SWAMI VIVEKANAND SCHOOL OF ENGG & TECH.

Renewable Energy Sources

Sonali Susmita Tripathy

# Renewable Energy Resources

Sonali Susmita Tripathy

# Introduction to Renewable Energy

**Renewable energy** :- Renewable energy is energy from sources that are naturally replenishing.
:- Renewable resources are virtually inexhaustible in duration but limited in amount of energy that is available per unit of time.
- the major types of renewable energy sources are wood, sun (solar), hydro power, wind, biomass etc.

## Environmental consequences of fossil fuel use

Fossil fuels are non-renewable resources which are classified into mainly below types.
→ Coal
→ Petroleum
→ Natural gasses.

✲ while burning of fossil fuel, there must be emission of CO & $CO_2$. That causes global warming.
✲ Global warming leads to climatic change in the environment.
✲ There must be release of Nitroge oxide ($NO_x$) and Sulphur oxide ($SO_x$), which may causes acid rain. $H_2SO_4$ & $HNO_3$ are two main element of acid rain.
✲ For fossil fuel there are mining action which causes deforestation.
✲ Deforestation leads to loss of biodiversity & land degradation.

* When we burn coal, it release one toxic element i.e mercury (Hg). It pollute the water resources. So cause harmful to aquatic animal.
* Burning of fossil fuel leads to Air pollution.
* There must be problem with oil spilling (petroleum)
* Leakage of natural gas is a huge problem. Natural gas contains methane which is a green house gas. Methane leads to global warming.

Importance of renewable sources of energy

* Renewable energy emits no or low green house gasses which prevent global warming i.e good for climate.
* Renewable energy emits no or low air pollutants that is better for our health.
* RE comes with low cost. That good for keeping energy price affordable levels.
* RE makes the energy system resilient.
* RE is important to prevent power shortage.
* RE is accessible to all. That's good for development.
* RE is secure and good for stability.
* RE is democratic and good for acceptance.

# Sustainable design and development

:- The sources of electricity production such as coal, oil and natural gasses have contributed to one-third of global green-house gas emission.

:- So it is essential to realise the standard of living by providing cleaner and and more reliable electricity.

:- there is an urgent need to find alternate sources for generating electricity.

:- world will have a rapid and global transition to renewable energy technology to achieve sustainable growth.

:- Renewable energy sources play a vital role in securing sustainable energy with lower emissions.

:- Awareness of saving energy has been promoted among citizens to increase the use of solar, wind, biomass waste and etc.

:- The clean energy is less harmful to ~~environment~~ and often cheaper.

:- India is aiming to attain 175 GW of renewable energy which would consist of 100 GW from solar energy

biopower, 60GW from wind power and 5GW from small hydropower plants by the year 2022.

:- The sustainable development mainly covers the use of renewable energy.

:- At present, the contribution of renewal energy is not high to meet the primary energy and electricity supply supplies.

:- But renewable energy system provide optimum efficiency and limit emissions.

:- Both developed and developing countries plan to enable the most appropriate energy system and improve human, economic, social and environmental condition for sustainable development.

:- Government policies should be carefully planned for the production, replacement, transportation, distribution and usage of energy.

## Types of Renewable Energy sources

→ Solar energy
→ wind energy
→ Biomass energy
→ Hydropower
→ Geothermal energy
→ Tidal and wave energy.

## Limitations Renewable energy resources

i → Higer capital cost :- The investment for the RE resources is quite high.

ii → Electricity production can be unreliable :- RE systems rely on natural resources such as sunlight, wind and water. Therefore their electricity generation can be as predictable as the weather.

iii → Energy storage is a challenge :- They need forms of energy storage to capture and release electricity.

iv → It's impacted by environmental condition :- RE systems depends on their location and surrounding environment.

v → RE systems still have some pollution factor :- Their manufacturing, transport and installation still creates carbon.

vi → the electricity generation capacity is still not large enough :- There are still challenges to the generation of large quantities of power in renewable energy technology compared to traditional forms of energy generation like fossil fuel.

vii) Takes a lots of space to install :- The plant need large and suitable space for installation.

## Present Indian and international energy scenario of conventional and RE sources

Indian energy scenario :- India has the 5th largest electricity generating capacity and is the 6th largest energy consumer amounting for around 3.4% of global energy consumption.

:- India has about 5% of world's coal production. Coal besides a prime source of industrial energy is also a raw material.

:- India is rich in radioactive materials. So there is a large efficiency in electricity production in India.

:- Mineral oil is very unevenly distributed over space. Natural gas reserves are generally found in association with oil fields.

:- In present day 60% of coal produced is utilized in generation of electricity which is in fact more than 95% of thermal power or about 70% of total installed capacity of electricity generated in India.

:- Rather than India has been implementing non-conventional energy sources. At present energy sources such as solar, wind, bio-mass have more than 3000MW of capacity which is around 3% of total installed power generating capacity of 103 thousand MW.

## International energy scenario

:- Globally involment of resources

- coal - 25.1%
- oil - 34.3%
- Natural gas - 20.9%
- Nuclear - 6.5%

} conventional

- Renewable energy resources - 13.3%

## India's energy scenario

### Resources

- coal - 54%
- oil - 34%,
- Natural gas, hydro and nuclear energy - 12%.

### power plants

- Thermal power plant - 75%
- Hydro electric power plant - 21%
- Nuclear power plant - 4%

———— * ————

# Solar Energy

:- The sun is a source of energy. The energy from the sun in the form of radiations is called solar energy.

## Solar photovoltaic system operating Principle

:- Solar photovoltaic system or Solar cell are device which directly convert incident solar radiation to electric current.

:- It works on the principle of photoelectric effect. Thats why this is called photovoltaic cell.

## photoelectric effect

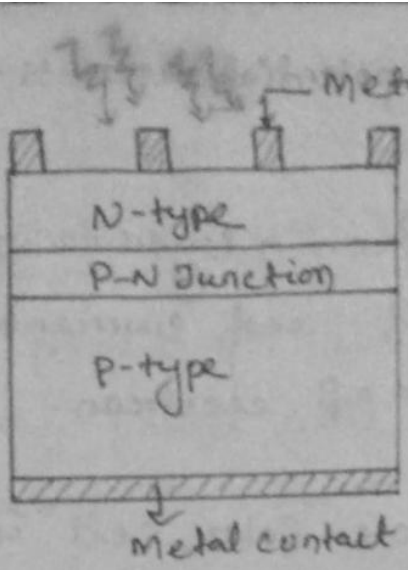
:- It is a phenomenon in which electrons are ejected from the surface of a metal when light is incident on it. these ejected electrons are called photoelectrons.

## photovoltaic cell concept

:- A photovoltaic cell (PV cell) or also known as Solar cell is defined as an electrical device that converts light energy into electrical energy through photovoltaic effect.

## Construction of photovoltaic cell

:- For construction all we need is P type and N type materials. Here P-type should be large layered and N type should be thin layered.

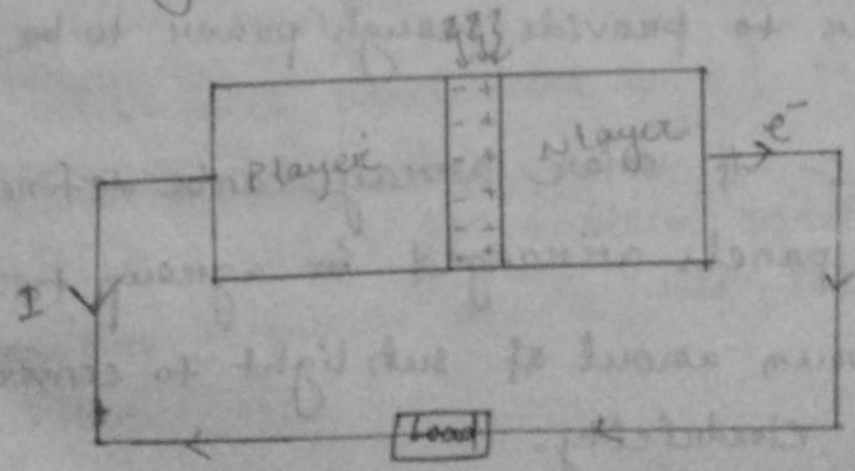



:- The N-type should be thin layere because thin layere make easy to penetreate the sunlight to the junction ore delpi depletion layere.

:- On N type metal fingere is placed and in p type is made in contact to the metal.

:- the metal fingere is covered with a treansparent sheet ore non-reflectable meterial.

## working of photovoltaic cell Q.3




:- when the sunlight is incident on N layer it is reached to the depletion layere.

:- when light falls on juction es are ejected according to intensity of light.

:- Now it is form a potential across the P-N junction.

:- The e⁻s will flow from n layer to p-layer by an external circuit and current will flow opposite to the flow of electron.

Cells :- The cell or Solar cell is an electrical device that convert light energy (Sun light) to electrical energy.

Modules :- PV cells are connected electrically in series and/or parallel circuit to produce higher voltages, currents and power levels. This is called Modules.

Panels :- A solar panel is a collection of solar modules so as solar cells. A lots of Solar cells spread over a large area can work together to provide enough power to be useful.

Solar Array :- A solar array can be defined as a solar panels arranged in a group to capture maximum amount of sun light to convert it into usable electricity.

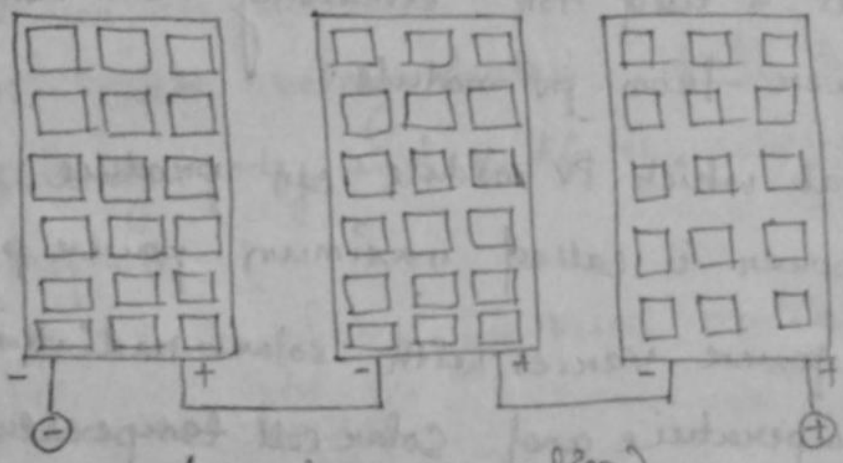
Series and parallel connection

Series connection :- Just like a battery, solar panels have two terminal: One positive and one negative.

:- when we connect the positive terminal of one panel to the negative terminal of another panel, then it will be the series connection.

:- when solar panels are wired in series the voltage of the panels adds together but the amperage remains the same.

:- Putting panels in series makes it so the voltage of the array increases.

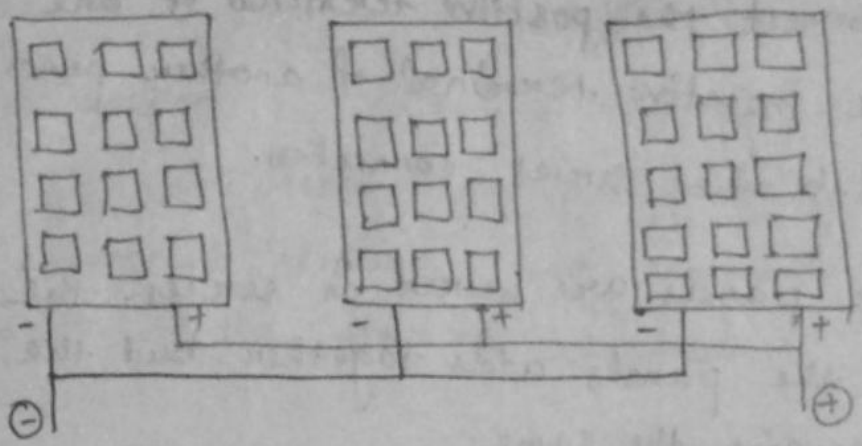



(Series connection)

Parallel connection

:- when solar panels are wired in parallel, the positive terminal from one panel is connected to the positive terminal of another panel and the negative terminals of the two panels are connected together.

:- Wiring solar panels in parallel causes the amperage to increases but the voltage remains the same.




## Maximum Power Point tracking (MPPT)

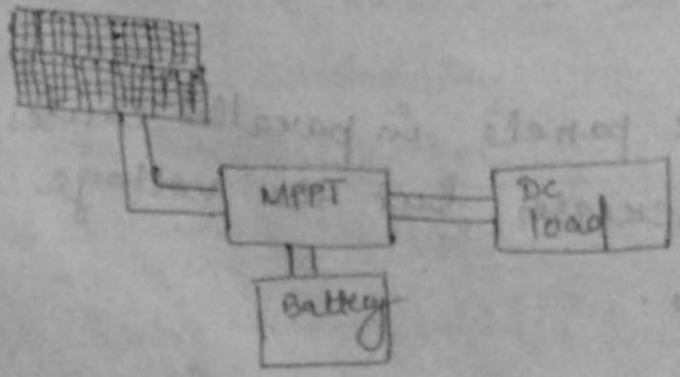
:- MPPT or maximum power point tracking is algorithm that is used for extracting maximum available power from PV module.

:- The voltage at which PV module can produce maximum power is called maximum power point.

:- Maximum power varies with solar radiation, ambient temperature and solar cell temperature.

## How MPPT works

:- MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery



## Terrestrial Radiation

:- The radiation from the sun first heat up the earth surface. Again the ~~ea~~ when the earth surface heat up it will reflect back the radiation to the atomsphere. The reflect radiation is called terrestrial radiation.

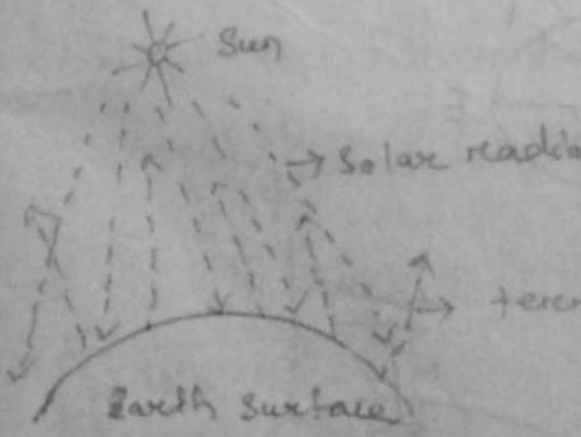
How the terrestrial radiation are formed?

:- The earth receives the solar radiation and heat up its surface.

:- The earth being heated itself becomes a radiating body and radiates energy to the atomsphere.

:- the atmosphere in turn radiates and transmit heat to the space.

:- The amount of heat received from the sun is returned to space (except usable heat), there by maintaining a constant temperature at the earth's surface and the atmosphere.



## Extra terrestrial radiation

:- Extra terrestrial radiation is the radiation which is incident outside the earth's surface.

:- Due to the change in distance between the earth and sun there is a variation in the extra terrestrial rate

:- The extra-terrestrial radiation is 1367 watt/m2.

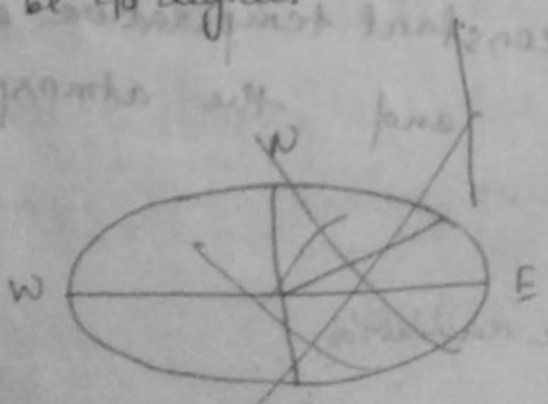
## Azimuth Angle

:- It is the compass direction from which the sunlight is coming.

:- It measures the sun's angle relative to North in the eastward direction.

:- If the sun is due north in the sky, the azimuth will be zero.

:- If the sun is due east in the sky, the azimuth angle will be 90 degrees.

