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Solar Energy-Introduction

- Energy is being produced in the sun through various nuclear fusion reactions
- Solar spectrum can be divided into 3 main regions: UV-9%, visible-45%,IR-46%, UV and IR are almost completely absorbed by oxygen and nitrogen gases and ions.
- Insolation is the amount of solar radiation received on a given surface in a given time period.
- Optimum orientation of the collectors to get maximum energy

Types

- Two ways of converting solar energy into electricity

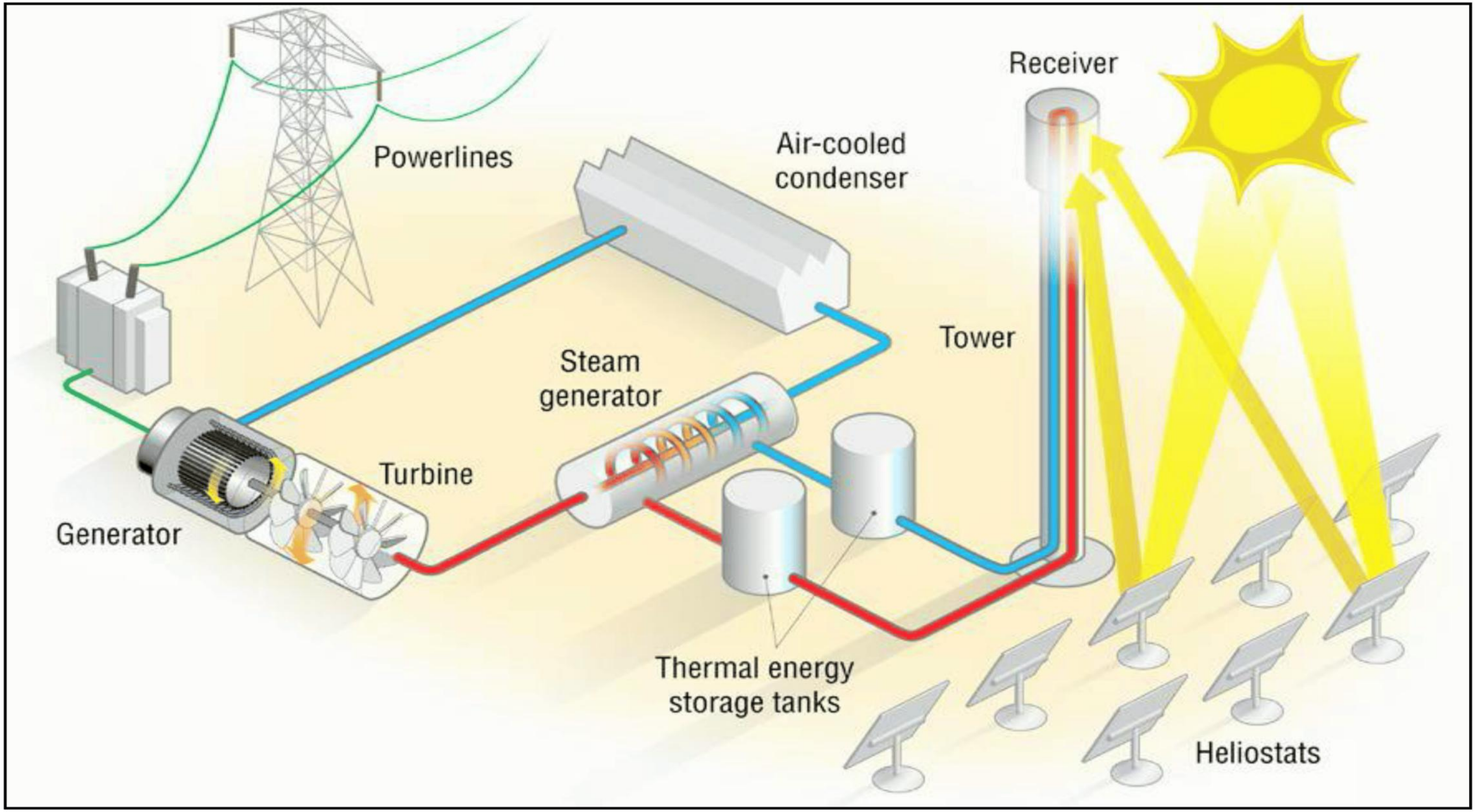
1. Solar thermomechanical Systems
2. Solar Photovoltaics

Solar Thermomechanical Systems

- Solar thermal power/electric generation systems collect and concentrate sunlight to produce the high temperature heat needed to generate electricity.
- All solar thermal power systems have solar energy collectors with two main components: *reflectors* (mirrors) that capture and focus sunlight onto a *receiver*.
- In most types of systems, a heat-transfer fluid is heated and circulated in the receiver and used to produce steam.

Solar Thermomechanical Systems

- The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity.
- Solar thermal power systems have tracking systems that keep sunlight focused onto the receiver throughout the day as the sun changes position in the sky.
- Solar thermal power plants usually have a large field or array of collectors that supply heat to a turbine and generator.



Powerlines
Receiver
Air-cooled
condenser
Tower
Steam
generator
Turbine
Generator
Thermal energy
storage tanks
Heliostats

A **heliostat** (from *helios*, the Greek word for *sun*, and *stat*, as in stationary) is a device that includes a mirror, usually a plane mirror, which turns so as to keep reflecting sunlight toward a predetermined target, compensating for the sun's apparent motions in the sky.

Concentrated Solar Power Plant

Disadvantages

- Low efficiency
- The efficiency of the collecting system decreases with increase in temperature, but efficiency of the heat engine increases with temperature
- Mechanical system needs good maintenance

Solar Photovoltaic Cells

- When light shines on a photovoltaic (PV) cell – also called a solar cell – that light may be reflected, absorbed, or pass right through the cell.
- The PV cell is composed of semiconductor material
- When the semiconductor is exposed to light, it absorbs the light's energy and transfers it to electrons. This extra energy allows the electrons to flow through the material current. This current is extracted through conductive metal contacts.

Photoelectric Effect

- Conversion of photons to electricity
- Observed in 1839 by A.E Becquerel
- Einstein won the Nobel Prize for the theory of Photoelectric effect in 1921
- First Patent on semiconductor junction-based PV cell- Russel Ohl in 1946
- Early Development of PV using amorphous Silicon in 60’s and 70’s

Material

- **Silicon** is, by far, the most common semiconductor material used in solar cells, representing approximately **95% of the modules sold** today.
- Crystalline silicon cells are made of silicon atoms connected to one another to form a crystal lattice. This lattice provides an organized structure that makes conversion of light into electricity more efficient.
- Solar cells made out of silicon currently provide a combination of high efficiency, low cost, and long lifetime. Modules are expected to last for 25 years or more, still producing more than 80% of their original power after this time.

