Brief History of PV Solar Power

The first conventional photovoltaic cells were produced in the late 1950s, and throughout the 1960s were principally used to provide electrical power for earth-orbiting satellites. In the 1970s, improvements in manufacturing, performance and quality of PV modules helped to reduce costs and opened up a number of opportunities for powering remote terrestrial applications, including battery charging for navigational aids, signals, telecommunications equipment and other critical, low-power needs.

In the 1980s, photo voltaic cells became a popular power source for consumer electronic devices, including calculators, watches, radios, lanterns and other small battery-charging applications. Following the energy crises of the 1970s, significant efforts also began to develop PV power systems for residential and commercial uses, both for stand-alone, remote power as well as for utility-connected applications. During the same period, international applications for PV systems to power rural health clinics, refrigeration, water pumping, telecommunications, and off-grid households increased dramatically, and remain a major portion of the present world market for PV products. Today, the industry's production of PV modules is growing at approximately 25 percent annually, and major programs in the U.S., Japan, Europe, China and India are rapidly accelerating the implementation of PV systems on buildings and interconnection to utility networks

Photo Voltaic Panels are made by embedding a number of Photo Voltaic (PV) cells in an array of cells. Each PV Cell contains solar photo-voltaic material that converts solar radiation into direct current electricity.

Materials presently used for photo voltaic panels include mono-crystalline silicon, polycrystalline silicon, microcrystalline silicon, cadmium telluride, and copper indium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacture of solar cells and photovoltaic panels has advanced dramatically in recent years.

Photo Voltaic cell and panel production has been doubling every 2 years, increasing by an average of 48 percent each year since 2002, making it the world's fastest-growing energy technology. At the end of 2009, the cumulative global PV installations reached 21,800 megawatts. Roughly 83% of this generating capacity consists of grid-tied large PV Solar Power Generating Plants. Such plants mostly use arrays of huge number of Solar Panels installed ground. Smaller Solar Power Generators use roof or terrace mounted arrays. Those installations that use panels built into the roof or walls of a building are called Building Integrated Photovoltaics or BIPV for short. Solar PV power stations today have capacities ranging from 10-60 MW although proposed solar PV power stations will have a capacity of even larger capacities.

Driven by advances in technology and increases in manufacturing scale and sophistication, the cost of photo voltaic panels has been declining steadily since the first solar cells were manufactured. Current prices from panel manufacturers are about 1.6 to 1.9 US Dollars per peak Watt, Wp. Net metering and financial incentives, such as preferential feed-in tariffs for solar-generated electricity, have supported solar PV installations in many countries.

How Photo Voltaic Cells work?

Photo Voltaic Cells are the best method for generating electric power to convert energy from the Sun into electricity. The photo voltaic effect refers to photons of light knocking electrons into a higher state of energy to create electricity. The term photo voltaic denotes the unbiased operating mode of a photo diode in which current through the device is entirely due to the transduced light energy. Virtually all photovoltaic devices are some type of photodiode.

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load

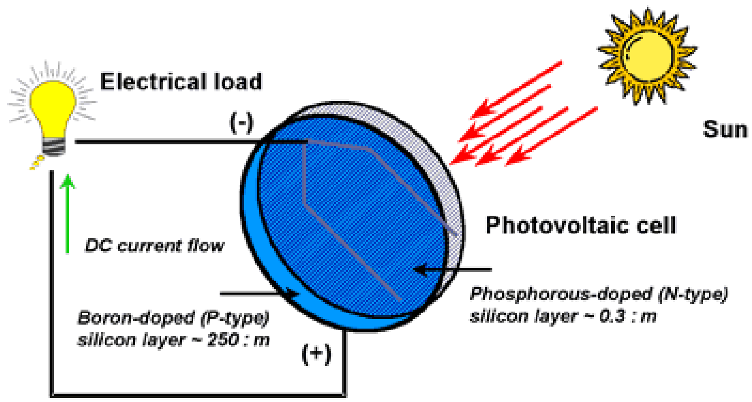


Figure 1. Diagram of a photovoltaic cell.

Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 1 sq Metre produces 150W peak power, Wp. This power output, Wp, is possible under ideal conditions but on an average in India power output per sq. metre on a sunny day is 0.7Wp. A 250Wp panel on a sunny day will generate about 1 kWh or One Unit of peak electrical energy.

How PC Cells are made?

