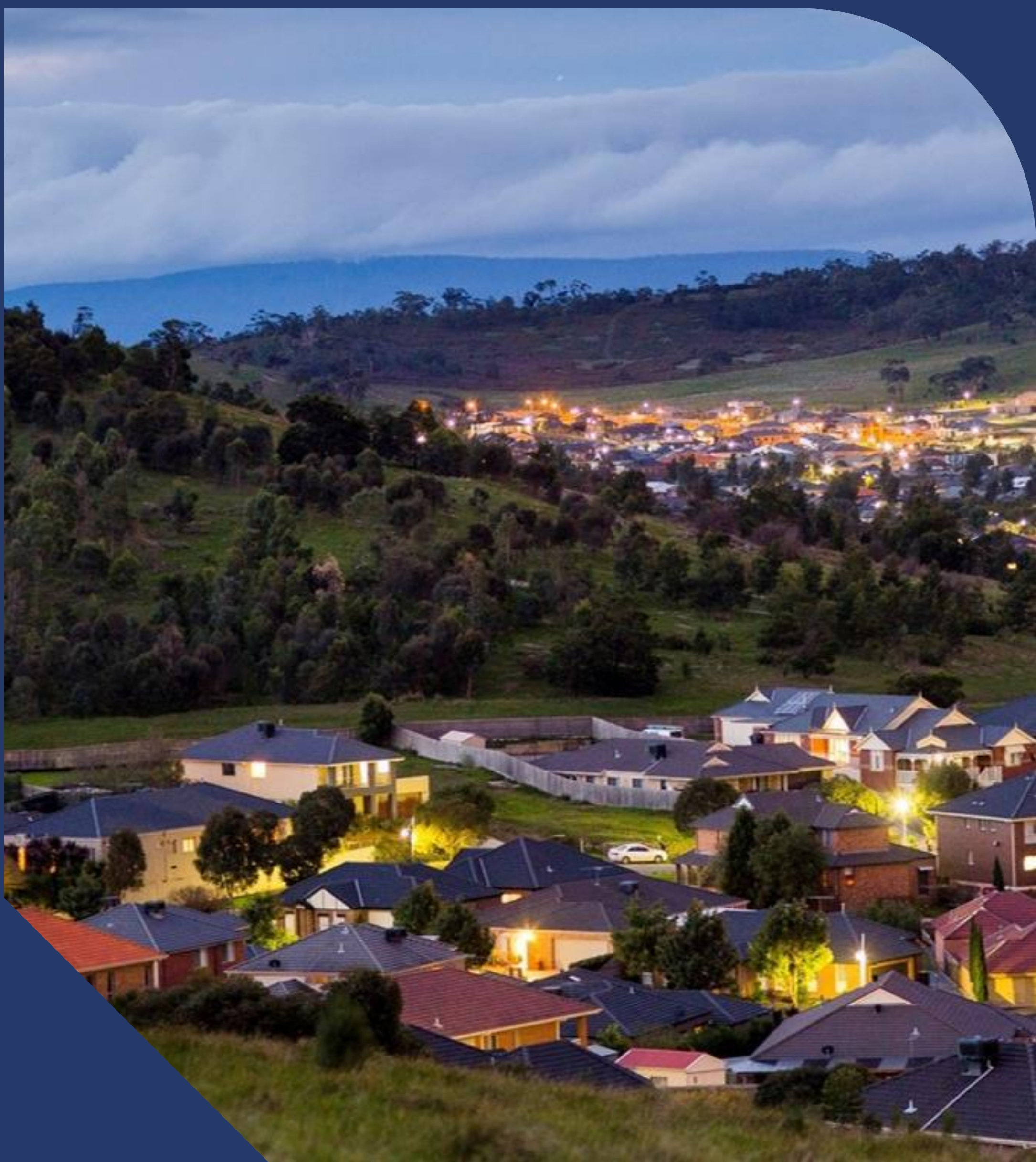
AusNet

Auxiliary Power Systems

Asset Management Strategy



AusNet

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Auxiliary Power Systems

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Abbreviations and Definitions

TERM	DEFINITION
AC	Alternating Current
ACM	Asbestos containing materials
AEMO	Australian Energy Market Operator
AGM	Absorbent Glass Mat
AUX	Auxiliary
CoF	Consequence of Failure
CB	Circuit Breaks
DC	Direct Current
EOL	End of Life
LV	Low Voltage (typically 230V/415V supply)
OH&S	Occupational health and Safety
PoF	Probability of Failure
PGI	Plant Guidance and Information
SAP	Systems, Applications, and Products
SCADA	Supervisory Control and Data Acquisition
SME	Subject Matter Expert
SMI	Standard Maintenance Instructions
S/S	Station Services
TS	Terminal Station
VRLA	Valve Regulated Lead Acid
VUE	Value of unserved energy

1. Executive Summary

This document is part of the suite of Asset Management Strategies relating to AusNet's Victorian regulated electricity transmission network. It outlines the inspection, maintenance, monitoring, and replacement activities required for the economic life cycle management of Auxiliary Power Systems.

This strategy applies to Auxiliary Power Systems, that is the Direct Current (DC) and Alternating Current (AC) supply systems installed in regulated electricity transmission network terminal stations and communication sites. The network comprises a total of 198 individual DC power systems (250V and 48V) installed at terminal stations, along with 77 DC power systems (48V and 24V) located at communication sites.

Key challenges include performance and functionality limitations of ageing battery systems that have exceeded their economic service life, occupational health and safety risks associated with regular maintenance of flooded cell batteries, remote visibility and monitoring of battery cells and the need to maintain compliance with current Australian and AusNet Standards.

A risk-based assessment has been undertaken, focusing on the consequences of failure, including safety impacts, market implications, and the value of unserved energy (VUE). These factors along with asset life, failure trends and spares management form the foundation of a risk-based assessment framework that supports a targeted replacement program for DC systems and AC LV system between 2027 and 2032.

Auxiliary power systems not just support infrastructure they are the critical enablers of control, protection, and operational continuity across the transmission network. Their performance directly influences the reliability, safety, and efficiency of high-voltage assets. To meet growing stakeholder expectations for cost effective operations, zero harm, minimal unplanned outages, it is essential to adopt a proactive lifecycle asset management approach that includes: Timely replacement of aging components, routine inspections to detect early signs of degradation, condition monitoring for predictive insights and risk mitigation are required for system integrity. Auxiliary system failures can lead to cascading failures, station outages, compromised safety, and regulatory non-compliance making their strategic management a cornerstone of transmission network resilience.

1.1. Asset Strategy Summary

The strategy focuses on reliability, safety, and future readiness of Auxiliary Power Systems across the regulated transmission network. New installations and replacement of existing assets will comply with the AusNet Station Design Manual REF: SDM 06-0302,0303 and relevant Australian Standards, featuring duplicated battery banks, chargers, monitoring systems, DC/DC convertors where other voltages are required, fireproofing, acid proofing of floors, ventilation systems and SCADA integration. These activities are to be integrated with broader station refurbishments or network upgrades wherever possible to minimise disruption.

Maintenance and inspection activities will continue under existing procedural guidelines REF: PGI 02-01-02 and the REF: SMI 32-01-01 suite of documents consistent with REF: AMS 01-09 Asset Risk Assessment Overview with emphasis on condition monitoring and online diagnostics to reduce manual effort.

Spares management includes maintaining mobile DC supply trailers and exploring options for emergency replacements. Replacement efforts prioritise ageing or high-risk assets, aligning with broader infrastructure upgrades where feasible. Refurbishment of battery rooms are integrated into replacement projects. The strategy also supports ongoing research into emerging battery technologies and maintenance-free solutions and remote monitoring of battery cells to enhance long-term performance and reduce operational risks. The preferred battery type is Valve Regulated Lead Acid (VRLA), chosen for its low maintenance, reduced OH&S risks, and space efficiency.

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 System. This document is intended 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

Included in this strategy is Auxiliary Power System, both DC and LV AC supply systems installed in the regulated electricity transmission network terminal stations and communication sites.

Excluded from this strategy is Auxiliary Power System associated with Lines Assets such as radio towers or pole top devices, fire system and standby diesel generators.

