Energy Resource Management

UNIT-3

SOLAR POWER

The light and heat emitted by the sun in the form of electromagnetic radiation is the main source solar energy. Solar energy is trapped and turned in to an utilizable form with the help of solar cells. Thus it is used for heating or for the preparation of low cost electricity.

Solar energy is one of the cleanest energy resources for your homes and offices. In order to get the maximum benefit of using solar energy, the user has to know certain basic facts. An average person who plans to use solar panel for the extraction of solar energy has to know only these and need not make a technical dissertation on the electromagnetic radiation obtained or the conversion of these radiations to solar energy. These basic facts will help the user to take wise and timely decisions about solar energy extraction and usage.

At its simplest, solar energy is the light produced by the Sun. Sunlight is a form of radiant energy that travels to the earth as electromagnetic waves.

In reality, the light we see is just a small part of the energy we receive from the Sun. The radiant energy from the Sun covers the full breadth of the electromagnetic spectrum.

Using solar technology, we are able to "capture" the Sun's radiant energy and convert it to either heat or electricity.

SOLAR HEATING PRINCIPLES

Solar heating systems perform three basic functions...

- **Collection**: Radiant energy from the Sun is captured and converted to solar thermal energy using solar collectors.
- **Storage**: The solar thermal energy is stored using thermal mass, water tanks, or rock bins.
- **Distribution**: Distribution of the heat can be done with both active solar energy and passive solar energy methods.

These three basic principles are used for solar space heating, solar water heating, and solar pool heating systems.

SOLAR ELECTRICITY PRINCIPLES

Solar electric systems use solar cells to convert the Sun's radiant energy into electricity. This is done using a principle known as the **photovoltaic effect**.

Since a solar cell only generates about 1-2 Watts of power, it is necessary to combine them into solar power panels in order to generate more power. *Solar panels* are in turn combined to form *solar arrays*.

These solar panels and arrays are the key component of all residential solar energy systems. The other components of the system convert the generated DC electricity into AC electricity so it can be used by the electrical appliances in your home.

So, *how does solar energy work*?

Simply put, **home solar power systems** work by converting the Sun's electromagnetic energy into either *solar thermal energy* or *solar electricity*.

Solar heating systems create solar thermal energy using solar collectors. The heat generated by the solar collectors is used for solar water heating, solar space heating, or solar pool heating.

Solar electric systems create solar electricity using solar power panels. The DC electricity generated by the solar panels is converted to AC current and can be used by all of your household appliances

SITE SELECTION FOR SOLAR POWER PLANT

Suitable locations for solar panels have specific characteristics and requirements. Identifying those locations requires that desirable characteristics be defined. For this study, suitable sites should have these characteristics:

- Suitable elevation: The location must be on top of a building. (It should not be at ground level.)
- Suitable aspect: The aspect should be south/north facing or horizontal. For example, in the northern hemisphere, solar panels located on south-facing slopes will have a higher solar power output than those located on north-facing slopes.
- Suitable slope: The slope should be less than 35 degrees.
- High radiation: The site should receive, on average, at least some minimum amount of solar radiation per year. That amount is determined by the analyst.

In general, the goal is to find rooftops that face south or are flat and have a slope that is not too steep for installing solar panels. The site should receive at least some minimum threshold of solar radiation each year. This last constraint eliminates sites located next to taller buildings that block sunlight for a significant portion of the day.

PHOTOVOLTAIC TECHNOLOGY

Photovoltaic solar power is the electricity generated with solar cells. A solar cell converts sunlight directly into solar power electricity using a process known as the photovoltaic effect.

In 1839, 19-year old French physicist **Alexandre Edmond Becquerel** discovered that certain materials would produce small amounts of electric current when exposed to light. This basic physical process of using light to generate an electric current is known as the **photovoltaic effect**.

However, it would be more than 100 years before engineers would develop a photovoltaic cell capable of converting enough solar energy into electricity to run electrical equipment.

The breakthrough came in 1954 when physicists at Bell Labs discovered that a **Silicon semiconductor** was able to convert light into electricity with 4-6% efficiency. Compared to earlier materials which were less than 1% efficient, this was a major accomplishment.

Semiconductors are the key to **PV solar power**. To understand why, let's take a look at the characteristics of solid matter.

There are three types of solid matter...

- **Conductors:** Conductors have a loose hold of their electrons which allows them to conduct electricity.
- **Insulators:** Insulators have a strong hold of their electrons. Since their electrons aren't able to move, they do not conduct electricity.
- **Semiconductors:** Semiconductors have the properties of an insulator, but when exposed to light or heat is capable of conducting electricity.

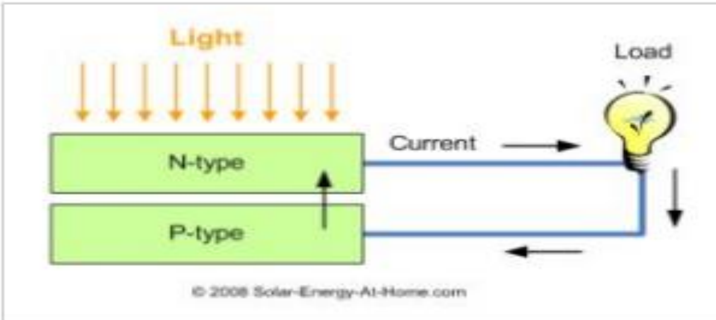
To generate solar electricity, semiconductors are needed. However, just shining light on a semiconductor will not create electricity. Yes, the electrons in the semiconductor will be released, but in order to generate electricity, they need to flow. To get the electrons flowing, two more pieces are needed to complete this puzzle.

First, you need to have a circuit. A circuit is simply a path for electrons to move on. The circuit creates a continuous loop which includes our semiconductor. The circuit will be made with a conductor such as copper wire.

Finally, you also need to have a positively charged semiconductor (P-type) and a negatively charged semiconductor (N-type). P-type and N-type semiconductors are created using a process known as doping. This process simply mixes another chemical element with the semiconductor to give it either a positive or a negative charge. With Silicon semiconductors, Boron is typically mixed in to create the P-type and Phosphorous the N-type.

Now we have all the pieces to the *photovoltaic solar energy* puzzle, so let's put them together!

A solar cell is made by joining a P-type semiconductor and an N-type semiconductor. The P-type will make up the bottom layer of the solar cell and the N-type will make up the top layer. The two layers form an electric field between them which only allows electrons to flow from the P-type semiconductor to the N-type semiconductor. This electric field provides our electric **voltage**.



Using Semiconductors to Create Solar Electricity

To generate the electricity, we simply need to create a circuit that goes from the N-type to the P-type. Now when the solar cell is exposed to light, electricity will flow from the N-type layer through the circuit to the P-type layer. This is our electric **current**.

Now that we have both voltage and current in our solar cell, we now have PV solar power! Power is the product of voltage and current and is measured in Watts. Now, if a load is placed on the circuit, it can use the electricity generated by the *PV solar energy*.

SOLAR CELL ENERGY BASICS

The *solar cell* is the basic component of *residential solar panels.*

Home solar power systems rely on *solar power cells* to convert sunlight into solar electricity. The science behind **solar cell energy** is based on semiconductor technology.

Photovoltaic cells are made out of materials known as semiconductors, usually silicon. A semiconductor has the properties of an insulator, but when exposed to light or heat is capable of conducting electricity.

However, in order to generate solar electricity, the silicon used for the semiconductor needs to be treated by a process known as "doping." Doping simply mixes an additional chemical element with the silicon to create either a positively charged or negatively charged layer of silicon.

A solar power cell consists of two layers of this treated silicon. The bottom layer is positively charged (P-type) and the top layer is negatively charged (N-type). The two layers form an electric field between them which only allows the electrons to flow from the P-type silicon to the N-type silicon. When the solar power cell is part of an external circuit, this will allow it to generate solar electricity when light strikes the top silicon surface

A Solar Power Cell

Types of Photovoltaic Cells

There are three primary types of photovoltaic cells made from silicon:

- Monocrystalline Photovoltaic Cells
- Polycrystalline Photovoltaic Cells
- Amorphous Silicon

Monocrystalline Photovoltaic Cells

Monocrystalline PV Cells are made by slicing thin wafers from a single long silicon crystal rod. These cells are highly efficient (15-18%) but expensive to manufacture due to the long, expensive process of creating silicon crystals and the high grade of silicon used.

Monocrystalline Photovoltaic Cell

Polycrystalline Photovoltaic Cells

Polycrystalline PV Cells are made from more than one silicon crystal. They are formed when molten silicon is poured into a mold and cooled to form an ingot. The ingot is then cut into smaller sections, each of which is then sliced into thin wafers.

Polycrystalline Photovoltaic Cell

Polycrystalline PV Cells are slightly less efficient (12-14%) than monocrystalline PV cells. However, they are also less expensive to manufacture since they use smaller crystals which are easier and quicker to grow than the single crystals used in monocrystalline PV cells.

