AMS 10-52 Auxiliary Power Systems

2023-27 Transmission Revenue Reset

PUBLIC

Document number	AMS 10-52
Issue number	11
Status	Approved
Approver	P Ascione
Date of approval	08/07/2020

ISSUE/AMENDMENT STATUS

Issue Number	Date	Description	Author	Approved by
5	21/11/06	Editorial review	G. Lukies D. Postlethwaite	G. Towns
6	23/01/07	Review and update	G. Lukies T. Page	G. Towns
7	17/03/07	Editorial review	G. Lukies D. Postlethwaite	G. Towns
8	06/03/08	Updated to include reference to the AC Station Service Supplies Review	G. Lukies	G. Towns
8.1	07/08/12	Redrafted as DC Power Supplies AMS	L. Koedijk	
8.2	09/08/12	Editorial review	D. Rendell	
8.3	30/09/12	Editorial review	P. Grove	
8.4	30/10/12	Updated to include comments from RNS	L. Koedijk	
9	21/01/13	Editorial review	D. Meade	E. Viel
10	25/06/15	Template and content update	J. Stojkovski	J. Bridge
11	08/07/20	Update and review	A Bughneau	P Ascione

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1 Executive Summary

The Victorian regulated electricity transmission network includes 236 individual Direct Current (DC) power supplies comprising batteries, battery chargers, DC power distribution switch boards, isolation, wiring and monitoring and alarm equipment.

The DC power supplies are located in terminal stations to provide critical DC power for the operation of electrical protection, control, metering, and SCADA systems associated with the electricity transmission network.

Key issues include:

- Performance risks and functionality limitations of deteriorating batteries and chargers beyond their economic service life;
- Occupational health and safety risks associated with maintaining batteries and battery rooms in compliance with current Australian Standards; and
- Establishment of a condition monitoring program for economic management of DC power supplies.

Strategies for DC power supplies are stated below.

The program of works for 2022 to 2027, targets fourteen high risk and high criticality sites as well as two high risk sites in CA5 and low criticality.

1.1 New Assets

- Where economic replace DC Supply asset in conjunction with future terminal station rebuild projects.
- All new battery rooms are to be constructed to be compliant with AusNet Services Station Design Manual and Australian Standards.
- Station design is to continue to ensure that battery capacity is sufficient to meet the station load for the required period.
- Periodically review innovations in battery technology for more reliable and economic energy storage options.
- Continue replacing old batteries with Valve Regulated Lead Acid (VRLA) batteries which are an alternative sealed battery type available to the electricity supply industry for the purposes of DC supply.

  The benefits of using VLRA include:

  - Less maintenance, providing more time for further detailed maintenance.
  - Net reduction in OH&S risk by reducing the risk of acid leakage. The cells are completely sealed units.
  - Less space requirements.

1.2 Maintenance

- Regularly inspect batteries for terminal corrosion, post growth, electrolyte level, electrolyte leakage, voltage level, connection lead conditions and cleanliness.
- Look into implementing extended online monitoring capability to reduce manual maintenance activity and increase visibility of battery condition.
- Continue to monitor DC-DC converters.

1.3 Spares

- Maintain the mobile temporary DC supply solution: this is a specifically designed trailer that contains a full vented lead acid battery bank (250V) and a charger. The trailer is used as a backup when a station battery bank is taken out of service during project work. Due to the risk associated with generation connections to terminal stations the trailer is required to remain in the eastern region. The trailer is not required under the system black restart process but could be utilised if required.

- Establish a mobile temporary DC supply solution to be used as a backup when a station battery bank is taken out of service during both project work and maintenance. The trailer is required to support project and maintenance works on all regions except eastern region.

1.4 Refurbishment

- DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced before 2025 as per AMS 10-01.
- Progressively augment charger functionality with temperature compensation and boost charging facilities where recommended by battery manufacturers.
- Where possible battery rooms are to be progressively upgraded to be compliant with AusNet Services Station Design Manual and Australian Standards

1.5 Replacement

- Selective DC power supply equipment replacements in 16 terminal stations as outlined in clause 4.4
- Maintain the mobile temporary DC supply solution.

2 Introduction

2.1 Purpose

This document defines the asset management strategies for DC power supplies installed in the AusNet Services' regulated electricity transmission network. This includes the inspection, maintenance, replacement and inspection/monitoring activities required for the life cycle management of these assets.

This document is intended to be used to inform asset management decisions and communicate the basis for these activities.

In addition, this document forms part of the 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 document details the condition and strategies for the regulated asset base DC power supplies at AusNet Services' electricity transmission terminal stations.

DC power supply components include:

- Batteries;
- Battery Chargers;
- Associated DC Equipment

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

This document's scope does not cover DC power supplies at AusNet Services' electricity distribution sites, radio communication sites or unregulated sites.

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 Summary

3.1 Asset Function

Terminal station DC power supplies are critical to providing power to the protection, control, metering and SCADA systems on the transmission network.

These DC energy supply provides Protection and control schemes for station plant and interconnecting lines:

Circuit Breaker (CB) control and auxiliary operating power;

Supervisory Control and Data Acquisition (SCADA) equipment;

Instrumentation and metering;

Communication equipment; and

Emergency access lighting and alarm systems.

