AMS 10-73 Surge Arresters in Terminal Stations

2023-27 Transmission Revenue Reset

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1 Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet Services' electricity Transmission. The purpose of this strategy is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of Terminal Station surge arresters.

Approximately 99% of surge arresters are of gapless metal oxide type. The remaining population compromise the older porcelain housed silicon carbide type.

Condition assessment shows that 76% of surge arresters are in a "very good condition" (C1), as there has been significant surge arresters replacement programs in last 10-20 years to replace poor condition silicon carbide porcelain housed surge arresters, with only approximately 13% of surge arresters in "poor condition" (C4) or "very poor condition" (C5). The consequence of failure has been assessed and approximately 29% of the surge arresters have very high criticality impact due to market impact (VCR), safety and collateral damage risks.

A risk assessment that considers both condition and criticality has identified a proactive replacement program for the 2022-27 period, excluding the replacements planned under current period projects.

Proactive management of surge arrester 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 the [C-I-C] metal oxide porcelain-housed surge arresters along with other older metal oxide types and the polymer housed metal oxide surge arresters more than 20 years

1.1.4 Spares

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

1.1.5 Replacement

- Proactively replace 18 off 22kV & 66kV porcelain housed surge arresters and 39 off 220kV porcelain housed metal oxide surge arresters
- Replace [C-I-C] surge arresters in high risk area with new metal oxide polymer housed surge arresters in conjunction with station rebuild projects during 2022-2027.

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 Terminal stations in AusNet Services' Victorian electricity transmission 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 transmission network regulated asset base that operate at 500kV, 330kV,275kV,220kV,66kV, 11kV and 6.6kV.

The following assets are also covered by other strategies.

GIS surge Arresters refer to AMS-10-62.

SVC surge arresters refer to AMS-10-71.

2.3 Asset Management Objectives

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

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

As stated in *AMS 10-01 Asset Management Strategy -Transmission Network*, the electricity transmission network objectives are:

- Maintain top quartile benchmarking;
- Maintain reliability;
- Minimise market impact;
- Maximise network capability;
- Leverage advances in technology and data analytics;
- Minimise explosive failure risk.

3 Asset Description

3.1 Asset Function

Surge arresters are devices used on electrical power systems to protect critical, or high value items of plant that are susceptible to internal failure due to transient lightning or voltage surges during network switching.

They are typically installed between each active phase and the electrical earth grid at line entries, on the high voltage and low voltage side of power transformers, and at the terminations of GIS and HV and EHV cables /overhead lines and at cable ends and on 22 kV, 11 kV and 6.6 kV feeder exits.

3.2 Asset Population

AusNet Services has a total of 2243 surge arrester installed in AusNet services terminal stations, as reported in 2018/2019 RIN. There are mainly two types of surge arresters installed in terminal stations namely gapped silicon carbide (SC) and gapless metal oxide type (MO) which is the newer technology. Silicon Carbide type surge arresters are all porcelain housed whereas gapless metal oxide surge arresters have both types of housing but predominantly are polymeric housed. A smaller 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.