Amorphous Silicon is the oldest thin film solar cell technology. It is a silicon alloy that is deposited directly onto the backing material, usually either glass or metal. Compared to crystalline photovoltaic cells, amorphous silicon is less efficient (5-6%), but the material costs and manufacturing costs are also much lower.

Making Solar Power Cells Practical

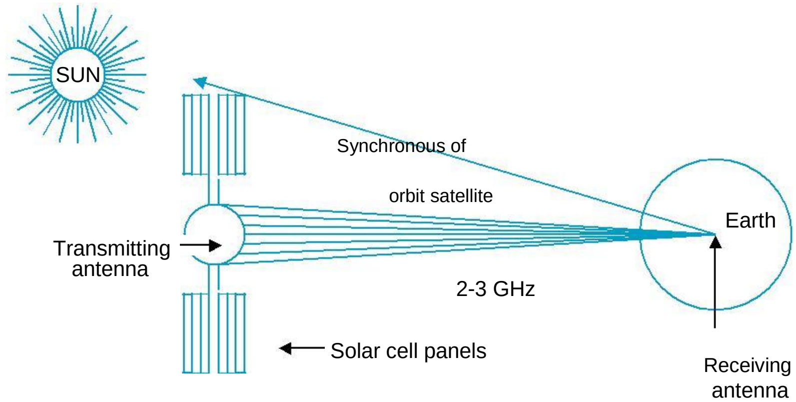
Amorphous Silicon

An individual *solar cell* will only produce about 1 or 2 watts of solar power electricity. For most home uses, much more power is needed. To meet that need, *solar power cells* can be joined together to create a **solar module** or **solar array**. These are commonly referred to as **solar panels.**

SOLAR POWER PLANT

It is known that only a small fraction of the energy radiated by the Sun reaches the Earth. It would, therefore, be an attractive proposition, if energy could be received from outside the atmosphere and then transmitted to the earth. A man-made satellite revolving around the earth will receive energy for all the 24 hours and will not be affected by the weather conditions.

Figure below shows the arrangement and general view of a solar power plant, carried by a man-made satellite. The solar cell panels to be installed on the satellite may vary in area from 16 to 100 sq km according to the plant capacity.



Solar Power Plant

The solar cells arranged in space would generate d.c. electric power and transmit it by means of microwaves (of about 10 cm. wave length), using a transmitting antenna. Microwave transmission may be at 2 to 3 GHz, as this keeps the losses at minimum. On the earth, this energy will be converted into high voltage d.c. or commercial frequency electric power.

The diameter of transmitting antenna would be around 1 km and that of the receiving antenna, 7 to 10 Kms. The efficiency of transmission is estimated to be in the range of 55 to 75%. The overall efficiency, with the present technology, is around 25% but is likely to go upto 60% in the near future.

The solar cells operate on the principle of photo electricity *i.e.*, electrons are liberated from the surface of a body when light is incident on it. Backed by semi-conductor technology, it is now possible to utilize the phenomenon of photo-electricity.

It is known that if an *n*-type semi-conductor is brought in contact with a *p*-type material, a contact potential difference is set-up at the junction (Schottky effect), due to diffusion of electrons. When the *p*-type material is exposed to light, its electrons get excited, by the photons of light, and pass into the *n*-type semi-conductor. Thus, an electric current is generated in a closed circuit. The *pn* junction silicon solar cells have emerged as the most important source of long duration power supply necessary for space vehicles. These cells are actuated by both, direct Sun rays and diffuse light. The efficiency of silicon solar cells increases with decreasing temperature. In cold weather the decreased luminous flux is compensated for, by higher efficiency. The efficiency of these solar cells varies from 15 to 20%.

Although the energy from the Sun is available free of cost, the cost of fabrication and installation of systems, for utilization of solar energy, is often too high to be economically viable. In order to make solar installations economically attractive, plastic materials are being increasingly used for the fabrication of various components of the system.

The efficiency of solar heating/cooling installation depends on the efficiency of collection of solar energy and its transfer to the working fluid (*e.g.* water, air etc.). There are two main classes of collectors. The flat plate collector is best suited for low and intermediate temperature applications (40°–60°, 80°–120°C) which include water heating for buildings, air heating and small industrial applications like agricultural drying etc. The concentrating collectors are usually employed for power generation and industrial process heating.

Solar Concentrators

Solar concentrators are the collection devices which increase the flux on the absorber surface as compared to the flux impinging on the concentrator surface. Optical concentration is achieved by the use of reflecting refracting elements, positioned to concentrate the incident flux onto a suitable absorber. Due to the apparent motion of the Sun, the concentrating surface, whether reflecting or refracting will not be in a position to redirect the sun rays onto the absorber, throughout the day if both the concentrator surface, and absorber are stationary. Ideally, the total system consisting of mirrors or lenses and the absorber should follow the Sun's apparent motion so that the Sun rays are always captured by the absorber. In general, a solar concentrator consists of the following:

(i) a focussing device

(ii) a blackened metallic absorber provided with a transparent cover

(iii) a tracking device for continuously following the Sun.

Temperatures as high as 300°C can be achieved with such devices and they find applications in both photo-thermal and photo-voltaic conversion of solar energy. The use of solar concentrators has the following advantages:

(*i*) Increased energy delivery temperature, facilitating their dynamic match between temperature level and the task.

(*ii*) Improved thermal efficiency due to reduced heat loss area.

(*iii*) Reduced cost due to replacement of large quantities of expensive hardware material for constructing flat plate solar collector systems, by less expensive reflecting and/or refracting element and a smaller absorber tube.

(*iv*) Increased number of thermal storage options at elevated temperatures, thereby reducing the storage cost.

Parameters Characterising Solar Concentrators

Several terms as used to specify concentrating collectors. These are:

(*i*) *The aperture area* is that plane area through which the incident solar flux is accepted. It is defined by the physical extremities of the concentrator.

(*ii*) *The acceptance angle* defines the limit to which the incident ray path may deviate, from the normal drawn to the aperture plane, and still reach the absorber.

(*iii*) *The absorber area* is the total area that receives the concentrated radiation. It is the area from which useful energy can be removed.

(*iv*) *Geometrical concentration ratio* or the radiation balance concentration ratio is defined as the ratio of the aperture area to the absorber area.

(*v*) *The optical efficiency* is defined as the ratio of the energy, absorbed by the absorber, to the energy, incident on the aperture.

(*vi*) *The thermal efficiency* is defined as the ratio of the useful energy delivered to the energy incident on the aperture.

Solar concentrators may be classified as point focus or line focus system. Point focus systems have circular symmetry and are generally used when high concentration is required as in the case of solar furnaces and central tower receiver systems. Line focus systems have cylindrical symmetry and generally used when medium concentration is sufficient to provide the desired operating temperature.

A solar concentrator consists of the following components:

(*i*) A reflecting or refracting surface, (*ii*) An absorbing surface *i.e.*, an absorber, (*iii*) A fluid flow system to carry away the heat, (*iv*) a cover around the absorber, (*v*) Insulation for the unirradiated portion of the absorber and (*vi*) A self supporting structural capability and well adjusted tracking mechanism.

Flat Plate Collector

The schematics of a flat plate collector are shown in Fig. 1.13. It usually consists of five main components viz.

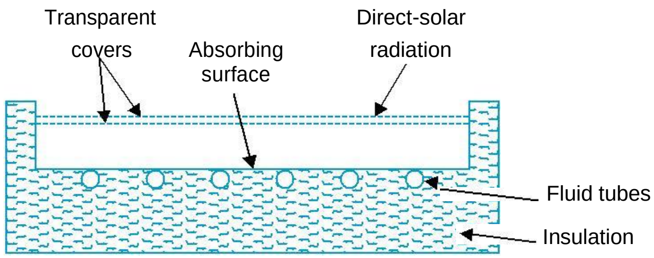
(*i*) An absorber plate (metallic or plastic),

(*ii*) Tubes or pipes for conducting or directing the heat transfer fluid, (*iii*) one or more cover,

(*iv*) Insulation to minimise the downward heat loss from the absorbing plate,

(*v*) Casing which encloses the foregoing components and keeps them free of dust and moisture and also reduces the thermal losses.

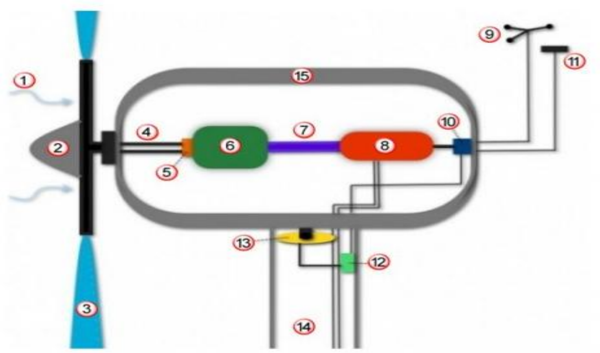
Generally flat plate collectors are framed sandwich structures, mounted on roofs or sloping walls. In most of these collectors, the absorber element is made of a metal such as galvanised iron, aluminium, copper etc. and the cover is usually of glass of 4 mm thickness. The back of the absorber is insulated with glass wool, asbestos wool or some other insulating material. The casing, enclosing all the components of the collector is either made of wood or some light metal like aluminium. The cost, with such meterials, is rather too high to be acceptable for common use. As the temperatures needed for space heating are rather low, plastics are being considered as potential material for fabrication of various components of the flat, plate collector. This would make solar energy systems comparable with other energy systems.