Auxiliary power supply components include:

- Batteries
- Battery Chargers
- Associated DC Equipment
- Associated AC Equipment

The associated DC Equipment covers those other DC system equipment items, such as battery room safety features, DC isolation and distribution boards, DC-DC convertors, and DC supply alarms and monitoring relays.

The associated AC Equipment covers AC system equipment items, such as Station service transformer, AC switchboards, changeovers and control, alarm and monitoring relay, and workshop and yard AC power outlets.

2.3. Asset Management Objectives

The high-level asset management objectives are outlined in REF: AMS 01-05 Asset Management System Overview.

Trusted to bring the energy today and build a cleaner tomorrow							
Strategic Pillars						Ambition	
Safely deliver our customer's energy needs today				Create the energy network of tomorrow	Enable the transition to a net zero future	Be a leader in asset management practice	
Asset Management Objectives						Enabling AMOs	
Safety: Minimise risk to our people, contractors, customers and communities AFAP across our networks	**Reliability:** Meet the reliability expectations of our customers and communities, and meet our reliability targets	**Resilience:** Improve the resilience of our network to adapt to a changing climate and energy system environment	**Compliance:** Comply with all legislation, regulations, relevant standards and industry codes	**Planning and decision-making:** Deliver valued planning and network outcomes through optimising asset lifecycle management	**Sustainability:** Build stakeholder trust and deliver social value. Reduce our environmental impact. Operate efficiently to sustain financial value creation.	**Competency and capability:** Develop asset management capability and competency in the organisation	**Continuous improvement:** Continually improve asset management maturity for effective delivery of services

3. Asset Description

3.1. Function

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

Each terminal station contains two components of Auxiliary Power System:

(1) LV AC Systems; and

(2) DC Systems.

3.1.1. AC Systems

Main Components of AC Systems:

- Auxiliary/Service Transformers: Step down voltage to supply low-voltage (LV) systems.
- Switchboards: Distribute LV power to various station facilities and equipment.
- Wiring and Circuits: Connect all LV components and facilitate reliable power delivery.

Purpose of LV AC Systems:

- Provide 400/230 V supply to essential station equipment such as
  - Air conditioning
  - Lighting
  - Ventilation
  - Water pumps
  - Fire panels
- Transformer cooling and OLTC
- Battery chargers for the DC Systems

Terminal stations have their AC supplied from within the station, usually via a station service transformer from a supply feeder or power transformer tertiary.

3.1.2. DC Systems

DC systems supply energy for protection and control systems, 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 station and require an uninterrupted power supply, even when the power supply into the station is interrupted.

A complete failure of the DC power supply at a terminal station can result in the loss of control over energy flows and station equipment and disable the electrical protection system, posing serious risks to consumers, the public and operational personnel.

Batteries

Batteries play a critical role in substations by storing energy and supplying the DC system during power interruptions. They maintain an uninterrupted power supply for essential systems such as control, protection, monitoring and communication They are vital for maintaining the continuous operation of substation control and protection equipment during outages or AC supply failures.

According to the Australian Energy Market Operator's (AEMO's) *Protection and Control Requirements*, substations must include Duplicated and Physically Segregated "X" and "Y" DC batteries and Chargers with sufficient capacity to support identified station DC services for up to 10 hours.

Most substations implement the following configurations:

- 250V "X" and "Y" batteries for general DC supply
- 48V "A" and "B" batteries for operational communication equipment
- 50V control supply provided via duplicated DC-DC converters from the 250V batteries (in newer designs)

Older station designs used dedicated single 250V protection batteries and 50V control batteries, but the 50V control supply is being progressively phased out.

For communication systems 24V or 48V communications batteries are installed at terminal stations and radio sites. This segregation isolates communication infrastructure from transient voltages and protects sensitive equipment from disturbances caused by high-voltage operations (e.g., circuit breakers)

Battery Chargers

Battery chargers are a vital component of the DC system, responsible for maintaining battery charge and supplying power during normal operations. Their primary functions include charging batteries to make sure they are always ready to supply power during outages, provide continuous DC power to station systems under normal conditions. Chargers perform AC to DC rectification, supporting the batteries and the DC system simultaneously.

Under current AusNet' design standards, DC chargers must support both "X" and "Y" DC loads with batteries fully charged, float charge one battery while supplying either "X" or "Y" load, be capable of recharging a fully discharged battery within 8 hours, provide float, equalise, and boost charge voltage levels and generate alarms in the event of charging circuit failures. These capabilities enable reliable battery performance and uninterrupted DC supply for critical substation operations.

DC Isolation and Distribution Boards

DC isolation and distribution boards are essential components in substations, responsible for the safe and reliable distribution of DC power to various systems. Their key functions include isolating different sections of the DC system to enhance safety and maintainability, distributing DC power to critical substation equipment, including control, protection, and monitoring systems. These boards enable that DC power is delivered efficiently and safely to all required loads, supporting the continuous operation of substation infrastructure.

3.2. Population Profile

3.2.1. Population Considerations

The population profile for Auxiliary Power System is crucial for effective lifecycle management. This profile includes detailed data on the quantity, types, locations, and specifications of these assets within the regulated electrical transmission network.

A comprehensive understanding of the population profile allows asset managers to:

- Identify critical assets: Determine which Auxiliary Power Systems are more essential for maintaining the integrity and reliability of the network.
- Allocate resources efficiently: Plan and allocate maintenance / replacement resources effectively by knowing the exact number and location of assets. For instance, knowing that certain stations with single battery bank can help in prioritising replacement program.
- Risk management: Assess and manage risks associated with different assets. For example, if the population profile indicates that certain sites with Auxiliary Power System are in bushfire-zone areas, battery banks must be maintained at a regular interval as per schedules.
- Optimise maintenance schedules: Develop optimised maintenance schedules based on the distribution and condition of assets. For instance, single or aging auxiliary power systems that are critical for SCADA and protection systems might be scheduled for more frequent inspections and maintenance or on-line monitoring retrofitted to prevent any potential failures.

- Enhance reliability and safety: that all components, including AC and DC Auxiliary Power Systems, meet the required standards for reliability and safety. For example, if the profile reveals that certain battery chargers are aged, outdated and no longer meet safety standards, these can be prioritised for replacement.
- Support strategic planning: Inform long-term strategic planning and investment decisions.

3.2.2. Population Profile

Understanding the population profile of station equipment is essential for assessing asset health, planning maintenance, and identifying risks associated with aging infrastructure. Within this context, the condition and lifecycle of both AC and DC systems play a critical role in station reliability and safety. The following sub-sections examine the individual AC and DC systems in detail, focusing on their type and age-related considerations.

3.2.3. AC Systems

Every Station is equipped with many Station Service Supply Boards i.e. LV Supply boards to provide LV supply to all electrical equipment and auxiliaries operating at 400/230V. Failure of a Station service supply board could potentially cause a shutdown of the terminal station resulting in reduced supply to the grid and loss of supply to customers. Hence to maintain a safe work environment, it's very essential to maintain Station Service Supply boards in a good condition

3.2.4. DC Systems

The main components of a DC system are batteries and battery chargers.

Batteries

There are 198 individual 250V and 48V batteries in AusNet regulated transmission stations and 77 individual 48V and 24V batteries in communication sites.

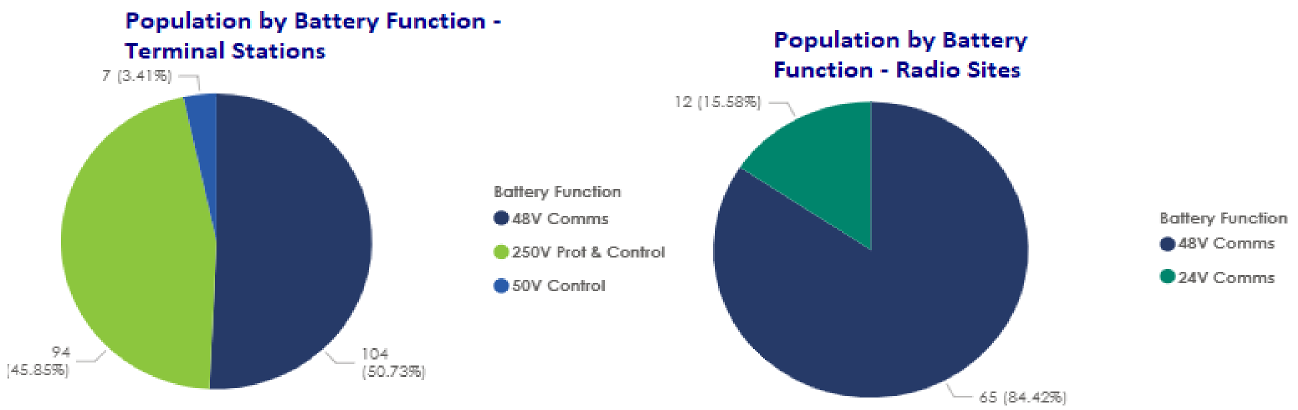


Figure 1: Batteries by voltage and function at terminal stations and radio sites

A duplicated system is counted as two battery banks. Capacities range, depending on size of station load varies from 100Ah up to 2000Ah.

