Solution for Renewable Energy Sources – 2018-10EE836

Answer any five full Questions :

Part A

1. (a)Advantages of Renewable energy sources
    - Renewable energy sources are safe, abundant and clean to when compared to fossil fuels
    - Multiple forms of renewable energy exist.
    - It provides the foundation for energy independence.
    - Renewable energy is stable.
    - It is a technology instead of a fuel.

    Disadvantages of Non - Renewable energy sources

    - Not every form of renewable energy is commercially viable.
    - Many forms of renewable energy are location-specific.
    - Many forms of renewable energy require storage capabilities.
    - Pollution is still generated with renewable energy.
    - Renewable energy sources often require subsidies to make them affordable.
    - Some forms of renewable energy require a massive amount of space.

    Non – conventional energy sources in India

- Electricity sector in India had an installed capacity of 250.256 GW as of July 2014.

- India became the world's third largest producer of electricity in the year 2013 with 4.8 % global share in electricity generation surpassing Japan and Russia.
- Captive power plants have an additional 39.375 GW capacity.
- Non – Renewable Power Plants constitute 87.55 % of the installed capacity.
- Renewable Power Plants constitute the remaining 12.45 % of total installed capacity.
- India generated about around 967,150.32 GWh of electricity during the 2013 – 2014.
- In terms of fuel coal – fired plants account for 59 % of India's installed electricity capacity, compared to South Africa - 92 %, China - 77 % and Australia - 76%.
- India is bestowed with solar irradiation ranging from 4 to 7 kWh / square meter / day across the country with western and southern regions having higher solar incidence.
- India is endowed with rich solar energy resource.
- India receives the highest global solar radiation on a horizontal surface.
- The Jawaharlal Nehru National Solar Mission was launched by the Government of India.
- The first Indian solar thermal power project(2X50MW) is in progress in Phalodi, Rajasthan.
- Land acquisition is a challenge to solar farm projects in India.

- After coal, renewable hydro power accounts for 17%, renewable energy for 12% and natural gas for about 9%.
- The international agency estimates that India will add between 600 GW to 1200 GW of additional new power generation capacity before 2050.
- This added new capacity is equivalent to 740 GW of total power generation capacity of European Union in 2005.
- India's electricity is amongst the world's most active players in renewable energy utilization especially wind energy.

----------(10 Marks)

(b)Energy consumption as a measure of prosperity

Energy is an important input in all sectors of any country's economy. The standard of living of a given country can be directly related to per capita energy consumption. Energy crisis is due to reasons :

- The population of the world has increased rapidly
- The standard of living of human beings has increased

If the annual per capita income of various countries are considered and plotted against per head energy consumption, it will appear that the per capita energy consumption is a measure of the per capita income or the per capita energy consumption is a measure of the prosperity of the nation. The per capita income of U. S. A. is about 50 times per capita income of India and so also is the per capita energy consumption.

Developing countries at present export primary products such as food, coffee, tea, jute and ores etc. This does not give them the full value of their resources. To get better value, the primary products should be processed to products for export. This needs energy. The conventional sources of energy are depleting and maybe exhausted by the end of the century or beginning of the next century. Nuclear energy requires skilled technicians and poses the safety as regards to radioactive waste disposal. Solar energy and other non – conventional energy sources are the sources, those are to be utilized in future.

----------(10 Marks)

2. **Zenith angle , Θz :**

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

Solar Azimuth angle(Ys)

It is the angle on a horizontal plane between the line due south and the projection of the sun's ray on the horizontal plane. It is taken as positive when measured from south towards west.

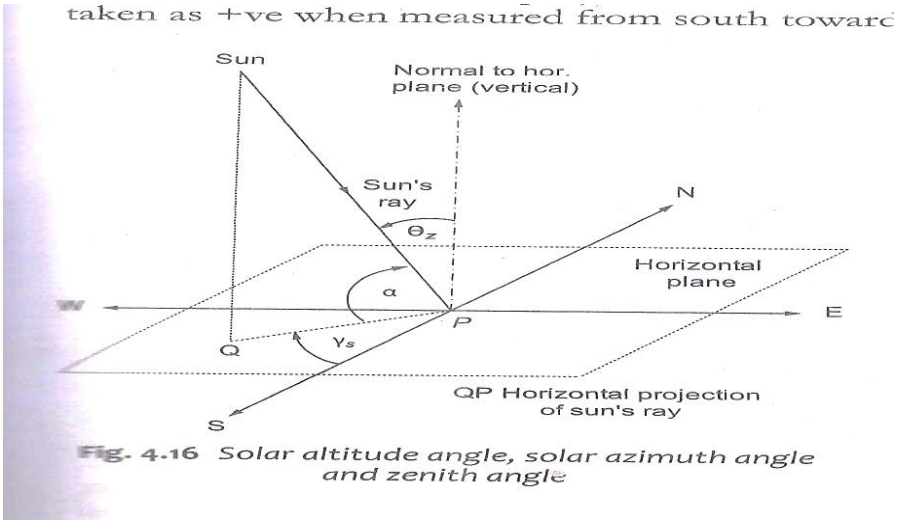


Fig. 4.16 *Solar altitude angle, solar azimuth angle and zenith angle*

Angle of Incidence,(Ɵi):

It is the angle between the sun's ray incident on the plane surface(collector) and the normal to the surface.

