Auxiliary Power Systems

AMS – Electricity Distribution Network

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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 document is to outline the inspection, maintenance, replacement and monitoring activities identified for economic life cycle management of Auxiliary Power Systems.

This strategy applies to Auxiliary Power Systems, that is the DC and AC supply systems installed in the electricity distribution network zone substations to allow network equipment to operate as required . There are 71 sites which contain auxiliary power supplies, with a total of 106 medium voltage station service transformers installed providing the 415V AC supply, that range in size from 25kVA to 750kVA. There are also 162 battery banks and associated DC chargers providing the DC supply at the sites. Battery sizes range up to 400Ah capacity and up to 250V DC.

Condition assessment shows approximately 31% of the total DC systems population are either in a "Poor" condition (C4, 16%) or "Very Poor" condition (C5, 15%). The AC system condition assessment shows approximately 18% of the total DC systems population are either in a "Poor" condition (C4, 16%) or "Very Poor" condition (C5, 2%).

Using the condition assessment and consequence criticality, based on unserved energy, a risk assessment for auxiliary supply systems was performed to establish an economically sound replacement program for the period 2022-26.

Proactive management of auxiliary systems 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

- All new DC Systems shall be installed with 125V DC X and Y batteries and chargers fully duplicated, SCADA monitoring and control, all in a new battery room with sufficient space and ability to control the envirionment.
- All new AC Systems will be installed with a new switchboard fitted with Auto-changeover and wired in compliancy with AS/NZS 3000.

1.1.2 Existing Assets

- Progressively replace DC distribution and monitoring boards that contain asbestos.
- Investigate and formulate a disaster-recovery strategy for each site that has only single batteries and implement appropriate measures.
- Replace ageing auxiliary DC supply cables that are causing battery earth problems.
- Progressively replace AC distribution and auto-changeover boards that contain asbestos.
- Replace the AC board in older stations where it is part of the 'horseshoe' mimic panel. Replace with fully enclosed metal cabinets, preferably located away from the DC panels.

1.1.3 Condition Monitoring

- Review existing SAP fault reporting methodologies and codes.

1.1.4 Maintenance

- Continue existing maintenance activities in line with: PGI 32-01-01, SMI 32-01-01, SMI 32-01-02.

1.1.5 Replacements

- Replace various DC auxiliary power systems and five AC auxiliary power systems as per the risk analysis

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 Auxiliary Power Systems. This document is intended to inform asset management decisions and communicate the basis for activities.

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

2.2 Scope

This strategy applies to Auxiliary Power Systems, bothe DC and AC supply systems installed in the electricity distribution network zone substation, 66kV regulator sites and various other smaller MV sites.

This strategy excludes auxiliary power supply systems associated with Lines Assets such as radio towers or pole top devices.

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

Auxiliary Power Systems are essential for the safe and reliable operation of zone substation equipment.

Each zone substation contains two types of auxiliary power systems:

1. AC Systems
2. DC Systems

3.1.1 AC Systems

AC systems supply energy for transformer cooling, battery chargers for the DC Systems, transformer on load tap changers (OLTCs), station lighting, air compressors, air conditioning and general purpose/maintenance outlets at 415V.

Station AC systems include auxiliary/service transformers, switchboards and all wiring associated with the AC supply circuits.

Zone substations have their AC supplied from within the station, usually via a station service transformer from a supply feeder or externally from a street supply.

3.1.2 DC Systems

DC systems supply energy for protection systems, system control and data acquisition (SCADA), instrumentation, metering, communications equipment, alarm systems, circuit breaker (CB) controls and CB auxiliary power.

These loads are critical for the safe and reliable operation of the substation and require an uninterrupted power supply, even when the power supply into the substation is interrupted.

Station DC systems include batteries, battery chargers, DC isolation and distribution boards and all wiring associated with the DC supply circuits.

3.2 Asset Population and Age Profile

There are 71 sites on the distribution network which contain auxiliary power supplies.

The majority of these are zone substations, however, some of these sites are simpler, having a single piece of equipment which requires auxiliary power supply such as a 66kV regulator site or some MV swithboards sites.

3.2.1 AC Systems

There are a total of 106 station service transformers (S/S Tx) installed within the distribution network with some zone substations having multiple station services transformers.

The rating of individual station service transformers range from 25kVA and can be as high as 750kVA.

AC systems will usually be the same age as the station they supply but may have been augmented as the station has grown. They are normally replaced and upgraded when a station is rebuilt.

Figure **1** illustrates the age profile of Station Service Transformer fleet as a percentage of the total population.

