Introduction, classification of Energy Resources. Conventional Energy resources. Availability and their limitations. Non conventional Energy resources- Classification, Advantages, Limitations. Comparison of Conventional and Non Conventional Energy Resources. World Energy Scenario. Indian Energy Scenario. Energy Storage. Sizing & Necessity of Energy Storage.

G.D. Rai, kothari
(S.khan-Text)

Non Conventional Energy Sources (Renewable Energy Source)

1) Sun	Conventional
2) Wind	
3) Biomass	
4) Water	
5) Geothermal	

① They are pollution free ② Inexhaustable.
③ Freely available.

Energy exist in different Forms such as
1) Mechanical Energy
2) Potential Energy
3) Kinetic Energy
4) Thermal Energy
5) Magnetic Energy
6) Electrical Energy
7) Radiation Energy
8) Nuclear Energy

All forms of Energy can be Converted to other forms of Energy. Thus energy is Conserved. They couldnot be destroyed. It can be transformed from one form to another.

Einsteins theory of relativity Suggested that mass Can be Converted into energy. and mass & energy are equivalent. ($m \leftrightarrow E$)

$$E = mc^2$$

C = velocity of light $= 3 \times 10^8$ m/s in freespace.

Energy Sectors:- Human activities requiring energy can be deveded into 4 major areas or sectors

1. Domestic Sector
2. Agricultural Sector
3. Transportation Sector
4. Industrial Sector.

Conventional Energy Sources

Those Energy Sources which has been traditionl used for many decade and were in Common use around Oil Crisis of 1973 are Called Conventional.

eg: 1) Fossil fuel
2) Nuclear
3) Hydro Resources.

Non Conventional

Those energy resources which are Considered for large scale use after the Oil Crisis of 1973. are Called non Conventional Sources.

eg 1) Solar
2) Wind
3) Biomass.

(Now non-conventional become Conventional after a few decade). So called alternate Source of Energy.

Renewable Energy Sources are being Continously produced in nature and they are inexhaustable

1) Biomass
2) Solar Power
3) Tidal Power
4) Geothermal
5) Wind
6) Hydro Power.

Non Renewable Energy Sources.

Those which are finite and donot get replenished after their Consumption.

1) Fossil fuel (coal, petroleum, natural gas)
2) Uranium.

Conventional Energy Sources:-

1) Fossil Fuel
2) Hydro Resources
3) Nuclear Resources.

Fossil Fuel:- Coal, Petroleum Oil, gases.

Coal:- It is supposed to be formed in several parts of earth at varying depth, during several millions years by the process of Carbonization of wood wher large plants & trees were buried inside earth

Lignite :- Brown Coal.
Bituminous :- Soft Coal
Anthracite :- Hardest Form of all Coals.

The high heat and pressure changed the wood into coal, slowly. Since the event of Industrialization Coal has been the most Common Source of Energy.

Continuing the Subterranean activity, reduces the Coal's gaseous Content progressively to form different ranks like peat, lignite, bituminous and anthracite.

Petroleum & Oil: are Supposed to be formed by decomposition and chemical action of buried Organic matter (tiny plants and animal) millions of year ago.

Agriculture and Organic Waste:- At present Small quantities of agricultural and Organic wastes Consisting of straw saw dust, garbage, animal dung, and paddy husk accounting a major energy Consumption.

Hydro Resources. (Water Power)

Among all renewables, hydro power is most established Source of electric power. Hydro power is developed by allowing water to fall under the force of gravity. Potential Energy of water is Converted into mechanical Energy by using Prime movers known as hydraulic turbines.

DISADVANTAGE

(V) These energy Source also release green house gases like CO_2 into atmosphere which Contribute to global warming

Nuclear Resources:- High energy can be obtained by fission of radio active materials (isotopes of elements) like U^{235}, U^{233} and Pu^{239}. These materials known as fissionable material. Out of these U^{235} occur in nature and U^{233} & Pu^{239} are produced from Th^{232} & U^{23} in fast breeder reactor.

ADVANTAGE OF CONVENTIONAL ENERGY SOURCES (Non Renewable)

(i) At Present Conventional Energy Sources are cheap.
(ii) By storing certain quantity, the energy availabili can be insured for a certain period
(iii) They are convenient to use.
(iv) Security good
(v) It is very convenience to use.

DISADVANTAGES OF CONVENTIONAL ENERGY SOURCES (Limita

(i) Fossil Fuels generate pollutants like CO, NOx, SO_x, particulate matter and heat. The excess CO_2 causes global warming.
(ii) Nuclear fuels causes pollution hazards and disposal of nuclear waste which create problem
iii) Hydroelectric plants are cleanest but cause some problems like
(a) Land area submerged in water cause deforestati
(b) Affects Wild life

NON CONVENTIONAL ENERGY SOURCES.

(1) Solar Energy
(2) Wind Energy
(3) Energy from biomass & biogas
(4) Geothermal Energy
(5) Energy from Oceans i.e Tidal Energy.
(6) Chemical Energy Sources
(7) MHD Magnetic hydro dynamics)
(8) Thermo nuclear fission
(9) Thermo ionic Converters.

Advantages of Non Conventional Energy Sources

(i) They are widely available
(ii) They are non-polluting
(iii) Renewable Source of Energy
(iv) Running Cost should be less
(v) They are cheap, clean energy resources.
(vi) The energy sources like wind, solar, heat waves etc Can stored in Original natural form.
(vii) Renewable energy Sources have low Capital Cost.
(viii) Eco friendly.
(ix) Leads to job Creation
(x) Renewable energy has Stabilised global energy prizes.

IMPORTANCE OF NON CONVENTIONAL ENERGY SOURCES

1. The demand of Energy is increasing by leaps and bounds due to rapid industrialization and population growth, the Conventional Sources will not be Sufficient to meet growing demand.
2. Conventional Sources are non-renewable and bound to finish One day.
3. Conventional Sources (fossil fuel, nuclear) Cause pollution and degrade the environment
4. Large hydro-resources affect wild life, Cause deforestation and pose very Serious problem.

Fossil fuels are used as raw material in chemical industry and need to be Conserved for future generation

DISADVANTAGES OF NON CONVENTIONAL ENERGY (Limitations)

1) High Cost of harnessing energy.
2) Uncertainity of availability.
3) Difficulty in transporting.
4) Biogas energy Causes greenhouse effect.
5) Nuclear energy Causes radioactive waste
6) Tidal energy is difficult to harness
7) Wind energy Causes noise pollution
8) Wind mills are Costly to takeup.
9) Low efficiency levels
10) Renewable energy Can be unreliable, Depending upon weather Condition it will change.
11) The electricity generation Capacity is still not large enough.

CONVENTIONAL SOURCES OF ENERGY

Oil

Advantages	Disadvantages
• Easier to transport (tankers) • Basis of petro-chemical industry	• Depletion of oxygen due to oil spillage and gas leakage • Pollutants released caused acid rain • Exploration of new fuel is not easy

Natural Gas

Advantages
• Easier to transport (Pipelines) • Cleaner than oil and coal • Cheaper than oil

Fire Wood

Advantages	Disadvantages
• Easy access • Provides energy to a large number of people	• Collection is time consuming • Polluting • Promoting green house effect • Deforestation

Coal

Advantages	Disadvantages
• Extensively available • Efficient conversion to electricity	• Polluting source • Bulky to transport

Hydel Power

Advantages	Disadvantages
• Non-polluting • Promotes irrigation and fishing • Cheap	• Displacement of local community • Inundates low • Expensive to setup

Wind Energy

Advantages	Disadvantages
• Non-polluting • Low cost production of electricity once setup • Safe and clean	• Noise pollution • Wind mills costly to setup • Disturbs radio and T.V . reception • Harmful to birds

Solar Energy

Advantages	Disadvantages
• Inexhaustible • Non polluting	• Expensive • Diffused source, so gets wasted

Tidal Energy

Advantages	Disadvantages
• Non-polluting • Inexhaustible	• Destroys wildlife habitat • Difficult to harness

NON- CONVENTIONAL SOURCES OF ENERGY

Nuclear Energy

Advantages	Disadvantages
mits large mount of energy	• Generates radioactive waste • Expensive

Bio Gas

Advantages	Disadvantages
• Low Cost • Easy to operate • Makes use of bio waste	• Causes green house effect

Geothermal Energy

Advantages	Disadvantages
• Clean ecofriendly and always available	• Located far away from cities and so costly to transport the electricity

Basis	Non Conventional Energy	Conventional energy.
① Example	Wind, Solar, Biomass, Biogas, Tidal, Wave, Hydro-electricity.	Coal, Oil, Natural gas, Nuclear Energy.
② Source	Natural local environment	Concentrated stock.
③ Normal State	A Current of energy and income	Static store of energy a capital
④ Life time Supply	Infinite	Finite
⑤ Cost at Source	Free	Increasingly expensive
⑥ Variation in Supply	Fluctuating	Steady.
⑦ Based on Eco Friendship	Very much ecofriendly.	Not ecofriendly.
⑧ Weather Condition.	Depend On weather Condition the source will vary	Not much depend on weather Condition
⑨		
⑩		

Feature	Conventional (Non renewable)	Non Conventional (Renewable)
Technologies	Established	Commercially weak.
Plant size	large (MW range)	Small (kW) range
Main power plant	Suitable	Not sufficient.
Pollution Problems	more	less
Energy resources	Limited	renewable
Storage	easy	Uneconomical
Cost of generation	low	high

Nonconventional Energy resources.

* SOLAR ENERGY:- The Sun is the source of almost all energy sources on the planet earth. Solar energy is a basic need of living plants and human beings on earth. The solar energy is intermittent in nature, eco-friendly, and non-polluting energy. It can be used for direct conversion into electricity by using photovoltaic conversio and into thermal energy.

Thermal energy conversion can be categorised according to temperature by

(i) Low temperature range ($< 10^{\circ}c$)
(ii) Medium temperature range ($10^{\circ} - 150^{\circ}c$)
(iii) High temperature range ($> 150^{\circ}c$)

The amount of solar radiation striking the earth is called insolation measured in BTU per square foot (Ft^2) per hour or watts per square metre per

Solar Thermal devices are

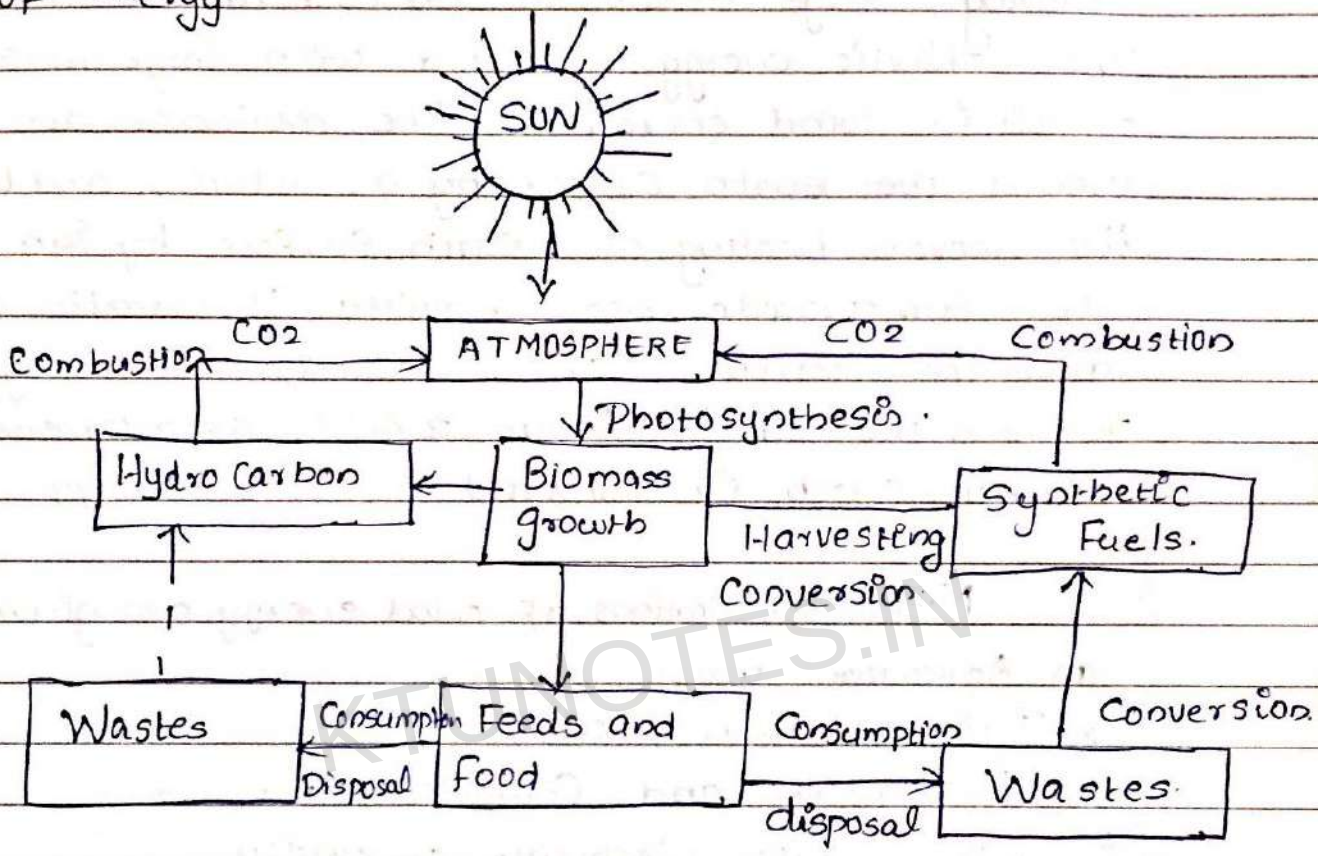
(1) Solar water heater
(2) Solar Cooker
(3) Solar desalination
(4) Solar drying
(5) Solar dryers
(6) Solar pumping
(7) Solar timber drying
(8) Solar ponds
(9) Solar refrigeration & air Conditioning
(10) Solar thermal power generation

BIOENERGY (Biomass and biogas)

Biogas:- It is a renewable source of energy produced from organic materials like human waste, cattle dung and different types of biomass.
It is a clean and smokeless domestic fuel.
Biomass like animal waste, vegetable waste etc undergo decomposition in the absence of oxygen in a biogas plant and form a mixture of gases. This mixture is called biogas. This is used for cooking and lighting in rural areas.
Methane is the main constituent of biogas.

Biomass:- Biomass accumilates in the earth's biosphere in vegetation by the process of Photosynthesis. During Photosynthesis, Carbon dioxide CO_2 is Converted to Carbohydrate which is the primary organic product.

The solar energy is Captured as fixed Carbon in biomas Each gram of fixed Carbon Contain 470kJ (112 kCal) of energy.



Main Features of biomass Energy.

WIND ENERGY

Moving large masses of air is termed as wind. The kinetic energy associated with large masses of air is wind energy. The motion of air around the earth caused by its rotation and by the uneven heating of earth surface by Sun. The Sun provide heat required to warm the air above the earth. So Wind is actually solar energy reaching the earth. About 2% of all solar energy reaching earth is converted to wind energy.

Modern applications of wind energy are given below
(1) Agricultural uses
(2) Rural and municipaluses
(3) To pumping and Compressed air
(4) Large scale electricity generation.

OCEAN ENERGY (WAVE AND TIDAL ENERGY)

About 71% of earth surface is covered by water. Ocean waves and its tides have vast energy potential. Due to wind motion across miles of Ocean surface, there is a temperature difference between upper and lower layers of water which results energy potential in waves.

Tides are a result of gravity of Sun, the moon and earth and its rotation. Temperature difference produces thermal energy and lower layer of water which results ~~Potential in wave~~

On other hand tides and waves produces mechanical energy
So Ocean Can produce 2type of energy
(1) Thermal energy (2) Mechanical energy.

OTEC utilizes the thermal gradient available in ocean to operate a heat engine to produce a work Output. The relative motion between earth, Sun and moon give rise to different tide cycles. These cycles affect the range of tides. Tidal power extract energy from tides using the same principle as hydropower facilities but Capturing tidal ebbs and flows rather than the flow of a river to generate electricity. The Captured water is released through a turbine to generate electrical

GEOTHERMAL ENERGY

Geo means earth and thermal means heat. Geotherm energy is natural heat generated from earth's interior. The earth core is very hot and it is Possible to make use of this geothermal energy. These are the areas where volcanoes, hot springs & geysers etc are found.

Geothermal energy comes in 3 forms
(1) Hydrothermal
(2) Geopressured
(3) Petrothermal.

NEED OF ENERGY STORAGE

Energy is useful only if available when and where it is wanted. Carrying energy to where it is wanted is called distribution, keeping it available until when it is required is called Storage

Means of storing energy in a recoverable form when the supply exceed the demand for use at other times. Storage of Primary fuel (coal, petrol, natural gas) is a form of energy storage, but the term applies to actual energy and secondary fuel (hydrogen) rather than primary fuel. The effective and utilization of intermittent and variable energy sources such as Solarenergy and wind energy, often require Storage. If the intermittent energy is Converted to electricity, as it is with photovoltaic cell and wind energy utilization then electrical energy in excess of demand need storage and might be fed directly into a utility grid or some other forms of energy.

Electrically Propelled vehicles which are expected to come into increasing use, require some form of energy storage. Thus energy storage is necessary for Continuous Supply at the time of need in near future.

Energy Can be Stored in various different forms, primary, intermediate or Secondary forms such as thermal, electrical, hydro, biomas, Chemical, mechanic fuel etc.

Energy storage brodly divided to 2 type.

Non electrical

1. Mechanical energy storage
2. Hydro potential energy storage
3. Thermal and chemical energy storage

Electrical

lead acid battery

Mechanical ← Pumped hydro electric Storage
← Compressed air
Flywheel.

Thermal Storage ← sensible heat
← latent heat
Chemical reaction.

Chemical Energy ← Ammonia
← hydrogen
← Reversible chemical reaction

WORLD ENERGY SCENARIO

INTRODUCTION

The primary sources of energy is fossil fuel, however the finiteness of fossil fuel reserves and large scale environmental degradation , caused by widespread use. So, harnessing of non-conventional sources is vital for steering the global energy supplies towards a sustainable path.

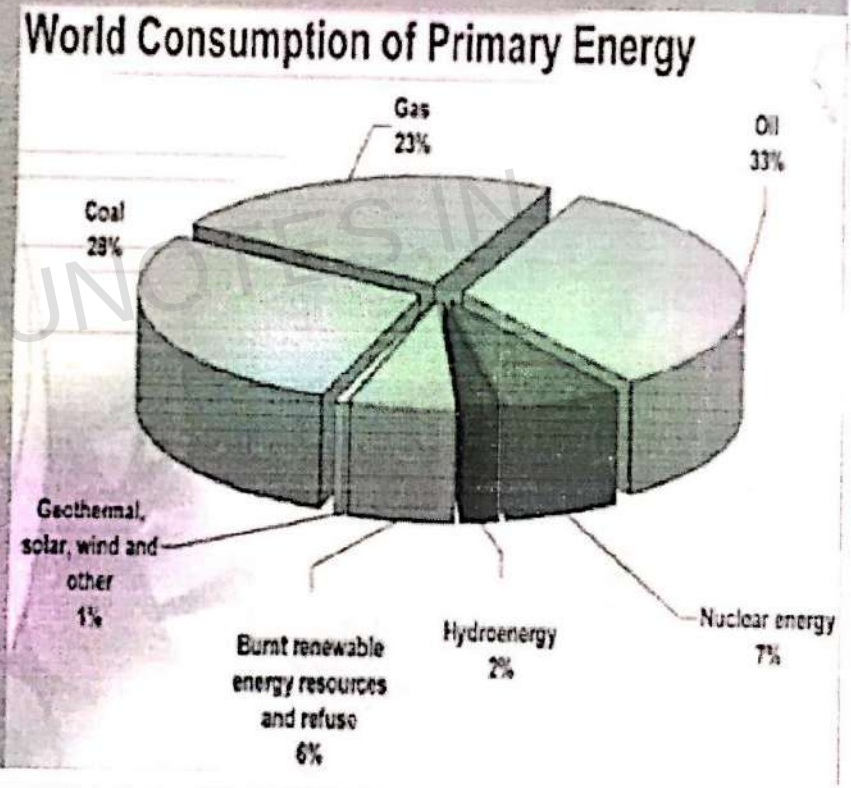
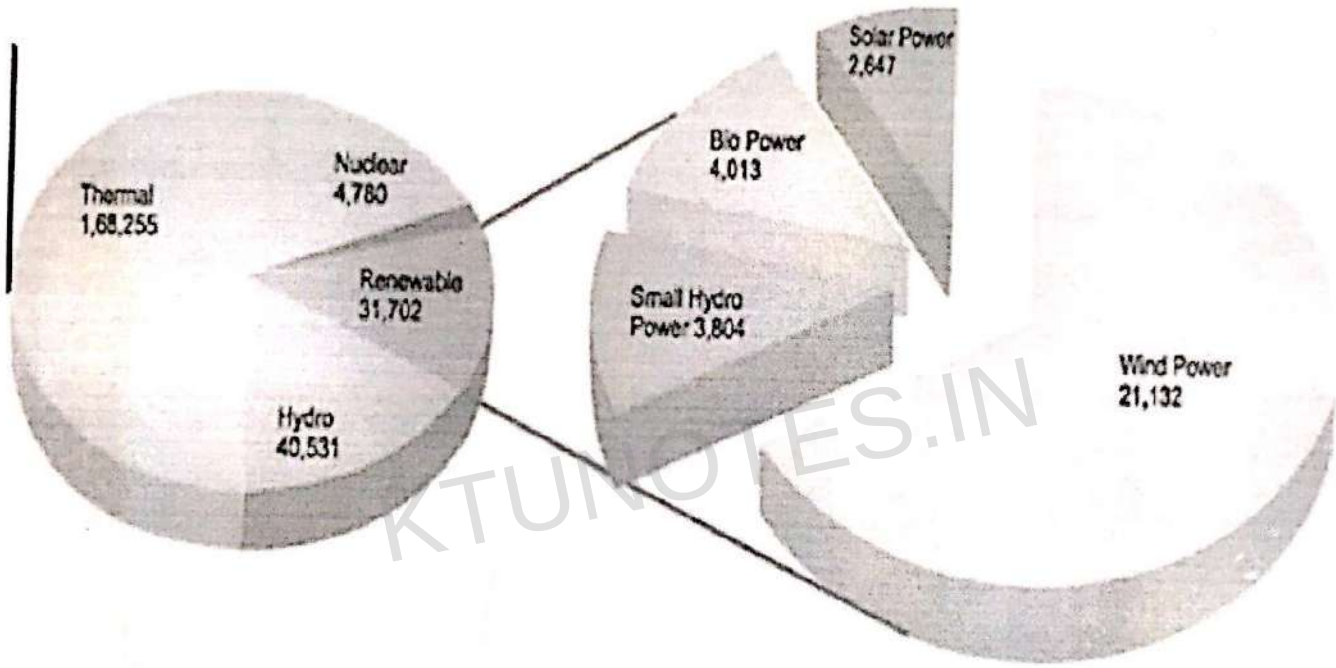


Figure 1. Installed Power Generation Capacity in MW as on 31.3.2014 in India



1) Coal
→ 56%
→ 3rd largest Producer
→ Energy Security
→ Geo

SOLAR RADIATION MEASUREMENTS

Measurement of solar radiation are important because of the increasing number of solar heating and cooling applications, and the need for accurate solar irradiation data to Predict Performance

The 2 basic types of instruments employed for solar radiation measurement are

(1) Pyrheliometer :- Which Collimates the radiation to determine the beam intensity as a function of incident angle

(2) Pyrometer :- Which measure the total hemi Spherical Solar radiation

PYRANOMETER :- It is an instrument which measure total or global radiation over a hemispherical field of view ~~It the~~ Basically Pyrometer Consist of a black surface which heats up when exposed to Solar radiation. Its temperature increases until the rate of heat gain by solar radiation equal the heat loss by Convection, Conduction and radiation. The hot junction of a thermopile are attached to black Surface, while the cold junction are located under a guard plate So that they donot receive the radiation directly. As a result an emf is generated. This emf is usually in the range of 0 to 10 mV can be read, record

PYR - Fire
anometer - up (Fire from up above)

Main parts of Pyrometer are

1) Black Surface
2) Glass dome
3) Guard plate
4) leveling screws
5) mounting plate
6) Grounded bolts
7) Platform.

Construction:

* It has its hot junction arranged in the form of a horizontal circular disc of diameter 25mm and Coated with special black lacquer having a very high absorptivity in the Solar wavelength region. Two Concentric hemisphere 30mm and 50mm in diameter made of optical glass having excellent transmission

Pyrometer measure Solar radiation falling on a horizontal Surface in watts Camount of meter. Insolat

Characteristics are used to protect the disc surface from the weather. An accuracy of ± 2% can be obtained.

The Pyrometer can be used for the measurement of diffuse radiation. This is done by mounting it at the centre of a semicircular shading ring. The shading ring is fixed in such a way that its plane is parallel to the plane of path of the sun's daily movement across the sky and it shades the thermopile element and the two glass domes of the Pyrometer at all times from direct sunshine. Diffuse radiation means scattered radiation reaching earth surface.

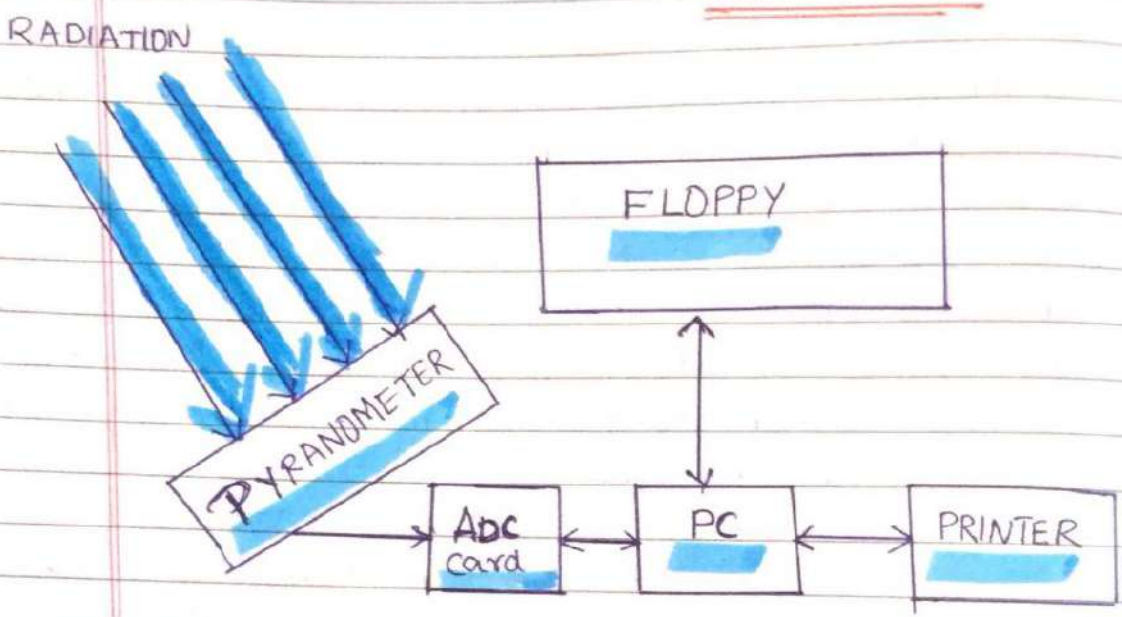
The construction of shading ring is as shown. ABCD is a horizontal rectangular frame 35 x 80cm with its long sides in an east west direction.

To the sides AB and CD of the frames are pivoted with 2 angle iron arms EF & GH. 70 cm long with slots along their length, carrying sliders, SS on which is mounted the semicircular shading ring R. The arms are pivoted ~~agai~~ about horizontal axis which passes through the centre of rectangular frame and can be adjusted at an angle to the horizontal equal to the latitude of the station. The movement of the ring up and down the arms allows for changes in the sun's declination.

The shading ring is of Aluminium 50mm broad, and is bent to a radius of 450mm. The inner surface of the ring is painted dull black, while the rest of the shading ring is painted dull matt white. To the bottom of the frame ABCD is a fixed thick metal plate P with a circular ~~xtag~~ slot so that the frame, when fixed on a masonry platform with nuts and bolts can be adjusted in its proper position by rotation about a vertical axis. To the top of the frame is fitted another thick metal plate P' on which the pyrometer is mounted

Ch

Data acquisition System For measurement of Solar radiation



This system does not require an instrument Operator to measure the radiation data. With a PC the System uses Analog to digital Converter (ADC) Card, which Serve as the vital interface between Pyrometer and PC to obtain analog data from Sensor. The data So received is Processed in PC with an appropriate Software.

The radiation falling on Pyrometer generates thermo-electric emf which is fed into One of the channel of ADC Card provided with PC. The numerical value of instantaneous voltage in digital form is Stored in Programmable Peripheral Interface (PPI). A Print Out of the Solar flux Can be Obtained by Processing the data.

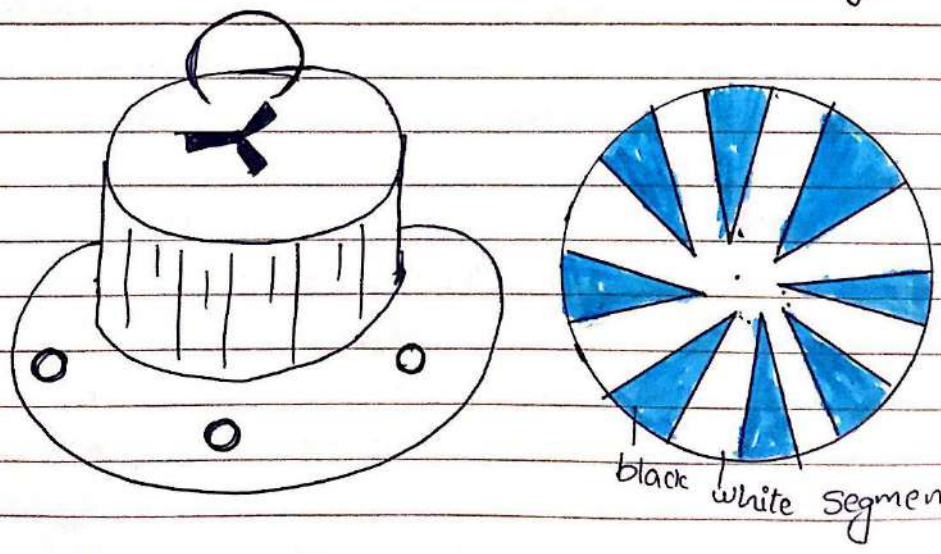
PYRHELIOMETER

These are the different types of Pyranometers

(i) Eppley Pyranometer
(ii) Yellot Solarimeter (photovoltaic solar cell)
(iii) Moll-Gorczybeski solarimeter.
(iv) Bimettallic Actinograph
(v) Velochme pyranometer
(vi) Thermo electric Pyranometer

Eppley Pyranometer. Working Principle is that there is a difference between temperature of black surface (which absorb most of the solar radiation) and white surface (which reflect most solar radiation) The detection is done by thermopile.

Thermopile :- It uses concentric silver rings 0.25mm thick alternately coated with black and white, with 10 or 50 thermocouple junctions to detect temperature differences between coated rings. The disk are enclosed in a bemispherical glass cover.



