View

Introduction

In this topic you will learn about the load profiles, energy management, and the purpose and application of battery storage systems, including the various different system configurations.

Energy Usage

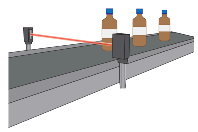
The average Australian household uses energy for a range of purposes, primarily for lighting, cooking, cleaning, heating and cooling, and entertainment. In fact, heating and cooling accounts for around 40% of energy used by the average Australian household!

Commercial premises use energy in an even wider variety of ways in order to provide services and products to consumers.

The following table provides some examples how energy is consumed in these different areas.

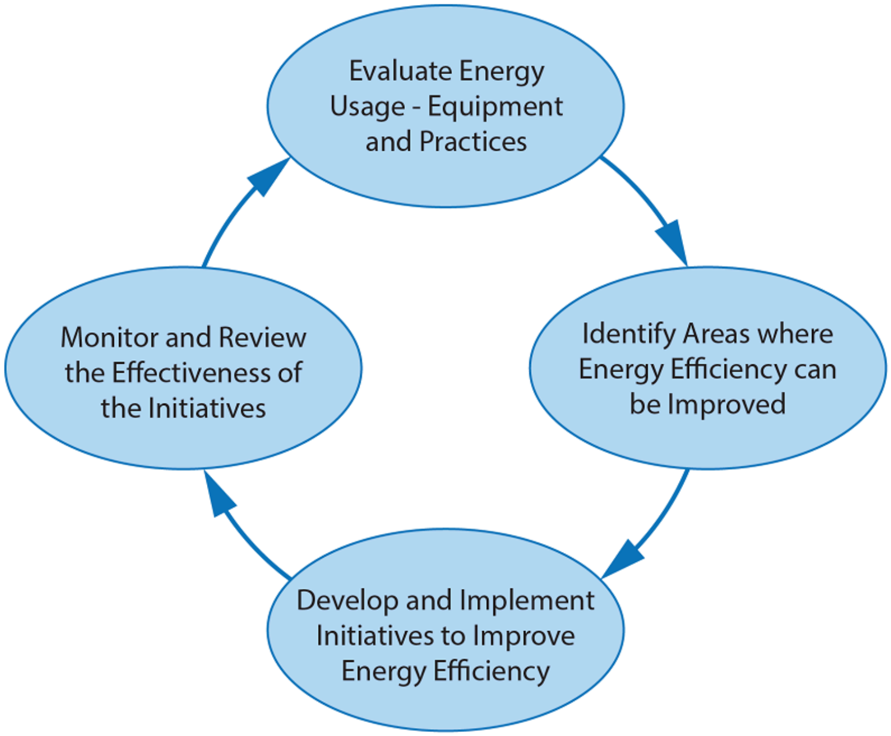
Energy Usage		
Usage Area	**Illustration**	**Types of Equipment**
Lighting		• General purpose lighting. • Spot/flood lighting. • Feature and special purpose lighting.
Cooking		• Ovens, stoves and cooktops. • Deep fryers and electric frypans. • Food processors and other kitchen appliances. • Water heaters.

?

Cleaning		• Washing machines and dryers. • Dishwashers. • Vacuum cleaners. • Water heaters.
Climate Control		• Radiant heaters. • Ducted and reverse cycle air conditioners. • Refrigerators, freezers and cool rooms.
Entertainment		• Televisions and media players. • Computers and gaming systems.
Commercial Usage (in addition to the above)		• Conveyor belts and pumps. • Lifts and hoists. • Welders and compressors. • Various other specialised tools and machines.

Energy Efficiency Auditing

An energy efficiency audit involves evaluating various characteristics and practices affecting energy usage at a given premises, identifying areas where energy consumption can be reduced, developing methods of achieving this, and monitoring/reviewing these methods.



There are a number of techniques for improving energy efficiency, including:

- Reducing the use or need for energy consuming equipment.
- Reducing the amount of energy needed to operate equipment.
- Reducing energy losses and wastage.
- Reducing reliance on the Electricity Network, e.g. through the use of PV power and battery storage systems.

Factors Affecting Energy Usage

The amount of energy used at a given premises depends on a range of factors, including:

- Type of Premises.
- Local Climate.
- Building Design and Construction.
- Appliance Efficiency.
- Consumer Practices and Awareness.

Type of Premises

The type, quantity and times of energy usage depends largely on what people are normally doing at a given premises. For example, the energy usage at a house, shop and factory will vary widely. The usage between two different types of shops, or two different types of factories, will also vary. It is important to understand the specific energy needs of the customer when assessing their usage and efficiency.

Local Climate

The extremes of climate at any given location will determine the degree of heating or cooling needed to provide personal comfort. Ideally, the local climate should be considered in the building design and construction, as discussed below.

Building Design and Construction

There are various ways in which the design of a building has a significant effect on energy usage and efficiency:

- Sustainable building materials can reduce the environmental impact of the construction project.
- Building materials can be selected to have a thermal mass that compliments the given climate. For example, it may be effective to use a material that absorbs heat during the day and releases that heat at night.
- Building layouts can be arranged to facilitate natural air flow, reducing the need for artificial cooling.
- Windows and skylights can be used to reduce the need for artificial lighting during the day. The size and type of windows should also be considered, as this can affect the transfer for heat into and out from the building.
- Shades and screens can be placed at certain locations to reduce the impact of direct sunlight.
- Thermal insulation in ceilings, walls and under floors can reduce the need for artificial space heating and cooling.
- Energy efficient showerheads reduce hot water usage.
- 'Smart' controls, timer systems and sensors can be arranged to reduce energy wastage, for example by automatically switching off lighting or other equipment when not in use.

It should be noted that many of these factors will be determined by the architect during the design phase of a building project. However, items such as smart controls, thermal insulation, screens, shades, windows and skylights can be installed in existing buildings to improve energy efficiency.

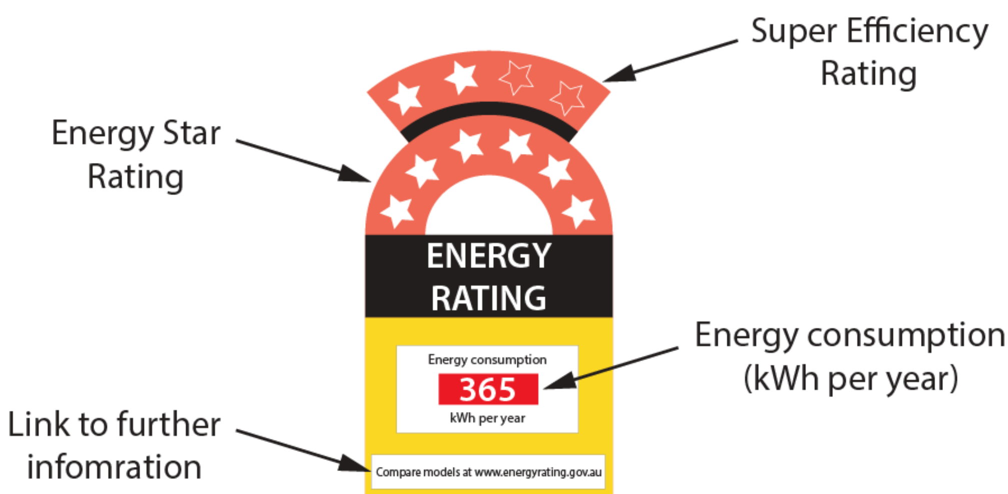
Appliance Efficiency

The types of electrical appliances used in a building will have a large impact on its overall efficiency. Some effective techniques for reducing the energy consumed by appliances and equipment include:

- Replacing incandescent lighting with more energy efficient types, such as CFLs or LEDs.
- Replacing conventional water heaters with solar water heating systems.
- Replacing existing appliances with more energy efficient models (particularly appliances that are used frequently, or even constantly such as a refrigerator).

Appliance Energy Ratings

The 'Energy Star' rating system requires certain appliances to be labelled to identify their efficiencies. The rating system is intended to inform consumers so that they can make more energy efficient choices. In turn, this gives further economic incentives to manufacturers to design more energy efficient products.



Energy Star Label

The following items are required to display an Energy Star rating sticker when being sold in Australia:

- Refrigerators and freezers.

- Single phase air conditioners.
- Televisions.
- Dishwashers.
- Washing machines and clothes dryers.

Consumer Practices and Awareness

Finally, changing the everyday practices and habits of the consumer can result in further energy savings. This can include:

- Turning off lights, televisions, computers, etc. when not in use.
- Performing tasks manually instead of using an energy consuming device, e.g. using a rake instead of a leaf blower.
- Only using air conditioning and heating appliances when absolutely necessary – could appropriate clothing warm you up or cool you down just as effectively?
- Closing doors and windows when using air conditioning or heating appliances.
- Closing blinds/curtains in the morning and evening to reduce heat transfer.
- Ensuring electrical equipment/appliances are regularly maintained.
- Having shorter showers to reduce hot water usage.
- Hanging clothes on a clothes line to dry rather than using a dryer.

This learning activity consists of 5 parts designed to develop your understanding of energy use, and the techniques that can be applied to reduce energy demand in domestic and commercial premises.

Topic 1.1 Learning Activity

Last modified: Wednesday, 28 August 2024, 10:35 AM

View

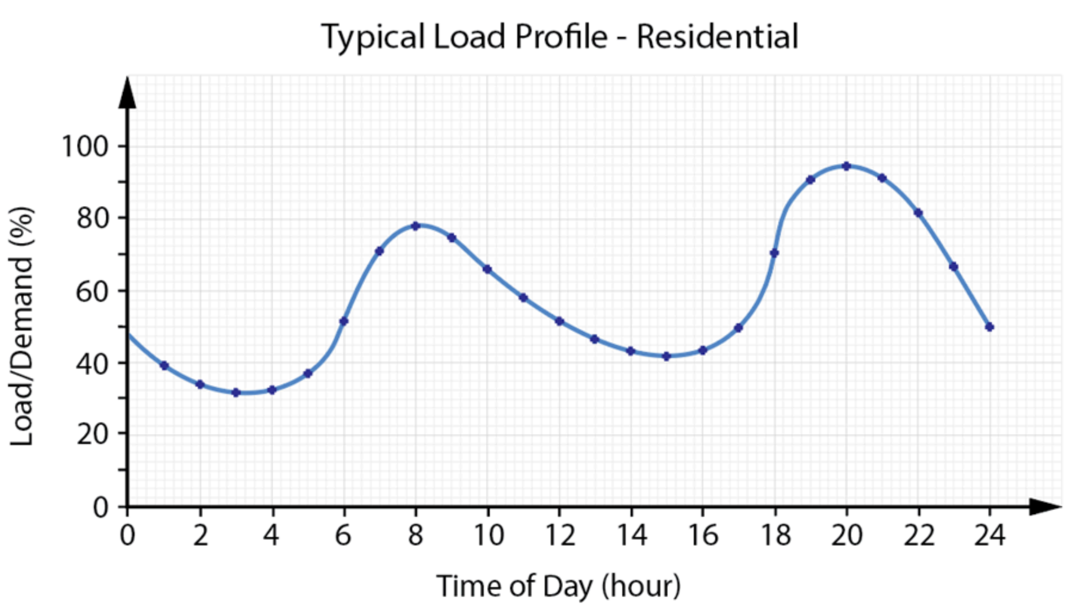
Battery Storage

The reliable and constant availability of energy may seem normal, but is actually incredibly abnormal in the context of human history. Fossil fuels such as coal have allowed our societies to develop under the assumption that energy will be available '24/7', whilst the availability of renewable energy is often dependent on the occurrence of natural phenomena such as wind or sunlight.

For this reason, energy storage has become a major focus of research and development over the past few decades. It is only with the use of renewable energy technologies in conjunction with effective energy storage technologies, that we will be able to maintain our current energy expectations.

Installation Load Profiles

The 'load profile' of an installation indicates how much energy the installation uses at different times throughout the day and night. This is typically represented graphically, for example:

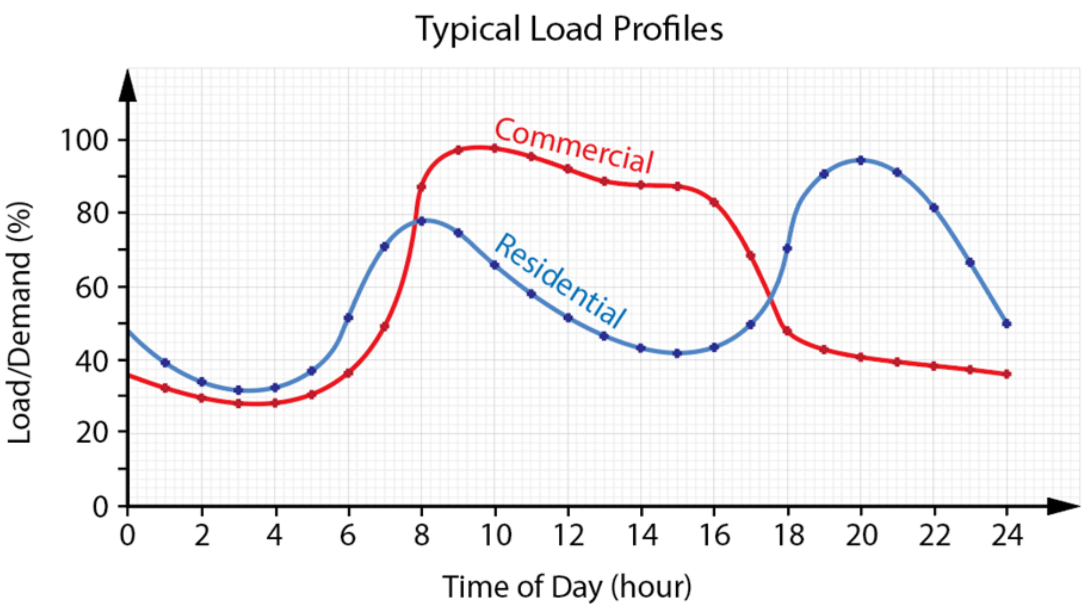


In the residential load profile above, it can be seen that:

- Energy use peaks at around 8 a.m. (when occupants are having showers and making breakfast) and around 6 p.m. to 10 p.m. (when occupants are cooking dinner, showering, watching TV etc.).

- There is a low energy demand through the middle of the day (when occupants are at work/school) and during the middle of the night (when occupants are asleep).

The energy profile of each electrical installation will be unique, and will depend on how the installation is used on a day-to-day basis. For example, the load profile for a commercial installation such as a café, will differ significantly to a residential home.

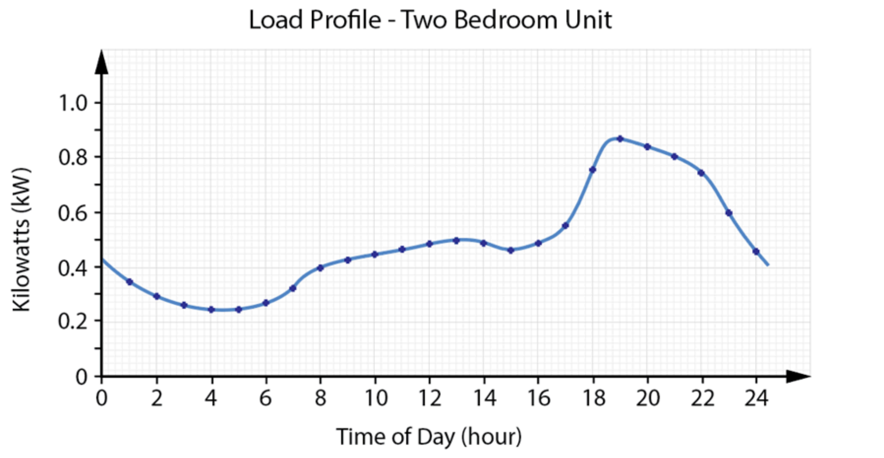


A load profile can be determined for a particular installation by taking regular energy usage measurements throughout a given period of time. The average demand for that period can be calculated by adding up all the measurements taken and dividing by the total number of measurements.

Worked Example – Load Profile Analysis

The following simple load profile was developed from taking hourly measurements of a two bedroom unit:

Measurements



Time	Power (W)	Time	Power (W)	Time	Power (W)
1 a.m.	346	**9 a.m.**	420	**5 p.m.**	556
2 a.m.	292	**10 a.m.**	442	**6 p.m.**	767
3 a.m.	272	**11 a.m.**	479	**7 p.m.**	882
4 a.m.	256	**12 p.m.**	490	**8 p.m.**	838
5 a.m.	259	**1 p.m.**	499	**9 p.m.**	805
6 a.m.	284	**2 p.m.**	488	**10 p.m.**	742
7 a.m.	318	**3 p.m.**	473	**11 p.m.**	603
8 a.m.	400	**4 p.m.**	487	**12 a.m.**	452

To determine the peak demand, simply identify the highest wattmeter reading:

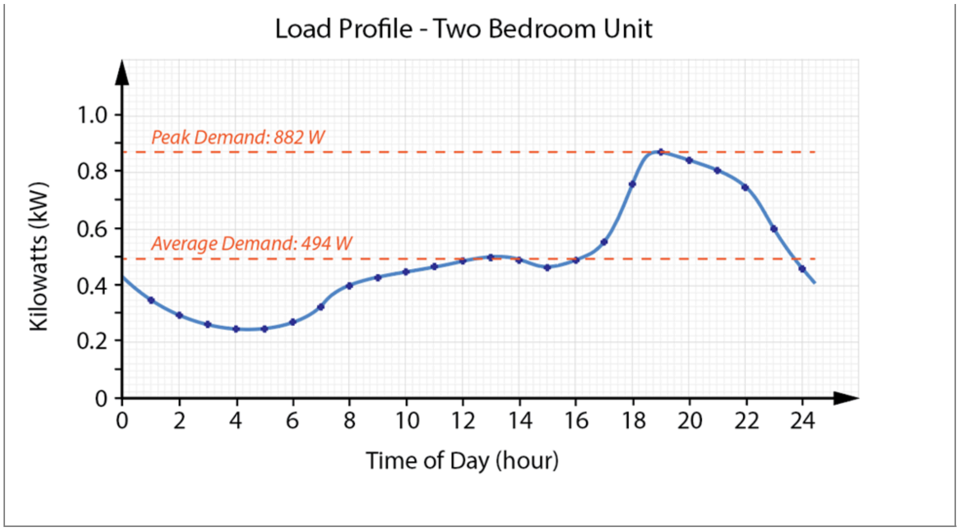
Peak Demand = <u>882 W</u>

To determine the average demand, simply add up all the wattmeter readings and divide by the number of readings:

346 + 292 + 272 + 256 + 259 + 284 + 318 + 400 + 420 + 442 + 479 + 490 + 499 + 488 + 473 + 487 + 556 + 767 + 882 + 838 + 805 + 742 + 603 + 452 = <u>11850 W</u>

Average Demand = 11850 / 24 = <u>494 W</u>

These values can be identified on the graph as follows:



This learning activity consists of 2 parts designed to develop your understanding of energy usage profiles in electrical installations.

Topic 1.2 Learning Activity

Last modified: Wednesday, 28 August 2024, 11:20 AM

CONTACT US

02 6262 7055

enquiries@energyspace.com.au

View

Purpose of Battery Storage

Adding battery storage to a grid-connected PV power system allows excess energy generated during sunlight hours to be stored for use at a later time (i.e. at night). This will significantly increase energy savings as:

- It further reduces the amount of energy the installation will need to import from the grid.
- It allows more of the generated PV energy to be used in the installation rather than exporting it (note that the cost of importing energy from the grid is higher than the price received for exporting that same amount of energy).

Another advantage is that supply can be maintained in the event of a grid outage. However this capability would need to be specified in the design phase, as not all inverters and system configurations provide this function.

This capability can be a significant advantage to the consumer. Typical timeframes for rectification of grid-outages can range from 20 minutes to 12 hours, or even several days in some circumstances. Particular outage times will depend on a number of factors:

- The cause of the outage – whether it was planned or unplanned.
- The extent of the rectification/maintenance work needed.
- The weather conditions.

Data published by a number of network providers indicates that the average time for grid outages in their networks in 2022 was around 3 hours.

Load Monitoring

Load monitoring tools allow consumers to view the operating parameters and performance of their electrical systems. Monitoring systems allow peak periods of generation and demand to be viewed, and provide tools to optimise energy usage, to take full advantage of the system.

Storage water heaters, for example, have traditionally been arranged so that the elements are energised at night, taking advantage of the cheaper "off-peak" energy tariffs. For the owner of a grid-connected solar battery system, however, it will likely be more cost effective to operate the elements during the middle of the day.

?