Complete failure of DC power supplies at Terminal station renders energy flows and station equipment uncontrollable and disables the electrical protection system placing consumer, public and workers at risk.

3.2 Population

3.2.1 Batteries

There are 234 battery banks in AusNet Services' transmission stations. A duplicated system is counted as two battery banks.

Battery bank voltages range from 48V DC to 250V DC, as shown in Figure 1. Capacities range, depending on size of Terminal Station load, from 100Ah up to 1300Ah. The vast majority are valve regulated lead acid batteries.

The remainder are flooded cell lead acid batteries, which are being phased out as they are obsolete technology. Newer types are the sealed absorbed glass mat (AGM) type.

Terminal Station batteries are:

- 250 V Protection and Control;
- 50 V Control;
- 48 V Communication; and
- Other batteries.

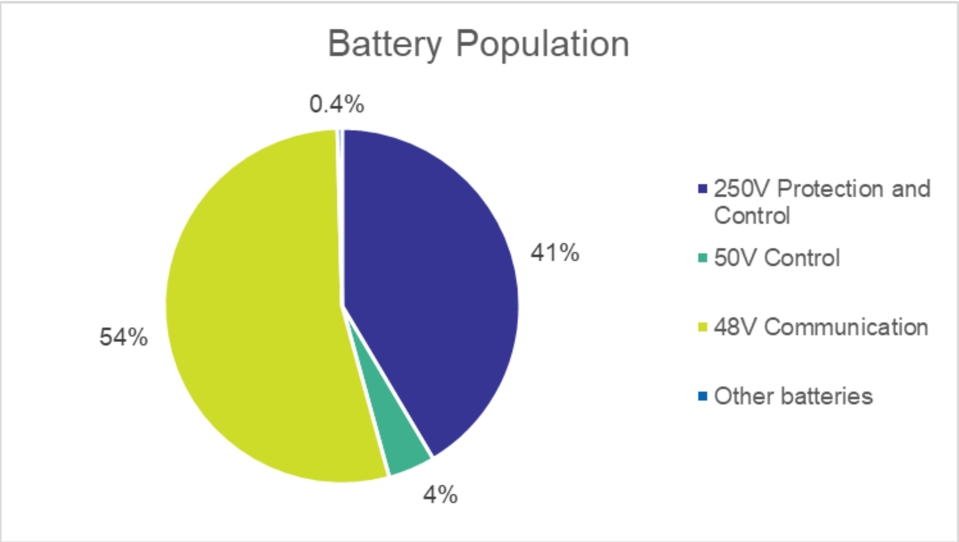

Figure 1 – Batteries by voltage and function

Figure 1 depicts that battery function is divided into two dominant areas, 53% per cent of batteries power 48 V communications equipment and 42% of batteries power 250V protection and control systems.

The Australian Energy Market Operator's (AEMO's) Protection and Control Requirements specify duplicated and physically segregated "X" & "Y" DC batteries and chargers are provided with sufficient capacity to run identified station DC services for up to 10 hours. Likewise, most stations have segregated 48V "A" and 48V "B batteries for operational communication equipment.

In addition, clause 5.1 (f) of the Electricity Network Agreement states that:

"Each terminal station must be provided with duplicated secondary equipment such that no single electrical or mechanical failure or malfunction within the secondary equipment prevents that terminal station supplying electrical energy from the Transmission Network to Connected Parties up to relevant Ratings"1.

Only a few Terminal Stations remain without duplicated DC supply system. These are due to be duplicated before 2022.

Most stations have 250V "X" and 250V "Y" batteries and, where required, provide the 50V control supply via duplicated DC-DC converters from the 250V batteries. Older station designs had separate dedicated single 250V control batteries and 50V control batteries, whereas the 50V control supply is progressively being phased out.

Separate control and communications batteries are provided to cater for the different rating times between control and protection functions and communication functions. Also, to segregate communications equipment from transient voltages imposed by the switchyard wiring and operation of electrical equipment such as circuit breaker equipment.

3.2.2 Battery Chargers

There are 236 battery chargers in service across all terminal stations, in addition, there are extra chargers on standby for an unlikely event of a complete failure of a charger. This brings the total population of chargers to 255.

The chargers support the batteries by providing AC to DC rectification. The current AusNet Services' design standards[2] require DC chargers to be able to support both "X" and "Y" loads and float charge one battery, and to be able to supply either "X" or "Y" load whilst charging a battery from fully discharged in 8 hours. Chargers must also be capable of supplying float, equalise and boost charge voltage levels and provide an alarm on failure of charging circuits. Some chargers are temperature compensated so that battery gassing is reduced by a lower float voltage on hot days.

[C-I-C]

Figure 2 – Charger Manufacturers

Figure 2 shows which manufacturers have supplied the battery chargers currently in service on the regulated electricity transmission network. The number of manufacturers reflects the fluid nature of the market with different

[1] Network Agreement between Power Net Victoria and Victorian Power Exchange 1997.

[2] SDM 06-0302 Station Design Manual - DC Supplies.

suppliers entering and leaving the market and several changing their brand names. Chargers can be considered stand-alone generic devices with some units readily interchangeable with that of another manufacturer. Modern battery chargers, such as Eltek manufactured, come with temperature compensation and battery monitoring.

3.2.3 DC Equipment

DC equipment population matches the associated battery charger's population.

