T. Y. B.Sc. (Physics) Semester: III

Elective-I: Renewable Energy Sources

Subject Code: PH-336

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MODULE 3 : PHOTOVOLTAIC SYSTEMS

Basic photo-voltaic system for power generation :

- Photo-voltaic arrays can be used to provide electricity for a wide variety of applications , many of which would make a meaningful contribution to economic development .
- There are two main types of systems .
- **A) Stand alone system :** In which the photo-voltaic array is the principal source of energy .
- The energy stored often in batteries , for periods when there is insufficient solar radiation .
- There may also be a back-up power supply such as an engine generator set .

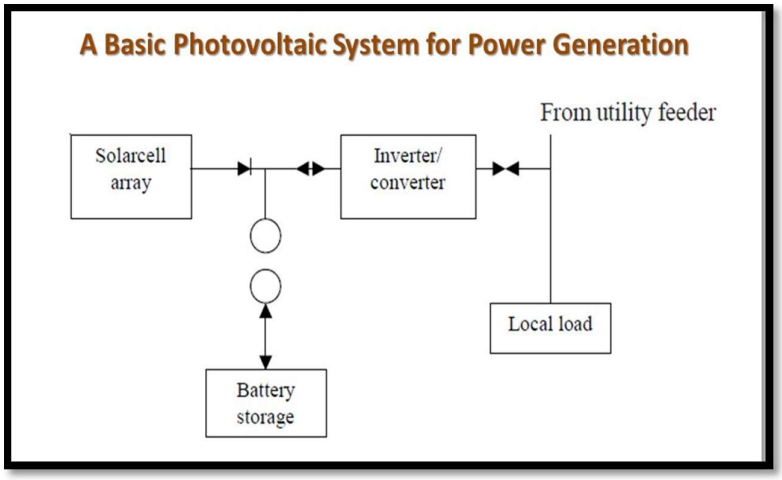
B) Grid connected system : In this type the load is connected to both a photovoltaic power system and an electricity grid .

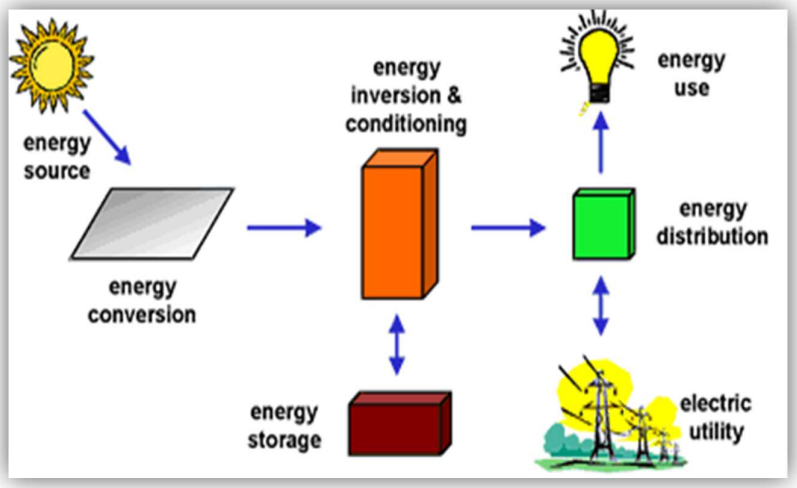
- In periods when there is sufficient solar radiation , the array powers the load , otherwise grid is used .
- In some cases , when the output exceeds the load the electricity is fed back into the grid .
- This type includes large MW sized systems .
- The large grid systems are not yet appropriate for most developing countries , but work on these is of considerable importance because their construction contributes to reducing the cost of photo-voltaic modules .

B) Grid connected system :

- A basic photo-voltaic system integrated with the utility grid is shown in figure.
- It permits solarly generated electric power to be delivered to a local load .

- It consists of different components such as ,
- **1. Solar array :** It is large or small , which converts the solar radiation energy into DC electrical power .
- **2. A blocking diode :** A blocking diode which lets the array-generated power flow only towards the battery or grid .
- Without a blocking diode the battery would discharge back through the solar array during times no solar radiation .
- **3. Battery storage :** In which the solarly generated electric energy may be stored .
- The simplest means of storage on a small or moderate scale is in electric storage batteries , especially as solar cells produce the direct electric current required for battery charging .