SOLAR RADIATION DATA

It available in several forms

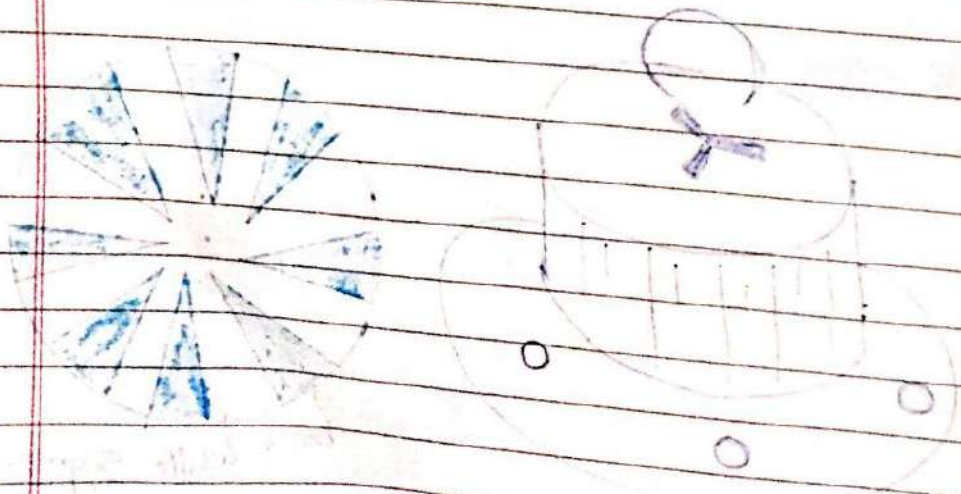
1) Wheather they are instantaneous measurement or values integrated over some period of time (usually hour or day)

2) The time or time period of measurement

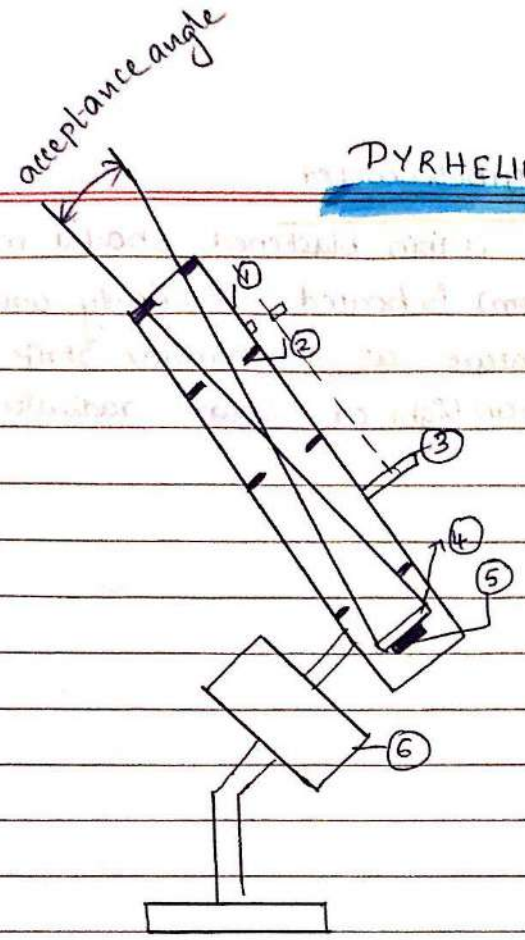
3) Whether the measurement are of beam, diffuse or total radiation and the instrument used.

4) Reciving Surface Orientation (Horizontal, inclined at fixed slope or normal)

5) If averaged, the period over which they are averaged.



PYRHELIOMETER



It is an instrument used to measure the beam radiation falling on a surface normal to sun's rays. Main parts are

1. Tube blacked on inner surface
2. baffle
3. Alignment Indicator
4. Black absorber plate
5. Thermopile junctions.
6. Two axis tracking Mechan sm

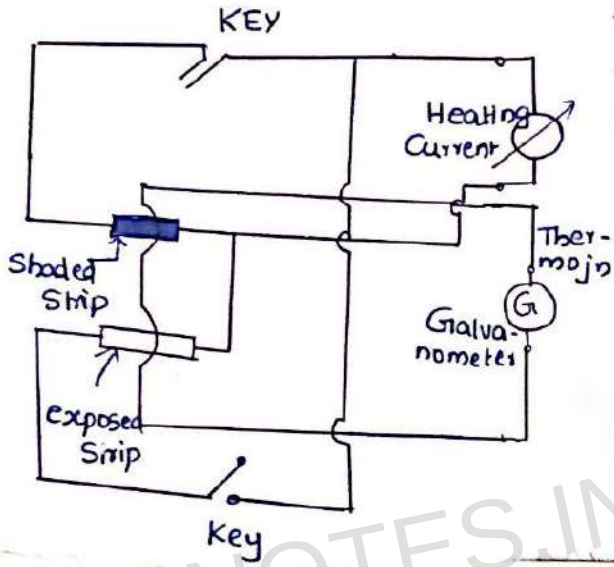
In Contrast to Pyranometer the sensor thermopile disc is located at the base of the tube, whose axis is aligned with the direction of Sun's rays. The working Concept is thermopile effect. The diffuse Components is avoided by a Collimato tube installed over a sensor with a circular Cone angle (acceptance angle) of 5°.

The Pyrheliometer have been in wide spread use to measure normal incident beam radiation.

(i) The Angstrom Pyrheliometer
(ii) The Abbot silver disc Pyrheliometer
(iii) Eppley Pyrheliometer

Angstrom Pyrheliometer

* In this Pyrheliometer, a thin blackened shaded manganin strip (size 20×2×0.1mm) is heated electrically until it is at the same temperature as a similar strip which is exposed to sun light or solar radiation.



Under Steady state condition (both strips at identical temperature) the energy used for heating is equal to the absorbed solar energy.
The thermocouples on the back of each strip is connected in opposition through a sensitive galvanometer are used to test for the equality of temperature. The energy H of direct radiation is calculated by means of formulae

$$H_{DN} = Ki^2$$

H_{DN} = Direct radiation incident on an area normal to Sun's rays
i = Heating Current in Ampere
K = is a dimension & Instrument Constant

$$H_{DN} = \frac{R}{W\alpha}$$

R - Resistance per unit length of absorption strip(Ω/m)
W - Mean width of the absorbing strip.
α - Absorbing Coefficient of absorbing strip.

2) Eppley pyrheliometer:- The sensitive element in an Eppley pyrheliometer is a temperature Compensated 15 junction bismuth silver thermopile mounted at the base of a brass tube, the limiting diaphragms of which subtend an angle of 5.7°. A thermopile is basically a series arrangement of thermo couples used to develop much greater voltage than is possibly using only One. The tube is filled with dry air and is sealed with a crystal quartz window which is removable. A filter wheel is standard.

Applications include
1) Scientific meteorological and climatic observation
2) Material testing research
3) Assessment of the efficiency of solar collectors and photovoltaic devices.

3) SUNSHINE RECORDER

1) The duration of bright sunshine in a day is measured by means of a sunshine recorder. The sun's rays are focussed by a glass sphere to point on a card strip held in groove in a spherical bowl mounted Concentrically with the sphere.

→ Whenever there is a bright Sun shine, the image formed is intense enough to burn a spot on the card strip.
→ Through the days the sun moves across the sky, the image moves along the strip.
→ Thus a burnt space whose length is proportional to the duration of sunshine is obtained on the strip.

PHYSICAL PRINCIPLES OF CONVERSION OF SOLAR RADIATION INTO HEAT

* The fundamental principle for heat conversion is green house effect.
* The name come from its first use in green houses, in which it is possible to grow exotic plants in cold climate through better utilization of the available sunlight.

NB **Greenhouse Effect**

→ A Greenhouse is an enclousure having transparent glass plates or sheets.
→ It behaves differently for incoming visible (short wave) radiation and outgoing infrared (log wave) radiation.
→ It appears as transparent for incoming solar radiation, and allows entry of sunlight, and becomes largely opaque for reflected infrared radiation from earth surface, preventing exist of heat.

→ Thus green house maintain a controlled warm environment inside for growth of plants, especially in places where the climate is cold.

→ The CO_2 envelope present in atmosphere is 0.03%, which present in the ~~globe~~ atmosphere behaves similar to a glass plate, and forms a big global greenhouse. This tends to prevent the escape of heat from earth, which leads to global warming. This phenomenon is called green house effect.

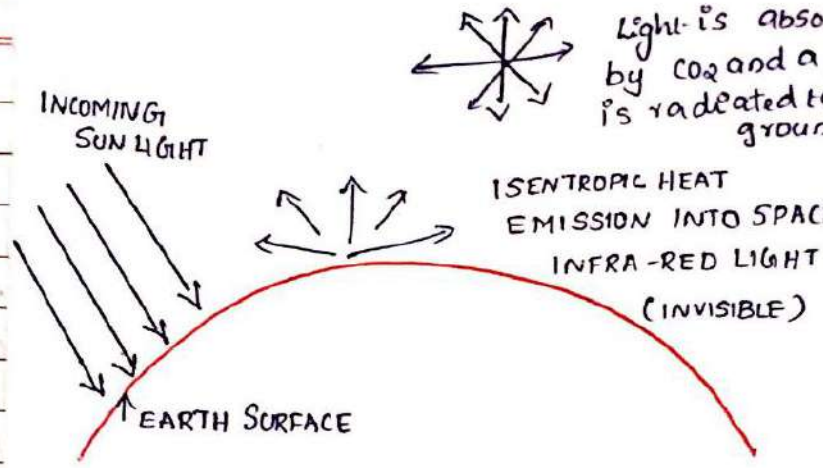
→ Due to the green house effect, the earth maintain an average surface temperature of 15° that is hospitable to life. In absence of this layer, the earth would be a frozen planet at about -25°C.

→ However any further increase in the Concentration of CO_2 from its present level will upset the temperature balance.

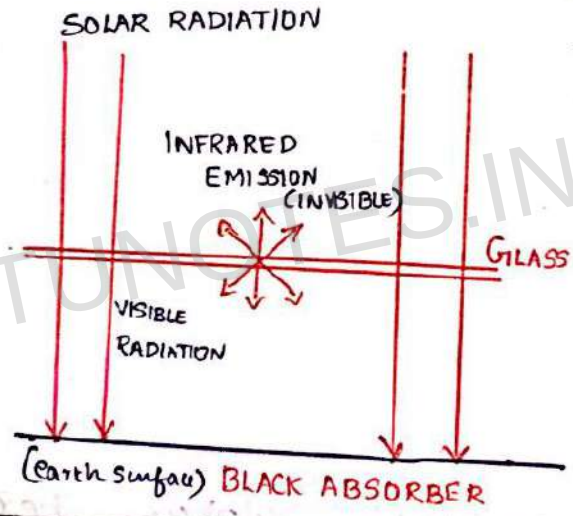
→ This would cause further warming of the globe, which may have disastrous Consequences.

→ Apart from CO_2, the other gases responsible for green house effect are methane, nitrous Oxide, hydrofluro Carbons, Sulphur hexafluoride and water ~~vap~~ vapour.

Figure shows the green house effect related to CO_2 content of atmosphere



Principle of green house effect



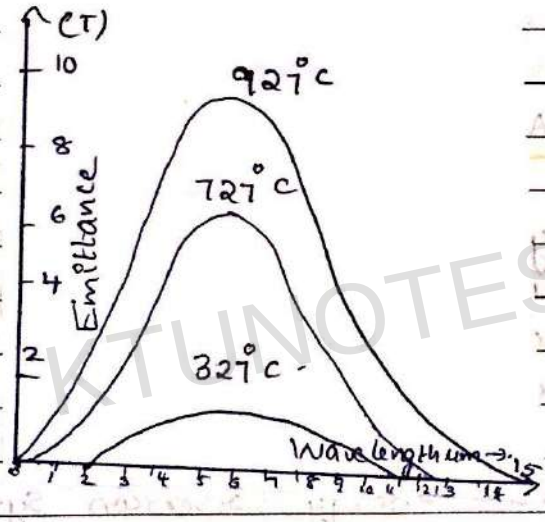
→ In this figure, a black painted plate absorbs the incoming Sunlight. About it, is fixed a plate of ordinary window glass. When the temperature of black plate increases, it emits an increment of the thermal heat in the form of infrared light. The black absorber has the properties of a black body.

→ Ideal black bodies not only have highest absorption rate but also the highest

emission Coefficient for all wavelength of light. Emission increases with temperature, following T^4 law. The re-emitted light if so Progressively shorter wavelength and greater energy as the temperature of black body increases. This is expressed by Wien's law

$\lambda max = T = Constant = 2989 \mu m$ kelvin.

Figure below shows emittance of black body at different temperature.



T = Surface temperature of black body ~~increas~~

λmax = Wave length at which light emission reaches a maximum.

⇒ Sun emits radiation "like" black body whose Surface temperature is 5700°c, this Corresponds to a maximum emission of 0.5 um. A black body at room temperature emits radiation with a maximum at about 10um, which is within the spectrum of inviseble of infra-red light.

⇒ The ordinary glass plate fixed above the black plate in a green house has a spectral absorption

The infrared light absorbed by glass is remitted in all directions. Half of it is emitted to Outside and lost, the other half re-emitted towards the black plate, whose temperature thus increases.

Equilibrium reached when the energy gained by absorption of visible light is balanced by loss of energy through infra-red emission of glass plate.

SOLAR THERMAL ENERGY CONVERSION SYSTEM

Solar energy can be utilised by 2 technologies
(i) Solar Thermal – Provide thermal Energy for various process
(ii) Solar Photovoltaic – This system Converts solar energy directly to electricity.

Solar thermal energy Conversion systems are classified into following categories of application in order of rising cost & complexity

1) Loco temperature application (<150°C):
In this type non focusing type Solar collector used

2) Medium Temperature Application (150°C to 300°C):
In this system line Focusing Collector tracking in One plane are used

3) High temperature (500°C to 1000°C): In this system Collectors with point focussing and tracking in 2 plane are used.

SOLAR COLLECTORS.

In solar collector a part of absorbed solar radiation is transfered to fluid like air or water which can be used to produce steam and then to generate electricity.

BASIC COMPONENTS OF SOLAR COLLECTOR.

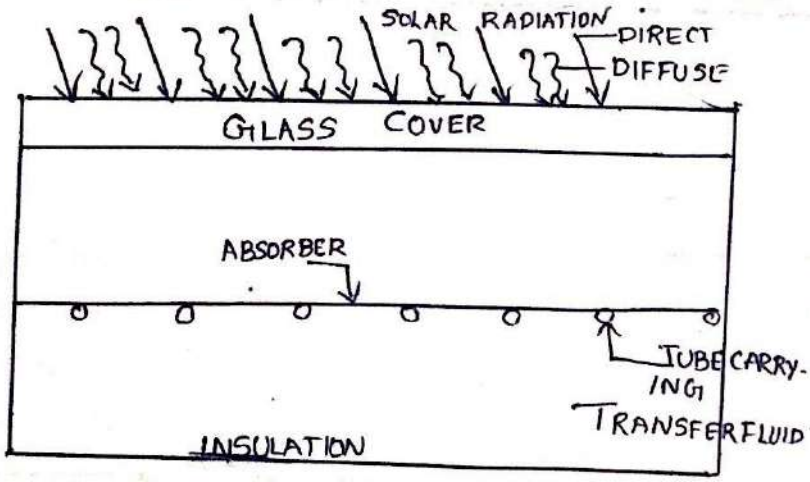
1) A transparent Cover which may be One or more Sheets of glass or radiation transmissing plastic film or sheet.

2) Tubes, fins, passages or channels are integral with the collector absorber plate or connected to it, which carry the water, air or other fluid.

3) The absorber plate:- Normally metallic or with a black surface.

4) Insulation:- Which should be provided at the back and sides to minimise heat loss. Standard insulating material seen as fibre glass or Styro-foam are used for this purpose.

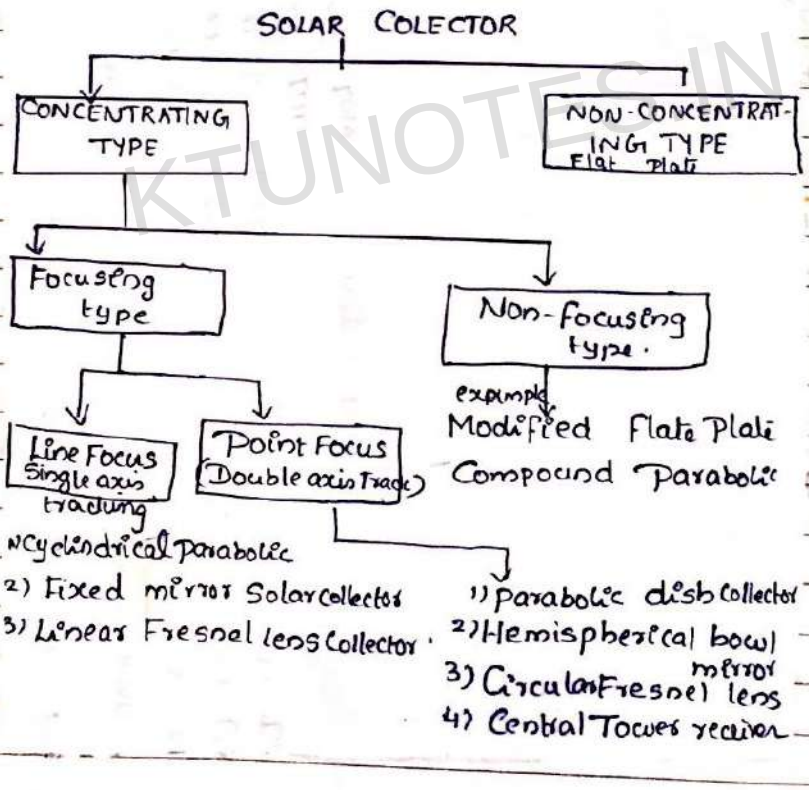
5) Casing or Container:- Which enclose the Other Components and protect them from weather.



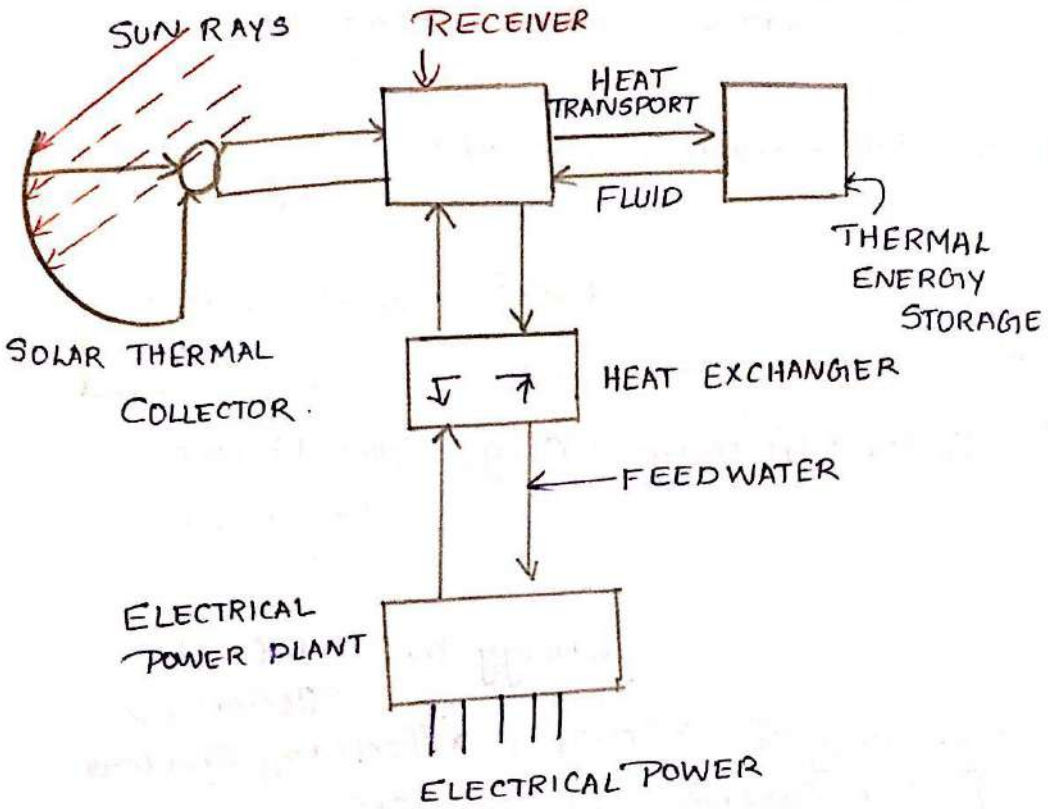
→ As solar radiation strikes on specially treated metallic absorber plate, it is absorbed and raises its temperature. This heat is transfered to heat transfer fluid circulating in the tube beneath the absorber plate and in intimate contact with it.

* Thermal insulation prevent heat loss from rear surface of the collector.

+ The glass cover is transparent to visible (short wave) solar radiation and not to infrared radiation (longwave). As a result heat remains trapped in the air space between absorber plate and glass cover like greenhouse.



Schematic of Solar Thermal Electrical Power Plant



Characteristic Features of a solar Collector

The Sun light is gathered by the thermal collector by various methods. The important Features of Collector system are

- whether focussing or nonfocussing?.
- Temperature of working fluid attained low temperature, Medium Temperature, Hight
- Non-Tracking type or tracking type in One plane or tracking in 2 plane
- Distributed receiver Collector or Central receiver collector
- Simple and low Cost or Complex or Costly
- Layout and Configuration of Collector in the Solar field.

Important aspects of Solar Thermal Collector

- Concentration Ratio & Themperature Range

→ * Concentration Ratio(CR) = $\frac{kW/m^2 \text{ in solar radiation on surface}}{kW/m^2 \text{ on surface of focus of collector}}$

* Collector efficiency = $\frac{\text{Energy Collected by the Collector (J)}}{\text{Energy incident on the collector (J)}}$

* Efficiency of collector is affected by shadow factor, cosine loss, dust etc

(1) Shadow factor = $\frac{\text{Surface of Collector receiving light}}{\text{Total surface of the collector.}}$ (<1.1, (<15)

(2) Cosine loss factor: The solar power collected is proportional to $\cos\theta$. Cosine loss varies due to daily & seasonal variation of direction of sun rays.

(3) Reflective loss factor:-

FLAT PLATE COLLECTOR (NON-CONCENTRIC)

It is designed for operation in low temperature range (60°C) or in medium temperature range (100°C)

Parts are

1) Absorber plate
2) Transparent Cover
3) A Frame
4) Insulation.

Construction:-

→ They are made of rectangular panels from about 1.7 to 2.9 sq. m, in area, and are relatively simple to construct and erect.

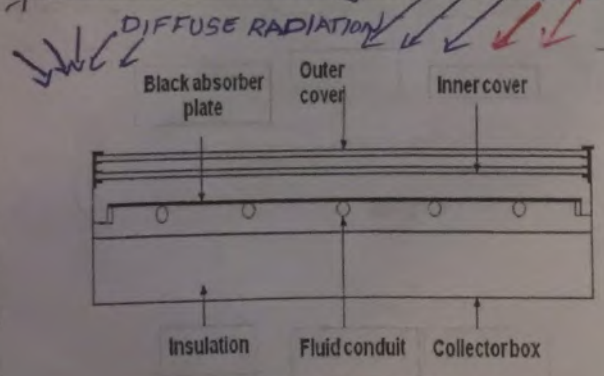
→ Usually an iron-pore Solar safety glass is used as a transparent Cover, as it transmits a great amount of short-wave light spectrum.

Tubes, Fines, Passages or channels are integral with the Collector absorber plate or Connected to it, which Carry the water, air or Other fluid.

Flat Plate Collector is of non-Concentrating type, ie the Collector area is the area that intercept the Solar radiation is same as absorber area.

In this type, ~~wall~~ whole Solar panel absorbs light.

In flat plate collector a part of the absorbed Solar radiation is transferred to fluid like air or water which can be used to produce steam and then to generate electricity

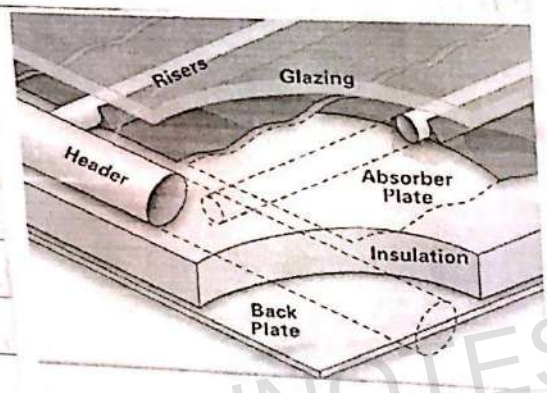


Construction diagram

The main advantage of it is that it utilizes beam and diffused radiation components of solar radiation.

PARTS DESCRIPTION

1) Transparent Cover:- It should be made of a material which is highly transparent to incoming solar radiation and opque to longwave infrared irradiation by absorber Plate



Glass with low ferric Oxide Content Satisfies this requirement. Toughned glass of 4 or 5 mm thickness is most fully used.

(2) Absorber Plate :- It is made from a thin metal sheet ranging from 0.2 to 0.7 mm which are also of metal range in diameter from 1 to 1.5 cm. In some designs, the tubes are bonded to the top or are in-line and integral with the absorber plate. Metal used is Copper, Steel or Aluminium having black surface.

(3) Header Pipes :- Which leads to liquid in and Out of the tubes.

(4) Tubes or Channels :- These are soldered to absorber plate. Water flowing through these tubes takes away the heat from absorber plate. The diameter of tube is around 1.25 cm, while that of header pipe which leads water in and Out of collector and distribute it to absorber tube is 2.5cm

(5) Insulation. The bottom and sides are insulated by fibre glass insulation of thickness 2.5 to 8 cm to minimize heat loss.

(6) Collector box or enclosure :- The whole assembly placed in a box made of metallic sheet or fibre glass. It is tilted by a suitable angle.

ADVANTAGES OF FLAT-PLATE COLLECTOR

1) They have the advantage of using both beam and diffuse solar radiation.
2) They do not require Orientation towards Sun
3) They require little maintanance
4) They are mechanically simpler than the Concentrating reflectors, absorbing Surface and Orientation device of focussing collectors
5) They are easy to design, make and have low c
6) Require low maintanance and long life
7) Their Operating efficiency is high

SOLAR CONCENTRATORS

While dealing with flate plate collectors with heat transport medium as water or air, the area of glass Cover and that of absorber plate are same. Thus solar radiation is uniformly distributed over the glass Cover and the absorber keeping the temperature rise of Solar device upto 100°c. If Solar radiation falling over a large Surface is Concentrated to smaller area of the absorber plate, the temperature can be enhanced upto 500°c. Concentration is achieved by an optical system either from the reflecting mirror or from the refracting lenses. These Concentrators are used in medium temperature or high temperature energy Conversion Cycles.

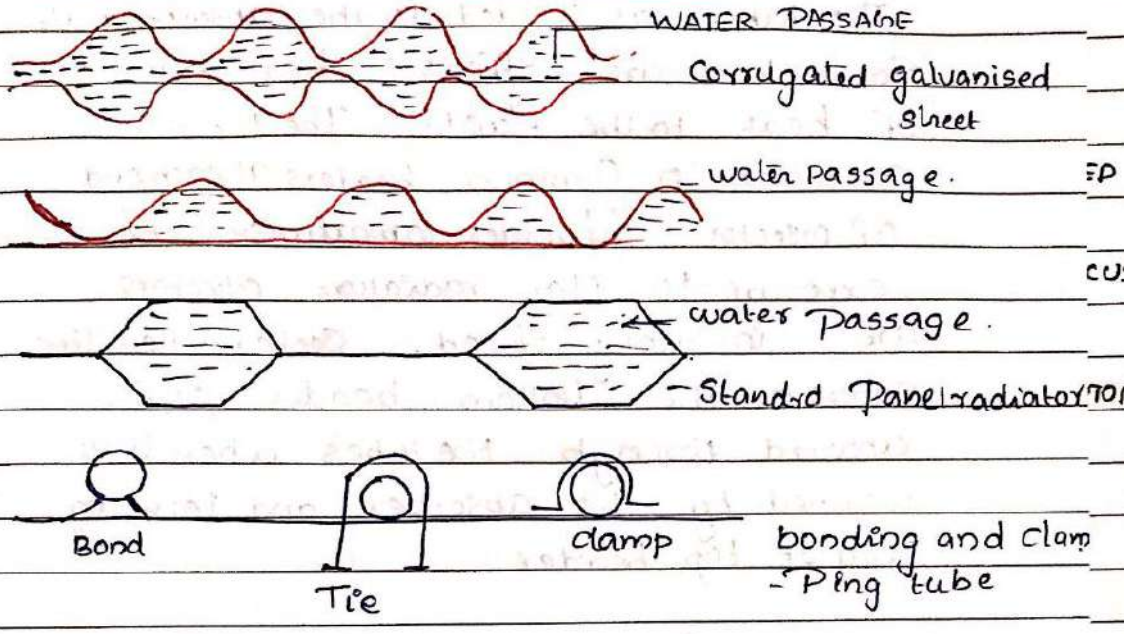
Classification of Solar Concentrators

1) Parabolic trough concentrator
2) Parabolic dish
3) Central Tower Collector.

FLAT PLATE COLLECTOR

classmate
Date
Page 57

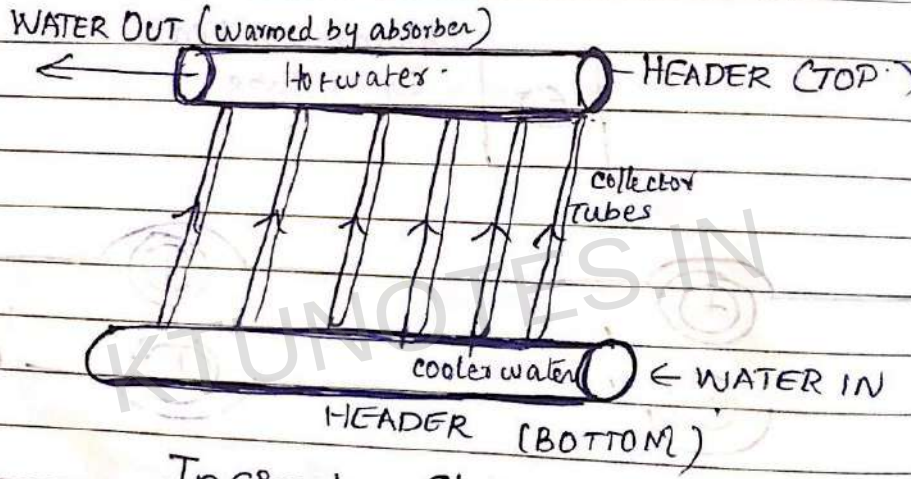
Conventional Standard Panel radiators.



HEAT TRANSFER PROCESS

The heat generated in the absorber is removed by continuous flow of a heat transport medium either water or air. When water is used, it is passed through metal tubes with either circular or rectangular cross section

The tubes are welded to the absorber plate so as to assure effective heat transfer of heat to the fluid. The tubes are connected to common headers at each end of collector. In order to maximise the exposure to solar radiation collectors are invariably sloped. Cooler water thus enters at the bottom header, flows upward through the tubes where it is warmed by the absorber and leaves by way of top header.



In simple flate plate collectors, the absorber is a blackened sheet with close corrugations running from top to bottom. The water flows through the grooves formed by corrugations

DRAWBACKS OF WATER MEDIUM:

1) Possibility of freezing in collector tubes in cold climate during cold night. Ethylene glycol is added to prevent freezing.
2) Adding of ethylene glycol cause complexity of heating system.

3) The antifreeze solutions are less effective than water for heat removed from the absorber. In some cases the water is drained from the collector tube if freezed.

4) It is very difficult to refilling all the tubes in morning.

