AusNet services

AMS – Victorian Electricity Transmission Network

DC Power Supplies (PUBLIC VERSION)

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Disclaimer

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1 Executive Summary

The Victorian electricity transmission network includes 255 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.

1.1 Batteries

Key strategies to maximise the economic life of batteries include:

- Where economic replace batteries in conjunction with future terminal station rebuild projects.
- As required replace selected batteries as part of DC Supply Upgrade Stage 3 project (XC84).
- Station design is to continue to ensure that battery capacity is sufficient to meet the station load for the required period.
- Regularly inspect batteries for terminal corrosion, post growth, electrolyte level, electrolyte leakage, voltage level, connection lead conditions and cleanliness.
- Periodically review innovations in battery technology for more reliable and economic energy storage options.
- Establish spare portable 250 V and 50 V batteries for emergency use.

1.2 Battery Chargers

- Where economic replace chargers in conjunction with battery replacements during future terminal station rebuild projects.
- As required replace selected chargers as part of DC Supply Upgrade Stage 3 project (XC84).
- Progressively augment charger functionality with temperature compensation and boost charging facilities as recommended by battery manufacturers.

1.3 Battery Rooms & Distribution Boards

- Battery rooms are to be progressively upgraded to Australian Standards in respect of ventilation, lighting, floor sealing, eyewash facilities and manual handling requirements.
- DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced before 2025 as per AMS 10-01.

1.4 DC Power Supply Alarms and Monitoring

- Continue to monitor DC-DC converters.

2 Introduction

2.1 Purpose

The purpose of this AMS document is to:

1. Present a current assessment of AusNet Services' transmission stations DC power supplies population and condition;
2. Specify key issues in the population;
3. Specify and present key risks associated with failure of DC supply systems; and
4. Present economic asset management strategies to manage the identified risks.

2.2 Scope

This document details the condition and strategies for DC power supplies at AusNet Services' electricity transmission terminal stations.

DC power supply components include:

- Batteries;
- Battery Chargers;
- Battery Rooms and Distribution Boards; and
- DC Power Supply Alarms and Monitoring.

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

3 Asset Summary

Terminal station DC power supplies are critical to providing power to the protection, control, metering and SCADA systems which control energy flow on the Extra High Voltage circuits. Complete failure of DC power supplies at a terminal station renders energy flows and station equipment uncontrollable and disables the electrical protection system placing consumer, public and workers at risk.

3.1 Population

3.1.1 Batteries

There are approximately 255 battery banks in AusNet Services' transmission stations. These batteries provide a DC energy supply for:

- 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.

Figure 1 – Standard 48V Battery Bank of 2V Cells

Batteries are typically identified by their voltage level, functionality, capacity and construction. Station batteries are:

- 250 V Protection X or X and Y;
- 250 V Control/Communications;
- 50 V Control; and
- 50 V Communications A and B.

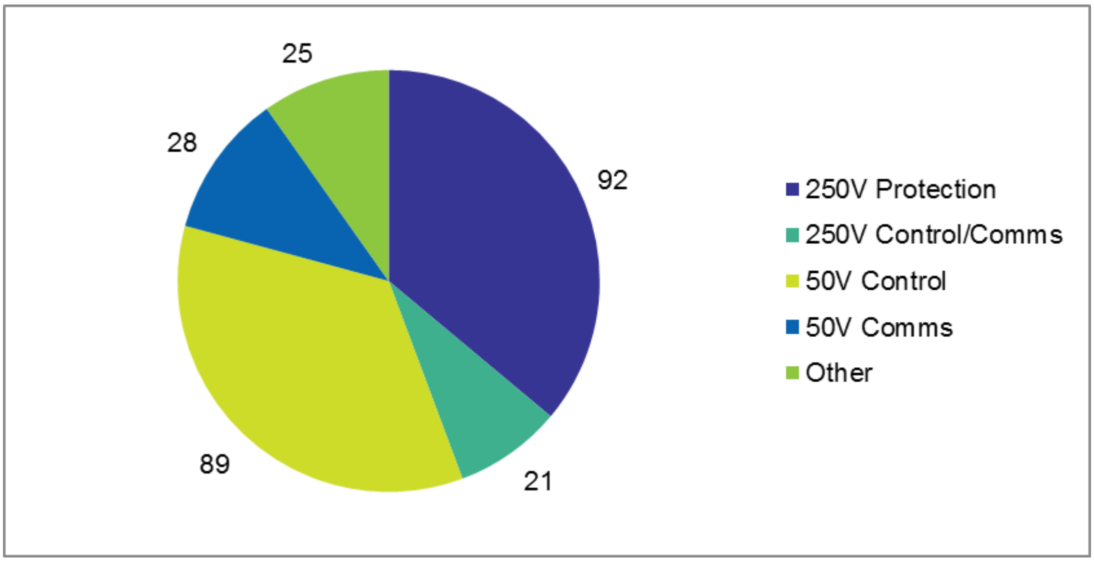

Figure 2 – Batteries by voltage and function

Figure 2, 79% of battery function is divided into two dominant areas. 43% per cent of batteries power 50 V communications equipment and 36% of batteries power 250V protection 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.

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].

Most stations now have 250 V "X" and 250 V "Y" control batteries and provide the 50 V control supply via duplicated DC-DC converters from the 250 V batteries. Older station designs had separate dedicated single 250 V control batteries and 50 V control batteries. Separate control and communications batteries are now provided to cater for the different rating times between control and protection functions and communication functions, but also to segregate communications equipment from transient voltages imposed by the switchyard wiring and operation of electrical equipment such as circuit breaker equipment.

Control batteries are "floating" with neither positive or negative earthed. The 250 V batteries normally comprise of 117 individual 2 V cells, although some older batteries are 114 cells formed from 19 individual 6 V batteries. The Amp Hour (A/hr) rating is appropriate to supplying the station load for 10 hours. The "X" battery and its DC power supply are fully segregated from the 'Y" battery and its DC power supply, but may be switched such that one battery can supply both the 'X" and "Y" DC power supply or so one charger can supply both batteries. This allows for both battery maintenance (cell replacement or boost charging) and for charger failures.

Communications batteries are positive earthed and usually comprise 24 individual 2 V cells, with a rating that allows the communications load to be supplied for up to 10 hours. The two batteries and DC power supplies are segregated and operate on tied buses, hence named 'A" and "B" rather than "X" and "Y". Some 250 V and 12 V communications batteries associated with Power Line Carrier (PLC) equipment are no longer required although not all have been removed.

Batteries are usually flooded cell Lead Acid Pasted Plate (LAPP) although there are a small number of Valve Regulated Lead Acid (VRLA) batteries in service.

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

The battery capacity is set by the standing load from the connected devices such as protection relays and SCADA, and the energy required for an operation cycle of each circuit breaker and isolator. A 10% allowance is made for each of ageing, temperature and future additional loads. Battery and charger capacity is reviewed as part of any station work.

Figure 3 shows the breakdown of battery manufacturers.

[C.I.C]

Figure 3 – Battery Manufacturers

The make of batteries in use has varied with the battery period order contract supplier at the time of installation. As displayed in Figure 3, the majority of batteries on the network are from Battery Energy (pre 1990s – 2005) and in more recent times the [C.I.C] model of battery has been utilised (2000 – present).

The volume of [C.I.C] batteries in service is expected to increase significantly as the current battery replacement project (XA29) is completed. Project XA29 is a targeted DC power supply upgrade project to replace twenty seven 250 V batteries and twenty-four 48 V batteries in 14 installations. Six of the 14 sites have had DC system upgrades and 8 remain to be installed. New batteries at Dederang, Heatherton, Moorabool, Rowville, Templestowe, Wodonga terminal stations and Hazelwood and Yallourn power stations still require installation. To facilitate the installation of these replacement batteries, new battery rooms are being constructed at Hazelwood power station and Moorabool, Heatherton, Rowville and Templestowe terminal stations.