Main Commercial Technologies

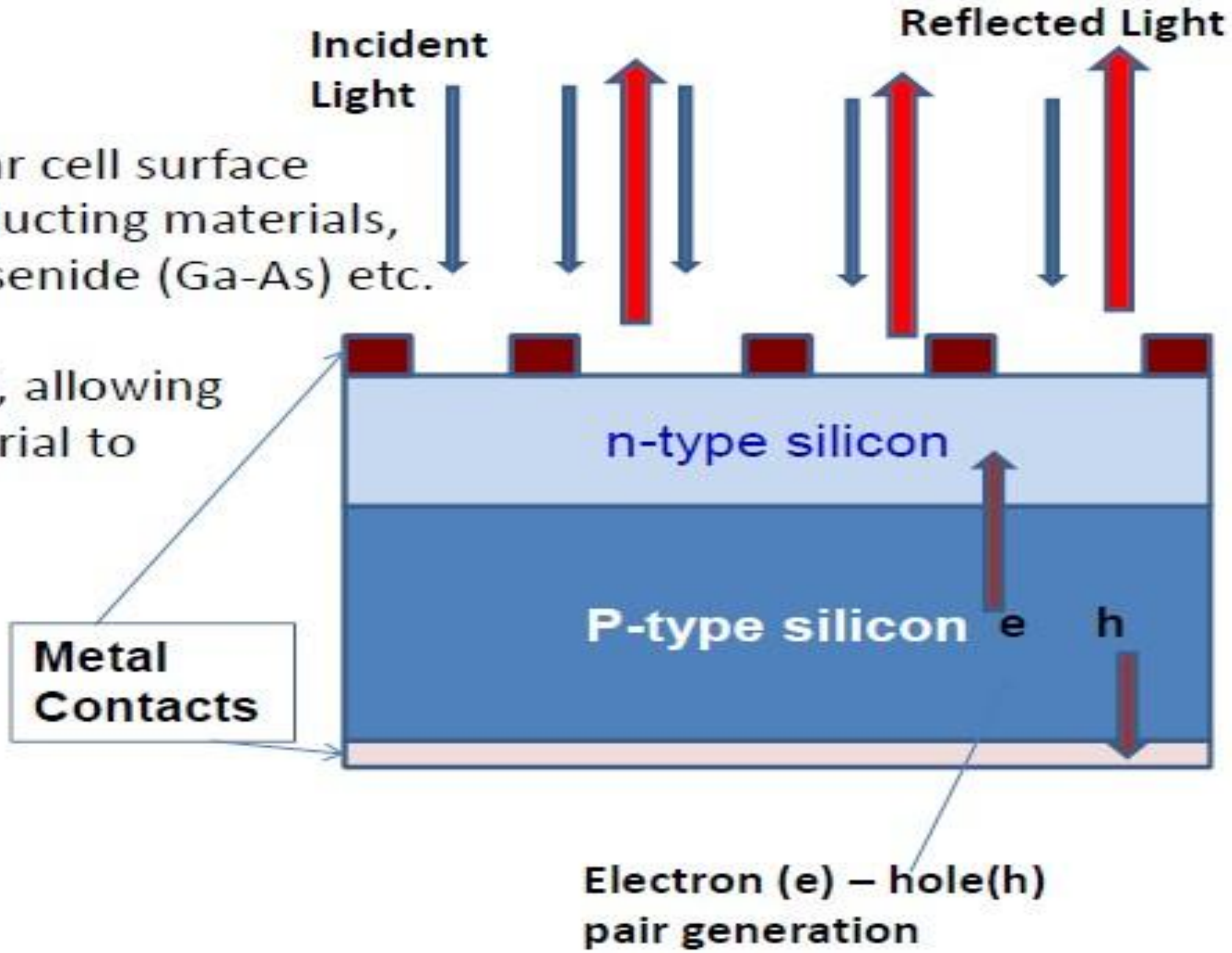
- Generations 1, 2, 3
- Thick film
  - Polycrystalline Si
  - Monocrystalline Si
- Thin film
  - Amorphous Si
  - Cadmium Telluride (CdTe)
  - Copper Indium Gallium Selenide (CIGS)
  - Multi-junction thin film
- *Lots of new technologies*

Solar Photovoltaic (PV) technology for Power Generation

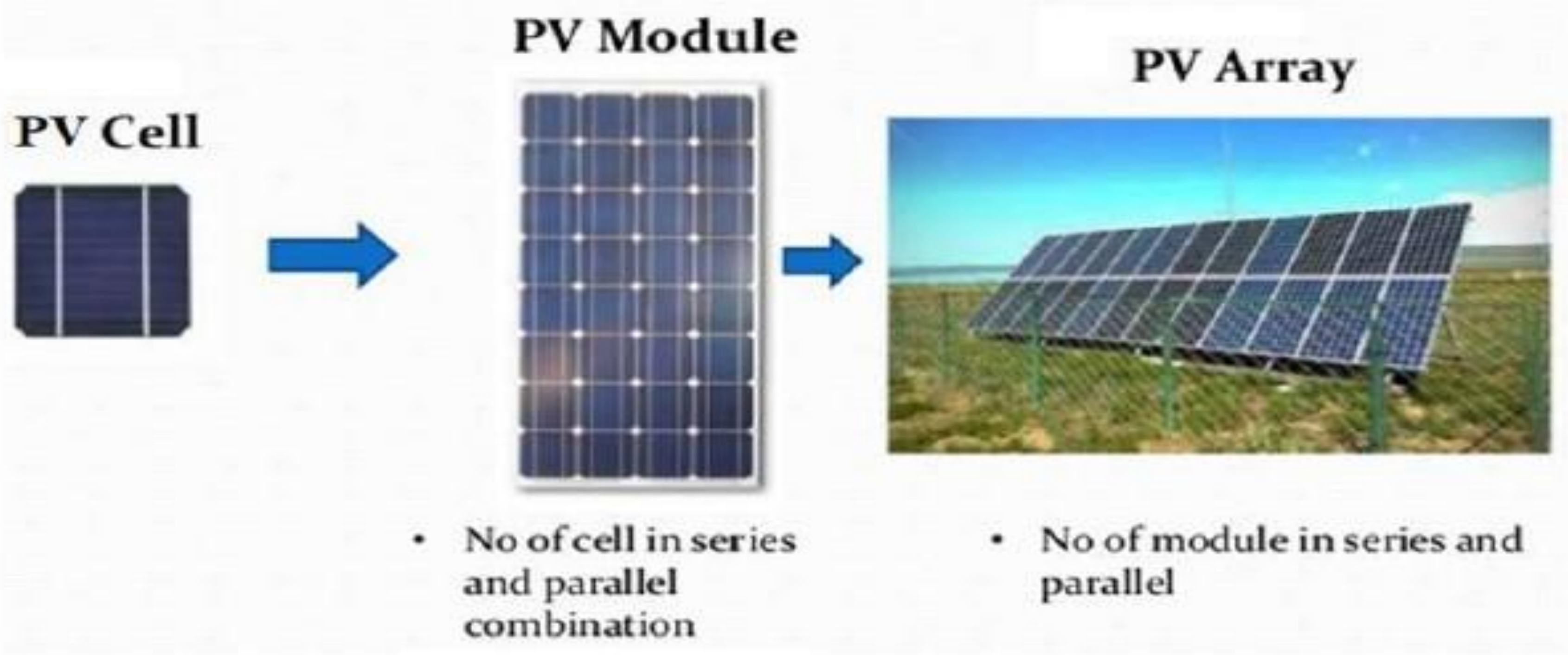
1. Photons in sunlight hit the solar cell surface and are absorbed by semiconducting materials, such as Silicon (Si), Gallium-Arsenide (Ga-As) etc.