- Because of the large variation in solar irradiance , both daily and seasonally , batteries are used for energy storage .
- They also act as buffer between the solar array and the load .
- The battery supplies energy to the load during periods of little or no solar irriadiance and stores energy from the array during periods of high irradiance .
- The two types of battery that have been used for photovoltaic systems are lead-acid and nickel-cadmium .
- Lead-acid batteries are generally used because they are available in many capacity sizes and types , ranging from car batteries for starting , lighting and ignition to sealed float sevice batteries .
- **4. Inverters :** Inverters are the devices which change the array DC output to AC of suitable voltage , frequency and phase to lead photovoltaically generated power into the power grid or local load .
- These functional blocks are sometimes reffered to as power conditioning .
- It is clear that the system photo-voltaic offers the option of DC power , AC power or sometimes a possible alternative is to use the direct current from solar cells to decompose water (by electrolysis) into hydrogen and oxygen gases from which electricity can be generated .
- **5. Power conditioner :** Because the voltage output of the photovoltaic array varied with solar intensity and temperature , systems with battery storage require voltage or shunt regulator to prevent excessive overcharging of the battery .
- Further controls are used , as required , to prevent discharge or to ensure that the array is operating at its maximum power point .
- The following figure shows the system with voltage or shunt regulator .

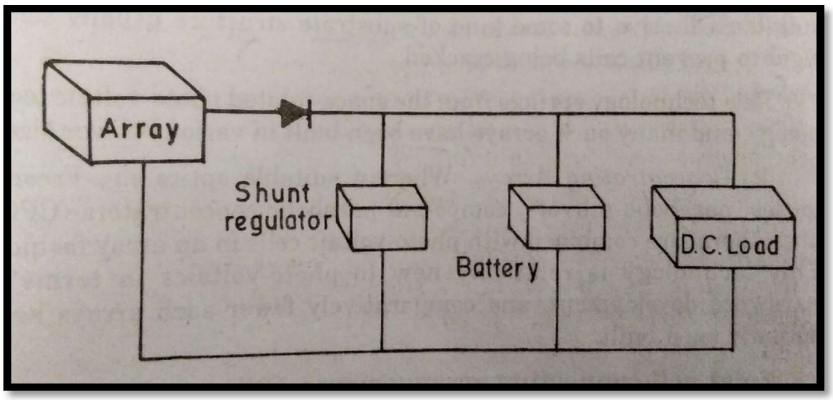


Figure : The system with voltage or shunt regulator .

6. Appropriate switches and circuit breakers :

- An appropriate switches are required , to permit isolating parts of the system , as the battery .
- One would also want to include breakers and fusing protection between the inverter output and the utility grid to protect both the photo- voltaic system and grid .

• Advantages and disadvantages of photo-voltaic solar energy conversion :

Advantages :

1. Renewable Energy Source

- Among all the benefits of solar panels, the most important thing is that solar energy is a truly renewable energy source.
- It can be harnessed in all areas of the world and is available every day.
- We cannot run out of solar energy, unlike some of the other sources of energy.
- Solar energy will be accessible as long as we have the sun, therefore sunlight will be available to us for at least 5 billion years when according to scientists the sun is going to die.

2. Reduces Electricity Bills

- Since you will be meeting some of your energy needs with the electricity your solar system has generated, your energy bills will drop.

- How much you save on your bill will be dependent on the size of the solar system and your electricity or heat usage.

3. Diverse Applications

- Solar energy can be used for diverse purposes.
- You can generate electricity (photovoltaics) or heat (solar thermal).
- Solar energy can be used to produce electricity in areas without access to the energy grid, to distil water in regions with limited clean water supplies and to power satellites in space.

4. Low Maintenance Costs

- Solar energy systems generally don't require a lot of maintenance.
- You only need to keep them relatively clean, so cleaning them a couple of times per year will do the job. Most reliable solar panel manufacturers offer 20-25 years warranty.
- Also, as there are no moving parts, there is no wear and tear.
- The inverter is usually the only part that needs to be changed after 5-10 years because it is continuously working to convert solar energy into electricity and heat .
- Apart from the inverter, the cables also need maintenance to ensure your solar power system runs at maximum efficiency.
- So, after covering the initial cost of the solar system, you can expect very little spending on maintenance and repair work.

5. Technology Development

- Technology in the solar power industry is constantly advancing and improvements will intensify in the future.
- Innovations in quantum physics and nanotechnology can potentially increase the effectiveness of solar panels and double, or even triple, the electrical input of the solar power systems.

Disadvantages of Solar Energy :

1. Cost

- The initial cost of purchasing a solar system is fairly high.