Most battery rooms are incorporated into the existing Control buildings. There are approximately 100 battery rooms. More recently designs have hosed batteries in standalone battery buildings to modern safety standards.

3.3 Age Profile

3.3.1 Batteries

Figure 3 shows approximately 12% of the battery population are over 15 years' service age and 34% will be 15 years of service age by 2025. The expected life of a typical battery installation is 15 years. Most commonly, batteries are replaced through:

station major replacement programs;

station specific DC power supply duplication projects; or

targeted battery replacement projects based on life expiry.

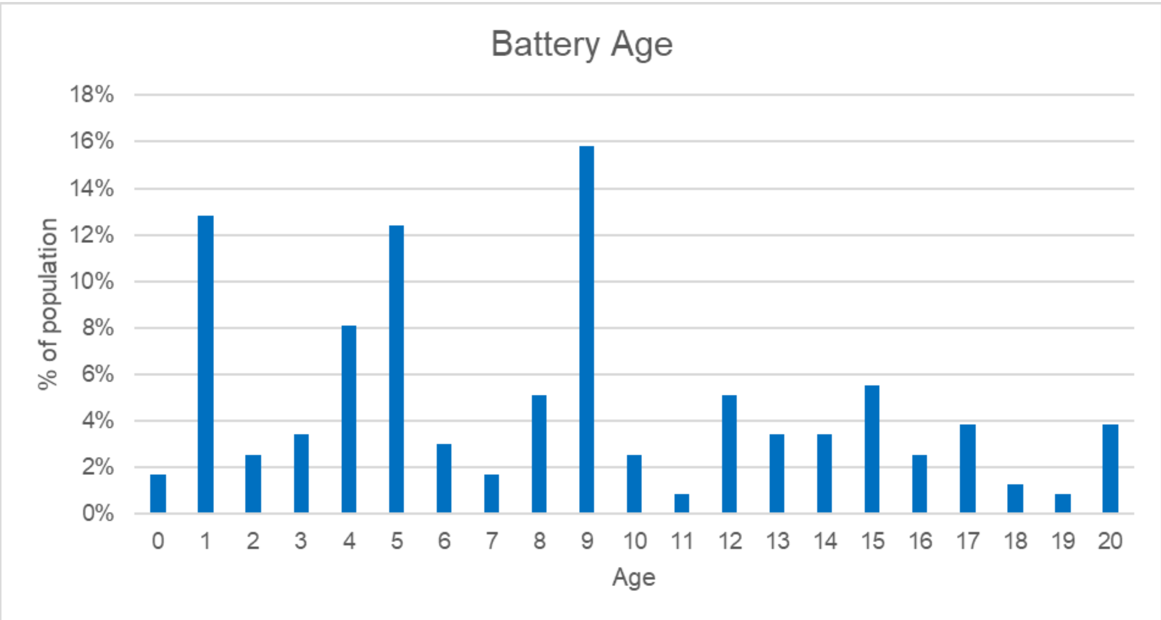

Figure 3 – Battery age profile

3.3.2 Battery Chargers

Figure 4 shows approximately 25% of chargers are over 15 years of service and 45% will have at least 15 years of service by 2025. Advanced service age is not of concern but obsolesce, the absence of charging controls, selfmonitoring and alarm which accompanies these older designs is constraining economic maintenance and reliable operation.

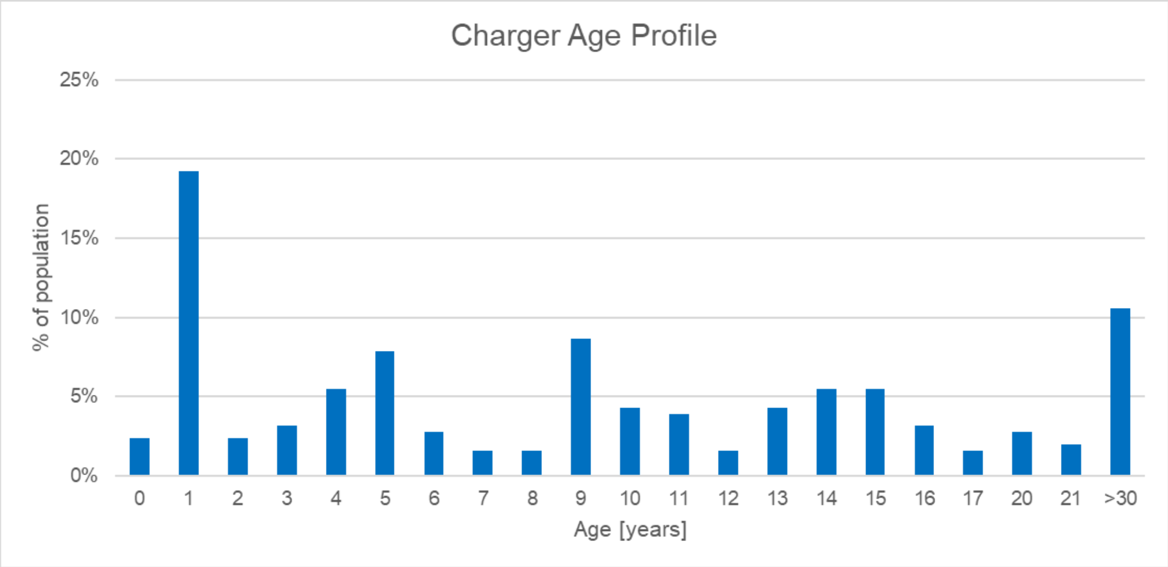

Figure 4 – Charger age profile

3.3.3 DC Equipment

The DC equipment population matches the associated battery charger's population age profile.

