E-LEARNING MATERIAL

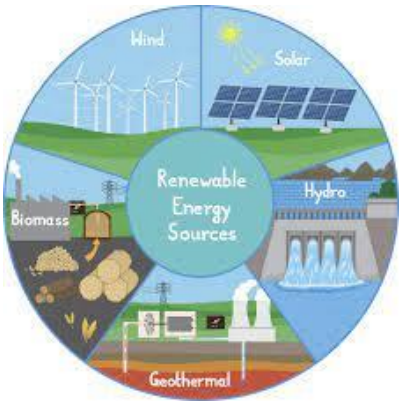
ON

RENEWABLE ENERGY SYSTEM (TH.4 (B))

OF 6TH SEMESTER

For

DIPLOMA IN ELECTRICAL ENGINEERING COURSE



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CHAPTER 1

INTRODUCTION OF RENEWABLE ENERGY

I. ENVIRONMENTAL CONSEQUENCES OF FOSSIL FUEL USE.

- Burning fossil fuels emits a no. of air pollutants that harmful to both the environment and public health.
- Burning any fossil fuel, produces CO_2, which contribute to the greenhouse effect warming the earth.
- Burning coal produced more CO_2 than burning Oil or gas.
- It also production SO_2, a gas that contributes to acid rain.
- Fossil fuels cause environmentally unsafe compounds to form in the atmospheres depleting Ozone level and thus creating skin cancer.
- Fossil fuels produces large quantities of CO_2 when burned carbon emissions of CO_2 when burned. Carbon emissions trap heat in the atmosphere and load to climate change.
- When fossil fuels are burned by power plants, automobiles and industries, they generate toxic gases which are very dangerous to environment.
- (Fossil fuel: Coal, Petroleum, Natural gas, Oil etc.)

II. IMPORTANCE OF RENEWABLE SOURCE OF ENERGY

- Renewable energy can play an important role in reducing green house gas emissions.
- Using renewable energy can reduce the use of fossil fuels, which are the largest sources of CO_2 emissions.
- Renewable resources also produce clean energy, less pollution and green house gas emissions which leads to climate change.
- Hydropower is the most widely used renewable power source.
- The main benefit of renewable energy are:
    - Generating energy that produces no green house gas emissions and reduces air pollution.
    - Diversifying energy supply and reducing dependence of imported fuels.
    - Creating economic development and jobs in manufacturing installation etc.

- Eg: Renewable source are- Solar, Hydro, Geothermal, Tidal etc.

III. TYPES OF ENERGY RESOURCES

1. BASED ON USABILITY OF ENERGY

a. PRIMARY RESOURECES – These are resources embodied in nature prior to undergoing any human made conversions.
Ex- Coal, Wind, Crude Oil, Uranium etc.

b. SECONDARY RESOURCES- The form of energy which is finally supplied to a consumer for utilization is known as secondary resources.
Ex- Electrical Energy, Thermal Energy, Chemical Energy etc.

2. BASED ON TRADITIONAL USE

a. CONVENTIONAL ENERGY RESOURCES- These are being traditionally used for many decades are called conventional resources.
Ex- Fossil Fuels, Nuclear, Hydro Resources, etc.

b. NONCONVENTIONAL RESOURCES- These are considered for large scale use after oil crisis are called nonconventional resources.
Ex- Solar, Wind, Biomass, etc.

3. BASED ON LONG TERM AVAILABILITY

a. NON RENEWABLE RESOURCES- These are finite and don't get replenished after their consumption are called nonrenewable resources.
Ex- Fossil fuels, Uranium, etc.

b. RENEWABLE RESOURCES- These are renewed by nature again and again and their supply is not affected by the rate of their consumption are called Renewable resources.
Ex- Solar, Wind, Biomass, Ocean, Hydro, Geothermal, etc.

4. BASED ON ORIGIN

a. Fossil fuel energy
b. Nuclear energy
c. Hydro energy
d. Solar energy
e. Wind energy
f. Biomass energy
g. Geothermal energy
h. Tidal energy
i. Ocean thermal energy
j. Ocean wave energy

IV. LIMITATIONS OF RESOURCES (CONVENTIONAL)

1. The demand of energy is increasing and bounds due to rapid industrialization and population growth and hence conventional sources of energy will not be sufficient to meet the growing need.
2. Conventional sources are non-renewable and are bound to finish up one day.
3. Conventional sources also cause pollution so their use degrades the environment.
4. Large hydro resources affect wildlife, cause deforestation and pose various social problems.

V. SUSTAINABLE DESIGN AND DEVELOPMENT

- Achieving solutions to environmental problems that we face today requires long term potential actions for sustainable development.
- In this regard, renewable energy resources appear to be the one of the most efficient and effective solution.
- That is why there is an intimate connection between renewable energy and sustainable development.
- In the next few decades fossil fuels will continue to be the principal source of energy driving economic development.
- There are three conditions for sustainability: -

1) The consumption rate of renewable resources is not higher that its recovery rate.
2) The consumption rate of nonrenewable resources is not higher than the rate of increase in the renewable resources supply.
3) The emission of pollutants is within the absorption capacity of the environment.

❖ A substantial reduction in resource consumption and emissions of pollutants is essential for the development of a sustainable human society.

VI. PRESENT INDIA AND INTERNATIONAL ENERGY SCENARIO OF CONVENTIONAL AND RESOURCES

- In India most of the power generation is carried out by conventional energy sources, coal and mineral oil based power plants which contribute heavily to greenhouse gases emissions.
- Setting up of new power plants is inevitably dependent on import of highly fossil fuels.
- Thus it is essential to tackle the energy crisis through utilization of abundant the renewable energy sources, such as biomass energy, solar energy, wind energy, geothermal energy, and ocean energy.
- India has obtained application of a variety of renewable energy technologies for use in different sectors too.
- At present the annual primary energy consumption of the world is 500exajoules (138.8×10^{12}Kwh).
- Fossil fuels provide about 90% of this energy.
  Approximately 25% of this energy is consumed in transportation sector and the remaining 75% by industries, domestic, agriculture and social consumers.
- The energy demand has grown astronomically in recent years.

EXERCISE

1) **What are conventional and non-conventional energy sources?**
2) **Discuss the main features of various types of renewable and non-renewable energy sources?**
3) **What are the environmental consequences of fossil fuel use?**
4) **What is meant by sustainable design and development?**
5) **What are the advantages and disadvantages of conventional energy sources?**
6) **Explain the types of resources and its limitations?**
7) **What is the present Indian and international energy scenario of conventional and resources?**

CHAPTER-2

SOLAR ENERGY

Solar energy: -

- Solar energy is the energy received by the earth from the sun.
- Solar energy is in the form of solar radiation, which makes the production of solar electricity.

Types of Solar Energy:-

- Passive Solar Energy
- Active Solar Energy
- Photovoltaic Solar Power
- Solar Thermal Energy
- Concentrated Solar Power

Passive Solar Energy:-

- Passive Solar Energy is a method in which solar energy is harnessed in its direct form without using any mechanical devices.
- Drying Clothes in daylight is an example of using solar energy passively.

Active Solar Energy:-

- Active Solar Energy employs mechanical or electrical equipment for functioning and increase system efficiency.
- For example water pumps are used to circulate water through the active solar energy water heating system.

Solar thermal Energy:-

- Solar Thermal Energy is the heat energy derived from incident solar energy (sunlight). This energy is used by the Solar Heating Panels.
- Electricity generated using solar energy commonly known as Solar Thermal Electricity.

Photovoltaic Energy:-

- Photovoltaic cells/ solar cells convert solar energy into electric energy. The energy generated is termed as Photovoltaic energy.

Concentrated Solar Energy:-

- Concentrated Solar Power is a branch of Solar Thermal Energy which is used to generate solar power electricity.
- Electricity is produced on a large scale by using this technology.

Advantages Of Solar Energy:-

- It's a renewable resource.
- It's eco-friendly.
- Reduces Electricity Bills.
- Can enhance the value of a home.

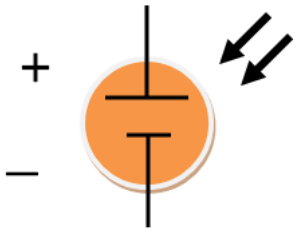
- Requires little maintenance.
- Easy Installation.
- Can Be Used in Remote Locations.

Disadvantages Of Solar Energy:-

- Solar Energy Storage is Expensive.
- Weather Dependent.
- Solar Energy is not always Reliable.

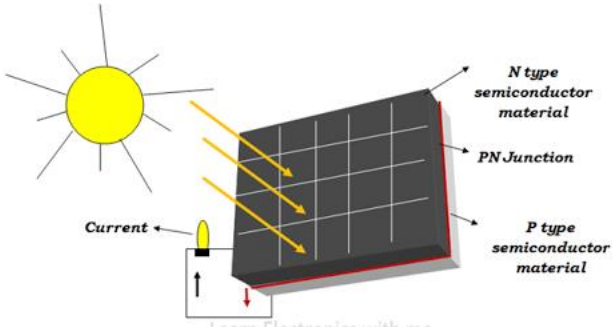
Solar Photovoltaic:-

This is a device which converts light energy into electrical energy by using photovoltaic effect. Solar cell is basically a normal PN Junction diode.

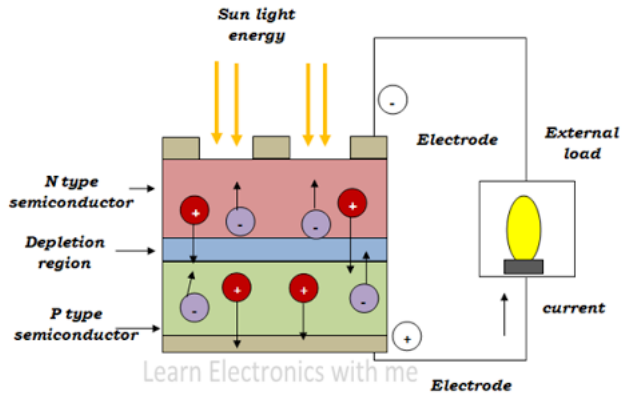


Construction of Solar Photovoltaic Cell:-

It consists of N type and P type semiconductor material. N type is highly doped and P type is lightly doped. Top and bottom is of conducting electrode to collect the current. The bottom is fully covered with the conductive layer and top layer is not fully covered because the sun rays should not be fully blocked. Since semiconductors are reflective in nature, antireflective coating is used. The whole arrangement is kept inside a thin glass to avoid mechanical shock.

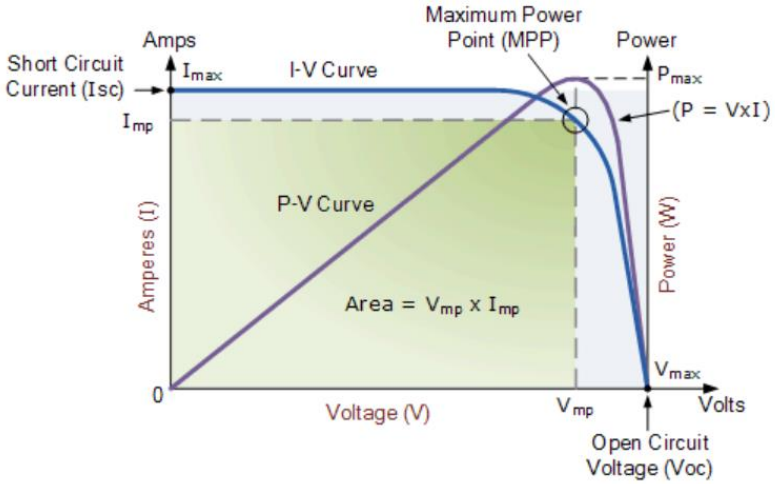


Operation of Solar Photovoltaic Cell:-



- The working of photovoltaic cell is based on photovoltaic effect. It is an effect in which current or voltage is generated when exposed to light. Through this effect solar cells convert sunlight into electrical energy.
- A depletion layer is formed at the junction of the N type and P type semiconductor material.
- When light energy of the sun rays falls on the solar panel, the photons which is the small bundle of energy whose energy is higher than the energy gap gives energy to the electrons and holes in the depletion region.
- The electrons and holes move to the higher level which is the conduction band. The electrons move towards N type and holes move towards P type and they act as a battery. So this movement of electrons and holes forms the electric current.

V-I Characteristics of Photovoltaic Cell:-



- The above graph shows the current-voltage (I-V) characteristics of a typical silicon PV cell operating under normal conditions. The power delivered by a single solar cell or panel is the product of its output current and voltage (I x V).
- With the solar cell open-circuited, that is not connected to any load, the current will be at its minimum (zero) and the voltage across the cell is at its maximum, known as the solar cells open circuit voltage, or Voc. At the other extreme, when the solar cell is short circuited, that is the positive and negative leads connected together, the voltage across the cell is at its minimum (zero) but the current flowing out of the cell reaches its maximum, known as the solar cells short circuit current, or Isc.
- Then the span of the solar cell I-V characteristics curve ranges from the short circuit current (Isc) at zero output volts, to zero current at the full open circuit voltage (Voc). In other words, the maximum voltage available from a cell is at open circuit, and the maximum current at closed circuit. Of course, neither of these two conditions generates any electrical

power, but there must be a point somewhere in between were the solar cell generates maximum power.

- However, there is one particular combination of current and voltage for which the power reaches its maximum value, at Imp and Vmp. In other words, the point at which the cell generates maximum electrical power and this is shown at the top right area of the green rectangle. This is the "maximum power point" or MPP. Therefore the ideal operation of a photovoltaic cell (or panel) is defined to be at the maximum power point.
- The maximum power point (MPP) of a solar cell is positioned near the bend in the I-V characteristics curve.

Cell:-

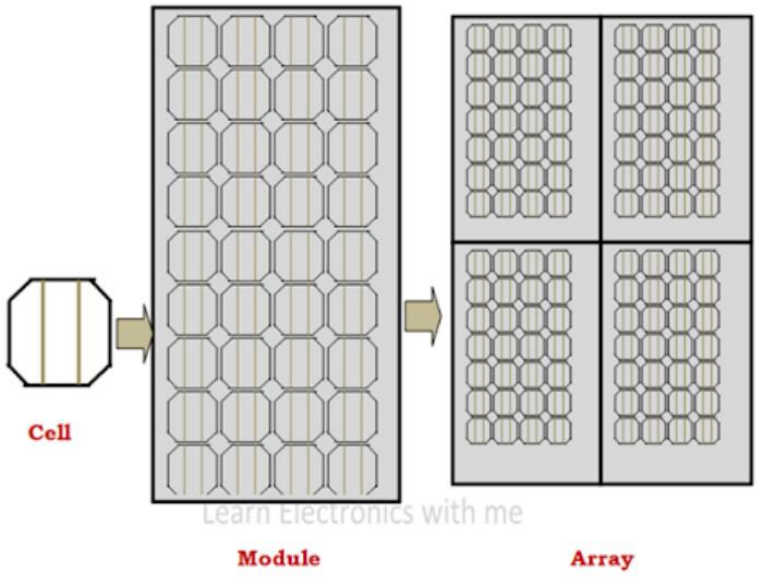
Solar cell is the basic building module and it is in octagonal shape and in bluish black color.

Module:-

Each cell produces 0.5 voltage. 36 to 60 solar cells in 9 to 10 rows of solar cells are joined together to form a solar module. For commercial use upto 72 cells are connected. By increasing the number of cells the wattage and voltage can be increased. The thickness of solar panel is in the range 2.5 to 4cm.

Array:-

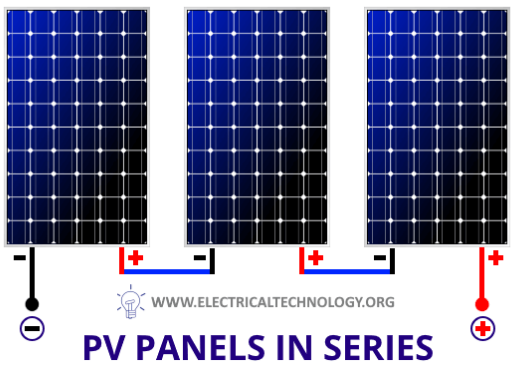
Many modules together form the solar array.

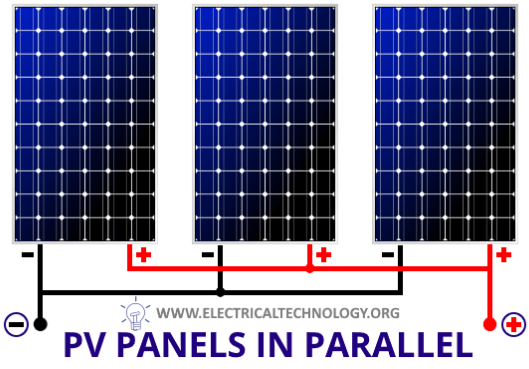


Series and Parallel Connection:-

The modules are connected in series to increase the voltage in the system. The current in the parallel combination of the PV modules array is the sum of individual currents of the modules.

Series Connection of Modules | **Parallel Connection of Modules**





Solar Radiation:

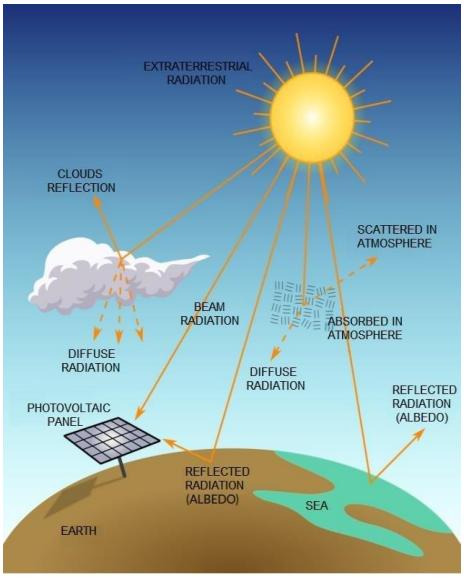
- Solar radiation is the electromagnetic energy emitted from the sun.
- Depending upon the nature of the surface, the radiation will be absorbed, reflected or transmitted through the object. This take place when solar radiation strikes any object.

Extraterrestrial Radiation:

- The extraterrestrial radiation is the radiation which is incident outside the earth's surface.
- The extraterrestrial radiation is 1367 watts/m^2.
- Due to the change in distance between earth and sun, there is a seasonal variation in the extraterrestrial rate.

Terrestrial Solar Radiation:

- It is the electromagnetic radiation which originates from earth and its atmosphere.
- Terrestrial Radiation is a longer wavelength which is totally infrared.
- When the terrestrial solar radiation reaches the earth's surface,it is broken into two components i.e.,diffuse radiation and beam radiation.
- Beam Radiation is the solar radiation which moves through the atmosphere in a straight line without being scattered, reflected or absorbed by particles in the air.
- Diffuse Radiation is the solar radiation which is being scattered, reflected or absorbed by the particles while passing through the atmosphere but ultimately reaches the earth's surface.