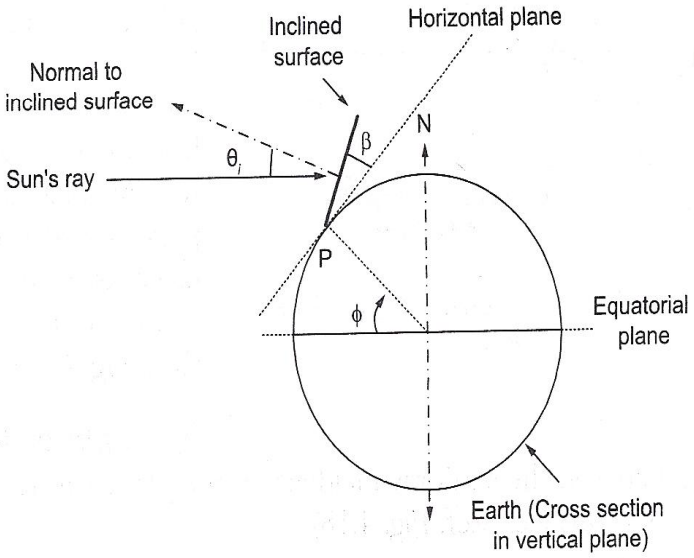
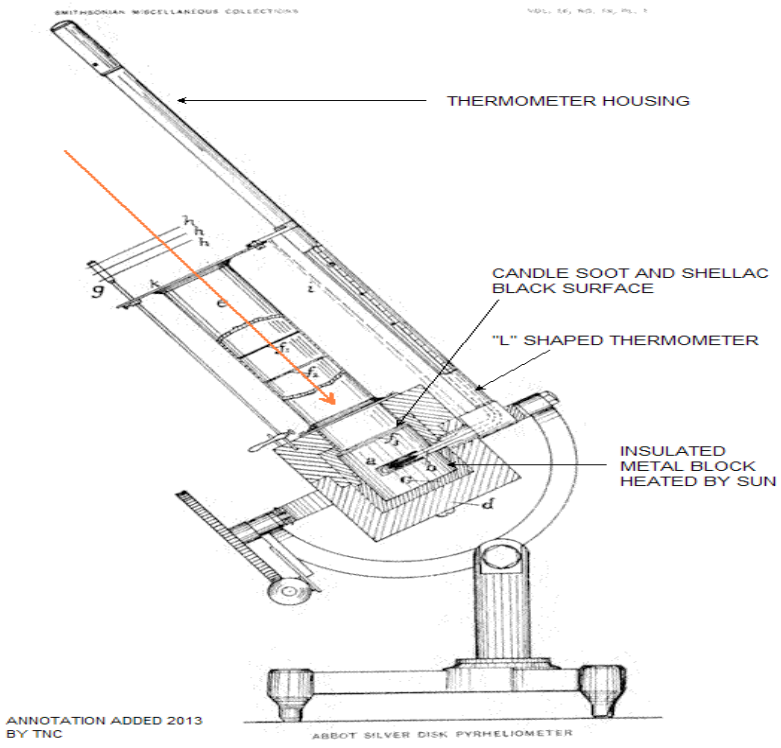


Fig. 4.18 *Angle of latitude, tilt angle, angle of incidence*

----------(10 Marks)

(b)Pyrheliometer

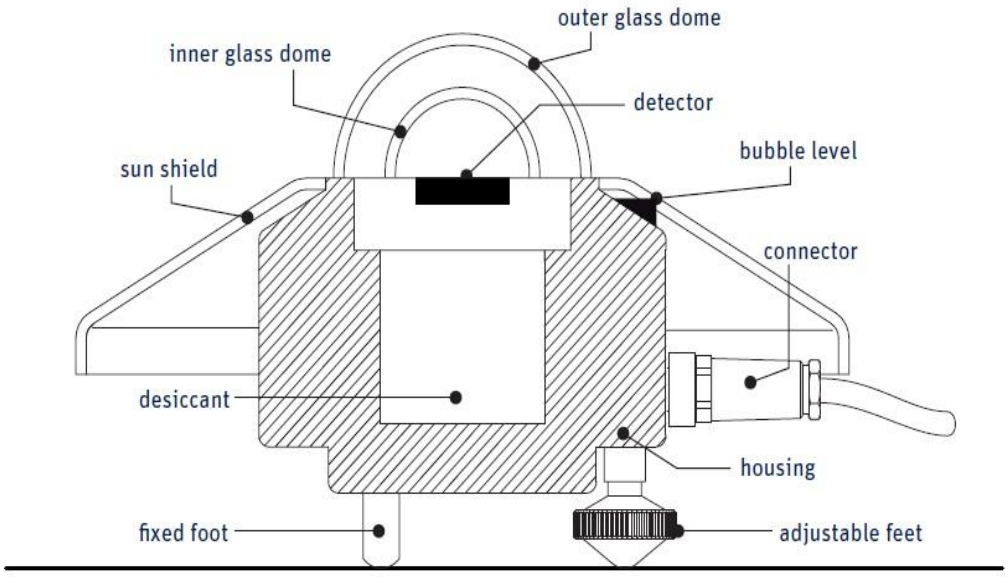
- A pyrheliometer is an instrument for measurement of direct beam solar irradiance.
- Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded.
- The beam radiation is measured by using a long narrow tube to collect only beam radiation from the sun at normal incidence
- The normal incidence pyranometer uses a long collimator tube to collect beam radiation whose field of view is limited to a solid angle of 5.5^{o} by appropriate diaphragms inside the tube
- The inside of the tube is blackened to absorb any radiation incident at angles outside the collection solid angle
- At the base of the tube a wire wound thermopile having a sensitivity of approximately $8\mu V/W/m^2$ and an output impedance of approximately 200Ω is provided
- The tube is sealed with dry air to eliminate absorption of beam radiation within the tube by water vapour
- A tracker is needed if continous readings are desired



Pyrheliometer

Pyranometer

- A Pyranometer is designed to measure global radiation usually on a horizontal surface, but can also be used on an inclined surface.
- When shaded from beam radiation by using a shading ring, a Pyranometer measures diffused radiation.
- A Pyranometer is used for measuring solar irradiance on a planar surface
- It is designed to measure the solar radiation flux density (W/m^2) from the hemisphere above within a wavelength range 0.3 µm to 3 µm