Most battery rooms are older and same age as the existing Control buildings. Battery room features are to a standard, at the same age profile as the battery age.

3.4 Condition

3.4.1 Condition Summary

A detailed condition assessment is given in the following sections. The condition of the main DC power supply items (i.e. batteries and chargers) can be summarised in Table 1 below.

Table 1 – Condition Score

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

3.4.2 Overall DC Supply System

The overall condition of the DC supply system at a Terminal Station, considering battery, battery charger and DC equipment condition is shown in Figure 5.

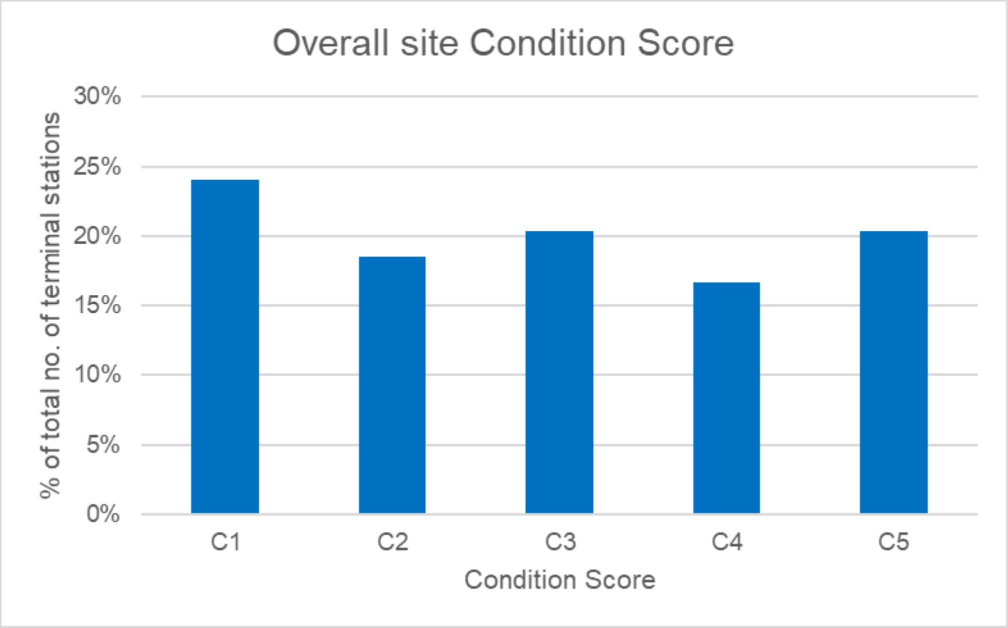

Figure 5 – Terminal Station Overall Auxiliary Power System condition profile

3.4.3 Batteries

Batteries have a nominal service life of 15 years although individual cells may fail within this period. During the battery life the capacity decreases and a 10% allowance for duty related deterioration is considered in selecting the battery rating.

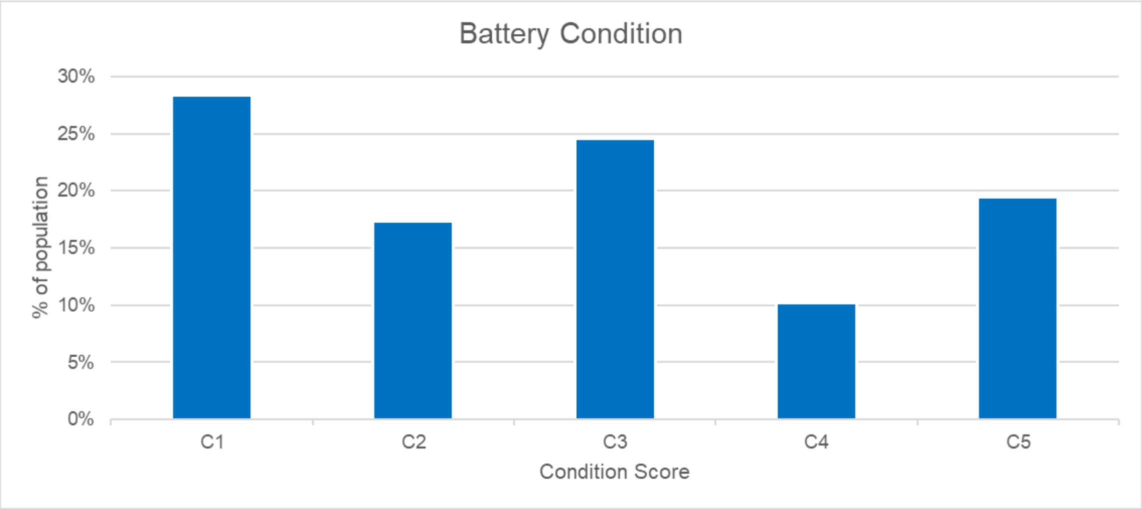

Figure 6 – Battery condition profile

Figure 6 shows that approximately 30% of batteries are in a C4 or C5 condition. This is in part attributed to their service life being greater than their expected life of 15 years by 2025.