Worked Example – Load Control

Consider the following scenario:

- The Network Provider pays a feed-in tariff of 5 c/kWh to the owner for each kWh they export to the grid.
- The Network Provider charges 11 c/kWh for energy used between 10 p.m. and 6 a.m.
- The consumer needs to operate their 6 kW water heater for 5 hours (6 x 5 = 30 kWh).
- The consumer's PV system generates at least 30 kWh per day.

If the consumer operates their water heater during the off-peak period, then the net cost will be $1.50:

Charges for using 30 kWh at night = 30 x 11 = 330 cents

Income for exporting 30 kWh during the day = 30 x 6 = 180 cents

Net Cost = 330 – 180 = 150 = $1.50

However, if the consumer sets the water heater to operate during the middle of the day (i.e. using solar energy), then the net cost will be $0.00:

Charges for using 0 kWh at night = 0 cents

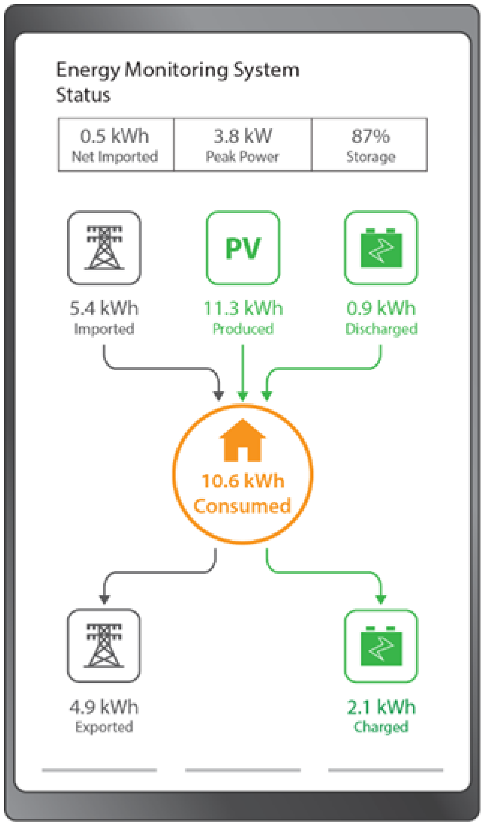
Income for exporting 0 kWh during the day = 0 cents

Net Cost = $0.00

This principle can have a significant impact on the return on investment (ROI) for both domestic and commercial premises. The example above would represent an annual saving of almost $550!

System Monitoring Tools

There are a range of energy monitoring systems available providing different degrees of detail and functionality. Most solar battery systems today will come with access to a system monitoring tool. For most modern systems wireless technology streams real-time data to cloud-based software, which can then be accessed through a computer or smartphone app using an appropriate login.



If additional data and control is desired, additional monitoring equipment can be installed. These systems typically involve the use of current transformers to monitor usage.

Depending on the sophistication of the system, monitoring can take place at the overall level, or on individual circuits, strings, or even at individual loads, modules or batteries. Some typical features and functions are outlined in the following table.

System Monitoring Tools	
Weather conditions	• Typically, ambient temperature and irradiation, and in some cases air pressure and humidity.
Operating parameters	• Real-time output voltage, current and power at the array/module. • Real-time battery charge/discharge parameters. • Real-time input and output voltage, current and power at the inverter. • Energy import/export values.
Fault detection and alerts	• Identifies faults/errors at the array, batteries or inverter. • Can be configured to send notifications in the event of a fault, e.g. via email.
Data logging and reporting	• Records and stores data for collation and analysis. • Reports can be generated manually and/or automatically to view operation and performance over time.

Public screens/displays	• A screen is sometimes provided in a public place to show the performance of the system, sometimes used by commercial premises for promotional/educational purposes.

Load Control Devices

Based on the data and analysis provided by load monitoring tools, a consumer is able to adjust their energy use to reduce costs and improve efficiency. This can be done using a range of equipment, such as:

- Relays and contactors.
- Timers.
- Load controllers.

Demand Response Mode (DRM) is a method of control that is now becoming more common in various appliances, such as water heaters, air conditioners, pool pumps and electric car chargers. DRM allows the appliance to be automatically controlled based on signals received from a DRM-compliant grid-connect inverter. For example, this would allow an air conditioning unit to be automatically powered down if battery charge drops below a particular pre-set level, or if energy imported from the grid exceeds a pre-set level.

There are nine DRMs specified in Table 3.1 of AS/NZS 4777.2:2020 *Grid connection of energy systems via inverters – Inverter requirements*, however inverters are only required to comply with DRM 0.

This learning activity consists of 5 parts designed to develop your understanding of energy monitoring and management methods in relation to battery storage for PV systems.

Topic 1.3 Learning Activity

Last modified: Wednesday, 28 August 2024, 11:24 AM

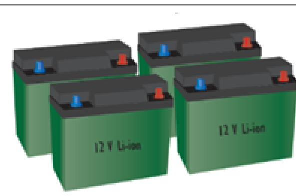
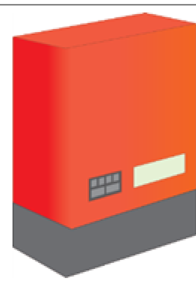
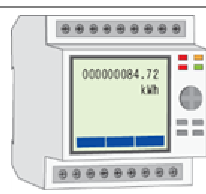
CONTACT US

02 6262 7055
enquiries@energyspace.com.au

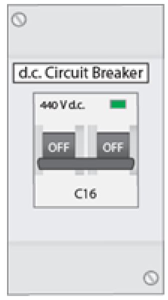
View

Battery Storage Systems

A basic battery storage system for a grid-connected PV installation has the following key components:

Battery Storage System Components		
Component	**Illustration**	**Function**
Batteries		Stores energy for use when needed.
Multimode Inverter		Converts direct current into alternating current.
Charge Controller		Controls the charging parameters applied to the batteries.
Metering / Monitoring		Monitors and logs system parameters for analysis.

?

Controls and Protection		Protects equipment against overcurrent and provides a point of isolation.

Battery Energy Storage System (BESS)

A battery energy storage system (BESS) is an assembly of components that makes retrofitting battery storage into existing installation quick and easy. Depending on the manufacturer, a BESS will include some or all of the following components:

- Batteries.
- Power Conversion Equipment (PCE) – battery inverter, charge controller.
- Cooling system.
- Isolation and protection devices.
- Battery management controls and indicators.

Network Provider Requirements

Due to potential impact on the electricity network, network providers have various requirements for grid-connected battery systems. These requirements may vary by State/Territory, but can cover issues such as:

- Minimum quality standards for output voltage and frequency.
- Access to remote monitoring/controls.
- Acceptable types of batteries and inverters.
- Limitations on the size of the system.
- Minimum protective requirements.

Many of these will be addressed simply by adhering to Australian Standards such as AS/NZS 5139 and AS/NZS 4777, however some additional requirements may apply in your jurisdiction. Theoretically these factors should've been factored in to the system design brief, but it's always best to confirm and understand the local requirements before starting a job.

Battery System Configurations

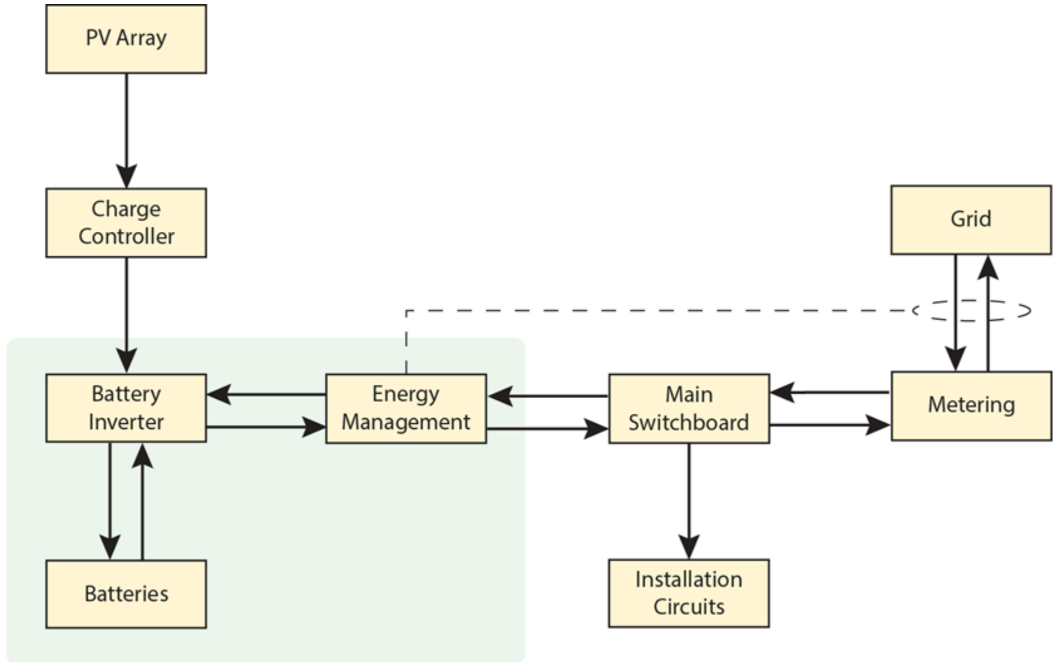
There are several different ways of arranging battery storage into a grid-connected PV power system. The best arrangement for a particular situation will depend on factors such as:

- Desired functionality, e.g. standalone operation.
- The arrangement of the existing PV system.
- The particular manufacturer/products used.

d.c. Coupled Systems

A PV battery system is said to be 'd.c. coupled' if the PV array and the battery system are connected via a d.c. circuit.

The following block diagram shows a typical arrangement for a d.c. coupled PV battery system, without emergency power capability:

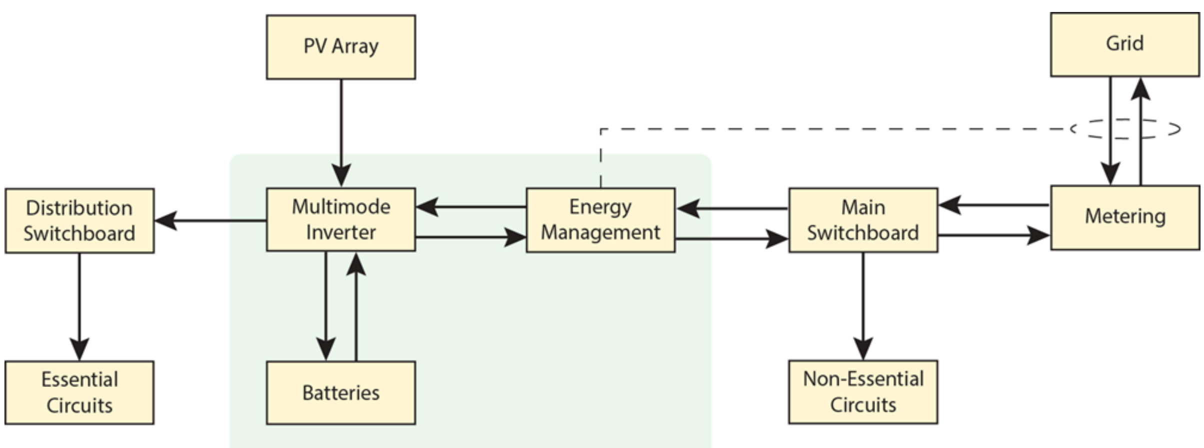


Battery Energy Storage System (BESS)

In this arrangement:

- The PV array is coupled to the battery system via a solar charge controller.
- The BESS energy management unit monitors the PV array, batteries and grid import/export, and adjusts the system parameters as necessary.
- In the event of a grid outage, a grid protection device in the BESS energy management unit will disconnect the alternate supplies from the grid, and so no supply will be available to the installation circuits.

This next diagram shows a similar system, except that this one is designed to be capable of maintaining supply to a set of essential circuits during a grid outage:



Battery Energy Storage System (BESS)

In this arrangement:

- The PV array is coupled to the battery system via a multimode inverter.
- The BESS energy management unit monitors the PV array, batteries and grid, and adjusts the system parameters as necessary.
- During normal operation, both the essential and non-essential circuits are supplied with energy, either from the array, batteries or grid.
- During a grid-outage, the BESS energy management system isolates the alternate supplies from the grid (grid protection), but continues to supply the essential circuits.

These arrangements can be a good option for customers who don't have an existing PV system.

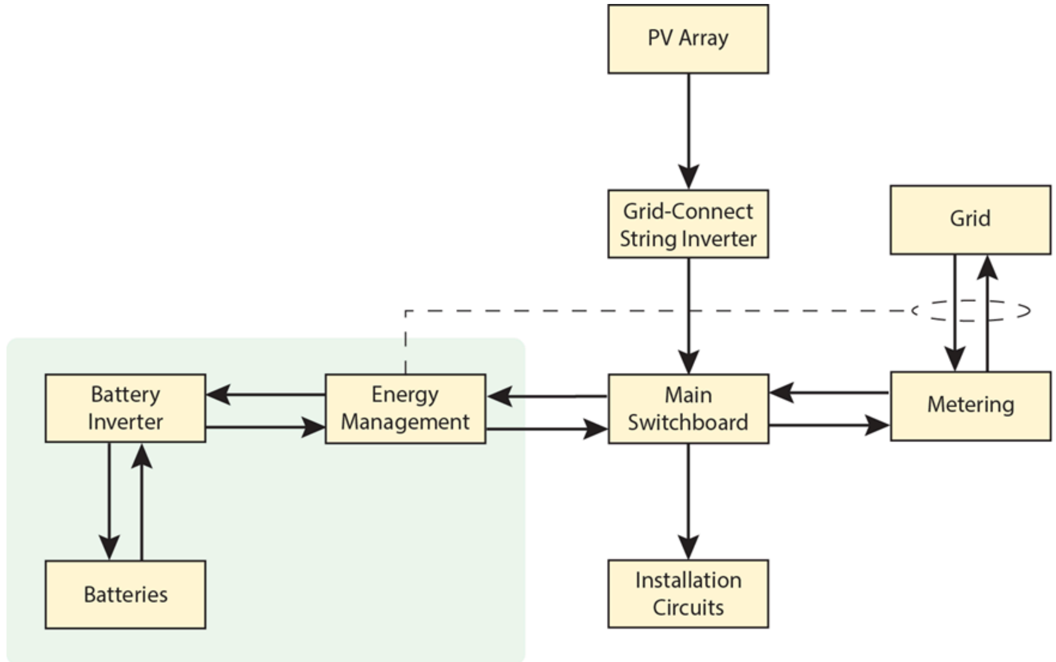
Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

a.c. Coupling

A PV battery system is said to be 'a.c. coupled' if the PV array and the battery system are connected via an a.c. circuit.

The following block diagram shows a typical arrangement for an a.c. coupled PV battery system, without emergency power capability:



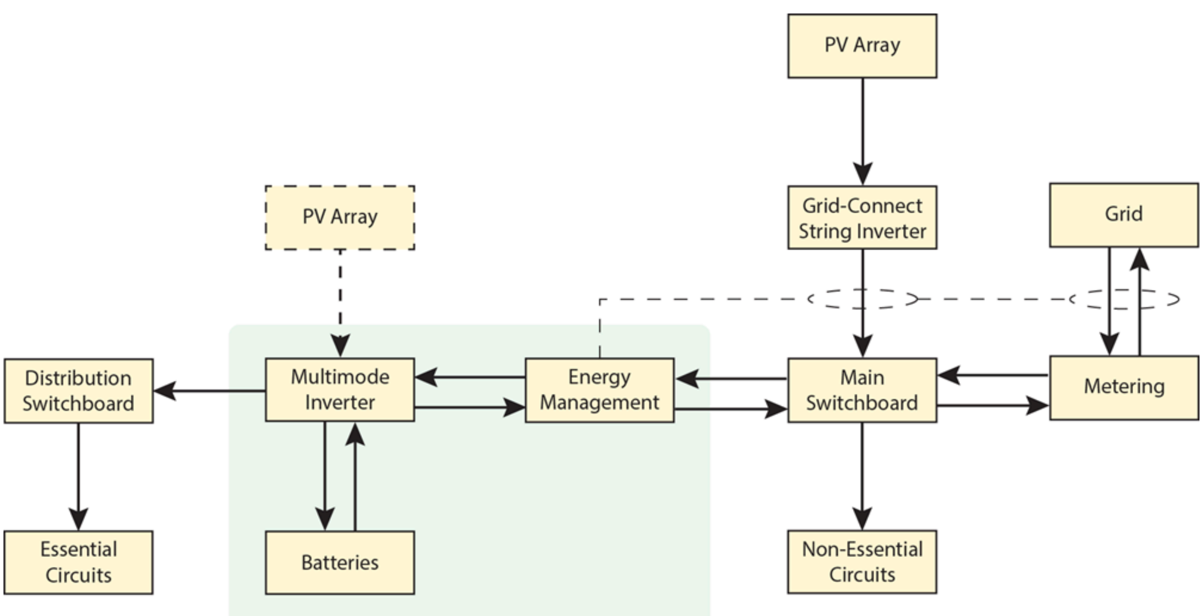
Battery Energy Storage System (BESS)

In this arrangement:

- The PV supply and the battery supply have both been inverted before they are connected together in the main switchboard – therefore the system is a.c. coupled.
- The BESS energy management unit monitors the PV array, batteries and grid import/export, and adjusts the system parameters as necessary.
- During a grid-outage, grid protection in the string inverter will disconnect the PV supply and grid protection in the BESS energy management unit will disconnect the battery supply, and therefore no supply will be available to the installation circuits.

This is a good arrangement for an installation with an existing grid-connect PV system, as it's relatively simple to retrofit.

This next diagram shows a similar arrangement that is capable of providing emergency supply to a set of essential circuits, and provides the option of having a second d.c. coupled PV array added:



Battery Energy Storage System (BESS)

In this arrangement:

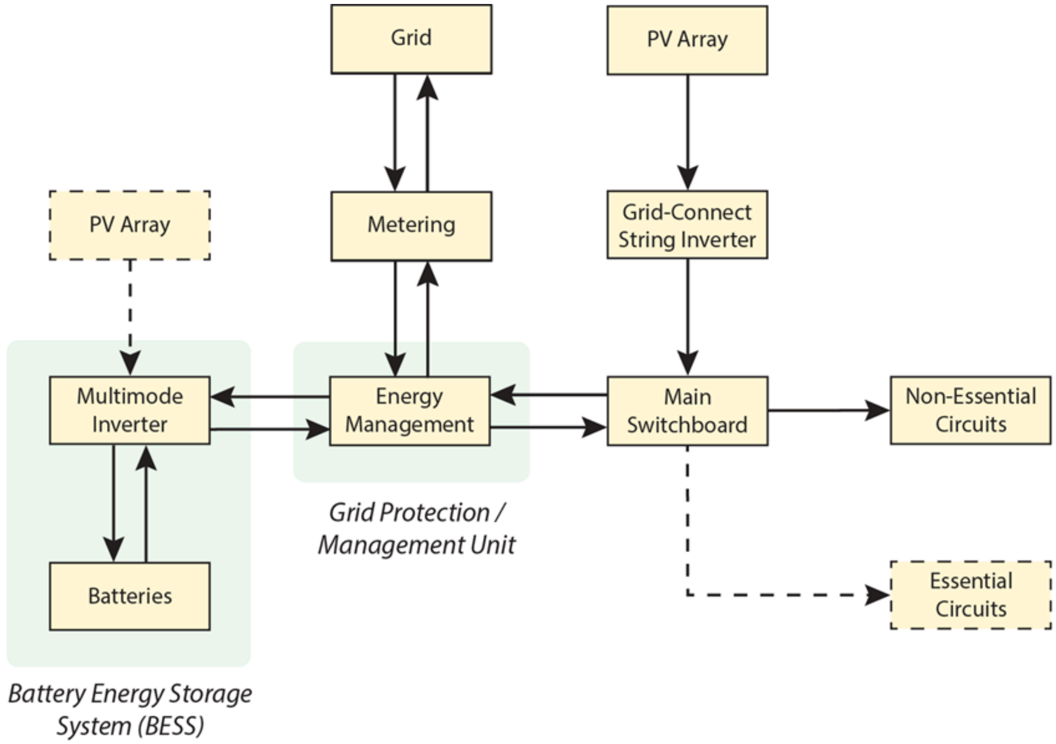
- The BESS energy management unit monitors the PV array(s), batteries and grid, and adjusts the system parameters as necessary.
- During normal operation, both the essential and non-essential circuits are supplied with energy, either from the array(s), batteries or grid.
- During a grid-outage:
    - The grid protection in the string inverter will disconnect the a.c. coupled PV supply.
    - The grid protection in the BESS energy management unit will isolate the battery and any d.c. coupled PV array from the grid.
    - The essential circuits will continue to be supplied via the multimode inverter from the battery and any d.c. coupled PV array.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Alternate System Arrangements

As mentioned above, the particular arrangement of components will depend on the specific product selected. This last block diagram shows the arrangement for a different battery system product that incorporates two separate modules:



For this installation:

- The energy management module is connected between the installation's metering and main switch(es).
- This arrangement allows any or all of the installation circuits to be provided with emergency power in the event of a grid outage (provided enough battery capacity is installed).