- The name Pyranometer is derived from pyr, meaning “fire” and ano meaning “above sky”
- A typical Pyranometer does not require any power to operate
- A Precision Pyranometer is designed to respond to radiation of all wavelengths and hence measures accurately the total power in the incident spectrum
- It contains a thermopile whose sensitive surface consists of circular, blackened, hot junctions exposed to the sun, the cold junctions being completely shaded
- The temperature difference between the hot and cold junctions is the function of radiation falling on the sensitive surface
- The sensing element is covered by two concentric hemispherical glass domes to shield it from wind and rain
- 

Pyranometer

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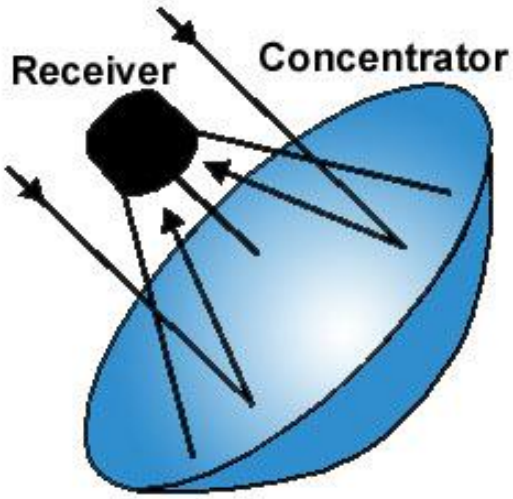
3(a)In concentrating type collectors, solar radiation is converged from a large area into a smaller area using optical means.

Beam radiation which has a unique and travels in a straight line, can be converged by reflection or refraction techniques.

Diffused radiation has no unique direction and therefore does not obey optical principles. The Diffused component cannot be concentrated. The concentrating type solar collectors mainly make use of the beam radiation component(plus very little diffused radiation).

1. Non – concentrating(flat plate) collectors absorb both **beam** as well as diffused radiation.
2. This is a distinct advantage of a flat plate collector.
3. A Flat plate collector is simple in construction and does not require sun tracking.
4. It can be properly secured on a rigid platform.
5. It is mechanically stronger than those requiring flexibility for tracking purpose.
6. As the collector is installed outdoors, the flat plate type is more likely to withstand harsh outdoor conditions.
7. Because of its simple stationary design, it requires less maintenance.

Concentrating type collector

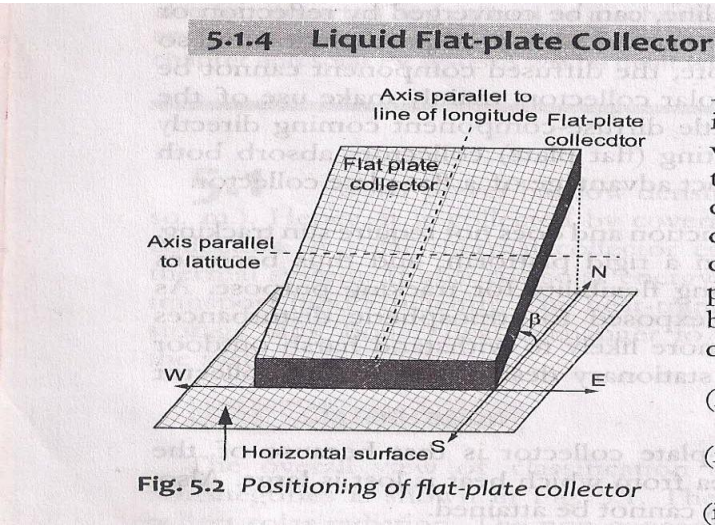


Advantages of concentrating type collectors

1. High temperatures can be attained due to concentration of radiation.
2. This also yields high temperature thermal energy.

Disadvantages of non – concentrating type collectors

1. Because of the absence of optical concentration, the area from which heat is lost is large.
2. Also high temperatures cannot be attained.



Liquid flat plate collector

----------(10 Marks)

(b)Working of a Solar cooker

- Solar energy is considered a suitable alternative for a variety of applications.
- Solar cooking offers an effective method of utilizing solar energy for meeting a considerable demand for cooking energy and hence protecting the environment.
- Cooking with solar cookers is an energy efficient, pollution free way to help fight global warming and take advantage of nature's free inexhaustible supply of energy.
- Solar cooker is a device that cooks food using only solar radiation and can save the conventional fuels to a significant amount.
- It is the simplest, safest, most convenient way to cook without consuming fuels or heating up the kitchen.
- It supplements the cooking fuel but cannot replace it in total.

There are four types of basic designs :

- ❖ Box type solar cooker
- ❖ Dish type solar cooker
- ❖ Community solar cooker
- ❖ Advanced solar cooker

Box type Solar cooker

- ❖ It is possible to cook lunch for 4 to 5 people in a normal box type solar cooker.
- ❖ Here we can bake and boil in the cooker for domestic use.
- ❖ This cooker is simple in construction and operation.
- ❖ An insulated box of blackened aluminium contains the utensils filled with food material.
- ❖ The box receives direct radiation and also reflected radiation from a reflector mirror fixed on the inner side of the box cover hinged to one side of the box.
- ❖ The angle of the reflector can be adjusted as required.
- ❖ A glass cover consisting of two layers of clear window glass sheets serves as the box door.
- ❖ The glass cover traps heat due to greenhouse effect.
- ❖ The maximum air temperature obtained inside the box is around $140 – 160^0$ C.
- ❖ This is enough for cooking, boiling type food stuffs slowly in about 2-3 hours.
- ❖ Electrical backup is also provided in some designs for use during non-sunshine hours.

❖ Its cost varies depending on the type, size, quality and electrical backup facility.