Schematics of a Flat Plate Solar Collector

WIND ENERGY PLANT

A wind turbine only operates when the wind is blowing, and understanding how a wind turbine works means understanding the aerodynamics of the wind and blades, while also knowing how a turbine generator creates electricity. At its most fundamental roots, a wind turbine works by allowing wind to rotate a turbine generator.



The diagram of the wind turbine above is a side view of a horizontal axis wind turbine with the turbine blades on the left. Most modern wind turbines are built with a horizontal-axis similar to the one seen in the figure.

Step-by-step look at each piece of a wind turbine from diagram above:

(1) Notice from the figure that the ***wind direction*** is blowing to the right and the nose of the wind turbine faces the wind.

(2) The ***nose*** of the wind turbine is constructed with an aerodynamic design and faces the wind.

(3) The ***blades*** of the wind turbine are attached to the nose and the rotor and begin to spin in ample wind speeds.

(4) The ***main turbine shaft*** is what connects the spinning blades to the inner workings of the machine. The turbine shaft spins with the blades and is the mechanism that transfers the rotational/mechanical energy of the blades towards the electrical generator.

(5) A ***brake*** is installed to prevent mechanical failure from high wind and high rotational speeds. It can also stop the turbine when it is unneeded.

(6) The ***gearbox*** is used to increase the rotational speed of the turbine shaft. The gearbox works like the gears on a bicycle, as the gears change, the rotational speeds will change too. Then, it transfers the rotational energy into the high-speed turbine shaft and into the generator.

(7) The ***high-speed turbine shaft*** connects the gear box and the generator. It's high rotating speeds are what spin the turbine generator.

(8) The ***turbine generator*** is the most essential part of how a wind turbine works. The turbine generator is what converts the mechanical energy from the wind into electrical energy using the rotating force that is transferred from the gears and turbine shaft.

(9) The ***anemometer*** is a device that measures wind speeds. They are usually installed to instruct the controller to stop or start the turbine in certain wind speed conditions.

(10) The ***controller*** is installed in case the wind speeds reach an undesired speed, the anemometer can instruct the controller to use the brake and stop the rotating blades. The controller is also used to help start spinning the blades and rotor in low wind speeds.

(11) The ***wind vane*** is an instrument that measures the direction of the wind. The wind vane is important for up-wind turbines that need to be facing the wind in order to operate properly.

(12) The ***yaw drive*** in the mechanism that receives data from the wind vane and instructs the wind turbine to rotate to be facing the wind.

(13) The ***yaw motor*** is the device that physically rotates the turbine to be facing the wind or as instructed by the yaw drive.

(14) The ***turbine tower*** contains wiring so the generator can send electricity into a transformer or a battery which will eventually distribute usable electric power. The tower is also a crucial structural support system that holds the turbine high in the air where wind speeds are more desirable.

(15) How a wind turbine works well outside, and during intense wind speeds is because all of the components are built at the top of the turbine tower and placed safely inside the turbine ***nacelle***. The tower and the nacelle of a wind turbine are usually made out of cylindrical steel and can either be supported by guy wires and guy tensions or stand alone using a lattice standing base.

Again, this diagram shows an example of an up-wind, horizontal axis wind turbine that may be made of steel and potentially stand several stories tall. How a wind turbine works not only involves great engineering, it also requires thoughtful analysis and strategy to find desirable locations with ample wind speeds.

Wind energy

Winds are caused because of two factors.

(1) The absorption of solar energy on the earth's surface and in the atmosphere.

(2) The rotation of the earth about its axis and its motion around the sun.

Because of these factors, alternate heating and cooling cycles occur, differences in pressure are obtained, and the air is caused to move. The potential of Wind energy as a source of power is large. This can be judged from the fact that energy available in the wind over the earth's surface is estimated to be 1.6×10^7 kW besides the energy available is free and clean.

The problems associated with Utilizing wind energy are that:

(i) The energy is available in dilute form, because of this conversion machines have to be necessarily large.

(ii) The availability of the energy varies considerably over a day and with the seasons.

For this reason some Means of storage have to be devised if a continuous supply of power is required.

A wind mill converts the kinetic energy of moving air into mechanical energy that can be either used directly to run the machine or to run the generator to produce electricity.

Classification of wind mills

Wind mills

- (a) Horizontal Windmills
  - Single Bladed
  - Double Bladed
  - Multi Bladed
- (b) Vertical Windmills
  - Darrieus rotor
  - Savonius rotor

(a) Horizontal Wind mills

i. Horizontal Axis single blade Wind mills

If extremely long blades are mounted on rigid hub. Large blade root bending moments can occur due to tower shadow, gravity and sudden shifts in wind directions on a 200 ft long blade. Fatigue load may be enough to cause blade root failure.

To reduce rotor cost, use of single long blade centrifugally balanced by a low cost counter Weight as shown in fig 3.1. The relatively simple rotor hub consists of a Universal Joint between the rotor shaft and blade allowing for blade. This type of hub design contains fewer parts and costs less.

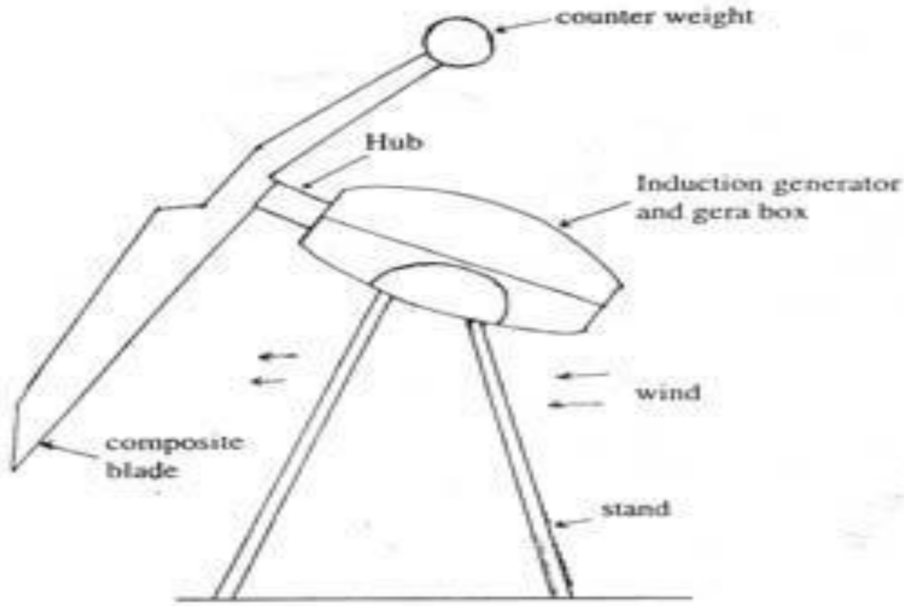


Fig 3.1 Single blade wind mill

(ii) Horizontal axis – two bladed wind mills

In this arrangement rotor drives generator through a step-up gear box. The components are mounted on a bed plate which is mounted on a pinttle at the Top of the tower. The two blade rotor is usually designed to be oriented downwind of the tower. The arrangement of all the Components used in horizontal axis wind mill is shown in fig 3.2.

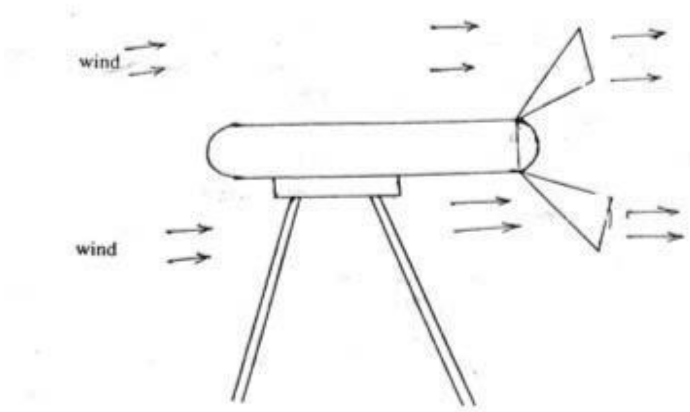
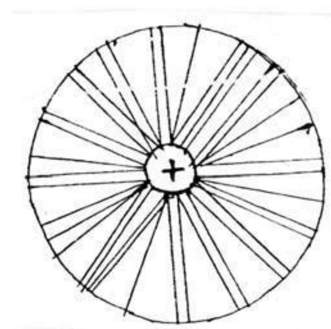


Fig 3.2 Double blade wind mill

When the machine is operating its rotor blades are continuously flexed by unsteady aerodynamic, gravitational and inertial loads. If the blades are metal, flexing reduces their fatigue life. The tower is also subjected to unsteady load and dynamic interactions between the components of the machine-tower system can cause serious damage.

