

Class-15<sup>th</sup>

- According to the Government of India's policy for the solar sector – Jawaharlal Nehru National Solar Mission (JNNSM) – a target of 20 GW of solar installations by 2022 has been set

<b>Properties</b>	<b>Thin film solar cells</b>	<b>Monocrystalline cells</b>	<b>Polycrystalline solar cells</b>
<b>Construction</b>	Thin film is made by depositing one or more thin layers (thin film) of photovoltaic material on a substrate.	Monocrystalline cells are cut from a chunk of silicon that has been grown from a single crystal.	A polycrystalline cell is cut from multifaceted silicon crystal.
<b>Efficiency</b>	Less efficient than polycrystalline and Monocrystalline panels: Efficiency range – 10% to 12%	Efficient compared to both poly crystalline and thin film: Efficiency range – 15 to 19%	Efficient than thin film solar cell but less efficient than Monocrystalline solar cell: Efficiency range -11-15%

<b>Appearance</b>	Thin film, uniform in color.	Monocrystalline cells tend to be uniform in appearance.	Polycrystalline solar cells tend to be non-uniform in appearance, Variations of blue color. Polycrystalline cells will appear "grainy"
<b>Flexibility</b>	Yes (using plastic glazing)	No	No
<b>Weight</b>	Light weight compared to monocrystalline cells and polycrystalline cells.	Heavier compared to thin film but less in weight compared to poly crystalline cells	Heaviest
<b>Cost (As of January 2011)</b>	\$1.37 per watt (€1.03 per watt)	\$2.07 per watt (€1.55 per watt)	\$1.95 per watt (€1.46 per watt)
<b>Area</b>			

# PV power system

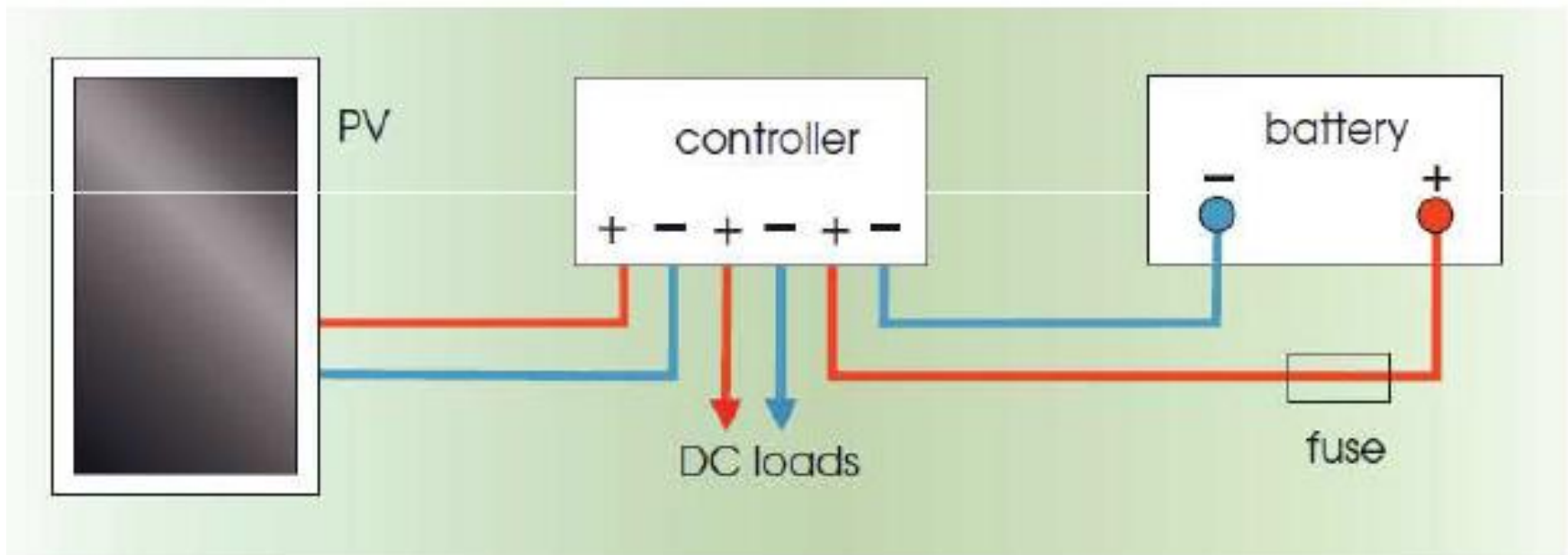
- ***Grid - connected systems:***
- ***Stand - alone systems***