This learning activity consists of 7 parts designed to develop your understanding of battery storage system components and arrangements.

Topic 1.4 Learning Activity

Undertaking this topic quiz will help you to confirm your understanding of installation load profiles, energy monitoring and reduction techniques, and battery system components and configurations.

Topic 1 Content Quiz

Last modified: Wednesday, 28 August 2024, 11:27 AM

CONTACT US

02 6262 7055

enquiries@energyspace.com.au

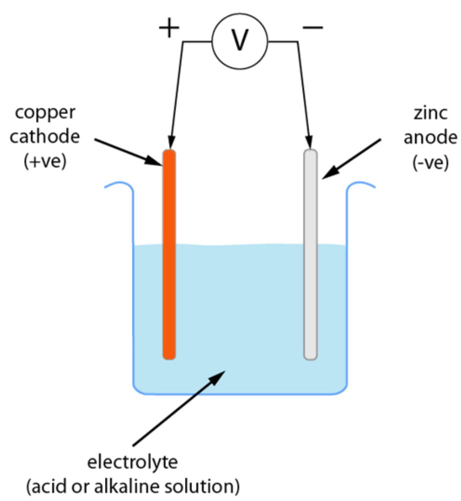
View

Introduction

In this topic you will learn about the types of batteries used in grid-connected storage systems, including terms, definitions and parameters, charging modes and battery life. You will also learn about the safe working practices for handling, installing, maintaining and disposing of storage system batteries.

Battery Concepts

In order to understand storage system battery banks, you will need to be familiar with a number of technical terms and definitions. The following table explains some key battery concepts.

Battery Concepts	
Cell	A cell consists of two electrodes immersed in an electrolyte. The two electrodes are made of dissimilar materials (typically metals), meaning that the chemical properties of each are different.  A voltage appears between the two electrodes due to a chemical reaction between the dissimilar metals and the electrolyte, that causes an excess of electrons at the negative terminal (the 'anode'), and a deficiency of electrons at the positive terminal (the 'cathode'). The electrolyte allows the movement of electrons between the two electrodes in the form of ions. The voltage across the electrodes depends on the particular combination of electrode materials.

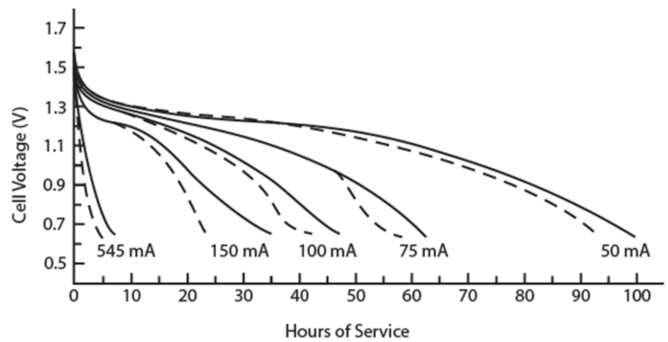
?

Primary cell	The chemical reaction in a primary cell is *irreversible*, this means that a primary cell can't be recharged. When a primary cell is discharged it must be discarded.
Secondary cell	The chemical reaction in a secondary cell can be reversed by applying an external voltage to the cell terminals. This means that secondary cells can be *recharged*.
Battery	Some batteries consist of a single cell, however the batteries used for grid-connect storage applications consist of several cells connected in series, parallel or series/parallel arrangements to produce batteries with larger terminal voltages and current capacities.

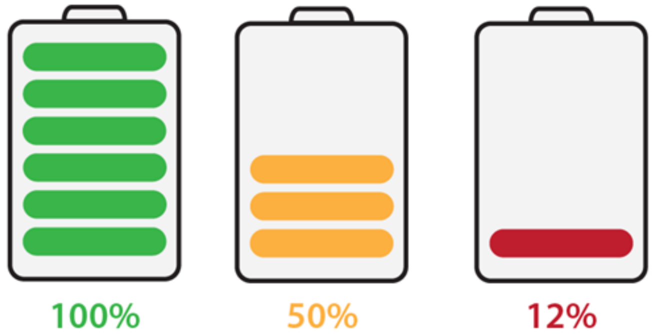
Battery Parameters

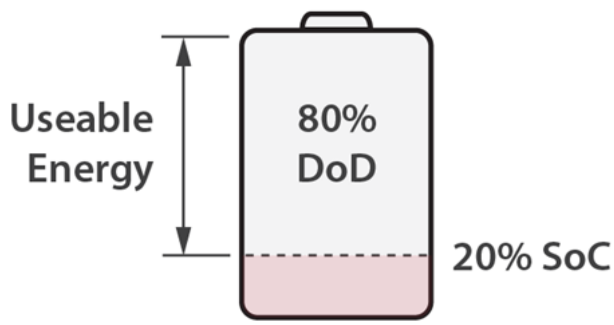
The following table explains the key parameters and ratings associated with grid-connect storage batteries.

Battery Parameters	
Nominal voltage	The average voltage that will be available at the terminals of the battery is referred to as the nominal voltage.
Ampere-hour capacity	Ampere-hour (Ah) capacity represents the amount of current a battery can supply for a given duration. An ideal cell with a capacity of 1 Ah can supply a current of 1 ampere for 1 hour, 2 amperes for 0.5 hours or 4 amperes for 0.25 hours.
Watt-hour capacity	Watt-hour (Wh) capacity represents the amount of power a battery can supply for a given duration, and can be calculated as follows: *Nominal voltage x ampere-hour capacity = watt-hour capacity* *(normally quoted in kWh for grid-connect storage systems)* For example a 12 V, 100 Ah battery has a watt-hour capacity of 1,200 Wh (12 x 100 = 1,200 or 1.2 kWh).

Charge/discharge rate	The charge/discharge rate represents the voltage and current characteristics of a battery when being charged and discharged.
	
	In order to charge a battery, a d.c. voltage that is slightly higher than the nominal battery voltage is applied to the terminals. As the battery charges, its terminal voltage increases until it exceeds that of the charging voltage, at which point charging stops.
	
	As a battery discharges, its internal resistance increases due to the chemical reaction occurring in the electrolyte, causing the battery's terminal voltage to drop.
	
	The following graph is an example of a discharge characteristic for a particular battery:
	
	
	
	Points to note about the discharge curves:
	
	• As the cell discharges, its terminal voltage decreases.
	• The hours of service are greater at a low rate of discharge compared to a high rate of discharge, for example:
	  ◦ At 50 mA discharge, hours of service are approximately 95 hours.
	  ◦ At 545 mA discharge, hours of service are approximately 5 hours.

Cycle life	The cycle life of a battery represents the number of charge/discharge cycles the battery can undergo before its capacity degrades. A complete charge and discharge represent one cycle.

<table>
<tr><td>State of charge</td><td>The state of charge (SoC) indicates how much energy is left in a battery, i.e. the percentage of capacity available. When a battery is full, it's SoC is 100%. When a battery is half full, it's SoC is 50%.


Most people will be familiar with this concept from looking at their smartphone – when the battery icon in the top corner of your screen indicates '83%', this is indicating the SoC of your phone battery.</td></tr>
<tr><td>Depth of discharge</td><td>The depth of discharge (DoD) indicates how far a battery can be discharged before the battery life will be negatively affected. Essentially this indicates how much of the battery energy is useable in practice.
For example, a DoD of 80% means the life of the battery will be reduced if the SoC drops below 20%.


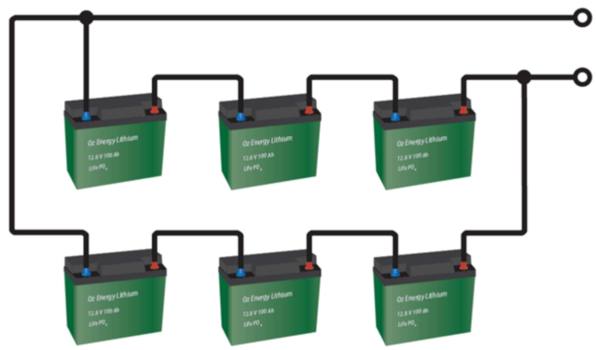
Batteries designed for grid-connect solar applications commonly have a DoD of 90% or more. Some even have a DoD of 100%.</td></tr>
<tr><td>Useable capacity</td><td>The useable capacity is equal to the DoD percentage of the total battery capacity, for example:
• A 100 Ah battery with a DoD of 90% has a useable capacity of 90 Ah.
Working: 100 x 0.9 = 90 Ah
• A 40 Ah battery with a DoD of 75% has a useable capacity of 30 Ah.
Working: 40 x 0.75 = 30 Ah</td></tr>
</table>

Battery Bank Arrangements

Battery banks consist of several batteries, generally connected in a series-parallel arrangement. The particular arrangement used will affect the output parameters of the bank as a whole.

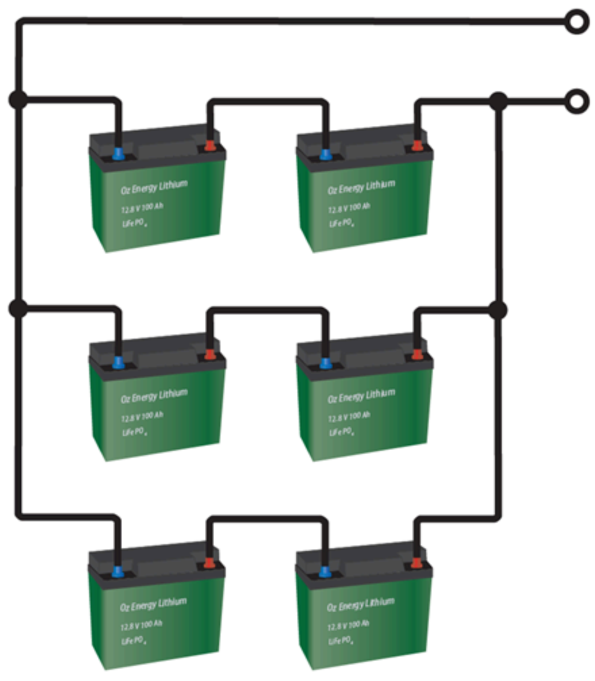
- Connecting batteries in series increases the output voltage, whilst the output current remains the same.
- Connecting batteries in parallel increases the output current, whilst the output voltage remains the same.

The following table shows a series-parallel arrangement of 6 x 12 V, 100 A rated batteries:

Arrangement 1	
The following configuration consists of two strings, each consisting of three batteries.	
	
Voltage	**Current**
12 + 12 + 12 = 36 V	100 + 100 = 200 A

This next table shows how these same six batteries arranged in a slightly different series-parallel configuration – note the different battery bank voltage and current parameters.

Arrangement 2
The following configuration consists of three strings, each consisting of two batteries.

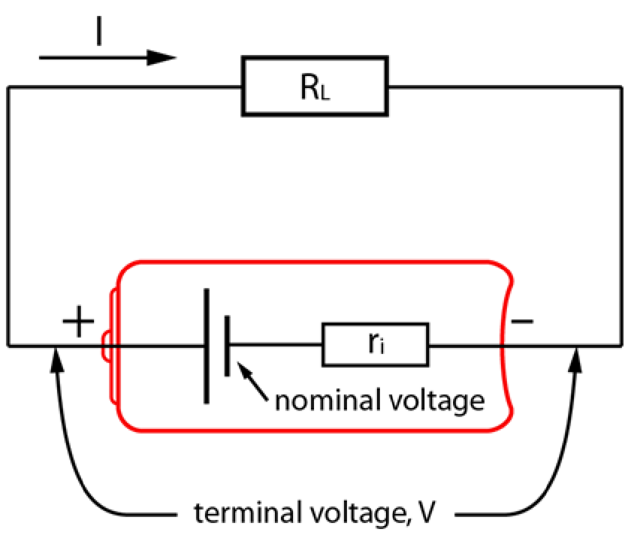


Voltage	Current
12 + 12 = 24 V	100 + 100 + 100 = 300 A

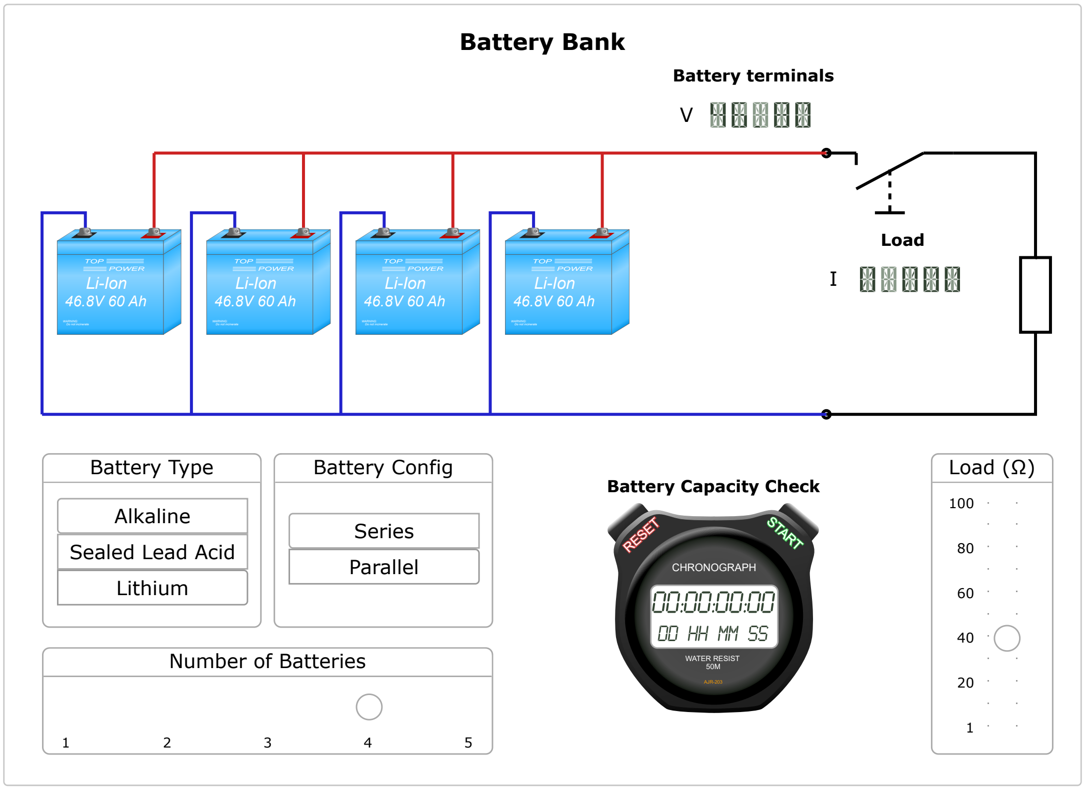
Internal Resistance

Something to be aware of is that batteries have a small internal resistance due to their physical construction (typically around 0.02 Ω to 0.08 Ω).

This means that when connected to a load the terminal voltage will drop slightly due to an internal voltage drop across the internal resistance (r_i). The equivalent circuit of a battery supplying a load (R_L) is pictured below:



The following interactive object demonstrates the effect of connecting different types of batteries in series and in parallel across a resistive load.



For this demonstration you will investigate the change in nominal (open circuit) voltage, load voltage and load current as each battery is connected in series and parallel configurations across the load.

Set Up

1. Set the load resistor to 10 Ω.

2. Open the load switch.

Lithium-ion Battery

1. Set the configuration to a single Li-ion battery and note the nominal voltage.

2. Close the switch and notice the load voltage and current. Why is the load voltage less than the nominal voltage? What is the load current?

3. Adjust the configuration so that there are multiple batteries in series and note the load voltage and load current. What is the effect of increasing the number of batteries in series?

4. Now adjust the configuration back to a single battery, close the switch and note the voltage.

5. This time increase the number of batteries in parallel configuration. Does the load terminal voltage change? Does the load current change?

6. Open the switch.

Now try similar experiments using some different types of batteries, configurations and loads.

Australian Standards

Australian Standards containing requirements related to the installation of grid-connected battery banks include:

- AS/NZS 5139:2019 Safety of battery systems for use with power conversion equipment.
- AS/NZS 4777.1:2024 Grid connection of energy systems via inverters – Installation requirements.
- AS/NZS 4777.2:2020 Grid connection of energy systems via inverters – Inverter requirements.
- AS/NZS 3000:2018 Wiring Rules.

This learning activity consists of 7 parts designed to develop your understanding of battery bank terms, definitions, and connection configurations.

Topic 2.1 Learning Activity

Last modified: Tuesday, 5 November 2024, 10:34 AM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Grid-Connect Batteries

Battery technology is a rapidly evolving field that has seen significant advancement in the past decade. The advent of electric cars and photovoltaics (PV) has created huge financial incentives for the research and development of lightweight high-capacity batteries.

At this current moment, lithium battery technology is the most commonly used type for grid-connect storage applications. However other types have been used historically, and some promising alternate battery technologies are currently in development.

Types of Grid-Connect Batteries	
Type	**Features**
Lead-acid Batteries	Types include: • Flooded lead-acid. • Valve regulated lead-acid (VRLA). Open-circuit cell voltage (OCV) is 2 V. Batteries are commonly available with nominal voltages of 6 V and 12 V. DoD is around 60% and expected service life is around 300 to 500 charge/discharge cycles. Lead-acid batteries have been used widely in the past for energy storage systems as they are reliable and relatively inexpensive. However flooded lead-acid batteries in particular, pose particular safety hazards and require more maintenance than other types of batteries.

?

<table>
<tr><td>Lithium Batteries</td><td>Types include:
Lithium-ion (Li-ion).
Lithium-polymer (LiPo).
Lithium iron phosphate (LiFePO4).
Lithium cells typically have an OCV of around 3.3 V to 3.7 V, depending on the particular type. Batteries are commonly available with nominal voltages of 6 V, 12 V, 24 and 48 V. DoD is around 80 to 90%.

When compared to lead-acid batteries, advantages of lithium batteries include:
Higher energy density.
Longer service life – around 1000 cycles (Li-ion) up to 5000 cycles (LiFePO4), depending on the quality of the battery.
Less maintenance required.</td></tr>
<tr><td>Flow Batteries</td><td>Flow batteries are an emerging technology that uses two electrolytes stored in separate tanks. The electrolytes are circulated in and out of a reaction cell where they react to produce electricity.

Flow batteries have several advantages compared to other batteries, including:
Scalability – the capacity of the battery can be increased simply by increasing the size of the storage tanks. For this reason, their main application is currently for large-scale energy storage.
DoD of 100%.
Good service life – around 4000 cycles.
Ability to be charged and discharged simultaneously.
Can be produced without using hazardous materials.
Some of the disadvantages of flow batteries include:
Low energy density.
More expensive.
Require various auxiliary equipment (pumps etc.).</td></tr>
</table>

Sodium Batteries	Sodium-based battery technology is currently in development as a potential replacement for lithium batteries in the future. When compared to lithium batteries, advantages of sodium battery technology include: • Cheaper and less environmental impacts – due to the abundance and relative ease of obtaining sodium. • Improved energy density. • Comparable and possibly improved service life. However, there are currently still some downsides to sodium battery technology, including: • High operating temperatures (300 to 350°C). • High self-discharge rate, meaning they lose their charge over time, e.g. whilst being stored.

Charging Modes

The three main charging modes used in grid-connected PV storage systems are:

- Constant voltage (CV) charging.
- Constant current (CC) charging.
- Smart/adaptive charging.

When in CV mode, the charger applies a constant voltage across the batteries until the SoC reaches the maximum charge voltage (or other pre-set value). This means that the charging current varies as the batteries charge.

When in CC mode, the charger delivers a constant current to the batteries until the SoC reaches the maximum charge voltage (or other pre-set value). This means that the charging voltage varies as the batteries charge.

When in smart/adaptive mode, the charger monitors a range of battery parameters (e.g. SoC, temperature, etc.) and automatically adjusts the charging voltage and current for optimal performance and battery life.

When batteries are at 100% SoC, the charger will switch over to trickle charging, which provides a continuous, constant charging current to maintain the battery at its nominal voltage. This is designed to compensate for the natural self-discharge rate of the batteries.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Factors Affecting Battery Life

All batteries will deteriorate over time, but there are several points to consider that can help to get the most out of a battery installation. The following table explains the various factors that can reduce the life of PV storage system batteries, and the ways to reduce their impact.