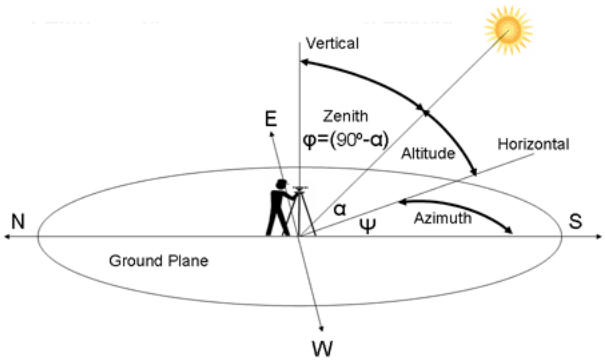


Azimuth Angle:-

Solar azimuth angle is defined as the angle between the projection of sun's centre onto the horizontal plane and due south direction.

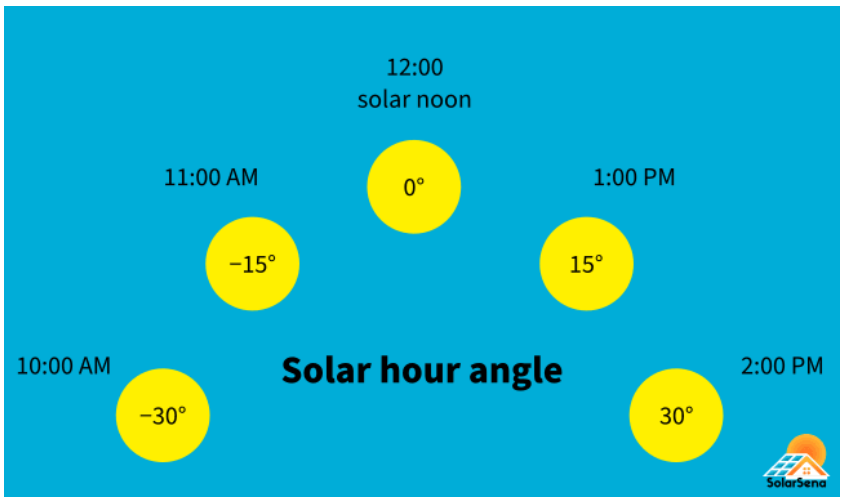
Zenith Angle:-

The solar zenith angle is the angle between the sun's rays and the vertical direction.



Hour Angle:-

It is the angle representing the position of sun with respect to clock hour and with reference to sun's position at 12 noon.



Irradiance:-

Irradiance is a measurement of solar power and is defined as the rate at which solar energy falls onto a surface. The unit of power is the Watt (abbreviated W). In the case of solar irradiance, we usually measure the power per unit area, so irradiance is typically quoted as W/m^2, that is, Watts per square meter.

Solar Constant:-

The total radiation energy received from the Sun per unit of time per unit of area on a theoretical surface perpendicular to the Sun's rays and at Earth's mean distance from the Sun. It is most accurately measured from satellites where atmospheric effects are absent. The value of the constant is approximately 1.366 kilowatts per square metre.

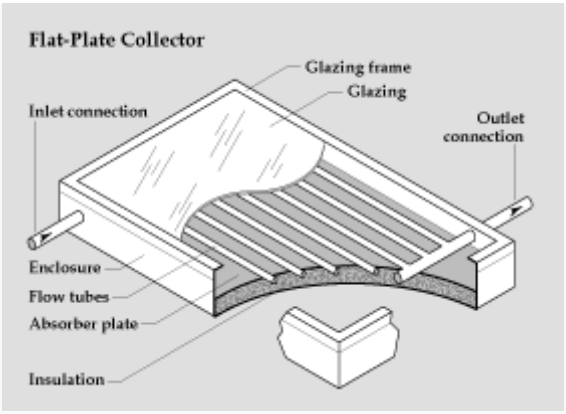
SOLAR COLLECTORS

A solar collector is a device that collects and/or concentrates solar radiation from the Sun. These devices are primarily used for active solar heating and allow for the heating of water for personal use.

TYPES OF SOLAR COLLECTORS:-

- There are many different types of solar collectors, but all of them are constructed with the same basic premise in mind.
- In general, there is some material that is used to collect and focus energy from the Sun and use it to heat water.
- The simplest of these devices uses a black material surrounding pipes that water flows through.
- The black material absorbs the solar radiation very well, and as the material heats up the water it surrounds.
- This is a very simple design, but collectors can get very complex.
- Absorber plates can be used if a high temperature increase isn't necessary, but generally devices that use reflective materials to focus sunlight result in a greater temperature increase.

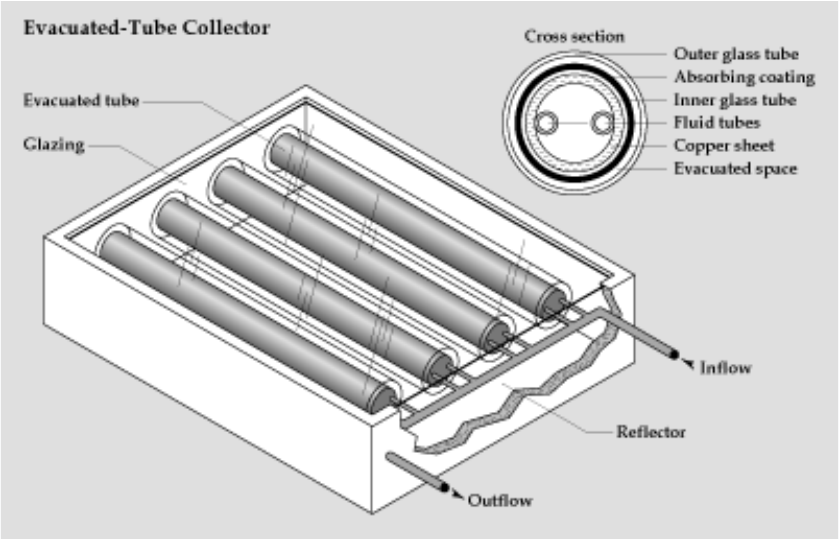
1. Flat Plate Collectors



- These collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a dark-coloured absorber plate.
- The sides and bottom of the collector are usually covered with insulation to minimize heat losses to other parts of the collector.
- Solar radiation passes through the transparent glazing material and hits the absorber plate.

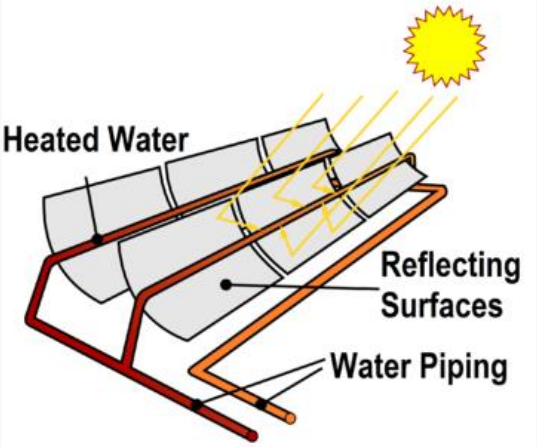
- This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate.
- Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than traditional black paint.
- These plates are usually made out of metal that is a good conductor - usually copper or aluminium.

2. Evacuated Tube Collectors



- This type of solar collector uses a series of evacuated tubes to heat water for use.
- These tubes utilize a vacuum, or evacuated space, to capture the suns energy while minimizing the loss of heat to the surroundings.
- They have an inner metal tube which acts as the absorber plate, which is connected to a heat pipe to carry the heat collected from the Sun to the water.
- This heat pipe is essentially a pipe where the fluid contents are under a very particular pressure.
- At this pressure, the "hot" end of the pipe has boiling liquid in it while the "cold" end has condensing vapour.
- This allows for thermal energy to move more efficiently from one end of the pipe to the other.
- Once the heat from the Sun moves from the hot end of the heat pipe to the condensing end, the thermal energy is transported into the water being heated for use.

3. Line Focus Collectors



- These collectors, sometimes known as parabolic troughs, use highly reflective materials to collect and concentrate the heat energy from solar radiation.
- These collectors are composed of parabolically shaped reflective sections connected into a long trough.
- A pipe that carries water is placed in the center of this trough so that sunlight collected by the reflective material is focused onto the pipe, heating the contents.
- These are very high powered collectors and are thus generally used to generate steam for Solar thermal power plants and are not used in residential applications.
- These troughs can be extremely effective in generating heat from the Sun, particularly those that can pivot, tracking the Sun in the sky to ensure maximum sunlight collection

4. Point Focus Collectors

- These collectors are large parabolic dishes composed of some reflective material that focus the Sun's energy onto a single point.

- The heat from these collectors is generally used for driving Stirling engines.
- Although very effective at collecting sunlight, they must actively track the Sun across the sky to be of any value.
- These dishes can work alone or be combined into an array to gather even more energy from the Sun Point focus collectors and similar apparatuses can also be utilized to concentrate solar energy for use with Concentrated photovoltaics.
- In this case, instead of producing heat, the Sun's energy is converted directly into electricity with high efficiency photovoltaic cells designed specifically to harness concentrated solar energy.

PERFORMANCE CHARACTERISTICS

- The thermal characteristics of the solar collector showed that the temperature of working fluid varied from 16.4˚C to 21.9˚C.
- The performance characteristics of the same solar air heating collector showed that the thermal performance of the same solar air heating collector showed that the thermal performance of solar air heating collector could satisfy the standard specification.
- Flat plate collector performance characteristics
  - **It uses air or water as working fluid.**
  - **Temperature upto 70˚C are easily attained by flat plate collector.**
  - **It is the most easiest and more economical to design, fabricate, setup and maintain.**
  - **Performance is estimated using 40% propylene glycol water instead of conventional fluids like water as working fluid.**

Performance and efficiency of solar collectors depends upon various factors like collectors depends upon various factors like collectors, and receiver materials, solar radiation intensity, nature of working fluid, etc.

- Evacuated flat plate collector performance characteristics
  - Such collectors can achieve high operational temperatures suitable for many industrial application.
  - It also operates efficiency in low irradiance conditions.
- Line focus collector performance characteristics

- These are simple in design and are easy to operate with single axis tracking.
- This includes parameters for solar collector field design, receiver , heat transfer fluid, thermal energy saturate and configuration of the plant etc.

➢ Point focus collector performance characteristics
- Concentrating solar technologies is particular point focusing system offers many benefits of higher efficiency in smaller collector area.
- A point focus solar collector converts directly into electricity with high efficiency photovoltaic cells designed specifically to harness concentrated solar energy.

APPLICATIONS: PHOTOVOLTAIC - BATTERY CHARGER, DOMESTIC LIGHTING, STREET LIGHTING, WATER PUMPING, SOLAR COOKER, SOLAR POND.

❖ **The application of solar energy is**

1. Heating and cooling residential buildings
2. Solar water heating
3. Solar drying of agricultural and chemical products.
4. Solar distillation of a small community scale
5. Salt production by evaporation of sea water
6. Solar cookers
7. Solar engines for water pumping
8. Food refrigeration
9. Bio conversion and wind energy and which are indirect source of solar energy
10. Solar furnaces
11. Solar electric power generation by i) Solar ponds ii) Steam generators heated by rotating reflectors iii) reflectors with lenses and pipes for fluid circulation
12. solar photovoltaic cells which can be used for conversion of solar energy directly into electricity (or) for water pumping in rural agriculture purposes.

❖ **Solar pond**

♦ A solar pond is a pool of saltwater which collects and stores solar thermal energy.

- The saltwater naturally forms a vertical salinity gradient also known as a "halocline", in which low-salinity water floats on top of high-salinity water.
- The layers of salt solutions increase in concentration (and therefore density) with depth.
- Below a certain depth, the solution has a uniformly high salt concentration.
- Advantages and disadvantages
  - The approach is particularly attractive for rural areas in developing countries. Very large area collectors can be set up for just the cost of the clay or plastic pond liner.
  - The accumulating salt crystals have to be removed and can be a valuable by-product and a maintenance expense.
  - No need for a separate collector.
  - The extremely-large thermal mass means power is generated night and day.
  - Relatively low-temperature operation means solar energy conversion is typically less than 2%.
  - Due to evaporation, non-saline water is constantly required to maintain salinity gradients.

❖ Solar cooker

- A solar cooker is a device which uses the energy of direct sunlight to heat, cook or pasteurize drink and other food materials.
- Many solar cookers currently in use are relatively inexpensive, low-tech devices, although some are as powerful or as expensive as traditional stoves, and advanced, large-scale solar cookers can cook for hundreds of people
- Because they use no fuel and cost nothing to operate, many non-profit organizations are promoting their use worldwide in order to help reduce fuel costs and air pollution, and to help slowdown deforestation and desertification.
- Advantages and Disadvantages
  - **Advantages -**
  - High-performance parabolic solar cookers and vacuum tube cookers can attain temperatures above 290 °C (550 °F). They can be used to grill meats, stir-fry vegetables, make soup, bake bread, and boil water in minutes. Vacuum tube type cookers can heat up even in the clouds and freezing cold.

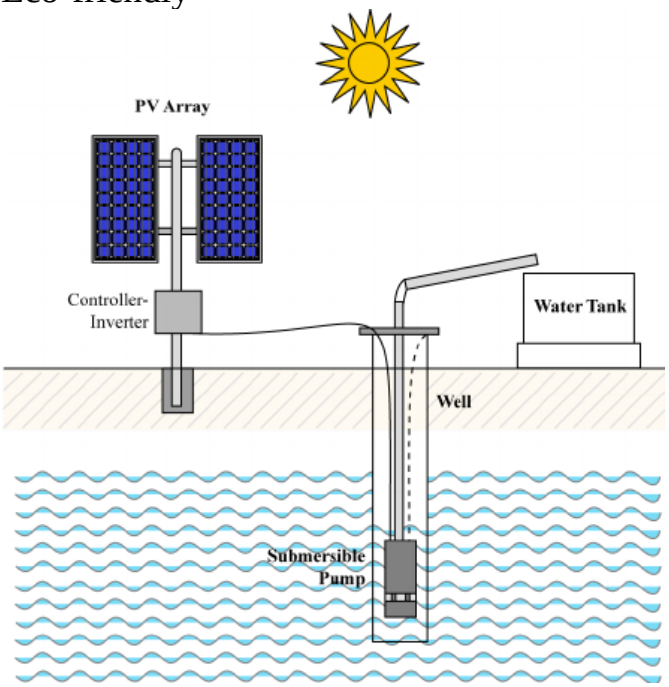
- Conventional solar box cookers attain temperatures up to 165 °C (325 °F). They can sterilize water or prepare most foods that can be made in a conventional oven or stove, including bread, vegetables and meat over a period of hours.
- Solar cookers use no fuel. This saves cost as well as reducing environmental damage caused by fuel use. Since 2.5 billion people cook on open fires using biomass fuels, solar cookers could have large economic and environmental benefits by reducing deforestation.
- When solar cookers are used outside, they do not contribute inside heat, potentially saving fuel costs for cooling as well. Any type of cooking may evaporate grease, oil, and other material into the air, hence there may be less cleanup.
- Reduces your carbon footprint by cooking without the use of carbon based fuels or grid electricity from traditional sources.

- **Disadvantages**
  - Solar cookers are less useful at night, in cloudy weather and near the poles, where the sun is low in the sky, so an alternative cooking source is still required in these conditions.
  - Solar cooking advocates suggest three devices for an integrated cooking solution: a) a solar cooker; b) a fuel-efficient cookstove; c) an insulated storage container such as a basket filled with straw to store heated food. Very hot food may continue to cook for hours in a well-insulated container. With this three-part solution, fuel use is minimized while still providing hot meals at any hour, reliably.
  - Some solar cookers, especially solar ovens, take longer to cook food than a conventional stove or oven. Using solar cookers may require food preparation start hours before the meal. However, it requires less hands-on time during the cooking, so this is often considered a reasonable trade-off.
  - Cooks may need to learn special cooking techniques to fry common foods, such as fried eggs or flatbreads like chapatis and tortillas. It may not be possible to safely or completely cook some thick foods, such as large roasts, loaves of bread, or pots of soup, particularly in small panel cookers; the cook may need to divide these into smaller portions before cooking.

- Some solar cooker designs are affected by strong winds, which can slow the cooking process, cool the food due to convective losses, and disturb the reflector. It may be necessary to anchor the reflector, such as with string and weighted objects like bricks.

❖ Water pump

- The system operates on power generated using solar PV (photovoltaic) system. The photovoltaic array converts the solar energy into electricity, which is used for running the motor pump set.
- The pumping system draws water from the open well, bore well, stream, pond, canal etc. The system requires a shadow-free area for installation of the Solar panel.
- A system with 1800 watt PV array capacity and 2 HP pump can give a water discharge of 1.4 lakh litres per day from a depth of 6 to 7 meters. This quantity of water is considered adequate for irrigating about 5-8 acres of land holding for several crops.
- Advantages
  - No fuel cost - as it uses available free sun light
  - No electricity required
  - Long operating life
  - Highly reliable and durable
  - Easy to operate and maintain
  - Eco-friendly



❖ Street light

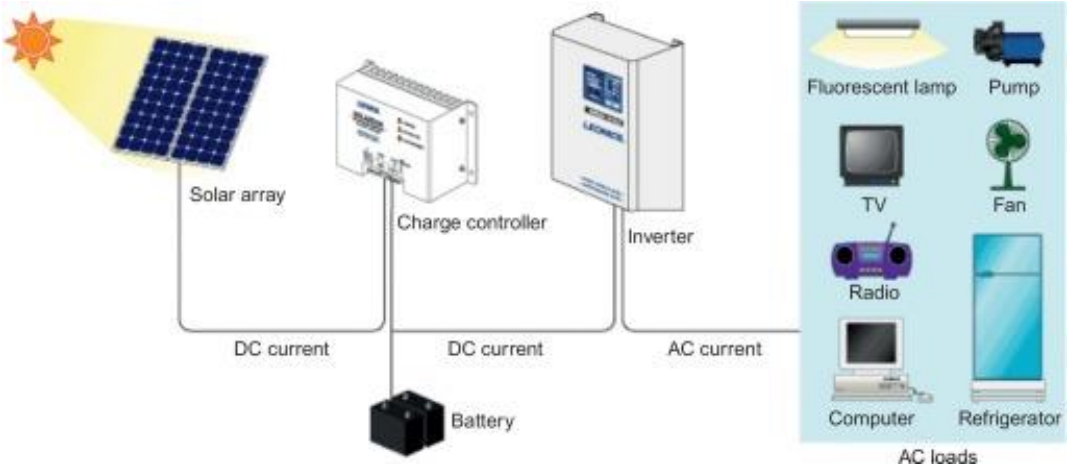
- Solar street lights are raised light sources which are powered by solar panels generally mounted on the lighting structure or integrated into the pole itself. The solar panels charge a rechargeable battery, which powers a fluorescent or LED lamp during the night.
- Most solar lights turn on and turn off automatically by sensing outdoor light using solar panel voltage. Solar streetlights are designed to work throughout the night. Many can stay lit for more than one night if the sun is not in the sky for an extended period of time. Older models included lamps that were not fluorescent or LED. Solar lights installed in windy regions are generally equipped with flat panels to better cope with the winds.
- Modern designs use wireless technology and fuzzy control theory for battery management. The street lights using this technology can operate as a network with each light having the capability of performing the turning on and off of the network.
- **Advantages**
  - Solar street lights are independent of the utility grid. Hence, the operation costs are minimized.
  - Solar street lights require much less maintenance compared to conventional street lights.
  - Since external wires are eliminated, risk of accidents are minimized.
  - Electricity produced from solar panels is non-pollutive.
  - Separate parts of a solar panel system can easily be transported.
  - Energy costs can be saved.

