Renewable Energy

(Diploma 6TH SEM)

Education for a World Stage

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① Introduction to Renewable Energy

1.1 Environmental Consiquences of fossil fuell use:-

* Fossil fuels which includes coal, natural gas, Petroleum, shale oil and bitumen are the main source of Heat and electrical energy. All these fuel contain - besides the major constituents (carbon, hydrogen, oxygen) – other materials including metal, sulfur and nitrogen compounds. During the combustion process different pollutants like fly ash, sulfur oxides (SO_2 and SO_3), Nitrogen oxides ($NO_3 = NO_2 + NO$) and volatile organic compounds are emitted. Fly ash contains different traee elements (heavy metals) Gross emission of pollutants is tremendous all over the world. These pollutants are present in the atmosphere in such conditions that they can affect man and his environment.

* Air pollution caused by particulate matter and other pollutants not only acts directly on the environment but by contamination of water and soil leads to their degradation. wet and dry deposition of inorganic pollutants leads to acidification of environment. These phenomena affect the health of the people, increase corrosion and destroy cultivated soil and forests. Most of the plants, especially coniferous tree are not resistant oxides. Following longer exposure leaves wither and fall. Widspread forest damage has been reported in Europe and North America. Many cultivated plants are not resistant to these pollutants, especially in the early period of vegetation.

1.2. Importance Of Renewable Sources Of Energy:

* Concern for the environment due to ever-increasing use of fossil fuels and rapid depletion of natural resources have led to developement of alternative source of energy which are renewable and environmental friendly. The following points may be mentioned in this connection:

(1) The demand of energy is increasing by leaps and bound due to rapid industrialization and population growth, and hence the conventional source of energy will not be sufficient to meet the growing demand.

(2) Conventional sources (Except hydro) are non-renewable and are bound to finish up one day.

(3) Conventional sources fossil fuels, nucleare also cause pollution, there by their use degrade the environment.

(4) Large hydro resources affect wildlife, cause deforestation and pose various social problems.

(5) In addition to supplying energy, fossil fuels are also used extensively as feed stock materials for the manufacture of organic chemicals. As reserve deplete, the need for using fossil fuels exclusively for such purpose may become greater.

* Due to these reasons it has become important to explore and devlope renewable energy resources to reduce too much dependence on conventional resources. However, the present trend of developement of non-conventional sources indicate that these will serve as supplement rather than substitute for conventional sources for some more time to come.

1.3. Sustainable design and Development:

* Global environmental degradation is one of the most serious threats facing Mankind as a result of the expansion of it's activities around the globe. One of the international responses to global environmental problems - the framework Convention on climate change was ratified and came into effect in March 1994.
* The convention aims not only at stablizing CO_2 emissions in developed countries but also at ultimately reducing man-made CO_2 emissions globally so as to stablize the global climate.
* However, with fossil fuels comprising nearby 90 per cent of primary energy sources in the world, the final target of the framework convention seems very ambitious.
* Environmental degradation cannot be signed out as an independent matter among various global issues. Also important are the interactions among economic development, stable energy supplies and globe environmental conservation.
* In the next few decades fossil fuels will continue to be the principal source of energy driving economic development. The source of fossil fuels is stable and their extraction is affordable.
* Attempts to restrict the use of fossil fuels for environmental reasons are likely to have a negative impact on economic development and the overall availability of energy. Thus the "three Es" - Environment Energy and economic development are closely interrelated in a complex manner.

* The strategy for mitigating "three Es" issues is a strategy for environmentally sustainable economic development. Herman Daly, a famous ecological economist laid down three conditions for sustainability:

① The consumption rate of renewable resources is not higher than its recovery rate.

② The consumption rate of non-renewable resources is not higher than the rate of increase in renewable resources supply.

③ The emission of pollutants is within the absorption capacity of the environment.

* Unfortunately, these conditions have been violated for years. Example of respective violations typically include deforestation, the depletion of fossil fuels, and the increase in CO_3 concentration in the air.

* Such violation may be hard to reverse in the short term but unless long term remedial action taken present global development trends will not be sustainable.

* In particular, a substaintial reduction in resocercee consumption and emission of pollutants is essential for the development of a sustainable human society on this planet.

* As evident from the above discussions, economy, environment and energy are closely interrelated and an overall policy is required to deal with them.

1.4. Types of Renewable Energy Sources:

- **Renewable Energy:**

* Renewable energy is useful energy that are obtained naturally from the environment. These energies are quikly becoming inexpensive as well as efficient. And that includes solar, biomass, wind, hydropower, geothermal etc. It is very benificial due to their partial negative ecological impact when costrasted to fossil fuels.
* A long time ago this energy is not used much due to their cost. But some of the energy sources are smart financial choices for hospitals, business and homes. Particularly, solar energy is the best option for house owners who want to reduce their environmental track while conserving money.

- **Different types of Renewable Energy Sources:**

There are different types of energies that are considered renewable energies namely solar energy, wind energy, tidal energy, hydroelectric energy, geothermal energy, Biomass energy etc.

(1) Solar Energy:

* Solar energy is one of the most popular and also the fastest growing renewable energy sources. As a free renewable energy source, technology has created a technique for connecting the energy of the sun through solar panels.
* Solar panels are classified into two types namely.
  (i) Solar PV cells.
  (ii) Solar thermal panel.

(i) Solar PV cells absorbs the sun's energy and change it into electrical energy, which is used in different applications like electric heating, power appliences, in electric cars, etc.

(ii) Solar thermal panels uses energy and these panels are used in taps, heating systems, showers, etc.

* A solar energy is the best option in rising renewable energy marketplace.

(2) Biomass Energy:

* Biomass energy is most widely used renewable energy. It uses organic materials like drimals, plants and converts them into another form of energy that can be used. For instance, when the plants absorb the solar energy through photosynthesis process, then this energy will pass on through the plant's organism for making biomass energy.
* The common type used for generating biomass energy is, crops, wood, and compost. If the Biomass energy technology is not controlled properly then it can have a harmful effect on the environment.

(3) Wind Energy:

* Wind energy has been using for several years for power windmills, pushing sails and also for generating force for water pumps. When we constrasted to other types of renewable energies wind energy is considered as well as very reliable.
* At first, the wind farm construction was an expensive venture but now the recent developments have begun for fixing the peak prices in wholesale energy markets globally and reduce the profits and revenues of the fossil fuel production companies.

(4) Hydroelectric Energy:

* The hydroelectric energy uses the flow of water to rotate turbines for generating electricity. According to the US survey of geological, this renewable energy provides 20% of the energy in the world energy requirements.
* There are some issues while using hydroelectric energy. This energy can be generated from the dammed rivers; otherwise it can have a major effect on the soil as well as wildlife and also affects on fish communities that must journey through the river dams.

(5) Tidal Energy:

* Tidal energy is the same as wind energy but these are predictable as well as steady. This is the main reason that tidal mills have been used sience the ancient days to middle ages similar to windmills.
* Usually, Tidal energy has faced from relatively high cost as well as incomplete accesibility of sites through suitably high tidal ranges. But, several current technological developments both in technology and design point outs that the entire tidal power availability may be superior to previous, and the environmental costs may be getting down to competitive stages.
* The "Rance Tidal power stations" is the world's largest tidal energy power plant in France. And in scotland and Orkney, the first world's marine energy enter, as well as European marine energy center, was established in the year 2003 for developing the tidal energy and wave energy industry in the UK.

(6) Geothermal Energy:

★ The term Geothermal taken from the Greek word Geo (Earth), and it receives the heat from the earth and converts it into energy. For instance, hot water or steam energy which are generated from the earth can be utilized for generating energy. it is called to be a renewable supply of energy because the water is filled by normal rainfall and the heat used is generated through the planet.

★ Grocend basis heat pumps can be fixed to connect the normal heat from underground using fluid tubes. Covered outside the assets. The fluid in the tubes absorbs the heat from the grocend so it can be used to heat your home and water. For assets that are located close to a river or lake, it is achivable to fix a heat pump for water source. These pipes are flooded in the water as well as a heat pump drives a heat absorbs liquid during the arrangement of piping. This liquid removes normal heat from the nearby water to be utilized in the seating arrangement.

★ Advantages of Renewable Energy Sources:

(1) Renewabl Energy is eco-friendly:

- Renewable energy is considered clean energy since it doesn't cause grave epvironmental pollution, and it has low or zero carbon and green house emmission.
- Fossil fuels emit high levels of greenhouse gas and carbon dioxide, which are greatly responsible for global warming, climate change and degradation of air quality.

(2) It's a Renewable Resource:

- This implies that they do not deplete over a lifetime, and there is zero possibility that they will reenout.
- Source of fossil fuels (oil, gas and coal) are considered limited resources and there is a strong posibility that they will reenout in the futcere.

(3) Renewable Energy is a Reliable Source of Energy:

- The fossil feel has sharply increased. This over-reliance on fossil fuels has led to our secerity being threatened. fossil fuels are prone to trade disputes, a spike in energy prices and cennecessary wars. These variable affect a lot more than a nations energy policy; They can significantly drain a country's economy.

(4) Although most argue that solar and wind energy is unreliable, a solid infrastructure puts this argument to rest. If solar and wind plants are distributed over a large geographical location, there can be minimal electricity generation interreption because wheather disreptions in one location cannot be the same in other locations.

(4) Leads to Job Creation:

- Renewable energy makes real economic sence because it is a cheaper alternative to most traditional Source of energy. Since the inception of renewable energy, new and stable jobs have been added to the most world economies.
- For instance, in Germany and UK, many jobs have already been created.

(5) Less maintenance of Facilities:

Renewable energy technology requires less overall maintenance than traditional generators that use traditional fuel sources. This renewable energy generating technology like solar panels and wind turbine either have few or no moving parts. Above all, they don't rely on flammable, combustible fuel source to operate, which makes the operating cost lower too.

(6) Renewable Energy has stabilized Global Energy prices:

Change upto renewable source of energy means the stability of energy prices across the globe. This because the cost of renewable energy depends on the initial cost of installation of renewable energy technology as opposed to fossil fuels.

(7) Boosts Public Health:

This is a no-brainer. The sources for renewable energy generation emit little to no greenhouse gases or pollutants into the air. This means a smaller carbon footprint and an overall healthier atmosphere.

(8) Empowering of people in countryside:

Renewable energy generation mainly takes place in remote settings. This means that local towns would get a fair share of power generated, ultimately catalyzing the regeneration of those depressed areas both socially and economically.

(9) It can be used to Recycle our waste products:

- Biomass energy tends to have this specific benifit that more than any other form of renewables. Biomass consume used organic products such as vegetable oil, corn and soyabean byproducts or even algae to generate energy.
- At the same time, it reduces the amount of waste that goes into landfills, also reducing the amount of overall carbon that goes into the atmosphere.

(10) It is offered in Multiple Formats:

We use many different forms of renewable energy today, even without realizing it. Energy diversity is possible through renewable energy. One of the most common forms of renewable energy is hydro power

1.5. Limitations Of Renewable Energy Sources:

(1) The Electricity Generation capacity is still not large Enough:

- There is still challenges to the generation of large quantities of power in renewable energy technology compared to traditional forms of energy like fossil fuel.
- Fossil fuel still produces large quantities of electricity today, by far. This essentially means that it can't be solely relied upon to power the whole nation.

(2) Renewable Energy can be Unreliable:

- Renewable energy technology totally depend on the weather (e.g. sun, rain and wind) to be able to harness any energy.
- In case of atmospheric conditions are not good enough, renewable energy would lack the ability to generate any electricity.

(3) Low efficiency levels:

Renewable energy technologies are still significantly new to the market, meaning, they still lack the much needed efficiency. Lack of sufficient knowledge on how to effectively harness these forms of energy makes the installation and maintenance cost for such facilities quite high.

(4) Requires a huge upfront capital outlay:

Setting up renewable energy generation facilities requires a huge financial outlay. The installation of wind turbines, solar panels and hydroelectricity plants is relatively expensive.

(5) Takes a Lot of Space:

It takes a lot of space for installation of generating plants like: (1) 40 hectares of panel to generate 20 megawatt.
(2) 259 hectares of nuclear plant generate 1000 Mwatt.
(3) 1.5 acres of wind energy plant generate 2 megawatt.

(6) Expensive Storage costs:

- We often overlook the storage cost of renewable energy in case of renewable energy you must store the energy collected having a battery installed or else you will lose it.
- The overall storage cost for the energy is about 9 cents per Kilowatt hour, however, the cost of the battery is upfront. That means $10,000 to $25,000 upon installation just for battery.

(7) Not always a commercially viable option:

To be effective, renewable energy must have a distribution network created to transfer the energy to where it is required. Those networks require non renewable energies to be generated, which offsets the benifits that renewable energy generated for many years, if not decades, after it's installation.

(8) It still generates pollution:

Renewable energy may be better option for emission than fossil fuels, but they are not completely free from pollution. It is partly because the resources needed for renewables are built using fossil fuels.

1.6. Present Indian and International Energy Scenario:

* World Energy status:

- At present (year 2008) the annual primary energy consumption of the world is 500 exajoules.
- Fossil fuels roughly provide about 90% of this energy and will continue to provide more than 80% of the total energy demand well into the future.
- Approximately 25% of this energy is consumed in transportation secton and remaining 75% by industries, domestic, agriculture and social consumers.
- The energy demand has grown astronomically in recent years with primary energy demand increasing by more than 50% since 1980.
- This growth is forecast to continue at an annual average rate of 2.2% during 2004 - 2030. over 70% of this growth will come from developing countries.

* Energy Scenario in Indlia:

- India is both a major energy producer and consumer. India currently ranks as the world's eleventh greatest energy producer, accounting for about 2.4% of the worlds total energy production, and as the world's sixth greatest energy consumer, accounting 3.3% of the world's total annual energy consumption.

- Thus, India is a net energy importer, mostly due the large imbalance between oil production and conscemption.
- As per 2005 data for India, the total annual primary energy production and consemption was 11.73 Quad BTU and 16.205 Quad BTU respectively.
- The per capita primary energy consumption is 520 KGOE for India, whereas the world average is 2366 KGOE.
- Similarly, the percapita annual electrical energy consemption in india is 702 KWh whereas the world average is 2600 KWh (2007 data).

* Sectorwise Energy Consumption:

Sector	Percentage Power Consumption
Industry	49 %.
Transport	22 %.
Residental	10 %.
Agriculture	5 %.
Others	14 %.

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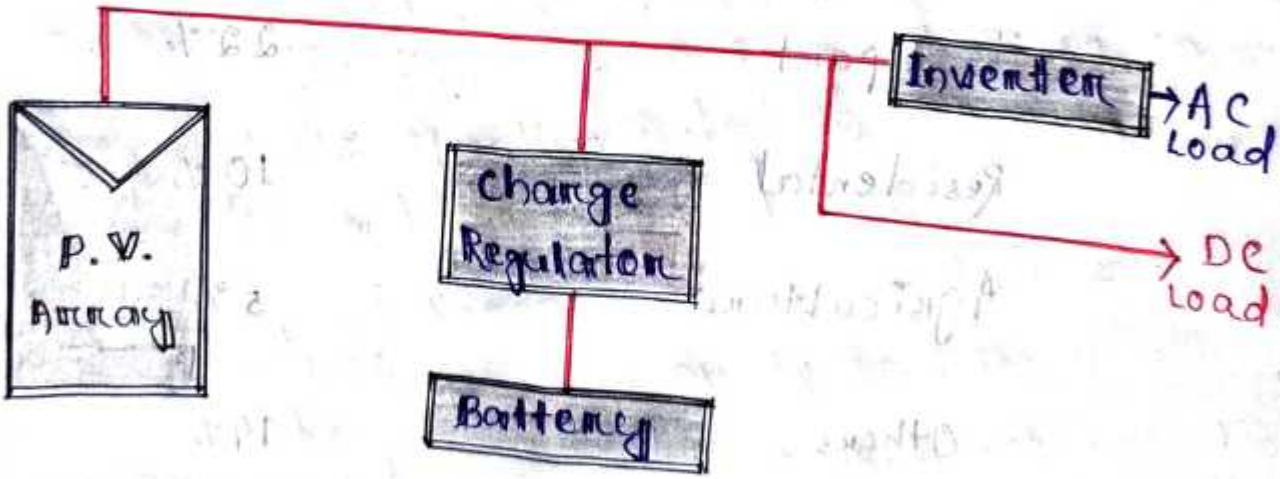
② Solar Energy

2.1. Solar Photovoltaic operating System:

* A pv module produces dc power. To operate electrical appliance used in households, inverters are used to convert dc power into 220V, 50Hz Ac power.
* Components other than PV module are collectively known as Balance of system (BOS) which includes storage batteries, an electronic charge collector and an inverter.
* Storage battery with charge regulators are provided for back-up power supply during periods of cloudy days and during night. Batteries are charged during the day and supply power to loads as detailed in below figure.



(Block Diagram of Solar PV Operating System)

* The capacity of a battery is expressed in ampere hours (Ah) and each cell of the lead acid type battery is 2 volts. Batteries are installed with a microprocessor based charge regulator to monitor the voltage and temperature and to regulate the input and the output currents to obviate overcharging and excessive discharge respectively.

* An inverter is provided for converting dc power from battery or PV array to Ac power. It needs to have an automatic switch-off in case the output voltage from the array is too low or to high. The inverter is also protected against overloading and short circuit.

2.2 Photovoltaic Cell concept:

• Solar Cell:

* The basic cell structure of a typical n-on-p, bulk silicon cell is shown in figure. The bulk material is p-type silicon with a thickness of 100 to 350 microns, depending on the technology used.

* A thin layer of n-type silicon is formed at the top surface by diffusing an impurity from the Vth group to get a pn junction.

* The top active surface of the n layer has an ohmic contact with metallic grid structure to collect the current produced by pinging photons.

* The metallic grid covers minimum possible top surface area to leave enough uncovered surface area for incoming photon. Similarly, the bottom inactive surface has an ohmic metallic contact over the entire area.

* These two metallic contacts on p and n layers respectively from the positive and negative terminal of the solar cell.

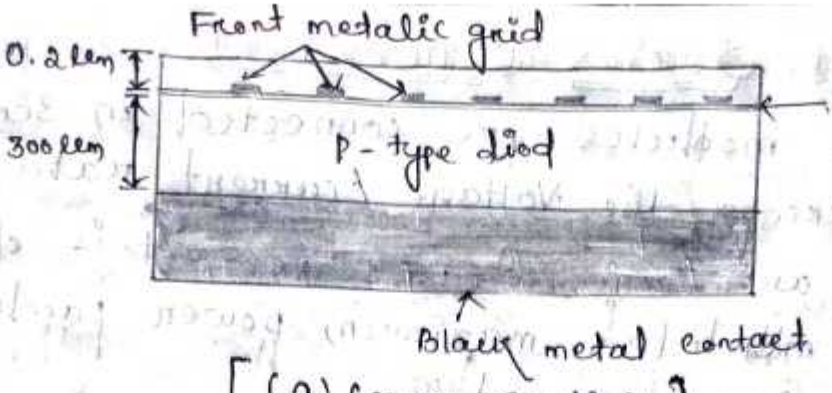
* In addition to basic elements, several enhancement features are also includes in the construction. For example, providing antireflective coating, textured finish of the top surface and reflective, textured rear surface, to capture maximum photons and direct them toward the junction.

• Solar PV Module:

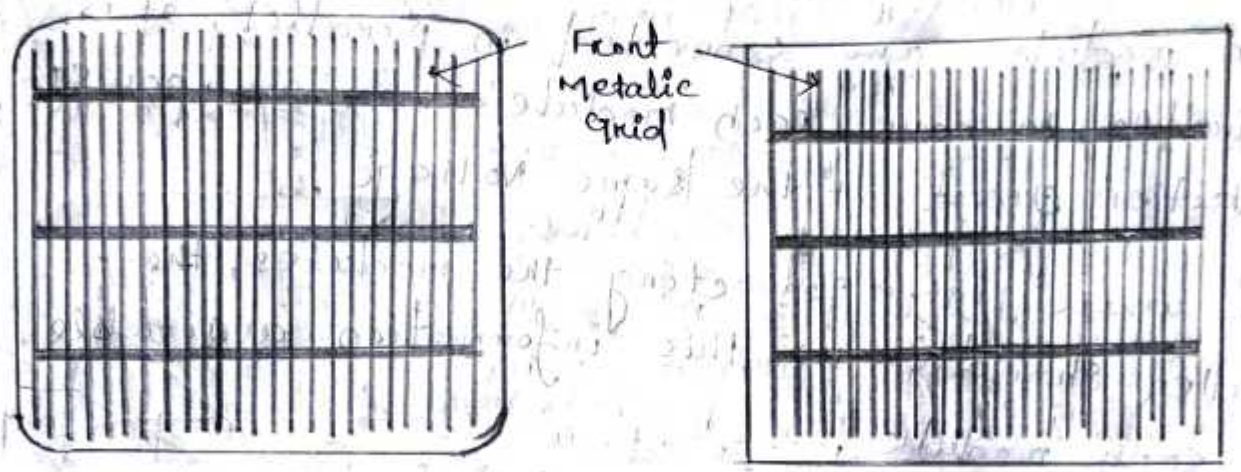
* A bare single cell cannot be used for outdoor energy generation by itself. It is because (i) the output of a single cell is very small, and (ii) it requires protection against dust, moisture, mechanical shocks and outdoor harsh conditions.

* Workable voltage and reasonable power is obtained by interconnecting an appropriate number 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 applications.

* This assembly is known as solar module - a basic building block of a PV system. The most common commercial modules have a series connection of 32 or 36 silicon cells to make it capable of charging a 12V storage battery. However, larger and smaller capacity modules are also available in the international market.



