Surge Arrestors in Zone Substations

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 zone substation surge arresters.

Approximately 89% of surge arresters are of gapless metal oxide type which is the newer technology. The remaining population compromise the older porcelain housed silicone carbide type.

Condition assessment shows that 79% of surge arresters are in a "Very Good" condition (C1), as there has been significant surge arrestors replacement programs in last 10 years, with only approximately 11% of surge arresters in "Poor" condition (C4) or "Very Poor" condition (C5).

The consequence of failure has been assessed and approximately 22% of the surge arresters have very high criticality impact due to safety, community impact due to outages (unserved energy) and collateral damage risks. A risk assessment that considers both condition and criticality has identified an economic proactive replacement program for the 2022-26 period.

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

1.1 Asset Strategies

1.1.1 New Assets

- Continue to purchase gapless polymer housed metal oxide surge arresters

1.1.2 Inspection

- Continue with routine visual inspection and annual thermo-vision scans

1.1.3 Condition Monitoring

- Consider monitoring first generation metal oxide porcelain housed surge arresters [C.I.C] and the polymer housed metal oxide surge arresters more than 20 years old [C.I.C] through a sample test program

1.1.4 Spares

- Maintain strategic spares holding of surge arresters for all voltage classes in service

1.1.5 Replacement

- Proactively replace 63 off 22kV silicon carbide porcelain housed units and 18 off 66kV silicon carbide porcelain housed units

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 surge arresters installed in zone substations in AusNet Services' Victorian electricity distribution network. This document is intended 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. It is intended to demonstrate responsible asset management practices by outlining economically justified outcomes.

2.2 Scope

This asset management strategy applies to all surge arresters located within AusNet Services' electricity distribution zone substations that operate at 66 kV, 22 kV, 11 kV and 6.6 kV.

The following assets are covered by other strategies;

Line surge Arresters refer to AMS-20 -67.

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

The AusNet Services electricity distribution network is located in the highest lightning impact areas in the state of Victoria. Surge arresters are used to protect key items of electrical plant within the zone substation that are susceptible to internal failure following transient lightning over-voltages or over-voltage surges created by network switching.

Surge arresters are installed between each active phase and the electrical earth grid at 66 kV line entries, on each side of power transformers, at cable ends and on 22 kV, 11 kV and 6.6 kV feeder exits from zone substations.

3.2 Asset Population

AusNet Services has a total of 1576 surge arresters installed in AusNet services zone substations as at end 2017. There are mainly two types of surge arresters installed in ZSS namely gapped silicone carbide and gapless metal oxide type which is the new technology. Silicone Carbide type surge arresters are all porcelain housed whereas gapless metal oxide surge arresters are predominantly have polymeric housings. However a small population of gap less metal oxide surge arresters manufactured in the 1980s have porcelain housings.

The population of surge arresters by service voltage and technology type is given in Figure 1.
The population of surge arresters by technology type and housing is shown in Figure 2.

