

Fundamentals of Solar Power Systems

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As our standard of living improves and even as more nations becomes industrialised, the demand for more energy gives rise to the increased use of fossil fuels for energy production. Inevitably, this gives rise to various problems which the world is only beginning to become aware of.

To cope with rising energy demand, the mining of our fossil resources such as oil, gas and coal had taken on an unprecedented scale ever imagined. Businesses exploiting such opportunities are impervious to the damage of such activities to the environment and ecosystems. The positive aspect of such activities had been a more extensive push by environmentalists and 'green' lobbies to educate the masses of the harm and damages done. This education had seemingly yielded positive results as more and more governments have a stronger political will to stem the problems arising from the use of fossil fuel energy and mitigate the harm and damages to the environment before we kill our own living space – Gaia (or Mother Earth).

One of the mitigation efforts by many countries had been to explore alternative energy to cope with rising demand and reduce the dependence on fossil fuel energy production. One such alternative energy is Renewable Solar Energy.

What is Renewable Solar Energy?

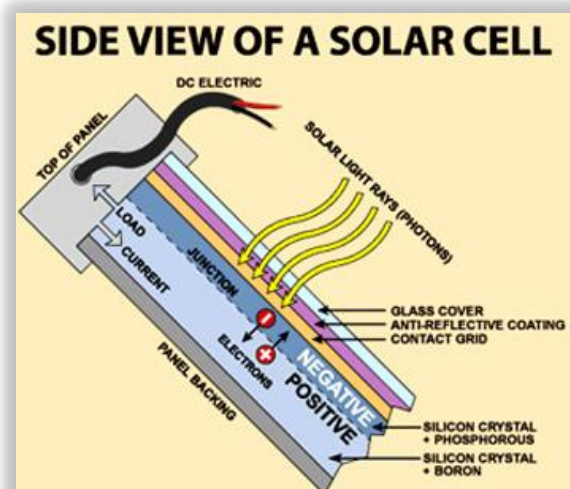
Solar energy takes advantage of the sun's rays to generate heat or electricity. Solar energy is renewable because it is powered by the sun, a constant source of energy. The planet will never run out of sunlight and thus, solar energy is infinite. This enables the world not to rely only on fossil fuels, which is a finite resource. This renders users of solar energy systems energy independence. There is enough sunlight all year round across the globe to provide enough power for consumer use. Solar energy is also unique for its ability

to generate energy in a quiet, clean, and consistent manner.

Using solar power to produce electricity is not the same as using solar to produce heat. Solar *thermal* principles are applied to produce hot fluids or air. *Photovoltaic* principles are used to produce electricity. A solar panel (PV panel) is made of the natural element, silicon, which becomes charged electrically when subjected to sunlight.

How is sunlight converted into Solar Energy?

PV systems, commonly known as solar panels, directly convert sunlight into energy using the principles of the photovoltaic (or PV) effect. The PV effect takes advantage of the properties of semiconductor materials, for example, silicon. When photons strike the semiconductor material, electrons within it are shaken loose and become free flowing electricity. This electricity generated will be in the form of a direct current (or DC) voltage, and can be used directly to charge batteries, or can be connected to an inverter to transform into alternating current (AC) voltage.



Picture courtesy of UTSolar.org

The most common DC voltage output from a PV System is intended for nominal 12V, with an effective output usually up to 17V. A 12V

nominal output is the reference voltage, but the operating voltage can be 17V or higher much like your car alternator charges your 12V battery at well over 12V. So there's a difference between the reference voltage and the actual operating voltage.

Installing Solar Panels or PV Systems

Solar panels are directed at solar south in the northern hemisphere and solar north in the southern hemisphere. Note that these are different than magnetic compass north-south directions) at an angle dictated by the geographic location and latitude of where they are to be installed. Typically, the angle of the solar array is set within a range of between site latitude ± 15 degrees, depending on whether a slight winter or summer bias is desirable in the system. Many solar arrays are placed at an angle equal to the site latitude with no bias for seasonal periods.

