snowyhydro Snowy Technical Standard		DC and Essential AC Design Philosophy
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1. Introduction

This document provides guidelines and general requirements for the design of the Essential AC (EAC) and DC Power supplies at Snowy Hydro Power Stations. This document is applicable to Hydro, Gas and Diesel Power Stations owned and operated by Snowy Hydro Ltd.

The function of DC and EAC power is to provide a non-failing DC system voltage and highly reliable AC and lower voltage DC power supply for protection, alarms, control, telemetry, indication, emergency lighting, and computer-based networks at Hydro, Gas and Diesel power stations.

2. Purpose

The objective of DC and EAC philosophy (standard) is to provide typical acceptable solutions and maintain consistency in the method of electrical supply to the equipment within power stations. Each situation and item of equipment is however unique, and this standard cannot cover every scenario that could arise now and in the future. The detailed design of each new installation should therefore be subjected to project-specific risk assessment and detailed design to ensure the general recommendations in this standard are appropriate in that particular case to ensure the safety of personnel and equipment.

3. Scope of this document

The intent of this document is to outline a consistent approach to the design and configuration of EAC and DC supplies and loads, which are to be designed in accordance with the Snowy Hydro Limited (SHL) General Electrical Requirements and It applies to the refurbishment of existing installations and to new installations at power stations, control centres, switching stations and pumping stations. It is also intended to apply in general terms to communications and outlying works. Some changes to detail may be required for these locations.

4. Definitions

AC Supply	Alternating Current Supply
AH	Ampere-Hour
Battery Hold-Up Time	Hold-up time is the time for which the battery can supply normal DC and inverter loads following the loss of the battery charging supply. It is time for the battery voltage to fall from the normal float voltage.
Boost Charge	When a battery has been partly Discharged the charge can be replaced relatively quickly by charging at a higher normal current during the first part of the recharging cycle. Some makers of sealed batteries do not recommend boost charging of their products.
CSB	Common Services Board
DAC	Data Acquisition and Control
DCS	Distributed Control System
DC Supply	Direct Current Supply
EAC Supply	Essential Alternating Current Supply
End Voltage	Lowest voltage to which the battery should be discharged. This voltage depends upon the rate of discharge & the battery construction. Discharge below the nominated end voltage will shorten battery life.
Equalising Charge (Freshening Charge)	The charging voltage is raised above the normal float voltage to bring all cells in the battery up to full charge. It is usually terminated when the cells are gassing freely and the specific gravity readings are no longer rising. Some water is consumed. Not possible for sealed cells.
Float Charge	A float-charged battery is charged at a constant voltage which is theoretically just enough to replace internal losses and keep it fully charged. In practice, it may discharge slowly and require extra charging at intervals ranging from monthly to annually.
UPS	Uninterruptible power systems
SHL	Snowy Hydro Limited
SLD	Single Line Diagram
VPC	Volts Per Cell

5. Standards

DC and essential AC installations may need to comply with one or more of the following Australian standards:

AS 1136	Low voltage switchgear and control gear assemblies (switchboards)
AS 1981	Stationary batteries of the lead-acid pasted plate type
AS 2191	Stationary batteries of the lead-acid Plante positive plate type
AS 2508.8.010	Safe storage and handling of information cards for hazardous materials (sulphuric acid)
AS 2598	Stabilised power supplies - DC output
AS 2668	Water for use in secondary batteries
AS 2669	Sulphuric acid for use in lead-acid batteries
AS 2676	Guide for the installation, maintenance testing, and replacement of secondary batteries in buildings part 1 - vented cells and part 2 sealed cells.
AS 2743	Stabilised power supplies - AC output
AS 3000	SAA Wiring Rules
AS 3011	Electrical installations - secondary batteries installed in buildings part 1 vented cells
AS 3100	Approval and test specification - general requirements for electrical equipment
AS 3193	Approval and test specification - transformer-type battery chargers
AS 3009	Emergency power supplies in hospitals - will provide background information
AS IEC 62040	Uninterruptible power systems (UPS)
AS 4044	Battery chargers for stationary batteries
AS 4029	Stationary batteries - Lead-acid
IEEE 1184-2006	Guide for Batteries for Uninterruptible Power Supply Systems
AS 4086.2	Secondary batteries for use with stand-alone power systems - Installation and maintenance

6. Source of Supply

6.1 Hydro Power Stations

The AC Power from the CSB (Item 1 on SLD) is the normal source of supply for DC and EAC Power distribution boards which then feed auxiliary power equipment at the stations. The rectifiers (Item 2 on SLD) fed from the two halves of the CSB provide the supply to charge the Battery Banks, the normal supply for the 250V DC switchboards, and the normal input to the inverters (Item 3 on SLD).