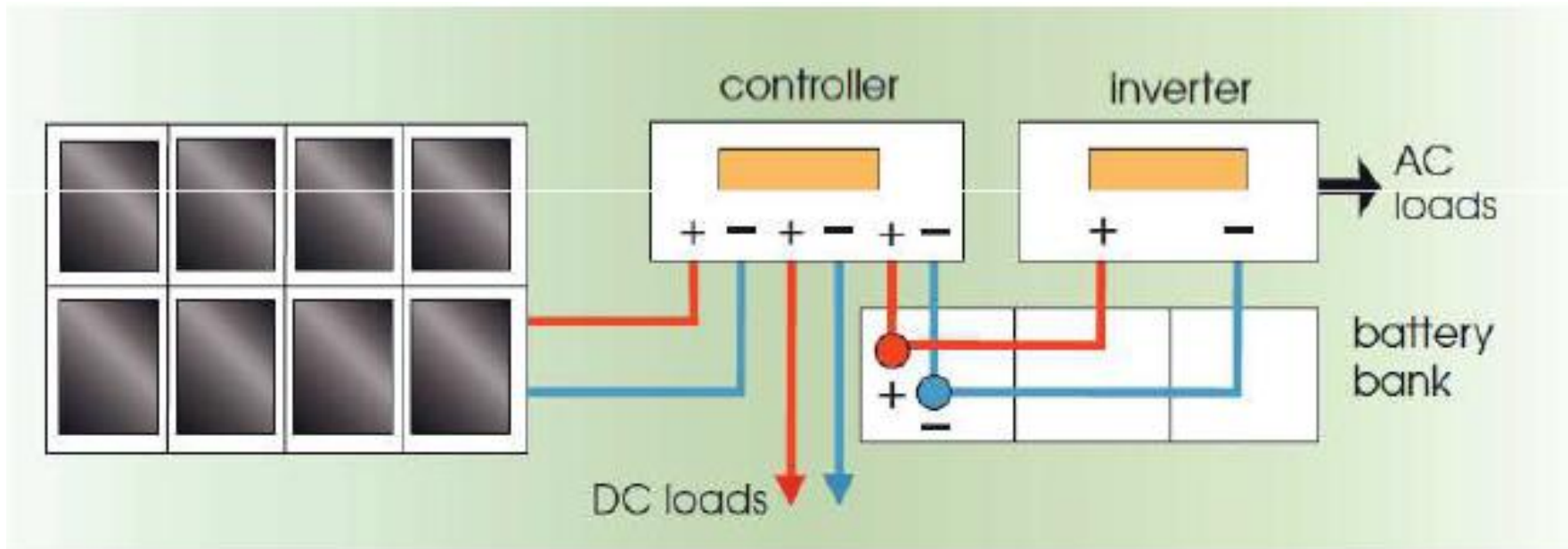
# ***Grid - connected systems:***

- 1. Building - integrated photovoltaics (BIPV) on**  
roofs or facades of individual houses,  
offices, factories and other commercial premises
- 2. Land - based PV power plants, often remote**  
from individual electricity consumers –typically 1  
– 20 MWp , with a few up to 50 MWp , and much  
larger ones planned.

