Batteries and inverters

Batteries and other energy storage devices store energy so that it can be used when needed. In a stand-alone power system, the energy stored in batteries can be used when energy demand exceeds the output from renewable energy sources like solar (e.g. on a cloudy day) and wind (e.g. on a still day).

Inverters and other energy conversion devices turn energy from one form to another. An inverter in a grid connected renewable energy system converts direct current (DC) electricity from solar panels or a wind turbine into alternating current (AC) mains power.

Any renewable energy system also includes switches, circuit breakers and fuses to ensure it is electrically safe and allow major equipment to be isolated for maintenance.

Grid connected systems

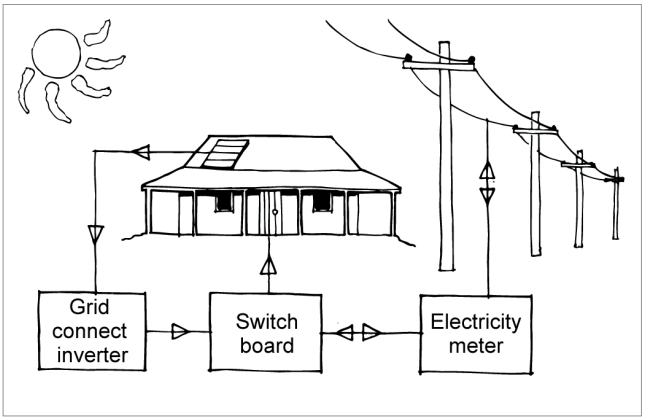
A grid connected renewable energy system converts DC electricity from a power source, such as solar panels, to AC mains power and feeds it into the grid. It usually consists of the energy source, an inverter and a meter.

If there is a mains grid power failure, a grid connected renewable energy system disconnects from the grid and energy from solar panels is not available.

Battery banks connected to the grid, with an appropriate inverter, may work as an uninterruptable power supply to make energy available during a power outage for all or some of the electrical loads in a home or business.

Although costs are currently very high and extra components are required, it is technically possible for such a system to enable one of these options:

- energy from the grid to be stored during off-peak times of lower price and supplied during peak times where energy is charged at a higher rate (at homes with a time-of-use tariff for energy)
- surplus energy from renewable energy generators to be stored for use on site (at homes without a premium feed-in tariff for exported energy).



Grid connected system.

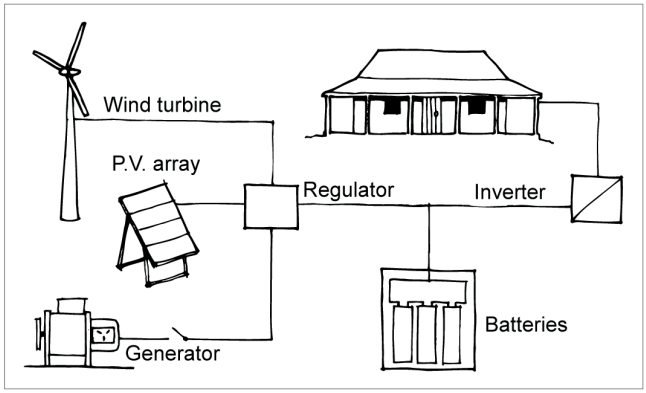
Stand-alone systems

A stand-alone power system is used for supplying energy at regional and remote locations where it is more cost effective to have on-site generation than to connect to the electricity grid. Stand-alone power systems typically include a power generation source like solar panels or wind turbines, a battery bank, inverter, battery charger and often a fuel generator for back-up power.

> *A stand-alone power system is used for supplying energy at regional and remote locations where it is more cost effective than connecting to the electricity grid.*

Each system also needs a charge controller/regulator, which can be part of the inverter or other equipment. In a stand-alone system, battery banks and inverters are needed whether the energy comes from solar, wind or micro-hydro.

The exact equipment needed to convert and store energy depends on the energy needs and budget of the user, as well as the available energy resource and physical constraints of the site.



Stand-alone system.

Batteries

Lead-acid batteries are most often used in renewable energy systems. Lithium batteries, though more expensive than lead-acid, can have a much longer life. Nickel iron batteries are harder to find and less efficient than lead-acid or lithium ion but have very long lives. Flow batteries (zinc bromine and vanadium redox) and flywheel batteries can be used in renewable energy systems but are complex and expensive.

Most batteries are composed of a number of cells. In stand-alone power systems, the battery bank voltages commonly used are 12V, 24V, 48V or 120V. Batteries can be supplied as a mono-block but usually come as individual 2V cells which are assembled into a complete battery on site. A 12V battery consists of six 2V cells, and so on. Battery banks should provide a number of days' energy reserve — three to seven days is typical.

The two types of lead-acid batteries that use an acidic electrolyte are wet cell and sealed. Wet cell use liquid electrolyte; sealed batteries use either a gel or liquid electrolyte absorbed into fibreglass matt. Wet batteries are typical for renewable energy systems but sealed batteries are becoming more common because they are safer and easier to maintain.