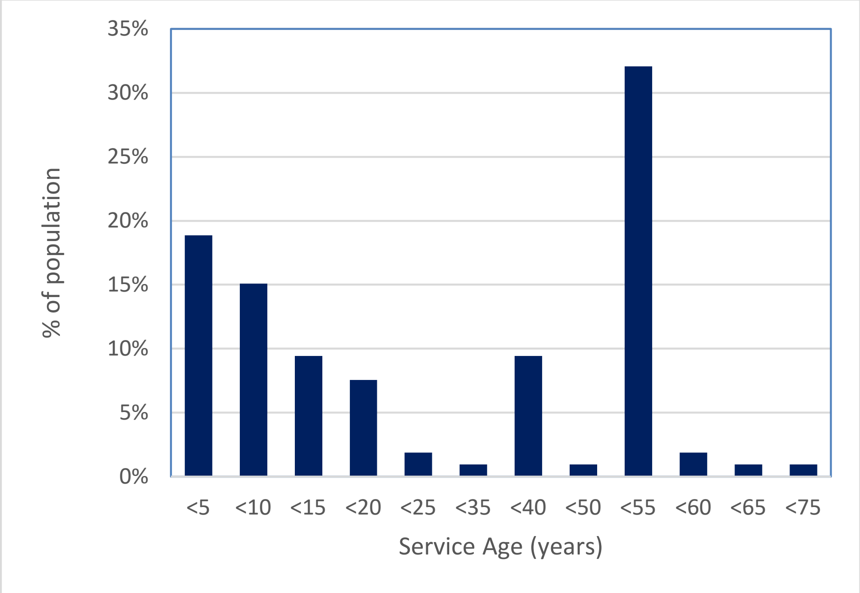

Figure 1 – Station Services Transformer Age Profile

3.2.2 DC Systems

The main components of a DC system are batteries and battery chargers. The current standard for DC Systems is for fully duplicated DC Systems. In this arrangement each DC System is fully segregated from the other system (ie separate batteries and battery chargers). Control and communication equipment is supplied by via DC/DC converters

Older station designs have dedicated single control batteries and communication batteries separate from the main DC systems.

Batteries

There are 162 battery banks providing power. This count is the number of individual battery banks, for example a duplicated system has two battery banks. Battery bank voltages range from 6V DC to 250V DC, with 125V DC the most common bank size as shown in Figure 2. Capacities range in size up to 400Ah.

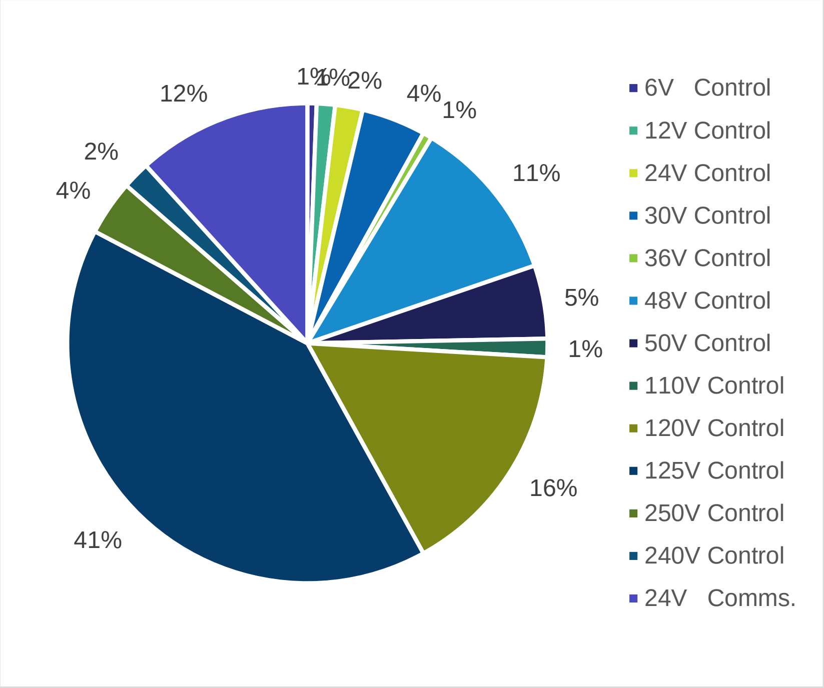

Figure 2 DC Battery Voltages

The vast majority are valve regulated lead acid gel batteries. The remainder are flooded lead acid batteries, which are being phased out as they are obsolete technology.

Figure 3 – Flooded Lead Acid Battery

Figure 4 – Valve Regulated Lead Acid Gel Battery

As shown in 5, the oldest battery is recorded as 21 years. The warranty life of a battery is typically 15 years. If the environment in which the battery is installed is not temperature controlled, the battery life may be substantially less than the warranty life and can be based on experience as low as 10 years life.