The batteries (Item 4 on SLD) are the backup source for DC and EAC in the event of a normal source of supply failure. They operate at the highest voltage because this minimises the AH capacity required to store any given quantity of energy. The inverters provide supply to the two halves of the 415/240V EAC distribution board (Item 8 on SLD). They are not necessarily designed to operate in parallel. The static transfer switches (Item 7 on SLD) are used when it is necessary to parallel the two halves of the EAC distribution board.

For stations, where EAC supplies other than 50 Hz 415v/240v, 3 phase, and neutral 4 wire, are still required (eg. 110V single phase), these will be derived from the EAC distribution board through a transformer and if necessary a sub-board. Duplicated supplies shall be provided from the two halves of the 415/240V EAC board where required.

Lower DC voltages will be supplied from the 250VDC supply via DC to DC Power supply units (converters) onto the lower DC Distribution boards. All Unit DC PSUs must be rated for parallel operation or shall be provided with appropriate decouplings, such as diodes or active redundancy controllers.

The Surge Arrestors (Item 6 on SLD) provide a surge-free bypass power supply to the EAC distribution board via two static transfer switches (Item 7 on SLD). These transfer switches can operate in parallel. In the event of an inverter failure, the static switch will operate to maintain supply to the AC load through the EAC distribution board. There will be no break if the inverter was previously synchronised with the CSB (normal) and a break of up to 30 milliseconds (estimated maximum) if the inverter was operating on its own internal timing oscillator. Failure of both an inverter and the bypass supply to one-half of the essential distribution board, Initiates the automatic closure of the coupler bus to re-energise the dead busbar from the live busbar with a short break.

6.2 Gas and Diesel Power Stations

The AC Power from the Station Low Voltage Aux Supply Switchboards is the normal source of supply for DC and EAC power distribution boards which then feed auxiliary power equipment at the stations. The rectifiers are fed from the two separate AC supplies to charge the battery banks. The DC Voltage varies from power station to power station (e.g. 220VDC, 125VDC, 110V DC, 48VDC) based on the design.

The batteries are the backup source for DC and EAC in the event of a normal source of supply failure. They operate at the highest voltage because this minimises the AH capacity required to store the given quantity of energy.

Inverters are used to supply 415/240 AC EAC distribution boards. For stations where EAC supplies other than 50 Hz 415v/240v, 3 phase, and neutral 4 wire are still required (eg. 110V single phase),

these will be derived from the EAC distribution board through a transformer and if necessary a sub board. Duplicated supplies shall be provided from the two halves of the 415/240V EAC board where required.
Lower DC Voltages will be supplied from the main station DC supply (220VDC, 125VDC, 110VDC or 48VDC). Generator starter batteries for diesel generators can be supplied from 240VAC/24VDC rectifiers.

7. Hydro Power Station DC and EAC Supply Voltages

7.1 250 V DC nominally unearthed

For circuit breaker control, protection, and supply to inverters. The power source will normally be a rectifier with battery backup. 250V DC batteries will comprise 114/115 cells operating within the range of 1.85 VPC (fully discharged) to 2.35 VPC on boost (210.9 V DC to 267.9 V DC).
There could be higher voltage values up to 2.4 VPC (≈ 300V DC) under the equalising charge.
Earth fault detection circuits are located in each section (A & B) of the DC switchboard and connected to the negative and positive terminals. The relay type currently used is wound with opposing balance coils 20k ohms positive & negative to earth to allow detection of an earth fault on either positive or negative of the DC system. This effectively applies high-resistance earth to the centre point of the system. It remains balanced at the system centre point even if some cells have been cut out of the battery.

7.2 48 V DC Positive Earthed

For alarms, communications, indications and DAC input & DCS input signals. Normally 48V DC will be provided through dual redundant 250/48 VDC power supply units from the 250V DC distribution boards. If a battery is necessary (e.g. outlying works with no higher-voltage DC and no EAC), 24 cells will be provided giving a voltage range from 44.4V (discharged) to 56.4V (equalising charge). It allows 3 cells or 6 cells (nominal 6V or 12V) assemblies to be used when required.

