EEE 102 Basic Electrical Engineering

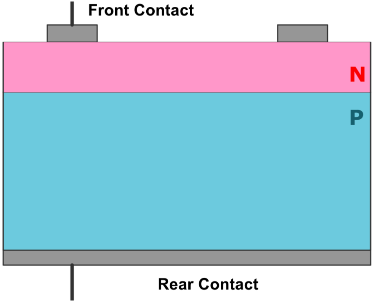
Lecture 4: Generation III

Parikshit Pareek

Department of Electrical Engineering, IIT Roorkee

Solar PhotoVoltaic (PV)

- PV Device: Generate Electricity from Light
- Photo-Electric Effect: Removal of electrons from a metal using light
- To generate power, we need to generate current – controlled flow of electrons
- Conductors – random flow; Insulators – no flow
- So need Semi-conductors (p-type, n-type)– Recall Class XII Physics

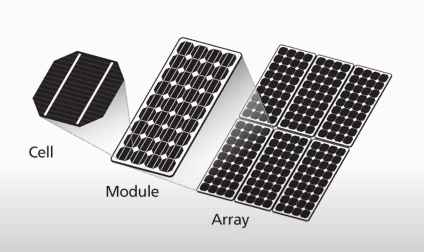


Picture taken from PV Education.

Cell Types

- Crystalline Silicon Solar Cells
  - Easy to manufacture — maximum market share
  - Efficiency: 14–28%
  - Efficiency depends on the type of silicon and the technology used to build the cells
- Thin Film Solar Cells
  - Thin films consist of p-n junctions in solar cells
  - Less market share, with innovations like organic cells as a focus
  - Cadmium Telluride (CdTe) technology offers competitive costs
- Multi-Junction (Tandem) Solar Cells
  - Incorporates multiple p-n junctions for higher efficiency
  - Uses different materials for absorbing different wavelengths
  - Offers higher efficiency compared to crystalline cells, but at a higher cost

PV Building Blocks



- Multiple cells in series – Module
- Multiple modules in series-parallel – Array
- Configuration depends upon voltage & current levels
- Configuration affects reliability & operatability

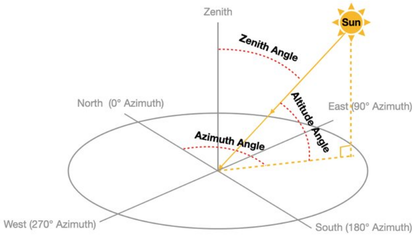
– **Standard Testing Conditions (STC):** Power rating of the module is output power produced by a solar module in a laboratory conditions at a particular temperature & irradiance.

– **Irradiance :** Radiant power received by per unit area $(\mathrm{W/m^2})$

Source: Internet

Input Power

- **Air Mass (AM):** Reciprocal of cosine of solar zenith angle(θ) i.e. AM $= 1/\cos\theta$



$$\text{Distance Traveled in Atmosphere} \approx \frac{1}{\cos\theta}\text{Thickness of Atmosphere}$$

$$\text{Power Input} \quad P_{in} = [\text{Area of the Module}]E$$

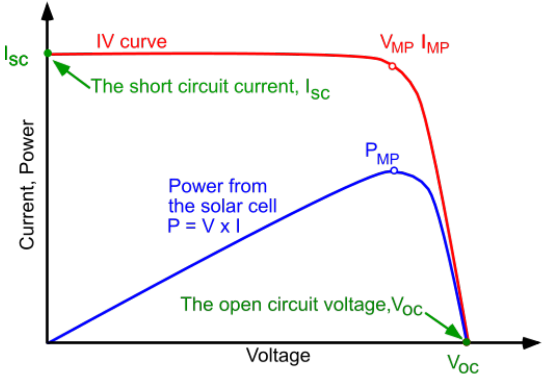
- Standard for solar is AM1.5 on Earth surface and E $= 1000\ \mathrm{W/m^2}$
  – E Irradiance $(\mathrm{W/m^2})$ – θ Solar Zenith Angle

Output Power– I-V Characteristics

$$P = VI = I^2R = \frac{V^2}{R}$$

For a solar module with V_{mp} & I_{mp} as maximum voltage & current at maximum power

$$P_{max} = V_{mp}\, I_{mp}$$



Fill Factor & Efficiency

- Fill Factor (FF): Ratio of the maximum power from the solar cell to the product of V_{oc} & I_{sc}

$$\mathrm{FF} = \frac{\mathrm{P_{max}}}{\mathrm{V_{oc}\,I_{sc}}} = \frac{\mathrm{V_{mp}\,I_{mp}}}{\mathrm{V_{oc}\,I_{sc}}}$$

- Panel Efficiency (η):

$$\eta = \frac{\mathrm{P_{out}}}{\mathrm{P_{in}}} = \frac{\mathrm{P_{max}}}{\mathrm{P_{in}}}$$

- Efficiency will always be a function of operating conditions like temperature, irradiance etc

Solar & Environment Impact

- No: Water, Emissions, Noise (also no moving parts, low maintenance, long life)
- Land Co-Use: Parking Lots, Rooftops, Substations, Airports, etc.
- Brownfield (contaminated site) OR Greenfield - especially non-arable/arid land

Solar & Environment Impact

- + No: Water, Emissions, Noise (also no moving parts, low maintenance, long life)
- + Land Co-Use: Parking Lots, Rooftops, Substations, Airports, etc.
- + Brownfield (contaminated site) OR Greenfield - especially non-arable/arid land

- − Environmental Drawbacks of Manufacturing:
  - Chemicals
  - Hazardous materials
  - Manufacturing waste
- − Energy Use & Embodied Energy
- − End-of-Life Concerns:
  - Some panels contain hazardous substances (e.g., cadmium, selenium, lead, arsenic)– Disposal & recycling remain challenges
- − Land Use Impact:
  - Potential trade-off if fertile, arable land is allocated for solar PV installations