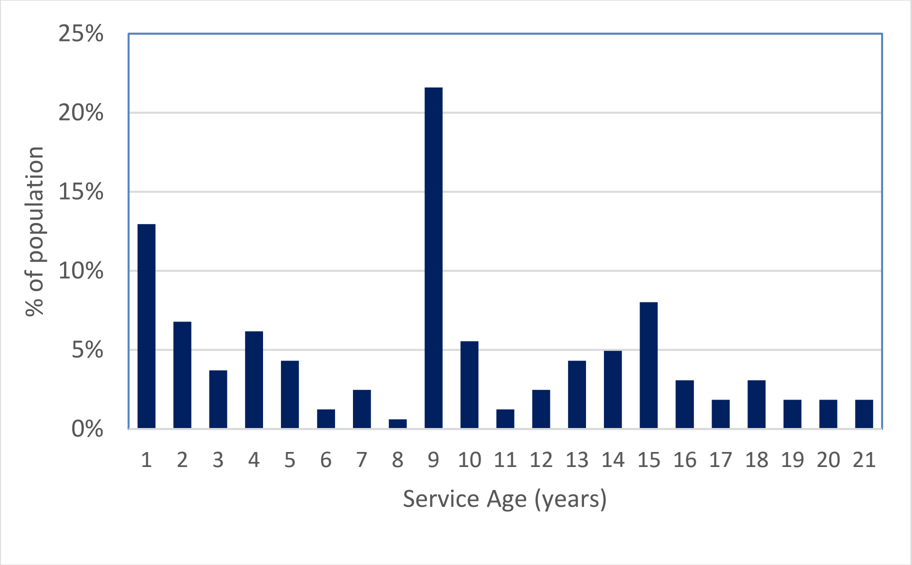

Figure 5 – DC Battery Age Profile

Over a 40% of the battery population is 10 years old or greater.

Battery Chargers

The number of battery chargers in service is equal to the number of battery banks on the network, that is 162 battery chargers. The battery chargers supply the DC panels and provide float charge to the batteries. In the event the AC systems fails, the batteries will supply the DC panels.

The current battery charger standard requires chargers to be installed with temperature control functionality. Temperature control functionality regulates the charge voltage in line with battery specification maximising the life span of individual battery cells. Figure 6 illustrates the battery charger population by whether or not the battery charger has temperature control.

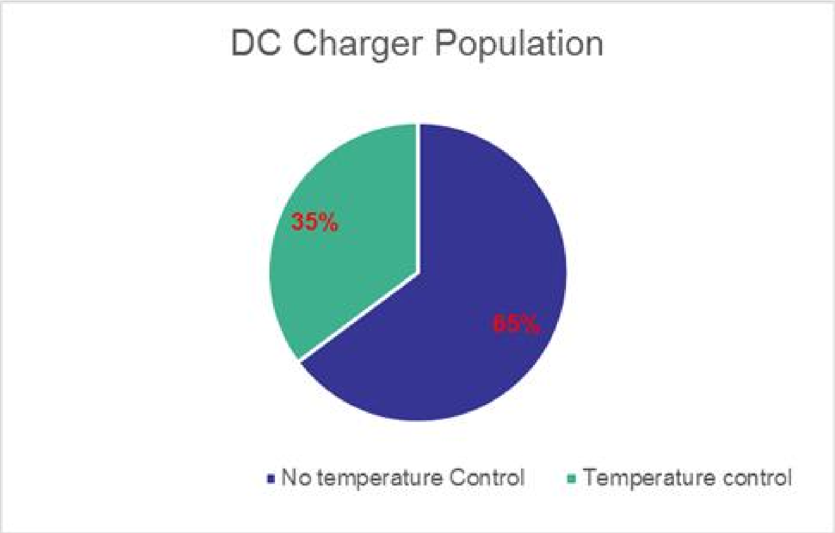

Figure 6 – Battery Charger Population and Temperature Control functionality

Figure 7 shows the age profile of battery chargers.

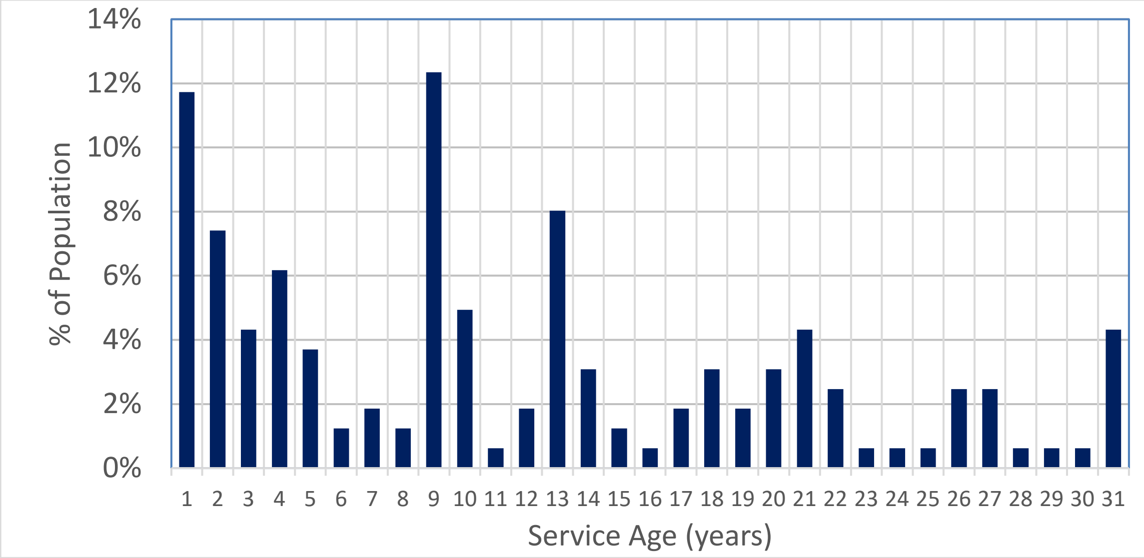

Figure 7 – Battery Charger Age Profile

As show in Figure 7, the recorded age of the oldest battery chargers is 31 years.