7.3 24 V DC and 12 V DC Voltages

24V DC is used for plant controls and derived from the station DC system (250V DC in general). Where 250V DC is not available in the outlying area 24V DC is derived either from a 48V DC battery system or 240V AC. 24V DC is frequently required as the starting voltage for standby diesel generator sets. Positive or negative earthing will usually be dictated by the generating set. 24V DC is also required for PLC and alarm inputs, where this is required a 250V DC to 24V DC duplicated converters are used. 24V DC used in the control system should be unearthed with earth fault monitoring.

12V DC is used for some communications purposes. Other DC systems of various voltages are used where appropriate. This practice will continue.

7.4 EAC Voltages

415/240V 50Hz 3 phase and neutral EAC will be the preferred voltage levels. 110V 50Hz single phase EAC will be retained and transformed from the 415V EAC where existing equipment requires retention of this voltage level. This voltage is regarded as obsolete. New equipment should preferably suit 240V operation.

8. Gas and Diesel Power Stations DC and EAC Supply Voltages

8.1 220 V DC/ 125 V DC /120 V DC / 110 V DC / 48 V DC

The power source will normally be a rectifier with battery backup. DC/EAC system configuration may vary from power station to power station for Gas/Diesel power stations. Appropriate options and cost analysis should be carried out when DC/EAC system upgrades are being planned.

Station Battery Bank configuration and low voltage DC system configuration may vary from Power Station to Power Station (Refer to site-specific DC/EAC SLDs for more information).

LV and EAC system configurations may also vary from power station to power station. Usually, 415 AC supply from the local utility will be a normal supply (via UPS/Battery Chargers) for the DC/EAC system with backup power available from a standby diesel generator. The diesel generator is connected to the 415V ESDB through a motorised circuit breaker (CB) to allow remote changeover. Battery monitoring systems are installed to provide monitoring of each battery bank.

The two battery chargers and UPS/Inverters operate normally as a parallel-redundant configuration but can be operated in a standalone configuration with one battery charger and UPS/Inverter supplying the full load.

8.2 24 V DC

24V DC is used for plant controls, communications and protection and is derived from the station DC system (220V DC/ 125 VDC / 120VDC/ 110VDC/ 48VDC). In the outlying area, 24V DC is derived either from a 48V DC battery system or 240V AC. 24V DC is frequently required as the starting voltage for production or standby diesel generator sets. Positive or negative earthing will usually be dictated by the generating set. 24V DC is also required for PLC and alarm inputs, where this is required a station DC system voltage to 24V DC duplicated converters are used. 24V DC used in the control system should be unearthed with earth fault monitoring.

8.3 EAC Voltages

415/240V 50Hz 3 phase and neutral EAC will be the preferred voltage levels. 110V 50Hz single phase EAC will be retained and transformed from the 415V EAC where existing equipment requires retention of this voltage level. This voltage is regarded as obsolete. New equipment should preferably suit 240V operation.

9. Redundancy

In general duplicated supplies will be provided to ensure reliability to suit the equipment to which power is supplied and to maintain supplies under most contingencies, ie, single component failures and maintenance operations. The DC and EAC systems in the SHL power stations, control centres, and switching stations provide a black start capability for the power stations which would be used to re-energise the grid following a power system shutdown in the states of Victoria, SA and NSW. This redundancy requirement is applicable for all the voltage levels except for the starting batteries.

10. Batteries

9.1 Limitations

A battery is not a constant voltage source. All circuits and systems using a battery backup supply must be designed to operate satisfactorily over a range of voltages. The voltage in the battery is dictated by the electrochemical reaction taking place within the battery. The voltage available at the consuming device when the battery is not being charged will also depend upon battery internal resistance (which may be significant for large currents), circuit external resistance and current. Each outgoing circuit from a battery-backed DC switchboard should be tested, as part of the commissioning process, to ensure that it will operate correctly at a voltage equal to the minimum battery voltage.

9.2 Battery Hold-Up Time

Hold-Up Time is the time for which the battery can supply normal DC and inverter loads following the loss of the battery charging supply. It is time for the battery voltage to fall from the normal float voltage to an end voltage.