[(a) Cross section]



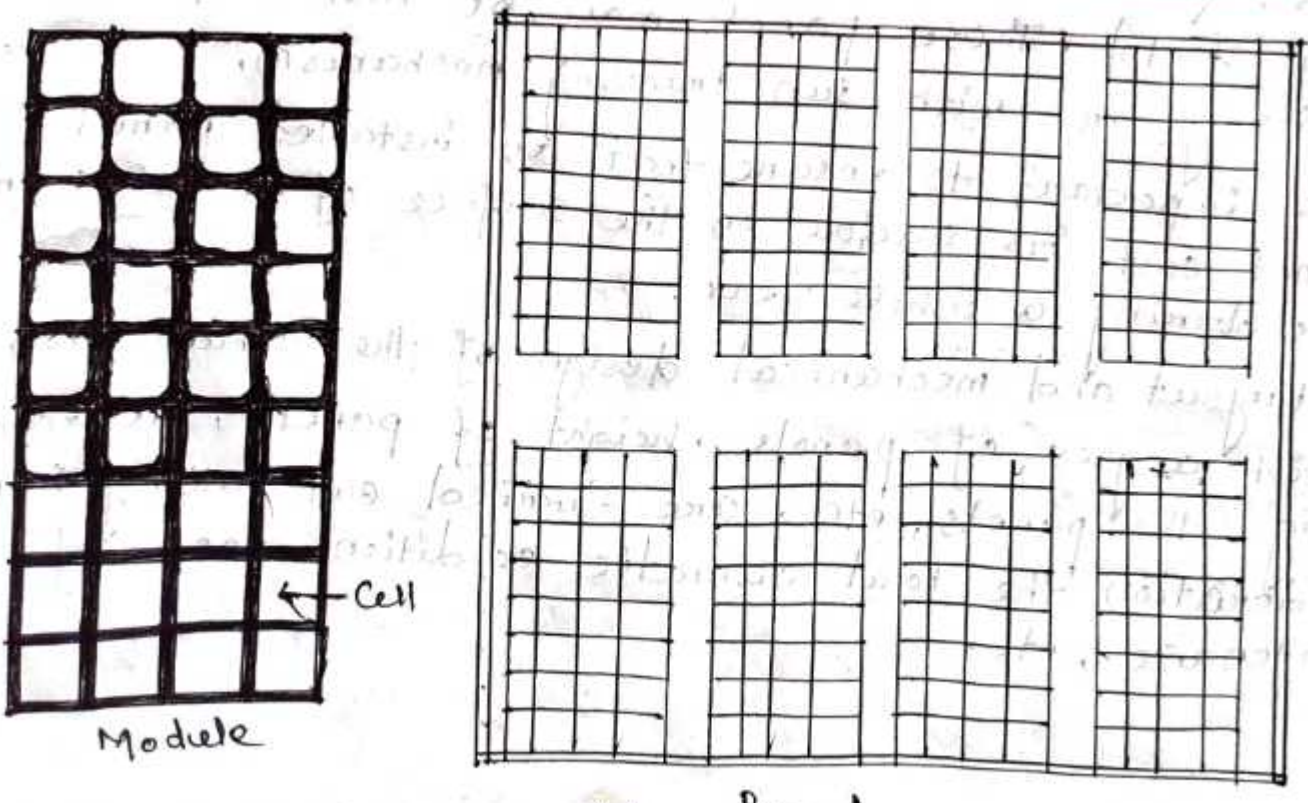
(Construction of bulk silicon cell)

• Solar PV Array:

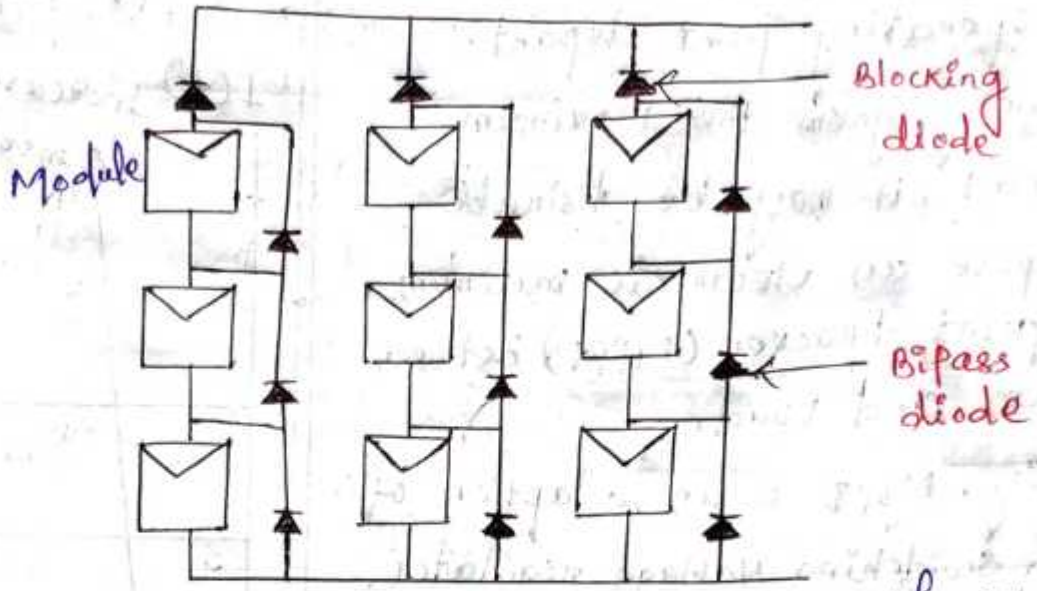
* In general, a large number of interconnected solar panels, known as solar PV array, are installed in an array field. Those panels may be installed as stationary or with sun tracking mechanism.
* It is important to ensure that an installed panel does not cast its shadow on the surface of its neighbouring panels during a whole year.
* The layout and mechanical design of the array such as tilt angles of panels, height of panels, clearance among the panels, etc. are carried out taking into consideration the local climatic conditions, ease of maintenance, etc.

• Parallel and Series Connection:

* Several solar modules are connected in series / parallel to increase the voltage / current ratings. When modules are connected in series, it is desirable to have each module's maximum power production occur at the same current.
* When modules are connected in parallel, it is desirable to have each module's maximum power production occur at the same voltage.
* Thus while interconnecting the modules, the installer should have this information available for each module.
* Solar panel is a group of several modules connected in a series-parallel combination in a frame that can be mounted on a structure. fig. shows the construction of module and panel.



(Cell, Module, Pannel)



(A typical panel series parallel connection of module)

* figure shows a series-parallel connection of module in a panel. In a parallel connection, blocking diodes are connected in series with each series string of modules, so that if any string should fail, the power output of the remaining series strings will not be absorbed by the failed string.
* Also, bypass diodes are installed across each module, so that if one module should fail, the output of the remaining modules in a string will bypass the failed module. Some modern PV modules come with such internally embedded bypass diodes.

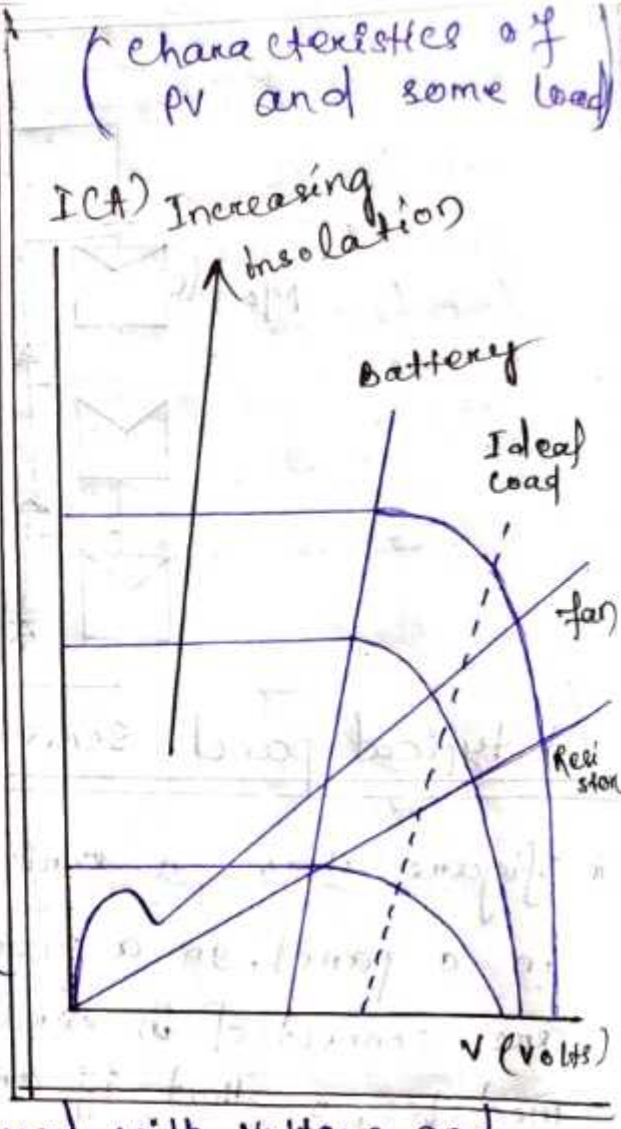
• Maximum Power Point Tracker (MPPT):-

* When a solar PV system is deployed for practical applications, the I-V characteristics keeps on changing with insolation and temperature.
* In order to recieve maximum power, the load must adjust itself accordingly to track the maximum power point.
* The I-V characteristics of PV system along with some common loads are shown in fig. An ideal load is one that tracks the

maximum power point.

* If the operating point departs significantly from the maximum power point, it may be desirable to interpose an electronic maximum power point tracker (MPPT) between PV system and load.

* Generally, MPPT is an adaption of dc-dc switching voltage regulator. coupling to the load for maximum power transfer may require either providing a higher voltage at a lower current or lower voltage for higher current.

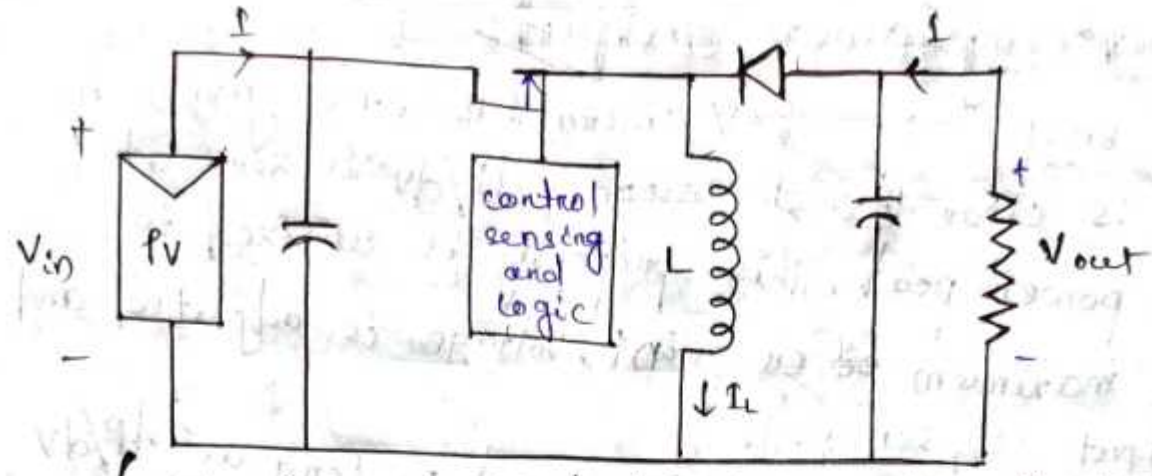


* A buck-boost scheme is commonly used with voltage and current sensors tied into a feedback loop using a controller to vary the switching times.

* Basic elements of a buck-boost converter that may be used in an MPPT are shown in fig the output voltage of the buck-boost converter is given by,

$$V_{out} = \frac{D}{1-D} V_{in}$$

* where D is the duty cycle of the mosfet, expressed as fraction ($0<D<1$). Details of operation and design of the converter may be found any standard book of power electronics.



(Maximum point tracker using Buck boost Conv)

⇒ The power output of a PV system is given by

$$\boxed{P = VI}$$

⇒ With incremental change in current and voltage, the modified power is given by,

$$\boxed{P + \Delta P = (I + \Delta I) \cdot (V + \Delta V)}$$

⇒ which, after small terms simplifies to

$$\boxed{\Delta P = \Delta V \cdot (I + \Delta I) \cdot V}$$

⇒ ΔP must be zero at peak point. Therefore, at peak point the above expression in the limit becomes

$$\boxed{\frac{dV}{dt} = \frac{V}{I}}$$

⇒ It may be noted here that $\frac{dv}{dI}$ is the dynamic impedance of the source, which is required to be equal to negative of static $\frac{V}{I}$.

• There are three possible strategies for equation of an MPPT:

i) **By Monitoring Dynamic & static Impedances:**
A small sinal signal current is periodically injected into the array bus and the dynamic as well as statics bus impendance are measured. The operating voltage is then ajusted until the condition $Z_d = -Z_s$ is achieved.

(ii) By Monitoring Power Output:

- From the shape of P-V characteristics given in figure it is clear that the slope, dP/dV is zero at maximum power point. This property is utilized to track the maximum power point. Voltage is adjusted and power output is sensed.
- The operating voltage is increased as long as dP/dV is positive. That is, voltage is increased as long as we get increased output.
- If dP/dV is sensed negative, the operating voltage is decreased. The voltage is held unaltered if dP/dV is near zero within a preset dead band.

(iii) By Fixing the Output voltage as a fraction of V_{oc}:

- This method makes use of the fact that for most PV cells, the ratio of the voltages at maximum power point to the open circuit voltage, is approximately constant (say K).
- This is also evident from figure for high quality crystalline silicon cell, $K = 0.72$. An additional identical unloaded cell is installed on the array to face same environment as the module in use and its open circuit V_{oc} is is continuously measured.
- The operating voltage of the array is then set at i.e. V_{oc} The implementation of this scheme is simplest among all the available schemes.

2.3. Classification of energy source:

(i) Central Power Stations:

- Central PV power stations are conceptually similarly to any other conventional central power station. They feed power to grid. These are being proposed in few MW range to meet daytime peak loads only.
- Central PV power sations of upto 6 MW (peak MV) capacities have already been experimented within USA and Europe. While the concept has been demonstrated through such experimental plants, the capital costs are currently somewhat high for their commercial exploitation.

(ii) Distributed System:

Distributed form of energy use is unique and much more successful with solar and most other renewable energy sources. These systems can be further devided into three parts:

(a) Stand alone System:

It is located at the load centre and dedicated to meet all the electrical loads of a village / community or a specific set of loads. Energy storage is generally essential. It is most relevent and successful in remote and rural areas having no access to grid supply. Indicative capacity of such a system is 10 Wp - 100 KWp.

(b) Grid-interactive System:

- This system in connected to the utility grid with two-way metering system. It may be a small rooftop system meant for the whole village or a community.
- It meets daytime requirements of the house owner without any battery backup and surplus power is fed to the grid. During peak hours and during nights, the energy shortage may be met from grid.

(C) Small System for Consumem Applications:

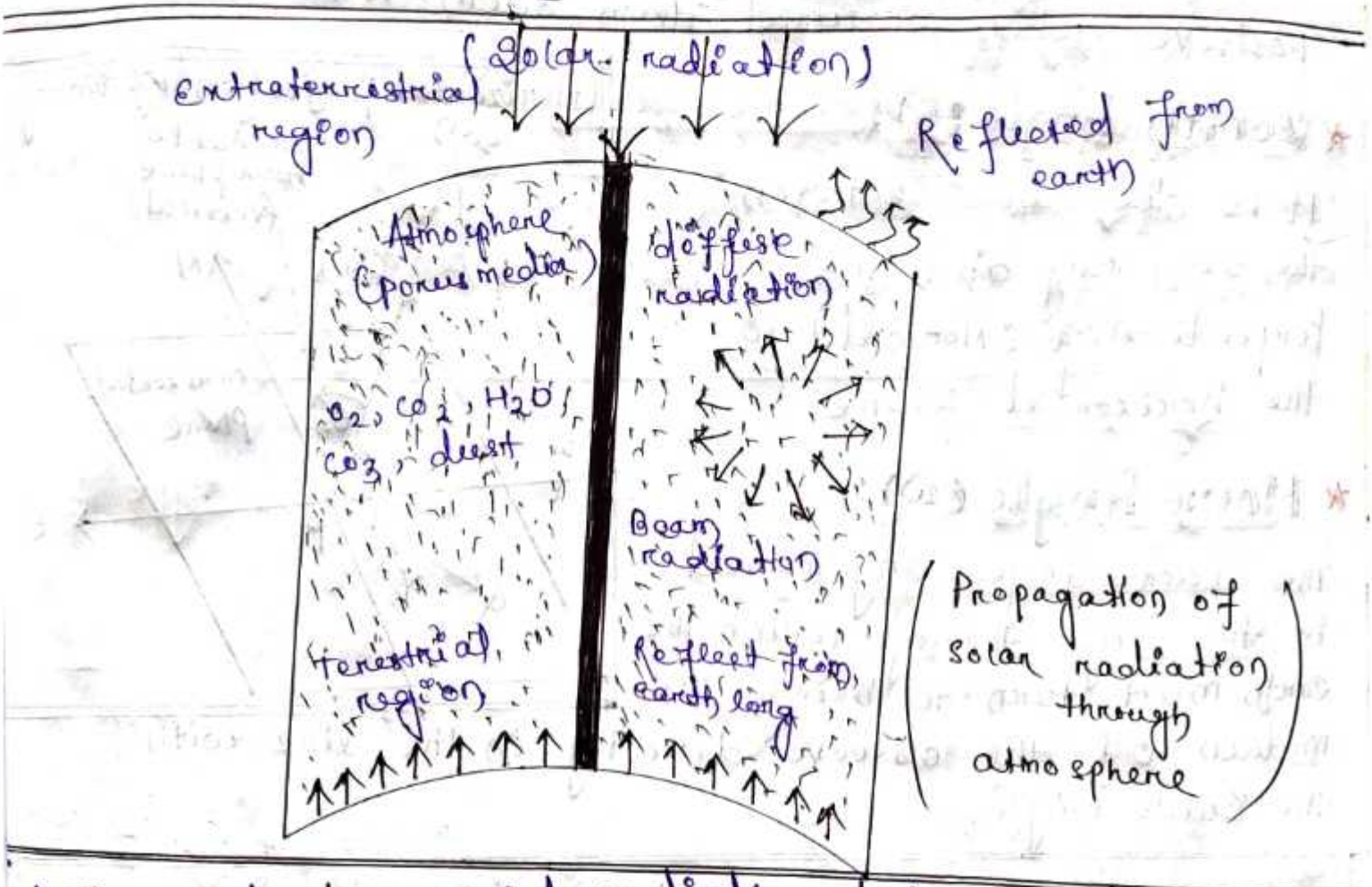
These systems are meant for low energy consumer devices requiring power in the range of microwatts to 10 W_p and mostly designed for indoor applications e.g. calculators, watches, electronic games, etc.

2.4. Extraterrestrial & Terrestrial Radiations:

* The intensity of solar radiation keeps on attenuating as it propagates away from the surface of the sun, though the wavelength remain unchanged.
* Solar radiation incident on the outer atmosphere of the earth is known as extraterrestrial radiation I_{sc}. The solar constant, I_{sc} is defined as the energy recieved from the sun per unit time, on a ~~time~~ unit area of surface perpendicular to the direction of propagation of the radiation at the top of the atmosphere and at the earth's mean distance from the sun.
* The world radiation center (WRC) has adopted the value of solar constant as 1367 W/m^2 (1.940 cal/cm^2 min, 432 $Btu/ft^2 h$ or 4.921 $mJ/m^2 s$) This has been accepted universally as a standard value of solar constant.
* The extraterrestrial radiation deviates from the solar constant value due to two reasons. The first is the variation in the radiation emitted by the sun it self. The variation due to this reason is less than ± 1.5% with different periodicities; The second variation of the earth sun distance arising from the earth's slightly

elliptic path. The variation due to this reason is ±3% and is given by,

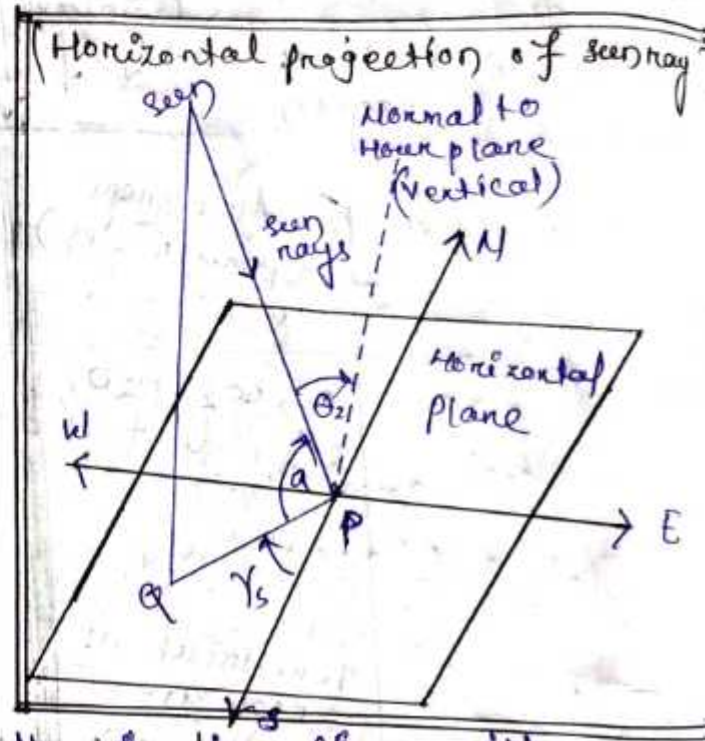
$$I_{ext} = I_{sc}\left[1.0 + 0.033 \cos(360n/365)\right] W/m^2$$



* The extraterrestrial radiation, being outside the atmosphere, is not affected by changes in atmospheric conditions. While passing through the atmosphere, it is subjected to mechanisms of atmospheric absorption and scattering depending on atmospheric conditions, depleting it's intensity.
* The solar radiation that reaches the earth surface after passing through the earth's atmosphere is known as terrestrial radiation.
* The term solar insolation (incident solar radiation) is defined as the solar radiation recieved on a flat horizontal surface on the earth. The position of terrestrial and extraterrestrial regions are indicated in figure.

2.5. Azimuth Angle (γ):

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

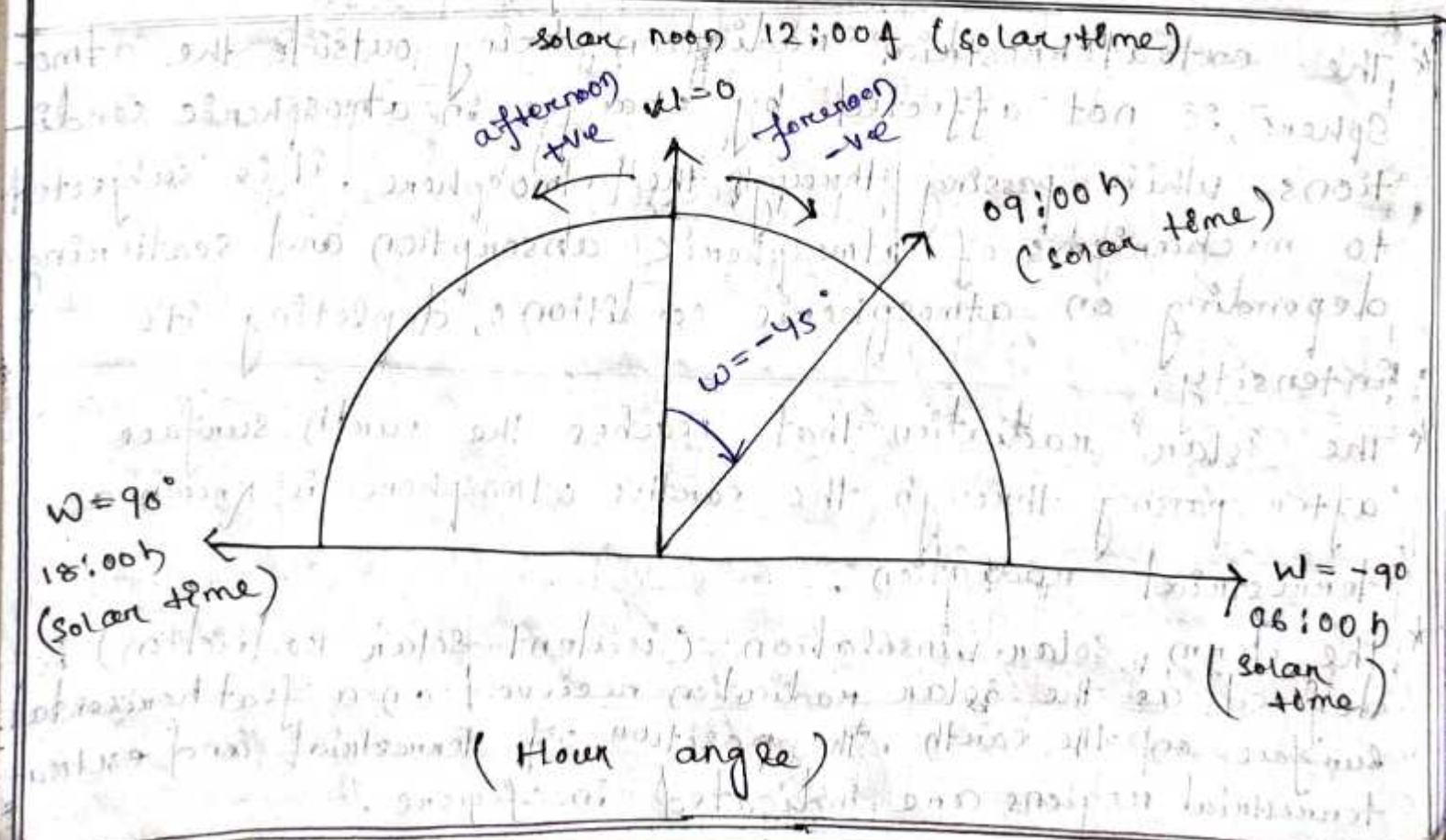


★ Zenith Angle (θ):

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

★ Hour Angle (ω):

The hour angle any moment is the angle through which the earth must turn to bring the median of the observe directly in the line with the sun's ray's.



★ Irrendiance:

- The rate of incident energy per unit area of surface is known as Irrendiance. It's unit is watt/m^2.