- **Disadvantages**
  - Initial investment is higher compared to conventional street lights.
  - Risk of theft is higher as equipment costs are comparatively higher.
  - Snow or dust, combined with moisture can accumulate on horizontal PV-panels and reduce or even stop energy production.

- Rechargeable batteries will need to be replaced several times over the lifetime of the fixtures adding to the total lifetime cost of the light.
- The charge and discharge cycles of the battery are also very important considering the overall cost of the project.

❖ Domestic lighting

- A solar lamp also known as solar light or solar lantern, is a lighting system composed of a LED lamp, solar panels, battery, charge controller and there may also be an inverter. The lamp operates on electricity from batteries, charged through the use of solar panel (solar photovoltaic panel)
- Solar-powered household lighting can replace other light sources like candles or kerosene lamps. Solar lamps have a lower operating cost than kerosene lamps because renewable energy from the sun is free, unlike fuel. In addition, solar lamps produce no indoor air pollution unlike kerosene lamps. However, solar lamps generally have a higher initial cost, and are weather dependent.
- Solar lamps for use in rural situations often have the capability of providing a supply of electricity for other devices, such as for charging cell phones. American investors have been working towards developing a RS. 10 / unit solar lantern for replacement of kerosene lamps.



❖ Solar charger

- A solar powered battery charger is presented, where a photovoltaic (PV) panel is used to convert solar power into electricity and a DC/DC converts is used to control the pv panel and the changing current for the battery.
- The solar charger adapts the output from the solar panels to the battery system.
- The built-in maximum power tracker control ensures that the maximum solar power available is processed in the battery system.
- Advantages –
  - Low electricity bills
  - Low contribution to pollution
  - Unlimited supply of solar batteries
  - Free source of power
- Disadvantages
  - High cost
  - Increased maintenance
  - Uses a lot of space.

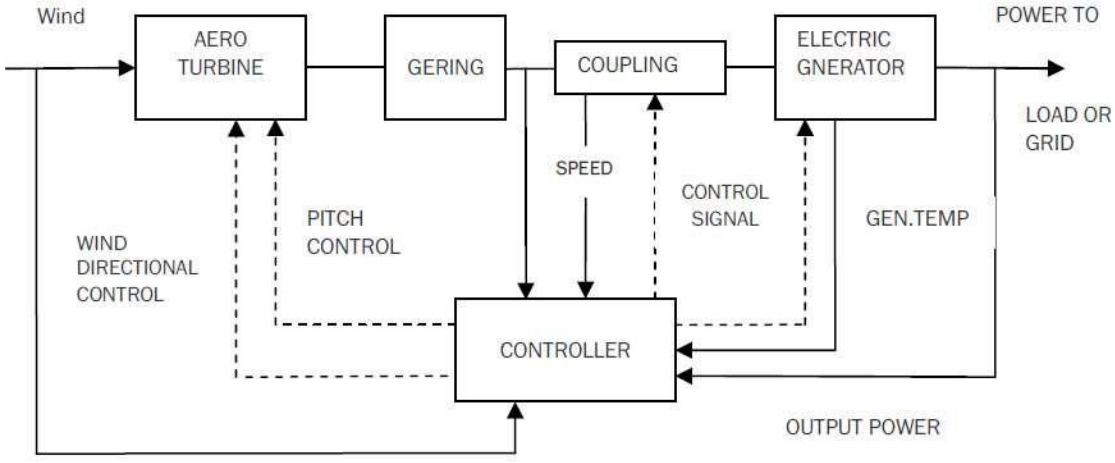
CHAPTER-3

WIND ENERGY

Introduction to Wind Energy:-

- Wind is simply defined as moving air. When the earth heats up from sunrays it releases wind, this is a balanced reaction meant to cool the earth. The sun heat is felt more on dry land than on the sea. The air expands and easily reaches maximum high altitudes, then cool air drops down and moves as wind.
- The wind turbine captures the wind's kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture. Numerous wind turbines are installed at one site to build a wind farm of the desired power generation capacity. Obviously, sites with steady high wind produce more energy over the year.

Wind Energy Conversion System: A wind energy conversion system is an apparatus for converting the kinetic energy available in the wind to mechanical energy that can be used to power machinery (grain mills, water pumps, etc) and/or to operate an electrical generator.



The components of Wind Energy Conversion System:-

- Aero turbine – convert energy in moving air to rotary mechanical energy.
- Gearing and Coupling – transmits the rotary mechanical energy into electrical generator.
- Controller – sense the wind speed, wind direction shafts speeds and torque at one or more points.

WIND TURBINE TYPES AND THEIR CONSTRUCTION:-

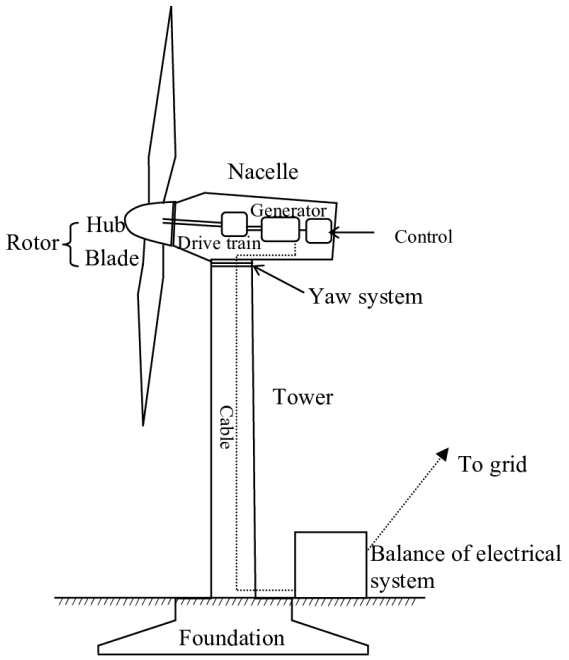
Wind turbines are broadly classified into two categories:

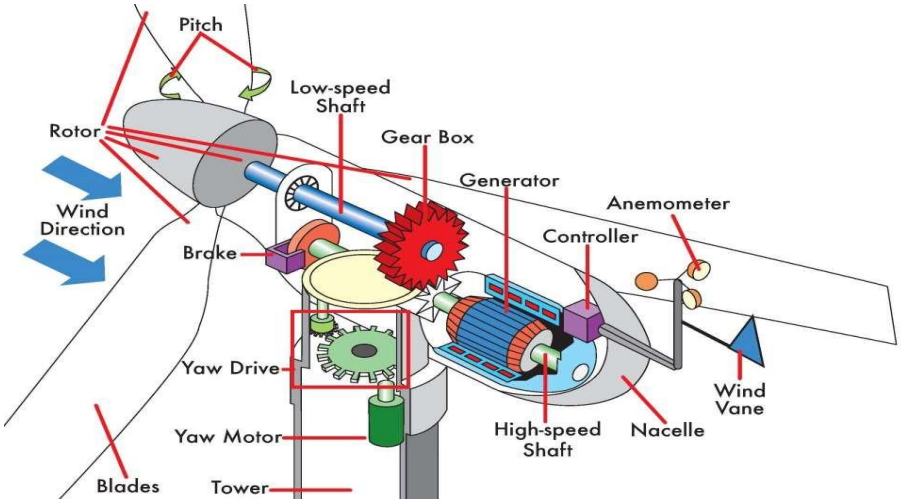
- When the axis of rotation is parallel to the air stream (i.e. Horizontal), the turbine is said to be a horizontal axis wind turbine (HAWT).
- And when it is perpendicular to the stream (i.e. Vertical), it is said to be a vertical axis wind turbine (VAWT).

The size of the rotor and it's speed depends on rating of the turbine.

HORIZONTAL AXIS WIND TURBINE (HAWT)

HAWT have emerged as the most successful type of turbines. These are being used for commercial energy generation in many parts of the world. Their theoretical basis is well researched and sufficient field experience is available with them.





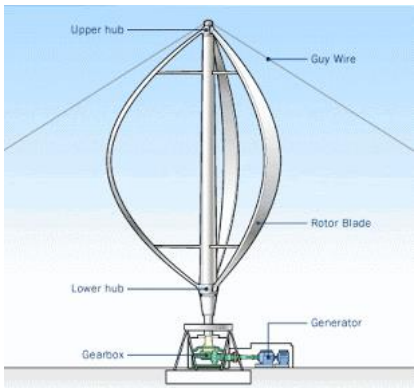
- Foundation: A very good foundation is required to support the tower and various parts of a wind turbine which weighs in tonnes.

- Tower: A tower that supports the nacelle and rotor hub at its top. These are made from tubular steel, concrete, or steel lattice. Height of the tower is an important in design of HWAT. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity. Generally output power of the wind system increase with increase in height and also reduces the turbulence in wind.
- Blades: Wind turbine blades are used to extract the kinetic energy of wind and convert to mechanical energy. These blades are made up of fiber glass-reinforced polyester or wood-epoxy. Wind turbines have one or two or three or multiple blades based up on the construction. Most of the HAWT have three blades. These are connected to rotor hub. Multiple blade concept is used in earlier days for pumping water and grinding etc.
- Nacelle: A housing which contains all the components which is essential to operate the turbine efficiently is called a nacelle. It is fitted at the top of a tower and includes the gear box, low- and high-speed shafts, generator, controller, and brakes. A wind speed anemometer and a wind vane are mounted on the nacelle.
- Hub: A rotor hub is provided for coupling a wind turbine rotor blade and a shaft. The hub assembly consists of hub, bolts, blade bearings, pitch system and internals. Rotor hubs are made with welded sheet steel, cast iron, forged steel.
- Gear box: Gear box used in wind energy systems to change low speed high toque power coming from a rotor blade to high speed low torque power which is used for generator. It is connected in between main shaft and generator shaft to increase rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 to 1800 rpm. Gearboxes used for wind turbine are made from superior quality aluminum alloys, stainless steel, cast iron etc.
- Generator: The output rotational mechanical energy of the gear box is connected to the generator through generator shaft. It works on the principle of 'Faraday's law of electromagnetic induction". It converts mechanical energy into electrical energy.
- Anemometers: Wind speed is the most important factor for determining the power content in the wind. The power content in the wind is directly proportional to cube of the wind velocity. Measuring wind speed is important for site selection. The device which is used for measuring wind speed is called anemometer. These are usually located on top of the nacelle.

- Wind vane: Wind vanes are used to measure the wind directions and communicates with the yaw system to orient the turbine properly with respective to wind directions, to extract maximum amount of power from wind. Wind turbines are oriented to upstream wind or down stream wind.
- Yaw Mechanism: Yaw mechanism turns the rotor into the upwind direction as the wind direction changes. Electric motors and gear boxes are used to keep the turbine yawed against wind. This can be also used as controlling mechanism during high wind speeds.
- Low Speed shaft: It is connected between blade hub and input to the gear box. It rotates at low speeds. So It is also called as 'Main shaft'.
- High Speed shaft: It connects the gear box output to the generator input. It rotates at very high speed equals to the rating of the generator. It is also called 'Generator shaft'.
- Pitch: is the rotational angle of the blades on a wind turbine.

Vertical Axis Wind Turbine(VAWT):

- The turbine starts rotating at 4m/s speed.
- VAWTs are rugged, quiet, Omni-directional.
- VAWT doesn't create as much stress on the support structure.
- It can be installed on chimneys and similar tall structures.
- Popularizing the wind energy for domestic application.
- The generator is mounted on a short tower.
- The blades point upward.



Parts of VAWT:

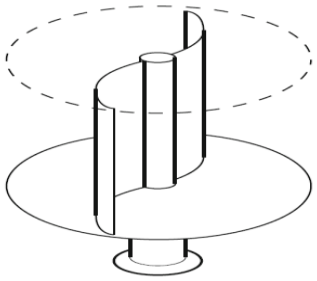
- Guide wire: Vertical axis wind turbine normally needs guide wire to keep the rotor shaft in a fixed position and maximized possible mechanical vibration.
- Hub: The hub is the centre of the rotor to which the rotor blades are attached. Cast iron or cast steel is most often used. In VAWT there are two hibs upper and lower because blades are attached at two points.
- Rotor : The rotor is the heart of a wind turbine and consists of multiple rotor blades attached to a hub. It is the turbine component responsible for collecting the energy present in the wind and transforming this energy into mechanical motion.
- Blades: Rotor blades are a crucial and basic part of a wind turbine. They are mainly made of aluminium, fibber glass or carbon fibber because they provide batter strength to weight ratio. The design of the individual blades also affects the overall design of the rotor. Rotor blades take the energy out of the wind; they “capture” the wind and convert its kinetic energy into the rotation of the hub. There are two types of blades use in VAWT.

(i) Drage force type blades (savonius wind turbine)
(ii) Lift force type blades (Darrieus and giromill wind turbine)

- Shaft : The shaft is the part that gets turned by the turbine blades. It in turn is connected to the generator within the main housing.
- Gear Box: The main function of the gear box is to take low rotational speed from shaft and increase it to increase the rotational speed of the generator.
- Generator: The conversion of rotational mechanical energy to electrical energy is performed by generator. Different types of generator have been used in wind energy system over the years.

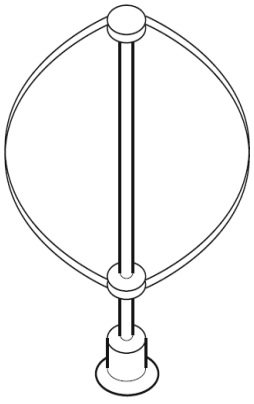
Savonius wind turbine:

- The Savonius rotor is an extremely simple vertical-axis device that works entirely because of the thrust force of wind.
- The basic equipment is a drum cut into two halves vertically.
- The two parts are attached to the two opposite sides of a vertical shaft.
- As the wind blowing into the structure meets with two dissimilar surfaces-one convex and the other concave-the forces exerted on the two surfaces are different, which gives the rotor a torque.



Darrieus wind turbine:

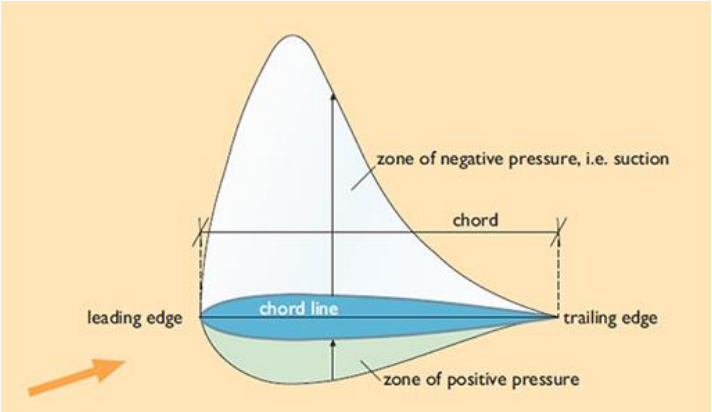
- Darrieus Wind Turbine is commonly known as an "Eggbeater" turbine.
- It was invented by Georges Darrieus in 1931.
- A Darrieus is a high speed, low torque machine suitable for generating alternating current (AC) electricity.
- Darrieus generally require manual push therefore some external power source to start turning as the starting torque is very low.
- Darrieus has two vertically oriented blades revolving around a vertical shaft.



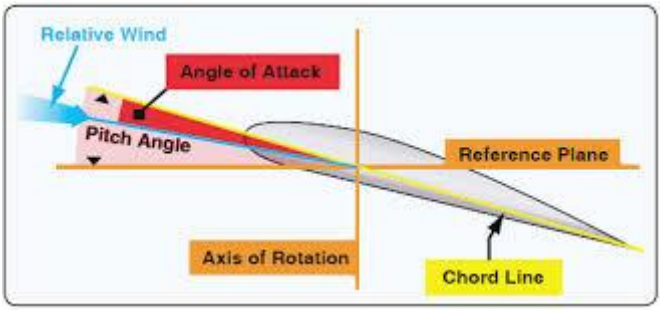
Aerodynamics of wind rotor:

Wind turbine blades are designed according to the aerofoil structure which is commonly used in the design of aeroplane wings. Wind turbine blades are long and slender structures where the span wise velocity component is much lower than the stream wise component, and it is therefore assumed in many

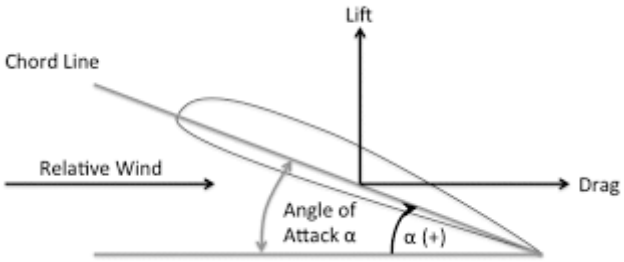
aerodynamic models that the flow at a given radial position is two dimensional and that 2-D aerofoil data can thus be applied.



- Leading edge: This is the point at the front of the aerofoil that has maximum curvature.
- Trailing Edge: This is defined similarly as the point of maximum curvature at the rear of the aerofoil.
- Chord Line: This is a straight line connecting the leading and trailing edges of the aerofoil.
- Chord Length: Chord Length, is the length of the chord line and is the characteristic dimension of the aerofoil section.



- Pitch angle (α): The angle between the chord of the aerofoil section and the plane of rotation, also called as setting angle.

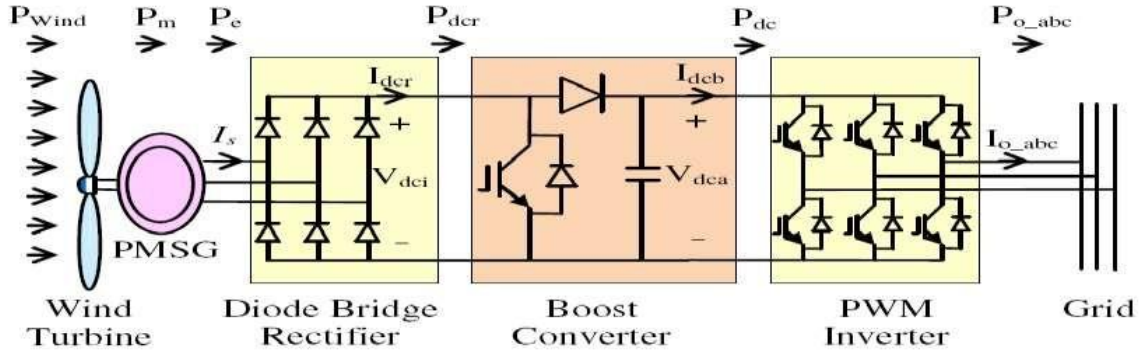


- Lift force: It is the component of aerodynamic force in the direction perpendicular to the relative wind
- Drag force: It is the component of aerodynamic force in the direction of relative wind.
- Total force (F): The total aerodynamic force of a blade is the sum of the lift force and the drag force.