Of concern is the population of batteries that are at expected life date. They consist mainly of communication battery installations. The expected asset life of 15 years is also supported by other industrial applications which state "Batteries with tubular plates have a typical shelf-life of 15-18 years"[3]. Past operational experience suggests an average battery life of 12 years given lack of room temperature control or the limited alarms and monitoring insatlled compared to modern systems.

3.4.4 Battery Chargers

Battery charger condition has been established by assessing the charger characteristics and its remaining useful service life. Chargers are grouped in categories which designate the charger technology score and their obsolesce. The technology score combined with the remaining useful service life make up the condition score.

Figure 7 illustrates the condition of chargers.

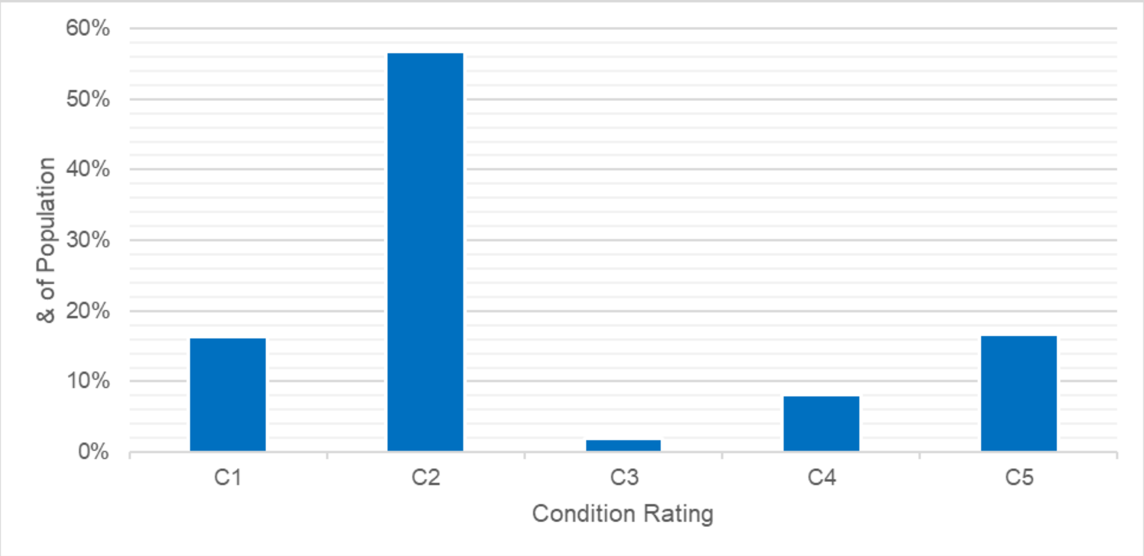

Figure 7 – Charger condition score

Approximately 22% of the charger fleet are in C4 and C5. Amongst these are obsolete chargers which do not have self-monitor functionality and consequently do not provide alarms for failures in the charging circuitry.

3.4.5 DC Equipment

DC Equipment is in similar condition to the battery chargers.

Battery room conditions reflect the standard at the time of the last battery installation and the original control building design.

Older locations have some issues, such as:

- floors not acid proof,
- limited space;
- combined X & Y battery rooms and
- asbestos.

3.5 Asset Criticality

Asset criticality is the consequence of DC power supply failure.

Auxiliary power systems failure presents the following consequences:

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

The criticality considers 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:

- Station black due to loss of protection (for DC and AC Systems); and
- The value of unserved energy of each consequence is multiplied by number of hours required to restore the auxiliary power supply

The relative base criticality is assigned by sorting the terminal station black consequence dollar value relative to replacement cost of a complete DC system. The sites are grouped in five criticality bands with highest station black dollar value consequence band 5 and least critical band 1.

Criticality banding is shown in Table 2.

Table 2 - Interpretation of Relative Base Criticality

Relative Base Criticality	Criticality Banding	Economic impact relative to replacement cost
Very low	1	Total failure effect cost < 1
Low	2	Total Effect Cost is ≥ 1
Medium	3	Total Effect Cost is ≥ 3
High	4	Total Effect Cost is ≥ 10
Very high	5	Total Effect Cost is > 30

[3] Battery Technology Handbook, H.A. Kiehne, 2003.

3.6 Asset Performance

The asset management system (SAP) includes 757 defect notifications between 2015 to 2019 relating to unscheduled maintenance work.

Figure 8 presents a breakdown of defect notifications by Auxiliary Power System component and year.

The ACEQUIP, the station services AC power supply equipment accounts for 1% of the total no. of defects.

The DCEquip category includes the DC equipment issues, BATT the battery issues, BATTCHRG, the battery charger defects.