★ Solar Constant:

- The solar constant I_{sc} is defined as the energy received from the sun per unit time on a unit area of surface perpendicular to the direction of propagation of radiation at the top of the atmosphere and the earth's mean distance from sun.
- The world radiation counter (WRC) adpoted the value of solar constant as 1367 W/m^2. This has been accepted universally as a standard value of solar constant.

2.6. Solar Collector, Types and performance characteristic:

★ Solar Collector:

- Solar power has low density per unit area (1Kg/sqm to 0.1 KW/Sqm). Hence it is collected by covering a large ground area by solar thermal collector.
- A solar thermal system essentially forms the first unit in a solar thermal system. It absorbs the solar energy as heat and then transfer it to the heat transfer fluid efficiently.
- The heat transport fluid delivers this heat to a thermal storage tank / boiler / heat exchanger to be utilize in the subsequent stages of system.

★Types of solar Collector:

Solar Collector

- Non-concentrating type (Flat-plat Collector)
  - (a) Liquid flat-plate collector
  - (b) Flat plate air heating collector
- Concentrating type
  - Focus type
    - Line focus one axis tracking
      - (a) Cylindrical parabolic concentrator.
      - (b) Fixed mirror solar concentrator.
      - (c) Linear presnel lens collector.
    - Point focus two-axis tracking
      - (a) Paraboloidal dish collector.
      - (b) Hemispherical bowl mirror concentrator.
      - (c) Circular presnel lens concentrator.
      - (d) Central tower receiver.
  - Non-focus type
    - (a) Modified flatplate collector.
    - (b) Compound parabolic concentrating type

• The overall view of classification of solar collectors into catagories and subcatagories in figure.

- The classification is based on the way they collect solar radiation. The non-concentrating types absorbs the radiation as it is received on the surface of the collector while the concentrating type first increase the concentration of radiation per unit area before absorbing it.

* Performance Characteristics:

- The performance characteristics of solar collectors are:-

(i) Collector efficiency.
(ii) concentration ratio.
(iii) Temperature Range.

(i) Collector Efficiency:

It is defined as the ratio of the energy actually absorbed and transfer to the heat transport fluid by the collector to the energy incident on the collector.

(ii) Concentration Ratio:

It is defined as the ratio of the area of appearance of the system to the area of the receiver. The aperature of the system is the projected area of the collector facing the beam.

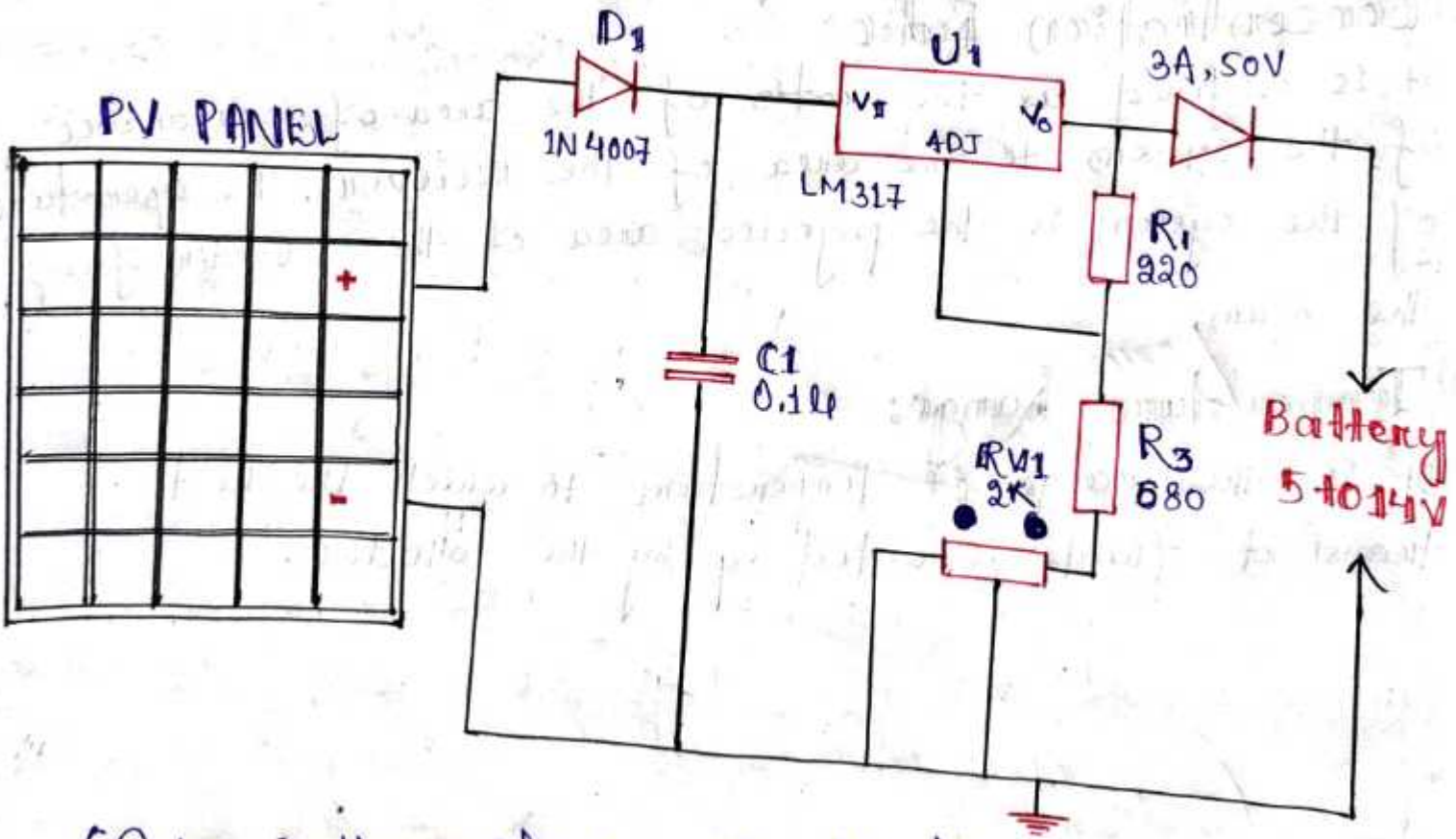
(iii) Temperature Range:

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

2.7. Application:

★ Photo-voltaic Battery Charger:

- Solar battery charger operated on the principle that the charge control circuit will produce the constant voltage.
- The charging current passes through LM317 voltage regulator through the diode D1. The output voltage and current are regulated by adjusting the adjust pin of LM317 voltage regulator. Battery is charged using same current.



(Solar Battery charger circuit diagram)

- Circuit Components:

⇒ Solar panel → 17V.
⇒ LM317 Voltage Regulator.
⇒ DC Battery.
⇒ Diode - IN4007
⇒ Capacitor - 0.1 μF
⇒ Schottky Diode - 3A, 50V
⇒ Resistor - 220, 680 Ω
⇒ POT - 2K
⇒ Connecting wires

- Solar Battery Charger Circuit Design:-

- Circuit must have adjustable voltage regulator, so Variable voltage regulator. LM317 is selected. Here LM317 can produce a voltage from 1.25 to 37 Volts maximum and maximum current of 1.5 Amps.
- Adjustable voltage regulator has typical voltage drop of 2v - 2.5v. So solar panel is selected such that it has more voltage than the load. Here, I am selecting 17 V/5W Solar panel.
- Lead acid battery which is used here has specification of which is used here has specification of 12V/1.3Amp. In order to charge this Battery following are required.
- Schottky diode is used to protect the LM317 and panel from reverse voltage generated by the battery when it is not charging. Any 3A diode can be used here.

- Advantages:

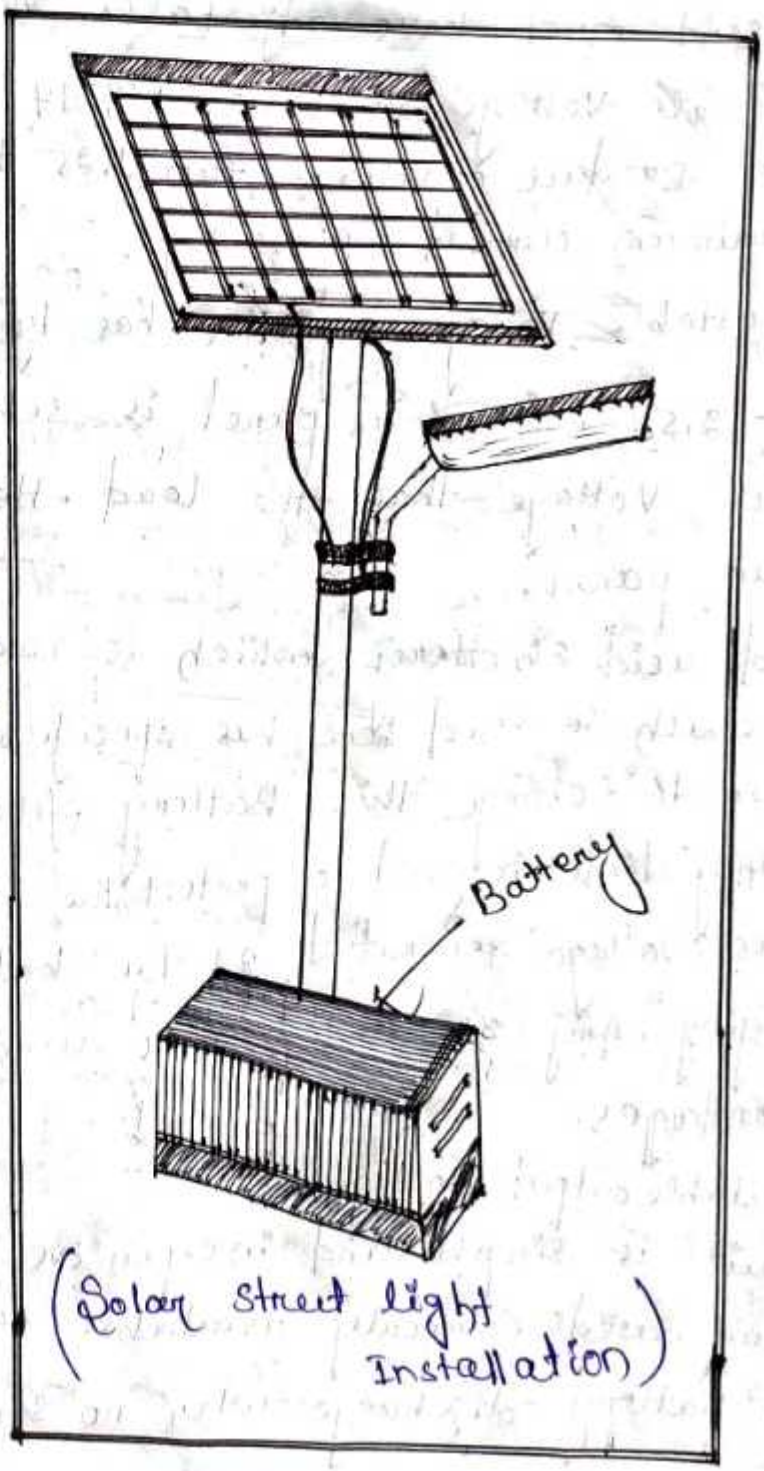
⇒ Adjustable output voltage.
⇒ Circuit is simple and inexpensive.
⇒ Circuit used commonly available components.
⇒ Zero battery discharge when no sunlight on the solar panel.

★ Domestic Lighting:

- Home lighting systems are the most popular Solar PV units typically designed to work with two light points and one TV point.
- When necessary, a small dc fan can also be run from this system.

★ Solar Street Lighting:

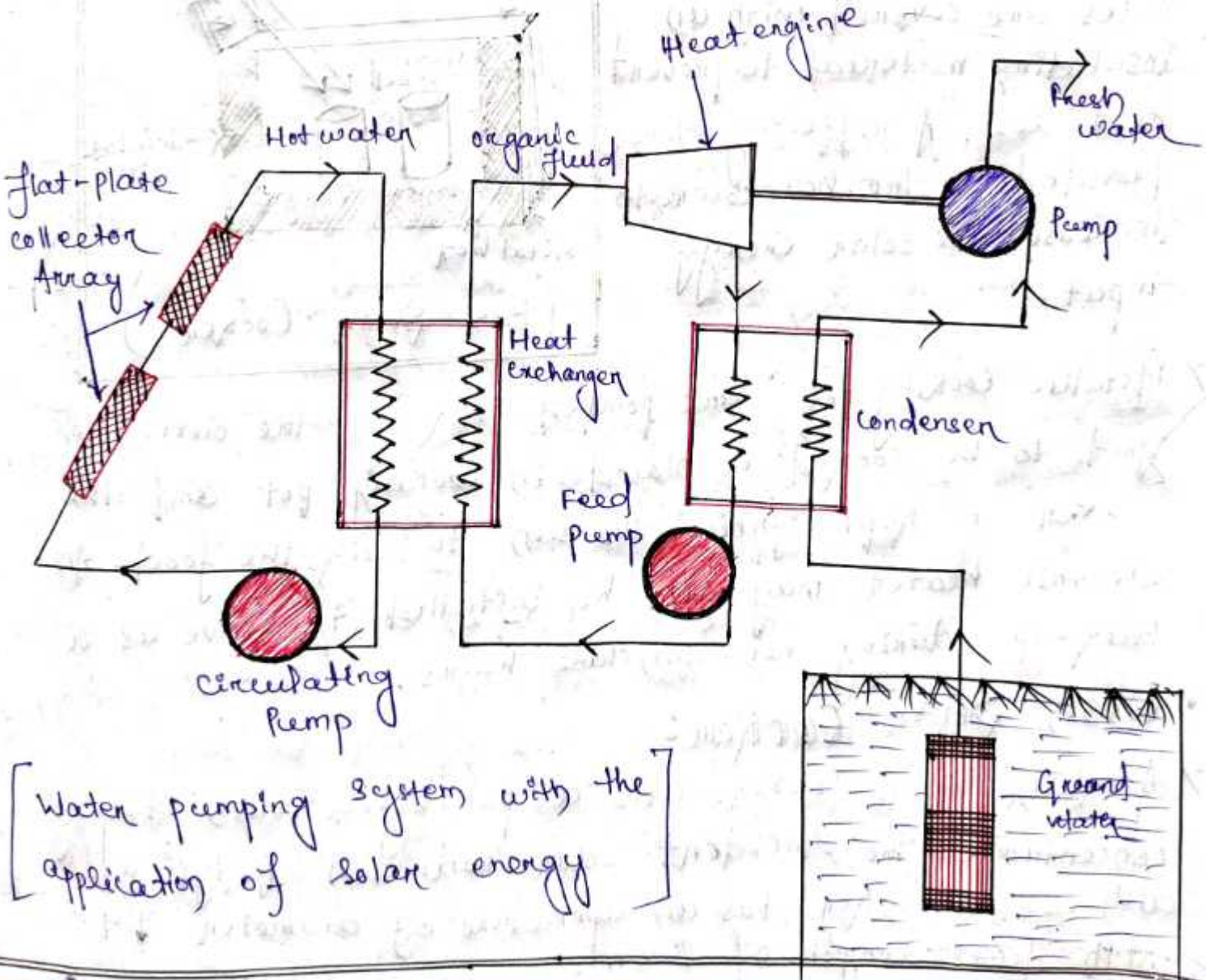
- Solar street lighting System is shown in figure. It describe a standalone PV power generating device.
- It comprises a compact fluorescent lamp, two 30 watt Solar modules and 80Ah tubular cell battery



(Solar street light Installation)

★ Water Pumping:

- Water pumps can be driven directly by solar heated water or fluid which operates either heat engine or turbine.
- For low heads, the pump driven by vapour of a low boiling point liquid heated by a flat plate collector is used as show in figure.
- For larger head, a parabolic though concentrator or a parabolic bowl concentrator is installed to drive a steam turbine.



[Water pumping system with the application of solar energy]

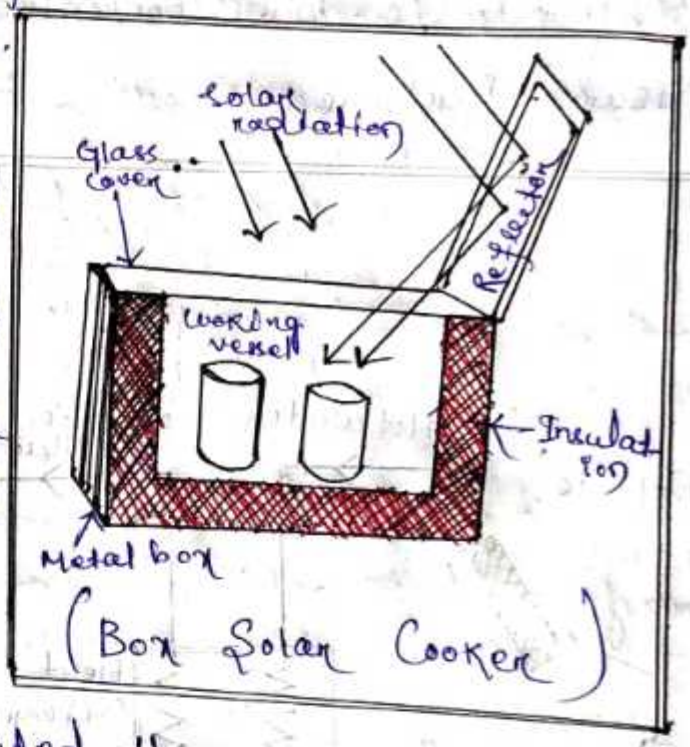
★ Solar Cooker:

- Cooking is common application of solar energy in India. Several verieties of solar cookers are available to seet different requirements.

• Box Solar Cooker:

➢ It consists of an outer box made of either fibre glass or aluminium sheet, a blackened aluminium tray, a double glass lid, a reflector, insulation and cooking pots as detailed in fegure.

➢ Blackened aluminium tray is fixed inside the box, and sides are covered with an insulating material to prevent heat loss. A reflecting mirror provided on the box cover to increase the solar energy input.



(Box Solar Cooker)

➢ Metallic cooking pots are painted black on the outer side food to be cooked is placed in cooking pot and the cooker is kept facing the sun to cook the food. An electric heater may also be installed to serve as a back-up during non-sunshine hours.

• Dish Solar Cooker:

➢ A dish solar cooker use a parabolic dish to concentrate the incident solar radiation. A typical dish solar cooker has an aperature of diameter 1.4 m with focal length of 0.8 m.

→ The reflecting material is an anodized aluminium sheet having respectively of after 80%.

→ The cooker needs to track the sun, to deliver power of about 0.6 KW the temperature at the bottom of the vessel may reach up to 400°C which is sufficient for roasting, frying and boiling. It can meet requirement of cooking for 15 people.

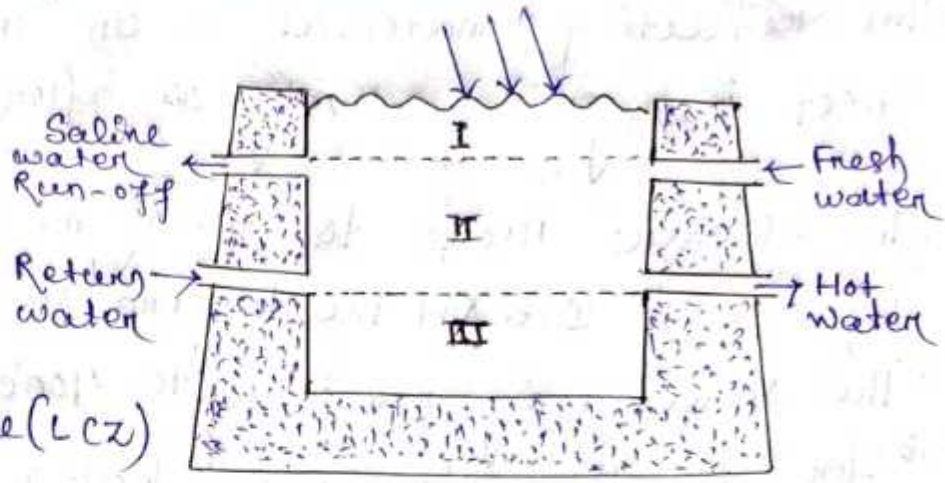
* Solar Pond:

- The concept of solar pond was derived from the natural lakes, where the temperature rises (of the order of 45°C) towards the bottom.
- It happens due to natural salt gradients in these lakes where water at the bottom is denser.
- In salt concentration lakes, convention does not occur and heat loss from hot water takes place only by conduction.
- This technique is utilized for collecting and storing solar energy. An artificially designed pond filled with salty water maintaining a definite concentration gradient is called a "solar pond".
- A schematic diagram of a solar pond shown in figure.
- The top layers remain at constant temperature while the bottom layer attains a maximum steady state temp. of about 60°C - 85°C.

I - Structure convective zone (SCZ)

II - Concentration gradient zone (CGZ)

III - Lower convective zone (LCZ)



(Schematic diagram of solar pond)

- For extracting heat energy from the pond, Hot water is taken out continuously from the bottom and returned after passing through the heat exchanger.
- Alternatively, Heat is extracted by water flowing through a submerged heat exchanger coil.
- As a result of continuous movement and mixing of salty water at the top and bottom, the solar pond can have three zones.

(I) Surface convective zone (SCZ) having a thickness of about 10cm - 20cm with a low uniform concentration at nearly the ambient air temperature.

(II) Concentration gradient zone (CGZ) occupying more than half the depth of the pond. It serves as an insulating layer from heat losses in the upward direction.

(III) Lower convective zone (LCZ) having thickness nearly equal to (CGZ). This zone is characterized by constant temperature and concentration.

- The largest solar pond so far build is the 250,000 m^2 Pond Beit Hafrava pond in Israel. Based on the Rankine cycle principle, this pond is used to generate 5 MW of electrical power with an organic fluid.
- In India the first solar pond with an area of 1200 m^2 was built at the central salt research institute, Bhavanagar in 1973.
- Since the several solar ponds have been buit and are in operation.
- The latest pond with an area of 6000 m^2 built at Bhuj, Gujarat is the second largest in the world.
- It provides daily 90,000 litres of hot water at 80°C as process heat for Can-sterlization.
- This pond maintains a stable salinity gradient with a maximum temperature of 99°C due to high radiation intensity and low thermal losses.
- The pond stores sufficient heat capable of generating 150 KW of power.

③ Wind Energy

3.1. Introduction to Wind Energy:

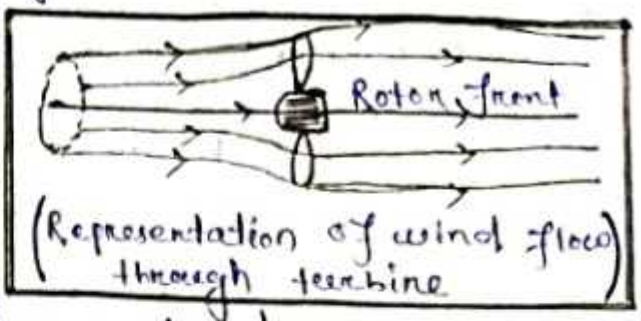
- Wind energy is the kinetic energy associated with movement of large masses of air. These motions result from uneven heating of the atmosphere by the sun, creating temperature, density and pressure differences.
- It is thus an indirect form of solar energy. In contrast to diurnal availability of direct solar radition, wind energy can be available continuously throughout a 24-hour day for much longer periods, thought it can vary a great extent including no wind periods. It is a clean, cheap, and eco-friendly renewable energy source. the main disadvantages are that it is a dispersed, erratic and location-specific source.
- Wind energy is harnessed: as mechanical energy with the help of a wind turbine. The mechanical energy thus obtained can either be used as such to operate farm appliances and water pumping or converted to electric power and used locally or fed to a grid.

3.2. Wind Energy Conversion:

- Wind turbines extract energy from wind energy by converting the kinetic energy of wind to rotational motion required to operate an electric generator.
- By virtue of the kinetic energy, the velocity of the following wind decreases.
- It is assumed that the mass of air which passes through rotor is only affected and remains separate from the air which does not pass through the rotor.
- Accordingly, a circular boundary surface is drawn showing the affected air mass and this boundary is extended upstream as

well as downstream as detailed in figure.