Wind Turbine Generation Scheme:

- Aero turbines convert Wind energy into rotary Mechanical energy.

- The Controller senses the Wind direction, speed, power output of the generator and necessary performance quantities of the system and initiates appropriate control signals to take suitable corrections.
- The Choice of an generator and control method to be employed can be decided by consideration of the following three factors ;
  I. The basis of operation i.e., either constant tip speed or constant tip speed ratio.
  II. The wind-power rating of the turbine,
  III. The type of load demand., e.g. Battery connection
- The electrical control strategy employed for any particular SCHEME can be designed to effect control of the generator, the power transmission link.



- The system is composed of a permanent magnet alternator, rectifier, dc-dc converter and inverter . The voltage generated by the permanent magnet machine is rectified using a three-phase passive rectifier, which converts the AC voltage generated by the PMA to a DC voltage. The DC output voltage is boosted to a higher dc voltage. This dc voltage is then converted to ac voltage using a pulse width modulated (PWM) inverter which is connected to the grid.

Schemes For Electric Generation:

I. Constant speed - Constant frequency systems (CSCF)
II. Variable speed - Constant frequency systems (VSCF)
III. Variable speed - Variable frequency systems (VSVF)

I. Constant speed constant frequency system (CSCF)

It has been used for large generators connected directly to the grid where constant frequency operation is essential.

a.Synchronous Generator

b.Induction Generator

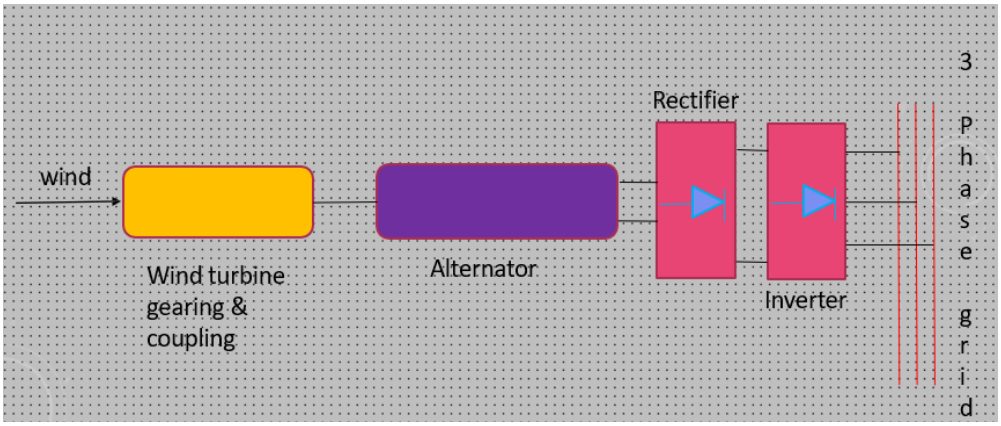
a.Synchronous Generator - For such machines the requirement of constant speed is very rigid and only minor fluctuations about 1% for short durations could be allowed.

b. Induction Generator – If the stator of an induction machine is connected to the power grid and if the rotor is driven above synchronous speed N_s the machine becomes a generator and delivers constant line frequency power to the grid. (*f*=line frequency & *p*=No of poles for which the stator winding is made). The per unit slip is 0 and 0.05, the output power of wind driven induction generator is uniquely determined by the operating speed.

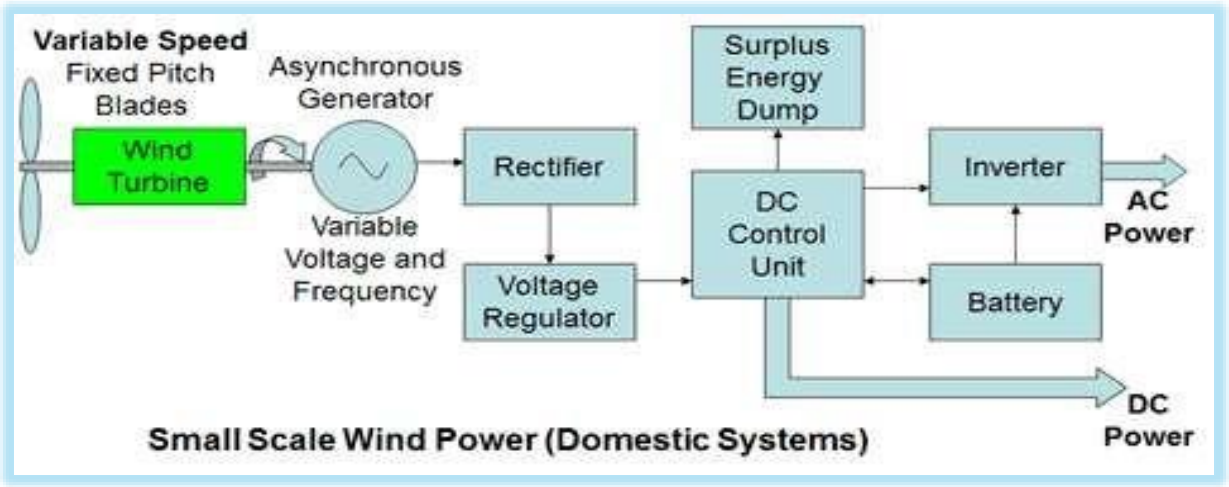
II. **<u>Variable speed - Constant frequency systems (VSCF)</u>**

- It is typical for most small wind generators used in autonomous applications, generally producing variable frequency and variable voltage output.
- The variable speed operation of wind electric system yield higher outputs for both low and high wind speeds. This results in higher annual energy yields per rated installed KW capacity.

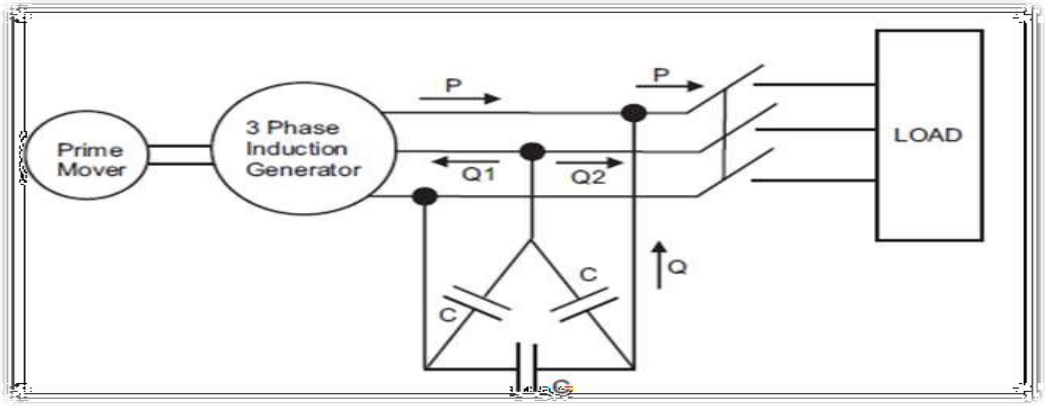
a. AC-DC-AC Link - With the advent of high powered thyristors and high voltage d.c transmission systems, a.c output of the 3 phases alternator is rectified using a bridge rectifier and then converted back to a.c using line commutated inverters. They utilize an a.c source which periodically reverses polarity and causes the commutation to occur naturally.



b. Double Output induction generator – In this system a slip- ring induction motor is used. Rotor power at slip frequency is converted to line frequency power by rectification and inversion output power is obtained both from stator and rotor and hence this device is called double output induction generator.



III. Variable Speed variable frequency (VSVF):



- Since resistive heating loads are essentially frequency insensitive, the a.c generator can be effected at a variable frequency corresponding to the changing derive speed. For this purpose capacitor excited squirrel cage induction machines can be conveniently used.

Characteristics Of Wind Power Plant:

Introduction of wind power generation has been increasing in the world, which has the following characteristics.

- No CO2 emission
- Wind is a safe Energy source existing everywhere.
- There is no need to worry about depletion like fossil fuel.
- Simple equipment used in wind power plant & easy operation.
- Few affection to nature environment.
- Wind turbines operate on a simple principle.
- Wind turbines generate clean electricity for a variety of power needs.

CHAPTER 4

BIOMASS ENERGY

INTRODUCTION :-

- Biomass is biological organic matter derived from living or recently-living organisms.
- Bioenergy is the energy contained (stored) in biomass.
- Biomass is an extremely important energy source, available nearly everywhere.
- Biomass encompasses a large variety of materials, including wood from various sources, agricultural and industrial residues, and animal and human waste.

ENERGY FROM BIOMASS:-

- Bioenergy is the energy retrieved from biomass sources.
- It is the largest used renewable energy resource in the world
- Large bioenergy potential: Biomass resource is widely available and diversified in the Kingdom: Livestock waste, Municipal and Industrial effluents (paper, plastic, food, etc.), Poultry waste, Sewage sludge .
- Bioenergy is a significant mean for waste disposal to prevent environmental pollution and allow economic stability
- Main Technologies: – Biogas based power plant technology
  – Gasification power plant technology
  – Biodiesel and Bioethanol Plants technology

ADVANTAGES OF BIOMASS ENERGY:-

- It is renewable source.
- The energy storage is an in-built feature of it.
- The forestry and agricultural industries that supply feed stocks also provides substantial economic development opportunities in rural areas.
- The pollutants emissions from combustion of biomass are usually lower than those from fossil fuels.
- Commercial use of biomass may avoid or reduce the problems of waste disposal in other industries, particularly municipal solid waste in urban centers.
- Use of biogas plants, apart from supplying clean gas, also leads to improved sanitation; better hygienic conditions in rural areas as the harmful decaying biomass get stabilized.

DISADVANTAGES OF BIOMASS ENERGY:-

- It is a dispersed and land- intensive source.
- It is often of low energy density.
- It is also labor intensive and the cost of collecting large quantities for commercial application is significant.
- Capacity is determined by availability of biomass and not suitable for varying loads.
- Not feasible to setup at all locations.

TYPES OF BIOMASS FUELS

1. Wood and Agriculture Product:
   Wood—logs, chips, bark, and sawdust—accounts for about 44 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources can include agricultural waste products like fruit pits and corncobs. Wood and wood waste are used to generate electricity. Much of the electricity is used by the industries making the waste; it is not distributed by utilities, it is a process called cogeneration. Paper mills and saw mills use much of their waste products to generate steam and electricity for their use. However, since they use so much energy, they need to buy additional electricity from utilities.
2. Solid Waste:
   Burning trash turns waste into a usable form of energy. One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal. Garbage is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas. Power plants that burn garbage for energy are called waste-to-energy plants. These plants generate electricity much as coal-red plants do, except that combustible garbage—not coal—is the fuel used to re their boilers.
3. Landfill and BioGas:
   Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting cellulose to sugars to feed itself. Although this process is slowed in a landfil, a substance called methane gas is still produced as the waste decays. New regulations require landfils to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless. The gas can cause res or explosions if it seeps into nearby homes and is ignited. Landfils can collect the methane gas, purify it, and use it as fuel. Methane can also be produced using energy from agricultural and human wastes. Biogas digesters are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen to

produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting.

4. Ethanol:

   Ethanol is an alcohol fuel (ethyl alcohol) made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose, starch, or sugar can be made into ethanol. The majority of the ethanol produced in the United States comes from corn. New technologies are producing ethanol from cellulose in woody bers from trees, grasses, and crop residues

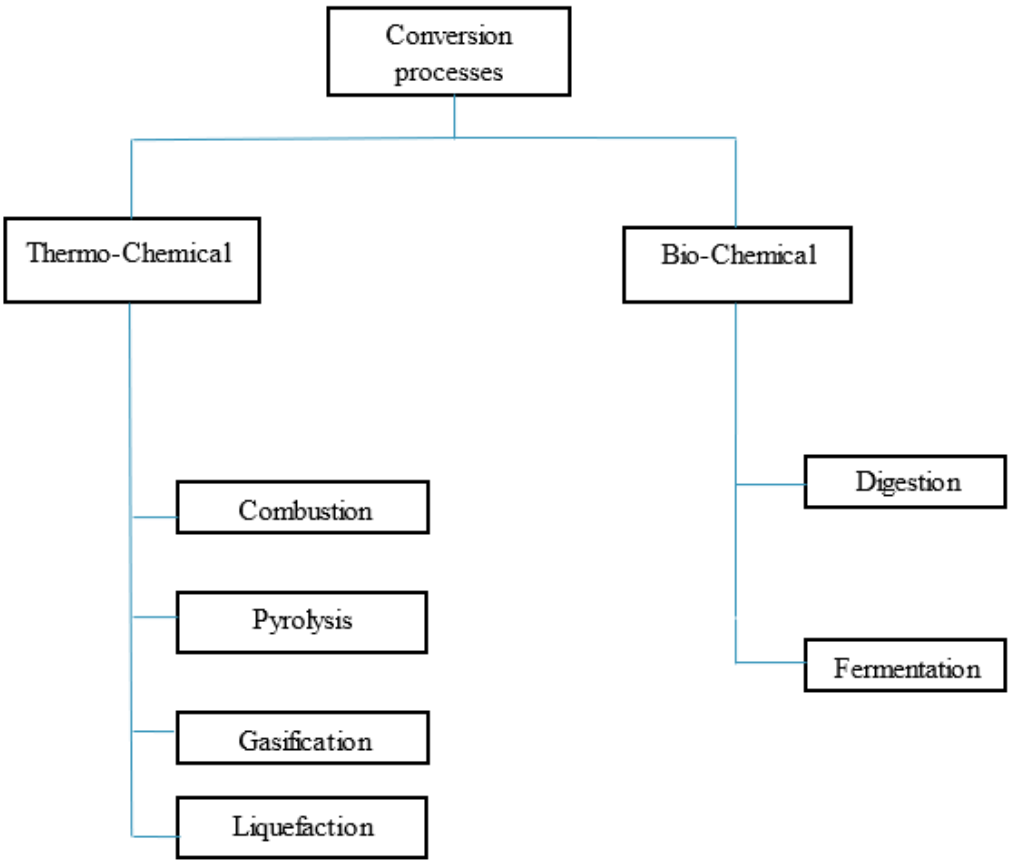
5. Biodiesel:

   It is a fuel made by chemically reacting alcohol with vegetableoils, animal fats, or greases, such as recycled restaurant grease. Mostbiodiesel today is made from soybean oil. Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as neat (pure) biodiesel (B100). Biodiesel fuels are compatible with and can be usedin unmodified diesel engines with the existing fuelling infrastructure

BIOMASS CONVERSION TECHNOLOGIES:

Biomass can be converted into different forms of energy by using various processes. Many factors affect the choice of the process like quantity of biomass feedstock, desired energy form, environmental standards, economic conditions, and project specific factors. Biomass can be converted into three main products: power or heat generation, transportation fuels and chemical feedstock.

Biomass conversion technologies are shown in following chart.

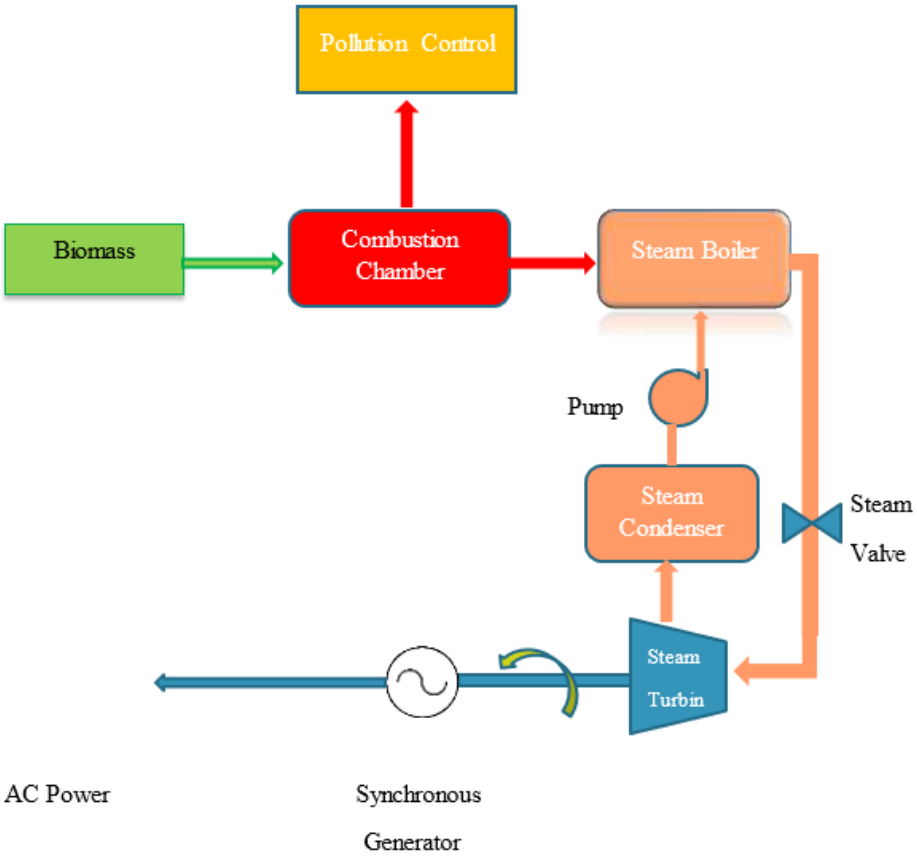


Thermo-chemical conversion

In thermo-chemical conversion, energy is produces by applying heat and chemical processes. There are four thermo-chemical conversion processes, which are given below.

