Substation DC Systems

Design Standard

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Version	Date	EDM Version	Summary of change
0	01/04/2019	1	First Issue
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1 Introduction

A DC System refers to the equipment used to create, maintain and supply DC to substation equipment. In the event of an AC power failure, the DC system will provide emergency power via the batteries for a nominated period of time.

This Engineering Design Instruction outlines the requirements of a substation DC system and guides engineers on how to design them in accordance with Western Power and Australian Standard requirements.

1.1 Purpose and scope

The objective of this Engineering Design Instruction is to ensure that Western Power and contractors working for Western Power produce safe, functional and economic designs which meet the requirements of Western Power and Australian Standards.

This Engineering Design Instruction covers all aspects of a substation DC system, including battery banks, battery chargers and paralleling boards. It discusses the requirements for both zone and terminal yards for greenfield and brownfield sites.

The battery system for the communications system is not discussed in this Engineering Design Instruction.

1.2 Acronyms

Acronym	Definition

1.3 Definitions

Term	Definition
Ampere Hour	Ampere hours (Ah) is the measurement used to indicate the battery's capacity. Therefore the capacity of a battery is derived by multiplying a certain current in amps (A) with the time in hours (h) for which the battery can supply that current.
Capacity	Capacity (C) is the amount of electricity in Ampere hours (Ah) that can be drawn from a cell or battery, for a given discharge rate, at a specified electrolyte temperature and specific gravity. Since capacity varies with the rate of discharge, a numeric suffix is used to denote the rate of discharge for which the capacity applies e.g. C5 is the capacity in Ah at the 5-hour rate of discharge. C5 is normally used for NiCad and C10 for Lead Acid.
Cell size	The rated capacity of a cell or the number of positive plates in a cell.

DC System	In the context of this standard, a DC System refers to the equipment used to create, maintain and supply DC to vital substation equipment. In the event of an AC power failure, the DC system will provide emergency power via the batteries for a nominated period of time.
Discharge Rate	The discharge rate is the rate at which electrical current is taken from the cell or battery.
Duty Cycle	The load (in Amperes or Watts) that a battery is expected to supply for a specified time period(s) over the duration of the batteries life.
Float Charge	A float charge is the charging process, performed in order to maintain the batteries at full charge.
Float Voltage	The float voltage is a charge voltage, set slightly higher than the cells nominal voltage in order to offset the internal losses whilst performing a float charge.
Minimum Cell Voltage	The voltage at which the useful discharge of the battery is considered depleted. This voltage level can vary for different battery types.
Sealed battery	Sealed batteries are batteries that are sealed at the top. These batteries do not leak when tipped over or release gas while charging under normal conditions. A common type of sealed battery is the sealed Lead Acid battery, also known as Valve Regulated Lead Acid (VRLA) battery (see below for definition).
Temperature Compensation	Temperature compensation is a feature of battery chargers where the surrounding air temperatures are measured constantly and the float voltage is varied accordingly, compensating for the variations in temperature. This feature is applicable to vented and sealed variants of both Lead Acid and Nickel Cadmium batteries. Typical values for temperature compensation are: NiCad above 20°C - 0 mV/°C/cell NiCad below 20°C - 2.5 mV/°C/cell Vented Lead Acid - 4.0 mV/°C/cell Sealed Lead Acid - 4.0 mV/°C/cell Generally Valve Regulated Lead Acid and NiCad cells use ambient or battery container temperatures readings, whereas Vented Lead Acid cells take temperature measurements from either above or at the electrolyte level.
Valve-regulated lead-acid (VRLA)	A lead-acid cell that is sealed with the exception of a valve that opens to the atmosphere when the internal pressure in the cell exceeds atmospheric pressure by a preselected amount. VRLA cells provide a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.
Vented battery	A battery in which the products of electrolysis and evaporation are allowed to escape to the atmosphere as they are generated. These batteries are also commonly referred to as “flooded”.

1.4 References

References which support implementation of this document

Table 1.1 References

Reference No.	Title

2 Supporting Documentation[1]

3 Compliance[2]

The Engineering Design Instruction must comply with higher level Western Power technical documents such as relevant Network Standards and Functional Specifications. The relevant Network Standards and other relevant documentation are listed in Table 3.1.

Document Title
Network Standard – Substation Auxiliary Supply and Electrical Services.
Engineering Design Instruction – Substation Secondary Systems Design
Engineering Design Instruction - Substation Building Design
Automation Design Guideline -Design
Engineering Design Instruction – Substation Labelling and Numbering
Substation Design Drawing Register – External Version

Table 3.1: Relevant documentation

There are also several applicable Australian Standards. These relevant Australian Standards are listed below in Table 3.2.