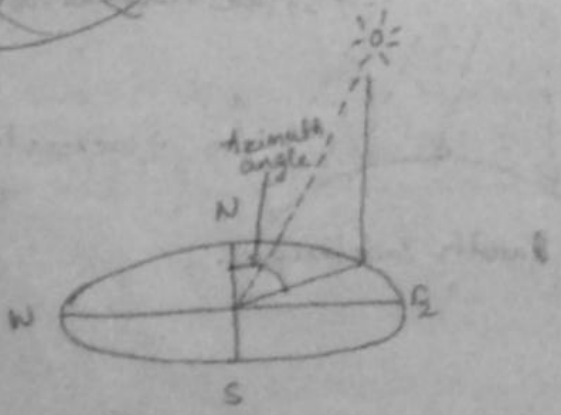



:- Azimuth angle varies based on the

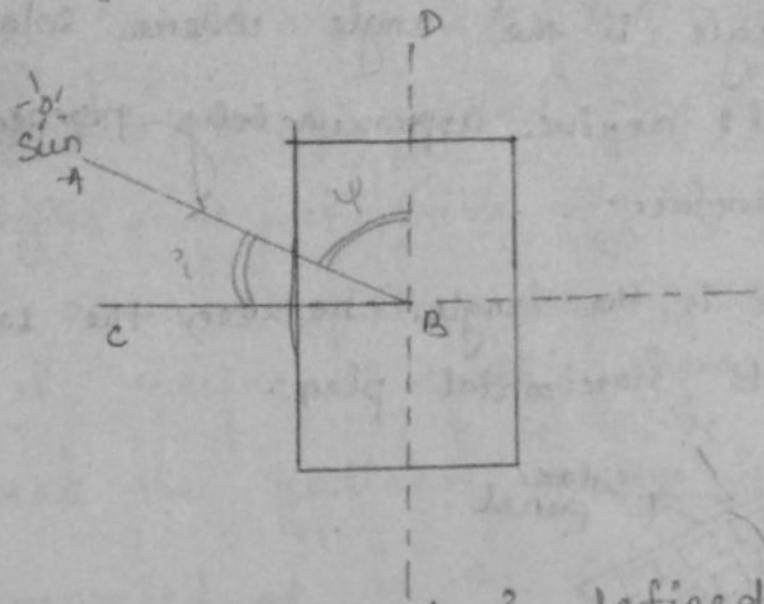
i- Times of day

ii- The latitude on earth

iii- The time of the year.



## ~~Zenith Angle~~ Inclination angle / Altitude Angle (i)




∴- Inclination angle is defined as the sun ray of its projection on horizontal plane.

∴- Sun ray is AB, BC is the horizontal plane

∴ $\angle ABC = i$ (inclination angle)

∴- This is also called of angle of Altitude.

## Zenith angle ($\psi$)

∴- The angle between the sun ray and the perpendicular line of its horizontal plane.

∴- AB is the sun ray BD is the perpendicular line of its horizontal plane. then,

$\angle ABD = \psi$ (zenith angle)

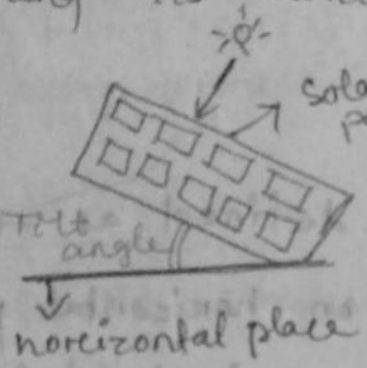
$$i + \psi = 90^\circ$$

$$\boxed{\Rightarrow \psi = 90^\circ - i}$$

## Tilt angle

:- The tilt angle is the angle where solar radiation will arrive approximately perependicular upon the surface.

:- Tilt angle is the angle between the solar panel and its horizontal place.

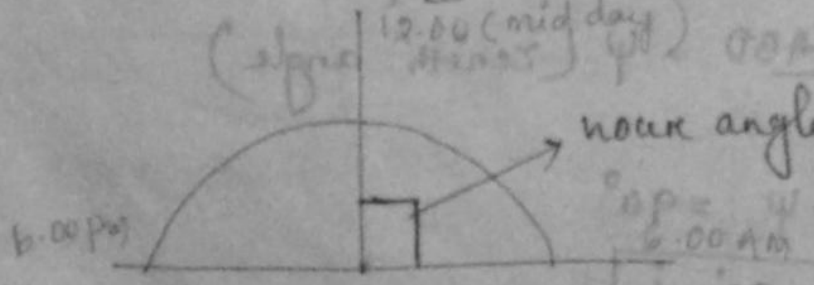



## Hour Angle (W)

:- It is the angle through which the earth must be rotated to bring the meridian of a point directly inline with the sun ray.

:- It is the angle representing the position of the sun with respect to clock hour & with reference to sun position at 12.00 noon.

$$W = 15(LST - 12)$$ [LST - local solar time]




* At 6.00 AM $\Rightarrow W = 15(6-12) = -90^\circ$

* At 6.00 PM $\Rightarrow W = 15(18-12) = 90^\circ$.

## Irradiance

:- Solar irradiance is defined as the amount of radiant energy emitted by the sun overall wavelengths, not just visible light falling each second on a 1 square meter perpendicular plane of outside of earth's atmosphere.

:- Overall the radiant energy is measured and reported as the solar irradiance.

:- When all of the radiation is measured it is called total solar irradiance (TSI)

:- The solar irradiance is measured in watt per square metre ($W/m^2$)

:- The study and measurement of solar irradiance have several important applications, including the prediction of energy generation from solar power plant, heating process, climate modeling and weather forecasting.

:- The measurements are taken by using

- ✓ pyranometers
- ✓ pyrheliometer
- ✓ Sunshine recorder (less accurate and less expensive)

**Insolation** :- The solar insolation is the total amount of solar energy received at a particular location during a specified time period.

## Solar Constant

~~The amount of~~ s

:- The amount of solar energy received per unit second by one square meter area on near earth space perpendicular to sun's ray and at earth's mean distance.

:- The value of solar constant is 1.366 KJ/S/m2 or 1.366 KW/m$^2$.

## Solar Collectors

:- A solar collector is a receiving device which absorbs the incident solar readiation and heat substances like water or air.

:- The solar radiation further can be converted into electrical power.

:- The two main types of collector are
a) flat plate collector
b) concentrating collector.

### a) flat plate collector

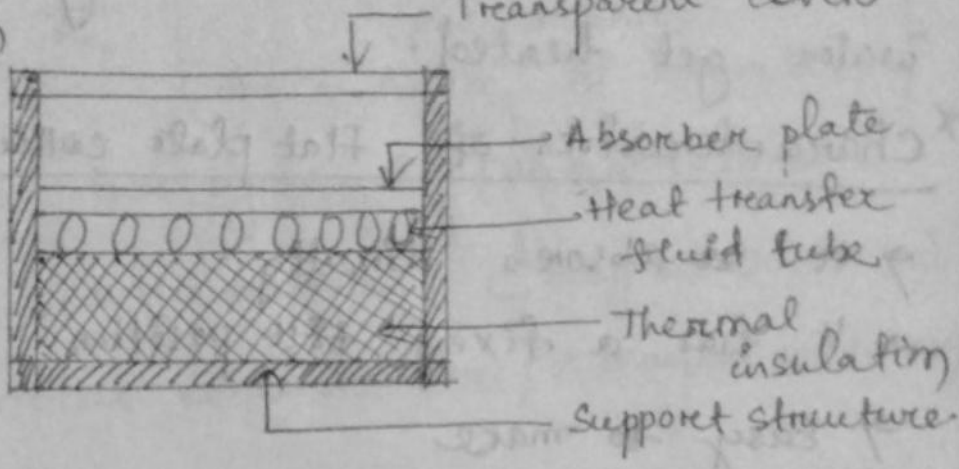
:- Flat plate collectors are used for the temperature below 100°C. They are always installed in a fixed tilted position oriented towards the equator.

:- The basic principle for this device is that the sun heats a dark flat surface which collects as much as energy as possible. Then the energy

is transferred to the air and other fluid for further use.

∴ It is otherwise called Solar thermal collector

* Construction




i) Absorber plate :- A black surface that absorbs the incident solar energy. It is a copper or aluminium sheet.

ii) Transparent cover :- A glazing cover that transmits radiation to the absorber. It prevent heat loss from the surface. It is made up of plastic or glass.

(iii) Heat transfer fluid tube :- Contain heating fluid to transfer the heat from the collector.

(iv) Support structure :- It protect the components and hold them in a place.

(v) Thermal insulation :- It covers bottom of the collector to reduce heat losses.

* working :- The black absorber plate absorbs radiant heat ft from sunlight. It is covered by transparent plate to reduce the heat loss.

:- There are tubes carrying water, which gets heated due to the light absorbed.

:- The absorbere plate absorbs the energy and transfer it to the tube by which the water get heated.

## * Characteristics of Flat plate collector

→ It absorb directly.
→ It has a fixed tilt position.
→ Easy to make
→ low in cost
→ Have comparatively low maintenance
→ Operate at high efficiency.

## b) Concentrating collectors

:- These are used fore medium and high temperature application.
:→ It can achieve higher temperature ranges because the solar radiation is concentrated on a smaller area.
:- This is used mainly to generate electricity.

## * Construction and working

:- There are various types of concentrating collectors which consist of concentrator, Absorbere
:- the beam of radiation first incident of on the concentrator then reflects to the Absorber.

Different types of collector have different values of concentration ratio which is given as

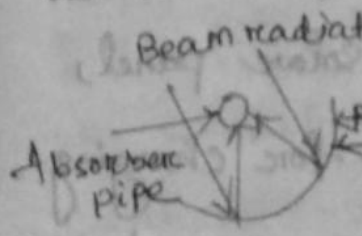
$$C = \frac{A_a}{A_r}$$

$A_a$ = Aperature area of the concentrator
$A_r$ = Area of absorber

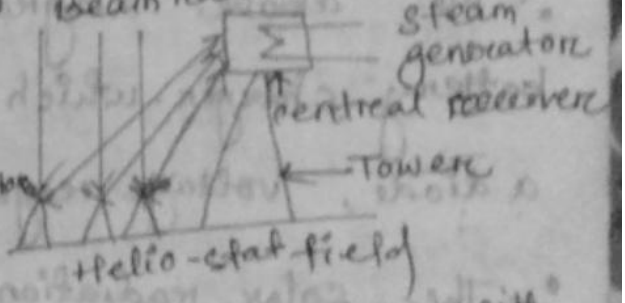
:- There are two types of concentrator
→ Linear concentrator ( C may be 20 to 100)
→ Point focus concentrator ( C maybe 100 to 4000)

:- These concentrators are rotated through tracking mechanism to follow the motion of the sun in the sky.

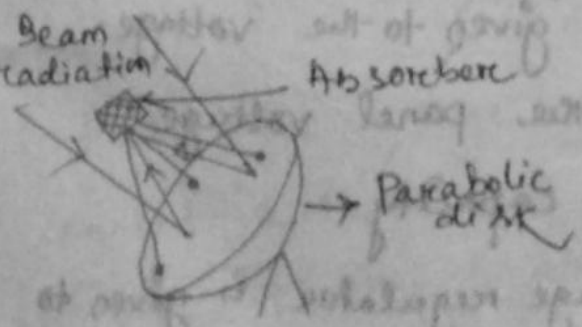
:- In this collector the temperature as high as 1000°c can be achieved.



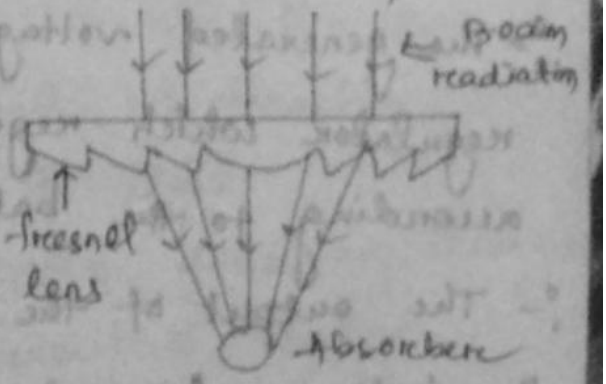

(a) parabolic trough concentrator




(b) central receiver with heliostat field




(c) Parabolic dish concentrator



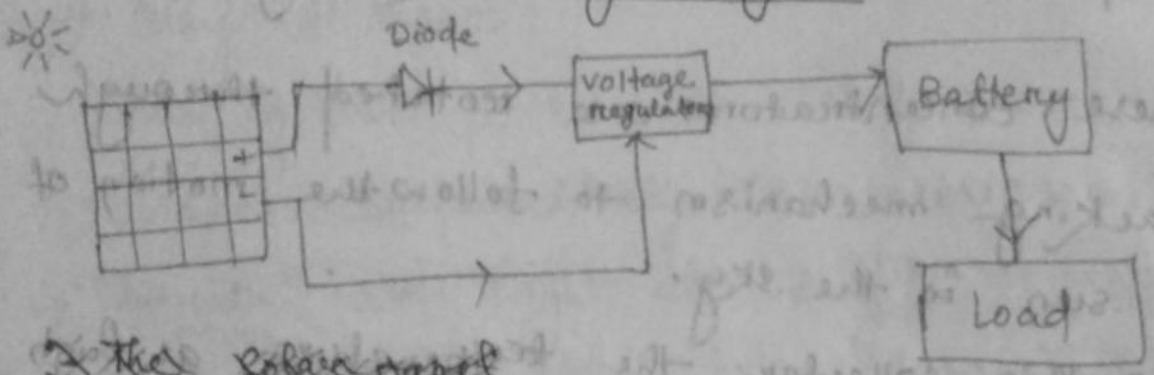

(d) Fresnel lens concentrator

## Characteristics of concentrating collector

→ It's temperature is very high
→ High intensity.
→ Less material required for the operation
→ Absorber area is small.
→ It's economically feasible.

## Applications

### ① photovoltaic - battery charger




∴ ~~The solar panel~~

∴ The above diagram is for photovoltaic - battery charger. which consist a solar panel, a diode, voltage reegulator, battery for charging.

∴ The solar readiation is incident on the solar-panel from which electricity is generated.

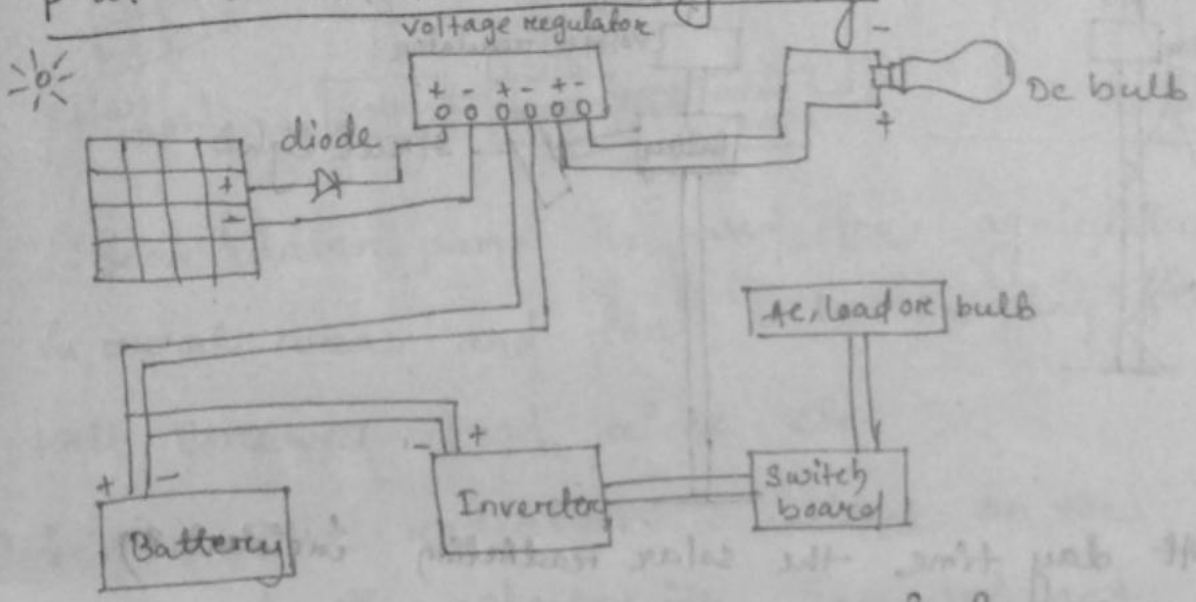
∴ The generated voltage is given to the voltage regulator which regulate the panel voltage according to the battery capacity.

∴ The output of the voltage regulator is given to the battery for charging.

∴ And we connect the battery ~~for~~ to any kind of load for further use.

:- One diode is connected to flow the current in one direction. the reverse charging is not possible here.

## photo-voltaic domestic lighting




:- The above line diagram is for the flow chart of domestic lighting using solar cell.

:- first solar light incident on solar panel. Here we connect a diode for the unidirection of current.