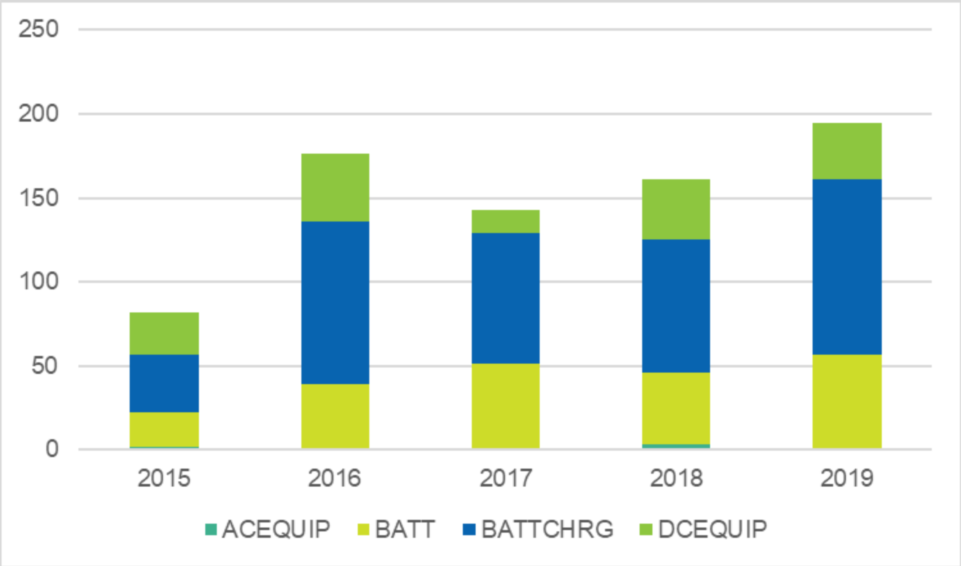

Figure 8 – Auxiliary Power System defects

The total no. of unscheduled maintenance notifications is split by notification type into “ZA” which represents suspended failures, i.e. unplanned maintenance done to prevent a component failure and “ZK” which represents work done to rectify a failure of an Auxiliary Power System component. Furthermore, each category is divided into “condition-based defects” and “Environment & 3rd Party Caused Defects”. The program of works targets prevention of the condition-based defects.

Out of all defect notifications 55% are faults (ZK), which triggered an electrical incident and 45% are defects which were remediated before an incident occurred (ZA).

Figure 9 illustrates that 35% of the unplanned maintenance works are done to rectify a “condition-based defect”, that’s is component failure or deterioration and 10% to rectify an “Environment &3rd party caused defect”, that is attributed, for e.g. vermin damage or excessive temperatures, on extreme hot weather days affecting performance.

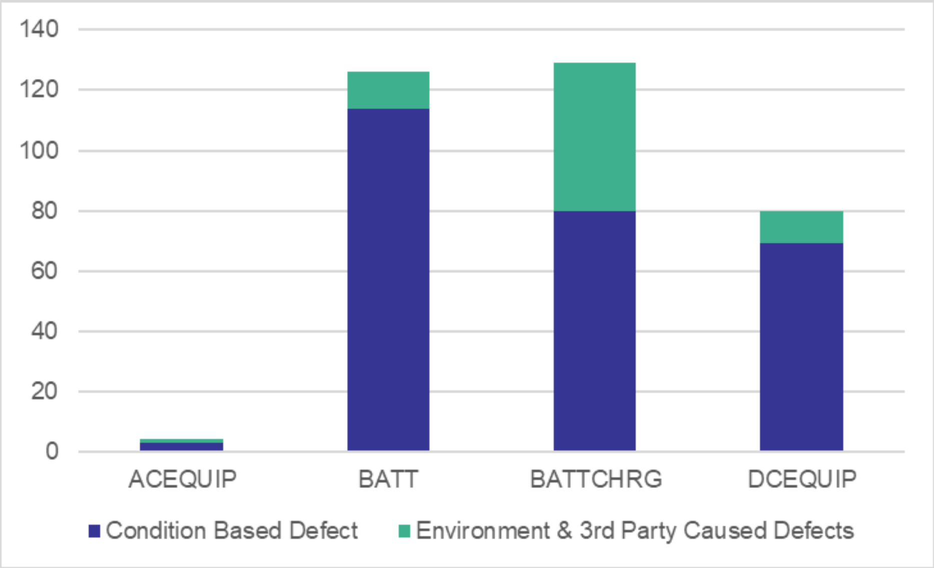

Figure 9 – Auxiliary Power Systems Suspended Failures

Figure 10 illustrates that 26% of the failures are "condition-based defects" and 30% are "Environment & 3rd party caused defects".