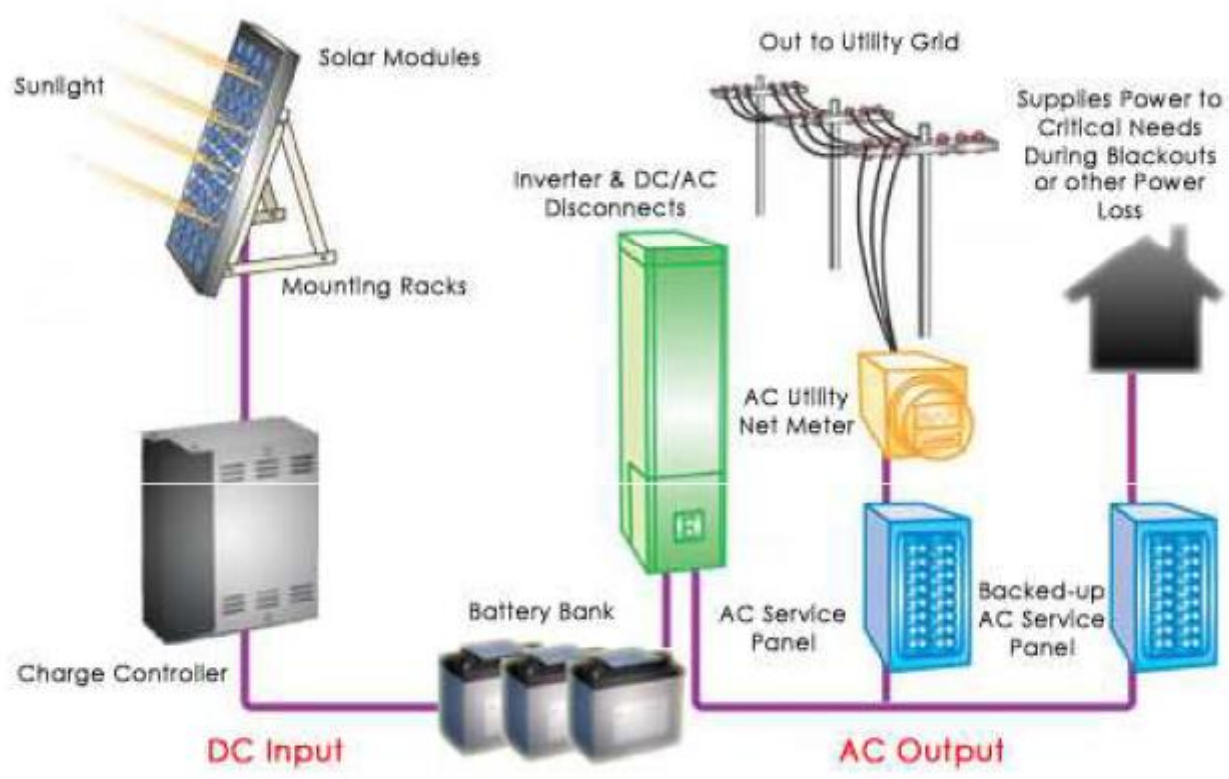
# ***Stand - alone systems***

1. Low - power solar home systems (SHSs), supplying small amounts of electricity to individual homes in developing countries – typically 30 – 100 Wp .
2. Higher - power systems for isolated homes and buildings in the developed world – typically 1 – 20 kWp .
3. PV systems for a wide range of applications, including water pumping and irrigation, isolated telecommunications equipment, marine buoys, traffic control signs, and solar - powered cars and boats.



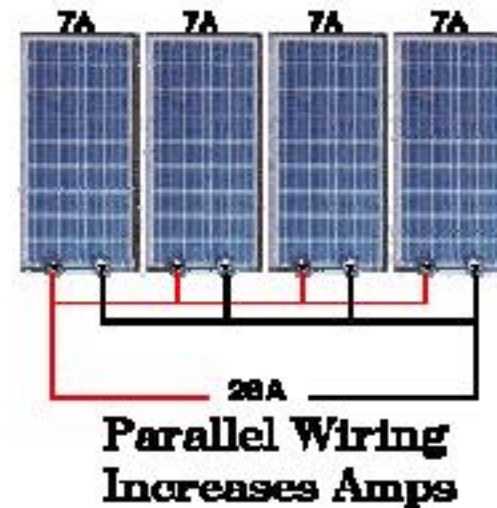
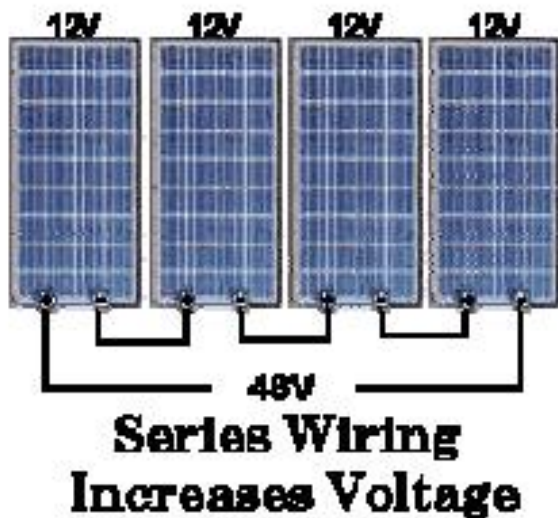






# Getting Desired Voltage and Amperage

- Series: Voltages are additive, current is equal
- Parallel: Currents are additive, voltage remains the same



# Solar PV system sizing:

## **1. Determine power consumption demands**

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system

### **1.1 Calculate total Watt-hours per day for each appliance used.**

Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

### **1.2 Calculate total Watt-hours per day needed from the PV modules.**

Multiply the total appliances Watt-hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

**2.0 Size the PV modules** Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. Then peak watt (Wp) produced depends on size of the PV module and climate of site location.