The process of fabricating conventional single- and polycrystalline silicon PV cells begins with very pure semiconductor-grade poly-silicon - a material processed from quartz and used extensively throughout the electronics industry. The poly-silicon is then heated to melting temperature, and trace amounts of boron are added to the melt to create a P-type semiconductor material. Next, an ingot, or block of silicon is formed, commonly using one of two methods: 1) by growing a pure crystalline silicon ingot from a seed crystal drawn from the molten poly-silicon or 2) by casting the molten poly-silicon in a block, creating a polycrystalline silicon material. Individual wafers are then sliced from the ingots using wire saws and then subjected to a surface etching process. After the wafers are cleaned, they are placed in a phosphorus diffusion furnace, creating a thin N-type semiconductor layer around the entire outer surface of the cell. Next, an anti-reflective coating is applied to the top surface of the cell, and electrical contacts are imprinted on the top (negative) surface of the cell. An aluminized conductive material is deposited on the back (positive) surface of each cell, restoring the P-type properties of the back surface by displacing the diffused phosphorus layer. Each cell is then electrically tested, sorted based on current output, and electrically connected to other cells to form cell circuits for assembly in PV modules.

Photo Voltaic Cells, modules, Panels and Arrays

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

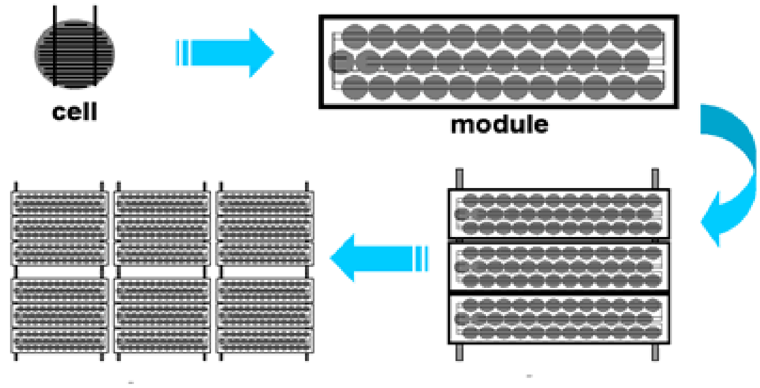


Figure 1. Photovoltaic cells, modules, panels and arrays.

The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25° C (77° F), and incident solar irradiance level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually about 80 percent of the STC rating.

Today's photovoltaic modules are extremely safe and reliable products, with minimal failure rates and projected service lifetimes of 20 to 30 years. Most major manufacturers offer warranties of 20 or more years for maintaining a high percentage of initial rated power output. When selecting PV modules, be careful to look for the product qualifications, testing and warranty information in the module manufacturer's specifications.

Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery. The first practical application of photo voltaic cells was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a small but fast growing market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines.

How PV Power System works?

Simply put, PV systems are like any other electrical power generating system. Just the equipment used is different than that used for conventional electromechanical generating systems. However, the principles of operation and interfacing with other electrical systems remain the same, and are guided by a well-established body of electrical codes and standards.

Although a PV array produces power when exposed to sunlight, a number of other components are required to properly conduct, control, convert, distribute, and store the energy produced by the array.

Depending on the functional and operational requirements of the system, the specific components required may include major components such as a DC-AC power inverter, battery bank and current controller, auxiliary energy sources and sometimes the specified electrical load (appliances). In addition, an assortment of balance of system (BOS) hardware, including wiring, over current, surge protection and disconnect devices, and other power processing equipment. Figure 3 show a basic diagram of a photovoltaic system and the relationship of individual components.

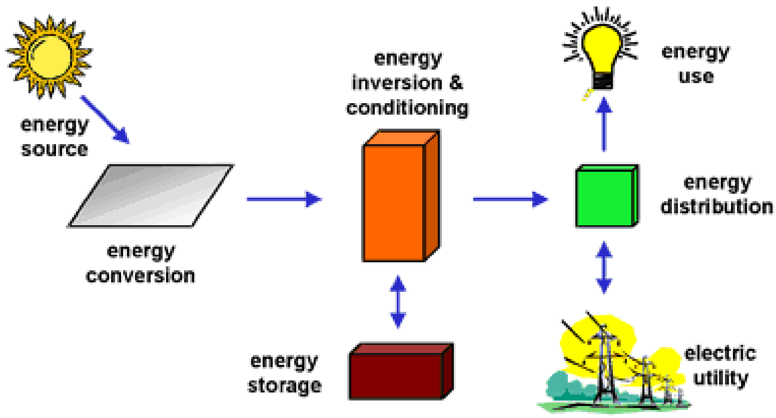


Figure 1. Major photovoltaic system components.

Why are battery banks used in Some PV Systems?

Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Other reasons batteries are used in PV systems are to operate the PV array near its maximum power point, to power electrical loads at stable voltages, and to supply surge currents to electrical loads and inverters. In most cases, a battery charge controller is used in these systems to protect the battery from overcharge and over discharge.

Types of PS Solar Systems

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads. The two principal classifications are (a) grid-connected or utility-interactive systems and (b) stand-alone systems. Photovoltaic systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems.

