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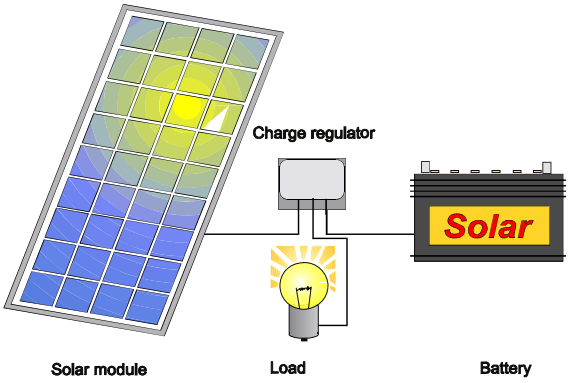
**System Overview**
A PV solar system comprises components that produce, store and deliver electricity to the application. The figure below shows a schematic of a PV system.




*The components of a stand-alone solar power generator.*

Energy generation

Solar modules convert sunlight directly into DC electricity. Solar modules have no moving parts, are highly reliable, have a long lifetime expectancy (>25 years), and require little maintenance. Solar modules are modular. It is easy to assemble Solar modules into an array of any size.

*Solar Module Construction*

Solar modules consist of individual cells that are wired together in series and in parallel to produce the desired voltage and current. The cells are encapsulated in a transparent protective material and housed in an aluminium frame.

*Performance Characterisation*

Solar modules are rated in terms of Watt peak (Wp). This rating is a function of both panel size and efficiency. This standard rating makes it easy to compare modules from different sources based upon cost per Wp. The rating is the amount of power that the module will produce under Standard Test Conditions (STC = 1kW/$m^2$ insolation, 25°C [77°F] cell temperature, air mass 1,5.) This is roughly the intensity of sunlight at noon on a clear summer day. Solar module power output is proportional with insolation.

*Module Operation*

Most solar modules are designed to charge 12-V battery banks. Larger solar power systems may have DC bus bar voltages of 24, 48 or 60 V. Connecting the appropriate number of solar modules in series enables them to charge batteries at these voltages.

For non-battery charging applications, such as when the panel is directly connected to a water pump, a maximum-point power tracker (MPPT) may be necessary. MPPT will match

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the electrical characteristics of the load to those of the module so that the array can efficiently power the load.

*Solar module mounting and tilt angles*

In order to maximise energy production, solar modules need to be mounted oriented towards the sun. This means at Northern latitudes towards the South and at Southern latitudes towards the North. Depending on the latitude and/or season the solar modules are mounted under a specified tilt angle to optimise overall energy output. The modules are usually mounted on fixed mounts. This type of mounting can be made of wood or metal.

*Solar module size*

Solar modules are available in a variety of ratings up to 300 Wp. Individual solar modules can be connected to form arrays of any size. Solar modules are connected in series to increase the voltage, and are connected in parallel to increase the current. This modularity makes it easy to start with a small array and add additional solar modules later.

Energy Storage

The most common energy storage device used in solar energy systems is the battery. Batteries store energy and release it when it is needed.

Batteries are electrochemical devices that store energy in chemical form. They store excess energy for later use in order to improve system availability and efficiency. By far the most common type of battery is the lead-acid type. A distant second is the nickel-cadmium type. The remainder of this section discusses the **lead-acid** battery.

**Battery Selection Considerations**

*Deep-Cycle versus Shallow-Cycle*

For remote power applications, deep-cycle batteries are recommended. Depending upon the specific model, they may be discharged down to a 20%–50% state of charge. Shallow-cycle batteries, such as car batteries, are not recommended. They are often used in small PV systems though because of the lack of good alternatives. They can be discharged only to an 80%–90% state of charge and will generally be destroyed by only a few deeper discharges.

*Flooded versus Valve Regulated*

Flooded (open or vented) batteries have their plates immersed in a liquid electrolyte and need periodic topping up. In valve-regulated (sealed or “maintenance free”) batteries, the electrolyte is in the form of a paste or contained within a glass mat. Valve regulated batteries do not need topping up. Flooded batteries generally have lower capital costs than valve regulated batteries and with proper maintenance, tend to last longer. On the other hand, where maintenance is difficult, valve regulated batteries may be the better choice.

*Lifetime*

Battery lifetime is measured both in terms of cumulative energy flow through the battery (full cycles) and by float life. A battery has reached its end of lifetime when it reaches either limit. For example, discharging a battery twice to 50% is one full cycle. For many batteries, as long as the Battery State of Charge is kept within the manufacturer’s recommended limits, the lifetime cumulative energy flow is independent of how deep the battery is cycled.

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Depending upon the brand and model, battery lifetimes vary widely, ranging from less than 100 full cycles to more than 1500 full cycles. Float life refers to how long a battery that is connected to a system will last, even if it is never or only lightly used. Typical float lives for good quality lead-acid batteries range between 3 and 10 years at 20°C (68°F). High ambient temperatures will severely shorten a battery's float life. A rule of thumb is that every 10°C (18°F) increase in average ambient temperature will halve the battery float life.

*Size*

The storage capacity of a battery is commonly given in amp hours at a given rate of discharge. When multiplied by the battery's nominal voltage (usually 2, 6, or 12 V), this gives the storage capacity of the battery in watt-hours. This storage capacity is not a fixed quantity, but rather varies somewhat depending on the rate at which the battery is discharged. A battery will provide more energy if it is discharged slowly than if it is discharged rapidly. In order to facilitate uniform comparison, most battery manufacturers give the storage for a given discharge time, usually 20 or 100 hours. Individual batteries used in solar energy systems are available in capacities ranging from 50 amp hours at 12 V to thousands of amp hours at 2 V.

Balance of System (BOS)

BOS items include regulating and control equipment, installation materials as cabling, sockets, switches, mounting materials, enclosures and mechanical solar module support structures.

Controllers

Controllers and meters act as the "brains and nervous system" of a Solar Energy system. Controllers route the energy through the system components to the load. Metering allows the user to assess system health and performance.

**Main functions**

*Battery high/low voltage disconnect:*

A high voltage disconnect protects the battery against overcharging. A low-voltage disconnect protects the battery against deep discharging. These are critical functions that should be included in all systems with batteries.

*System protection:*

A controller can include fuses or breakers to protect against short circuits and current surges.

*Battery charging:*

A controller with a proper battery charge algorithm (with temperature compensation) will increase battery lifetime.

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*AC and DC bus current and voltage monitoring:*

Monitoring the current and voltage on the DC and AC buses lets the user check that the components and system are properly operating.

*Turn components on or off:*

The controller can be programmed to turn components on and off as needed without user intervention.

*Blocking diode function:*

The controller performs a blocking diode function for prevention of overnight discharge of the batteries through the solar module.

*Reverse polarity protection:*

Protection against reverse polarity of batteries and solar modules.