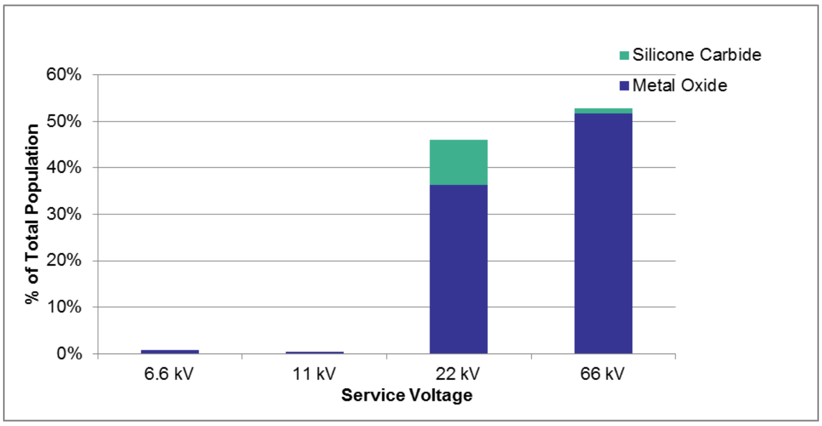

Figure 1 – Population of surge arresters by service voltage and technology type

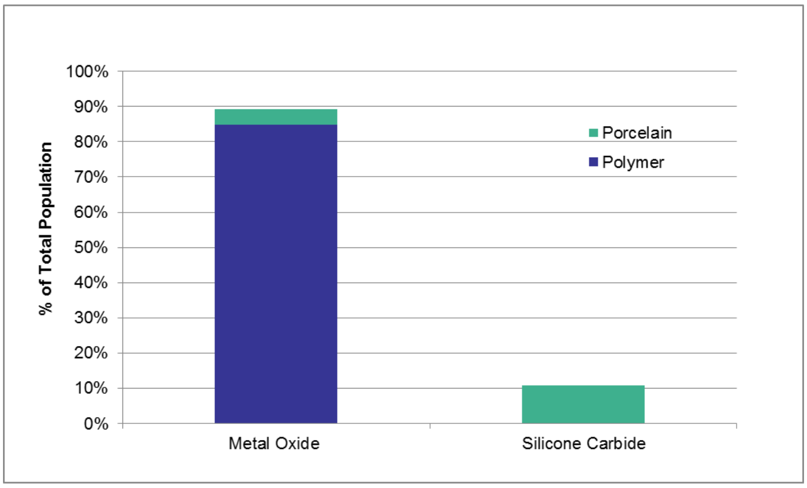

Figure 2 – Population of surge arresters by technology and housing type

Figure 3 below provides the surge arresters by manufacturer. [C.I.C] have the highest population of surge arresters in zone substations.

C.I.C

3.3 Asset Age Profile

The service age profile of zone substation surge arresters is shown in figure 4. Average age of 22kV and below surge arresters and 66kV surge arresters are 15 years and 11 years respectively. This is mainly due to the implementation of a surge arrester replacement program under the two previous EDPR programs.

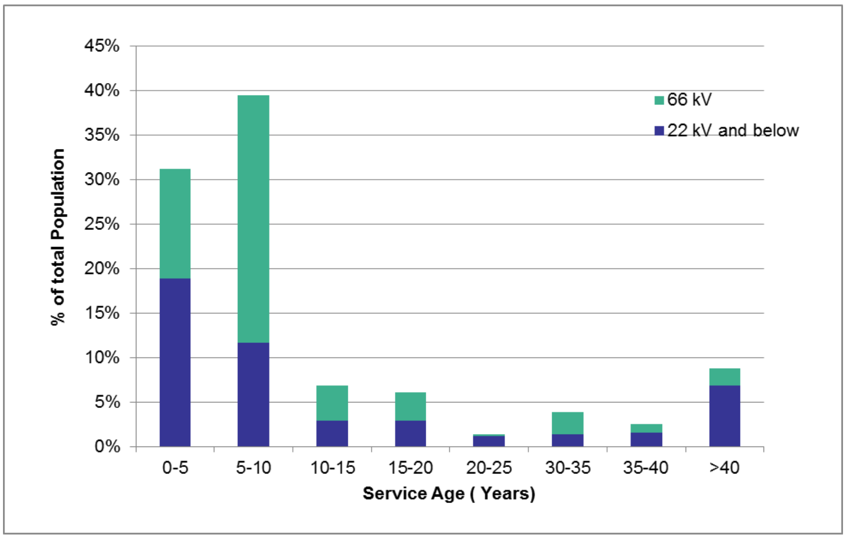

Figure 4 – Age profile of surge arresters by Voltage

Surge Arrester population by technology type is shown in figure 5. It can be observed that the metal oxide type surge arresters are relatively new compared to a smaller population of silicone carbide type arresters in service introduced in the 1970s. Older metal oxide type such as [C.I.C] had porcelain housing compared to the newer versions which have polymeric housings. Older porcelain housed metal oxide surge arresters are still in service and they are performing satisfactorily.

