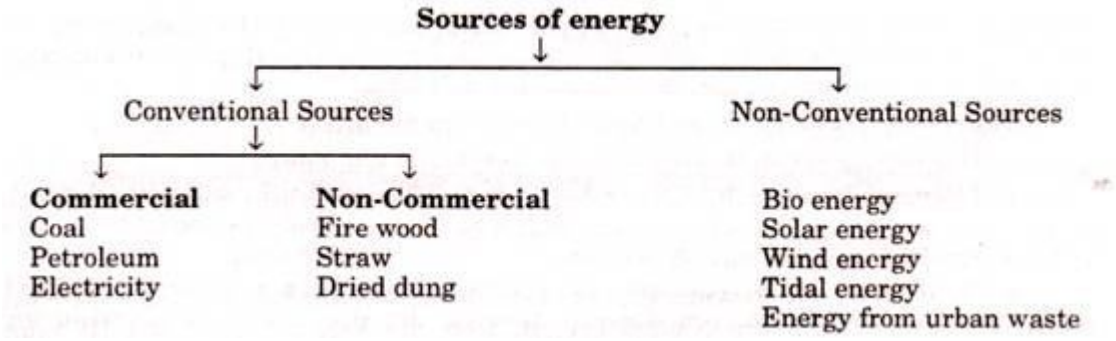
Unit 1:



Primary & Secondary energy sources:

Primary energy sources: are those which are found or stored in nature. e.g. coal, oil, natural gas and biomass like wood etc.

Other primary energy sources:are as found on earth are nuclear energy from radioactive substances, geothermal energy, potential energy due to earth's gravity etc.

Secondary energy sources: are usually converted from primary energy sources. e.g. the electricity sources converted from oil, natural gas or coal etc.

Commercial & Non-commercial energy sources:

Commercial energy sources: are those which are available in the market and can purchased at a definite price from the producing agencies. e.g. electricity, coal, oil etc.

Non-commercial energy sources :are those which are not available in commercial market for a price. These are also called traditional fuels. e.g. agro waste, animal dung etc.

Renewable & Non-renewable energy sources:

Renewable energy: is energy obtained from the sources that are essentially inexhaustible.

Examples of renewable resources :include wind power, solar power, geothermal energy etc.

Non-renewable energy: is the conventional fossil fuels such as coal, oil, gas etc. This form of energy is exhaustible and likely to deplete with t

Conventional Energy: Energy that has been used from ancient times is known as conventional energy. Coal, natural gas, oil, and firewood are examples of conventional energy sources.

Non conventional energy: A large amount of energy can be derived from non-commercial resource like agricultural waste, firewood, so are, wind. These resources are known as non-conventional energy resources. Conventional energy resources cannot be easily stored.

Classification non- conventional energy resources:

1) Solar energy
2) Bio-gas and bio-mass
3) Ocean energy and tidal energy
4) Geothermal energy
5) Wind energy
6) Magneto Hydrodynamic generation (MHD)

Advantage: 1)Socially relevant and useful and variety of choice available in practice to shift for renewable energy.
2) pollution free and have much less environment impact compared with conventional energy sources
3) the system have long life of 10-15 years or more.
4)The country does not depend on other country for fuel supply

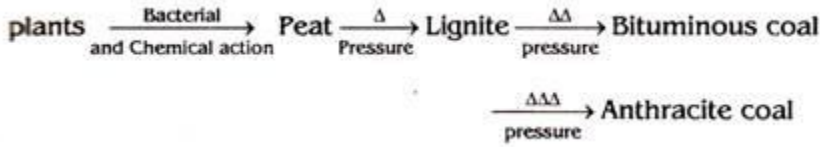
Disadvantage: 1)low energy density and need large size plant
2) conversion efficiency is low

3) large land area is required for installing the system to get same power as conventional plants.