- As the free wind interacts with the turbine rotor, the wind transfers part of its energy into the rotor and the speed of the wind decreases to a minimum leaving a trail of disturbed wind called wake. The variation in velocity is considered to smooth from far upstream to far downstream.



(Representation of wind flow through turbine)

3.3. Types Of Wind Turbine:

- Wind turbines are classified as horizontal-axis turbines or vertical-axis turbines depending upon the orientation of axis of rotation of their rotors. A wind turbine operates by slowing down the wind and extracting a part of its energy in the process.
- For a horizontal-axis turbine, the rotor axis is kept horizontal and aligned parallel in the direction of the wind stream. In a vertical axis turbine, the rotor axis is vertical and fixed and remains perpendicular to the wind stream.
- In general, wind turbines have blades, sails or buckets fixed to a central shaft. The extracted energy causes the shaft to rotate. This rotating shaft is used to drive a pump, to grind seeds or to generates electric power. Wind turbines are further classified into 'lift' and 'drag' type.

3.3.1 Lift Type and Drag Type Wind Turbines:

- Two important aerodynamic principles are used in wind turbine operation, i.e. lift and drag. Wind can rotate the rotor of a wind turbine either by lifting (lift) the blades or by simply passing against the blades (drag). Wind turbine

wind turbine can be identified based on their geometry and the manner in which the wind passes over the blades.

- Slow-speed turbines are mainly driven by the drag forces acting on the rotor. The torque at the rotor shaft is comparatively high which is of prime importance for mechanical application such as water pumps. For slower turbines, a greater blade area is required, so the fabrication of blade is undertaken using curved plates.

- High speed turbines utilise lift forces to move the blades, which phenomenon is similar to what acts on the wings of an aeroplane. Faster turbines required aerofoil-type blades to minimize the adverse effect of the drag forces. The blades are fabricated from aerofoil sections with a high thickness-to-chord ratio in order to produce a high lift relative to drag.

- For electric power generation, the shaft of the generator requires to be driven at a high speed, for the same swept area. The energy extracted by a wind turbine operating on lift forces is several times greater than the energy from the drag-type turbine. Thus the lift type turbines are more suitable compared to drag-type turbines for electrical power generation.

★ Types of Rotors:

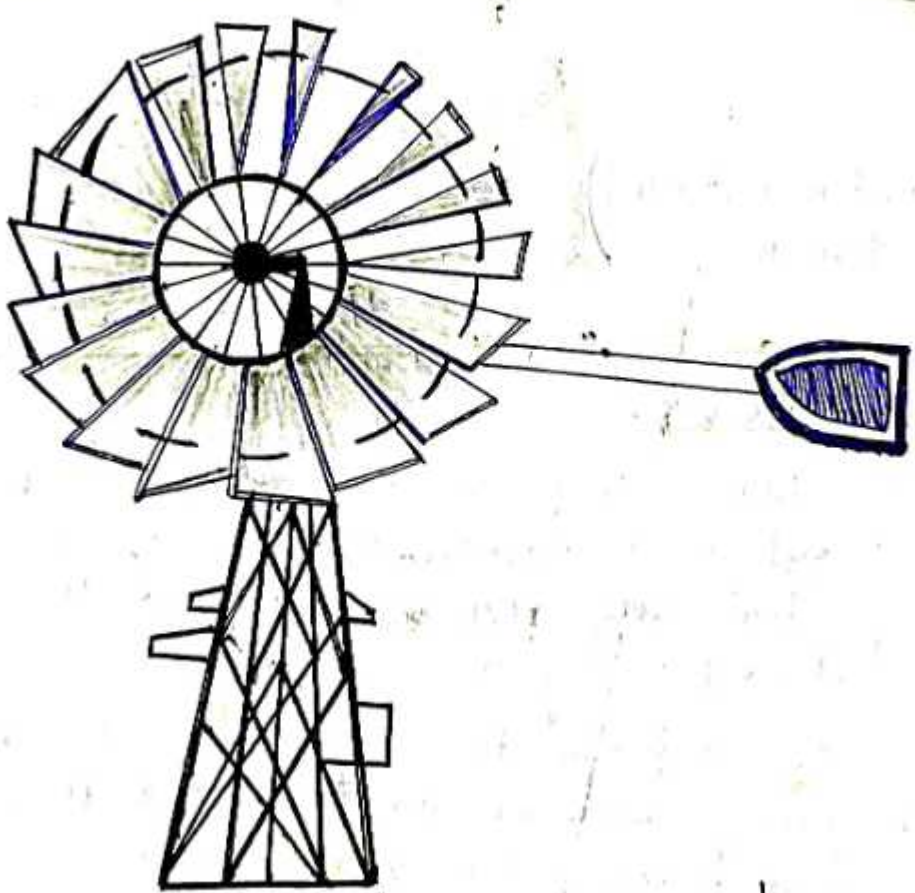
Different types of rotors used in wind turbines are :-

(i) Multiblade type. } Horizontal axis turbine.
(ii) Propeller type. }

(iii) Savonious type. } Vertical axis turbine.
(iv) Darrieus type. }

(i) Multiblade Type:

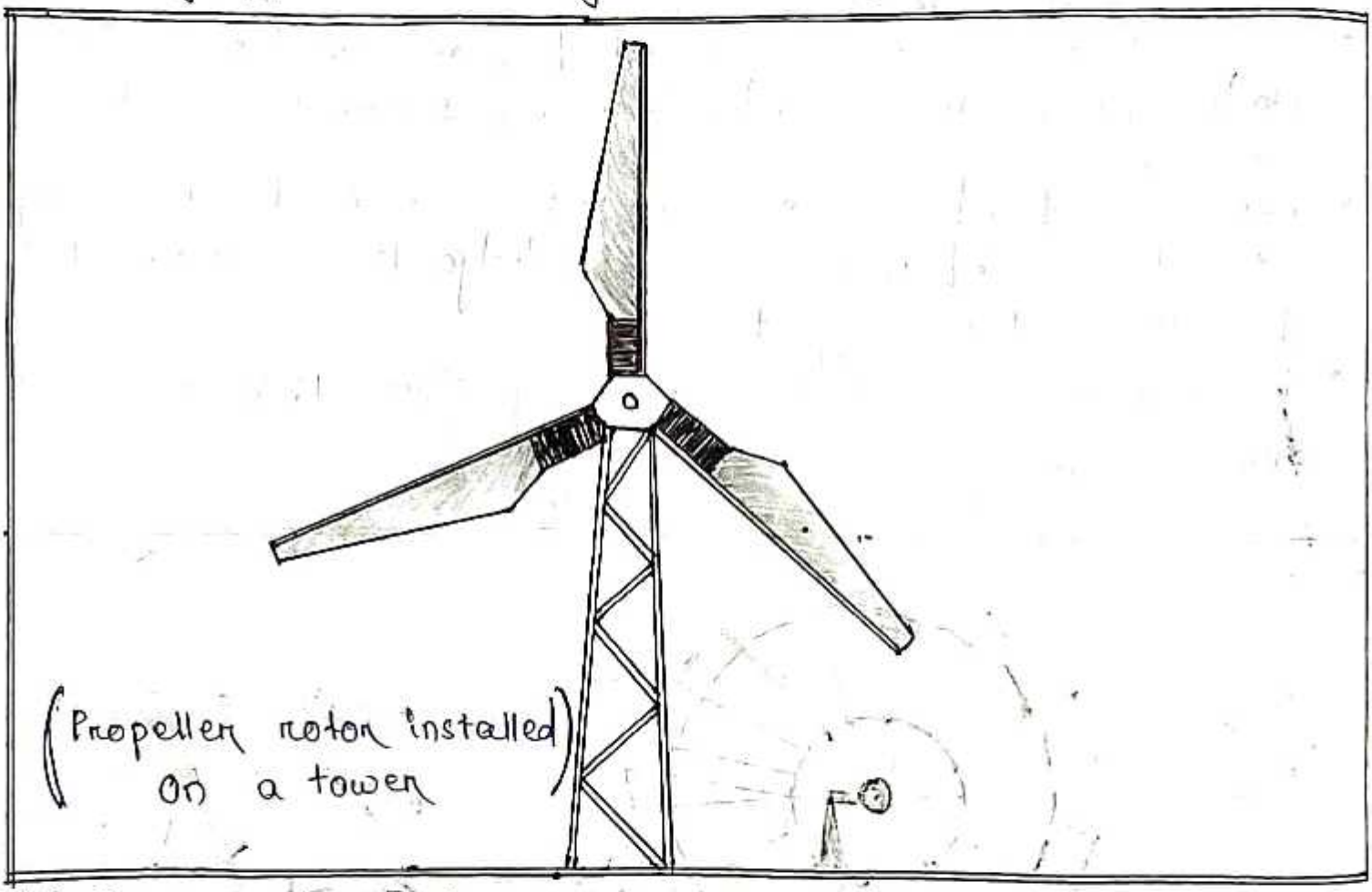
- The multiblade rotor is fabricated from curved steel metal blades. The width of blades increases outwards from the centre.
- Blades are fixed at their inner ends on a circular rim. They are also welded near their outer edge to another rim to provide a stable support.
- The members of blades used ranges from 12 to 18 as shown in the figure



(Multiblade rotor installed in a tower)

(ii) Propeller Roter:

- The propeller roter comprises two or three aerodynamic blades made from strong but lightweight material such as fibre glass reinforced plastic.
- The diameter of the roter ranges from 2m to 25m as detailed in figure. The blade slope is designed by using the same aerodynamic theory as for aircraft.

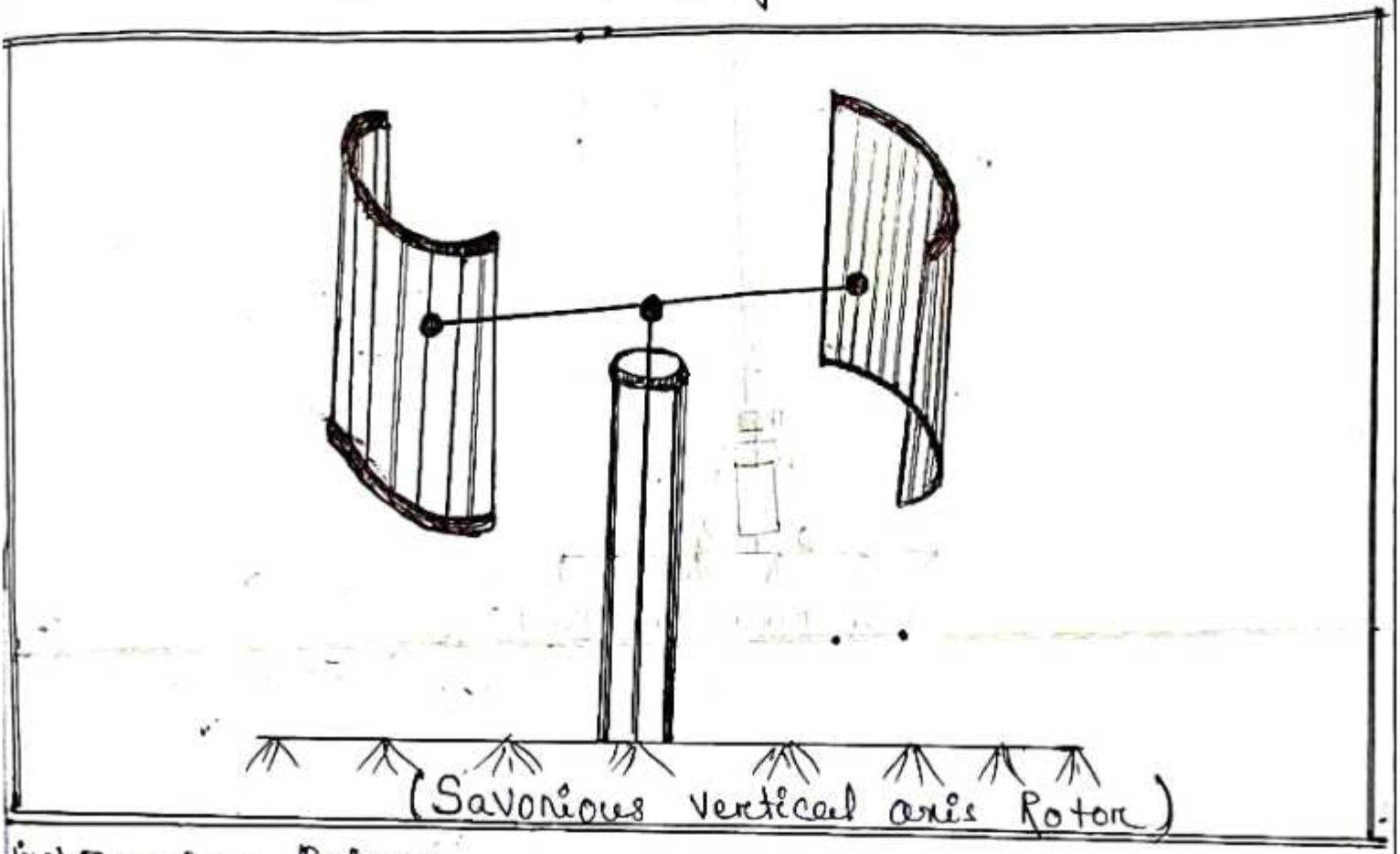


(Propeller roter installed on a tower)

(iii) Savonious Roter:

- The Savonious Roter comprises two identical hollow semi-cylinders fixed to a vertical axis. the inner side of two two half-cylinders face each other to have an S shaped cross section as detailed in figure.
- Irrespective of wind direction, the roter rotates due to pressure difference between the two sides. This vertical axis roter was developed by an engineer Savonious of finland in the year 1920.

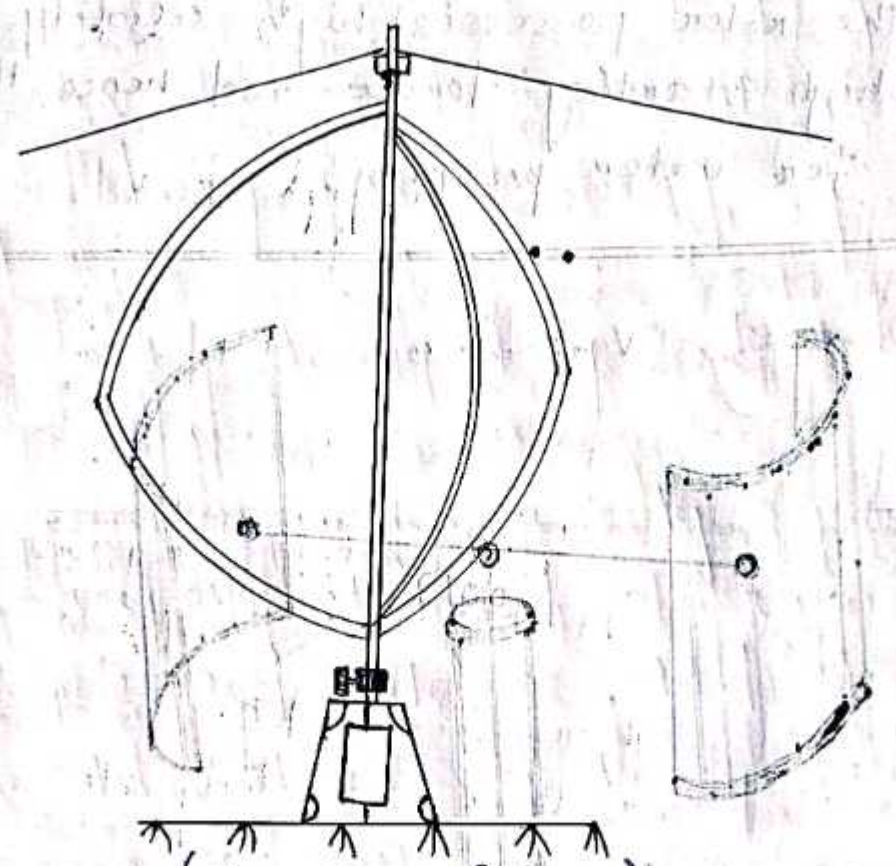
- It is self starting and the driving force is mainly of drag type. The rotor possesses high solidity so as to produce a high starting torque and hence this rotor is suitable for water pumping.



(Savonious Vertical axis Rotor)

(iv) Darrieus Rotor:

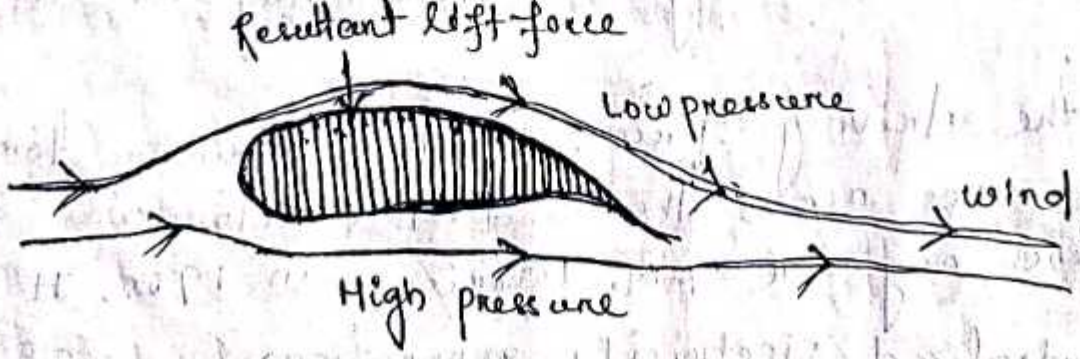
- This Rotor has two or three thin curved blades of flexible metal strips. Its looks like an egg beater and operates with the wind coming from any direction.
- Both the ends of the blades are attached to a vertical shaft as shown in the figure. It has an advantage that it can be installed in the ground eliminating the cost of tower structure.
- Lift is the driving force, creating maximum torque when the blade moves across the wind. This rotor was designed by a french engineer G.M. Darrieus in 1925. It is used for decentralized electricity generation.



(Darrieus Rotor)

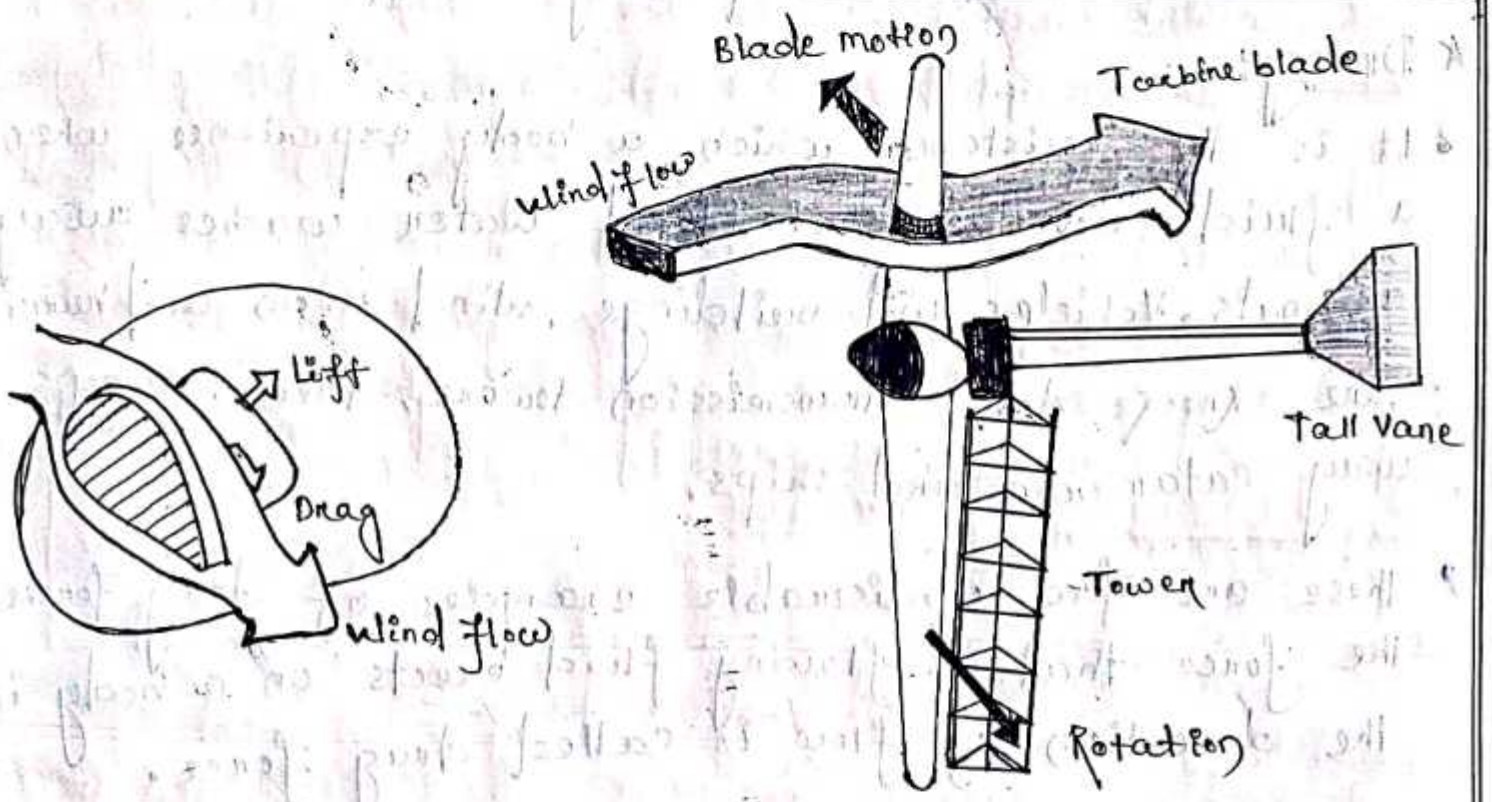
3.4. Aerodynamics of Wind Turbines:

- Aerodynamics deals with the movement of solid bodies through the air. In wind turbines, aerodynamics provides a method to explain the relative motion between airfoil and air. Airfoil is the cross-section of wind turbine blades.
- When the wind passes through the surface of the rotor blade, it automatically passes over the longer or upper sides of blade, creating a low pressure area above the airfoil as shown in figure.



(Aerodynamic lift force on blade cross-section of wind turbine)

- The difference between the top and bottom surfaces results in a force called the aerodynamic lift that causes the air foil to rise.
- As the blades can only move in a plane with the hub as their centre, the lift force cause rotation about the hub as shown in figure.



(The basic operating principle of wind turbine aerodynamic lift)

- The turbine thus extract energy from the wind stream by converting the winds linear kinetic energy into Rotational energy / motion.
- In addition to the lift force, a drag force perpendicular to the lift force also acts on the blade which impedes rotor rotation.
- The prime objective in wind turbine design is the desired lift to drag ratio of the blade (airfoil structure). The basic principles of lift and drag forces are dealt with in the next section.

- When air flows over solid bodies, several physical phenomenona are noticed such as drag force acting on object like trees and electric towers, the lift force developed by air plane wings, the lift force experienced by dust particles in a wind stream and the blade motion developed by a turbine.