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

Terminal Station batteries are:

- 250V Protection and Control.
- 48V Communication.
- 50V Control.
- Other batteries (i.e. fire and diesel generator starter batteries)

Radio sites batteries are

- 24V and 48V Communication.

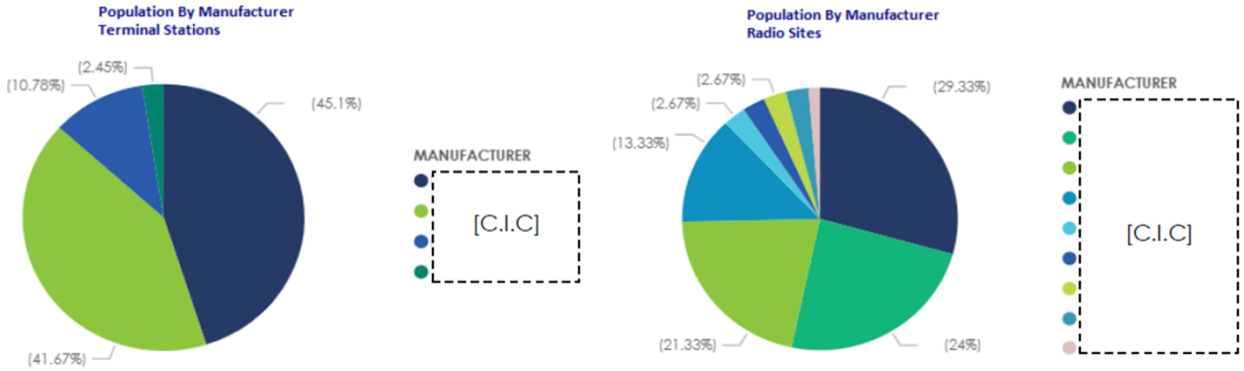


Figure 2: Battery population by Manufacturer

The current battery fleet in regulated terminal stations consists predominantly of two manufacturers:

- [C.I.C] 45.1%
- [C.I.C] 41.67%
- [C.I.C] 10.78%
- [C.I.C] 2.45%

[C.I.C] batteries are modern AGM valve-regulated lead-acid (VRLA) batteries. These batteries are widely used due to their low maintenance design, sealed construction, and reliable performance in critical applications.

The Classic and [C.I.C] batteries are flooded cell vented batteries. These are older technology, requiring regular maintenance such as electrolyte level checks, terminal sulphation and topping up with distilled water, terminal sulphation and require regular cleaning.

The battery fleet at radio sites is distributed among several manufacturers, with the majority being AGM valve-regulated batteries. [C.I.C] , [C.I.C] , [C.I.C] and [C.I.C] together make 88% of the batteries fleet at radio sites.

Lead times for procuring both Classic and [C.I.C] batteries have increased significantly. This is primarily due to ongoing supply chain challenges, lower production volumes, and the aging status of these product lines. In light of these extended lead times and the associated maintenance difficulties, it is recommended to prioritise the adoption of current standard AGM VRLA batteries for future replacements and to limit reliance on legacy batteries, especially when failed battery cells are identified.

Battery Chargers

There are 207 250V and 48V battery chargers in service across all regulated transmission terminal stations and 77 48V and 24V battery chargers at communication sites.

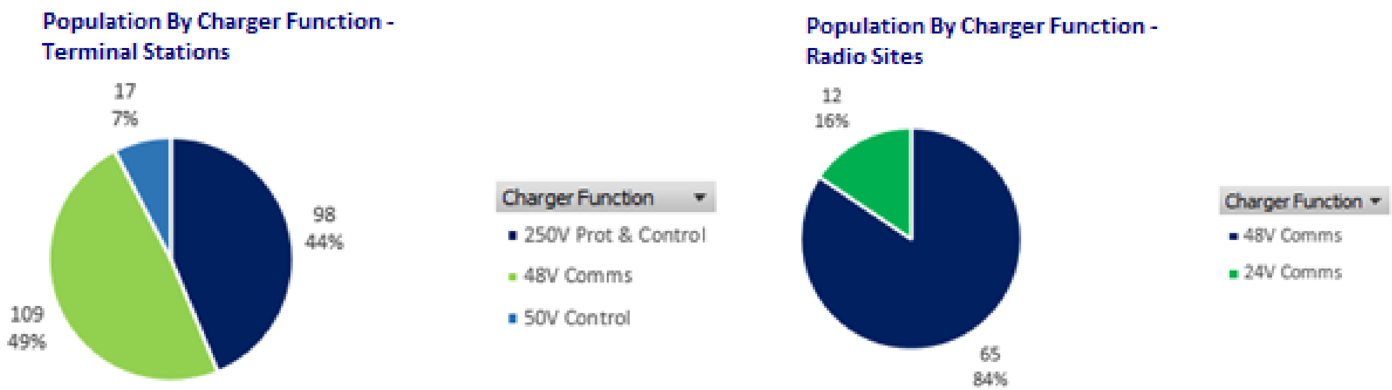


Figure 3: Battery Charger voltage and function at terminal stations and radio sites

Figure 3 shows the population of battery chargers currently in service on the regulated electricity transmission network. Chargers can be considered stand-alone generic devices with some units readily interchangeable with that of another manufacturer. Modern battery chargers come with temperature compensation and battery monitoring.

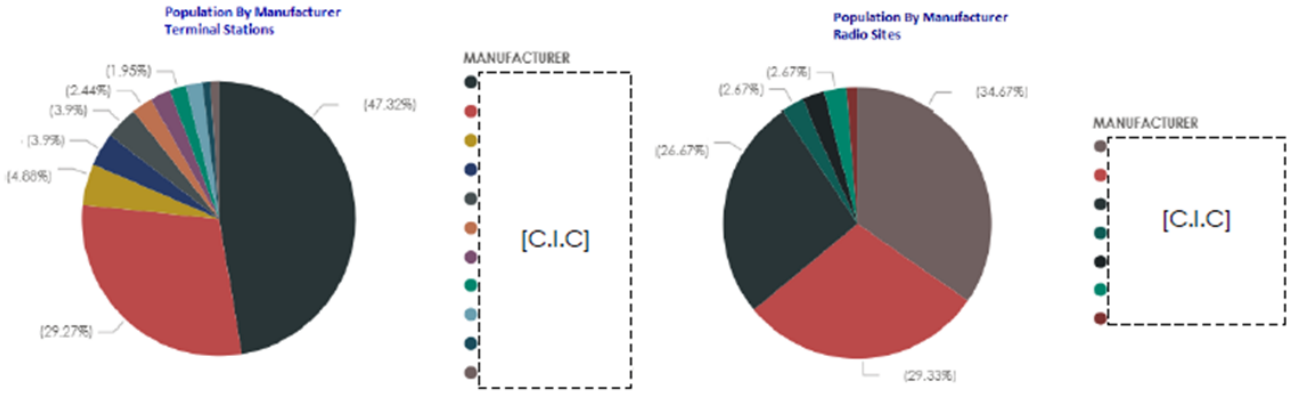


Figure 4: Battery Charger population by Manufacturer

Figure 4 shows the distribution of battery chargers across terminal stations and radio sites, segmented by voltage levels (250V, 48V, and 24V). The fleet is primarily dominated by two manufacturers [C.I.C] & [C.I.C].