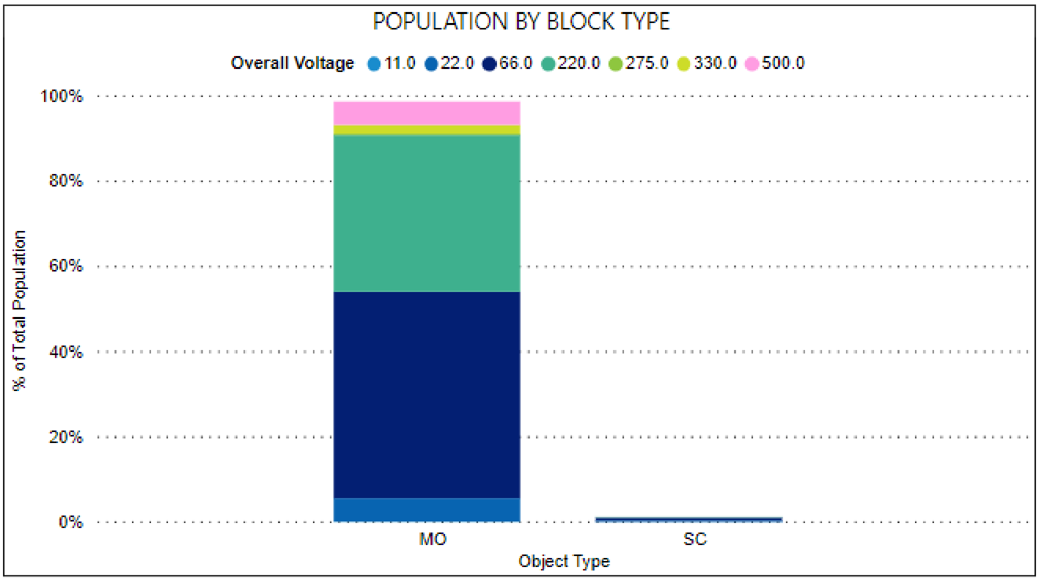

Figure 1 – Population of surge arresters by service voltage and technology type

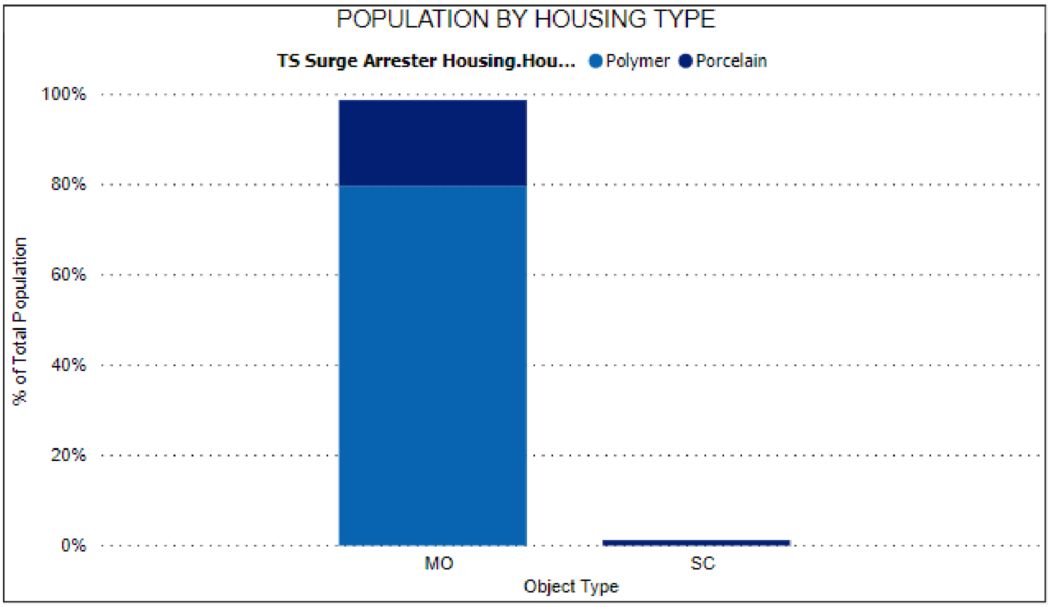

Figure 2 – Population of surge arresters by technology and housing type

Figure 3 below provides the surge arresters by manufacturer. [C-I-C] (55.2%) and [C-I-C] (20.7%) contribute to approximately 75.9% of the total population of surge arresters in terminal stations.

[C-I-C]

Figure 3 – Surge Arresters by Manufacturer

3.3 Asset Age Profile

The service age profile of terminal station surge arresters is shown in figure 4. The average age of all surge arresters is about 14.2 years. This is mainly due to the implementation of a surge arrester replacement program and Station Rebuild programs over the last 20 years.