Availability of Conventional energy resources:

1. Coal:

Coal is a major conventional energy sources. It was formed from the remains of the trees and ferns grew in swamps around 500 millions year ago. The bacterial and chemical decomposition of such plant debris (which remained buried under water or clay) produced an intermediate product known as peat which is mainly cellulose $(C_6H_{10}O_5)_n$. Due to progressive decomposition by heat and pressure, the cellulose lost moisture H_2 and O_z and got converted in to coal as per the given equation



The average formula of coal is $(C_3H_4)_n$. Out of the 6000 billion tons coal stocks under earth crust, 200 tons have been exploited the present society. The coal reserves are found in the states like Jharkhand, Orissa, West Bengal, M.P. and A.P. Some important coal fields are : Talcher, Raniganj, Jharia, Bokaro, Panch Konkam, Signoulli, Chanda etc.

2. Petroleum and natural gases:

Petroleum is a complex mixture of hydrocarbons, mostly alkanes and cycloalkanes. It occurs below the earth crust entrapped under rocky strata. In its crude form, the viscous black liquid is known as petroleum and a gas in contact with petroleum layer which flows naturally from oil wells is termed as natural gases. The composition of natural gas is a mixture of mainly methane, (95.0%), small amounts of ethane, propane and butane (3.6%) and traces of CO_2 (0.48%) and N_2 (1.92%).

A liquid mixture of propane and butane can be obtained from natural gas or refinery gases at room temperature under a pressure of 3-5 atmosphere. This is stored and distributed in 40-100 litre capacity steel cylinders.The crude petroleum after being refined and purified, are available as petrol, diesel, kerosene, lubricating oil, plastic etc. for commercial and domestic use. In India, the oil deposits, are found at Ganga-Brahmaputra Valley, Bombay high, plains of Gujarat, Thar desert of Rajasthan and area around Andaman Nicobar islands.On the world basis, petroleum deposits are found at Saudi Arab, Iraq, Iran, Kuwait, USA, Mexico, Russia etc. As per the current survey, it is found that world petroleum deposits are diminishing at a very faster rate. If preventive steps are not taken, the existing petroleum will be available maximum up to 40 years.

3. Fuel woods:

The rural peoples require fuel wood or fire Wood for their day to day cooking which are obtained from natural forests and plantations. Due to rapid deforestation, the availability of fire wood or fuel wood becomes difficult. This problem can be avoided by massive afforestation (plantation) on degraded forest land, culturable waste land, barren land grazing land etc.

4. Hydropower:

Energy obtainable from water flow or water falling from a higher potential to lower potential, is known is hydro- power. It is a conventional and renewable form of energy which can be transmitted to long distance through cables and wires.

In India, hydroelectric power is generated by a number of multipurpose river valley projects e.g. Hydro-power project Hirakud, Bhakra Mangal project, Narmada valley project, Nagarjun Sagar project, Sardar Sarovar project etc.

5. Nuclear energy:

A small amount of radioactive substance (U^{235}) can produce a lot of energy through the process of nuclear fission. For example, one ton of uranium can provide energy which is much higher than three million tons of coal or 12 million barrels of oil. In order to obtain nuclear energy, nuclear reactors are required. There are around 300 nuclear reactors all over the world. India has only four nuclear power stations (reactors).

The nuclear energy can be used in production of electrical energy, as a fuel for marine vessel and space crafts and for the generation of heat in chemical processing plants. In India, Uranium deposits are found at different parts of Rajasthan and Singhbum of Jharkhand.
Thorium is recovered from monazite sand found in the state of Kerala. Due to the higher energy releasing tendency of these radioactive substances, these can be used in nuclear reactors to release energy crisis. But the radioactive substances are exhaustible and can be used to develop nuclear weapons of mass destruction. In addition, dumping or radioactive wastes cause serious environmental hazards.

Availability of Non-Conventional energy resources:

1. Solar energy:

Solar energy, a primary energy source, is non-polluting and inexhaustible.

There are three methods to harness solar energy:

(i) Converting solar energy directly into electrical energy in solar power stations using photo cells or photovoltaic cells or silicon solar cell.
(ii) Using photosynthetic and biological process for energy trapping. In the process of photosynthesis, green plants absorb solar energy and convert it into chemical energy, stored in the form of carbohydrate.
(iii) Converting solar energy in to thermal energy by suitable devices which may be subsequently converted into mechanical, chemical or electrical energy.
Since solar energy is non-ending and its conversion to some other energy form is nonpolluting, attention should be paid for the maximum utilization of solar energy.