[1] See Western Power Internal Document
[2] See Western Power Internal Document

Standard Number	Standard Title
AS3011.1	Electrical installation – Secondary batteries installed in buildings Part 1: Vented cells
AS3011.2	Electrical installation – Secondary batteries installed in buildings Part 2: Sealed cells
AS/NZS3000	Electrical installations : Wiring Rules
AS/NZS3008.1.1	Electrical installations – Selection of cables Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV – Typical Australian installation conditions
AS4044	Battery Chargers for stationary batteries
AS2067	Substations and high voltage installations exceeding 1kV a.c.
AS2676.1	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings – Vented cells
AS2676.2	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings – Sealed cells
IEEE1115	IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications
IEEE485	IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications
IEEE946	IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Systems

Table 3.2: Australian Standards

4 Safety in Design[3]

5 Overview of the Main Design Elements

The design process consists of the following considerations.

1. The type of battery to suit the application must be determined. Refer to Section 8.
2. The designer must assess the DC loading of the substation and calculate the required size of battery banks. Refer to Section 9.
3. Battery accommodation must be designed to suit requirements for ventilation, air-conditioning and eye-wash etc. Refer to Section 10 .

[3] See Western Power Internal Document

4. The designer will also decide on a suitable battery charger that will support the steady DC load of the substation and be able to recharge the battery within the required time. Refer to Section 11.
5. A paralleling board must also be designed to connect the loads to the batteries and battery chargers. Refer to Section 12.
6. Appropriate fuse and cable sizes must be chosen for the design. Refer to Section 13.

6 Functional Requirements

The DC system in a substation comprises of the following components:

- Battery banks
- Battery chargers
- DC paralleling board
- Battery Fuse – Disconnector

Two battery banks and chargers are required– one for each protection system.

The DC system is required to supply power to critical equipment when there is a loss of AC supply or a fault in the battery charger. The protection system, SCADA system and the circuit breaker switching in substations rely on the batteries to continue to operate in this scenario.

New DC systems are designed with 110V DC to supply these loads. Previously, the SCADA system required a separate 50V supply but current design now use the same 110V supply as the protection system.

There are also sites with 32V and 230V DC systems which are a legacy of earlier standards.

It is important to confirm the voltage requirements with the SCADA design team prior to commencing a DC system design.

The communications system is supplied from a separate battery system that meets their specific requirements. This will not be discussed in this Engineering Design Instruction.

The functional requirements for DC Systems shall conform to relevant Australian, IEC and IEEE standards and Western Power's requirements as outlined in this document.

6.1 Required battery standalone duration[4]

The DC system shall be designed to supply DC loads for a period of 8 hours for zone substations and 24 hours for terminal substations[5]. This standby time is considered for the loss of AC supply only and does not take into account additional failures, i.e. n-2 contingencies.

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4 See Western Power Internal Document

5 Network Standard – Substation Auxiliary Supply & Electrical Services provides the standby time requirement. This Network Standard is for internal use only.

During normal operation, the batteries are also required to supply the high transient loads, such as circuit breaker switching so that chargers do not need to be sized as large.

7 Battery Types

Western Power installs the following battery types in substations:

Sealed batteries:

- Valve Regulated Lead Acid (VRLA)

Vented batteries:

- Vented Nickel Cadmium (NiCad)
- Vented Lead Acid (VLA)

VRLA is the standard battery type used for greenfield applications.

For brownfield applications, factors such as existing battery types, space, ventilation and air-conditioning must be considered when selecting a suitable battery type.

The following section outlines the characteristics of the available battery types so the system best suited to the requirements can be selected.

7.1 VRLA Characteristics

7.1.1 Temperature withstand

Battery capacity decreases as temperature drops below 25°C. A derating factor should be considered if the battery will be in a cold environment to ensure sufficient capacity is available.

Battery life decreases as temperature rises above 25°C. A 10°C average temperature rise decreases battery life by 50%.

This type of battery is more sensitive to temperature than vented lead acid batteries due to the sealed nature of the design giving it poorer heat dissipation capability.

VRLA batteries should be installed in an environment with temperature controlled to 22°C. If this is not possible, Substation Design and Asset Performance should be consulted, with temperature derating and temperature compensated charging considered.

7.1.2 Hydrogen gas

VRLA batteries use an oxygen-recombination cycle that suppresses hydrogen gas evolution. Although VRLA batteries emit a very small fraction of hydrogen compared to vented batteries, the design must account for possible hydrogen gas emission. Ventilation requirements shall be determined as per AS2676.2 and the Building EDI.

7.1.3 Space requirement

VRLA batteries are usually more compact in size for the same energy density. They can also be installed in different orientations as the electrolyte is immobilised. Therefore, it takes up a smaller footprint compared to vented batteries.

As the electrolyte is sealed, these batteries can be installed in the relay room where a separate battery room is not available. This is typically the case for greenfield and brownfield sites. Adequate ventilation shall then be installed in the relay room.