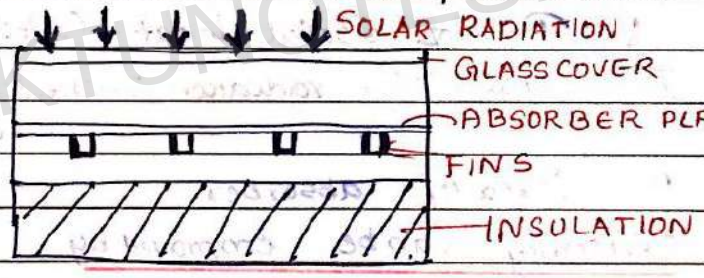
5) Corrosion is occuring due to water in metal tubes.

6) Periodic chemical treatment of water is not practical.

7) Leaks in water circulation system require immediate attention.

TYPICAL AIR HEATER OR AIR COLLECTOR.

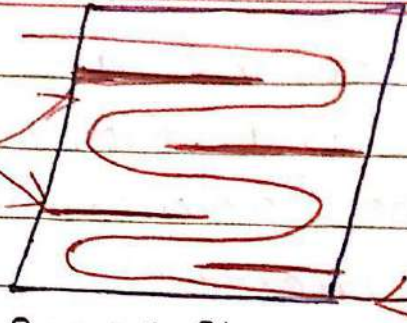
It is the schematic of flate plate collector where



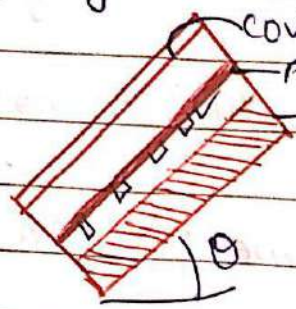
air stream is heated by the back side of collector plate Fins attached to the plate increase the contact surface. The back side of the collector is heavily insulated with mineral wool

Advantage of air heater (Air as medium)

1) The air can be passed through a space between the absorber plate and insulator with baffles arranged to provide a long (zig zag) flow path



Zig zag air flow path in flat-plate collector



Efficiency of flat plate collector (η)

η = Actual useful energy collected / Solar energy incident on the collector.

$$\eta = \frac{Q}{I \cdot A}$$

Q = Rate of useful heat collected from collector

I = Total solar radiation on the collector per unit area & time

A = Area of absorber

Efficiency can be improved by

i) Improving the amount of transmittance of the transparent cover plate

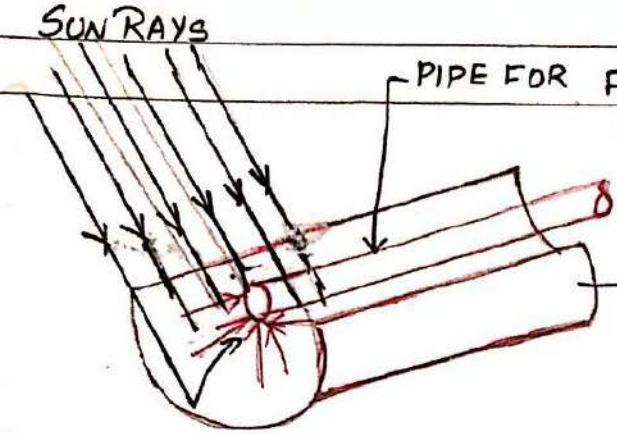
ii) By improving the absorptance of the absorber plate

iii) By improving the heat transfer coefficients from the absorbing surface of the plate to the working fluid.

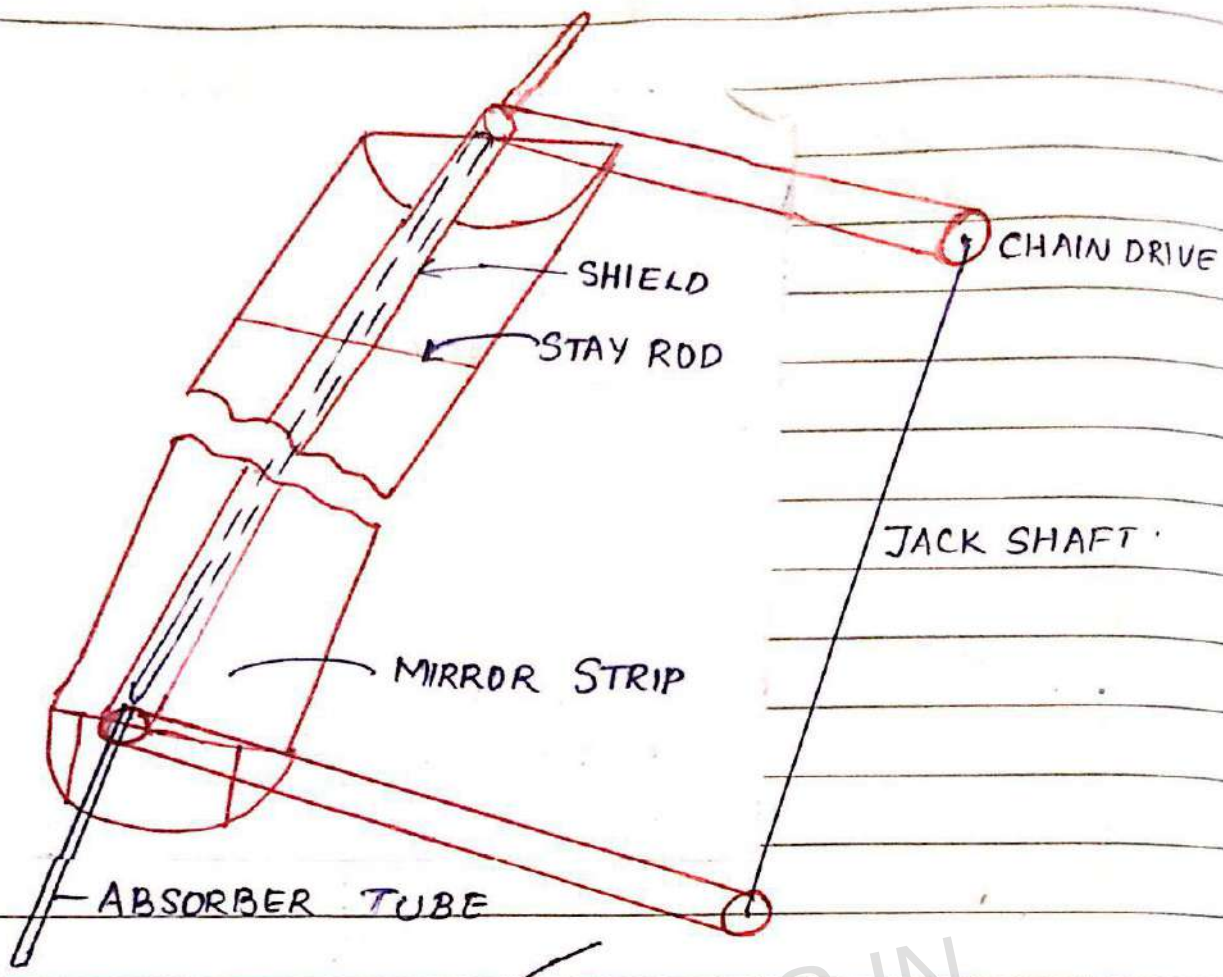
iv) Reducing thermal loss

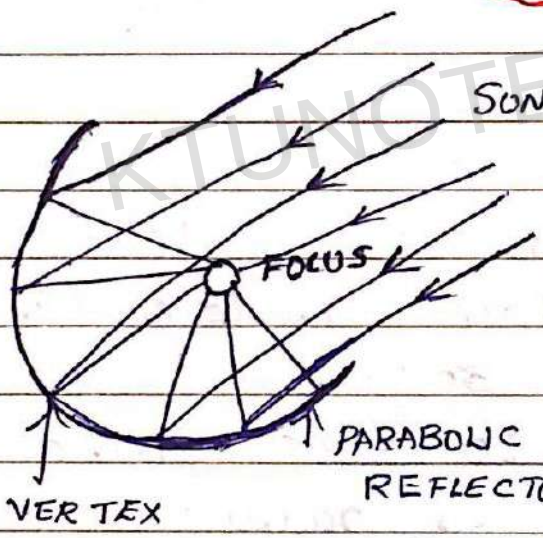
CONCENTRATING TYPE COLLECTOR

(1) PARABOLIC TROUGH COLLECTOR



* Parabolic trough with line focussing reflecting surface provide Concentration ratio from 30 to 50. Hence higher temperature upto 300°C can be obtained.
* Only direct solar radiation (beam radiation) can be collected.
* Tracking the sun is only one plane for daily movement of Sun. (The reflected light is focused on central line of Parabolic trough.
* The pipe located at the Centre line absorb the heat and working fluid is circulated through the pipe.





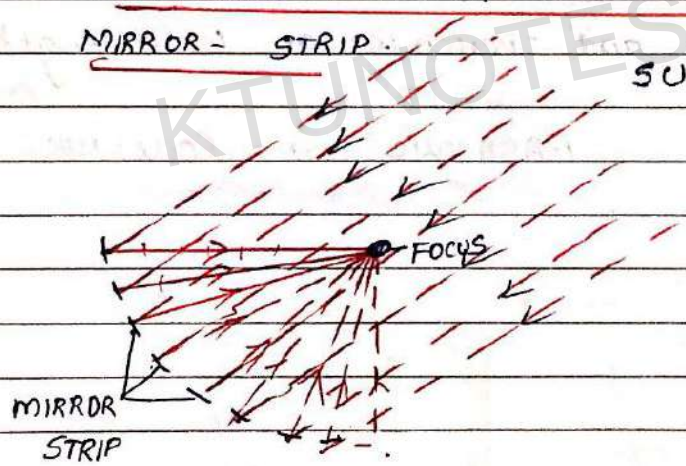
WORKING PRINCIPLE:- Solar radiation coming from the particular direction is collected over the area of the reflecting surface and is concentrated at the focus of parabola. If the reflector is in the form of trough with parabolic cross section, the solar radiation is focused along a line

The collector pipe with selective absorber coating is used as absorber.

For the solar radiation to be brought to focus by Parabolic trough reflectors, the sun must be in such a direction that it lies on the plane passing through the focal line and the vertex (base) of the parabola. Since the elevation of sun is always changing either the reflector trough or the collector pipe (absorber) must be turn continuously about its long axis to maintain the required orientation.

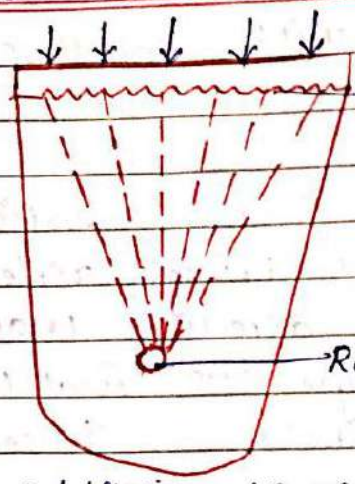
Trough type collectors are normally oriented in east west or north-south directions.

DIFFERENT TYPES OF SOLAR COLLECTOR.



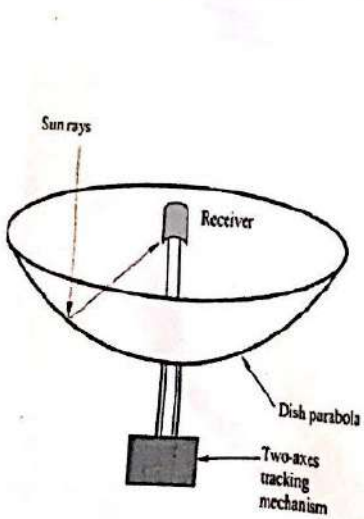
A no of slightly curved mirror strips are mounted on flat base. The angles of individual mirrors are such that they reflect solar radiation from a specific direction on to the same focal line. The angles of the mirrors must be adjusted to allow for changes in sun's elevation, while the focal line remain in fixed position.

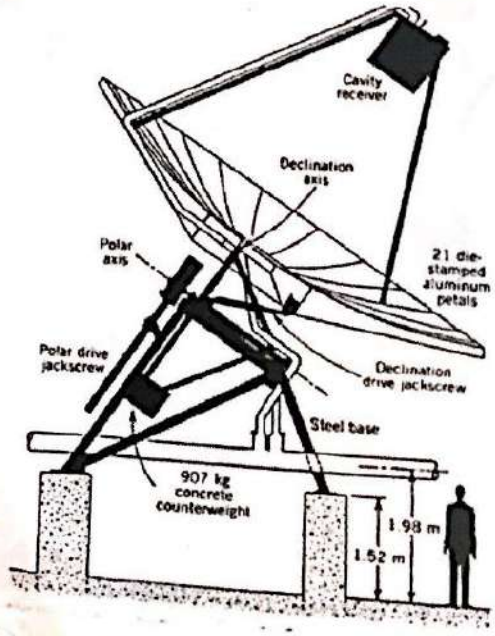
FRESNEL LENS COLLECTOR



Here in addition to reflecting collectors, a refractive type of focussing collector is used. For a trough type collector, the lens is rectangle about 1.7cm in overall length and 0.95 m in width. To be fully effective, the Fresnel lens must be continuously aligned with sun in two directions both along and perpendicular to its length.

PARABOLIC DISH COLLECTOR

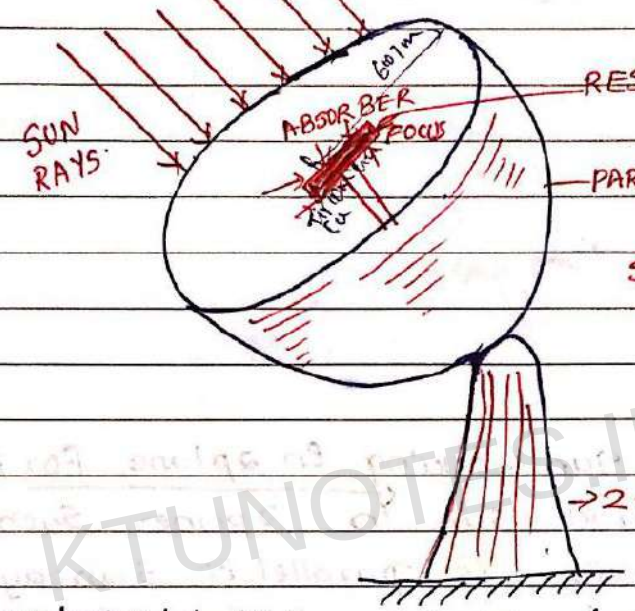




59

(2) PARABOLIC DISH COLLECTOR.

All the radiation from the Sun are focused at a point in the paraboloed dish collector. This collector can generate temperature upto 3000°c and concentration ratio upto to fecus thousands. The diameter of dish collector is of the range between 6 to 7m and it can be commercially manufactured.



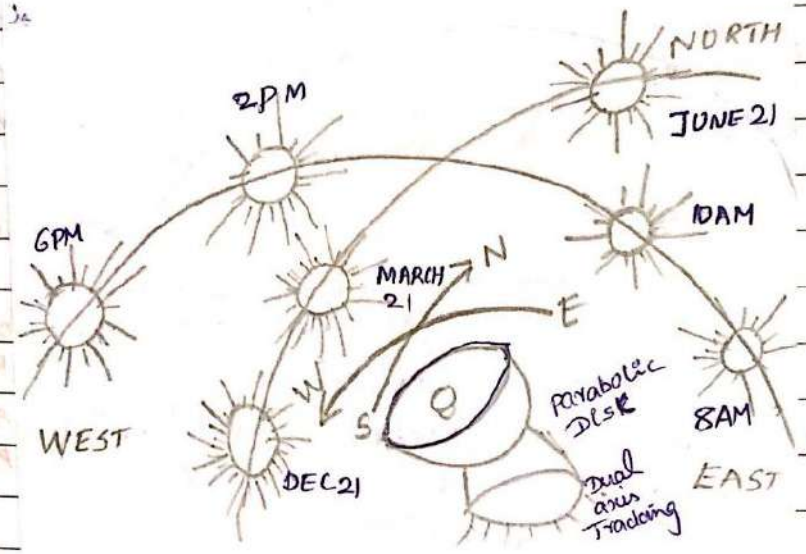
WORKING:-

A paraboloidal dish collector brings solar radiation to focus at a point actually a small central volume. The absorber located at the focus is a cavity made of zirconium-copper alloy with a black chrome selective coating. The heat transport fluid flows into and out of absorber cavity through pipes bonded to the interior. The dish can be turned about 2 axis so that the sun is always kept in a line with the focus.

The concentration ratios are very high in case of paraboloidal system and temperat in the range of 300°C to 500°C is achieved

Dual Axis Tracking Mechanism

Paraboloid dish collects should track Sun in 2 planes. If tracking not provided efficieny will be very low.



Sun tracking in 2 plane for point focus

It ~~tot~~ track sun in 2 planes such that their axis is parallel to sun rays. Hence. Concentration ratio is highest among the various types of collectors.

* Advantage of parabolic dish Collector

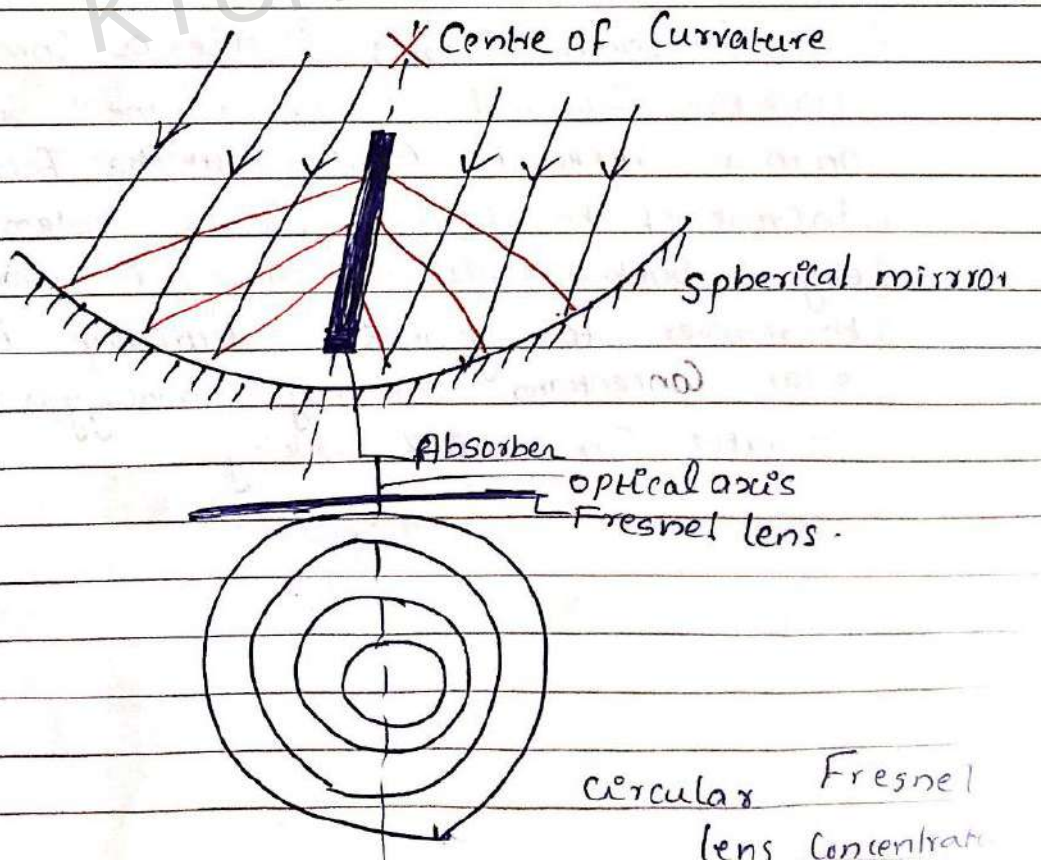
1) Reflecting Surface require less material and are structurally simpler than flat plate collector
2) Because of smaller absorber area insulation intensity is greater than that of a flat plate system.
3) The temperature obtained is higher than flat plate collector
4) No anti freeze is required to protect the absorber whereas the entire solar

energy collector surface requires antifreeze protection in an flat plate collector.

* Disadvantage of Paraboloidal dish collector:

1. High initial cost in case of Paraboloidal dish collector
2. Additional requirement of maintanance is retain the quality of reflecting surface against dirt, weather oxidation etc
3. Non uniform flux on the absorber whereas flux in plate collector is uniform
4. Additional optical losses such as reluctance loss and intercept loss.

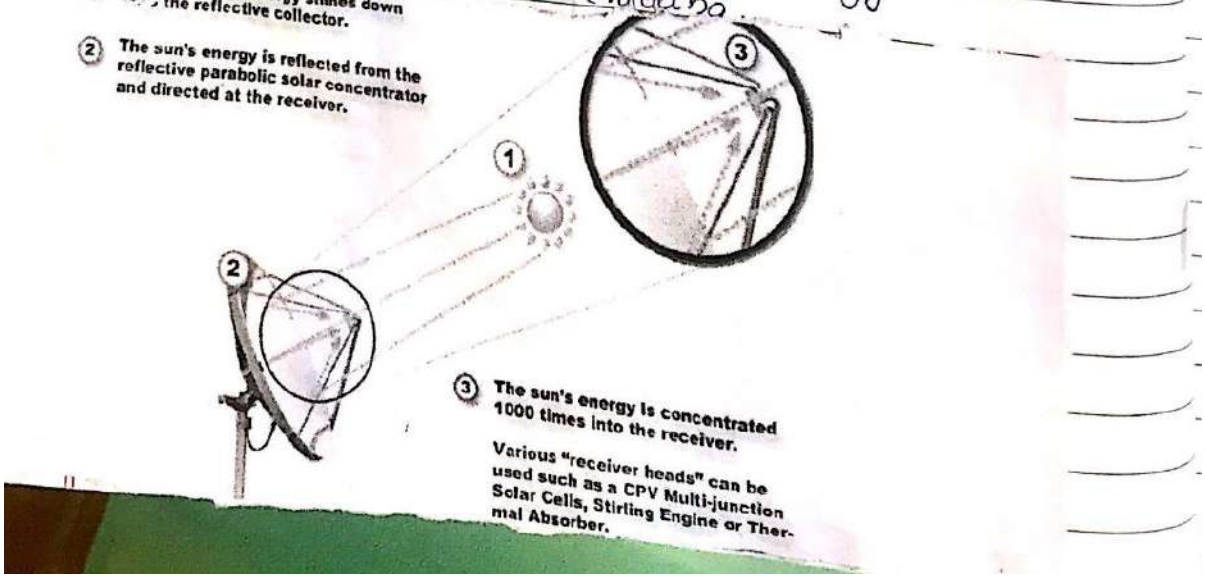
Hemispherical bowl mirror Concentrator:



Hemispherical bowl Concentrator in which absorber can be moved with 15°/hour so that the axis of absorber is always parallel to the rays.

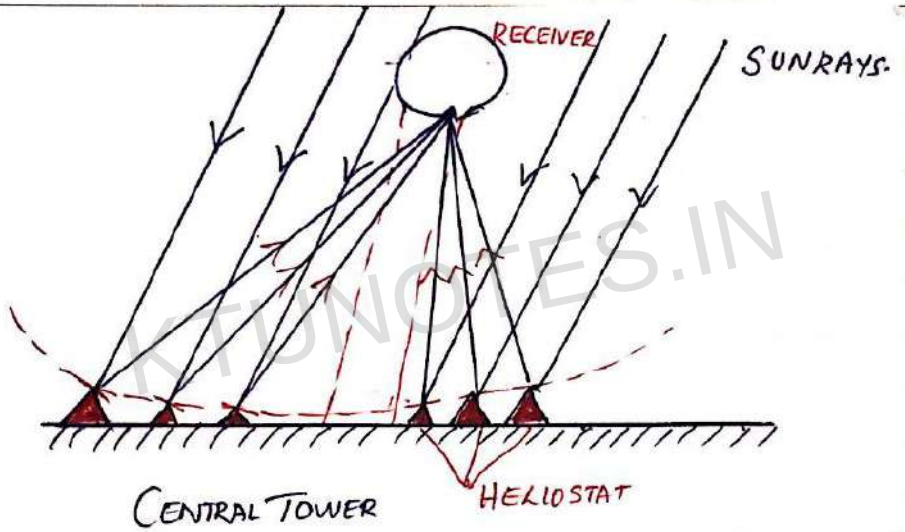
Circular fresnel lens Concentrator:
Concentration ratio (approx. 2000) of circular fresnel lens Concentrator is higher than hemispherical bowl Concentrator but less than paraboloidal Collector in which Concentrator is divided into number of thin circular zones. The adjustment of each zone is so fitted as it takes the shade of this spherical lens. In this high flux is generated.

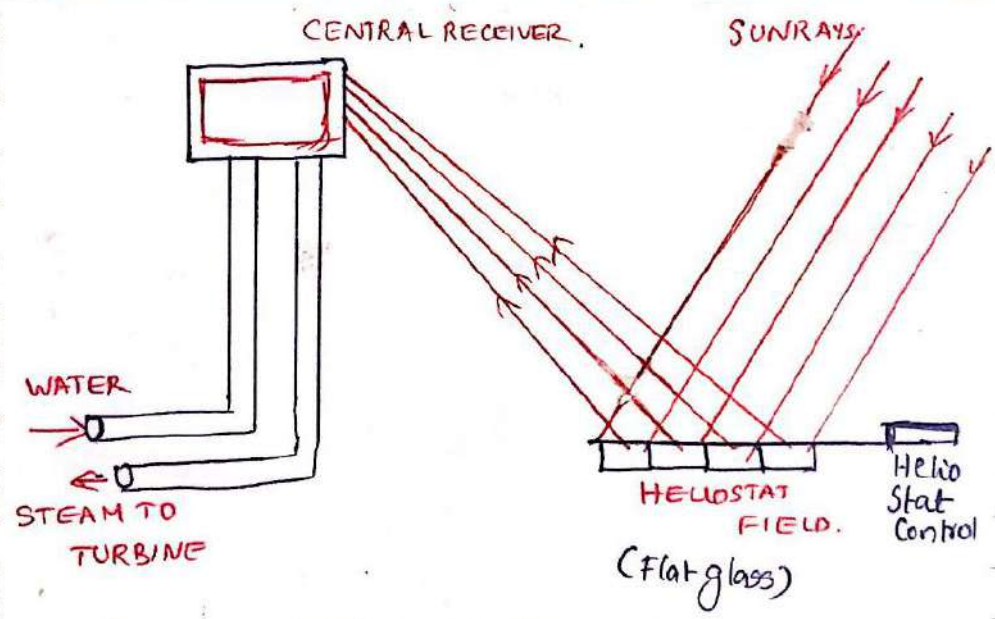
In some cases it uses a Computer to track the Sun and Concentrate the Sun rays on to a receiver located at the focal point infront of the dish. In some systems, a heat engine such as Stirling engine is linked to the receiver to generate electricity. Most solar Concentrator tracking technology use an actuator for vertical tracking.



(3) Central Tower Receiver.

In this arrangement receiver is placed above the tower and receives beam radiation from large number of heliostat (flat mirror) placed below the receiver above ground. The whole placement of heliostat looks like a large paraboloidal. The Concentration ratio of Central tower receiver is high as zero. This Concept of generation of electrical energy from solar energy is based on the use of very large Concentrating collectors





DESIGN

- Some concentrating solar power towers are air-cooled instead of water-cooled, to avoid using limited desert water[3]
- Flat glass is used instead of the more expensive curved glass[3]
- Thermal storage to store the heat in molten salt containers to continue producing electricity while the sun is not shining
- Steam is heated to 500 °C to drive turbines that are coupled to generators which produce electricity
- Control systems to supervise and control all the plant activity including the heliostat array positions, alarms, other data acquisition and communication.
- Generally, installations use from 150 hectares (1,500,000 m^2) to 320 hectares (3,200,000 m^2).

- The **solar power tower**, also known as 'central tower' power plants or 'heliostat' power plants or power towers, is a type of solar furnace using a tower to receive the focused sunlight.
- It uses an array of flat, movable mirrors (called heliostats) to focus the sun's rays upon a collector tower (the target). Concentrated solar thermal is seen as one viable solution for renewable, pollution-free energy.
- Early designs used these focused rays to heat water, and used the resulting steam to power a turbine. Newer designs using liquid sodium have been demonstrated, and systems using molten salts (40% potassium nitrate, 60% sodium nitrate) as the working fluids are now in operation.
- These working fluids have high heat capacity, which can be used to store the energy before using it to boil water to drive turbines. These designs also allow power to be generated when the sun is not shining.

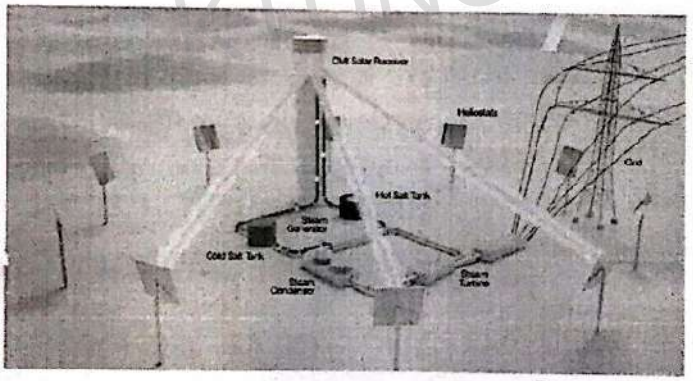
Advantage of Central Tower.

1) Higher Concentration ratio allows higher temperatur and thus better efficiencies.

2) The receiver is capable of withstanding high pressure This allows direct production of high pressure Super heated steam upto 185 bars.

3) A short and mostly vertical piping layout allows fast and easy drainage of the heat transfer fluid and makes the receiver the safest arrangement for molten salt plants.

4) No need for dangerously flammable and polluting thermal oils used in Parabolic trough Plants which limits the generated steam temperature below 400°C with negative impact on plant efficiency.

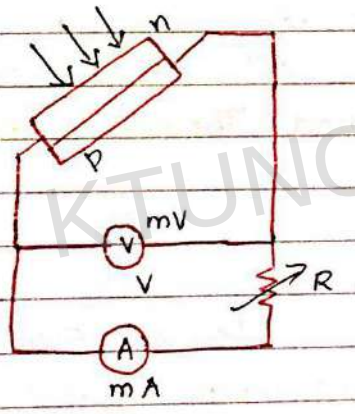


Solar Electric Systems
Solar Photo voltaic
Solar Cell fundamentals
Characterestics (V-I)
Classification, Construction of module, panel, array
Solar PV systems - Stand alone and grid Connected
Street lighting, Domestic lighting, Solar water Pumping sln

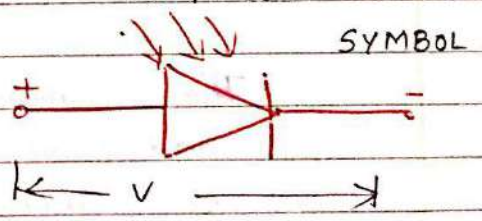
VI Characterestics of Solar Cell

The voltage, current and power delivered by Solarcell are influenced by

1) Condition of Sunlight, intensity, wavelength, angle of incidence
2) Condition of function, temperature, termination
3) External resistance



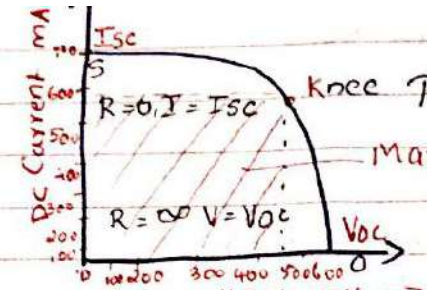
V - Direct vlg
I - Direct current measured in PV cell



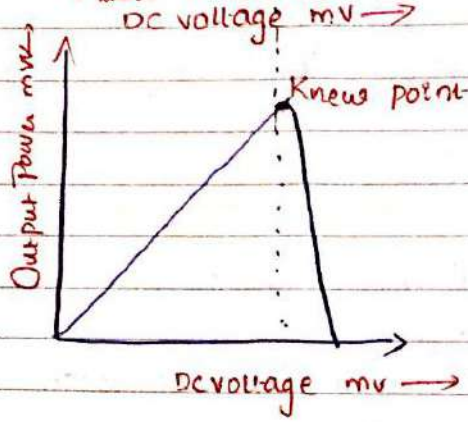
Condition 1:- When external resistance R is very high(MΩ) i.e Open Circuit Condition

$V_{oc} \simeq 0.5$ V DC Max. voltage across P.V cell
$I_{oc} \simeq 0$.
$R_{external} \simeq$ infinity

Condition 2:- When the external resistance is (R) reduced, Vsc (short Circuit Condition)
$V_{sc} \simeq 0$, I_{sc} = max. value $R \simeq 0$



(V I characteristics)



(Efficiency Curve of PV cell)

As external resistance is reduced from high value to low value, the terminal voltage of cell falls and current increases. A steep characteristics is obtained At knee point chara undergo a smooth change and become flat for K-S. When external resistance is 0 the Isc is obtained. The voltage for short circuit condition is zero.