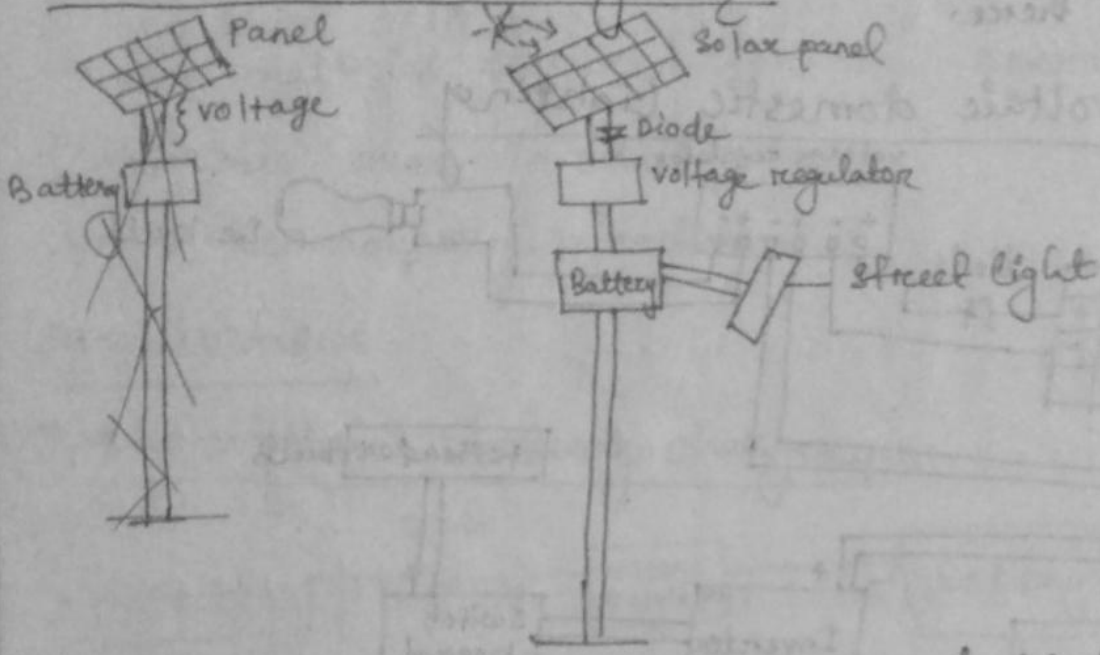
:- the electricity is given to the voltage regulator which regulate the input voltage according to the load.

:- From the voltage regulator we directly connect a dc load or dc-light.

:- But for Ac lighting system first we charge the battery from the output of voltage regulator and connect the battery to the inverter.

:- From Inverter power is given to the switch board and can operate the AC loads.

## photovoltaic Street lighting




:- At day time the solar radiation incident on solar panel and charge the battery.

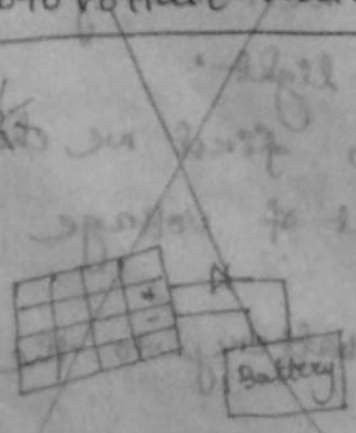
:- Here also we connect a diode fore the flowing of current in one direction.

:- the voltage regulator regulates the voltage according to the load.

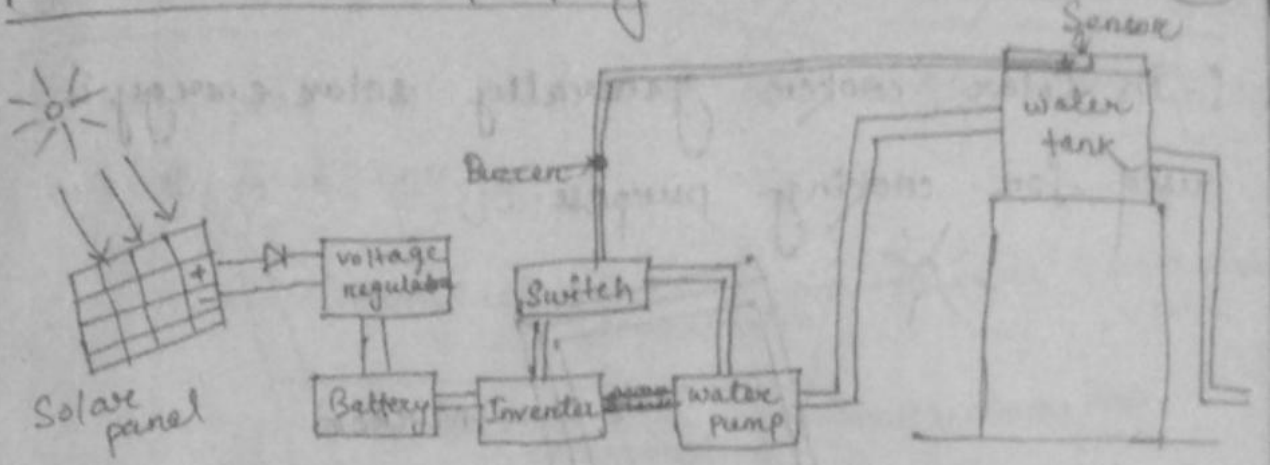
:- During night the battery discharge the power and give it to the load (street light)

:- And the street light blows at nights.

## photovoltaic water pumping



# photovoltaic - waterpumping




:- Solar water pump is used for agriculture in rural areas and for water pumping from well, Borewell, Pond, river etc.

:- when solar radiation is incident on the solar panel, the electricity generated and stored in the battery.

:- Here also we connect a diode for its unidirectional property and a voltage regulator to maintain the voltage.

:- The battery is connected to the inverter which convert DC power to AC power and fed to the switch board.

:- when we turn on the switch power is given to the waterpump and it pulls the water from the sources and fill the water tanker.

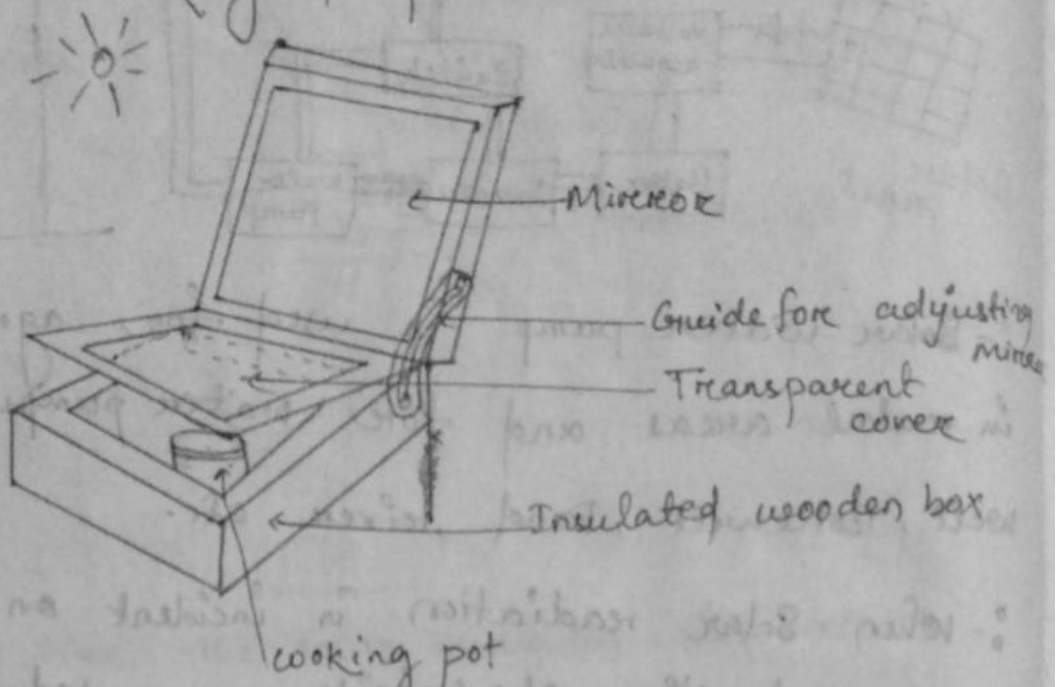
:- while the water ~~tak~~ tanker is fill up completely there is a sensor which senses it and give signal to the buzzer and it sounds

:- After it sounds we turn the switch off and use the tanker water in various cases.

# Solar cooker

Q.12

:- In Solar cookers generally solar energy is used for cooking purpose.




:- The Solar cooker consist of a wooden box which is insulated from inside for which the heat is not discharging from the box.

:- The box is fitted with a mirror which reflects the sun light.

:- The box is covered with a transparent cover mostly made with glass which reflects the sunlight inside the box.

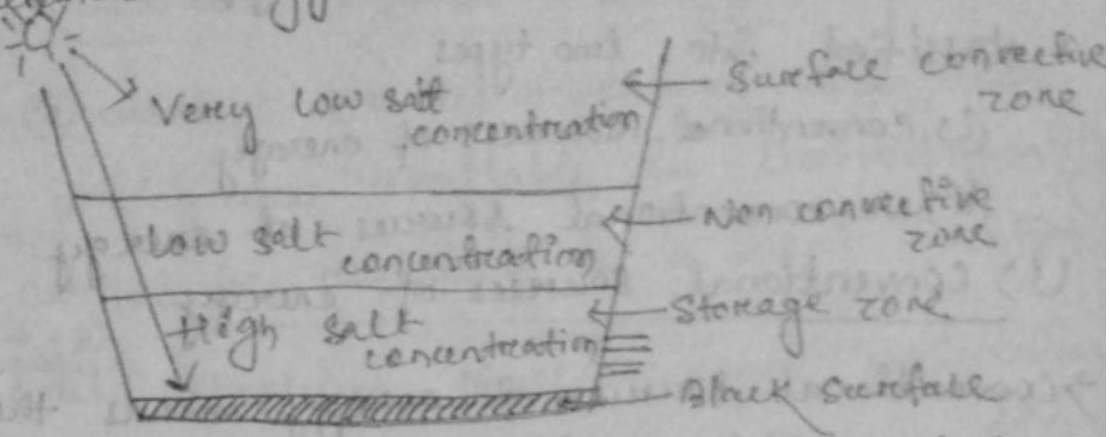
:- Inside the box it coloured with black as we know black absorbs more radiation.

:- The cooking pot is kept inside the box.

:- The mirror should be adjusted according to the solar radiation. The time taken for cooking depends on the solar radiation.

# Solar pond

:- Solar pond is used for generating electricity by thermal energy.




:- A simplest type of solar pond is very shallow about 5 to 10 cm deep, with a radiation absorbing material such as black plastic bottom.

:- It consist of three layer. The upper layer contains very less salt which is called surface convective zone

:- The middle layer contain less salt called Non convective zone.

:- The third layer is called storage zone which contain high salt concentration.

:- The sun radiation fall on water layers and the bottom layer doesnot take part in convection process of water heating due to high concentration of salt.

:- So in this area the temperature increases randomly and water is converted into steam

:- we take out the steam by pipes and rotate the ~~pip~~ turbine and hence generator from which we generate electricity.

# Classification of energy sources

## * Based on treditional use

:- Based on treaditional use energy sources are classified into two types

(i) Conventional sources of energy

(ii) Non conventional sources of energy

### (i) Conventional sources of energy

Q.2

→ Conventional sources of energy means those sources which we have been using since a long while.

→ Eg:- Wood, coal, petroleum, Natural gases etc.

### (ii) Non-conventional sources of energy.

→ Non-conventional sources of energy means those sources which are newly discovered, which we have just started using.

→ eg:- Solar power, wind power, Hydro energy, energy from ocean, Biomass etc.

## * Based on long term availability

:- Based on long term availability energy sources are classified into two types

(i) Renewable energy sources

(ii) Non-renewable energy sources.

### (i) Renewable energy sources

→ Renewable sources of energy are those sources of energy which can be renewed naturally over time. They are inexhaustible.

→ Eg:- Solar energy, wind energy, geothermal energy, biomass, Tidal energy, Hydro power etc.

(ii) Non-Renewable sources of energy

→ Non-Renewable sources of energy are those sources which are available in limited quantity.
→ They cannot be renewed in a short duration.
→ Eg:- coal, Petroleum, Nuclear power, natural gas etc.

———— * ————

# Wind Energy

## Introduction to wind energy

:- Wind energy is a source of renewable power which comes from air, flowing across the earth's surface.

:- It is one of the most effective non-conventional energy used in now-a-days.

## Benefits with wind energy

Green Power :- The electricity produced from wind power is said to be "clean" because its generation produces no pollution or greenhouse gases.

Sustainable :- It is a renewable energy resource, It requires no fuel.

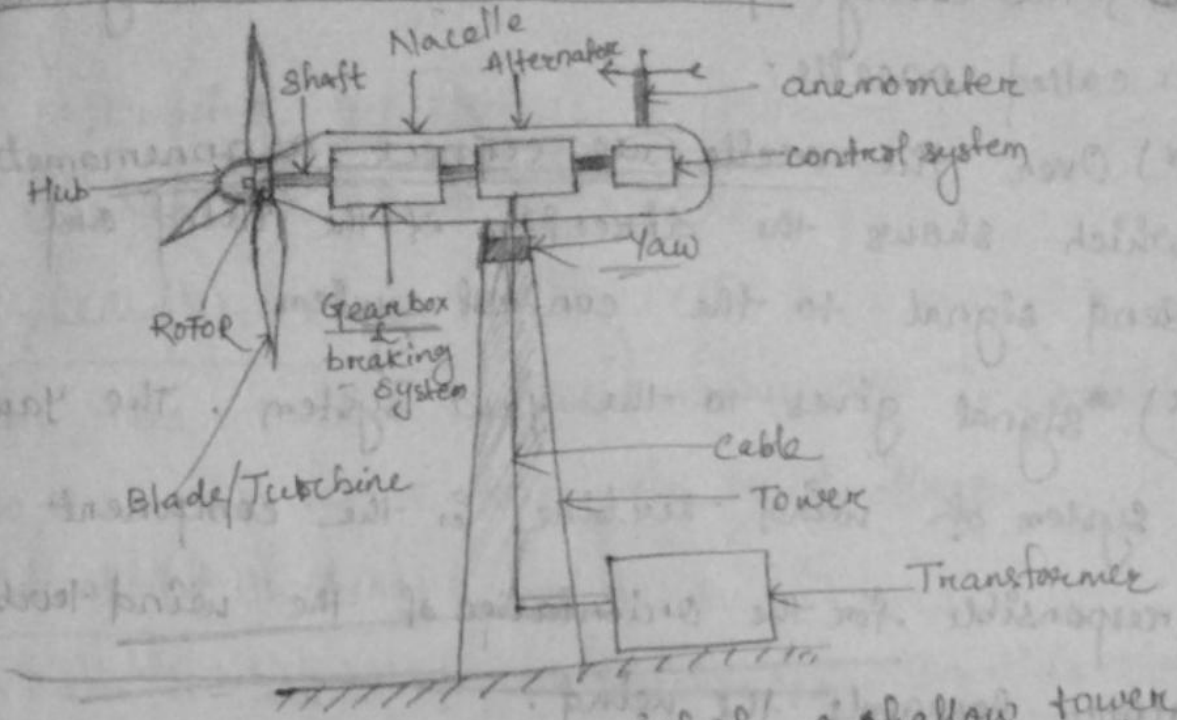
Affordable :- Wind power is a cost-competitive source of electricity.

Economic development :- The economic development of a country increases.

## Wind energy conversion

:- The basic device in the wind energy conversion system is the wind turbine which convert kinetic energy into mechanical energy. Mechanical energy is further converted to electrical energy by alternator.

## Horizontal-axis wind Turbine




(i) The wind turbine consist of a shallow tower. Inside the tower some ladder like structure is there.

(ii) The pointed part near the the blade is called hub which is connected to the rotor. The rotor is connected with blades.

(iii) When the blade rotates the rotor is also rotates, which connect to the gear box with a shaft.

(iv) The gear box increases the rotation about 1:90 ratio.

(v) There is also a breaking system. If the speed of the blade increases with increase in wind it gives a breake.

(vi) The shaft is coupling with the alternator which work is to convert mechanical energy to electrical energy and send it through cables.

(vii) The control system consist of electrical controls, sensores etc.

(viii) The rotary part of the whole arrangement is called nacelle.

(ix) Over the nacelle we connect a annemometer which shows the direction of the wind and send signal to the control system.

(x) Signal gives to the yaw system. The yaw system of wind turbine is the component responsible for the orientation of the wind turbine rotor towards the wind.

(xi) Through the cables we collect the current which is inside the tower and send it to the transformer for further use.

## Types of wind Turbine

There are mainly two types of wind turbine

(i) Horizontal axis wind turbine (HAWT)

(ii) Vertical axis wind turbine (VAWT)

## Horizontal axis wind turbine

HAWT is the most common type of wind turbine. HAWT have the main rotor shaft and electrical generator at the top of the tower

The whole mechanism arrangements are horizontal to the surface.

Here the rotation is also parallel to wind direction.