At terminal Stations, [C.I.C] chargers represent the largest share at 47.32%, followed by [C.I.C] at 29.27%. Other manufacturers include [C.I.C], [C.I.C], [C.I.C], [C.I.C] and several minor contributors.

At Radio Sites, [C.I.C] leads with 34.67%, followed by [C.I.C] at 29.33%, and [C.I.C] at 26.67%. Additional manufacturers include [C.I.C], [C.I.C,/

] ,h[C.I.C] chargers are modern, high efficiency units that have recently been installed across multiple sites. Their widespread adoption reflects a strategic move toward standardisation and improved reliability. These chargers support a range of voltage configurations and are well suited for both terminal stations and radio sites. [C.I.C] chargers have a long-standing presence in the fleet and continue to be a reliable choice. While not as recently refreshed as [C.I.C] units, they still represent a significant portion of the installed base and are actively maintained.

The charger fleet is transitioning toward newer, more efficient models, with [C.I.C] from [C.I.C] leading recent upgrades. [C.I.C] remains a key legacy manufacturer with continued operational relevance. The mix of manufacturers across sites maintains coverage of various technical and environmental needs, though future planning should consider further standardisation to streamline maintenance and procurement.

3.3. Age Profile

Understanding the age profile of auxiliary power systems is essential for effective asset management and lifecycle planning. Assessing the age distribution of the assets enables informed decisions regarding maintenance, upgrades, and replacements, helping to optimise performance and minimise risk.

The age profile can highlight potential risks associated with component ageing and degradation. Older systems may require more frequent inspections, targeted condition assessments, proactive testing and monitoring. These measures help prevent unexpected failures and extend the operational life of aging equipment.

3.3.1. AC Systems

The age of the AC systems can reveal the condition and the need for the replacement to enable proper function and operation of the LV supply systems. Most of the AC supply systems are dated back to the station commissioning date and hence the aging boards with the presence of ACM (Asbestos containing materials) is a major concern among these assets. Periodic replacements have occurred at some of the station sites either through major station replacement programs or Targeted replacement initiatives which helped improving the condition of these assets.

3.3.2. DC Systems

The age profile of DC systems, including batteries and battery chargers, can reveal areas where performance may decline over time. By analysing the age profile, asset managers can identify systems at higher risk of failure and prioritise them for maintenance or replacement. For instance, replacing aging battery banks and chargers or performing discharge testing of aging battery banks can prevent costly outages and enhance network reliability.

Batteries

The typical lifespan of a battery installation is 15 years. Figure 5 illustrates that approximately 27% of batteries in terminal stations have exceeded their 15-year service life, with an additional 15% expected to reach this threshold by 2032. At radio sites, around 10% of batteries are currently over 15 years old, and by 2032, 60% more will surpass their expected service life.

Battery replacements are most carried out through:

- Major station replacement programs
- Station-specific DC power supply duplication projects
- Targeted replacement initiatives based on end-of-life assessments

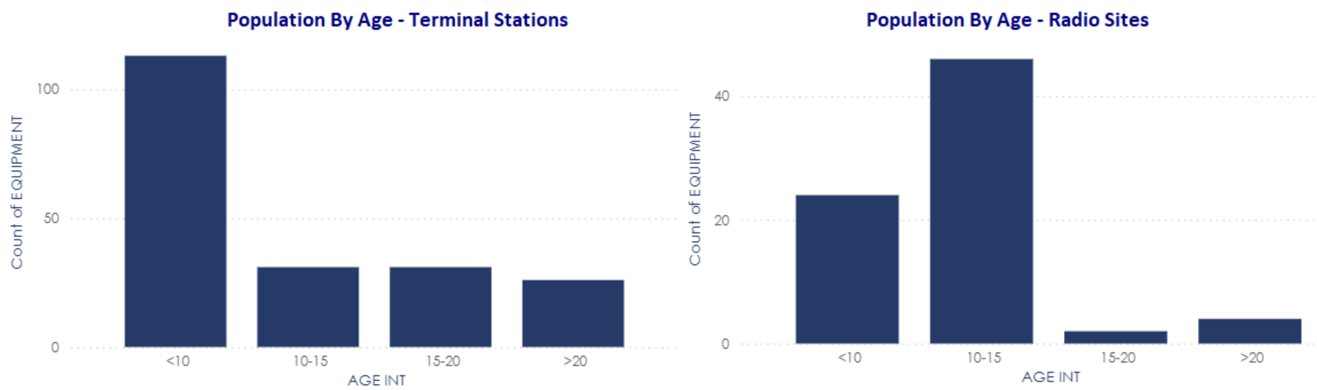


Figure 5: Battery age profile

Battery Chargers

Figure 4 indicates that approximately 36% of chargers at terminal stations have exceeded 15 years of service, with an additional 15% projected to reach this age by 2032. At radio sites, around 9% of chargers are currently over 20 years old, and by 2032, a further 62% will be over 15 years of age.

While extended service life itself is not a major concern, obsolescence is. Many older charger designs lack essential features such as charging controls, self-monitoring, and alarm capabilities, which significantly hinder cost effective maintenance and reliable operation.

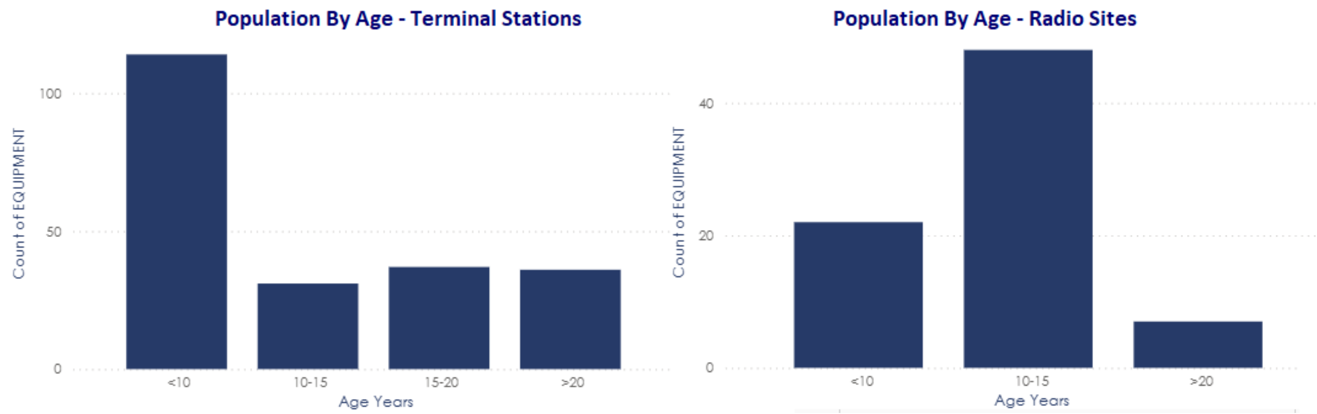


Figure 6: Charger age profile

4. Asset Performance

Performance assessment of auxiliary power supplies is a key element of AusNet's lifecycle management strategy. These assessments provide critical insights into asset behaviour under varying operational conditions, supporting informed decision-making to enhance network reliability, safety, and efficiency.

By analysing performance data, asset managers can identify trends and patterns that inform strategic actions such as maintenance scheduling, system upgrades, and asset replacement. Understanding how auxiliary power systems perform over time enables proactive management, reducing the likelihood of unexpected failures and improving overall system resilience.

AusNet's assessment methodology includes detailed analysis of failure trends and the operational impacts of asset failures. This approach creates a comprehensive understanding of asset health and supports targeted interventions that maintain the integrity and reliability of the electrical distribution network.

4.1. Performance Profile

Records of unplanned maintenance work undertaken on DC and AC Systems are maintained in the Asset management system, SAP. Figure 7 shows the key defects with high priority of P1, P2 and P7 level in Auxiliary Systems during the period of the last five years.