7.2 Vented Lead Acid Characteristics

7.2.1 Temperature withstand

Vented lead acid batteries can dissipate heat more effectively and is less sensitive to high temperature than VRLA. When compared to NiCad batteries, it is more sensitive to high temperatures.

Vented lead acid batteries do not need to be installed in a temperature controlled environment. However, temperature derating should be considered in the design. Refer to Section 9.5.1.

7.2.2 Hydrogen gas

All vented batteries produce hydrogen gas during charging. Vented batteries require appropriate ventilation to prevent build-up of hydrogen gas.

Ventilation requirements shall be determined as per AS2676.1.

7.2.3 Space requirement

Vented batteries require a larger footprint as the cells must be arranged in open racks to allow access to the cells to refill the electrolyte.

Dedicated battery rooms are required due to risk of exposure to electrolyte and explosive gas.

7.3 Vented Nickel Cadmium Characteristics

7.3.1 Temperature withstand

Battery capacity decreases as temperature drops below 25°C. A derating factor should be considered if the battery will be in a cold environment to ensure sufficient capacity is available.

Nickel Cadmium batteries do not need to be installed in a temperature controlled environment as the reduction in battery life with increased temperature is much lower for Nickel Cadmium batteries than Lead Acid batteries (A 9°C average temperature rise decreases battery life by 20%).

7.3.2 Hydrogen gas

All vented batteries produce hydrogen gas during charging. Vented batteries require appropriate ventilation to prevent build-up of hydrogen gas.

Ventilation requirements shall be determined as per AS2676.1.

7.3.3 Space requirement

Vented batteries require more space as the cells must be arranged in open racks to allow access to the cells to refill the electrolyte.

Dedicated battery rooms are required due to risk of exposure to electrolyte and explosive gas.

8 Battery Type Selection

8.1 Greenfield Applications

Valve Regulated Lead Acid (VRLA) batteries shall be installed in all green-field applications.

Greenfield sites require only 110V DC supply for the protection and SCADA system. Previously, the SCADA system required a separate 50V supply but current design now use the same 110V supply as the protection system.

Refer to Section 7.1 for the required operating environment.

8.2 Brownfield Applications[6]

In brownfield applications, each site has to be assessed on a case-by-case basis, taking into consideration factors such as existing battery types, space, ventilation and air-conditioning requirements. In addition to this, the scope of the replacement work must also be considered.

Generally for battery replacements, if the charger is not being replaced, the new battery will be of the same type as the existing battery.

Another consideration is whether battery 1 and battery 2 can be paralleled together. Both batteries must be of the same type (i.e. both lead acid or both NiCad) in order to parallel them with the same charger[7]. Batteries may be paralleled when one charger fails and the battery connected to that charger no longer has sufficient capacity to supply its load for the required time. Paralleling the batteries allows that battery to continue to be charged from the healthy charger and maintain supply to its DC loads for an extended period of time.

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6 See Western Power Internal Document

7 When paralleling batteries, the float voltage must be within the manufacturer's recommended range for both battery 1 and battery 2. Using batteries of the same type on battery 1 and battery 2 allows this to occur.

In order to allow the batteries to be paralleled, if the battery type of one system is to change, the second battery system will have to be changed to the same battery type at the same time or within a reasonable period of time.

The selection of battery type is done in consultation with Substation Design, Operational Asset Performance and Operational Maintenance.

VRLA batteries may also be used as a replacement if there is an issue with space as these batteries have a smaller footprint and do not require a dedicated battery room.

For vented batteries, only one type of battery (Nickel Cadmium or Lead Acid) shall be installed in the same room to avoid cross contamination of electrolyte.

8.2.1 Existing Vented Nickel Cadmium

Vented Nickel Cadmium was previously Western Power's standard battery for zone substations. Therefore, there are a large number of existing sites with Vented Nickel Cadmium batteries. These batteries should be installed in a separate battery room with ventilation.

When the battery is replaced together with the charger, it may be replaced with a VRLA battery if the requirements in Section 7.1 can be met, the capacity of the remaining battery system is adequate and paralleling the batteries is not required (as discussed in Section 8.2). The installation of air-conditioners at brown field sites is to be done in consultation with Substation Design and Operational Asset Performance.

When only the batteries are replaced, they are typically replaced with Vented Nickel Cadmium batteries. If the existing battery operating requirements outlined in Section 7.3 will not be met, battery accommodation and/or battery type may need to be altered.

For example, existing Vented Nickel Cadmium batteries may be installed in a relay room without appropriate ventilation. A dedicated battery room with ventilation would be required for this type of battery. Instead of building a dedicated battery room, VRLA batteries and chargers could be installed in the relay room with ventilation fitted.