The current curve is almost flat blw knee point and short circuit. Hence solar cell is called constant current source with current output nearly equal to short circuit current. The current remain constant for the portion SK.

3 important points in V-I chara

1) Open Circuit Point (O)
2) knee point (K)
3) Short Circuit Point (S)
4) Operating point is flat current portion ks

$$V_{oc} = V_T \ln\left\{(I_{sc}/I_o)+1\right\}$$

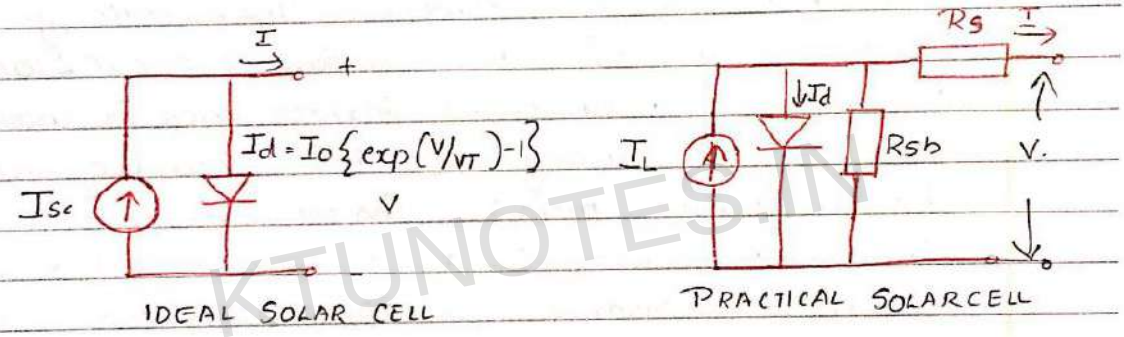
$$I_{sc} = I + I_o\left\{\exp\left(V/V_T\right)-1\right\}$$

$$V_T = \frac{kT}{q}$$

T = Temperature in °k
q = charge of electron
V_T = Voltage equivalent of temperature
I_o = Reverse Saturation Current

Equivalent Circuit

V-I characterestics is derived for ideal condition, Considering internal series resistance of the cell as zero and shant resistance as infinite In practical case both have finite value



Efficiency of Solarcell

$$\eta = \frac{\text{Incident Radiation (W)}}{\text{power Delivered (W)}}$$

Maximum efficiency occur at
① Full solar radiation on PVcell
② knee point on VI Curve

Max. η obtained is 15 to 20 %. Theoretical value 25%
η depend on Fill factor (Quality of Solar cell)
If FF = 1, η max. $FF = \frac{I_m V_m}{I_{sc} V_{oc}}$

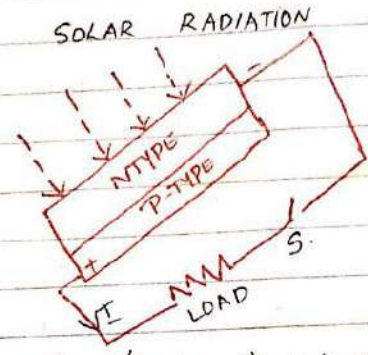
$$\eta = \frac{I_m V_m}{I_s A_c}$$

I_s - Incident Solar Current
A_c = Cell area

(Q) Explain the Construction of Solarcell, array, module

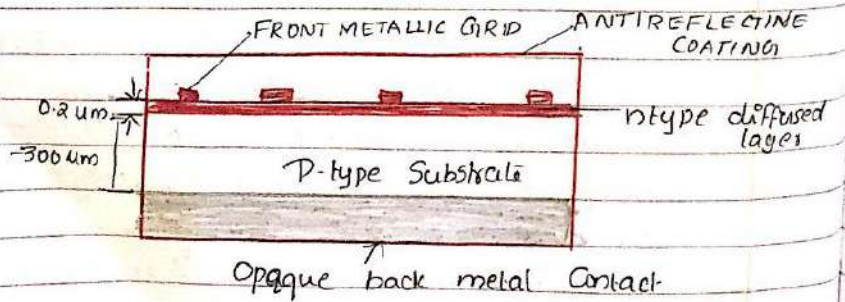
I CONSTRUCTION OF SOLAR CELL

A thin layer of n-type Silicon is formed at the top surface by diffusing an impurity from $\overline{V}^{th}$ group (Phosphorous) A bulk material is used as P-type material with thickness of 100 to 350 microns to get a P-n junction



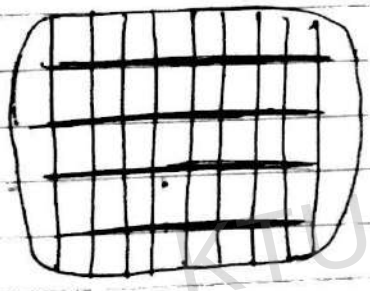
The top active layer is n type has a Ohmic Contact with mettalic grid structure to collect the Current Produced by impinging Photons. The metallic grid Covers minimum Possible top surface area (< 10% of total A) to leave enough un Covered Surface area For incoming Photons. Similarly the bottom inactive surface has an Ohmic metallic Contact over the entire area. These 2 metallic Contact Form the +ve and -ve terminal of Solar cell. Now the technologies are improving. So by providing antireflecting Coating, textured finish of top surface and reflective, textured rear surface, Capture maximum photons and direct them towards function.

II SOLAR PV MODULE CONSTRUCTION

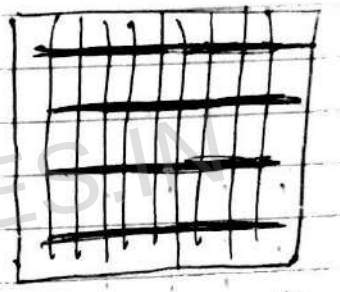


A single cell cannot be used for outdoor energy generation by itself. Because ① Output of single cell is small ② It require protection against dust, moisture mechanical shock. Workable voltage & reasonable power is obtained by interconnecting an appropriate no. of cells

The unit is fixed on a durable back cover of several square feet with a transparent cover on the top. and hermetically sealed to make it suitable for outdoor application. This assembly is known as solar module

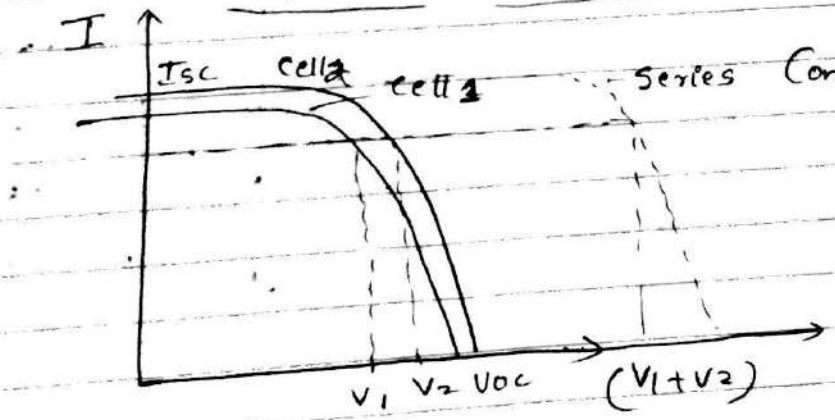


Single Crystal cell



Multi Crystalline cell

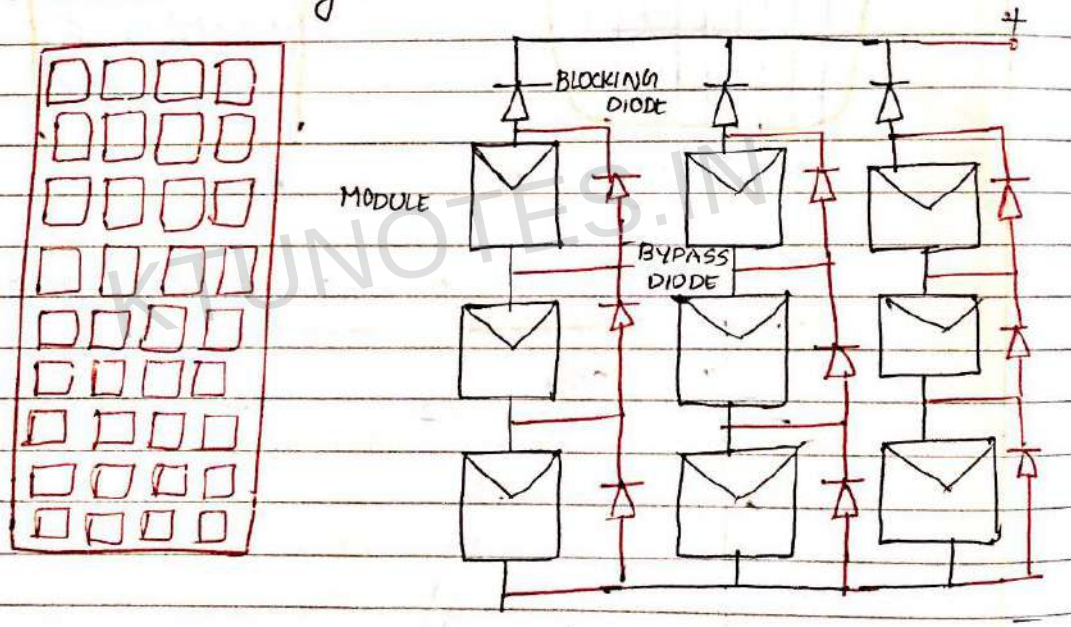
Composite characteristics of 2 cells in series



III SOLAR CELL MODULE (SOLAR PHOTOVOLTAIC ARRAY)

There may be tracking arrays or modules or fixed arrays. A tracking array is defined as one which is always kept mechanically perpendicular to the Sun-array line so that all times it intercepts the maximum insolation. Such arrays must be physically movable by a suitable prime mover and are considerably more complex than fixed arrays. The array construction mainly devided into 2 types

① Flat Plate Array :- Here solar cells are attached with a suitable adhesive to some kind of substrate structure usually semigrid to prevent cell being cracked.

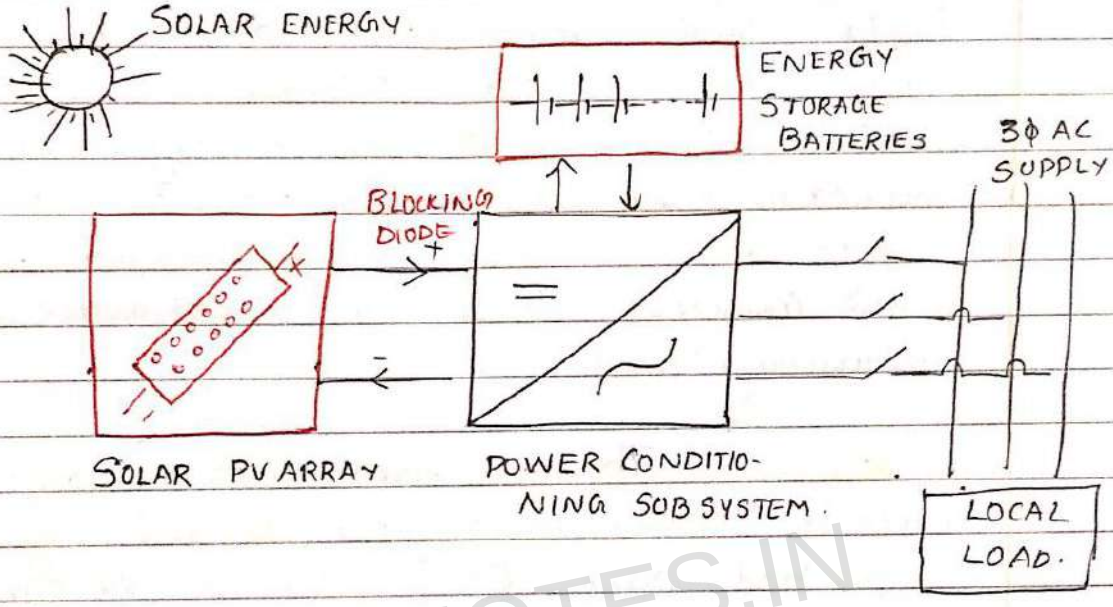


A typical panel- series Parallel Connection.

2) Concentrating Arrays:- Suitable optics eg. Fresnel lens, parabolic mirrors, Compound Parabolic Concentrator are combined with photovoltaic cell enon array fashion. This technology is relatively new photovoltaics in terms of hardware develop

Solar PV-array:- A large no. of interconnected Solar panel is known as Solar PV array.

Explain A SCHEMATIC OF BASIC PHOTOVOLTAIC SOLAR PV SYSTEM



In Solar PV System the intermediate thermal energy state is omitted and the energy is converted directly from the Solar energy form to electrical energy form. The vital component in Solar PV System is Solar cell called photovoltaic cell (PV cell). A Solar Cell is a light sensitive N-P junction. When Solar radiation strikes on N-P junction, DC emf is generated.

Voltage - 0.45 V DC
Current - 0.75 A DC
Power - 0.33 W

Several Solar cells are Connected in series to form string. Several strings Connected together to form Solar module. Several module Connected series - parallel to form Solar array.

The solar PV panel delives DC electrical power only in favourable conditions of sunlight. To obtain electrical power a cloudy weather or during night the energy storage batteries are needed.

During the favourable sunlight hours and low load conditions, the batteries get charged. During night and cloudy weather, the storage battery supply electrical energy to load. Some of the electrical load require 50 Hz AC supply. Hence DC power supplied by PV panel & storage battery should be converted to single phase or 3ϕ 50 Hz AC power. So So DC to AC conversion is achieved through static inverters. These are incoperated in power conditioning unit.

The AC waveform is regulated and made of desired quantity by conditioning unit is provided on the output side of PV sim for

→ Improving AC wave form by harmonic filter
→ Regulating the voltage
→ Inverting DC to AC
→ Protective control and monitoring functions.

Q) Explain the merits and limitations of solar PV system (5)

MERITS OF SOLAR PV SYSTEMS.

1) Use of clean, cheap, noiseless, safe, renewable solar energy to produce electrical energy at the locations of utilization, Conservation of non-renewable fuels.
2) Suitable for remote loads away from main electrical nlw and at places where other fuels are scarce and costly.
3) The cost of installation of long distribution line, distribution substions etc is eliminated.
4) Suitable for portable or mobile loads eg radio set, car, bus, space craft
5) Reliable service
6) Long life (15 years)
7) Modest Maintanance.
8) Used in modern applications like water pamping, lighting, Medical Refrigeration, village power telecomunication and signalling.
9) They are highly reliable and easy to fabricate (PV)

LIMITATIONS OF PV SYSTEM

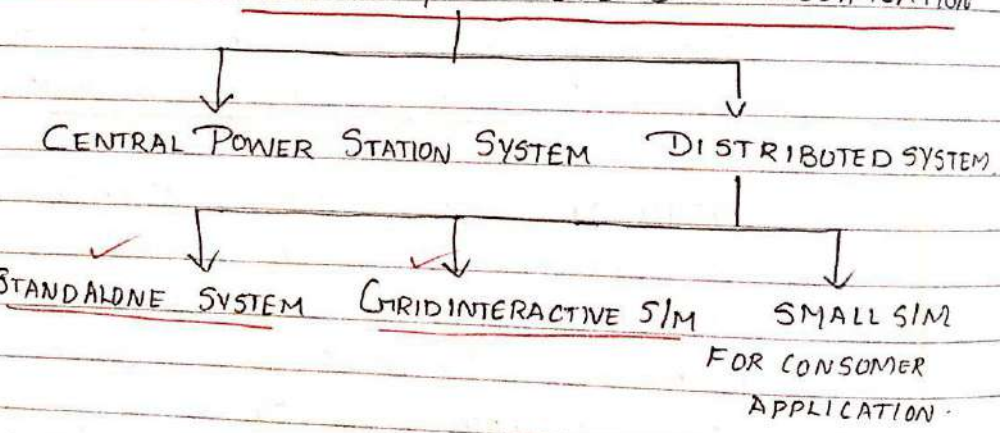
1) Irregular, Intermittent supply of solar energy.
2) Need for storage batteries.
3) High Capital cost (Rs/kw) due to large number of PV cells
4) Low Output power
5) Low Efficeency of PV cell (10 to 14%)
6) High technologies are needed for producing PV
7) Not economical for Central Power plant of MW
8) Require storage batteries and additional diesel generator set for supplying power during night
9) very Space for Installing PV panel is not available in large cities.
10) Energy storage is required at Night

Q) What are the APPLICATIONS OF PV CELL

1) Street lighting systems
2) Community TV centers.
3) Onsite power supply
4) Microwave Repeater stations
5) Cathodic protection installation for long gas pipe lines
6) Navigational aids
7) Telemetry systems & signaling
8) Space station power supply
9) Off shore oil-rigs
10) Domestic lighting
11) Solar water pumping systems.
12) Medical refrigeration
13) Rete Village power

Q) Explain the classification of solar PV system

SOLAR PV SYSTEMS CLASSIFICATION



Central power station systems:- It is similar to
→ Central power stations in conventional. They feed power to grid. These are proposed in few MW range to meet daytime peak loads only.
→ These are upto 6 MW (peak MW) capacity. experienced in USA and Europe.
→ These Capital costs high.

DISTRIBUTED POWER SYSTEM.

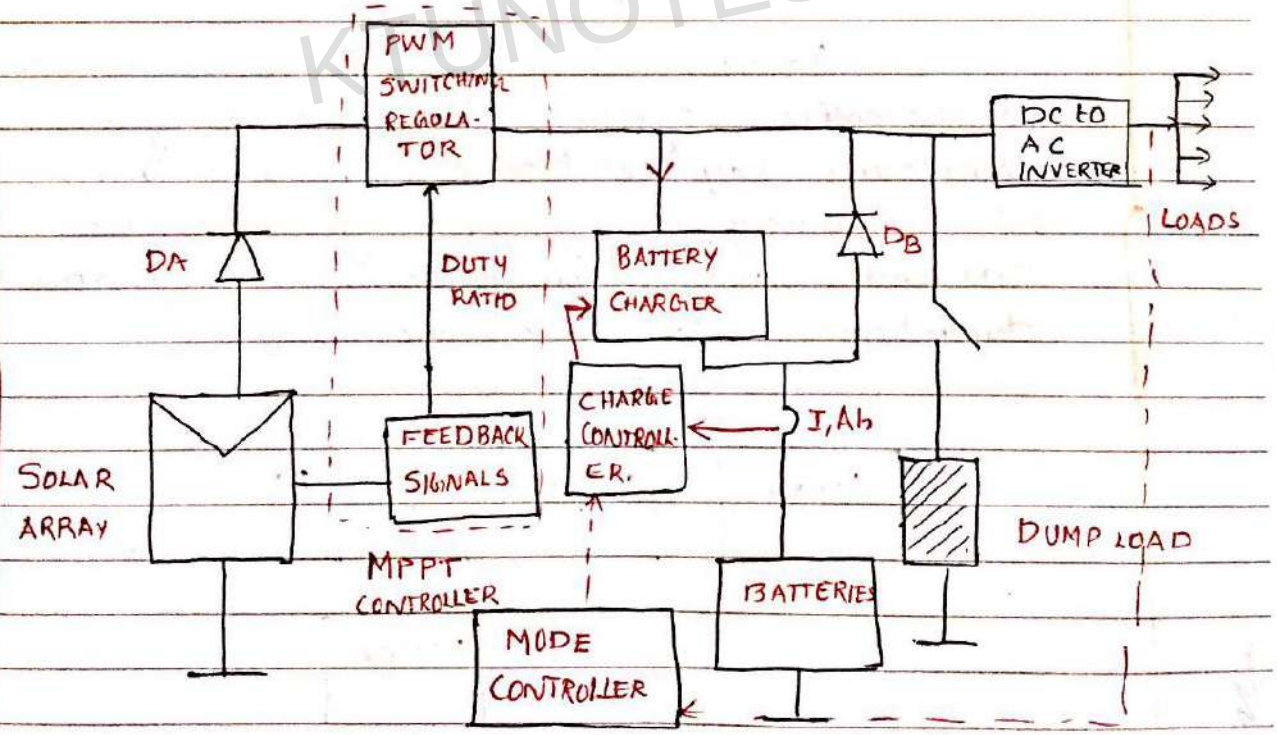
Distributed form of energy use is unique and much more sucessful with Solar and most other renewable Sources. 3 types

1) STAND ALONE SYSTEM:-

* It is located at the load centre and dedicated to meet all the electrical loads of village/Community or a Specific Set of loads.
* Energy Storage is generally essential.
* It is more sucessful in remote and rural areas.
* The Capacity of such Slm is 10 W_p - 100k W_p.

Construction:-

The main Components are as shown



STAND ALONE

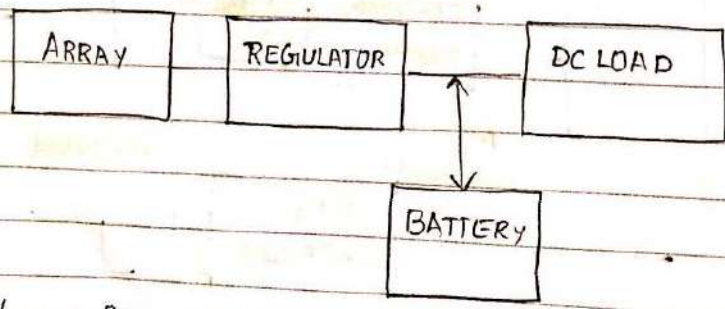
WORKING

The MPPT Senses the voltage and Current Output of the array and adjust the operating point to extract maximum power under the given climatic conditions. The Output of the array after Converting to AC is fed to loads. The array Output in excess of load requirement is used to charge the battery If excess power is still available after fully charging the battery, it may be shunted to dump heaters.

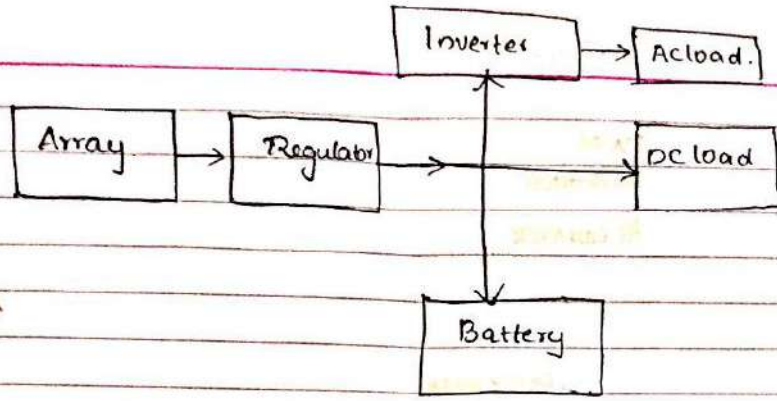
When the Sun is not available, the battery Supplies the load through an inverter.

D_B - The battery discharge diode Prevent the battery from Overcharged after the charger is opened. The array diode D_A is to isolate the diode array from battery to prevent battery discharge through array during night.

A mode Controller is a Central Controller for the entire system. It Collects the system Signals and keep the track of charge/discharge State of the battery, matches the generated power and load and Commands the charger and dump heater on-off operation.



A schematic of a basic DC Stand alone system in which the PV array is Connected to the load and the battery bank via Vg regulator.



A schematic of AC/DC Stand alone PV system equiped with a voltage regulator, battery storage and DC to AC Inverter.

GRID CONNECTED PV SYSTEMS

Components

1) Charge Controller regulator (CC)
   - → Charge/discharge battery
   - → Protect Over charge/discharge
   - → It have MPPT
2) Inverter (DC ⇒ AC)
   - → Modified Square wave (limited appliances) or Sine wave.
   - → Efficiency 85-95%.
   - → May have MPT or CC
3) Batteries - (η 80-90%)
4) Diesel generator
5) Fuses mounting rails, posts, wiring, ground rod. disconnects Smart System monitor.

In grid Connected System, the battery charging and dump load part is eliminated. The energy obtained from the solar array is directly given to a grid Connected to the System through MPPT Controller.

) Explain the classification of solarcell

SOLAR CELL CLASSIFICATION

BASED ON

- CELL SIZE
- THICKNESS OF ACTIVE MATERIAL
- JUNCTION STRUCTURE
- TYPE OF ACTIVE MATERIAL

BASED ON

CELL SIZE :-

As silicon is a brittle material, this fact tends to limit the area of Commercially produced Silicon due to handling difficulty. The current industry standards can be classified into 4 groups

1) 100mm (4inch) diameter, round Single Crystalline
2) $100cm^2$ off Square Single Crystalline
3) 100mm x 100mm (4inch x 4 inch) Square Multicrystalline
4) 125mm x 125mm (5inch x 5inch) Square multicrystalli

On the basis of Thickness of active material.

- Bulk material cell
- Thin film Cell

Bulk Material Cell :- The base material - The starting material in fabrication process is an active material. At present bulk material Single Crystal and multicrystalline cells are most successful for terrestrial application.

Thin Film Cell :- A thin film (a fraction of a micron) deposition of active material is carried out on the back support sheet known as substrate. It is having the possibility of continous sequence of production process. Cell area larger than $25cm^2$ is very difficult.

Amorphus - Silicon, Compound Semiconductor cell are developed by thin film technology.

III On the basis of junction Structure

1) P-n homojunction Cell
2) P-n heterojunction cell
3) P-n multijunction cell
4) P-i-n (p-type - intrinsic - n-type) junction Cell.

P-n homojunction Cell :-

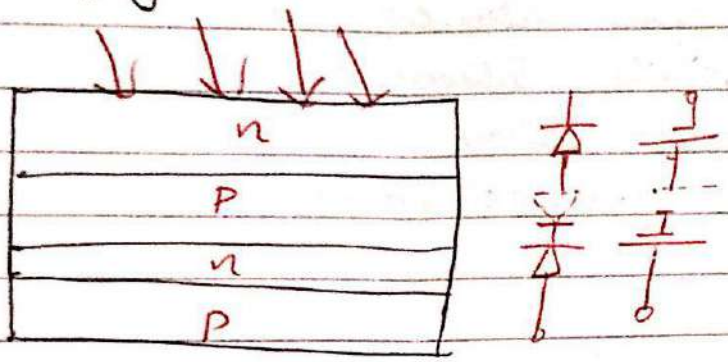
* Semi Conductor material On both side Same material
* Doping materials are different
* Band gap remain Same throughout cell

P-n hetero junction Cell :-

* 2 dissimilar Semi Conductor material III-V or group II-VI Compound SemiConductor with closely maching Crystal lattice are used to form function.
* The band gap of top material exposed Sunlight wider than bandgap of bottom material below the function.
* As a result, the higher bandgap region will appear transparent to photon with lower energies so they can Penetrate to the function where the bandgap is less than incident photon energy.
* Thus electron- hole pair are generated in the junction regeon where they are Collected before they recombine.

Eg:- (1) Galium Arsenide- Galium Aluminum Arsenide (GaAs- GaAlAs)
(2) Cadmium Sulphide- Copper Sulphide (CdS-Cu_2S)
(3) Cadmium- Sulphide- Copper Indium diselenide (CdS-$CuInSe_2$)

When a Contact is made between metal and Semicon either an Ohmic Contact (bidirectional current) or rectifying Contact (unidirectional current) is formed



As the photon is most efficiently absorbed when its energy is closed to band gap, a clever way to stack jn of different band gap, what is known as multijunction Structure

Multi Junction Structure

The top junction has relatively wider band gap followed by decreasing order of bandgap in series. High energy photons will be absored at the top jn. followed by absorption of lower energy photons at subsequent jn But the main Problem is the presence of unwanted reverse p-n junction which cause power dissipation.

P-i-n type junction Structure

P-type - intrinsic - ntype junction Structure where intrinsic Silicon is interposed between p and n layer.

(iv) On the basis of type of active Material

Depending on the type of material used for fabrication

1) Single Crystal Silicon cell
2) Multicrystalline Silicon cell
3) Amorphous Silicon (a-Si)
4) Gallium arsenide (GaAs)

Single Crystal Silicon cell.

* First PV cell where of single crystal variety.
* Single Crystal Silicon cell are more efficient

The main draw backs are

(1) They are most energy intensive in their production
(2) The unit consumption of silicon to produce one unit of PV electricity is also quite high.

Stages:-

1) Production of metallurgical grade (99% Pure) Silicon MgSi from its Ore.
2) SiO_2 by reduction reaction with Carbon in an arc furnace.
3) The energy cost is 50 kWh/kg of Silicon. In this process CO_2 is produced as a byproduct which is a greenhouse gas.
4) Electronic grade pure C an impurity of about 1 part in 10^7) poly Silicon (or polycrystalline Silicon) is then obtained by refining it further through various complex operations at an energy cost of 200 kWh/kg of silicon

Multicrystalline:-

1) Less Energy intensive
2) Less costly Compared to Single crystal
3) But less efficient. η in the range of 10% to 14%

The first 2 steps of manufacturing is same as Single Crystalline cell. The polycrystalline obtained is melted and after proper doping an ingot of multicrystalline silicon cannot grown in square shape and so physically trimmed into it.

(iii) Amorphous Silicon (a-Si) Solar cell:- It is developed by thin film technology. These are cheaper.

Main draw backs

1) Low efficiency (4% to 8%)
2) Degrade in Outdoor applications.

Application

(1) Pocket Calculator
(2) Electronic watches
(3) Small radio receivers
(4) Low Power hand held electronic instrument

(iv) Gallium Arsenide Cell: GaAs has a bandgap of 1.43eV which makes it an attractive PV material. GaAs have thin film of n-type & P type GaAs grown on Suitable Substrate.