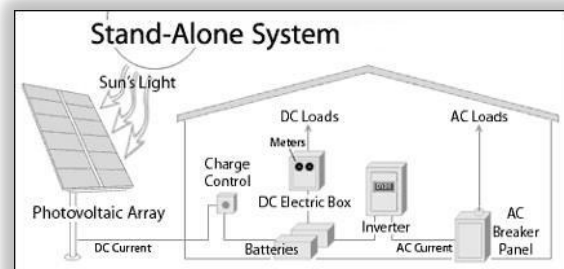
The intensity of the Sun's radiation changes with the hour of the day, time of the year and weather conditions. To be able to make calculations in planning a system, the total amount of solar radiation energy is expressed in hours of full sunlight per m^2 , or Peak Sun Hours. This term, Peak Sun Hours, represents the average amount of sun available per day throughout the year.

It is presumed that at "peak sun", $1000W/m^2$ of power reaches the surface of the earth. One hour of full sun provides $1000Wh/m^2 = 1 kWh/m^2$ - representing the solar energy received in one hour on a cloudless summer day on a one-square meter surface directed towards the sun. The daily average of Peak Sun Hours, based on either full year statistics, or average worst month of the year statistics, for example, is used for calculation purposes in the design of the system.

So it can be concluded that the power of a system varies, depending on the intended geographical location.

Main components of Solar Power System

In using a Solar Power System, the four primary components for producing electricity are: solar panels, charge controller, battery and inverter. Solar panels charge the battery, and the charge controller regulates charging of the battery. The battery provides DC voltage to the inverter, and the inverter converts the DC voltage to normal AC voltage.



Picture courtesy of UTSolar.org

Solar Panels

The output of a solar panel is usually stated in watts, and the wattage is determined by multiplying the rated voltage by the rated amperage. The formula for wattage is VOLTS times AMPS equals WATTS. So for example, a 12V 60W solar panel measuring about 50cm X 120cm has a rated voltage of 17.1 and rated 3.5 amperage.

$$V \times A = W$$
$$17.1 V \times 3.5 A = 60 W$$

If an average of 6 hours of peak sun per day is available in an area, then the above solar panel can produce an average 360 watt hours of power per day; $60W \times 6hrs. = 360 Wh$. Since the intensity of sunlight contacting the solar panel varies throughout the day, we use the term "peak sun hours" as a method to smooth out the variations into a daily average. Naturally, cloudy days will produce less power than bright sunny days as well.

Solar panels can be wired in series or in parallel to increase voltage or amperage respectively, and they can be wired both in series and in parallel to increase both volts and amps. Series wiring refers to connecting the positive terminal of one panel to the

negative terminal of another. The resulting outer positive and negative terminals will produce voltage the sum of the two panels, but the amperage stays the same as one panel. So two 12 V/3.5A panels wired in series produces 24V at 3.5A. Similarly, four of these wired in series would produce 48V at 3.5A. Parallel wiring refers to connecting positive terminals to positive terminals and negative to negative. The result is that voltage stays the same, but amperage becomes the sum of the number of panels. So to produce 12V/7A, we can wire in parallel two 12V/3.5A panels. Likewise, four panels would produce 12V at 14A.

Series/parallel wiring refers to doing both of the above - increasing volts and amps to achieve the desired voltage as in 24V or 48V systems.

Charge Controller

A charge controller monitors the battery's state-of-charge to insure that when the battery needs charge-current it gets it, and also insures the battery isn't over-charged. Connecting a solar panel to a battery without a regulator seriously risks damaging the battery and potentially causing a safety concern.

Charge controllers (or often called charge regulator) are rated based on the amount of amperage they can process from a solar array. If a controller is rated at 20A it means that you can connect up to 20A of solar panel output current to this one controller. The most advanced charge controllers utilize a charging principal referred to as Pulse Width Modulation (PWM) - which insures the most efficient battery charging and extends the life of the battery. Even more advanced controllers also include Maximum Power Point Tracking (MPPT) which maximizes the amount of current going into the battery from the solar array by lowering the panel's output voltage, which increases the charging amps to the battery - because if a panel can produce 60W with 17.2V and 3.5A, then if the voltage is lowered to say 14V then the amperage increases to

4.28A ($14V \times 4.28A = 60W$) resulting in a 19% increase in charging amps for this example.