2. Electron-hole pairs are created, allowing them to flow through the material to produce electricity.

3. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity.



Solar PV Cell – Module/Panel – Array

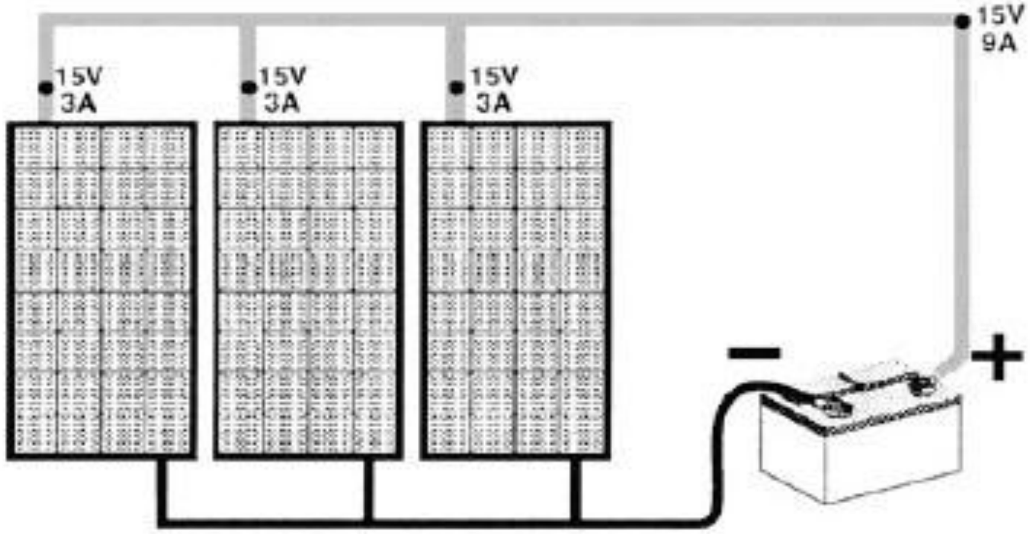


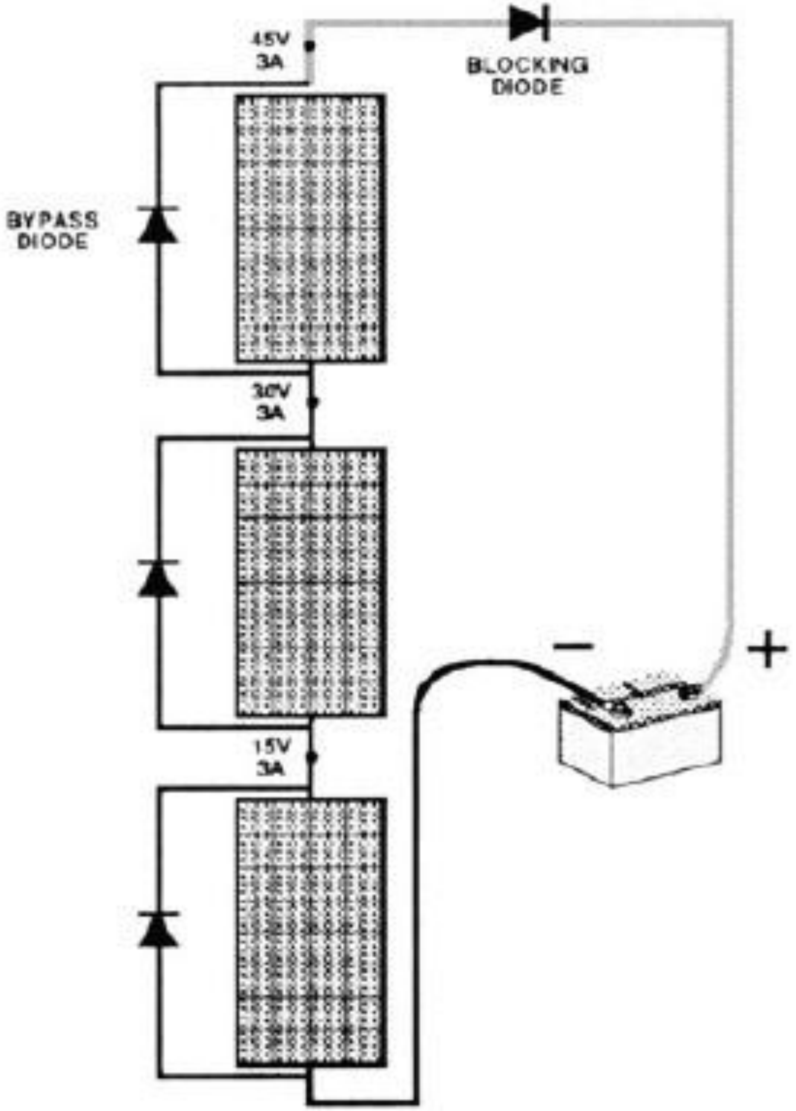
** Open circuit voltage (OCV) of a typical solar PV cell is around 0.6 Volts*