**2.1 Divide the total peak watt by 5 sunshine hours/day**

**2.2 Calculate the number of PV panels for the system**

Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required.

# Battery Sizing

3.1: Calculate total Watt-hours per day used by appliances

3.2 :Divide the total Watt-hours per day used by 0.85 for battery loss.

3.3 :Divide the answer obtained in item 3.2 by 0.6 for depth of discharge.

3.4 :Divide the answer obtained in item 3.3 by the nominal battery voltage.

3.5: Multiply the answer obtained in item 3.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

- Battery Capacity (Ah) = 
$$\frac{\text{Total Watt - hours per day used by appliances}}{0.85 \times 0.6 \times \text{nominal battery voltage}} \times \text{Days of autonomy}$$

# Solar charge controller sizing

- According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3
- Solar charge controller rating = Total short circuit current of PV array x 1.3

*Total load = (ac load × hours of operation per day)*

*Required battery bank capacity =  $\frac{\text{average Wh per day} \times \text{days of autonomy}}{\text{Battery voltage} \times \text{DoD}}$*

*Number of batteries in series =  $\frac{\text{voltage of the system}}{\text{nominal voltage of battery}}$*

*Number of batteries in parallel =  $\frac{\text{Ah rating of battery bank}}{\text{Ah of Battery}}$*

*avg Ah per day to be supplied by the array =  $\frac{\text{daily avg taken From the battery}}{\text{efficiency of the battery}}$*

*Array peak amps =  $\frac{\text{average Ah per day to be supplied by the array}}{\text{peak Sunshine hours per day}}$*

*Module connected in parallel =  $\frac{\text{array peak amps}}{\text{peak amps per module}}$*

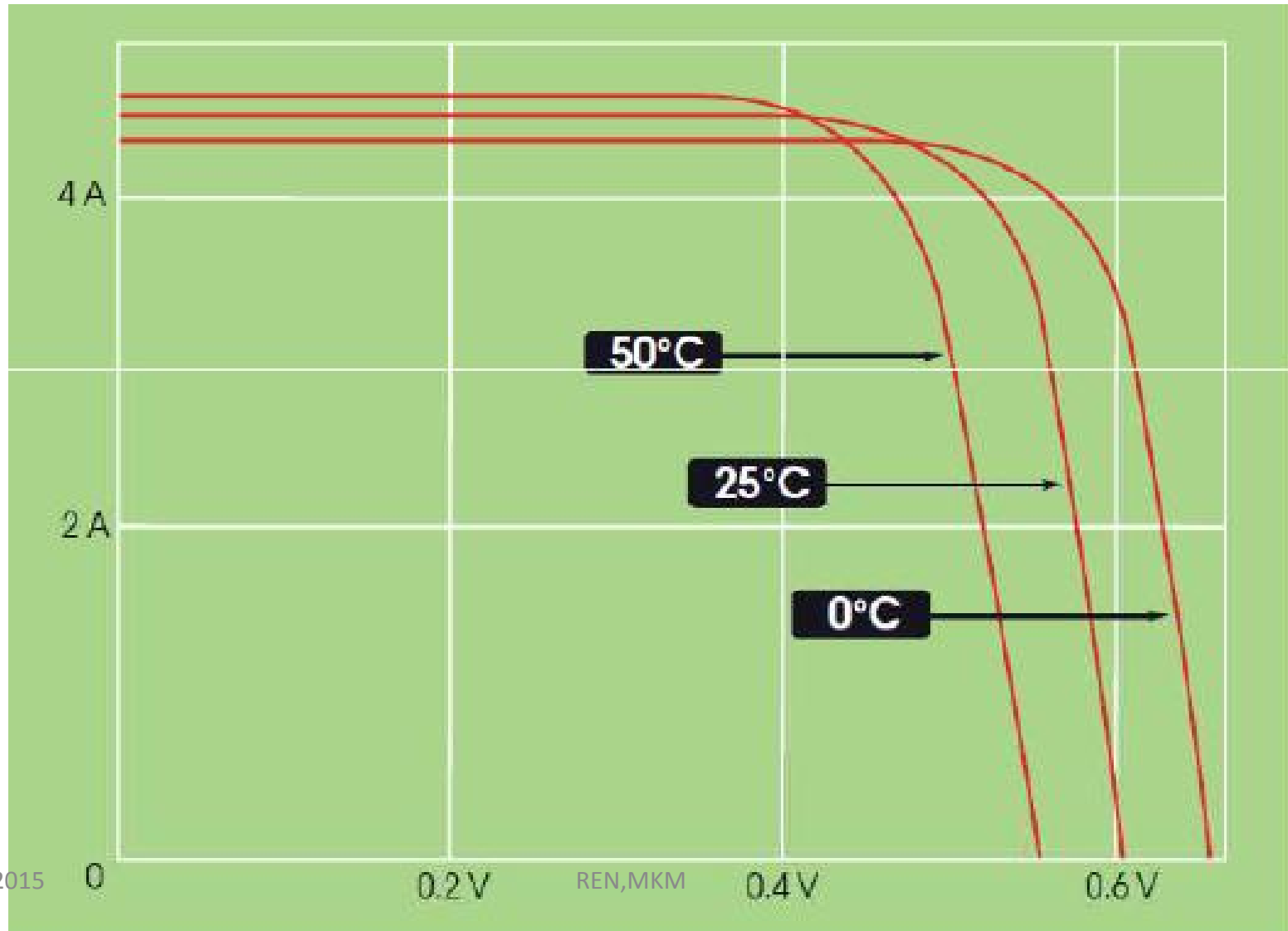
*Module connected in series =  $\frac{\text{battery bank voltage}}{\text{nominal module voltage}}$*