3.1.2 Battery Chargers

The number of battery chargers in service is equivalent to the number of battery banks on the network, with 255 across all terminal stations. Additionally, there are extra chargers on standby for an unlikely event of a complete failure of a charger, bringing the total population of chargers to 263 chargers. The chargers support the batteries by providing AC to DC rectification. Typically chargers are set up to continuously float charge at 2.25 Volt per cell. 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.

The more recently supplied chargers are temperature compensated so that battery gassing is reduced by a lower float voltage on hot days.

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

Figure 4 – 48V Battery Charger at KTS

Figure 5 shows which manufacturers have supplied the battery chargers currently in service on the electricity transmission network. The number of manufacturers reflects the fluid nature of the market with different suppliers entering and leaving the market and several changing their brand names. Chargers can be considered stand-alone generic devices with units readily interchangeable with that of another manufacturer.

[C.I.C]

Figure 5 – Charger Manufacturers

The current period order contract for supply of battery chargers has requested [C.I.C] chargers for installation in project XA29.

3.1.3 Battery Rooms and Distribution Boards

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.

Distribution boards and cabling are components of the DC power supply however are not given a condition. DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced before 2025.

3.1.4 DC Power Supply Alarms and Monitoring

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.

3.2 Age Profile

3.2.1 Batteries

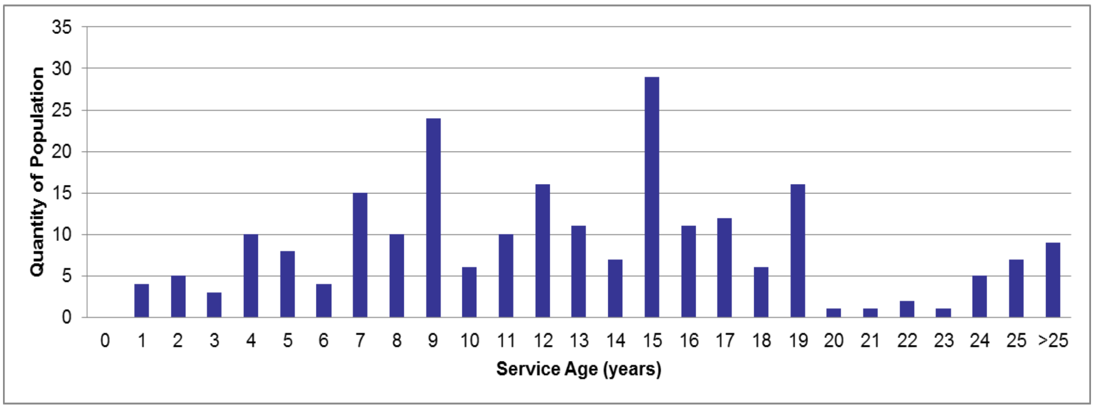

Figure 6 – Battery age profile

Figure 6 shows approximately 40% of the battery population are over 15 years' service age which is greater than the expected life of a battery installation. Assessments carried out by [C.I.C] indicate that the usable life of the batteries may be prolonged if the batteries are regularly fully charged and well equalised, a controlled boost/gassing charge is completed or a complete discharge and charge cycle is completed. Most commonly, batteries are replaced through:

- station rebuilds;
- station specific DC power supply duplication projects; or
- targeted battery replacement projects based on life expiry.

Targeted battery replacement projects are:

- XA29 – Replacements of selected chargers, battery rooms and DC isolation panels as well as batteries at Dederang, Glenrowan, Heatherton, Hazelwood Heywood, Moorabool, Morwell, Rowville, Templestowe, Wodonga terminal stations and Hazelwood, Loy Yang, and Yallourn power stations and substation Loy Yang (DDTS, GNTS, HTS, HWPS, HWTS, HYTS, LYPS, SUB LY, MLTS, MWTS, ROTS, TSTS, WOTS & YPS). Six of the 14 sites have been completed. The remaining 8 sites are scheduled to be completed before 2017 pending on business case revision approval.
- XC84 – This project is a proposed project to upgrade condition 4 and 5 DC power supplies at terminal stations not covered by XA29 above.

3.2.2 Battery Chargers

Figure 7 shows approximately 55% of chargers have provided well over 15 years of service, many are well past their expected useful service life. Advanced service age is not of particular concern but the absence of sophisticated charging controls and self-monitoring and alarming which accompanies these older designs is constraining economic maintenance and reliable operation.

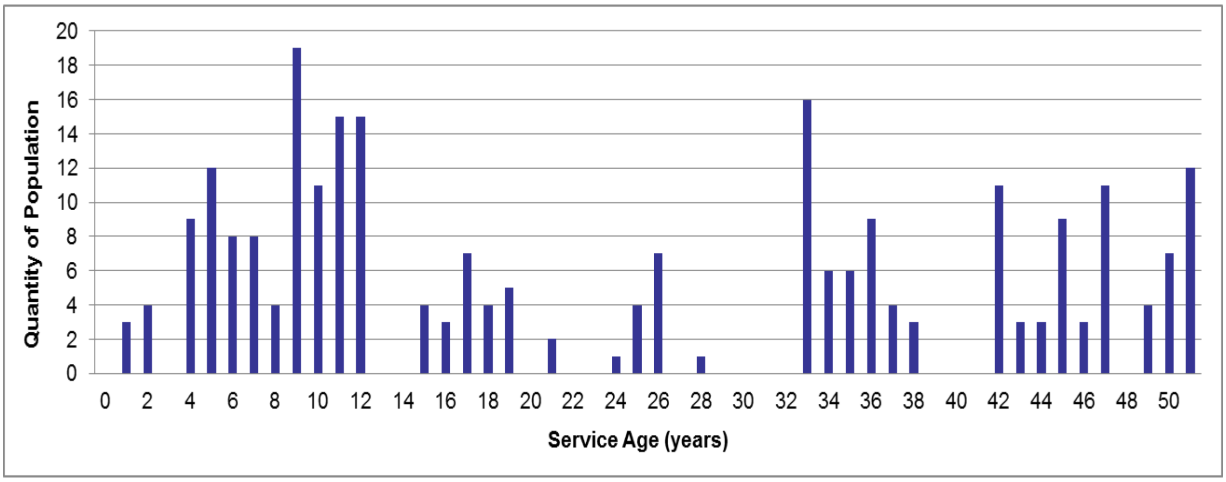

Figure 7 – Charger age profile

3.2.3 Battery Rooms

Typically battery rooms have been constructed as part of the station control building. Some sites where battery duplication has occurred have had prefabricated battery housings installed or have had vacant rooms refurbished to be used as battery rooms. Battery rooms that do not meet current Australian Standards are generally refurbished as part of station rebuild projects. Five battery rooms are being refurbished under project XA29 at Hazelwood power station and Moorabool, Heatherton, Rowville and Templestowe terminal stations (HWPS, MLTS, HTS, ROTS & TSTS).

3.2.4 DC Power Supply Alarms and Monitoring

All battery sites have DC power supply monitoring via earth fault alarms, charger fail alarms and battery under-voltage alarms. Battery monitoring schemes have been installed across stations which have recently been refurbished. The monitoring addresses reliability concerns and enhances security of the battery bank as detailed in section 3.1.4.

3.3 Condition

3.3.1 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.