3.3 Asset Condition

A condition rating is assigned to each auxiliary power system components as outlined in following sections.

3.3.1 DC Systems

The condition scoring framework for DC Systems has been created by taking into consideration five contributing factors:

- Battery age and temperature control
- Battery charger age and technology type
- Presence of asbestos
- DC system duplication
- Modernisation capability

A condition assessment (CA) score was calculated for each dc system component and then grouped into an overall condition score per site.

The condition score is a five point scale ranging from “Very Good” (C1) to “Very Poor” (C5). Table 1 provides further details of the condition scores.

Table 1 – DC Systems Condition Score Definition

Condition Score	Condition Description	Summary of Condition Score Main Characteristics	Recommended Action
C1	Very good service	These DC supplies are generally new and in very good operating condition with no past history of significant defects or failures. No action is required for these DC supplies.	No action required.
C2	Better than average service	These DC supplies are in better than average service condition. They require routine maintenance and condition monitoring to prevent failures occurring.	Routine maintenance and condition monitoring.
C3	Average	These DC supplies are in average service condition. They require routine maintenance and condition monitoring to prevent failures occurring.	Routine maintenance and condition monitoring. mid
C4	Poor service	These DC supplies are in poor service condition. They require routine maintenance and condition monitoring and may require individual cell replacement. Expected batteries to remain in service for less than 5 years.	Less than 25% remaining life
C5	Very poor service	These DC supplies are in very poor service condition. They require routine maintenance and condition monitoring and some individual cell replacement. occurring and expected batteries require replacement with 2 years.	Less than 15% remaining life

Figure 8 shows the distribution of condition scores by as a percentage of total number of zone substations.

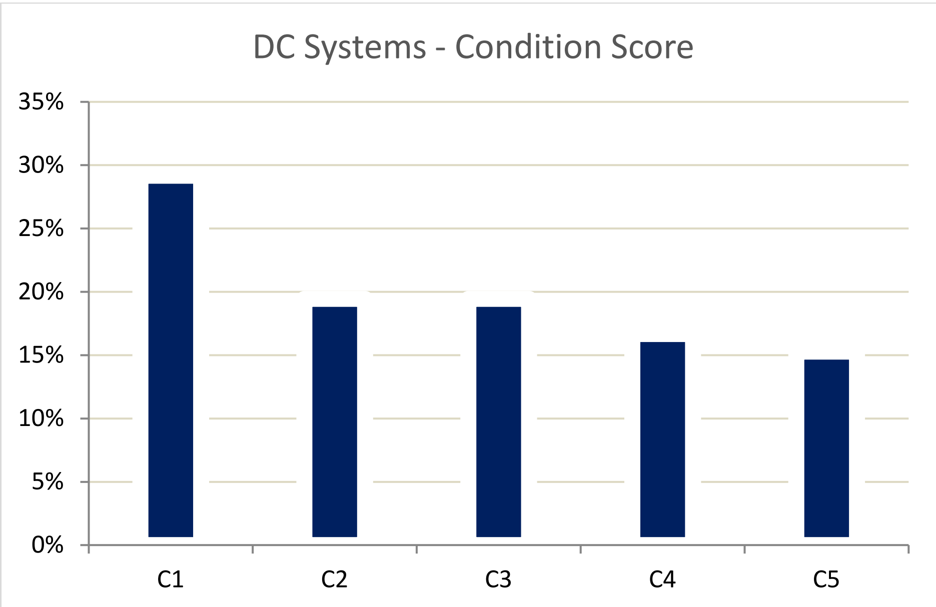

Figure 8 – DC Systems Condition Scores

The condition criteria assign C5 to approaching end of life batteries and C3 and C4 to batteries which will reach end of life by the end of next regulatory reset.

For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussion of failures, refer to the condition scoring methodology which can be found in the Asset Health Report (AHR) for Auxiliary Power Systems.