# Factors for Annual Energy Production

- **Cumulative solar irradiance: varies between a reduction by about 25% for a vertical surface to over 30% increase for two axis tracking, in comparison with a latitude-tilt fixed system**
- **Module power rating at standard test conditions: 5% calculation error**
  - **Operating temperature: annual production can be reduced due to the operating temperature by a factor between 2 and 10%,**
- **Maximum power point voltage dependence on irradiance level**
- **Soiling. Soiling may account for up to a 10% of reduction of the annual energy production**
- **Variation in solar spectrum. It is found that the effects of the hourly variation of the solar spectrum almost cancel out in a yearly basis. Amorphous silicon technology has the highest sensitivity to this effect, but the observed usually remain under 3%.**
- **Optical losses when the sun is at a high angle of incidence (AOI). The optical losses are due to the increased reflectance of the cover glass of the PV modules for AOI greater than approximately 60". However, the effect on a long term basis is relatively small (typically under 5%) although it may have larger effect on a seasonal basis (close to 10% for a vertical inclination).**

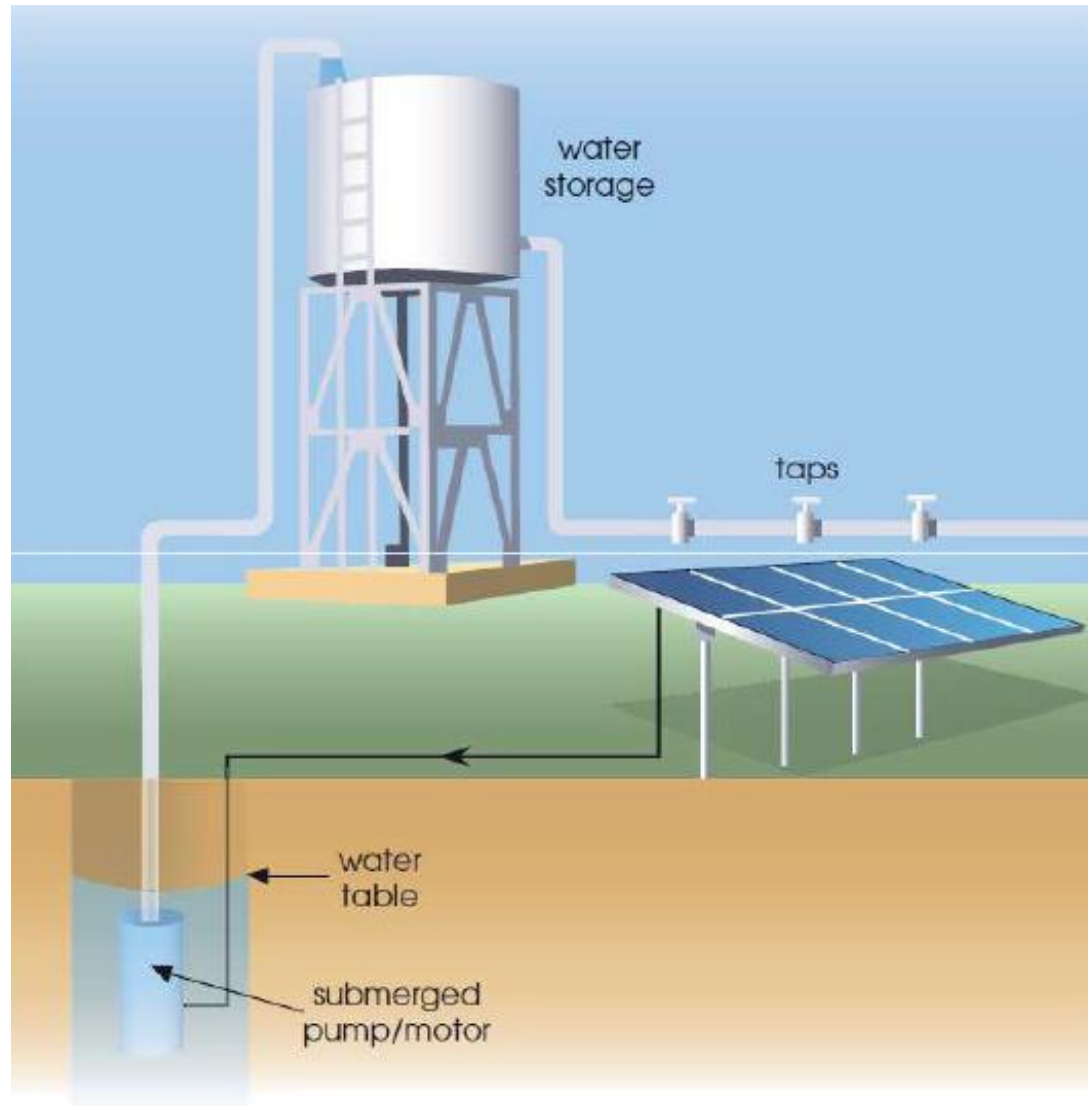
# Effects of temperature on the $I - V$ characteristic



# **PV water pumping**

Water pumping is one of the most successful applications of stand – alone PV in developing countries.

# PV water pumping



- *Type of pump*
- *Type of motor*
- *Matching the motor and PV array*