They are further divided into two types

(i) Upwind turbine

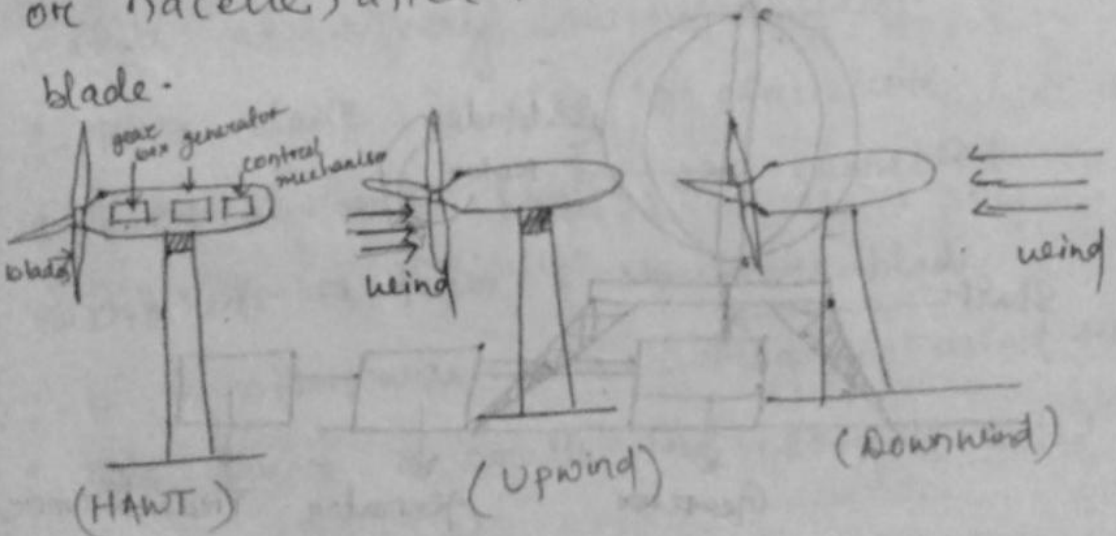
(ii) Downwind turbine

## Upwind turbine

In this turbine yaw mechanism is present so that the rotor faces the wind first.

## Downwind turbine

:- There is absent of yaw mechanism. In this type of wind turbine the wind first faces the the tower or nacelle, after that it faces the rotor blade.




## Vertical axis wind turbine

:- It is the turbine in which the axis of rotation of the rotor is perpendicular to the ground and also perpendicular to the wind direction.

:- It is easier to build up and for transportation.

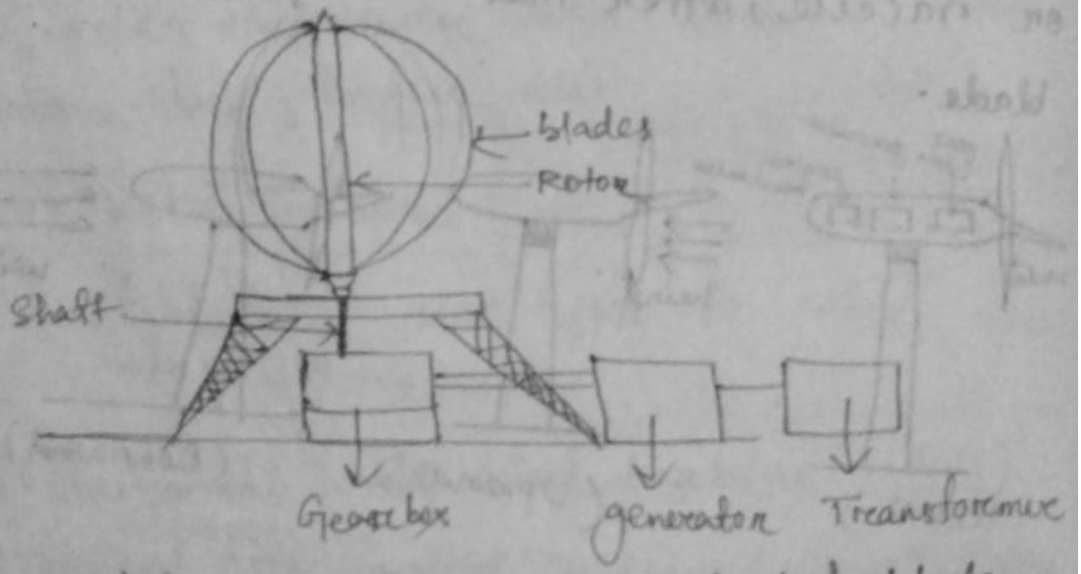
:- Its efficiency is less than HAWT.

VAWT are furthure classified as

(i) Darrieus turbine
(ii) Gircomill turbine
(iii) Savonius turbine

## Darrieus turbine

:- It consist of vertically oriented blade. It is also known as egg beater turbine because its blades are like egg beater shaped.




:- It consist of vertically oriented blade which is mounted on vertical rotor

Some darrieus turbine

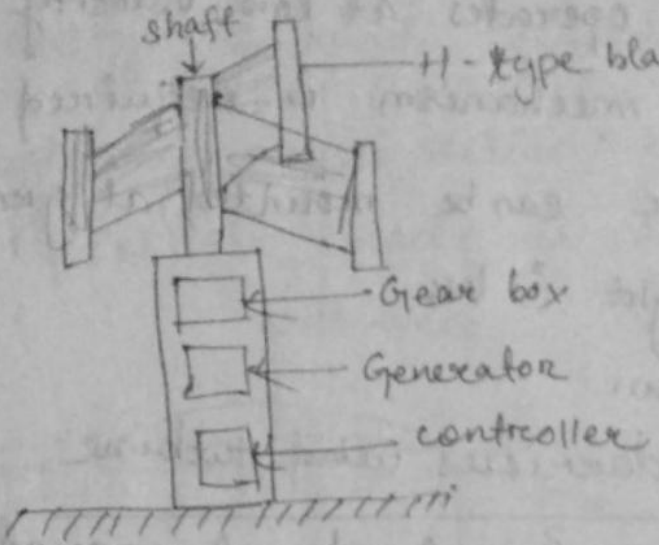
:- It is not a self starting turbine a very small power is requierred to start its rotation

:- As the rotor rotates it rotate the generator and electricity is produced.

## Gircomill turbine

:- It is similar to Darrieus turbine but it has

H shaped rotor. H works same principle of darrieus turbine.



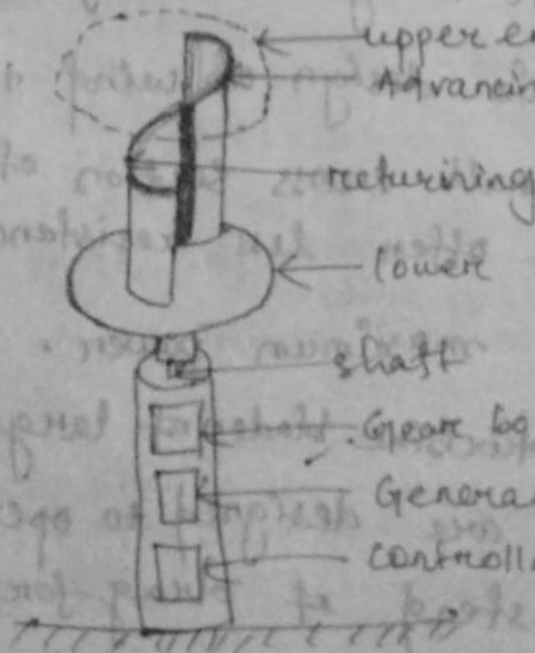

## Savonius turbine

:- It the simplest type of wind turbine and rotate at a very low wind speed.

:- It's blade is like 'S' structure i.e two cylindrical half blades are connected to eachother to form 'S' structure blade.

:- It is other wise called drag type wind turbine

:- This device is small and easy to build.



## Advantages of Savonius turbine

:- The machine operates at low velocity of wind.
:- No yawing mechanism is required
:- The generator can be mounted at ground level.
:- Overall weight is less
:- cost is low.

## Advantages of Darrieus wind turbine

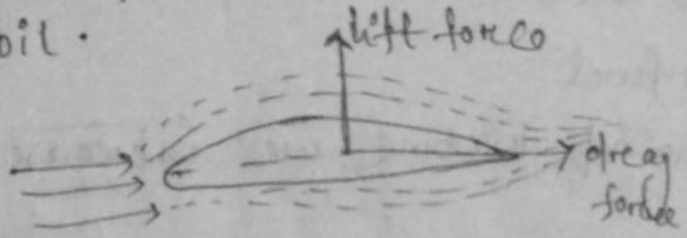
:- The generator is placed at ground level.
:- The rotor can take wind from any direction.
:- Easily integrated into buildings.

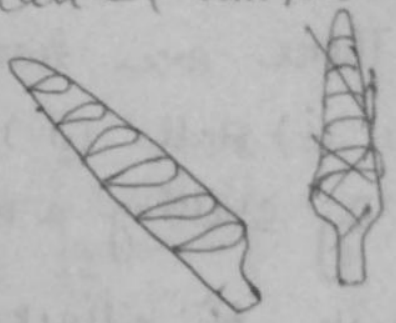
## Aerodynamics of wind rotors

:- A turbine blade is always aerodynamically designed to produce maximum power from wind energy.
:- They are designed on the same principles by which aircraft wings are designed.
:- The aerodynamic design of wind turbine blade need very small cross section of the blade so that they offer less resistance to the wind and develop maximum power.
:- The wind turbine blades of large size wind turbine units are designed to operate on lift forces instead of drag force.
:- Lift force give better speed which is necessary

:- In order to generate optimum lift on blades some main factores are considered they are speed & density of wind, surface area etc.

:- The imaginary cross section of blades from root to tip of the blade is called airfoil or aerofoil.



:- When wind flows across the blade, the air pressure on one side of blade decreases.

:- This cause both lift force and drag force across the blade.

:- The force of lift is stronger than the drag and this cause the rotor spin.

## Wind turbine control system

:- There are different control system to either optimize or limit power output.

:- We can control the a turbine by controlling

1. generator speed
2. Blade angle adjustment
3. Rotation of the entire wind turbine

:- Blade angle adjustment is called pitch control and rotation of the entire wind turbine is called yaw control

## Pitch control

:- The purpose of pitch control is to maintain the optimum blade angle to achieve certain rotor speed and power output.

:- There are two methods of pitch control.

(i) stall (ii) furl

:- By stalling a wind turbine we increase the angle of attack, which cause the flat side of the blade to face the wind.

:- Furling decreases the angle of attack, causing the edge of the blade to face the incoming wind.

:- Pitch angle adjustment is the most effective way to limit output power by changing aerodynamic force on the blade at high wind speed.

## Yaw control

:- Yaw refers to the rotation of the entire wind turbine in the horizontal axis.

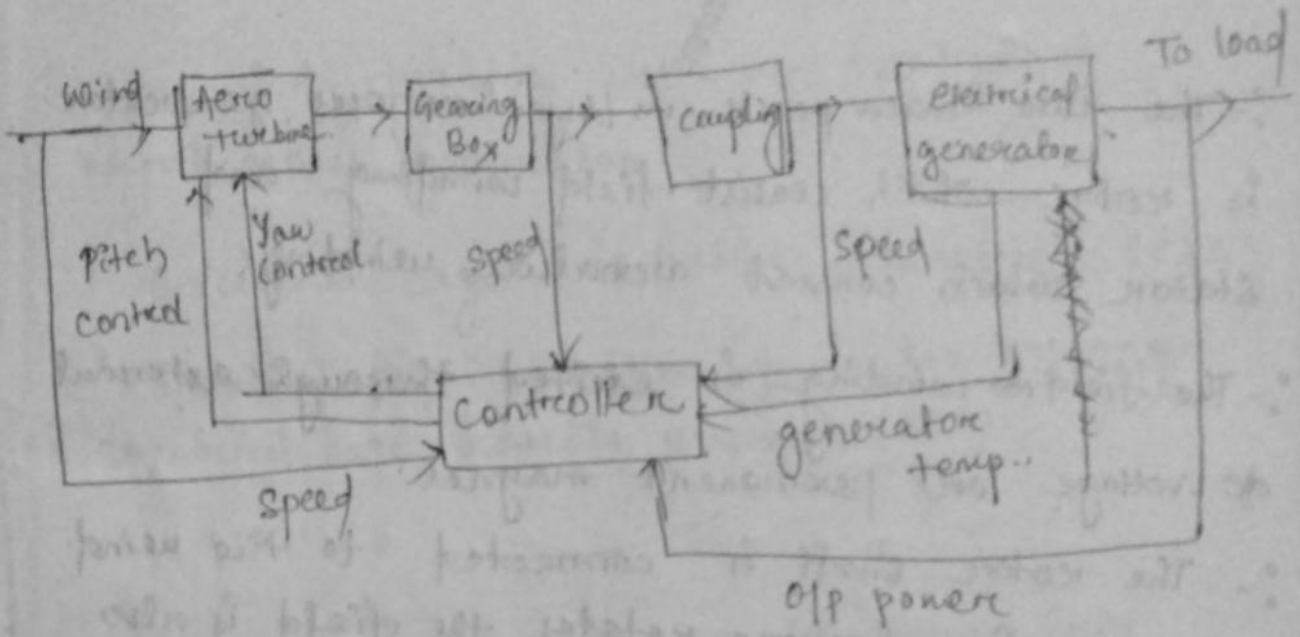
:- Yaw control ensures that the turbine is constantly facing into the wind to maximize the effective rotor area as a result power.

## Generator speed control

:- The two types of generator and are control stactor and rotor. the stactor and rotor are the stationary and nonstationary parts of a generator respectively.

:- In each case we disconnect the starter and rotore from the grid to change the synchronous speed

Block diagram of conversion of wind turbine




Aero turbine :- convert wind energy into rotary motion.

Gearing :- Increase speed of the turbine shaft

coupling :- Connect the gear shaft to the generator shaft.

Generator :- Convert mechanical energy into electrical energy.

Controller :- Yaw control :- Orientation of rotor Into wind

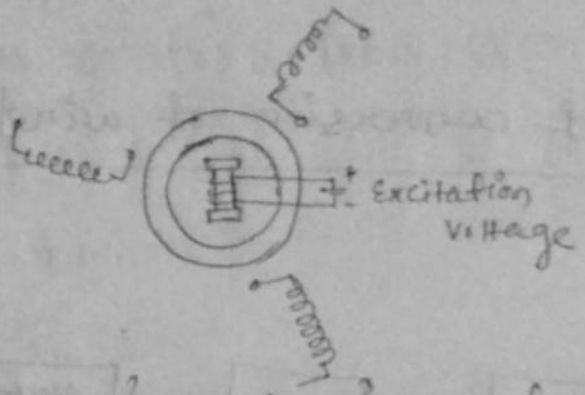
:- Pitch control :- Power control of rotor by varying pitch of the blade

:- Temperature of generator should maintain

:- Store the data output.

:- Shut the system at very high speed

# Synchronous Generator




:- The two main parts in synchronous generator is rotore which consist field winding and stator which consist armature windings.

:- The field winding is excited through external dc voltage or permanent magnet.

:- The rotor shaft is connected to the wind trocbine. when turbine rotates the field is also rotate.

:- And there is a reate of change of flux is there and emf is induced in it.

:- Synchronous generators are forced to spin at a precise rotational speed determined by the member of poles and the frequency needed for the powere lines.

$$N = \frac{120f}{P}$$

:- So when the speed of gear-generator shaft is less than synchronous speed the generator will not work.

:- Thats the reason at many cases this generator is not used

## Asynchronous Generator

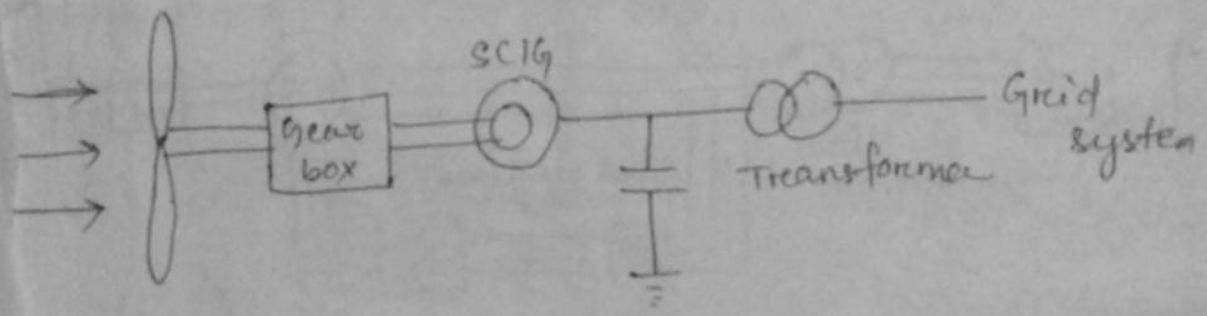
:- In contrast to a synchronous generator, induction machine do not turn at a fixed speed, so they are often described as asynchronous generator.