Factors Affecting Battery Life		
Factor	**Description**	**Solution**
Environmental Conditions	High temperatures, humidity and the build-up of dust or other contaminants can accelerate the deterioration of a battery, thereby reducing their service life.	*Installation location* – batteries should be installed in cool, dry conditions where there is good ventilation. *Maintenance* – environmental conditions should be checked, and batteries should be cleaned periodically.

<table>
<tr><td>Charge/Discharge Rate</td><td>Discharging or charging batteries at a high rate can cause overheating which can damage battery components and reduce battery life.</td><td rowspan="2">System design – the battery installation should be suitably sized for the given load requirements. This will help to reduce the likelihood of excessive discharge rate/depth.

Charger settings – the charger should be set to ensure that charge/discharge rates and allowable DoD are suitable for the batteries and the installation conditions.

Battery Monitoring – monitoring systems will help to optimise the operating conditions of batteries, thereby improving their service life.</td></tr>
<tr><td>Depth of Discharge (DoD)</td><td>Discharging batteries beyond their rated DoD will reduce their service life. In general it is good practice to avoid discharging batteries beyond 80% DoD.</td></tr>
</table>

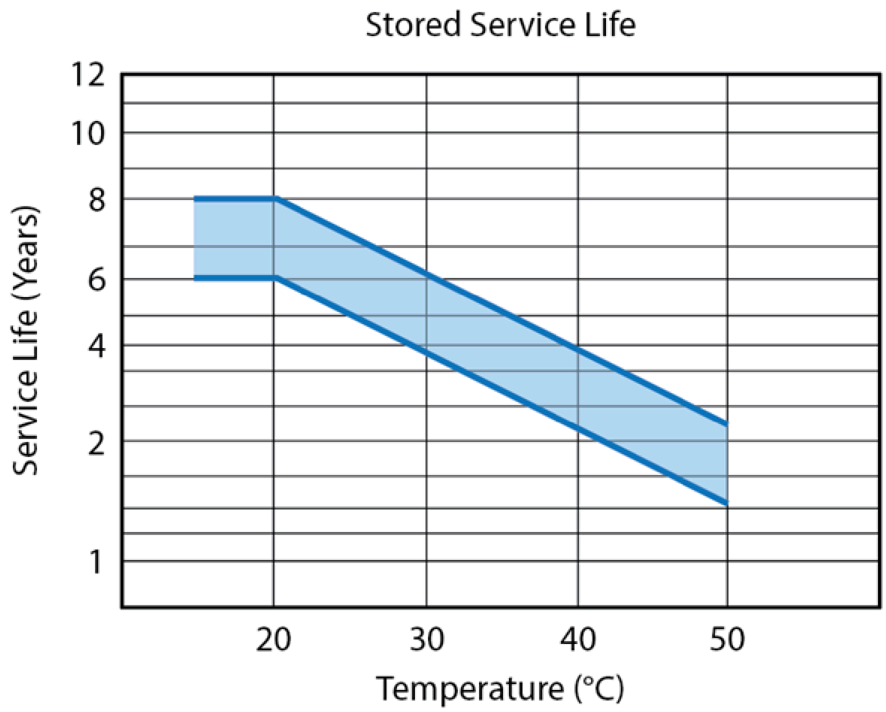
Estimating Battery System Life

When installing a battery system, it’s important to inform the customer of its expected service life. There are several factors to consider when developing an appropriate estimate of a system’s service life, including:

- Battery type and ratings:
  - Rated service life cycles.
  - Rated DoD.
- Operating conditions:
  - Environmental conditions – temperature and humidity.
  - Frequency and depth of charge/discharge cycles.

The manufacturer data sheet should provide information about how to de-rate service life based on particular conditions. Some examples of manufacturer data relating to service life are shown below:

From this graph you can see that increasing the depth of discharge significantly reduces the number of effective charge/discharge cycles for this particular battery.



From this graph you can see that storing these particular batteries in temperatures above 20°C significantly reduces the service life.

This learning activity consists of 7 parts designed to develop your understanding of the different battery technologies currently available for grid-connected storage systems, including battery types, charging modes and factors affecting battery life.

Topic 2.2 Learning Activity

Last modified: Wednesday, 28 August 2024, 11:32 AM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Battery Hazards and Safety

There are a number of safety factors that need to be considered when handling, installing or maintaining battery storage banks. The following table described the hazards, risks and safety practices associated with grid-connect battery storage systems.

Battery Hazards and Safety		
Risks	**Contributing Factors**	**Safety Practices**
Electric shock	• Battery banks for alternative supplies commonly operate at voltages exceeding ELV. • Batteries with large capacities can produce high currents. • Mains voltage will be present at input side of charging equipment. • Direct current is more likely to produce arcs compared to alternating current.	• Safe isolation procedures. • Disconnect/isolate batteries from the bank. • Insulating barriers and shrouds. • Remove conductive jewellery such as rings and piercings. • PPE such as safety glasses and rubber gloves. • Insulated tools.
Chemical burns	• Some electrolytes can burn the skin and eyes on contact.	• PPE such as rubber gloves, PVC apron, and safety glasses. • Emergency spill kits and eye wash facilities available. • Acidic electrolytes can be neutralised with baking soda. • Alkaline electrolytes can be neutralised with boric acid.
Corrosion	• Some electrolytes can corrode structural equipment.	• Regular checks of equipment for signs of corrosion.
Explosion	• Explosive gases (oxygen and hydrogen) may be produced when charging some batteries (e.g. lead-acid). This is referred to as gassing.	• Sources of sparking should be kept clear of batteries and battery rooms. • Battery enclosures and rooms should be kept well ventilated.

?

Sprains and strains	• Batteries can be quite heavy, resulting in injuries from incorrect manual handling techniques.	• Correct manual techniques. • Use of mechanical lifting aids.

Safe Storage and Disposal of Batteries

Batteries should always be stored and handled in accordance with manufacturer's instructions, generally they should be kept in cool, dry and well-ventilated conditions.

Care must be taken when disposing of batteries as they contain chemicals which can be harmful to people and the environment. Electrolytes can be very corrosive. When in doubt, always refer to the manufacturer's instructions, and where possible they should be recycled.

Battery Failure

There are several factors that can cause battery failure, as described in the following table.

Common Causes of Battery Failure		
Cause	**Description**	**Mitigation**
Age	• All batteries have a limited lifespan, and will eventually fail with age.	• There is no way to mitigate aging.
Misuse	• Overuse can lead to exhaustion of the battery's energy storage capacity. • Overcharging can damage the battery's internal components.	• Correct system sizing. • Correct charger settings – don't overcharge and don't discharge beyond rated DoD.
Mechanical Damage	• Can break or loosen internal components and connections.	• Handle with care. • Install with adequate mechanical protection.
Excessive Temperatures	• Can cause deterioration or damage to internal components. • Lithium-ion batteries are particularly susceptible to heat.	• Install/store in cool, dry and well-ventilated conditions. • Provide cooling equipment if needed.
Manufacturing Defects	• In some cases batteries may be improperly assembled or have been assembled with faulty components in the manufacturing process.	• Return faulty batteries to the manufacturer.

Sulphation and Stratification

Sulphation and stratification are effects that arise in lead-acid batteries, resulting in reduced battery capacity.

- Sulphation is when lead sulphate crystals build up on the lead plates of a lead-acid battery. This reduces the effective conductive area of the plates, thereby reducing the battery's ability to hold a charge.
- Stratification occurs when the electrolyte of a lead-acid battery starts to separate, with the acid concentrating at the bottom. This increases sulphation, and the associated detrimental effects.

A degree of sulphation and stratification will be unavoidable as the battery ages; however these effects are accelerated by:

- Undercharging or overcharging.
- Exposure to high temperatures.
- Being stored for long periods.
- Being stored when not fully charged.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 8 parts designed to develop your understanding of the hazards and associated safe working practices for handling, installing, and maintaining batteries.

Topic 2.3 Learning Activity

In this skills practice, you are required to perform a risk assessment for a work task involving the handling, installation, or maintenance of battery storage banks.

Topic 2.3 Skills Practice

Undertaking this topic quiz will help you to confirm your understanding of the batteries currently used in grid-connected storage systems, including terms and definitions, battery configurations, types of batteries, charging modes, battery life, hazards, and safe working practices.

Topic 2 Content Quiz

Last modified: Wednesday, 28 August 2024, 11:35 AM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

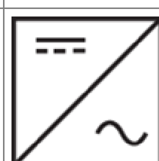
View

Introduction

In this topic you will learn about the different types, features and ratings of PCE used in grid-connected PV battery storage systems. You will also learn how to connect different types of PCE and measure the input and output parameters.

Power Conversion Equipment (PCE)

There are two main types of PCE used in grid-connected PV battery storage systems, as described in the following table:

Power Conversion Equipment (PCE)			
Type	**Illustration**	**Symbol**	**Function**
Charge controller			Converts a d.c. input to a d.c. output, to control the charging parameters applied to the batteries.
Inverter			Converts a d.c. input to an a.c. output, to allow use of PV and battery energy to supply a.c. loads.

Types of Charge Controllers

There are three main types of charge controller – these are:

- Pulse Width Modulation (PWM) type.
- Maximum Power Point Tracking (MPPT) type.
- Hybrid type.

The following table compares and contrasts these different types.

?

Types of Charge Controllers	
Type	**Description**
PWM Controller	• Uses transistors (BJTs, MOSFETs or IGBTs) to rapidly switch the PV array output on and off to achieve a constant and stable charging voltage for the batteries. • The array voltage is essentially 'chopped down' to the required charging voltage. • Inexpensive and relatively simple circuitry. • Most suitable for smaller PV storage systems.
MPPT Controller	• A more sophisticated d.c. to d.c. converter. • Uses logic algorithms to optimise the array output and then convert it to the required battery charging voltage. • When the voltage is converted down, the charging current is correspondingly boosted in the process. • More efficient and also more expensive than PWM controllers. • Most suitable for larger PV storage systems, or for systems in colder climates.
Hybrid Controller	• Uses a combination of PWM and MPPT technology. • Available with enhanced features such as load control, inverter control and data logging. • On the more expensive side, in a similar price range to MPPT controllers depending on the size and features. • Suitable for all systems.

Types of Inverters

There are three main types of inverters that are suitable for grid-connection, as summarised in the following table.

Types of Grid-Connect Inverters	
Central/string inverters	Central/string inverters are intended for use with PV arrays, and are typically mounted on the wall or in a d.c. control panel near the installation metering/main switchboard. The inverter is designed to connect to one or more strings of PV modules.
Micro-inverters	Micro-inverter systems consist of several small inverters, each connected to individual modules within the array, typically mounted directly onto the array assembly. PV modules are also now commonly available with in-built micro-inverters, reducing installation time.

Multiple mode Inverters (MMI)	A multiple mode inverter is a more versatile inverter when compared to central and micro-inverters. Features include: • Allow connection of both the grid and multiple other power sources, e.g. grid, PV array and battery bank. • Able to operate in several different modes that suit different operational requirements. • Can be configured to enable continuity of supply in the event of grid failure. • Manages and optimises the amount of energy that flows between the grid, PV array and battery bank. A multiple mode inverter is required for a PV battery storage installation where standalone functionality is desired.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 6 parts designed to develop your understanding of the basic types and functions of a multiple mode inverter.

Topic 3.1 Learning Activity

Last modified: Tuesday, 5 November 2024, 12:26 PM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Battery Controls and Equipment

Charge controllers are available with a broad range of features and functions, depending on the model, to suit different types of installations. The following table summarises some of these main features:

Charge Controllers	
Feature	**Purpose**
Battery Monitoring	• Monitors and indicates the batteries' state of charge (SOC).
Voltage Regulation	• Adjusts the charging voltage to suit the requirements of the batteries – usually includes multiple changing modes. • Ensures a consistent output voltage is supplied to the load during discharge.
Temperature Compensation	• Adjusts the charging voltage based on the battery temperature (as detected by a temperature sensor) to optimise charging. • As battery temperature increases, charging voltage can be reduced. • As battery temperature decreases, charging voltage can be increased.
Deep Discharge Protection	• Protects batteries against excessive discharging by disconnecting loads when the battery drops below a specified SOC.

?

Other Protective Features	• Other protective features include protection against: o Overcharging. o Reverse polarity. o Reverse current. o Short circuits and overloads. o Overvoltage. o Overtemperature.
Night/Day Switching	• Can be used to prevent battery discharge during daylight hours (e.g. when electricity will be available from a connected PV array).
Self-Test and Diagnostics	• Periodic automated self-checking feature to ensure continued functionality and identify any problems.

Controller Input/Output Ratings

The following table details the key input and output ratings of charge controllers.

Controller Input/Output Ratings	
Rating	**Description**
Nominal battery voltage	Indicates the nominal charging voltage that the controller will apply to the batteries – typically 12, 24 or 48 V. Some controllers are designed with multiple charging voltages, either manually selectable or automatically detected and set. This rating must be matched to the nominal voltage of the particular battery bank.
Max charging current	Indicates the maximum charging current that the controller is capable of delivering to the batteries. This rating must be matched to the current requirements of the particular battery bank.
Max PV voltage	Indicates the maximum input voltage that the controller is capable of receiving from the PV array without sustaining damage. The maximum PV voltage rating should be equal to or greater than the open circuit voltage (Voc) of the array.

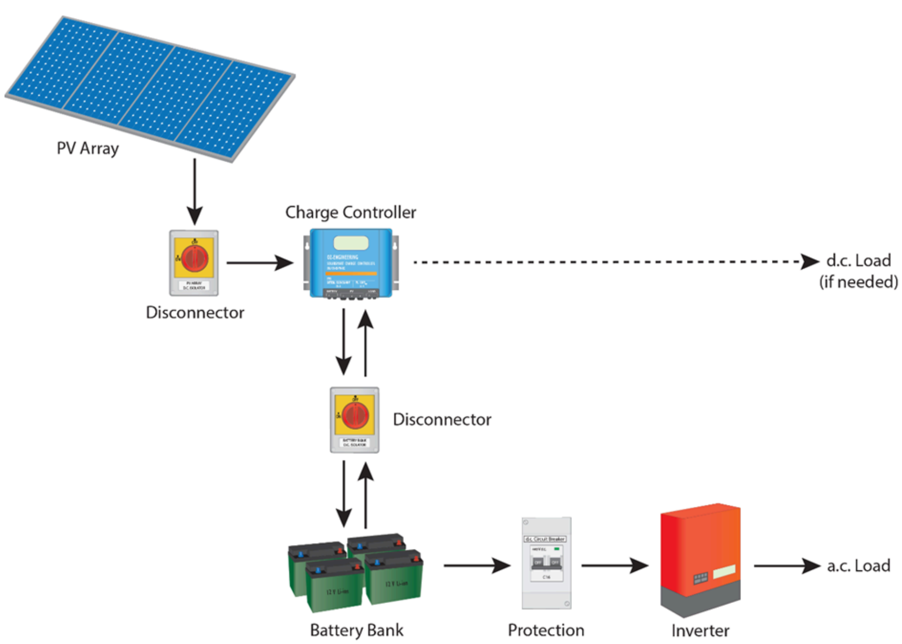
Operating window (d.c. voltage range)	The upper and lower d.c. input voltage limits. If the PV array delivers a voltage that is outside of these limits, then the controller will not be able to deliver an output. Consideration should be given to ensure the operating window is suitable for the expected variations in array output.
Max PV current	Indicates the maximum input current that the controller is capable of receiving from the PV array without sustaining damage. The maximum PV current rating should be equal to or greater than the short circuit current (Isc) of the array.
Max PV power	Indicates the maximum input power that the controller is capable of receiving from the PV array without sustaining damage. The maximum PV power rating is simply the product of the maximum PV voltage rating and the maximum PV current rating.
Efficiency	Indicates the percentage of PV input energy that is effectively transferred to the battery charging output terminals. • PWM controllers typically operate at 90 to 95% efficiency. • MPPT controllers typically have an efficiency of 98% or more.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Charge Controller Arrangements

The following diagram shows the basic arrangement of a charge controller within a PV battery storage system:



Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 6 parts designed to develop your understanding of the key features, ratings and specifications of charge controllers.

Topic 3.2 Learning Activity

Last modified: Thursday, 7 December 2023, 12:10 PM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Multiple Mode Inverter Operating Modes

The specific operating modes of a multiple mode inverter may vary depending on the manufacturer and particular model, but in general the main modes are:

- Grid-connect mode.
- Standalone mode.
- Hybrid mode.

When operating in grid-connect mode, the inverter functions as a standard string inverter, allowing usage of PV energy and importing/exporting energy to/from the grid as needed.

When operating in standalone mode, the grid supply is not used. The inverter supplies circuits from the PV array or batteries, and uses any excess PV energy to charge the batteries. The grid protection prevents backflow of energy into the grid.

Hybrid mode functions as a combination of the grid-connect and standalone modes, depending on the availability of the different energy sources. Energy supply can be optimised based on the particular energy profile of the installation, e.g. to minimise grid-import.

For some hybrid inverters there will be a delay when switching between grid-connect and standalone mode, meaning that supply to essential circuits will be interrupted. However, some hybrid inverters provide UPS functionality, meaning that switchover from grid to alternate supplies is instant.

Supply Types and Definitions

AS/NZS 4777.1:2024 defines the following types of supply that can be associated with a grid-connected inverter energy system (IES).

AS/NZS 4777.1:2024 – Supply Types and Definitions		
Type	**Definition**	**Example**
Normal supply	The source of supply that the electrical installation is supplied from under normal conditions of operation.	The grid supply, or could possibly be a generator supply for off-grid situations.
Supplementary supply	A supply system intended to operate in conjunction with the normal supply, i.e. operating in parallel.	A PV array with a grid-connected inverter.
Alternative supply	A supply system intended to maintain the functioning of all or part of an electrical installation when the normal supply is interrupted.	A PV array with a multiple mode grid-connected inverter capable of supplying essential circuits when the grid fails.

?

Independent supply	A system intended to supply the functioning of all or part of an electrical installation, as an islanded operation instead of the grid supply, whilst the grid supply remains connected to the electrical installation.	A PV array and battery system connected to a multiple mode grid-connected inverter which does not allow export to the grid, i.e. the grid supply is for charging only.
Substitute supply	An electrically separated supply to a single socket-outlet intended for use when the normal supply is interrupted, where another energy source is available, but the substitute supply is limited to the energy source available.	A 15 A single socket outlet provided on some multiple mode inverters, intended to supply a load in the event of grid failure.

Multiple Mode Inverter Ratings

When selecting a multiple mode inverter for a PV battery storage system, the ratings must be carefully matched to the installation requirements. The following table shows some of the key ratings to be considered.

Multiple Mode Inverter Ratings	
Battery Ratings	**Description**
Nominal battery voltage	Indicates the nominal charging voltage that the controller will apply to the batteries – typically 12, 24 or 48 V, typically manually selectable or auto-detect.
Max charge current	Indicates the maximum charging current that the inverter is capable of delivering to the batteries.
Max discharge current	Indicates the maximum discharge current that the inverter is capable of receiving from the batteries.
PV Rating	**Description**
Max input power	The maximum power the inverter is capable of receiving from the PV array.
d.c. operating window (voltage range)	The upper and lower d.c. input voltage limits, i.e. from the PV array/batteries. The inverter will not be able to utilise a PV input that is outside of these limits.
Max input current	Indicates the maximum current that the inverter is capable of receiving from the PV array.
a.c. Ratings	**Description**
Continuous rating	The maximum power at which the inverter can operate continuously without overheating.

Half hour rating	The maximum power at which the inverter can operate over a half hour period without overheating.
a.c. operating window (voltage range)	The upper and lower a.c. input voltage limits, i.e. from the grid. The inverter will not be able to transfer energy from the grid that is outside of these limits.
Max output current	The maximum a.c. output current that the inverter is capable of exporting to the grid.
Surge rating	The maximum inrush current the inverter can withstand without damage.
Standalone Ratings	**Description**
Max output power	The maximum power that the inverter is capable of supplying to essential circuits during an outage.
Max output current	The maximum current that the inverter is capable of supplying to essential circuits during an outage.
Nominal voltage	The nominal voltage that the inverter will supply to essential circuits during an outage.
Other Ratings	**Description**
Peak efficiency	The maximum efficiency the inverter can achieve.
Temperature range	The upper and lower temperature limits at which the inverter can operate.
IP rating	The ability of the inverter to withstand the ingress of water and dust.

Inverter Regions

There are three ‘regions’ in Australia that will affect some of the particular operating parameters required for a grid-connected inverter. Each region is based on the type of grid to which the inverter will be connected. The reason for this is that a given inverter system has the potential to have a more significant effect on a smaller grid than a larger grid.

Region	Grid Connection
Australia A	Connected to large, interconnected power grid
Australia B	Connected to small, interconnected power grid

Australia C	Connected to isolated/remote power grid

Most installations will fall into the 'Australia A' category. Several requirements in AS/NZS 4777.2:2020 require slightly different operating parameters depending on the particular region.