3.3.2 AC Systems

The condition scoring framework for AC supplies has been created by taking into consideration five contributing factors:

- Transformer duplication
- Transformer age
- Transformer type
- Auto-changeover on switchboard
- Switchboard age

A condition assessment score was calculated for each AC station supply transformer and then an overall condition score was assigned per site. The condition score is a five point scale ranging from “Very Good” (C1) to “Very Poor” (C5). Table 2 provides further details of the condition scores

Table 2 – AC Systems Condition Score Definition

Condition Score	Condition Description	Summary of Condition Score Main Characteristics	Recommended Action
C1	Very good service	These AC supplies satisfy all of the following criteria: duplicated supply transformers, switchboard with auto-changeover , compliant to AS/NZS 3000 and pole mounted supply transformers. The AC system components are in good conditon with no past history of significant defects or failures. No action is required .	No action required.
C2	Better than average service	These AC supplies satisfy any two of the following criteria: duplicated supply transformers, switchboard with auto-changeover, compliant to AS/NZS 3000 and pole mounted supply transformers. The AC system components are in reasonable condition.	Routine maintenance and condition monitoring.
C3	Average	These AC supplies satisfy at least one of the following criteria: duplicated supply transformers, switchboard with auto-changeover, compliant to AS/NZS 3000 and pole mounted S/S Tx. The AC system components are in average condition. They require routing maintenance and condition monitoring to prevent failures occurring.	Routine maintenance and condition monitoring. Expected to remain in service for next 5 years.
C4	Poor service	The AC system components are in poor condition. They require routing maintenance/component replacements and condition monitoring to prevent failures occurring.	Less than 25% remaining life

Condition Score	Condition Description	Summary of Condition Score Main Characteristics	Recommended Action
C5	Very poor service	These AC supplies do not satisfy any of the following criteria: duplicated supply transformers, switchboard in with auto-changeover, compliant to AS/NZS 3000 and pole mounted supply transformers. The AC system components are in very poor condition. They require routing maintenance and condition monitoring to prevent failures occurring and require replacement.	Less than 15% remaining life

Figure 10 shows the distribution of condition scores by as a percentage of total number of zone substations.

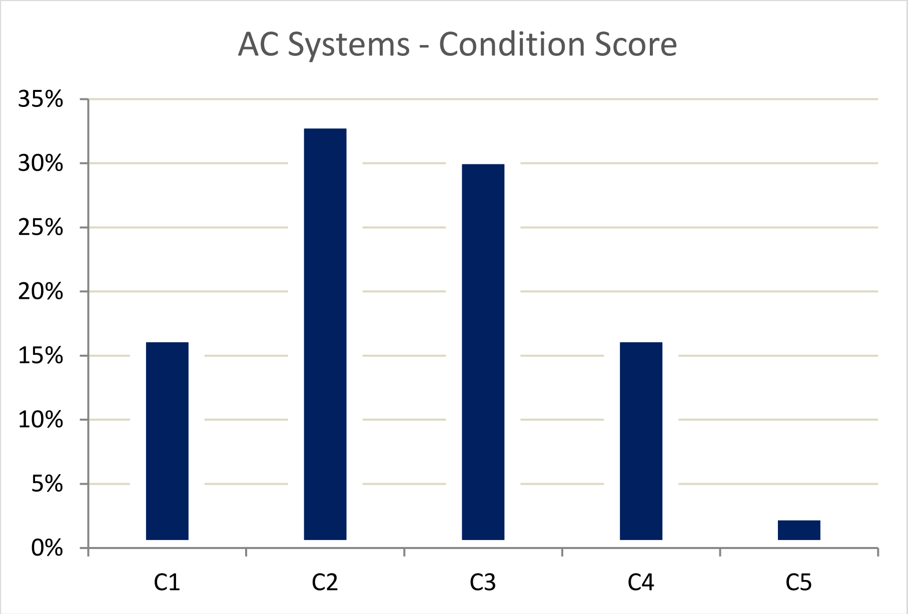

Figure 10 – AC Systems Condition Score

For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussion of failures, refer to the condition scoring methodology which can be found in the Asset Health Report (AHR) for Auxiliary Power Systems.

3.4 Asset Criticality

Auxiliary power systems failure present the following consequences:

- Network reliability impacts (refer Section 4.3)
- Ocupational risk (contamination due to asbestos presence in older battery rooms and switchboards and fumes should inadequate ventilation is provided to battery rooms) (refer Section 4.4).

The criticality was derived through the network reliability impact posed by each auxiliary power system. The occupational risks are factored into the cost of the solution, but not quantified in the benefits.

The characteristics considered as a quantification of the supply risk are:

- Zone substation black due to loss of protection (for DC and AC Systems); and
- Zone substation derating due to loss of power transformer cooling (for AC Systems only).

The value of unserved energy of each consequence is multiplied by number of hours required to restore the auxiliary power supply.

Considering the particular auxiliary power supply needs at each zone substation, there was 3 options available as a cost of replacement for DC auxiliary power systems as shown as per Table 3.

Table 3 – DC Auxiliary Power System Replacement Cost Options

DC Auxiliary Power System Options	Replacement Cost Basis	Relative cost ratio
1	Major replacement works of complete DC systems (Batteries, Charger, Isolation and Distribution) requiring a new Battery room (to eliminate asbestos and compliance issues)	6.6
2	Partial Replacement works (Battery and chargers) within the existing battery room	3.9
3	Like for like replacement of the DC Battery system cells within the existing battery room	1

The applied interpretation of relative base criticality is shown in Table 4.