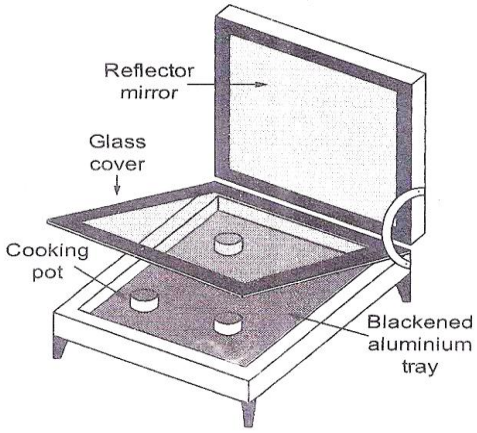
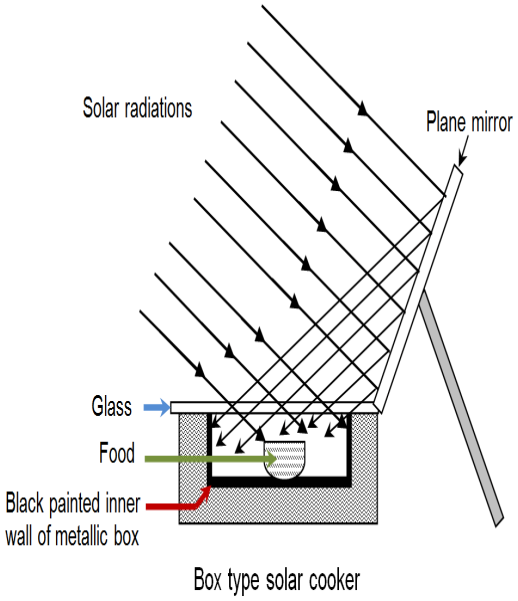


Fig. 5.27 *Box-type solar cooker*



Box type solar cooker

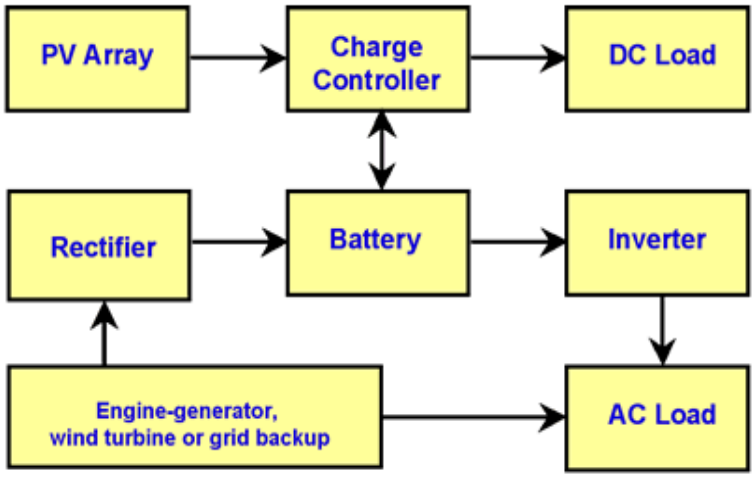
----------(10 Marks)

4(a)Principle of working of a Solar Photovoltaic power generation

The Sun is the most abundant form of renewable energy

available on our planet. The amount of energy that Earth receives from the Sun is immense. It has been calculated that the amount of solar energy that Earth receives in one minute from the Sun would be enough to satisfy the energy needs of entire human population for one year. The world, uses only a tiny fraction of totally available solar energy, primarily because solar power technologies need to improve their cost effectiveness (solar panels cost a lot and they are not that efficient).When explaining the working principle of photovoltaic (solar) cells we first need to know that sunlight is made out of tiny energy pockets called photons and that each individual solar cell is designed with a positive and negative layer thus being able to create an electric field (similar to the one in batteries). As photons are absorbed in the cell their energy causes electrons to get free and they move to the bottom of the cell, and exit through the connecting wire which creates electricity (flow of electrons). The bigger amount of the available sunlight the greater the flow of electrons, and the more electricity gets produced in the process. Photovoltaic or solar panels are devices that are used to convert sunlight into electricity. Photovoltaic panels consist of numerous solar cells. By combining these individual solar cells into photovoltaic panels we

can produce enough energy to power our homes as well as for many other purposes (space satellites).Solar cells absorb photons. Photovoltaic cells are usually made of expensive materials such as silicon, thus explaining the high costs of solar panels. The electricity generated by photovoltaic panels is direct current. This means that there is a need for installing inverter. With the installation of inverter this direct current can be converted into alternating current. The amount of sunlight at the given location plays key role in determining the economics of the solar power installation.



Solar photovoltaic power generation system

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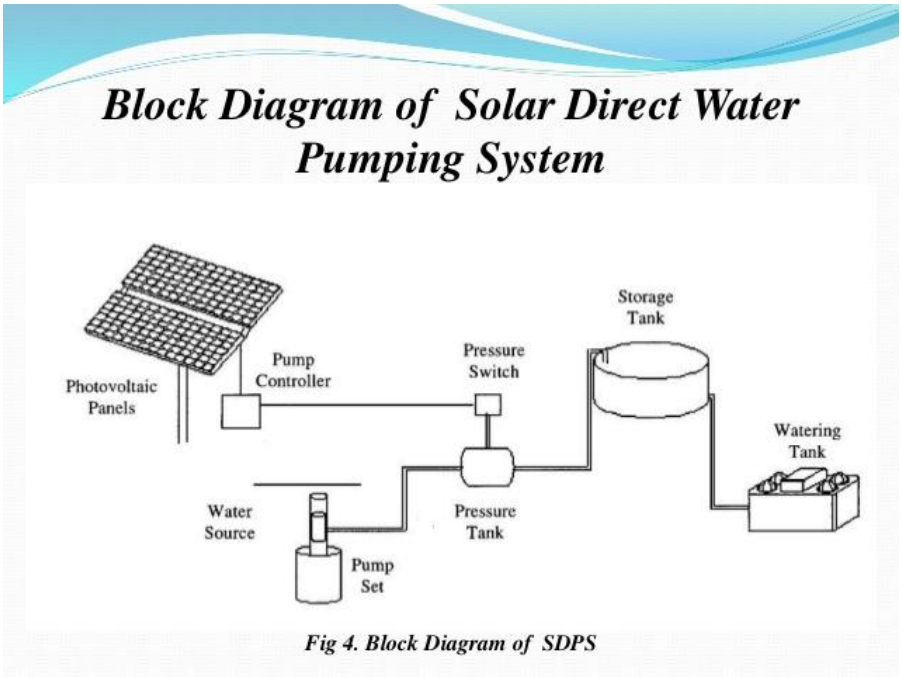