2. Wind energy:

Wind is air in motion. The movement of air takes place due to the convection current set out in the atmosphere which is again due to heating of earth's surface by solar radiation, rotation of earth etc. The movement of air occurs both horizontally and vertically.
The average annual wind density is 3 kW/m^2/day along costal lines of Gujarat, western ghat central parts of India which may show a seasonal variation (i.e., in winter it may go up to 10kW/m^2/day).]
Since wind has a tremendous amount of energy, its energy can be converted into mechanical or electrical energy using suitable devices, now days, wind energy s converted in to electrical energy which is subsequently used for pumping water, grinding of corns etc. As per available data dearly 20,000 mW of electricity can be generated from wind. In Puri, wind farms are set up which can generate 550 kW of electricity.

3. Tidal energy:

The energy associated with the tides of the Ocean can be converted in to electrical energy. France constructed the first tidal power plant in 1966. India could take up Ocean thermal energy conversion (OTEC) and by the process it will be capable of generating 50,000 mW of electricity, to meet the power requirements of remote oceanic islands and coastal towns. The Netherlands is famous for windmills. In India, Gujarat and Tamil nadu have windmills. The largest wind farm has been set at Kanyakumari which generates 380 mW of electricity.

4. Geothermal energy:

The geothermal energy may be defined as the heat energy obtainable from hot rocks present inside the earth crust. At the deeper region of earth crust, the solid rock gets melted in to magma, due to very high temperature. The magma layer is pushed up due to some geological changes and get concentrated below the earth crust. The places of hot magma concentration at fairly less depth are known as hot spots. These hot spots are known as sources of geothermal energy. Now a days, efforts are being made to use this energy for generating power and creating refrigeration etc. There are a quite few number of methods of harnessing geothermal energy. Different sites of geothermal energy generation are Puga (Ladakh), Tattapani (Suraguja, M.P.), Cambay Basin (Alkananda Valley, Uttaranchal).

5. Bio-mass based energy:

The organic matters originated from living organisms (plants and animals) like wood, cattle dung, sewage, agricultural wastes etc. are called as biomass. These substances can be burnt to produce heat energy which can be used in the generation of electricity. Thus, the energy produced from the biomass is known as biomass energy.

There are three forms of biomass:

(i) Biomass in traditional form:

Energy is released by direct burning of biomass (e.g. wood, agricultural residue etc.)

(ii) Biomass in nontraditional form:

The biomass may be converted in to some other form of fuel which can release energy. For example carbohydrate can be converted into methanol or ethanol which may be used as a liquid fuel.

(iii) Biomass for domestic use:

When organic matters like cow dung, agricultural wastes, human excreta etc. subjected to bacterial decomposition in presence of water in absence of air, a mixture of CH_4, $C0_2$, H_2, H_2S etc. is produced. These gases together is known as biogas. The residue left after the removal of biogas is a good source of manure and biogas is used as a good source of non-polluting fuel.

6. Biogas:

Biogas is an important source of energy to meet energy, requirements of rural area. As per given data, around 22,420-million m^3 of gas can be produced from the large amount of cow dungs obtained in rural areas in a year. The gas is generated by the action of bacteria on cow dung in absence of air (oxygen). There are two types of biogas plants namely. Fixed done type and floating gas holder type (Fig.4.3 & 4.4).

These plants are commonly known as Gobar gas plants because the usual raw material is cow dung (Gobar). The methodology involves in the process is to prepare a slurry of cow dung with water. Sometimes form waters can also be added to the slurry.

The slurry is subjected to bacterial decomposition at 35 .C. There are about 330, 00 biogas plants in India. All India dung production is about 11.30 kg per cattle and 11.60 kg per buffalo with about 67.10 m^3 of gas per ton of wet dung.