(iii) Horizontal Axis – Multi bladed Wind Mills



This type of wheel has narrow rims and Wire spokes. The wire spokes support light weight aluminium blades. The rotors of this design have high strength to weight ratios and have been known to survive hours of freewheeling operation in 100 kmph winds. They have good power Co-efficient, high starting torque and added advantage of simplicity and low cost.

(b) Vertical Wind Mills

Wind turbines mounted with the axis of rotation in a vertical Position have advantage that they are omni-directional that is, they need not to be turned to Force the wind. The Vertical mounted Wind Machines eliminates the need for some of the complex mechanical devices and control systems necessary for horizontal mounted wind Machines.

Two types of vertical axis Wind Machines have received attention. The Darrievs rotor consists of two or three convex metal blades with an air foil cross section, mounted on a Central shaft which is supported by bearings at the top and bottom. The rotor assembly is held in position by guy wires running from the top of the rotor to the ground.

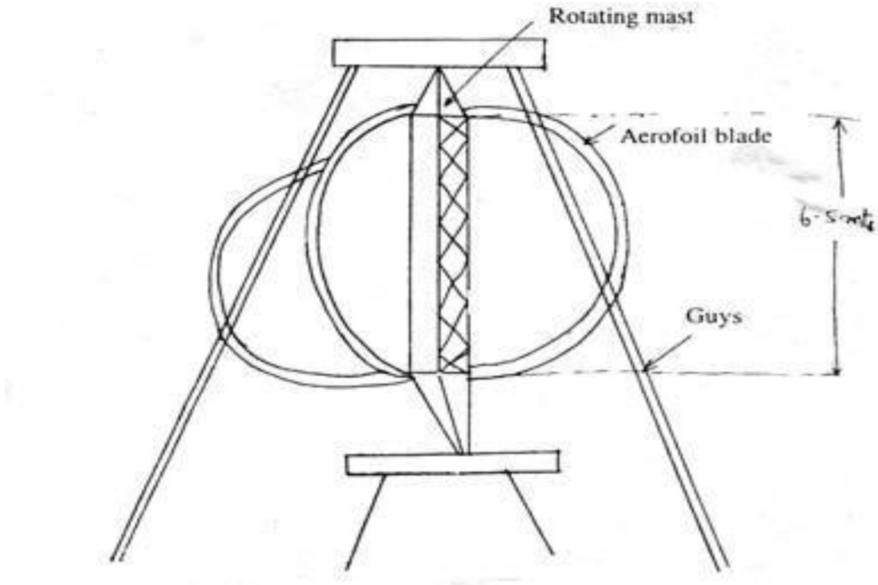
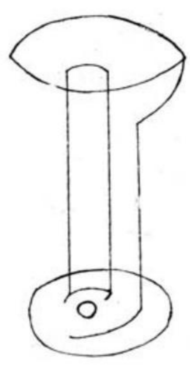


Fig 3.5 Vertical wind mill (Darrieus rotar)

The savonius rotor consists of a long solid's- shaped surface mounted to turn at the center of 's' the savonius rotor is self starting and has an efficiency of about 31% while the Darrievs rotor has a slightly higher efficiency of 35% but is not self starting.



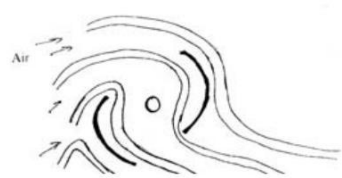


Fig 3.6 (a) Savonius rotor **Fig 3.6 (b) Air flow through a savonius rotor**

Advantages of Wind energy

(1) The wind energy is free, inexhaustible and does not need transportation.
(2) Wind mills will be highly desirable and economical to the rural areas which are far from existing grids.
(3) Wind power can be used in combination with hydroelectric plants. Such that the water level in the reservoir can be maintained for longer periods.

Disadvantage of Wind energy

(1) Wind power is not consistent and steady, which makes the complications in designing the whole plant.
(2) The wind is a very hazard one. Special and costly designs and controls are always required.
(3) The cost factor, which has restricted the development of wind power in large scale for feeding to the existing grid.
(4) It has low power coefficient.
(5) Careful survey is necessary for plant location.

TIDAL POWER PLANTS

5.0 Introduction to Tidal Power Plants

The development of a nation is estimated from the total amount of energy it produces and consumes in relation to its size and Population. Human-Progress has been judged from the ways in which man has been able to develop and harness energy.

The present shortage of the energy production sources due to deplitable nature of fossil flues has awakened the world human community to search for new unconventional and replenishable energy sources. According to the energy experts, exhaustible resources extracted from the ground (coal, oil, gas, and uranium), in the face increasing demand, results into a cycle. This cycle starts at zero production increases exponentially than decreases exponentially and finally comes to zero. It is estimated that Petroleum reserves of the world will be nearly exhausted by 2020. Under such circumstances, man has to find out some source of energy for his survival. In this context, three sources of energy, tidal, wind and solar have been brought to be most promising.

What is tidal power? Tide is periodic rise and fall of the water level of the sea. Tides occur due to the attraction of seawater by the moon. These tides can be used to produce electrical power which is known as tidal power.

When the water is above the mean sea level, it is called flood tide and when the level is below the mean level, it is called ebb tide. A dam is constructed in such a away that a basin gets separated from the sea and a difference in the water level is obtained between the basin and sea. The constructed basin is filled during high tide and emptied during low tide passing through sluices and turbine respectively. The Potential energy of the water stored in the basin is used to drive the turbine which in turn generates electricity as it is directly coupled to an alternator.

Though the idea of utilizing tides for human service relates to eleventh century when tidal mills were used in England but the use of tidal power for electric power generation is hardly a decade old as the world's first Rance tidal power plant of 240 MW capacity in France was commissioned by President be Gaulle in 1965 who described it a magnificent achievement in the human life.

Tidal power has been a dream for engineers for many years and it remained dream because of large capital cost involved in its development. But after the inauguration of Rance Tidal Project, a new chapter in the history is now opened.

5.1 Factors affecting the suitability of the site for tidal power plant

The feasibility and economic vulnerability of a tidal power depends upon the following factors.

1. The power produced by a tidal plant depends mainly on the range of tide and the cubature of the tidal flow occurring in the estuary during a tidal cycle which can be stored and utilized for power generation. The cubature of the tidal flow not only depends on the tidal range but on the width of estuary mouth.
2. The minimum average tide range required for economical power production is more.
3. The site should be such that with a minimum cost of barrage it should be possible to create maximum storage volume. In addition to this, the site selected should be well protected from wave's action.
4. The site should not create interruption to the shipping traffic running through the estuary otherwise the cost of the plant will increase as locks are to be provided.
5. Silt index of the water of the estuary should be as small as possible to avoid the siltation troubles. The siltation leads to reduction of the range of tides and reduces the power potential of the plant.
6. The fresh water prism that falls into the reservoir of the tidal plant (due to the surface flows in the streams having out fall in the estuary) eats away the valuable storage created for storing the tidal prism. Therefore, the ratio of fresh water prism to tidal water prism

becomes an important index in determining the economic feasibility of a tidal scheme. The effective and cheaper will be the power production with decreasing the ratio mentioned above.

5.2 Classification of tidal Power Plants

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation.

The classification is represented with the help of a line diagram as given below

Classification

- Single basin systems
  - One-way System
  - Two-way System
  - Two-way with pump storage
- Double basin systems
  - Simple double Basic
  - Double basin with pumping

5.3 Working of Different Tidal Power Plants 5.3.1 Single basin-One-way cycle

This is the simplest form of tidal power plant. In this system, a basin is allowed to get filled during flood tide and during the ebb tide. The water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration during ebb tide.

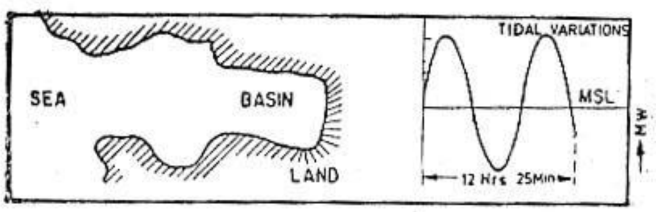
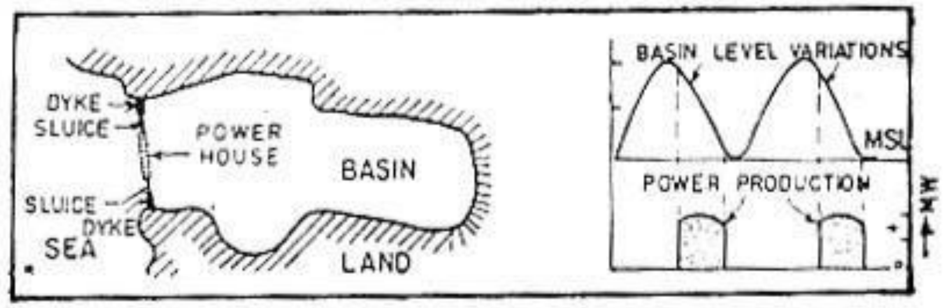


Fig 5.1 Single basin Tidal Power Plant

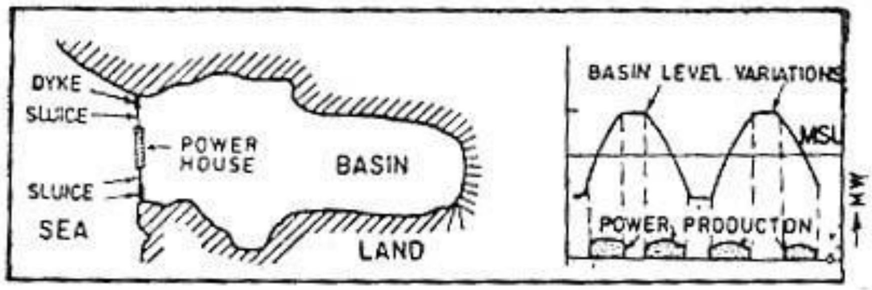
Fig 5.1 shows a single tide basin before the construction of dam and Fig 5.2 shows the diagrammatic representation of a dam at the mouth of the basin and power generation during the falling tide.