Table 4- Interpretation of Relative Base Criticality

Relative Base Criticality	Criticality Banding	Definition
Very low	1	Total failure effect cost < 3 times Replacement Cost
Low	2	Total Effect Cost is between 0.3-1 times of replacement cost
Medium	3	Total Effect Cost is between 1-3 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

Figure 11 and Figure 12 show the distribution of criticality scores for DC and respectively AC Systems as a percentage of total number of zone substation.

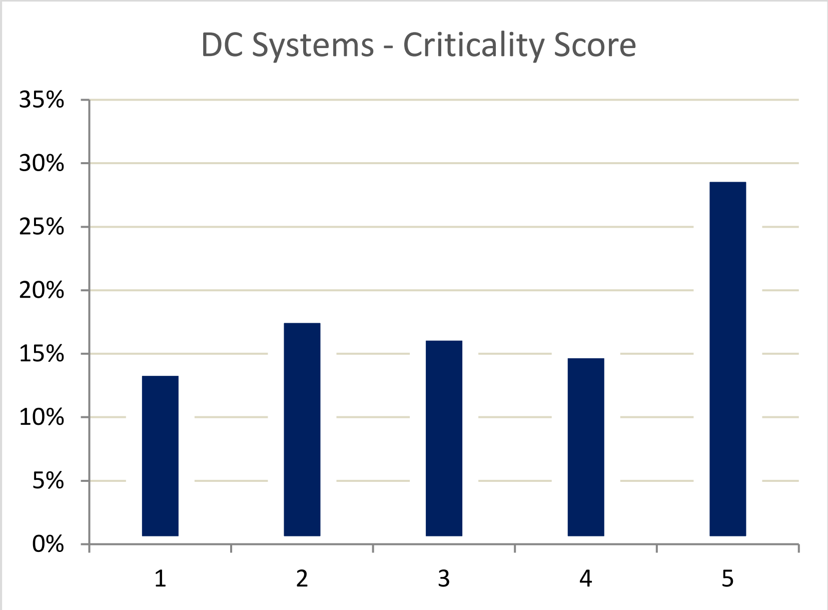

Figure 11 – DC Systems Criticality Score

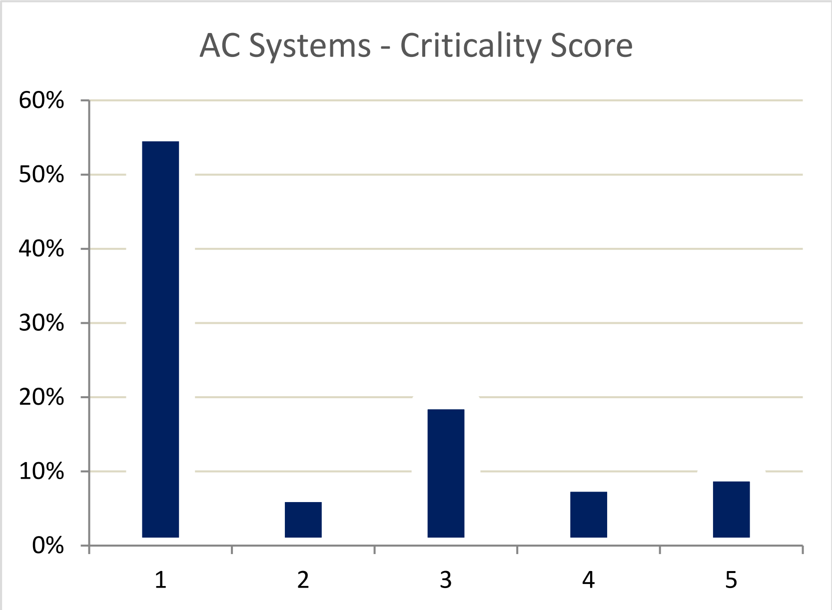

Figure 12 – AC Systems Asset Criticality Score

3.5 Asset Performance

Records of unplanned maintenance work undertaken on circuit breaker population on the CB population are maintained in the Asset management system, SAP. Typical source of defects found during planned & unplanned maintenance inspections carried out in DC Systems during the period 2015 -2018 are shown in Figure 13 below.