Fig 4. Block Diagram of SDPS

(b)

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Working Principle of Solar water pumping system

A solar-powered pump is a pump running on electricity generated by photovoltaic panels or the radiated thermal energy available from collected sunlight as opposed to grid electricity or diesel run water pumps.

The solar panels make up most (up to 80%) of the systems cost. The size of the PV-system is directly dependent on the size of the pump, the amount of water that is required (m^3/d) and the solar irradiance available.

The solar powered water pumps, use solar energy to run. These solar powered water pumps are extremely cost-effective, durable,

easy to install and require minimum maintenance. The life of an installed pump can be as long as 20 years. The maintenance and running cost is also very low as compared to the normal water pumps. The solar modules need to be cleaned from time to time for efficient running. These systems are best alternatives in areas where there is no electricity or reliable supply is not available.

The main components of Solar powered Water Pumps

- Solar Panels
- Pump
- Electric Motor and
- Controller

The pump uses the electricity generated by solar energy stored in solar panels to function. The electric motor is used to manage the AC or DC current and the controller is used to adjust the speed and output power. Solar Powered water pumps are much more economical and efficient to run than the traditional diesel powered pumps, since solar energy is free. Solar powered water pumps can be extremely useful for farmers who work on a small scale. These are also useful in cattle feeding, horticulture farms, gardens and irrigation. Solar powered water pumps are also finding usage in Oil

and gas extraction.

Solar Energy in the form of light rays falls on the solar photovoltaic panels and got converted into electrical energy through silicon wafers embedded in the solar photovoltaic panels. This electrical energy then goes to the DC based motor pumping system through the cables and operates this motor. By rotation of the shaft coupled to mono-block pump, the pump starts lifting the ground water and throw it out for use.

----------(10 Marks)

Part B

5(a)Functions of different components of a Wind energy conversion system :

A wind energy conversion system converts wind energy into some form of electrical energy.

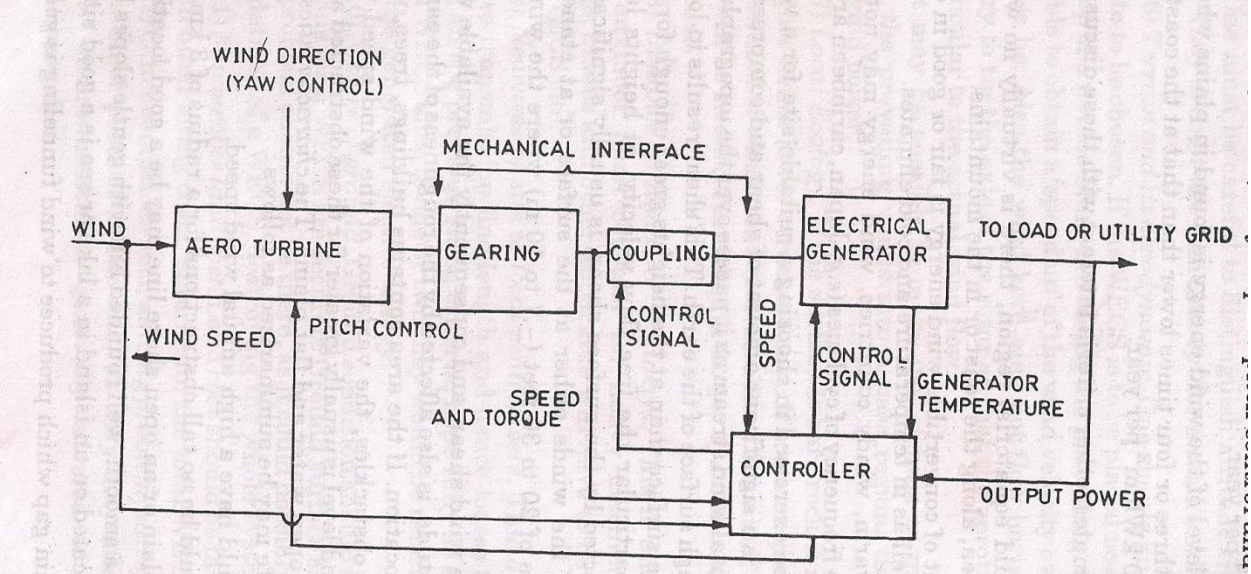


Fig. 6.5.1. Basic components of a Wind Electric System.

Basic components of a Wind Electric system

- Aero turbines convert the energy in moving air to rotary mechanical energy.
- They require pitch control and yaw control(only in the case of horizontal or wind axis machines) for proper operation.
- A mechanical interface consisting of a step up gear and a suitable coupling transmits the rotary mechanical energy to an electrical generator.
- The output of this generator is connected to the load or power grid based on the application.
- Yaw control The rotor can be in a fixed orientation with the swept area perpendicular to the predominant wind direction.
- Such a machine is said to be yaw fixed.
- Most wind turbines are yaw active.
- In these turbines, as the wind direction changes, a motor rotates the turbine slowly about the vertical(yaw) axis so as to face the blades into the wind.
- The area of the wind stream swept by the wind rotor is then a maximum.