→ High performance, extraterrestrial quality cell
- Fill factor - 80%
→ Efficiency - 20%
- High Production cost

v. Copper Indium (Gallium) Diselenide (CIS) cell:

- Band gap of 1 ev.
- Incoperation of Gallium to CIS mixture increases the bandgap beyond 1.1ev. heterogeneous jn

OCEAN ENERGY

- Tidal energy exploits the natural rise and fall of Coastal tidal waters caused principally by interaction of gravitational field of Sun and moon.
- The Ocean level difference caused due to tides Contain large amount of potential energy.
- The highest level of tidal water is known as flood tide or high tide. Low tide is known as tidal range b/w low tide or ebb.
- The level difference blw low tide and high tide is known as tidal range.
- The sites with large tidal range (5m or more) are Considered Suitable for power generation. The total Combined potential - 120000 MW. The principle used for harnessing this energy Consisted of a Pond filled through sluice

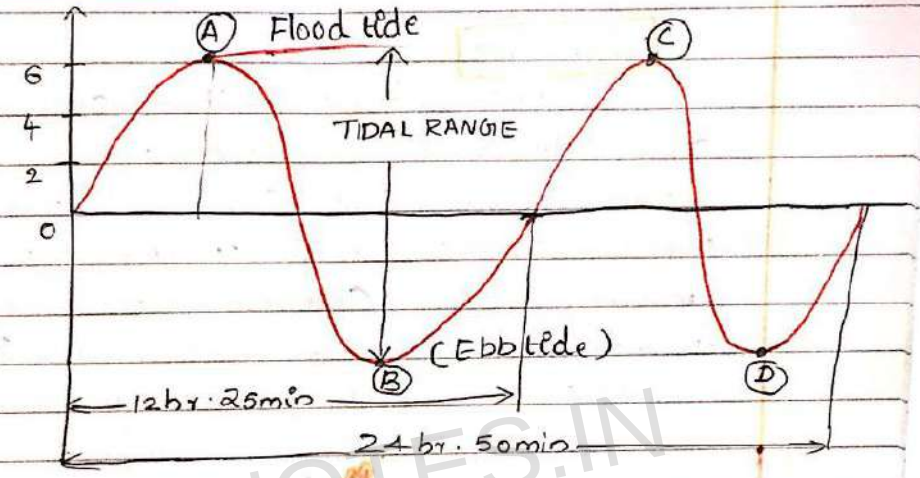
The Origin and nature of tidal energy

The tides are produced by the gravitational attraction of the moon and Sun upon the rotating earth. The moon exerts a larger gravitation force (70% of tide-producing force) on the earth as it is a great deal closer than Sun. Surface water is pulled away from the earth on the side facing the moon and at the same time the solid earth is pulled away from the water on the opposite side. Thus Ocean height increases near and far side of earth resulting high tide

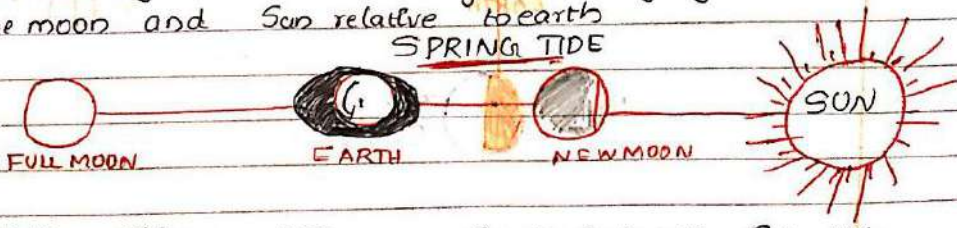
and low tide in the intermediate side

70% of tide is produced due to the moon on earth. Because moon is near to earth than Sun. As earth rotates the position of given area of earth relative to moon changes and so also tides. Thus a periodic succession of high and low tide occur.

TIDAL RANGE



Tidal range can be defined as the difference between water elevation at high tide and water elevation at low tide. Tidal range can be expressed as the difference in water level between 2 consequetive high tide and low tide. Tidal range varies according to changing position of the moon and Sun relative to earth.



Due to slight difference of periods of Solar tide (Sun-earth) and Lunar tide (earth-moon interaction) Solar tide move in and out of phase with Lunar tide. When Sun, earth and moon are aligned in same line (in conjunction), then the lunar and Solar tide are in phase, Producing net tide of maximum range. These tides are called Spring tides.

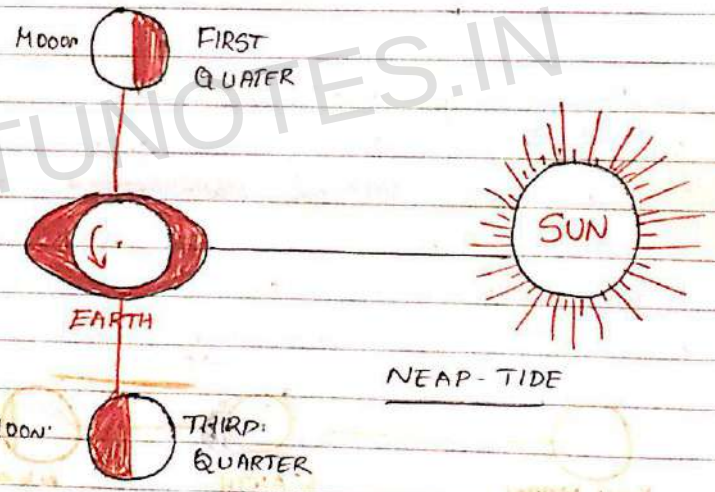
NB

SPRING TIDE

Spring tide occur twice per lunar month. at the time of both full moon & new moon The tidal range is maximum in case of Spring tide The revolution of earth and moon together around the sun gives rise to further variation, and due to this effect the highest Spring tide occur at equinox in March and September.

NEAP TIDE:

When first and third quarters of the moon comes and when Sun moon are right angle with respect to earth, the Solar tide and lunar tide are out of phase producing net tide of minimum tide and that again occur twice per month at times of half-moon (1st & 3rd quarter cycle of moon). The tide range is minimum.

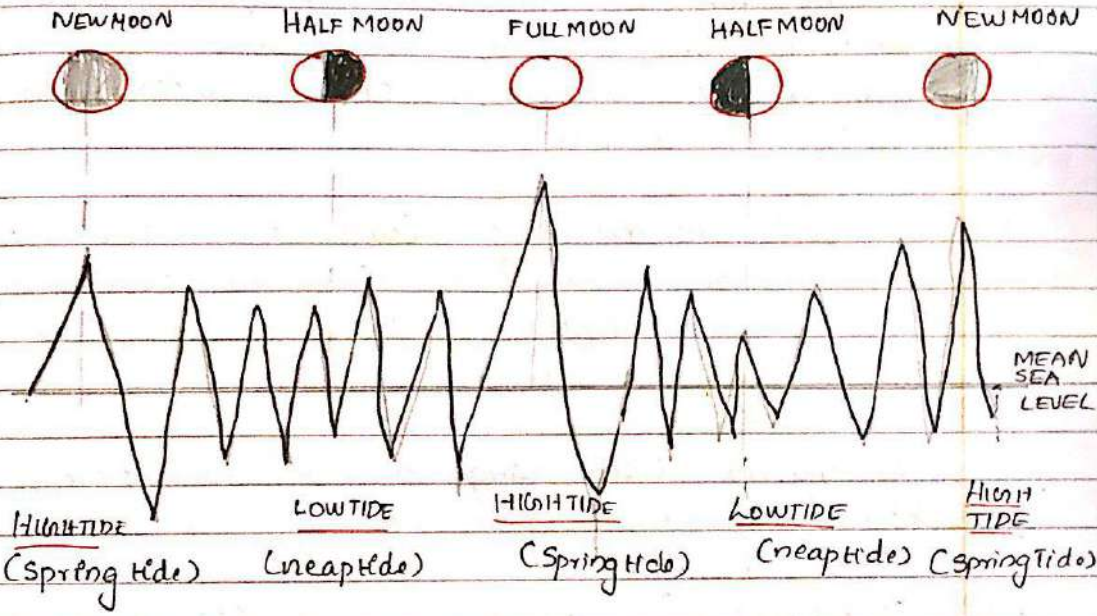


In the Open Ocean, the tidal range are commonly of the order of 0.6-0.9m. When the ocean tidal wave impringed on Continental shelve and coastal line their range can amplify through run up, funneling & resonance.

So tidal wave varies place to place.

TIDAL ENERGY ESTIMATION (One lunar Month)

Tidal water level variation during one lunar month follows the pattern.



TIDAL VARIATION IN LUNAR MONTH

→ It contain 2 maxima and 2 minima during a lunar month.

→ It can be seen that amplitude of tidal range reduces steadely from spring tide to neap tide and increases to same pattern to spring tide.

→ The tides are caused by cosmic phenomena and are not affected by weather condition and yearly range.

ADVANTAGES OF USING TIDAL POWER:

- Predictable source of "green" energy during lifetime of barrage
- It produces no greenhouse gases or other waste; it needs no fuel.
- Not expensive to maintain.
- Tidal energy has an efficiency of 80% in converting the potential energy of the water into electricity
- Vertical-axis tidal generators may be joined together in series to create a 'tidal fence' capable of generating electricity on a scale comparable to the largest existing fossil fuel based, hydroelectric and nuclear energy generation facilities

LIMITATIONS OF TIDAL ENERGY

1) Economic recovery of energy from tides is feasible only at those sites where energy is concentrated in the form of tidal range of about 5m or more and geography provides a favourable site for economic construction of a tidal plant. Thus it is site specific.

2) Due to mismatch of lunar driven period of 12 hr 25 min and human (solar) period of 24 hr. the optimum tidal power is not in phase with demand.

3) Changing tidal range in two-week period produces changing power. Power obtained is not steady.

4) The turbines are required to operate at variable head. (11)

5) Tidal plant disrupts the marine life at location and can cause potential harm to ecology.

ADVANTAGES

1) The biggest advantage of tidal power, besides being inexhaustible, is that it is completely independent of uncertainty of precipitation. ND

2) Continous utilisation of tidal energy for a long time is possible (2)

3) Tidal power generation is free from pollution.

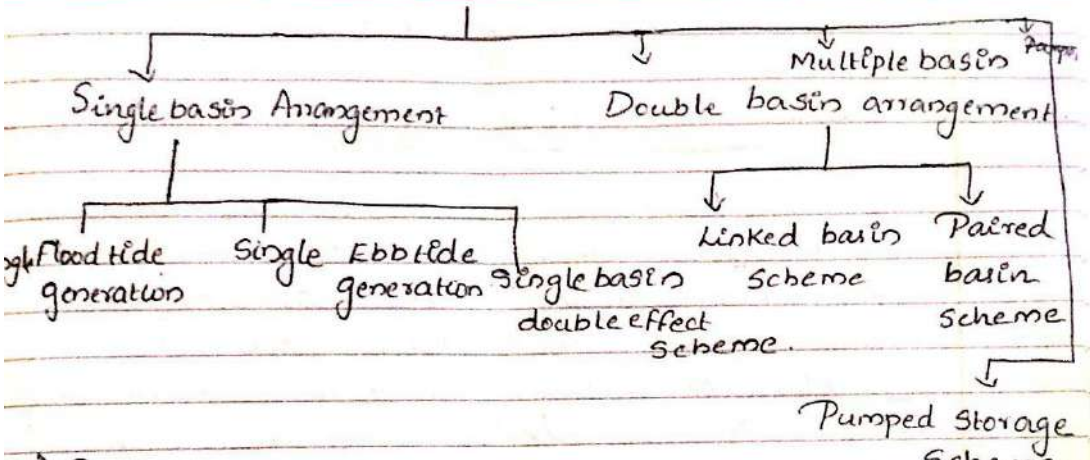
4) It does not use any fuel and does not produce any unhealthy waste like gases, ash or atomic refuse.

5) Tidal power plant doesnot require large area of valuable land because they are on the bay (sea shore)

6) Peak power demand can effectively met when it works in combination with thermal or hydroelectric system.

Q) NB (5 mark) OCEAN TIDAL ENERGY CONVERSION SCHEME

MAIN TYPES OF TIDAL POWER GENERATION SYSTEMS



I) Single basin scheme
- a) Single effect scheme (One way scheme)
  - i) Flood tide cycle generation
  - ii) Ebb tide cycle generation.
- b) Double effect scheme (Two way scheme).

II) Two basin Scheme
- a) Linked basin scheme
- b) Paired basin Scheme

III) Modified (Modulated) Single effect scheme

IV) Multiple basin scheme

V) Pumped Storage scheme.

Explain different parts of Ocean tidal Energy scheme

1) One or more barrages (Dam) dyke: ~~with~~

The Barrage, dam or dyke are Constructed to store water in a basin. The dam should be capable of withstanding the potential energy or pressure of water

2) Ducts in the barrage:- Ducts are the passage to the Flow of water

3) Sluice ways:- These are the gates which allow water in to and Out of the basin, which will emptying and filling the

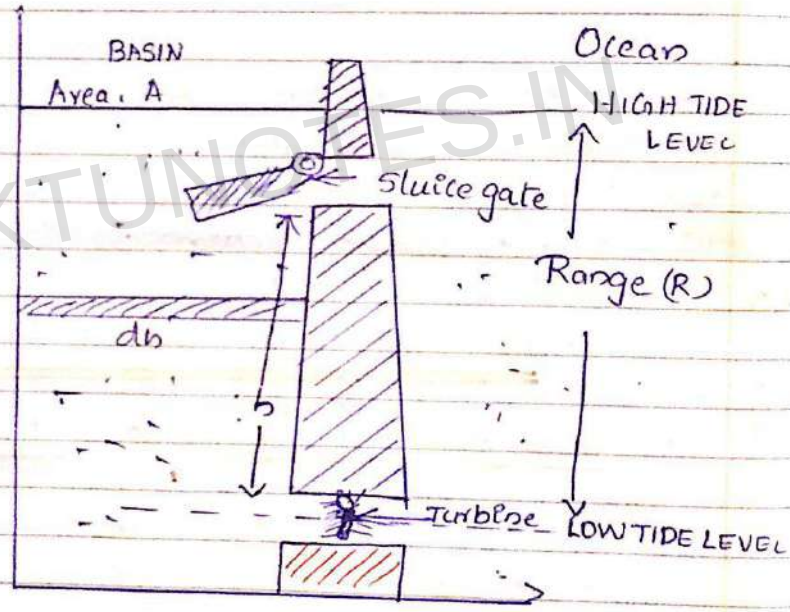
basen for tidal energy Conversion

4) Turbine generator Units in Ducts:-

→ Different types of turbines are used based on the application. Usually propeller type (kaplan) turbines which are used when tidal range height is more than 8m.

→ Propeller type turbines can use different angles for blades for better generation of electrical output. Different types are ① Bulb turbine ② Tube turbine ③ Straight Flow rim turbine.

5) Electrical and Mechanical auxillaries & Power station



NB (2) Explain main parts of TPP

POWER GENERATED FROM TIDES:

Let A = Basin Area
h = Height
R = Range of tide
W = Potential Energy

ρ = Density of water , t = time in s

g = Gravitational Constant

Pavg = Average value of power generated from tide

Average sea water density = 1025 kg/m^3.

E = Energy Converted equal to work done J.

$dW = dmgb$

But $dm = \rho A db$

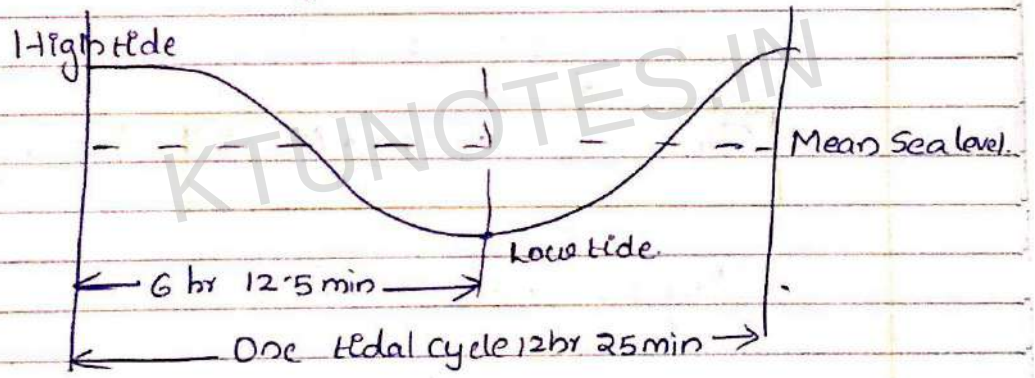
$dW = \rho A g b db$ (Total PE for small distance db)

Total potential Energy $W = \int_0^R \rho A g b db$

NB

$$W = \frac{1}{2} \rho A g R^2 \text{ Joules.}$$

Consecutive high and low tide is 6hr 12.5 min.



6 hr 12.5 min = 22350 sec

1025 kg/m^2 = Average Sea-water density

$$P_{avg} = \frac{W}{t} = \frac{1025 \times 9.8 \times A R^2}{2 \times 22350}$$

$$P_{avg} = 0.225 A R^2 \text{ Watts}$$

Pavg is directly proportional to ① area of basin and ② square of range.

Due to frictional loss and other factors, the the actual power obtained from tides will be less than the actual derived from equation.

Turbine cannot be operated down to zero head. So turbine has to be stopped when head reaches a minimum value of 'r' below which the operation become uneconomical

So $W = \int_r^R \rho A g h \, dh$

$$W = \frac{1}{2} \rho A g (R^2 - r^2)$$

$$\boxed{P_{avg} = \frac{W}{t} = 0.225 A (R^2 - r^2)}$$ (For single effect Plant).

$P_{avg} = 0.45 (R^2 - r^2) A$ (For double effect plant)

TERMS AND DEFINITIONS

1. Amplitude (tidal) :- A synonyms of tidal range
2. Bay: An inlet of a sea between 2 capes.
3. Barrage :- A dam usually of smaller height than dam. Barrage is designed for lesser head of water
4. Change of tide :- change in mode of tide. Rising to falling or falling to rising
5. Crest :- Highest level of water tide (flood tide)
6. Delta :- Depositional area near river mouth where sediments get deposited

7) Sluice way :- Passage way (gated) or artificial Channel to let water through

8) Tidal basin :- Basin which get filled by high tide to desired level by opening the gates in the barrage (dam)

9) Tidal range :- Difference between water level of Consecutive low tide and high tide

10) Pool :- Same as Basin. Retained water.

11) Tropical tide :- The tide Occuring twice in a lunar month when the moons maximum declination north to South of equator is the greatest.

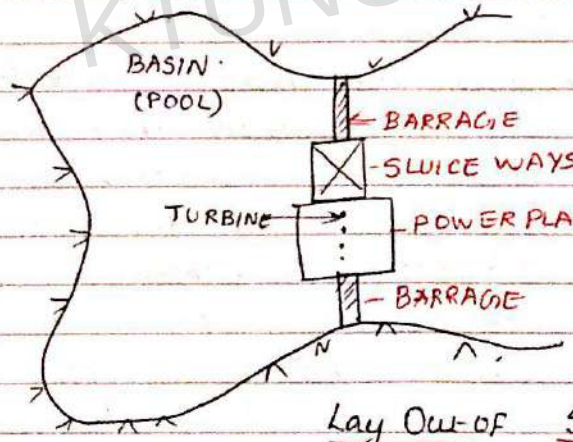
(1 omark)

(NB) Explain Classification of tidal power plant (TPP)

1) Single basin arrangement

→ Only ~~only~~ One basin (pool)

→ A barrage seperate a basin from Ocean



Lay Out of Single basin tidal Scheme

→ The sluice way is Opened during high tide to fill the basin

→ The turbine-generator units are mounted within the ducts inside the barrage.

Ebb generation :- During low tide
Flood generation :- During high tide

(I) → Ebb generation :-
- ~~It generate power~~
- During flood tide basin is filled and sluice gates are closed after filling of basins, trapping water,
- Gates are kept closed until the tide has ebbed sufficiently and thus turbine starts spinning and generate electricity.

- Flood generation :-

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

WORKING :- (Single effect single basin scheme)

→ It generate power only in one-way flow of water through the turbines, during low tide.
→ The basin is filled during high tide by opening the gate in the barrage.
→ The water level in the basin reaches the maximum level (crust)
→ Tidal range gives the head of water during low tide, & the level in the basin is 'R' and the level in the sea is zero. So
→ Potential energy is developed during this head difference and water is released during the generating mode through the turbines, located within the barrage into sea.

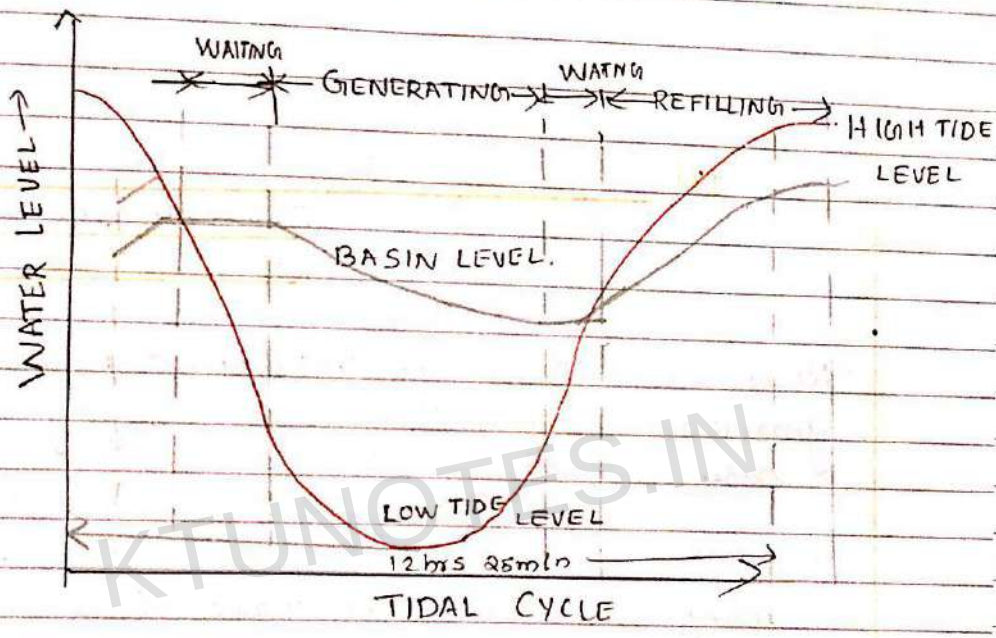
→ Turbine started working when the water in the basin is at high tidal level. and the water in sea at low tide level.
→ Only one way operation for turbine.

DISADVA Power generation is intermittent and mostly during off-peak load period on daily load curve

Total = 6 hr 12 min

The Operating modes include

1) Waiting mode (1st)
2) Generating mode (Emptying mode) - Water flows from basin to sea through turbine
3) Refilling mode (Water flows from sea to pool through the sluice way)
4) Second waiting mode



Total = 6 hr 12 min

1) (2.5 hr) First waiting mode :- It begins with falling of water level in sea and last for approximately 1.5 hours to allow the ocean water level to reduce and head H to increase. The basin level remain at top during 1st waiting mode.

2) (4.5 hr) Generating mode :- When Ocean level reduces to required mark, head H reaches a required value and generation begins.

HEAD = Basin water level - Sea level

→ The turbine gates are opened and basin water flows through turbine during this mode.
→ The generating mode continues during 'emptying' of the basin and lasts for 4.5 hours

(4hr)(2 hr)

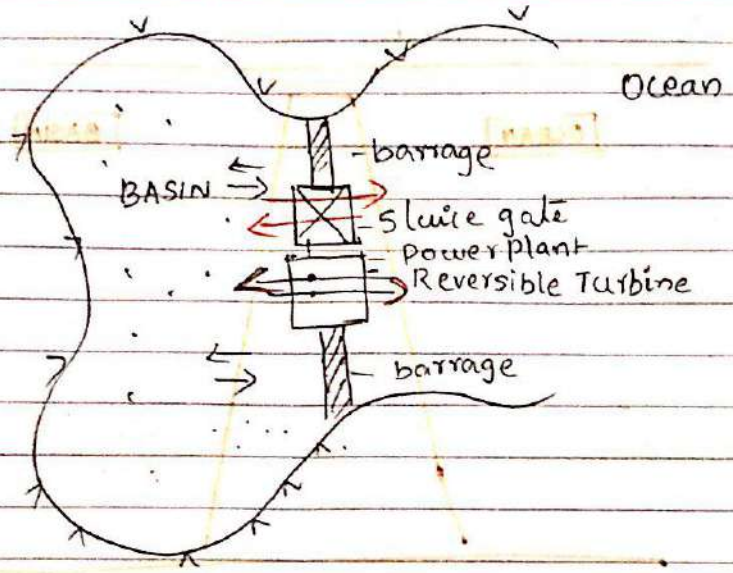
3) Second Waiting mode :- The generating mode is followed by waiting mode, during rising tide.
4) Refilling mode :- Duration is 4 hours during the rising tide

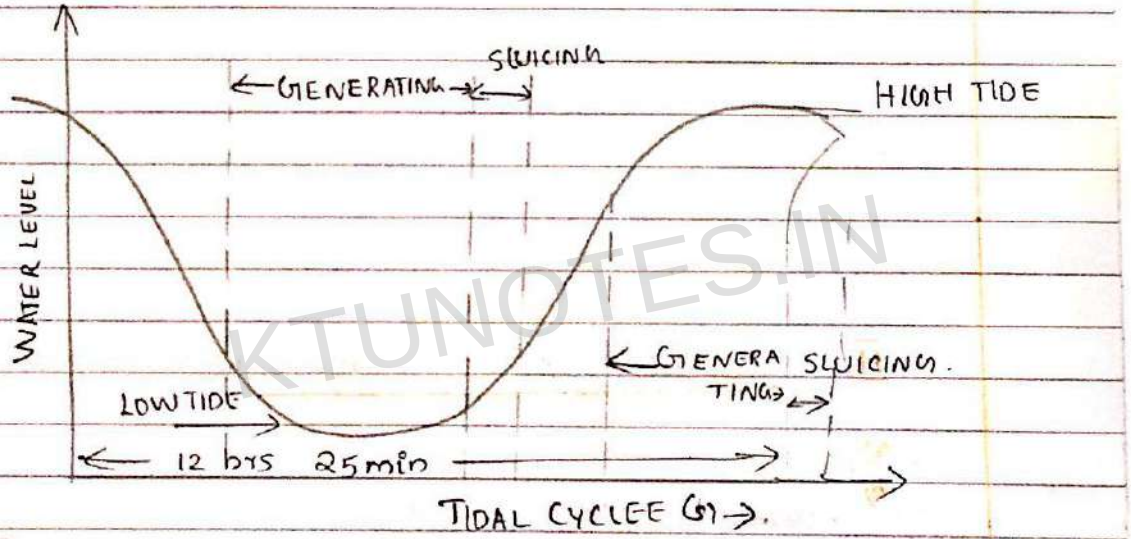
(2) Single Pool Double effect scheme (Two way scheme Ebb & Flood Operation)

Reversible turbines are installed and power is generated during filling and emptying of the basin.

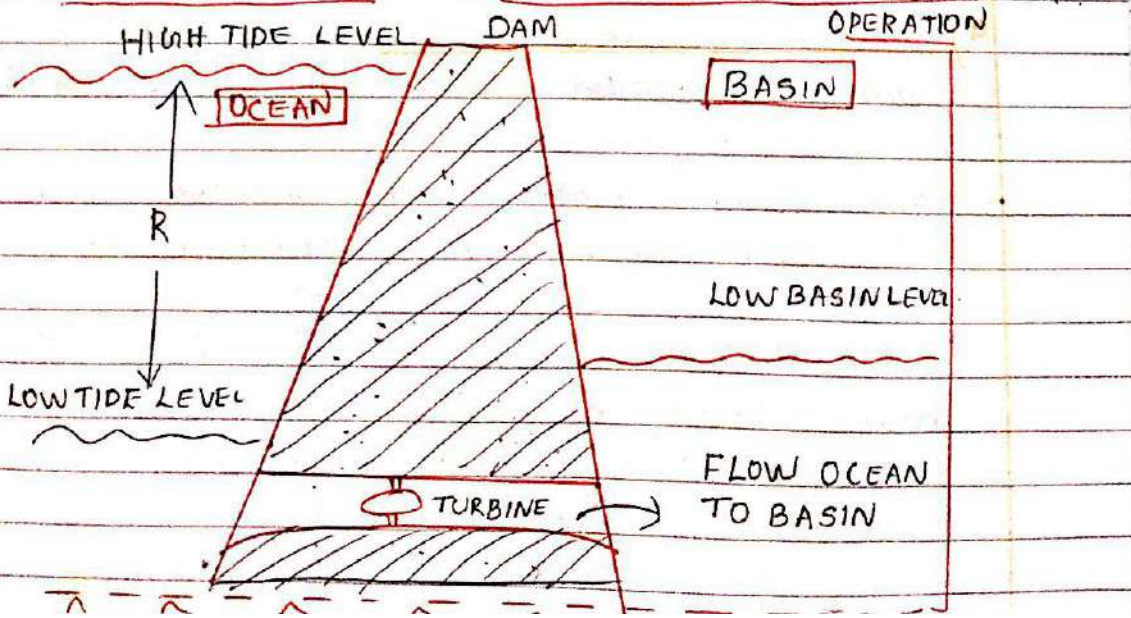
Flood Operation :- The basin fills in during rising tide and the water flows from sea to basin and drives the reversible turbine
Ebbing operation :- The water flows from basin to sea and drives the reversible turbine

The Operating mode during 12.4 hr half-tidal cycle are
1) Generating mode during emptying
2) Sluicing - letting out water through sluice during low net head
3) Generating Period during filling (sluices are closed, water is let out from basin through turbines)
4) Second sluicing period.

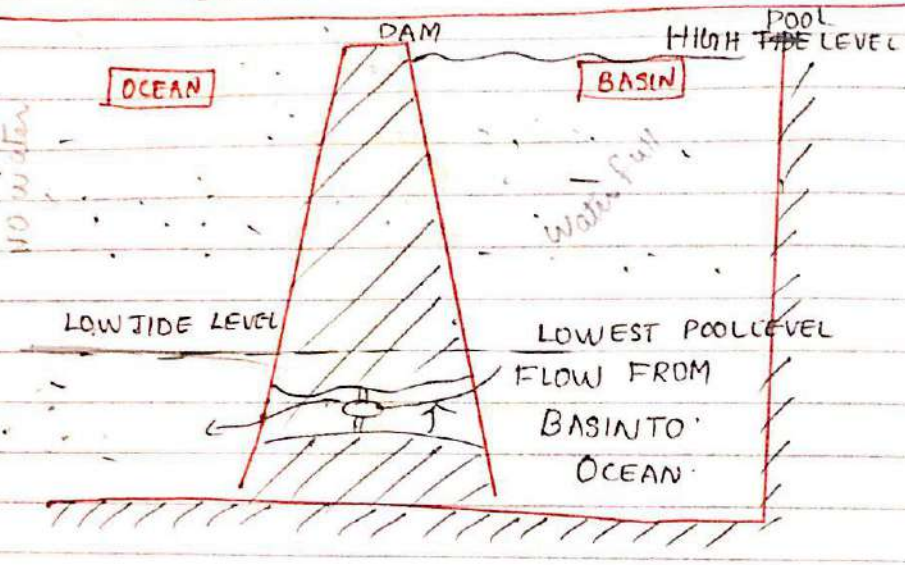




(1) TURBINE- GENERATOR FORWORD MODE GENERATING OPERATION



II TURBINE- GENERATOR REVERSE MODE OPERATION

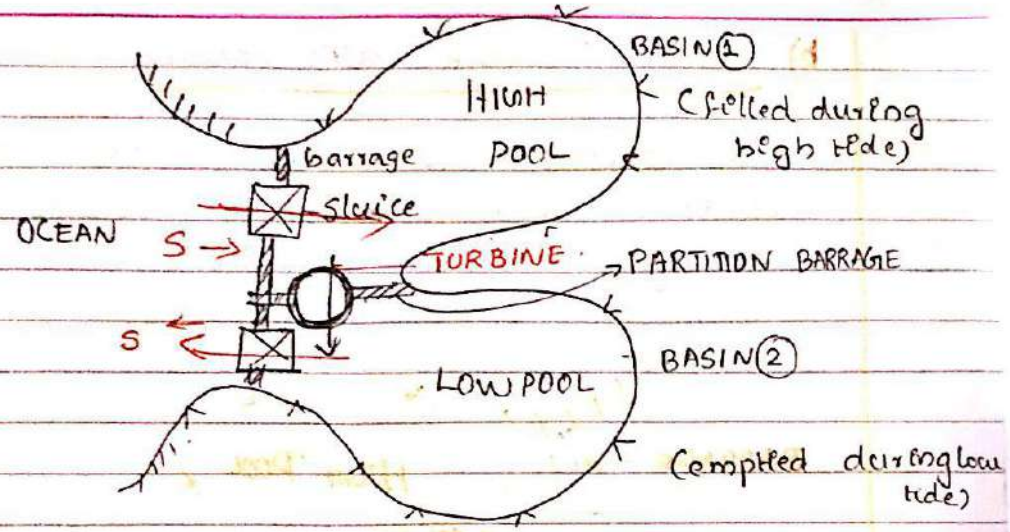


III DOUBLE BASIN ARRANGEMENT

→ a) Linked Double basin Scheme
→ b) Paired Double basin Scheme

a) **Linked double basin scheme:-** The tidal power Plant is installed in the barrage located in between a high pool and low pool.