- Note 1: The load should be supplied satisfactorily right through until the end of the holdup time. The load should be designed not to require more than the minimum end voltage
- Note 2: Battery voltage will fall from float voltage (or boost voltage) to the open-circuit voltage almost immediately when the charging current is interrupted and will continue to fall gradually to the end voltage as the battery is discharged.
- Note 3: A battery that has reached its end voltage is still able to supply either a load current or a substantially short circuit current for a brief period. It must be treated as live equipment.

For Hydropower Stations and control centres, the designed hold-up time has been set at 10 hours. (communications in remote areas will require a much longer hold-up time - refer to datasheets for the specific installations). For Gas/Diesel power stations, the designed hold-up time has been set to 4 hours.
This period is expected to be sufficient to allow power to be restored. The actual hold-up time achieved in practice will depend upon:

- The initial state of charge of the battery
- The age of the battery
- The temperature of the battery
- The load

These factors are considered in the selection of the battery design capacity.

9.3 Selection of Capacity of Battery

To determine the capacity of replacement battery banks, both the steady DC load current and the essential AC load current have to be measured - the latter being converted into kW (to account for 110V and 240V requirements).

Battery capacity selection takes into account the following factors

- Ageing of the battery
- Operating temperature
- Potential load growth

- Initial DC load
- Initial inverter input load
- Hold uptime

A. Ageing

The ageing of the battery reduces its active capacity. A battery is considered to be in need of replacement when its amp-hour capacity as determined by a discharge capacity test, has fallen by 20% from its initial capacity.

When replacement is due, the battery must still have adequate capacity. A factor of 1/0.8 (= 1.25) is therefore included when sizing a new battery.
Factor A = 1.25

B. Operating Temperature

The operating temperature in SHL installations is usually below the nominal temperature of 25℃ at which lead-acid batteries are rated and at which they have a maximum capacity.

To determine the revised rating due to temperature, the following formula is used:

C25 = Ct / (1 + k (t - 25))
Where C25 = capacity at 25℃ in amp hours
Ct = capacity at t℃
k = 0.012 for 10-hour discharge rate
t = Temperature of electrolyte

For conditions in the Snowy Mountains an operating temperature of 1 is a reasonable assumption. This leads to a temperature derating factor of 1.1.
Factor B = 1.1.

C. Potential Load Growth

A load growth allowance of 40% giving a load growth factor of 1.4 has been nominated as an appropriate factor for main power, pumping and switching stations and control centres. This factor needs to be applied with caution e.g. the starting battery for a particular standby diesel generator is unlikely to experience load growth.
Factor C = 1.4.

D. Initial DC Load

Initial DC load is peculiar to each installation. The initial inverter input load is also unique to each installation. However, inverter efficiency varies from about 85% at a very light load to about 93% at a half load. A reasonable factor to apply to the inverter output load in order to estimate input load is 89% efficiency giving a multiplication factor of 1.125 x inverter output = inverter input.
Factor D = 1.125.

E. Hold-up Time

Design Battery hold-up time for Hydro Power installations has been set at 10 hours
Factor E = 10

Please Note: For Gas and Diesel stations battery hold-up time is different from hydro power stations (Refer to datasheets for specific installation). Confirm hold-up time before planning DC/UPS upgrades or battery replacements for Gas/Diesel power stations.

Battery capacity (Ampere Hours)

= (A) x (B) x (C) x (E) (DC requirement + inverter requirement)

= 1.25 x 1.1 x 1.4 x 10 { I (250V dc) + inverter kW output x 1000 x (1.125) /250v}

= 19.25 x {I(250V dc) + 4.5 x inverter kW output}

9.4 Types of Battery Cells

9.4.1 Ventilated Cells

Lead acid batteries are the most popular secondary battery, accounting for approximately 70% of all storage batteries globally. 2V Lead-acid stationary vented (flooded) with 10-hour nominal rated cells have been selected as the standard for future purchases by SHL (and by some electricity commissions) in the past. These cells offer the most economical cost /life combination during the period. They offer a life of above 20 years under operating conditions. The life cycle cost of vented cells is lower compared to VRLA cells over the 20-year lifespan. SHL and other industry experience suggest that if the vented lead acid batteries are properly maintained they can last for more than 20 years. They are suitable for switchgear application and electrolyte monitoring is possible.