:- In wind turbine we use two types of asynchronous generator.

(i) Squirrel cage - induction generator (SCIG)

(ii) Doubly fed induction generator (DFIG)

(i) Squirrel cage induction generator (SCIG)




:- Squirrel cage induction generator is called fixed speed induction generator.

:- Induction machines draw reactive power from the grid and thus some form of reactive power compensation or capacitor bank is used to increase active power or improve power factor.

:- The rotor speed is ~~rarely~~ varying with in narrow range so it is called fixed speed induction generator.

:- Output voltage from generator is stepped up by 3 phase step-up transformer, to suit the connection to grid system.

Disadvantages

:- Noisy operation
:- Power converter is costly
:- Efficiency is less, as it is fixed speed.
:- Additional components such as reactive power compensator is required.
:- High maintenance is required.

Advantages

:- We can reduce reactive power by capacitor bank.
:- Reliable operation.
:- Simple in construction.
:- Cheaper in cost.
:- No frequency conversion so no problem of current harmonics.
:- Better wind energy utilization.

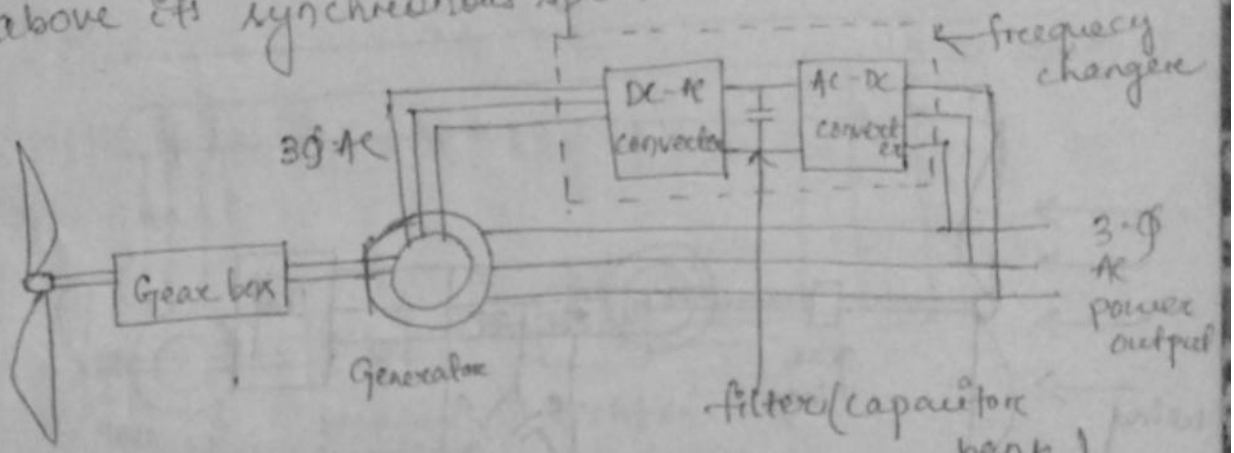
## (ii) Doubly fed Induction Generator (DFIG)

:- This used in large speed wind turbine, where wind speed varies.

:- There are two main reason why we use DFIG that

(i) The powere flow from both the sides

(ii) The wind turbine also work below and above its synchronous speed.




:- This is the diagram for DFIG where we use back to back converter which is a frequency changere (Variable frequency drive)

:- It consist of rectifiere and inverter which combinely formed a VFD.

:- Here the 3ϕ AC powere is fed to the rotor of the generator for the excitation purpose

:- In between this we connect the back to back converter which change the frequency

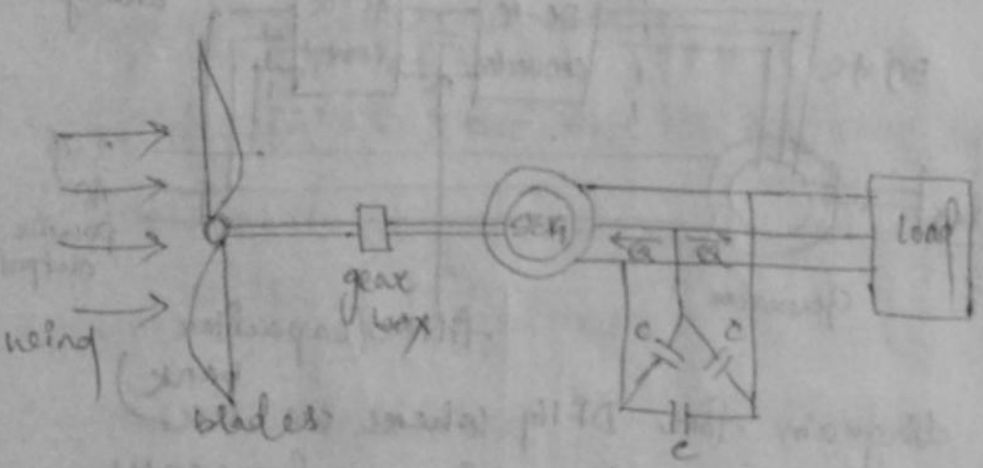
As we know $N_s = 120\frac{f}{p}$, so we have to change the frequency to change the synchronous speed.

:- Here also one capacitor bank is connected to reduce the reactive power or improve the power factor.

:- Now the variable frequency excitation is given to the generator and we collect the fixed frequency power.

Grid connected generator

## Self excited Induction generator




:- In SEIG we use capacitor bank for reactive power supply. so it is called isolated Induction generator.

:- The function of the capacitor bank is to Provide the lagging reactive power to the Induction generator as well as load.

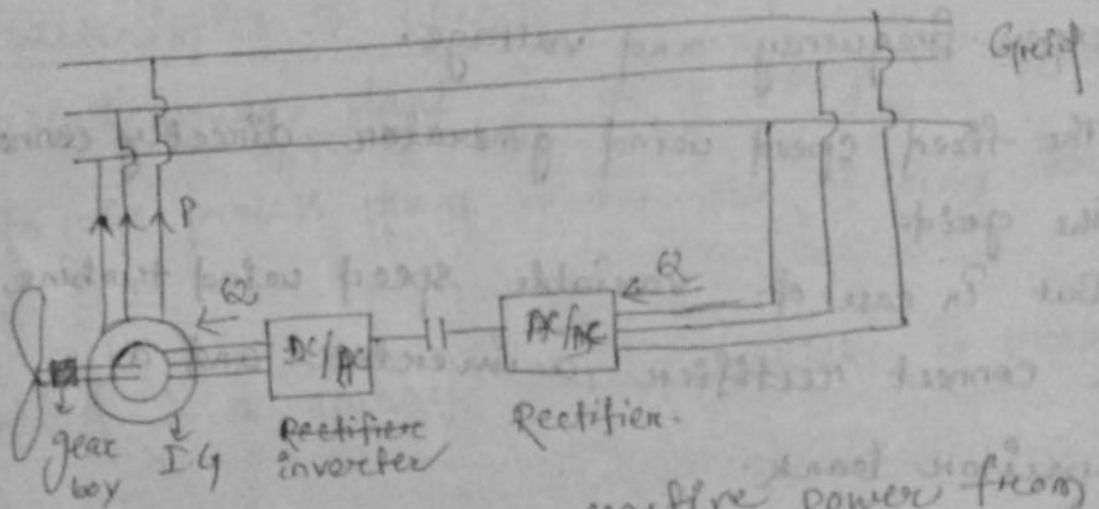
:- By the reactive power in the induction machine get excited.

:- The induction generator will self-excite using these external capacitor only if the rotor has sufficient residual magnetism.

:- This type of induction generators donot require any external power for its excitation.

:- It is used in remote areas for the wind powered electric generation because they donot need external power supply to produce the magnetic field.

Induction
Grid connected generator



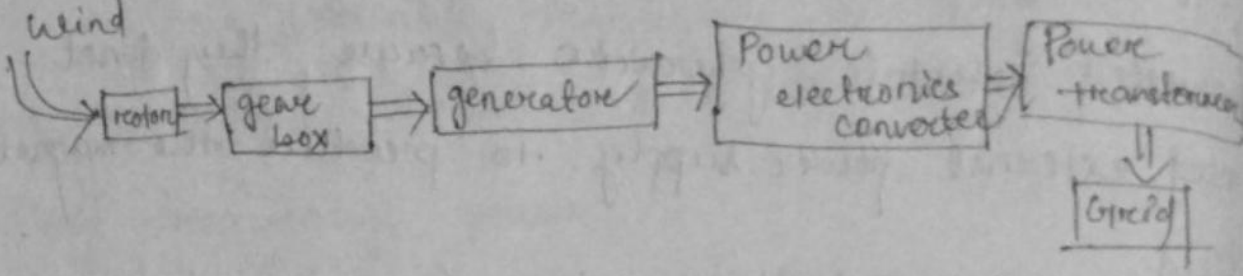

:- Here we collect the reactive power from the grid it is fed to the rotors for the excitation.

:- The back to back converter is used for changing the frequency.

:- Again the grid is connected to the stators for collecting real power.

:- For the performance of I.G the rotor should have magnetic field which is ~~generated from the~~ collected from grid as reactive Power.

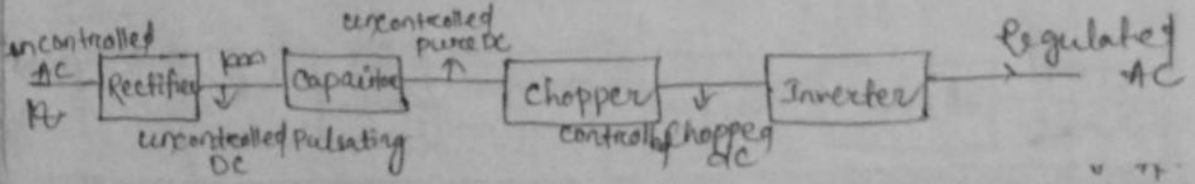
# Regulation of voltage and freequency in generation of wind energy




:- In generation of wind energy we have to use some power electronics converter to maintain proper freequency and voltage.

:- The fixed speed wind generator directly connect to the grid.

:- But In case of variable speed wind turbine we connect rectifier, a inverter and a capacitor bank.




:- The whole mechanism forem a variable freequency drive (VFD), which regulate the freequency.

:- The rectifier circuit is ~~converted~~ connected to grid from which AC signal from grid is ~~DC~~ converted to pulsating dc.

:- If we use controlled rectifier we can regulate the voltage as we use thyristor in controlled rectifier or converter.

:- The pulsating dc obtained for capacitor bank and then fed to inverter where the dc is converted ac chopper where the dc is controlled (if we use uncontrolled rectifier)

:- The controlled dc is fed to inverter in which PWM technique takes place and frequency and voltage is controlled.

## Characteristics of wind power plant

:- wind power plant is very easy to operate.

:- In the process there is no need of any fossil fuel.

:- wind is a energy source which is present every where.

:- Toxic gasses emission is less.

:- Its construction and maintenance is very tough.

:- Modern wind turbines are remarkably quite

:- The wind turbine blades are affect the birds So it who would be good to pf practice to not install a wind turbine in an area that had special birds.

:- Very reliable generators are used.

# Biomass Power

## Energy from biomass

* **Biomass** :- Biomass is a organic material or organic waste that comes from plants and animals.
:- Biomass continues to be an important fuel in many countries, especially for cooking and heating.
:- Use of biomass fuels for transportation and for electricity generation is increasing in many developing countries.

**Biomass includes**

1. **Wood and wood processing waste** :- firewood, wood pellets, wood chips, furniture mill sawdust and waste, Black liquor from pulp and paper mill

2. **Agricultural crops and waste material** :- corn, soybean, sugarcane, switch grass, woody plant.

3. **Biogenic material in municipal solid waste**- paper, cotton, wool products, food wastes

4. Animal manure and human sewage

## ✱ Biomass Energy

:- The energy produced from biomass is called biomass energy

:- All the biomass contain energy because they are organic materials they all absorbed

:- From biomass chemical energy naturally from sun.

:- Biomass can be used to create 3 types of energy

1. Heat
2. Electricity
3. Biofuel such as biodiesel

:- Biomass contains stored chemical energy from the sun plants produce biomass through photosynthesis and it released energy when biomass is burned or decomposes

### Biomass as renewable energy source

:- Biomass is renewable organic material that comes from plants and animals.

:- Biomass contains energy from sun. In the process of photosynthesis plants convert radiant energy from the sun in to chemical energy in the forms of glucose.

$$6H_2O + 6CO_2 + \text{Sunlight} \longrightarrow C_6H_{12}O_6 + 6O_2$$

- Biomass is a renewable source of fuel to produce energy because

1. properly managed forest will always have more trees and we always have crops and the residual from crops.
2. The waste residues will always exist from both plants and animals.
3. The sun is always present to transfer energy to plants and from plants to animals

- Advantages

→ Biomass is always available. Humans and animals will always create waste and plants will always grow.

→ Burning biomass doesnot release sulfur or mercury and release less nitrogen than burning coal.

→ It is cheap

→ We can produce biomass energy in our own home

→ Bio oils can used in medicines.

Disadvantages

→ The burning process releases $CO_2$.

→ It release carbon monoxide which adds to air pollution.

→ Crops grown in order to be burnt for energy take up alot of land

→ It is worse for the environment, when trees are cut down specifically to create energy.

Types of biomass fuel

:- Any fuel derived from biomass is called biofuel

:- Bio energy are stored in the form of liquid solid and gas

Solid biofuel :- Solid fuels refers to various types of solid bio material that are used as fuel to produce energy and provide heating

:- Solid biofuels include wood pellets, woodchips, forest waste, solid wastes, wastes from corn, wheat and other grains.

:- Normally it is used for cooking and heating

Liquid biofuel :- this biofuel consist energy in the liquid form.

:- It includes ethanol - made from corn and sugar cane

biodiesel - made from vegetable oils and liquid animal fats

green diesel - made from algae and other plant sources.

∴ Liquid biofuels normally used for transportation

## bio-gas fuels

∴ Bio gas is a types of biofuel naturally produced from the decomposition of organic matter.

∴ when this organic matter is exposed to an environment without oxygen they free a blend of gasses.

∴ the mostly released gas is methane which is used as fuel.

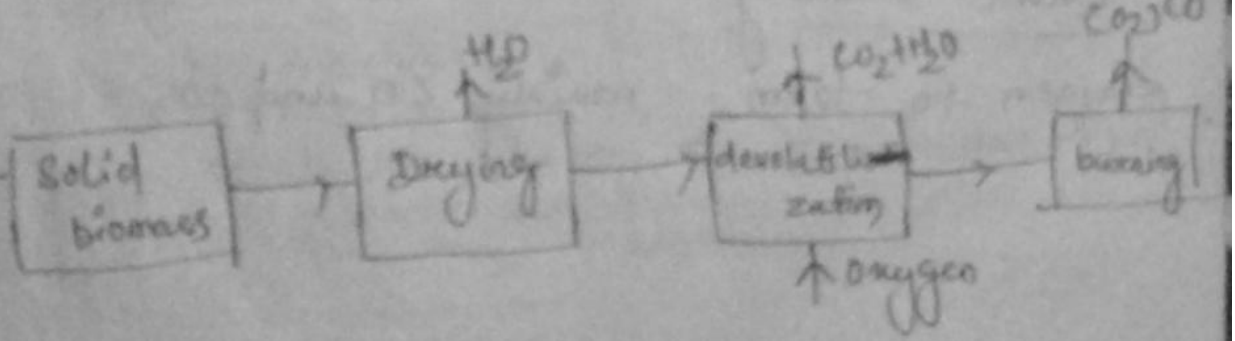
## Combustion of biomass

∴ Combustion is a scientific term for burning. which is a chemical process where any fuel that a reaction with air to produce heat energy.

∴ when this heat energy release it will also produce light in the form of a flame.

∴ Biomass + Oxygen ⟶ water vapore + carbon dioxide + heat

∴



:- Solid biomass particle first dry itself and then enter entering to a combustor.

:- Solid biomass particle entering a combustor undergoes four distinct stages

→ drying
→ devolatilization
→ combustion of gases
→ char burning.

:- Drying :- when solid biomass is fed to hot environment, some amount of water is evaporat naturally.