Scoring Methodology			
Condition Score	**Condition Description**	**Summary of details of condition score**	**Recommended Action**
C1	Very good service condition	The DC supplies in this category have a total weighted calculated condition score higher than and including 4.5 out of 5. 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 condition	The DC supplies in this category have a total weighted calculated condition score between 3.5 and 4.5 out of 5, inclusive of 3.5. 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 service condition	The DC supplies in this category have a total weighted calculated condition score between 2.5 and 3.5 out of 5, inclusive of 2.5. These DC supplies are in average service condition. They require routine maintenance and condition monitoring to prevent failures occurring.	Routine maintenance and condition monitoring. Expected to remain in service for next 5 years.
C4	Poor service condition	The DC supplies in this category have a total weighted calculated condition score between 1.5 and 2.5 out of 5. Inclusive of 1.5 These DC supplies are in poor service condition. They require routine maintenance and condition monitoring to prevent failures occurring and are expected to remain in service for less than 5 years.	Replace in the next 5 years.
C5	Very poor service condition	The DC supplies in this category have a total weighted calculated condition score lower than 1.5 out of 5. These DC supplies are in very poor service condition. They require routine maintenance and condition monitoring to prevent failures occurring and require replacement as soon as possible.	Replace as soon as reasonably practical.

Table 1 – Condition Score

Figure 8 shows the overall condition score for DC power supplies at all terminal stations. 76% of terminal stations are in an average or below average condition, with the battery age at these stations contributing the greatest to these results.

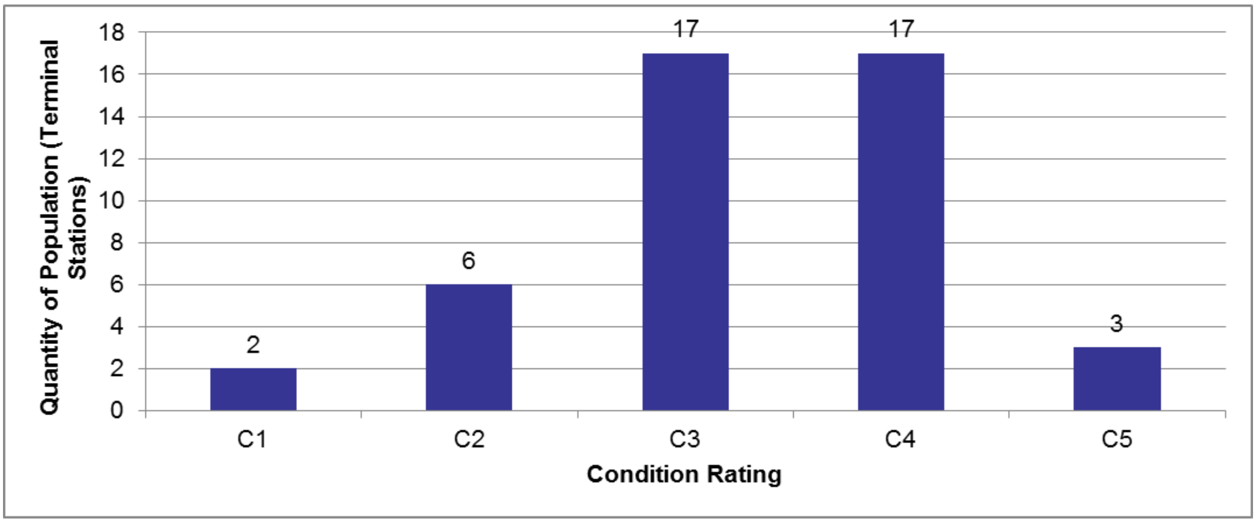

Figure 8 – Terminal station DC power supply condition scores

3.3.2 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. Common battery problems are:

- Terminal corrosion;
- Post growth;
- Cracked cases and electrolyte leakage;
- Connection lead failures; and
- Batteries poorly equalised and not fully charged.

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.

A network wide DC power supply audit was conducted in July 2011. All battery installations were inspected, recorded and conditions assessed. Batteries are inspected on a 3 month interval for class 1 overhauls and a 12 month interval for class 2, class 3 and class 4 overhauls.

A battery condition assessment project[3] was conducted in February 2012 on a selection of sites that were identified in the poorest of condition but had not previously been included in replacement projects.

[3] [C.I.C] (2012), Battery Condition Assessment (Stage 1) of vented lead-acid batteries in selected SP AusNet terminal stations, [C.I.C], Rowville, Victoria.

From this audit of 37 battery banks, the findings were:

- Generally banks were poorly equalised and not fully charged;
- Five banks are exhibiting excessive corrosion and/or excessive post growth and must be considered at end of useful service life;
- Three banks were found with one or more discharged cells; and
- Eight banks were considered beyond corrective action with replacement recommended.

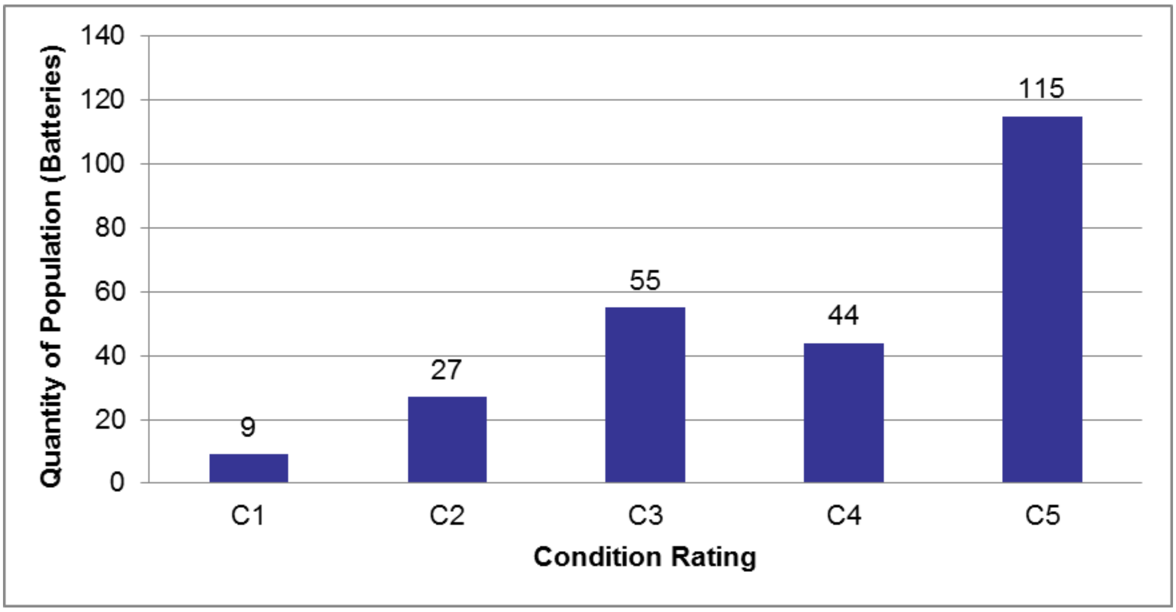

Figure 9 – Battery condition profile

Figure 9 shows that approximately 60% of batteries are in a C4 or C5 condition. This is attributed to their service life being greater than their expected life of 15 years. Project XA29 will replace a portion of these C4 and C5 assets and project XC84 aims to replace the majority of the remaining DC power supplies in C4 and C5 not covered by XA29.

Of concern is the population of batteries that are past end of life or at end of life and not included in current battery projects, they consist mainly of communication battery installations.