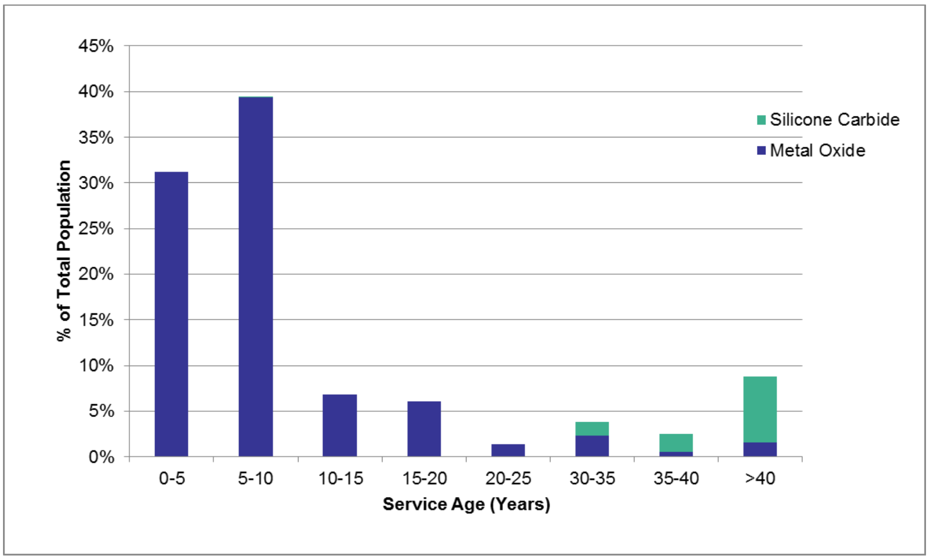

Figure 5 – Age profile of surge arresters by Voltage

3.4 Asset Condition

Table 1 provides the condition assessment criteria of surge arresters in zone substations.

Table 1 – Condition Assessment Criteria

Condition Score	Condition Description	Summary of details of condition score	Remaining Life
C1	Very Good	• Incorporates the new metal oxide designs with polymer housings. • Are in an acceptable visual condition with no signs of corrosion, tracking or damage. • Typically in new condition • Have no historical problems and • If available, test results will show consistent insulation resistance and power loss measurements across all levels of the surge arrestor relative to each phase.	95%
C2	Good	• Incorporates the new metal oxide designs with polymer housings. • Are in an acceptable visual condition with no signs of corrosion, tracking or damage. • • Have no historical problems and • If available, test results with show consistent insulation resistance and power loss measurements across all levels of the surge arrestor relative to each phase.	70%
C3	Average	• Incorporates metal oxide designs with porcelain housings. (mainly ASEA XAR type surge arresters , earliest design of metal oxide surge arresters) • Are in an acceptable visual condition with no signs of corrosion, tracking or damage. • If available, the test results will be consistent across all phases or may show minor inconsistencies in the insulation resistance and power loss measurements across all levels of the surge arrestor relative to each phase • Will be continually monitored over the duration of their life in order to identify if any remedial works will be necessary to mitigate the risk of failure.	45%
C4	Poor/ Bad	• Incorporates silicon carbide designs with porcelain housings. • Are beginning to develop signs of corrosion on the insulator material, the housing, venting duct covers and/or diaphragm. • Typically has been in service for greater than 20 years. • If available, the test results may be consistent across all phases or may show minor inconsistencies in the insulation resistance and power loss measurements across all levels of the surge arrestor relative to each phase. • Includes makes such as ASEA XA's/XB's/XR's, BBC HMP/HML's, Meidensha ZSE's, Brown Boveri HM's • Will include any types of metal oxide designed sure arrestors with porcelain housings that have shown signs of rapid deterioration whilst being monitored closely over their life.	25%
C5	Very Poor	If any of the following criterion's are evident, the surge arrestor will be classified as very poor: • The visual condition of the surge arrestor is unacceptable as major signs of corrosion on the insulator material, seals or caps are visible or tracking and mechanical damage to the housing, venting duct covers and diaphragm is strongly evident. • Providing test results are available, the insulation resistance and power loss test results are significantly inconsistent across one or more levels of the surge arrestor relative to other phases. • The surge arrestor is of a Siemens 3EM2, GE9L, EMP/Bowthorpe CM, EMP/Bowthorpe BM, Bowthorpe/ASEA XCA model or Bowthorpe 21FC2E0, Bowthorpe 22S/22D's. These surge arrestors have the potential to explode. In addition, this category of surge arrestors: • Are typically of the old technology type that incorporates silicon carbide designs with porcelain housings. • Present a high consequence of risk.	15%