8.2.2 Existing Valve Regulated Lead Acid (VRLA)

If existing VRLA batteries require replacement, they should be replaced with VRLA batteries. These batteries should be in a temperature controlled environment with adequate ventilation. The installation of air-conditioners at brown field sites is to be done in consultation with Substation Design and Operational Asset Performance.

The batteries can be installed in the relay room where a separate battery room is not available. Adequate ventilation shall be installed in the relay room.

8.2.3 Existing Vented Lead Acid

A relatively small number of substations have Vented Lead Acid batteries. This was the standard battery type for Terminal Substations. These batteries should be installed in a separate battery room with ventilation.

When the battery is replaced together with the charger, it may be replaced with a VRLA battery if the requirements in Section 7.1 can be met, the capacity of the remaining battery system is adequate and paralleling the batteries is not required (as discussed in Section 8.2).

The installation of air-conditioners at brown field sites is to be done in consultation with Substation Design and Operational Asset Performance.

When only the batteries are replaced, they may only be replaced with Vented Lead Acid batteries.

8.2.4 Existing 50V batteries and chargers

The replacement of 50V batteries and chargers is to be done in consultation with Substation Design, Operational Asset Performance and Operational Maintenance as any plans to upgrade the existing SCADA equipment need to be taken into consideration.

9 Battery Sizing

Factors such as minimum and maximum system voltage, number of battery cells, minimum cell voltage and duty cycle determine the ampere-hour capacity of the battery. Battery sizing calculations shall be based on IEEE Std 485-2010 for Lead-Acid batteries and IEEE Std 1115:2000 for Nickel-Cadmium batteries.

9.1 Number of Cells

The number of cells in a battery bank is dependent on the maximum DC load voltage and the cell charging voltages.

Refer to A.1 for example calculations.

The standard number of cells used for various system voltage applications are shown in 0.

The number of cells may vary in brownfield sites. Where only the battery is being replaced, the same number of cells shall be retained.

9.2 Minimum Cell Voltage

The minimum cell voltage depends on the minimum DC load voltage required and the number of battery cells. It should be known in order to choose the appropriate battery capacity.

The standard minimum cell voltage used are shown in Table 9.1.

Table 9.1: Standard minimum cell voltage

Battery	Minimum cell voltage
NiCad	1.0
Lead Acid	1.8

9.3 DC Loads[8]

When calculating battery sizes, continuous and momentary loads in a substation are both considered. Continuous loads typically consist of protection relays and SCADA equipment. Momentary loads are of short durations and can have numerous occurrences. In a substation these loads are typically circuit breaker tripping, closing and spring charging.

Under normal operation, the charger supplies the continuous loads and at the same time keeps the battery fully charged and maintains float voltage. In this state, the battery only gives supply to momentary loads.

New DC system installations should be designed to include any expansions planned in the future. Life expectancy of batteries typically range between 10 to 20 years[9] depending on the battery type. The battery charging systems are expected to have a minimum life expectancy of 20 years[10]. Future loads should be considered in the duty cycle by including future switchboards, transformer and line circuits in the load calculations. For terminal substations, the number of future bays to be considered will depend on the expected load growth.

When there is a loss of the AC supply or a fault on the charger, the batteries are required to support anticipated DC loads in the substation for the minimum required duration as per Section 6.1.

[8] See Western Power Internal Document

[9] Transmission and Distribution Electrical Engineering, Colin Bayliss, Brian Hardy

9.4 Duty Cycle

A duty cycle is used to show the anticipated loads the battery must supply for a required time period.

According to AS2067:2016, batteries shall have enough capacity to trip breakers and switches at the beginning of the discharge period and, to supply power to the continuous DC load and to close the elements of the installation that will restore AC services.