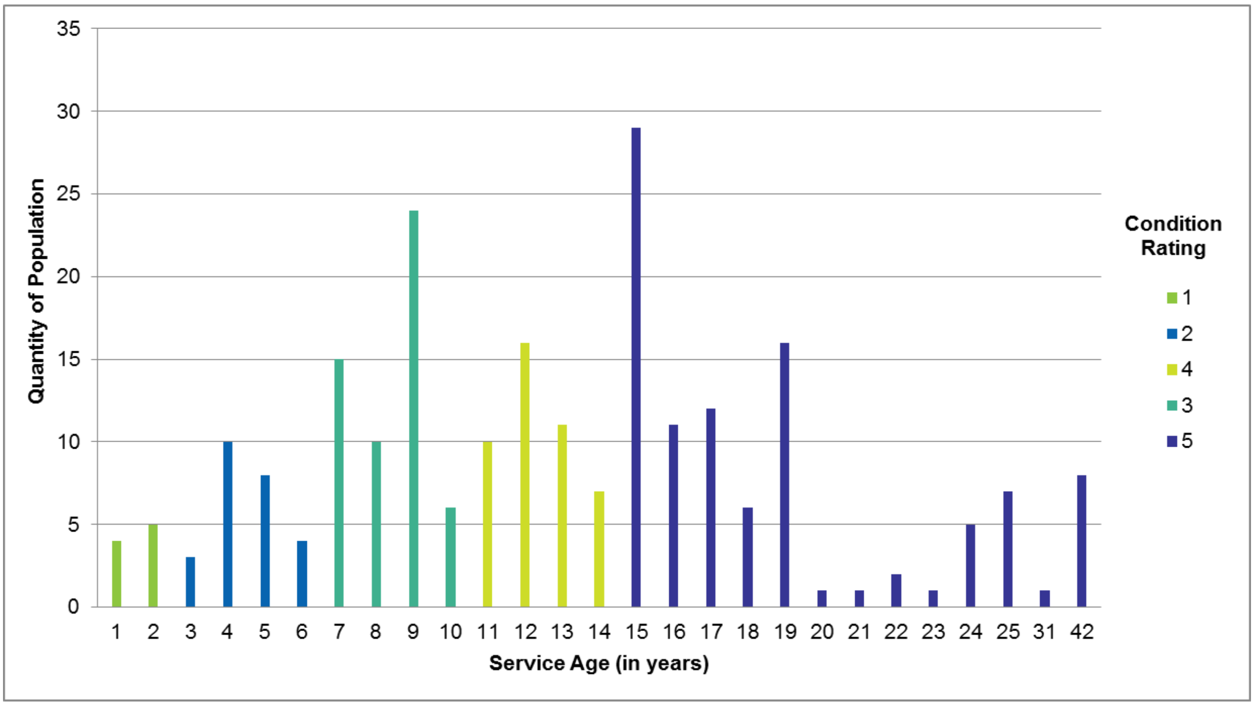

Figure 10 – Battery profile by age and condition

Figure 10 illustrates that the condition of the batteries is heavily dependent on the number of charging cycles they have served and hence the age the battery has been in service. The expected asset life of 15 years is also supported by other industrial applications which state "Batteries with tubular plates … a typical shelf-life of 15-18 years"[4]

3.3.3 Battery Chargers

Battery charger condition has been established through a visual inspection of the battery charger and its remaining useful service life. Note, redundancy for charger failure is provided by a permanently installed spare charger or by use of the alternate X or Y charger to charge both X and Y batteries. Figure 11 illustrates the condition of chargers.

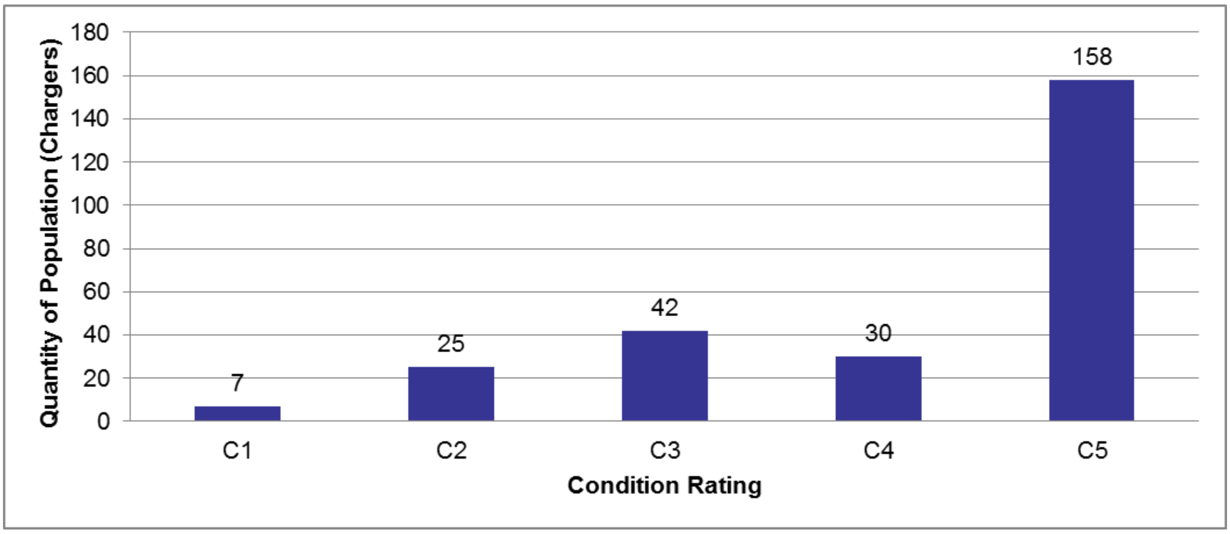

Figure 11 – Battery charger condition

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

Of the charger fleet, 60% of the chargers are beyond their designed lifespan of 15 years and these chargers are still in service. This may be attributed to the nature of older valve type chargers as they do not rely on modern electronic components, which may degrade over a much shorter time period. Having chargers of this vintage poses an elevated risk to the batteries they are charging, as many do not have facilities to self-monitor and consequently provide alarms for any failures in the charging circuitry.

From the audit conducted in July 2011[5] it was found that there were chargers with minor faults including:

- Malfunctioning measurement LCDs; and
- Missing labels and signs.

3.3.4 Battery Rooms

Battery room conditions vary from site to site. New battery room installations meet standards as discussed in section 0. A number of stations do not meet the requirement of duplicate battery rooms, see section 6.2.

Project XA29, across 14 sites) required all but 1 site to have the battery rooms either refurbished or newly constructed to meet the Australian Standards. Minor condition defects identified from inspected station battery rooms include:

1. Floors not acid proof or the acid proof paint is peeling away;
2. Lighting not working;
3. Venting broken;
4. Spilt acid on floor; and
5. Missing signage.

3.3.5 DC Power Supply Alarms and Battery Monitoring

The DC power supply alarms are being progressively upgraded in conjunction with secondary equipment replacements in station rebuild projects.

Battery monitoring relays have only been installed within the past 10 years and they function well. No issues are yet evident which would limit their expected useful service life or performance.

3.3.6 Defects and failures

MAXIMO contains 328 work orders relating to unscheduled maintenance work for batteries, battery chargers and DC power supplies as a whole. Figure 12 shows that of these 328 work orders, batteries contribute to the most work orders. This is closely followed by the DC power supply system itself and then battery chargers.

[5] Protection, Control and Automation, internal network wide DC systems audit.