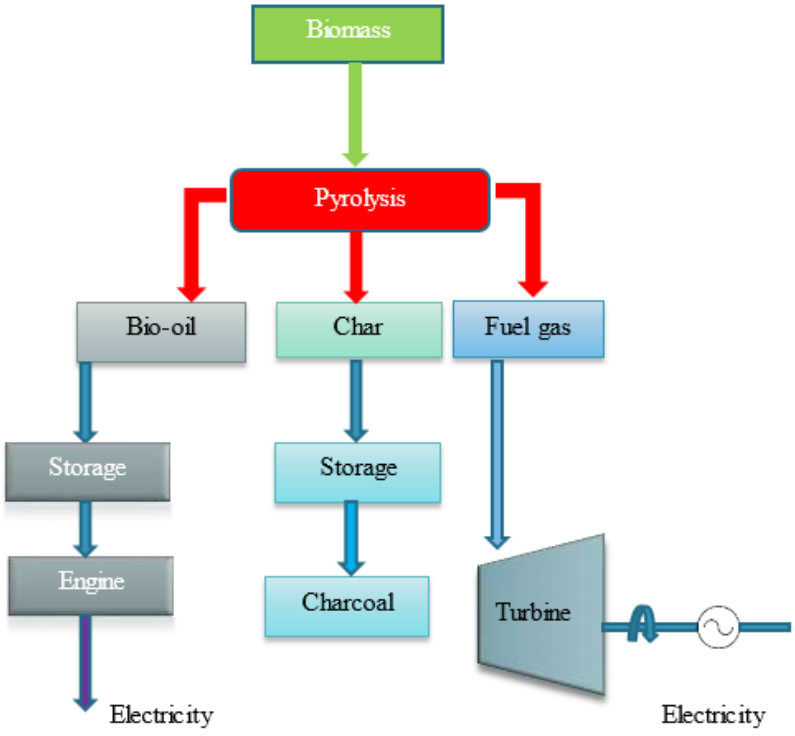
Combustion process

Combustion is an exothermic chemical reaction, in which biomass is burned in the presence of air. In this process chemical energy which is stored in the biomass is converted in the mechanical and electrical energies. This process is suitable for dry biomass containing moisture less than 50%. Biomass is burned at the temperature of 800-1000 °C. This process is used for domestic applications as well as commercially in biomass power plants in order to produce electricity.



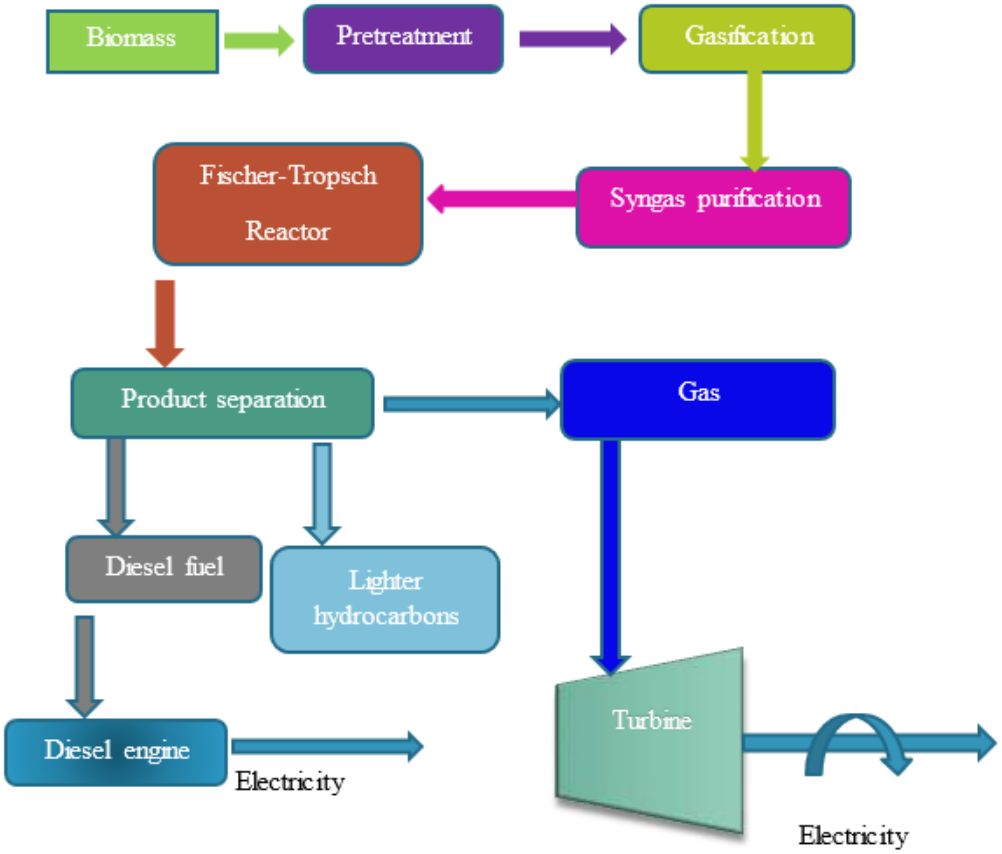
Pyrolysis Process

It is the process of conversion of biomass to liquid (bio-oil), solid (charcoal) and gaseous (fuel gases) products by heating in the absence of air at 500 °C. There are two types of pyrolysis : Fast pyrolysis, conventional (Carbonization) pyrolysis and slow pyrolysis. Fast pyrolysis process has high heating value and heat transfer rate and completes within seconds. Fast pyrolysis yields 60% bio-oil, 20% bio-char and 20% biogas. Conventional pyrolysis process is the process in which mostly carbon (35%) is leaved as residue. Slow pyrolysis takes more time than fast pyrolysis, it also has low temperature and heating values. Flash pyrolysis is the type of fast pyrolysis, in which 80% bio-oil is obtained at keeping temperature low. If flash pyrolysis is used for converting biomass to bio-crude, it has up to 80% efficiency.



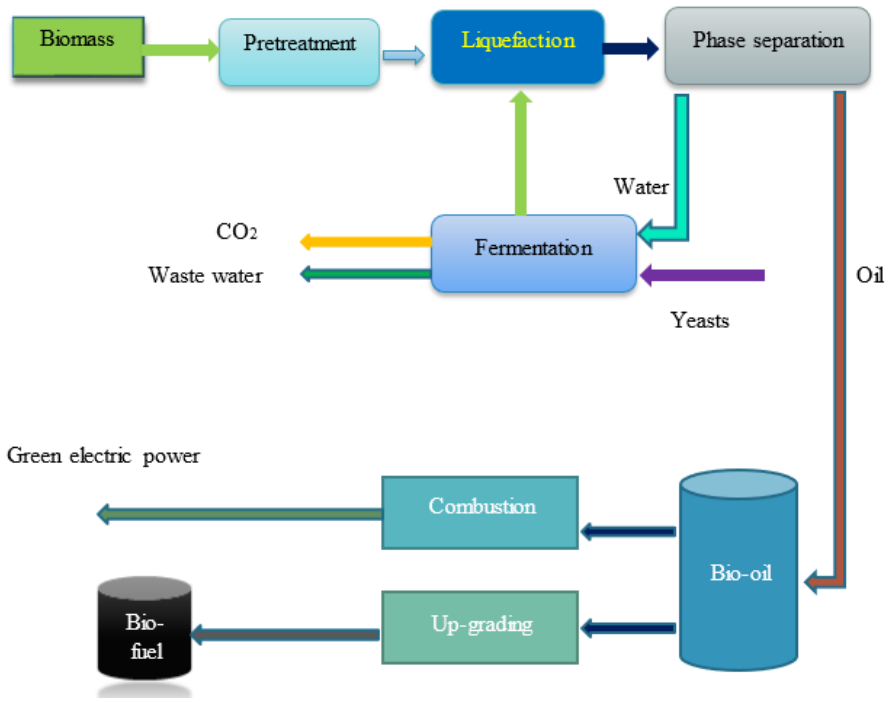
Gasification process

In biomass gasification, charcoal, wood chips, energy crops, forestry residues, agricultural waste and other wastes are transformed into flammable gases at high temperature (800-1000°C. In this process fuel (biomass) reacts with a gasifying medium such as oxygen enriched air, pure oxygen, steam or a combination of both. The product gas composition and energy content depends upon the gasifying media's nature and amount of it. Low calorific Value (CV) gas obtained by gasification about 4-6 MJ/N m^3. The product gas can be used as a feedstock (syngas) in the production of chemicals like methanol. One promising concept is the biomass integrated gasification/ combined cycle (BIG/CC), in which gas turbines convert the gaseous fuel to electricity with a high overall conversion efficiency. The syngas can be converted into hydrogen gas, and it may have a future as fuel for transportation.



Liquefaction process

It is the process in which biomass is converted into liquid phase at low temperatures (250-350°C) and high pressures (100-200 bar), usually with a high hydrogen partial pressure and catalysts to increase the rate of reaction. This process is used to get maximum liquid yields with higher quality than from the pyrolysis process. The product have higher heating value and lower oxygen content which makes the fuel chemically stable. The main purpose of the liquefaction is to obtain high H/C ratio of the product oil.

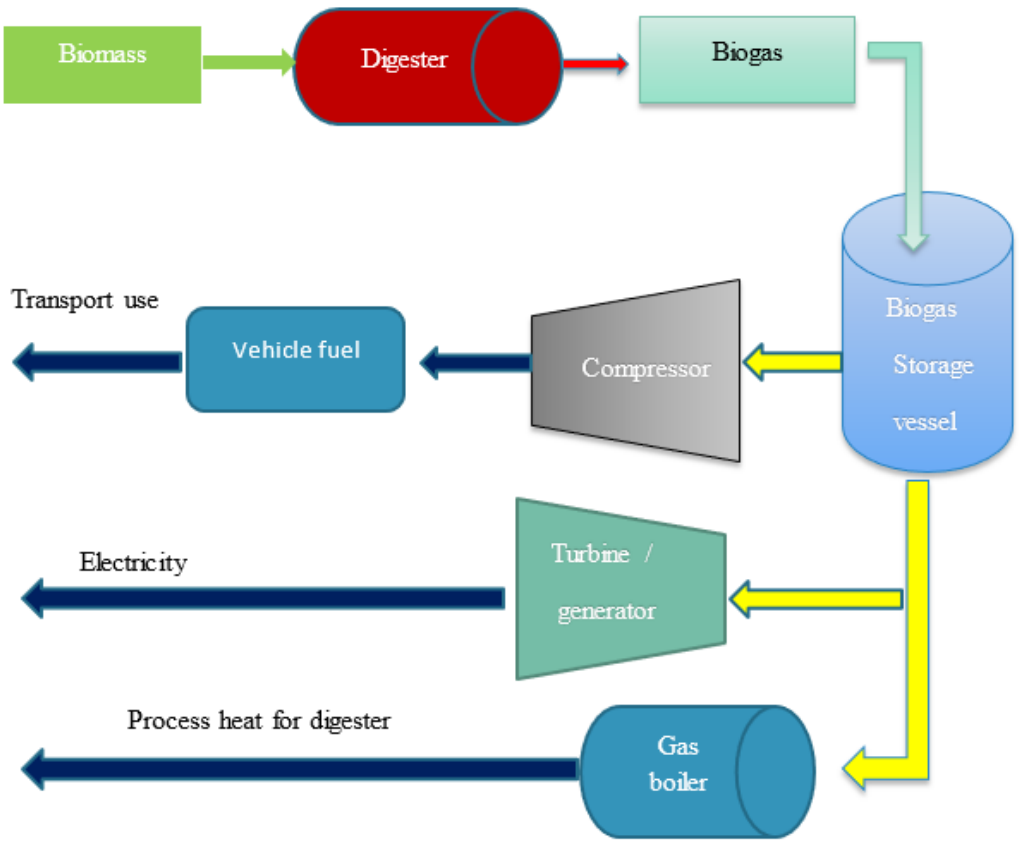


Bio-Chemical conversion

Biochemical conversion makes use of the enzymes of bacteria and other living organisms to break down biomass and convert it into fuels. This conversion process includes anaerobic digestion and fermentation.

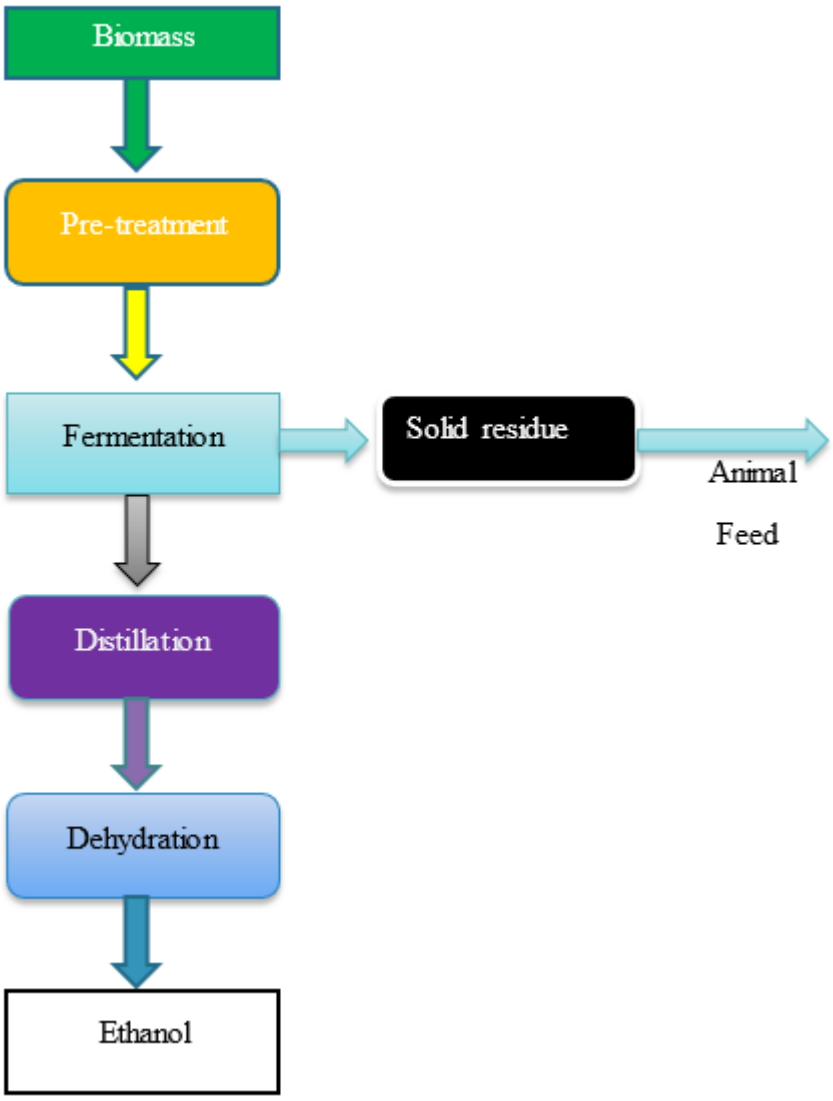
Anaerobic digestion process

This is a process in which organic material directly converted to a gas which is termed as biogas. It is mixture of methane, carbon dioxide and other gases like hydrogen sulphide in small quantities. Biomass is converted in anaerobic environment by bacteria, which produces a gas having an energy of 20-40% of lower heating value of the feedstock. This process is suitable for organic wastes having high moisture about 80-90%. This biogas can be directly used in spark ignition gas engines and gas turbines and can be upgraded to higher quality natural gas by removing carbon dioxide. The overall conversion efficiency of this process is 21%. Waste heat from engines and turbines can be recovered by using combined heat and power system.


Biomass
Digester
Biogas
Biogas
Storage
vessel
Transport use
Vehicle fuel
Compressor
Electricity
Turbine /
generator
Process heat for digester
Gas
boiler

Fermentation process

Fermentation is an anaerobic process that breaks down the glucose within organic materials. It is a series of chemical reactions that convert sugars to ethanol. The basic fermentation process involves the conversion of a plant's glucose (or carbohydrate) into an alcohol or acid. Yeast or bacteria are added to the biomass material, which feed on the sugars to produce ethanol and carbon dioxide. The ethanol is distilled and dehydrated to obtain a higher concentration of alcohol to achieve the required purity for the use as automotive fuel. The solid residue from the fermentation process can be used as cattle-feed and in the case of sugar cane; the bio gas can be used as a fuel for boilers or for subsequent gasification.



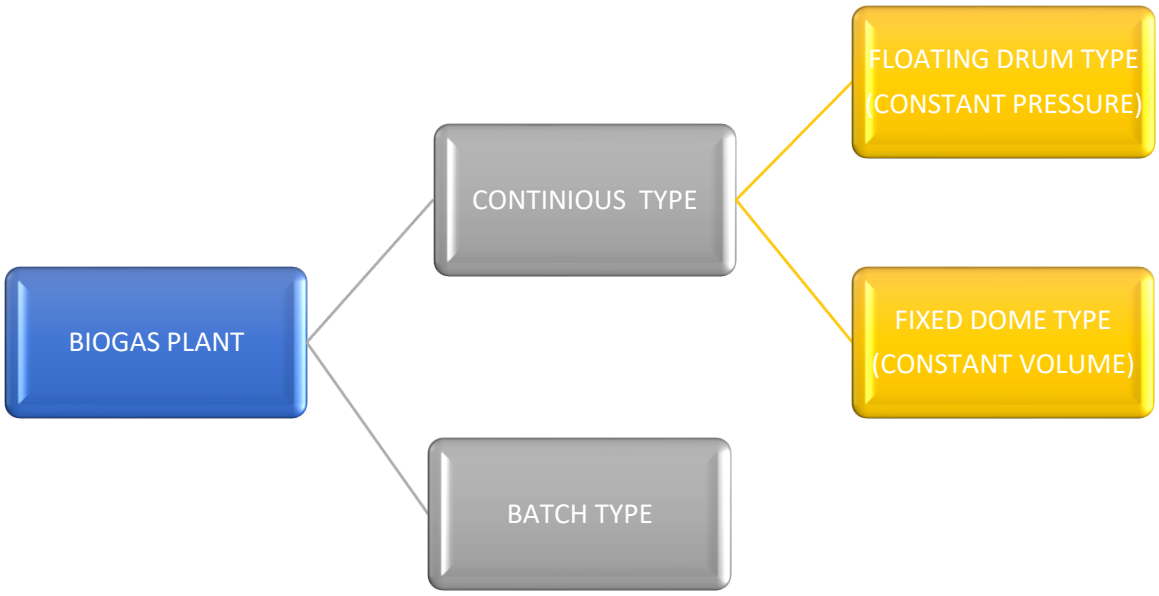
TYPES OF BIOGAS DIGESTER

- Biogas digesters are used to anaerobically decompose biodegradable materials such as kitchen waste, human and animal excreta to produce biogas.
- Gasification involves combustion and reduction operation of biomass.
- Biogas plants are mainly classified as

i. Batch type
ii. Continuous type

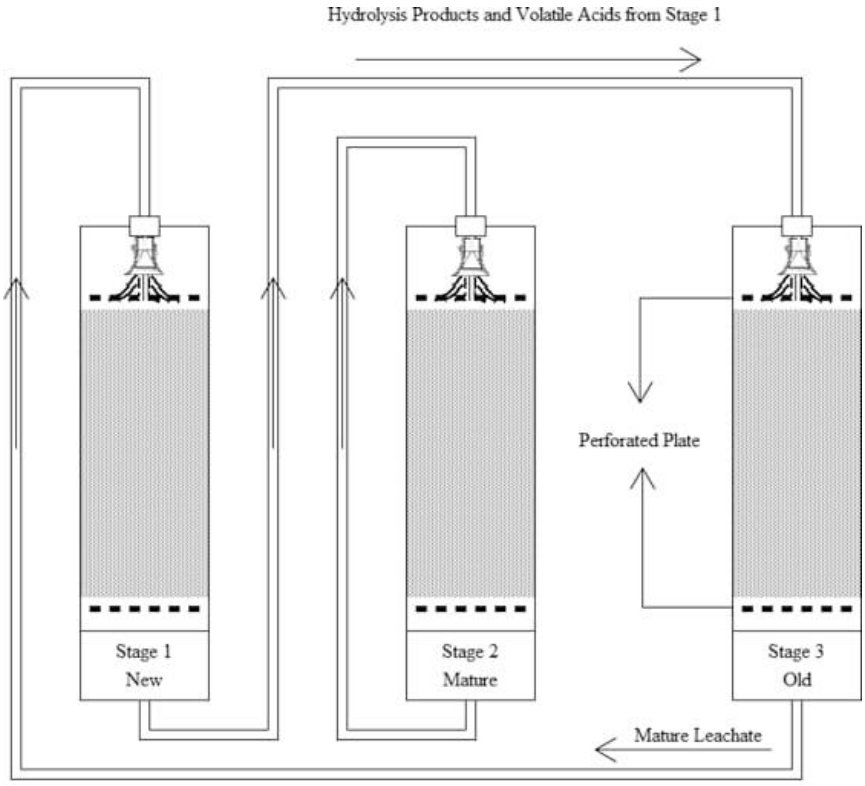
Continuous type plants are further classified into

a. Floating- drum (constant pressure) type
b. Fixed dome type (constant volume)