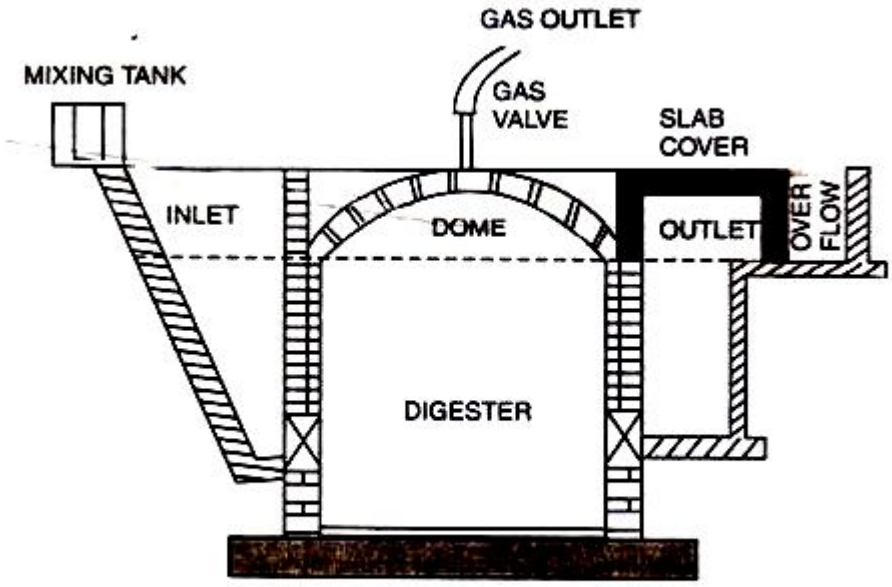


FIG. 4.3 : FIXED DOME TYPE BIOGAS PLANT

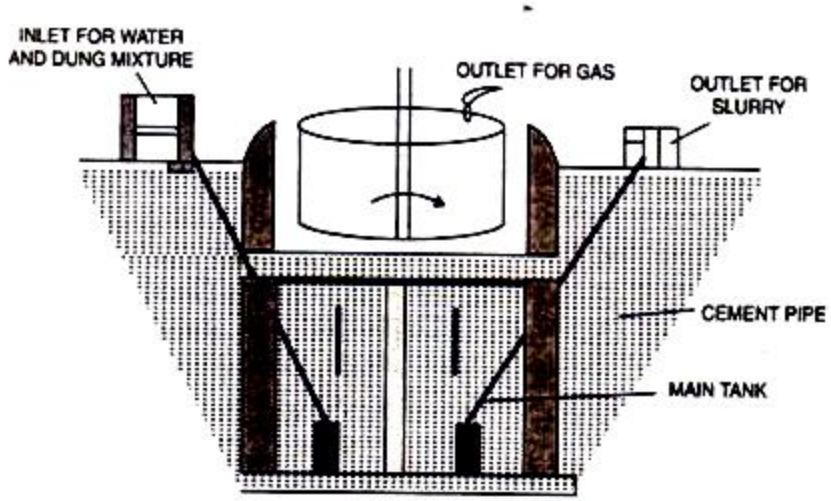


FIG. 4.4 : FLOATING GAS HOLDER TYPE BIOGAS PLANT

7. Petro plants:

In order to release the pressure on mineral oils (a nonrenewable resource), the scientists have discovered some potential plant species from which liquid hydrocarbons can be extracted. The liquid hydrocarbons present in such plants can be converted in to petroleum.

Such plants are known as petro plants which belong to families Apocynaceae, Ascalepiadaceae, Euphrobiaceae; Convolvulaceae and Spontaceae. Still research is on to increase the biomass of the petro plants and effective method of converting their hydrocarbons in petroleum.

8. Dendrothermal energy (Energy plantation):

Due to rapid deforestation and overgrazing, a number of denuded wastelands are formed. On these wastelands, fast growing trees and shrubs may be planted which will provide fuel wood, charcoal, fodder, etc. Through gasification, these plants can produce a lot of energy-

9. Baggasse-based plants:

Bagggasse is generated as a waste product in sugar mills. This can be utilised to produce electrical energy. As per available data, the sugar mills in India can generate about 2000 mW surplus electricity during crushing season.

10. Energy from urban waste:

Sewage and solid municipal wastes can also generate energy on their suitable treatments.

