BHADRAK ENGINEERING SCHOOL & TECHNOLOGY (BEST),
ASURALI, BHADRAK

Renewable Energy Systems (Th- 04-B)

(As per the 2020-21 syllabus of the SCTE&VT, Bhubaneswar, Odisha)

Sixth Semester

Electrical Engg.

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RENEWABLE ENERGY SYSTEMS

CHAPTER-WISE DISTRIBUTION OF PERIODS & MARKS

Sl No	Chapter No	Topics	Periods as per syllabus	Expected Marks
01	01	Introduction to Renewable energy	05	15
02	02	Solar Energy	15	25
03	03	Wind energy	12	20
04	04	Biomass Power	12	25
05	05	Other Energy Sources	16	25
Total			60	110

CHAPTER NO.-01
INTRODUCTION TO RENEWABLE ENERGY

Learning Objectives:

1.1. Environmental consequences of fossil fuel use.
1.2. Importance of renewable sources of energy.
1.3. Sustainable Design and development.
1.4. Types of RE sources.
1.5. Limitations of RE sources.
1.6. Present Indian and international energy scenario of conventional and RE sources

Renewable Energy

- Renewable energy is often referred to as clean energy that comes from natural sources or processes that are constantly replenished.Example-Solar Energy, Wind Energy.
- Non-renewable or dirty energy are available in limited amounts and take long time to replenish. Example- fossil fuels such oil, gas,coal.

1.1Environmental Consequences of Fossil Fuel Use.

- These are energy rich substances formed from long buried plantsand micro-organisms. Example- coal, crude oil, natural gas.
- The use of fossil fuels has the following Environmentalconsequences

Emission-

- Fossil fuels are burned to release energy being rich in carbon concentration they release CO2 and CO by incomplete combustion of carbon. Fine particle emissions known as particulate matter are also released

Effects-

- Increase in CO2 concentration in the atmosphere makes it warmer leading to global warming effect, these results in drastic climatecondition such as floods, draughts etc.

- Air pollutants such as NOx and SOx can travel long distances, chemicallyreact in the atmosphere to produce acid rain and ozone.

1.2 Importance of Renewable Sources of Energy

- Large inexhaustible source.
- Available in nature free of cost.
- Clean source of energy.
- Availability varies with respect to time, geographic, location.
- They have low gestation period
- Can be developed into modular units.

1.3 Sustainable Design and Sustainable Development

- Global environmental degradation is one of the most seriousthreats faced by mankind.
- One of the international responses to global environmental problems is the Framework Convention on Climate Change wasratified and came into effect in March 1994.

- The convention aimed at reducing the emission of CO_2 andstabilizing it in developed countries.
- Attempts to restrict the use of fossil fuels for environmentalreasons are likely to have a negative impact on economic development and the overall availability of energy. The three E's – environment, energy, and economic developmentare closely interrelated.
- Herman Daly a famous economist, laid down three conditions forsustainability.

1. The consumption rate of renewable resources is not higherthan its recovery rate.
2. The consumption rate of non- renewable resources is not higher than the rate of increase in renewable resource supply.
3. The emission of pollutants is within the absorption capacityof the environment.

- A substantial reduction in resource consumption and emission of pollutants is essential for the development of a sustainable humansociety.

1.4 Types of Renewable Energy Source

There are seven types of renewable energy source. They are as follows.

1. Solar Energy.
2. Wind Energy.
3. Biomass Energy
4. Geothermal Energy.
5. Ocean Tidal Energy.
6. Ocean wave Energy.
7. Ocean Thermal Energy Conversion.

1. Solar Energy

- Solar energy can be a major source of power and can be utilized byusing thermal and photovoltaic conversion system.
- Its technologies are broadly characterized as either passive solaror active solar depending on how they capture or distribute solar energy or convert it into solar power.
- Active solar techniques include use of photovoltaic system, concentrated solar power and solar water heating to harnessenergy.
- Passive solar techniques include orienting a building to the sun,selecting materials with favorable thermal mass or light dispersing properties.
- The solar radiation received on earth surface on a bright sunny dayat noon is approximately $1KW/m^2$.
- According to an estimate, if all buildings of the world are covered with solar PV panels, it can fulfill the electrical power requirements of the world.

2.Wind Energy

- Wind Energy is the use of wind to provide mechanical powerthrough wind turbines to turn generators for electrical power.
- Wind energy is a popular sustainable, renewable source of power.Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network.
- The power available in the wind flowing over the earth surface is estimated to be$1.6*10^7$MW, which is more than the present energyrequirement of the world.
- Wind power has emerged as the most economical of all renewableenergy sources and it is the fastest growing energy sources.
- It accounts for approximately 19% of electricity production in Denmark,9% in Spain and Portugal and 6% in Germany and theRepublic of Ireland.

3.Biomass Energy

- Energy resources available from animal and vegetation are called biomass energy resources.
- The principal biomass are trees, cultivated plants grown for energy are urban waste, algae and other vegetation from oceans and lakes,rural waste.
- Biomass may be transformed by chemical or biological processesto produce bio fuels.
- Upgrading raw biomass to higher grade fuels can be achieved bydifferent methods, broadly classified as thermal, chemical, or biochemical.

4.Geothermal Energy

- Geothermal energy is derived from huge amount of stored thermalenergy in the interior of earth. Its overall contribution in total energy requirement is negligible.
- Global use of geothermal power is growing annually at a rate of 3%electrical and 7.5% thermal.
- Geothermal power is cost- effective, reliable, sustainable and environment friendly.
- The oldest geothermal power generator is located at Lordarello inItaly.

5.Ocean Tidal Energy

- Tidal energy is a form of hydro power that converts energy of Ocean tides into electricity or other useful forms of power.
- Tides are more predictable than wind energy and solar power.
- Tidal power is taken from Oceanic tides. Tidal forces are periodicvariations in gravitational attraction exerted by celestial bodies.
- The first and biggest tidal power plant was built in France havingcapacity of 240MW.

6.Ocean Wave Energy

- Wave power refers to the energy of ocean surface waves and thecapture of that energy to do useful work.
- Good wave power locations have a flux of about 50 kilowatts permeter of shoreline.
- The world's first 2250MW commercial wave farm is based inPortugal.

7.Ocean Thermal Energy Conversion

- OTEC uses ocean thermal gradient between cooler deep and warmer shallow or surface seawaters to run a heat engine a produce useful work.
- The resource potential for OTEC is considered to be much larger than other ocean energy forms.
- OTEC systems are of two types closed -cycle, open-cycle
- OTEC technology is still in its infant stage. Conceptual design of small OTEC plants have been finalized.
- Their commercial prospective is very low.

1.5 Limitations of RE Source

- Energy available is in dilute form from these sources.
- Cost of harnessing energy from these sources is high.
- Availability is uncertain.
- Difficulty in transporting such forms of energy.

1.6 Present India and International Scenario of Conventional and RE Sources:

The global energy supply and consumption is given in the table below

Table: Annual primary energy consumption by fuel in Mtones

Country	Oil	Natural Gas	Coal	Nuclear Energy	Hydro Electric	Renewable energy	Total
USA	884	594	615.4	83.8	28.2	77.3	2,283
Canada	152	83	31	9.4	68.2	NA	344
France	83	45	12.4	43.9	14.8	67.4	266.5
Russian Foundation	494	438	153	16.3	35.6	NA	1136.9
United Kingdom	76.8	71.2	39.1	20.1	1.3	NA	2805
China	436	98.1	2500	12.3	58.5	103.1	3208
India	205.5	47.1	352	4.1	11.4	98.4	718.5
Japan	199	93	71.6	25.8	8.3	98.1	495.8
Others	1807.3	1276.6	114.5	501.4	70.0	524.1	4293.9
Total	4337.6	27446	3889.3	717.1	296.7	968.4	12995.1

Mtone -Million tons of oil equivalent.

India's Energy Reserves

- The Ministry of statistics and program Implementation, Govt of India,2012 has produced the following data.

Coal	Main fossil energy reserves in India at 286 billion tons and 41billion tons of lignite. These are available in eastern and southern belts of the country.
Crude Oil	Limited to 757 million tons m^3
Natural Gas	Limited to 1241 billion tons m^3
Nuclear	Uranium can fuel only 10,000 MW pressurized heavy water reactors (PHWR).

- India depends primarily on Uranium to run the reactors. Thorium is also another source for nuclear energy which runs in fast breeder reactor.
- The fast breeder reactor has been rejected by Europe and USA due to safety concerns

Renewable Energy Sources

The capacity addition in renewable energy was about 27,300 MW in 2012.

Technology	Capacity Installed in MW by 2012
Coal	11,202
Hydro	38,990
Renewable	27,300

Gas	18,381
Nuclear	4,780
Total	201,473

India's installed power generation capacity

Thermal	54.4%
Hydro	21.60%
Renewable	10.90%
Gas	10.10%
Nuclear	2.7%

- So, total renewable energy's contribution becomes almost 33% (includes Hydro power), plan wise grid connected renewable energy contribution is given in table below.

Power densities of renewable energy sources and the conventional energy forms.

Renewable Energy Sources	**In KW/m^2**
Wave	<100
Extra-terrestrial solar radiations	<1.35
Wind	<3
Solar radiation	0.2
Tidal	0.002
Biomass Production	0.002
Geothermal Heat	0.00006

Conventional Energy	**In KWh/m^2**
Hot plate	100
Coal	500
Nuclear	650
Power cable	1000,000

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

1. **Define Renewable Energy and Non-Renewable Energy.[s-23]**

Ans -Renewable energy is often referred to as clean energy that comesfrom natural sources or processes that are constantly replenished.
Example-Solar Energy, Wind Energy.
Non-renewable or dirty energy are available in limited amounts and takelong time to replenish.
Example- fossil fuels such oil, gas, coal.

2. **Write the importance of renewable source of energy.[s-23]**

Ans- The following are the importance of renewable energy sources.

- Large inexhaustible source.
- Clean source of energy.
- Availability varies with respect to time, geographic, location.
- They have low gestation period
- Can be developed into modular units.
- Available in nature free of cost

3 **What are the types of RE source?**

Ans-There are 7 types of RE Source.

- Solar Energy
- Wind Energy
- Biomass Energy
- Geothermal Energy
- Ocean Tidal Energy
- Ocean Wave Energy
- Ocean Thermal Energy Conversion

4. **What are the limitations of RE source? [s-24]**

Ans-The following are the limitations of RE sources.

- Energy available is in dilute form from these sources.
- Cost of harnessing energy from these sources is high.
- Availability is uncertain.
- Difficulty in transporting such forms of energy.

POSSIBLE LONG TYPE QUESTIONS

1. Write in brief about the types of RE source.
2. Briefly explain the energy scenario in India and world.
3. Write shortnote on sustainable design & development.[s-23]

CHAPTER NO.-02
SOLAR ENERGY

Learning Objectives:

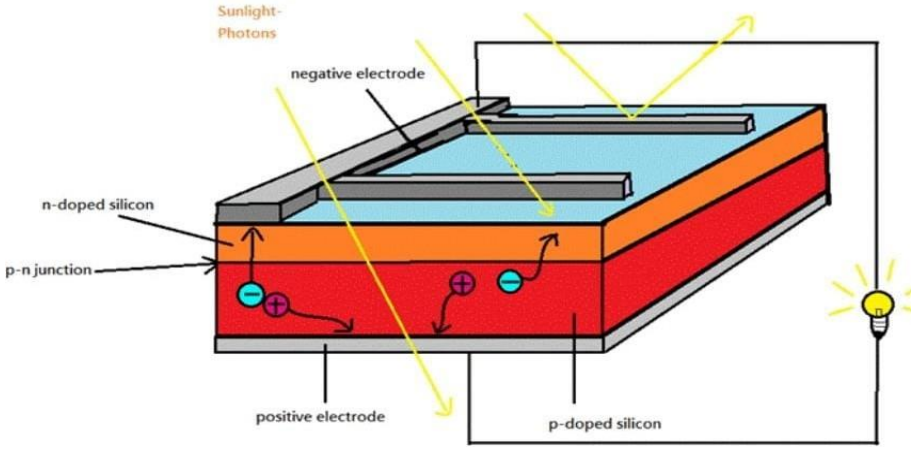
2.1. Solar photovoltaic system-Operating principle.
2.2. Photovoltaic cell concepts
2.2.1. Cell, module, array, Series and parallel connections. Maximum power point tracking (MPPT).
2.3. Classification of energy Sources.
2.4. Extra-terrestrial and terrestrial Radiation.
2.5. Azimuth angle, Zenith angle, Hour angle, Irradiance, Solar constant.
2.6. Solar collectors, Types and performance characteristics,
2.7. Applications: Photovoltaic - battery charger, domestic lighting, street lighting, water pumping, solar cooker, Solar Pond.

2.1Solar Photo Voltaic System-Operating Principle

- Solar photovoltaic (PV) system converts solar energy directly intoelectrical energy.
- The basic conversion device used is solar photo voltaic cell or solarcell.

Operating Principle

- Semiconducting material in the PV cell are doped to form P-Nstructure as an internal electric field.
- The p-type(positive) silicon has a tendency to give up electrons and acquire holes, while n-type (negative) silicon accepts electrons.When sunlight hits the cell the electrons in the semiconductor getsexcited to form electron-hole pair.
- Since there is an internal electric field, these pairs are induced toseparate as a result the electrons move to negative electrodes while holes move to the positive electrode.
- A conducting wire connects the negative electrode, the load, and the positive electrode in series to form a circuit, as a result, an electric current is generated to supply the external load.



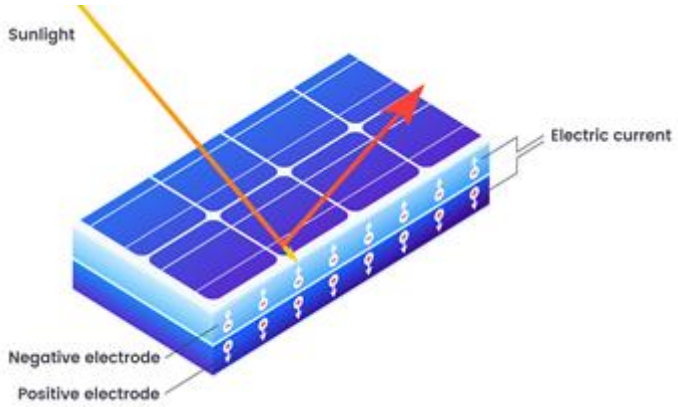
2.2PhotoVoltaic Cell Concept

- Photovoltaic=Photo(light)+Volt (Electric Potential)
- Photovoltaic cell is a semiconductor device that converts lightinto electrical energy.
- The voltage induced by the PV cell depends upon the intensity oflight incident on it.
- When the photons are incident on the electron they becomeenergized and start emitting.
- The energized electrons are photoelectrons and the phenomenon of emission of electrons is photoelectric effect.

2.2.1Cell, module, array, Series and parallel connections. Maximum power point tracking (MPPT).