(b) Single basin, one-way tidal power plant.

5.3.2 Single-basin two-way cycle

In this arrangement power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However the peak power obtained is less than the one-way cycle. The arrangement of the basin and the power cycle is shown in Fig 5.3.



Single-basin two-way tidal power plant.

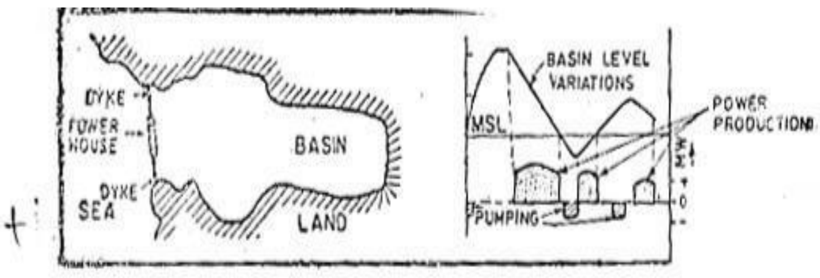
Fig 5.3

The main difficulty with this arrangement, the same turbine must be used as Prime mover as ebb and tide flows pass through the turbine in opposite directions. Variable pitch turbine and dual rotation generator are used for such schemes.

5.3.3. Single-basin two-way cycle with pump storage

The Rance tidal power plant in France uses this type of arrangement. In this system, power is generated both during flood and ebb tides. Complex machines capable of generation Power and Pumping the water in either direction are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and the sea at any time of the tide and this is done by pumping water into the basin up or down. The period of power production with this system is much longer than the other two described earlier. The cycle of operation is shown in Fig 5.4.

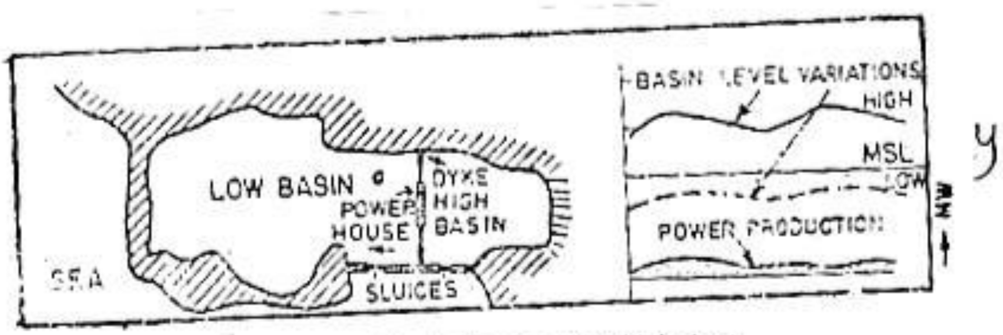
Fig 5.4



Single-basin, two-way tidal plant coupled with pump storage system.

5.3.4 Double basin type

In this arrangement, the turbine is set up between the two basins as shown in Fig 5.5. one basin is intermittently filled by the flood tide and other is intermittently drained by the ebb tide. Therefore a small capacity but continues power is made available with this system as shown in Fig 5.5. The main disadvantage of this system is that 50% of the Potential energy is sacrificed in introducing the variation in the water levels of the two basins.



Double basin, one-way tidal plant.

Fig 5.5

5.3.5 Double basin with Pumping

In this case, off peak power from the base load plant in a interconnected transmission system is used either to pump the water up the high basin. Net energy gain is possible with such a system if the pumping head is lower than the basin-to-basin turbine generating head.

5.4 Advantages and disadvantages of Tidal Power Plants Advantages

1. Exploitation of tidal energy will in no case make demand for large area of valuable land because they are on bays.
2. It is free from pollution as it does not use any fuel.

3. It is much superior to hydro-power plant as it is totally independent of rain which always fluctuates year to year. Therefore, there is certainty of power supply a the tide cycle is very definite.

4. As in every form of water power, this will also not produce any unhealthy waste like gases, ash, atomic refuse which entails heavy removal costs.
5. Tidal Power is superior to conventional hydro power as the hydro plants are know for their large seasonal and yearly fluctuations in the output of energy because they are entirely dependent upon the nature's cycle of rainfall, which is not the case with tidal as monthly certain power is assured. The tides are totally independent on nature's cycle of rainfall.
6. Another notable advantage of tidal power is that it has a unique capacity to meet the peak power demand effectively when it works in combinatiion with thermal or hydroelectric system.

7. It can provide better recreational facilities to visitors and holiday makers, in addition to the possibility of fish forming in the tidal basins.

Disadvantages

1. These Power plants can be developed only if natural sites are available.

2. As the sites are available on the bay which will be always far away from the load centers. The power generated must be transported to long distances. This increases the transportation cost.
3. The supply of power is not continuous as it depends upon the timing of tides. Therefore some arrangements (double basin or double basin with pump storage) must be made to supply the continuous power. This also further increases the capital cost of the plant.

4. The capital cost of the plant (Rs.5000/kw) is considerably large compared with conventional-power plants (hydro, thermal)
5. Sedimentation and siltration of the basins are some of the added problems with tidal power plants.

6. The navigation is obstructed.

7. It is interesting to note that the output of power from tidal power plant varies with lunar cycle, because the moon largely influences the tidal rhythm, where as our daily power requirement is directly related to solar cycle.

In addition to all the above mentioned (imitations of tidal power, the utilization of tidal energy on small scale has not yet proved economical.

Components of Tidal Power plants

There are three main Components of a tidal Power plant. i.e,

(i) The Power house

(ii) The dam or barrage

(iii) Sluice-ways from the basins to the sea and vice versa.

The turbines, electric generators and other auxiliary equipment's are the main equipments of a power house. The function of dam to form a barrier between the sea and the basin or between one basin and the other in case of multiple basins.

The sluice ways are used either to fill the basin during the high tide or empty the basin during the low tide, as per operational requirement. These are gate controlled devices.

It is generally convenient to have the power house as well as the sluice-ways in alignment with the dam.

The design cycle may also provide for pumping between the basin and the sea in either direction. If reversible pump turbines are provided, the pumping operation can be taken over at any time by the same machine. The modern tubular turbines are so versatile that they can be used either as turbines or as pumps in either direction of flow. In addition, the tubular passages can also be used as sluice-ways by locking the machine in to a stand still. As compared to conventional plants, this, however, imposes a great number of operations in tidal power plants. For instance, the periodic opening and closing of the sluice-way of a tidal plant are about 730 times in a year.

Dam (Barrage)

Dam and barrage are synonymous terms. Barrage has been suggested as a more accurate term for tidal power scheme, because it has only to with stand heads a fraction of the structure's height, and stability problems are far more modest. However, the literature does not always make the distinction, even though heads are small with tidal power cutoffs.

Tidal power barrages have to resist waves whose shock can be severe and where pressure changes sides continuously.

The barrage needs to provide channels for the turbines in reinforced concrete. To build these channels a temporary coffer dam in necessary, but it is now possible to built them on land, float them to the site, and sink them into place.

Tidal barrages require sites where there is a sufficiently high tidal range to give a good head of water – the minimum useful range is around three meters. The best sites are bays and estuaries, but water, can also be impounded behind bounded reservoir built between two points on the same shore line.

The location of the barrage is important, because the energy available is related to the size of trapped basin and to the square of the tidal range. The nearer it is built to the mouth of bay, the larger the basin, but the smaller the tidal range. A balance must also be struck between increased output and increased material requirements and construction costs.

Gates and Locks

Tidal power basins have to be filled and emptied. Gates are opened regularly and frequently but heads very in height and on the side where they occur, which is not the case with conventional river projects. The gates must be opened and closed rapidly and this operation should use a minimum of power. Leakage is tolerable for gates and barrages. Since we are dealing with seawater, corrosion problems are actuate, they have been very successfully solved by the catholic protection and where not possible by paint. Gate structures can be floated as modular units into place.