Grid Protection

Grid-connect inverter systems are required to incorporate a grid protection device that disconnects the inverter system from the grid in the event that the supply is disrupted, or operates outside of pre-determined voltage or frequency limits. Grid protection is typically incorporated within the inverter and consists of:

- Passive anti-islanding protection.
- Active anti-islanding protection.

Passive Anti-islanding Protection

Passive protection disconnects the inverter from the grid when an abnormal grid voltage or frequency is sensed. The voltage limits for passive protection are the same for all regions:

- A voltage of ≤70 V must be disconnected within 2 seconds.
- A voltage of ≤180 V must be disconnected within 11 seconds.
- A voltage of ≥265 V must be disconnected within 2 seconds.
- A voltage of ≥275 V must be disconnected within 0.2 seconds.

The passive protection frequency limits vary slightly by region, as described in the following table.

Region	Passive Protection Frequency Limits
Australia A and Australia B	• A frequency of ≤47 Hz must be disconnected within 2 seconds. • A frequency of ≥52 Hz must be disconnected within 0.2 seconds.
Australia C	• A frequency of ≤45 Hz must be disconnected within 6 seconds. • A frequency of ≥55 Hz must be disconnected within 0.2 seconds.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Multiple Mode Inverter Settings

The specific settings and functions available on a multiple mode inverter will depend on the particular model and application. However, some common setting and features that may be available are described in the following table:

Multiple Mode Inverter Settings	
Country/region	Selecting the country/region should enable the inverter to automatically set up various other parameters, such as language, grid voltage, frequency and grid protection limits.
Time/date	Setting the time and date is important for the correct functioning of energy monitoring, management and data logging features.
Power source priority	Sets how the inverter should optimise energy usage by prioritising the use of different energy sources at different times, i.e. grid, PV and battery.

Battery charging	Provides a means of setting parameters such as battery type, charging voltage, max charge voltage, depth of discharge, and charging mode.
Standalone supply	Provision may be provided to set the electrical parameters for the standalone supply.
Overload protection	Provision may be provided to adjust the overload trip settings of the inverter's internal protection.
Network settings	Allows for connection of the inverter to a local network.

You should always refer to the manufacturer's instructions when setting up a multiple mode inverter for the first time.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 8 parts designed to develop your understanding of multiple mode inverter waveforms, ratings, and specifications.

Topic 3.3 Learning Activity

In this skills practice, you are required to select PCE, including charge controllers and multiple mode inverters, for given grid-connect system scenarios.

Topic 3.3 Skills Practice

Undertaking this topic quiz will help you to confirm your understanding of the different types, features and ratings of inverters and charge controllers used in grid-connected battery storage systems.

Topic 3 Content Quiz

Last modified: Tuesday, 5 November 2024, 2:21 PM

CONTACT US

02 6262 7055

enquiries@energyspace.com.au

View

Introduction

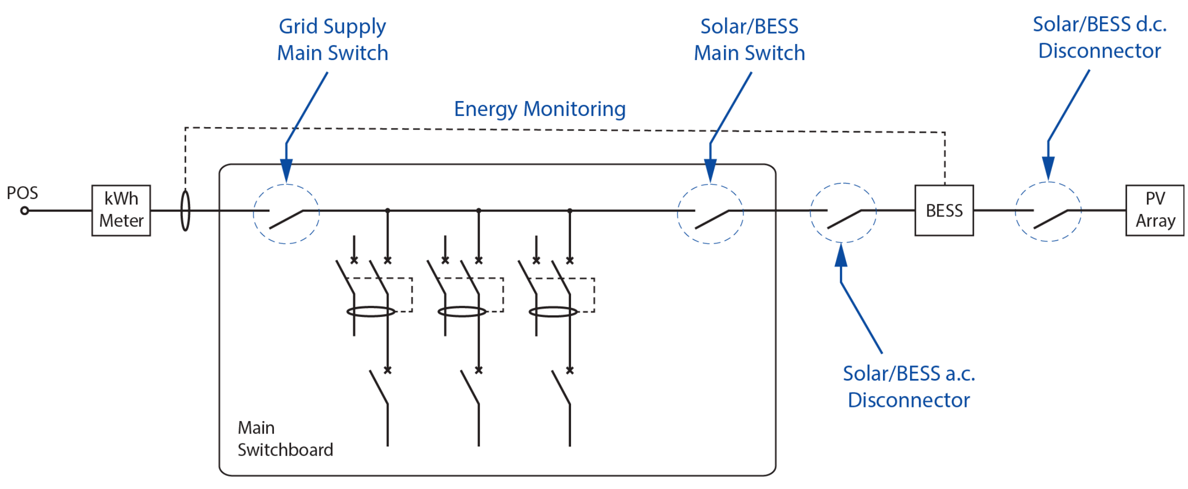
In this topic you will learn the various factors, standards and safety practices associated with the installation of grid-connected PV battery storage systems, including interpreting specifications, installation layouts and requirements for batteries, charge controllers, inverters, balance of system (BoS) equipment, and labelling/identification.

Battery System Diagrams

As discussed in Topic 1, there are several ways of arranging battery storage in an installation, depending both on the manufacturer and the desired functionality. The following schematic diagrams show the arrangement of the a.c. and d.c. coupled systems discussed previously on Content Page 1.4.

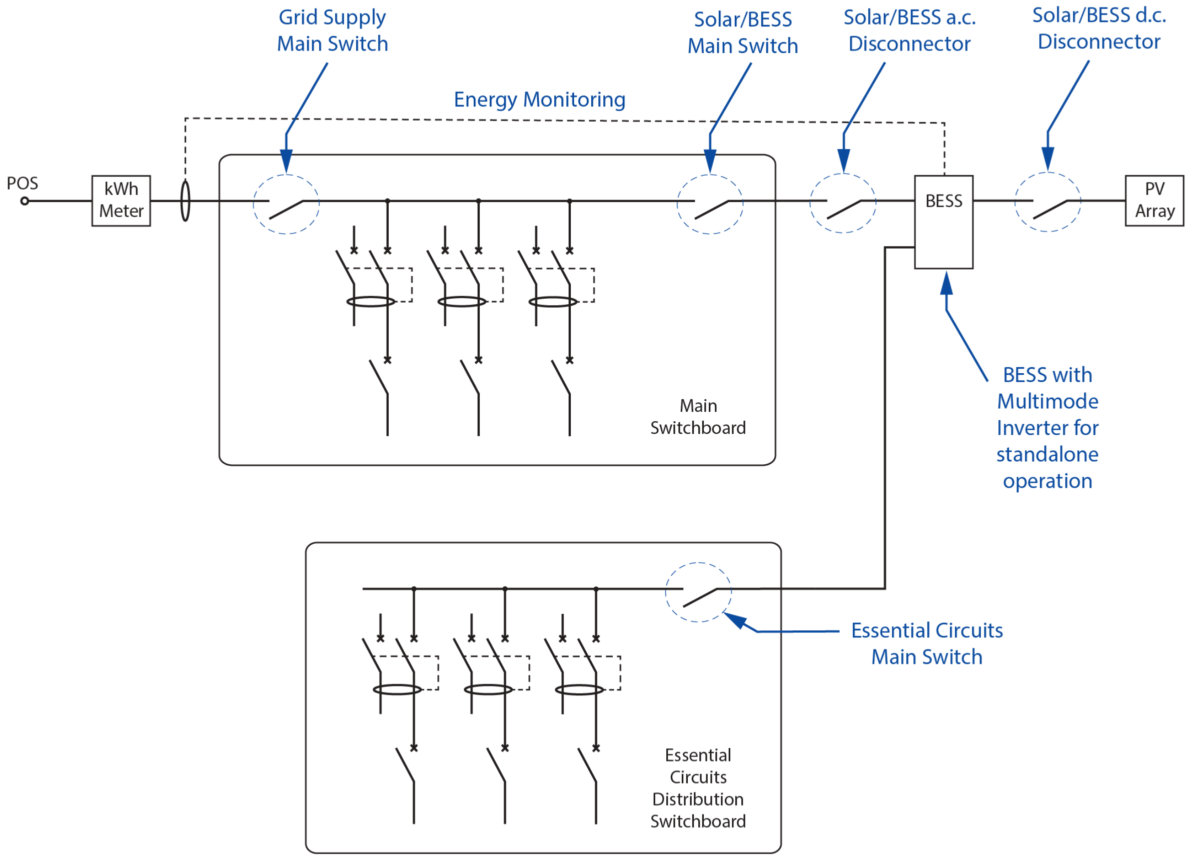
d.c. Coupled Systems

The following diagram shows the arrangement for a d.c. coupled integrated BESS, without emergency power capability. Note that a pre-assembled integrated BESS is one that incorporates PCE and therefore has an a.c. output:

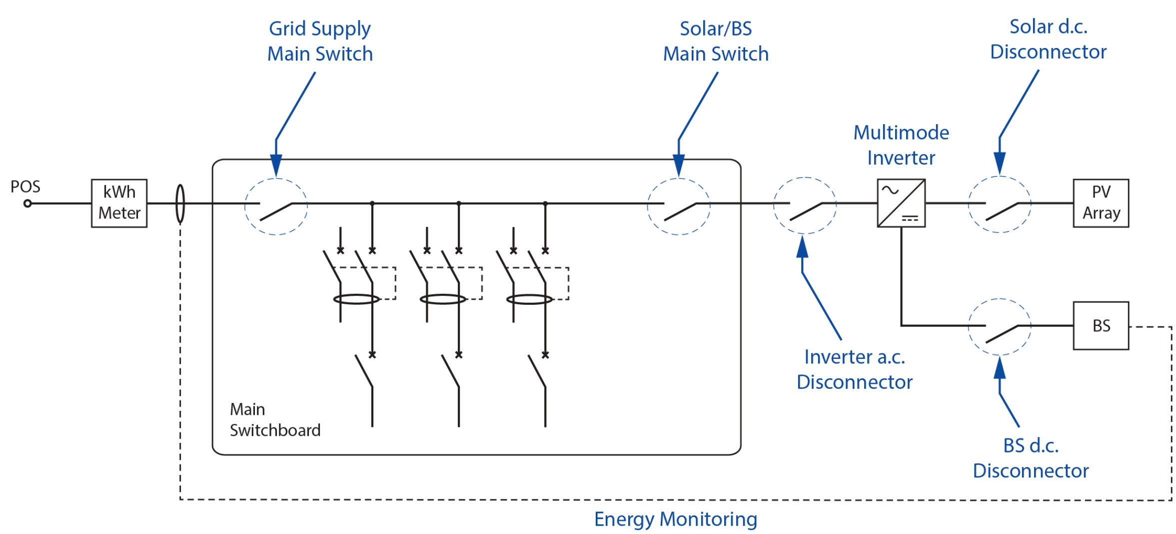


This next diagram shows a similar system, except that this one is designed to be capable of maintaining supply to a set of essential circuits during a grid outage:

?



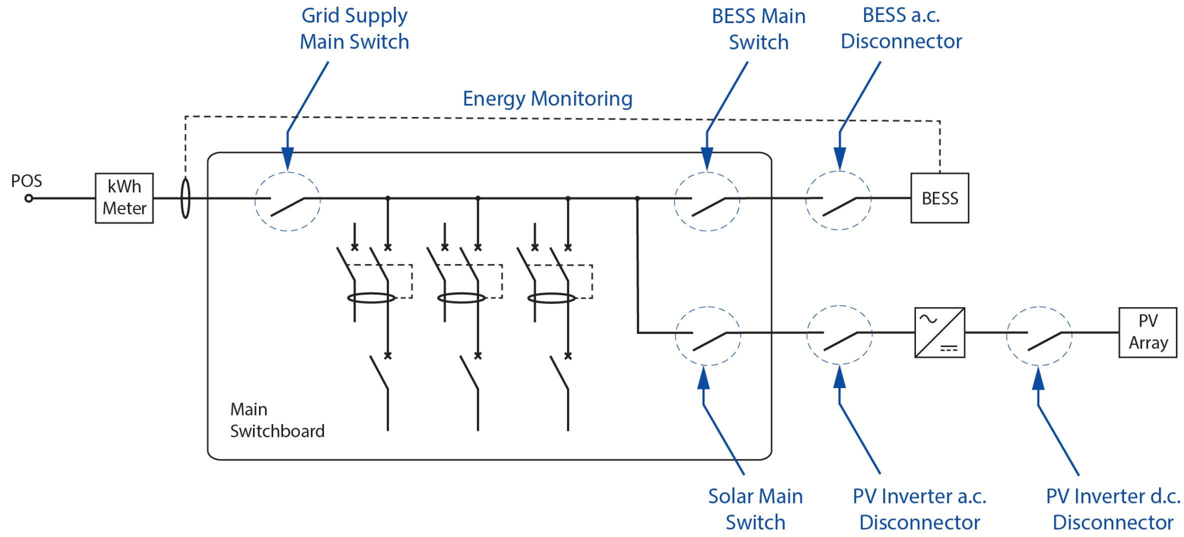
This next diagram shows a pre-assembled battery system (BS) arrangement. Note that a pre-assembled battery system is one that does not incorporate PCE, and therefore has a d.c. output:



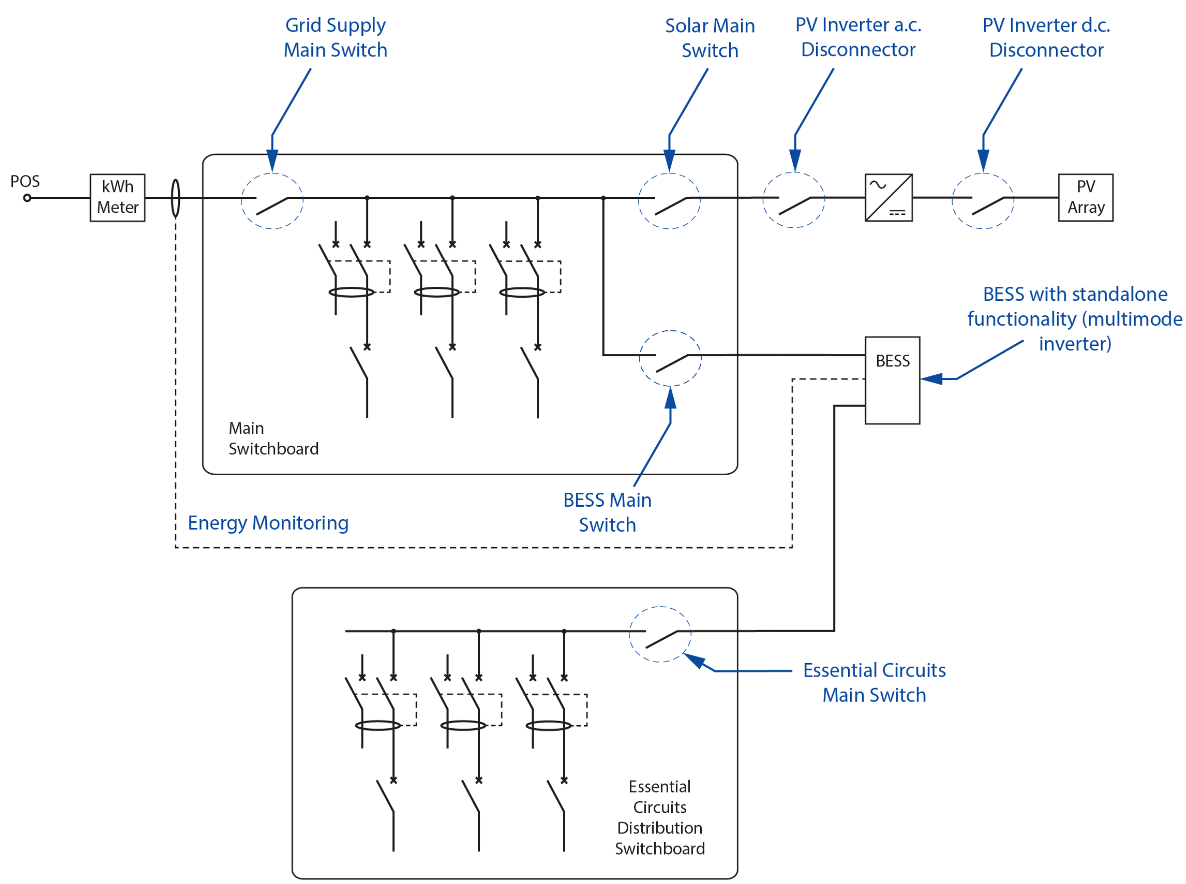
The arrangement above is shown with no emergency supply, however if the multiple mode inverter has standalone supply port, then a set of emergency circuits can be connected for continued supply in the event of grid failure.

a.c. Coupled Systems

The following diagram shows an arrangement for an a.c. coupled PV battery system, without emergency power capability:



This next diagram shows a similar arrangement that is capable of providing emergency supply to a set of essential circuits:

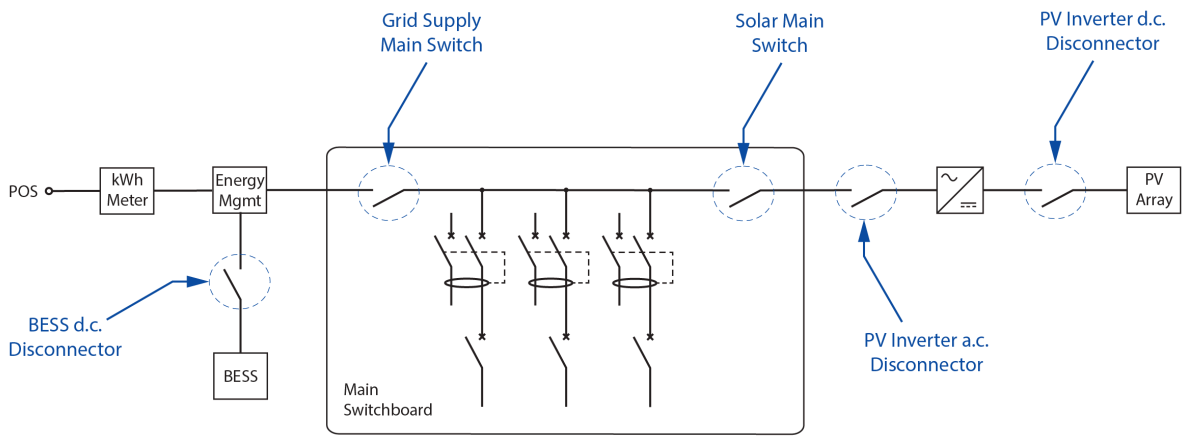


Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Other System Arrangements

The diagram below shows the arrangement for a different battery system product that incorporates a separate energy management module, installed between the installation metering and grid supply main switch:



Earthing of Battery Systems

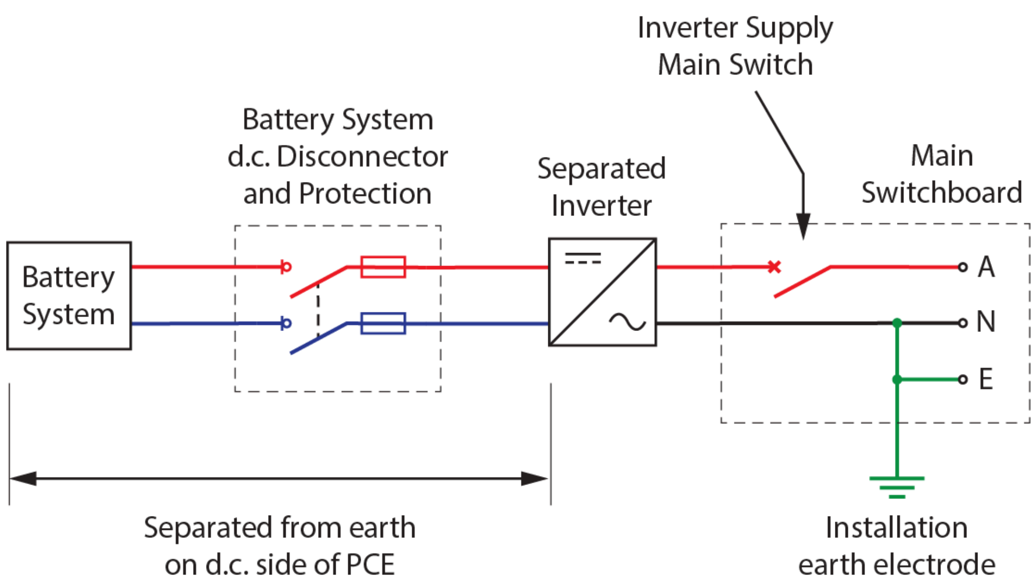
Every BESS installed in a low voltage electrical installation will need to be connected to the MEN system. AS/NZS 5139:2019 states that a BESS must be earthed in accordance with the manufacturer's instructions and AS/NZS 3000 earthing requirements.