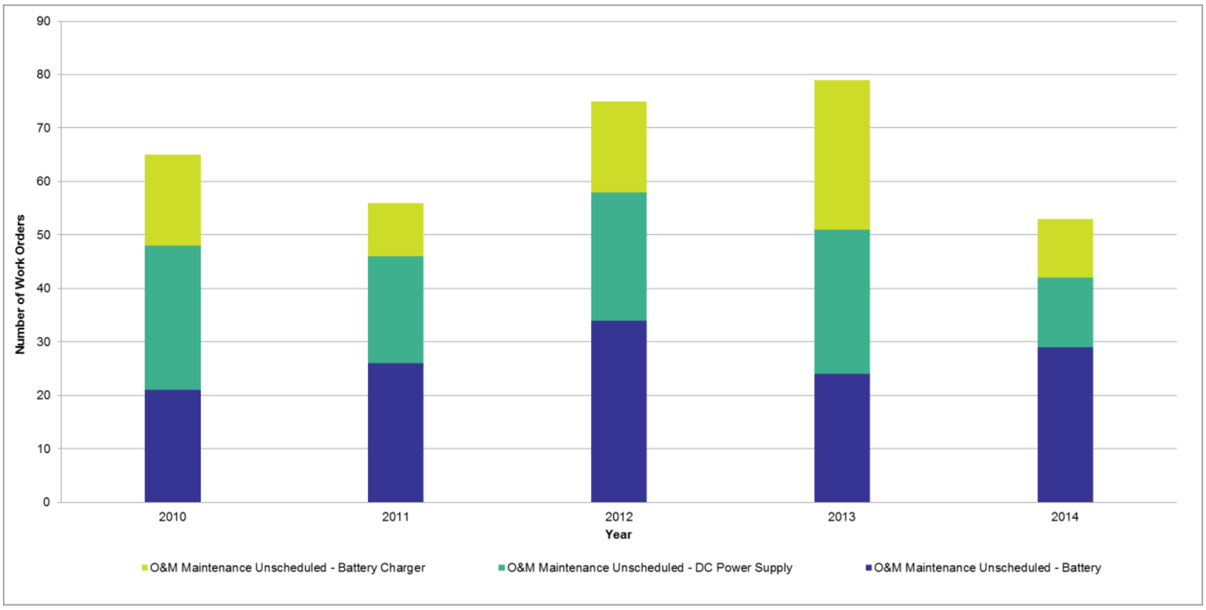

Figure 12 – Work orders categorised by batteries, DC power supply systems and chargers

Beside the 'other' category, Figure 13 shows that earth faults, poorly conditioned DC power systems, charger faults and instrument/alarm failures are the main root causes of failures. The major categories of failure have remained constant over the 2010 to 2015 period.

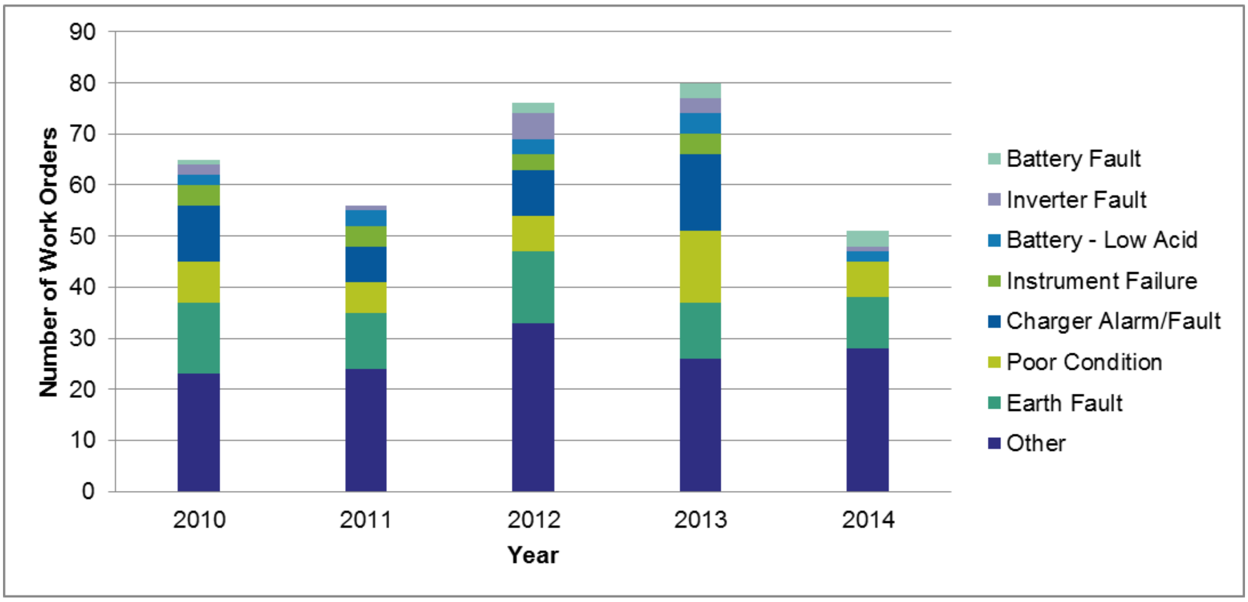

Figure 13 – Root cause of failures

4 Risk Assessment

4.1 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 consumers, transmission network circuit availability, asset damage and worker safety, operational capability and regulatory responsibilities. Consequences include:

Network	• Inability to isolate network faults. Uncleared faults can lead to major plant damage and a network Black. • Inadvertent tripping of protection circuits.
Safety	• Acid spill, corrosive work environment. • Build-up of highly flammable hydrogen gas within battery room.
Operational	• Loss of remote control and monitoring. • Human Error Incident (HEI) event.
Regulatory	• Non-compliance to regulatory requirements for DC availability.

Table 2 – Risk drivers for DC power supplies

The likelihood of failure for a DC power supply is strongly related to the volume of charging cycles or service duty and hence age of the asset as shown in section 3.3.2. Batteries and battery chargers in condition C4 and C5 can be found in Appendix A.

5 Strategic Factors

5.1 Valve Regulated Lead Acid Batteries

Valve Regulated Lead Acid (VRLA) batteries are an alternative sealed battery type available to the electricity supply industry for the purposes of DC supply.

The benefits of using VLRA include:

1. Less maintenance, providing more time for further detailed maintenance.
2. Less risk of acid leakage as the cells are completely sealed units.
3. Lower space requirements.

VRLA batteries typically have shorter service lives than vented batteries, typically 10 years of service. Some of the higher quality units have expected service lives near equivalent to LAPP batteries.

5.2 Temporary Battery

A mobile temporary DC supply solution is available in the Eastern Region. It 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 and refurbishment 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.

6 Key Issues

6.1 Battery sites requiring duplicated 250V X and Y batteries

Most stations have now been upgraded to duplicate batteries. Strategies must be devised for those remaining stations that have no duplication. These batteries are expected to be duplicated under project XC84.

6.2 Stations without duplicate battery rooms

Most stations have been augmented or upgraded to have isolated and separate battery rooms for DC power supplies. Strategies must be devised for those remaining stations that do not have duplicate battery rooms.

6.3 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.

7 Strategies

7.1 Batteries

Key strategies to maximise the economic life of batteries include:

- Where economic replace batteries in conjunction with future terminal station rebuild projects.
- As required replace selected batteries as part of DC Supply Upgrade Stage 3 project (XC84).
- Station design is to continue to ensure that battery capacity is sufficient to meet the station load for the required period.
- Regularly inspect batteries for terminal corrosion, post growth, electrolyte level, electrolyte leakage, voltage level, connection lead conditions and cleanliness.
- Periodically review innovations in battery technology for more reliable and economic energy storage options.
- Establish spare portable 250 V and 50 V batteries for emergency use.

7.2 Battery Chargers

- Where economic, replace chargers in conjunction with battery replacements during future terminal station rebuild projects.
- As required replace selected chargers as part of DC Supply Upgrade Stage 3 project (XC84).
- Progressively augment charger functionality with temperature compensation and boost charging facilities as recommended by battery manufacturers.

7.3 Battery Rooms & Distribution Boards

- Battery rooms are to be progressively upgraded to Australian Standards in respect of ventilation, lighting, floor sealing, eyewash facilities and manual handling requirements.
- DC power distribution boards manufactured from or containing asbestos reinforced panels shall be replaced before 2025 as per AMS 10-01.

7.4 DC Power Supply Alarms and Monitoring

- Continue to monitor DC-DC converters.