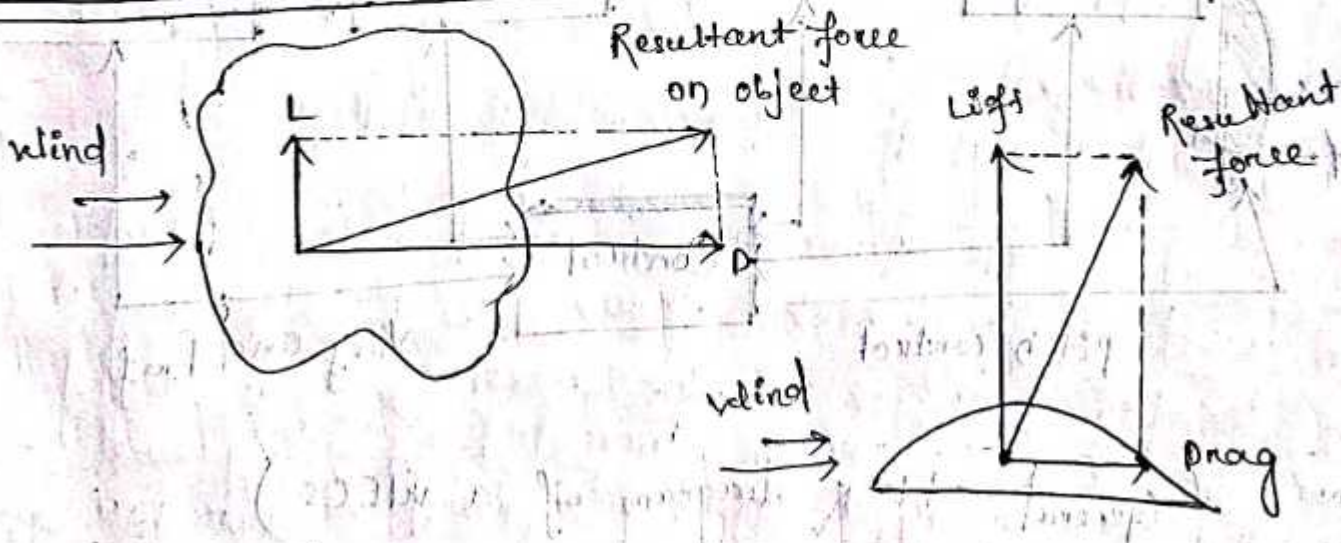
★ Drag:

- It is the resistance which a body experience when a fluid moves over it. Flood water washes away animals, Vehicles and buildings. Wind storm and hurricane knocks down transmission towers, trees, sweeps away catamaran and ships.
- These are few undiserable examples of drag forces. The force that a flowing fluid exerts on a body in the direction of flow is called drag force.
- Drag may bring an undesirable effect of friction, such as burning of space vehicles on entering into the earth's atmosphere.
- Reduction of drag is the basic engineering approach, associated with the reduction in fuel consumption in automobiles, aircraft and submarines.
- However, In certain engineering activities the drag produces a useful effect. A meteor from outer space burns due to friction with the earth's atmosphere, saving the inhabitants on earth from catastropic impact.

- Friction acts to help us as a "life saver" in brakes of automobiles, similarly, the drag force is useful in safe landing with a parachute.

* **Lift:**

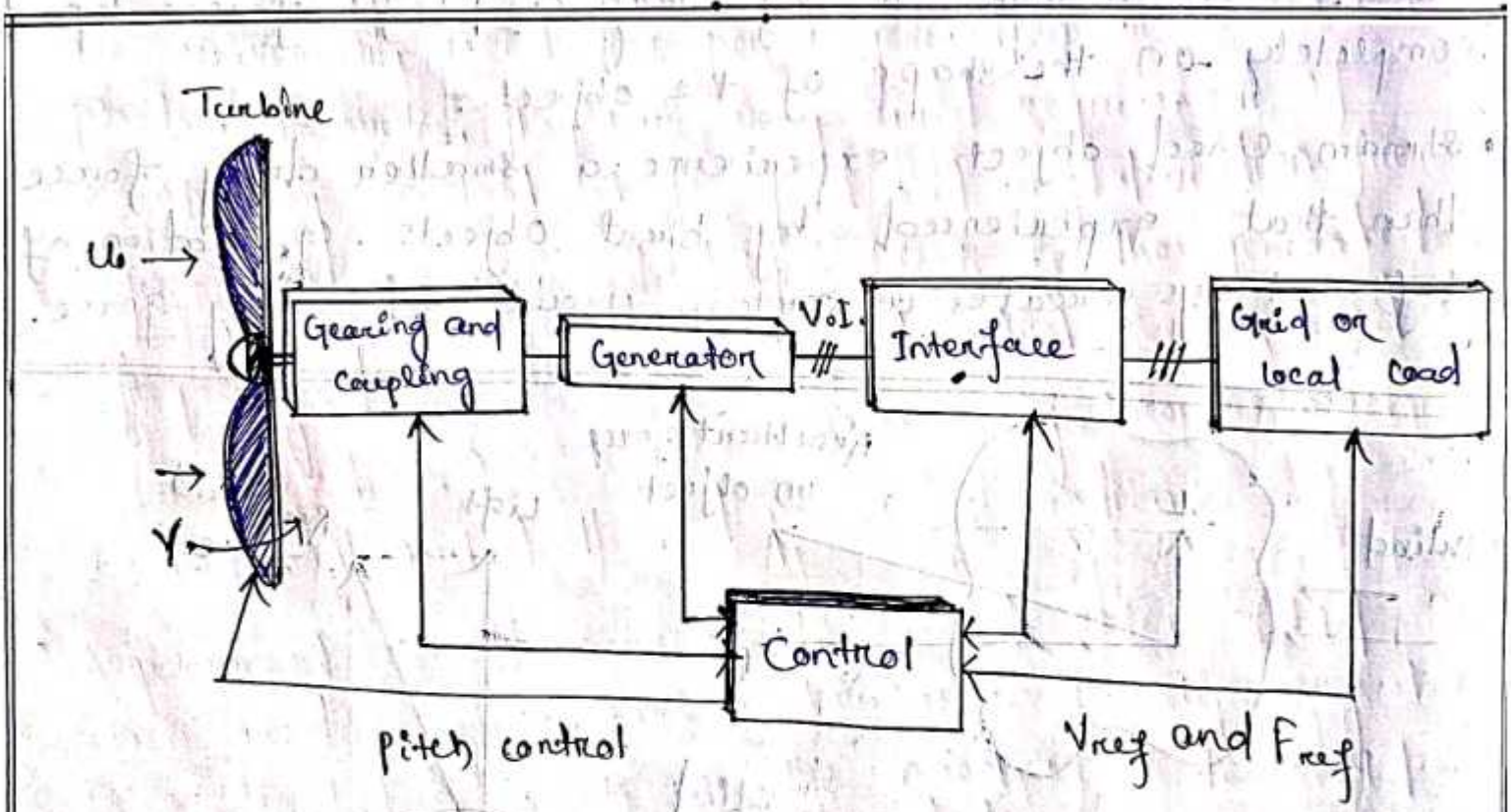
- When a body is immersed in a standstill fluid, only the normal pressure force is exerted on it. A flowing fluid in addition exerts tangential shear forces on the surface.
- Both these forces have two components one is drag in the flow direction, the other is perpendicular to the fluid flow called "lift".
- It causes the body to move in the upward direction. The relative magnitude of drag and lift forces depend completely on the shape of the object.
- Stream lined objects experience a smaller drag force than that experienced by blunt objects. Generation of lift always creates a certain amount of drag force.



(Relative Magnitude of lift and drag force on a blunt object and a streamlined airfoil)

3.5. Wind turbines Control System: Conversion to electrical power:

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



(General block diagram of a WECS)

- ratio to suit the electrical generator and fine-tuning of speed is incorporated by pitch control. This block act as a drive for the generator.
- Use of variable gear ratio has been considered in the past and was found to add more problem than benefits.
- Hence dc, synchronous or induction generators are used for mechanical to electrical power conversion depending on design of the system. The interface conditions the generated power to grid-quality power.
- It may be consist of a power electronic converter, transformer and filter etc. The control unit monitors and controls the interaction among various blocks.
- It derives the reference voltage and frequency signals from the grid and receives wind speed, wind direction, wind turbine speed signals, etc. processes them accordingly controls various blocks for optimal energy balance.

3.6. Induction and Synchronous Generation:

• Induction Generation:

- The primary advantages of an induction machines are the rugged brushless construction no need of separate dc field power and tolerate of shlight variation of shaft speed (±10%) as there variation are absorbed in the slip. compared to dc and synchronous machines. they have low capital cost, low maintenance and better transient

Performance, for these reasons, induction generation are extensively used in wind and micro-hydroelectric plants. The machine is available from very low to several megawatt ratings.

- The induction machine requires ac excitation current, which is mainly reactive. In case of a grid-connected system, the excitation current is drawn from the grid and therefore, the network must be capable of supplying the reactive power. The voltage and frequency are determined by the grid. In a standalone system, the induction generation is self-excited by shunt

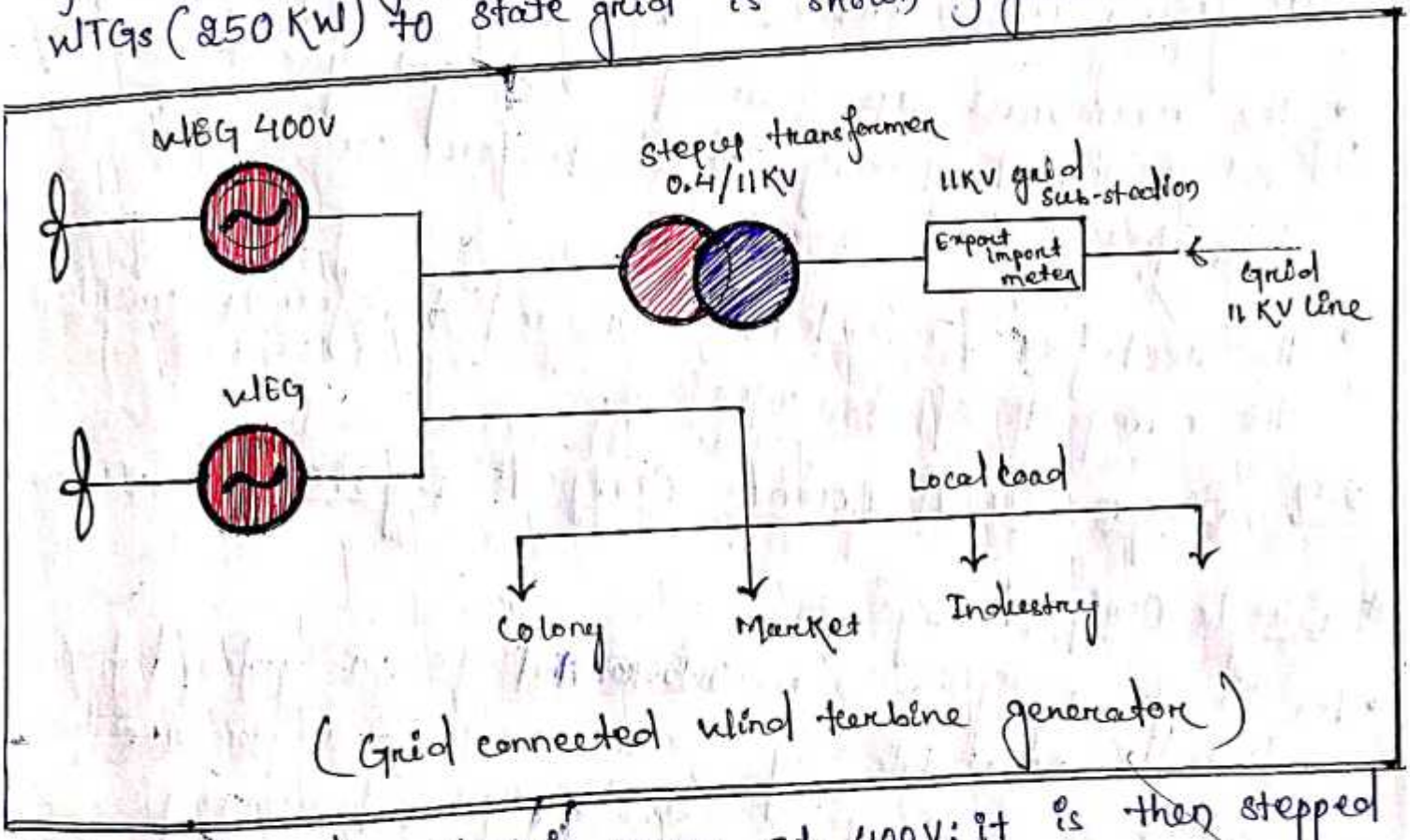
Synchronous Generator:

- Synchronous generators produce high quality output and are universally used for power generation in conventional plants. However, they have very rigid requirement of maintaining constant shaft speed and any deviation from synchronous value immediately reflects in the generated frequency. Also, Precise rotor speed control is required for synchronization. Due to this reason, a synchronous machine is not well suited to wind power generation.
- Requirement of dc current to excited rotor field, which needs sliding carbon brushes on the slip rings also poses limitation on its use. The need of a dc field current and brushes can be eliminated by using reluctance rotor. The reliability is greatly improved while reducing the cost.

- The machine rating, However, is limited to tens of KW. synchronisation of a wind-driven generator with the power grid also poses problems especially during during gusty winds. The main advantages is that it generating both active as well as reactive powers.

3.7. Grid Connected and Self excited induction - generator Operation:

- A common arrangement for connecting medium capacity WTGs (250 KW) to "state grid" is shown figure.



(Grid connected wind turbine generator)

- WTGs generates electric power at 400V; it is then stepped up to make this voltage compatible to the grid (11KV). In India, grid-connected WEGs constitute wind farms where the generated power is distributed among the nearby consumers and the excess power is exported to the grid. Electrical energy is purchased from the grid during periods of no wind.

3.8. Constant Voltage and constant frequency generation with power electronic Control:

- Modern variable speed drive schemes make use of power electronic converters for power conditioning.
- The variable voltage and variable frequency output available from a generator (synchronous or self excited induction generator) is first rectified to dc and then converted to constant voltage and constant frequency ac using an inverter.
- The harmonics are filtered out to get quality output/ to get grid quality output before connecting to the grid.
- The rectifier, inverter, filter and transformer constitute the main parts of the interface.

3.9. Single and Double Output Systems:

★ Single Output System:

- For a power system with substantial power generation from wind farms, controllability of the wind farm power outputs is critical to power system reliability and economy.
- Both the active power and reactive powers need to be maintained at appropriate levels. Indeed, recent experience with wind farm operation and research suggest that a farm should have at least two operating modes
  (i) Maximum power tracking (MPT).
  (ii) Power Regulation (PR).

(i) MPT:
MPT is traditional operating mode, aimed at enabling wind turbines in wind farm to convert as much of the electrical energy as possible under normal operation conditions.

(ii) PR:
PR is concerned with adjusting the wind turbine power outputs as needed by power system reliability or economic condition.

- The system of single output is a non linear controller, which enables the wind turbine to maximize it's active power in the MPT mode, regulate it's active power in PR mode, switch between two modes and adjust it's reactive power to achieve a desired power factor. While coping with uncertainities in most of it's parameter.

* Double Output System:

- The double rotor speed regulating wind power generation system has the ability of speed regulation and power generation at the same time in a certain period of time and reduces the capacity of the generator and converter as a new type of driving chain of speed regulating turbine.
- Moreover, the system can realize the capacity of active power overload and reactive power support of the grid since the synchronous generator is directly connected with the power grid at the end of the driving chain.
- Furthermore, the variable speed constant frequency operation of the system in the whole wind speed range is guaranteed by Multimode operating of the system state under different wind speeds. so as to capture the maximum wind power.

- In addition, the damage of the synchronous generator caused by wind speed fluctuation is reduced as the double rotor speed-regulating generator connecting the gear box and the synchronous generator, so the reliability of the system is improved.
- Therefore, the double rotor speed-regulating wind power generation system has a wide application prospect to alleviate the energy crisis and respond to the worsening natural environment.

3.10 Characteristics of Wind Energy Power plant:

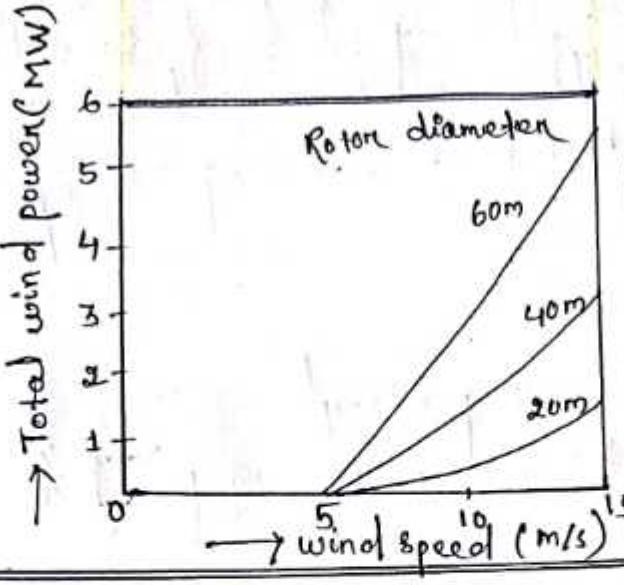
- Power in the wind is perportional to cube of wind speed. and is highly site specific. It is necessary to carry out wind measurement if the performance of the wind turbine is to be estimated accurately. The highest wind speed sites are exposed hills tops, off shore or on the coastal sites. For developing wind energy at any site the different parameters required are:

(i) Mean wind speed.

(ii) Daily, seasonal and annual variations in wind speed. Wind speed frequency distribution generally described by Weibull probability distribution.

(iii) Direction of wind by studying the "wind rose" data for micro siting of WEGs (Wind energy generation system). The map of wind roses gives the frequency distribution of main wind flow.

(iv) Wind speed variation with height above ground. (power in the wind increases with height)



[Variation of wind turbine power with rotor diameter and wind speed]

- Definitive wind resources data can be obtained from the Indian meteorological department (IMD) where microprocessor based anemometers are used at wind mapping stations.
- These instruments can make highly accurate wind measurement for the estimation of power production. These readings are analyzed to assess the performance and economic viability of a wind energy conversion system (WECS).

④ Biomass Power

4.1 Energy From Biomass:

- Biomass is a general term for living material - plants, animals, fungi, bacteria, Taken togather, the earth's biomass represents an enormous store of energy.
- It has been essential that just one-eight of the total biomass produced annually would provide all of humanity's current demand for energy. And since biomass can be regrown, it is a potentially renewable resource.
- The energy obtained from biomass is known as biomass energy. Animals feed on plants, and plants grow through the photosynthesis process using solar energy.
- Thus, the photosynthesis process is primary responsible for generation of biomass energy. A small portion of the solar radiation is captured and stored in plants during the photosynthesis process.
- Therefore, it is an indirect form of solar energy. The average efficiency of photosynthetic conversion of solar energy into biomass energy is estimated to be 0.5 - 1.0%.
- To use biomass energy, the initial biomass may be transform-ed by chemical or biological processes to produce more convenient intermidiate biofuels such as methane, producer gas, ethanol and charcoal.
- On combustion, it reacts with oxygen to release heat, but the elements of the material should be available for recycling in natural ecological or agricultural processes.

- Thus, the use of industrial biofuels, when linked carefully to the natural ecological cycle, may non-polluting and sustainable.
- For biomass to be considered as renewable, growth must at least keep pace with its use. It is disastrous that forest and firewood consumption is significantly outpacing their growth in ever-increasing areas of the world.
- It is estimated that biomass, 90% of which comprises plant matter, is equivalent to the current proven extractable fossil-fuel reserves in the world. The dry-matter mass of biological material cycling in the biosphere is about 250×10^3 t/y. The associated energy bound in photosynthesis is 2×10^{21} J/y (0.7×10^{21}

4.2. Biomass as Renewable Energy:

- Biomass being organic matter from terrestrial and marine vegetation, renews naturally in a short span of time. Thus classified as a renewable source of energy. It is a derivative of solar energy as plants grow by the process of photosynthesis by absorbing CO_2 from the atmosphere to form hexose (dextrose, glucose etc) expressed by the reaction.

$$6CO_2 + H_2O \xrightarrow[\text{photo synthesis}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

- Biomass does not add CO_2 to the atmosphere as it absorbs the same amount of carbon in growing the plants as it release when consumed as fuel. it is superior fuel as the energy produced from biomass is "carbon cycle neutral".

- Bio mass fuel is used in over 90% of rural household and in about 15% urban dwellings, Agriculture products rich in starch and sugar like wheat, maize, sugarcane can be fermented to produce ethanol (C_6H_5OH).
- Methanol (CH_3OH) is also produced by distillation of biomass that contains cellulose like wood and bagasse. Both these alcohols can be used to fuel vehicles and can be mixed with diesel to make biodisel.

★ Advantages:

(i) it is a renewable energy source.

(ii) The energy storage is an inbuilt feature of it.

(iii) It is an indigenous source requiring little or no foreign exchange.

(iv) The forestry and agricultural industries that supply feed stocks also provide substantial economic development opportunities in rural areas.

(v) The pollutant emissions from combustion of biomass are usually lower than those from fossil fuel.

(vi) use of biogas plants, apart from supplying clean gas, also leads to improved sanitation, better hygienic conditions in rural areas as the harmful decaying biomass get stabilized.

(vii) Commercial use of bio mass may avoid or reduce the problems of waste disposal in other industries, particularly municipal solid wastes in urban centres.

(viii) The nitrogen rich bio-digested slurry and sludge from a biogas plant serves as a very good soil conditioner and improves the fertility of the soil sand.

(ix) Varying capacity can be installed · any capacity can be operated, even at lower loads, with no seasonality involved.

★ Disadvantage:

(i) It is dispersed and land intensive source.

(ii) It is often of low energy density.

(iii) It is also labour intensive and the cost of collecting large quantities for commercial application is significant. most current commercial applications of biomass energy use material that has been collected for other reasons, such as timber and food processing residues and urban waste.

(iv) capacity is determined by availability of biomass and not suitable for varying loads.

(v) Not feasible to set up at all location.

4.3. Types Of Biomass Fuels - Solid, Liquid & Gas:

· Solid fuels:

· Forest Residue:

· Forests natural or cultivated are a rich source of timber, fuel wood, charcoal and raw material for paper mills and other industries. Fastest growing trees like Eucalyptus, Neem, Kikar and Gulmohar are grown along canals, railway tracks and on lands of marginal quality.

- Wood, saw dust and dark residue are generated in saw mills forest also provides foliage and logging residues. Its important characteristics of forest residue is it's calorific value. which is 4399 to 4977 Kcal/kg for softwood foliage and 3888 to 5219 Kcal/kg for hard wood species.
- **Agricultural Crop Residue:**
- Crop residues are available in abudance as natural resources, easily collected and stored. These are rice husk, wheat straw, corn cobes, cotton sticks, sugarcane bagasse, groundnut and coconut shells.
- These are converted into briquettes or pallets for use as clean fuel. These are called bio fuels which are high efficiency solid fuel.
- **Energy Crop:**
- Energy farming refers to the cultivation of fast growing plants which supply fuel wood, biomass that can be convert-ed into gaseous and liquid fuels like bio gas, vegetable oil and alcohol. To harvest bio mass for power generation, energy plantation is done on degraded or wastelands which are saline, wind eroded lands in arid areas and water-logged lands.
- Energy farming is promoted by MNRE in nine different agro-climate regions, namely, Gartwal (U.P.), Gwalpahan (Haryana), Udaipur (Rajastan) and shantiniketan (West bengal), The other four centres are madurai (Tamilnadu), calicut (Kerala), Raipur (Chhatisgarh), Bhubaneswar (Orissa).

- These centres produce quality seedings of about 35 tree species through clonal propagation. These fast growing fuel wood species produce 20-25 tonnes of biomass per hector per year.
- The Biomass Research centre Lucknow found the "Kubabul" tree that grows well on saline and rocky soils, provide woods of high calorific value (4500 Kcal/Kg).

- **Animal Wastes:**
- Animal waste, an organic material with combustible property, is a rich source of fuel. Dung cakes prepared with animal water are used for cooking in natural and semi-urban areas. It is also a raw material for biogass plant.

- **Industrial Waste:**
- Every energy recovery from industrial waste was taken up in 1994. Projects are implemented with technical assistance of national laboratories. projects developed under this programme are:

Pulp and paper industry influent, starch and glucose industry waste, Palm oil industry, distillary waste and Tanneries waste. Each project is aimed to treat its waste for the production of bio-energy which can be used for power generation.

- **Vegetable oil crops:**
- Oil can be extracted from fertile area crops such as; Sun flower, cotton seeds, ground nut, rapeseed, palm and coconut. These oils after purification can be blend with diesel oil suitable as engine oil.
- There is an arid area shrub 'jojoba'. Its seeds provide oil which is an important source of renewable energy. It is cultivated in Rajasthan, Gujarat and Orissa under hot arid condition.
- It is an ideal plant for areas of scanty rain with low fertility soil and produces upto 2000 Kg of seed per hector annually. It can be used as transformer oil due to its insulating property.