11. Magneto-hydrodynamics: is the physical-mathematical framework that concerns the dynamics of magnetic fields in electrically conducting fluids, e.g. in plasmas and liquid metals. The word *magnetohydrodynamics* is comprised of the words *magneto*-meaning magnetic, *hydro*- meaning water (or liquid) and -*dynamics* referring to the movement of an object by forces. Synonyms of MHD that are less frequently used are the terms *magnetofluiddynamics* and *hydromagnetics*.

Solar cell

Solar Energy: Sun is the fundamental source of all type of energy. The sun releases the enormous amount of energy due to continuous nuclear fusion reaction taking place in it. It sends the energy in the form of radiations at the rate of 3.7×1020 MW. However, the energy received by the earth is about 1.85×1011 MW.

Advantages of Solar Energy:

1. It is available in abundance and free of cost. It is inexhaustible form of energy and will be sufficient to sustain as far as we think of our existence.

2. It is free from pollution and having low operating and maintenance cost.

3. No elaborated arrangements are needed for transportation, storage or handling as in the case of fossil fuels.

4. The operation of Solar thermal energy ranges from Solar cookers of 1 kW to power plant of 200 MW.

Disadvantages of Solar Energy:

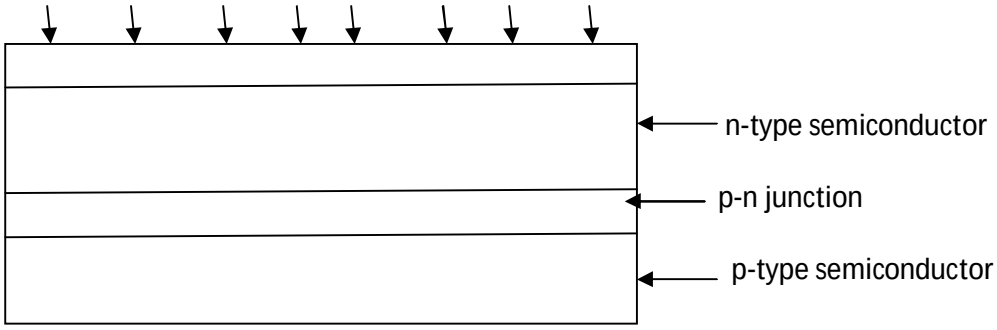
1. Availability depends on several conditions, like weather, climate, month, time of day, and during the year.

2. Needs very large collector area to harness solar energy involving high capital cost.

3. Solar collectors, panels and cells are relatively expensive to manufacture although prices are falling rapidly.

4. Solar power is used to charge batteries so that solar powered devices can be used at night. However, the batteries are large and heavy and need storage space. They also need replacing from time to time.

Solar Cell: Solar Cells are solid electronic devices used to convert the electromagnetic energy of solar radiation directly into direct current electricity. Thus a solar cell is a transducer which converts the sun's radiant energy directly into electricity and is basically a semiconductor diode capable of developing a voltage of 0.5-1V and current density of 20-40 mA/cm2 depending on the materials used and the sun light conditions. This makes the system far more convenient and compact compared to thermal methods of solar energy conversion



Solar Cell

Solar Cell Materials: Solar cells are made of different materials and Silicon (Si) is one used in nearly 90% applications. The choice of the materials depends on the energy gap, efficiency and cost. The maximum efficiency of solar cell is achieved with the band energy of 1.12 eV – 2.3 eV. Other commonly used Materials are Cadmium Telluride (CdTe), Gallium Arsenide (GaAs), Zinc Telluride (ZnTe) etc.

Performance Characteristic of Solar Cell: Performance characteristics of PV cell is dependent on solar radiation, climate conditions etc. The cell is tested at standard test conditions of 1000 W/m2 solar radiation and 25 0C cell temperature. The testing setup is shown in figure. When the circuit is open, the flowing current is zero and this open circuit voltage (Voc) is nearly 0.6 V

Performance analysis:

current I_1. The net p-n junction current, in the reverse bias direction is

$$I = I_L - I_1$$

$$I = I_L - I_0\left[\exp\left(\frac{eV}{KT}\right) - 1\right] \quad ...(3.1)$$

When the junction becomes forward biased, the magnitude of electric field in depletion region decreases but does not change the direction.