Efficiency

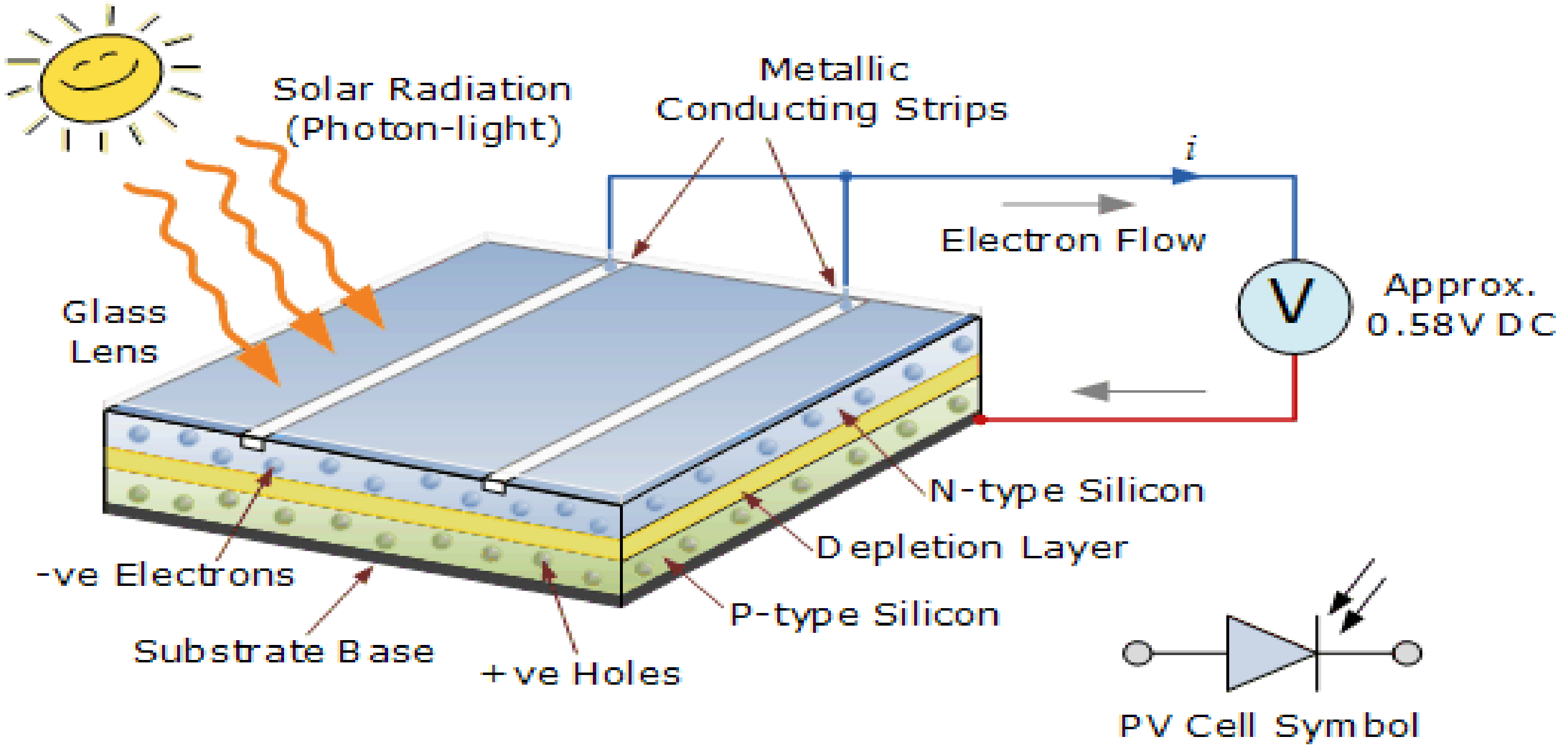
- The efficiency of a PV cell is simply the amount of electrical power coming out of the cell compared to the energy from the light shining on it
- The amount of electricity produced from PV cells depends on the characteristics (such as intensity and wavelengths) of the light available and multiple performance attributes of the cell.
- An important property of PV semiconductors is the bandgap, which indicates what wavelengths of light the material can absorb and convert to electrical energy. If the semiconductor's bandgap matches the wavelengths of light shining on the PV cell, then that cell can efficiently make use of all the available energy.

Series-Parallel connection of solar PV panels





Solar Cell



Solar Radiation
(Photon-light)
Metallic
Conducting Strips
i
Electron Flow
V
Approx.
0.58V DC
Glass
Lens
N-type Silicon
Depletion Layer
-ve Electrons
P-type Silicon
Substrate Base
+ve Holes
PV Cell Symbol

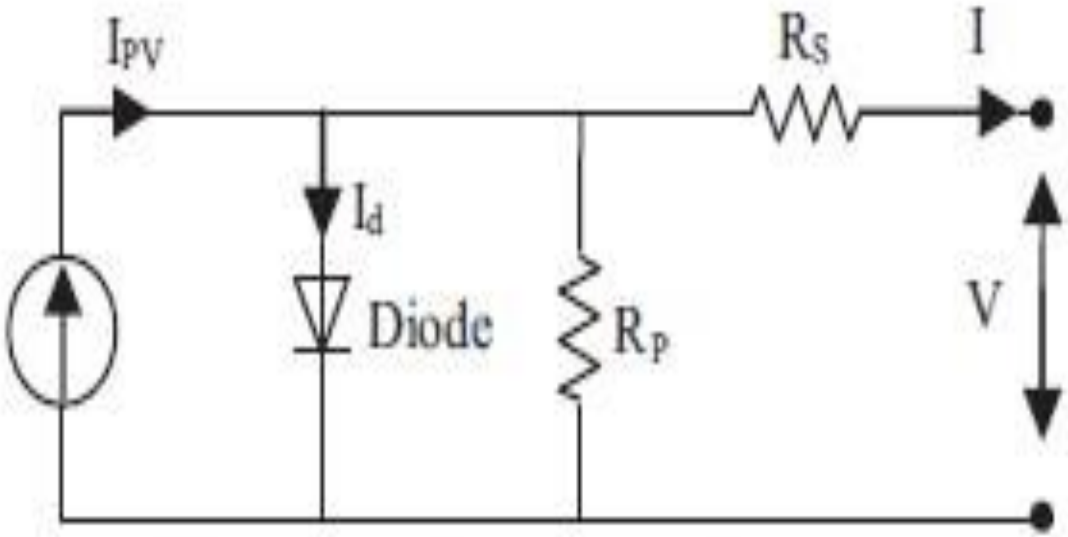
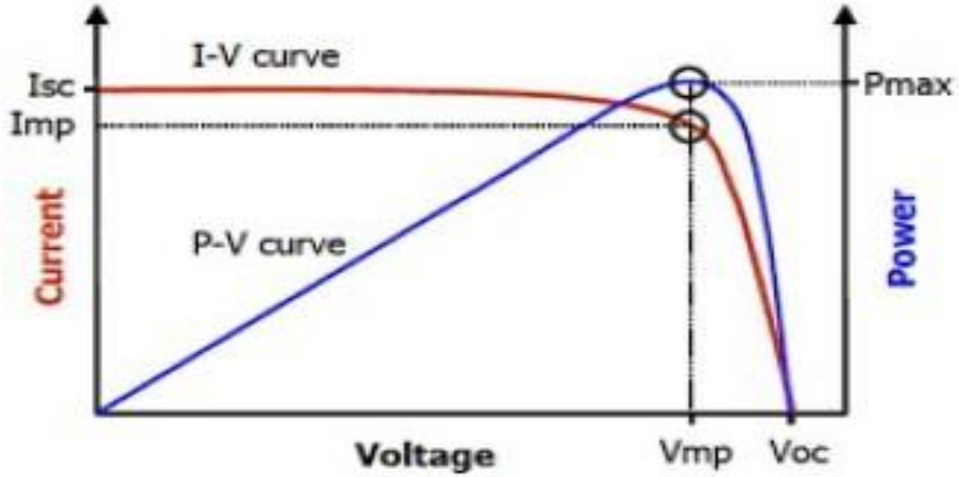


Fig. 2. Equivalent circuit of solar panel.