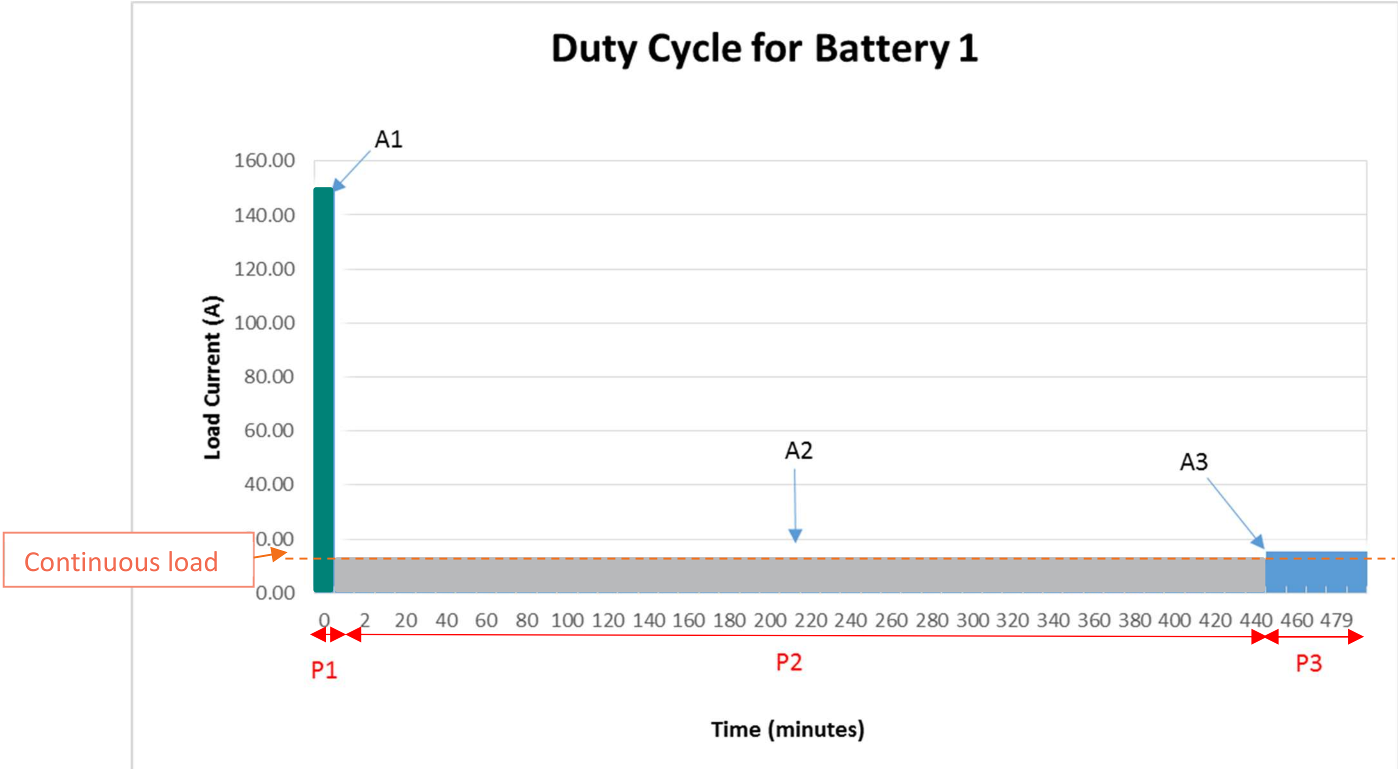

Figure 1 : Typical Duty Cycle

Figure 1 shows the typical duty cycle for batteries in a zone substation. The batteries are required to support the DC loads for 8 hours. A1 is made up of the continuous load which is energised throughout the duty cycle and the momentary load from breakers tripping at the beginning of the discharge period. A2 is only the continuous load. A3 is the load from closing breakers to restore AC services at the end of the discharge period and the continuous load.

Refer to Appendix B for additional notes on establishing duty cycles.

9.5 Sizing Methodology[11]

Once the duty cycle has been established, the battery capacity calculations can be carried out based on IEEE Std 485-2010 and IEEE Std 1115:2000.

[11] See Western Power Internal Document

The closest battery size in Western Power's stock item that meets the calculated capacity should be selected.

9.5.1 Factors to consider

9.5.1.1 Capacity rating factor (Kt or Rb) [12]

9.5.1.2 Temperature derating factor (Tt) [13]

9.5.1.3 Design margin

A design margin of 15%[14] should be used to allow for unexpected operating conditions due to improper maintenance, recent discharge and lower ambient temperatures.

9.5.1.4 Aging factor

An aging factor of 25%[15] should be used.

9.5.1.5 Capacity factor

Capacity factor accounts for new batteries having less than rated capacities when delivered. However, this will increase to rated capacity after being in service for some time.

A capacity factor is not required if an aging factor of 25% is used, as the capacity required is already larger than the duty cycle when delivered.

10 Battery Accommodation

10.1 General

1. Battery room requirements shall be in accordance Engineering Design Instruction - Substation Building Design.
2. For vented batteries, only one type of battery (Nickel Cadmium or Lead Acid) shall be installed in the same room to avoid contamination of electrolyte.
3. Eyewash is required for vented batteries. For VRLA, eyewash shall be installed where there is water and drainage services connected to the building. This allows for the use of

[12] See Western Power Internal Document

[13] See Western Power Internal Document

[14] IEEE Std 485-2010 recommends a design margin of 10% to 15%.

[15] IEEE Std 485-2010 recommends that an aging factor of at least 25%. This is based on IEEE Std 1188, AS2676.1-1992 and AS2676.2-1992 which recommend that a battery is replaced when its actual capacity drops to 80% of rated capacity.

other batteries types in contingency situations. Refer to Engineering Design Instruction - Substation Building Design for eye wash installation requirements.