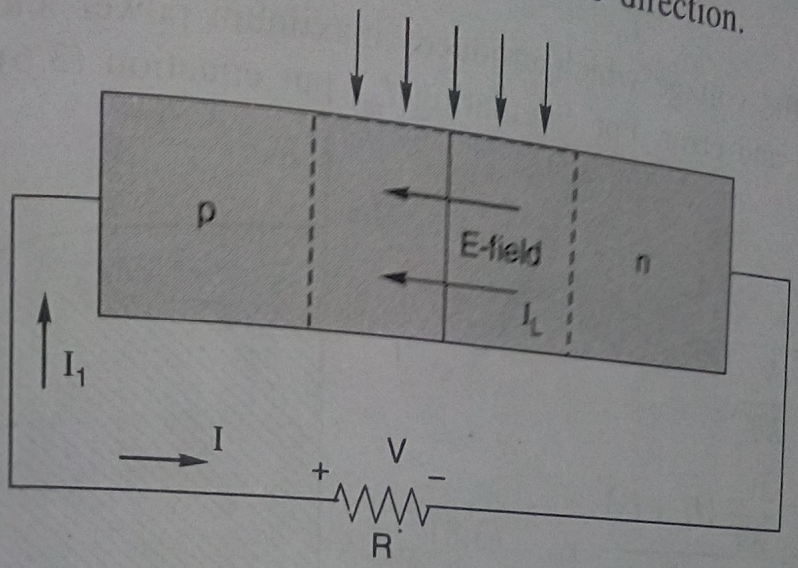


Fig. 3.11.

When $R = 0$, *i.e.* $V = 0$, then $I_1 = 0$. This is short circuit condition. The current under this condition is called short-circuit current I_{sc}.

$$I = I_L = I_{sc} \quad ...(3.2)$$

Open circuit condition occurs when $R \to \infty$, the net current is zero. Then from Eq. (3.1)

$$I = 0 = I_L - I_0\left[\exp\left(\frac{eV_{oc}}{KT}\right) - 1\right] \quad ...(3.3)$$

or

$$I_L = I_0\left[\exp\left(\frac{eV_{oc}}{KT}\right) - 1\right]$$

$$\frac{I_L}{I_0} + 1 = \exp\left(\frac{eV_{oc}}{KT}\right)$$

$$eV_{oc} = \ln\left(1 + \frac{I_L}{I_0}\right)$$

$$I_L = I_0 \exp\left(\frac{eV_m}{KT}\right) - I_0 + I_0 V_m \left(\frac{e}{KT}\right) \exp\left(\frac{eV_m}{KT}\right)$$

$$\frac{I_L}{I_0} = \exp\left(\frac{eV_m}{KT}\right) - 1 + V_m \left(\frac{e}{KT}\right) \exp\left(\frac{eV_m}{KT}\right)$$

$$1 + \frac{I_L}{I_0} = \exp\left(\frac{eV_m}{KT}\right)\left[1 + \frac{eV_m}{KT}\right] \quad \text{...(3.6)}$$

Where V_m is the voltage which produces maximum power and its value can be calculated by trial and error. For calculating I_m, put equation (3.6) in equation (3.5) and solve for I_m.

$$I_m = \frac{\frac{eV_m}{KT}(I_L + I_0)}{1 + \frac{eV_m}{KT}} \quad \text{...(3.7)}$$

$$P_m = V_m I_m = \frac{\frac{eV_m}{KT}(I_L + I_0)}{1 + \frac{eV_m}{KT}} V_m \quad \text{...(3.8)}$$

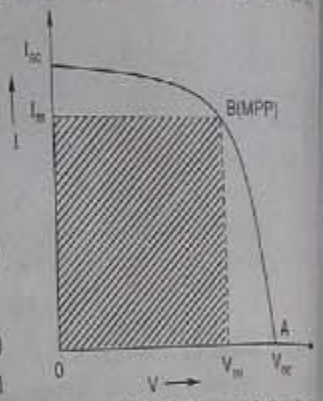


Fig. 3.12. V-I Characteristic of Solar Cell.