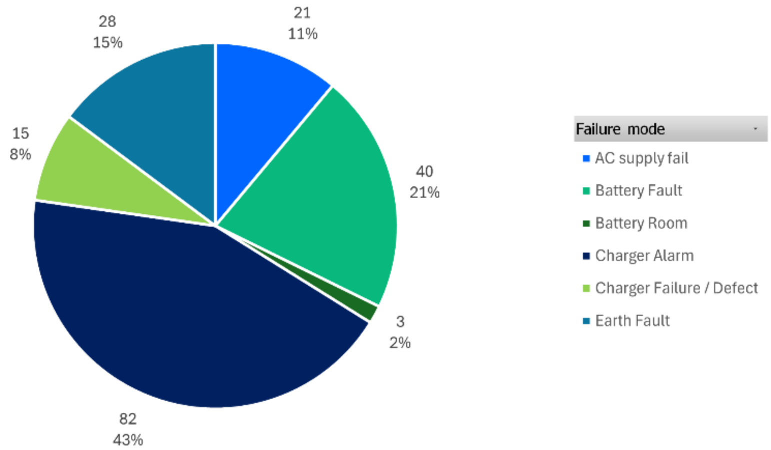


Figure 7: Auxiliary Power System notifications

The majority of issues reported in auxiliary power systems relate to battery charger component alarms or failures, which typically necessitate the replacement of a card, individual component, or the entire charger unit. Approximately 50% of these faults are detected through alarm signalling.

Across The AC and DC systems, the typical failure modes that can be seen includes the following:

- Insulation breakdown
- Terminal corrosion
- Moisture Ingress
- Environmental degradation
- Overvoltage / undervoltage
- Electrolyte leakage
- Capacity loss
- Component failure
- Electrolyte degradation
- Mechanical damage
- Earth Faults

The most prevalent battery charger issue is loss of output, primarily caused by unit or component failure or incorrect charger type used to charge batteries due to battery replacements while keeping old chargers in service. The second most common set of issues involves battery degradation, including terminal corrosion, cracked battery cases, low electrolyte levels or contamination, electrolyte leakage, connection lead failures, and DC cells that are unable to retain adequate charge.

At several stations, legacy battery systems have been upgraded to provide fully segregated X and Y configurations with VRLA batteries, ensuring redundancy in DC supply and less regular maintenance requirements with battery monitoring systems installed on individual cells. However, multiple instances have been reported where a single charger is supplying both battery banks and mixing of DC supplies at load connection points due to legacy installations. This unintended mixing of DC supplies undermines the redundancy strategy and increases the risk of failure. In such scenarios, proactive battery replacement for both batteries and compatible chargers becomes critical, as a fault in one bank or charger could compromise the entire station's DC supply, potentially leading to a station black event. The replacement program is designed to upgrade both X and Y battery systems in legacy installations, ensuring that in the event of such failures, a single battery can support the station load enhancing overall network resilience.

The performance of battery systems has been evaluated across three key dimensions: damage types, root causes, and maintenance activities. This analysis helps identify recurring issues and informs targeted asset management strategies. Figure 8 shows the key notifications raised for batteries from 2021-2025

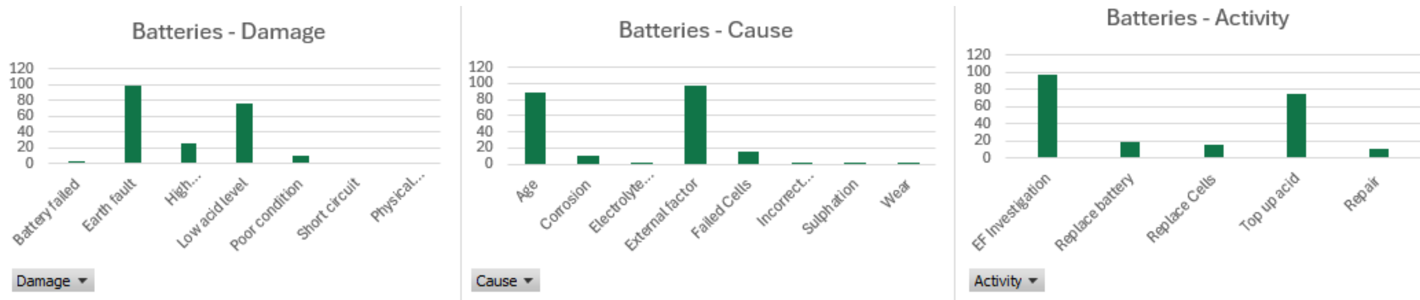


Figure 8: Batteries Damage, cause and activity notifications at terminal stations

Damage Analysis

Battery damage notifications reveal that the most prevalent issues are:

Earth fault due to positive or negative shorted to ground, poor condition due to low acid levels leading to cell / bank failure and degrading battery performance. Other notable and critical damage types include Short Circuit, Physical Damage.

Cause Analysis

The root causes of battery failures are primarily:

Age: Natural degradation over time remains the leading factor.

Failed Cells: Points to internal component breakdown or electrolyte degradation over time.

Sulphation and Corrosion also contribute significantly.

External factors: Due to earth fault on battery positive or negative connections at load.

Activity Analysis

Maintenance and corrective actions show a strong focus on:

Earth Fault Investigations: Reflecting proactive fault detection and analysis.

Top-Up Acid: A common remedial measure for electrolyte-related issues in aging batteries.

Battery and Cell Replacements are also regularly performed, indicating a need for improved lifecycle management and proactive replacement.

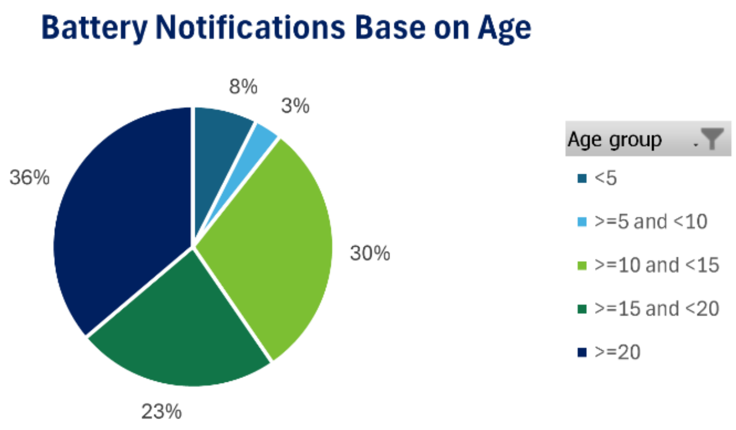


Figure 9: Batteries key notifications based on age at terminal stations

Analysis of battery critical notifications by age group reveals a clear correlation between age and issue frequency. A key driver for this program is the increasing unreliability of the aging battery fleet. Notably, 89% of critical notifications were associated with batteries that had either exceeded or were nearing the end of their service life, with most issues occurring in units older than 10 years indicating that aging infrastructure significantly impacts reliability.

This trend supports prioritising asset replacement or refurbishment for units exceeding 15 years of service. To address this, the program focuses on replacing assets that have surpassed or near end of their service life, particularly at critical sites. By targeting batteries that are already beyond or approaching their end of life, the program not only improves operational reliability but also minimises ongoing frequent maintenance requirements, supporting a more sustainable and resilient network.

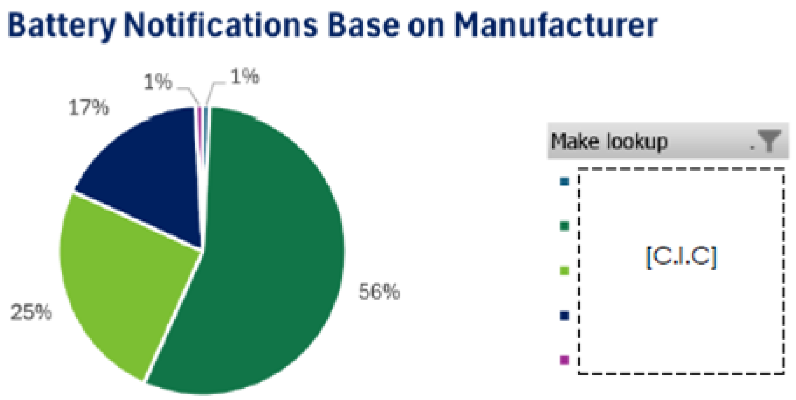


Figure 10: Batteries key notifications based on Manufacturer at terminal stations

Analysis of battery related notifications within these stations reveals a disproportionately high number of issues linked to [C.I.C] and [C.I.C] batteries. This aging fleet, particularly those older than 15 years, shows a clear trend of increased failure rates and maintenance demands. Given the high frequency of notifications and the declining reliability of these older systems, [C.I.C] and [C.I.C] batteries require closer monitoring, regular maintenance, and proactive replacement. The replacement program focuses on replacing [C.I.C] and [C.I.C] battery systems at terminal stations with VRLA batteries with individual cell monitoring where assets have already exceeded or are approaching their end of life to maintain system reliability and reduce operational risks.