Condition profile of surge arresters by technology and service voltage is shown in Figure 6 and 7 respectively.

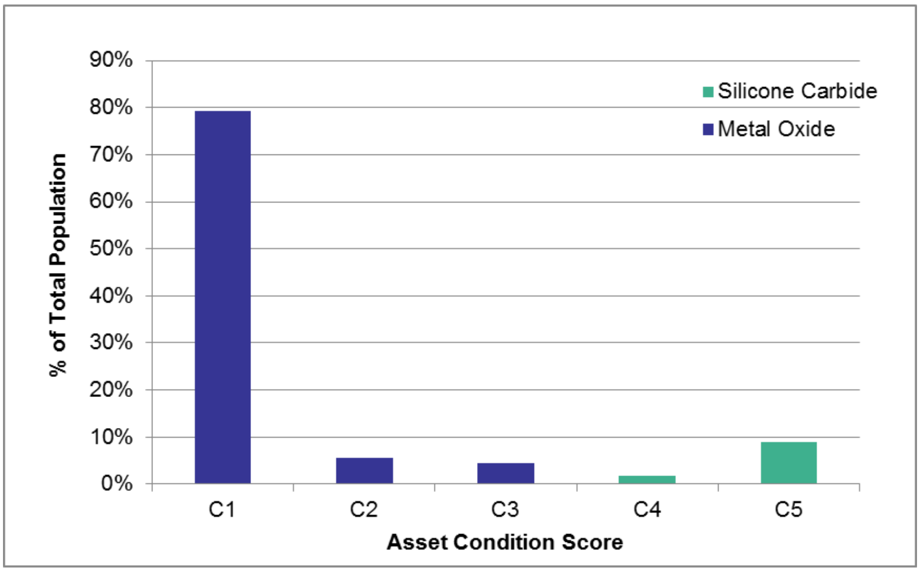

Figure 6 – Condition Profile of Surge Arresters by technology type

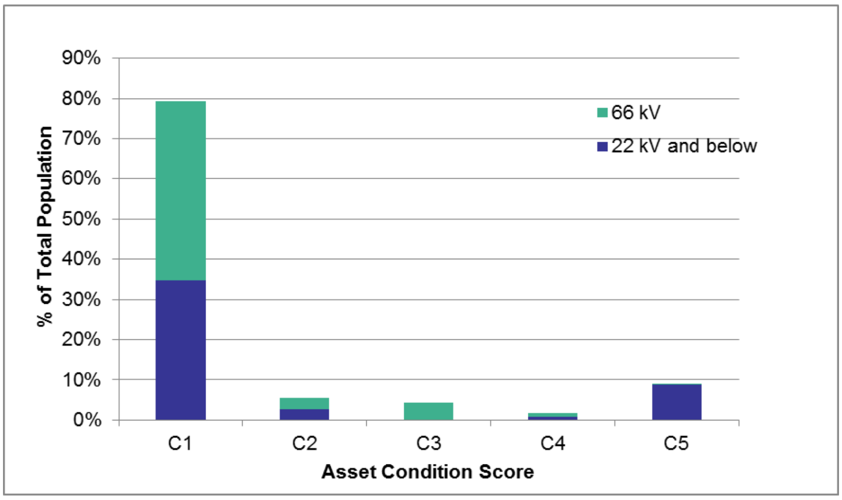

Figure 7 – Condition Profile of Surge Arresters by voltage

3.5 Asset Criticality

Asset Criticality was determined by considering the following consequences of surge arrester failure with the failure effects mentioned below.