Power is zero at point A because $I = 0$

Power is maximum at point B (equal to area under the rectangle)

Power is zero at point C because $V = 0$

It is preferable to operate a solar cell with maximum possible light and at point B for obtaining maximum power and, therefore, maximum efficiency. The point B is known as maximum power point (MPP).

The conversion efficiency of a solar cell is defined as the ratio of output power to incident optical power. For maximum power output

$$\eta = \frac{P_m}{P_{in}} \times 100\%$$

$$= \frac{V_m I_m}{P_{in}} \times 100\%$$

Maximum possible current in the solar cell = I_{sc}

Maximum possible voltage in the solar cell = V_{oc}

Filling factor is the ratio of maximum (peak) power to the product of I_{sc} and

$$\therefore \quad \text{Filling factor (F.F)} = \frac{V_m I_m}{I_{sc} V_{oc}}$$

$$P_m = I_{sc} V_{oc} \text{ F.F}$$

or, P_{in} = Incident solar radiation × Area of solar cell

$$\eta = \frac{V_{oc} I_{sc} F.F}{\text{Incident solar radiation} \times \text{Area of solar cell}}$$

$\therefore$

The value of F.F lies between 0.7 to 0.8.

Solar Cell Power Plant:

Depending on the method of utilization there can be two configurations:
1. Stand alone system 2. Grid connected system

Stand Alone System:

This system having following characteristics:
_ Operates autonomously and independently.
_ Commonly used for backup power where connecting to grids are very costly.
_ Can be used to power DC loads and by the use of an inverter it may used for AC loads also.
_ Hybrid stand alone systems may include other power producing devices also for backup.
Stand alone systems may be of any one of the categories:
• Direct Coupled Stand alone system.
• Stand alone system with Battery storage.
• Stand alone system with battery and charge control.
• Stand alone system with AC and DC loads.
• Hybrid Stand alone systems.

Fig. Direct coupled stand alone systems

In this the solar array is directly connected to the DC load.
_ There is no energy storage.
_ It can be used only in sunshine hours.
_ Basically uses for water supply pumps for agricultural purpose.

Stand Alone System with Battery Storage:

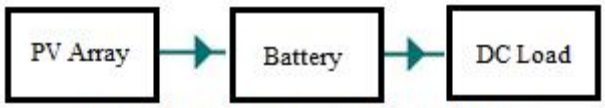


Fig. Stand alone system with battery storage

_ In this the PV array charges the battery and the battery supplies DC power to the loads.
_ There is no charge control and is susceptible to overcharge and over discharge

1.12.1(c) Stand Alone System with Batteries and Charge Control:

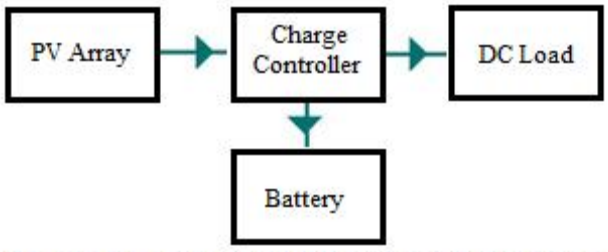


Fig. Stand alone system with batteries and charge control

.

_ This has got charge control for controlling the

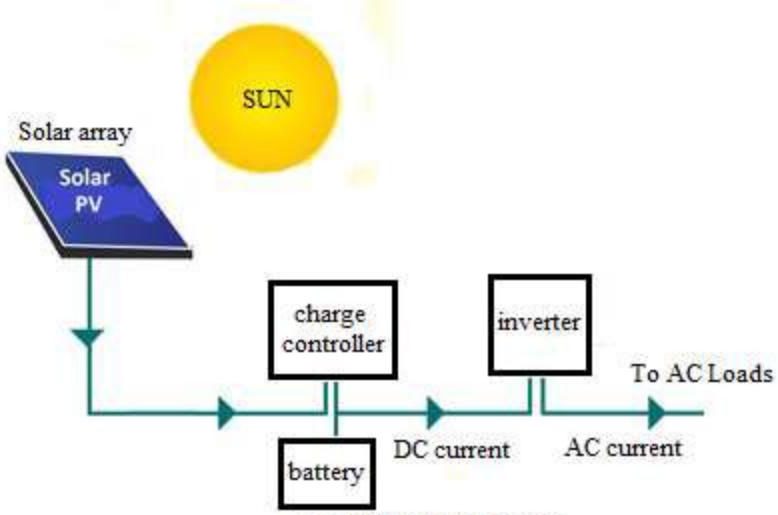


Fig. Stand Alone System

charge / discharge.