- ❖ In small machines, yaw action is controlled by a tail vane, similar to that in a typical pumping windmill.
- ❖ In large machines, a servomechanism operated by a wind direction sensor controls the yaw motor that keeps the turbine properly oriented
- ❖ The purpose of the controller is to sense wind speed, wind direction, shaft speeds and torques at one or more points, output power and generator temperature as necessary.
- ❖ Appropriate control signals for matching the electrical output to the wind energy input is given.
- ❖ Also protection of the system from extreme conditions brought upon by strong winds and electrical faults.

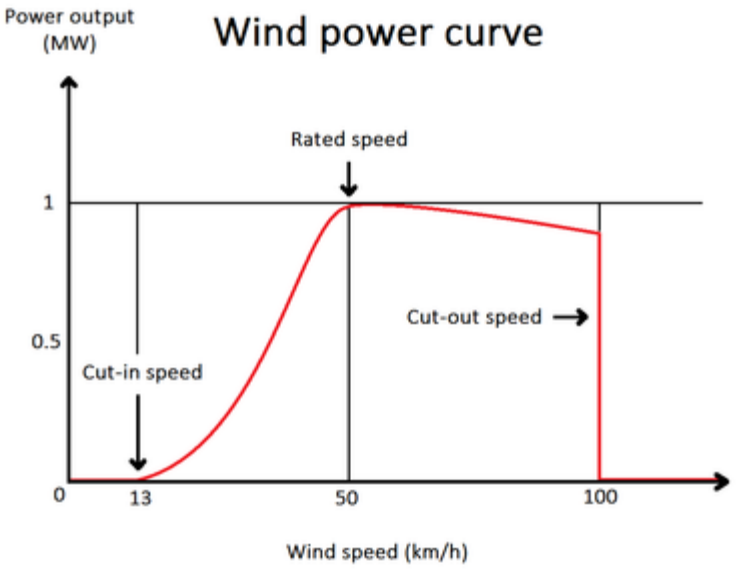
----------(10 Marks)

(b)The factors that determine output power from wind energy :

- Wind speed
- Cross section of wind swept by rotor
- Overall conversion efficiency of motor

A Windmill captures wind energy and then uses a generator to convert it to electrical energy. The design of a windmill is an integral part of how efficient it will be. When designing a windmill, one must decide on the size of the turbine, and the size of the generator. Wind power generators convert wind energy (mechanical energy) to electrical energy. The generator is attached at one end to the wind turbine, which provides the mechanical energy. At the other end, the generator is connected to the electrical grid. The generator needs to have a cooling system to make sure there is no overheating.

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. Wind turbines need to be in areas with a lot of wind on a regular basis, which is more important than having occasional high winds.



----------(10 Marks)

6(a)Factors affecting Biogas generation

- pH or the hydrogen ion concentration(6.5-7.5)
- Temperature (33-35˚C)
- Total solid content of the feed material
- Loading rate
- Seeding
- Uniform feeding
- Diameter to depth ratio
- Carbon to nitrogen ratio
- Nutrients
- Mixing or stirring or agitation of the digester
- Retention time or rate of feeding
- Type of feed stocks
- Toxicity due end product
- Pressure
- Acid accumulation inside the digester

- Acid formers and methane fomenters must remain in a state of dynamic equilibrium, which can be achieved by proper design of digester.
- Anaerobic fermentation of raw cow dung can takes place at any temperature between 8 and 55°C. The value of 35°C is taken as optimum.
- The rate of biogas formation is very slow at 8°C. For anaerobic digestion, temperature variation should not be more than 2 to 3°C.
- Methane bacteria work best in the temperature range of 35 and 38 ^{0}C .

The different biogas plants in India are – KVIC and Janata model.

----------(10 Marks)

(b)Working of Janata model Biogas plant

Fixed Dome type – Janata Model Biogas Plant Construction

Biogas can be a great alternative of fossil fuels. It is already in use in many rural areas. Biogasplants use animal waste, plant waste and human waste. All this wastes have great combustible property. Biogas is an excellent renewable energy source. It is produced by the digestion of waste materials by the means of anaerobic reaction. Anaerobic means the absence of Oxygen. In most of the rural areas cow and buffalo dungs is used as biomass fuel for producing gas. The typical composition of biogas is

Methane - CH_4 (55 - 65 %)
Carbon dioxide CO_2 (30-40%)
H_2 , H_2S , N_2 (< 10%)

Biogas Technology involves the bacterial breakdown of the waste materials to produce Methane,Carbon Dioxide and Water . The process involves the following three steps -

Hydrolysis

Organics materials contains mainly carbohydrate mainly in the form of cellulose, hemicellulose and lignin. These have very complex structure which is not suitable for absorption. So these matters are converted into simple soluble materials by the action of celluolytic or hydrolytic bacteria. Concentration of bacteria in the organic materials, temperature and pH controls the rate of hydrolysis. pH between 6 to 7 and temperature between 30-40 degree Celsius is good for bacteria to work.

Acid Formation

Simple organic materials are turned into acid by acetogenic bacteria.