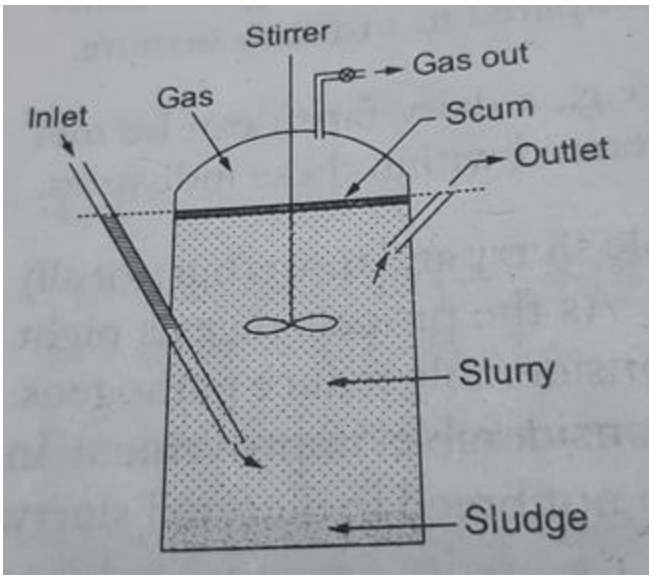
1. Batch type
    - A batch type plant is charged at 50-60 day intervals.
    - Once charged, it starts supplying the gas after 8-10 days and continuous to do so for about 40-50 days till the process of digestion is completed.
    - Batch type biogas plants are appropriate where daily supplies are raw waste materials are difficult to be obtained.
    - Gas production in batch type is uneven.
        - Several digesters occupy more space.
        - Such plants are installed in European countries.

- Don’t suit the conditions in Indian rural areas.



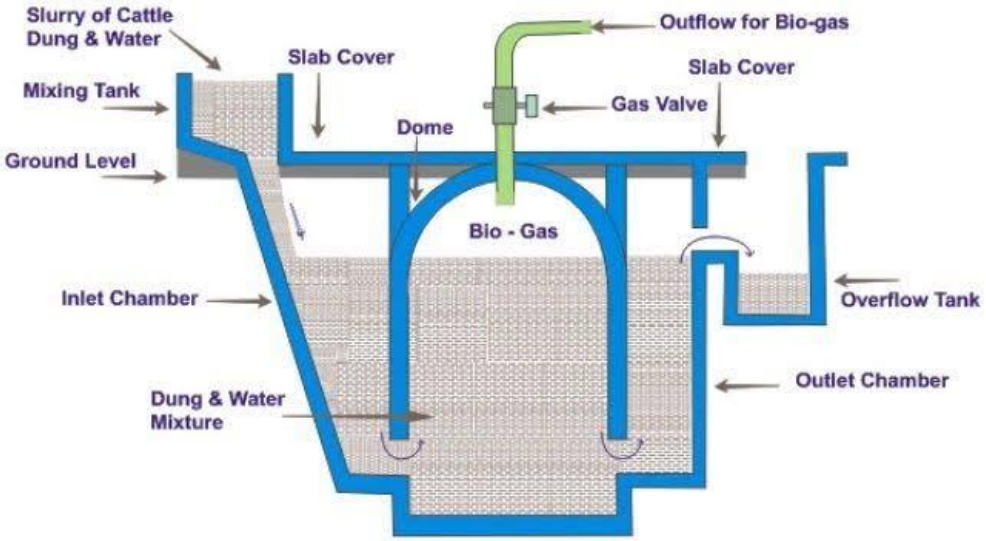
Batch Flow Digester

2. Continuous type
   - In continuous type biogas plant, the supply of the gas is continuous and the digester is fed with biomass regularly.
   - Plant operates continuously and is stopped only for maintenance or for sludge removal.
   - The gas produced is stored in the plant or in a separate gas holder.
   - The period during which the biomass remains in the digester is known as the retention period.
   - The thin dry layer often formed at the top of the slurry is known as scum.
   - This type of plant are very popular in india and china.
   - Other features :
   - ✓ Retention period is less.
   - ✓ Less problems as compared to batch type.
   - ✓ Small digestion chambers are required.



- There are two types of continuous type biogas plant
  a) Fixed dome (constant volume) type biogas plants
  - A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester.
  - When gas production starts, the slurry is displaced into the compensation tank.
  - Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank.
  - The costs of a fixed-dome biogas plant are relatively low.
  - It is simple as no moving parts exist.
  - There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected.
  - The plant is constructed underground, protecting it from physical damage and saving space.
  - While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester.
  - No day/night fluctuations of temperature in the digester positively influence the bacteriological processes.
  - The construction of fixed dome plants is labor-intensive, thus creating local employment.

- Fixed-dome plants are not easy to build.
- They should only be built where construction can be supervised by experienced biogas technicians.
- Otherwise plants may not be gas-tight (porosity and cracks).

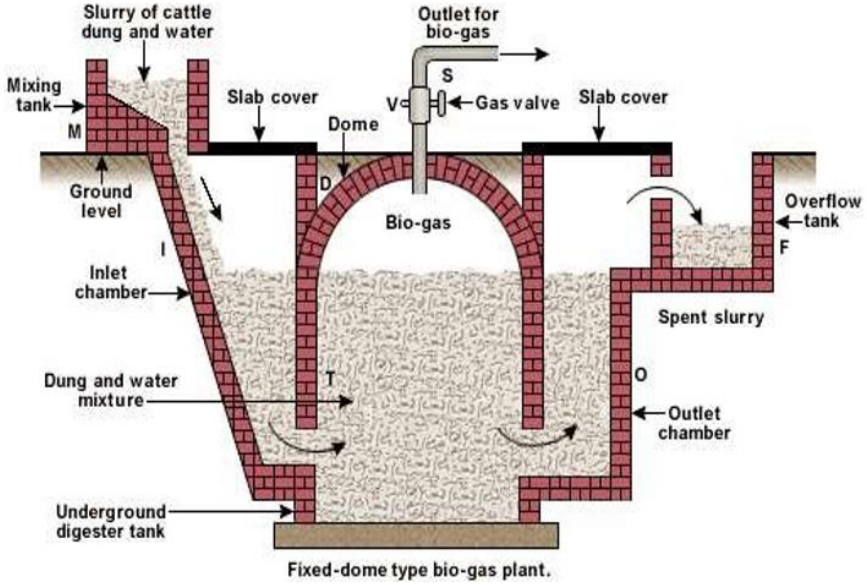


Fixed Dome type Bio-gas Plant

b) Floating drum (constant pressure) type biogas plants

- Floating-drum plants consist of an underground digester (cylindrical or dome-shaped) and a moving gas-holder.
- The gas-holder floats either directly on the fermentation slurry or in a water jacket of its own.
- The gas is collected in the gas drum, which rises or moves down, according to the amount of gas stored.
- The gas drum is prevented from tilting by a guiding frame. When biogas is produced, the drum moves up adn when it is consumed, the drum goes down.
- If the drum floats in a water jacket, it cannot get stuck, even in substrate with high solid content.
- After the introduction of cheap Fixed-dome Chinese model, the floating drum plants became obsolete as they have high investment and maintenance cost along with other design weakness.

- They are used most frequently by small to middle-sized farms (digester size: 5-15m^3) or in institutions and larger agro-industrial estates (digester size: 20-100m^3)**.**



Fixed-dome type bio-gas plant.

Gasifier:

Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (>700 °C), without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called syngas (from synthesis gas or synthetic gas) or producer gas and is itself a fuel.

Types of Gasifier:-

1. **Fixed Bed:**

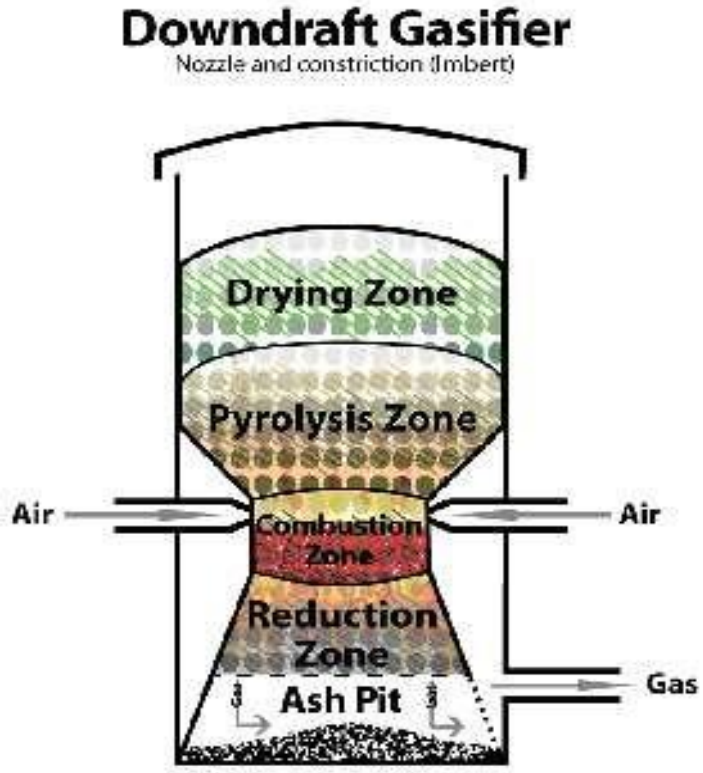
(a) Updraught or counter current gasifier:

- The air intake is at the bottom and the gas leaves at the top. Near the grate at the bottom the combustion reactions occur, which are followed by reduction reactions somewhat higher up in the gasifier.
- In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones.
- The tars and volatiles produced during this process will be carried in the gas stream. Ashes are removed from the bottom of the gasifier.
- The major advantages of this type of gasifier are its simplicity, high charcoal burn-out and internal heat exchange leading to low gas exit temperatures and high equipment efficiency, as well as the possibility of operation with many types of feedstock (sawdust, cereal hulls, etc.) .
- Major drawbacks result from the possibility of "channelling" in the equipment, which can lead to oxygen break-through and dangerous, explosive situations and the necessity to install automatic moving grates, as well as from the problems associated with disposal of the tar-containing condensates that result from the gas cleaning operations. The

latter is of minor importance if the gas is used for direct heat applications, in which case the tars are simply burnt.

(b) Downdraught or co-current gasifiers:

- A solution to the problem of tar entrainment in the gas stream has been found by designing co-current or downdraught gasifiers, in which primary gasification air is introduced at or above the oxidation zone in the gasifier. The producer gas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction

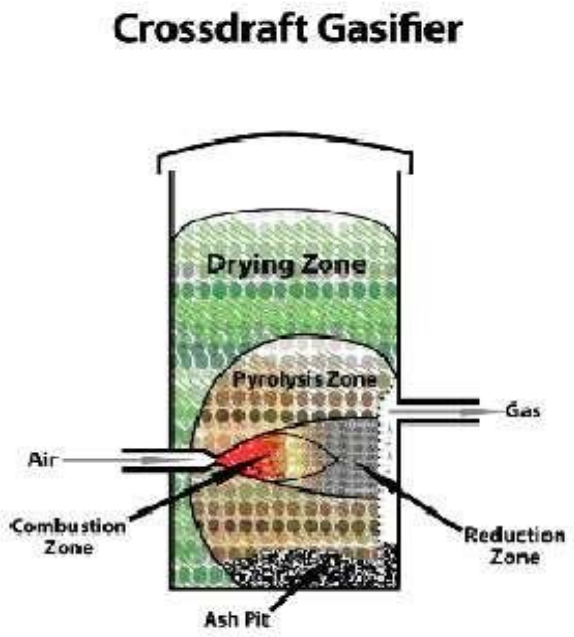


- In updraft gasifier there is a problem of tar entrainment in the product gas leaving stream. A solution is to have primary gasification air introduced at or above the oxidation zone in the gasifier. The produced gas is taken out from the bottom.
- On their way down, the acid and tarry distillation products from the fuel must pass through a glowing bed of charcoal and therefore are converted into permanent gases hydrogen, carbon dioxide, carbon monoxide and methane.
- Main advantage of downdraft gasifier lies in the possibility of producing tar free gas for engine operation. However in practice very rarely tar free gas is produced but the % of tar leaving in product stream is considerably lower than leaving through the updraft gasifier.
- Main disadvantage is that downdraft gasifier cannot be operated with range of different feedstocks. Low density feedstock gives rise to flow

problems and excessive pressure drop. High ash content coal also gives more problem with this kind of gasifier than updraft gasifier.

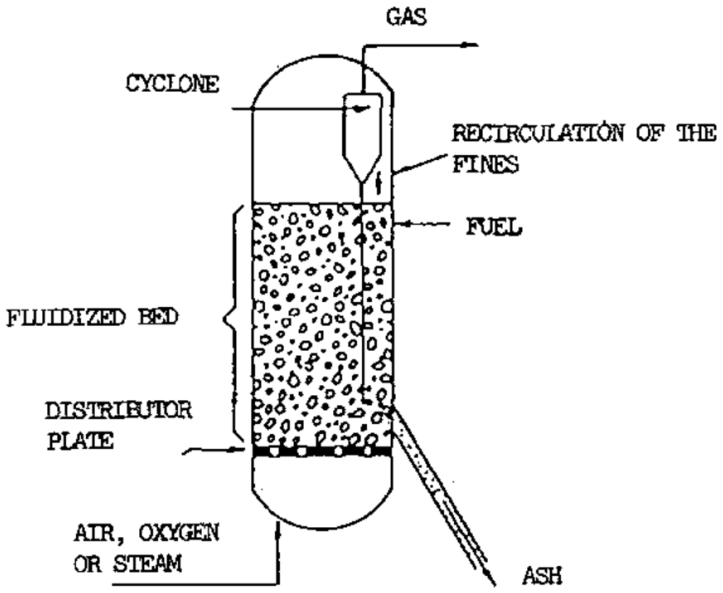
- Other disadvantage is it gives lower efficiency, since there is no provision internal heat exchange compare to updraft gasifier. The product stream also has low calorific value.

(c) Cross-draught gasifier:



- Cross-draught gasifiers, are an adaptation for the use of charcoal. Charcoal gasification results in very high temperatures (1500 °C and higher) in the oxidation zone which can lead to material problems. In cross draught gasifiers insulation against these high temperatures is provided by the fuel (charcoal) itself.
- Advantages of the system lie in the very small scale at which it can be operated. Installations below 10 kW (shaft power) can under certain conditions be economically feasible. The reason is the very simple gas-cleaning train (only a cyclone and a hot filter) which can be employed when using this type of gasifier in conjunction with small engines.
- A disadvantage of cross-draught gasifiers is their minimal tar-converting capabilities and the consequent need for high quality (low volatile content) charcoal.
- It is because of the uncertainty of charcoal quality that a number of charcoal gasifiers employ the downdraught principle, in order to maintain at least a minimal tar-cracking capability.

2. Fluidized Bed Gasifier:-

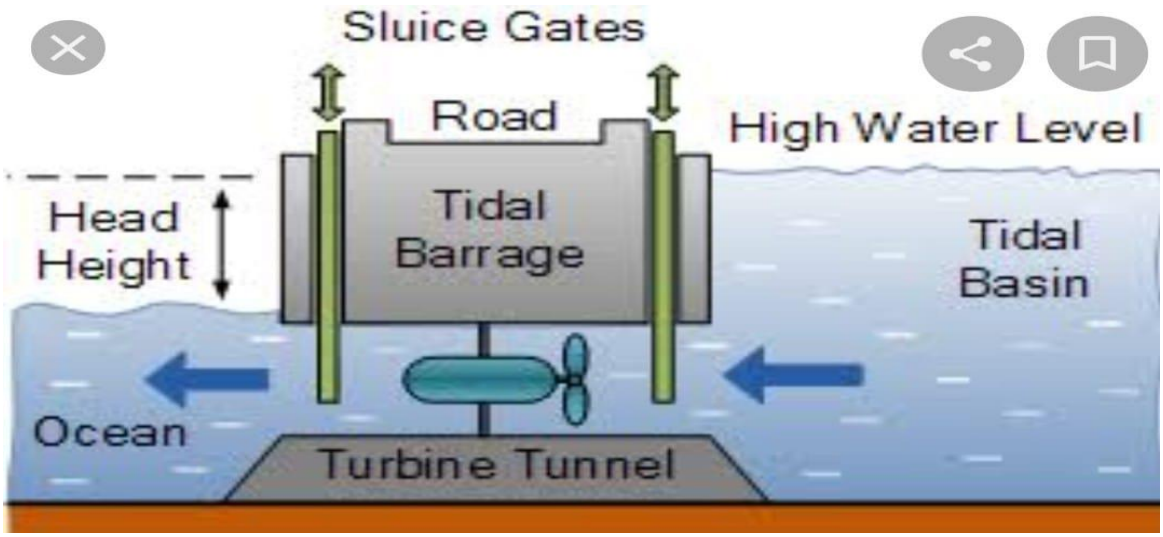


- The operation of both up and downdraught gasifiers is influenced by the morphological, physical and chemical properties of the fuel. Problems commonly encountered are: lack of bunker flow, slagging and extreme pressure drop over the gasifier.
- Air is blown through a bed of solid particles at a sufficient velocity to keep these in a state of suspension.
- The bed is originally externally heated and the feedstock is introduced as soon as a sufficiently high temperature is reached.
- The fuel particles are introduced at the bottom of the reactor, very quickly mixed with the bed material and almost instantaneously heated up to the bed temperature. As a result of this treatment the fuel is pyrolysed very fast, resulting in a component mix with a relatively large amount of gaseous materials.
- Further gasification and tar-conversion reactions occur in the gas phase.
- Most systems are equipped with an internal cyclone in order to minimize char blow-out as much as possible. Ash particles are also carried over the top of the reactor and have to be removed from the gas stream if the gas is used in engine applications.