A. Grid connected Photovoltaic Systems

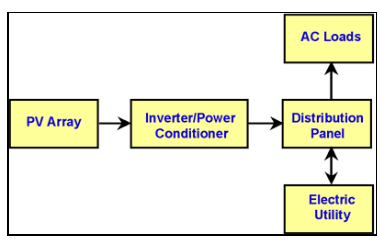


Figure 1 Diagram of grid-connected photovoltaic system

Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid. The primary component in grid-connected PV systems is the inverter, or power conditioning unit (PCU). The PCU converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid, and automatically stops supplying power to the grid when the utility grid is not energized. A bi-directional interface is made between the PV system AC output circuits and the electric utility network, typically at an on-site distribution panel or service entrance. This allows the AC power produced by the PV system to either supply on-site electrical loads, or to back-feed the grid when the PV system output is greater than the on-site load demand. At night and during other periods when the electrical loads are greater than the PV system output, the balance of power required by the loads is received from the electric utility This safety feature is required in all grid-connected PV systems, and ensures that the PV system will not continue to operate and feed back into the utility grid when the grid is down for service or repair.

B. Off-Grid (Stand-Alone) Photovoltaic Systems

Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC and/or AC electrical loads. These types of systems may be powered by a PV array only, or may use wind, an engine-generator or utility power as an auxiliary power source in what is called a PV-hybrid system. The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load (Figure 5). Since there is no electrical energy storage (batteries) in direct-coupled systems, the load only operates during sunlight hours, making these designs suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems. Matching the impedance of the electrical load to the maximum power output of the PV array is a critical part of designing well-performing direct-coupled system. For certain loads such as positive-displacement water pumps, a type of electronic DC-DC converter, called a maximum power point tracker (MPPT), is used between the array and load to help better utilize the available array maximum power output.

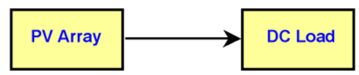


Figure 2 Direct-coupled PV system

In many stand-alone PV systems, batteries are used for energy storage. Figure 6 shows a diagram of

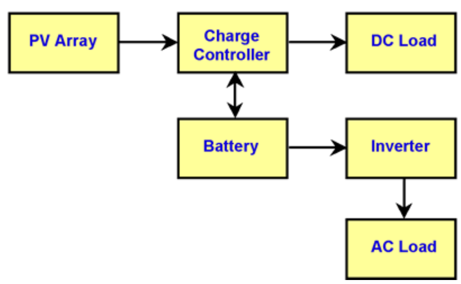


Figure 3 Diagram of stand-alone PV system with battery storage powering DC and AC loads.

a typical stand-alone PV system powering DC and AC loads. Figure 7 shows how a typical PV hybrid system might be configured.

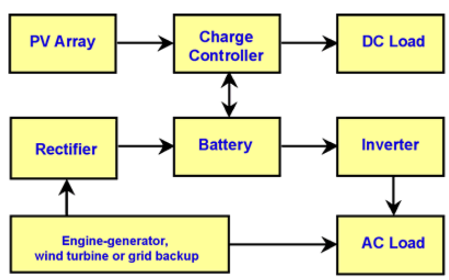


Figure 4. Diagram of photovoltaic hybrid system

Thin Film Photo Voltaic Modules

Thin-film photovoltaic modules are manufactured by depositing ultra-thin layers of semiconductor material on a glass or thin stainless-steel substrate in a vacuum chamber. A laser-scribing process is used to separate and weld the electrical connections between individual cells in a module. Thin-film photovoltaic materials offer great promise for reducing the materials requirements and manufacturing costs of PV modules and systems

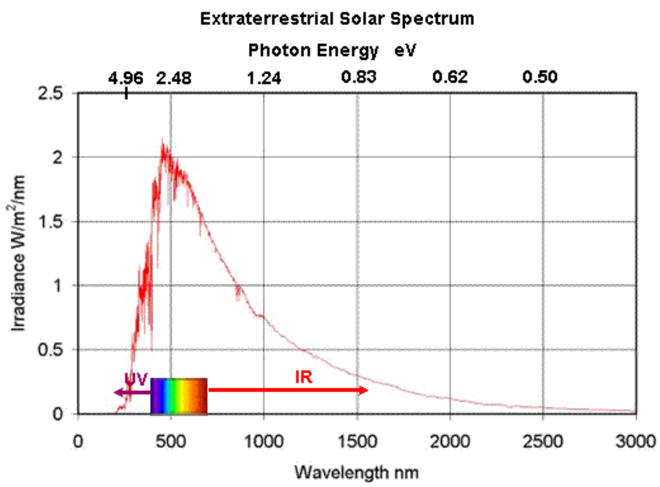
Solar Power

The earth receives more energy from the Sun in just one hour than the world's population uses in a whole year. The total solar energy flux intercepted by the earth on any particular day is 4.2 X 1018 Watthours or 1.5 X 1022 Joules (or 6.26 X 1020 Joules per hour). This is equivalent to burning 360 billion tons of oil per day or 15 Billion Tons of Oil per hour. In fact the world's total energy consumption of all forms in the year 2000 was only 4.24 X 1020 Joules. In year 2005 it was 10,537 M Tons of Oil (Source BP Statistical Review of World Energy 2006)

Solar Radiation

Sunlight comes in many colours, combining low-energy infrared photons (1.1 eV) with high-energy ultraviolet photons (3.5 eV) and all the visible-light photons between.