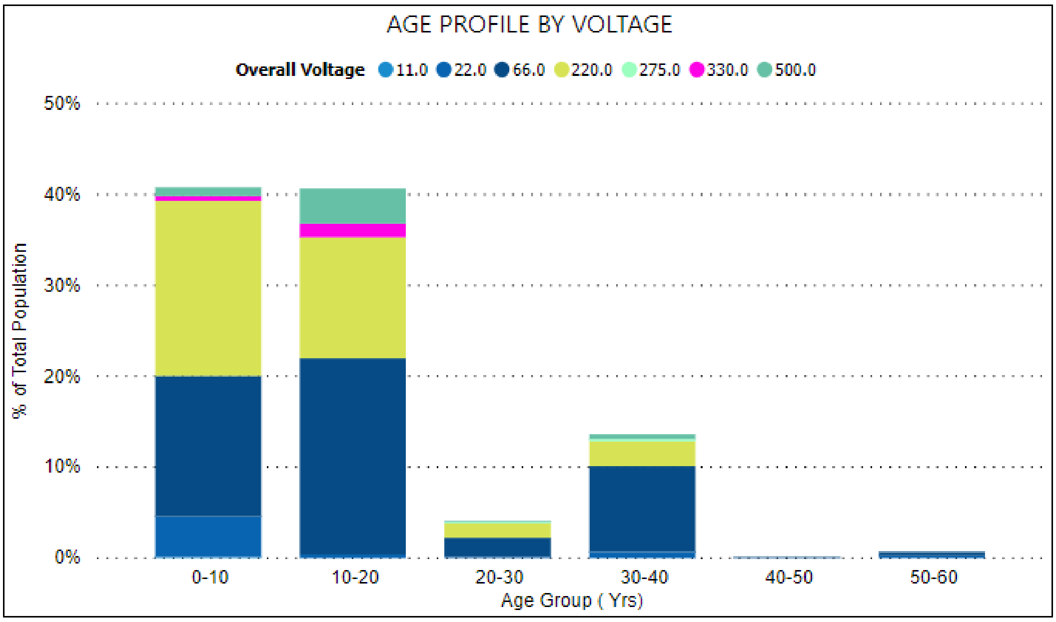

Figure 4 – Age Profile of surge arresters by Voltage

Surge Arrester population by technology type is shown in figure 5. It can be observed that the metal oxide type surge arresters are newer compared to a smaller population of silicon carbide type arresters. Older metal oxide types such as [C-I-C], [C-I-C] and [C-I-C] types have porcelain housing compared to the newer versions which all have polymeric housings.

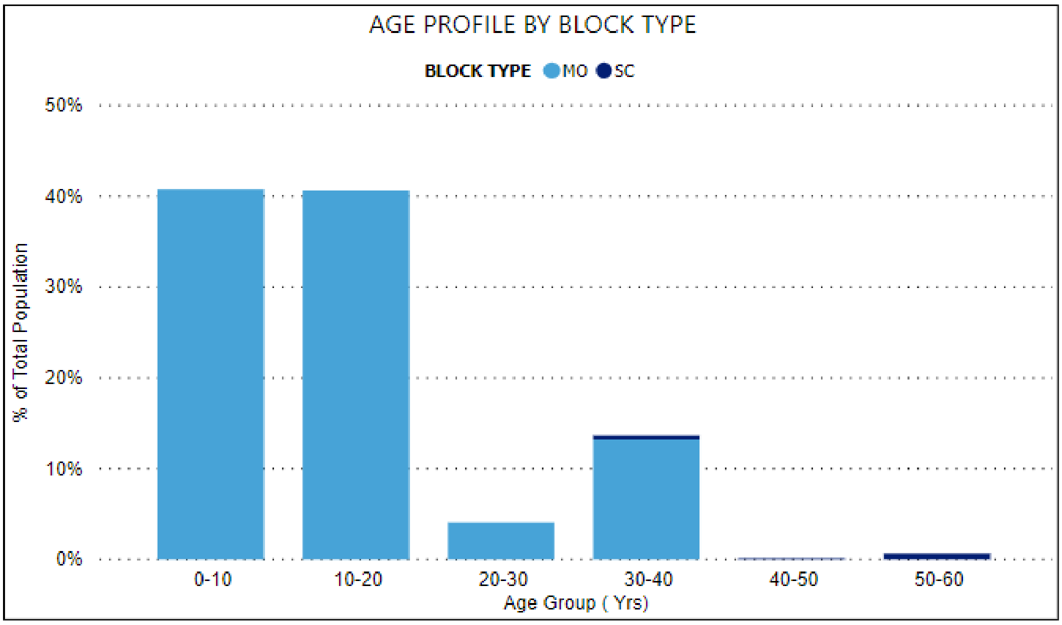

Figure 5 – Age profile of surge arresters by Voltage

3.4 Asset Condition

Table 1 provides the condition assessment criteria of surge arresters in terminal stations.