- This includes paying for solar panels, inverter, batteries, wiring, and the installation.
- Nevertheless, solar technologies are constantly developing, so it is safe to assume that prices will go down in the future.

2. Weather-Dependent

- Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops .
- A few cloudy, rainy days can have a noticeable effect on the energy system.
- On the other hand, if you also require your water heating solution to work at night or during wintertime, thermodynamic panels are an alternative to consider.

3. Solar Energy Storage Is Expensive

- Solar energy has to be used right away, or it can be stored in large batteries.
- These batteries, used in off-the-grid solar systems , can be charged during the day so that the energy is used at night.
- This is a good solution for using solar energy all day long but it is also quite expensive.
- In most cases , it is smarter to just use solar energy during the day and take energy from the grid during the night.

4. Uses a Lot of Space

- The more electricity you want to produce, the more solar panels you will need, as you want to collect as much sunlight as possible.
- Solar PV panels require a lot of space and some roofs are not big enough to fit the number of solar panels that you would like to have.

Types of solar cells :

- Apart from the differences in the nature of the semiconductor used , the following different cell configurations have been used such as ,

✓ 1. p-n homojunction solar cells

- ✓ 2. p-n heterojunction solar cells
- ✓ 3. Metal semiconductor Schottky junction solar cells
- ✓ 4. p-n multi-junction solar cells
- ✓ 5. MIS (metal insulator semiconductor solar cells)
- ✓ 6. SIS (semiconductor insulator semiconductor solar cells) .

1. p-n homojunction solar cells :

- In homogeneous p-n junction , the semiconductor material on both sides of the junction is same .
- Thus , the band gap remains the same throghout the cell material .

2. p-n heterojunction solar cells :

- In heterojunction p-n junction , two dissimilar semiconductor material , such as Groups II-IV compound semiconductors with closely matching crystal lattice are used to form the junction .
- The band gap of the top material , exposed to sunlight is wider than the band gap of the material below the junction .

3. Metal semiconductor Schottky junction solar cell :

- When a contact is amde between a metal and semiconductor , either an ohmic contact or a rectifying contact is formed depending on the workfunctions of metal and semiconductor .
- The rectifying contact is known as schottky junction .
- The schottky junction has depletion layer and built in electric field on the semiconductor side of the junction .

4. p-n multi-junction solar cells :

- As a photon is most efficiently absorbed when its energy is close to band gap , a intelligent way to absorb more photon energy is to stack junctions of different band gaps , what is known as multi-junction structure .
- The top junction has a relatively wider band gap followed by one or two more junctions in decreasing order of band gaps .
- **5. MIS (metal insulator semiconductor solar cells) :**

- The MIS solar cell is a modification of metal semiconductor schottky junction solar cell.
- A thin layer of 10 to 20 Å of insulator such as titanium oxide is placed between metal and semiconductor .
- **6. SIS (semiconductor insulator semiconductor solar cells) :**
- The SIS solar cell is a modification of MIS solar cell .
- In MIS solar cell on the both sides of the insulator there is semiconductor material .

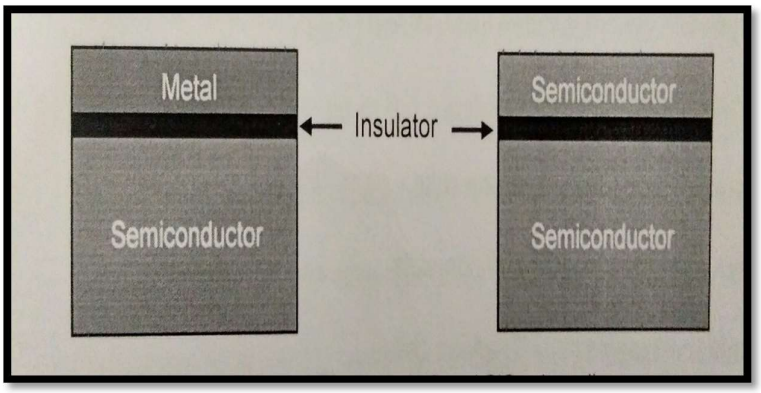


Figure : Basic MIS and SIS solar cell .

- **Types of solar cells :**
- **Depending on the type of the material used for fabrication of a junction , they are classified as ,**

➢ 1. Silicon solar cell

➢ 2. Copper sulphide cells / cadmium sulphide solar cells

➢ 3. Gallium Arsenide (GaAs) cells

1. Silicon solar cell :

- The silicon solar cell has been the most developed and used cell to date .
- Silicon is the most common element on earth and is usually obtained from sand .
- At present , large crystals of silicon are grown and sliced into thin cells for further processing into p-n junctions .