At present SHL has several types of lead-acid batteries in service, they are pasted plate, tubular, and the latest hybrid constructions. In most cases, like-for-like replacements will be considered for battery bank configurations considering technological improvements, flexibility and cost.

Electrolyte density in fully charged cells should not exceed 1.245 ± 0.005 kg/m3 at 20℃. To eliminate the possibility of copper poisoning and reduction of cell life, the presence of copper within the cell electrodes and terminal posts should be avoided.

9.4.2 Solar Cells - Specific Application

Lead-acid cells used with solar-powered charging systems in some outlying work situations are basically ventilated cells with a much larger than normal electrolyte reservoir. This allows the maintenance interval to be extended. Because they are ventilated cells, all of the installation and maintenance safety requirements included in the Australian standards will apply. The capacity of these cells is frequently specified at the 10-hour discharge rate to an end-of-discharge voltage of 1.8 VPC.

9.4.3 Low Maintenance Cells

Lead-acid batteries with reduced antimony content in the grids of the plates consume less water than batteries with high antimony content. These are frequently described by the makers as low-maintenance batteries. As far as installation and maintenance safety requirements are concerned these are identical to ventilated cells.

9.4.4 Sealed Cells

Sealed lead-acid cells (with an over-pressure relief valve) are used where it is difficult to provide safety showers and eyewash facilities, particularly in outlying work situations. They are frequently referred to by the makers as maintenance-free. There is usually no free liquid electrolyte. The electrolyte is absorbed within the battery materials consequently the battery can not spill but the electrolyte volume is very small. The battery relies on internal gas recombination to avoid water loss. As a result, these batteries usually have very specific float charge voltage requirements specified by the makers to avoid overcharging and undercharging, both of which shorten battery life. Some sealed batteries can accept a boost charge others can not - follow makers' instructions.

VRLA cells may be cheaper however their lifespan is 10-12 years. Recent industry experience indicates that a 5 to 8-year lifespan is more realistic for VRLA batteries regardless of cell size or warranty claims. These batteries sometimes experience failures called “sudden death failures” where deposits form on the plates causing a short. This type of failure is difficult to detect and makes this battery less reliable than the flooded lead-acid design and the Ni-Cad design.

At present SHL has several types of sealed batteries (VRLA and AGM) in service at Gas and Diesel stations.

9.4.5 Lithium Ion Cells

Lithium Batteries can be used in applications where suitable following an appropriate risk assessment. Li-ion batteries have high energy densities, low self-discharge and no memory effect and are touted as maintenance-free. The most common and safest Li-Io technology is LiFePO4 batteries. They also have a longer service life and faster charging than lead-acid batteries. They have flammable electrolytes and if damaged or incorrectly charged, can lead to explosions and fires. Cell balancing is required to maintain a consistent state of charge across all cells of a battery. Some Lithium batteries are not self-balancing. Cell voltage monitoring and battery control for over/under voltage conditions are essential to ensure safety and long battery life. Effective BMS will be essential for Lithium battery banks. Lithium Ion batteries need to be held at a temperature above 0°C in order to be charged. These types of batteries are widely used for solar and other renewable systems, passenger cars, and buses.

At present SHL has Lithium Ferro Phosphate batteries (LiFePO4) in service at Port Stanvac diesel power station.

9.4.6 Ni-cd cells - Specific application

SHL used Ni-cd batteries in the past for certain applications but is now phasing them out of the system. Pocket-plate Ni-cd cells offer 15 to 20 years of design service life. They have a superior operating temperature range of -50°C to 60C but require significant maintenance. It is not recommended to use Ni-cd battery for any application within SHL.

10. Battery Installation

10.1 Battery systems are to be installed in purpose-built rooms that meet the requirements of AS 2676, AS 3011 and AS5139. Doors into rooms or buildings containing lead-acid battery systems must be provided with approved signs. The signs must state that the room contains lead-acid battery systems, that the battery room contains energised electrical circuits and that the battery electrolyte solutions are corrosive liquids. Safety signs must take the form depicted in Australian Standard AS 2676. DC low-voltage switchboards must be located externally or appropriately segregated from the battery room.