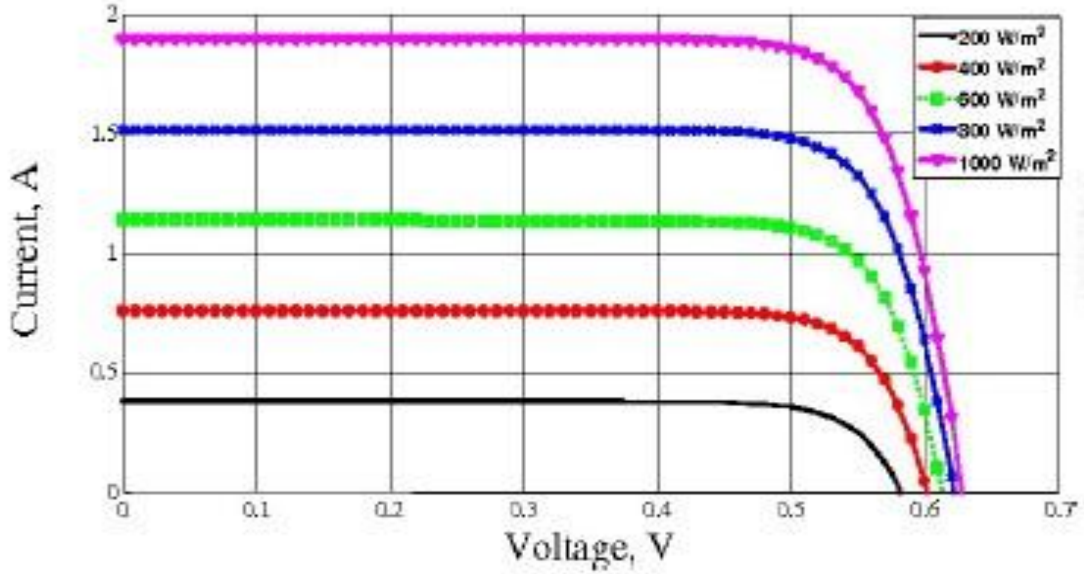
where, I_{PV} is the PV current, I_o is the saturated reverse current, "a" is a constant known as the diode ideality factor, $V_t = N_s KT/q$ is the thermal voltage associated with the cells, N_S is the number of cells connected in series, q is the charge of the electron, K is the Boltzmann constant, T is the absolute temperature of the p–n junction, and R_S and R_P are the series and parallel equivalent resistances of the solar panel respectively.

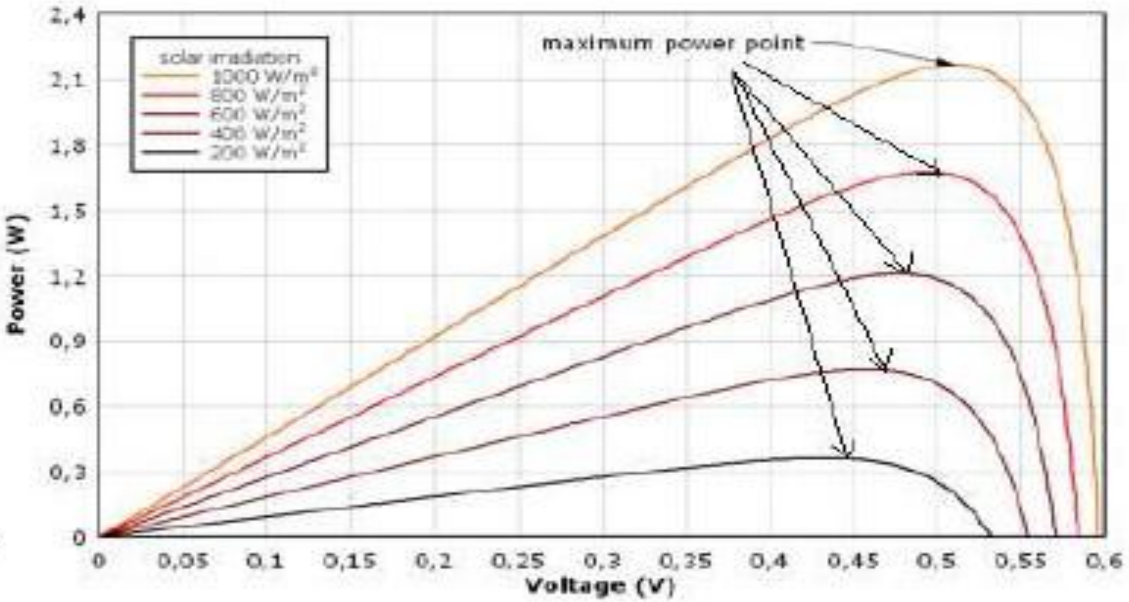
$$I = I_{PV} - I_O \left[\exp\left(\frac{V + R_S I}{a V_t} \right) - 1 \right] - \frac{V + R_S I}{R_P}$$

Electrical characteristics of Solar PV cell

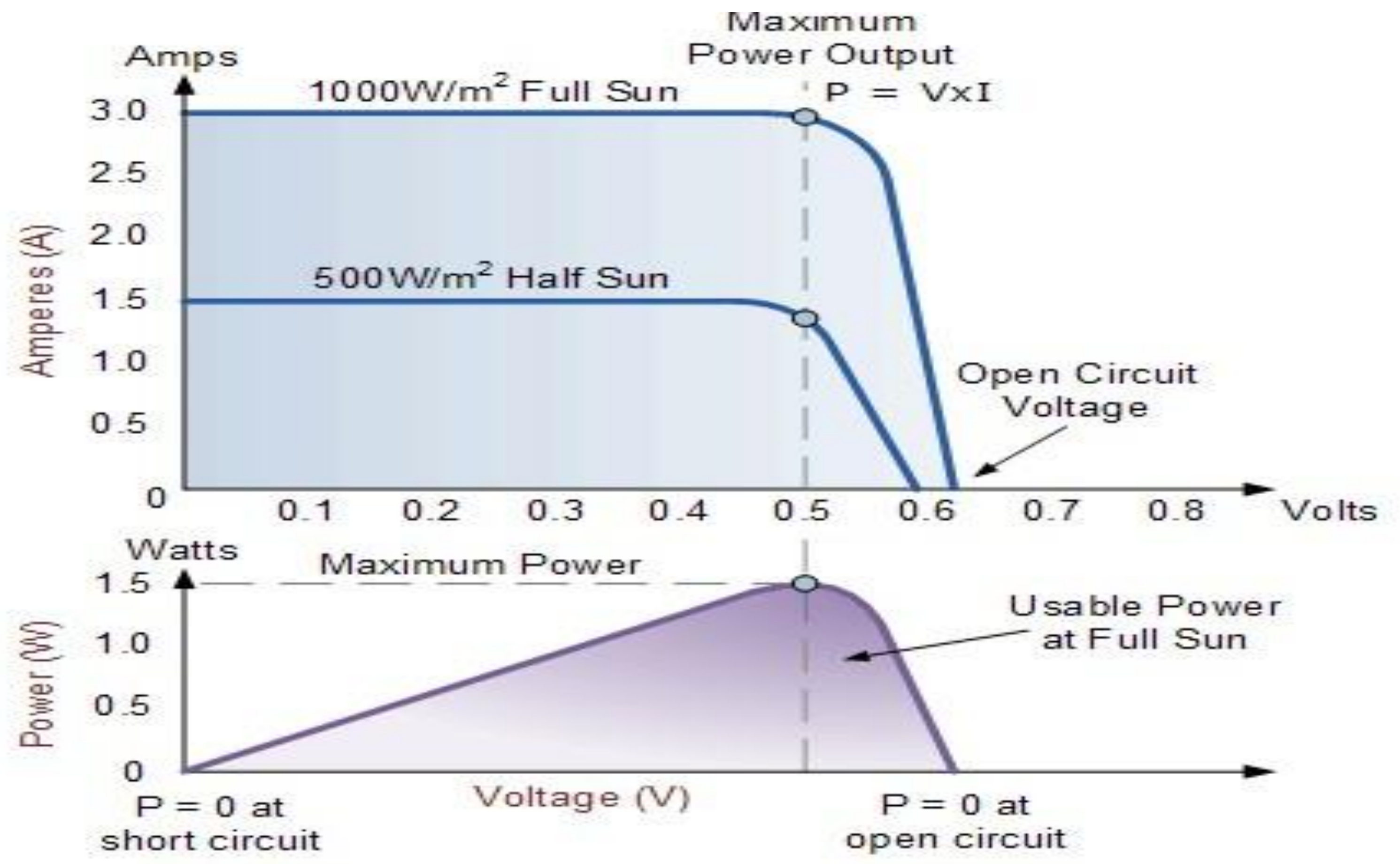


Irradiance Dependency:



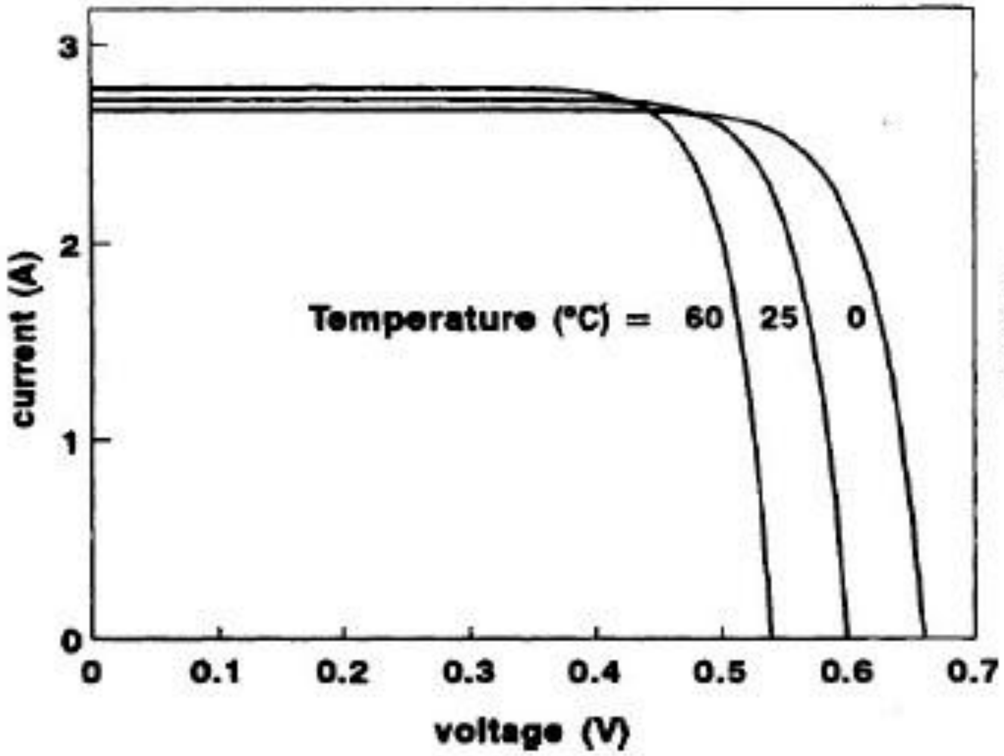


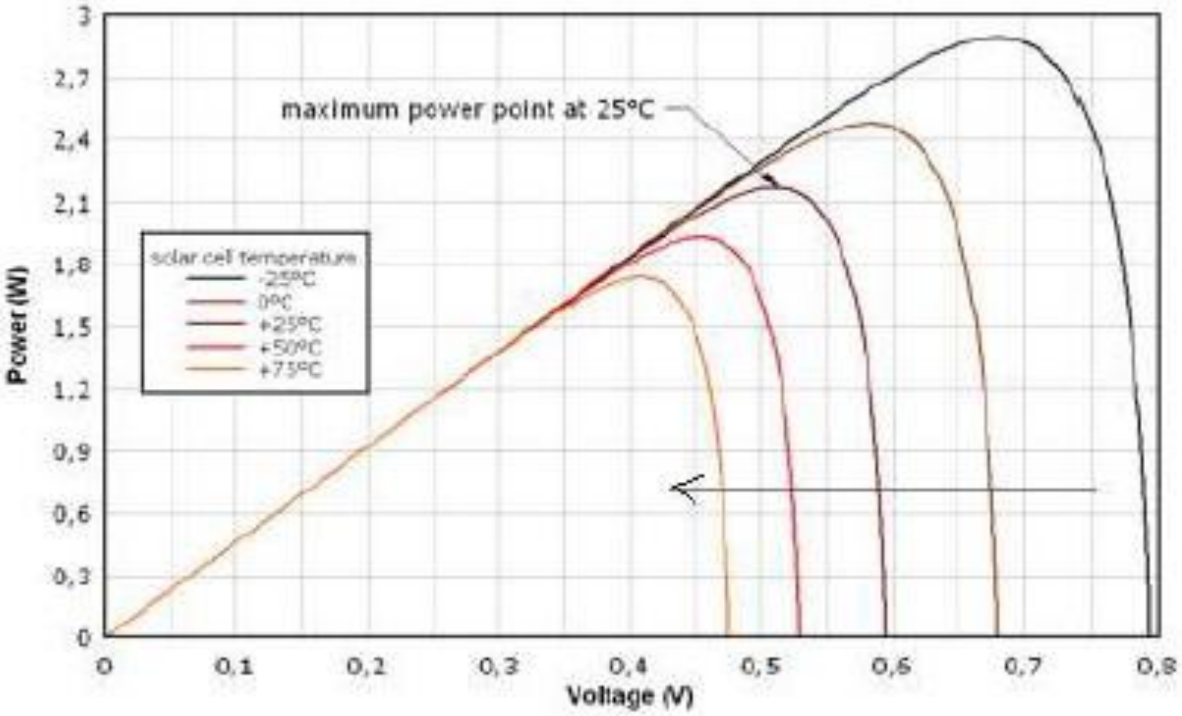
Photovoltaic Solar Cell I-V Characteristics



Electrical characteristics of Solar PV cell

Temperature Dependency:

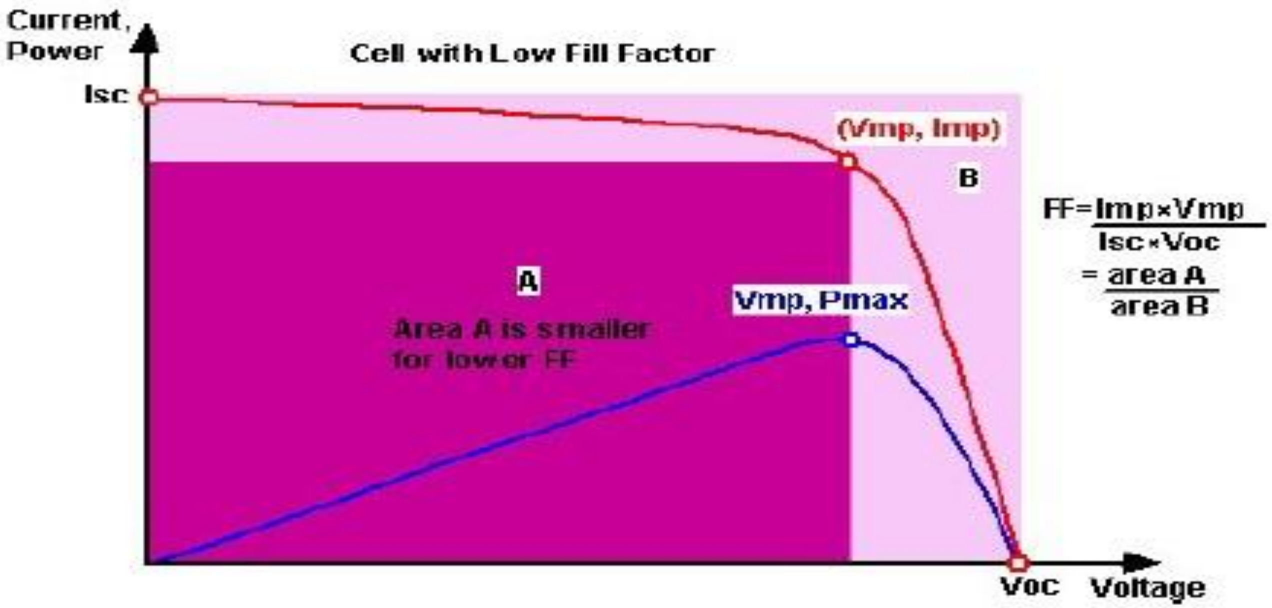




Efficiency of a Solar PV cell

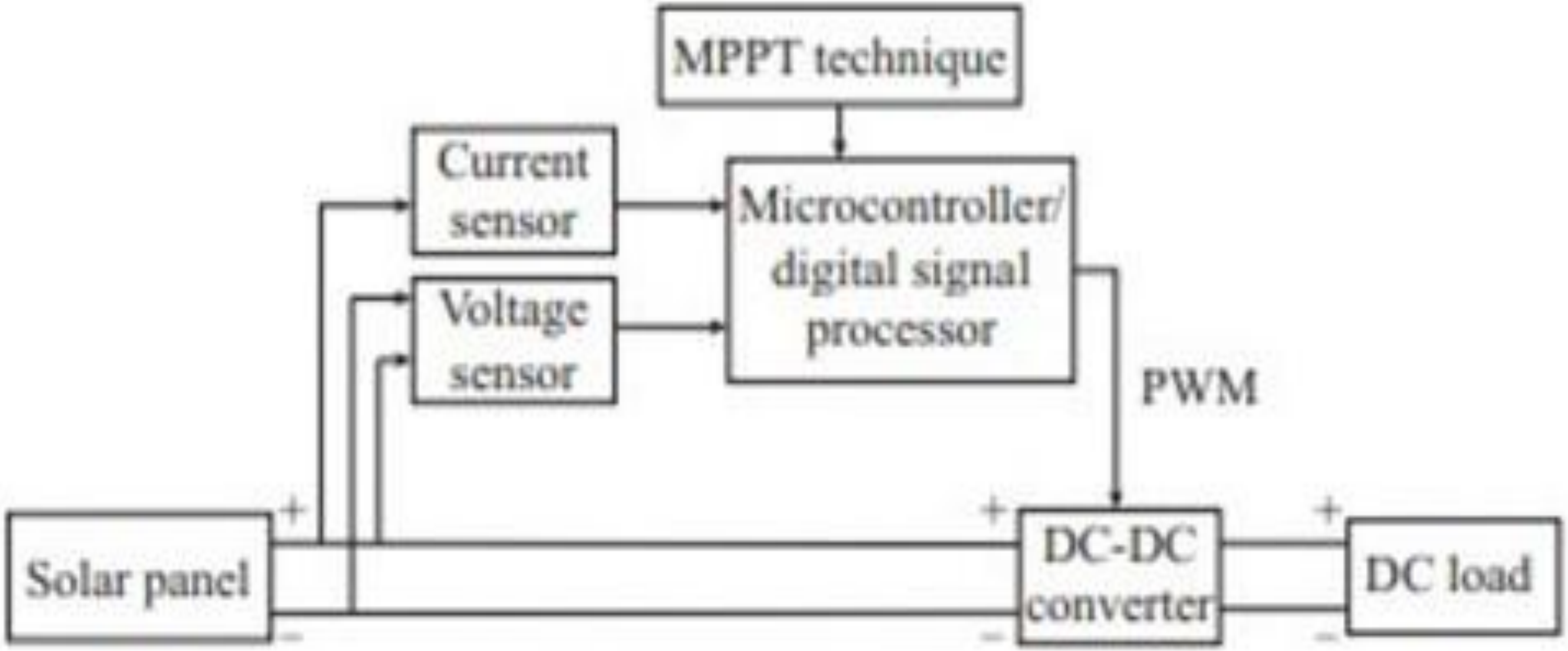
$$Fill\ Factor\ (FF) = \frac{P_{max}}{V_{oc}.I_{sc}}$$

$$Efficiency = \frac{P_{max}}{P_{in}} = \frac{V_{oc}.I_{sc}.FF}{P_{in}}$$



- Fill factor determines the quality of the cell
- MPPT –Maximum Power Point Tracking