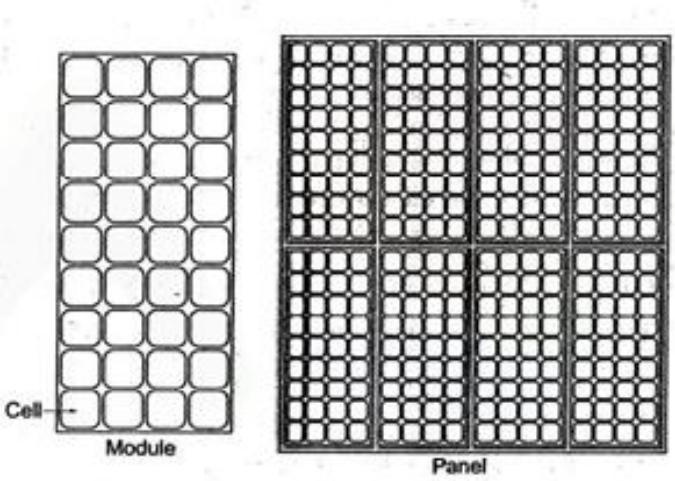
Solar Cell:

- It is defined as an electrical device that converts light into
- electrical energy by photovoltaic effect.
- It is a form of photovoltaic cell whose electrical characteristicsvary when exposed to light.
- It is used in electronic toys, handheld calculator and portable radios.



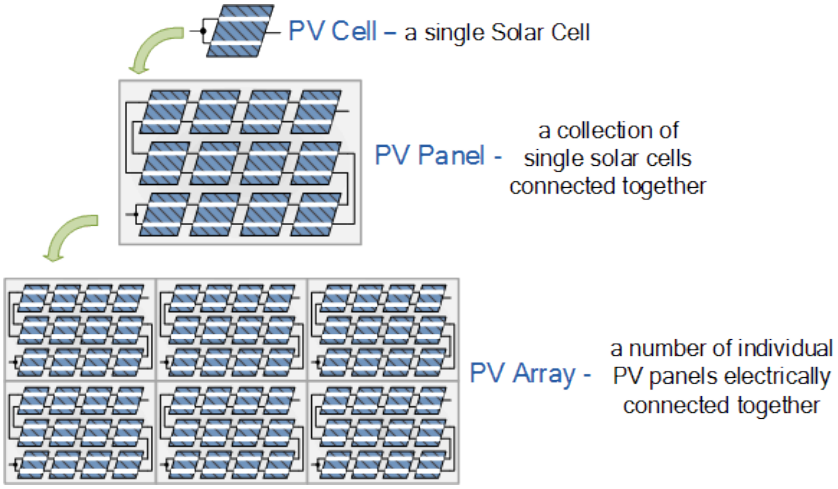
Solar Panel:

- It is an assembly of photovoltaic cells to achieve required voltage and current. A solar panel is group of several modules connected in series- parallel combination in a frame that can be mounted on a structure.

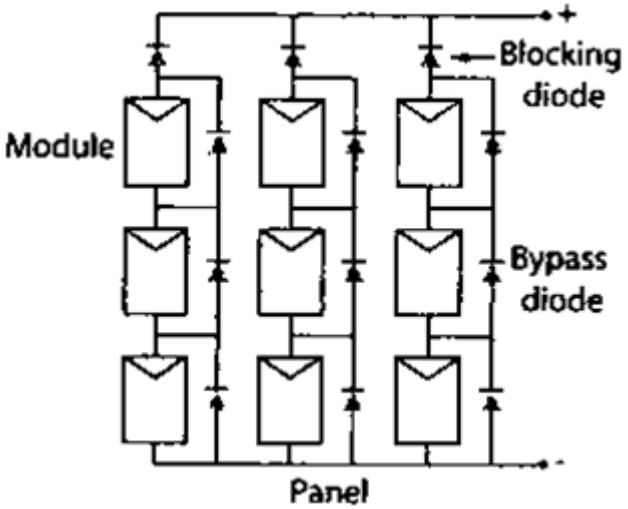


Solar PV Array:

- A large number of interconnected solar panels is known as solarPV array.



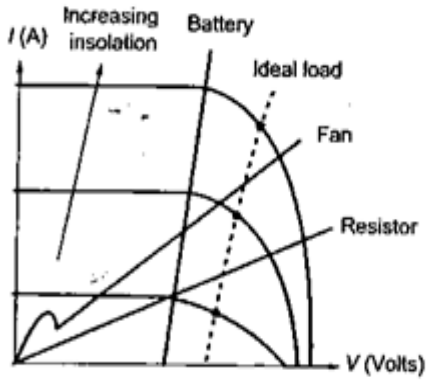
Series and Parallel connections:

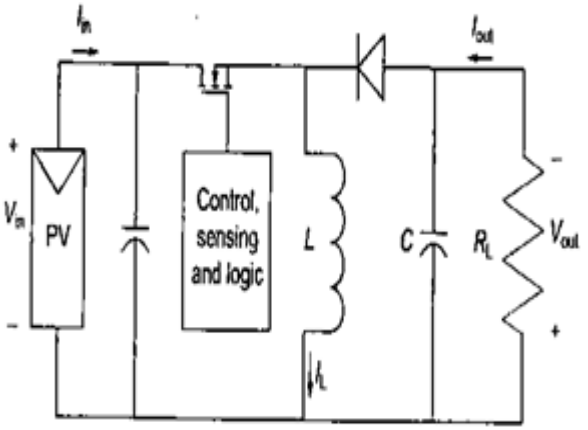


- The above figure shows the series -parallel connection of modulesin a panel.
- In parallel connection blocking diodes are connected in series witheach series string of modules. If any string fails the power output of remaining string is not absorbed by the failed string.
- Also bypass diodes are installed across each module, if one module fails, output of remaining modules in a string bypass thefailed module.

Maximum Power Point Tracker (MPPT)

- It is a device used in solar PV system to extract maximum powerfrom solar PV module throughout all day.
- When a solar PV system is deployed for practical applications, the IV characteristics keeps on changing with isolation and temperature.
- In order to achieve maximum power, the load must adjust itselfaccordingly to track the maximum power point
- Generally, MPPT is an adaption of dc-dc switching voltage regulator, coupling to the load for maximum power transfer may require either providing a higher voltage at lower current or lower voltage at high current.
- A buck-boost scheme along with voltage and current sensor aretied into a feedback loop using a controller to vary the switching time.
- The output voltage of a buck- boost converter is given byVout=(D/1-D) Vin
- Where D is duty cycle of MOSFET.





2.3Classification of Energy Sources

Solar energy is the mother of all forms of energy i.e.conventional or non-convectional, renewable or non-renewable the only exception being nuclear energy.

Various sources of energy find their origin in the sun are asfollows

- Wind Energy.
- Biomass Energy.
- Tidal Energy.
- Ocean Wave Energy.
- Ocean Thermal Energy.
- Fossil fuels and other organic chemicals.
- Hydro Energy.

2.4 Extraterrestrial and Terrestrial Radiation:

- The solar radiation incident on the outer atmosphere of earth isknown as Extraterrestrial radiation.
- Solar constant Isc is defined as the energy received from the sunper unit time, on a unit area of surface perpendicular to the direction of propagation of the radiation at the top of the atmosphere and at the earth's mean distance from the sun.
- The World Radiation Centre has adopted the value of solarconstant as 1367W/m^2 (1.940 cal/cm^2min,432 Btu/ft^2h or4.921MJ/m^2h).
- Iext. = Isc (1.0+0.033cos(360n/365)) W/m^2
  Where Iex=Extraterrestrial radiation Isc=Solar constant.
- The solar radiation that reaches the earth surface after passing throughearth's atmosphere is known as Terrestrial Radiation.

2.5 Azimuth angle, Zenith angle, Hour angle, Irradiance, Solar constant.

Solar Azimuth Angle (γs)

- It is the angle on a horizontal plane, between the line due southand the projection of sun ray on the horizontal plane.
- It is taken positive when taken measured from south towards west.

Surface Azimuth Angle (γ)

- It is the angle on a horizontal plane, between the line due southand the horizontal projection of normal to the incident plane surface (collector).
- It is taken positive when taken measured from south towardswest.

Zenith Angle (Θs)

- It is the angle between the angle between the sun's ray and theperpendicular (normal) to the horizontal plane.

Hour Angle (ω)

- Hour angle at any moment is the angle through which the earth must turn to bring the meridian of the observer directly in line withthe sun's rays.
- ω= (solar time-12) (in hours) *15 degree

Solar Constant (Isc)

- It is defined as the energy received from the sun per unit time, on aunit area of surface perpendicular to the direction of propagation of the radiation at the top of the atmosphere and at the earth's mean distance from the sun.
- The World Radiation Centre has adopted the value of solarconstant as 1367W/m^2(1.940 cal/cm^2min,432 Btu/ft^2h or4.921MJ/m^2h)

Solar Irradiance

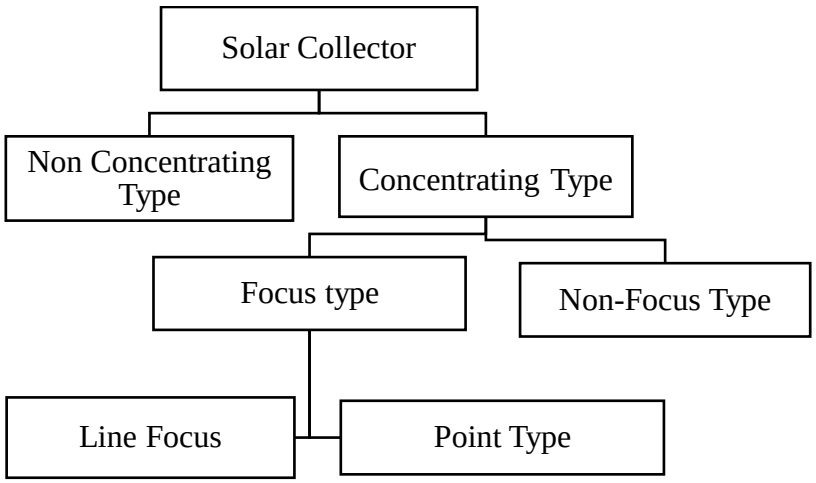
- It is the power per unit area received from the sun in the form of electromagnetic radiation as measured in the wavelength range ofthe measuring instrument.
- The solar irradiance is measured in watt per square meter(W/m^2)in SI units.

2.6Solar Collectors, Types and Performance Characteristics

- A solar thermal collector forms the first unit in a solar thermal system. It absorbs solar energy as heat and transfer it to the heat transfer fluid. The heat transfer fluid delivers this heat to a thermal storage tank/boiler/ heat exchanger.

Classification

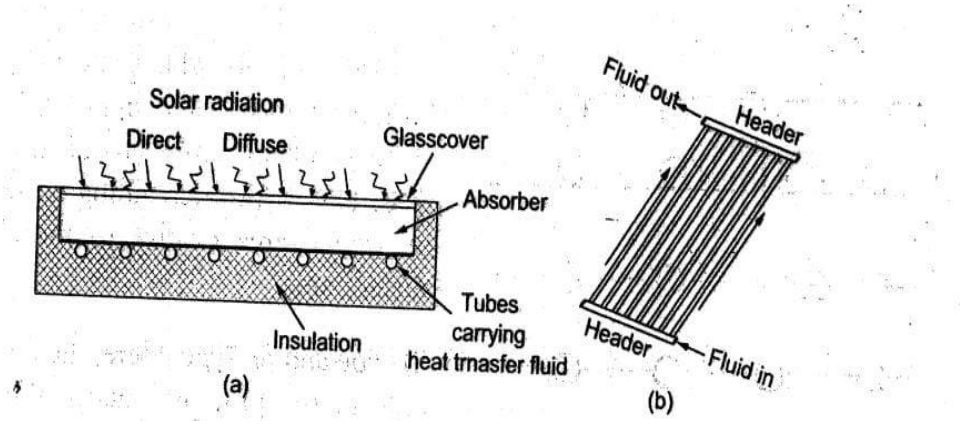
- The overall view of classification of solar collectors into categoriesand subcategories.



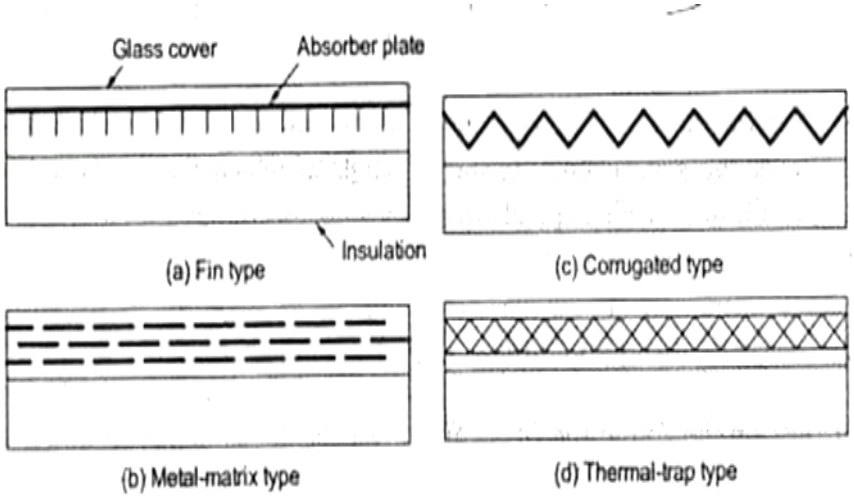
- Non concentrating type absorbs the radiation as it is received onthe surface of the collector.
- These collectors absorb both beam and diffused radiation, as these collectors don't use any optical system the concentrationratio is 1.

Liquid flat –plate collector:

- A flat plate collector is placed at a location in a position such that its length aligns with line of longitude and tilted towards south to have maximum collection.
- A flat plate collector is placed at a location in a position such that its length aligns with line of longitude and tilted towards south to have maximum collection.
- The basic elements of these collectors are transparent cover of glass or plastic, blackened absorber plate, tube channels, weather tight insulated container to enclose the components.
- The absorber plate is of three types that is pipe and fin type, rectangular or cylindrical full sandwich type, roll band or semi- sandwich type.



Flat plate air heating collector:

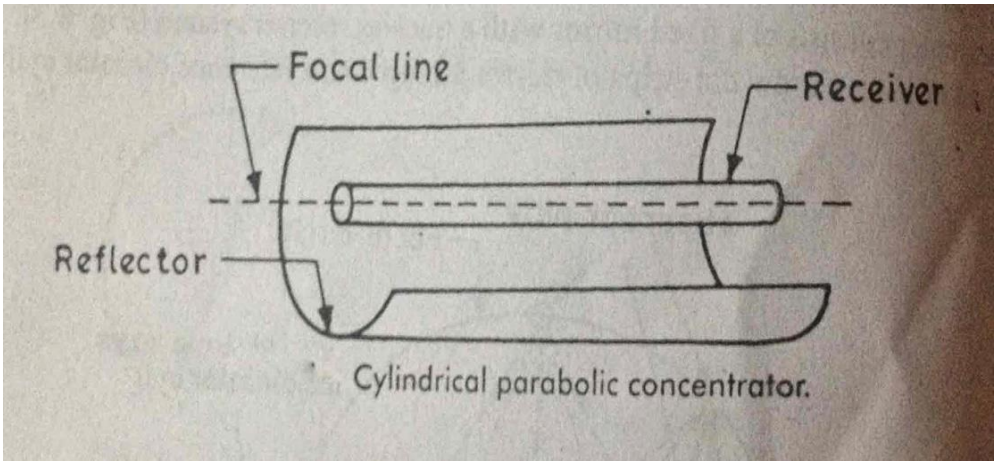


- It is very similar to liquid flat plate collector with change in configuration of absorber and tube.
- The value of heat transfer- coefficient between absorber plate and the air is low.
- The main application is drying agricultural and industrial purpose and space heating.
- Concentrating type-it first increases the concentration of radiation per unit area before absorbing it.
- It is again of two types

1. Focus type.
2. Non focus type.

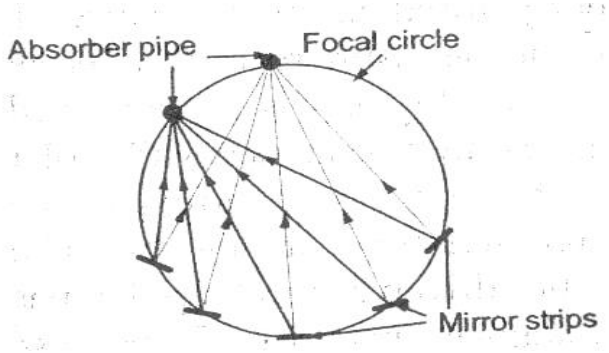
Focus type (Line focus)

Cylindrical parabolic concentrator.