8 Appendix A

8.1 Batteries and Battery Chargers in C4 and C5

8.1.1 Batteries

The following table shows batteries in condition 4:

Terminal Station	Battery Description	Battery Years in Service
EPS-Y	48V COMMS A BATTERY	11
EPS-Y	48V COMMS B BATTERY	11
EPS-Y	250V Y CONTROL BATTERY	11
EPS-Y	250V X CONTROL BATTERY	11
EPS-Y	48V COMMS A BATTERY	11
EPS-Y	48V COMMS B BATTERY	11
EPS-Y	50V CONTROL BATTERY	11
HYTS	48V COMMS A BATTERY	12
HYTS	48V COMMS A BATTERY	13
HYTS	48V COMMS A BATTERY	12
HYTS	48V COMMS B BATTERY	12
HYTS	48V COMMS B BATTERY	13
HYTS	48V COMMS B BATTERY	12
JLTS	48V COMMS A BATTERY	12
JLTS	48V COMMS B BATTERY	12
JLTS	50V CONTROL BATTERY	12
KGTS	250V X CONTROL BATTERY	12
KGTS	250V Y CONTROL BATTERY	12
KGTS	48V COMMS A BATTERY	13
KGTS	48V COMMS B BATTERY	13
KGTS	50V CONTROL BATTERY	11
MBTS	250V X CONTROL BATTERY	12
MBTS	250V Y CONTROL BATTERY	12
MBTS	48V COMMS A BATTERY	14
MBTS	48V COMMS B BATTERY	14
MLTS	250V X CONTROL BATTERY	14
MLTS	50V CONTROL BATTERY	14
MLTS	48V COMMS B BATTERY	14
MWTS	250V Y CONTROL BATTERY (NTH)	12
MWTS	250V X CONTROL BATTERY (NTH)	12
NPSD	250V X CONTROL BATTERY	11
NPSD	250V Y CONTROL BATTERY	11
RWTS	48V COMMS B BATTERY	13
RWTS	250V CONTROL BATTERY	13
RWTS	50V CONTROL BATTERY	14

Terminal Station	Battery Description	Battery Years in Service
RWTS	48V COMMS A BATTERY	13
SHTS	48V COMMS A BATTERY	13
SHTS	48V COMMS B BATTERY	13
SVTS	50V CONTROL BATTERY	12
SVTS	48V COMMS A BATTERY	12
SVTS	48V COMMS B BATTERY	12
SYTS	48V COMMS A BATTERY (M/W BLDG)	13
SYTS	48V COMMS B BATTERY (M/W BLDG)	13
WMTS	50V CONTROL BATTERY	14

Table 3 – Batteries in C4

The following table shows batteries in condition 5:

Terminal Station	Battery Description	Battery Years in Service
BETS	48V COMMS A BATTERY	25
BETS	48V COMMS B BATTERY	25
BETS	50V CONTROL BATTERY	25
BETS	250V CONTROL BATTERY	25
DDTS	48V COMMS A BATTERY	19
DDTS	48V COMMS B BATTERY	19
DDTS	50V CONTROL BATTERY	19
DDTS	48V COMMS A BATTERY	19
DDTS	250V CONTROL BATTERY	19
DDTS	48V COMMS B BATTERY	19
EPS-Y	48V COMMS A BATTERY CHARGER (SOUTH RLY HSE)	42
FBTS	250V Y CONTROL BATTERY	24
FBTS	250V X CONTROL BATTERY	22
FBTS	250V X CONTROL BATTERY	24
GNTS	12V COMMS BATTERY	31
HTS	250V CONTROL BATTERY	19
HTS	12V FAULT RECORDER BATTERY	19
HWPS	50V INV & E/REC BATTERY	20
HWTS	12V FIRE PROTECTION BATTERY (HWTS STH)	42
HWTS	24V BATTERY FIRE PROTECTION (BAY 6)	42
HWTS	24V BATTERY FIRE PROTECTION (BAY 5)	42
HWTS	48V COMMS A BATTERY	17
HWTS	48V COMMS B BATTERY	17
HWTS	12V FILAMENT BATTERY CHARGER (BAY 9 RLY HSE)	42
HWTS	250V CARRIER BATTERY (BAY 6 RLY HSE)	19
HWTS	250V CARRIER BATTERY (BAY 9 RLY HSE)	19
HYTS	250V Y CONTROL BATTERY	15
HYTS	50V CONTROL BATTERY	16
HYTS	48V COMMS A BATTERY	16

Terminal Station	Battery Description	Battery Years in Service
HYTS	48V COMMS B BATTERY	16
HYTS	250V Y CONTROL BATTERY	17
HYTS	250V CARRIER BATTERY (CONTROL BLDG)	19
HYTS	48V COMMS A BATTERY (HUT NEXT TO MW MAST)	15
HYTS	250V CARRIER BATTERY CHARGER (BAY 6 RLY HSE)	42
HYTS	250V CARRIER BATTERY CHARGER (BAY 9 RLY HSE)	42
HYTS	250V CARRIER BATTERY CHARGER (CONTROL BLDG)	42
HYTS	250V X CONTROL BATTERY BANK (2ND FLOOR)	15
HYTS	250V STATION BATTERY	15
HYTS	250V Y CONTROL BATTERY BANK (GND FLOOR)	15
HYTS	250V X CONTROL BATTERY (CONTROL BLDG)	15
HYTS	250V X CONTROL BATTERY	17
KTS	50V CONTROL BATTERY (220KV CONTROL BLDG)	15
KTS	50V CONTROL BATTERY (500KV RLY HSE)	15
MLTS	250V Y CONTROL BATTERY	15
MLTS	48V COMMS A BATTERY	15
MWTS	50V CONTROL BATTERY (STH)	18
MWTS	250V CONTROL BATTERY (STH)	18
MWTS	48V COMMS A BATTERY (STH)	18
MWTS	48V COMMS B BATTERY (STH)	18
NPSD	48V COMMS A BATTERY	15
NPSD	48V COMMS B BATTERY	15
NPSD	50V CONTROL BATTERY	15
ROTS	250V X CONTROL BATTERY (220KV SW/YD)	15
ROTS	50V CONTROL BATTERY	15
RTF	110V X CONTROL BATTERY	15
RTF	110V Y CONTROL BATTERY	15
RTS	48V COMMS A BATTERY	25
RTS	50V CONTROL BATTERY	25
RTS	250V X CONTROL BATTERY	15
RTS	48V COMMS A BATTERY	25
SMTS	250V Y CONTROL BATTERY (500KV RLY HSE)	15
SMTS	250V X CONTROL BATTERY (500KV RLY HSE)	15
SMTS	125V Y CONTROL BATTERY (SERIES CAP BLDG)	17
SMTS	125V X CONTROL BATTERY (SERIES CAP BLDG)	17
SMTS	48V COMMS B BATTERY (500KV RLY HSE)	15
SMTS	48V COMMS A BATTERY (500KV RLY HSE)	15
SMTS	24V DIESEL SPRAY PUMP BATTERY	23
SYTS	48V COMMS A BATTERY (CONTROL BLDG)	15
SYTS	48V COMMS B BATTERY (CONTROL BLDG)	15
SYTS	250V X CONTROL BATTERY	15
SYTS	250V Y CONTROL BATTERY	15
SYTS	50V CONTROL BATTERY	15
TSTS	250V X CONTROL BATTERY	16
TSTS	48V COMMS A BATTERY	16