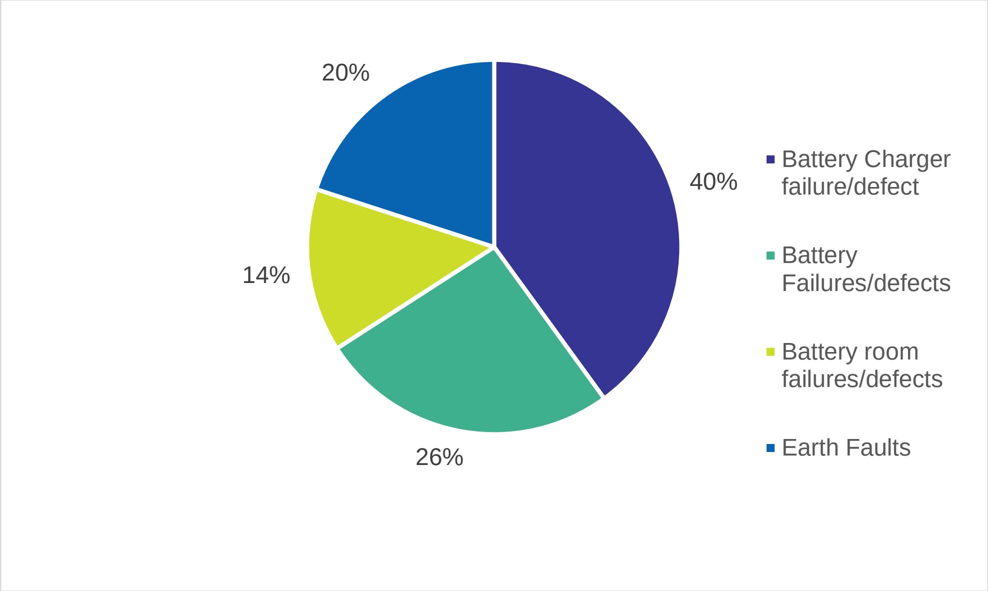

Figure 13 Corrective Mainteance analysis 2015 - 2018

There was 85 recorded failures and defects over the 3 years period. The majority of issues are charger component failures that typically requiring card , component or complete charger replacement.

The second dominant issues is battery terminal corrosion, cracked cases and electrolyte leakage, connection lead failure and DC cells unable to hold suffcient charge.

4 Other Issues

4.1 DC System

DC Systems exhibit a number of different issues:

- Old battery rooms do not have sufficient space for duplicated X and Y battery banks and the presence of asbestos makes augmentation financially impractical.
- Lack of SCADA monitoring in old battery rooms:
  - lack of monitoring equipment voids the DC cell warranty as the manufacturer requires proof that the DC cell was operated in a controlled regime and environment.
- Maintenance:
  - full discharge test is impractical on zone substations with a single battery bank as this would leave the zone substation without an auxiliary power supply for several hours during the test. This leads to a reduction in a DC cell lifespan.
  - discharge rate test is impractical on zone substations with a single battery bank thus the accurate measurement of the DC system available capacity is not possible. There is a risk (increasing with the age of the battery) that certain battery banks can not supply the control and communication loads for 10 hrs as required. This may result in a loss of protection hence ZSS black if the case of a charger or AC S/S Tx failure.
  -

4.2 AC System

AC Systems exhibit a number of different issues:

Old AC switchbords:

- do not have auto-changeover functionality. The lack of auto-changeover functionality may result in up to two hours loss of auxiliary power supply in case of a S/S Tx failure.
- contain asbestos, which is a health and safety hazard.
- the wiring is not compliant with AS/NZS 3000. Switchboards which are not AS/NZS 3000 compliant are prone to result in earth fault incidents.

Station services transformer maintenance and testing is impractical in zone substations with single station services transformer. This may impact on the auxiliary power supply reliability.

4.3 Supply Risk

All modern secondary equipment requires reliable and secure auxiliary DC system.

Complete failure of auxiliary DC system renders much of the secondary system inoperable. For this reason, especially where DC systems are not duplicated, it is essential that the DC Systems are maintained adequately.

Station security is at risk due to a single source of 120V DC supply for most substations. A loss of the DC system will require the zone substation to be de-energised.

Ageing auxiliary DC supply cables can cause battery earths that can be time consuming to remedy.

Station security is also at risk if AC auxiliary supplies, including their cables, are not adequately rated. Loss of AC system will reduce the main power transformer rating and prevent OLTC operation. In this situation it is possible to damage or reduce the life of power transformers.

On the AC system, ageing cables can cause fuse failure and the loss of station rating and OLTC control. Such an event may incur a significant reliability incentive scheme penalty.

4.4 Ocupational Safety Risk

Older battery rooms are sized for a single DC battery bank and without equipment to monitor the battery temperature and room envirionment in terms of temperature and ventilation.

Additionally older battery rooms and AC switchboards contain asbestos.

The solution adopted to mitigate these risks is installing a new modern battery room in the zone substation in the vicinity of the old battery room.

4.5 Asset maintenance

Existing conditional maintenance procedures in place for DC supplies includes Class 2 and Class 3 overhauls that occur on a 12 month cycle. A Class 2 overhaul includes voltage and impedance tests of all battery blocks and Class 3 overhauls consist of battery functional checks and charger alarms tests. Further information on batteries and chargers can be found in the following documents:

- PGI 32-01-01: Plant Guidance and Information – Batteries: Vented Lead Acid and Valve Regulated Lead Acid
- SMI 32-01-01: Standard Maintenance Instruction – Batteries: Vented Lead Acid and Sealed Lead Acid Class 1, Class 2 and Class 3 Overhauls
- SMI 32-01-02: Standard Maintenance Instruction – Battery Chargers

Ensuring routine maintenance activities are conducted allows any issues to be resolved as soon as practical. This ensures Auxiliary Power Systems remain in a functional condition.