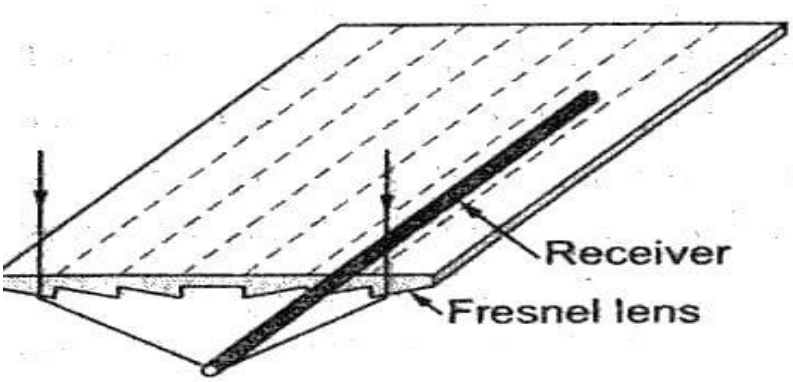


- It consists of a cylindrical parabolic trough reflector and a metaltube receiver at its focal line.
- The receiver tube is blackened outside to increase absorption.
- It may be oriented in any of three directions i.e. east-west, north-south, polar.
- The concentration ratio is in the ratio of 5-30.

Fixed mirror solar concentrator.



- The concentrator consists of fixed mirror strips arranged on acircular reference cylinder with a tracking receiver tube.
- The concentration ratio is approximately same as the number ofmirror strips.

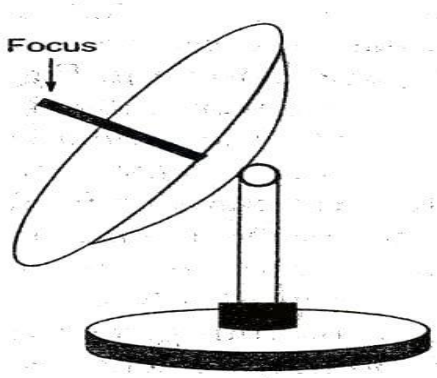


Linear Fresnel lens collector.

- In this collector a Fresnel lens, which consists of fine, linear grooves on the surface of reflecting material on one side and flaton the other side is used.
- The concentration ratio of10 to 30 and yields temperature between150 to 300˚c.

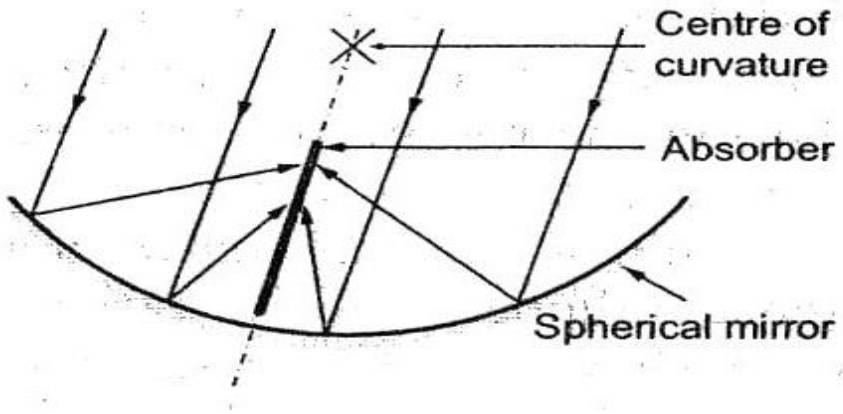
Point focus:

Paraboloidal Dish Collector:



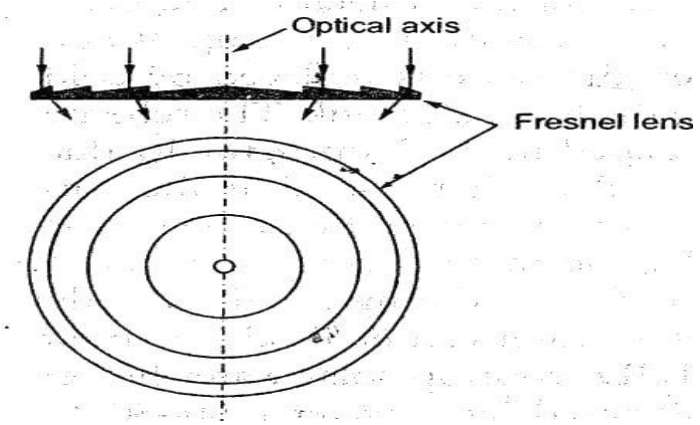
- When a parabola is rotated about its optical axis, a parabola shape is obtained. This requires two axis tracking.
- It can have a concentration ratio from 10 to few thousands and yield a temperature up to 3000°c

Hemispherical Bowl Mirror Concentration:



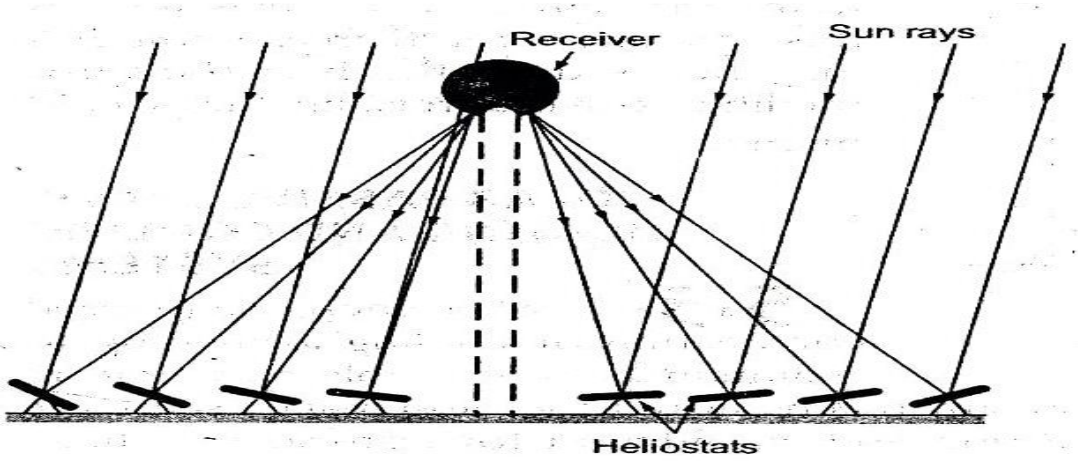
- It consists of a hemispherical fixed mirror, a tracking absorber and a support system.
- This type of concentrator gives lesser concentration than obtained in paraboloidal concentrator

Circular Fresnel lens concentrator:



- These lenses are generally used where high flux is required.
- Its concentration ratio may be as highas2000, but is less than thatobtained from paraboloidal reflector.

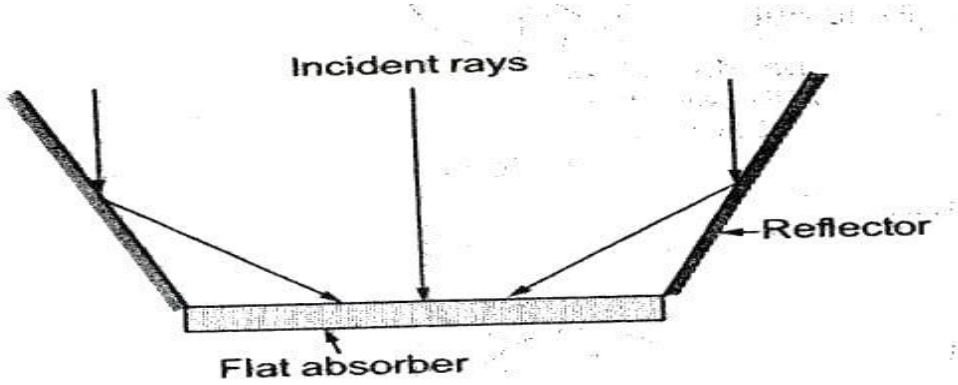
Central tower receiver:



- In this type if collector, the receiver is located at the top of a tower.
- Beam radiation is reflected on it through a number of independently controlled flat mirrors called heliostats.
- Concentration ratio as high as 3000 can be achieved.

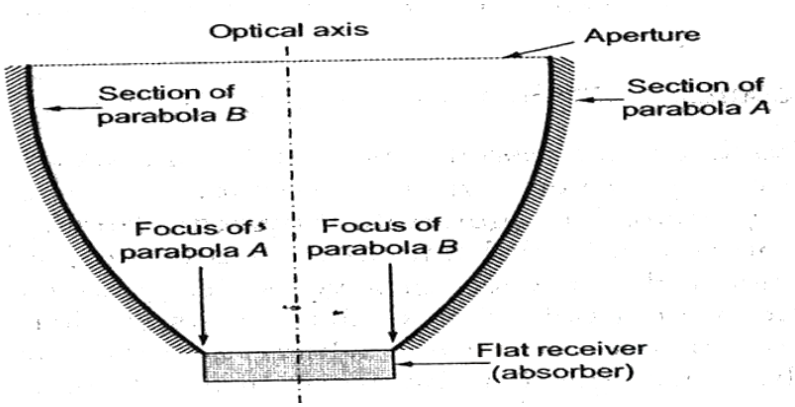
Non-focus type

Modified flat plate collector:



- By providing plane reflector at the edges of a flat plate collector to reflect additional radiation into the receiver, the concentration of solar radiation can be increased.
- The concentration ratio has a maximum value of 4.

Compound Parabolic Concentrator:



- It consists of two parabolic mirror segments, attached to a flat receiver. It has large acceptance angle and need to be adjusted intermittently.
- The concentration ratio is in the range of 3-7.

Performance Indices:

The important performance indices of a solar collector are

1.Collector Efficiency- It is defined as the ratio of the energy actually absorbed and transferred to the heat transport fluid by the collector to the energy incident on the collector.

2.Concentration Ratio-It is defined as the ratio of the area of aperture of the system to the area of the receiver.

3.Temperature Range-It is the range of temperature to which the heat transport fluid is heated up by the collector.

2.7 Applications: Photovoltaic - battery charger, domestic lighting, street lighting, water pumping, solar cooker, Solar Pond.

1.BATTERY CHARGER:

- A solar charger is a charger that employs solar energy to supply electricity to device or batteries
- They are generally portable.
- Solar chargers can charge lead acid or Ni-Cd battery bank up to 48v.
- A series of solar cells is installed in a stationary location (rooftops of homes, base-station locations on ground) and can be connected to a battery bank to store energy for off-peak usage.
- Example-public solar chargers permanently installed in public places as parks, streets.

2.DOMESTIC LIGHTING:

- The best solar lighting system harnesses the energy of sun for lighting up homes.
- The solar cells transform the solar energy into electricity and this electricity is preserved in batteries.
- The components of this system include solar cells, solar battery, controller, lamps.
- The main advantages that it fits in budget and environment friendly.

3.STREET LIGHTING:

- Solar street light uses photo voltaic technology to convert sunlight into dc electricity through solar cells.
- The solar street lighting system comprises of PV module, battery box, lamp with charge controller, lamp post.
- It is ideal for street lighting in remote village.
- The system is provided with automatic on/off time switch for dusk to dawn operation.
- It has lower power consumption, higher intensity, saves electricity cost.

4.WATER PUNMPING:

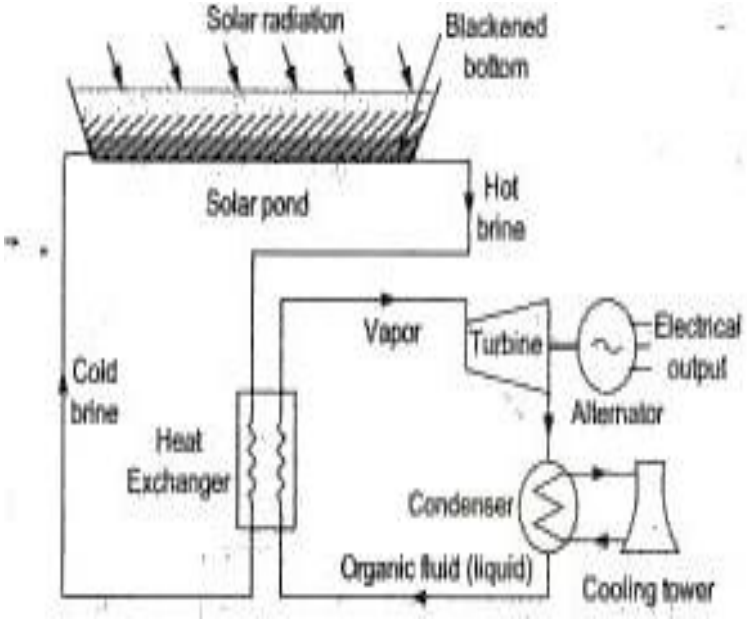
- A solar thermal water pump consists of a flat plate collector, non-focusing type collectors or sun tracking collectors.
- Water is used as a heat transport fluid. Surplus heat is stored in the thermal storage to be used later the high-pressure vapor of the working fluid expand in the turbine, condense in the condenser and return in the heat exchange.

5.SOLAR COOKER:

- Thermal energy requirements for cooking forms a major share of total energy consumed especially in rural areas.
- Harnessing solar energy for cooking purpose is an attractive and relevant option
- On the basis of design, it can be classified into four types

i.e., box type solar cooker, dish type solar cooker, community solar cooker, advanced solar cooker.

6.SOLAR POND ELECTRIC POWER PLANT:



- A solar pond serves the purpose of a large flat- collector as well as long term thermal storage and can provide sufficient heat for the entire year. The black bottom serves as an absorber and layer of still water above it is used as an insulator rather than normal glazing and air space.
- In large area pond a vertical slat gradient is maintained
- . The salt concentration varies from 20-30 percent at the bottom to almost zero at the top.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWERS

Q 1- Define solar photo voltaic system.

Ans- Solar photovoltaic (PV) system converts solar energy directly into electrical energy.
The basic conversion device used is solar photo voltaic cell or solar cell.

Q- 2 What is Solar Cell?

Ans-It is defined as an electrical device that converts light into

- electrical energy by photovoltaic effect.
- It is a form of photovoltaic cell whose electrical characteristics vary when exposed to light.
- It is used in electronic toys, handheld calculator and portable radios.

Q-3 Define solar panel?

Ans-It is an assembly of photovoltaic cells to achieve required voltage and current.
A solar panel is group of several modules connected in series- parallel combination in a frame that can be mounted on a structure.