4. Batteries to be installed in racks or cabinets in accordance with manufacturer recommendations for cell separation to allow for air flow and access for removal.
5. Battery terminals and busbars connections shall be shrouded to prevent accidental contact.
6. Batteries shall be located with sufficient separation to enable maintenance or similar activities. Work on one battery system should not affect operation of the other.
7. Location of batteries should be determined in accordance to AS3011 and AS2676.
8. Minimum aisle width shall be 900mm in accordance to AS3011.
9. Battery stands and cell arrangement shall be in accordance with AS2676 and AS3011.
10. Floor loading shall be calculated and designed in accordance to Engineering Design Instruction - Substation Building Design.
11. Safety signs, in accordance with AS2676 and Engineering Design Instruction – Substation Labelling and Numbering, shall be permanently displayed in appropriate prominent positions.

10.2 Ventilation and air-conditioning

1. For greenfield sites with a separate battery room, new VRLA batteries shall be installed in the battery room with air-conditioning and ventilation.
2. Some VRLA batteries can be installed in a battery/charger combined unit. For greenfield customer connection sites where the relay room is installed as an annex, battery/charger combined units can be installed in the relay room with adequate ventilation installed as outlined in AS2676.2.
3. Battery/charger combined units installed in the relay room at brownfield sites require vents to be installed in the relay room as outlined in AS2676.2.
4. Battery/chargers combined units are available as Western Power Stock items.
5. For vented batteries, a separate battery room with appropriate ventilation is required as outlined in AS2676.1.
6. Natural ventilation is the preferred form of ventilation wherever practicable.
7. Ventilation requirements are outlined in Engineering Design Instruction - Substation Building Design, AS2676.1 and AS2676.2. These requirements apply to dedicated battery rooms for vented batteries and VRLA batteries and relay rooms with VRLA batteries.
8. Air-conditioner sizing calculations shall be performed for relay rooms or battery rooms taking into account any fitted ventilation and additional heat load from the batteries. A larger air-conditioner capacity may be required when VRLA batteries and vents are installed in a relay room.
9. Where an existing NiCad battery system is being replaced with a VRLA battery system, an air-conditioner must be installed. In the instance of AC auxiliary supply issues, OAP must be consulted for a decision.

10.3 Ventilation Calculation[16]

Rooms and enclosures housing batteries shall have ventilation provided in accordance with the requirements of AS2676.1 and AS2676.2.

If there is more than one battery in a room or enclosure then the total exhaust ventilation is the sum of the rates of all batteries.

11 Battery Charger

11.1 Input

Chargers can have a 1 phase 240V AC ±10% input or a 3 phase 415V AC ±10% input. The choice is usually dependent on the required charger size. Larger sized chargers are usually available only with 3 phase input.

11.2 Output

Nominal 110V DC voltage output is to be connected to the battery and to the DC paralleling board.

Brownfield sites may have 32V DC and 230V DC voltage outputs.

For existing sites with 50V SCADA supplies, a charger with nominal 50V DC voltage output is also required.

DC current output required to supply the anticipated load shall be calculated as per Section 11.3. A suitable charger can then be selected from the available stock items.

11.3 Battery Charger Sizing

Battery chargers are sized to supply continuous loads in the substation while recharging the battery within a reasonable time. They are not required to supply high transient loads, such as circuit breaker operations, as this would result in a charger that is much larger than necessary.

Battery chargers shall be capable of supplying both protection 1 and protection 2 loads, when the loads are paralleled for maintenance or operational requirements. This is reflected in the continuous DC load value in the calculation.

In accordance with IEEE946 – 2004, the following equation should be used to determine the charger size.

$$I_1 = I_{LC} + (R \times Q) / T \qquad \textbf{Equation 1}$$

where

I_1 is the minimum required rated output of the charger in amperes.

16 See Western Power Internal Document

I_{LC} is the continuous DC load for the substation (includes protection 1 and protection 2 loads) (in amperes), including expected future loads.

R is the efficiency factor of the battery that compensates for losses. (Use 1.15 for lead acid and 1.4 for nickel-cadmium)[17].

Q is ampere hour discharged from the battery. The rated capacity of the battery can be used.

T is the time to recharge the battery to approximately 95% of capacity (in hours). Typically 8 or 12 hours are used. This data can be obtained from battery manufacturers.

11.4 Charger Alarms

Charger alarms are to be sent to the Control Centre. These alarms can warn against conditions that could shorten the life of the batteries, overcharge the batteries and cause damage to battery charging equipment.

Where the SCADA system uses the Ethernet network, the alarms are sent via protocol over an Ethernet connection from the charger to the Local Area Network for forwarding to the Control Centre. The Battery Charger Defective and Earth Fault alarm shall also be combined up at the charger and hardwired to the SCADA I/O system as backup.

Where possible, normally open contacts shall be used for hardwired alarms.

Previously, all charger alarm contacts were hardwired to the SCADA I/O system and then sent over the Local Area Network and then onto the Control Centre.