Where the battery voltage exceeds 120 V the installation shall be fitted with isolating switches (mid-string isolators) to separate the battery into sections of less than 120V for maintenance. Clearly identified intercell connectors, for example, with insulation of different colours to other inter-cell connectors should be used for this purpose. Isolating switches will be required to be operated only for major maintenance of batteries, such as removal or replacement of cells, or corrosion repair, to provide protection from electric shock to operators.

10.2 Battery stands should be either totally hardwood or for future installations electrolyte-resistant coated steel with bearers complying with AS 2676 to provide a compact installation at an acceptable working height. In the case of large-capacity cells (> 1000 amp-hour), polyurethane pallets are an acceptable alternative. The stands should have a rail on either side of the battery or in the case of polyurethane pallets a lip around the cell(s). The battery stands or pallets must have removable drip trays designed to hold the volume of electrolyte from one cell + 25% for the vented batteries

The battery stands must be fitted with adjustable insulated feet to ensure that the stands are level. Stands must be constructed so that a failed cell can be replaced without having to dismantle a complete battery.

All battery stands must be bolted to the floor and braced as required to meet AS 1170.4.

10.3 Intercell connections maybe

Option 1

(i) Bolted and lead burned where terminal posts are adjacent

(ii) Cable and moulded on lead lugs, bolted, and lead burned to the terminal posts.
Inter-tier connections are to be cable

Or Option 2

(i) Bolted flexible connection

Inter-cell and battery terminal connections should be constructed of materials either intrinsically resistant to corrosion or suitably protected by surface finish against corrosion. The joining of materials that are incompatible with a corrosive atmosphere should be avoided. All exposed terminals should be provided with insulated covers or shrouds.

10.4 The sizing rigidity and support of all cables used for inter-Cell inter-tier or battery to main fuse connection must cater for the thermal and mechanical stresses of the full fault current of the battery. The maximum fault current at the battery terminals for a series-connected bank of cells is:

Maximum charge voltage per cell / Internal resistance per cell $V/\Omega = I$

This will of course be reduced by the resistance of inter-cell or inter-tier connections. As an approximation, the full fault current in amperes can be taken as 13 - 14 times the nominal cell capacity in ampere-hours at the 10-hour discharge rate.

10.5 The main battery fuses are located in a separate CFS cubicle outside the battery room. The CFS unit is fitted with one fuse on the positive and one for the negative. Cubicle protection rating is IP 41 or higher with gland plates top and bottom to accommodate cable glands. The cubicle doors and the CFS operating handle are to be padlockable. The fuse position is monitored by PLC and an alarm for an open position is communicated to the SCADA and HMI.

Other fuses are also provided with over-current protection for both positive and negative conductors.

10.6 Each battery portion is to be identified with a label with

(i) Bank Voltage and Bank ID (A/B etc. or 1/2 etc.)
(ii) Type of cell
(iii) Fault current
(iv) Installed date
(v) Ah rating (C10)
(vi) Cell numbers for the particular bank

10.7 Battery Monitoring System
A Permanent Battery Monitoring System (BMS) should be provided for each battery bank. BCM should be capable of providing real-time and historical information. The main role of BMS is to keep the battery within the safe operating region in terms of voltage, current, impedance and temperature during the charge and discharge. Parameters measured can include the DC & AC voltage of each block, the ohmic value of each block, the temperature of each block, DC string voltage, DC & AC string current, ambient temperature and ambient humidity.
Advantages of BMS:

1. Reduce the risks of electric shocks associated with maintenance/condition monitoring tasks
2. Reduce the time and effort required for manual recording and processing of battery data required for condition assessment.
3. Prevention of fault using the aid of alarms or warnings before any failures occur by monitoring the parameters.
4. Visibility of process information and access to historical data for effective fault tracing.

11. Uninterruptible Power Supplies

All DC load is treated as essential and the supply is to be maintained uninterrupted. Critical AC loads are supplied from the uninterrupted essential AC supply.

The DC and essential AC may be provided either by a rectifier and an inverter or these may be combined into an uninterruptible power supply unit depending upon what is offered most economically at the time of purchase.