Q-4 What is an PV array? [s-23]

Ans- A large number of interconnected solar panels is known as solar PV array.

Q-5 What is solar thermal collector?

Ans- A solar thermal collector forms the first unit in a solar thermal system. It absorbs solar energy as heat and transfer it to the heat transfer fluid. The heat transfer fluid delivers this heat to a thermal storage tank/boiler/ heat exchanger.

Q-6 Define Zenith Angle

Ans- It is the angle between the angle between the sun's ray and the perpendicular (normal) to the horizontal plane.

Q-7 Define Solar Irradiance & state it's SI unit. [s-23]

Ans- It is the power per unit area received from the sun in the form of electromagnetic radiation as measured in the wavelength range of the measuring instrument. The solar irradiance is measured in watt per square meter(W/m^2) in SI units.

Q-8 Define altitude angle [s-24]

Ans- This is the angle between the line that points to the sun & the horizontal .
-It is the complement of the Zenith angle .

POSSIBLE LONG TYPE QUESTIONS

1. Describe in brief about Maximum Power Point Tracker with neat diagram. [S-23]
2. Explain about solar collector and its type.
3. Write short notes on

a) Solar Charger.

b) Solar Pond.

4. write short note on solar cooker. [S-24]

CHAPTER NO.-03
WIND ENERGY

Learning Objectives:

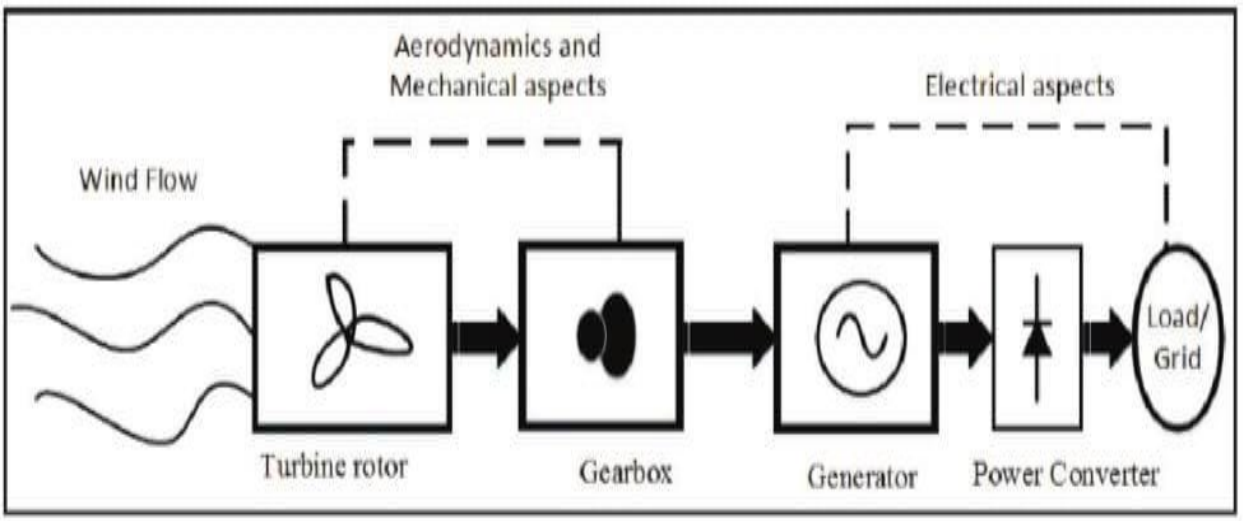
3.1. Introduction to Wind energy.
3.2. Wind energy conversion.
3.3. Types of wind turbines
3.4. Aerodynamics of wind rotors.
3.5. Wind turbine control systems; conversion to electrical power:
3.6. Induction and synchronous generators.
3.7. Grid connected and self-excited induction generator operation.
3.8. Constant voltage and constant frequency generation with power electronic control.
3.9. Single and double output systems.
3.10. Characteristics of wind power plant.

3.1 Introduction to wind energy:

- Wind energy is the kinetic energy associated with movement of large masses of air. These motions result from uneven heating ofthe atmosphere by the sun, creating temperature, density and pressure differences.
- Wind Energy is harnessed as mechanical energy with the help ofwind turbine. The mechanical energy obtained can either be used such as to operate farm appliances and water pumping or converted to electric power and used locally or fed to a grid.
- The generator coupled to a wind turbine is called aero-generator.

3.2.Wind energy conversion:

- Physical energy (kinetic) of wind is first captured by speciallydesigned blade of turbine to rotate it. Mechanical energy of rotating blades is transferred to the rotor of the generator withthe help of shaft.
- The generator then converts the mechanical energy intoelectrical energy. This electrical energy is sent to grids orstandalone load through a transformer.
- A general layout for WECS depicting different parts and system shown in the figure



Turbine Rotor-

- The production of power due to wind turbine depends upon the interaction between wind and rotor. The rotorconsists of large turbine blades and hub.

Gear Box-

- The rotational speed of wind turbine is typically around 100 RPM, which is not sufficient to produce electricity as most generators need the speed of 1000-3600 RPM. Gearbox is used to increase the speed of the generator rotor to1000-3600 RPM to make the generator functional.

Generator-

- The mechanical energy of wind turbine rotor is converted into electrical energy through generator. The ac generator (asynchronous and synchronous) are generally foundin wind turbine motor.

Power Converter-

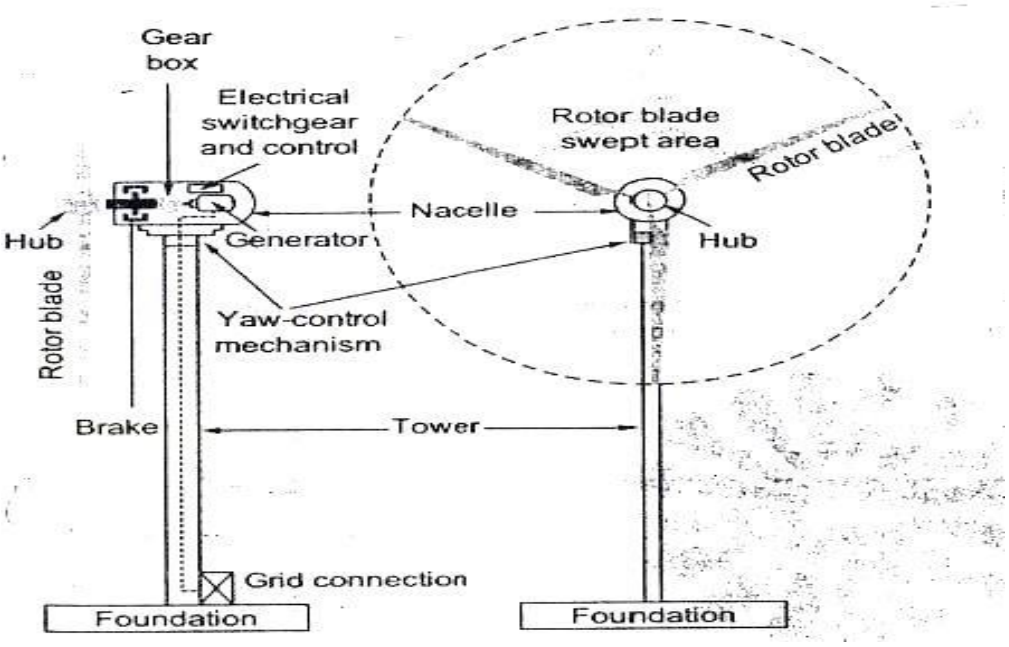
- It eliminates the need of gearbox which is the main reason of power losses and failure in wind turbine system. To meet the huge growing demand of the wind energy conversion system power converter are developed to achieve power conversion at higher voltage level.

3.3Types of Wind Turbines

- Wind turbines are broadly classified into two categories
- Horizontal Axis Wind Turbine. (HAWT)
- Vertical Axis Wind Turbine. (VAWT)

Horizontal Axis Wind Turbine. (HAWT)

- When the axis of rotation is parallel to air stream it is calledHorizontal Axis Wind Turbine. (HAWT).
- HAWTs have emerged as the most successful type of turbines. These are used for commercial energy generationin many parts of the world.
- The constructional details of a three-blade rotor, horizontalaxis wind turbine is shown below. The main parts are as follows.



Turbine Blade-

- It is made of high-density wood or glass fiber and epoxy composites. The blades are slightly twisted from the outer tip to the rotor to reduce the tendency to stall. Diameter ofa typical, MW range modern rotor may be of the order of 100m.
- Modern wind turbines have two or three blades. Two/threerotor HAWT are known as propeller – type wind turbine.

Hub-

- The central solid portion of the rotor wheel is known as hub. All blades are attached to the hub. The mechanism for pitch angle control is also provided inside hub.

Nacelle-

- The rotor is attached to the nacelle and mounted at thetop of a tower. It contains rotor brakes, gearbox, generator and electricalswitchgears and control.

Yaw -control Mechanism-

- The mechanism to adjust the nacelle around the vertical axis to keep it facing the wind is provided at the base of the nacelle.

Tower-

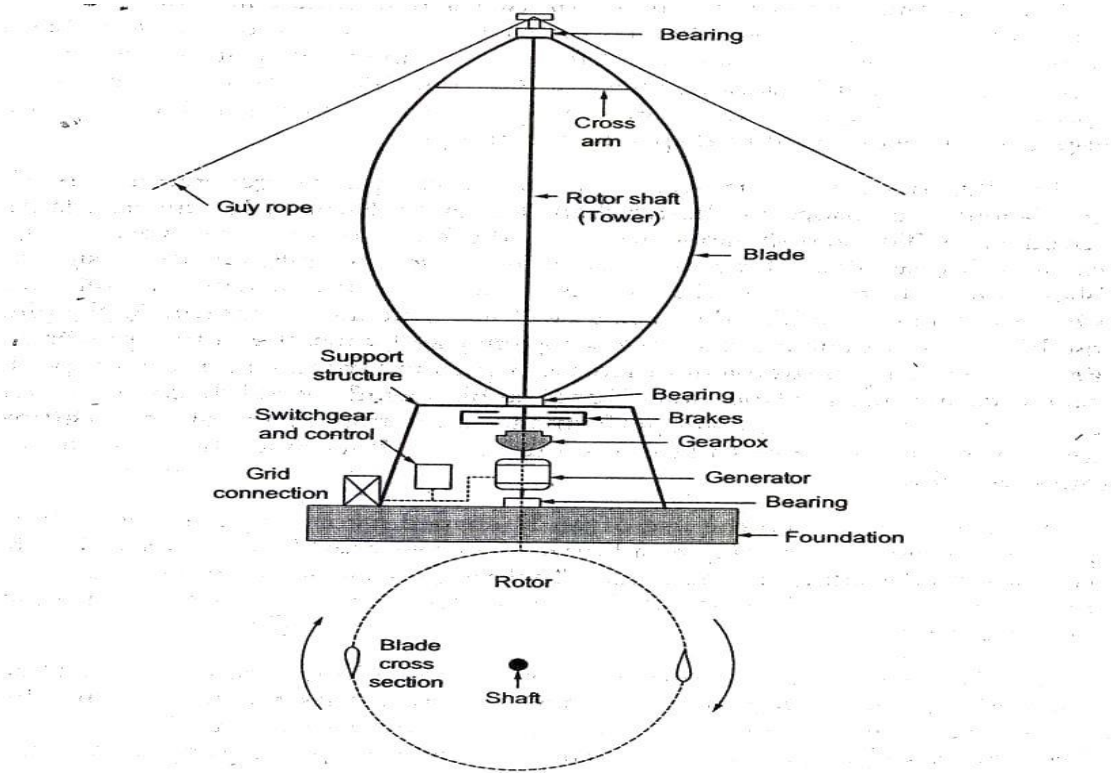
- The tower supports the nacelle and rotor. For mediumand large sized turbines, the tower is slightly taller than the rotor diameter. Both steel and concrete towers are being used. The construction can be either tubular or lattice.

Vertical Axis Wind Turbine. (VAWT):

- When the axis of rotation is perpendicular to the stream it issaid to be vertical axis wind turbine.

The main attraction of a VAWT are as follows

- It can accept wind from any direction eliminating theneed of yaw control.
- The gearbox, generator, etc are located at the groundeliminating the need of heavy nacelle at the top of thetower.
- Inspection and maintenance is easier.
- Overall cost is reduced.
- The main components of a (Darrieus type rotor) VAWT are asfollows



Tower or Rotor Shaft

- The tower is a hollow vertical rotor shaft, which rotates freely about the vertical axis between the top and bottom bearing. The upper part of the tower is supported by guy ropes.
- The height of the tower of a large turbine is around 100m.

Blades:

- It has two or three thin, curved blades like an eggbeater in a profile, with blades curved in a form that minimizes the bending stress caused by the centrifugal forces–so called "Troposkien" profile. The diameter of the rotor isslightly less than the tower height.

Support Structure:

- It is provided at the ground to support the weight of the rotor, gearbox, brakes, electrical switchgear andcontrols and housed within this structure.

3.4. Aerodynamics of Wind Rotors:

- Aerodynamics deals with the movement of solid bodies through the air. Itprovides a method to explain the relative motion between airfoil and air.
- Airfoil is the cross-section of the wind turbine blade when the wind passesover the surface of the rotor blade, then it automatically passes over the longer and upper side of the blades which creates a low pressure are abovethe airfoil.
- The pressure difference between the top and the bottom surface results in aforce called aerodynamic lift that causes the airfoil to rise.
- When air flows over solid bodies, several physical phenomena are noticed such as drag force acting on the objects like trees, electric towers and lift force developed by airplane wings and experienced by dust particles in a windstorm and the blade motion developed by a turbine.
- Drag Force- It is the force exerted on the solid body by the fluid in the directionof flow.
- Lift Force-It is the force exerted on the solid body by the fluid andperpendicular to the direction of flow.
- Wind turbine control systems
- Wind turbine requires certain control mechanism to protect generator and turbine from strong winds and to capture the power as much as possible atlow and medium winds.

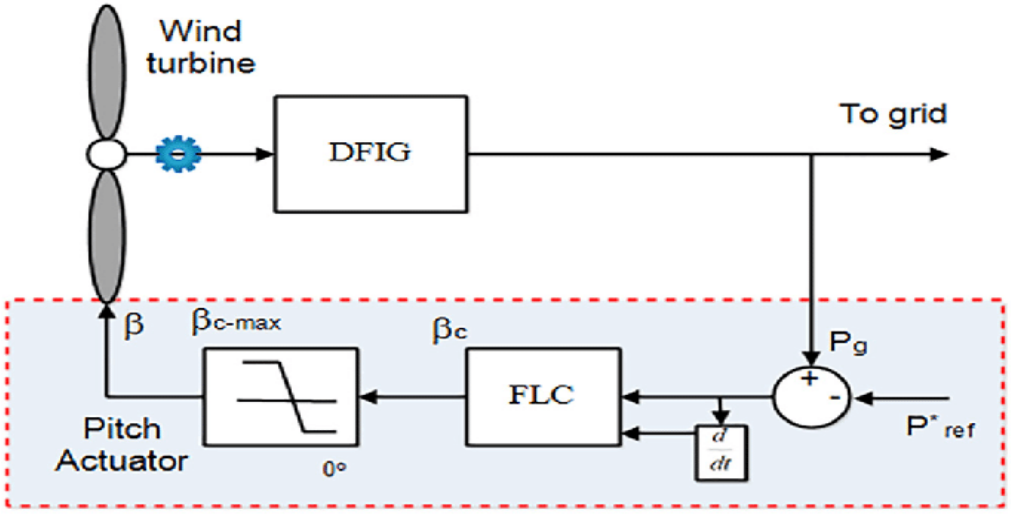
3.5. Wind turbine control systems; conversion to electrical power:

The wind turbine has 4 different control mechanism such as

- Pitch angle control (Y-control).
- Stall (α) control.
- Yaw control.
- Power electronic control.