- There are three types of silicon solar cell such as , single crystal silicon solar cell , polycrystalline or multicrystalline silicon solar cell and amorphous silicon solar cell .
- Pasts cells that have been made of polycrystalline material have had relatively low efficiencies .
- The grain boundries inhibit electron flow and recombination results .
- However , if the grains can be made much larger than the thickness of the cell , it may approch the characteristics of a single crystal cell .
- The amorphous silicon cell is made of thin film from amorphous silicon .
- The cells are made from layers having a thickness less than 1 µm .

2. Copper sulphide (Cu_2S) / cadmium sulphide (CdS) solar cells :

- These can be a cheaper alternative to silicon solar cell .
- But difficulties of encapsulation and preventation of deterioration are yet to be mastered .
- The highest efficiency observed in this film solar cells is ~ 9 % .
- A thin layer of metal such as thin oxide is deposited on the glass substrate .
- This is followed by a thicker layer of n-type cadmium sulphide and thin layer of p-type copper sulphide .

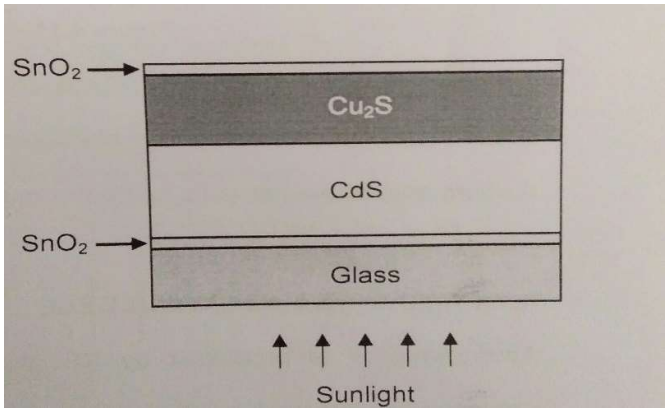


Figure : Basic CdS solar cell.

3. Gallium Arsenide (GaAs) cells :

- It is called as homojunction solar cell.

- The thin film gallium arsenide solar cell provides efficiencies of 15% whereas bulk gallium arsenide solar cell provides efficiencies of 25 % .
- The high efficiency of this solar cell is due to absortion of broad range of the solar spectrum .
- They stands at high temperature without losing efficiency . Hence these solar cells are used in concentrators .
- The following figure shows the schematic of gallium arsenide solar cell .

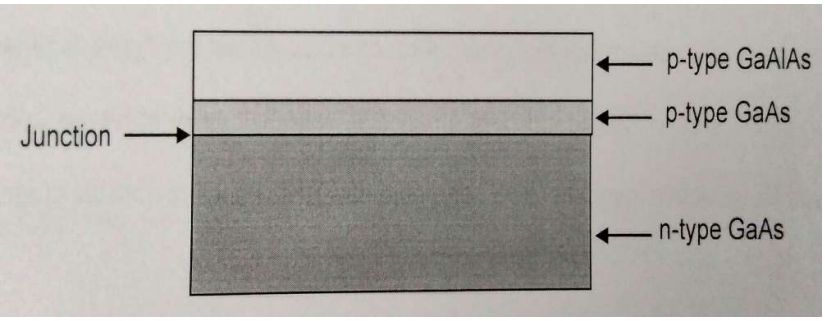


Figure : Basic of Gallium Arsenide solar cell .

- As shown in the figure , p-type gallium arsenide is diffused on n-type gallium arsenide .
- The another layer of p-type gallium aluminium arsenide is diffused over the p-type gallium arsenide .
- The gallium arsenide solar cells can be manufactured as single crystal or polycrystalline materials .

Applications of solar photo-voltaic systems :

- Various solar photovoltaic systems have been developed and installed at different sites for demonstration and field trial purposes .
- The terrestrial applications of these systems include provision of power supply to :

➢ Water pumping sets for micro irrigation , agriculture and drinking water supply ,

➢ Radio beacons (signal fire) for ship navigations at ports ,

➢ Community radio and television sets ,

➢ Cathodic protection of oil pipe lines ,

- Weather monitoring ,
- Railway signalling equipment ,
- Battery charging ,
- Street lightning , etc .