The Essential features of the equipment are as follows:

11.1 Rectifier

The rectifier can be powered by an available AC supply at the power station - 415V 3-phase AC supply or 240V 1-phase AC supply.
Each rectifier has the following functions:

- To rectify 415V 3-phase AC or 240V 1 Phase AC to nominal 250V/ 220V/ 125V/ 120V/ 110V/ 48V DC
- To supply starting, float, boost and equalising voltages to maintain each battery bank to maximum capacity. Each charging setting should be adjustable and have automatic and manual boost charging facilities as required. Boost charge should initiate automatically after AC supply restoration and the charging time should be adjustable.
- Rectifiers should also be capable of recharging their respective batteries in an adjustable period of less than 12 hours at any point in the battery discharge cycle while supplying the normal load of their respective batteries.
- To supply the entire DC load if the other rectifier fails (including the charging of its own battery) with. “When the rectifier is in the equalising charge the load should be disconnected.. Rectifiers should be capable of recharging their respective batteries in an adjustable period of less than 12 hours in the deep battery discharge recovery state, while not supplying the normal load of their respective batteries.
- To supply the input stage of the static inverter
- To maintain the RMS AC ripple to an acceptable low level. This is currently specified at less than 1% of float output voltage.
- The rectifier units should have adjustable current limiting and temperature compensation charging features.

The following features are required:

- Input isolation/protection fuse switch or circuit -breaker
- Input isolation transformer to prevent circulating currents between rectifiers working in parallel and to prevent rectifier bridge short circuits in the event of earth faults.
- Adjustable current limited output for charging the battery bank with overcurrent protection and isolated facility. The current limit will be set to the current corresponding to the 10-hour discharge rate for the battery.
- Output with overcurrent protection (fuse switch or CB) for station DC load.
- Output to suit inverter input. If the rectifier and inverter are separate units an overcurrent protection and isolation point will be required. If a UPS is purchased this facility may not be available.
- The alarm equipment must indicate appropriate individual alarm conditions, including those shown below, but not limited to
    - Charger output volts high/low;
    - Charger AC supply failed;
    - Charger overload;
    - Charger rectifier or capacitor fuses blown; and
    - Charger cooling/fans failure

- All necessary facilities required for safe operation and maintenance of the battery chargers must be provided, including the following:

- LCD/LED HMI, mounted on the front panel of the battery charger, for control, indication, measurement and alarm facilities. The LCD/LED device must have communication ports for remote data and alarm signalling to the power station control system (or local control system) via EtherNet/IP™ protocol;

11.2 Static Inverter

The inverter input supply is derived from the rectifier output or from the 250V/ 125V/ 120V / 110V/ 48V battery in the event of an AC input or rectifier output failure.

The inverter serves the following functions:

- Output AC Sinusoidal waveform
- To maintain a regulated AC output ± 2% with an available DC input voltage range (e.g 200-300 V for 250V DC) as required by the design specification.
- Phase to neutral voltage, which is the major voltage used, is adjustable (e.g 228.0 - 252.0v for 250VDC).
- To maintain a regulated frequency of 50 Hz ±1.0%. *(±4.0%)
- If the input frequency is within the range of 50 Hz ±1.0% then output frequency tracks input frequency.
  * range can be widened to ±4.0% if necessary.
- If the input frequency is outside the range of 50 Hz ± 1.0% then the output frequency switches to an internally regulated frequency of 50 Hz ±0.5%.
- To achieve the capability of a reliable- AC supply in the event of station external AC supply failure.
- To supply the total essential AC load if the other inverter fails.

The following features are required:

- If the inverter and rectifier are separate units, an inverter input isolation point, and overcurrent protection are required. This isolation point is to be separate from the rectifier output isolation so that either the rectifier and DC outputs can operate independently from the inverter or the battery can supply the DC output and inverter independently from the rectifier.
- Inverter output isolation and overcurrent protection are required.

11.3 Bypass Supply

Static Transfer Switch

The static transfer switch is a thyristor/contactor configuration to transfer the output supply of the inverter to the bypass supply without breaking. The static transfer switch will operate automatically in the event the inverter output is out of tolerance. It is operated manually when paralleling the essential AC bus or removing an inverter from service. Static switches may be purchased as part of the inverter or as independently mounted units.

Maintenance bypass switches

A maintenance bypass switch shall be provided for each inverter for the time when inverter isolation is required. It shall be mounted in a separate cubicle to the inverter and the static bypass switch. It shall bypass the static bypass switch.