Pitch angle control (Y-control)

- This system changes the pitch angle of the blades according to the variation of wind speed. It is possible to achieve a high efficiency by continuously aligning the blades in the direction of relative wind.
- The input variable to the pitch controller is a error signal which is the difference between the output electrical power and reference power.
- The pitch controller operates the blades actuator to change the pitch angle.The generator must be able to absorb the mechanical power output of the turbine and deliver output power needs to be simultaneously adjusted.



Stall control:

- It means control of the angle of attack w.r.t increase in wind speed. These areof two types such as passive stall control and active stall control.
- Passive control is used to limit the power output at high winds which isapplied to constant pitch turbines driving induction generators.
- Active stall control involves rotation of blades by a few degrees in the directionopposite to the pitch control machine at high wind speeds.
- This control is also called as deep control.

Yaw Control:

- This control orients the turbine continuously along the direction of wind flow.This is achieved by mounting a small turbine perpendicular to the main turbine in case of large machines and by providing a tail-vain in case of smallmachines.
- Yaw control can also be achieved without any additional mechanism bymounting the turbine downward.

Power Electronic Control:

- The electrical power delivered by the generator to the load can be dynamicallycontrolled in a system incorporating a power electronic interface between the generator and the grid.

Wind Energy to Electrical Energy:

- Wind turbines use blades to collect the wind's kinetic energy. Wind flows overthe blades creating lift which causes the blades to turn. The blades are connected to a drive shaft that turns an electric generator which generates electricity.
- The amount of wind electricity generation has grown significantly in past 30years.
- Advances in wind energy technology has decreased the cost of producing electricity from wind.

3.6. Induction and Synchronous Generators

Induction Generator-

- These are used because of constant frequency output, low capital cost, low maintenance and better transient performance.
- The induction generators require an ac excitation current which is mainly reactive. The current can be drawn from grid or utility bus where the voltage and frequency are determined by the grid or from the generator itself by providing shunt capacitors known as standalone system.
- The variation of shaft speed is absorbed in the slip.

Synchronous Generator-

- Synchronous generators which produce high qualityoutput are universally used for power generation in conventional plants.
- But these are not suitable for wind power plants because of variation in frequency of generated output w.r.t rotor speed. Also, precise rotor speedcontrol is required for synchronization.

3.7. Grid Connected and Self-Excited Induction Generator Operation:

- Induction generators are not self-starting, they require an electric supply to produce rotating magnetic flux. The current can be drawn from grid or utilitybus where the voltage and frequency are determined by the grid or from the generator itself, once it starts producing power the rotating magnetic flux from the stator induces current in the rotor which also produces a magneticfield.
- If the rotor turns faster than the rate of rotating flux, then the machine actslike a generator which produces power at synchronous frequency.

Grid Connected Induction Generator Operation

- The generated power is feed to the supply system when the rotor is drivenabove synchronous speed.
- Machines with cage type rotor feed only through the stator and generallyoperate at low negative slip.
- Wound rotor machines can feed power through the stator as well as the rotorto the bus over a wide speed range.

Self-Excited Induction Generator Operation

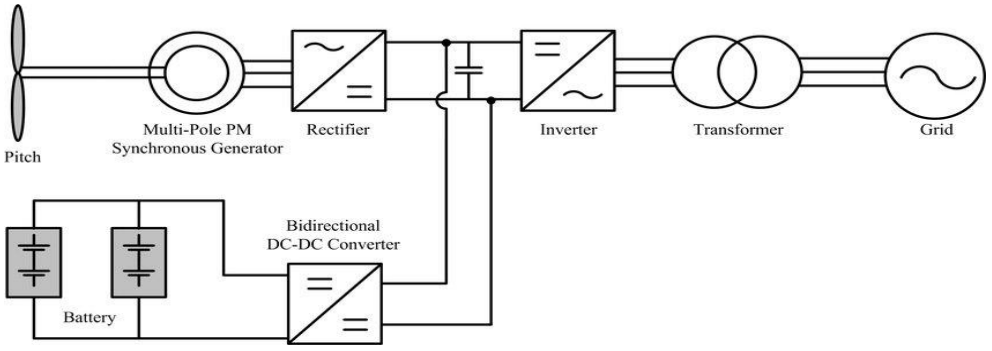
- A capacitor when connected across the induction machine helps in buildingup the terminal voltage. But the buildup of the voltage also depends on factors such as speed, capacitor value and load.
- The squirrel cage machine is generally used as self-excited inductiongenerator.
- Based on the methods of excitation, induction generators are classified intotwo categories such as
- Constant-voltage-constant-frequency generators
- Variable-voltage-variable-frequency generators.

3.8. Constant Voltage and Constant Frequency Generation with Power-Electronic Control

- An induction machine in the generating mode operates fundamentally in the same manner as in the rotating mode expect for the reversal of power flow. Hence, the equivalent circuit and the associated performance equations usingmotoring convections are valid for all values of slip.
- If the rotor is driven by a prime mover above the synchronous speed in thedirection of the air-gap field with the stator winding remaining connected tothe utility grid and the prime-mover is converted into electrical power.

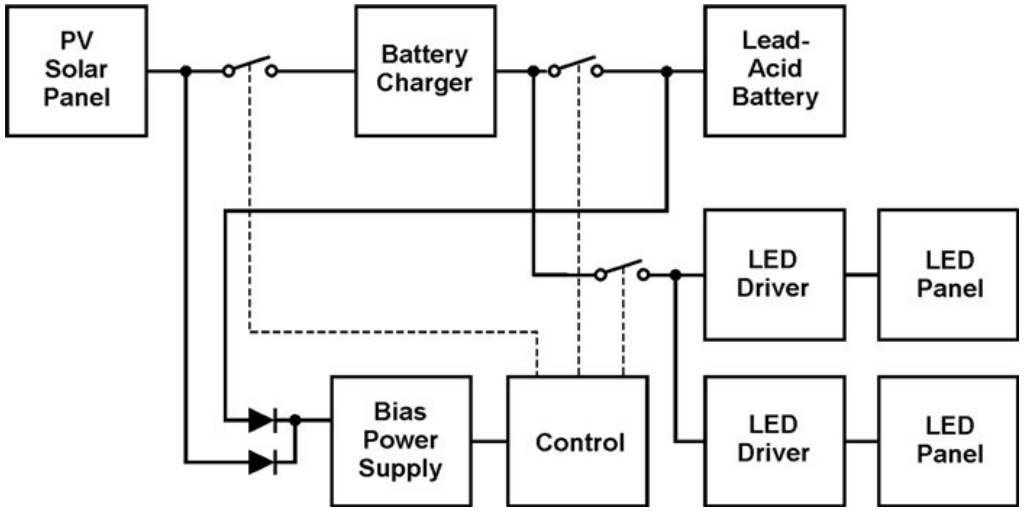
3.9. Single And Double Output Systems:

Single output system:



- The system consists of a grid connected squirrel cage induction generator coupled to turbine through gear box.
- The gear box steps up the rotor speed to a value matching a 50Hz or 60Hz utility n/w. The generator always draws reactive power from the network.
- Capacitors are used to compensate lagging VAR. As the generator is coupled to the grid the speed varies over a very small range above synchronous speed which is around 1%.
- As the speed variation is small, so the system is commonly known as a fixed speed system.

Double output system



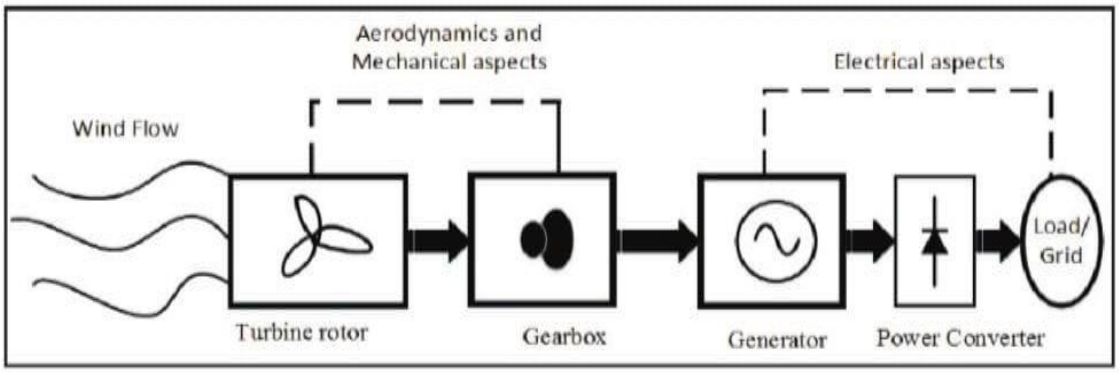
- Power can be feed into the supply system over a wide range of speed by appropriately controlling the rotor power from a variable frequency sourcewith a slip-ring induction machine.
- The provision for bidirectional flow of power through the rotor circuit can beachieved by the use of a slip-ring induction motor with an ac/dc/ac converterconnected between the slip-ring terminals and the utility grid.
- The system is known as a double-output induction generator because powercan be tapped both from the stator and from rotor.

3.10. Characteristics of Wind Power Plant:

- No Co2 emission.
- Wind is a safe energy source existing everywhere, and there is no need toworry about its depletion like fossil fuels.
- Simple Equipment's and easy operation.
- Few affections to nature environment.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWERS

1.Draw the basic diagram of Wind Energy Conversion System.



2.Write the types of Wind Turbines.

Ans- Wind turbines are broadly classified into two categories

- Horizontal Axis Wind Turbine. (HAWT)
- Vertical Axis Wind Turbine. (VAWT)

3.Write the types of Wind turbine control systems

Ans-Wind turbine requires certain control mechanism to protect generator and turbine from strong winds and to capture the power as much as possibleat low and medium winds.

The wind turbine has 4 different control mechanism such as

- Pitch angle control (Y-control).
- Stall (α) control.
- Yaw control
- Power electronic control.

4.Based on the type of excitation induction generator are classified into howmany types?

Ans- Induction generators are classified into two categories such as

- Constant-voltage-constant frequency generator.
- Variable-voltage-variable frequency generator.

5. What are factors that determine the output from a wind energy coverter ?[S-22]

Ans- Wind Resource. Several different factors influence the potential wind resource in an area. The three main factors that influence power output are: wind speed, air density, and blade radius.

6. What are the characteristics of wind power plant ? [S-23]

Ans-Introduction of wind power generation has been increasing in the world, which has the following characteristics: No CO_2 emission. Wind is a safe energy source existing everywhere, and there is no need to worry about depletion like fossil fuel. Simple equipments and easy operation.

POSSIBLE LONG TYPE QUESTIONS

1. With a neat diagram explain wind energy conversion system.
2. With a neat diagram explain Horizontal Axis Wind Turbine. (HAWT).
3. With a neat diagram explain Vertical Axis Wind Turbine. (VAWT).[S-23]
4. Explain in brief about the different Wind turbine control systems.
5. Write short notes on

a) Single output

b) Double output system.

6.Explain the advantages & disadvantages of wind energy systems. [S-24]

7.Write short notes of wind power.[S-24]

CHAPTER NO.-04
BIOMASS POWER

Learning Objectives:

4.1. Energy from Biomass.
4.2. Biomass as Renewable Energy Source
4.3. Types of Biomass Fuels - Solid, Liquid and Gas.
4.4. Combustion and fermentation.
4.5. Anaerobic digestion.
4.6. Types of biogas digester.
4.7. Wood gasifier.
4.8. Pyrolysis,
4.9. Applications: Bio gas, Bio diesel

4.1. Energy from Biomass:

- Biomass is a general term which refers to the mass of biological material produced from the living processes. This includes the material derived fromthe plants as well as from animals.
- The energy obtained from biomass is known as biomass energy. Animals feed on plants and plants grow through photosynthesis process using solar energy, thus photosynthesis process is primarily responsible for generation ofbiomass energy.
- The average efficiency of photosynthesis conversion of solar energy isestimated to be 0.5% to 1%.
- Biomass is a derivative of solar energy as plants grow by the process of photosynthesis by absorbing co2 from the atmosphere to from carbohydratessuch as sugar, starch, and cellulose etc. or hexose such as glucose etc.
- $6CO2 + 6 H2O + Light \rightarrow C6H12O6 + 6CO2$
- Biomass does not add CO2 to the atmosphere as it absorbs the same amountof carbon in growing the plants as it releases when consumed as fuel.

4.2. Biomass as Renewable Energy Source:

- Biomass is a key renewable energy source that includes plant and animalmaterial. The energy contained in biomass originally came from plants through photosynthesis.
- In the process of photosynthesis carbon dioxide in air is transformed into other carbon containing molecules like sugar, starch and cellulose in plants.
- The chemical energy that is stored in plants and animals or in their waste iscalled biomass energy or bioenergy.
- Biomass comes from a variety of source which include, Wood from woodland and natural forest. Forestry Plantation, Agricultural residue such as straw, strove, cane trash and greenagricultural wastes, Animal waste like cow manure, poultry litter, Sewage, Municipal Solid Waste, Food Processing Waste.

4.3. Types Of Biomass Fuels:

- Biomass is an organic material that reacts with oxygen in combustion andmetabolic processes to release heat.
- Sometimes it is used in its original form but more often it is transformed into modern energy forms such as liquid and gaseous fuels, electricity and processes heat to provide energy service to

rural and urban areas. Some of itsform available to user are as follows.

- Fuel Wood-It is the most obvious and oldest source of biomass energyand direct combustion is the simplest way to obtain heat energy from it.It can also be converted to more useful forms such as charcoal and producer gas. Its energy density is 16-20 MJ/Kg.
- Charcoal- It is a clean, dry, solid fuel, black in colour. Its energy densityis about 30MJ/Kg. It is obtained by carbonization process of woody biomass to achieve higher energy density per unit mass.
- Fuel Pellets and Briquettes-Crop residue such as straw, rice husk and waste wood are pressed to form lumps, known as fuel pellets or briquettes and used as solid fuel. The purpose is to reduce the moisture content and increase the energy density of biomass to makeit more feasible for long distance transportation.
- Bio-diesel- Some vegetable oils, edible as well as non-edible, can beused in pure form or blended with petroleum diesel as a fuel in a compression –ignition engine. Bio-diesel is simple to use, biodegradable, non- toxic and free of Sulphur and aromatics.

4.4. Combustion And Fermentation:

Combustion:

- Incineration means direct combustion of biomass for immediate usefulheat. The heat or steam produced are either used to generate electricity or provide the heat for industrial process, space heating, cooking.
- Furnaces and boiler have been developed for large- scale burning of various types ofbiomasses such as wood, waste wood, black liquid from pulp industry, food industry and MSW.