→ The power Plant can be operated continously.
→ The flow of water from Ocean to both the basins is controlled.
→ A single larger Basin is divided into 2 basins called high basin and low basin
→ The high and low basins are seperated by means of partition barrage.



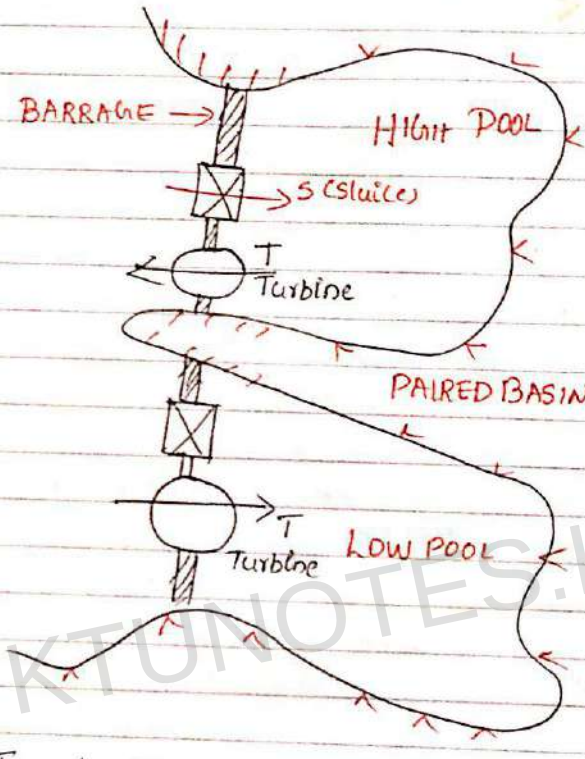
S = Sluicing
T = Turbining

→ The main barrage is built between the sea and 2 basins.
→ High basin get periodically filled during every high tide from Ocean water through sluice.
→ Low basin get periodically emptied by flow to Ocean through sluice during low tide.

→ Turbine generators are installed in the Partition barrage. Water flow from high basin to low basin & through turbines.
→ The continous power is obtained from the plant without waiting for tidal sequence.
→ The head of water is the difference in level between high pool and low pool.

b) Paired Double basin scheme

- In paired basin scheme, the 2 basins are located apart and their waters are never exchanged.



- Two basins are physically segregated.
- During high tide, high pool is filled by Slu
- During low tide, high pool discharge via turbine (T)
- During rising tide, low pool is felled via turbine (T)
- During low tide, low pool is sluiced via (S)
- Power is generated during low tide & high tide

Q Explain Detail about the selection Creteria of site

SITE SELECTION

- Site must have large tidal range
- Must be capable of storing a large quantity of water for energy production with minimum dam Construction
- Site should be located in an estuary
- Site should be near to a load Centre to minimize the transmission requirements.

To Develop tidal power Scheme the following requirements are needed for a tidal power plant

1) Pre-Feasibility Study:-
Acquisition of data Such as tides, local topography, Infra Structure etc is the first requirement

2. Feasibility Study:- Mathematical modelling Preliminary energy Computation, foundation, investigation, hydraulic model Studies, detailed analysis of various modes of Operation.

3) Detailed design, preparation of Specification and tender documents

4) Construction of plant

Existing Tidal Plants (MW)

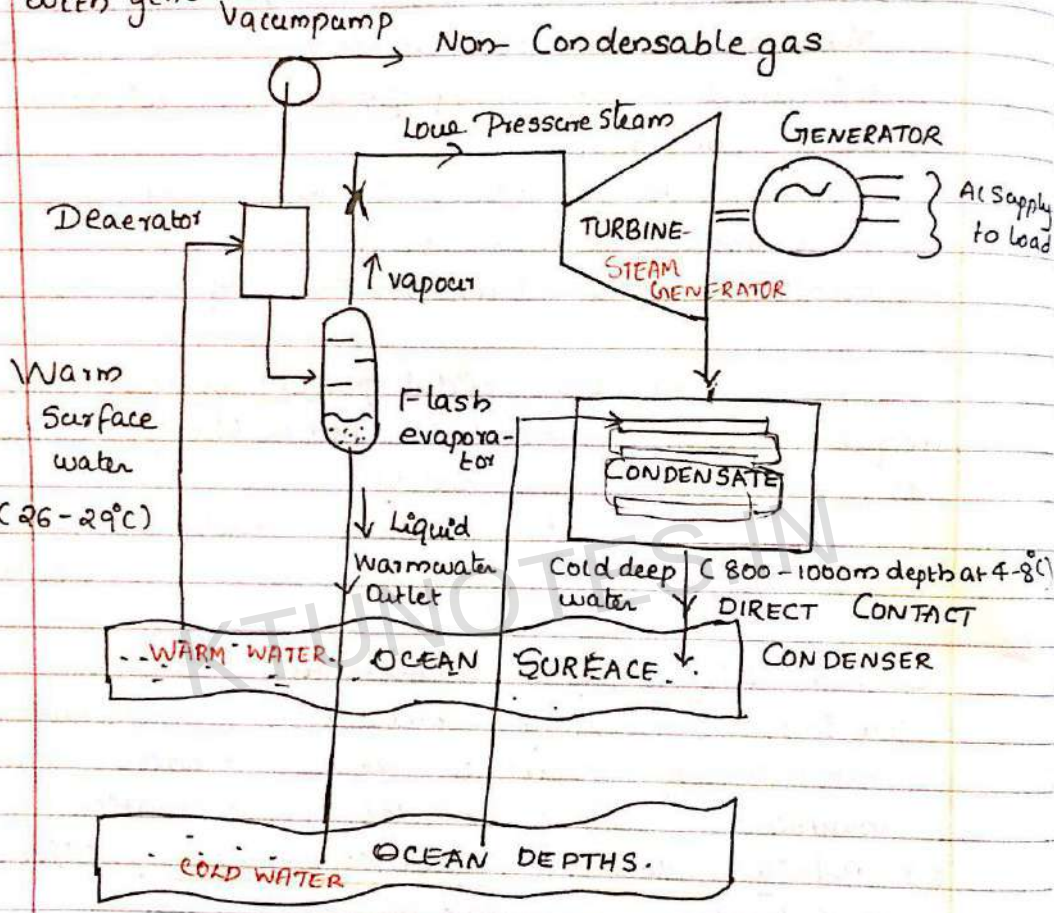
SN	SITE	Mean Tidal range (m)	Basin Area (km^2)	Installed Capacity	Year of Installation
1.	La Rance (France	8	17	240	1966
2.	Kislaya Guba (Near Murmansk, on Barentssea) Russia	2.4	2	0.4	1968
3	Jiangxia (China)	7.1	2	3.2	1980
4	Annapolis (in Nova Scotia, Bay of Fundy Canada)	6.4	6	17.8	1984

(OTEC) Ocean Thermal Energy Conversion System

Based on Power cycle, OTEC s/m dievededinto 2cycle

— OTEC plant Can operate On Open and Closed cycle

— In an Open cycle (claude cycle) plant, warm Surface (Claudecycle) water From the Ocean Surface is flash evaporated under partial vacuum (↑vacuum) and generated vapour is utilized to drive a low pressure turbine Connected to with generator.



OPEN CYCLE OTEC PLANT

— OTEC Open cycle system, which uses sea water as the working fluid.

— The exhaust steam is Condensed using cold sea water taken from the Ocean depth.

— For an Open cycle, the Condensate Can be used as a means of For Fresh water Production.

— If a Surface Contact Condenser is employed, the Condensate Could be used as desalinated water. Thus Ocean OTEC plant Provide a Substantial desalinated water.

PRINCIPLE OF OTEC SYSTEM

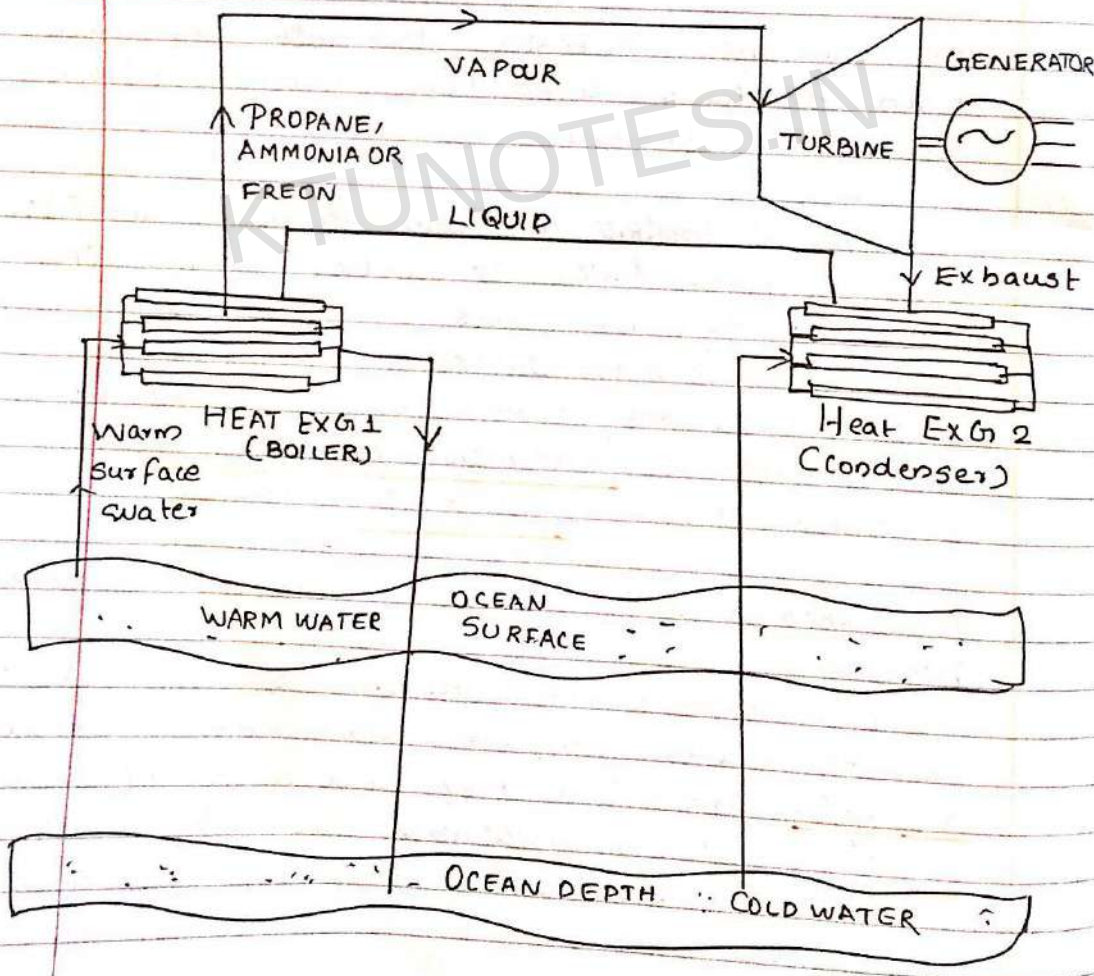
- In tropical Ocean within 25° North-South latitude a temperature difference of 20°C exist between Surface of the Ocean and water at a depth of 2000 m.
- Due to various physical processes, it is as if a clear stratification exists between warm Surface water and Cold deepwater.
- The process of harnessing the energy due to this temperature difference is called Ocean Thermal energy Conversion (OTEC).
- OTEC is an untapped, non-polluting renewable energy source, which is appropriate for an energy-starved nation like India.
- OTEC is Capital intensive, but unit Cost Comes down drastically with higher plants and improvements in technology.
- The national Institute of Ocean Technology arm of DOE Government of India is building world's first 1MW floating OTEC plants.
- This project is under Jal vigyan Mission was sactioned in 1998, to be Commissioned 60km South-east of Tuticorin, Tamil Nadu, where an Ocean depth of 1200m is available
- Now this's Plant is running from September 2002.

Principle

OTEC utilises temperature difference existing between warm Surface Sea water of around 27-29°C and Cold deep Sea water of around 5-7°C, which is available at a depth of 800 to 1000m in tropical waters to run a heat engine to produce work.

CLOSED CYCLE (ANDERSON CYCLE) PLANT

- The closed cycle system utilizes a low boiling point liquid, like Freon or Ammonia, ~~or~~ Propane as working fluid.
- The warm surface water is used to evaporate a low boiling pt working fluid (Freon, Ammonia, Propane)
- The vapour flows through turbine and is then cooled and condensed by cold water pumped from the ocean depth.
- Because of low quality of the heat, large surface area of heat exchangers i.e evapourator and condenser are required to transfer significant amount of heat and a large amount of water need to be circulated



This Condensate is pumped back to the evaporator and recycled using the working fluid pump.

- The operating pressure of the working fluid at the boiler / evaporator and condenser are much higher and its specific volume is much lower as compared to that of water in an open cycle system.
- Such pressure and specific volume result in turbine that is much smaller in size and hence less costly as compared to that in an open cycle system.

- Both open and closed cycle plants are mounted on ship or built on shore. The ship option require submarine power cable for power transport. If the plant is located far (more than 50km) from shore, the transmission cost becomes prohibitive.
- Alternatively for a plant, which is hundreds of kilometers from the shore, it has been suggested that electricity be used on boards to produce chemical storage of energy (eg. H_2). The hydrogen could be liquefied and transported by a tanker to the point of use. The shore option is feasible only at certain favourable locations where the sea bottom slopes sharply downwards. Their main advantage is the lower cost of installation, operation and maintanance.

Comparison of Open Cycle and Closed cycle

Open cycle system Advantages

1) The warm sea water is flash evaporated and need for having a surface heat exchanger of larger size is eliminated
2) The potable water is obtained when the exhaust steam from turbine is condensed

DISADVANTAGES

1. Steam is generated at very low pressure (0.02 bar) So the volume of steam to be handled is very high, leading to a very large diameter for the steam turbine. C I MW OTEC plant require a steam turbine of 12m in diameter
2. To maintain vaccum in flash evaporator massive vacuum pumps are requered.

CLOSED LOOP YCLE SIM (DISADVANTAGE)

1) It require expensive working fluid like freon, Ammonia or propane.
2) The net cost become very high.
3)

ADVANTAGES

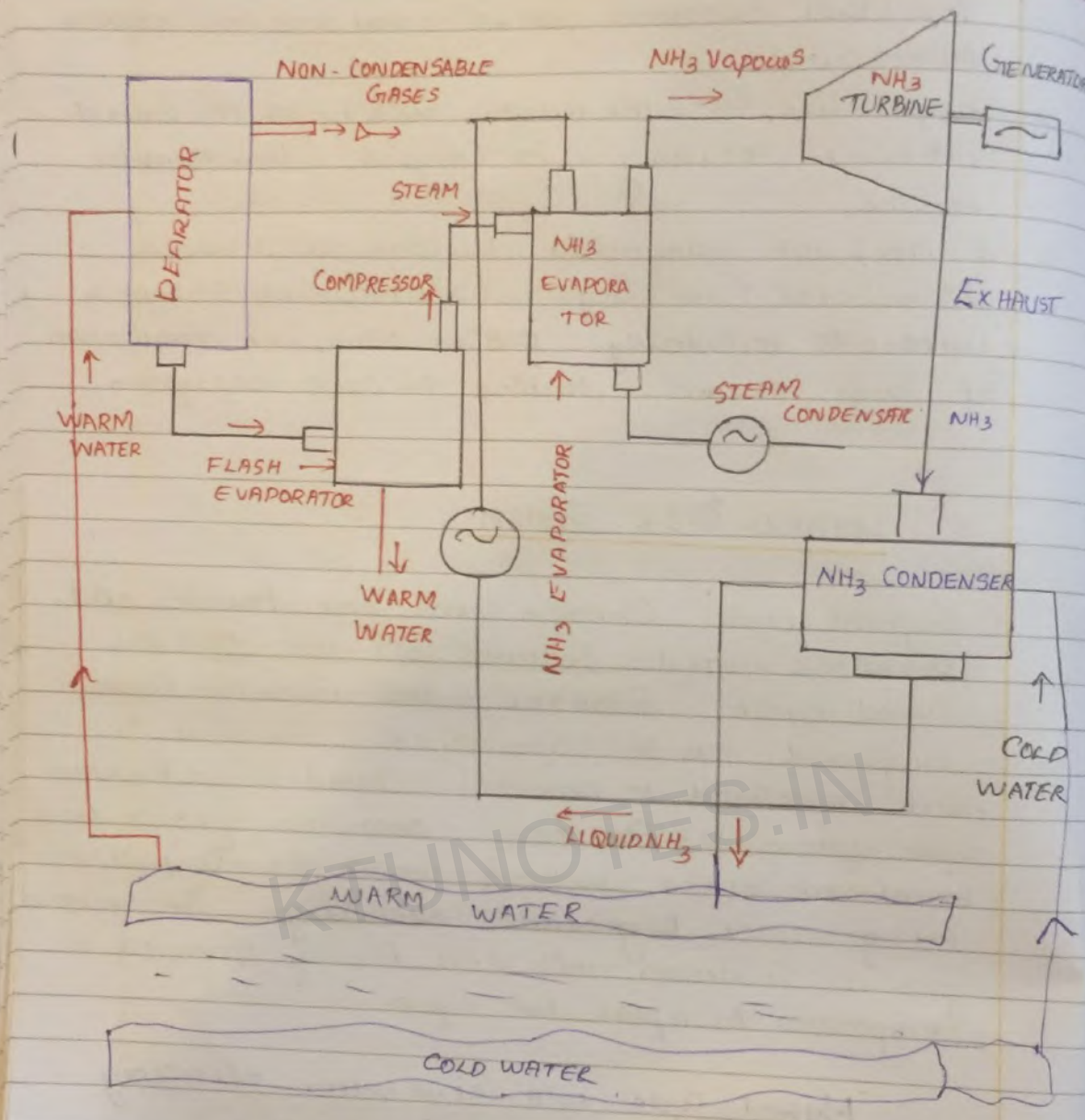
1. The fluid evaporates at 25°C and does not require vaccum pumps.
2. The pressure at the turbine will be of the order of 9 to 6 bar resulting in Compact, low-diameter turbine.
3. A 1MW plant ammonia turbine will have a diameter of 1.1m only. So fabrication of such a turbine is technically easier than the fabrication of large steam turbine of open loop system.

HYBRID OTEC SYSTEM.

Hybrid cycle Combine the best features and avoid the worst features of the Open and Closed cycle. First the Sea water is Flash evaporated as in Open cycle. The heat is then transferred to ammonia based closed Rankine cycle system. The hot ammonia gas is then transferred to the turbine which is Coupled to the generator to generate electricity. Then ammonia goes to Condenser unit and finally pumped to evaporator to repeat the cycle

Hybrid Cycle will give better effeciency than Open cycle and closed cycle.

HYBRID CYCLE OTEC S/M



BIOFOULING

The gradual accumulation of organisms such as algae, bacteria, barnacles and protozoa on underwater equipments, pipes and surfaces, corroding and impairing structures and systems.

Fouling is the accumulation of unwanted materials on solid surfaces of underwater system. 2 type fouling

i) Biofouling :- If fouling material is living organism

ii) Inorganic or Organic fouling :- Non living substrate

Antifouling is the ability of specially designed materials and coatings to remove or prevent biofouling by any number of organisms on wetted surfaces. Since biofouling can occur almost anywhere water is present, biofouling poses risks to a wide variety of objects such as medical devices and membranes as well as to entire industries such as paper manufacturing food processing mainly underwater construction.

ADVERSE EFFECTS OF BIOFOULING

1.) Buildup of biofouling on marine vessels poses a significant problem

2) In some instances, the hull structure and propulsion system can be damaged.

3) Turbines used in ocean energy conversion will get corroded and damaged easily.

4) Increased fuel use due to biofouling contribute to adverse environmental effects and increase emission of carbon dioxide & sulphur dioxide between 38 and 72% by 2020

WAVE ENERGY

Waves are caused by the transfer of energy from surface wind to the sea. The rate of energy transfer depends on wind speed and distance over which it interact with water

The energy flux in wave is more compared to solar, wind and other renewable sources. The power in wave is directly proportional to square of its amplitude and to the period of motion. Larger waves in deep sea, lose energy quite slowly and can effectively store it for many days and transmit it for great distances.

ADVANTAGE OF WAVE POWER ARE.

1) Availability of large energy fluxes.
2) Predictability of wave condition over periods of days

POWER IN WAVES

$$y = a\sin\left(\frac{2\pi}{\lambda}x - \frac{2\pi}{T}t\right)$$ Travelling wave equation

y = Displacement above mean sea level in m
a = Amplitude, m
λ = Wavelength, m
T = Time period, Sec
t = time, s.

$y = a\sin(kx - \omega t)$, $k = \frac{2\pi}{\lambda}$ = wave number

$\omega = \frac{2\pi}{T}$ angular frequency rad/sec

POWER GENERATION FROM TIDAL PLANTS.

The energy available from tidal plant depends on the following 2 factors

(1) The tidal range (2) The volume of water accumilated in the basin.

The tidal energy is slowly increasing hydro-energy during falling of basin and after a period of nearly 3 hour, it attains its peak value. When the tide recedes water is allowed to flow from basin to sea, it is the slowly decreasing hydro-energy and attains its lowest value when the turbine stops after a period of 3 hr. Thus the energy available for a tidal point can be calculated in a similar way as for a tidal point can be calculated in a Sir hydro power plant.

Considering average discharge & available bead at any instant

Volume of basin, $V = AH \ m^3$

Average discharge, $Q = \frac{AH}{t}$

A - Average cross sectional area of basin in m^2

H - Diff. b/w maximum and minimum water levels

t - Total duration of generation in one filling / emptying operation in sec.

Power generated at any instant

$$P_{inst} = \frac{\rho Q h}{75} \times \eta \times HP.$$

$$= \frac{\eta Q h \times \eta \times 0.736 \ kW}{75}$$

Where $h \rightarrow$ Available head at that instant

$\rho = 1025 \ kg/m^3$ For Sea water

- Introduction
- Wind and its properties
- History of wind energy
- World & Indian Wind energy Scenario
- Basic principle of WECS
- Classification of WECS
- Parts of WECS
- Derivation of power in wind
- Electrical power Output and Capacity factor of WECS
- Advant & Disad of WECS

Wave Energy

Waves are caused by the transfer of energy from surface wind to sea. The rate of energy transfer depend on wind speed and distance over which it interact with water.

Differentiate between Ocean wave and Ocean tide.

Ocean Wave	Ocean Tide
1. Originate from wind blowing across the water surface	1. Ocean tide are largest of all Ocean waves.
2 Time between gravity wave is 30 sec	2. Time between Low tide and high tide is 6 Hours but in lunar day it takes 24 hrs 50 minute
3. Energy Flux in Ocean wave is more than Other renewable Sources.	3) Energy Flux in Ocean tide is lower than Ocean wave
4. The power in wave is proportional to period of its motion and Square of amplitud	4) The Power Output varies due to variation in tidal range
5 Efficiency of Ocean wave remain constant	5) Efficiency of plant varies because turbine works on different head,

WIND AND ITS PROPERTIES

- Wind is caused by difference in the atmospheric pressure. When a difference in atmospheric Pressure exist, air moves from higher to lower pressure area, resulting in winds of various speed.

- The strongest Observed wind on a planet in the solar system occur on Neptune and Saturn. Winds have various aspects, an important one being its velocity is wind speed, another the density of gas involved; other one is its energy content or wind energy.

Winds are the motion of air about earth caused by rotation and by uneven heating of earth surface by sun.

Nature of wind

Sun continuously releases heat in to the atmosphere but the heat received by earth atmosphere is unevenly. In the areas where less heat is released (cool air zones), the pressure of atmospheric gases increases, whereas where more heat is released air warms up and gas pressure decreases.

Major factors that have led to an accelerated developments of wind power are

1) Availability of high Strength fibre Composites for constructing large low cost rotor blades
2) Falling price of power electronics.
3) Variable Speed operation of electrical generators to capture maximum energy
4) Improved Plant Operation, Pushing the availability

6) Accumilated field experience improving the capacity factor

7) Short energy pay back (energy recovery) period of 1 year

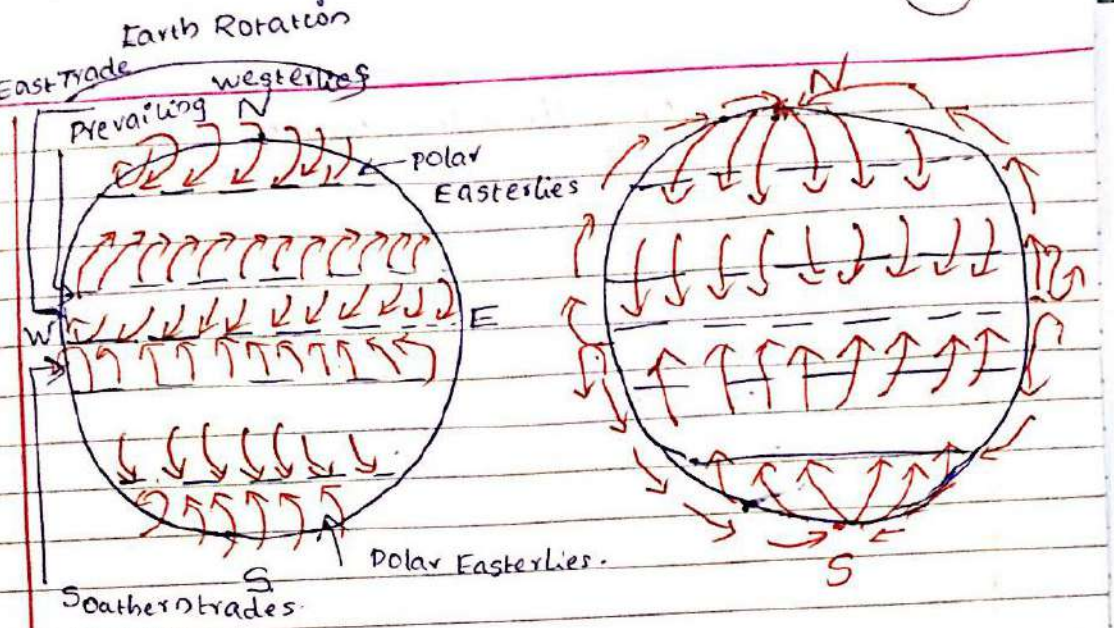
ORIGIN OF WIND → local wind, Global wind

Global (Planetary) Wind :- (That wind move is the upper surface)

The 2 major forces determine the speed and direction of wind on a global bases.

(i) The primary force for global winds is developed due to differential heating of earth at equatorial and polar regions.
Large circulating air streams are generated by more intensive heating near the equator than at poles which results in movement of hot air from tropical region towards poles while cool surface winds from pole replace warmer tropical air
So in tropical region there is a net gain of heat and due to solar radiation and in polar regions, there is a net loss of heat.

ii) Spinning of earth about its axis produces a Coriolis force which is responsible for deviation of air currents towards west. The moving colder air from the poles tends to twist towards west because of its own inertia. The warm air from the equator tends to shift towards the east because of its inertia which result in large counter clockwise circulation of air in northern hemisphere and clockwise in Southern hemisphere.



Direction of wind affected by earth's rotation

Direction of wind if the earth did not rotate.

Between 30°N & 30°S. heated air at the equator rises and is replaced by cooler air coming from North and South. This is known as Hadly Circulation. Due to Coriolis force, these winds deviates towards west. These air currents are known as trade winds because of their use in sailing ship for trades in the past. There is little wind near equator and (±5°) as the air slowly rises upwards rather than moving westward. Between 30°N(S) and 70°N(S) predominantly western winds are founds. These winds form wave like circulation. transfer Cold air Southward and warm air Northward. This pattern is called Rossby Circulation.

PROPERTIES OF WIND (ADVANTAGES)

1) Wind is free and the power it generates has been harnessed for centuries
2) Wind is completely renewable source because it is something which occur naturally.
3) It can be harnessed constantly with out destructive effect
4) Generation and maintanance cost for turbine have decreased significantly in recent years
5) Wind power is well suited to rural areas.

6) Wind is inexhaustable and doesnot require transportation.
7) Clean, non polluting and ecofriendly and can be used safely at remote places.
8) Low operating & Installation cost.
9) Used at off shore and Onshore sites.

DISADVANTAGES.

1) Wind energy maynot be available regularly and uniformly.
2) Supply is unreliable and intermittent.
3) It is not used as a Continuous Supply Soure because wind velocity is not Constant through Out the year.
4) Wind power generation is Only possible in large Coastal hill and deserst area.
5) Not favourable near large populated Sities.

Nature of Wind.

Rapid fluctuations in the wind velocity over a wide range of frequencies and amplitudes, due to turbulence caused by mechanical mixing of lower layers of atmosphere by surface roughness are known as gusts.

Unit ratings of wind turbine generator cover a wide range from 0.5 kW to 14 kW.

- Very Small 0.5 to 1 kW
- Small 1 to 15 kW
- Medium 15 to 200 kW
- Large 250 to 1000 kW
- Very large 1000 kW to 6000 kW

Energy chain of Wind Energy:

① Wind Energy → Mechanical Energy at Wind turbine shaft → Mechanical Energy Utilisation

② Wind energy → Mechanical energy at Turbine shaft → Electrical Energy by Generator → Electrical Energy for Utilisation

History of Wind Energy

→ Application of wind energy for producing electrical energy was introduced first in 1985. Several units was installed in Europe during early part of ~~1985~~ 20th century.

→ Wind turbine generators have become used in Commercial scale and have received more importance in 1980.

→ The wind-turbine generator units have become commercially successful after 1988 and being accepted for rural, remote and other suitable areas.

→ A wind turbine converts the kinetic energy of wind to rotary mechanical energy and drives the gears and shaft.

— The electrical generator converts mechanical energy to electrical energy.

— The wind turbine, gears, generator together form a wind turbine generator unit.

- The first propeller type wind mill to drive electrical generator was built by Pro. P. La. Cour of Denmark in 1985.
- It consist of 4 blades prolleler (rotor) driving a gear chain and shaft. The wind turbine and gear chain were mounted on a 24m tall tower generated in denmark over 200 MW.
- By 1930s, several wind power generators were installed in various parts of world. Allmost all of them were small and medium units with horizontal shaft and with three or 4 blades in vertical plane.
- First large wind-turbine generator unit (1.25 MW) was installed in USA around 1941 and operated for 4 years successfully. It was located in Grandpas-knob, near Rutland, Vermount USA on a 610m high mountain. The wind turbine generator was designed by Palmer Putman and Theodore Von karman.

The Power in Wind. Affecting Factors

The wind posses energy due to virtue of its motion. 3 factors determine the Output from wind energy Converter.