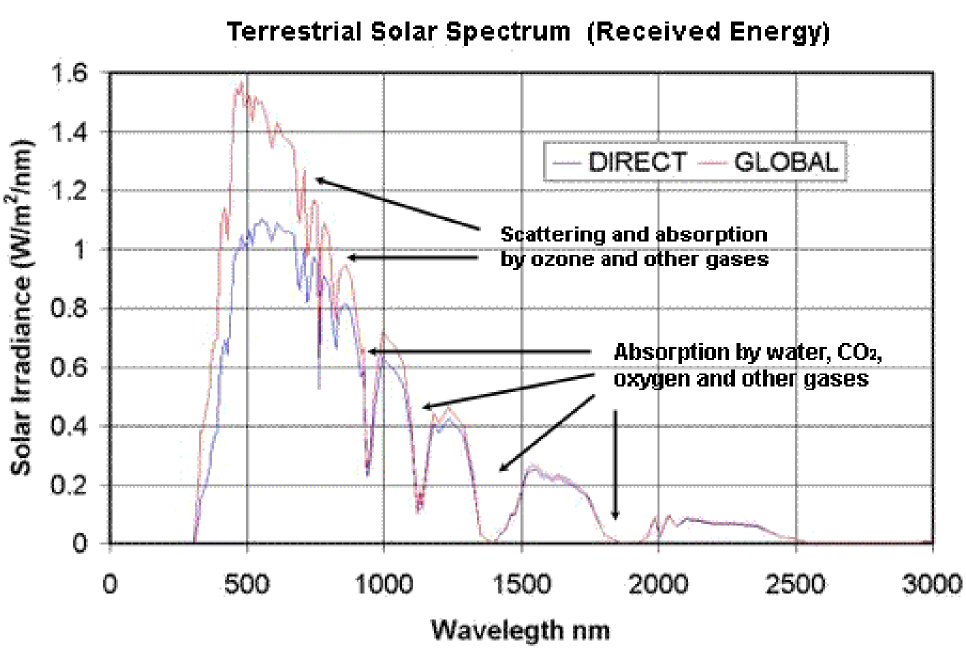
The graph below shows the spectrum of the solar energy impinging on a plane, directly facing the sun, outside the Earth's atmosphere at the Earth's mean distance from the Sun. The area under the curve represents the total energy in the spectrum. Known as the "Solar Constant" G0, it is equal to 1367 Watts per square metre (W/m2).



The radiant energy falling within the visible spectrum is about 43% of the total with about 52% in the infra red region and 5% in the ultra violet region.

The graph below shows the energy at sea level.

Direct energy is the energy received directly from the sun. Global energy includes energy diffused, scattered or reflected from clouds and energy re-radiated by the earth itself.



Energy received at sea level is about 1kW/m2 at noon near the equator

Irradiance and Insolation

Total solar irradiance is defined as the the amount of radiant energy emitted by the Sun over all wavelengths, not just visible light, falling each second on a 1 square metre perpendicular plane outside Earth's atmosphere at a given distance from the Sun. It is roughly constant, fluctuating by only a few parts per thousand from day to day. On the outer surface of the Earth's atmosphere the irradiance is known as the solar constant and is equal to about 1367 Watts per square meter.

The amount of solar energy that actually passes through the atmosphere and strikes a given area on the Earth over a specific time varies with latitude and with the seasons as well as the weather and is known as the insolation (incident solar radiation).

When he Sun is directly overhead the insolation, that is the incident energy arriving on a surface on the ground perpendicular to the Sun's rays, is typically 1000 Watts per square metre. This is due to the absorption of the Sun's energy by the Earth's atmosphere which dissipates about 25% to 30% of the radiant energy.

Sun's bounty can only be harvested during daylight hours and some energy must be stored for use during the hours of darkness and the requirement to distribute the energy over great distances to where it is needed make this proposition impractical. The example merely serves to illustrate the abundance of the sun's energy.

The best way to use Solar Power is to build smaller, more efficient solar power plants to serve the demands of local communities using free solar energy when it is available in conjunction with other other energy sources or some local energy storage where possible. Despite this, less than 0.1% of the world's primary energy demand is supplied by solar energy.