Fermentation:

- It is the process of decomposition in the absence of air of simple hexose sugars in aqueous solution by action of an enzyme present in yeast in acidiccondition thus the products are ethanol and carbon dioxide.

$$C_6H_{12}O_6 \xrightarrow[Fermentation]{32^{\circ}c} 2C_2H_5OH + 2CO_2$$

4.5. Anaerobic Digestion:

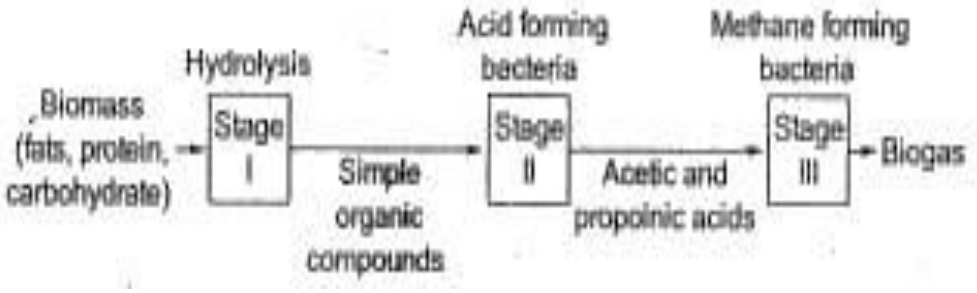
- This process converts decaying wet biomass and animal wastes into biogasthrough the decomposition process by the action of anaerobic bacteria. Carbon present in biomass may be divided between fully oxidized CO2 andfully reduced CH4.

  Decaying wet biomass $\xrightarrow[Anaerobic\ Fermentation]{20-55^{\circ}c}$ Biogas (largely CH_4 and CO_2)

- The biomass material in the form of water slurry is digested by the bacteria anaerobically for several days in an air tight container. The reactions are slightly exothermic and small amount of heat is also generated to maintain a temperature
- The most useful biomass material appears to be animal manure, algae, kelp, hyacinth, plant residues and other organic material with high moisture content.
- Anaerobic digestion has three stages

Stage I-

First of all the original organic matter containing complex compounds is broken through the influence of water known as hydrolysis to simple water-soluble compounds.



Stage II-

The anaerobic micro-organisms and facultative together known as acid former produce acetic and propionic acid, this process takes about one day at 25℃ and mostly carbon dioxide is released at this stage.

Stage III-

The anaerobic bacteria also known as methane formers slowly digest the products available from second stage to produce methane, carbon dioxide, a small amount of hydrogen and a trace amount of other gas. The process takes about two weeks' time to complete at 25℃. Third stage is carried out strictly by anaerobic bacteria.

Advantages :

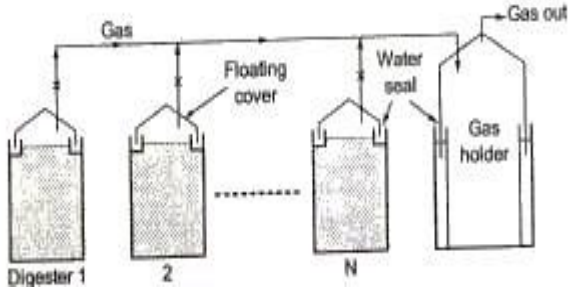
- Discarded waste material is used to produce energy.
- In anaerobic digestion we obtain both fuel and fertilizer.
- Anaerobically obtained manure is better in terms of both quantity andquality as compared to ordinary manure.
- Since the system is enclosed, the digested slurry is odorless.

4.6. Types Of Biogas Digester:

- A biogas digester is a closed container in which the segregation and feedingof the organic substrate takes place. In this digester the biodegradation of substrate takes place under anaerobic conditions and in the presence of methanogenic bacteria, producing a methane rich bio-gas.
- Biogas digester are mainly classified as
    1. Batch type
    2. Continuous type.
    3. Continuous type is again divided into two types
    4. Floating- drum type.
    5. Fixed-dome type.

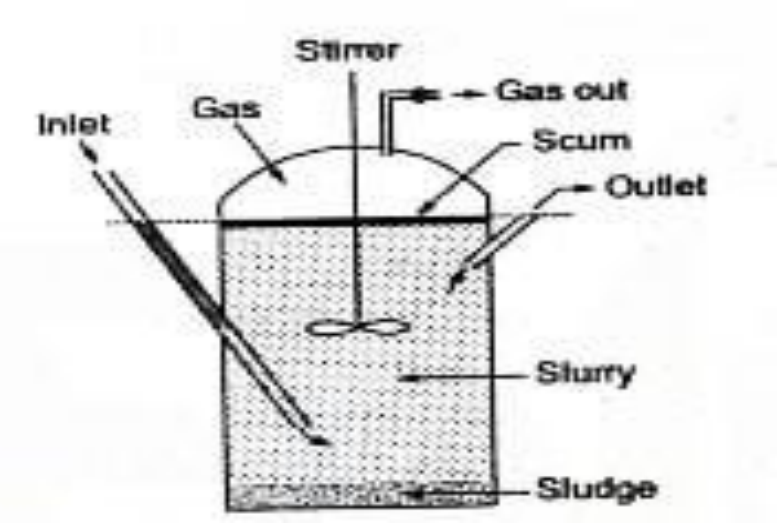
Batch type:

- A batch-type plant is charged at 50–60-day intervals. Once charged it starts supplying gas after 8-10 days and continues to do so for about 40-50 days till the process of digestion is completed.
- The battery of the digester is charged and emptied one by one in a synchronous manner to maintain a regular supply of gas through a common gas holder.
- The installation and operation of such plants are capital and labour intensive and are not economical unless operated on large scale.
- These plants are installed in European countries and it is not suitable for Indian rural areas.



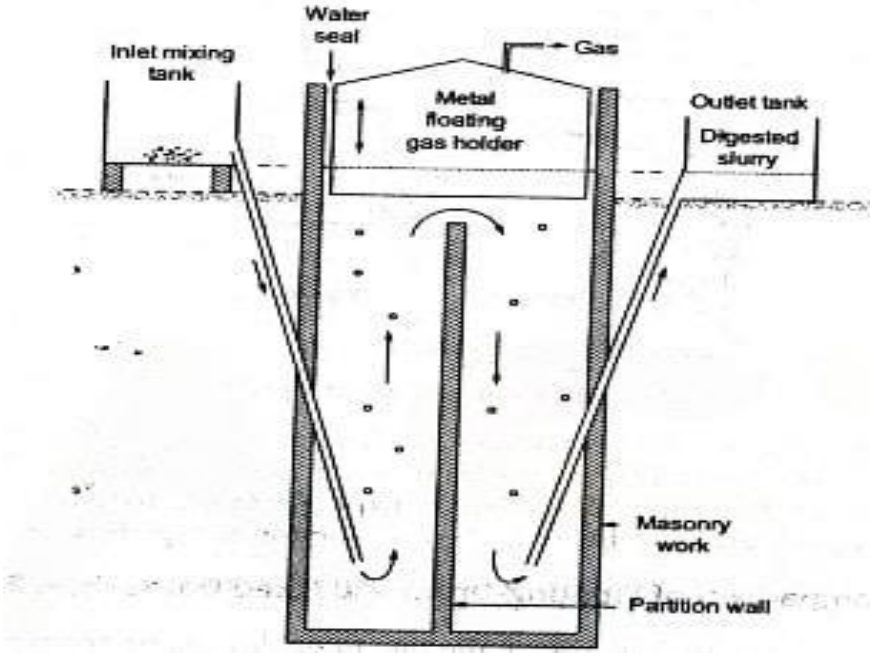
Continuous type;

- The plant is fed daily with a certain quantity of biomass. The gas produced is stored in the plant or in a separate gas holder and remains available for use as required. The biomass while slowly passing through the digester is completely digested and the digested slurry is rejected through an outlet.
- The period during which the biomass remains in the digester is known as the retention period, which depends mainly on the type of biomass and operating temperature.
- The plant operates continuously and is stopped only for maintenance or for removal of sludge. A thin dry layer often formed at the top of the slurry known as scum.
- The scum tends to prevent the escape of gas from slurry. This type of plants are very popular in India and China.



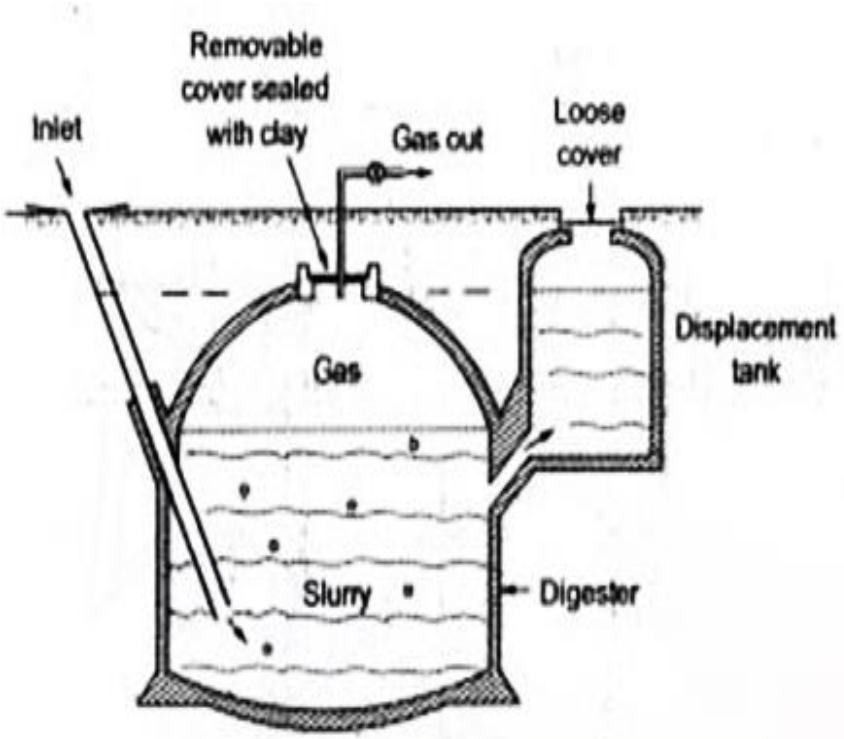
Floating Drum Type Biogas Plant:

- It has an inverted mild steel drum to work as gasholder.
- The digester is an underground masonry construction with partition wall, which provides optimum conditions for growth of acid formers and methane formers as pH value required for these bacteria are different. Therefore, the plant operates very well with good gas yield



Fixed-Dome Type Biogas Plant

- These plants are more economical as only masonry work is required.
- Gas pressure in the dome varies depending on the production/consumption rate.
- The slurry enters from an inlet and the digested slurry is collected in a displacement tank, stirring is required if the raw material is crop residue.
- There is no bifurcation in the digester chamber and therefore the gas production is less as compared to floating-drum type biogas plant.
- The gas produced is stored in the dome and displaces the liquids in inlet and outlet, often leading to gas pressure as high as 100cm of water. The gas occupies about 10% of the volume of the digester.
- As the complete plant is constructed underground the temperature tends to remain constant and is often considerably higher than the ambient temperature in winter.



4.7. Wood gasifier:

- It is capable of burning wood fuel or wood derived biomass fuel.
- It consists of a solid metal usually cast iron or steel closed fire chamber, agrate and an adjustable air control.
- The appliance will be connected to a suitable chimney or flue which will fillwith hot combustion gases once the fuel is ignited.
- It is critical that the chimney or flue gases be hotter than the outside temperature as this will result in combustion gases being drawn out of the firechamber and up the chimney.

Advantages;

- Availability- The fuel is readily available in most locations, as wood isharvested locally or can be provided by vendors.
- Renewability-Wood is a renewable fuel. The growth of new forests for timberand fuel is a huge and established industry.
- Simplicity- They are easy to use as they tend to have few moving parts.
- Reliability- These are highly reliable as they do not require electricity tooperate.

Disadvantages:

- Maintenance- It need to be maintained regularly as they add ashes which need tobe removed periodically.
- Fuel cost-Firewood are expensive in some parts of the country because there isno nearby source particularly in urban areas.

4.8. Pyrolysis:

- It is most commonly used in the treatment of organic materials. It is the firststep in the processes of gasification.
- It is one of the processes involved in charring wood.
- The process is used heavily in the chemical industry, for example to produceethylene, many forms of carbon and other chemicals from petroleum, coal, and even wood, to produce coke from coal.
- Pyrolysis generally consists in heating the material above its decompositiontemperature, breaking chemical bonds in its molecules.
- When organic matter is heated at increasing temperature in open containers,the following processes generally occur.
- Below about 100 c, volatiles including some water, heat sensitive substances such as vitamin c and proteins, may partially change ordecompose at this stage.
- At above 100 c or slightly higher, any remaining water that is merely absorbed in the material is driven off. This process consumes a lot ofenergy, so the temperature may stop rising until all water has evaporated.
- Some solid substances like fats, waxes, and sugar, may melt andseparate.
- Below 100 and 500c, many common organic molecules breakdown. At this point the matter is said to have been charred or carbonized.
- At 200-300c, if oxygen has not been excluded, the carbonaceous residue may start to burn in a highly exothermic reaction.
- Once combustion of the carbonaceous residue is complete, a powderyor solid mineral residue is left behind.

4.9.Application of Biogas, Bio-diesel:

The following are the application of Biogas

- Electricity generation- Biogas made from plant material offers a renewable way to generate electricity.
- Biogas possesses chemical energy, and electricity is produced by converting this chemical energy to mechanical energy and finally intoelectricity. This electricity can be used both domestically and commercially since it can be made in small and large scale.
- Waste management in agriculture- After electricity generation anothermost important application of biogas is for agriculture waste management.
- Crop waste and manure can be digested either alone or in co-digestionwith other material employing either wet or dry processes.
- As a Renewable fuel for transport vehicles- If concentrated andcompressed an ideal application of biogas exists in vehicle transportation.
- Compressed biogas is widely used in Sweden, Switzerland andGermany.
- Fuel Cells- Theoretically, biogas can be converted directly intoelectricity using a fuel cell.
- The following are the applications of Bio-diesel
    1. It can be used as heating oil in domestic and commercial boilers.
    2. It is also used to clean oil-spills.
    3. Bio-diesels are used in generators allowing companies to avoiddamaging blackouts.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWER

1.What is Biomass?

Ans- Biomass is a general term which refers to the mass of biological material produced from the living processes. This includes the material derived from theplants as well as from animals.

2.What are the source of biomass

Ans-Biomass comes from a variety of source which include

- Wood from woodland and natural forest.
- Forestry Plantation.
- Agricultural residue such as straw, strove, cane trash and greenagricultural wastes.
- Animal waste like cow manure, poultry litter.
- Sewage.
- Municipal Solid Waste.
- Food Processing Waste.

3.What are the advantages of anaerobic digestion?

Ans- Advantages of Anaerobic Digestion are as follows

- Discarded waste material is used to produce energy.
- In anaerobic digestion we obtain both fuel and fertilizer.
- Anaerobically obtained manure is better in terms of both quantity andquality as compared to ordinary manure.
- Since the system is enclosed, the digested slurry is odorless.

4.What are the advantage of wood gasifier.

Ans- The following are the advantages of wood gasifier

Advantage:

- Availability- The fuel is readily available in most locations, as wood isharvested locally or can be provided by vendors.
- Renewability-Wood is a renewable fuel. The growth of new forests for timberand fuel is a huge and established industry.
- Simplicity- They are easy to use as they tend to have few moving parts.
- Reliability- These are highly reliable as they do not require electricity tooperate.