There are four categories of earthing arrangements for grid-connected battery systems

- Floating/separated.
- Direct earthed.
- Resistive earthed.
- Non-separated PCE output circuit referenced to earth.

Floating Systems

There are two arrangements that are classified as a floating system. The first arrangement involves a system where the battery supply is not earthed, as shown below:



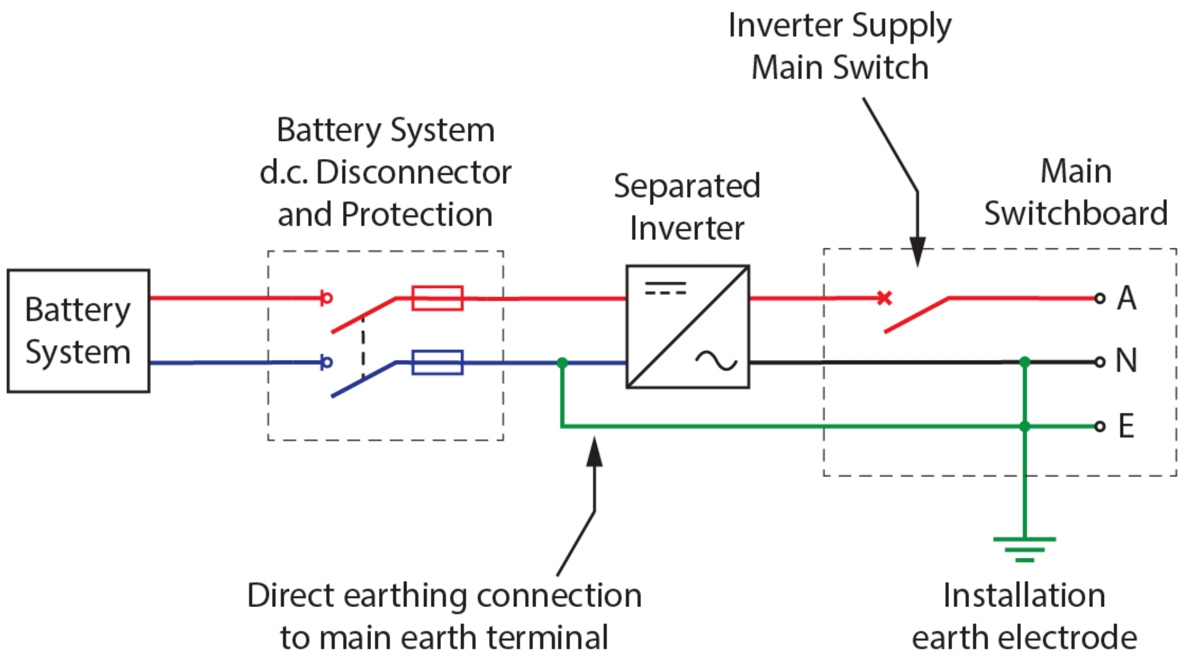
The second floating arrangement is one in which both sides of the inverter are unearthed, however given the widespread use of the MEN system, this is not generally applicable to grid-connected systems.

In a floating system arrangement:

- The power conversion equipment (PCE) (e.g. inverter) is an electrically separated type.
- The battery side of the inverter must not be connected to earth.
- For systems operating above 60 V d.c.
  - Earth fault monitoring is required.
  - Metallic equipment enclosures must be equipotentially bonded.
- Note that an additional inverter d.c. disconnector is required to be installed adjacent to the inverter if the interconnecting cabling between the battery system and the inverter are more than 2 metres in length.

Direct Earthed Systems

A direct earthed system is one in which one of the battery supply conductors is earthed, as shown below:

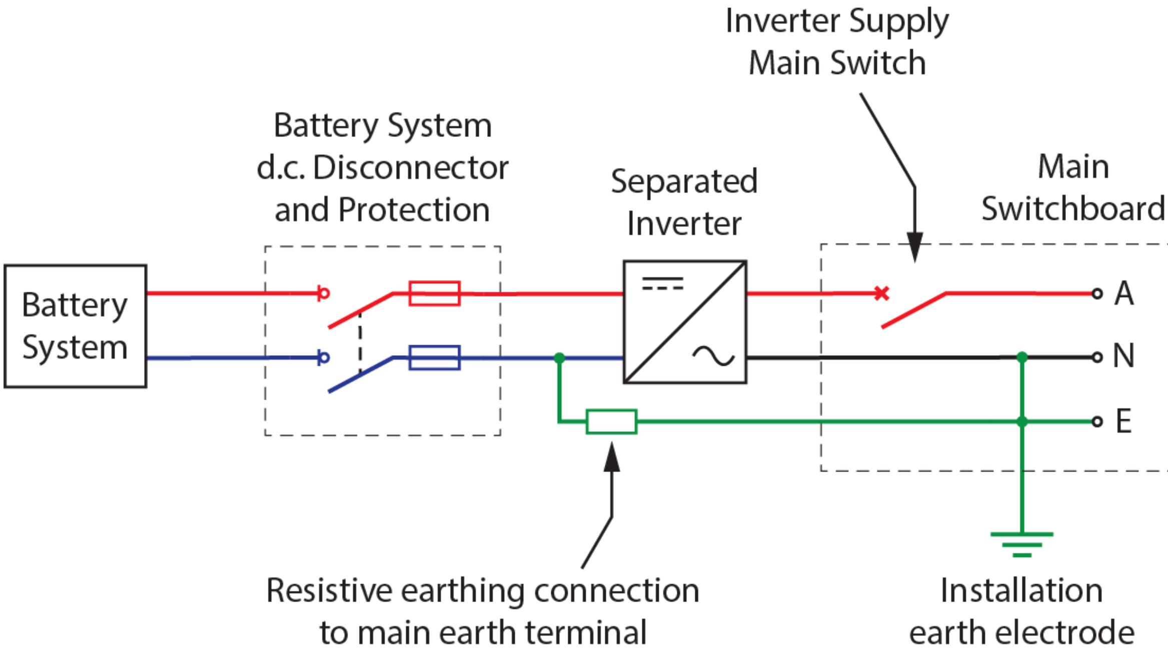


In a direct earthed system arrangement:

- The PCE (e.g. inverter) is an electrically separated type.
- The direct earth connection must be made between the battery system d.c. disconnector and the inverter. Having the earth connection on the load side of the battery isolator allows the batteries to become 'floating' when isolated, which is safer when undertaking maintenance etc.
- The battery system earthing conductor must be sized to be capable of carrying the prospective earth fault current for the battery system protection device trip time.
- Note that an additional inverter d.c. disconnector is required to be installed adjacent to the inverter if the interconnecting cabling between the battery system and the inverter are more than 2 metres in length.

Resistive Earthed Systems

In a resistive earthed system, one of the battery supply conductors is earthed through a series resistance, as shown below:

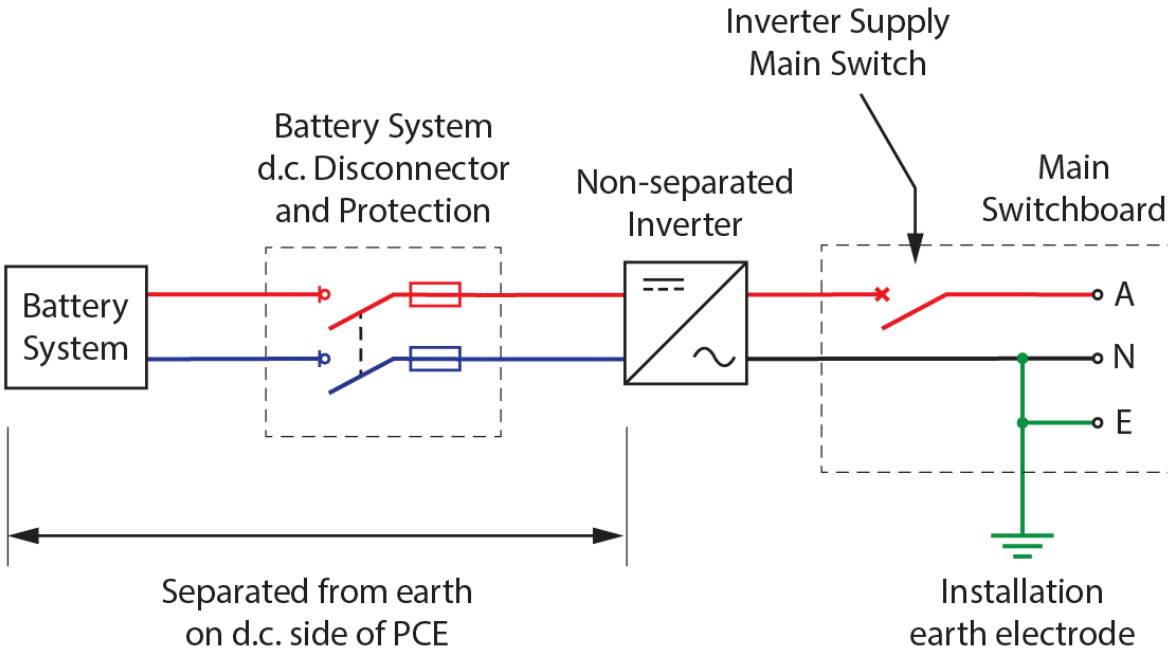


In a resistive earthed system arrangement:

- The PCE (e.g. inverter) is an electrically separated type.
- The resistive earth connection must be made between the battery system d.c. disconnector and the inverter.
- The battery system earthing conductor must be sized to be capable of carrying the prospective earth fault current for the battery system protection device trip time.
- The resistive earth significantly reduces the prospective earth fault current.
- Note that an additional inverter d.c. disconnector is required to be installed adjacent to the inverter if the interconnecting cabling between the battery system and the inverter are more than 2 metres in length.

Non-separated PCE Output Referenced to Earth

This last system is one in which a non-separated inverter is used and the battery system is not earthed:



In this type of system:

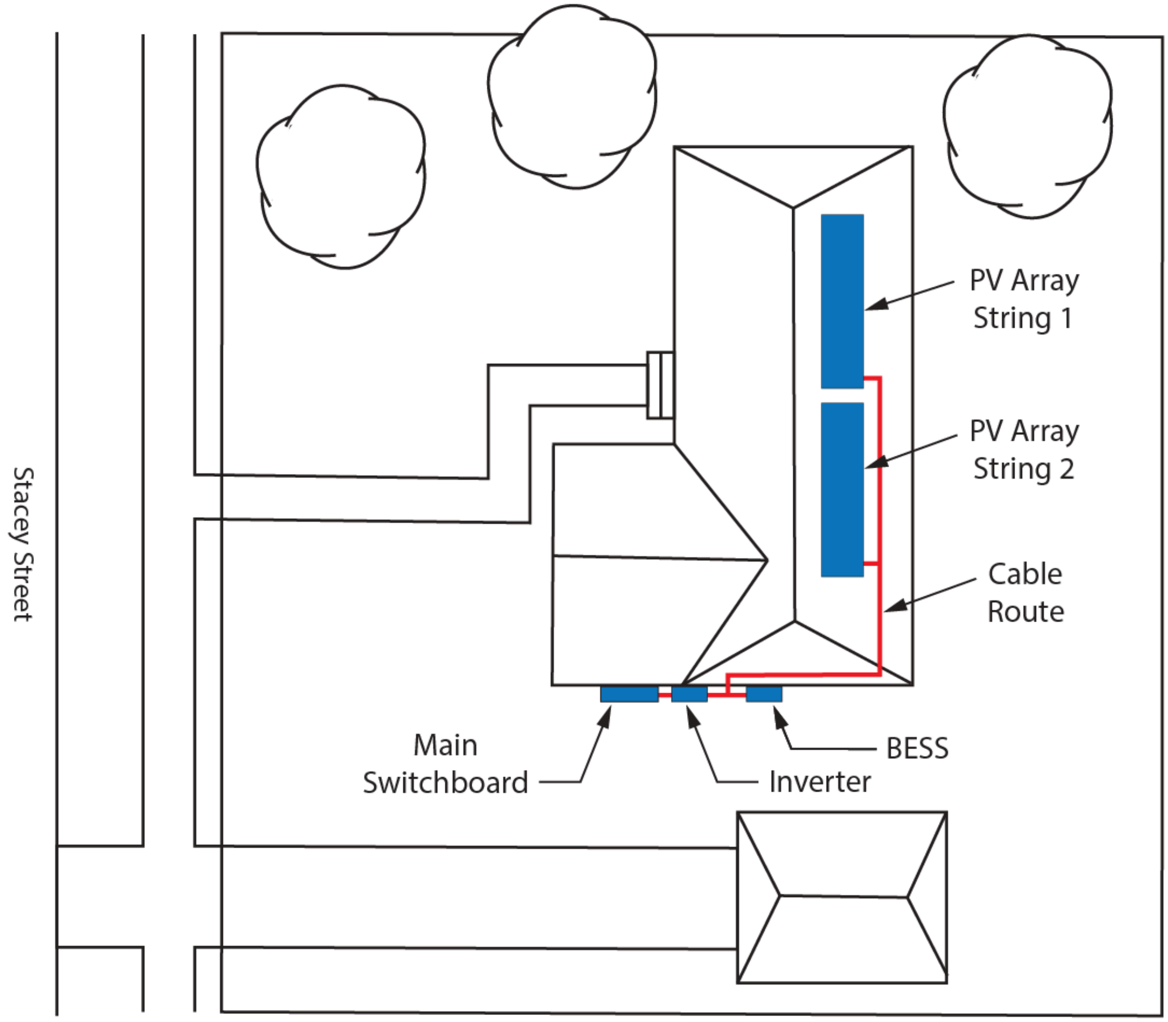
- The PCE (e.g. inverter) is a non-separated type.
- The battery side of the inverter must not be connected to earth.
- For systems operating above 60 V d.c.
  - Earth fault monitoring is required.
  - Metallic equipment enclosures must be equipotentially bonded.
- Note that an additional inverter d.c. disconnector is required to be installed adjacent to the inverter if the interconnecting cabling between the battery system and the inverter are more than 2 metres in length.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

Equipment Layout Diagrams

The positioning and cable routes for grid-connected battery system are typically specified on floor plans and site plans. The purpose of these diagrams is to show workers where to position, install and locate equipment for the purposes of installation, maintenance and for general safety and isolation purposes. An example of a site plan is provided below:



Types of battery system equipment that may be indicated on a site or floor plan includes:

- PV arrays.
- Batteries/BESS.
- PCE – inverters, charge controllers.
- Energy metering/management equipment.
- Isolation points.
- Main switchboard.
- Wiring routes.

This learning activity consists of 10 parts designed to develop your understanding of schematic and physical layout diagrams for grid-connected battery storage systems.

Topic 4.1 Learning Activity

In this skills practice, you are required to interpret schematic and system layout diagrams to determine the quantity and locations of equipment for a battery storage system.

Topic 4.1 Skills Practice

Last modified: Tuesday, 5 November 2024, 3:31 PM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Battery System Identification

Where an electrical installation includes a grid-connected battery storage system, a variety of signs and labels must be provided to ensure the safety of personnel who need to work on the installation.

The key requirements for labels and safety signage are provided in AS/NZS 4777.1:2024 and AS/NZS 5139:2019:

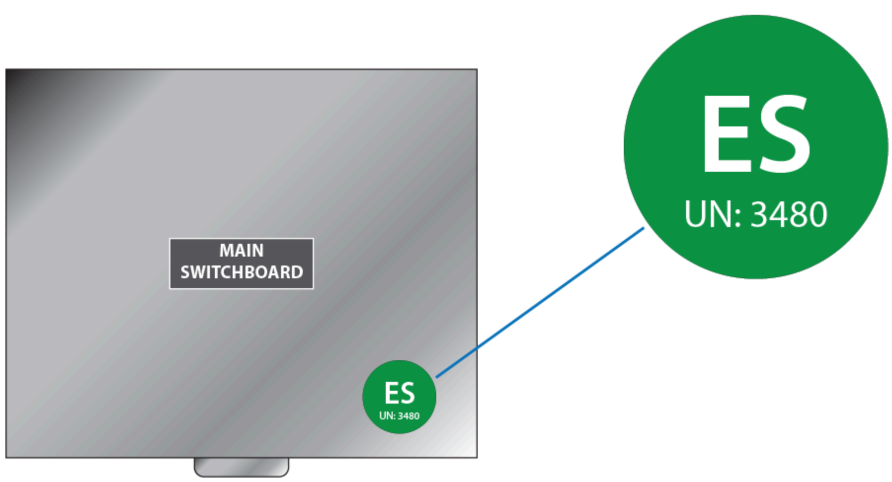
- Section 6 of AS/NZS 4777.1:2024 specifies the required signage and labelling relating to grid-connected inverter supplies. Appendix A provides further guidance and examples of compliant signs.
- Section 7 of AS/NZS 5139:2019 specifies the required signage and labelling relating to battery storage systems. Appendix B provides further guidance and examples of compliant signs.

Parts of the system that need to be clearly identified include:

- Battery type, location and parameters.
- Particular hazards and controls for the system.
- Switchgear and controlgear.
- The inverter and associated switchboard(s).
- System wiring.
- The normal supply main switch (in the connecting switchboard).
- Safe shutdown procedures.

Identification of Battery System

A green circular sign must be placed on the main switchboard to warn emergency services that a battery supply exists. The sign must indicate the battery chemistry using the standard UN code. The following example shows a compliant sign where lithium-ion batteries are installed:



?

Note that 'UN 3480' indicates lithium ion or lithium polymer batteries. Some other common UN battery codes are indicated in AS/NZS 5139:2019 Table B.1.

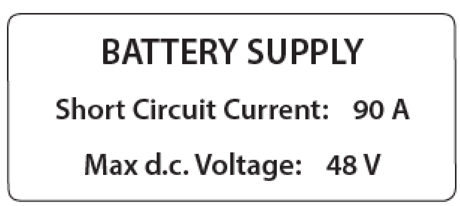
In addition, a layout diagram must be provided if the location of the system equipment is not obvious. The diagram should show the locations of batteries, PCE etc., as well as where to find the shutdown procedures, and should be mounted either at the main switchboard, meter box and/or fire panel.

Battery System Signage

Where battery systems are accessible in an enclosure or battery room, they must have signage either on or adjacent to the enclosure or entries to the room that states:

- Danger – restricted access – authorised personnel only.
- The maximum system voltage and current.
- Required PPE.

Examples of compliant signage are provided below:



System Hazards

If a battery system presents any of the following particular hazards then danger or warning signs must be provided:

- Explosive gas.
- Toxic fumes.
- Chemical hazards (e.g. corrosive).

- Arc flash hazard.

Signage indicating how to deal with a chemical leak or spill must also be provided adjacent to the battery system. In addition, the Safety Data Sheet (SDS) for the particular battery chemistry must be provided and stored at the main switchboard and/or the fire panel of the installation.

Identification of Wiring

Wiring between the batteries and the inverter must be labelled at least every 2 m to indicate the type of energy source (e.g. 'SOLAR' or 'BATTERY'). An example of compliant labelling, designed to be attached with cable ties, is shown below:

Switchgear and Controlgear

Battery system isolators and protection devices must be clearly identified. The following images show typical examples of these signs/labels:

In addition, these devices must be given a unique number that corresponds to the system wiring diagrams.

For system switches designed to disconnect DVC-B or DVC-C systems into blocks that operate at DVC-A (in accordance with AS/NZS 5139:2019 Clause 6.3.1.3.10), the following warning sign must be fixed to the device:

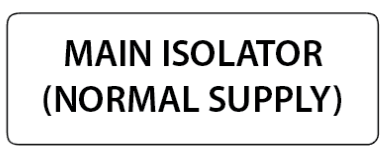
Any metering, shunts and alarms must also be labelled and identified by a unique number that corresponds to the system diagrams.

Inverter Signage

Where there are multiple parallel battery systems connecting to the PCE, a warning sign must be provided adjacent to the PCE to ensure personnel understand that isolating just one isolator will not completely isolate the battery supply.

Switchboard Signage

There are several items that must be identified at the switchboard to which the battery system inverter directly connects (i.e. the connecting switchboard), as shown in the following table:

Connecting Switchboard Signage Requirements	
Signage Requirements	**Example**
A warning sign must be provided indicating that there are multiple supplies.	
The main switch for the inverter system must be clearly labelled.	
The main isolator/switch for the normal supply must also be labelled.	 (where the connecting switchboard is the main switchboard)  (where the connecting switchboard is a distribution board)
If the inverter is not installed next to the switchboard, then its location must be indicated.	