Terminal Station	Battery Description	Battery Years in Service
TSTS	50V CONTROL BATTERY	16
TSTS	250V Y CONTROL BATTERY	15
TSTS	48V COMMS B BATTERY	16
TTS	48V COMMS A BATTERY (M/W BLDG)	17
TTS	48V COMMS B BATTERY (M/W BLDG)	17
TTS	12V OSCILLOGRAPH BATTERY	21
TTS	24V DIESEL GENERATOR BATTERY	22
WMTS	250V X CONTROL BATTERY	24
WMTS	48V COMMS B BATTERY	24
WMTS	48V COMMS A BATTERY	24
WOTS	50V CONTROL BATTERY	17
WOTS	48V COMMS A BATTERY	18
WOTS	48V COMMS B BATTERY	18
WOTS	250V X CONTROL BATTERY	19
WOTS	250V Y CONTROL BATTERY	19
WOTS	24V STANDBY DIESEL BATTERY	17
YPS	250V Y CONTROL BATTERY (CDE C BLDG)	15
YPS	250V X CONTROL BATTERY (CDE C BLDG)	17
YPS	48V COMMS A BATTERY (RLY HSE A)	16
YPS	48V COMMS B BATTERY (RLY HSE A)	16
YPS	50V CONTROL BATTERY (RLY HSE C)	16
YPS	48V COMMS A BATTERY (RLY HSE C)	16
YPS	48V COMMS B BATTERY (RLY HSE C)	17
YPS	50V CONTROL BATTERY (CDE C BLDG)	19
YPS	12V FILAMENT BATTERY A (RLY HSE C)	19
YPS	12V FILAMENT BATTERY B (RLY HSE C)	19

Table 4 – Batteries in C5

8.1.2 Battery chargers

The following table shows battery chargers in condition 4:

Terminal Station	Charger Description	Charger Years in Service
BATS	250V Y CONTROL BATTERY CHARGER AT ERTS	12
EPS-Y	48V COMMS A BATTERY CHARGER AT EPSY	11
EPS-Y	48V COMMS B BATTERY CHARGER AT EPSY	11
EPS-Y	250V Y CONTROL BATTERY CHARGER AT EPSY	11
EPS-Y	250V X CONTROL BATTERY CHARGER AT EPSY	11
EPS-Y	48V COMMS A BATTERY CHARGER AT FVTS	11
EPS-Y	48V COMMS B BATTERY CHARGER AT FVTS	11
EPS-Y	50V CONTROL BATTERY CHARGER AT FBTS	11
ERTS	250V X CONTROL BATTERY CHARGER AT ERTS	12
ERTS	50V STANDBY BATTERY CHARGER AT ERTS	12
FBTS	250V X CONTROL BATTERY CHARGER AT DDTS	12
GNTS	250V X CONTROL BATTERY CHARGER AT GNTS	12
HWTS	50V CONTROL BATTERY (BAY 6 RLY HSE) AT HWTS	11
JLTS	48V COMMS A BATTERY CHARGER AT JLTS	12
JLTS	48V COMMS B BATTERY CHARGER AT JLTS	12
JLTS	50V CONTROL BATTERY CHARGER AT JLTS	12
KGTS	250V X CONTROL BATTERY CHARGER AT KGTS	12
KGTS	250V Y CONTROL BATTERY CHARGER AT KGTS	12
KGTS	48V COMMS A BATTERY CHARGER AT KGTS	12
KGTS	48V COMMS B BATTERY CHARGER AT KGTS	12
MBTS	250V X CONTROL BATTERY CHARGER AT MBTS	11
MBTS	250V Y CONTROL BATTERY CHARGER AT MBTS	11
MBTS	48V COMMS A BATTERY CHARGER AT MBTS	11
MBTS	48V COMMS B BATTERY CHARGER AT MBTS	11
MWTS	250V X CONTROL CHARGER (NTH) AT MWTS	12
MWTS	250V Y CONTROL CHARGER (NTH) AT MWTS	12
MWTS	250V X CONTROL CHARGER (NTH) AT MWTS	12
NPSD	250V X CONTROL BATTERY CHARGER AT NPSD	11
NPSD	250V Y CONTROL BATTERY CHARGER AT NPSD	11
RTS	50V CONTROL BATTERY CHARGER AT RTS	11

Table 5 – Battery chargers in C4

The following table shows battery chargers in condition 5:

Terminal Station	Charger Description	Charger Years in Service
BETS	48V COMMS A BATTERY CHARGER AT HYTS	26
BETS	48V COMMS B BATTERY CHARGER AT HYTS	26
BETS	50V CONTROL BATTERY CHARGER AT HYTS	26
BLTS	50V CONTROL BATTERY CHARGER AT BLTS	33
BLTS	50V STANDBY BATTERY CHARGER AT BLTS	33
BLTS	48V COMMS A BATTERY CHARGER AT BLTS	36
BLTS	48V COMMS B BATTERY CHARGER AT BLTS	58
CBTS	250V X CONTROL BATTERY CHARGER AT HYTS	26
CBTS	250V Y CONTROL BATTERY CHARGER AT HYTS	26
DDTS	48V COMMS A BATTERY AT ERTS	19
DDTS	48V COMMS B BATTERY AT ERTS	19
DDTS	50V CONTROL BATTERY CHARGER AT DDTS	38
DDTS	48V COMMS A BATTERY CHARGER AT DDTS	38
DDTS	250V CONTROL BATTERY CHARGER AT DDTS	38
DDTS	48V COMMS B BATTERY CHARGER AT DDTS	54
DDTS	48V STANDBY BATTERY CHARGER AT DDTS	54
DDTS	50V STANDBY BATTERY CHARGER AT DDTS	54
DDTS	250V STANDBY BATTERY CHARGER AT DDTS	54
EPS-Y	50V CARRIER BATTERY (BAY 5 RLY HSE) AT HWTS	18
EPS-Y	50V CARRIER BATTERY CHARGER (BAY 5 RLY HSE) AT HWTS	46
FBTS	250V X CONTROL BATTERY CHARGER AT FBTS	44
FBTS	50V STANDBY BATTERY CHARGER AT FBTS	44
FBTS	250V STANDBY BATTERY CHARGER AT FBTS	44
FTS	50V CONTROL BATTERY CHARGER AT FTS	47
FTS	250V CONTROL BATTERY CHARGER AT FTS	47
GNTS	12V COMMS BATTERY CHARGER NO.1 AT GNTS	49
GTS	250V CONTROL BATTERY CHARGER AT JLTS	35
HTS	250V CONTROL BATTERY	49
HTS	12V FAULT RECORDER BATTERY CHARGER AT HWPS	47
HWPS	250V STATION NO.2 CHARGER AT HWPS	47
HWTS	50V CONTROL BATTERY CHARGER (BAY 6 RLY HSE) AT HWTS	42
HWTS	50V CONTROL BATTERY CHARGER (BAY 9 RLY HSE) AT HWTS	42
HWTS	48V COMMS B BATTERY CHARGER (NEXT TO M/WAVE MAST) AT HWTS	42
HWTS	50V CARRIER BATTERY CHARGER (BAY 9 RLY HSE) AT HWTS	46
HWTS	50V CONTROL BATTERY (CONTROL BLDG) AT HWTS	19
HWTS	48V COMMS A BATTERY CHARGER AT BATS	45
HWTS	48V COMMS B BATTERY CHARGER AT BATS	45
HWTS	48V COMMS B BATTERY CHARGER (SOUTH RLY HSE) AT HWTS	42
HWTS	50V CARRIER BATTERY CHARGER (BAY 6 RLY HSE) AT	46