1. Water Pumping :

- Solar power is commonly used for water pumping facility which has been proved more effective in villages for agricultural purposes and also in water pumping for drinking water supply .
- The energy from the solar panel is used to operate the pump that is used to lift the water from lower level to higher level.
- The photo-voltaic water pumping system essentially consists of :

a) A photo-voltaic (PV) array ,

b) Storage batteries ,

c) Power control equipment ,

d) Motor pump sets ,

e) Water storage tank .

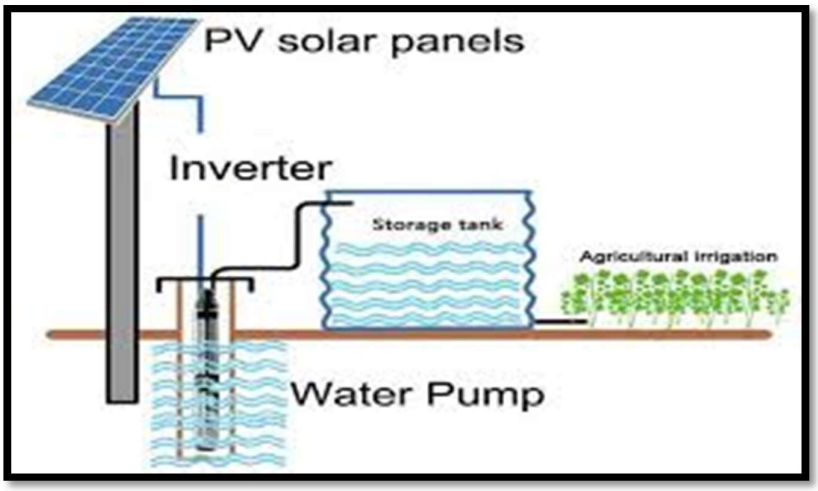


Fig : Solar Water Pumping System .

2. Solar Power Cathodic Protection:

- Pipelines, well heads and other metallic structures are prone to corrosion due to exposure to water .

- Corrosion occurs due to the electrolytic activity of metals as they lose ions in contact with water.
- This electrolytic process leading to corrosion can be reduced by applying an external voltage.
- This external voltage will prevent the ion loss from the metal. To that end, only a small DC voltage will be enough.
- PV are a suitable candidate for this purpose as they produce low voltage DC power that can be used directly.

Fig : Cathodic protection of oil pipe lines using PV system .

3. Lighting

- Solar photo-voltaic operated devices are handy for direct application for lighting .
- This lighting is at present used for the following specific cases :

a) Street lighting :

- The solar photovoltaic lighting system can be used for street lights, in rural areas.
- A Small sized panels can easily harness enough energy to glow a street light and LEDs.

b) Traffic Signals :

- Traffic signals at all areas can easily be operated using solar panels. Shadow free area is the only concern for this.

- **c) Community centre lighting and TV systems :** The community centre lighting has helped in television (TV) operation and conducting adult education and cultural programmes .
- This has community in improving the general level of awarness and improves community living .

4. Refrigeration :

- The PV system can be exceptionally suitable for storage and transport of medicines and vaccines that require refrigeration .
- There is a large market for such refrigerators in hospitals and health centres .

5. Telecommunication :

- Solar PV power is ideally suited for telecommunication applications such as local telephone exchange, radio and TV broadcasting, microwave and other forms of electronic communication links.

6. Photovoltaic power generation :

- The photovoltaic power generating systems can be divided in the following categories :

A) Small stand-alone systems :

- Stand-alone systems directly use the generated produced electricity. Stand-alone systems do not rely on utility/grid connections.
- When the requirement arises during night time or poor sunlight, a battery storage system is used.
- In some situations, stand-alone systems use conventional generators as backup systems.
- The potential applications of these small stand alone systems include telecommunications , pumping of drinking and irrigation water , refrigerations and ice making plant , community light ,community TV and street light , etc .

B) Large stand alone systems :

- These sytems can replace decentralised power units presently being occupied by diesel generators or can be installed in totally un-electrified remote areas .
- Batteries or another form of energy storage will generally be required with these systems to provide continuous power capability .

C) Central generation station :

- Considering a very optimistic future of low cost electricity from solar photovoltaics , central generating stations based on photovoltaics have been designed .
- The capacity of such central generating stations may be in the multi megawatt (MW) range .

6. Battery charging systems :

- Solar photovoltaic modules can be conveniently used for charging batteries used in the vehicles and in communication equipments in police stations , border out-posts and other remote locations .