Disadvantage;

- Maintenance- It need to be maintained regularly as they add ashes which needto be removed periodically.
- Fuel cost-Firewood are expensive in some parts of the country because thereis no nearby source particularly in urban areas.

5.What is anaerobic Digestion?

Ans- This process converts decaying wet biomass and animal wastes into biogas through the decomposition process by the action of anaerobic bacteria. Carbon present in biomass may be divided between fully oxidized CO2 and fully reduced CH4.

Decaying wet biomass $\xrightarrow[Anaerobic\ Fermentation]{20-55^{\circ}c}$ Biogas (largely CH_4 and CO_2)

6.what are the application of bio-diesel.[S-23]

Ans-For heating systems. Electric generator. As an industrial solvent. As a lubricant, thanks to its sulfur reduction.

7.What is wood gasfier ? [S-23]

Ans-A wood gas generator is a gasification unit which converts timber or charcoal into wood gas, a producer gas consisting of atmospheric nitrogen, carbon monoxide.

8.What is pyrolysis ? [S-24]

Ans-Pyrolysis is the process of **thermal decomposition of materials at elevated temperatures**, often in an inert atmosphere without access to oxygen.

9.What are the factors that affect the generator of bio gas ?[S-24]

Ans-Temperature is the important factor which affects the biogas production. At higher temperature, maximum biogas is produced. There are other factors like the C/N ratio, pH value, compression ratio, and solid concentration which are affecting the biogas production.

POSSIBLE LONG TYPE QUESTIONS

1. Explain the process of anaerobic digestion.
2. Explain in brief the types of biogas digester.
3. Explain in brief the process of pyrolysis.[S-22]
4. What are the advantages of anaerobic digestion.[S-23]
5. Write the short notes on
   - i) combustion & fermentation .
   - *ii)* Liquid flat plate solar collector. [S-23]

6.Write short notes on fluidized bed gasifier with neat diagram.[S-24]

CHAPTER NO.-05
OTHER ENERGY SOURCES

Learning Objectives:

5.1. Tidal Energy: Energy from the tides, Barrage and Non-Barrage Tidal power systems.
5.2. Ocean Thermal Energy Conversion (OTEC).
5.3. Geothermal Energy – Classification.
5.4. Hybrid Energy Systems.
5.5. Need for Hybrid Systems.
5.6. Diesel-PV, Wind-PV, Microhydel -PV.
5.7. Electric and hybrid electric vehicles.

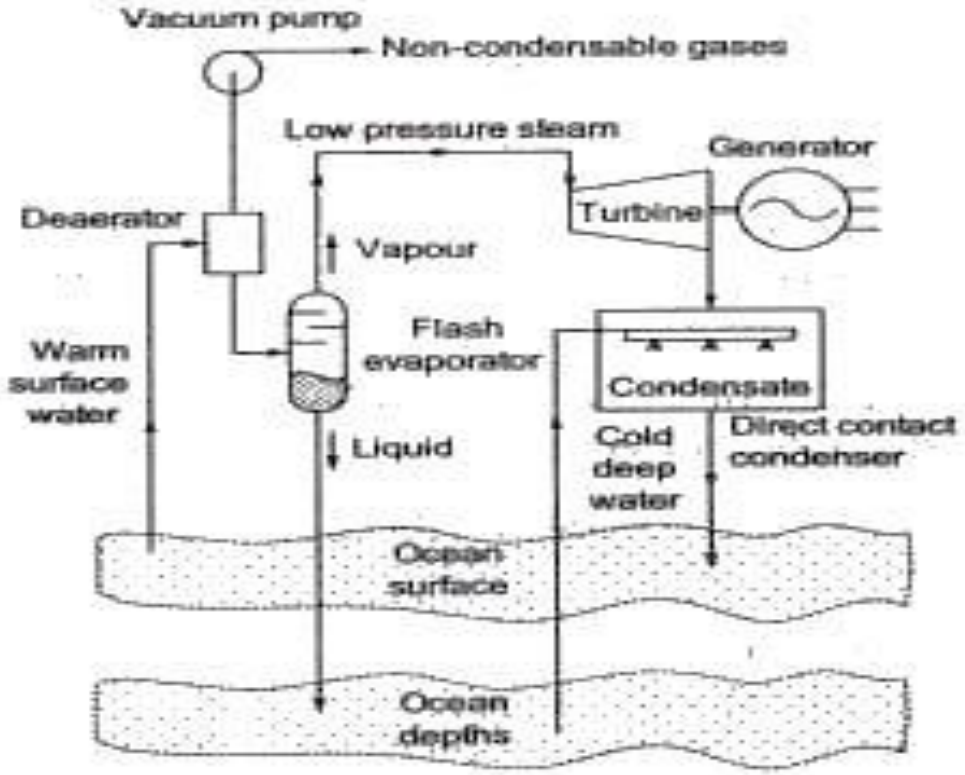
5.1. Tidal Energy: Energy from the tides, Barrage and Non-Barrage Tidal Power System.

- Tidal energy exploits the natural rise and fall of coastal tidal waters caused principally by the interaction of the gravitational fields of the sun and the moon.
- The highest level of tidal water is known as flood tide or high tide, and the lowest level is known as low tide or ebb. The level difference between the high and low tide is known as tidal range. Sites with large tidal ranges (about 5m or more) are considered suitable for power generation.
- A tidal barrage is a dam like structure used to capture the energy from masses of water moving in and out of a bay or river due to tidal forces. Instead of damming water on one side like a conventional dam, a tidal barrage allows water to flow into a bay or river during high tide, and release the water during low tide.
- This is done by measuring the tidal flow and controlling the sluice gates at key times of the tidal cycle.
- Turbines are placed at these sluices to capture the energy as the water flows in and out.
- The barrage method of extracting tidal energy involves building a barrage across a bay or river that is subjected to tidal flow. Turbines installed in the barrage walls generate power as water flows in and out of the estuary basin, bay, or river.
- These types of dams are not only use to produce renewable energy, but also to reduce flooding. Furthermore, the moon and sun are not going anywhere any time soon nor their influence on tidal forces, which means we can easily produce this type of tidal power for as long as we need.
- Tidal barrage alters the flow of saltwater in and out of estuaries, which alter the quality of seawater and thus impact and displace marine life in the area.

5.2. Ocean Thermal Energy Conversion (OTEC)

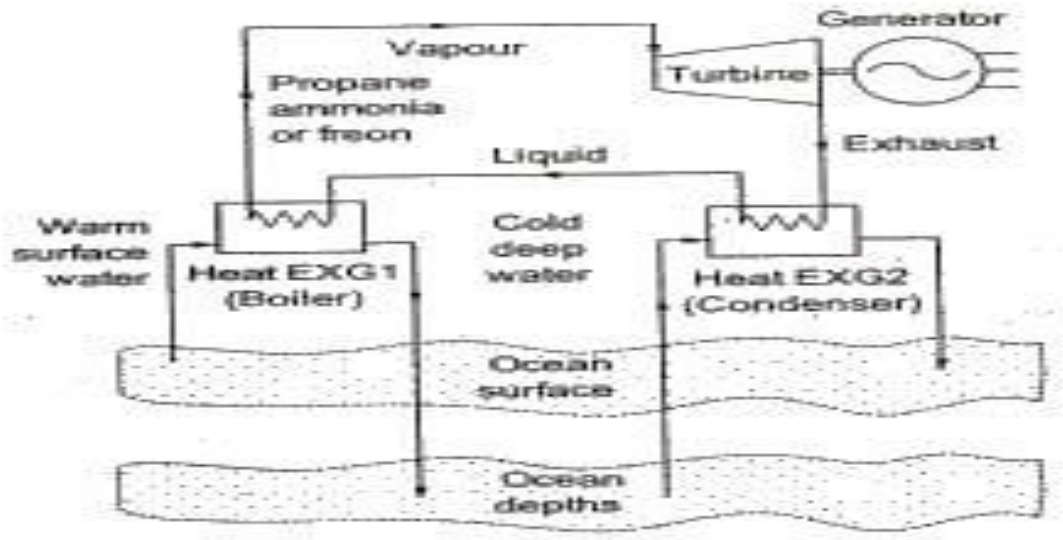
- Ocean thermal energy exists in the form of temperature difference between thewarm surface water and colder deep water.
- The facility proposed to achieve theconversion of ocean thermal energy to other form of energy is OTEC.
- OTEC plant operate on open loop and closed loop cycles

Open loop cycle:



- In an open loop cycle plant, warm water from the ocean surface is flash evaporated under partial vacuum. Low –pressure steam obtained is separated and passed through turbine to extract energy.
- The exhaust of the turbine is condensed in a direct contact condenser. Cold water drawn from a depth of 1000 m is used as cooling water in a direct contact condenser.
- 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.

Closed loop cycle:



- In a closed cycle plant, warm surface water is used to evaporate a low boilingpoint working fluid such as ammonia, Freon or propane. The vapour flows through the turbine and is then cooled and condensed by cold water pumpedfrom the ocean depths.
- Because of the low quality of the heat, large surface areas of heat exchangersare required to transfer significant amount of heat and a large amount of water needs to be circulated.

Advantages of OTEC:

- The resource supplies steady power without fluctuations and independent ofvagaries of weather.
- The availability hardly varies from season to season.
- It has the ability to produce some useful by-products such as desalinatedwater and nutrients for mariculture.

Disadvantage of OTEC

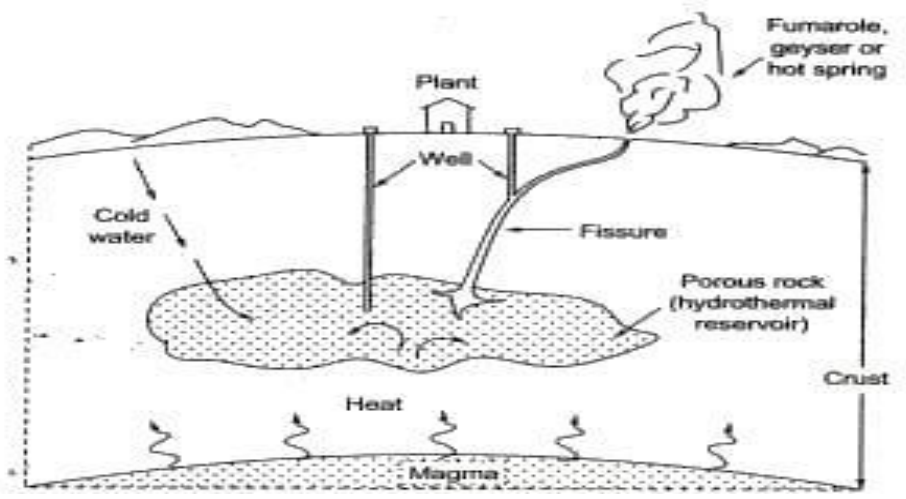
- Low efficiency.
- High installation cost.

5.3. Geothermal Energy and its classification.

- Geothermal energy originates from the earth's interior in the form of heat. Volcanoes, geysers, hot springs and boiling mud pots are visible evidence of the great reservoirs of heat that lies beneath the earth.
- There are four types of geothermal resources. They are as follows.
    - Hydrothermal Resources
    - Geo pressured.
    - Hot dry rock (HDR).
    - Magma. Hydrothermal Resources.

Hydrothermal Resources:

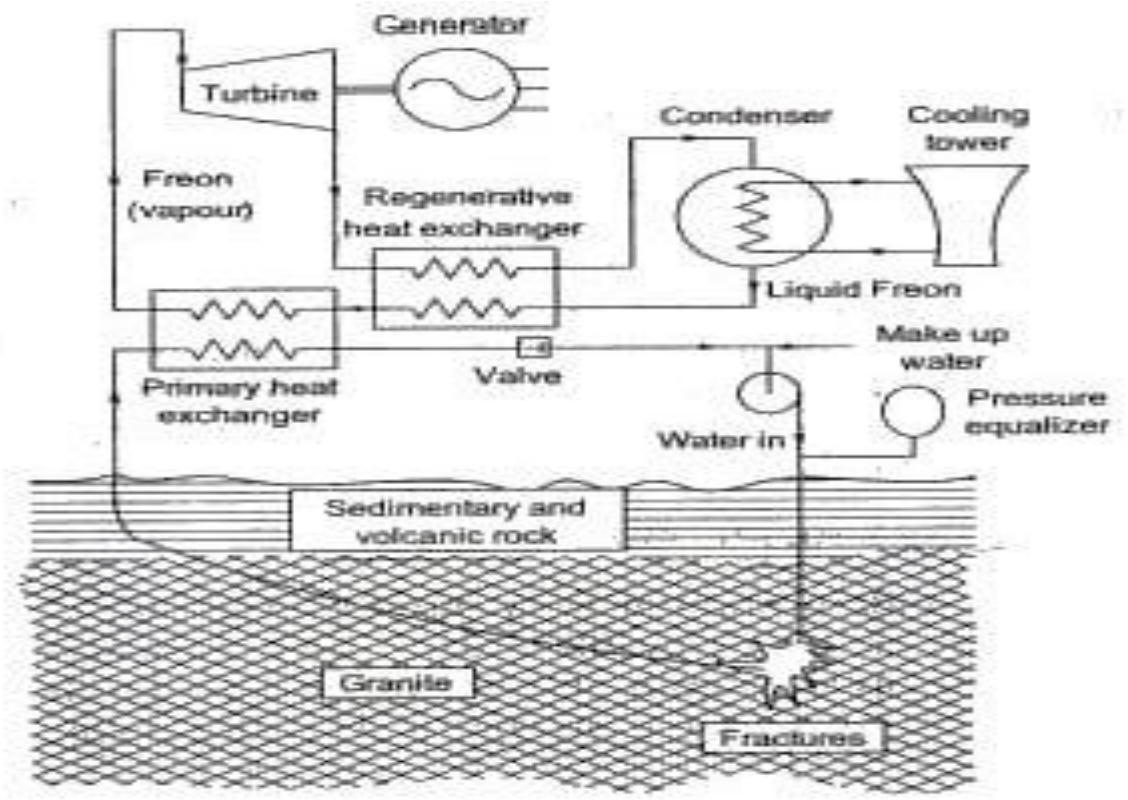
- Hydrothermal resources occur when underground water has access to high temperature porous rocks, capped by a layer of solid impervious rock. Thus, water is trapped in the underground reservoir and is heated by surrounding rocks.
- Heat is supplied by magma by upward conduction through solid rocks below the reservoir, it forms a giant underground boiler. Under high pressure, the temperature can reach as high as 350℃.
- The hot water often escapes through fissures in the rock forming hot springs or geysers, sometimes steam escapes through cracks in the surface called fumaroles.
- The hydrothermal resources are located at shallow to moderate depths approximately 100m to 4,500m.
- Temperatures for hydrothermal reserves used for electricity generation range from 90℃ to 350℃ but roughly two-thirds are estimated to be in the moderate temperature range 150℃ to 200℃.
- For practical purpose hydrothermal resources are further classified into
    1. Vapour dominated.
    2. Liquid dominated.
    3. Hot water resources.



Geo pressured Resources:

- While drilling for oil and gas, hot salt water reservoirs, at moderately high temperature, and under great pressure are found to be at a depth of 3to 6km, because of the very high pressure of water about 1350atm in the deepest layer, these reservoirs are called geo pressured.
- A special feature of geo pressured water is that it also contains a significant amount of dissolved methane gas usually 1.9-3.8m3perm3 of water. The solubility of methane increases with pressure.
- The resource is potentially very promising because three types of energy can be extracted from the wells
- Thermal energy from the heated fluid
- Mechanical energy from the high pressure involved.
- Chemical energy from the burning of methane gas.