Recent Events

Battery degradation and charger instability have been observed across multiple sites, impacting operational reliability and requiring urgent mitigation measures. These issues have often recurred due to aging batteries, delays in replacement planning, limitations of inventory in stores and long lead times for procurement. The battery failures are only reported during maintenance or if station service transformer / charger fail hence making it even more challenging to respond.

Event 1 – During annual maintenance, two faulty cells were identified in the 250V DC Y battery bank. Due to the need for a special order, replacement cells faced a long delivery lead time. This pre-existing issue led to a battery bank failure, prompting an *urgent replacement* project to install a temporary emergency battery bank. The interim solution enabled operational continuity while new battery banks were procured and installed.

Event 2 – 250V X battery bank exhibited signs of advanced degradation, with cells showing very high impedance and low voltage levels with clear indicators of failure. Although these issues had been previously identified, replacement was delayed due to supply chain constraints to procure obsolete battery cells. Later the Y battery system at the same location showed physical deterioration, including corrosion and post growth out of the battery housing. The failure and isolation of the 250V Y battery charger triggered urgent replacement works. The Y battery bank was subsequently taken out of service due to poor serviceability and elevated cell impedance, which posed a risk if paralleled with the X charger and battery bank. The instability observed during X charger operation further reinforced the need to install temporary battery trailer to prevent broader system impacts.

Event 3 – Cooling fail alarm on transformer led to investigation of failed Y batteries in station. The charger output was haunting between 40-50A with unstable voltage. High internal impedance of Y Battery (~0.56 ohms) suspected to prevent successful charging and caused charger overheating. The batteries were immediately isolated and whole station was fed from X battery charger and X batteries. The replacement became more critical due to unavailability of temporary battery trailer. The X batteries were not in good condition to support both X and Y loads adding further risks of offloading terminal station.

Event 4 - During a planned outage of the transformer, station service supply failed to automatically transfer to the alternative source resulting in a complete loss of DC supply to protection systems. This result in loss of supply to the RTU, resulting in no control or status visibility from site. On-site staff were unable to manually initiate supply changeover. All DC supply to protection relays was lost due to dead batteries. This happened due to long standing battery fault identified only when AC supply to chargers was disconnected. Temporary DC supply was established to restore protection and control systems.

Contributing factors / Root cause Analysis

REF	DETAILS
01	**Delayed Replacement Planning** Battery replacement plannings not aligned with realistic replacement lead times.
02	**Obsolescence** Most of the batteries failed already exceeded their service life with no spare's availability in stores.
03	**Inadequate Availability of Spare Batteries** Spare batteries not available/ maintained in stores with increased dependability on manufacturer lead times.
04	**Temporary Solutions Becoming Only Solution** With network expanding dependability only on mobile battery trailers does not fully support emergency response. Spares shall be procured and well maintained for emergency deployment.
05	**Absence of Centralised Digital Battery Performance Management System** No centralised system exists to track battery performance, individual cells health, spare cells availability, status for sites where batteries are not fully isolated where single battery bank or charger failure can lead to inefficiencies and reduced responsiveness.

Table 1: Contributing factors during recent event

Recent event analysis has identified battery age as a major contributing factor to failures at terminal stations, particularly affecting protection and control systems. These failures pose a significant risk to operational reliability, especially when batteries are not replaced within their designed service life. Faults in aging batteries are often latent and only detected during maintenance or when the AC supply or battery charger fails making fault rectification complex and time sensitive.

To address these risks, the battery replacement program prioritises the proactive replacement of aging battery systems. The program also supports the adoption of modern sealed battery technologies, such as AGM VRLA with individual cell monitoring capability which offer improved reliability, reduced maintenance, and better fault tolerance.

5. Related Matters

5.1. Regulatory Framework

5.1.1. Compliance Factors

Regulatory and Legislative Reference

Effectively managing compliance obligations specific to legislation and regulatory frameworks is a core element of Asset Class Planning and supports the sustainable operation and management of transmission network assets. Adherence to relevant laws, codes, and standards helps prevent legal and regulatory breaches, which could result in significant penalties, operational disruptions, and reputational damage.

No specific Auxiliary Power system is mandated for compliance. However, AusNet Auxiliary Power system has been designed to maintain DC supply to 10 hours after AC interruption for reliable operation of primary plant.

Technical Standards and Procedures

Compliance with technical standards and operational procedures is essential to facilitating that transmission assets are designed, constructed, maintained, and operated in accordance with industry best practices. This enhances safety, reliability, and interoperability across the transmission network. It also supports consistent performance, reduces asset-related risks, and facilitates alignment with regulatory expectations.

AusNet Auxiliary Power System must be designed or upgraded to where required in accordance with

- AS/NZS 3000
- AS 2676.2
- AusNet SDM

Key regulatory standards

REF	DETAILS
01	*Electricity Safety Act 1998 (Vic)* – Section 98(a) Mandates the safe design, construction, operation, and maintenance of electrical infrastructure.
02	*National Electricity Rules* – Clause 5.2A.4 Outlines obligations for maintaining system security and performance standards in the National Electricity Market (NEM).
03	NER 4.6.5 Partial outage of power protection systems Where there is an outage of one or both protection system of a transmission line, AEMO must determine, in consultation with the relevant Network Service Provider, the most appropriate action.
04	NER Clause S5.1.2.1(d) Network Service Providers (NSPs) must provide maintenance so that all protection systems for lines above 66 kV including intercropping schemes are well maintained and available. Protection systems may be out of service only for short periods, specifically not greater than eight hours and only while maintenance is being carried out.

Table 2: Key regulator standards

5.2. Internal Factors

5.2.1. Technical Factors

Understanding and managing the technical factors that can directly impact the lifecycle planning for Network Assets across all the AusNet Asset Classes is a core element of effective asset management. These factors encompass various design, engineering, and technical performance considerations that directly impact the ability to manage and maintain these assets efficiently. Ensuring that Network Assets meet specific technical performance standards is vital for maintaining the reliability and safety of the electrical distribution network.

Targeted Activities (Technical Factors)

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	**DC System** DC Systems exhibit several different issues: • Old battery rooms may 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 may void the DC cell warranty as the manufacturer requires proof that the DC cell was operated in a controlled regime and environment. • There is a risk (increasing with the age of the battery) that certain battery banks cannot supply the control and communication loads for 10 hours as designed. This may result in a loss of protection hence station black if the case of a charger or AC S/S Tx failure
02	**AC System** AC Systems exhibit several different issues: Old AC switchboards: 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.

Table 3: AC and DC equipment technical factors

5.1.1 Safety Factors

Safety is a paramount concern in the management of electricity transmission network assets. Effective asset management planning and activities are crucial for protecting employees, contractors, the public, and the environment from potential hazards associated with electrical infrastructure. Ensuring adherence to safety regulations and standards through diligent asset management helps prevent accidents, minimise risks, and maintain the integrity of the network.

Targeted asset management activities include conducting regular safety audits and risk assessments, maintaining a robust Bushfire Mitigation Plan, providing ongoing safety training and competency assessments, regularly reviewing and updating emergency response plans, engaging with the community to raise awareness about electrical safety, and adopting new technologies and practices to enhance network safety. By integrating these safety-focused activities into asset management planning, AusNet can effectively minimise safety risks "as far as practicable," as outlined in the Electricity Safety Act 1998 and reflected in REF: ESMS 10-01 Electricity Safety Management System.

Auxiliary system failure may have a safety impact including:

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	**Occupational Safety Risk** Older battery rooms are sized for a single DC battery bank and without equipment to monitor the battery temperature and room environment 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 station in the vicinity of the old battery room.
02	**Risk to Personnel and plant** Without auxiliary supplies the protection and control system will not operate and live equipment may remain energised during fault conditions and can lead to equipment damage, fire hazards, and safety risk to personals.