- *The hydraulic energy  $E_h$  required to raise  $1 \text{ m}^3$  of water against a head of  $H_w$  metres is given by:*
  - *$Eh = \rho g H_w$  joules*
  - $= 0.0027 V_w H_w$  kWh/day*
  - *where  $\rho$  is the density of water ( $1000 \text{ kg/m}^3$ )*
  - *$g$  is the acceleration due to gravity ( $9.81 \text{ m/s}^2$ ).*
  - *$H_w$  is the height of the holding tank 's input pipe above the water table*
  - *$V_w$  cubic metres of water per day*

$$P_{PV} = \frac{E_h}{S_p \eta}$$

- $S_p$  is the number of peak sun hours for the particular location and  $\eta$  is the overall system efficiency
- The system efficiency must take account of electrical losses in the motor and cabling, hydraulic and friction losses in the pump and pipe work, and
- mismatch between the motor and the PV that prevents the array from working at its maximum power point.
- An average efficiency of about 40% is fairly typical for a centrifugal pump and, together with other losses, gives a typical system efficiency of around 25% (0.25)

# Example

- A village population of 300 needs an average of 50 litres of water per person per day – a total of 15 000 litres or  $15 \text{ m}^3 / \text{day}$  – and that the tank 's inlet pipe is 20 m above the water table.
- The hydraulic energy required is:  $E_h = 15 \times 20 \times 0.0027 = 0.81 \text{ kWh day}$
- $P_{PV} = E_h / S_p \eta$
- $S_p$  is the number of peak sun hours for the particular location and  $\eta$  is the overall system efficiency
- An average efficiency of about 40% is fairly typical for a centrifugal pump and, together with other losses, gives a typical system efficiency of around 25% (0.25)