Older sites without Ethernet capabilities have hardwired alarm contacts to the RTU.

11.5 VRLA Battery monitoring requirements

VRLA batteries are more susceptible to sudden death (an unexpected failure when a load is placed on the battery) than vented lead-acid or vented nickel cadmium batteries. They are also more sensitive to high temperatures, variation in float voltage, overcharges and over-discharges.

Visual inspections provide limited information about the health of the battery. In addition to alarms from the charger, condition monitoring is important for this type of battery.

A battery condition monitoring unit/system is required to monitor the internal rate of degradation and can provide information to predict and warn for battery failure.

Where the infrastructure is available, the battery condition monitoring unit/system will be capable of being remotely accessed. Refer to Automation Design Guideline -Design for information about remote access.

[17] Proper Charger Sizing for Utility/Stationary Battery Chargers By Art Salander; Cyberex

11.6 Accommodation

Each battery charger is housed in a freestanding cabinet, adjacent to each other.

They are installed in the relay room, as close as possible to the associated batteries.

The charger for battery bank 1 shall be positioned on the left side.

11.7 Battery charger requirements

Only technical requirements relevant to the design of the DC system have been included in the document. Technical specification of the battery charger is not covered in this document.

12 DC Paralleling Boards

All charger outputs shall be connected to a paralleling board.

Both 110V and 50V DC paralleling boards shall have two sets of inputs that are capable of being paralleled. An alarm shall be provided when the supplies are paralleled.

Refer to Substation Design Drawing Register – EXTERNAL Version for standard/template paralleling board drawings.

12.1 110V Paralleling Boards

The DC load circuits must be arranged on the DC paralleling board to ensure reliable operation of the protection and SCADA system.

Load circuits on Protection 1 shall be connected to Battery Charger 1 through one input and load circuits on Protection 2 shall be connected to Battery Charger 2 through the second input.

In terminal substations, there is generally a third group of loads for miscellaneous supplies to DC lighting and controls. These loads shall be able to be connected to either Battery Charger 1 or Battery Charger 2 through either inputs.

Load circuits on Protection 1 and Protection 2 may be operated in parallel through a switch on the DC paralleling board. This would be used when one battery or charger fails.

If a battery system fails, the remaining healthy battery system would supply both protection 1 and protection 2 load circuits.

If a charger fails, it would also be possible to parallel the batteries through the load paralleling switch or battery paralleling switch. The healthy charger can supply the load circuits for protection 1 and protection 2 and continue charging the second battery.

Each input shall have links to isolate the DC paralleling board from battery chargers.

Separately fused voltmeters (within the isolation provided by the links) shall be provided across each input.

12.2 50V Paralleling Boards

At sites with 50V supplies to the SCADA system, a 50V paralleling board would be installed. If a 50V battery bank is used, one of the inputs shall be connected to the charger/battery system, with the other reserved for the connection of a temporary charger/battery system should the permanent supply fail.

The permanent input shall contain links for isolating the charger/battery system from the paralleling board. The input for a temporary charger/battery system shall be through MCB instead of links.

50V boards shall contain a separate fused voltmeter across each of the inputs (within the isolation provided by links). The voltmeter across the inputs for a temporary connection is to allow the voltage of the temporary supply to be checked before paralleling.

13 Cables and Fused Disconnector

The type and size of cables for connections from the batteries to the paralleling board must be based on AS2676.1, AS2676.2, AS/NZS3008.1.1 and AS/NZS3000.

- AS 2676.1 and AS2676.2 describes requirements for the installation, maintenance, testing and replacement of vented and sealed cell batteries, respectively.
- AS/NZS 3008.1.1 is concerned with the selection of cables for use in AC systems, though the same general principles can be used for DC circuits with minor variations relating to volt-drop calculations, where the DC resistance is relevant rather than the AC impedance.
- AS/NZS 3000:2018 describes the coordination required between cable ratings and overload protection devices. (Part B3.2)

The criteria considered when selecting suitable cables are:

10. Current carrying capacity.
11. Voltage drop.
12. Short circuit temperature rise.

Refer to Engineering Design Instruction - Substation Secondary Systems Design for general cable selection guidelines.

This document will discuss specific requirements and considerations related to the batteries and chargers.

13.1 Cable from battery to charger

Single core and double insulated cables (with insulation and jacket) shall be installed in conduit between the battery and charger.

13.1.1 Short circuit temperature rise

This cable should be able to withstand the prospective fault current that could be delivered by the battery for 1 second as described in AS2676.1 Part2.7.1. An adiabatic temperature rise method of calculating short circuit current carrying capacity of cables as described in AS/NZS 3008.1.1 Part 5.3 should be carried out to determine the minimum cable size.

13.1.2 Current carrying capacity

AS/NZ3000, Part B3.2 requires that for cables protected by MCBs, the current carrying capacity of the cable between the battery and charger must be greater than or equal to the rating the MCB.