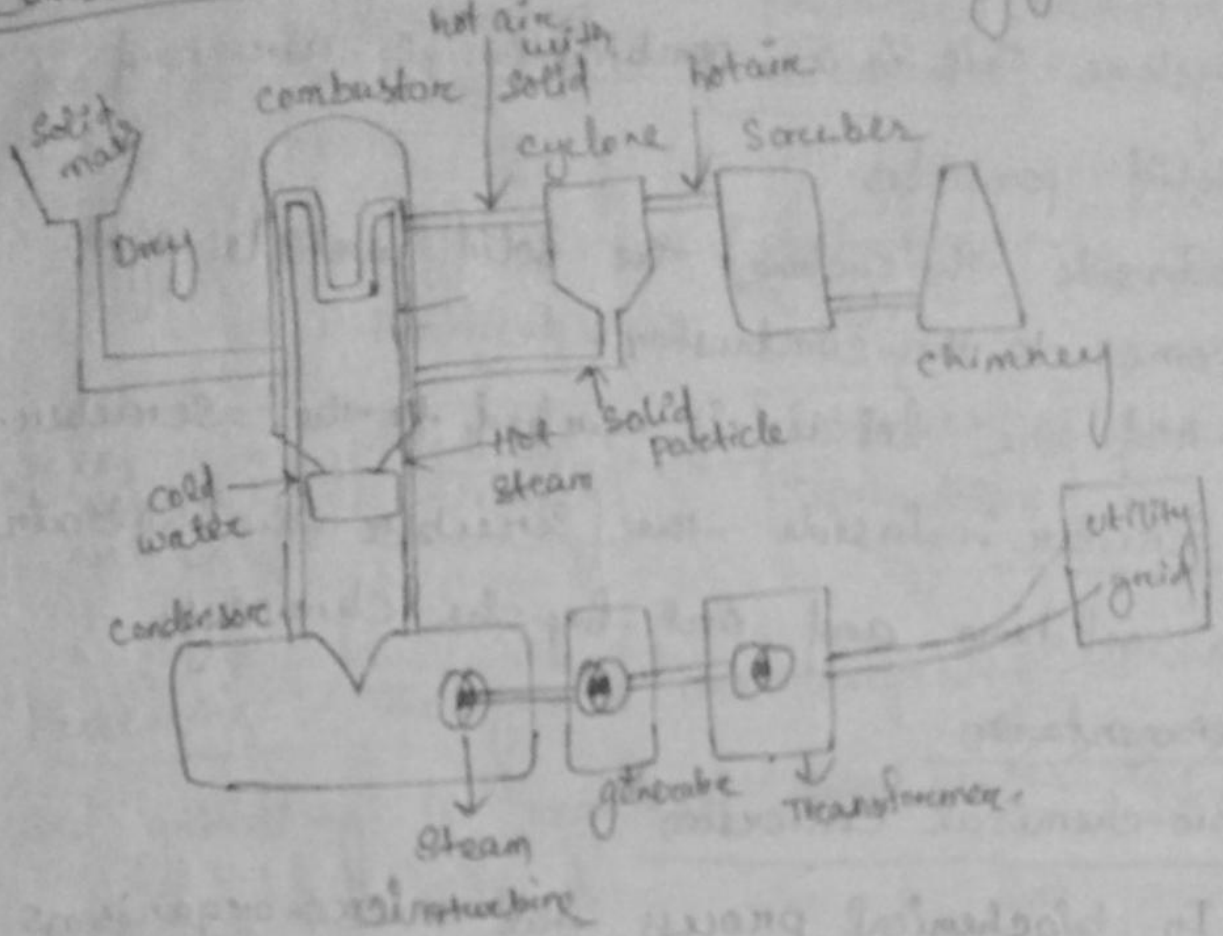
:- devolatilization :- During this stage combustion takes place with the presence of oxygen.

:- devolatilization :- During this stage volatile gases and tars are released from the particle

:- combustion of gases :- Combustion takes place at the presence of oxygen

:- Char burning :- The char reacts with oxygen to form mainly CO and $CO_2$

# Combustion of Biomass used for electricity generation




:- Solid mass is entered to the combustor for combustion.

:- From condensor coldwater is supplied to the combustor and it will converted to steam.

:- By the steam, steam turbine rotates and turbine shaft is connected to the generator shaft for which generator will rotated and the mechanical energy is converted to electrical energy.

:- Then it is step-up by the transformer and it will go for the transmission.

:- Cyclone :- The hot air is reached to the cyclone. This is a combination of air and solid particles.

:- Inside the cyclone the solid particle again comes to the combustor.

:- And the hot air is reached to the Scrubber

:- Scrubber :- Inside the Scrubber the hot air is cool down and out by the chimney.

Fermentation

Bio-chemical Conversion

:- In biochemical process micro-organisms are used to transform raw bio-mass into energy like methane and ethane gas.

:- There are two processes for bio-chemical conversion

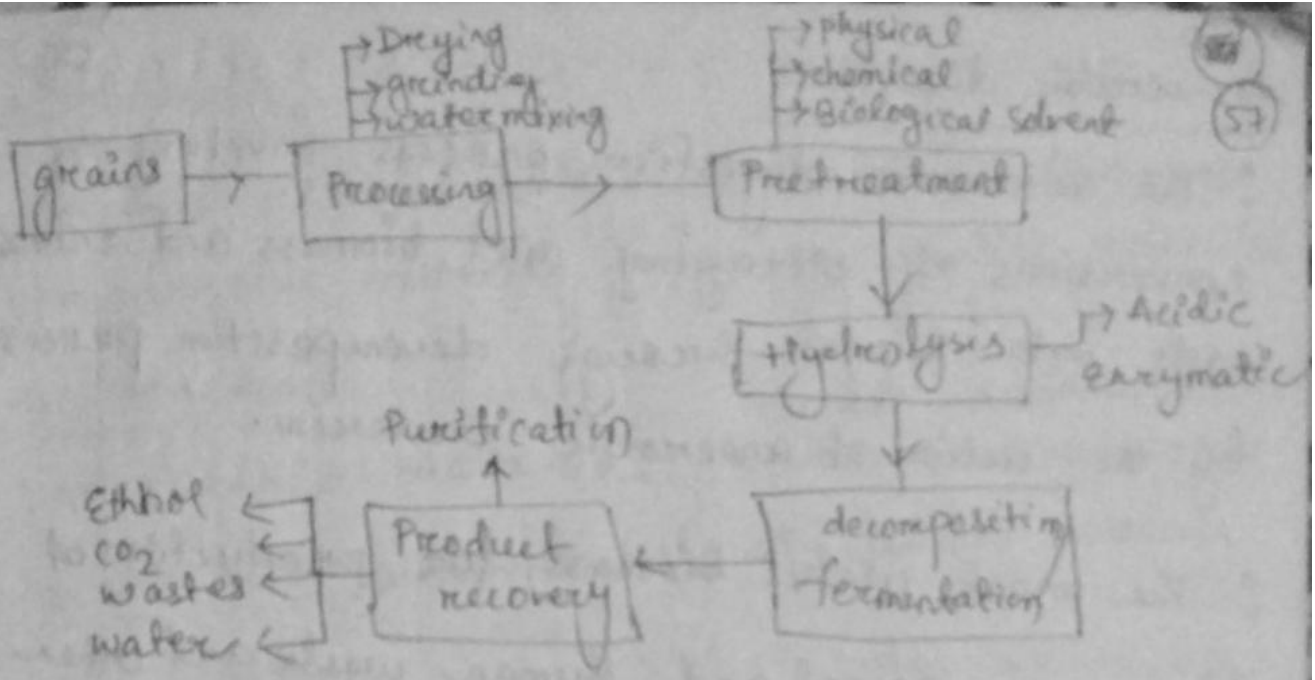
(i) fermentation of biomass / Aerobic digestion

(ii) Anaerobic digestion.

i) Fermentation / Aerobic digestion

:- fermentation is a process of decomposition of complex molecules of organic compound under the influence of microorganism like yeast and bacteria

:- Aerobic process is done under the presence of oxygen.




Processing :- The grains are subjected for drying and grinding. If required then water is adding in this stage.

Pretreatment :- Any physical, chemical or biological solvent required is adding in this stage and forward for hydrolysis.

Hydrolysis :- Required acid is subjected in this stage.

fermentation :- Under the presence of oxygen the decomposition takes place and complex molecules breaks down.

Purification :-

Product recovery :- This is the stage of purification by which the ethanol, $CO_2$, $H_2O$ and other wastes are distinct.

## An-aerobic digestion

:- The an-aerobic digestion process involves the conversions of decaying wet biomass and animal waste into biogas through decomposition process by the action of anaerobic bacteria.

:- The most useful biomass for production of biogas are animal and human waste and other organic waste material with high moisture content.

:- In this process the organic material is broken down by bacteria, in the absence of oxygen to create methane-rich biogas.

:- This can be burned to generate heat and electricity.

## Stages of Anaerobic digestion

1. Hydrolysis
2. Acedogenesis
3. Acetogenesis
4. Methanogenesis

Hydrolysis :- In this process larger molecules of organic compound like protein ~~was~~ converted to smaller particle like amino-acid and in this process hydrogen and acetate is generated

## Acidogenesis

In this process acidogenic bacteria decompose the organic material into very smaller molecules

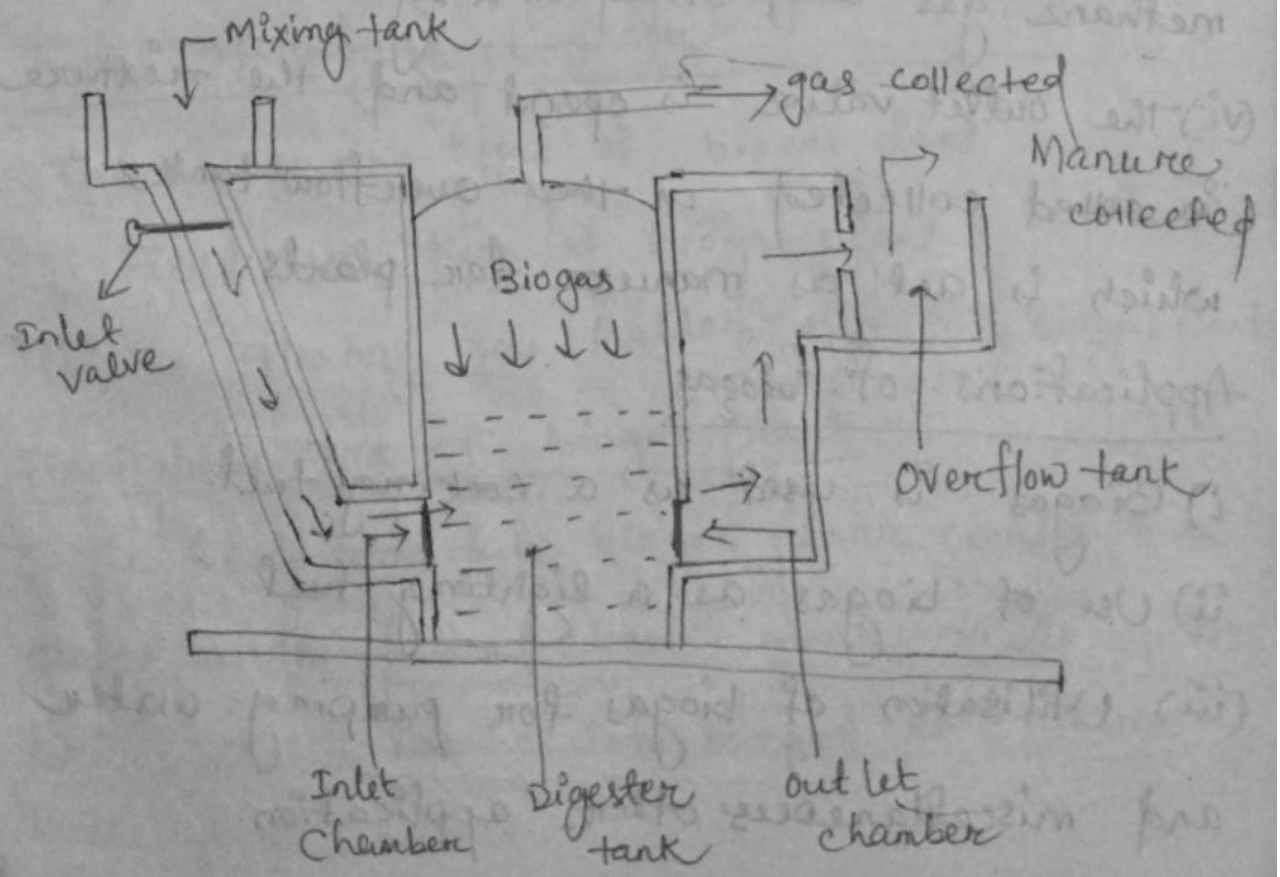
## Acetogenesis

Acetogenic bacteria create acetate or acetic acid with the help of carbon molecule and energy.

## Methanogenesis

This process is the final stage in which methanogens produce methane with the help of intermediate product by hydrolysis, Acidogenesis and acetogenesis.

## Process of production of Methane



i) In the mixing tank, we preepare a mixture (60) of animal dung and water, at the same time the inlet valve is closed.

ii) when it is properly mixed up the valve open and also the inlet chamber valve is open, the mixture comes inside. Make sure the outlet valve is closed.

iii) The mixture is fed to the digester tank and filled it pasefially with the mixture.

(iv) Keep this at same for 2 to 3 months. In this period the methanogens present in the dung decomposes and produce methane.

(v) After 2 to 3 month we can collect the methane gas and stored in a cylinder.

(vi) The outlet valve is opend and the mixture is called collected in the overflow tank which is act as manure for plants.

## Applications of biogas

i) Biogas is used as a cooking fuel.

ii) Use of biogas as a lighting fuel.

(iii) Utilisation of biogas for pumping water and miscellaneous other application.

(iv) Biogas is used as a fuel for vehicle and fuel for various engines.

(v) Biogas is used for power generation.

## Applications of biofuels

(i) Bio fuels are used for power generation.

(ii) It provide heat by not emitting or reduce the emission of both nitrogen and sulphur dioxide

(iii) We can use it as cooking purpose at the place of kerosene.

(iv) It act as a lubricate.

(v) It is used for transportation.

(vi) It reduce cost and need for imported oil.

## Types of biogas ~~digester~~ plant / digester plant

There are two types of biogas plant

(i) Fixed dome type of biogas plant

(ii) The floating gas holder type of biogas plant.

## Fixed dome type of biogas plant

:- The fixed dome type biogas plant consist of a closed underground digester tank made up of bricks which has a dome shaped roof also made up of bricks.

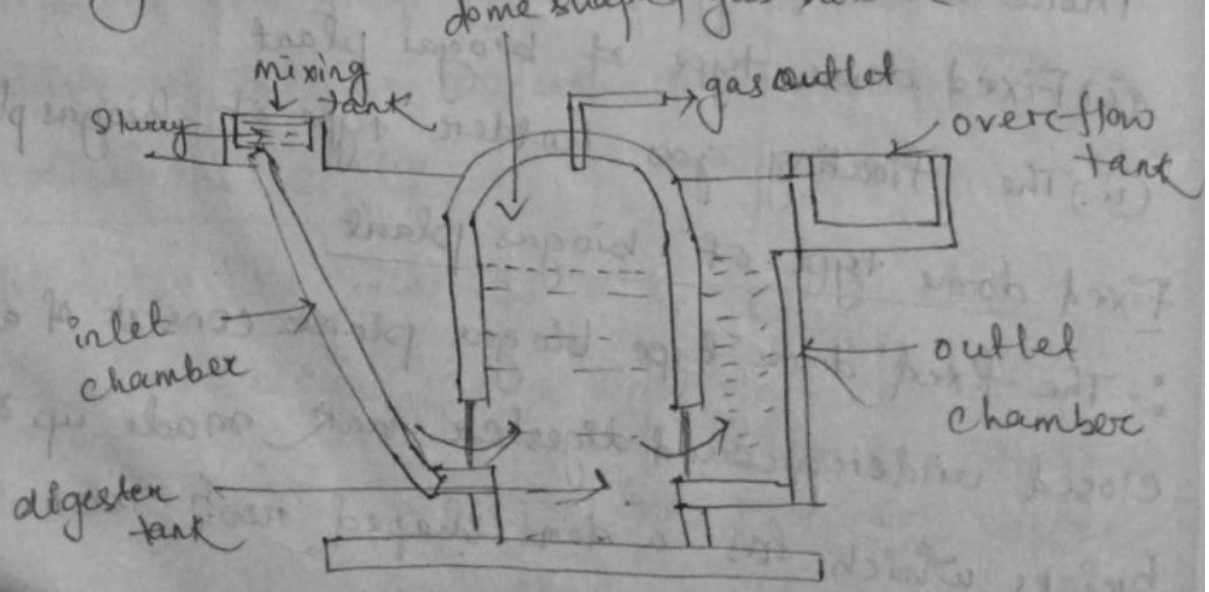
:- This dome shape roof of the digester tank functions as gas holder and has an outlet pipe at the top to supply gas.

:- The slurry is prepared by mixing water and animal dung in mixing tank is fed to the digester tank by inlet chamber.