MPPT Control Circuit

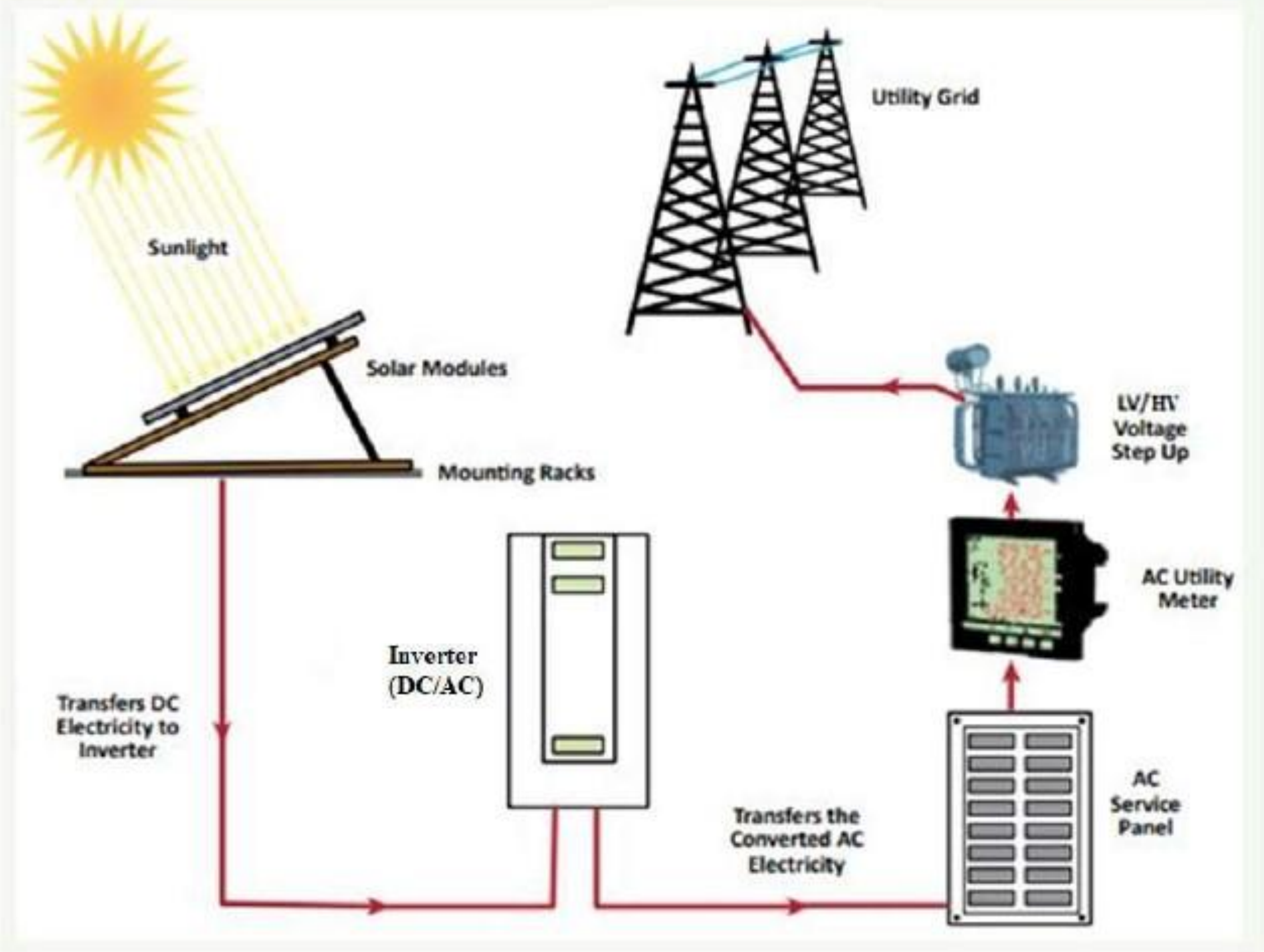


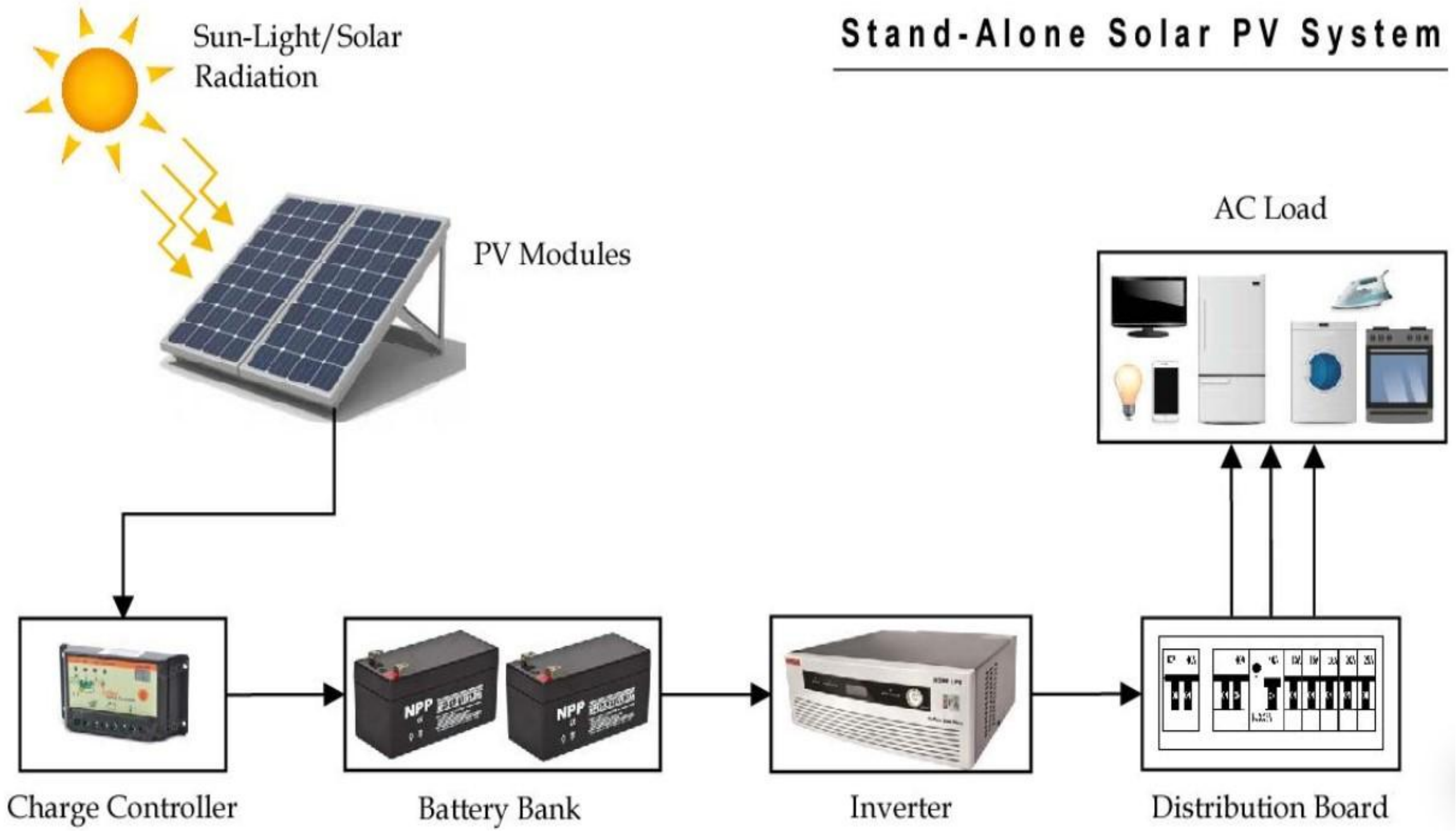
Largest Solar Plant of India

- Bhadla Solar Park is the largest solar farm in the world. The facility, spanning over an area of 14000 acres, is located in the Jodhpur district of Rajasthan.
- The solar farm has a capacity of 2.25 GW.
- Commissioned in 2017, the massive solar project contains over 10 million solar panels.


BHADLA SOLAR POWER PLANT
mers who migrate to OCI

Grid connected (On-Grid) Solar PV system




Stand-Alone Solar PV System
Sun-Light/Solar Radiation
PV Modules
AC Load
Charge Controller
Battery Bank
Inverter
Distribution Board

Different Structures





Floating Solar

- **Floating solar** or **floating photovoltaics** (FPV), sometimes called **floatovoltaics**, are solar panels mounted on a structure that floats on a body of water, typically a reservoir or a lake
- Water surfaces may be less expensive than the cost of land, and there are fewer rules and regulations for structures built on bodies of water not used for recreation.
- The costs for a floating system are about 10-20% higher than for ground-mounted systems.
- The market for this renewable energy technology has grown rapidly since 2016.

Floating Solar

PV power station	Location	Country	Nominal Power[45] (MW_p)	Year
Wenzhou Taihan	Wenzhou, Zhejiang	China	550	2021
Dezhou Dingzhuang	Dezhou, Shandong	China	320	
Three Gorges	Huainan City, Anhui	China	150	2019
NTPC Ramagundam (BHEL)	Peddapalli, Telangana	India	145	
Xinji Huainan	Xinji Huainan	China	102	2017
Yuanjiang Yiyang	Yiyang, Hunan	China	100	2019
NTPC Kayamkulam (TATA POWER)	Kayamkulam, Kerala	India	92	