CHAPTER 5

OTHER ENERGY SOURCE

1. **TIDAL ENERGY:**
    - Tidal energy is a form of hydropower that converts energy obtained from tides into useful forms of power, such as electricity.
    - Tides are created by the gravitational effect of the moon & sun on the earth causing cyclical movement of the seas.
    - Tidal energy is created using the movement of our tides & ocean, where the intensity of the water From the rise and fall of tides is a form of kinetic energy.
    - Tidal power gravitational hydropower, Which uses the movement of water to push a turbine to generate electricity.
    - Use:- Tidal power is already currently located in a number of countries including South Korea, United Kingdom, France, Russia & china etc.
    - According to the estimate of Indian government the country has a potential of 8,000MW of tidal energy. This includes about 7,000MW in Gujarat, 1,200MW in the Gulf of katch & 100MW in WB.
2. **ADVANTAGES:**



- Tides are easily predictable.
- Inexpensive to maintain.
- Reliable & renewable source of energy.
- High energy density than other renewable energy form.

3. **DISADVANTAGES:**

- High tidal power plant construction cost.
- Negative influence on marine life forms.
- Location limits.
- The various intensity of sea waves.

4. BARRAGE AND NON-BARRAGE TIDAL POWER SYSTEM:

- Tidal barrage are low- walled dams, usually installed at tidal inlet or estuaries.
- During an incoming high tide, water flow over the turbines as the water rises.
- Then the water flows back through the turbines as it becomes low tide.
- The turbines are connected to a generator which produces the electricity.
- Tidal barrages are long concrete structures usually built across river estuaries.
- Instead of damming water on one side like a conventional dam, a tidal barrage allows water to flow into a river during high tide and releases the water during low tide.
- Turbines are placed at these sluices to capture the energy as the water flows in and out.

5. ADVANTAGES

- Renewable source of energy.
- Zero carbon emissions.
- High power output.
- Predictable source than wind & solar.

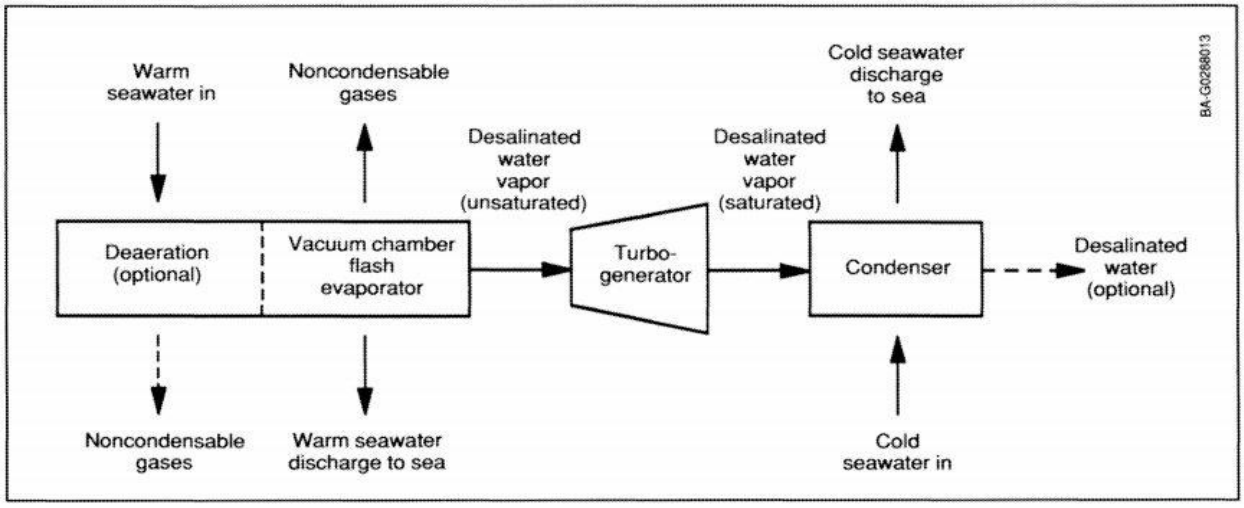
6. DISADVANTAGES (TIDAL BARRAGE)

- They can change the movement of water into and out of estuaries, which can disrupt the life cycle of certain marine life.
- They can prevent the movement of fish & other wildlife into and out of estuaries which can disrupt spawning.

7. OCEAN THERMAL ENERGY CONVERSION TECHNOLOGY

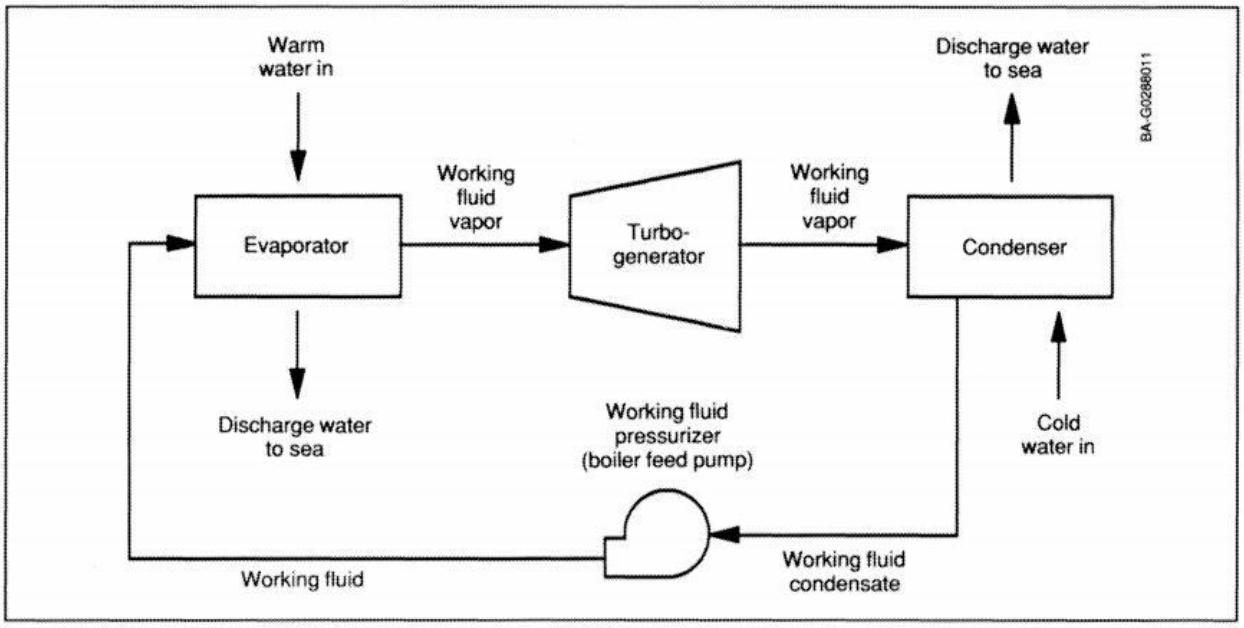
- OTEC Plants can operate on open and closed cycles. In an **open cycle** (also known as Claude cycle) plant, warm water from the ocean surface is flash evaporated under partial vacuum.
- Low- pressure stream obtained is separated and passed through a turbine to extract energy.
- The exhaust of the turbine is condensed in a direct contact condenser. Cold water drawn from a depth of about 1000m is used as cooling water in a direct contact condenser.
- The resulting mixture of used cooling water and condensate is disposed in the sea.

- If a surface contact condenser is employed, the condensate could be used as desalinated water. Thus, an open-loop OTEC plant can provide a substantial quantity of desalinated water.



Open Cycle OTEC Plants

- In a **closed cycle** (also known as Anderson cycle) plant, warm surface water is used to evaporate a low- boiling- point working fluid such as ammonia, freon on propane.
- The vapor flows through the turbine and is then cooled and condensed by cold water pumped From the ocean depth.
- The operating pressure of the working fluid at the boiler/ evaporator and condenser are much higher and it's specific volume is much lower as compared to that open- cycle system.
- Although both systems are being explored, the closed- cycle system appears to be more promising in the near future.
- Both open and closed cycle plants can be mounted on a ship or built on shore.
- The ship option requires submarine power cable for power transport.
- The hydrogen could be liquefied and transported by a tanker to the point of use.



Closed cycle OTEC Plants

- **ADVANTAGES:**
- Their main advantage is the lower cost of installation, operation and maintenance.
- In both open and closed cycle, cooling water taken from the sea depth is nutrient-rich can be diverted to lagoon to develop Marin culture after utilizing it's cooling effect.

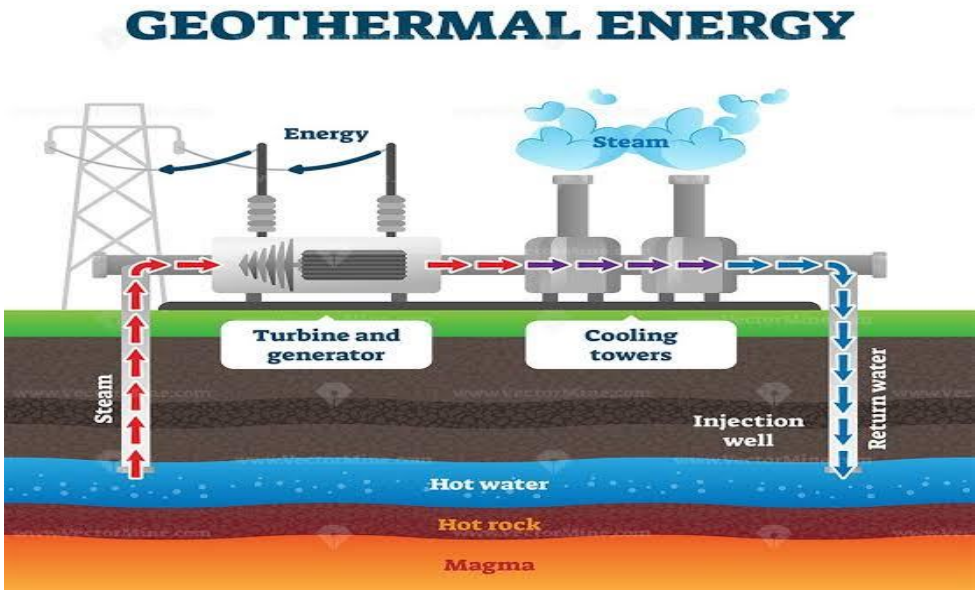
8. PRESENT STATUS:

- A 50-KWe Floating closed-cycle test plant was installed off Hawaii in1979.
- The Tokyo Electric power co. Built and operated a 100-KWe shore-based closed-cycle plant in the republic of Nauru.
- Encouraged by the performance of this plant, the company is now planning a 20-MWe plant on the same island of Nauru.
- The Japanese government is designing a 10-MWe floating plant and also considering a land- based plant.
- Several others counties are designing/ proposing pilot OTEC Plants. Commercialization of OTEC will require demonstration of technical performance, reliability and cost effectiveness.

- In India, conceptual studies on OTEC plants for Kavaratti (Lakshadweep Island), Andaman Nicobar islands and at Kulasekharapatnam (Tamil Nadu) were initiated in 1980.

9. GEOTHERMAL ENERGY

- Geothermal energy originates from the Earth's interior in the form of heat .
- Volumes, geysers, hot springs and boiling mud pots are visible, evidence of the great reservoirs of heat that lie beneath the earth.
- Although the amount of thermal energy within the earth is very large, useful geothermal energy is limited to certain site's only.
- The entire heat content of the Earth's crust up to a depth of 10Km above 15 degree Celsius is defined as geothermal resource.
- It is considered an in exhaustible and renewable source.
- **USE:** Low temp. Resources i.e , geysers have been used for Applications such as hot baths , cooking, space & water heating.
- Most geothermal resources produce heat at about 50-70 degree Celsius, Which can be used directly for thermal Applications.
- The world's total present installed Electrical power generation capacity from geothermal resources is about 9,031 MW.
- The estimated potential for geothermal energy in India is about 10,000 MW.
- **The Main Advantages of geothermal energy are:**
  i. It is a reliable & cheap source of energy.
  ii. It is available 24 hours per day.
  iii. Geothermal plant's require little land area.
- **The main disadvantages are:**
  i. It is a site specific.
  ii. Generally energy is available as low grade heat.
  iii. The available thermal energy cannot be distributed easily over long distances.



TYPES OF GEOTHERMAL RESOURCES

- There are four types of geothermal resources:
- Hydrothermal
- Geopressured
- Hot dry rock (HDR)
- Magma
- At present, the technology for economic recovery of energy is available for hydrothermal resources only.
- Thus, this is the only commercially used resources at present.
- Other resources are going through a development phase and have not become commercial so far.

- **Hydrothermal Resources :-**

- Hydrothermal resources occur when underground water has access to high temperature porous rocks, capped by a layer of solid impervious rock.

- Thus, water is trapped in the underground reservoir (aquifers) and is heated by surrounding rocks.
- Heat is supplied by magma by upward conditions through solid rocks below the reservoir.
- Thus, it forms a gaint underground boiler.
- Under high pressure, the temperature can reach as high as 350˚ C.
- The hot water often escapes through fissures in the rock, thus forming hot springs or Geysers.
- The hydrothermal resources are located at shallow to moderate depths (from approximately 100m to 4500m).
- Temperature for hydrothermal reserves used for electricity generation range from 90˚C to 350˚C but roughly two-thirds are estimated to be in the moderate temperature range (150˚C to 200˚C).

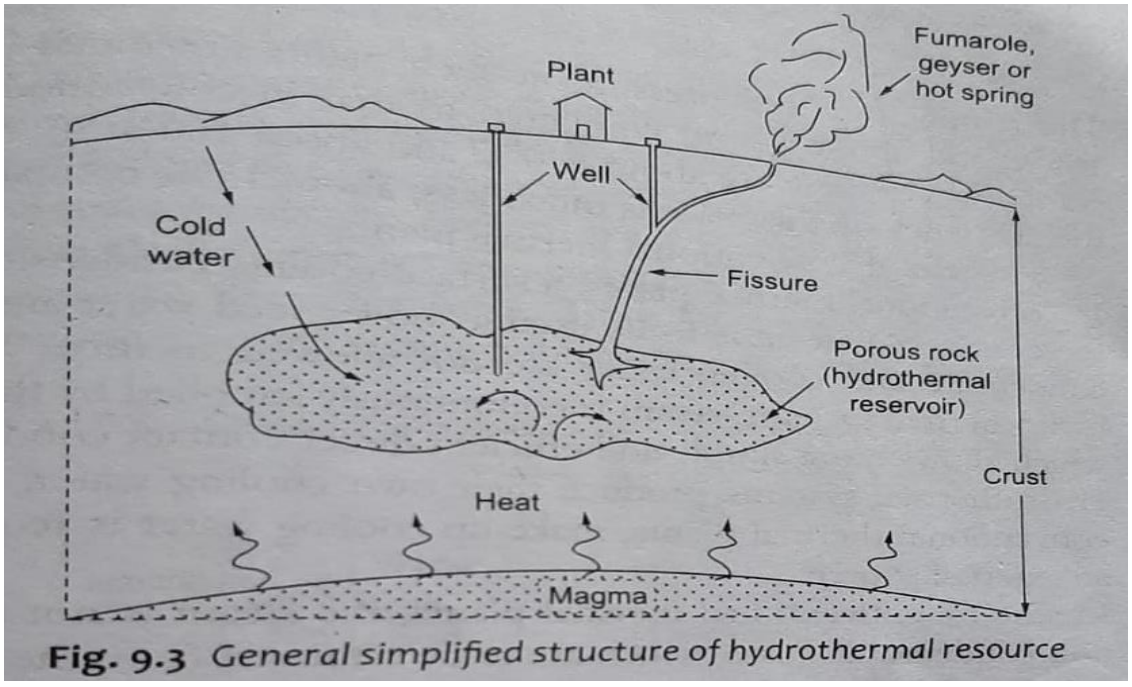


Fig. 9.3 *General simplified structure of hydrothermal resource*

10.Geopressured Resources :-

- While drilling for oil and gas, hot salt-water (brine) reservoirs at moderately high temperatures, (90˚C to 200˚C), and under great pressure are found at a depth of 3km to 6km.
- Because of the very high pressure of the water up to 1350 atm in the deepest layer, these reservoirs are referred as Geopressured.

- When the water is brought to the surface and its pressure reduced, the methane gas is released from the solution.
- Thus, methane can be extracted from brine by simple and economical gravity separation techniques.
- The resources is potentially very promising because three types of energy can be extracted from the well :

- Thermal energy from the heated fluids,
- Mechanical (hydraulic) energy from the high pressures involved
- Chemical energy from the burning of methane gas.
- The extent of Geopressured reserves is not yet well known worldwide, and the only major resources area identified to date is along the Texas and Louisiana coast of the Gulf of Mexico.
- The potential of Geopressured resources of this area has been estimated as 23 to 240 〖GW〗_e for 30 years.

11.Hot Dry Rock Resources :-

- There are regions underground at temperatures exceeding 200˚C, with little or no water.
- The rocks are impermeable and/or there is no surface water in the vicinity.
- Such resources up to a depth of 5km are estimated to be significant and worthy of development as a sources of energy.
- Hot dry rocks are much more common than hydrothermal reservoirs and are more accessible.
- So their potential is quite high.
- The recovery of heat from HDR involves forming a manmade reservoir by drilling deep into the hot rocks and then cracking it to form cavity or fractures.
- Such a system is known as an enhanced geothermal system (EGS) , sometimes also called engineered geothermal systems.
- This can be achieved by
- Detonating high explosives at the bottom of the well,
- Nuclear explosion
- Hydraulic fracturing

- Hydraulic fracturing which is performed by pumping of water at high pressure into the rock formation, is commonly used in oil and gas fields to improve the flow.
- Nuclear explosives are associated with environmental and safety issues and, therefore, hydraulic fracturing seems to be more promising.