:- Inside the digester tank the decomposition takes place by the micro-organisms and it produces bio gas.

:- The bio gas so produced starts to collect in dome shaped roof of bio gas plant is supplied through pipes.

:- The spent slurry is replaced from time to time with fresh slurry to continue the product of biogas.



# Floating gas holder type biogas plant

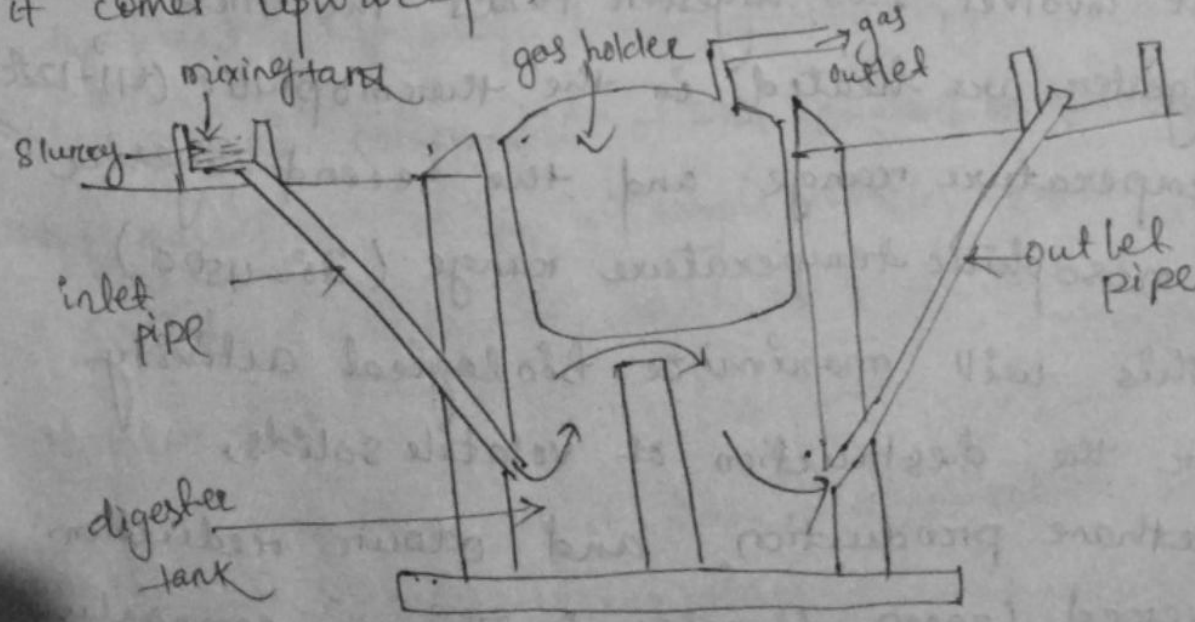
:- The floating gas holder type bio gas plant consist of a dome shaped gas holder made of steel for collecting bio gas

:- the dome shaped gas holder is not fixed but is moveable and floats over the slurry present in the digester tank.

:- The operation of floating gas holder type is same as fixed dome type gas holder bio gas plant.

:- But here the bio gas produced start to collect in floating gas holder and supplied to homes.

:- when the gas is filled up to the gas holder it comes upwarded for collection.



## Types of biogass digester

Complete mix digester :- They are larger vessels that can either be above or below ground. They are used largere amount of manure.

plug flow digester :- It is used for ruminant animal manure and require little maintenance. It is better for smaller operation.

fixed film digester :- A tank designed as part of a manure management system to handle manure up to 3percent solids.

:- This design allows the microbial populations to attach to the media and grow as a biofilm (fixed film), thus preventing the microbes from being removed with the effluent.

Temperature-phased anaerobic digerester (TPAD)

:- It involves two digester tanks. The first digesters are heated in the thermophilic (41°-122°c) temperature range and the second digester in mesophilic temperature range (20°-45°c)

:- This will maximize biological activity for the destruction of volatile solids, methane production and odour reeduction.

Covered lagoon digester :- This is commonly used when manure has less than 2 percent solids.

:- The lagoon is covered with a gas tight cover to capture the bio-gas.

:- Decomposition of manure occures inside the digester, methane is produced and odour is reduced.

A landfill gas to energy :- It consist of a series of wells drilled into the landfill. A piping system connects the well and collect the gas.

Wood gassifier

:- Gassification is the process of converting solid into gas.

:- wood biomass can either be used directly as a fuel to heat a conventional type of boile and produce steam for power production or a completely seperate process can supported where the wood is used to produce a gas.

:- The main component of the conversion process is the gassifier. It is a simple device consisting of a cylindrical container, which is made out of stainless steel.

:- The gassifier must have a chemical reactor where the processes takes place.

:- The fuel wood first dried, heated, pyrolysed, partially oxidised and reduced inside the reactor.

## Processes of gassification

i) Drying :- In the drying zone, moisture in the wood pallets is evaporate by the heat from the lower zone at a temperature of 150°-200°C

ii) Pyrolysis :- In this zone the temperature is 400° to 650°C

:- In this process large molecules such as cellulose, polucellulose are broken down into medium-chain hydrocarbons and carbons (charcoal)

:- pyrolysis product then move downwards to the hotter area with in the gassifier, some of these burn while other break down further into smaller molecules and atoms such as hydrogen, methane, CO, etc.

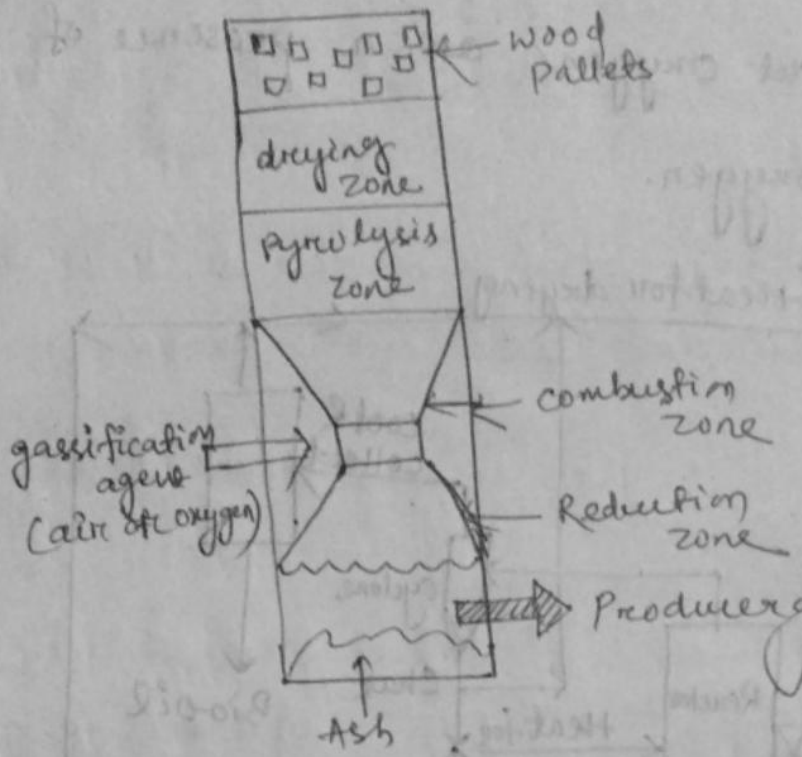
(iii) Oxidation :- At this level air is injected into the gasifier leading to the following chemical reaction.

$$C + O_2 \rightarrow CO_2$$

$$H + \frac{1}{2}O_2 = H_2O$$

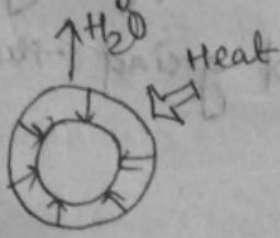
(iv) Reduction :- In the oxidation stage more thermal energy is generated. This thermal energy is converted to chemical energy

- This reaction reduce the temperature of gas existing the oxidation zone.
- The producer gas is formed in this zone.

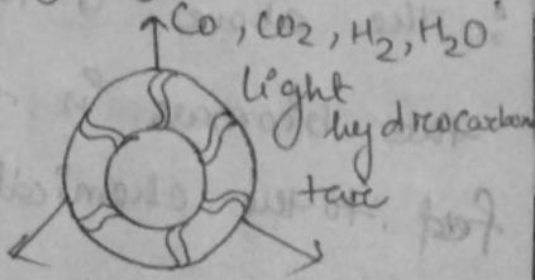



wood gassifier

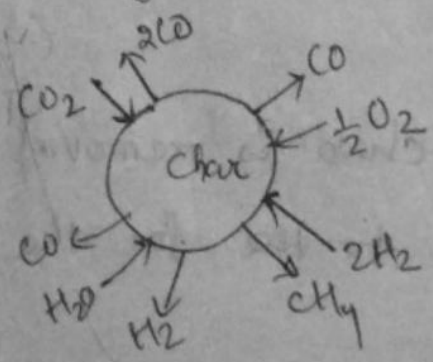
* Heating and drying




* Pyrolysis




* Solid gas reaction




Gas phase reaction

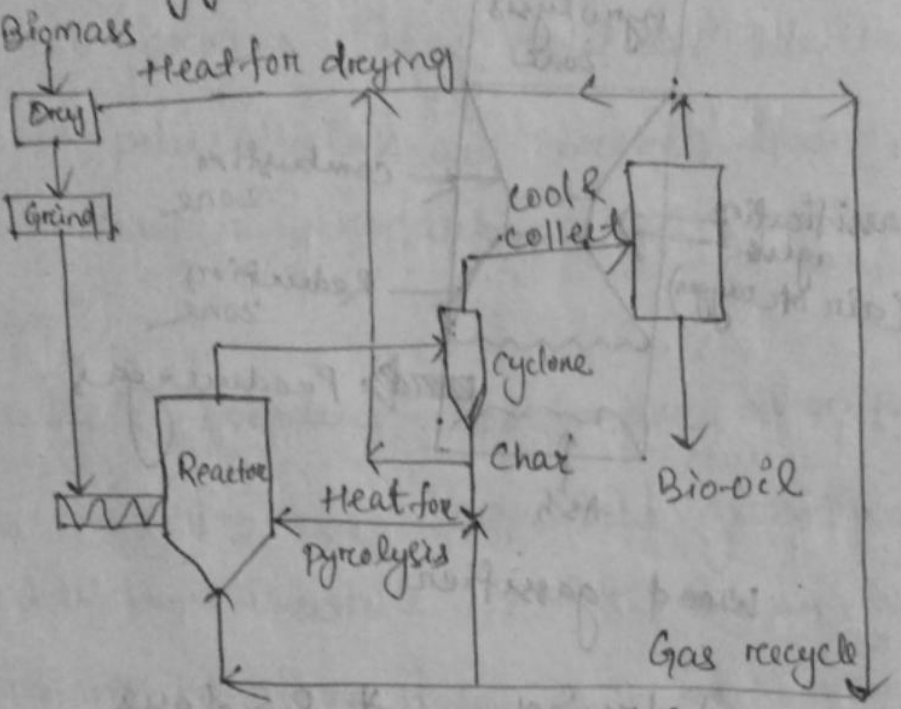
$CO + H_2O \rightarrow CO_2 + H_2$

$CO + 3H_2 \rightarrow CH_4 + H_2O$

## B) Pyrolysis

:- Pyrolysis process is used for biogas and biofuel production from the bio-mass.

:- Pyrolysis is a combustion process which takes place without oxygen or a presence of controlled oxygen.




:- The above is the diagram for pyrolysis. The biomass is first dry and grind then feed to the chemical reactor.

:- In the ~~reacti~~ reactor the breakdown takes place at high temperature and the substances is fed to the cyclone.

:- In side the cyclone the char is removed and oil and gas is fed ~~to the~~ for the cooling purpose.

# Other Energy Sources

## Tidal Energy :-

**Tides :-** Tides are the long period waves that occur in the ocean.

:- These are caused by the combined gravitational effects of the sun, the moon and by the rotation of the earth.

:- The two forces that give rise to tides are gravitational and centrifugal force.

**Tidal Energy :-** The energy obtained from tides is called tidal energy.

:- Tidal power is a form of hydropower which converts tidal energy to other useful energy.

:- Tidal energy is also called tidal power. Tidal power utilizes the energy obtained in tides to produce electricity.

:- Tidal barrages or dams are constructed across a narrow opening to the sea. Water rushes into the dam area when the sea level rises.

:- This moves the blades of the turbines which are attached to the opening of the dam and the generator rotates which results generation of electricity.

## Tidal barrages

:- A tidal barrage is like a huge dam that's placed in the ocean to capture tidal energy.
:- water flows through tunnels inside the dam
:- when the tide goes in and out it pushes the turbine hidden inside these tunnels.

## Tidal energy as renewable energy source

:- Tidal energy is a renewable source of energy, because it comes from the natural and rise and fall of the ocean.
:- And ocean is the resource we won't run out of.

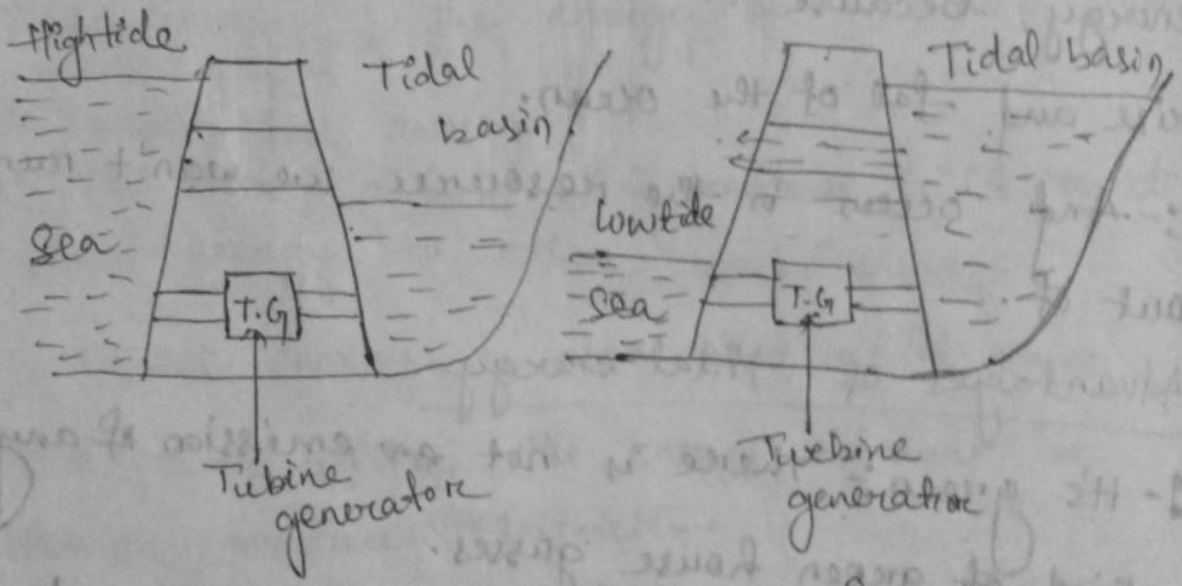
## Advantages of tidal energy

1- It's green:- there is not an emission of any kind of green house gasses.
2- The tides are predictable:- Unlike the wind and sun, the power of tide is predictable.
3- Tidal power plants last a long time than wind and solar farms.
4- Hig power:- water is so dense, tidal power plant can generate alot of energy even at low speed.

## Disadvantages of tidal power

1- The cost of building of barrages in the ocean is high.
2. The fish and other aquatic animal may caught in the turbines.
3. The location for making barrages is limited.
4. The intensity of the sea waves varries.

## Barrage tidal system




→ The above is the diagram for barrage tidal system.
→ Here the turbine is rotate by the high tide and low tide.
→ During high tide the water from sea flows to the tidal basin and the turbine rotates and hence generator which leads to electricity generation.

:- During low tide the water flows from tidal basin to sea and again the turbine rotates and it generate electricity.