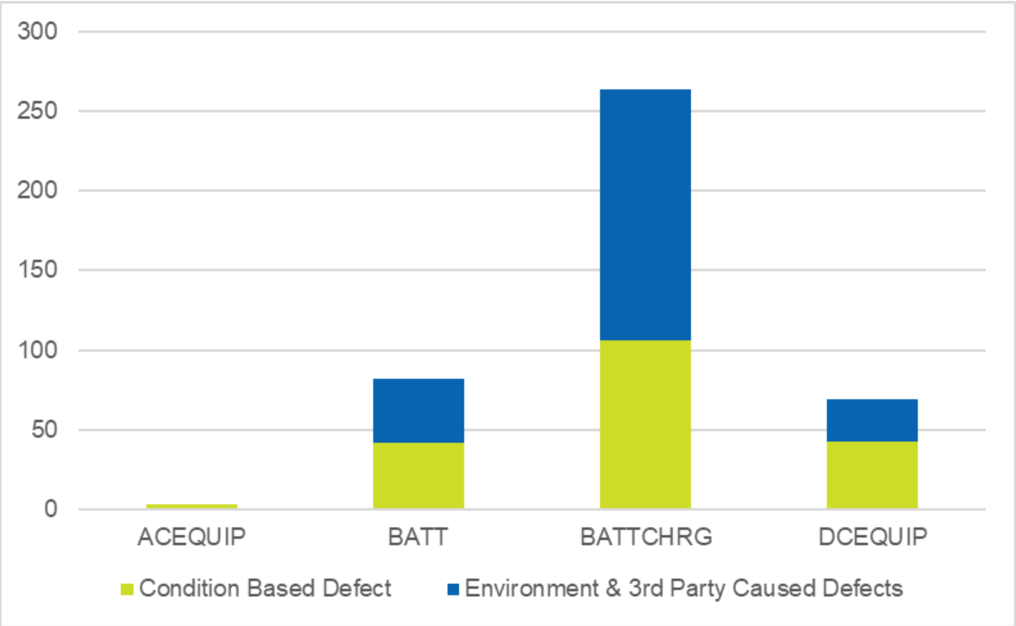

Figure 10 – Auxiliary Power Systems failures

Given the DC Supply system components age and condition profile the maintenance activity is considered relatively successful as there are more failures due to environment & 3rd party than due to condition.

Approximately 50% of the component faults are signalled by alarms. The most common battery charger problems are loss of output due to Unit or component failure. The most dominant battery problems are poor connections and low electrolyte levels requiring top up and leaks.

4 Other Issues

4.1 Battery sites requiring duplicated 250V X and Y batteries

Most stations have now been upgraded to duplicate batteries as required by AEMO. All sites will be duplicated by 2022.

4.2 Stations without duplicate battery rooms

Most stations have been augmented or upgraded to have isolated and separate battery rooms for the separate X and Y DC power supplies. Those remaining stations that do not have duplicate battery rooms the current solution to bring them up to current standard is to install a standalone battery building during DC system replacement.

4.3 Battery maintenance regime and condition assessment

The previous battery maintenance regime was based on the station having only a single battery and thus maintenance activity has been constrained by the need to keep this single battery in service. Discharge tests allow more extensive maintenance to be undertaken with the current standard which allows the station DC to be switched to one battery and release the other battery for boost charging.

Extensive periodic battery equalisation charging, and discharge tests ensure the functionality of a DC power supply is at its expected capability. Equalisation charging lessens stratification of battery cells in a bank and mitigates early deterioration factors such as accelerated plate corrosion. Discharge testing provides a thorough method for determining the functional capacity of battery banks at any point in their service life and is the best indicator of remaining battery service life.

Batteries need to be regularly inspected and maintained to have corrosion-free connections and sufficient electrolyte levels. The float voltage is checked to be 2.25 Volts/cell so that the battery is at the rated Amp Hour capacity.

4.4 Battery Rooms and Occupational Safety Risk

Although battery room installations are in a variety of conditions, all newly constructed rooms conform to AusNet Services' design standards[1] and Australian Standards (AS 2676.1 and AS 3011.1), key criteria for battery rooms are:

1. 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.
2. Floors must be coated with acid proof paint to ensure integrity of the floor construction is not compromised.
3. Eye-wash stations must be installed.
4. 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.
5. Battery stands must allow batteries to be installed above the floor, and be adequate for their loading, non-corrosive and durable.
6. Battery stands, and the room layout must be such that it allows maintenance staff to remove and install the heavy batteries with minimal risk of injury.
7. Separate battery rooms are used as, in the event of a fire or explosion within one battery room or nearby building, the segregation will ensure that not all the batteries affected.

4.5 DC Power Supply Alarms and Monitoring, and Distribution boards

All DC power supplies are monitored for and alarmed on "under voltage, charger fail, and battery earth" (only for control DC power supplies).

Battery specific monitoring systems have been installed at sites which have been most recently constructed or refurbished. Key measures are temperature, impedance and individual cell voltage.

On early installations data is compiled in a [C-I-C] to provide a continuous record of the health of the battery. The current monitoring system design is more elegant and uses a [C-I-C] relay. The data provides information for enhanced reliability of the battery bank and indication of early deterioration.

DC-DC converters supply control equipment throughout terminal stations. In the event of a DC-DC converter failure, there would be limited or no power supply to control equipment. Hence, it is important to monitor DC-DC converters.

Distribution boards and cabling are components of the DC power supply however are not given an individual condition rating. DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced during station DC supply system replacement projects.

5 Risk Assessment

5.1 Risk Drivers

The drivers for a DC power supply risk assessment include consequences and likelihood of occurrence of a functional failure.

A DC power supply failure has risk impacts on: power supply to costumers, constrains in the power flow, transmission network circuit availability, primary and secondary asset damage, worker safety, operational capability and regulatory responsibilities.

The highest network performance risk caused by failure of DC power supply is terminal station black therefore AER prevents a utility to run a terminal station on DC power supply single contingency for more than eight hours.

The likelihood of failure for a DC power supply is related to the condition of the asset as shown in section 3.4.

5.2 Risk Assessment Methodology

A semiquantitative risk assessment is adopted for DC Power Supply Systems. Given the interdependence between individual sub-components of the system and the duplication of control batteries and DC-DC converters - see clause 3.2.1, it is impractical to assess an entire array of failure scenarios and how each individual asset contributes to it. Therefore, it is assumed that maintaining the DC Power supply Systems components in a reliable state will mitigate all risks outlined above.