(d) Stand Alone Systems with AC and DC Loads:

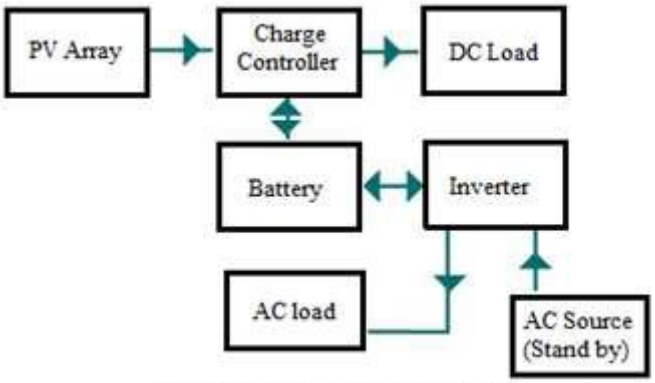


Fig. Stand alone system with AC and DC loads

_ This system can be used to power AC as well as DC loads
_ It needs inverter in the circuit.
_ In addition the main AC supply also may be used for charging only in the case of emergency.

(e) Hybrid Standalone Systems:

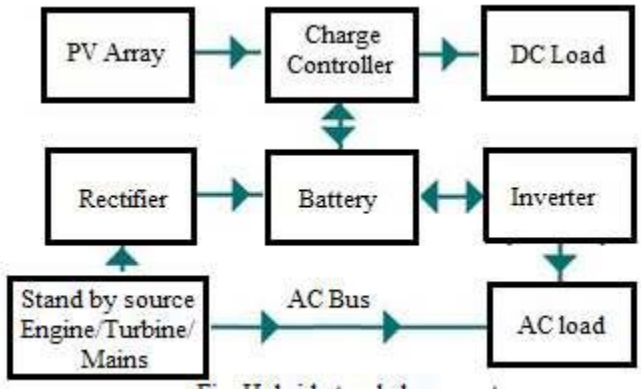


Fig. Hybrid stand alone system

In such systems one or more sources in addition to the PV panels are used.

_ Sources like stand by engines, turbines, fuel cells etc may be used in conjunction with PV arrays which reduces the dependency
on any single source.
_ This also reduces battery storage capacity and size of PV arrays.

Solar Cell Terminology:
1.13.1 Solar Cell Efficiency: The efficiency of a solar cell can be defined as:

Efficiency=maimum power output/incident intensityxarea of the device exposed

Where, V_m = cell voltage
I_m = current
F_F is called the fill factor
V_{OC} = open circuit voltage
I_{SC} = short circuit current

Advantages & Disadvantages of PV Systems:
Advantages:
_ PV channel provides clean form of energy with any harmful greenhouse gas emissions thus it is environmentally friendly.
_ These systems produce electricity in a direct electricity way of generation.
_ These systems have no mechanical moving parts, expect in case of solar- tracking mechanical bases, hence having very low
breakage or require less maintenance.
_ Solar energy is especially appropriate for smart energy networks with distributed power generation – DPG is indeed the next
generation power network structure!

Disadvantages:
_ Solar panels efficiency levels are relatively low (maximum 30%) compared to the efficiency levels of other renewable energy
systems.
_ Solar power is a variable energy source, with energy production dependent on the sun. Solar facilities may produce no power at
all some of the time, which could lead to an energy shortage if too much of a region's power comes from solar power.
_ In case of land-mounted PV panel installations, they require relatively large areas for deployment; usually the land space is
committed for this purpose for a period of 15-20 years – or even longer.