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 ABB EXLIM,COOPER AZG and ASEA XAR type surge arresters (30 yrs age) , later designs 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 30 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 and older ASEA XARs and ,Hitachi -ZLA types • 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, GE9LA, BRown Boveri HMP , 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. Approximately 76% are C1, 4% C2, 7% C3, 12% C4 and 1% C5.

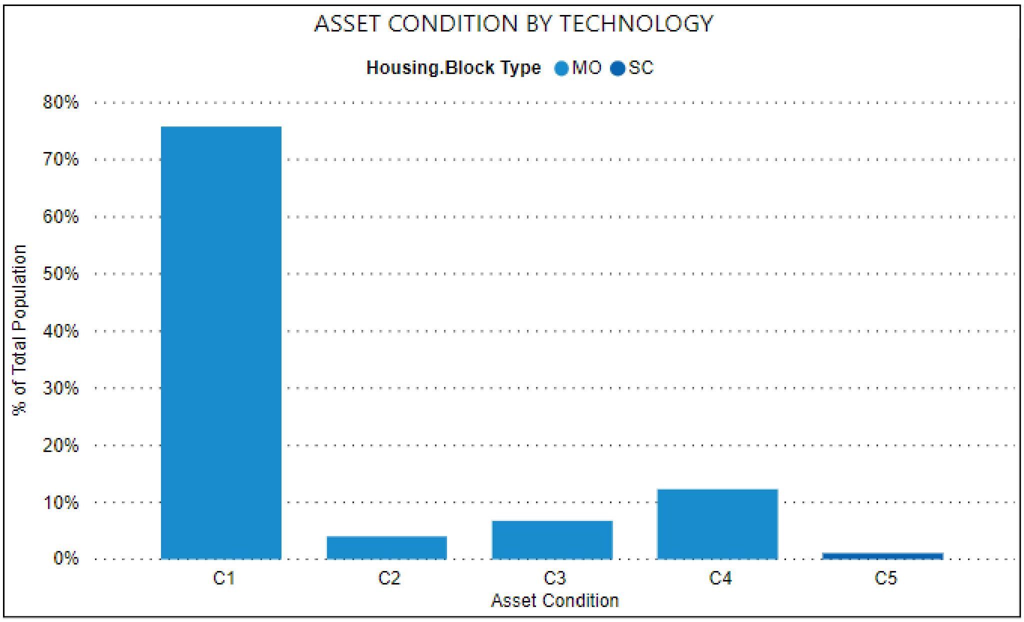

Figure 6 – Condition Profile of Surge Arresters by technology type

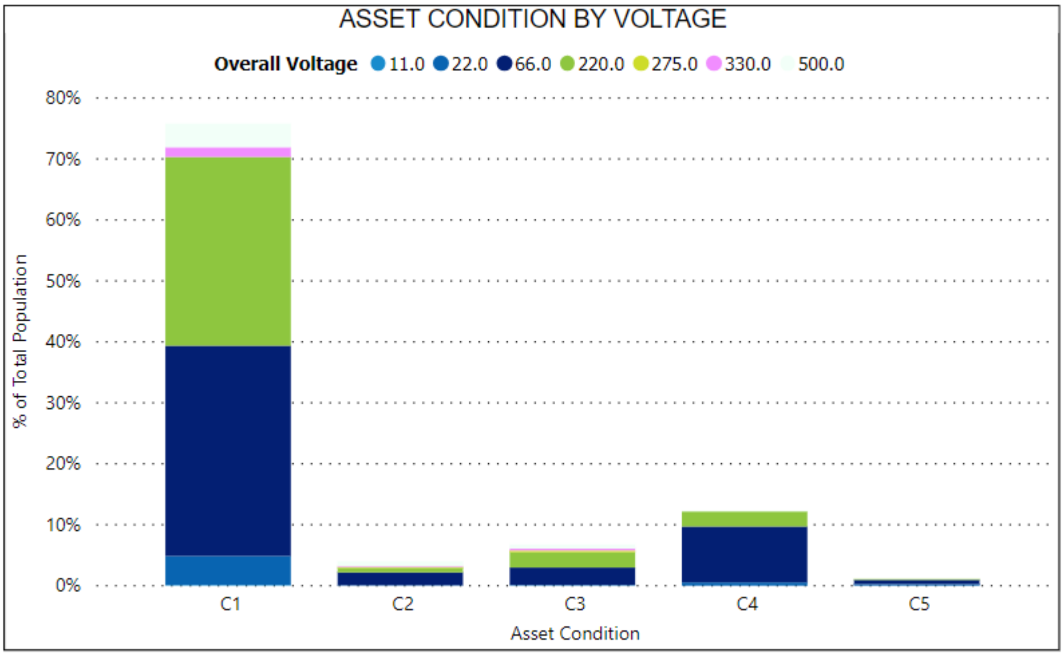

Figure 7 – Condition Profile of Surge Arresters by voltage

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. Modern surge arresters are metal oxide type with polymeric housings failure in most cases are benign. Also, 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 and criticality of the plant item it is protecting.

Figure 8 show the relative base criticality against service voltage. Approximately 60% of surge arresters have shown very high criticality majority driven mainly by market impact (VCR) due to their location on key assets and to a lesser extent due to the safety impact.

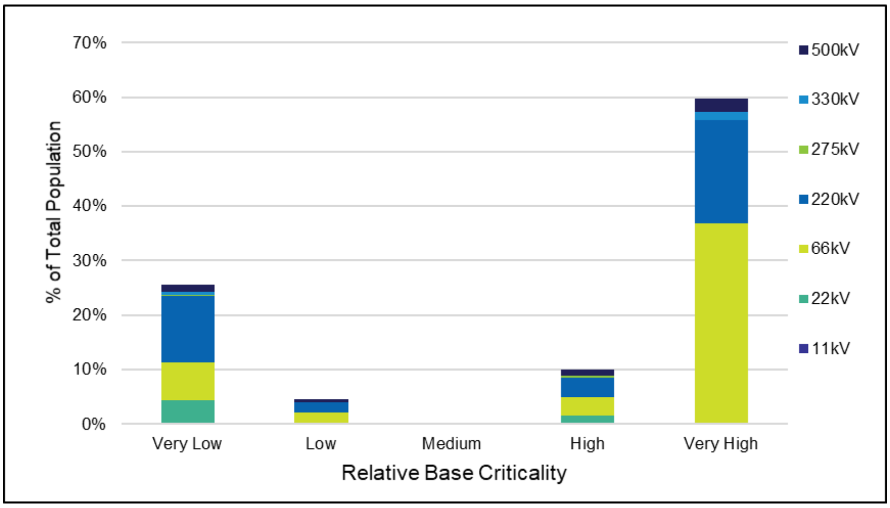

Figure 8 – Relative Base Criticality Profile against service voltage

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

3.6 Asset Performance