## Non-barrage tidal system

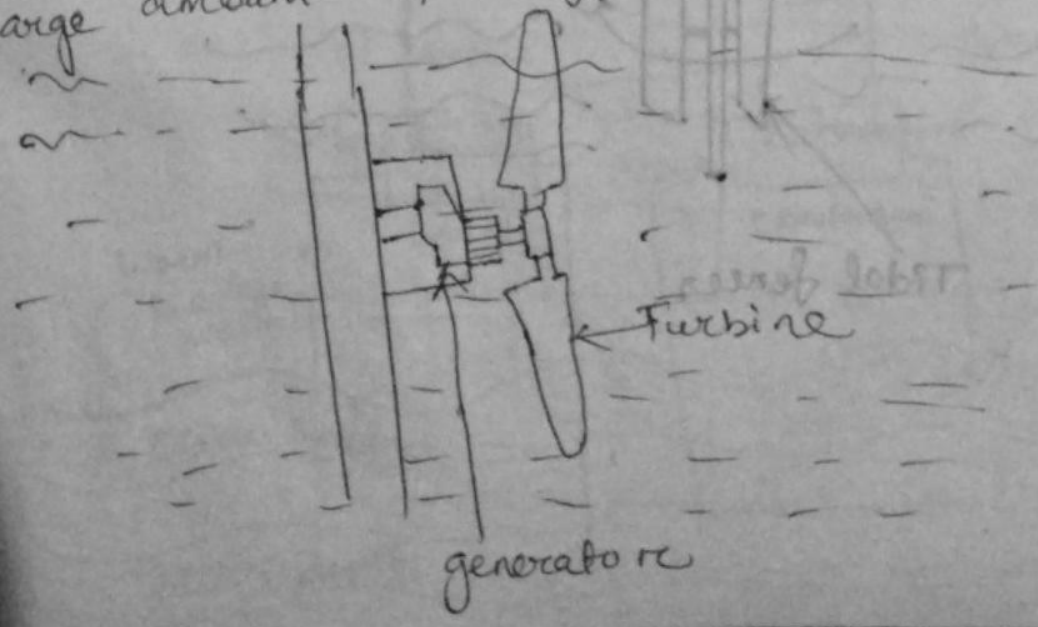
## Tidal Turbines

:- Tidal turbines are very similar to wind turbine, however they are located under water.

:- A tidal turbine utilizes the tides under water to push against a generator, forcing it to move.

:- This turbine is connected to a generator allowing for electricity generation.

:- Tidal turbines are individual turbines that are often placed closely to each other to produce large amount of energy.



## Ocean thermal energy conversion (OTEC)

:- OTEC refers to a method of using the temperature difference between the deep parts of the sea which are cold and shallow parts of the sea which are hot to run a heat engine.

:- The sunlight penetration is highest upper layer than low layers of the sea.

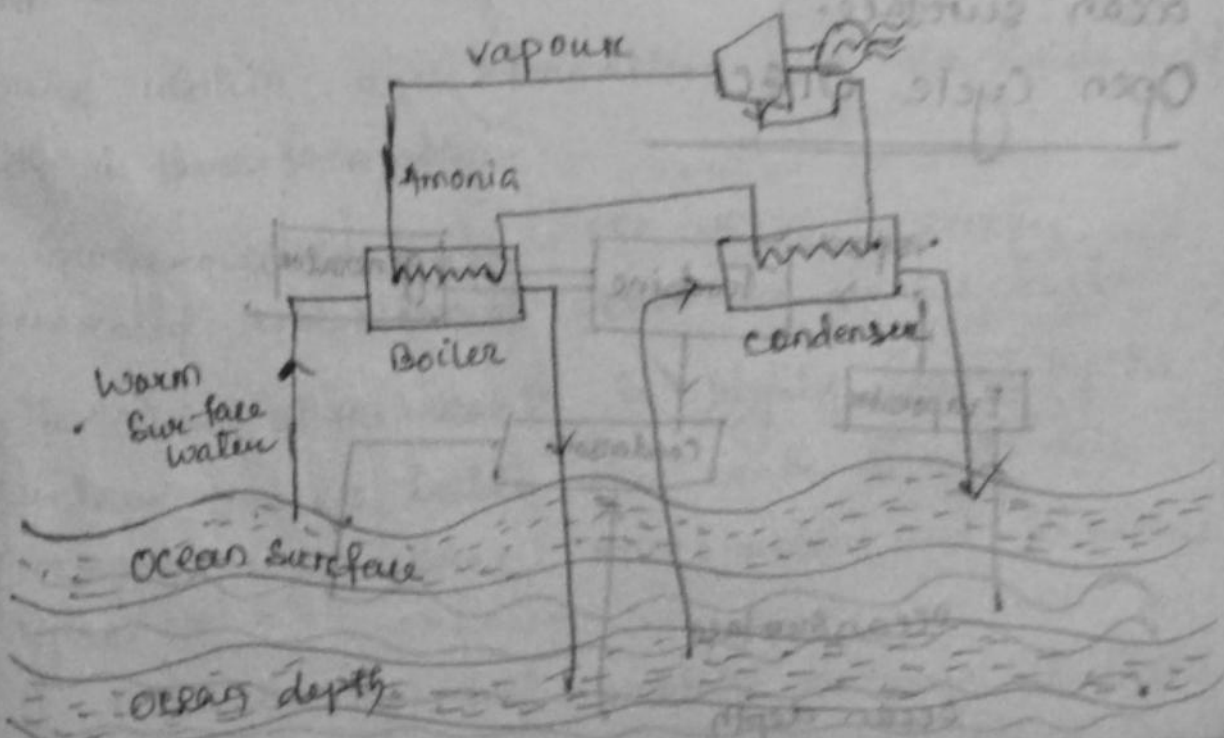
:- OTEC is mainly efficient in tropic region where the sunlight is more.

:- There is two types of OTEC

(i) Closed cycle OTEC

(ii) Open cycle OTEC

## Closed cycle OTEC



:- In closed cycle OTEC ~~Ammonia~~ Ammonia act as a working fluid because Ammonia have low boiling point.

:- Now the warm water is pumped to the heat exchanger where the liquid amonia converts to vapour and fed to the turbine.

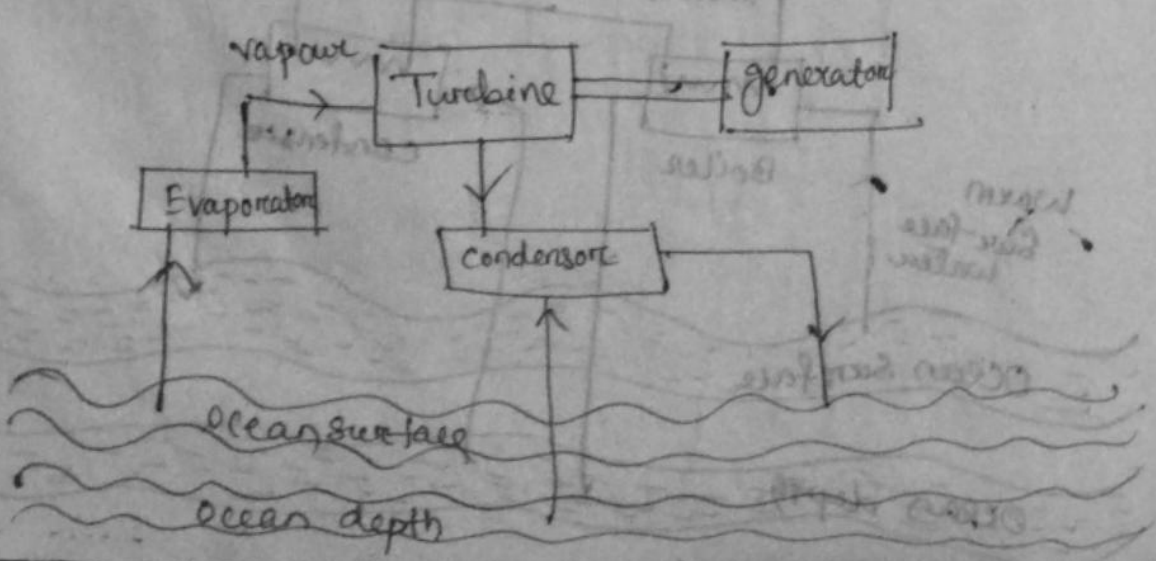
:- The cold water from the ~~boiled~~ boiler fed to the ocean depth.

:- By the vapour the turbine rotates and hence the generator. The hot vapour ammonia fed to the condenser.

:- In the condenser the cold water is there from the ocean depth and ~~again~~ the vapour converted to liquid. and ~~feed~~ fed to the boiler.

:- And the exhusted water is fed to the ocean surface.

## Open Cycle OTEC



:- In open cycle OTEC water is used as working substance.

:- The warm water from ocean surface is pumped to the evaporator. In the evaporator the water is converted to vapour.

:- By the vapour the turbine rotates and the generator from which we generate electricity.

:- From the turbine the vapour comes to the condenser. The cold water from ocean depth is pumped to the condenser and the vapour becomes liquid.

:- This liquid is fed to the sea.

## Geothermal Energy

:- Geothermal energy is the heat of the earth and is the naturally occurring thermal energy found within rock formations and the fluids held with in those formation.

:- Geothermal energy is the thermal energy generated and stored inside the earth's crust.

:- The centre of the earth is highly heated by the nuclear process inside the earth. Due to this temperature some rocks melt and it become magma.

- It results upward motion because of light

## Classification of geo-thermal energy

There are three types of geothermal power plant

i) dry steam

ii) flash steam

(iii) Binary cycle

i) dry steam :- Dry steam power plant draw from underground resources of steam. The steam is piped directly from underground well to the power plant.

ii) Flash steam :- Flash steam power plants are the most common. They use geothermal reservoirs of water with temperature greater than 360°F

:- This very hot water flows up through wells in the ground under its own pressure.

:- As it flows upward, the pressure decreases and some hot water boils into steam. The steam is then separated from the water.

iii) Binary cycle :- Binary cycle power plants operate on water at lower temperature of about 225° - 360°F.

:- These plants use the heat from the hot water to boil a working fluid, usually an organic compound with a low boiling point and the working fluid vapourized.

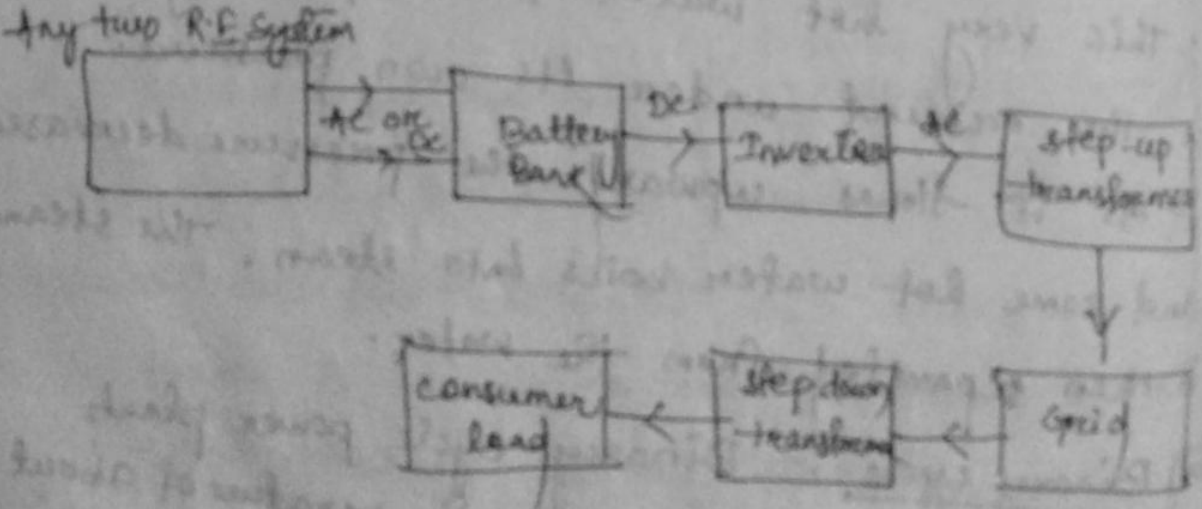
## Hybrid Energy System

The combination of two or more type of renewable energy system is called hybrid energy system.

## Types of hybrid energy system

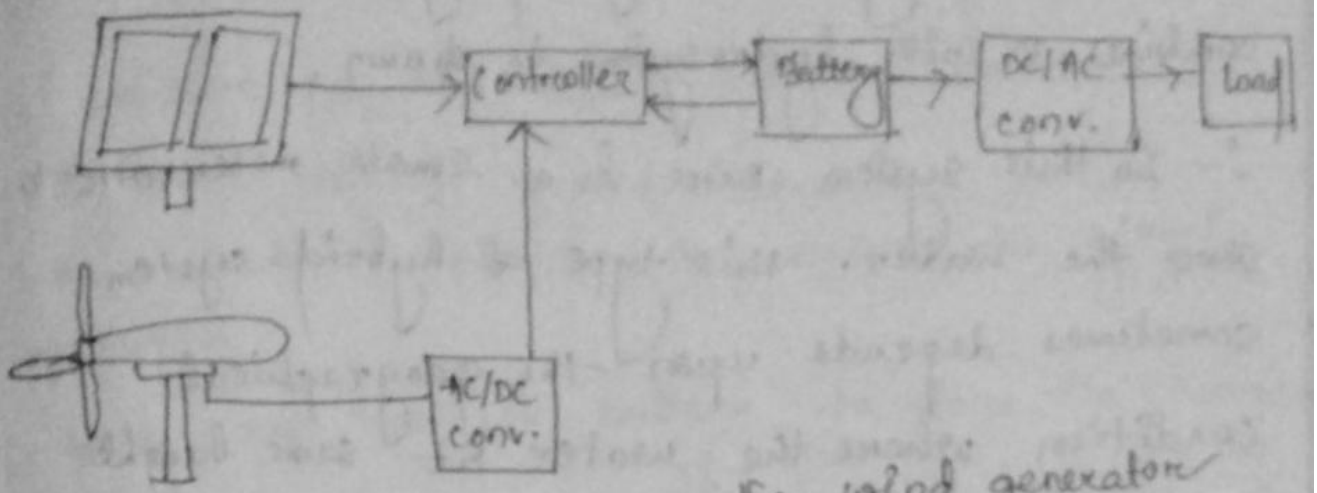
1. Wind solar hybrid system
2. Wind biogas hybrid energy system.
3. Wind diesel hybrid energy system.
4. Biogas - solar hybrid energy system.
5. PV - diesel hybrid energy system.
6. Biomass - solar hybrid energy system.
7. Micro hydel - PV wind energy system.

## Block diagram of hybrid energy system




## Need - Need of hybrid energy system

1. Continuous power supply :- The hybrid energy system provide power continuously without any interruption, as the battery is connected to store energy.

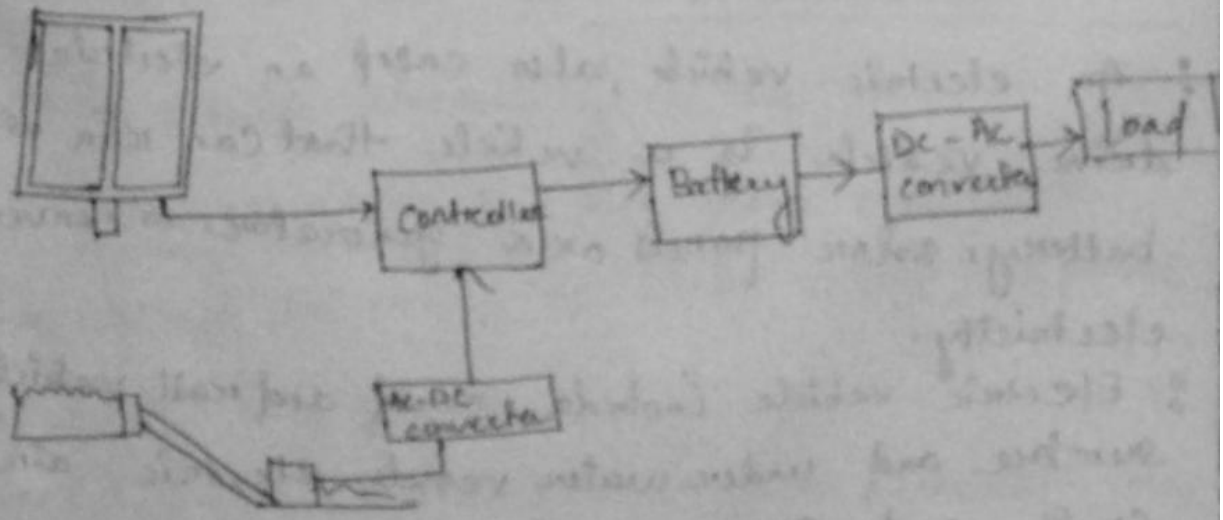



:- The power produced by the wind generator is an AC voltage but have variable amplitude and frequency, that can be transfered into DC to charge the battery.

:- The controller protects the battery from over charging.

:- An Inverter is connected to transform the low DC voltage to an AC voltage of 230V of frequency 50Hz

Microhydel ~ PV hybride



the rotating wheels while breaking



## Need of electric & hybrid vehicles

→ Over dependence on petrol / diesel.
→ Rising petrol / diesel prices.
→ pollution and global warming
→ Noisy operation in conventional vehicle
→ Need for alternate power source.
→ Need of environment friendly operation.

## Disadvantages of electric and hybrid vehicle

→ High initial cost
→ short driving range
→ Recharging takes much longer time than refueling gasoline.
→ For battery back the weight increases and weight of the vehicle increases.