compound may result in the separation of the top shed, which has the function to hold the conductor from the insulator base.

Mechanical damage can also occur through lightning storm or by vandalism in some cases.

5 Risk and Options Analysis

This section outlines the key risks presented by HV and MV insulators and to discuss how these risks should be addressed.

5.1 Risks

The risk matrix, showing condition and consequence of HV and MV insulators in all locations is tabulated in Table 4.

Table 4 - Risk and Condition Matrix of HV and MV insulators

		Condition – HV and MV insulator by all locations					
		1	**2**	**3**	**4**	**5**	Quantity by Location
Criticality Band	**5**	58821	22990	44822	17026	7190	58821
	4	26868	9153	17107	8225	4218	26868
	3	10107	4340	8119	3915	1941	10107
	2	15612	7651	12681	5937	3893	15612
	1	30026	12018	21066	10704	4732	30026
	Quantity by Location	141434	56152	103795	45807	21974	141434

The risk matrix, showing condition and consequence of HV and MV insulators in codified areas is tabulated in Table 5.

Table 5 - Risk and Condition Matrix of HV and MV insulators located in Codified Areas

		Condition – HV and MV insulator by Codified Areas					
		1	**2**	**3**	**4**	**5**	Quantity by Location
Criticality Band	5	1897	979	1291	443	115	4725
	4	1561	556	1013	696	240	4066
	3	904	394	870	381	191	2740
	2	633	421	564	382	291	2291
	1	534	159	252	159	127	1231
	Quantity by Location	5529	2509	3990	2061	964	15053

In Table 4 and Table 5, the greatest risks appear in the top right corner, whereas the lowest risks are in the bottom left corner.

5.2 Options

5.2.1 Proactive Replacement

As discussed in Section 4.4.1, fog pin type insulators frequently exhibit electrical tracking will may lead to cross-arm or pole fires. Thus all fog pin type insulators are considered as high risk and a targeted replacement program is required to mitigate the risk.

Replacement forecast is derived from a semi-quantitative risk assessment method using a consequence/likelihood matrix. The consequence of a HV and MV insulators malfunction is assigned with a consequence cost which is determined by the bushfire effect cost, value of unserved energy and health and safety cost.

The replacement cost is derived from historical financial records. The components of the unit replacement cost are the cost of equipment and labour to install the equipment. The labour component of the replacement cost includes the amount of time required to perform the corrective maintenance activity on a per hour basis.

HV and MV insulators may be replaced with other asset replacement works, such as pole and cross-arm replacement. SAP notification analysis shows that an estimated one-third of the HV and MV insulators will be replaced due to the above reason.

In order to manage the risk “as far as practicable” as per the Electricity Safety Act, it is recommended to proactively replace HV and MV insulator located in:

- Criticality 5 and Condition 5 insulators, located in Codified Regions as these areas are prone to higher bushfire risk
- Criticality 4 and Condition 5 insulators, located in Codified Regions as these areas are prone to higher bushfire risk
- Criticality 3 and Condition 5 insulators

5.2.2 Reactive Replacement

Historical fault analysis shows an estimated count of 85 insulator locations were replaced per year due to a fault.

5.2.3 Overall Replacement Forecast

As the result of the risk and options evaluation, the replacement forecast is summarised in Table 6.

Table 6 - Replacement Forecast

Identifier	Justification	EDPR 2022 - 26
Proactive Replacement	Probabilistic replacement on asset with high consequence effect and worst condition	1584
Reactive Replacement	Probabilistic replacement due to defect or fault	425
	Total Replacement Location	2009

In summary, an estimated count of 2009 HV and MV insulators’ locations will be replaced in 2022 – 2026.

6 Asset Strategies

6.1 New Assets

- Install new assets as per EVX9/7020/91 and *Standard Maintenance Guideline SOP 70-03*.

6.2 Inspection

- Inspect insulators in conjunction with the inspection of other pole mounted assets in accordance with the criteria established in the *Asset Inspection Manual 30-4111.*

6.3 Maintenance

- Upon line conductor re-tying, identify insulator condition and replace if required
- Install animal/bird proofing if requires as per the *Standard Maintenance Guideline SOP 70-03*.
- Re-fasten insulator attachments to cross-arms or poles in conjunction with maintenance works

6.4 Replacement

- Replace insulators in conjunction with the replacement of cross-arm and poles in accordance with the criteria established in the *Asset Inspection Manual 30-4111* and *Standard Maintenance Guideline SOP 70-03*.
- Proactively replace Condition 5 insulators in high consequence effect areas
- Reactively replace defective or faulty insulators