- **Charcoal:**
- Charcoal is a smokeless dry solid fuel with high energy density. Morden charcoal retorts (Fernale) operate about 600°C to produce charcoal from dry biomass feed. It contains 75-80 % carbon and is useful as a compact fuel. It can be burnt to provide heat for domestic, commercial and industrial application.
- **Briquetting:**
- Biomass briquetting is densification of loose biomass into a high density fuel. Biomass of any form such as cotton sticks, rice husk, coconut shells, saw dust and wood chips can be converted into briquets.
- It reduce the volume to weight ratio, thus making transportation easy for efficient commercial and Industrial use. The calorific value is about 3500 Kcal/Kg. Biomass briquets can replace 'c' grade coal used in industrial boiler.

* Liquid Fuels:

• Vegetable Oil:

• Vegetable oil such as Rapeseed, palm, coconut and cotton seeds oil can substitute diesel as engine fuel. Jojoba trees are cultivated in marginal lands produce oil seeds. Jojoba oil is considered liquid gold like crude oil as it can be processed into wide range of products like motor oil, lubricant, mono-unsaturated alcohols and oils of cosmetic value. Euphorbia species produce latex which after water removal give light hydrocarbon oil.

• Ethanol:

• Ethanol (C_2H_5OH) is a colourless biofuels. It can be produce by fermentation of any feed stock which contains sugar or starch and even cellulose material.

• Biomass containing sugar are: Sugar-beet, sugar cane, sweet sorghum, starch crop covers corn, wheat, cassava and potato, cellulose is found in all plant tissues is available in wood, solid waste and agricultural residue.

• Ethanol is suitably use as a fuel additive to reduce a vehicle's carbon monoxide and other smog causing emission. In Nine sugar producing Indian states, Petrol blended with 5% ethanol is supplied.

* Gas Fuels:

• BioGas:

• Biogas can be produced by digestion of animal, plant and human wastes. Digestion is a biological process that takes place in a digester with anaerobic organism in absence of oxygen at a temperature between 35°C and 70°C.

- In rural areas, household biogas plants operate from cow and buffalo dung which provides gas for cooking and lighting. Biogas is a mixture of CH_4 (55% to 65%), CO_2 (30% to 40%), H_2, H_2S and N_2 (<10%) having a calorific value between 5000 and 5500 Kcal/Kg.

- **Producer Gas:**
- Producer gas is obtained by partial combustion of wood or any cellulose organic material of plant origin. It is a mixture of a few gases and its constituents are CO_2 (19%), CH_4 (1%), H_2 (18%), CO_2 (11%) and N_2 (45-60%)
- Hydrogen and methane keep heating value between 4.5 MJ/m^3 and 6 MJ/m^3 depending upon the volume of its constituents.
- Producer gas can be burnt in a boiler to generate steam. It is used as fuel in IC engines used for irrigation pumps, in spark ignition engines and gas turbines for power generation.

4.4. Combustion and Fermentation:

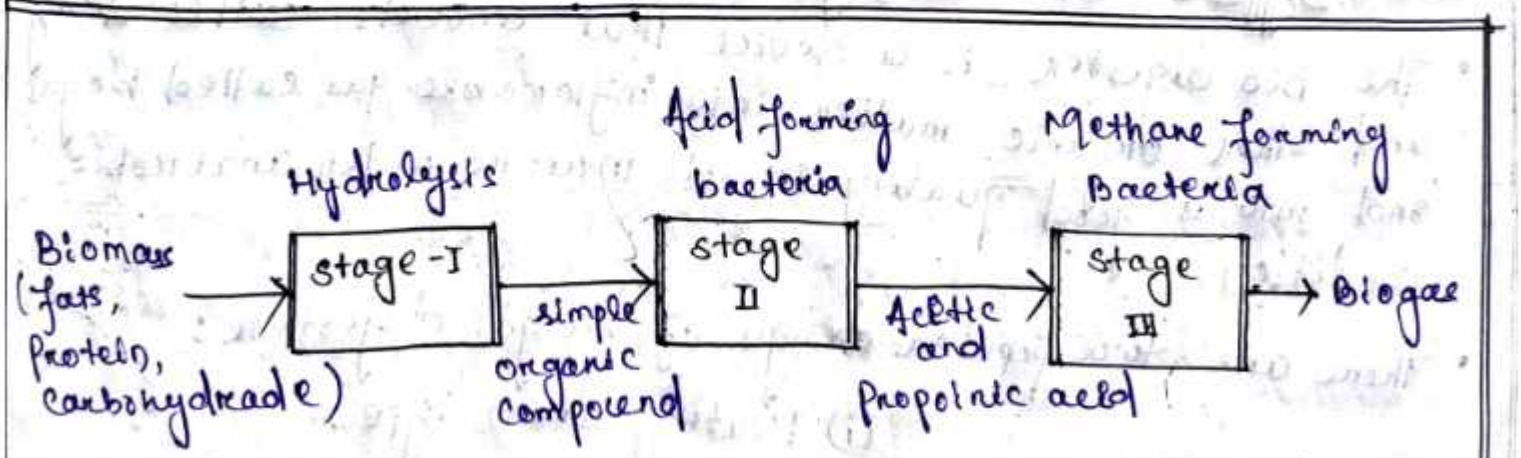
- **Combustion:**
- Direct combustion is the main process adopted for utilizing biomass energy. It is burnt to produce heat utilized for cooking, space heating, Industrial processes and Electricity generation.
- This utilisation method is very inefficient with heat transfer losses of 30% - 90% of the original energy contained in biomass. The problem is addressed through the use of more efficient cook-stove for burning solid fuels.

• Fermentation:

- This process converts the cattle dung, human waste and other organic waste with high moisture content into biogas through anaerobic fermentation in absence of air.
- Fermentation occurs in two stages by two different metabolic groups of bacteria. Initially the organic matter is hydrolized into fatty acids, alcohols, sugars, H_2 and CO_2.
- Methane forming bacteria then converts the products of the first stage to CH_4 and CO_2, in the temperature range 30-55°C.
- Biogas produced can be used for heating, or for operating engine driven generator to produce electricity.
- Fermentation occurs in a sealed tank called "digester" where the sludge left behind is used as enriched fertilizer.

4.5. Anaerobic Digestion:

- Anaerobic fermentation is also known as anaerobic digestion which is complete it's bio-chemical process in three stages:-



(Various stages of anaerobic digestion)

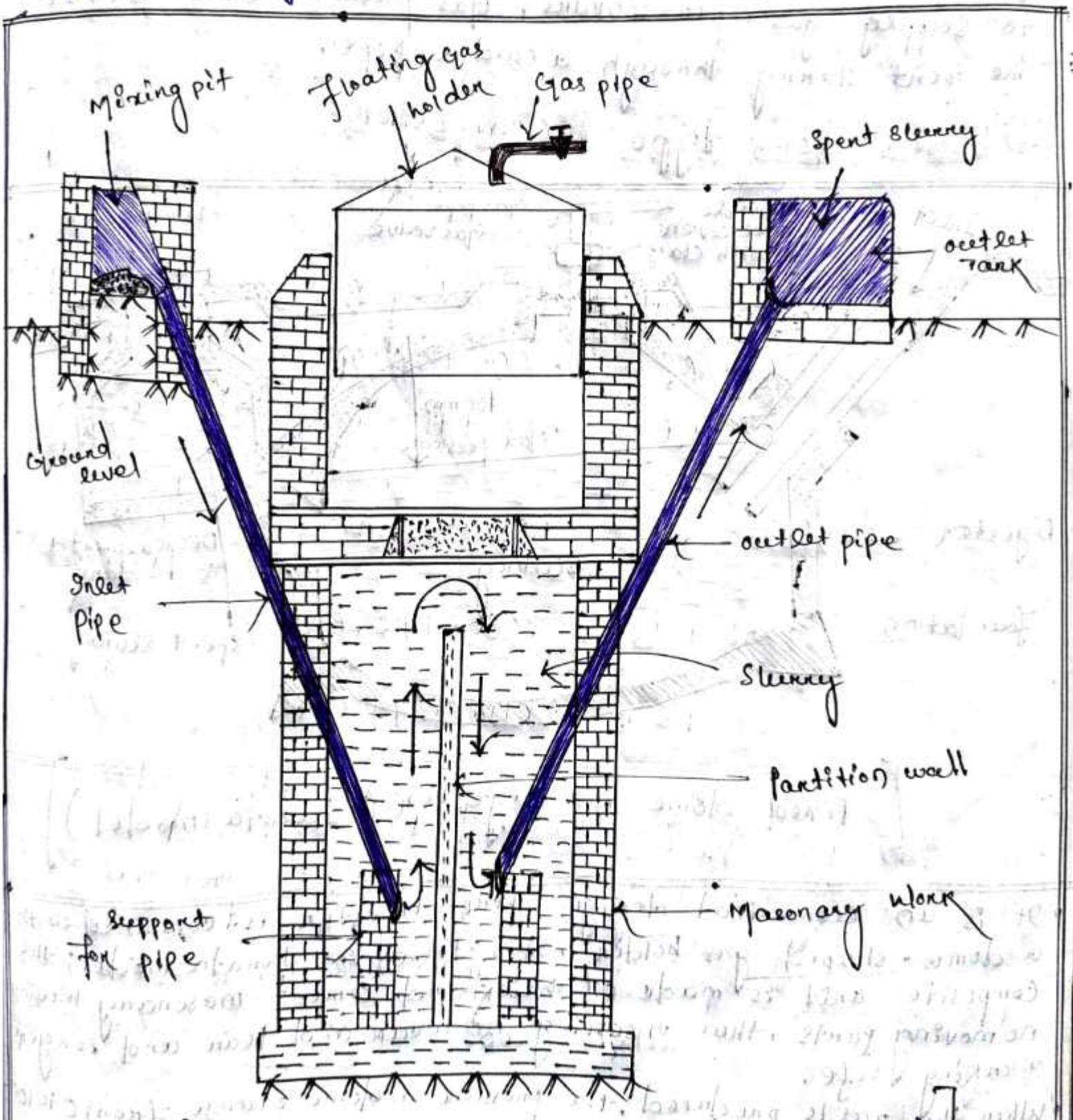
- **Stage - I**
- First of all, the original organic matter containing complex compounds, e.g. carbohydrates, protein and fats is broken down through the influence of water to simple water soluble compounds. The polymers are reduced to monomers. The process takes about a day at 25°C in an active digester.
- **Stage - II**
- The micro-organisms of anaerobic and facultative groups, together known as acid formers, produce mainly acetic and propionic acid. This stage also takes about one day at 25°C much of CO_2 is released in this stage.
- **Stage - III**
- Anaerobic bacteria, also known as methane formers slowly digest the products available from the second stage to produce methane, carbon dioxide, a small amount of hydrogen and a trace amount of other gases.
- The process take about two weeks time to complete at 25°C. This 3rd stage i.e. methane formation stage is carried out strictly by the action of anaerobic bacteria.

4.6. Types Of Biodigester:

- The Bio digester is a device that converts cattle dung and other organic matter into inflamable gas called biogas and into a good quality organic manure under anaerobic condition.
- There are two popular design of biogas digester:
  - (i) Floating dream type.
  - (ii) Fixed dome type.

(i) Floating drum type Bio-digestem:

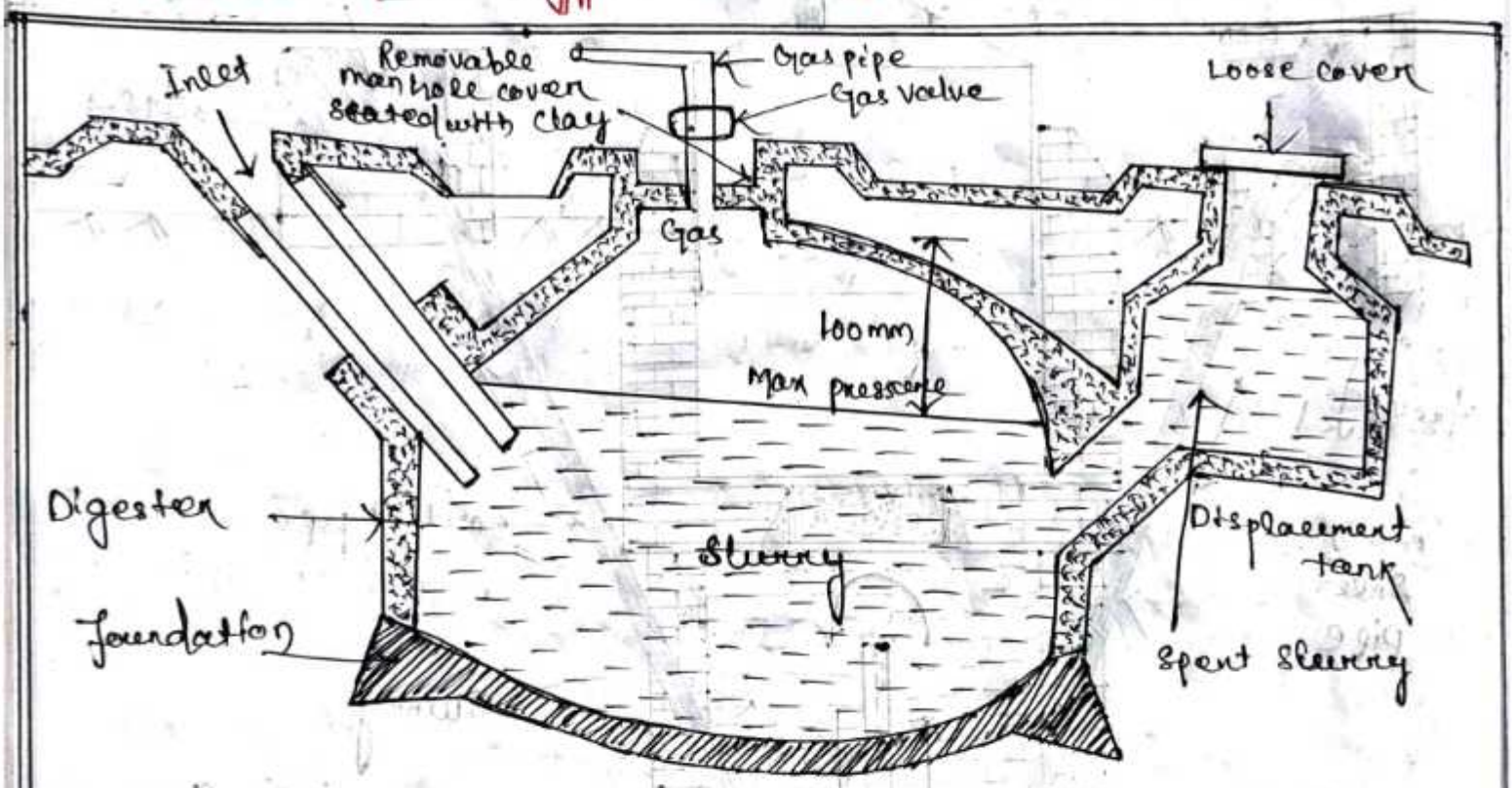
- A popular model developed by Khadi Village Industries Commission (KVIC) was standardized in 1961. It comprises an underground cylindrical masonary digester having an inlet pipe for feeding animal dung and outlet pipe for sludge.



[Floating drum biodigester (KVIC Model)]

- There is a steel drum for gas collection which float over the slurry. It moves up and down depending upon accumulation and discharge of gas guided by the dome guide shaft.
- A partition wall is provided in between to improve circulation necessary for fermentation. The floating gas holder builds gas pressure of about 10 cm of water column, sufficient to supply gas upto 100mtrs. Gas pressure also forces out the spent slurry through a sludge pipe.

(ii) Fixed dome type Bio-digester:

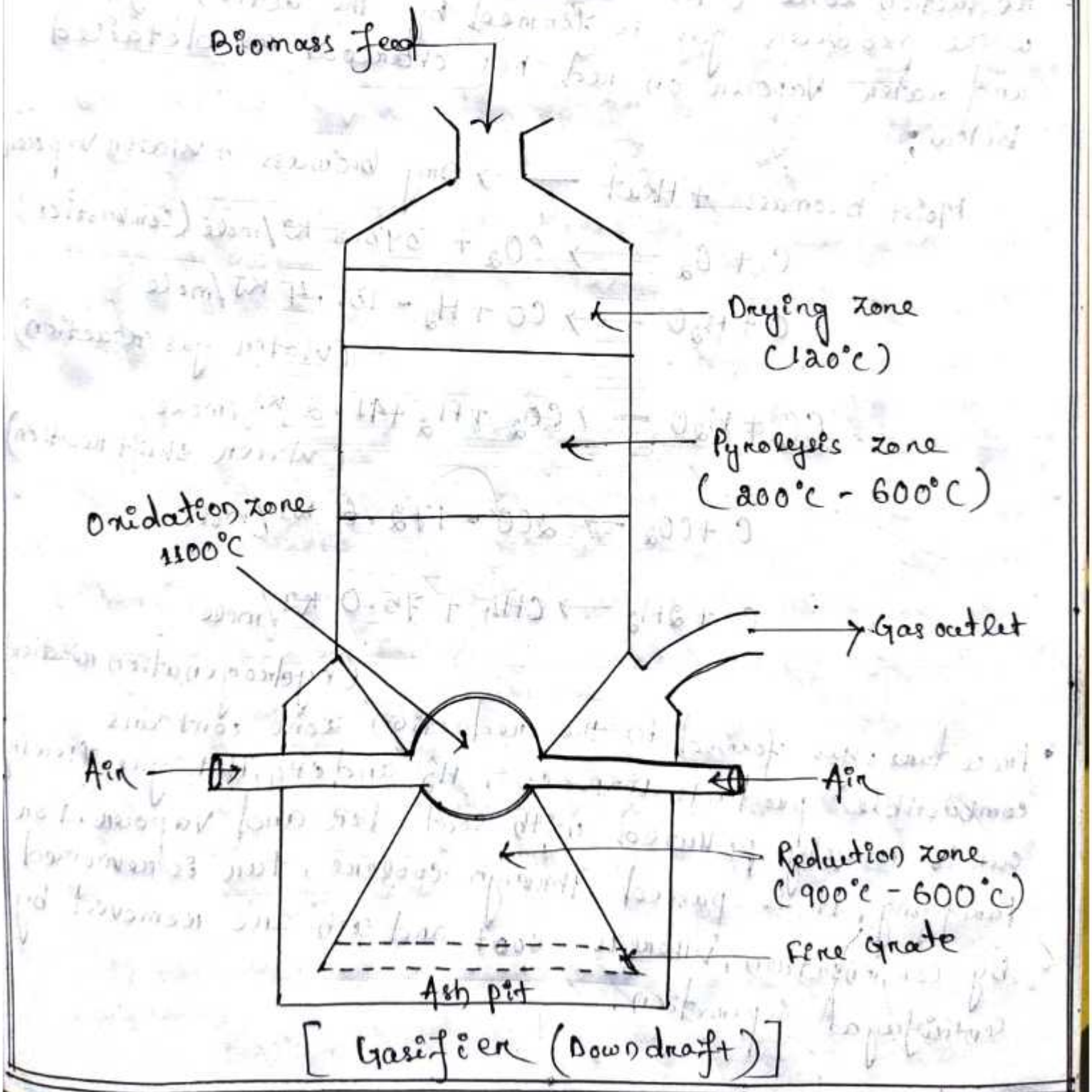


[Fixed dome bio digester (Janata model)]

- It is an economical design where digester is combined with a dome-shaped gas holder. It is known as Janata model; the composite unit is made of brick and cement masonary having no moving parts, thus ensuring no wear and tear and longer working life.
- When the gas is produced, the pressure in dome change from 0 to 100 cm of water column. It regulates the gas distribution & outflow.

4.7 Wood Gasifier:

- Gasifier (fixed bed type) can be "updraft" or "downdraft" type depending upon the direction of the air flow. The working of biomass gasification can be explained by considering a typical downshaft gasifier where fuel and air move in a co-current manner. In updraft gasifier fuel and air move in a count current manner. However, the basic reaction zone remain the same.



[Gasifier (Downdraft)]

- Feed is loaded in the reactor from the top. As the feed moves down it is subjected to drying (120°C) and then pyrolysis (200 - 600°C) where solid char, acetic acid, methanol and water vapour are produced. Descending volatiles and char reach the oxidation zone where air is injected to complete combustion. It is reaction zone and the temperature rises to 1100°C this helps in breaking down the heavier hydrocarbons and tars.
- As these products move downwards, They enter the "reduction zone" (900 - 600°C, reaction being endothermic) where producer gas is formed by the action of CO_2 and water vapour on red hot charcoal as detailed below;

Moist biomass + Heat ⟶ Dry biomass + water vapour

$$C + O_2 \longrightarrow CO_2 + 393.8 \text{ KJ/mole (combustion)}$$

$$C + H_2O \longrightarrow CO + H_2 - 131.4 \text{ KJ/mole}$$

(water gas reaction)

$$CO + H_2O \longrightarrow CO_2 + H_2 + 41.2 \text{ KJ/mole}$$

(water shift reaction)

$$C + CO_2 \rightarrow 2CO - 172.6 \text{ KJ/mole}$$

$$C + 2H_2 \rightarrow CH_4 + 75.0 \text{ KJ/mole}$$

(hydrogenation reaction)

- Producer gas formed in the reduction zone contains combustible products like CO, H_2 and CH_4, Hot gas flowing out is usually polluted with soot, tar and vapour. For purifying, it is passed through coolers, tar is removed by condensation, whereas soot and ash are removed by centrifugal separation.

- Clean producer gas provides the process heat to operate stoves (for cooking), boilers, driers, ovens, and furnaces. The major application is in area of electric power generation either through dual-fuel IC engines (where diesel oil is replaced to an extent 60 % - 80 %), or through 100% gas-fired spark ignition engines.
- A biomass gasifier-based electricity generation system costs from ₹ 4.0 Crores to 4.5 crores/MW and the power generation cost is between ₹ 2.50 and ₹ 3.50 per Kwh.
- Fixed bed gasifiers can attain effiency upto 75 % for conversion of solid biomass to gaseous fuel. However, the performance depends on fuel size and moisture content, volatiles and ash content.

4.8. Pyrolysis:

- Biomass is heated in absence of oxygen, or partially combusted in a limited oxygen supply, to produce hydro-carbon, rich in a gas mixture (H_2, CO_2, CO CH_4 and lower hydrocarbons), an oil like liquid and a carbon rich solid residue (charcoal).
- The pyrolitic or "bio-oil" produced can be easily transported and refined into a series of products similar to refining crude oil.
- There is no waste product, the conversion efficiency is high (82%) depending upon the feedstock used, the process temperature in reactor and the fuel/air ratio during combustion.

11.9. Application : Biogas, Biodiesel

(i) Electricity Generation:

- The application of biogas to electricity generation is the most common of all uses.
- Biogas made from plant material offers a renewable way to generate electricity.
- Biogas posseses chemical energy, and therefore electricity from biogas comes as a result of coverting this chemical energy to mechanical energy and finally into electricity.
- This electricity can be used with both domestically and commercially, since it can be made in small and large scale.

(ii) In Combined Heat and Power (CHP) Plants:

- The application of biogas to produce combined heat and power should be as common as electricity generation, but the additional CHP plants requiring additional investment, so the add-on equipment needed to use the waste heat may not be installed.
- The valuable components of biogases is methane (CH_4) which typically makes up 60%, with the balance being carbon dioxide (CO_2) and small percentage of other gases.
- Biogas is streetered and contains H_2S, and the simplest use is in a boiler to produce hot water or steam.

- The most common use is where the biogas fuels an internal combustion gas engine in a combined heat and power (CHP) unit to produce electricity and heat.