Terminal Station	Charger Description	Charger Years in Service
	HWTS	
HYTS	50V CONTROL BATTERY CHARGER	49
HYTS	48V COMMS A BATTERY CHARGER	36
HYTS	48V COMMS B BATTERY CHARGER	36
HYTS	NO.1 50V CONTROL BATTERY CHARGER (CONTROL BLDG) AT HWTS	42
HYTS	50V STANDBY BATTERY CHARGER AT HYTS	26
HYTS	48V COMMS A BATTERY CHARGER AT GNTS	34
HYTS	48V COMMS A BATTERY CHARGER AT HWPS	37
HYTS	NO.1 TELEMETERING INVERTER LV NO.5 AT HWTS	42
HYTS	NO.2 50V CONTROL BATTERY CHARGER (CONTROL BLDG) AT HWTS	42
HYTS	6V COMMS A BATTERY AT HWTS	18
HYTS	50V DC TELEPHONE CHARGER (CONTROL BLDG) AT HWTS	42
HYTS	50V CONTROL BATTERY CHARGER (SOUTH RLY HSE) AT HWTS	42
HYTS	48V COMMS A BATTERY CHARGER AT FBTS	43
HYTS	48V COMMS B BATTERY CHARGER AT FBTS	43
HYTS	48V COMMS B BATTERY CHARGER AT HWPS	47
HYTS	250V X CONTROL BATTERY BANK CHARGER (2ND FLOOR) AT HWPS	47
HYTS	250V STATION NO.1 CHARGER AT HWPS	47
HYTS	250V Y CONTROL BATTERY BANK CHARGER (GND FLOOR) AT HWPS	47
HYTS	48V COMMS B BATTERY CHARGER AT GNTS	49
KGTS	50V CONTROL BATTERY CHARGER AT BETS	55
KTS	250V X CONTROL BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	16
KTS	250V Y CONTROL BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	16
KTS	50V CONTROL BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	21
KTS	48V COMMS A BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	36
KTS	48V COMMS B BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	36
KTS	50V STANDBY BATTERY CHARGER (220KV CONTROL BLDG) AT KTS	51
LYPS	48V COMMS A BATTERY CHARGER (LYPS A) AT LYPS	35
LYPS	48V COMMS B BATTERY CHARGER (LYPS A) AT LYPS	35
MLTS	250V X CONTROL BATTERY CHARGER AT MLTS	33
MLTS	50V CONTROL BATTERY CHARGER AT MLTS	33
MLTS	48V COMMS B BATTERY CHARGER AT MLTS	33
MLTS	250V Y CONTROL BATTERY CHARGER AT MLTS	33
MLTS	48V COMMS A BATTERY CHARGER AT MLTS	33
MWTS	48V COMMS BATTERY CHARGER (NTH) AT MWTS	34
MWTS	50V CONTROL CHARGER (STH) AT MWTS	34

Terminal Station	Charger Description	Charger Years in Service
MWTS	250V CONTROL CHARGER (STH) AT MWTS	67
MWTS	48V COMMS A CHARGER (STH) AT MWTS	67
MWTS	48V COMMS B CHARGER (STH) AT MWTS	67
NPSD	48V COMMS A BATTERY CHARGER AT NPSD	26
NPSD	48V COMMS B BATTERY CHARGER AT NPSD	36
NPSD	50V CONTROL BATTERY CHARGER AT NPSD	37
RCTS	48V COMMS B BATTERY CHARGER AT RCTS	17
RCTS	48V COMMS A BATTERY CHARGER AT RCTS	17
ROTS	48V COMMS A BATTERY CHARGER AT ROTS	25
ROTS	48V COMMS B BATTERY CHARGER AT ROTS	25
ROTS	50V CONTROL BATTERY CHARGER AT ROTS	50
RTF	110V X CONTROL BATTERY CHARGER	15
RTF	110V Y CONTROL BATTERY CHARGER	15
RTS	250V X CONTROL BATTERY CHARGER AT RTS	15
RTS	250V Y CONTROL BATTERY CHARGER AT RTS	25
RWTS	250V CONTROL BATTERY CHARGER AT RWTS	21
RWTS	50V CONTROL BATTERY CHARGER AT RWTS	34
RWTS	48V COMMS A BATTERY CHARGER AT RWTS	36
SHTS	48V COMMS A BATTERY CHARGER AT SHTS	34
SHTS	48V COMMS B BATTERY CHARGER AT SHTS	34
SMTS	125V Y CONTROL BATTERY CHARGER (SERIES CAP BLDG) AT SMTS	17
SMTS	125V X CONTROL BATTERY CHARGER (SERIES CAP BLDG) AT SMTS	17
SMTS	48V COMMS B BATTERY CHARGER (500KV RLY HSE) AT SMTS	35
SMTS	48V COMMS A BATTERY CHARGER (500KV RLY HSE) AT SMTS	35
SMTS	48V COMMS A BATTERY CHARGER (CONTROL BLDG) AT SMTS	37
SMTS	48V COMMS B BATTERY CHARGER (CONTROL BLDG) AT SMTS	37
SMTS	250V X CONTROL BATTERY CHARGER (CONTROL BLDG) AT SMTS	47
SMTS	250V Y CONTROL BATTERY CHARGER (CONTROL BLDG) AT SMTS	47
SMTS	24V DIESEL SPRAY PUMP BATTERY CHARGER AT SMTS	47
SYTS	48V COMMS A BATTERY CHARGER (M/W BLDG) AT SYTS	33
SYTS	48V COMMS B BATTERY CHARGER (M/W BLDG) AT SYTS	33
SYTS	48V COMMS A BATTERY CHARGER (CONTROL BLDG) AT SYTS	33
SYTS	48V COMMS B BATTERY CHARGER (CONTROL BLDG) AT SYTS	33
SYTS	250V X CONTROL BATTERY CHARGER AT SYTS	33
SYTS	250V Y CONTROL BATTERY CHARGER AT SYTS	33
SYTS	50V CONTROL BATTERY CHARGER AT SYTS	33
SYTS	50V STANDBY BATTERY CHARGER AT SYTS	33
TSTS	250V X CONTROL BATTERY CHARGER AT TSTS	16

Terminal Station	Charger Description	Charger Years in Service
TSTS	48V COMMS A BATTERY CHARGER AT TSTS	36
TSTS	50V CONTROL BATTERY CHARGER AT TSTS	42
TSTS	250V Y CONTROL BATTERY CHARGER AT TSTS	50
TSTS	48V COMMS B BATTERY CHARGER AT TSTS	50
TTS	48V COMMS A BATTERY CHARGER (M/W BLDG) AT TTS	50
TTS	48V COMMS B BATTERY CHARGER (M/W BLDG) AT TTS	50
TTS	12V OSCILLOGRAPH BATTERY CHARGER AT TTS	50
TTS	24V DIESEL GENERATOR BATTERY CHARGER AT TTS	50
WMTS	250V CONTROL BATTERY CHARGER AT WMTS	24
WMTS	50V CONTROL BATTERY CHARGER AT WMTS	35
WMTS	48V COMMS A BATTERY CHARGER AT WMTS	43
WMTS	250V STANDBY BATTERY CHARGER AT WMTS	51
WMTS	48V COMMS B BATTERY CHARGER AT WMTS	58
WOTS	50V CONTROL BATTERY CHARGER AT WOTS	17
WOTS	48V COMMS A BATTERY CHARGER AT WOTS	18
WOTS	48V COMMS B BATTERY CHARGER AT WOTS	18
WOTS	250V X CONTROL BATTERY CHARGER AT WOTS	19
WOTS	250V Y CONTROL BATTERY CHARGER AT WOTS	19
WOTS	24V STANDBY DIESEL BATTERY CHARGER AT WOTS	28
YPS	250V Y CONTROL BATTERY CHARGER (CDE C BLDG) AT YPS	15
YPS	250V X CONTROL BATTERY CHARGER (CDE C BLDG) AT YPS	17
YPS	48V COMMS A BATTERY CHARGER (RLY HSE A) AT YPS	45
YPS	48V COMMS B BATTERY CHARGER (RLY HSE A) AT YPS	45
YPS	50V CONTROL BATTERY CHARGER (RLY HSE C) AT YPS	45
YPS	48V COMMS A BATTERY CHARGER (RLY HSE C) AT YPS	45
YPS	48V COMMS B BATTERY CHARGER (RLY HSE C) AT YPS	45
YPS	50V CONTROL BATTERY CHARGER (CDE C BLDG) AT YPS	45

Table 6 – Battery chargers in C5