11.4 Surge Filters

The surge filter is powered from the Station Low Voltage Aux Supply Switchboards (AC supply) and has the following functions:

- To provide a common stabilised bypass AC supply through either of the IPS static transfer switches in the event of an inverter failure.
- The continuous rating of the surge filter must be equivalent to or greater than the rating of the individual UPS. A surge rating of at least 700% of rated UPS output for 3 seconds is required to ensure switchboard fault isolation.
- To provide an alternative supply during UPS maintenance.

The surge filter has two isolating switch outputs - one to each UPS static transfer switch input. Full AC and/or DC isolation of the UPS is possible during maintenance with no interruption to AC or DC loads or battery charging.

12. Switchboards

Fully segregated switchboards with full arc containment (Form 3 or better AS 1136.1 1988) will generally be selected for the Common Services Board/Station low voltage auxiliary supply switchboard. Other boards will generally be Form 2b partially segregated.

12.1. Main Station DC supply switchboard (250 V/ 125 V/ 120 V/ 110 V / 48V)

The switchboard will normally be operated in two halves with outgoing circuits distributed to maximise reliability. The halves of the switchboard should be able to parallel manually when required eg. to allow a battery or rectifier to be taken out of service without interruption of the DC supply to the loads. The electrical components should be designed for the fault level of the paralleled system.
For the switchboard above 250A, each bus section must be fully arc-contained and with insulated busbars.
A minimum of the following instruments should be supplied for each bus section:

- Local and remote voltage and DC load current measurements.
- The voltage measurements should be +ve to earth and -Ve to earth separately.
- Under voltage relay.
- Earth Fault monitoring relay as per 7.1.

12.2. Lower Voltage DC switchboard (48V / 24V)

The lower voltage DC switchboard(s) will normally be located near the load to minimise voltage drop. The two halves of the board will normally be uncoupled as each is fully redundant. The halves of the switchboard can be paralleled when required, e.g. to allow a battery or rectifier to be taken out of service.

12.3. Essential AC switchboard

The essential AC switchboard will provide 415/240V 3 phase & neutral 50 Hz supplies. Normal operation in auto mode is in 2 halves with outgoing circuits distributed to maximise reliability. Failure of power supply to one-half board causes a timed automatic closure of a bus coupler to restore supply from the other half board. The delay time of closure may be varied from approximately 0.5 seconds up to several minutes. An off or reset mode allows for a manually controlled return to normal operation without a break. Refer to O&M manuals for details of each individual installation.

Due to the interruption that occurs, it is considered unnecessary for the inverters to be specified to be capable of operating in parallel. The parallel operation should not be attempted unless the O&M manual for the individual installation specifically allows this.

For servicing one UPS, a manual mode allows manual closure of the switchboard bus coupler. It is however necessary to change to a Static Transfer Switch supply (bypass supply) before closing the bus coupler. The whole load can then be transferred to one inverter.
For the upgraded EAC boards there should be a facility to isolate both bus section cubicles to complete volt-free status (2 bus coupler circuit breakers in series).

13. Seismic Requirements

AS2676.1 - 1990 makes passing reference to seismic requirements at clause 3.5-floor loadings. SHL specifications require that " the battery stand shall have a rail on either side of the battery to contain the cells due to vibration or earth tremor". See also section 10.2 of this document. Many tremors have been experienced, particularly during the initial stage of filling large storage dams. The specified requirements have proven satisfactory until now.

14. Maintenance Procedures

These are addressed by the Australian standards listed in section 3, operating and maintenance instructions for each site and the maintenance strategy as per Equipment Management Standard.

15. Protection and Isolation Requirements.

To maximise the reliability of control protection & communication facilities, the following equipment will normally be operated as segregated halves - Battery banks A & B, 250V DC boards A & B. Essential AC boards A & B. Common services boards & 48V DC boards require suitable protection in the bus section to ensure that a fault on one half of the board does not affect the other half.

16. References

- SHL-ELE-156 Snowy Hydro Limited (SHL) General Electrical Requirements
- Snowy Mountains Hydro-Electric Authority - DC and Essential AC Supplies Key Diagram and Plant schedule dated February 1992 (Datasheet D-GEN-2-52/16, Rev B, Sheet 16 of 16)
- WSP - EAC and DC design Philosophy (Tumut 1) dated May 2017
- DC and essential AC supplies working team report to strategic maintenance review group, report 8 of 9 dated 1989.

17. DC/EAC Single Line Diagram - Hydro Stations