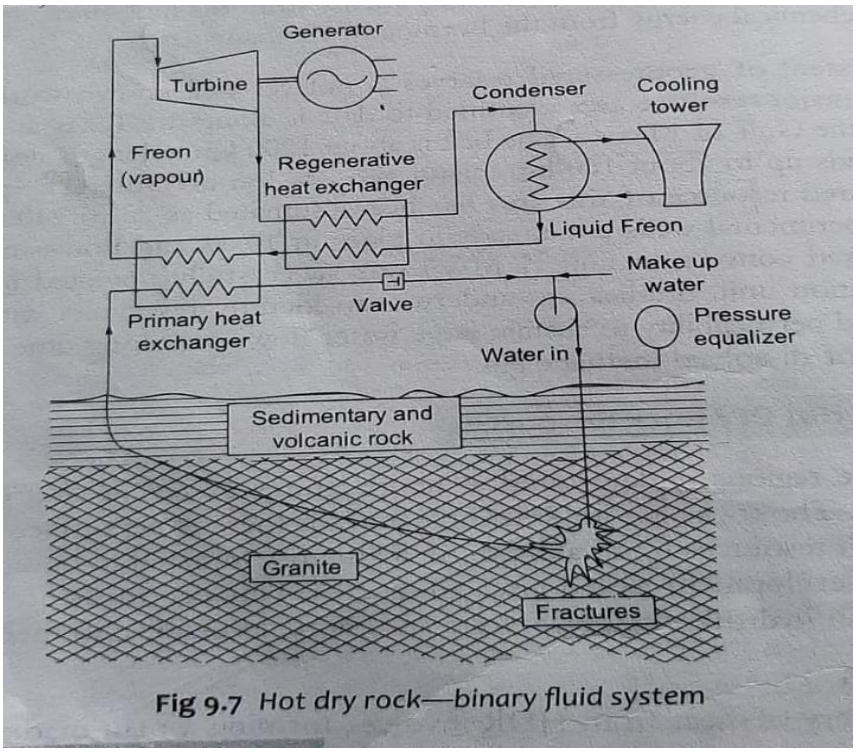


Fig 9.7 *Hot dry rock—binary fluid system*

12.Magma Resources :-

- At some places, molten or partially molten rock (magma chamber), at temperature of 650˚C to 1200˚C occurs at depths of 5km – 10km.
- These resources are located especially in the vicinity of recent volcanic activity.
- Very high temperature and large volume make magma a huge potential energy sources, the largest of all geothermal resources.
- Successful magma drilling technology has not been established yet.
- Extracting magma energy is expected to be the most difficult of all types of resources utilization.
- Magma technology will require special drilling technology to deal with the interaction of the drill bit with molten rock, the effects of dissolved gases, and mechanisms of heat transport in molten magma.

13.Hybrid energy system:

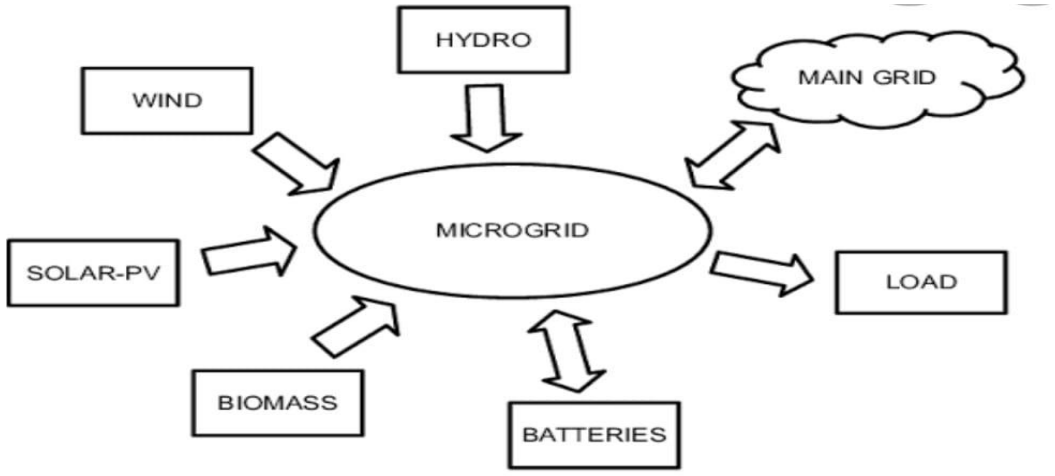
- A hybrid energy system or hybrid power usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply.
- Hybrid energy systems are defined as the integration of several types of energy generation equipment such as Electrical energy generators, Electrical energy storage system and renewable energy sources.
- Hybrid energy system may be utilized in grid- connected mode, isolated From grid & special aims.

ADVANTAGES

- Fuel saving (up to 50%)
- Lower atmospheric contamination
- Saving in maintenance
- Silent system
- Connection to other power supply.

DISADVANTAGES

- It has a higher cost than grid solar
- It has a battery life of 7-15 years
- It can limit the no. Of appliances we can run at one time.

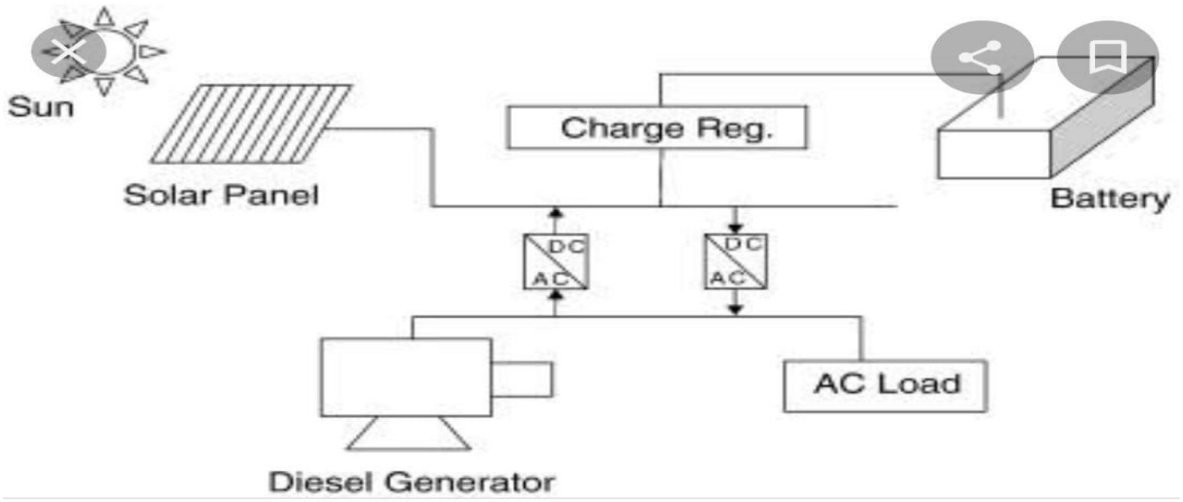


14. Need for Hybrid Energy System (HES)

- The hybrid energy system was designed to overcome the problem of climate change, to ensure a reliable supply without interruption.
- HES being together different generation storage & consumption technologies in a single system, improving the overall benefits compared to a system that depends on a single source.
- HES have also grown in capacity from small , off- grid system of a few kilowatt, typically designed for low voltage DC & AC to large megawatt systems expanding to medium voltage grid- connected system.
- The specific use cases for HES, availability of resources, power & voltage level and grid connections are among the main reasons that define the requirements for the power electronics converters used in HES.
- **Diesel PV (Hybrid Energy System)**
- The PV- Diesel hybrid system is the integration of photovoltaic system with diesel generator to supply the load.
- The purpose of this technology is providing electricity.
- The hybrid system was designed to ensure a reliable supply without interruption and to improve the overall system efficiency.
- Implementing PV- Diesel hybrid system is to reduce diesel consumption and the import of fossil fuel used in electricity power supply.
- **WORKING:** One of the most common hybrid system being PV diesel hybrid system, coupling PV and diesel generators.
- The diesel generators are used to steadily fill in the gap between the load and the power generated by the PV system.
- Depending on the consumer and their situation the main energy can be the grid power, the PV system or the diesel Generator set
- The PV system can supply additional energy & batteries can also be used to store the excess energy to be used later on.

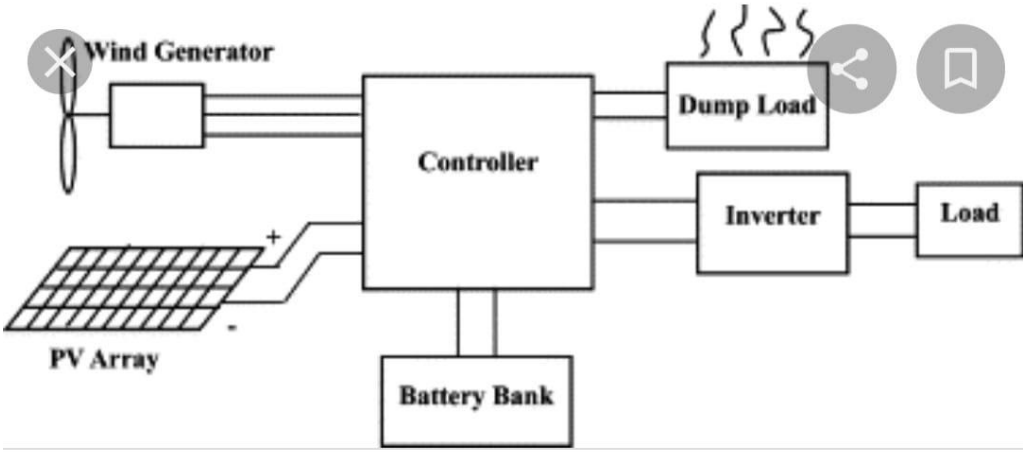
ADVANTAGES

- A hybrid power supply system using a diesel generator and a solar module combined with a single energy source independent system provides much less dependence on the weather.
- The best thing about hybrid solar system is that they store solar energy & low cost electricity.



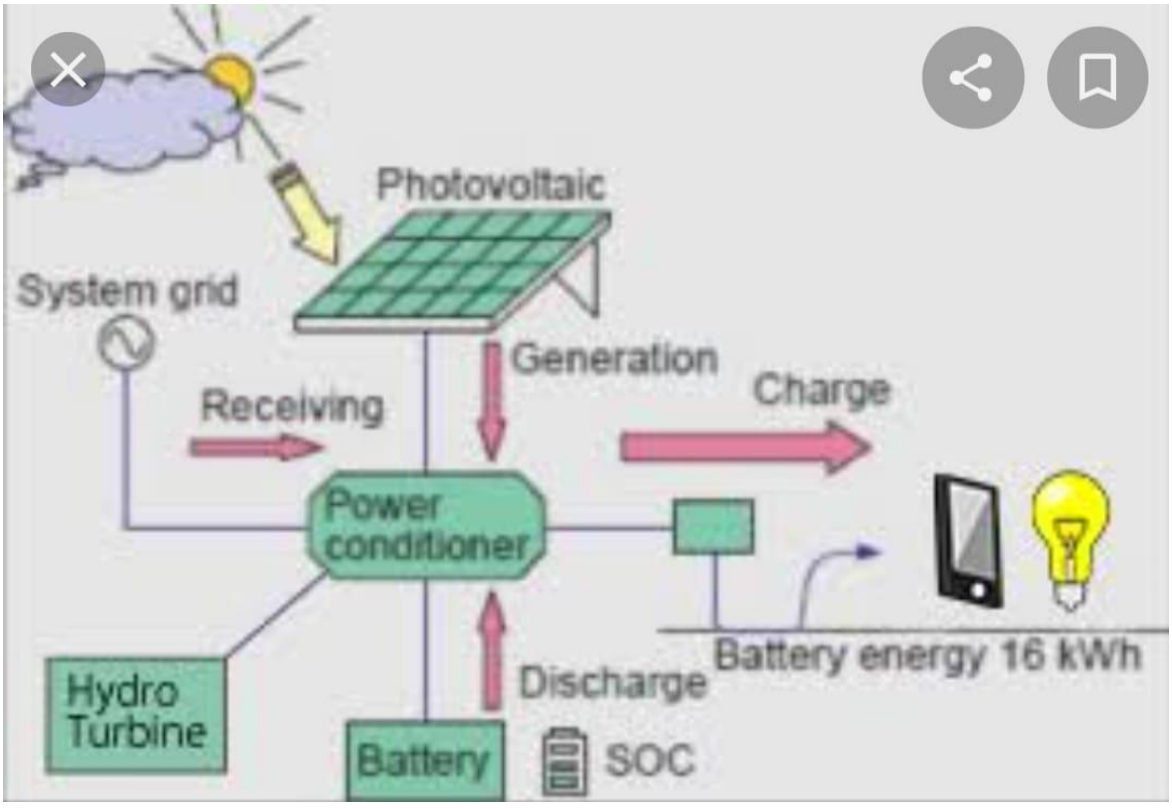
15.WIND PV- HYBRID SYSTEM:

- Describe Wind energy with one or more additional sources (e.g- Solar, biomass)
- A hybrid renewable PV- Wind energy system is a combination of solar PV, wind turbine, inverter, battery & other additional components.
- The photovoltaic & wind hybrid energy system have been found to be more economically viable alternative to fulfill the energy demands of numerous isolated consumers worldwide.
- The wind- Solar hybrid system generates electricity that can be used for charging batteries and with the use of inverter we can run AC appliances.
- **WORKING:** Sola/ wind hybrid use Solar panels and small wind turbine generators to generate electricity.
- They work in small capacities typically capacities are in the range of 1 KW to 10 KW for the solar panel & the wind turbine system.



16.MICRO-HYDEL PV SYSTEM

- Micro- Hydropower is one of the most cost effective energy technologies to be considered for rural electrification where available.
- In most countries, it is difficult to satisfy power demand all year long by hydro source alone.
- In some remote areas, where this is the case , a combination of other renewable source to form a hybrid system can help solve rural electrification problem.
- One of these combinations is the use of PV together with a diesel and batteries.
- Hybrid power plant were Able to meet the need of Electrical energy in the villages.
- The possibility of using a Micro hydro hybrid power system for low cost electricity production which can satisfy the energy load requirements of a typical remote and isolated rural area.
- In this context, the optical dimensions to improve the economical & technical performance of the hybrid system are determined according to the load energy requirements, the solar & water resources and the importance of supply continuity.



17.Electric and hybrid electric vehicles

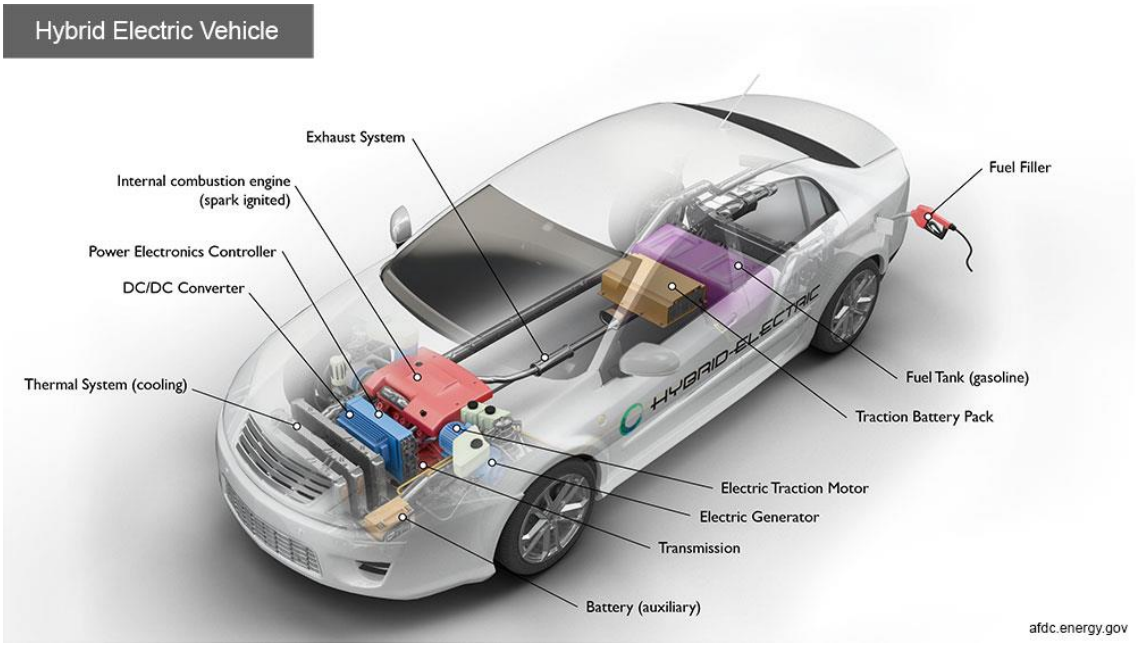
- Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries.
- A hybrid electric vehicle cannot be plugged into charges the battery. Instead, the battery is charged through regenerative breaking and by the internal combustion engine.
- The extra power provided by the electric motor can potentially allow for a smaller engine.
- The battery can also power auxiliary loads and reduce engine idling when stopped.
- Electric vehicles function by plugging into a charge point and taking electricity from the grid.
- They stored the electricity in rechargeable batteries that power an electric motor, which turns the wheels.
- Electric cars accelerate faster than vehicles with traditional fuel engines.

18. Advantages of hybrid car :-

- A hybrid car is one that uses two or more engines i.e., an electric motor and a conventional engine (either petrol or diesel).
- The electric engine powers the car at lower speeds and the gas engine power it at higher speed.
- A hybrid car like Toyota prius and civic hybrid not only conserves fuel but also produces less CO_2 emissions.
- One of the biggest advantages of a hybrid car over a gasoline- powered car is that it runs cleaner and has better gas mileage, which makes environmentally friendly.

19. How Do Hybrid Electric Cars Work?

- Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries.
- A hybrid electric vehicle cannot be plugged in to charge the battery.
- Instead, the battery is charged through regenerative braking and by the internal combustion engine.
- The extra power provided by the electric motor can potentially allow for a smaller engine.
- The battery can also power auxiliary loads and reduce engine idling when stopped.
- Together, these features result in better fuel economy without sacrificing performance.



20.Key Components of a Hybrid Electric Car:-

- **Battery (auxiliary):** In an electric drive vehicle, the auxiliary battery provides electricity to start the car before the traction battery is engaged and also powers vehicle accessories.
- **DC/DC converter:** This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.
- **Electric generator:** Generates electricity from the rotating wheels while braking, transferring that energy back to the traction battery pack. Some vehicles use motor generators that perform both the drive and regeneration functions.
- **Electric traction motor:** Using power from the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.
- **Exhaust system:** The exhaust system channels the exhaust gases from the engine out through the tailpipe. A three-way catalyst is designed to reduce engine-out emissions within the exhaust system.
- **Fuel filler:** A nozzle from a fuel dispenser attaches to the receptacle on the vehicle to fill the tank.
- **Fuel tank (gasoline):** This tank stores gasoline on board the vehicle until it's needed by the engine.

- **Internal combustion engine (spark-ignited):** In this configuration, fuel is injected into either the intake manifold or the combustion chamber, where it is combined with air, and the air/fuel mixture is ignited by the spark from a spark plug.
- **Power electronics controller:** This unit manages the flow of electrical energy delivered by the traction battery, controlling the speed of the electric traction motor and the torque it produces.
- **Thermal system (cooling):** This system maintains a proper operating temperature range of the engine, electric motor, power electronics, and other components.
- **Traction battery pack:** Stores electricity for use by the electric traction motor.
- **Transmission:** The transmission transfers mechanical power from the engine and/or electric traction motor to drive the wheels.