Methane Formation

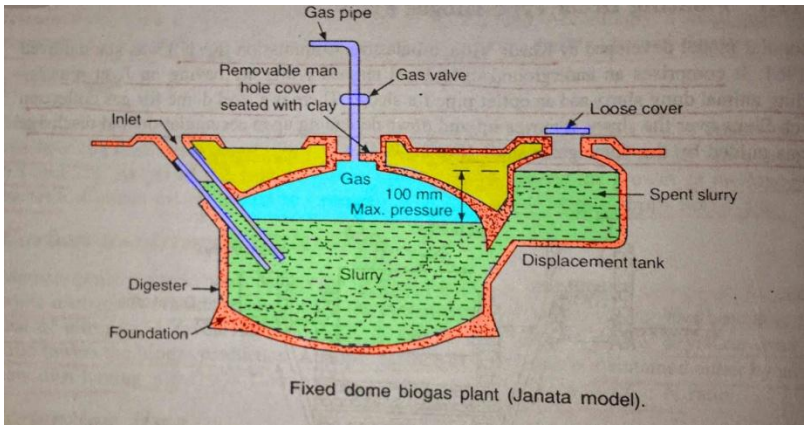
Methanogenic bacteria turns the acid into methane, carbon dioxide, hydrogen, nitrogen and oxygen. The methane content is 60%. It has high calorific value. Very good for combustion and producing energy.

Biogas plants

Biogas plant converts the organic wastes like dung, human waste and plant wastes into a inflammable and it also produces a high quality organic manure as a by product. Most popular two designs of biogas plant is

1. Fixed Dome Type Biogas plant (Janata Model) (Operates in constant volume)
2. Floating Drum type Biogas plant. (Operates in constant pressure)

Fixed Dome Type Biogas Plant - Janata Model

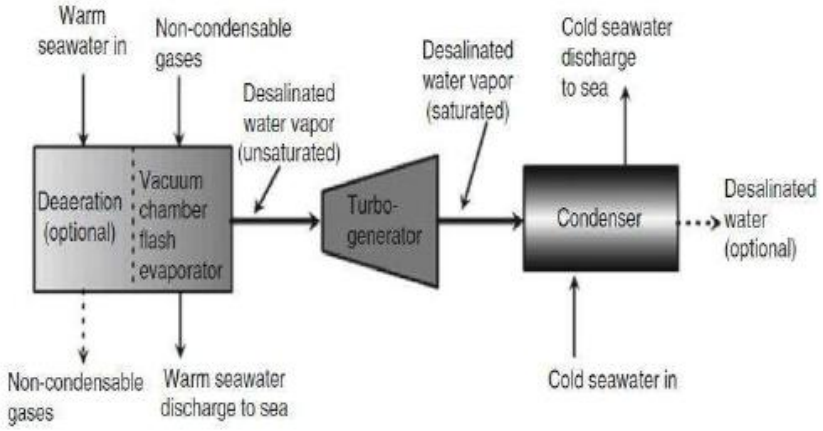


Fixed dome biogas plant (Janata model).

This type of biogas plant is very economical is design. It works with the constant volume principle. The main structure is made up of brick and cement masonry. This type of plant doesn't have any moving parts so it is safe from wear and tear. The operating pressure varies from 0 to 100 cm of water column. It is also known as Janata model.

----------(10 Marks)

7(a)Open cycle Ocean Thermal energy conversion(OTEC)



Ocean thermal energy conversion (**OTEC**) uses the temperature difference between cooler deep and warmer shallow or surface seawaters to run a heat engine and produce useful work, usually

in the form of electricity. OTEC can operate with a very high capacity factor and so can operate in base load mode.

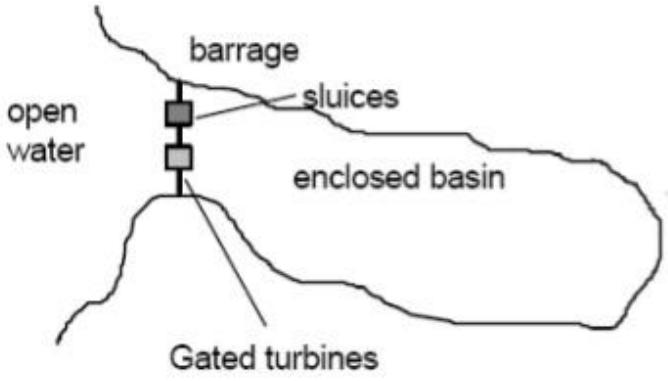
Among ocean energy sources, OTEC is one of the continuously available renewable energy resources that could contribute to base-load power supply. The resource potential for OTEC is considered to be much larger than for other ocean energy forms [World Energy Council, 2000]. Up to 88,000 TWh/yr of power could be generated from OTEC without affecting the ocean's thermal structure . Systems may be either closed-cycle or open-cycle. Closed-cycle OTEC uses working fluids that are typically thought of as refrigerants such as ammonia or R-134a. These fluids have low boiling points, and are therefore suitable for powering the system's generator to generate electricity. The most commonly used heat cycle for OTEC to date is the Rankine cycle, using a low-pressure turbine. Open-cycle engines use vapour from the seawater itself as the working fluid.

OTEC can also supply quantities of cold water as a by-product. This can be used for air conditioning and refrigeration and the nutrient-rich deep ocean water can feed biological technologies.

----------(10 Marks)

(b)Working of Single basin tidal power plant

Single Basin Scheme: This scheme has one barrage and one water storage basin, one way system, the incoming tide is allowed to fill the basin through sluice ways during the tide and the impounded water is used to generate electricity by letting the water flow from basin to the sea through the turbines during single basin schemes is intermittent generation power.



In Single basin system, there is only one interaction with the sequence. The two are separated by dam and flow between through sluice valves. The generation of power is by

- Single ebb cycle system
- Single tide cycle system
- Double cycle system

Single basin system-

Ebb generation: During flood tide basin is filled and sluice gates are closed , trapping water. Gates are kept closed until the tide has ebbed sufficiently and thus turbines start spinning and generating electricity.

Flood generation: The basin is filled through the turbine which generate at flood tide.