4.6 Rapid Earth Fault Current Limiter (REFCL)

In line with the Victorian Electrical Safety (Bushfire Mitigation) Amendment Regulations 2016 AusNet Services needs to install the Rapid Earth Fault Current Limiter (REFCL).

The installation and application of REFCL technology are governed by two key legislations:

1. Electricity Safety (Bushfire Mitigation) Regulations 2013
2. Electricity Safety Act 1998

The introduction of REFCL on designated zone substations and feeders leads to load creep on the secondary systems.

As a result in zone substations where the auxiliary systems load can not be supplied from existing auxiliary power systems there are augmentation works included in the REFCL installation.

From a design perspective the REFCL auxiliary load is supplied from the Y battery and the traditional protection systems from the X battery to ensure the REFCL is in use even in the case of a protection failure.

For more information on REFCL policies see REF-30-06 and REF-30-09.

5 Risk and Options Analysis

5.1 Overview

The 2022-26 proactive replacement scope of works was derived through a semi-quantitative risk assessment and considers the network reliability impact posed by each auxiliary power system together with the condition assessment.

For each zone substation the DC assets (chargers and battery) and the AC assets (station services transformer and AC switchboard) were scored at a station level. Where multiple DC auxiliary power systems (control and communicationss) are installed at one zone substation, the scores are consolidated in one overall DC system condition score per zone substation. Criticality has been graded as explained in Section 3.4.

The risk analysis does not consider the auxiliary power systems in zone substation required where the REFCL program forecasted auxiliary power system upgrades.

5.1.1 AC Systems

Table 4 – AC Auxiliary Systems Risk Matrix

		Condition				
		C1	C2	C3	C4	C5
CRITICALITY	5		2		2	1
	4	1	1	1	1	
	3		1	8	1	
	2		1	3	1	
	1	11	18	6	3	1

Risk analysis indicates that priority is to replace the four extreme risk assets (the red region in the matrix) and one C5 high risk asset (in the orange region of the matrix).

5.1.2 DC Systems

Risk analysis requires analysis to be considered against the various replacement options of battery only replacement, partial replacement with duplication, and complete system replacement requiring new compliant building. Criticality has been graded as explained in Section 3.4 and assessed as against the one of the three replacement options. As DC battery systems life is shorter than AC system and battery can transition to C3 to C5 within a regulatory submission period.

Table 5 – DC Auxiliary Systems with Battery replacement

		Condition				
		C1	C2	C3	C4	C5
CRITICALITY	5	10	2	9	8	7
	4	6	3	1	2	3
	3	2	2	2	1	1
	2	2	3	0	1	0
	1	1	3	1	0	0

The risk analysis recommends that up to 30 sites in the higher risk zone would require some battery, partial replacement or full system replacement. The analysis has factored in a preferred replacement, which amounts to 10 sites with battery replacement, 8 sites with battery /DC charger partial replacement and 12 sites with full DC system replacement during the period.

The battery only replacement only sites are those currently scored at C3 and criticality 5 which would deteriorate in condition over the 2022-26 period.

Delivery would be combined with Station major project work where practical. It is expected 6 will be delivered in this manner and remaining 24 sites as DC Supply Replacement program.

5.2 Summary of Expenditure Forecast

The next regulatory period 2022-26 proactive replacement program includes the replacement of five AC auxiliary power systems and DC supply system replacement program at up to 30 Zone substations sites.

6 Asset Strategies

The following strategies shall be used to manage risks associated with Auxiliary Power Systems.

6.1 New Assets

- All new DC Systems shall be installed with 125V DC X and Y batteries and chargers fully duplicated, SCADA monitoring and control, all in a new battery room with sufficient space and ability to control the envirionment.
- All new AC Systems will be installed with a new switchboard fitted with Auto-changeover and wired in compliancy with AS/NZS 3000.

6.2 Existing Assets

- Progressively replace DC distribution and monitoring boards that contain asbestos.
- Investigate and formulate a disaster-recovery strategy for each site that has only single batteries and implement appropriate measures.
- Replace ageing auxiliary DC supply cables that are causing battery earth problems.
- Progressively replace AC distribution and auto-changeover boards that contain asbestos.
- Replace the AC board in older stations where it is part of the 'horseshoe' mimic panel. Replace with fully enclosed metal cabinets, preferably located away from the DC panels.

6.3 Condition Monitoring

- Review existing SAP fault reporting methodologies and codes.

6.4 Maintenance

- Continue existing maintenance activities in line with: PGI 32-01-01, SMI 32-01-01, SMI 32-01-02.

6.5 Replacements

- Replace various DC auxiliary power systems and five AC auxiliary power systems as per the risk analysis