In the case that the connecting switchboard is a distribution board, then a warning sign must be provided at the main switchboard, and at each intermediate switchboard. The sign must indicate where to isolate the inverter supply. An example is shown below:

In larger installations, it may be necessary to indicate the locations of inverters on a building layout drawing, provided at the main switchboard and/or fire panel.

Shutdown Procedure Signage

Signage indicating the shutdown procedure for the battery system must be provided adjacent to the battery system PCE and adjacent to the relevant switchgear to be operated.

Consideration also needs to be given to the risks posed to emergency services workers. If the building has a fire panel, a sign that states “MULTIPLE SUPPLIES” must be provided that indicates the location of the shutdown procedure signage and switchgear.

If the alternative energy source will not be de-energised when the IES is shutdown, for example the batteries, then this must be stated in the emergency shutdown procedure.

This learning activity consists of 5 parts designed to develop your understanding of the standards and requirements for identification and labelling of grid-connected battery storage systems.

 **Topic 4.2 Learning Activity**

Undertaking this topic quiz will help you to confirm your understanding of the standards and safety practices for installing grid connected battery storage systems.

Topic 4 Content Quiz

Last modified: Tuesday, 5 November 2024, 3:34 PM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Introduction

In this topic you will learn about the factors to consider when selecting and sizing battery banks, wiring, earthing, control and protection. You will practice selecting equipment for given scenarios, and also learn how to estimate the energy capacity/yield for a given system.

Health and Safety Considerations

Once the proposed site has been surveyed and the relevant data collected, the task of selecting and arranging equipment for battery systems is primarily a desktop/computer-based job.

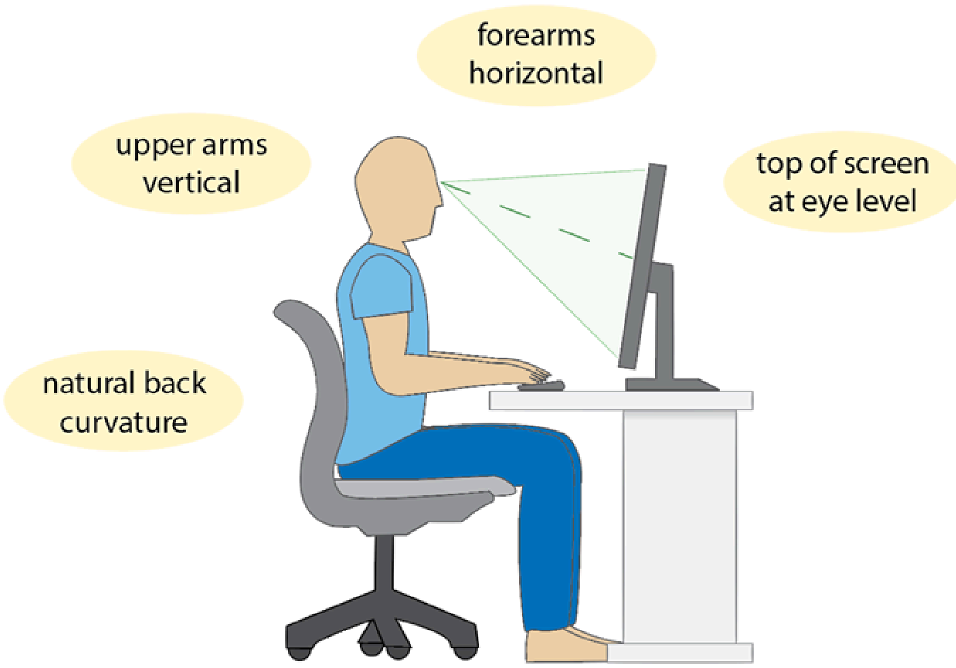
Although it may not appear hazardous, there are several health and safety risks associated with using a computer, particularly when used for extended periods. Some of the main hazards, risks and control measures associated with computer use are detailed in the following table.

Hazards and Safety – Computer Use		
Hazard	**Risk**	**Control Measures**
Poor lighting (too much or too little).	• Eye strain. • Headaches.	• Adequate workplace lighting. • Position computer display to minimise glare and reflection. • Set suitable screen brightness and contrast.
Incorrect posture.	• Muscle strains.	• Maintain correct posture.
Repetitive movements (mouse use, typing).	• Occupational overuse syndrome (OOS).	• Take regular breaks and conduct stretches of hands, arms, shoulders, neck and back.

When using a computer, your chair, desk and computer should be arranged so that:

- Your elbows are bent at roughly 90^o.
- Your forearms are parallel with the floor.
- Your wrists are straight.
- Your shoulders are relaxed.
- You don't need to twist your body or over-reach to use the computer equipment.

The following diagram highlights the correct posture for computer use to reduce the risks of muscle strains, ligament damage and occupatic overuse syndrome (OOS).



This learning activity consists of 3 parts designed to develop your understanding of the health and safety considerations for undertaking design work.

Topic 5.1 Learning Activity

Last modified: Wednesday, 28 August 2024, 11:54 AM

CONTACT US

02 6262 7055

enquiries@energyspace.com.au

View

Battery System Selection Factors

There are several factors that need to be considered when selecting and sizing a battery storage system for an installation with an existing PV array. Some of the main factors are described in the following table.

Battery System Selection and Sizing	
Factor	**Considerations**
Site Features and Characteristics	*Load Profile* It's important to factor in the energy needs of the installation when sizing the battery system. Details of the load profile of the site should be included in the site survey report. *Grid Supply* It's important to consider the reliability of the grid supply. A larger battery capacity may be required if the area is subject to regular grid outages. It's also important to consider the network provider import and export tariffs. This will impact how to optimise battery usage to minimise energy bills. *PV Supply* The size of the PV system will affect the optimal size for the battery storage. The larger the PV system, the more excess energy is potentially available for storage. *Regulatory Requirements* It's essential to verify the local network provider requirements relating to grid-connected energy systems, to confirm that all equipment selections are compliant.

?

Customer Requirements	*Energy Goals* What is the customer looking to achieve? E.g. maximising PV energy usage, or reducing reliance on grid. Is blackout protection required for essential circuits? If so, what is the essential load? The greater the essential load, the higher the battery system surge rating will be needed. The higher the load and the longer the duration of autonomous operation required, the larger the battery capacity will be needed. *Budget* What is the customer willing to spend, and what is the financial viability of the system? Factors to consider include the cost of equipment, installation costs, ongoing maintenance costs, potential savings on energy bills, and payback period.
Battery System Features	*Battery Type* What is the appropriate battery chemistry (e.g., lithium-ion, lead-acid) for the situation? Factors to consider include cost, cycle life, DoD, warranty and potential environmental impacts. *System Management* What degree of monitoring and control is desired? System management software can be used to optimise battery performance by controlling when to charge and discharge the battery.

Battery Sizing

Optimal battery capacity will depend on the amount of excess PV energy generated during the day, and the amount of imported energy the customer wishes to offset in the evening/at night.

Worked Example – Sizing a Battery System

Consider that a customer uses an average of 16 kWh per day. 6 kWh of this is consumed during daylight hours, and the remaining 10 kWh is consumed at night. A PV array installed at the premises provides an average daily energy output of 24 kWh.

If 6 kWh of PV energy are consumed during the day to supply the installation's energy needs, it can be determined that there will be 18 kWh of excess PV energy available to be stored:

24 – 6 = 18 kWh

This is the maximum viable size for the battery system based on the installation.

If the customer wants to reduce their reliance on the grid as low as possible, then the batteries need to be capable of providing 10 kWh of energy each night. However, the selected Li-ion batteries have a DoD of 90%, therefore:

10 / 0.9 = 11.1 kWh

This is the minimum viable size for the battery system based on the customer's needs.

Consider that based on the advice provided, the customer chooses a 13 kWh battery system, for a total cost of $14,000 installed.

The system should effectively offset the customer's energy bill, with an additional 5 kWh being exported to the grid each day.

If the import tariff at the site is 33 c/kWh, then the customer will save $1,204.50 each year by using the batteries instead of importing energy at night:

$0.33 x 10 kWh = $3.30 saved per day

Note that the customer will also forgo the income from exporting the 10 kWh. If the export tariff is 5 c/kWh, then this will equate to a loss of $

-$0.05 x 10 kWh = -$0.50 per day

This means that the net gain for the customer is $2.80 per day:

$3.33 – $0.50 = $2.80 net savings per day

Over the course of a year, this will equal:

$2.80 x 365 days = $1,022 saved per year

This means that the 'payback period' for the selected battery system would be approximately 13.7 years:

14,000 / 1,022 = 13.7 years

Warranty Period

Currently available battery storage systems typically offer a warranty period of 10 years. It is generally understood that after this period, the battery performance is likely to be reduced. For this reason, the payback period should ideally be less than 10 years to ensure the system will be economically viable for the customer.

A customer who purchases a system with a 10-year warranty, and a payback period of 10 years, is essentially just paying for 10 years' worth of electricity bills upfront.

This learning activity consists of 5 parts designed to develop your understanding of the factors to consider when selecting and sizing battery storage banks.

Topic 5.2 Learning Activity

Last modified: Wednesday, 28 August 2024, 11:56 AM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Selection of Switchgear, Wiring and Earthing

Selecting and sizing switchgear, wiring, and earthing equipment for grid-connected battery systems is crucial to ensure safe and reliable operation. The following table outlines the fundamental factors to consider.

Switchgear, Wiring and Earthing Selection	
Factor	**Impact**
Battery System Voltage	The voltage rating of d.c. switchgear and wiring must be greater than or equal to the nominal voltage of the battery system. Common battery system voltages include 48 V, 120 V, 240 V, 480 V, or higher.
Battery System Current	Switchgear and wiring must be rated to carry the maximum expected current for the battery system. Protection devices must also be rated to safely break the prospective battery short circuit current.
Installation Conditions	Switchgear and wiring systems must be suitably rated for the environmental conditions in which they're installed. For example, equipment installed outdoors may be subject to dust or rain, and must have a suitable ingress protection (IP) rating.
Australian Standards	Switchgear, wiring, and earthing must be selected and arranged in accordance with the requirements of relevant Australian standards, including: • AS/NZS 3000:2018 Electrical installations (Wiring Rules) • AS/NZS 5139:2019 Installation and safety requirements for photovoltaic (PV) arrays. • AS/NZS 4777.1:2024 Grid connection of energy systems via inverters – Installation requirements.

Proper selection and sizing of switchgear, wiring, and earthing equipment are critical to the safety and reliability of the battery system. It's al ? important to discuss the potential for future expansion of the system with the customer, and ensure that this is factored into the design if applicable.

Switchgear Requirements

Battery system protection devices and switch disconnectors must be selected in accordance with AS/NZS 3000:2018 and the additional requirements of AS/NZS 5139:2019. Some key requirements include:

- Battery isolators must disconnect all live conductors, including the battery system conductor that is earthed.
- Overcurrent protection devices and disconnectors must:
  - Be non-polarised.
  - Be rated for d.c.
  - Be rated to withstand maximum system voltage and short circuit current.
- In addition, switch disconnectors must:
  - Be rated to interrupt the full load current.
  - Have at least a pollution degree 3 classification.
  - Have a utilisation category of at least DC21B.

Wiring Requirements

Battery system d.c. wiring must be selected in accordance with AS/NZS 3000 and AS/NZS 3008.1.1, and must be:

- Double insulated (exceptions apply).
- Flexible cables.
- Segregated from a.c. wiring.

Decisive Voltage Classifications (DVC)

The decisive voltage classification (DVC) of multimode inverters/PCE is based on the rated operating voltages and the degree of separation between the battery port and ports for other energy sources (e.g. the grid port). The requirements for protection and enclosure of battery equipment will vary depending on the DVC of the system.

DVCs are defined in IEC62109-1 and some guidance is provided in Section 3 of AS/NZS 5139:2019. The following table shows the key voltage limits associated with the different classifications:

Decisive Voltage Classifications (DVC)		
Class	**a.c. Voltage Limit**	**d.c. Voltage Limit**
DVC-A	≤ 25 V r.m.s.	≤ 60 V d.c.
DVC-B	≤ 50 V r.m.s.	≤ 120 V d.c.
DVC-C	> 50 V r.m.s.	> 120 V d.c.

Earthing Requirements

Some key AS/NZS 5139:2019 requirements to consider when designing the battery storage earthing system are that:

- The size of earthing cables should be determined using AS/NZS 3000:2018 Table 5.1 (or by calculation in accordance with AS/NZS 3000:2018 Clause 5.3.3.1.3).
- If the installation earthing is not capable of carrying the battery system fault current then the BESS earthing cable should be connected directly to the earth electrode.
- A pre-assembled BESS that doesn't have electrical separation between the d.c. and a.c. ports must not be earthed.
- For DVC-B and DVC-C systems, all metallic enclosures must be equipotentially bonded with 6 mm^2 (minimum) cable.

- Floating or resistive earthed systems operating at DVC-B or DVC-C require earth fault monitoring and alarm.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 8 parts designed to develop your understanding of the factors to consider when selecting control devices, protection devices, earthing and wiring for grid-connected battery storage systems.

You will need access to copies of AS/NZS 4777.1:2024 and AS/NZS 5139:2019 to complete this learning activity.

Topic 5.3 Learning Activity

Last modified: Tuesday, 5 November 2024, 3:41 PM

CONTACT US

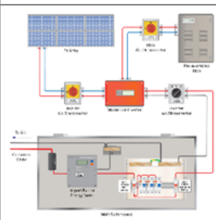
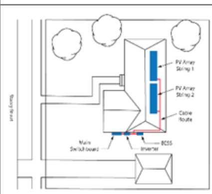
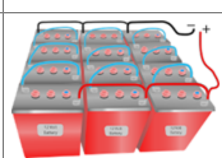
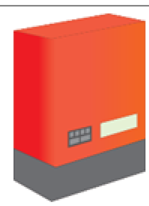
02 6262 7055

enquiries@energyspace.com.au

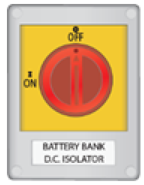
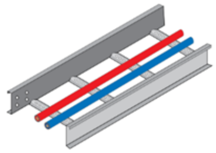
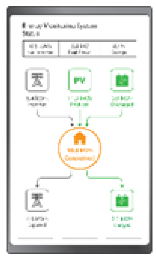
View

Battery System Documentation

To ensure compliance and correct functionality of the installation, it's important to provide detailed design documentation to the installer. The following table highlights the details to be documented in the design brief:

Design Documentation		
Element	**Illustration**	**Contents**
System Information		• Description of the system – purpose, capacity, intended use and warranty details. • Operating parameters – voltage, current, temperature etc.
Electrical Diagrams		• Site plan – showing equipment locations and cable runs. • Single-line diagram – showing electrical layout. • Circuit diagrams – showing system configuration and operation. • Wiring diagrams – showing required system connections.
Battery Selection		• Battery specifications – chemistry, make and model, configuration, capacity, voltage, and any other ratings.
PCE Selection		• PCE specifications – make and model, voltage, current and any other ratings. • Recommended settings – region, operating mode, protection, charging, supply priority etc.

?

BoS Equipment Selection	 	• Switchgear – types and descriptions, ratings and specifications. • Wiring systems – cable and insulation types, conductor sizes, support/protection, installation methods. • Calculations – current carrying capacity, voltage drop, prospective fault current etc.
Monitoring and Data Logging		• Monitoring system – type and description, equipment, frequency of data logging, storage, remote monitoring and recommended settings.
Safety Information		• Health, safety and environmental risk assessment – identified hazards, risks and controls. • Relevant standards – AS/NZS 3000, AS/NZS 4777, AS/NZS 5139 etc. • Safety procedures – start-up, operation, shut-down, emergency procedures, and maintenance schedules.
Contractor Details		• Designer name and contact details. • Installer name and contact details.

Check your understanding of the content by clicking the link below then undertaking the activity.

Load the Activity

This learning activity consists of 6 parts designed to develop your understanding of the information and documentation required to finalise the design of a grid-connected battery storage system.

Topic 5.4 Learning Activity

In this skills practice, you are required to select and size battery storage equipment for a given installation with an existing grid-connected PV power system.

Topic 5.4 Skills Practice

Undertaking this topic quiz will help you to confirm your understanding of the factors to consider when selecting and sizing battery banks, wiring, earthing, switchgear, and documenting system design. You will need access to copies of AS/NZS 4777.1:2024 and AS/NZS 5139:2019 to complete this topic quiz.

Topic 5 Content Quiz

Last modified: Tuesday, 5 November 2024, 3:42 PM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

View

Introduction

In this topic you will learn how to carry out isolation and shutdown procedures to allow maintenance tasks to be performed. You will also learn how to perform routine maintenance tasks on battery storage systems.

Battery System Maintenance

Battery storage systems require routine maintenance to ensure long life and correct functionality. The degree and frequency of maintenance is up to the owner – there are no mandated minimum maintenance requirements, however recommendations are provided in AS/NZS 5139:2019 Appendix H.

As a minimum, the manufacturer's guidance and relevant Safety Data Sheet (SDS) should be followed, and the outcomes of maintenance should be recorded in the owner's documentation. Typical maintenance procedures are outlined below:

Battery System Maintenance Procedures	
Environmental / Installation conditions	• Check ambient temperature and humidity. • Check that ventilation is adequate. • Check for the presence of heat sources. • Check that access and clearances are adequate.
Visual inspection	• Check for signs of damage or deterioration. • Check battery connections. • Check for the accumulation of dust, dirt and debris. • Check the condition of shrouds. • Check system logs (settings, state of charge, state of health, voltages, any alarms, fault modes or abnormal operation etc.). • Check status and operation of alarms (if applicable). • Check that all signage and labelling is present. • Check for electrolyte levels/leakage (flooded cells). • Check currency of system documentation (procedures, SDS etc.) and update if needed.

?

Testing	• Check battery system voltage(s). • Check continuity of earth connections. • Check the functionality of system isolators. • Check the functionality of alarms and indicators. • Check for hot spots at terminals (e.g. thermal imaging). • Perform a battery system test cycle. • Perform battery cell or module impedance tests. • Check electrolyte specific gravity and temperature (flooded cells).
Preventative actions	• Clean batteries and around battery enclosure. • Tighten battery connections to the required torque. • Replace damaged or deteriorated batteries. • Perform required maintenance on any fans or other motors. • Top-up low electrolytes with distilled water (flooded cells).

This learning activity consists of 5 parts designed to develop your understanding of battery storage system maintenance procedures and requirements.

Topic 6.1 Learning Activity

In this skills practice, you are required to develop a maintenance schedule for a grid-connected battery storage system, in accordance with AS/NZS 5139.

Topic 6.1 Skills Practice

Undertaking this topic quiz will help you to confirm your understanding of the general isolation and maintenance procedures and requirements for grid-connected battery storage systems.

Topic 6 Content Quiz

Last modified: Wednesday, 28 August 2024, 12:02 PM

CONTACT US

02 6262 7055

enquiries@energyspace.com.au

Mark as done

Unit Introduction

This unit consists of 6 topics, exploring the design of grid-connected battery storage equipment, including components, arrangements, configuration, standards, requirements, and associated safe working practices.

Each topic includes technical explanations, diagrams and activities designed to help you develop and reinforce your understanding. Topic skills practices give you the opportunity to practice the practical skills you'll need on the job, such as interpreting specifications and sizing equipment. Finally, a quiz at the end of each topic allows you to check your progress against the topic requirements.

When you feel you have achieved the knowledge and skills in each topic, ask your teacher/trainer if you can sit the unit tests. The Unit Knowledge Test (UKT) is designed to determine your understanding of the unit concepts, whilst the Unit Skills Test (UST) gives you the opportunity to demonstrate the planning, carrying out and completion of the practical tasks in the unit.

Unit of Competence:

This course has been designed to facilitate blended delivery of the knowledge and skills contained in the Competency Standard Unit:

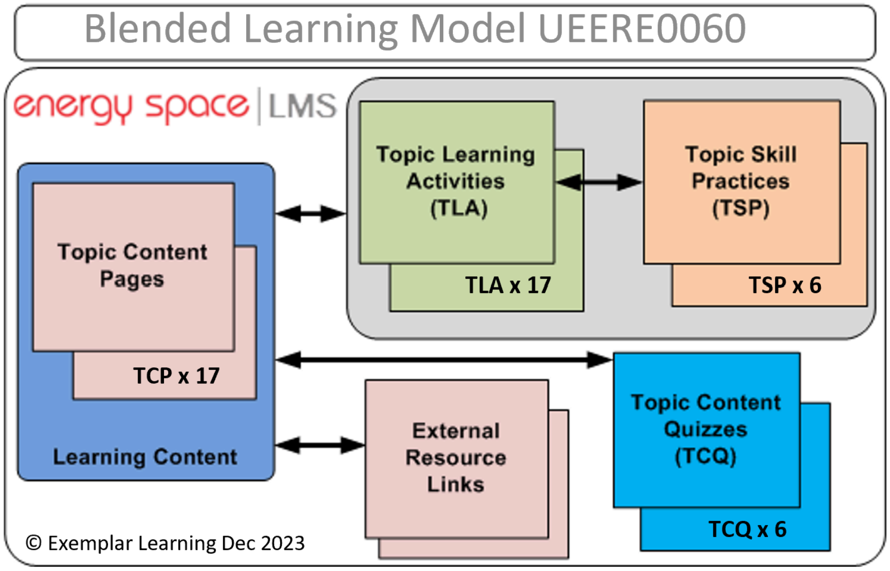
UEERE0060 Design grid-connected battery storage systems

Unit Learning Plan

The **Unit Learning Plan** (ULP) specifies the assessment requirements, and defines the depth and breadth of knowledge and skills required for the Unit. It lists related learning and assessment resources, and provides a structured framework for delivery that is suitable for both traditional and blended approaches.