Though, in existing plants, vertical lift gates have been used. The technology is about ready to substitute a series of flap gates that operates by water pressure. Flap gates are gates that are positioned so as to allow water in to the holding basin and require no mechanical means of operation. The flap gates allow only in the direction of the sea to basin. Hence, the basin level rises well above to sea level as ebb flow area is far less than flood flow area.

Power house

Because small heads only are available, large size turbines are needed; hence, the power house is also a large structure. Both the French and Soviet operating plants use the bulb type of turbine of the propeller type, with revisable blades, bulbs have horizontal shafts coupled to a single generator. The cost per installed kilowatt drops with turbine size, and perhaps larger turbines might be installed in a future major tidal power plant.

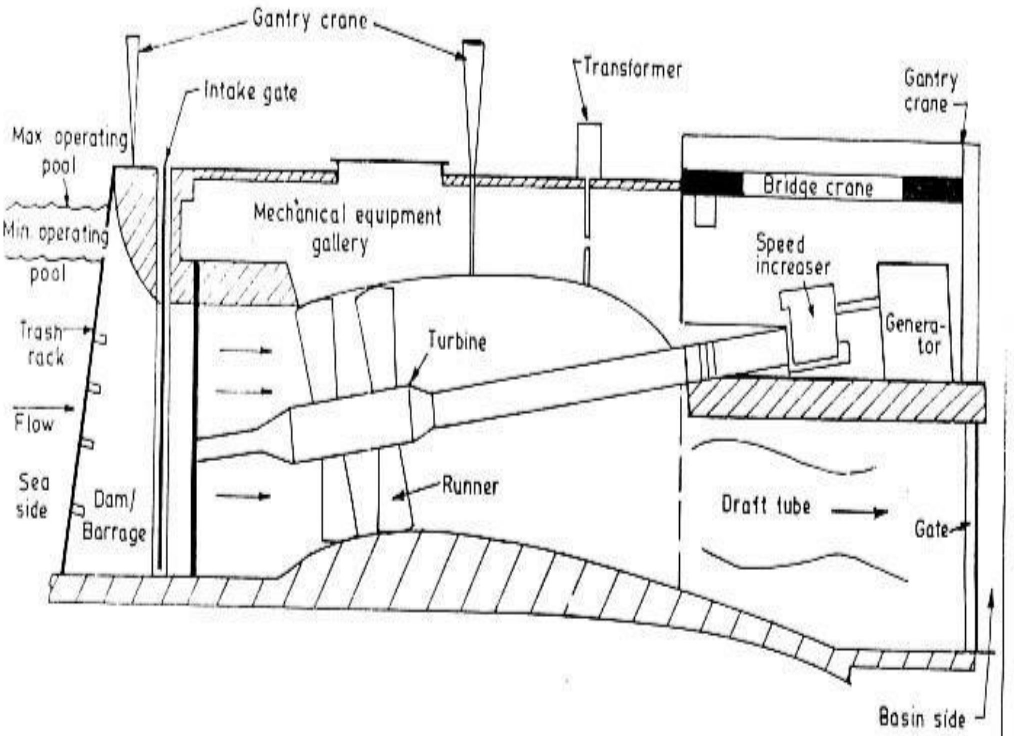


Fig 5.6 Schematic Lay out of Tidal Power House

MAGNETO HYDRO DYNAMIC (MHD) GENERATION

Introduction

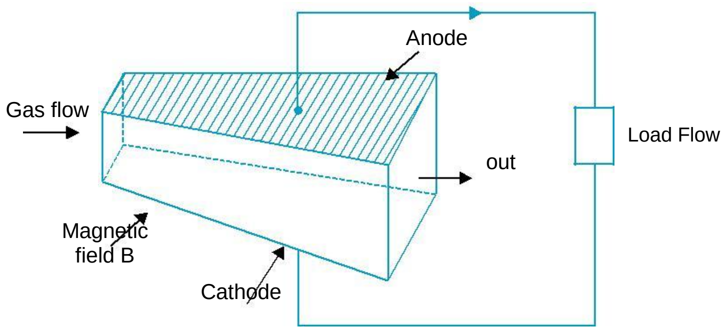
In the conventional steam power plants, the heat released by combustion of fuel is transformed into the internal energy of steam. The temperature and pressure of steam increase in the process. The steam turbine, then, converts steam energy into mechanical energy, which drives a generator. This way, the mechanical energy is converted into electric energy. The repeated conversion of various forms of energy involves losses and, hence, the overall efficiency
of thermal power plant decreases. The typical range of effciency of thermal plants is 37 to 40%. The direct conversion of heat to electricity would enable the industry to use the fuel resources more efficiently. MHD generation is one form of energy technology, wherein direct conversion of heat into electric energy has been devised. The technological development in the field of plasma physics and metallurgy etc. and other branches of science and technology has made it possible for this kind of direct transformation of energy.

An ionized gas is used as conducting medium in the MHD generator. The gas can be made electrically conducting when it is maintained at least at a temperature of 2000°C. This fact does not allow MHD generation from being used in the entire temperature range from 3000 K to 300 K. It is therefore, thought beneficial that MHD generators be used in conjunction with steam operated thermal plants utilising the heat of the gas leaving the MHD ducts. The combined operation of MHD generators alongwith the conventional thermal plant, will raise the overall efficiency to nearly 60%, thereby lot of saving in the fuel cost will result.

Principle of Operation of MHD Generator

The basic principle of operation is based on Faraday's law of electro magnetic induction, which states an e.m.f. is induced in a conductor moving in magnetic field. The conductor may be a soild, liquid or a gaseous one. The study of the dynamics of an electrically conducting fluid interacting with a magnetic field, is called magneto hydro dynamics.

In this method (Fig. 1.9) gases at about 2500°C are passed through the MHD duct across which a strong magnetic field has been applied. Since the gases are hot, and partly ionized they form an electrically conducting conductor moving in the magnetic field. An e.m.f. (direct-current) is thus induced, which can be collected at suitable electrodes. Block diagram of a typical open cycle MHD power plant is shown in Fig.



Basic Principle of MHD Generator

BIO ENERGY

Introduction

Bio gas is generated through a process of anaerobic digestion of Bio Mass. Bio Mass is organic matter produced by plants, both terrestrial (those grown on land) and aquatic (those grown in water) and their derivatives. It includes forest crops and residues, crops grown especially for their energy content on "energy farms" and animal manure. Unlike coal, oil and natural gas, which takes Millions of years to form, bio mass can be considered as a renewable energy source because plant life renews and adds to itself energy year. It can also be considered a form of solar energy as the latter is used indirectly to grow these plants by photosynthesis.

Bio Mass means organic matter and Photo Chemical approach to harness solar energy means harnessing of solar energy by photo synthesis. Solar energy is stored in the form of chemical energy. Hence solar energy –> Photosynthesis –> Bio Mass->energy generation.

Out of several sources of renewable energy like solar, wind, tidal, wave energy, Geothermal energy, nuclear energy, energy through bio mass are important features in our Country. Biogas Production Technology contributes in following ways.

Advantages of Bio Gas technology

(1) It provides a better and cheaper fuel cooking, lighting and for power generation.

(2) It produces good quality, enriched manure to improve soil fertility.

(3) It proves an effective and convenient way for sanitary disposal of human excreta, improving the hygienic conditions.

(5) It generates social benefits such as reducing burden on forest for meeting cooking fuel by cutting of tree for fuel wood, reduction in the drudgery of women and children etc.

(6) As a smokeless domestic fuel, it reduces the incidence of eye and lung diseases.

(7) It also helps in generation of productive employment

Bio Gas and its Compositions

Bio gas contains 55-70% methane and 30-45% carbon dioxide as well as small quantities of(N_2, H_2, H_2S) some gases. It is lighter than the air and has an ignition temperature of approximately 700^{o}C. The temperature of the flame is 870^{o}C. its calorific value is approximately 4713kcal/m^3. The methane content of bio gas produced from different feed stock is given in Table .1.

Content of Methane in Bio-gas produced from different feed stocks

S.No.	Feed Stock	Content of Methane in Bio gas in Percentage
1.	Cattle Manure	54-56
2.	Pig Manure	57
3.	Poultry Manure	55
4.	Farm yard Manure	55
5.	Straw	55
6.	Grass	60

7.	Leaves	58
8.	Kitchen Waste	50-52
9.	Human excreta	60

The bio gas system is most suitable technology to solve the energy problems in rural areas, as it Produces Manure, clean fuel and improves rural sanitation. It's thermal energy Per Unit volume is sufficient to meet domestic energy needs the comparison of bio gas with other fuels is given in table II.