(iii) Waste Management in Agriculture:

- In the agricultural sector one possible solution to processing crop biomass is co-digested together with animal manures, the largest agricultural waste streams.
- In addition to the production of renewable energy, controlled anaerobic digestion of animal manures reduces emissions of greenhouse gases, nitrogen and odor from manure management, and intensifies the recycling of nutrients within agriculture.
- co digestion offers good opportunity to barriers to treat their own waste together with other organic substrates.
- As a result, farmers can treat their own residues properly and also generates additional revenues by treating and managing organic waste from other source and by selling and using products. i.e. Heat, electrical energy and stabilized fertilization.

(iv) Biogas Applied to use as a Cooking Fuel - A Sustainable Energy Source:

- The application of biogas for cooking and baking is a promising option for improving the energy apply of the poor i.e. over 2.7 billion people who rely on inefficient and unhealthy burning of biomass as main energy source.

- Provided the biogas is properly combusted, biogas stoves produce the lowest level of greenhouse gas emissions compared to other technologies that use fuel combustions. e.g. Biomass or fossil fuel.
- Stoves and ovens using biogas have the potential to improve the well being of marginalized people.
- The production of fuel wood and charcoal has resulted in deforestation and soil erosion in some regions.

(v) Injection into natural gas pipe line:

- To understand the application of biogas as a fuel added into fossil fuel natural gas supply pipelines, needs to be understood.
- When purified to suitable extent to be injects in a natural gas pipe line, the pure gas is usually called 'biomethane'.
- Biomethane injected in this way is in demand in many countries where the population is K to comply with climate change reduction methods.
- The potential for RNG and biomethane in gas applications in the U.S. is virtually untapped.

(vii) As a renewable fuel for transport vehicles:

- In concentrated and compressed and ideal application of biogas exists in vehicles transportation.
- Compressed biogas is becoming widely used in sweden switzerland, and Germany.

- A biogas-powered train, named biogaståget amanda (The biogas train Amanda) has been in service in sweden since 2005.
- Biogas powers automobiles in 1974, a British documentary film titled sweet as a nut detailed the biogas production process from pig manure and showed how it fueled a custom-adapted combustion engine.
- The big advantage for transport use can be that a fleet of trains can be fueled by biogas very efficiently. If the vehicles are fueled at the same location as the biogas plant. If so there is no cost for transporting the biogas to the point of use.

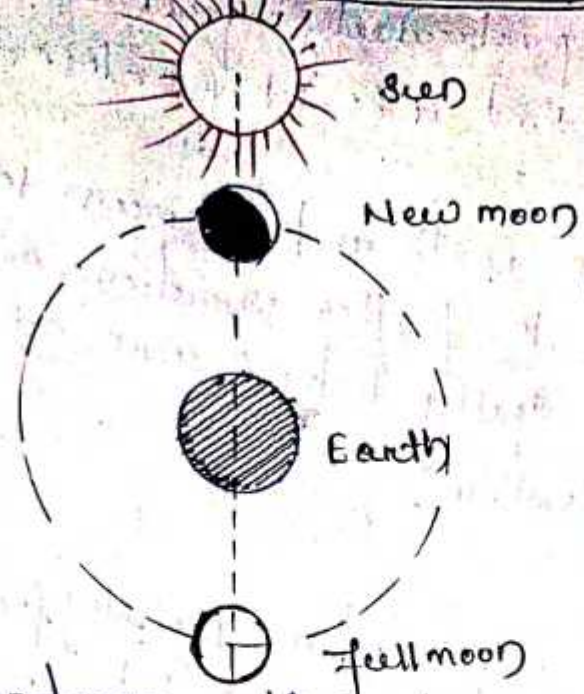
(iii) Fuel Cells:

- Theoritically, biogas can be converted directly into electricity by using fuel cell.
- However, this process requires very clean gas and expensive fuel cells.
- Therefore, this option is still a matter for research and is not currently a practical option.
- The conversion of biogas to electric power by a generator set is much more important.

⑤ Other Sources of Energy

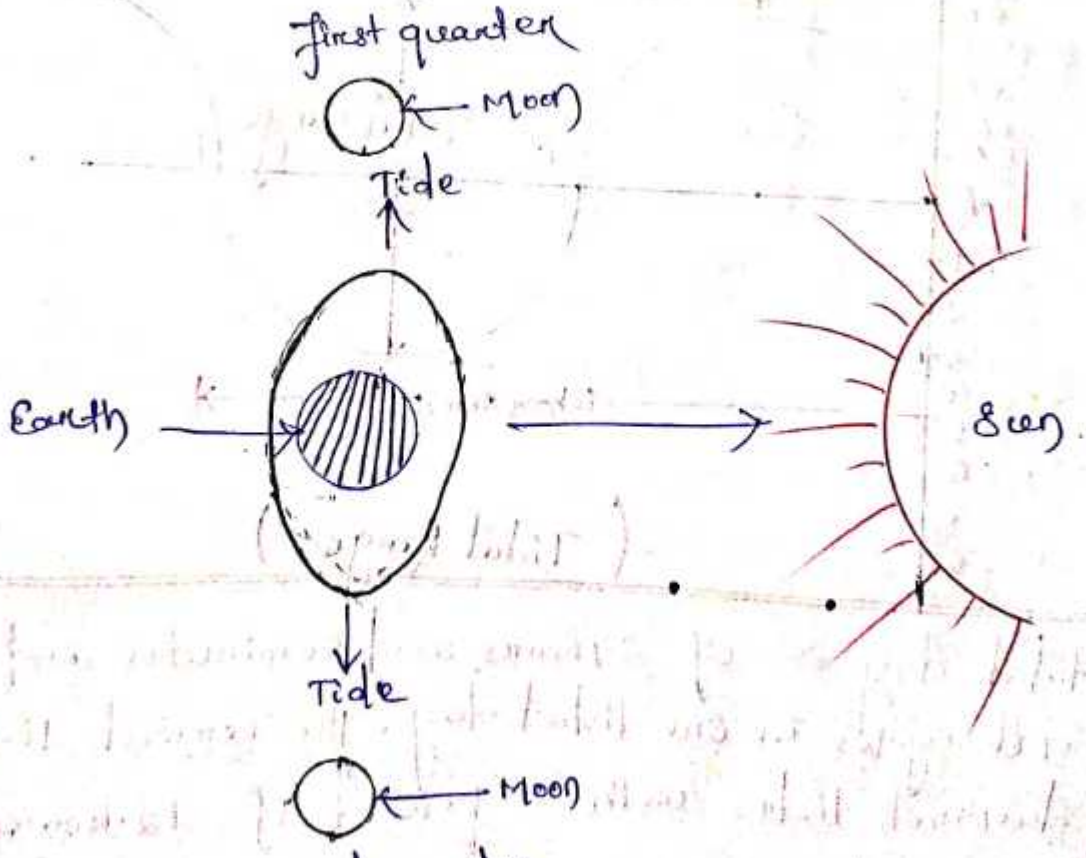
5.1. Tidal Energy:

- The tides are caused by the combined attraction of the sun and the moon on the waters of the revolving globe. The effect of the moon is about 2.6 times more than that of sun, influencing the tides of Oceans.
- Thus, tide is a periodic rise and fall of water level of the ocean twice during a lunar day (i.e. within 24 hours 50 mins) the water in the oceans and seas rises and falls. The excess of 50 min over the solar day results in the maximum water level, occurring at different times on different days.
- The amplitude of water level variation at different points on the earth depends on the latitude and the nature of the shore. The rotation of earth causes two high tides and two low tides to occur daily at any place.
- The revolution of the moon around the earth increases the time interval between two successive high tides from 12 hours to about 12 hours and 25 minutes.
- As the moon revolution takes about 28 days, the three bodies, i.e. the sun, the moon and the earth are in alignment every two weeks at new and full moon. During these periods the sun and the moon act in combination to produce tides of maximum range as shown in figure.



(The sun and moon acting in combination to create spring tide)

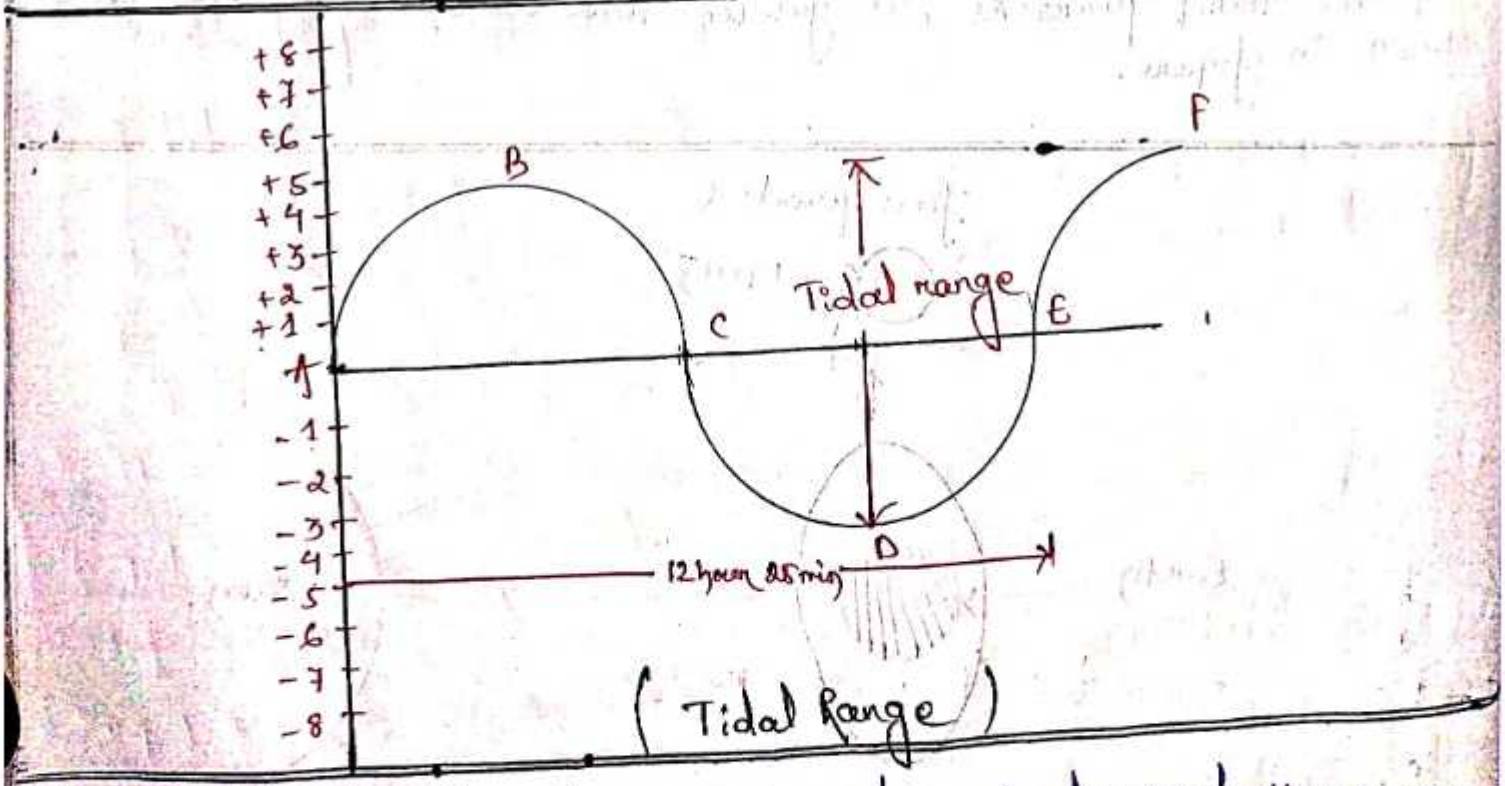
- The solar pull comes in line with the lunar pull at "new moon" and "full moon", causing greater flow and ebb, known as spring tides.
- On other hand, if the two pulls act at right angles to each other, as at waxing and waning "Half moons", i.e. in the first and the third quarters, we get low tides called "Neap tides" as shown in figure.



(The sun and moon are at right angle to each other, causing neap tides)

- The spring tide is particularly great when the moon is "New and "full" at which time it is at the closest point of it's Orbit to the earth.
- The revolution of the earth and the moon together aroound the sun gives rise to further variation, and due to this effect the highest spring tides occurs at the equinoxes in march and september.

- **Tidal Range:**
- The "tidal range" is expressed as the difference in water levels between two consecutive high tides and low tides. The rise and fall of water level in the sea during tides can be represented by a sine curve shown in figure. The figure shows the point B, a position high tide, while the point D represents a position of low tides.

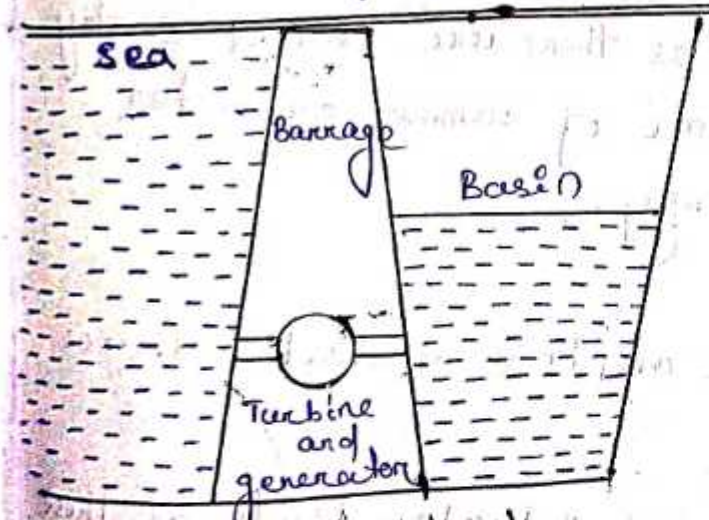


- One tidal day is of 24 hours and 50 minutes and there are two tidal cycles in one tidal day. The normal tide is a semi-diurnal tide with a period of 12 hours and 25 minutes.

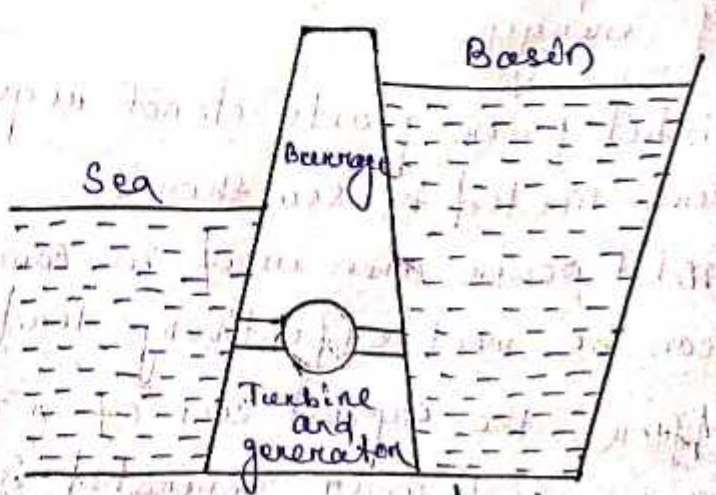
- Diurnal means daily, i.e. activities of tide pattern during 24 hours. Diurnal tides indicate two high and two low tides created by the moon during one rotation of the earth on its axis. The daily tidal cycle follows a sinusoidal pattern.

• Energy and Power In a double Cycle System:

- In a double effect system as shown in figure, the energy available in tide sea water is converted into electrical energy during flood tide (rising tide) when the basin is filled and also during the ebb tide (falling tide) when the basin is emptied.
- The flow of water through the turbine during rising and falling tides is in opposite directions. for this reason, a reversible water turbine is used, which acts as a turbine for ~~either~~ direction of flow. During rising tides a large quality of water flows into the basin through the turbine by opening the sluice gates.



(1a) Rising tide)



(Falling tide)

- Filling of the basin continues with the generation of electric power until the tide water levels of the sea and the basin become equal. At this position the sluice gate is closed.
- Subsequently, during falling the tide water from the basin flows into the sea through the turbine and electric power is generated.
- As the water level in the basin drops, a point reached when the difference in water levels between the sea and the basin becomes too small to generate power.
- At these point of time the generating unit are shut down. The basin is again filled during rising tide and the cycle repeats to convert tidal energy into electrical power.

• Advantages of Tidal power:

1. Tidal power is predictable.
2. Available tidal power is firm as there are no wet or dry years, nor is there any influence of summer or winter on the availability of tidal energy.
3. It is free from pollution.
4. Tidal power is inexhaustible and is a renewable source of energy.
5. Tidal power plants do not requires valuable lands as these are located on sea shores.
6. Tidal power when used in combination with a thermal plant can be meet effectively load demand.
7. After the capital cost of a tidal power scheme is paid off, the cost of power generated is very low.

- **Disadvantages:**

1. Tidal power plants output varies with the variation in tidal range.
2. Tidal power supply is intermittent.
3. Capital cost of a tidal plant is not economical when compared with conventional sources of energy.
4. Silting of basins is a problem with tidal power plants.

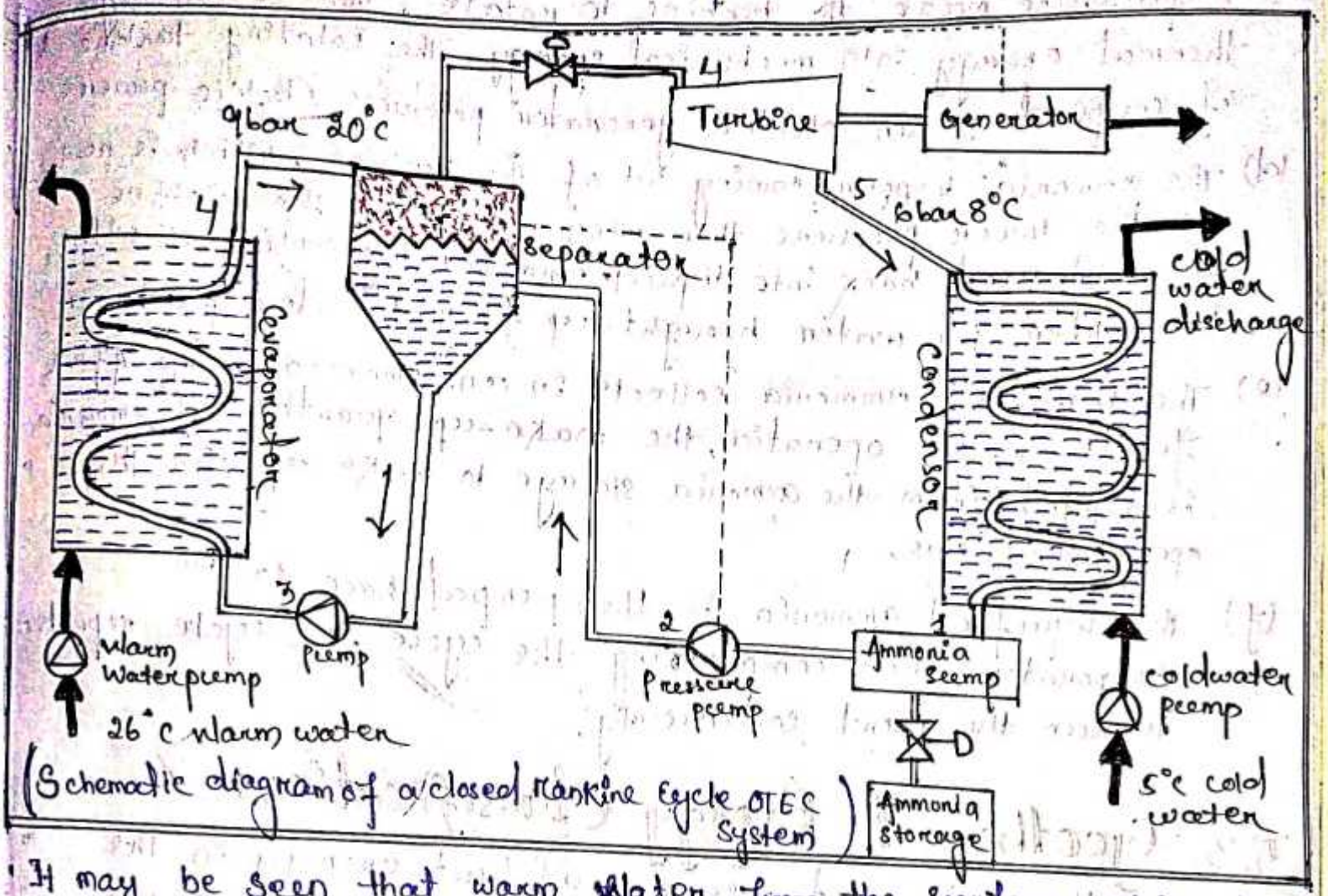
5.2. Ocean Thermal Energy Conversion:

- The oceans and seas which cover about 70% of the earth are constantly receiving solar radiation and act as the largest natural solar collector.
- An ocean as a collector has an enormous storage capacity. Energy from the ocean is available in several forms, such as ocean thermal energy, wave energy and tidal energy.
- Ocean thermal energy conversion (OTEC) is a new technology, needed to be harnessed especially in India where the coastline is about 6000 Km.
- Basically, the OTEC converts the thermal energy, available due to temperature difference between the warm surface water and the cold deep water, into electricity.
- Power from the OTEC is renewable and eco-friendly. An OTEC plant can operate in remote islands and sea-shore continuously.
- It is very low grade solar thermal energy, so the efficiency of energy recovery is quite low. However, since the ocean thermal energy is dispersed over a large ocean surface area, it has a big potential.
- According to MNRE, the overall potential of ocean energy in the country may be in excess of 50,000 MW. There is an enormous opportunity to tap this renewable source of energy.

Working Principle - OTEC:

- There exists a temperature difference of about 20°C between the warm surface water of the sea (receiving and absorbing solar radiation) and the cold deep water (which flows from the Arctic regions in deep layers) in equatorial areas between latitude 30°S and 30°N. Solar heat energy is absorbed by ocean water.
- It can be explained by "Lambert's law of absorption", the law states that "each water layer of identical thickness absorbs an equal function of light that passes through it.
- Thus, the intensity of heat decreases with the increase in water depth. Due to large heat transfer at the ocean surface water, the highest temperature is attained just below the top surface.
- It may be seen that the temperature at the surface changes slowly, then remains constants at depths of about 200m. Subsequently, the temperature decreases asymptotically and approaches a low value of about 4°C at a depth of 1000 metres.
- The difference in temperature between the surface and the deeper parts of the ocean is utilised to generate electrical energy.
- The basic process of OTEC is to bring the warm surface water and the cold water from a certain depth of the sea through pipes so as to act as "heat source" and "heat sink" for operating a heating engine. It will form the same system as that of conventional thermal power station with nil fuel consumption.
- The OTEC plants are three types, namely "closed", "open" and thermoelectric. The important board features of these plants are as

Closed Rankine Cycle OR Anderson closed cycle OTEC System:



(Schematic diagram of a closed Rankine cycle OTEC System)

- It may be seen that warm water from the surface which is at a temperature about 26°C is brought in one pipe, and cold water at a temperature of around 5°C is brought in another pipe from a depth of about 1000 metres.
- In OTEC plants two water pipes are used in conjunction with a working fluid to generate electric power. Different operational activities of the plants are:

(a) The warm sea water evaporates the liquid ammonia into vapour in a unit called an evaporator. this can be done because ammonia exists in the form of gas at the temperature corresponding to the surface sea water.

(b) the liquid ammonia which is not evaporated collects in a unit known as separator, which again recirculates through the evaporator.

(c) The evaporated ammonia in the form of high pressure vapour is made to pass through a turbine where its pressure and temperature make the turbine to rotate, thus converting thermal energy into mechanical energy. The rotating turbine if coupled to an electric generator produces electric power.

(d) The ammonia vapour coming out of the turbine, which is now at the lower pressure than when it entered the turbine is condensed back into liquid ammonia by cooling it with the colder sea water brought up from the deep part.

(e) The liquified ammonia collects in an ammonia sump. After few hours of operation, the make-up quantity of ammonia is added from the ammonia storage to make up for the operational loss.

(f) The liquified ammonia is then pumped back to the evaporator, thus completing the cycle. The cycle repeats to keep the plant continuously.