Battery

The Deep Cycle batteries used are designed to be discharged and then re-charged hundreds or thousands of times. These batteries are rated in Amp Hours (Ah) - usually at 20hours and 100hours. Simply stated, amp hours refers to the amount of current - in amps - which can be supplied by the battery over the period of hours. For example, a 350Ah battery could supply 17.5A over 20hours or 35A for 10hours. To quickly express the total watts potentially available in a 6V, 360Ah battery; $360Ah \times 6V = 2160W$ or 2.16 kWh (kilowatt-hours). Like solar panels, batteries are wired in series and/or parallel to increase voltage to the desired level and increase amp hours.

The battery should have sufficient amp hour capacity to supply needed power during the longest expected period "no sun" or extremely cloudy conditions. A lead-acid battery should be sized at least 20% larger than this amount. If there is a source of back-up power, such as a standby generator along with a battery charger, the battery bank does not have to be sized for worst case weather conditions.

The size of the battery bank required will depend on the storage capacity required, the maximum discharge rate, the maximum charge rate, and the minimum temperature at which the batteries will be used. During planning, all of these factors are looked at, and the one requiring the largest capacity will dictate the battery size.

One of the biggest mistakes made is not having an understanding of the relationship between amps (A) and amp-hour (Ah) requirements of AC items versus the effects on their DC low voltage batteries. For example, a 24V nominal system and an inverter powering a load of 3A, 240VAC, which has a duty cycle of 4 hours/day. You would have a 12Ah load ($3A \times 4h = 12Ah$). However, in order to determine the true drain on your batteries you

have to divide your nominal battery voltage (24V) into the voltage of the load (240V), which is 10, and then multiply this by your AC amp hours (10 x 12Ah). So in this case the calculation would be 120Ah drained from your batteries - not the 12Ah. Another simple way is to take the total watt-hours of your AC device and divide by nominal system voltage. Using the above example; $3A \times 240V \times 4h = 2880Wh$ divided by $24VDC = 120Ah$.

Lead-acid batteries are the most common in PV systems because their initial cost is lower and because they are readily available nearly everywhere in the world. There are many different sizes and designs of lead-acid batteries, but the most important designation is that they are deep cycle batteries. Lead-acid batteries are available in both wet-cell (requires maintenance) and sealed no-maintenance versions. AGM and Gel-cell deep-cycle batteries are also popular because they are maintenance free and they last a lot longer.

Using an Inverter

An inverter is a device which changes DC power stored in a battery to standard 120/240VAC electricity. Most solar power systems generate DC current which is stored in batteries. Nearly all lighting, appliances, motors, etc., are designed to use AC power, so it takes an inverter to make the switch from battery-stored DC to standard power (120/240VAC).

In an inverter, direct current (DC) is switched back and forth to produce alternating current (AC). Then it is transformed, filtered and processed to get it to an acceptable output waveform. The more processing, the cleaner and quieter the output, but the lower will be the efficiency of the conversion. The goal becomes to produce a waveform that is acceptable to all loads without sacrificing too much power into the conversion process.

Inverters are made with various internal features and many permit external equipment interface. Common internal features are

internal battery chargers which can rapidly charge batteries when an AC source such as a generator or utility power is connected to the inverter's INPUT terminals. Auto-transfer switching is also a common internal feature which enables switching from either one AC source to another and/or from utility power to inverter power for designated loads. Battery temperature compensation, internal relays to control loads, automatic remote generator starting/stopping and many other programmable features are available.

Benefits of using Solar Power System

Solar power is harnessed from the sun, an infinite resource. This means energy independence (as compared finite fossil fuel resource).

Solar power is also environmentally friendly. It does not emit greenhouse gases. It does not damage our ecosystem.

Solar power is quiet during use. It is also safe to use. Many users install their Solar Power System in their own home and still sleep soundly at night!

Solar power requires only minimal maintenance. Advances in technology have made the components of a solar power system become more reliable, durable, user-friendly and safe.

A GREEN MESSAGE

Using renewable solar energy enables us to reduce the use of fossil fuels to generate energy. Fossil fuel energy generation pollutes our environment. You are empowered to help. Do your part. Be a responsible global citizen.

SAVE GAIA.