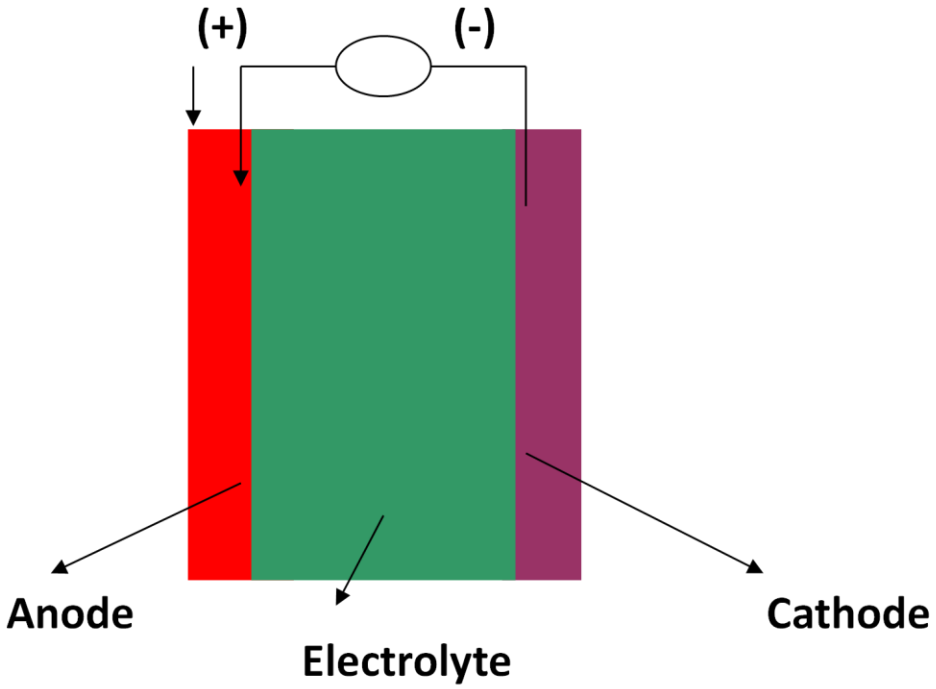
Two way generation: Sluice gates and turbines are closed until near the end of the flood tide when water is allowed to flow through the turbines into the basin creating electricity. At the point where the hydrostatic head is insufficient for power generation the sluice gates are opened and kept open until high tide when they are closed. When the tide outside the barrage has dropped sufficiently water is allowed to flow out of the basin through the turbines again creating electricity.

----------(10 Marks)

8(a)Describe fuel cells and their functions

A Fuel cell is a electrochemical device that converts chemical energy into electrical energy. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the cathode and anode. The reactions that produce electricity take place at the electrodes. In all types of fuel cell, hydrogen is used as fuel and can be obtained from any source of hydrocarbon. The fuel cell transform hydrogen and oxygen into electric power, emitting water as their only waste product.

- Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.
- A single fuel cell generates a tiny amount of direct current (DC) electricity.
- A converter is used to produce AC current.
- In practice, many fuel cells are usually assembled into a stack. Cell or stack, the principles are the same.



Fuel cell configuration

- A fuel cell consists of two electrodes namely an anode and a cathode and sandwiched around an electrolyte.
- An electrolyte is a substance, solid or liquid, capable of conducting owing ions from one electrode to other.

Functions of Fuel cells

- A fuel cell is a device that uses a source of fuel, such as hydrogen, and an oxidant to create electricity from an electrochemical process.
- A fuel cell converts chemical energy to electrical energy.
- A fuel cell is an electrochemical cell that converts the chemical energy from a fuel into electricity through an electrochemical reaction of hydrogen fuel with oxygen or another oxidizing agent.

----------(10 Marks)

(b)Wave energy conversion

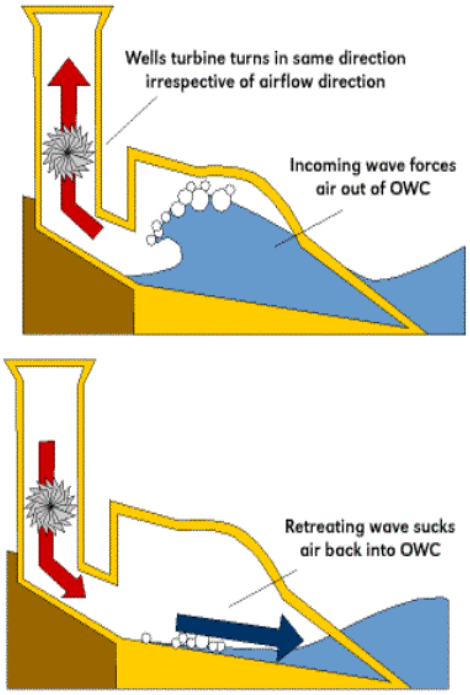
Among other types of renewable energy, oceans contain energy in the form of (1)waves (2)tidal currents

Differential warming of the earth causes pressure differences in the atmosphere, which generate winds. As winds move across the surface of open bodies of water, they transfer some of their energy to the water and create waves. The amount of energy transferred and the size of the resulting wave depend on the wind speed, the length of time for which the wind blows, the distance over which the wind blows, or fetch. Therefore, coasts that have exposure to the prevailing wind direction and that face long expanses of open ocean have the greatest wave energy levels. In order to extract this energy, wave energy conversion devices must create a system of reacting forces, in which two or more bodies move relative to each other, while at least one body interacts with the waves. There are many ways that such a system could be configured.

Wave energy technologies

- One wave energy conversion system that has proven successful is the Oscillating water column.
- An Oscillating Water Column (OWC) consists of a partially submerged structure that opens to the ocean below the water surface. This structure is called a wave collector.
- This design creates a water column in the central chamber of the collector, with a volume of air trapped above it.

Oscillating water column



- As a wave enters the collector, the surface of the water column rises and compresses the volume of air above it.
- The compressed air is forced into an aperture at the top of the chamber, moving past a turbine.
- As the wave retreats, the air is drawn back through the turbine due to the reduced pressure in the chamber.
- The turning of the turbine drives a generator, producing electricity

----------(10 Marks)