If a battery bank capacity is large enough and usage is low (less than 10% capacity per day), battery life should be at least 10 years. Battery makers give information on how long their products last and installers should design and install battery banks to comply with standards and maximise battery life.

Standards relating to lead-acid batteries for stationary purposes include AS 2676-1992, Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings; AS 3011-1992, Electrical installations — secondary batteries installed in buildings; AS 4029-1994, Stationary batteries — lead-acid; and AS 4086-1993, Secondary batteries for use with stand-alone power systems.

A battery bank.

Other storage and generation types

Other methods of storage are occasionally used in domestic energy systems. One is pumped water storage, where excess energy is used to pump water from a creek or dam to a higher level, for example to a large water tank on top of a hill. To produce electricity the water is fed from the tank through a micro-hydro turbine. This set-up is generally inefficient but can be much cheaper than battery storage in some places, and is possibly of lower environmental impact because chemicals and metals in batteries aren't used.

Some electric vehicle makers are looking at making their car charging devices 'bi-directional'. This means the electric car's battery charger is also a grid-interactive inverter, so energy stored in the battery can be used in the home or sent to the grid. This opens the possibility of charging a car at night when electricity costs are low and feeding the stored energy back into the grid at other times to offset a house's energy cost. No cars have this capability yet in Australia, but it is likely to become common in the future.

Domestic-sized fuel cell generators can also produce electricity and heat for your home. They consist of a complete fuel cell and grid connect system in a unit about the size of a washing machine. They can't be used to provide power during a grid power failure. Fuel cells are very much more expensive than other forms of generating energy.

Battery installation

Batteries emit a corrosive and explosive mix of hydrogen and oxygen gases during the final stages of charging, which can ignite if exposed to a flame or spark. They must be installed in a well-ventilated enclosure, preferably away from the house.

> *Install batteries in a well-ventilated enclosure, preferably away from the house.*

Because the gases rise, ventilation design must permit air to enter the enclosure at the base of the batteries and exit at the highest point.

Ventilate naturally by allowing the gas to rise and escape safely or by installing fans and electrical vents. How much ventilation is needed increases with the size of the battery bank and the rate of charge. Your installer will design appropriate battery storage in accordance with standards.

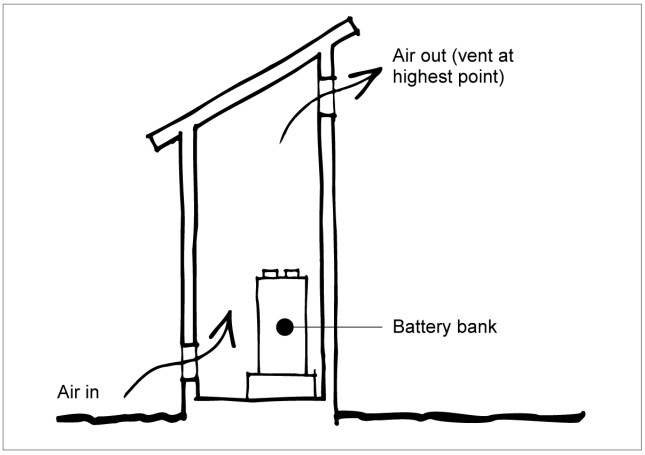
Mount batteries on stands to keep them clear of the ground; otherwise, they need to be thermally insulated from the ground temperature. Do not install batteries directly onto concrete, which cools to ground temperature. The resultant electrolyte stratification is detrimental to a battery's long-term life and performance. Low electrolyte temperatures also reduce the capacity of a battery. Install batteries out of direct sunlight and away from excessive heat. High temperatures can cause electrodes to buckle or erode more rapidly than normal.

Battery banks for stand-alone systems can be large and heavy, often requiring 1–5m^2 of floor space and weighing hundreds of kilograms. The floor area required may be reduced by using heavy-duty shelves, and some sealed batteries can be safely mounted on their side.

Batteries can be as high as 70cm, and if installed in a box it must be one with a removable lid or at least 50cm clearance above the batteries to allow for a hygrometer to check the charge level.

Limit access to the battery room or container to people trained in maintenance and shut-down procedures. Never open it to children. Safety signs are required in accordance with Australian Standards.

The installation must include a switch or quick-disconnect fuse near the batteries so the bank can be electrically isolated from the rest of the system.



A battery enclosure.

Battery maintenance

Battery maintenance includes keeping terminals clean and tight, and ensuring the electrolyte is kept above minimum levels. Use distilled water only when topping up electrolyte levels. Neutralise any electrolyte spilt or splashed on the top of the batteries (e.g. with sodium bicarbonate) and wash away with water at frequent intervals.

Batteries are dangerous and must be treated cautiously. The three main dangers are:

- explosion or fire from battery gases
- short-circuiting of the terminals
- acid burns from flooded lead-acid batteries.

Do not short across the battery terminals. Under Australian Standards the terminals must be covered to prevent accidental shorting. Tools, such as spanners, used on the battery terminals should be single ended and have fully insulated handles.