Surge Arresters are inspected during routine station inspections and in closer detail 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 other than replacement with modern metal oxide type to fix a defect or replace after a 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. These surge arrester types that are porcelain housed have had a history of catastrophic failures due to corrosion, seal failure, moisture ingress and then insulation failure.

3.6.1 Major failures

3.6.1.1. Porcelain housed metal oxide type

- [C-I-C] CS type – an early/ mid-1980's porcelain housed metal oxide surge arrester design. In 2010 there was operation and venting/internal failure of 500 kV [C-I-C] CS type at LYPS (owned by the power station) and two off 330 kV [C-I-C] CS type venting/internal failures at WOTS (on 91/1/10 and later 2/2/10). Both are a similar design, and, in these cases, the failure mode was benign, arresters vented externally. The LYPS failure has been linked to pollution effects. The WOTS failures have been attributed to deterioration of the metal oxide block characteristics. All this type has now been all replaced or scheduled for replacement.
- [C-I-C] type- an early/mid-1980's porcelain housed metal oxide surge arrester design located on B phase at HYTS M2 Power transformer had to be replaced in 2019 due to high leakage current (power losses) found during routine Power transformer testing. All are now scheduled for replacement.
- [C-I-C] type; in early 2000's [C-I-C] type had failed due to flange corrosion and moisture entry. Entire fleet was replaced.