LMS Learner Components

?



Topic Content Pages present the topic technical content using simple explanations, diagrams and interactive objects. These pages also provide links to external resources, learning activities, skills practices and quizzes, positioned like 'checkpoints' throughout the learning journey.

Load the Activity **Check Your Progress** activities provide short answer, drag and drop, and other interactions designed to assist in understanding the content.

External Resource Links and videos provide related information from external sources. All links to third party content are correct at the time of this course's publication.

Topic Learner Activities are intended to work in combination with RTO activities to support and reinforce learning..

Topic Skills Practices provide structured opportunities for the learner to develop their skills in an RTO or workplace environment.

Topic Content Quizzes provide the student with a way to confirm their understanding of the topic in preparation for the Unit Knowledge Assessment. The Topic Content Quiz contains multiple choice, matching and calculation questions that cover all aspects of the topic knowledge content. It is recommended that each Topic Content Quiz is completed prior to progressing to the next topic, and all quizzes should be completed prior to attempting the Unit Knowledge Assessment.

The Performance Indicator light will show according to your Topic Content Quiz score:


Score below 65%


Score between 65% and 85%


Score over 85%

Course Navigation

Navigate course content by selecting the required sub topic pages from the Home page, clicking on a link within the left hand navigation pane, or by clicking on the page navigation icons within each sub topic page, as per example below:

Previous

Home

Next

Get Started

Last modified: Wednesday, 28 August 2024, 10:32 AM

CONTACT US

02 6262 7055
enquiries@energyspace.com.au

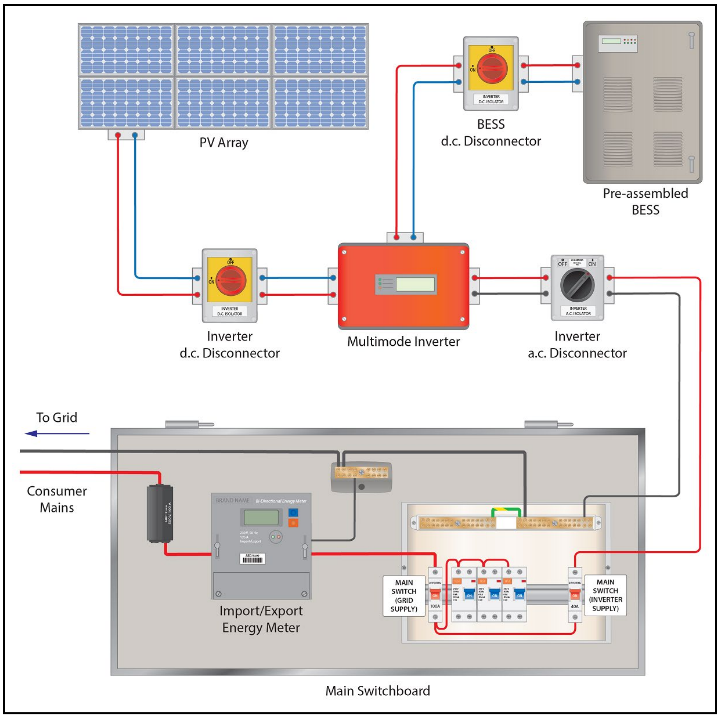
energy space

online resources

Unit Learning Plan

UEERE0060 – Design grid-connected battery storage systems

November 2023
Release No. 1.0



A division of exemplar LEARNING

Contents

A. Overview

Competency Standard Unit (CSU)	**UEERE0060 Design grid-connected battery storage systems**	
CSU Application	This unit involves the skills and knowledge required to design battery storage systems. This unit applies to a person with a sound knowledge of the components and different system configurations of battery storage systems for grid-connected photovoltaic (PV) systems and suitable energy management strategies that can be applied to the site where a system can be installed. A person competent in this unit will be able to design a system, which includes calculating and selecting the correct sized equipment, so the system output performance meets the client specific objectives, within the guidelines of relevant industry standards, regulations and manufacturer requirements. The unit involves designing a system taking into consideration all necessary work health and safety requirements relevant for the selected system and documenting the design including all calculations, equipment specifications and layouts. This unit is appropriate for Licenced Electricians or Electrical Engineers with responsibility for designing grid-connected battery storage systems. Licensing, legislative or certification requirements that apply to this unit may differ between jurisdictions and system types. They should be checked prior to commencing this unit.	
Purpose of ULP	The purpose of the Unit Learning Plan (ULP) is to define the depth and breadth of the knowledge and skills required to address the Competency Standard Unit (CSU) Assessment Requirements. It also indicates the recommended sequence and duration for the structured learning program, and provides a list of resources suitable for the delivery of the material using a blended approach. In the context of this ULP, the term 'structured learning program' encompasses both the imparting of knowledge and skills and the completion of evidence gathering activities designed to address the Assessment Requirements. The structured learning program is generally undertaken off-the-job in a controlled learning environment.	
Unit aspects addressed in this ULP	PC-UEERE0060	Performance Criteria
	KE-UEERE0060	Knowledge Evidence
	PE-UEERE0060	Performance Evidence
Suggested Durations	Completion of ULP topics 1 to 6	34 hours
	Completion of Unit Knowledge Test	2 hours
	Completion of Unit Skills Test	4 hours

	Total duration of structured learning program	40 hours
	Note: These durations do not include the necessary workplace experience and final assessment of all evidence that must occur before competence can be determined.	
Sequence	Before undertaking this ULP a learner is to have completed the following Competency Standard Units or equivalent: • UEERE0054 Conduct site survey for grid-connected photovoltaic and battery storage systems • UEERE0061 Design grid-connected photovoltaic power supply systems **AND** • UEEEL0039 Design, install and verify compliance and functionality of general electrical installations* **OR** • UEERE0051 Apply electrical principles to renewable energy design *Note that UEEEL0039 has the following pre-requisites: • HLTAID001 Provide cardiopulmonary resuscitation • UEECD0007 Apply work health and safety regulations, codes and practices in the workplace • UEECD0019 Fabricate, dismantle and assemble utilities industry components • UEECD0020 Fix and secure electrotechnology equipment • UEECD0051 Use drawings, diagrams, schedules, standards, codes and specifications • UEECD0016 Document and apply measures to control WHS risks associated with electrotechnology work • UEEEL0003 Arrange circuits, control and protection for general electrical installations • UEEEL0020 Solve problems in low voltage a.c. circuit • UEEEL0023 Terminate cables, cords and accessories for low voltage circuits • UEEEL0018 Select wiring systems and cables for low voltage general electrical installations • UEEEL0005 Develop and connect electrical control circuits • UEEEL0047 Identify, shut down and restart systems with alternate supplies • UEEEL0019 Solve problems in direct current (d.c.) machines • UEEEL0021 Solve problems in electromagnetic devices • UEEEL0014 Isolate, test and troubleshoot low voltage electrical circuits • UEEEL0008 Evaluate and modify low voltage heating equipment and controls	

	• UEEEL0009 Evaluate and modify low voltage lighting circuits, equipment, and controls • UEEEL0010 Evaluate and modify low voltage socket outlets circuits • UEEEL0024 Solve problems in alternating current (a.c.) rotating machines • UEEEL0025 Test and connect transformers • UEEEL0012 Install low voltage wiring, appliances, switchgear and associated accessories • UETTDRRF06 Perform rescue from a live LV panel **and** • UEECD0043 Solve problems in direct current circuits **or** • UEECD0044 Solve problems in multiple path circuits • UEECD0046 Solve problems in single path circuits

B. Knowledge and Skills Delivery

1 Grid-Connected Battery Systems

Purpose:	In this topic you will learn about the purpose and application of battery storage systems designed for use as part of a grid-connected PV power system, including the various different system configurations.
Duration:	This topic represents around 15% of the knowledge and skills specification contents, and should take the learner approximately 6 hours to achieve the objectives.

Knowledge and Skills Specification Content Areas	**Unit Mapping[1]**			**Energy Space Resources**
	KE	**PC**	**PE**	
1.1 Energy Use				
Knowledge				
Explain how energy is typically used in domestic and commercial premises.	2.1, 2.2.1	-	-	Topic 1 Content Quiz Topic 1.1 Learning Activity
List the strategies that can be used to reduce energy use at a given premises.	6	-	-	
1.2 Energy Usage Profiles				
Knowledge				
Explain typical load profiles, including identification of peak and average demand.	2.1, 2.2.1	-	-	Topic 1 Content Quiz Topic 1.2 Learning Activity
1.3 Energy Management				
Knowledge				

1 Grid-Connected Battery Systems				
State the typical time frames for rectification of grid-outages.	2.2.2	-	-	Topic 1 Content Quiz Topic 1.2 Learning Activity
List the applications for battery storage systems, including: • To provide electrical supply during grid outages. • To provide electrical supply to loads during peak periods.	3.1.1, 3.1.2, 3.3, 6, 7.4	-	-	
Explain the current techniques available for consumers to monitor and switch between energy sources to reduce reliance on grid-supply.	3.2, 3.3, 6	-	-	
1.4 Battery System Configurations				
Knowledge				
List and explain the purpose of each major component in a grid-connected PV battery storage system, including: • Batteries. • Charge controller. • Inverter. • Control and protection devices. • Interconnecting wiring.	3.3, 3.4, 6	-	-	Topic 1 Content Quiz Topic 1.4 Learning Activity
Explain the common types of local requirements relating to gid-connected battery storage imposed by network providers.	3.1.3, 9	-	-	
Describe the different functional arrangements and configurations of grid-connected PV battery storage systems.	3.5, 6, 7.4	-	-	
Skills				

1 Grid-Connected Battery Systems				
Draw the block diagrams of different grid-connected PV battery storage system configurations.	3.5, 7.4	-	-	Topic 1.4 Skills Practice

Standards:

- AS/NZS 5139 Safety of battery systems for use with power conversion equipment.
- AS/NZS 4777 (series) Grid connection of energy systems via inverters.
- AS/NZS 5033 Installation and safety requirements for photovoltaic (PV) arrays.

2 Grid-Connect Batteries	
Purpose:	In this topic you will learn about the types of batteries used in grid-connected storage systems, including terms, definitions and parameters, charging modes and battery life. You will also learn about the safe working practices for handling, installing, maintaining and disposing of storage system batteries.
Duration:	This topic represents around 10% of the knowledge and skills specification contents, and should take the learner approximately 4 hours to achieve the objectives.

Knowledge and Skills Specification Content Areas	Unit Mapping[1]			Energy Space Resources
	KE	**PC**	**PE**	
2.1 Terms and Definitions				
Knowledge				
Define the following terms in relation to grid-connected battery systems: • Battery. • Cell. • Primary and secondary cells. • Nominal voltage. • Charge and discharge rate. • Ampere hour capacity. • Watt hour capacity. • State of charge (SOC). • Depth of discharge (DOD). • Useable capacity. • Cycle life.	1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5, 1.1.6, 1.1.7, 1.1.8, 1.1.9, 1.1.10, 1.1.11	-	-	Topic 2 Content Quiz Topic 2.1 Learning Activity
Describe the arrangement of battery banks and the effect of connecting batteries in series and parallel.	3.5	-	-	
2.2 Types of Batteries				
Knowledge				

2 Grid-Connect Batteries				
List the major types and features of batteries suitable for grid-connected PV battery storage systems.	1.3	-	-	Topic 2 Content Quiz Topic 2.2 Learning Activity
Explain the different charging modes used with grid-connected PV battery storage systems.	1.6	-	-	
State the factors that can affect the life of commercially available storage system batteries.	1.4	-	-	
2.3 Battery Safety				
Knowledge				
State the hazards and associated risk control measures when handling, installing or maintaining battery storage banks.	1.2, 10	-	-	Topic 2 Content Quiz Topic 2.2 Learning Activity
State the common causes of battery failure in commercially available batteries, including sulphation and stratification in lead acid batteries.	1.5	-	-	
State the procedures for safe disposal and recycling of batteries.	1.7	-	-	
Skills				
Perform a risk assessment for a work task involving the handling, installation, or maintenance of battery storage banks.	1.2, 10	1.1	1	Topic 2.3 Skills Practice

Standards:

- AS/NZS 5139 Safety of battery systems for use with power conversion equipment.

Equipment:

- Manufacturer's catalogues.

3 Power Conversion Equipment (PCE)				
Purpose:	In this topic you will learn about the different types, features and ratings of PCE used in grid-connected PV battery storage systems. You will also learn how to connect different types of PCE and measure the input and output parameters.			
Duration:	This topic represents around 10% of the knowledge and skills specification contents, and should take the learner approximately 4 hours to achieve the objectives.			

Knowledge and Skills Specification Content Areas	Unit Mapping[1]			Energy Space Resources
	KE	PC	PE	
3.1 Types of PCE				
Knowledge				
List the different types of PCE used in grid-connected PV systems with battery storage.	4	-	-	Topic 3 Content Quiz Topic 3.1 Learning Activity
Describe the basic function of inverters and charge controllers.	4	-	-	
State the differences between a grid-connect inverter and a multimode inverter.	7.1	-	-	
Identify the standard symbols for a charge controller and an inverter.	4	-	-	
3.2 Charge Controller Specifications				
Knowledge				
List the key input and output ratings for a charge controller, including: • d.c. voltages. • d.c. currents. • Efficiency.	4, 7.2.1, 7.2.2	-	-	Topic 3 Content Quiz Topic 3.2 Learning Activity
Explain what is meant by the 'operating window' of a charge controller.	4, 7.2.2	-	-	

3 Power Conversion Equipment (PCE)				
3.3 Multimode Inverter Specifications				
Knowledge				
List the key output ratings for a multimode inverter, including: • Required maximum demand. • Battery charging capacity. • d.c. voltages. • d.c. currents. • Efficiency.	4, 7.2.1, 7.2.2	-	-	Topic 3 Content Quiz Topic 3.2 Learning Activity
List the typical features and settings of multimode inverters that may need to be adjusted to ensure correct operation.	4, 6, 7.3, 7.4	-	-	
Skills				
Select PCE for given applications.	4, 7.2.1, 7.2.2, 7.3, 7.4	1.1, 2.1	1, 2, 3	Topic 3.3 Skills Practice

Standards:
- AS/NZS 4777 (Series) Grid connection of energy systems via inverters.
- AS/NZS 5139 Safety of battery systems for use with power conversion equipment.

Equipment:
- Manufacturer catalogues/data sheets (PCE).

4 Battery System Layout	
Purpose:	In this topic you will learn to interpret battery system specification schematic and physical layout diagrams to determine the quantity and locations for battery system equipment.
Duration:	This topic represents around 10% of the knowledge and skills specification contents, and should take the learner approximately 4 hours to achieve the topic requirements.

Knowledge and Skills Specification Content Areas	**Unit Mapping[1]**			**Energy Space Resources**
	KE	**PC**	**PE**	
4.1 Installation Specifications				
Knowledge				
Describe typical schematic and physical layouts of the major components in a grid-connected PV battery storage system, including: • Batteries • Charge controller. • Inverter. • Control and protection devices. • Interconnecting wiring. • Earthing. • PV and grid supplies. • Metering.	5.1, 5.2	-	-	Topic 4 Content Quiz Topic 4.1 Learning Activity
Skills				
Interpret schematic and layout diagrams to determine the quantity and locations for battery system equipment.	5.1, 5.2	-	-	Topic 4.1 Skills Practice
4.2 Identification and Labelling				
Knowledge				
Outline the labelling and signage requirements for grid connected PV battery storage systems, as set out in AS/NZS 4777.1 and AS/NZS 5139.	8.4	-	-	Topic 4 Content Quiz Topic 4.2 Learning Activity

4 Battery System Layout
Standards: • AS/NZS 4777 (Series) Grid connection of energy systems via inverters. • AS/NZS 5139 Safety of battery systems for use with power conversion equipment. **Equipment:** • Battery system schematic drawings. • Battery system layout drawings.

5 Battery System Design					
Purpose:	In this topic you will learn about the factors to consider when selecting and sizing battery banks, interconnecting wiring, earthing, control and protection. You will practice selecting equipment for given scenarios, and also learn how to estimate the energy capacity/yield for a given system.				
Duration:	This topic represents around 30% of the knowledge and skills specification contents, and should take the learner approximately 12 hours to achieve the topic requirements.				

Knowledge and Skills Specification Content Areas	Unit Mapping[1]			Energy Space Resources
	KE	**PC**	**PE**	
5.1 WHS/OHS Practices				
Knowledge				
State the WHS/OHS requirements and risk management for selecting battery system equipment.	10	-	-	Topic 5 Content Quiz Topic 5.1 Learning Activity
5.2 Battery Sizing and Selection				
Knowledge				
Explain the factors and methods for selecting and sizing battery storage banks for grid-connected battery systems, including: • Customer objectives and budget. • Upfront costs, ongoing costs, warranty and payback period. • Energy profile, monitoring and metering. • Local network requirements.	3.1.3, 3.2, 8.1, 8.2, 9	-	-	Topic 5 Content Quiz Topic 5.2 Learning Activity
5.3 BoS Equipment Selection				
Knowledge				
Explain the factors and methods for selecting and sizing switchgear, wiring and earthing equipment for grid-connected battery systems.	8.1, 8.3	-	-	Topic 5 Content Quiz Topic 5.3 Learning Activity

5 Battery System Design				
5.4 Battery System Documentation				
Knowledge				
List the details to be documented in battery system design documentation to meet relevant industry standards, regulations and manufacturer requirements.	8.6	-	-	Topic 5 Content Quiz Topic 5.4 Learning Activity
Skills				
Design and document the proposed battery installation, including: • Battery storage type, capacity and configuration. • Inverter type and capacity. • Charge controller type, capacity and settings. • Selecting and sizing cables, protection and isolation devices • Equipment locations and cable routes. • Required system signage. • System cost. • Warranty periods.	3.1.3, 3.2, 8.1, 8.2, 8.3, 8.6, 9	1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 2.3	1, 2, 3	Topic 5.4 Skills Practice
Present system design to teacher/trainer/assessor and finalise any alternations if necessary.	-	2.4	3	

Standards:

- AS/NZS 3000 Wiring Rules.
- AS/NZS 3008.1.1 Selection of cables.
- AS/NZS 4777 (Series) Grid connection of energy systems via inverters.
- AS/NZS 5139 Safety of battery systems for use with power conversion equipment.

Equipment:

- Manufacturer catalogues/data sheets (battery system equipment).
- Battery system schematic drawings.

5 Battery System Design
• Battery system layout drawings.

6 Battery System Maintenance				
Purpose:	In this topic you will learn about the maintenance requirements for battery storage systems, and the methods for developing and specifying a compliant maintenance schedule.			
Duration:	This topic represents around 10% of the knowledge and skills specification contents, and should take the learner approximately 4 hours to achieve the objectives.			

Knowledge and Skills Specification Content Areas	Unit Mapping[1]			Energy Space Resources
	KE	PC	PE	
6.1 Battery System Maintenance				
Knowledge				
State the individual maintenance requirements for: • Battery storage devices. • Charge controllers. • Inverters. • Balance of system (BoS) equipment.	8.5	-	-	Topic 6 Content Quiz Topic 6.1 Learning Activity
State the maintenance requirements for grid-connected PV battery storage systems.	8.5	-	-	
Skills				
Develop a maintenance schedule for a given grid-connected PV battery storage system.	8.5	2.1	1, 2	Topic 6.1 Skills Practice

Standards:

- AS/NZS 4777 (Series) Grid connection of energy systems via inverters.
- AS/NZS 4836 Safe working on or near low-voltage electrical installations and equipment.
- AS/NZS 5139 Safety of battery systems for use with power conversion equipment.

Equipment:

- Battery storage installation/specifications.

Legend:

KE	Knowledge Evidence	**PE**	Performance Evidence
PC	Performance Criteria		