Lead-acid batteries hold a liquid electrolyte with sulphuric acid which can cause serious burns. Always wear protective clothing and eye protection when near them. Acid spilt on the floor or equipment must be diluted with water and neutralised with sodium bicarbonate. Keep all personal protective equipment and other safety materials easily accessible at all times and stored near the battery bank.

Batteries have specific charge regimes and may require periodic equalisation charging. The system designer will explain this process. The equalisation charge is controlled automatically by the system or requires the owner to connect a generator and battery charger at regular intervals (about once a month).

Specific gravity readings are the most accurate method for determining the state of charge of cells in a battery bank. A safe method for performing this will be explained by the system designer.

System owners should read and fully understand the manufacturer's manual for their battery bank.

Battery disposal

Batteries contain materials such as lead and acid that are harmful to the environment. When replacing a battery bank, dispose of the old batteries at a battery recycling station or other suitable site. Metals inside batteries can be valuable and many recyclers will pay for old batteries.

Inverters

Inverter installation

Inverters are commonly a part of both grid connected and stand-alone renewable energy systems.

Inverters convert DC power from batteries or solar modules into usable AC power, normally 240V AC (single phase) or 415V AC (three-phase). Inverters are complex electronic devices and must be installed in relatively clean areas. Standards for inverters include AS 4777-2005, Grid connection of energy systems via inverters; AS/NZS 4763:2011, Safety of portable inverters; and AS/NZS 5603:2009, Stand-alone inverters — performance requirements.

Inverters may be either wall or shelf mounted. They can be large and heavy — a 5kW unit could weigh as much as 60kg.

Inverters can become very warm when operating at large power outputs and need suitable ventilation and cooling airflow. Insects often like to nest in the heat dissipation vents, so site your inverter carefully and check it often.

Inverters should be installed out of direct sunlight as direct exposure can cause them to overheat. They should be easily accessible in case they need to be electrically isolated in an emergency.

Install inverters where there is suitable ventilation, no direct sunlight and easy access.

Install inverters in an accessible place out of direct sunlight.

The DC currents in the battery leads between the battery and inverter can be very large. To avoid overheating and voltage drop, the leads must be of an appropriate size and kept to a minimum practical length. Many inverters are supplied with leads, which should be used wherever possible. Place the inverter as close as safely possible to the battery bank.

Lightning can damage inverters. The risk should be assessed by the designer and appropriate protection installed if required.

Only a suitably trained and qualified person can undertake AC hard wiring to an inverter.

Grid connected inverters

Grid connected inverters convert power from solar panels, wind turbines or micro-hydro systems into AC power. They automatically match the voltage and synchronise the frequency so that it can be fed into the mains grid. On the DC side, the grid inverter is connected directly to the renewable energy charging source.

The AC output of the inverter connects with the building switchboard in accordance with regulations and standards. The inverter can be installed in any suitable place between the energy source and the switchboard.

Battery charging

Battery charging in stand-alone systems

Battery charging is needed in stand-alone systems when the energy from the renewable sources is intermittent. By using multiple renewable energy sources and/or oversizing solar arrays or wind generators it is possible to eliminate the need for a battery charger and generator, if the risk of occasionally going without power is acceptable. This is more easily done now that the price of solar panels has dropped.

The battery charger can be a separate unit or incorporated in a combined inverter-charger. The inverter supplies 240V AC power from the battery bank. When the generator starts, the inverter-charger switches the load to the generator and becomes a battery charger, recharging the batteries from the generator.

Any battery charging source requires a manual or automatic regulator/controller to correctly charge batteries. Automatic controls start a generator when the batteries reach a low charge level and, with inverters that have genset synchronisation, when the load is greater than the maximum power output of the inverter. With manual controls the state of battery charge must be monitored.

Connecting an unregulated charge source such as a solar panel directly to a battery without an appropriate charge controller is dangerous and risks permanently damaging the battery.

Battery charger installation

If a stand-alone power system is installed with a separate battery charger, it should be treated like an inverter.

The charger must be installed close to the batteries and can be floor or shelf mounted. The input power to the charger must be a generator-only power point. In grid connected systems with battery back-up, the charger is usually mains powered.

Generator installation

Install the generator in a separate room or enclosure. If it must be in the same room as the rest of the system, locate it as far away from other components as possible and cover it with an enclosure ventilated to the outside. This helps stop overheating and fumes from a malfunctioning exhaust as well as reducing fire risks from fuel leaks.

Allow sufficient space around the generator for maintenance.

If the generator is automatically started by other equipment, it must carry appropriate signs and the auto-start system must have an isolator to disable it during repair.

Generators can be noisy, which will affect where you put them. This is more of an issue for stand-alone power systems with a low proportion of energy from renewable sources, requiring the generator to run more often to meet energy needs. Sound reducing generator enclosures are available.

Keep generator fuel in an approved container in a safe location.

References and additional reading

Available rebates can be found at www.yourenergysavings.gov.au

Going off-grid? Your essential battery buyers guide. 2010. Renew, 113. http://renew.org.au

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