The major failure and deterioration signs have become evident on the original early 1980's EHV metal oxide type surge arresters, namely the [C-I-C] and [C-I-C] type. There still remains some [C-I-C] type on the network, At HV voltages there still remains a relatively large population of early 1980's HV metal oxide surge arresters, namely [C-I-C] type, of which there have been no major failures to date.

3.6.1.2. Polymer housed metal oxide type

- [C-I-C]: Early life failure of a polymer housed metal oxide surge arrester, that's occurred in February 2011. Arrester was installed at HWTS in 2000, operated/vented and failed in the absence of any system incident. Failure mode was safe. There was no evidence of moisture entry and the investigation was inconclusive, but there have been no subsequent failures of a similar nature. In the absence of a network transient that could have initiated the event, it has been assumed that the failure was an isolated material / batch defect.
- [C-I-C] type: Early life failure of a polymer housed metal oxide surge arrester at ERTS occurred in 2014. No cause determined.
- [C-I-C] type: Mechanical failure of a 220kV surge arrester at NRCS due to undue force on the terminal during the process of installing the line conductor during associated plant maintenance.

3.6.1.3. Siilcon Carbide type

There has been no failures of Silicon carbide type in recent years, although the remaining population is very low due to targeted replacement programs. The inherent air gaps in the design, mean the arrester block is not continuously energised and so can remain defective, and not fully functioning correctly without any knowledge until the surge arresters has to function to limit overvoltage. Whereas metal oxide type are gapless and are effectively in operation all the time and block weaknesses are revealed more quickly result in insulation failure.

4 Other Issues

4.1 Surge Arrester Condition Monitoring

There are no cost-effective techniques available to accurately condition assess the internal deterioration of older surge arresters. Currently they are visually inspected for corrosion and external defects/ damages during their associated plant maintenance. Surge arresters on power transformers are also checked by a lower voltage power loss / leakage current measurement during the offline Power Transformer condition monitoring test program. Both of these are limited in being able to accurately condition assess internal health.

Long term performance of metal oxide surge arresters depends on the quality of manufacturer and its seal performance. The porcelain housed gapless surge arresters are now all exceeding 30 years and need for 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 a current Risk Assessment using the condition of the assets (C1 – C5) and the monetised consequence of failure (criticality bands 1 – 5).

Surge Arresters that are under replacement during the current period have been excluded from the risk matrix.

Table 3 - Surge Arrester Risk Assessment

Criticality Band	C1	C2	C3	C4	C5
5	923	42	72	120	9
4	84	6	60	55	9
3	90	3			
2	90	3			
1	471	38			

There are 138 surge arresters in the high risk red zone. The 18 units in C5 condition are mainly 22kV & 66kV old silicon carbide [C-I-C] types and are to be replaced. The 120 in C4 condition, Criticality 5, includes 39 older 220kV porcelain housed metal oxide surge arresters (mainly [C-I-C] and [C-I-C] types) which are also to be replaced. The remaining 81 are mainly 66kV [C-I-C] types which are porcelain housed metal oxide surge arresters. 15 of these have been identified to be replaced in the 2022-2027 TRR period in conjunction with station rebuild projects. The remaining [C-I-C] units will be monitored and considered for replacement in subsequent regulatory periods.

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 the [C-I-C] metal oxide porcelain-housed surge arresters along with other older metal oxide types and the polymer housed metal oxide surge arresters more than 20 years

6.4 Spares

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

6.5 Replacement

- Proactively replace 18 of 22kV & 66kV porcelain housed surge arresters and 39 of 220kV porcelain housed metal oxide surge arresters
- Replace [C-I-C] surge arresters in high risk area with new metal oxide polymer housed surge arresters in conjunction with station rebuild projects during 2022-2027.