Table 4: Safety factors

6. Proposed Program of Work

6.1. Approach

6.1.1. Risk

AusNet's asset management decisions within the transmission network are guided by a risk-based approach, ensuring alignment with our organisational risk appetite. For secondary systems, risk treatment required to achieve this over time involves replacement & maintenance activities. Justification for these projects are developed based on current risk and extrapolated risk.

The risk of each asset is calculated as the product of Probably of Failure (PoF) of the asset and the Consequence of Failure (CoF). This risk is then extrapolated into the future accounting for forecast changes in PoF and CoF.

AusNet's approach to asset risk management is detailed in REF: AMS 01-09 Asset Risk Assessment Overview.

6.1.2. Asset Quantification Methods

Probability of Failure

The PoF forecasts for AUX power supplies are calculated using Weibull distribution with SAP parameters that have been calculated based on methods established by AusNet. The asset age, replacement and failure notifications are analysed using the Weibull distribution models that determine the PoF for the remaining life of the asset.

Consequence of Failure

AusNet assigns a monetised value to CoF which provides an economic basis of calculating potential consequence.

The cost of failure is assessed through three key lenses: Customer / Market Impact, safety and financial impact. These lenses provide a structured view of the potential impacts resulting insulator failure, resulting in outages and/or line drops. 5 summarises the focus of each lens:

CONSEQUENCE LENSES	DESCRIPTION
Customer / Market	Loss of Supply to Customer Impact on energy market
Safety	Threat to health and safety of the public and employees
Financial impact	Asset / component replacement costs Emergency and repairs

Table 5: Auxiliary Power System consequence lens description

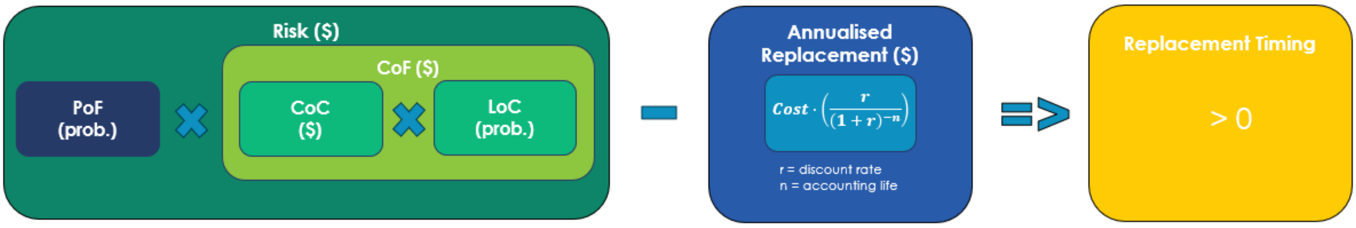
6.2. Economics Viability

6.2.1. Economic Model

Asset Managers use the calculated risk based on PoF and CoF outputs to identify optimal intervention years, balancing technical feasibility with economic efficiency. These outputs are incorporated into an economic model. The economic model demonstrates the year when the calculated annualised risk is higher than the annualised replacement cost, and as such when the asset becomes economically viable to replace.

The economic model is producing a structured approach for each asset in the fleet. The economic model for the justified replacement program is available in asset class economic model REF: ANT – TRR 2027-32 Asset Replacement

Economic Model – Auxiliary Power Supplies – DC System - Final and ANT – TRR 2027-32 Asset Replacement Economic Model – Transmission Infrastructure – Final



6.3. Engineering Validation

Following the generation of economic models and asset Weibull models, a structured validation process is undertaken by Senior subject matter experts. This step allows that model outputs are interpreted within the broader context of engineering intervention options, operational experience, and current asset condition knowledge

SMEs assess whether the asset replacement or refurbishment or change in maintenance regime or no action are reasonably practicable choices. This involves verifying condition data, evaluating operational priorities, and considering strategic timing of interventions. Where appropriate, SMEs may recommend alternative actions based on their professional assessment.

This validation process complements the use of economic model. It supports a balanced and accountable approach to asset management, one that upholds technical integrity while remaining responsive to operational realities.

Please note that AC Auxiliary supplies follow the same process as mentioned in REF: AMS 10-55 Transmission Infrastructure

6.4. Proposed Program

The proposed replacement program of works is developed based on the finding in the NPV model and key assets are picked for replacements that are end of life, already exceeded their life span. Due to criticality of the assets AusNet prioritise proactive replacement of Auxiliary power systems to maintain the network in reliable state.

Works include replacements of complete DC system including battery, chargers, battery monitoring, DC/DC system, isolation panel, distribution panel, under-voltage and earth fault relay panels instead of replacing individual items.

6.4.1. Replacement Strategy

The proposed program for the current program allows for targeted, proactive and economic replacement of poor condition batteries already exceeded their life consistent with legislation and regulatory requirements to minimise the primary equipment shutdown times due to failure of the auxiliary power supplies.

The prerequisites for replacing assets:

CRITERIA	DESCRIPTION
Cost-Benefit Justification	Long-term cost savings through reduced maintenance and improved energy efficiency. Avoidance of reactive replacement costs during emergency failures.
Risk Mitigation	Proactive replacement to avoid catastrophic failure or unplanned outages. Supports business continuity and asset management strategy.
End-of-Life (EOL) Status	The asset has reached or exceeded its expected service life. Increased operational risk.
Reliability Concerns	Increased frequency of failures or faults. Historical data shows declining performance or increased maintenance needs due to cell failures
Procurement lead times	Noticeable increase in lead times for procuring batteries due to a combination of supply chain constraints, reduced manufacturing volumes, aging nature of product lines and unavailability of spares

Table 6: Criteria for replacement program

6.4.2. AC System

The legacy switchboards lack automatic changeover capability, which can result in auxiliary power loss during a substation transformer failure. The program includes the installation of modern switchboards with auto-changeover features to facilitate uninterrupted auxiliary power supply and enhance operational resilience. The program also prioritises the removal and replacement of asbestos-containing switchboards to meet current safety standards and protect personnel.

The program targets replacements of AC systems at following terminal stations.

Stations: HOTS, RCTS

Scope: Replace 415V station AC isolation and change over boards along with cabling, Install switchyard lighting box.

6.4.3. DC Systems

The DC system replacement program is strategically aligned with asset condition and performance insights derived from field data and event analysis. Aging battery systems, particularly those exceeded or near end of service, have shown significant increase in fault frequency and reduced reliability. These faults often remain undetected until routine maintenance or system failures occur, posing significant risks to protection and control systems and personal safety. The program promotes targeted replacement of high-risk units. This condition-based approach improves system reliability, reduces emergency maintenance, and supports long-term resilience of DC supply infrastructure.

DC systems at Terminal Stations

The program of works targets replacement of both X and Y, 48V and 250V DC system at following terminal stations.

Station Name	48V		250V	
	Manufacturer	Age Group	Manufacturer	Age Group
Altona TS	[C.I.C.]	>15 and < 20	[C.I.C.]	>15 and < 20
Brooklyn TS	[C.I.C.]	>=20		
Cranbourne TS	[C.I.C.]	>15 and < 20		
Geelong TS	[C.I.C.]	>=20	[C.I.C.]	>=20
Kerang TS	[C.I.C.]	>15 and < 20	[C.I.C.]	>15 and < 20
Rowville CC	[C.I.C.]	>15 and < 20		
Ringwood TS	[C.I.C.]	>=20	[C.I.C.]	>15 and < 20
Tyabb TS			[C.I.C.]	>15 and < 20
Wemen TS	[C.I.C.]	>15 and < 20	[C.I.C.]	>15 and < 20

Table 7: Proposed Program of Works DC Systems – Terminal Stations

In addition, replacement of both X and Y, DC system are proposed as part of in Major Station replacement projects scope at following terminal stations NPSD, SMTS and TTS.

DC systems at Radio Sites

Table shows the details of DC system at radio sites included in proposed program of works for 2028 to 2032, targets replacement of both X and Y 48V and 24V Communication DC system at following sites.