The reliability benchmark is given by regulations, standards, instruction manuals and operational experience and was assessed by a subject matter expert.
The methodology includes:

- condition scoring of each individual DC supply system component
- ranking/condition scoring of each Terminal Station (site - entire DC Supply System), with sites requiring highest volume of works in C5 and least volume of works in C1:
  - assessment of works required to maintain systems reliable in service,
  - costing of works required
- criticality scoring of each Terminal Station (site), based on with sites having a highest station black $/hr consequence in criticality 5 and least consequence in criticality 1, as per section 3.5
- developing of a risk matrix which outlines sites with DC Supply system highest failure likelihood and highest criticality,
- finalising the program of works for following 5 years period.

5.3 Risk Matrix

The risk matrix is developed at terminal station level and it counts the number of sites by overall site condition score and criticality.

Table 3: Risk Matrix – No. of terminal stations/sites

Criticality	Condition Score				
Score	C1	C2	C3	C4	C5
Cr5	2	3	1		3
Cr4	8	5	5	2	2
Cr3	2	1	2	5	5
Cr2	1				
Cr1		1	3	2	1

There are 13 sites in the highest risk zone - marked in red.

5.4 Program of Works

The program of works includes several categories of works required to maintain the DC Supply Systems in a reliable state. Works include replacements of battery, chargers, battery enclosure and monitoring as well as works on DC/DC system, isolation panel, distribution panel, under-voltage and earth fault relay panels.
On sites in red and some in amber the program of works includes a combination of the works outlined above while on nine sites in red, amber and yellow the program of works includes replacement of batteries only.

The program of works for 2022 to 2027, targets 21 terminal stations in total as follows:

- Thirteen sites in highest risk area, highlighted in red in the risk matrix,
- Five sites with high likelihood of failure in C4, highlighted in amber in the risk matrix,
- Three sites in C4 and C5 and criticality 1 where only batteries are included for replacement by 2027.

The list of Terminal Stations is included in Appendix A.
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6 Strategies

6.1 New Assets

- Where economic replace DC Supply asset in conjunction with future terminal station rebuild projects.
- All new battery rooms are to be constructed to be compliant with AusNet Services Station Design Manual and Australian Standards.
- Station design is to continue to ensure that battery capacity is sufficient to meet the station load for the required period.
- Periodically review innovations in battery technology for more reliable and economic energy storage options.
- Continue replacing old batteries with Valve Regulated Lead Acid (VRLA) batteries which are an alternative sealed battery type available to the electricity supply industry for the purposes of DC supply.

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  - Net reduction in OH&S risk by reducing the risk of acid leakage. The cells are completely sealed units.
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6.2 Maintenance

- Regularly inspect batteries for terminal corrosion, post growth, electrolyte level, electrolyte leakage, voltage level, connection lead conditions and cleanliness.
- Look into implementing extended online monitoring capability to reduce manual maintenance activity and increase visibility of battery condition.
- Continue to monitor DC-DC converters.

6.3 Spares

- Maintain the mobile temporary DC supply solution: this is a specifically designed trailer that contains a full vented lead acid battery bank (250V) and a charger. The trailer is used as a backup when a station battery bank is taken out of service during project work. Due to the risk associated with generation connections to terminal stations the trailer is required to remain in the eastern region. The trailer is not required under the system black restart process but could be utilised if required.
- Establish a mobile temporary DC supply solution to be used as a backup when a station battery bank is taken out of service during both project work and maintenance. The trailer is required to support project and maintenance works on all regions except eastern region.

6.4 Refurbishment

- DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced before 2025 as per AMS 10-01.
- Progressively augment charger functionality with temperature compensation and boost charging facilities where recommended by battery manufacturers.
- Where possible battery rooms are to be progressively upgraded to be compliant with AusNet Services Station Design Manual and Australian Standards.

6.5 Replacement

- Selective DC power supply equipment replacements in 16 terminal stations as outlined in clause 4.4
- Maintain the mobile temporary DC supply solution.

7 Appendix A – Program of works

Table 4 outlines the terminal station sites included in the program of works as well as the proposed works at each site in (units of equipment).

Table 4 – Program of works summary

Site/Equipment	ERTS	HWTS	MLTS	MTS	SYTS	ROTS A2	BETS	EPS	HOTS	MBTS	VNSC	YA	HWPS	SMTS	TBTS	FVTS	BATS	GNTS	NPSD	RCTS	TGTS	Total
250V_battery	2			2	2	2	2	2	2	2	3	2		3			2		2	2	2	32
250V_enclosure	2				2		2	2	2	2		1										13
250V_charger	2		2	2	2	2	2	2	2	2	3	2										23
250V_monitoring	2			2	2	2	2	2	2	2	3	2										21
48V_battery			2	2			2	2	2	2			2		2	2		2		2		22
48V_enclosure			2				2	2	2	2												10
48V_charger				2			2	2	2	2												10
48V_monitoring			2	2			2	2	2	2												12
DC/DC	2				2							2										6
isolation	2		2	4	2	2	4	4	4	4	5	2										35
distribution	4	20	5						4													33
EF & UV	4					2	2			4		2										14
Connect to ethernet	2	4	2																			8