Hot dry rock resources



- These are regions underground at temperature exceeding 200℃, 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 source of energy.
- To recover heat, water is pumped into the cracks from the surface and withdrawn by another well at a distance. Injection and projection wall are joined to form a circulating loop through this man-made reservoir to achieve a steady flow of high temperature water. Electricity is produced by a binary fluid system.

Magma Resources

- At some places molten or partially molten rock, at temperature of 650℃ to 1,200℃ occurs at depths of 5km-10km.These resources are located in the vicinity of recent volcanic activity.
- Very high temperature and large volume make magma a huge potential energy source, largest of all geothermal resources.

5.4. Hybrid Energy System

- It is a combination of two or more energy system for producing electricity combining two or three energy sources to form capable of generating efficient energy to power a house or small industrial unit.
- There are many sources of combining renewable energy source to produce power. The hybrid energy source is much more cost effective and environment friendly.
- The use of hybrid power generation came forward due to high prices of oil. The use of hybrid energy system can optimize the power supply especially in rural areas.
- The hybrid energy system particularly renewable coupled with conventional energy source can significantly reduce the total lifecycle cost of a standalone power supplies in many off grid situations.
- Hybrid energy systems are used as an alternative to more conventional system which typically based on a single fossil fuel source.
- Hybrid energy systems may also be used as part of distributed generation application in conventional electricity grid.
- Types of hybrid energy systems
    - Central grid connected hybrid system.
    - Isolated grid hybrid system.

Central grid connected hybrid system:

- If the hybrid system is connected to a central utility grid, then the design is simplified to certain degree and the number of components may be reduced. It is because the voltage and frequency are set by the utility system and need to be controlled by the hybrid system.
- The grid normally provides the reactive power when more energy is required then the deficit can be provided by the utility, similarly any excess produced by the grid can be absorbed by the utility.

Isolated Grid Hybrid System

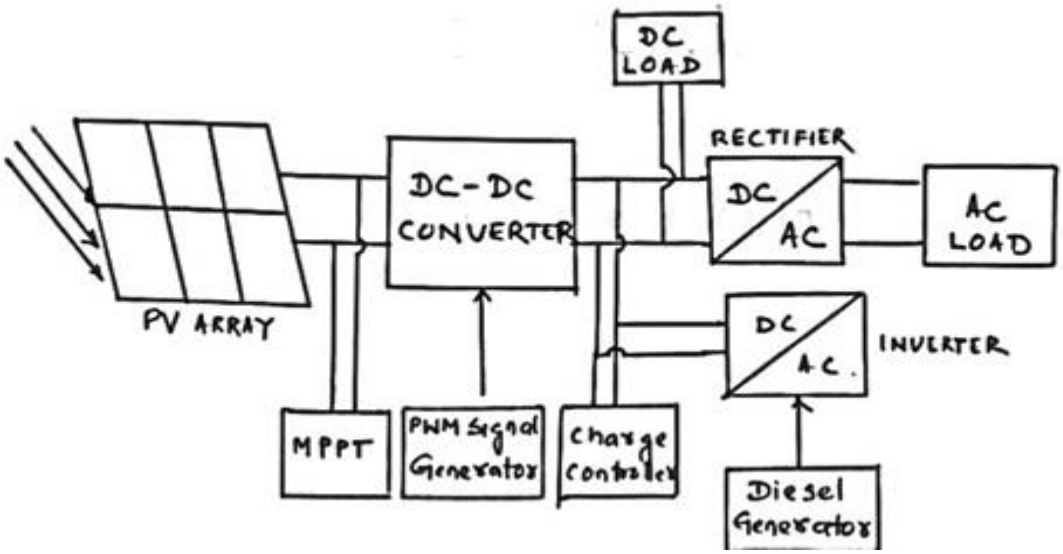
- The hybrid system which are used for a dedicated purpose without use of real distribution network.
- These special purposes include water pumping, aerating, heating, desalination or running grinders or other machines.
- Design of these systems is usually such that system frequency and voltage control are not major issues nor in excess power production.

5.5. Need For Hybrid System

- Fossil fuel can be costly.
- Alternative to power line construction.
- To provide the difference between the total load and what the existing line can carry.
- Reduction of air pollution, noise and risk associated with fuel transport.

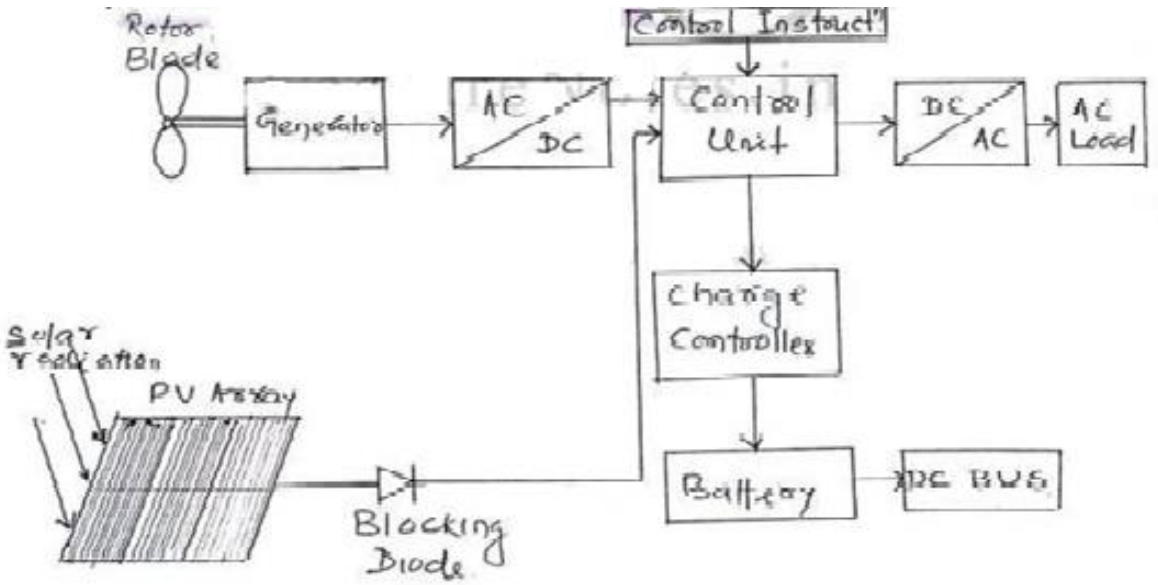
5.6. Diesel- PV, Wind-PV, Micro hydel-PV

Diesel- PV



- A diesel fueled power plant is a form of IC engine which uses diesel fuel andworks on compression ignition principle. This employs a four-stroke cycle operation. The four strokes are suction, compression, expansion, exhaust. These result in rotational motion of generator shaft producing ac power.
- A diesel engine has no starting torque and is started by some auxiliarymeans.
- Photovoltaic power generation involves the technology converting radiationof sun directly into electrical energy.
- Modern PV systems are accompanied by balance of system (BOS) i.e., battery,charger controller, power conditioning equipment's, MPPT etc.

Wind- PV:

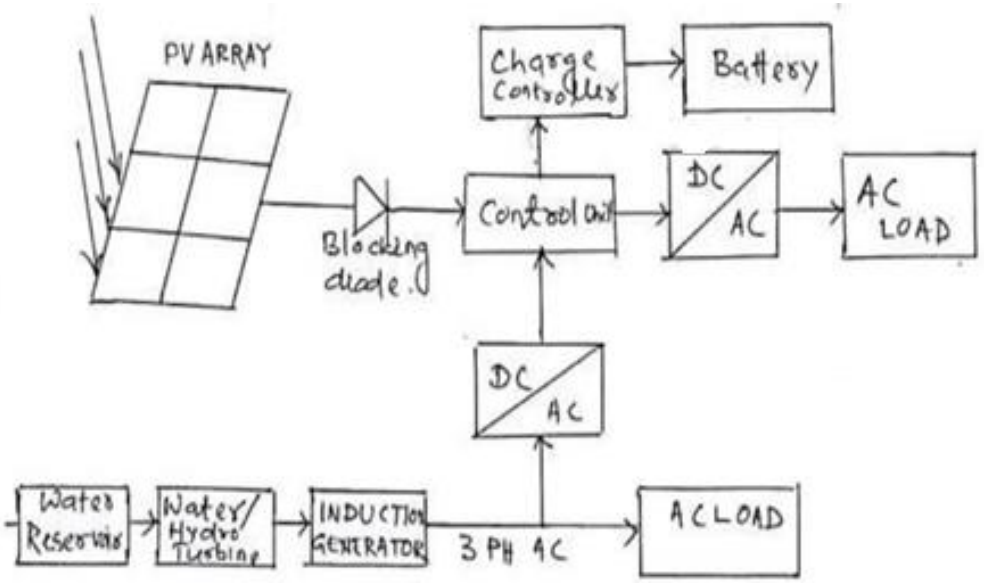


- A wind PV hybrid system couples a photovoltaic array with a wind turbine. This type of system is expected to give more output from wind turbine duringwinter whereas during summer solar panel would produce more power than wind.
- The wind turbine is connected to the synchronous generator. The variable power produced is

converted to DC and fed to AC loads through a inverter.

- The PV system produces DC voltage and is fed to DC bus or loads.
- A blocking diode is used to prevent back feeding from battery. The controlunit houses the MPPT to track maximum power.
- The PV system employs a DC-DC converter circuit to increase the output tothe maximum power level.

Micro hydel-PV:



- Micro hydro is hydroelectric power installation that produce upto100KW ofelectricity, Microhydel system complements PV system because in manyareas where water flow is highest in winter when the solar energy is minimum.
- The MH-PV hybrid system is composed of PV array, system control, battery,micro- hydro generators, rectifiers, converter.
- In this plant the potential energy of the reservoir is converted to kinetic energy of hydro turbine. The rotational motion of the turbine shaft rotates thegenerator shaft and produces electricity.
- The alternating voltage produced is rectified and fed to the dc bus systemwhere the PV output is also fed.

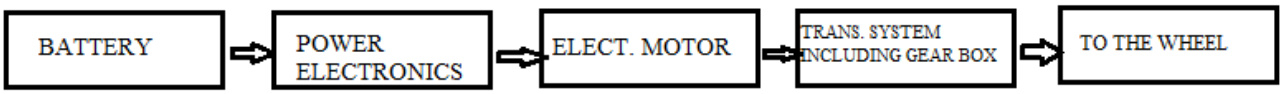
5.7. Electric and Hybrid electric vehicles.

Electric Vehicles

- It is also referred as an electric drive vehicle which uses one or more electric motors or traction motor for propulsion.
- There are three types of electric vehicles which exists such as
    - EV's those are directly powered from an external power station.
    - Those that are powered by stored electricity originally from anexternal power source.
    - Those that are powered by an on-board electrical generator such asengine or a hybrid electric vehicle or a hydrogen fuel cell.
- Electric vehicle differs from fossil fuel powered vehicle in that the electricity they consume can be generated from a wide range of sources including fossil fuels, nuclear power, renewable resources such as tidal power, solar power, wind power or any combination of these. The generated electricity is transmitted to the vehicle through overhead lines, wireless energy transfer such as inductive charging or a direct connection through an electrical cable.

Hybrid Electric Vehicle:

MECHANICAL DRIVE TRAIN



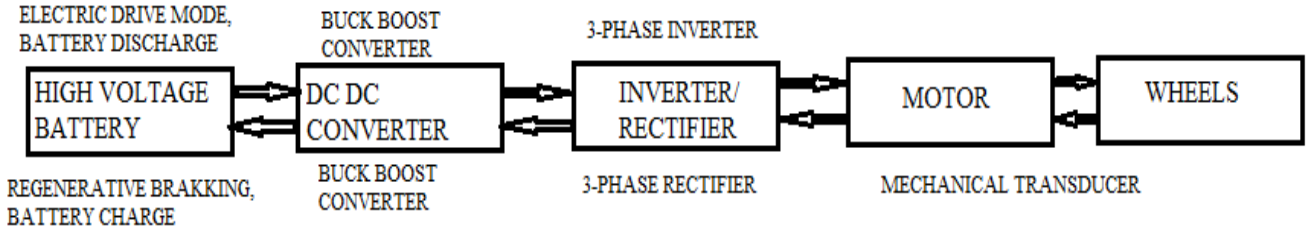
ELECTRICAL DRIVE TRAIN

- A HEV has two driver trains i.e., one mechanical and one electric as shown inthe figure.
- The mechanical driven train includes fuel tank, combustion engine, gearbox, wheel.
- The electric driven train has battery, power electronic control, electricmotor.
- Power electronic device are used for power conditioning and power savingwhich increases the output of the vehicle thus increasing the efficiency.
- Power electronic equipment's are used in two modes.

1.Electric drive mode

- Battery discharges and feeds the motor through a buck-boost converter. The upgraded DC is converted to AC through inverter. Theconverter provides voltage control for the motor there by controlling the motor output and vehicle speed.

2.Regenerative breaking mode:



- During regenerative breaking the motor reverses its direction till Stopping and battery power cut off.
- The motor works on generatingmode charging the battery passing through various power conditioning stages.

POSSIBLE SHORT TYPE QUESTIONS WITH ANSWERS

1. Define Ocean Thermal Energy Conversion (OTEC).

Ans- Ocean thermal energy exists in the form of temperature difference between thewarm surface water and colder deep water. The facility proposed to achieve the conversion of ocean thermal energy to other form of energy is OTEC.

2.What Geothermal Energy and its classification.

Ans-Geothermal energy originates from the earth's interior in the form of heat. Volcanoes, geysers, hot springs and boiling mud pots are visible evidence of thegreat reservoirs of heat that lies beneath the earth There are four types of geothermal resources.

- Hydrothermal Resources
- Geo pressured
- Hot dry rock (HDR).
- Magma.

3.Write the need for Hybrid System.[S-24]

Ans-

- Fossil fuel can be costly.
- Alternative to power line construction.
- To provide the difference between the total load and what the existing line can carry.
- Reduction of air pollution, noise and risk associated with fuel transport.

4.What is Hybrid Energy System & give an example ? [S-23]

Ans-It is a combination of two or more energy system for producing electricity combining two or three energy sources to form capable of generating efficient energy to power a houseor small industrial unit.

5.Write the advantages and disadvantages if OTEC.

Ans

Advantages of OTEC

- The resource supplies steady power without fluctuations and independent ofvagaries of weather.
- The availability hardly varies from season to season.
- It has the ability to produce some useful by-products such as desalinatedwater and nutrients for mariculture.

Disadvantage of OTEC

- Low efficiency.
- High installation cost.

6.What are the types of tidal power plant [S-24]

Ans Tidal power can be classified into four generating methods**:**

- Tidal stream generator.
- Tidal barrage.
- Tidal lagoon.
- Dynamic tidal power.

POSSIBLE LONG TYPE QUESTIONS

1. Briefly explain OTEC and its type with diagram.
2. Explain about the barrage tidal power system briefly [S-23].
3. Write short note on

   I) Diesel- PV.

   ii)Micro hydel-PV. [S-24]
4. With neat diagram explain geothermal energy and its process of generation.[S-24]