13.1.3 Voltage drop

Voltage drop must be considered when selecting this cable.

13.2 Cable from charger to paralleling board output fuses

13.2.1 Short circuit temperature rise

These cables are protected by MCBs in the charger. The operating time of these MCBs must interrupt the short circuit before the I^2t value of the cable is reached.

13.2.2 Current carrying capacity

AS/NZ3000, Part B3.2 requires that for cables protected by MCBs, the current carrying capacity of the cable must be greater than or equal to the combined rated currents of the MCBs.

13.2.3 Voltage drop

Voltage drop must be considered when selecting this cable.

13.3 Cable within paralleling board between output fuses and output terminal

13.3.1 Short circuit temperature rise

These cables are protected by 32A fuses. In order to protect the cables, the I^2t value of the cable must be greater than I^2t value of the fuse.

13.4 Fuse Disconnector

The fuse disconnector will protect the cable between the battery and the charger. It must also allow load current through without operating. The following conditions must be satisfied:

13. AS/NZ3000, Part B3.2 requires that for cables protected by fuses, the nominal rating of the fuse should not exceed 90% of the continuous current carrying capacity of the cable.
14. The fuse should not operate for the maximum load on the batteries. This is typically the sum of the tripping and continuous loads at the beginning of the battery duty cycle as discussed in Section 9.4.
15. The fuse must discriminate with MCB in the charger.

Appendix A: Approval Record and Document Control

A.1 Number of cells[18]

A.2 Standard number of cells

110V Battery	Number of Cells
Vented NiCad	88
Vented Lead Acid	55
Sealed VRLA (2V/Batt)	54
Sealed VRLA (12V/Batt)	9
32V Battery	Number of Cells
Vented NiCad	26
Vented Lead Acid	16
Sealed VRLA (2V/Batt)	-
Sealed VRLA (12V/Batt)	3
230V Battery	Number of Cells
Vented NiCad	-
Vented Lead Acid	115
Sealed VRLA (2V/Batt)	113
Sealed VRLA (12V/Batt)	-
50V Battery	Number of Cells
Vented NiCad	40
Vented Lead Acid	25
Sealed VRLA (2V/Batt)	24
Sealed VRLA (12V/Batt)	4

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Appendix B: Approval Record and Document Control

B.1 Calculation for A1

The number of breakers to trip should be based on the worst case scenario. It can be assumed that the protection has operated all the circuit breakers on the HV busbar. In practice this would also require the LV circuit breakers to be open before the transformers can be restored. For simplicity, all circuit breakers are assumed to have tripped at the beginning of the discharge period.

A1 is required over a period of 1 minute for Lead Acid batteries as IEEE485:2010 states that although momentary loads may exist for only a fraction of a second, it is common practice to consider each load will last for a full minute because the battery voltage drop after several seconds often determines the battery's 1 minute rating.

For Nickel-Cadmium batteries, IEEE1115:2000 states that if a load lasts for less than 1 second, it is normally considered to last for a full second.

B.2 Calculation for A2

The continuous load should be based on the power consumption of the protection and SCADA equipment installed. Note that the power consumption quoted in the equipment manuals are usually the maximum that will be drawn with all elements (e.g. inputs, outputs and LEDs) energised. This may be significantly larger than the steady state operation of the equipment. Tests can be performed to measure the steady state power consumption for the equipment in the test lab or by the manufacturer.

For brownfield applications, the existing continuous loads can be measured at the substation and added to any new loads that are being installed or planned.

A2 is required for the standby duration as per Section 6.1.

B.3 Calculation for A3

A3 is only calculated for the battery that is connected to circuit breaker controls. The breakers and switches closed to restore AC supply are assumed to occur at the end of the discharge period to cater for the most onerous scenario.

The circuit breakers on the HV bus are restored, where possible. The associated LV circuit breakers to restore AC supply should then be closed. However, in practice other breakers may be closed before those required to restore AC supply. Guidelines for network operators to restore supply following an event need to consider safety, large customers, outage duration, sensitive loads, life support customers, utility services and commercial loads. It is possible that the AC supply will be last to be restored. Therefore, A3 is based on the load from closing all the HV breakers and transformer LV breakers.

As a worst case scenario, A3 is assumed to occur at the end of the duty cycle. These closing loads are considered discreet loads and therefore, the maximum load at any one time will be used. The period of time will depend on the number of circuit breakers to be closed.

Each circuit breaker closing load will be considered to last for 1 second each for Nickel-Cadmium batteries and 1 minute each for lead acid batteries based on IEEE1115:2000 and

IEEE485:2010 respectively. Each circuit breaker closing time is added together and assumed to occur at the end of the duty cycle.

Appendix C: Approval Record and Document Control[19]

[19] See Western Power Internal Document