Comparison of Bio-gas with other fuels

S.No.	Name of fuel and Unit	Calorific value (K Cal)	Mode of Burning
1.	Gobar (M^3)	4713	Standard burner
2.	Kerosene (lit)	9122	Pressure stove
3.	Fire wood (Kg)	4700	Open chulla
4.	Cow-dung cake (Kg)	2092	Open chulla
5.	Charcoal (Kg)	6930	Open chulla
6.	Soft cake (Kg)	6292	Open chulla
7.	Butane (LPG) Kg	10882	Standard burner
8.	Coal gas (M^3)	4004	Standard burner
9.	Electricity (Kwn)	860	Hot plate

Process of Bio gas, generation – Wet Process, dry Process

(i) Wet process

(a) Anaerobic digestion

Bio gas is produced by the bacterial decomposition of wet sewage sludge, animal dung or green plants in the absence of oxygen. Feed stocks like – wood shavings, straw, and refuse maybe used, but digestion takes much longer. The natural decay process 'anaerobic decomposition' can be speeded up by using a thermally insulated, air-tight tank with a stirrer Unit and heating system. The gas collect in the digester tank above the slurry and can be piped off continuously. At the optimum temperature (35^oC) complete decomposition of animal or human farces takes around 10 days. Gas yields depend critically on the nature of the waste-Pig manure, for example, is better than cow dung or house hold refuse. The residue left after digestion is valuable fertilizer. It is also rich in protein and could be dried and used as animal feed-supplement.

(b) Fermentation

As stated, ethanol or ethyl alcohol is produced by the Fermentation of sugar solution by natural yeast's. After 30 hours of fermentation the brew or 'beer' contains 6-10% alcohol and this can readily by removed by distillation. Traditionally, the fibrous residues from plant crops like sugar cane bagasse have been burnt to provide the heat. Suitable feed stocks include crushed sugar came and beet, fruit etc sugar can also be manufactured from vegetable starches and Cellulose, Maize, Wheat grain, or Potatoes. For they must be ground or pulped and then cooked with enzymes to release the starch and convert it to fermentable sugars. Cellulose materials like wood, paper waste or straw, require harsher pre-treatment typically milling and hydrolysis with hot acid. One tonne of sugar will produce up to 520 liters of Alcohol, a tonne of grain, 350 liters and a tonne of wood, an estimated 260 to 540 liters. After fermentation, the residue from grains and other feed syffs contains high protein content and is a useful cattle-feed supplement.

The hydrolysis and distillation step require a high energy input; for woody feed stocks direct combustion or pyrolysis is probably more productive at present, although stem treatment and new low-energy enzymatic hydrolysis techniques are under development. The energy requirement for distillation is also likely to be cut drastically. Alcohol can be separated from the beer by many methods which are now under intensive development. These include solvent extraction, reverse osmosis, molecular sieves and use of new desiccants for alcohol drying. It may soon be possible to have the energy required for alcohol production to produce a greater net energy gain.

(iii) Dry Process

Pyrolysis

A wide range of energy-rich fuels can be produced by roasting dry woody matter like straw and wood-chips. The material is fed into a reactor vessel or retort in a pulverized or shredded form and heated in the absence of air. As the temperature rises the cellulose and lignin break down to simpler substances which are driven off leaving a char residue behind. This process has been used for conturies to produce charcoal.

The end products of the reaction depend critically on the conditions employed, at lower temperatures around 500^{o}C, organic liquid predominate, whilst at temperatures nearer 1000^{o}C combustible mixture of gases results.

Raw Materials available for Bio gas Fermentation

(i) Manure: This kind of Material is available from animal waste and poultry waste. Their compositions vary with the feeding stuff. In chines rural areas, the fresh manure is used to be fermented with shorter retention time (about two months). The manure from human, cattle, chicken and pigs are subject to inhabitation when fermented without other Carbon source. Manures can be used as Bio mass.

(ii) Plants: Most of the Plants of the grass family can be used for fermentation. Both aqnolic and terrestrial plants can be used as Bio mass. As such they are difficult to be biodegraded. In order to ferment them more easily, pretreatment and a longer retention time are generally needed. Adequate amount of nitrogen rich elements urea etc; should be added for the fermentation.

(iii) Industrial Organic Waste Water: Industrial effluents from food processing, biochemical pharmacy, paper making etc; can be treated by anaerobic fermentation. Most organic matters of these liquid are soluble and their composition are more stable than that of agricultural wastes, while the water quantities may fluctuate. Some effluents may be nutrient deficient or even toxic. Thus pre-treatment, such as the elimination of toxicity, adding nutritional additives and so on, or necessary for anaerobic digestion. In food processing Industries plenty of organic waste will available. By utilizing two organic wastes we can produce Bio gas by anaerobic digestion.

(iv) Organic Matter in Municipal Wastes: They are in solid and inorganic contents need separation. Organic matter is available in Municipal wastes. By utilizing this organic matter. Bio-gas can be produced.

4.4 Selection of site for Installation of a Bio gas plant

Careful selection of the best site for installation of a bio gas unit should be done for every beneficiary. The following points should be taken into consideration.

(1) The distance between the plant and site of gas consumption or kitchen should be less to Minimize cost on gas pipe line and gas leakage. For a plant of capacity $2m^3$, the optimum distance is 10 cm.

(2) It should be near the cattle-shed to minimize the distance for carrying cattle dung and transportation cost.

(3) There should be enough space for storage of digested slurry or construction of compost pit.

(4) It is should be 10 to 15 meters away from any drinking water well to prevent contamination of water.

(5) The area should be free from roots of trees which are likely to creep into the digester and cause damage.

(6) It should be open to receive the Sun’s rays for most part of the day and to keep the plant in warm. The sunlight should fall on the plant as temperature between 15^oC to 30^oC is essential for gas generation at good rate.

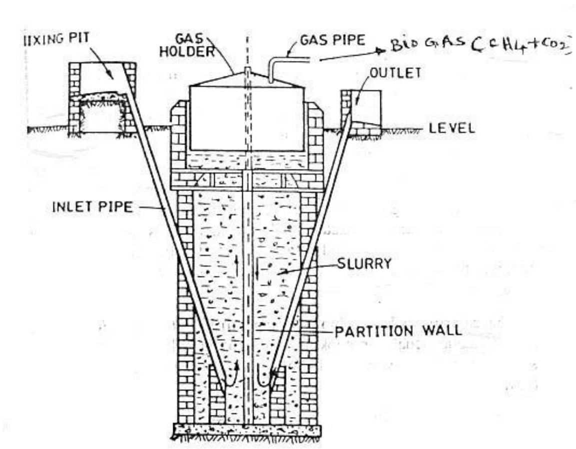
(7) It should be on an elevated area so that the plant does not get submerged during normal rains.

(8) Sufficient space must be available for day to day Operation and Maintenance. As a guide line 10 to 12 M^2 area is needed per M^3 of the gas.

(9) Plenty of water must be available as the Cow dung slurry with a solid concentration of 7% to 9% is used.

KVIC Bio gas Plant

The Floating gas holder digester developed in India is of Masonry construction with gas holder made of M.S. Plates. The drum in the KVIC Model is the costliest component and its life is comparatively less.



The design of KVIC plant was

developed and perfected in India in the year 1945. This was taken up propagation in the villages in the year 1962, by Khadi and village industries commission, Bombay. Therefore, it is known as KVIC design. The design is available in sizes of 1 cum to 140 cum gas per day. In KVIC plant the gas is stored in mild steel drum of storage capacity of 30-40 percent of plant size at a pressure of about 10cm of water column. Which is sufficient to carry it up to a length of 20 meters to 100 meters, depending on the size of the plant.

The plant consists of two parts. The digester, which is well containing the animal waste in the form of slurry, and the dome which floats on the slurry and serves as the gas holder.

The digester is normally below ground level and two pipe lines lead to its bottom. One for feeding the animal waste slurry and the other for spent slurry called sludge to come out after it has under gone fermentation. It is worth noting that the sludge to come out retains all the nitrogen, phosphorous and potassium and in an excellent fertilizer. A vertical partition wall divides it into two equal parts and serves to direct the flow of the slurry.

The gas generation process occurs in two stages. In the first stage, the complex organic substance contained in the waste are acted upon by a certain kind of bacteria called acid formers and are broken up into small chain simple acids. In the second stage, these acids are acted upon by another kind of bacteria which produces Methane and Carbon dioxide

The calorific value of bio gas ranges from 1600 to 2500 KJ/m^3. It is an excellent fuel for cooking and lighting. When compared with diesel it is also be a very good fuel for compression, ignition engines and can save 70 to 80 percent of diesel.

4.10.1 Pragathi Design Bio gas Plant

The design has been developed by United Socio-Economic Development and Research Programme (UNDARP) Pune, in order to have a cheaper floating drum bio gas plant. In this design the depth of pit is less than K.V.I.C plant so that it can be constructed in hilly and high water tabel areas. The cost of Pragathi plant is 20% less than KVIC plant.

The design shown in fig 4.5, indicates its different parts. The foundation of this plant is of conical shape, with difference of one feet between outer periphery and its center so as to reduce the earth and digester wall work. It is constructed at the base of the pit with cement, sand and concrete, keeping the site conditions in view so it can bear the load due to weight of slurry in the digester.