Nature of wind Depend On 3 factors

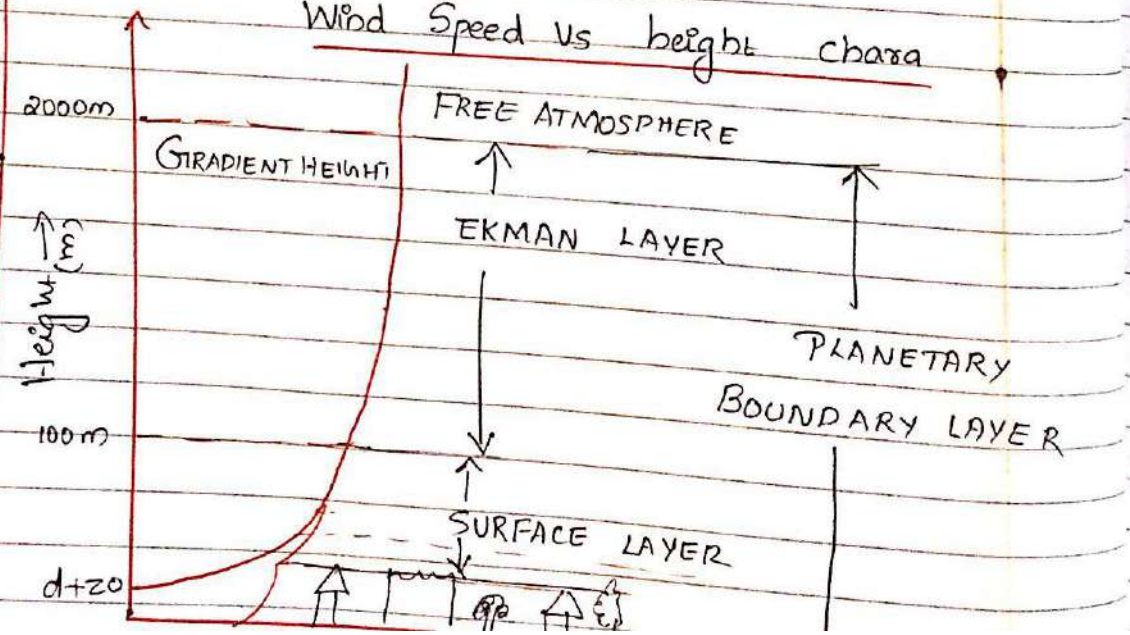
1. Wind Speed
2. Cross Section of wind Swept by rotor
3. Overall Conversion efficiency of the rotor, transmission system and generator pump.

100% efficient aerogenerator Can able to Convert upto maximum 60% of available energy in wind into mechanical energy blades Well designed will typically extract 70% of the theoretical maximum but losses in gear box, transmission sys and generator will decrease Overall wind turbine efficiency to 35%.

Wind Data Depends on
- Variation of wind Speed with HEIGHT
- Variation of wind speed with TIME
- Wind Turbulence

1) Wind speed Increases with height

Wind Speed Vs height chara



- At earth surface wind speed = 0
- If increase in height the wind speed also increases
- The wind near earth surface is retarded by surface roughness
- The rate of change of wind speed with height is called wind shear.
- The lowest layer of air retard those above, them resulting in change in mean wind speed with height zero $\frac{dv}{dt} = 0$ called Gradient Height
- Free Atmosphere:- Changes in wind speed is not affected by ground condition
- Planetary Boundary layer: The layer of air from ground to gradient height is known as planetary boundary layer. 2 parts
  1) Surface layer
  2) Ekman layer

Surface layer:- The layer which extend from height of local obstruction to a height of 100m

Ekman layer:- Which starts from 100 m to extend to gradient ht

Power Law Model

$$u_z = u_H \left[\frac{Z}{H}\right]^{\alpha}$$

u_z - Wind speed at height Z relative to that available at standard reference height 'H'.

u_H - Mean wind speed at reference height H (10m)

α = Depends on surface roughness (0.14 for open site)

Variation of Wind Speed with TIME

- Wind Speed fluctuate with time
- For electric power generation, minimum average wind speed is 5 m/s.
  - → Less than 5 m/s - No generation is possible
  - → Above 25 m/s - No generation. So Best site should have wind speed blw 5 to 25 m/s.
- So we will get 70% to 80% this speed in all time

WIND TURBINE TYPES

It is mainly classified into 2 type

1) Horizontal axis wind turbine (HAWT)
When the axis of rotation is parallel to the air stream

2) Vertical axis wind turbine (VAWT)
When the axis of rotation is perpendicular to air steam (vertical)

Wind energy Conversion System further classified as

A) According to their axis of rotation
1) Horizontal axis ~~rotat~~ Machine
a) Horizontal axis using two aerodynamic blade
b) Horizontal axis propeller type using Single blade
c) Horizontal axis multi bladed type
d) Horizontal axis ~~multibladed~~ Wind mill - Dutch type
e) Sail type

B) 2) Vertical axis Machines
a) The Savonious rotor
b) Darrius type Machine

B) According to Size.

(i) Small scale (upto 2kW)
(ii) Medium Size Machine (2-100kW)
(iii) Large size Machine (100kW and more)
a) Single generator at a single site
b) Multiple generator sites at several places Over an area

C) According to type of Output Power
   i) DC Output
   ii) AC Output

D) According to rotational Speed
   (i) Constant speed with variable pitch blades
   (ii) Nearly constant speed with fixed pitch blades
   (iii) Variable speed with fixed pitch blades.

E) According to Utilisation of Output
   (i) Battery Storage
   (ii) Direct Connection to an electromagnetic energy Converter
   (iii) Other forms of Storage
   (iv) Inter Connection with Conventional electric utility grids

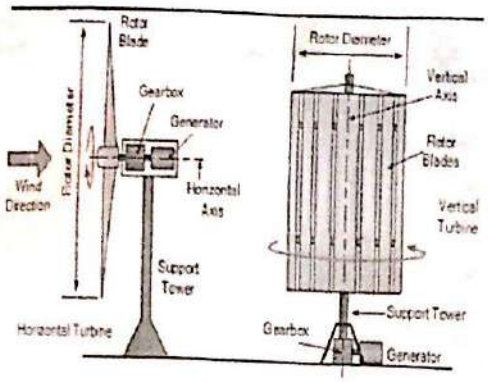
Horizontal Axis Wind Turbine (HAWT)

Main Components:

These are used for Commercial energy generation in many parts of the world. The construction feature of 3 blade rotor shown.

TURBINE BLADE: Turbine blades are made of high density wood or glass fibre and epoxy Composites They have an airfoil type of cross section. The blades are slightly twisted from the Outer tip to the root to reduce the tendency to stall. In addition to Centrifugal force and fatigue due to Continuous vibration there are many extraneous Forces acting Or arising from wind turbulence, gust, gravitational force and directional changes in wind. The diameter of modern rotor maybe of the Order of 100m.

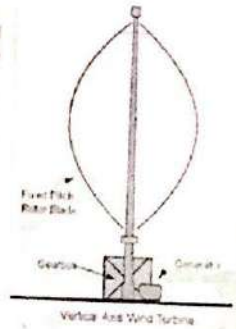
Modern wind turbine have 2 or 3 blades. 2 or 3 blade rotor HAWT are known as propeller type.



Horizontal Axis

Vertical Axis

Vertical Axis



Vertical Axis Wind Turbine

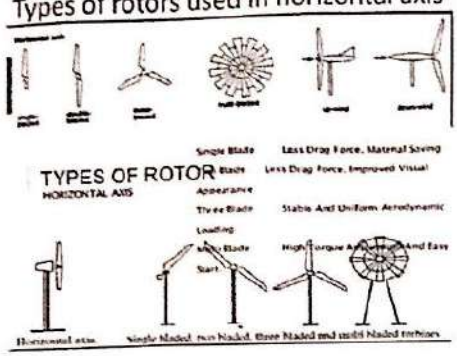
HAWT

- Today, the most common design of wind turbine, is the horizontal axis wind turbine (HAWT).
- That is, the axis of rotation is parallel to the ground.
- HAWT rotors are usually classified according to
- The rotor orientation (upwind or downwind of the tower),
- Hub design (rigid or teetering),
- Rotor control (pitch vs. stall),
- Number of blades (usually two or thee blades), and
- How they are aligned with the wind (free yaw or active yaw).

VAWT(Vertical axis wind turbine)

- It accept wind from any direction,eliminating the need of yaw control
- The gear box,generator are located at the ground eliminating the heavy nacelle at the top of tower thus simplifying the design and installation of whole structure including tower
- The inspection and maintanace is easy
- It breduces the overall cost

Horizontal Axis Types



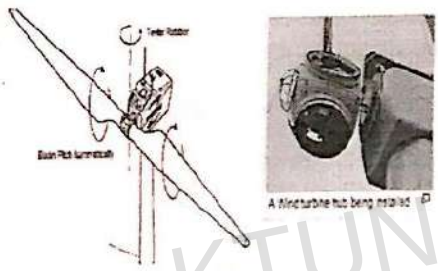
Single blade rotor: With a balancing counter weight it is economical. But it produces unbalanced forces

- It can be used for low power applications

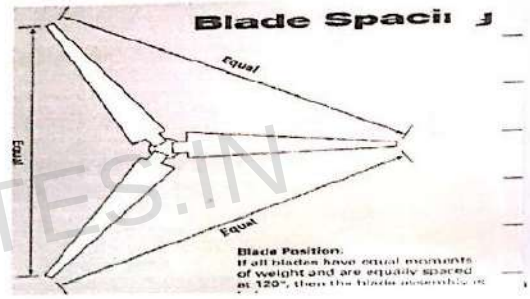
Two blade rotor: Two blades are attached to the hub. The problem with this design is that at high wind speed ,the forces on the upper position blade is higher than lower position. Due to this the rotor experience a severe vibrations. This problem can be overcome by teetering control hinge (a pivot within a hub). This allow a see-saw motion take place out of the plane of rotation

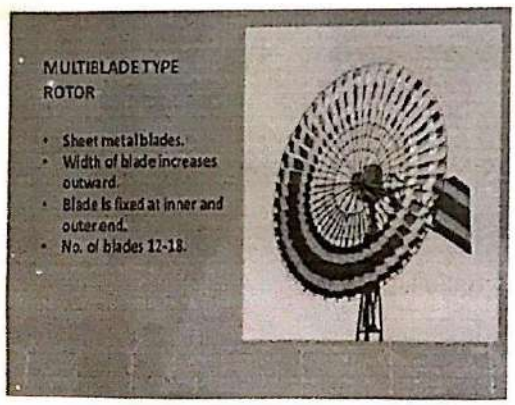
Three blade rotor: No need of providing teethering control because the third blade has same effect as that of hinge. The symmetry of the rotor averages out the loads on the hub

Teether: pivot within the hub



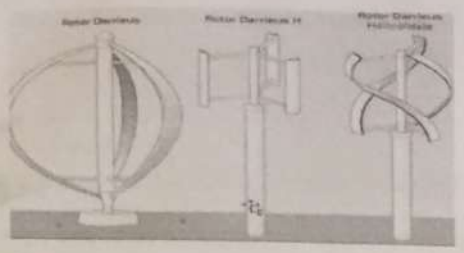
3 blade arrangement





- **Multi blade rotor:** It is fabricated from curved sheet metal blades. The width of the blade increases outwards from the centre
- The blades are fixed at their inner ends on a circular rim.
- They are also welded near their outer edge to another rim to provide a stable support
- The number of blades used ranges from 12 to 18. They are low speed rotors and most suited for water lifting applications which require high starting torque

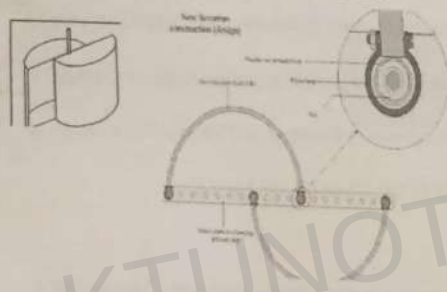
VERTICAL AXIS WIND TURBINE:DARRIEUS TYPE



DARRIEUS ROTOR

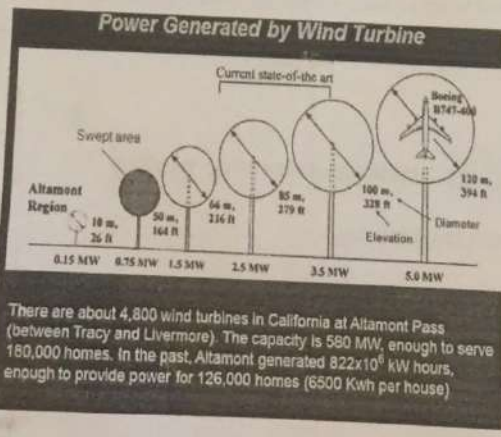
- This rotor has two or three curved blades of flexible metal strip. It operate with the wind coming from any direction.
- Both the ends of blades are attached to a verti shaft.It has an advantage that it can be installe close to the ground eliminating the cost of the tower structure. Lift is the driving force creati maximum torque when the blades moves acro the wind.This roror is designed by a French engineer G.H Darrieus in 1925

SAVONIOUS ROTOR



SAVONIOUS ROTOR

- It consist of identical hollow semi-cylinders fixe a vertical axis.The inner side of two half cylinder each other to have an S-Shaped cross section as shown. Irrespective of wind direction the rotor ro due to pressure difference between 2 sides
- It is having high starting torque
- Used for water pumping



SITE SELECTION CRETER

1) No tall obstruction for some distance (3 the upwind direction
2) Site should be close to power grid
3) Altitude of propsed site survey
4) Anemometer data collection
5) Favourable land cost
6) Local ecology

RATERGY FOR SITING

- of historical wind data
- maps of terrain and wind are
- ed
- al sites are visited
- es are instrumented for one year
- optimal site

: A WECS block diagram with the capability to change the pitch angle

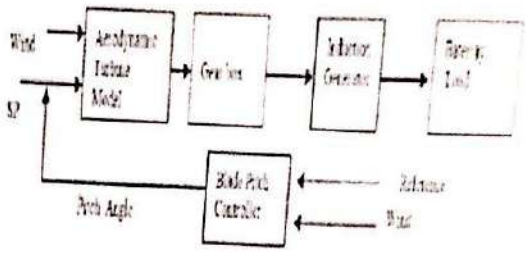


Table 4 : Historical development of Wind Energy Conversion System

	Machine	Application
	Persian wind mills	Grinding, etc
AD	Chinese sail type wind mill	Grinding, water pumping, etc
D	Dutch wind mills	Grinding, water pumping, etc
	Dutch w/mill to America	
AD	American Multi-bladed	Water pumping, 35 VDC power
	Brush wind turbine, Dia 17m, Tower 18.3m	12 kW Electric power
	Jacob's 3 bladed propeller Dia 5m, 10-20m/h, 125 to 225 rpm	0.8 to 2.5 kW at 32 VDC
	Yalta Propeller, Russia, 2 bladed, dia 100 ft	100 kW
	Smith-Putnam Propeller 2 bladed, dia 175ft, 30 m/h, 28 rpm	1250 kW
	Savonius Machine	Mechanical or Electrical power
	Darrius	Electrical power
	2 bladed propeller (Commercially available)	225 kW
	HAWT, VAWT	400-625kW, 1.2-3.2 MW

Typical modern wind farm is shown in Figure 34 and off-shore wind machine installation is shown in Figure 35. Wind machine farm in the hills of District Satara, Maharashtra, India is shown in Figure 36.

Figure 34 : Typical modern wind farm

Figure35. Off-shore wind machine installation

TSR

Tip-Speed Ratio (TSR)

(NB) POWER IN WIND

Wind mill works on the principle of converting kinetic energy of wind to mechanical energy. A wind stream has total power P_t which is equal to the time rate of kinetic energy KE.

$$P_t = m \cdot K.E_w$$
$$= \dot{m} \cdot \frac{V_i^2}{2} \quad \text{—(1)}$$

where $\dot{m}$ = Air mass flow rate, kg/s
V_i = Incoming wind velocity, m/s
P_t = Total power in wind stream, W

The Air mass flow rate $\dot{m}$ is given by

$$\dot{m} = \rho A V_i \quad \text{—(2)}$$

ρ = Wind density of incoming wind, kg/m^3
$= 1.226\ kg/m^2$ for 1 atm and 15°C
A = Cross sectional area of wind stream m^2

Substituting (2) in (1)

$$P_t = \frac{\rho A V_i^3}{2} \text{ Watts.} \quad \text{—(3)}$$

Thus total power in wind stream is

→ Directly proportional to wind density
→ Directly proportional to area of stream, A.
→ Proportional to V_i^3

~~The~~ A wind turbine rotor should have blades of very long length so that swept area

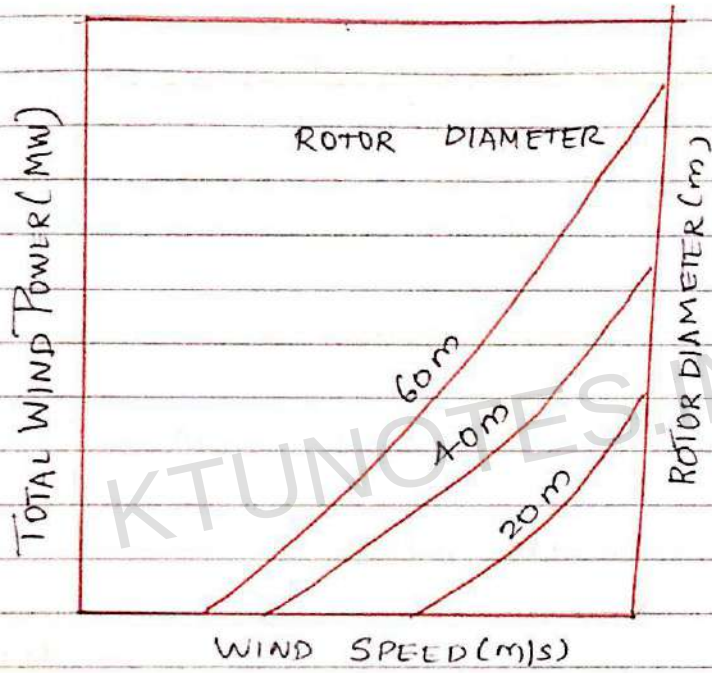
$$A = \frac{\pi D^2}{4} \text{ is adequate } \pi r^2 \quad \text{—(4)}$$

Wind turbine should be located at place having favourable wind speed through out the year.
C_v = 10 m/s in (ideal)

Substitute (4) in (3)

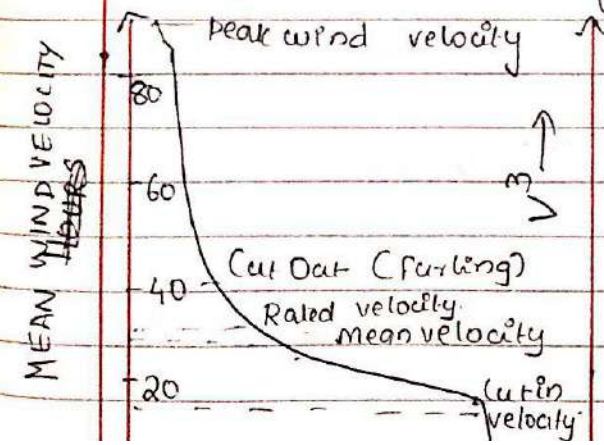
$$P_t = \frac{1}{2} \rho \frac{\pi}{4} D^2 V^3 = \frac{1}{8} \rho \pi D^2 V^3 \text{ watts}$$

P_t is varied proportional to square of diameter of intercept area (Square of rotor diameter).



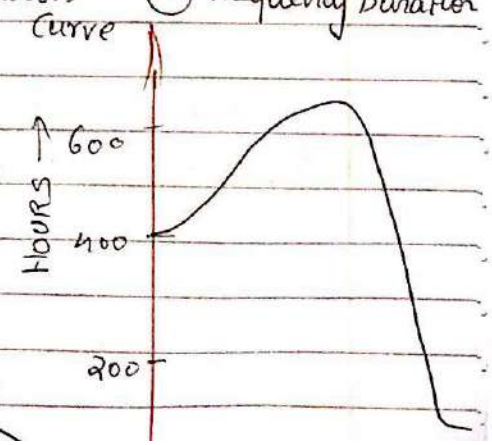
So wind machine intended for generating substantial amount of power should have large rotors and be located in areas of high wind speed

(1) Velocity Duration Curve



(2) Power Duration Curve

(3) Frequency Duration



Efficiency Factor of Wind Turbine.

η = Energy Output by Wind Turbine / Energy in Wind = P_o / P_w.

For Same interval of time
Efficiency factor is also known as Coefficient of performance.

Wind Energy Pattern factor (WEPF)

EPF is the ratio between power from speed distribution to the power from average speed of turbine blades.

EPF = Power From Speed distribution / Power from average Speed

It lies between 2 to 2.

Wind Power Density (P_{wd})

Wind is flowing air mass. Let V be wind velocity or wind speed
The air has mass density ρ_d. Flowing air has K.E as

$$P_w = K V^3 \ W/m^3.$$

P_w = Wind Power density W/m^2
K = Conversion Factor For wind Power

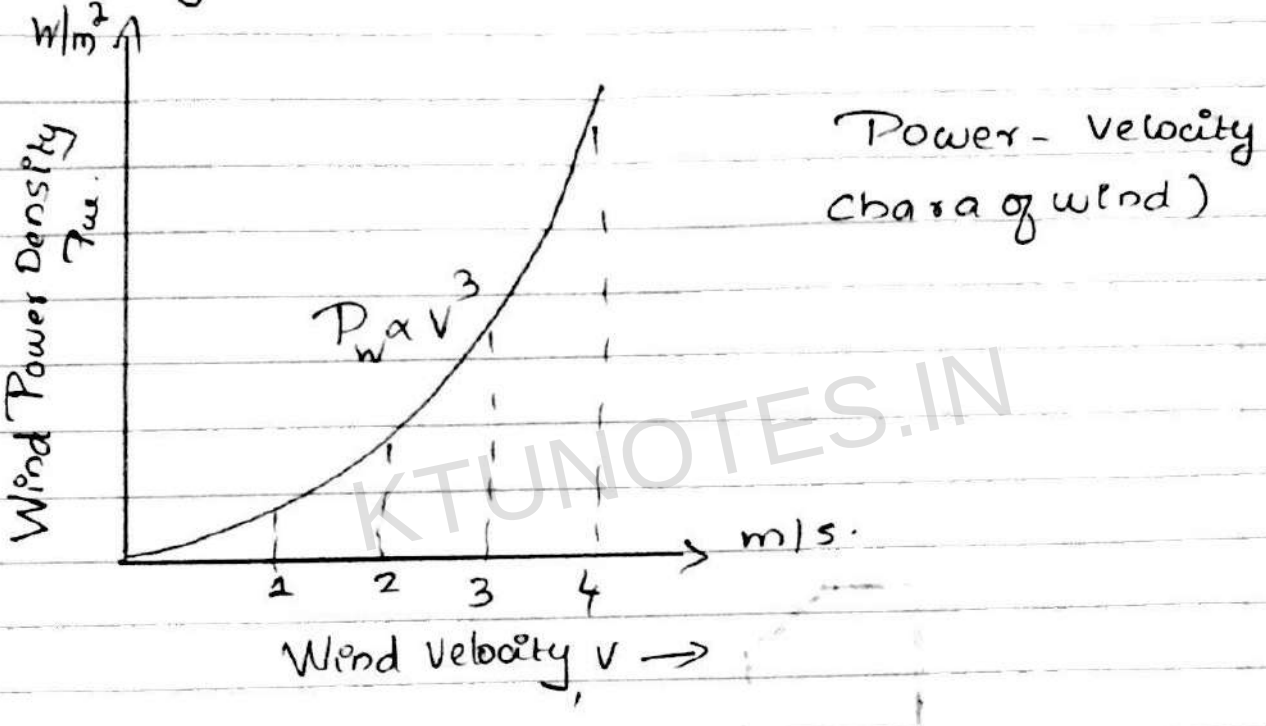
$$[K] = \left[\frac{W/m^2}{m^3/s^3}\right] = \left[\frac{W \cdot s^3}{m^5}\right] = W s^3 m^{-5}$$

The value of k in SI unit is $k = 0.6386$.
When P_w is in W/m^2 and V in m/s

Thus in SI units

$$P_w = 0.6386 V^3 \ W/m^2.$$

Power by wind turbine $P = P_w \cdot A$ watts.



Power - Velocity
Chara of wind)

P_w = Wind power density.

Energy in Wind :- Energy in time interval of power.

Energy in 'n' hours given by

$$E = \int_0^n P \, dn \ \text{Wh}$$

where E = Energy

Power Vs Hours Characteristics

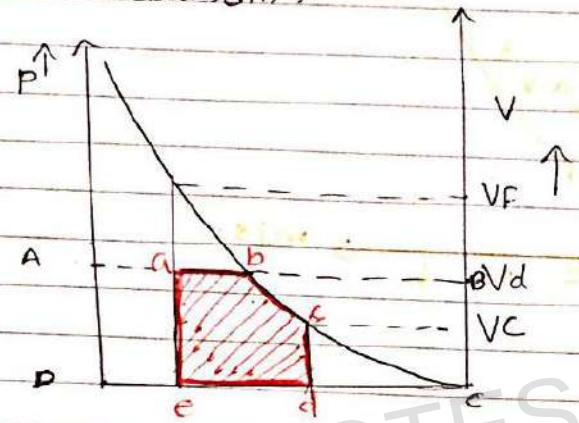
Three Speeds are associated with the design of wind mill

Vc – Cut in Speed, the Speed below which, the wind mill does not operate

Vd – Design Speed, the Speed for which the rotor is designed

Vf – Furling Speed, the Speed at which the rotor is turned away from facing the wind or stopped Otherwise with a view to protect the wind mill

Vrat – The rated velocity at which the plant Output is maximum.



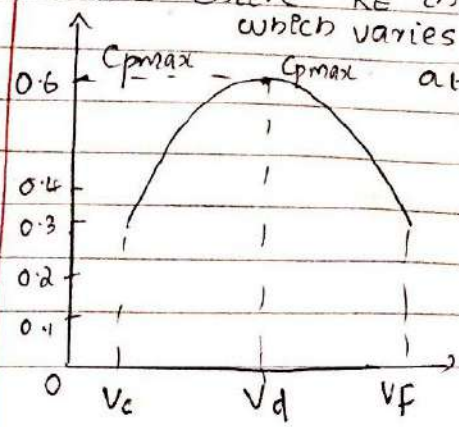
Ideal Power plant

The batched area abcde represents the annual energy Output from an ideal plant

ABCD represent the Output Obtainable From an ideal plant, if the wind mill were to operate at the design Speed all the time

The ratio of areas of $\frac{abcde}{ABCD}$ is the annual load Factor of plant

The actual Output will be smaller than that represented by area abcde due to inability of rotor to Convert the entire KE in the wind. This is represented by C_p which varies as a Fn of velocity having max. C_{pmax} at design wind Speed.



So Annual Output from plant

$$E = \int \eta_m C_p \rho A V^3 \delta_T$$

δ_T - Time increments

Site Selection Of wind Mill

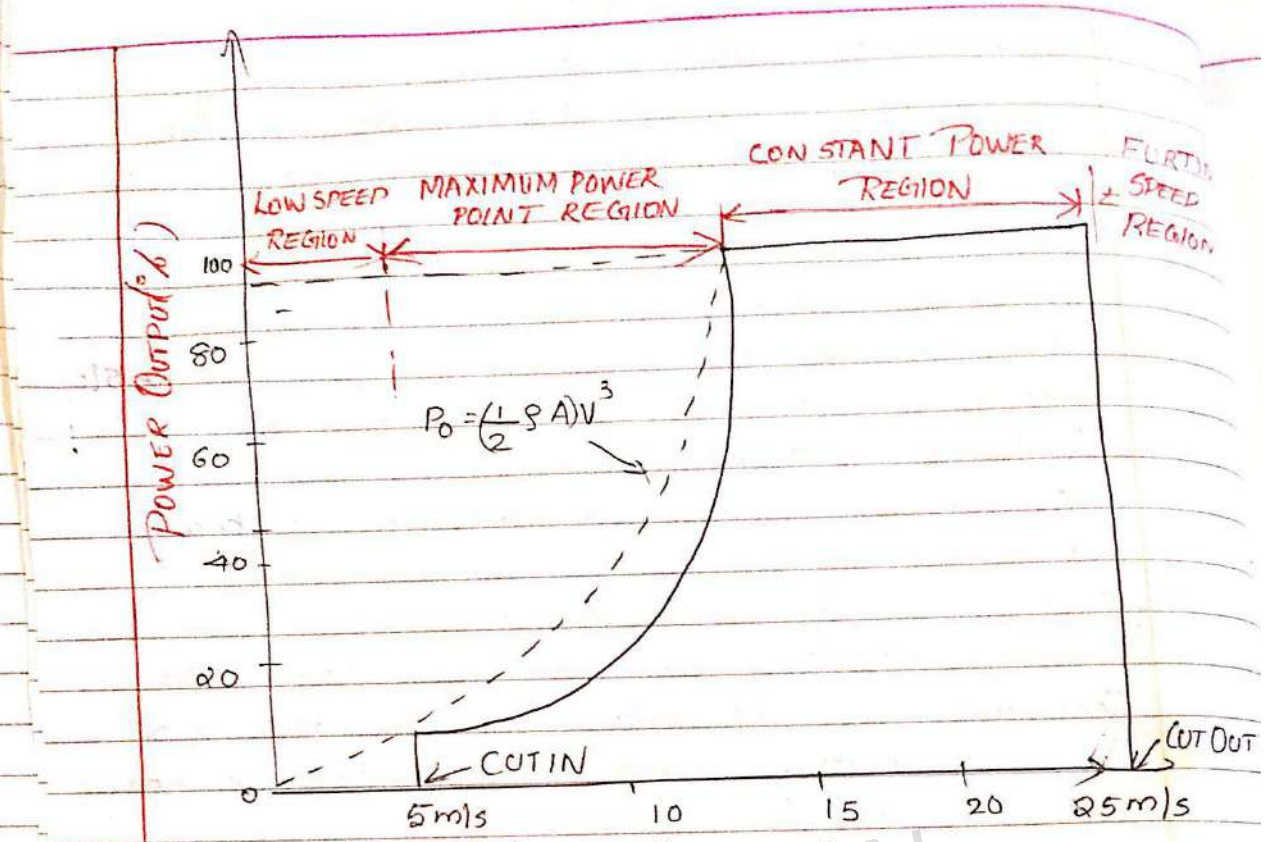
1) No tall obstructions for some distance (abt 3km) in the upwind direction (i.e the direction of incoming wind) and also as low a roughness as possible in the samedirection
2) A wide and open view i.e open plain, open shoreline or offshore locations
3) Top of smooth well-rounded hill with gentle slopes (about 1:3 or less) on a flat plain
4) An island in a lake or the sea
5) A narrow mountain gap through which wind is channelled
6) Site reasonably close to power grid
7) Soil conditions must be such that building of foundation of the turbines and transport of road-construction materials loaded on heavy trucks is feasible
8) Production results of existing wind turbine in the area to act as a guide to local wind conditions.

Strategy For Siting

(1) Survey of historical wind data
2) Contour maps of terrain and wind are consulted
3) Potential sites are visited.
4) Best sites are instrumented for approximately one year
5) Choose optimal size.

