Solar PV Theory & Performance

The Theory

A **photovoltaic module** or **photovoltaic panel** is a packaged interconnected assembly of photovoltaic cells, also known as **solar cells**. The photovoltaic module, known more commonly as the solar panel, is then used as a component in a larger photovoltaic system to offer electricity for commercial and residential applications.

Because a single photovoltaic module can only produce a limited amount of power, many installations contain several modules or panels and this is known as a photovoltaic array. A photovoltaic installation typically includes an array of photovoltaic modules or panels, an inverter, batteries and interconnection wiring.

Solar panels use light energy (photons) from the sun to generate electricity through the photovoltaic effect (this is the photo-electric effect). The structural (load carrying) member of a module can either be the top layer (superstrate) or the back layer (substrate). The majority of modules use wafer-based crystalline silicon cells or a thin-film cell based on cadmium telluride or silicon. Crystalline silicon, which is commonly used in the wafer form in photovoltaic (PV) modules, is derived from silicon, a commonly used semi-conductor.

In order to use the cells in practical applications, they must be:

- connected electrically to one another and to the rest of the system

- protected from mechanical damage during manufacture, transport, installation and use (in particular against hail impact, wind and snow loads). This is especially important for wafer-based silicon cells which are brittle.

- protected from moisture, which corrodes metal contacts and interconnects, (and for thin-film cells the transparent conductive oxide layer) thus decreasing performance and lifetime.

Most modules are usually rigid, but there are some flexible modules available, based on thin-film cells.

Electrical connections are made in series to achieve a desired output voltage and/or in parallel to provide a desired amount of current source capability.

Diodes are included to avoid overheating of cells in case of partial shading. Since cell heating reduces the operating efficiency it is desirable to minimize the heating. Very few modules incorporate any design features to decrease temperature, however installers try to provide good ventilation behind the module.

New designs of module include concentrator modules in which the light is concentrated by an array of lenses or mirrors onto an array of small cells. This allows the use of cells with a very high-cost per unit area (such as gallium arsenide) in a cost-competitive way.

Depending on construction, the photovoltaic can cover a range of frequencies of light and can produce electricity from them, but sometimes cannot cover the entire solar spectrum (specifically, ultraviolet, infrared and low or diffused light). Hence much of incident sunlight energy is wasted when used for solar panels, although they can give far higher efficiencies if illuminated with monochromatic light. Another design concept is to split the light into different wavelength ranges and direct the beams onto different cells tuned to the appropriate wavelength ranges. This is projected to raise efficiency by 50%. Also, the use of infrared photovoltaic cells can increase the efficiencies, producing power at night.

Sunlight conversion rates (module efficiencies) can vary from 5-18% in commercial production (solar panels), that can be lower than cell conversion.

Module performance and lifetime

Module performance is generally rated under **Standard Test Conditions** (STC) : irradiance of 1,000 W/m², solar spectrum of AM 1.5 and module temperature at 25°C.

Electrical characteristics include nominal power (PMAX, measured in W), open circuit voltage (VOC), short circuit

current (ISC, measured in amperes), maximum power voltage (VMPP), maximum power current (IMPP) and module efficiency (%).

In kWp, kW is kilowatt and the p means “peak” as peak performance. The “p” however does not show the peak performance, but rather the maximum output according to STC.

Solar panels must withstand heat, cold, rain and hail for many years. Specialist Glass Systems offer warranties that guarantee electrical production for 12 years at 90% of rated power output and 25 years at 80%.