I. Safety impact,
II. Community impact due to outages (unserved energy)
III. Collateral damage

Asset criticality is the severity of consequence in a major failure of a surge arrester at a certain location due to above failure effects irrespective of the likelihood of the actual failure. This gives an idea of surge arrester types, located critical locations which represent the total value of risk $.

Safety impact is assessed on catastrophic failure risk and it depends mainly on explosive failure mode of porcelain housings associated with older surge arresters, mainly silicone carbide types. Modern surge arresters are metal oxide type with polymeric housings failure in most cases are benign. Hence collateral damage cost is assumed as negligible risk for polymer housed surge arresters.

Community impact due potential value of unserved energy is dependent on where the surge arrester is located. Ex: surge arresters located on transformer side of single transformer stations could result in station black. In two or three transformer configurations, it could result in N-1, N-2 or even station black depending on their locations. Surge arresters located on feeder exits will result in loss of feeder customers. In all situations, loss of power supply of duration of 60 minutes is assumed to calculate the penalty cost.

Figure 8 and 9 show the relative base criticality against service voltage and technology type.

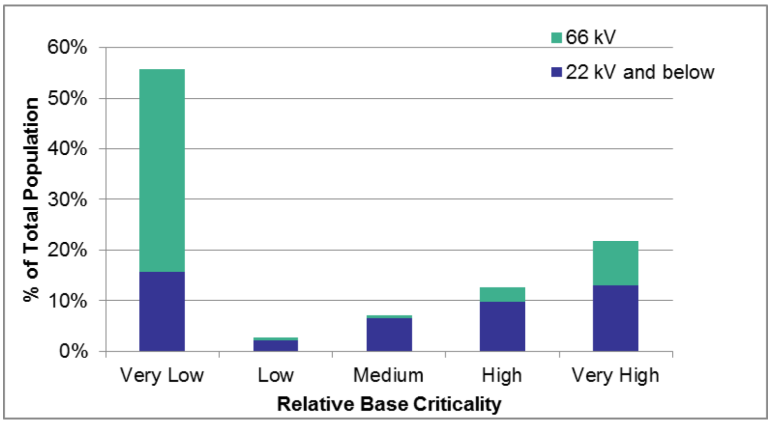

Figure 8 – Relative Base Criticality Profile against service voltage

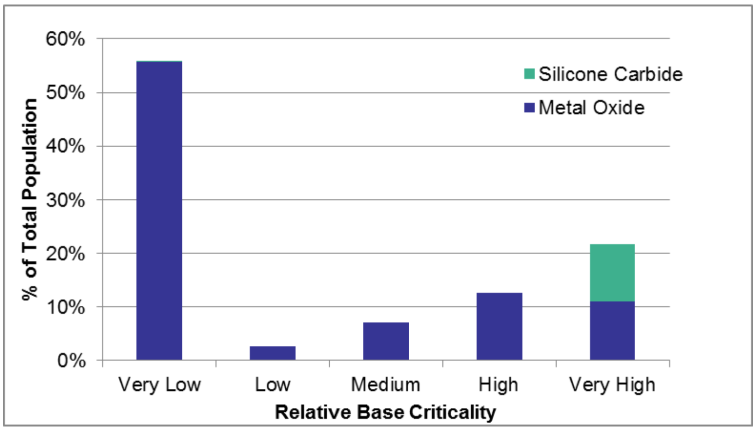

Figure 9 – Relative Base Criticality Profile against technology

The applied interpretation of relative base criticality is shown in Table 2.