COMMUNICATION SITE	MANUFACTURER	AGE GROUP	VOLTAGE LEVEL
CAMH	[C.I.C.]	>15 and < 20	48V
COCK	[C.I.C.]	>15 and < 20	48V
JERH	[C.I.C.]	>15 and < 20	48V
MTBW	[C.I.C.]	>10 and < 15	48V
MTMD	[C.I.C.]	>10 and < 15	24V
MTST	[C.I.C.]	>15 and < 20	48V
OTBH	[C.I.C.]	>10 and < 15	24V

Table 8: Proposed Program of Works DC systems – Radio sites

7. Asset Strategy

The strategic asset approach for auxiliary power systems focuses on long-term planning, reliability, and sustainability. It provides guiding principles for the introduction, upgrade, and replacement of DC and AC supply systems across terminal stations, ensuring alignment with AusNet' operational standards and future network requirements.

This strategy does not promote like-for-like replacement but encourages strategic upgrades that incorporate advanced technologies, improve system efficiency, and support economic maintenance. It serves as a roadmap for integrating new auxiliary power assets into the transmission network, particularly during major station rebuilds or refurbishment programs.

7.1. New Assets

The strategy for the introduction of new assets provides high level guiding principles and goals for asset management. All new installations shall meet AusNet REF: Station Design Manual (SDM) and relevant Australian Standards and improve system redundancy, monitoring, and control capabilities, support proactive lifecycle management through performance data and failure trend analysis and promote technology innovation and adoption of more reliable, low-maintenance solutions.

Targeted Activities (New Asset Strategies)

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	All new DC systems shall include fully duplicated and segregated X and Y battery banks and chargers.
02	Install isolation boards and distribution cubicles compliant with Australian Standards and AusNet SDM.
03	Install DC / DC converters where other voltage levels are required
04	Integrate individual battery cell monitoring systems (voltage and impedance) for early fault investigation
05	Enable SCADA alarm monitoring and control for all new DC systems.
06	Construct battery rooms, containers, or kiosks in compliance with AusNet SDM and Australian Standards.
07	All new AC systems shall include auto-changeover switchboards wired in accordance with AS/NZS 3000.

Table 9: New asset strategy activities

7.2. Maintenance

A strategic maintenance plan for auxiliary power systems provides high-level guiding principles to support long-term asset reliability, safety, and sustainability. This strategy establishes a structured framework for conducting maintenance activities across transmission network focusing on proactive condition monitoring, risk mitigation, and integration of advanced technologies.

The strategy aims to:

- Enhance system reliability and reduce unplanned outages
- Improve operational efficiency through targeted inspections and predictive maintenance
- Support compliance with AusNet' Station Design Manual (SDM) and relevant Australian Standards
- Enable data-driven decision-making through performance and failure trend analysis

Targeted Activities (Maintenance Strategies)

REF	DETAILS OF MATERIAL CONSIDERATIONS
01	Continue routine inspections of battery systems, including checks for terminal corrosion, post growth, electrolyte levels, leakage, voltage, connection lead condition, and cleanliness.
02	Maintain inspection and monitoring practices in line with REF: PGI 02-01-02 and REF: SMI 32-01-01, ensuring timely resolution of identified issues.
03	Investigate and implement extended online monitoring capabilities to reduce manual maintenance and improve visibility of battery health.
04	Continue monitoring of DC-DC converters and associated components for performance degradation.
05	Periodically review and update maintenance procedures to remain consistent with REF: AMS 01-09 and incorporate emerging best practices.
06	Maintain the mobile temporary DC supply solution.
07	Procure and maintain strategic spares for critical battery and charger systems used in protection, control, and communication infrastructure to mitigate downtime risk and rapid replacement considering lead times, failure history, manufacturer support and obsolescence.
08	Review existing method of fault reporting and analysis for better outcome. Collect and manage maintenance data in digital format and feed it to performance management system enabling predictive maintenance, trend analysis and continuous improvement.

Table 10: Asset maintenance activities

7.3. Replacement

A strategic asset strategy for renewals and replacements provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the aspects of asset refurbishments or like-for-like replacements, detailing the conditions under which existing assets may be renewed or replaced within the network. This process supports continued reliability and efficiency and manages obsolescence. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for renewing or replacing assets within the AusNet network

Targeted Activities (Replacement)

Ref	DETAILS OF MATERIAL CONSIDERATIONS
01	Continue selective replacement of auxiliary power supply equipment as per risk and economic analysis across identified sites in transmission network, prioritising those with recurring faults or nearing end-of-life
02	Replace DC supply assets in conjunction with major terminal station rebuilds or refurbishment projects where economically viable.
03	Supports battery capacity in all station designs meets the required backup duration for critical loads. Perform load calculations prior to replacement.
04	Continue transitioning to Valve Regulated Lead Acid (VRLA) batteries, which offer: • Reduced maintenance • Lower OH&S risks due to sealed design • Space-saving installation
05	Replace / refurbish complete auxiliary system instead of replacing individual banks or chargers.

Table 11: Asset replacement activities

7.4. Battery Rooms Upgrade

Although battery room installations are in a variety of conditions, all newly constructed rooms and battery system upgrade projects shall follow AusNet' design standards[1] and Australian Standards (AS 2676.1 and AS 3011.1)

Targeted Activities (Battery Rooms)

Ref	DETAILS OF MATERIAL CONSIDERATIONS
01	Ventilation must be installed in the room. Vented cell batteries by their nature produce hydrogen gas as a by-product of cell charging and discharging, hydrogen gas is highly flammable and must be vented out of the battery room.
02	Floors must be coated with acid proof paint to supports integrity of the floor construction is not compromised.
03	Eye-wash stations must be installed.
04	Appropriate hazards and warning signs must be installed to inform any personnel working in the area of restricted access due to the corrosive environment presented by the batteries and the risk of hydrogen gas build up if ventilation is not functioning correctly.
05	Battery stands must allow batteries to be installed above the floor, and be adequate for their loading, non-corrosive and durable.
06	Separate battery rooms are used as, in the event of a fire or explosion within one battery room or nearby building, the segregation will facilitates that not all the batteries affected.

Table 12: Battery room activities

7.5. Research and Development

A strategic asset strategy for research and development provides high-level guiding principles and overarching goals for asset management, focusing on long-term planning and sustainability. This strategy outlines the aspects of safely and efficiently introducing assets into service, detailing the conditions under which it may occur. It works to support the process is conducted in a way that minimises disruption, manages environmental impacts, and complies with regulatory requirements. It serves as a roadmap that is ideal to follow if possible, guiding the decision-making process for decommissioning assets from within the AusNet network.

Targeted Activities (Research and Development)

Develop and implement a centralised remote server system to monitor battery health across all sites, enabling data-driven maintenance decisions and reducing the need for manual site inspections.

Target profiles:

- Battery impedance
- Battery cells Voltage profile
- Temperature and charge / discharge cycles

8. Resource References

NO.	TITLE
1	AMS 01-05 Asset Management System Overview
2	AMS 01-09 Asset Risk Assessment Overview
3	AMS 10-55 Asset management strategy – Transmission Infrastructure
4	Electricity Safety Management System
5	Electricity Safety Act 1998
6	PGI 02-01-02 - Summary of Maintenance Intervals – Transmission Plant Guidance and Information
7	SMI 32-01-01 – Standard Maintenance Instruction Batteries
8	Station Design Manual
9	WorkSafe Victoria - Occupational Health and Safety Act 2004

9. Issue/Amendment Status

ISSUE NUMBER	DATE	DESCRIPTION	AUTHOR	APPROVED BY
5	21/11/06	Editorial review	[C.I.C]	[C.I.C]
6	23/01/07	Review and update	[C.I.C]	[C.I.C]
7	17/03/07	Editorial review	[C.I.C]	[C.I.C]
8	06/03/08	Updated to include reference to the AC Station Service Supplies Review	[C.I.C]	[C.I.C]
8.1	07/08/12	Redrafted as DC Power Supplies AMS	[C.I.C]	[C.I.C]
8.2	09/08/12	Editorial review	[C.I.C]	[C.I.C]
8.3	30/09/12	Editorial review	[C.I.C]	[C.I.C]
8.4	30/10/12	Updated to include comments from RNS	[C.I.C]	[C.I.C]
9	21/01/13	Editorial review	[C.I.C]	[C.I.C]
10	25/06/15	Template and content update	[C.I.C]	[C.I.C]
11	08/07/20	Update and review	[C.I.C]	[C.I.C]
12	30/09/2025	Update and review	[C.I.C]	[C.I.C]

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