The digester of Pragathi design plant start from the foundation in dome shape there by reducing the constructional area, for same digester volume, thus reducing the cost of construction of the plant. The wall thickness of digester is kept 75mm only. Dome shape construction takes place up to a collar base, where a central guide frame is provided. the digester wall above guide-frame is constructed in cylindrical shape,

Partition wall is constructed in the digester for 4cum.and bigger sizes so as to control the flow of slurry inside the digester It divides digester in two parts separating inlet and outlet.

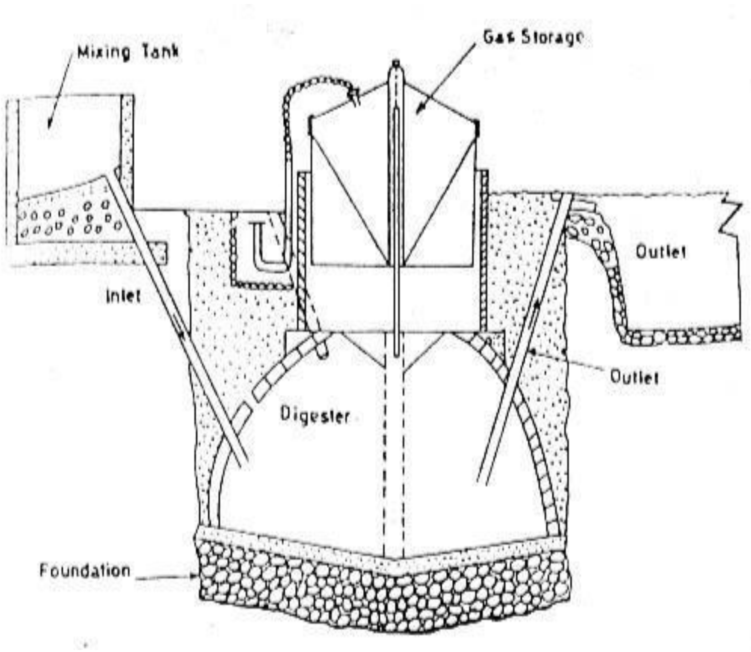


Fig 4.5 Pragathi Design Bio gas Plant

The inlet is through pipe, placed while construction digester wall. It is used for feeding daily slurry in to the digester and is generally of 100mm diameter. The out let pipe is also 100mm in diameter, and fixed while constructing digester wall. The asbestos cement pipe can be used for inlet and out let.

The guide frame is made of angle iron and steel pipe, is embedded in the digester wall at top of spherical portion of digester. The central guide pipe holds gas holder which is also made of M.S sheet and angle iron. It floats up and down along pipe depending on the quantity of gas in the drum.

4.10.2 Janata Bio gas Plant

This was first developed by the planning, Research and Action division, Lucknow, in 1978. It is an improved version of the Chinese fixed-dome bio gas plant. The plant is shown in fig4.6 with different parts. The foundation of Janata Bio gas plant is laid at the base of the under ground pit on a leveled ground bear the load of the slurry as well as digester walls.

Digester is cylindrical in shape constructed with bricks and cements the dung slurry for a retention. Time, so that the bio gas is produced from the slurry in the digester. It should be noted that the diameter and height ratio of the digester is kept 1.75:1.

The gas is stored in gas portion which is an integral part of plant, between dome and digester. Where the usable gas is stored, the heights of the gas portion is above the inlet and out let openings to the beginning of dome, and is equal to maximum volume of the gas to be stored(30-40) (Percent of plant Capacity) and equal to volume of slurry to be displaced in inlet and outlet.

Dome is constructed over the gas portion, with volume of 60 percent of the plant capacity. It must be constructed very carefully integrated it with digester and gas portion so that no leakage of gas can take place. The gas out let pipe is fixed at the top of dome for laying the line.

Inlet and outlet portions are constructed for putting the fresh slurry in side the plant and to take the digested slurry out. The inlet and outlet are of larger sizes. Provided on each side of the digester, facing each other. The opening to the digester for feeding the waste material and effluent out let from it are also of large sizes. The discharge of slurry out of the plant is due to pressure of the gas in the plant. Over the inlet portion an inlet Mixing tank is also constructed to mix the dung and water.

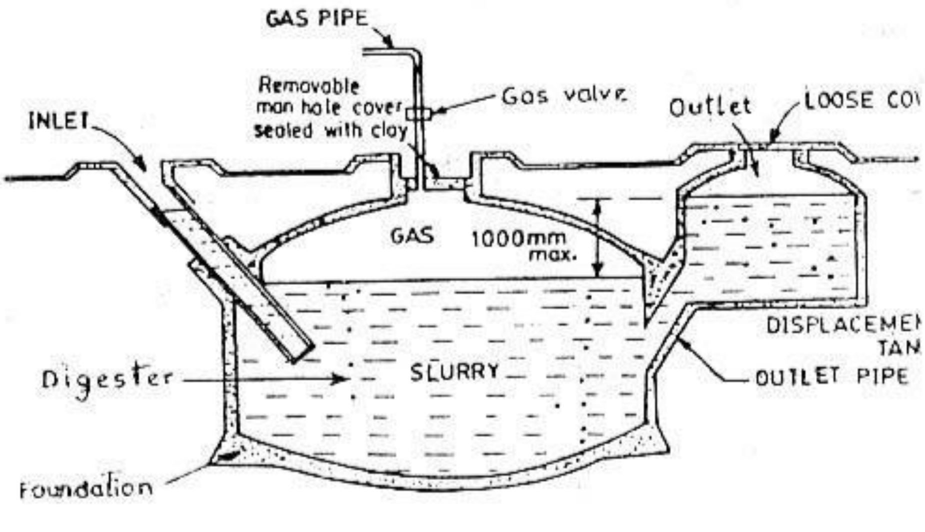


Fig 4.6 Jnanatha Bio gas Plant

4.10.3 Deenbandhu Bio Gas Plant

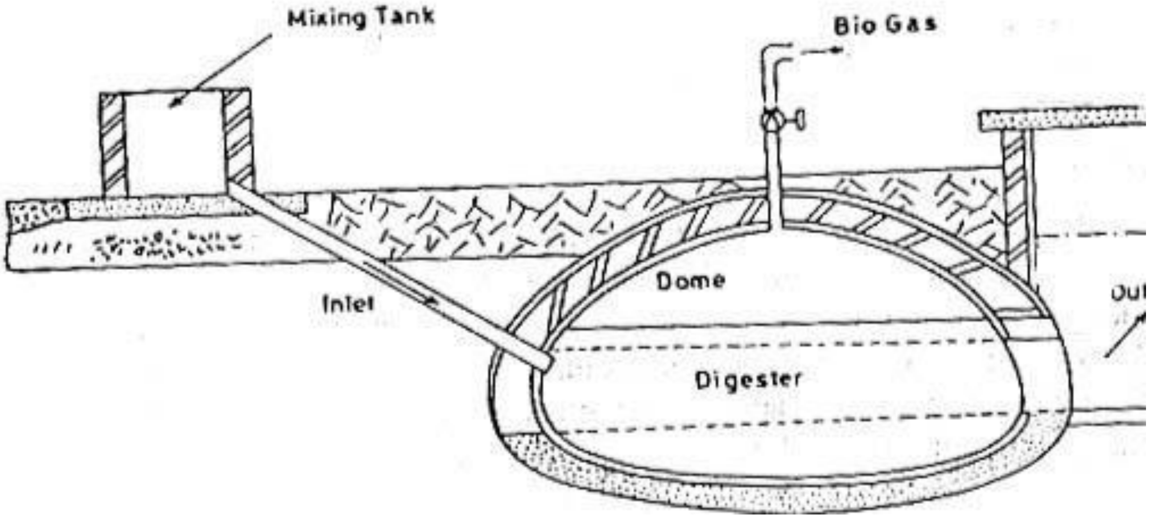


Fig 4.7 Deenbandhu Bio gas Plant

This is also a fixed dome plant development by action for food production, New Delhi, which is a allow cost bio gas plant. The principle of working of this plant is same as that of Janata model, except configuration of inlet entrance and digester.

The foundation of the plant is constructed in the segment of spherical shape as shown fig4.7 on the outer periphery of this foundation the dome shaped digester is constructed with same base diameter. In this way the digester, gas portion and dome look as a single unit. The surface area of bio gas plant is reduced with same digester volume, reducing the earth work and cost of construction without sacrificing the efficiency. The higher compressive strength of the brick masonry and concrete makes it a safe structure as the plant is always under compression. A spherical, Structure loaded from the convex side will be under compression and therefore, the internal load will not have any residual effect on the structure.

At the top of the foundation a window opening is kept (outlet portion) for the out ward movement of the digested slurry. The asbestos cement pipe of 15 cm diameter is used for inlet instead of separate opening. The pipe is embedded in the digester wall at a fixed position, just opposite to out let opening, to avoid short circuiting of fresh material and digested slurry.

The volume of the out let is increased to produce requisite gas pressure through the weight of the displaced slurry. At the top of the dome a gas outlet pipe is fixed as in case of Janata plant.