Table 2 – Interpretation of Relative Base Criticality

Relative Base Criticality	Criticality Banding	Economic Impact
Very low	1	Total failure effect cost < 0.30 times Replacement Cost
Low	2	Total Effect Cost is between 0.30 – 1.0 times of replacement cost
Medium	3	Total Effect Cost is between 1.0 - 3 times of replacement cost
High	4	Total Effect Cost is between 3 -10 times of replacement cost
Very high	5	Total Effect Cost exceeds 10 times of replacement cost

Following observations are made on asset criticality:

- Approximately 21.7% of surge arresters have shown very high criticality mainly driven by community impact (unserved energy) out of which approximately 9% are poor condition silicone carbide surge arresters.

3.6 Asset Performance

Surge Arresters are inspected at the intervals for maintenance of their associated Transformer or Circuit Breaker or line entry equipment. Surge arresters are not maintainable and very minimal corrective action can be performed on them and replacement with modern metal oxide type is the only option on defect or failure.

Surge arresters generally reach end of life when the voltage-impedance characteristics deteriorate beyond acceptable limits or when corrosion or deterioration of seals allows moisture to ingress into the unit. Under a previous surge arrester replacement program, 91% of the ZSS surge arresters were replaced during the period 2009-2017 and hence only a small portion poor condition silicone carbide surge arresters currently in service.

There were no known surge arrester failures during the period 2015 -2018 mainly due to implementation of zone substation surge arrester replacement programs undertaken. However there is a small population of gapped silicone carbide 22kV and 66kV surge arresters of make [C.I.C] in 22kV feeder exits and 66kV line entries and bus bars. These surge arrester types are porcelain housed and build to old technology which had a past history of catastrophic failures due to corrosion, seal failure, moisture ingress and insulation failure.

4 Other Issues

4.1 Surge Arrester Condition Monitoring

There are no cost effective techniques available to assess the internal deterioration of surge arresters other than costly offline testing. Currently they are visually inspected for corrosion and external defects/ damages during their associated plant maintenance. Long term performance of metal oxide modern surge arresters depends on the quality of manufacturer and its seal performance. The oldest porcelain and polymer housed gapless surge arresters are now exceeding 20 years and need for sample testing of older arresters is becoming imperative to understand the arrester performance and developing issues.

5 Risk and Option Analysis

The key drivers of this program are managing safety risk, supply risk and collateral damage risk.

Table 3 is an assessment of the risk based on the condition of the assets and the monetised consequence of failure. The 81 assets in the high risk area of the matrix correspond to the silicon carbide porcelain-housed surge arresters in C4 and C5 asset condition.

The matrix excludes 296 of 22kV surge arresters that will be replaced during the current period under current period major projects and REFCL projects.

Metal oxide, porcelain housed 66kV surge arresters are assessed as in C3 asset condition. There are recommended to be monitored under a sample test program and not required to be replaced during the next EDPR 2022-26 period.

Table 3 – Zone Substation Surge Arrestor Risk Assessment

Criticality Banding	C1	C2	C3	C4	C5
5	61	11	66	21	60
4	125	12			
3	72	8			
2	45	3			
1	762	40			

The following work is proposed to be undertaken under EDPR 2022-26 under the program:

- Proactive replace 63 off 22kV silicon carbide porcelain housed units and 18 off 66kV silicon carbide porcelain housed units

6 Asset Strategies

6.1 New Assets

- Continue to purchase gapless polymer housed metal oxide surge arresters

6.2 Inspection

- Continue with routine visual inspection and annual thermo-vision scans

6.3 Condition Monitoring

- Consider monitoring first generation metal oxide porcelain housed surge arresters [C.I.C] and the polymer housed metal oxide surge arresters more than 20 years old [C.I.C] through a sample test program

6.4 Spares

- Maintain strategic spares holding of surge arresters for all voltage classes in service

6.5 Replacement

- Proactively replace 63 off 22kV silicon carbide porcelain housed units and 18 off 66kV silicon carbide porcelain housed units