9) Favourable land cost
10) Local Ecology
11) Altitude of proposed site

Wind Speed Vs Power Characteristics



Wind Energy Conversion Systems (WECS)

Methods of Wecs Control

Based on the fundamentals, following schemes are commonly adopted and broadly classified as:

- Mechanical control methods
- Aerodynamic control methods
- Electrical control methods
- Yaw control

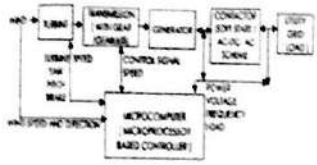
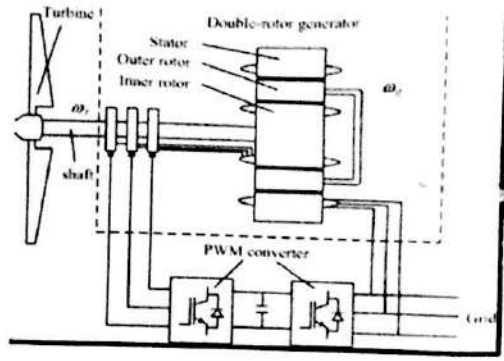
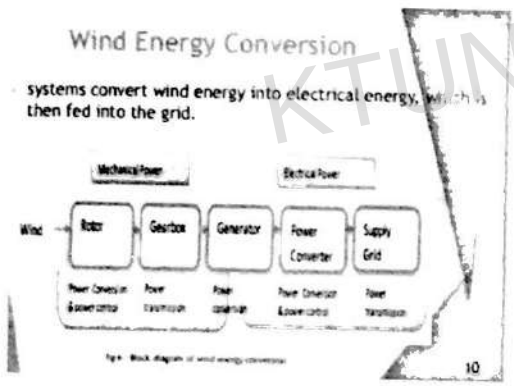


Fig. 2: Block Diagram of Wind Energy Conversion System





- WECS convert wind energy to some form of electrical energy. In medium and large scale WECS are designed to operate in parallel with a public or local ac grid. This is known as grid connected system
- A small system isolated from the grid ,feeding only to the local load is known as autonomous, remote, decentralized stand alone or isolated power system

WORKING PRINCIPLE

- The turbine shaft speed is stepped up with the help of gears,with a fixed gear ratio,to suit the electrical generator and fine tuning of speed is incoperated by pith control
- This block act as the drive for generator
- Use of variable gear ratio has been considered in the past and was found to add more problems than benefit
- Hence dc synchronous or induction generators are used
- The interface condition the generated power to grid quality power
- It consist of power electronic converter ,transformer and filter
- The control unit monitor and control the interaction amoung various blocks
- It derives the referance voltage and frewquency signal from grid and

VARIOUS TYPES OF GENERATORS

- **DC GENERATOR**: Not favoured due to high cost,weight and maintanance problemsof commutator.So PM DC motor used
- **SYNCHRONOUS GENERATOR**:Produce high quality output.But deviation from synchronous value reflect in frequency deviation.Synchronisation of wind –driven generator
- **INDUCTION GENERATOR**:It is having rugged and brushless construction,No need of separate dc power and it is having the tolerance of slight variation of shaft speed +- 10% as slip

Types of Wind Energy Conversion Schemes.

BASED ON GENERATOR DRIVE 2 SCHEMES ARE DEVELOPED FOR THE OPERATION OF WECS

1)FIXED SPEED DRIVE SCHEME
2)VARIOUS SPEED DRIVE SCHEME

FIXED SPEED DRIVE SCHEME:2 TYPE

a)one fixed speed drive
b)Two fixed speed drive

In this scheme a constant speed is maintained at the shaft of a generator by pitch control

a)one fixed speed drive

- The shaft speed is held fixed for the whole range of wind speed
- It never capture the wind energy at peak value

Of power coefficient

Wind energy is wasted when wind speed is higher or lower than optimum value

Because of low annual energy yield, the use of fixed speed drive limited to small machines

Two fixed speed drive

- It increases the energy capture and reduces the electrical losses and reduce gear noise
- Speed setting is changed by changing the gear ratio
- Two operating speeds are selected to optimize the annual energy production with expected annual wind speed distribution at the site
- The induction generator is designed to operate at 2 speeds 1)having 2 stator winding with different number of poles 2) using single winding with pole changing arrangement by connecting the winding coils in series or parallel.The pole changing with 1 pole or 2 pole 2:1 ratio

VARIABLE SPEED DRIVE

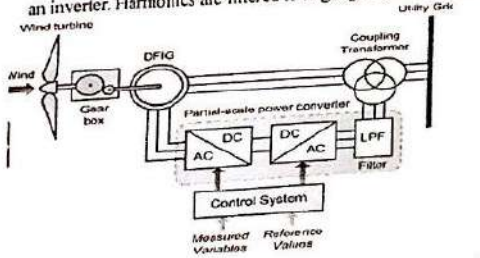
- Rotor speed is allowed to vary optimally with wind speed to capture maximum power
- As a result it can capture more power per year as compared to fixed speed drive

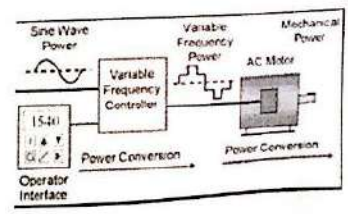
mainly divided in to 3 type

1)Variable speed driver using power electronics
2)Scherbius variable speed drive
3)Variable speed direct drive

1)VARIABLE SPEED USING POWER ELECTRONICS

- Using power electronic devices for power conditioning
- The variable voltage and variable frequency available from output available from a generator is first rectified to DC and then converted to fixed frequency and fixed voltage ac using an inverter. Harmonics are filtered to to get grid quality output





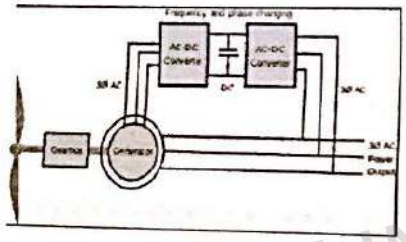
2 major benefits

1) Opportunity for remote control which make it attractive for offshore applications
2) Fine tuning for superior grid connection to make it better suitable for meeting the demand of weak signals

2)Scherbius variable speed drive

- It make use of wound rotor IM
- The stator is connected to grid and rotor is connected to variable frequency source via slip rings
- The speed is controlled by controlling the frequency of the external voltage injected in to the rotor
- It offers low cost and eliminates the power quality disadvantages
- Sliding contact at the slip ring lead to increased maintanance and range of speed control

Variable Speed Drives (VSDs), also known as **adjustable speed drives**, are large industrial electric motors whose **speed** can be adjusted by means of an external controller. They are used in process control and help saving energy in plants that use many powerful electric motors.



SLIP POWER RECOVRY SYSTEM

Static Scherbius Drive - allows operation above and below synchronous speed.

Static Kramer Drive - only allows operation at sub-synchronous speed

The case for variable speed wind turbines [edit]

Originally wind turbines were fixed speed. This has the benefit that the rotor speed in the generator is constant, thus the frequency of the AC voltage is fixed. This allows the wind turbine to be directly connected to a transmission system. However, as in the figure above, we can see that the power coefficient is a function of the tip-speed ratio. The efficiency of the wind turbine is a function of the tip-speed ratio.

Ideally, one would like to have a turbine operating at the maximum value of C_p at all wind speeds. This means that as the wind speed changes, the rotor speed must change to such that $C_p = C_{p,max}$. A wind turbine with a variable rotor speed is called a variable speed wind turbine. While this does mean that the wind turbine operates at or close to $C_{p,max}$ for a range of wind speeds, the frequency of the AC voltage generated will not be constant. This can be seen in the following equation:

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

where N is the rotor angular speed, f is the frequency of the AC voltage generated in the stator windings, P is the number of poles in the generator, and the factor 120 is a conversion factor. Thus, if direct connection to a transmission system for a variable speed is not permissible. What is required is a power converter which converts the signal generated by the turbine generator into DC and then converts that signal to an AC signal with the grid/transmission system frequency.

A. Fixed Speed Wind Turbine

In the early 1990s the standard installed wind turbines operated at fixed speed. That means that regardless of the wind speed, the wind turbines rotor speed is fixed and determined by the frequency of the supply grid, the gear ratio and the generator design. It is characteristic of fixed-speed wind turbines that they are equipped with an induction generator (squirrel cage or wound rotor) that is directly connected to the grid, with a soft starter and a capacitor bank for reducing reactive power consumption. They are designed to achieve maximum efficiency at one particular wind speed. In order to increase power production, the generator of some fixed-speed wind turbines has two winding sets, one is used at low wind speeds (typically 4 poles) and the other at medium and high wind speeds (typically 4–6 poles). Construction of fixed speed wind turbine is simple, robust and reliable. Cost of the electrical part is low.

B. Variable Speed Wind Turbine

During the past few years the variable-speed wind turbine has become the dominant type among the installed wind turbines. Variable-speed wind turbines are designed to achieve maximum aerodynamic efficiency over a wide range of wind speeds. With a variable speed operation it has become possible continuously to adapt (accelerate or decelerate) the rotational speed w_r of the wind turbine to the wind speed V. This way, the tip speed ratio λ is kept constant at a predefined value that corresponds to the maximum power coefficient. Contrary to a fixed speed system a variable speed system keeps the generator torque nearly constant and the variations in wind are absorbed by changes in the generator speed. The electrical system of a variable speed wind turbine is more complicated than that of a fixed-speed wind turbine. It is typically equipped with an induction or synchronous generator and connected to the grid through a power converter. The power converter controls the generator speed so that is, the power fluctuations caused by wind variations are absorbed mainly by changes in the rotor generator speed and consequently in the wind turbine rotor speed. The variable wind turbine increases the energy capture. This are improved the power quality and reduced mechanical stress on the wind turbine system.

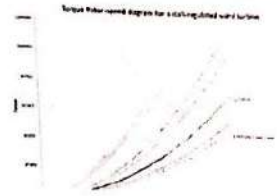
3)Variable speed direct drive

- The generator is directly coupled to the turbine shaft without gear and operate at turbine speed also doe not make use of power electronic devices
- 1)lower nacelle weight
- 2)reduced noise and vibration
- 3)lower power loss
- 4)less frequent servicing needed at nacelle

Operating strategies for variable speed wind turbines

Stall regulated

Below rated power



CAPACITY FACTOR

- The **capacity factor** is the average **power** generated, divided by the rated peak **power**. Let's take a five-megawatt **wind turbine**. If it produces **power** at an average of two megawatts, then its **capacity factor** is 40% (2÷5 = 0.40, i.e. 40%)

- To calculate the average power generated, just divide the total electricity generated, by the number of hours.
- You can find the capacity factors for Danish offshore wind here, the capacity factors for UK offshore wind are here, and here are the capacity factors for German offshore wind.
- You could do an equivalent calculation for a car. Let's say your car's top speed is 100 miles per hour, and you drove 240 miles in a day. There are 24 hours in a day, so your average speed for the whole day is 240÷24 i.e. 10 miles per hour. And so your car's capacity factor for the day is 10% (10÷100). That's different to the average speed for the journey: the calculation includes the entire time period – the whole day – not just the length of the journey, and not just the time when the vehicle was moving. It's just the same for the capacity factor of a power station, whether it's a windfarm or any other kind of generator. it includes the entire duration of time in question, not just the time it was in full working order, and not just the period it was actively generating.
- Now, given that you drove 240 miles in a day, you probably spent very little time driving at 10 miles per hour. And you probably spent very little time driving at the car's top speed either. The 240 miles you travelled were made at a wide range of speeds. It's just the same for turbine output: a turbine might spend very little time at its average output, and some of its time at its peak output, and some time at other values; and, for a typical onshore turbine, about 20% of the time at zero output, of which about 19% would be because wind speeds are too low or the turbine is offline fo

(Capacity factor)

Capacity factor is one of the important indices for assessing the field performance of a wind turbine. The capacity factor (C_F) of a WECS at a given site is defined as the ratio of the energy actually produced by the system to the energy that could have been produced by it, if the machine would have operated at its rated power throughout the time period. Thus

$$C_F = \frac{E_T}{T P_r} \qquad (5.28)$$

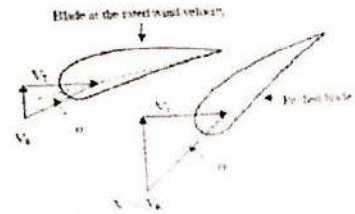


Fig. 4.10 Principle of pitch control

MODULE 6

1. BIOMASS ENERGY : Introduction
2. Photosynthesis process
3. Biomass fuels
4. Biomass conversion technologies
5. Urban waste to energy conversion
6. Biomass Gasification
7. Biomass to Ethanol Pdn
8. Biomass prdouction from waste biomass
9. Factors affecting biogas generation
10. Types of biogas plants :- KVIC & Janata model
11. Biomass pgm in India.
12. Small hydro power :- Classification as micro, mini & small hydro projects
13. Basic concepts & types of turbines
14. Design & selection considerations
15. EMERGING TECHNOLOGIES :
16. Fuel cell
17. Small Hydro Resources
18. Hydrogen Energy
19. Alcohol energy
20. Nuclear fusion & power from satellite stations

org. → organisms
pdt → product

1) PHOTOSYNTHESIS PROCESS.

→ Solar radiation incident on green plants & other photosynthesis org. perform 2 basic functions :-

(i) temperature control for chemical reactions to proceed.
(ii) photosynthesis process

→ Photosynthesis :-

* fundamental conversion process in green plants
* they are the ultimate source of most of our food, cloth, furniture, etc.
* complex process

$$xCO_2 + yH_2O + \text{light energy} \xrightarrow{\text{Photosynthesis}} xO_2 + C_x(H_2O)_y$$

(carbohydrate)

→ The pdt of this reaction are about 5eV per carbon atom higher in energy than the initial material.

$$6CO_2 + 6H_2O + \text{light energy} \xrightarrow{\text{Photosynthesis}} 6O_2 + C_6H_{12}O_6$$

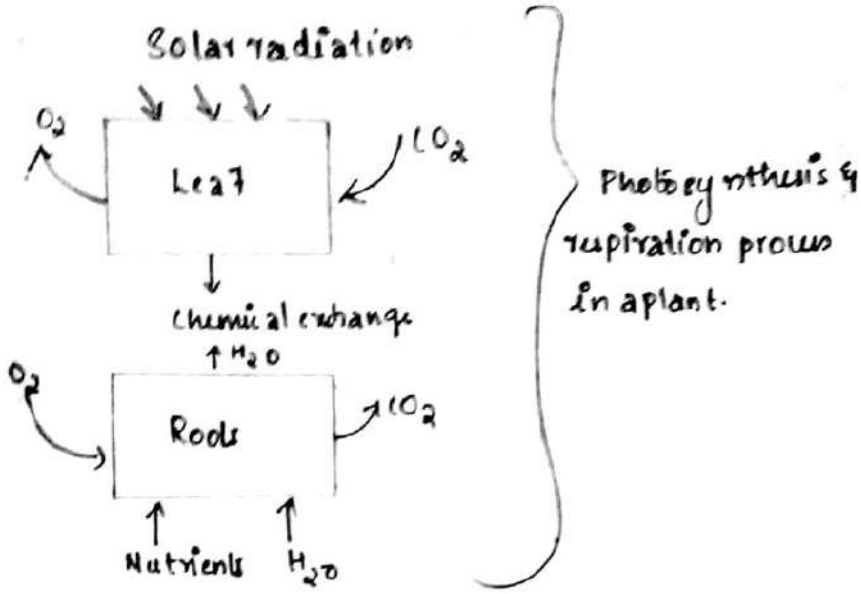
→ The reverse of photosynthesis is called respiration, in which CO_2, H_2O

and energy are produced using carbohydrate & oxygen.

→ In green plants :-

both photosynthesis & respiration occur during : day

only respiration at : night



→ The net energy absorbed from solar radiation during photosynthesis can be measured from its combustion.

$$xCO_2 + yH_2O + \Delta Q \underset{\text{combustion}}{\overset{\text{Photosynthesis}}{\rightleftharpoons}} xO_2 + C_x(H_2O)_y$$

ΔQ → enthalpy change of combustion process

ΔQ = energy absorbed from photons of solar radiation, less the energy of respiration during growth.

ΔQ = 4·8 eV per carbon atom

470 kJ per mole of carbon

16 MJ/kg of dry carbohydrate material.

→ Combustion requires the temp. of approximately 400°C, whereas respiration occurs at 20°C through catalytic enzyme reactions.

→ The uptake of CO_2 by a plant leaf is a function of :-

→ temperature → concentration & intensity & wavelength distribution of light.

→ CO_2

2) BIOMASS CONVERSION TECHNOLOGIES:

→ 4 types:-

* physical method
* incineration (direct combustion)
* thermo-chemical method
* biochemical method

1) Physical method.

→ It is through ~~combustion~~ compression of combustible material.

↓ = decreases

→ Using compression:-

→ Volume ↓s

→ Density = mass / volume ; density ↑s. } through process called:- pelletization, briquetting.

Pelletization:

→ Pelletization is a process in which waste wood is pulverized, dried & forced under pressure through an extrusion device.

→ The extracted mass is in the form of pellets, facilitating its use in steam power plants & gasification system.

→ It reduces the moisture to about 7 to 10% & is the heat-value of biomass.

Briquetting:

→ Briquetting is brought about by compression & squeezing out moisture & breaking down the elasticity of wood & bark.

→ Densification is carried out by compression under a die at high temperature & pressure.

→ Biomass briquettes serve as replacement for fossil fuels such as oil or coal, & can be used to heat boilers in manufacturing plants.

→ Burning a wood briquette is far more efficient than burning firewood.

Expelling agro products:

→ concentrated vege. oils may be obtained from certain agro pdts & may be used as fuel in diesel engines.

(2)

→ However, difficulties arise with direct use of plant oil due to high viscosity & combustion deposits.

→ ∴ These oils are upgraded by a chemical method known as trans esterification to overcome these difficulties.

- Seeds : sunflower, rapeseed, soya bean, etc.
- Nuts : oil palm, coconut copra, jojoba nuts, etc.
- Fruits : olive
- Leaves : eucalyptus

Fuel extraction

→ Milky latex obtained from freshly cut plants is called exudate

→ It is obtained by :-
cutting / tapping the stems or trunks of living plants.

→ Some plants are not amenable to tapping & in such cases the whole plant is crushed to obtain the product
eg. Euphorbia lathyris

2) Incineration.

→ Incineration means direct combustion of biomass for immidiate useful heat.

→ The heat produced is used to generate electricity or provide heat for industrial process, space heating, etc.

3) Thermochemical method.

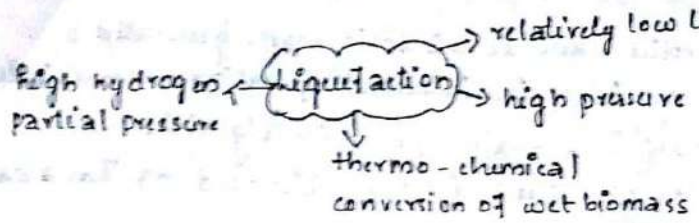
→ The basic thermo-chemical process to convert biomass into a convenient pdt is known as pyrolysis.

→ High temp. pyrolysis (≈1000°c) maximizes the gaseous pdt. This process is known as gasification.

→ Low temp pyrolysis (upto 600°c) maximizes the char o/p.

→ The process is used for production of charcoal. This process is known as carbonization.

→ liquid product is obtained through catalytic liquefaction process.



4) Biochemical method

→ This method makes use of metabolic action of microbial org. on biomass to produce liquid & gaseous fuel.

→ Two major biochemical process:-

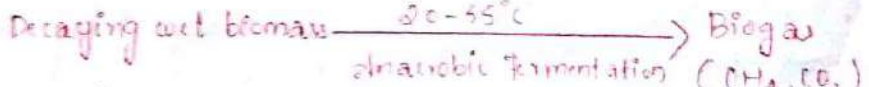
1) Ethanol Fermentation
2) Anaerobic Fermentation

1) Ethanol Fermentation

→ It occurs in the absence of air.

2) Anaerobic Fermentation

→ This process converts decaying wet biomass & animal waste into biogas through decomposition process by the action of anaerobic bacteria.



→ The biomass material in the form of water slurry is digested by the bacteria anaerobically for several days in an airtight container.

→ The reactions are slightly exothermic & small amt. of heat is also generated that helps in maintaining favorable temp.

→ The most useful biomass materials are:-

animal manure, algae, plant residues, etc.

URBAN WASTE TO ENERGY CONVERSION

1) MSW Incineration Plant

→ Municipal solid waste is the solid waste generated by households, commercial & institutional operations & some industries

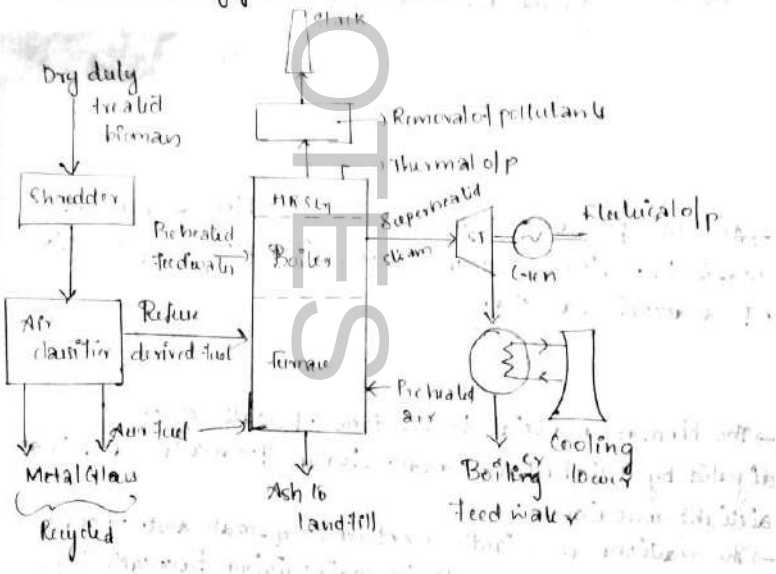
→ Disposal of MSW is a major pblm in big cities where large quantities of waste is to be disposed of, far away from the city limits.

→ The emerging solution is to use this waste biomass as an energy resource in a waste-to-energy conversion plant near city limits.

→ The energy thus generated is used within city itself & only a relatively small residue of used biomass is disposed away in landfills.

→

MSW to energy incineration plant :-



Steps:-

The dry biomass is shredded to pieces of about 2-5cm diameter.

↓

An air stream segregates refuse derived fuel (RDF) (RDF is lighter than heavier metal & glass pieces).

↓ → The heavier part is reclaimed & recycled.

The RDF thus obtained is burnt in the furnace at about 1000°C to produce steam in boiler.

↓

The superheated steam obtained from boiler is used in a steam turbine coupled with an alternator to produce electrical o/p

↓

The flue gases are discharged to atmosphere through stack after removal of pollutants such as particulate matter, SO_x, NO_x, etc.

↓

Heat recovery ~~steam~~ steam generator extracts maximum possible heat from flue gases to form thermal o/p.

↓

The ash is removed & disposed of to land fills.

→ PCDD: Polychlorinated dibenzo-p-dioxins
PCDF: " " furans.
} carcinogenic compounds

→ PCDD & PCDF cause cancer & genetic defects. They are ~~present for~~ formed either in combustion chamber or after combustion when the gases cool in the exhaust stack.

BIOMASS GASIFICATION

The process of converting solid fuel into a gaseous fuel by thermo-chemical method without leaving any solid carbonaceous residue is called biomass gasification.

Gasifier is the equipment that converts biomass into producer gas.

→ Most common raw materials are:-

- → wood chips
- → waste from wood industry, coconut shells, etc.

→ Gasification involves :-

- * partial combustion
- * reduction

→ In a typical combustion process generally oxygen is surplus, while in gasification process fuel is surplus.

$C + O_2 \longrightarrow CO_2$ (Combustion)

$C + CO_2 \longrightarrow 2CO$ (Boudouard reaction)

$C + H_2O \longrightarrow CO + H_2$ (Water gas reaction)

$CO + H_2O \longrightarrow CO_2 + H_2$ (Water shift reaction)

$C + 2H_2 \longrightarrow CH_4$ (Methane reaction)

Gasifiers are broadly classified into:-

(i) Fixed bed gasifier → downdraft, updraft, cross draft

(ii) Fluidized bed gasifier

(iii)

BIOMASS TO ETHANOL PRODUCTION.

→ Ethanol is manufactured by action of microorganisms on carbohydrate. This process is known as alcoholic fermentation.

Carbohydrate

- Monosaccharides
- Oligo
- Poly.

Monosaccharides :-

→ eg:- glucose ($C_6H_{12}O_6$), fructose ($C_6H_{12}O_6$).

→ They are simple hydrocarbons, which can't be hydrolysed into simpler compounds.

Oligosaccharides :-

→ eg:- disaccharide :- sucrose, maltose, etc.

→ oligosaccharides yield few but definite numbers (2-10) of monosaccharide molecule on hydrolysis.

Polysaccharides :-

→ These are high molecular mass carbohydrates, which yield large no. of monosaccharide molecules on hydrolysis.

→ eg:- starch, cellulose.

Mono } crystalline solids
Oligo } soluble in water, sweet in taste
∴ They are collectively known as sugars.

Polysaccharides → amorphous, insoluble in water, tasteless
⇓
non sugars

→ The hexose required for ethanol fermentation is derived from:-
1) sucrose 2) starch 3) cellulose.

From sucrose:- $C_{12}H_{22}O_{11}$ (sucrose) $\xrightarrow{\text{hydrolysis}}$ $C_6H_{12}O_6$ (glucose) + $C_6H_{12}O_6$ (Fructose)

From starch:-

$2(C_6H_{10}O_5)_n$ (starch) $+ n H_2O \longrightarrow n C_{12}H_{22}O_{11}$ (maltose)

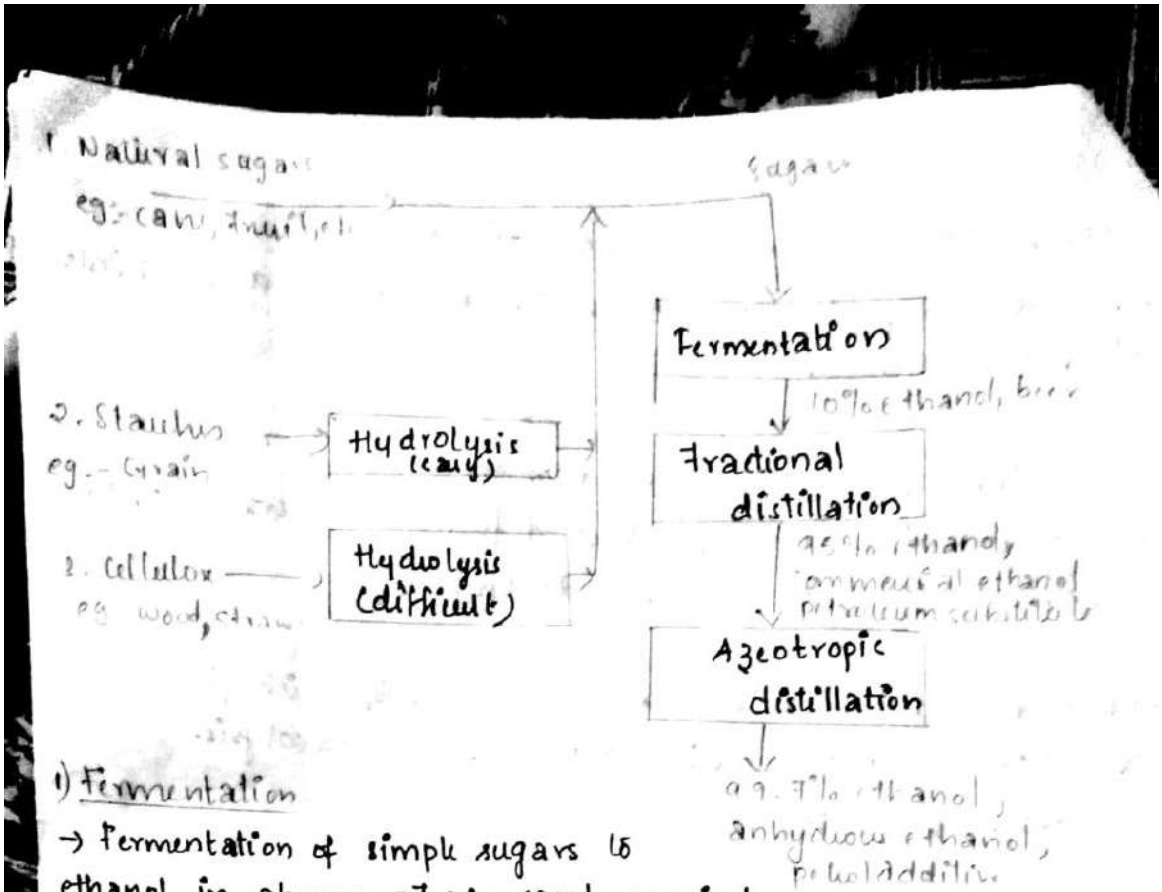
$+ n H_2O$ ⇓

$\longrightarrow 2n(C_6H_{12}O_6)$ (Glucose)

From cellulose :-

$(C_6H_{10}O_5)_n$ (cellulose) $+ n H_2O \rightarrow n(C_6H_{12}O_6)$ (glucose)

$C_6H_{12}O_6$ (hexose) $\xrightarrow[\text{fermentation}]{32^\circ C}$ $2(C_2H_5OH)$ (ethanol) + energy



1) Fermentation

→ Fermentation of simple sugars to ethanol in absence of air, can be carried out either in batches or continously.

→ This is a slow reaction & after 36 hrs, 94% sugar is utilized.

→ The most common microorg. yeast, is poisened by ethanol concentration greater than 10% so the fermentation process ceases when the resulting liquid contains about 10-12% ethanol.

2) Fractional distillation

→ The concentration of ethanol is ↑d to 95% by successive fractional distillational.

→ The pdt is known as pure commercial alcohol & used as fuel in IC engines or other thermal applications.

3) Azeotropic distillation.

→ The remaining 5% water cannot be removed by simple distillation.

→ Special procedure called azeotropic distillation (co-distillation with solvent such as benzene) is used to reduce water content to get 99.7% pure ethanol.

→ This is known as absolute or anhydrous ethanol.

→ This ~~anhyd~~ ~~abs~~ anhydrous ethanol is used for blending with

→ The second distillation process, accounts for about 40–60% of total plant energy requirements.

→ Ethanol fermentation process produces considerable quantities of CO_2, which can be easily recovered, compressed & used as an additive in beverage & food industries.

→ It can also be made into dry ice & used for refrigeration process.

BIOMASS PRODUCTION FROM WASTE BIOMASS

→ anaerobic fermentation :-

Wet biomass with about 90-95% water content —(anaerobic bacteria)→ biogas

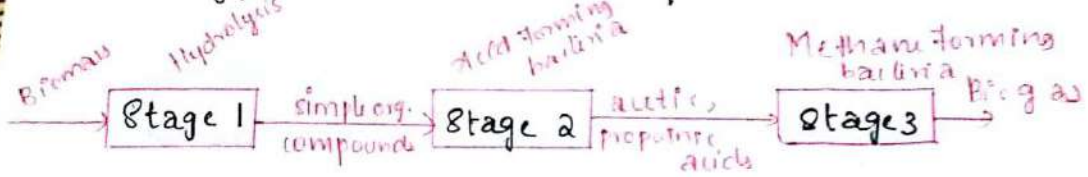
↓

part of C is oxidised & another part reduced to produce CO_2 & CH_4.

→ The above process is favoured by wet, warm & dark condition.

→ The airtight equipment used for conversion is known as biogas plant / digester

→ The Energy conversion efficiency = 60-90%.



Stage 1 :- The process takes about a day at 25°C in an active digester.

All original organic matter containing complex compounds —(broken with the influence of water)→ simple water soluble compounds

HYDROLYSIS

Stage 2 :-

→ The micro org. of anaerobic & facultative gps, together known as acid formers produce mainly acetic & propionic acids.

→ It also take about one day at 25°C.

Much of CO_2 is released in this stage.

Stage 3

Anaerobic bacteria, also known as methane formers slowly digest the acids available from 2nd stage to produce methane, CO_2, small amt of H_2 & trace amt of other gases.

→The process takes about 2 weeks time to complete at 25°C.