5.3. Geothermal Energy Classification:

- The earth is a great reservoir of heat energy in the form of molten interior. Surface manifestation of this heat energy is indicated by hot water springs and geysers discovered at several places.
- Heat can be experienced from the temperature rise of the earth's crust with increasing depth below the surface.
- Radial temperature gradient increases proportionally to depth at a rate of about 30°C per Km. At a depth of 3-4 Km, water bubbles up; while at a depth of 10-15 Km the earth's interior is hot as 1000° to 1200°C. The core of the earth consists of a liquid rock known as "Magma" having a temperature of about 4000°C.

- This geothermal heat is transfered to the underground of the reservior of water which also circulates under the earth's crust.
- Its heat dissipates into the atmosphere as warm water and the steam vents up through the fissures in the ground as hot springs and geysers.
- Limitless heat content in magma plus the heat generated by radioactive decay of unstable elements such as K_{40}, Th_{232} and U_{235} which are abundant in the earth's crust are forms of geothermal energy and considered as a renewable energy source.

* Geothermal Resources:

Geothermal resources are of five types:-

(1) Hydrothermal
  (a) Hot water.
  (b) Wet steam.
(2) Vapour dominated resources.
(3) Hot dry rock resources.
(4) Geo-pressured resources.
(5) Magma resources.

1) Hydrothermal ((a) Hot water):-

- Hydrothermal resources (geothermal reservoirs) are hot water or steam reservoirs that can be tapped by drilling to deliver heat to the surface for thermal use or generation of electricity. Such feilds exist in zones of structural weakness.
- It may be seen that only a part of rock is permiable constituting the geo-fluid reservoir, so the feild is able to produce commercially, a viable resources.

- Sites of these resources adopt the geographical name of their locality such as Larderello field in Italy, Wairakei field in New Zealand and Geysers geothermal field in California.

(b) Wet Steam Fields:

- The pressurized water is at more than 100°C and contains small quantities of steam and vapour in the geothermal reservoir (370°C).
- With this formation, liquid is in dominant phase that controls pressure in the reservoir. Steam occurs in the form of bubbles surrounded by liquid water. Sites where the steam escapes through cracks in the surface are called fumaroles.
- An impermeable cap-rock prevents the fluid from escaping into the atmosphere. Drilling is carried out to bring the fluid to the surface. The fluid is used to produce steam and boiling water in predominant phase.
- Examples of wet steam fields generating electrical energy are: Los Azufre (Mexico), Puna (Hawaii, USA), Dieng (Indonesia) Azores (Portugal), Lafora (Italy) and Zunil (Guatemala).

(a) Vapour-dominated Resource:

- Vapour dominated reservoirs produce dry saturated steam of pressure above the atmosphere and at high temperature about 350°C.
- Water and steam co-exist, but steam is in dominant phase and regulates pressure in the reservoirs.
- Steam obtained from such a geothermal field directly drives a turbine. Major geothermal power plants in the world are: Matsukawa (Japan), The Geysers California (USA), Mt. Amiata (Italy) and Kamojang (Indonesia).

(3) Hot Rock Dry Resource:

- A hot dry rock field also comes under this category. This is the geological formation with high temperature rocks at 650°C, heated by conductive heat flow from magma but contains no water.
- To tap its energy the impermeable rock is fractured and water is injected to create an artificial reservoir.
- Water circulate and hot fluid returns to the surface through the other drilled well as steam and hot water which are used to generate electricity.

(4) Geo-Pressured Resources:

- Geopressured resources contain moderate temperature brines (160°) containing dissolved methane. These are trapped under high pressure (nearly 1000 bar or 987 bars atmosphere) in a deep sedimentary formation sealed between impermeable layers of shale and clay at depth of 2000 m - 10,000m. When tapped by boring wells, three sources of energy are available - thermal, Mechanical and chemical (Methane).
- Technologies are available to tap geopressured brines as investigated in off-shore wells in Texas and Louisiana at the US Gulf coast zone upto a depth of nearly 6570m but have not proved economically competitive. Extensive research is yet to confirm the long-term use of this resource.

(5) Magma Resource:

- Magma is a molten rock at temperature ranging from 700°C to 1600°C. This hot viscous liquid comes out at active volcanic vents and solidifies. It may from reservoirs at some depth from earth's surface. Magma chambers represent a huge energy source, but the existing technology does not allow recovery of heat from these resources.

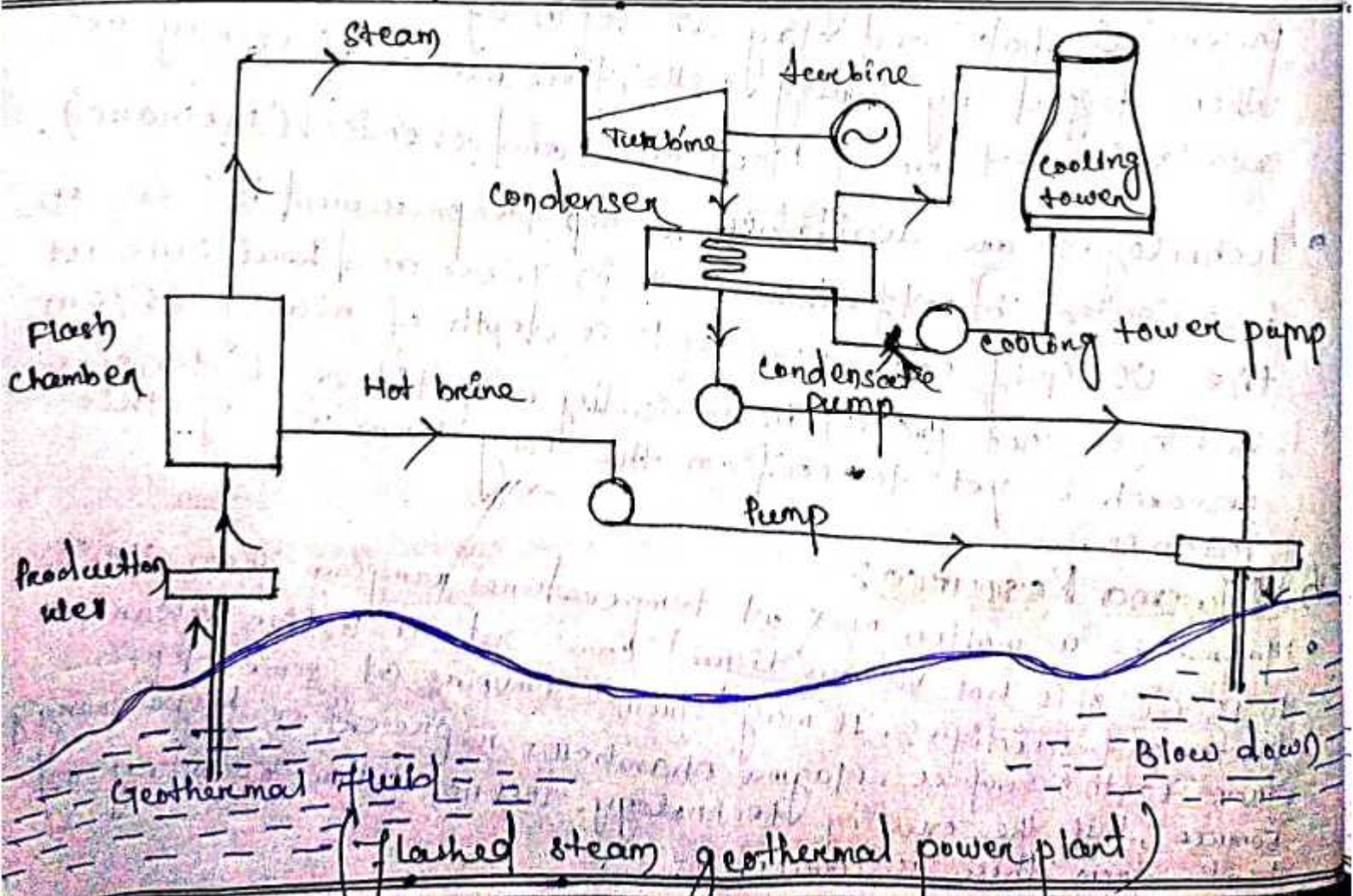
* Geothermal Power Generation:

- Electric power from geothermal resources can be developed in the following manner:-
  (1) Liquid - dominating resources
    (a) Flashed steam system.
    (b) Binary cycle system.
  (2) Vapour - dominated resource

(1) Liquid - dominated Resource:

- Geothermal fluid is either available from natural outflow or from a bored well. The drilling cost increases greatly with depth and technically viable depth is 10 Km.
- Thus, only the geothermal wells of maximum output at shallow depths offer the best prospects for power generation.

(a) Flashed Steam System:



(Flashed steam geothermal power plant)

• The choice of geothermal power plant is influenced by brine characteristics and its temperature more than 180°C, the geothermal fluid is used. This flashed steam system is suitable for power generation as detailed in figure.

• Geothermal fluid is a mixture of steam and brine, it passes through a flash chamber where a large part of the fluid is converted to steam.

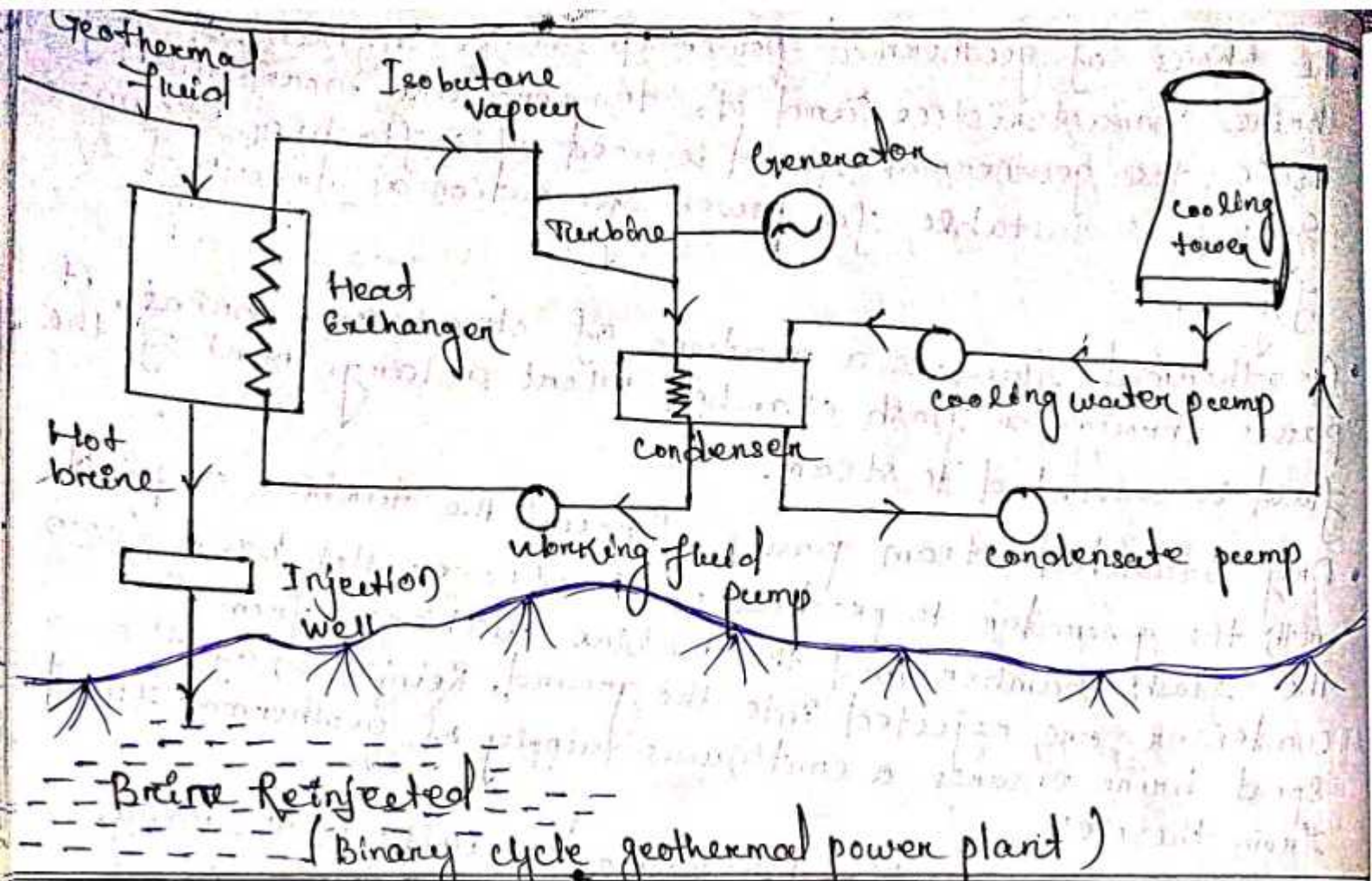
• Dry saturated steam passes through the turbine coupled with the generator to produce electric power. Hot brine from the flash chamber and the turbine discharge from the condenser are rejected into the ground. Reinjection of the spent brine ensures a continuous supply of geothermal fluid from the well.

• Commercially available turbogenerator units in the range of 5-20 MWe are in use. To improve the total efficiency of the system, hot water is utilised for poultry farming in cold regions.

(b) Binary Cycle System:

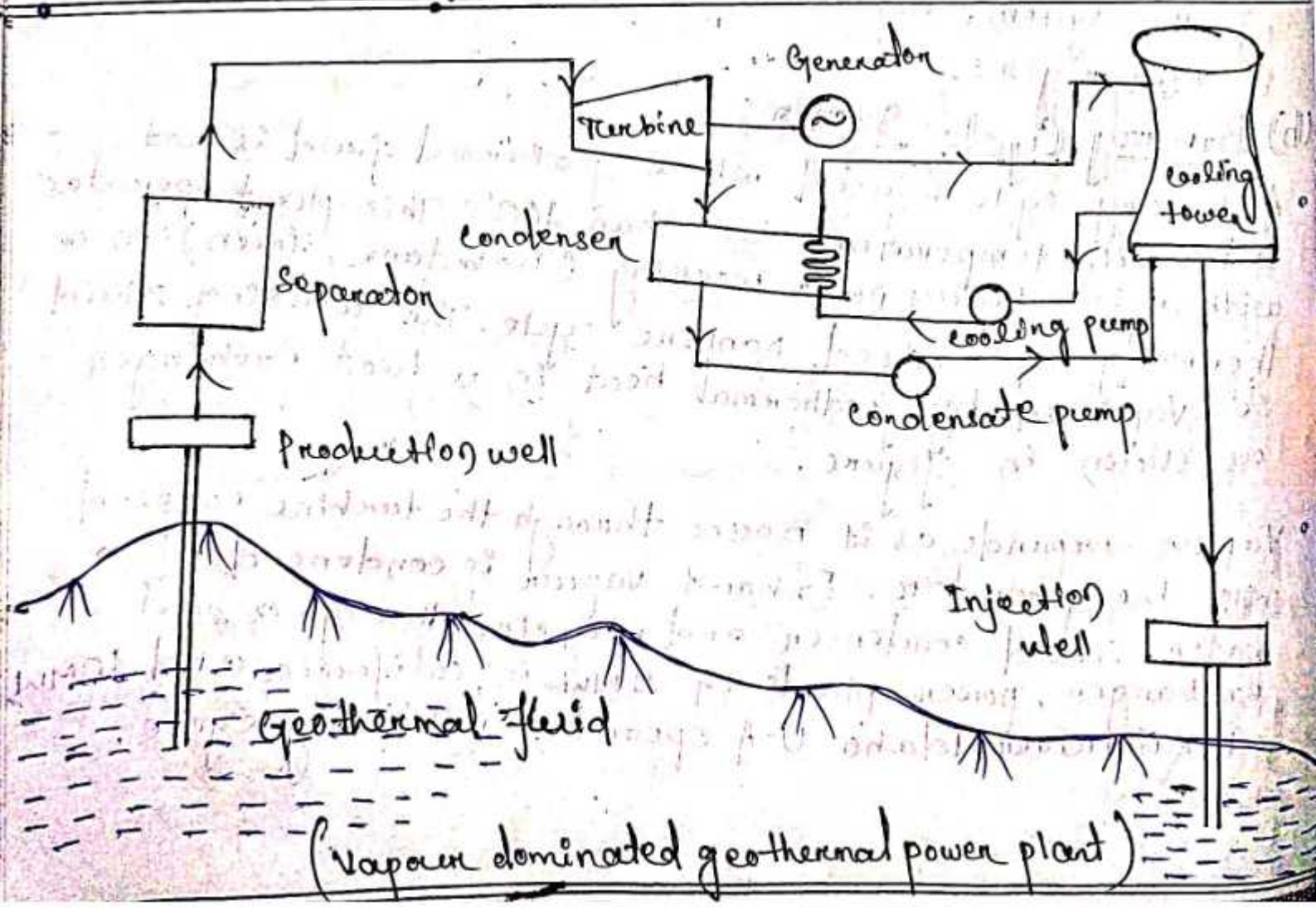
• A binary cycle is used where geothermal fluid is hot water with temperature less than 100°C. This plant operates with a low boiling point working (isobutane, freon) in a thermodynamic closed Rankine cycle. The working fluid is vaporized by geothermal heat in a heat exchanger as shown in figure.

• Vapour expands as it passes through the turbine coupled with the generator. Exhaust vapour is condensed in a water-cooled condenser and recycled through a heat exchanger. power plants of 11 MW in California and 10MW at Raft river Idaho USA operates on binary cycle.



(Binary cycle geothermal power plant)

(2) Vapour - dominated Geothermal power plant:



(Vapour dominated geothermal power plant)

- In a Vapour-dominant plant, steam is extracted from geothermal wells, passed through a separator to remove particulate contents and flows directly to a steam turbine.
- steam that operates the turbine coupled with the generator is at a temperature of about 245°C and pressure 7 Kg/cm² (7 bar) which are less than those in conventional steam cycle plants (540°C and 130 Kg/cm²). Thus, the efficiency of geothermal plants is low, i.e. about 20%.
- Exhaust steam from the turbine passes through a condenser and the water so formed circulate through the cooling tower.
- It improves the effiency of the turbine and controls environmental pollution associated with the direct release of steam into the atmosphere.
- Waste water from the cooling tower seemp is reinjected into the geothermal well to ensure continuous supply.
- At present such a system is being operated to generate power at Larderallo Italy, and at the Geysers in California.

5.4. Hybrid Energy System:

- Hybrid energy systems are defined as the integration of several types of energy generation equipment such as electrical energy generators, electrical energy storage systems, and renewable energy source.
- Hybrid energy systems may be utilized in grid-connected mode, isolated from grid and special aim.
- Uncertainties associated with renewable power production and load demand are considered in recent studies in the area of scheduling of hybrid energy systems.

5.5. Need for hybrid system:

- Solar water heaters, air heaters, solar distillation and wax melters, PV arrays, PV pumps, operate at optimal efficiency for the months of April to september when solar radiation contain high energy flux.
- To meet the load demand during night and cloudy days, battery bank is provided, during winter, load demand shoots up and solar energy reduces, so designer is compelled to select large size equipment, PV arrays and battery bank.
- Similar situation is faced for a stand alone wind power generating systems, when wind speed drops below cut-in speed and wind turbine generator (WTG) stops.
- For emergency, loads of hospitals, defence installation, and communication service, a back up source (1) diesel generator, (2) gas turbine generator, (3) biogas, (4) small hydro, and (5) fuel cell is required.
- Two different energy systems installed at a location to ensure continuity of electrical supply is known as hybrid energy system.
- Thus, hybrid energy system provides an edge over the stand alone and even grid interactive systems for reliability of energy supply and lower capital cost.
- However, engineers selection of back up source is done by maximum capacity of the prime energy source at peak energy demand period.

5.6. Diesel-PV, Wind-PV, Microhydel-PV:

- **Types of hybrid System:**
- Few hybrid energy systems that are operative in prevailing Indian conditions in various states are given:

(A) PV-Diesel *
(B) Wind-Diesel
(C) Biomass-Diesel
(D) Wind-PV *
(E) Microhydel-PV *
(F) Biogas-Solar thermal.
(G) Solar-Biomass.
(H) Electric and electric hybrid vehicles. *

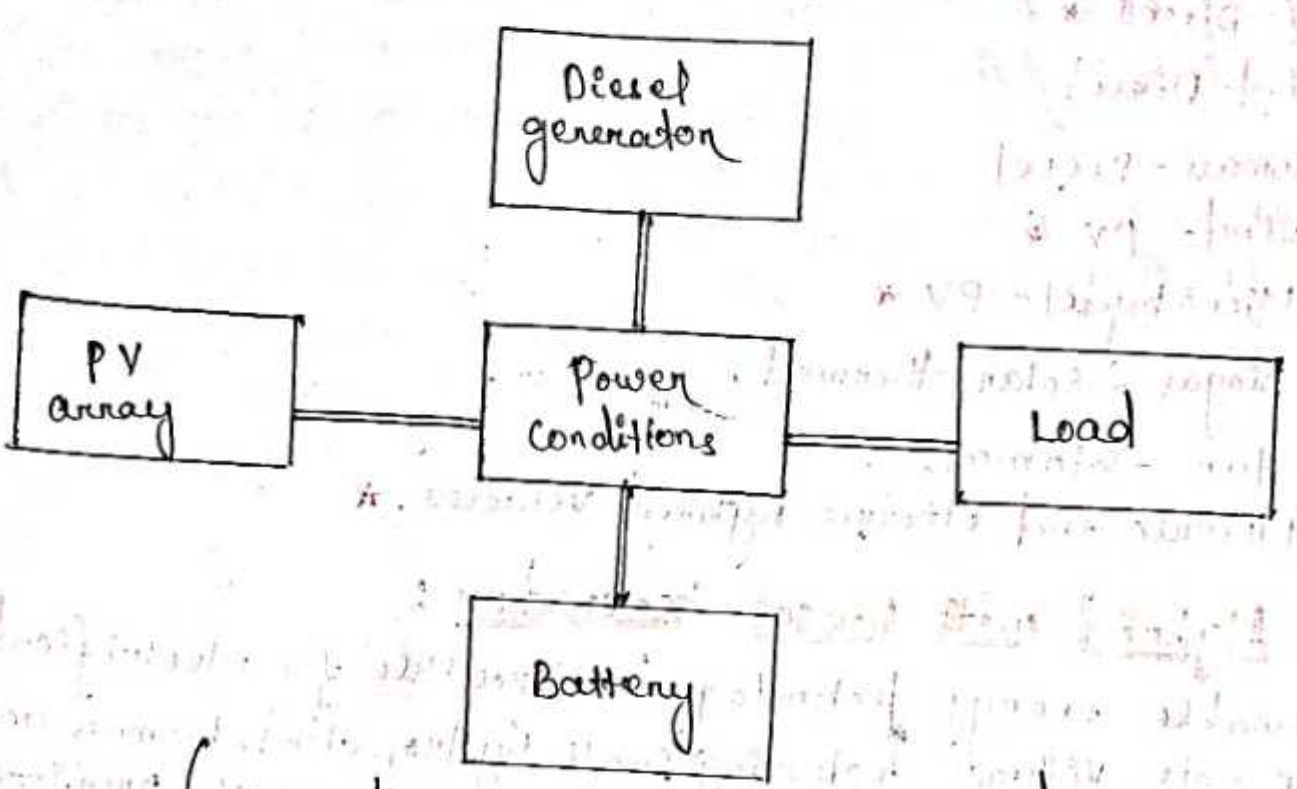
* PV Hybrid with Diesel Generator:

- Renewable energy technology are possible for electrification of remote villages including small hydro, wind, biomass and solar energy, yet solar pv lighting remains most preffered.
- Such systems are used in Orissa, Assam, Jammu and Kashmir and Uttarakhand. This power plant contains one PV array with a Diesel electric generator and a battery bank.
- Energy generated from PV array feeds load demand and then charges the battery bank. Diesel generator keeps the battery fully charged and some times supplies load demand when pv output is not sufficient and battery charge is so low to supplement. The given below figure is a block diagram of such power plant where power conditioner perform three functions;

(1) To convert alternating current (ac) diesel generated output into direct current (dc) for charging battery bank.

(ii) To invert direct current (dc) from PV array and battery bank into ac for feeding load.

(iii) To regulate battery current and voltage for input from generator and output for load.



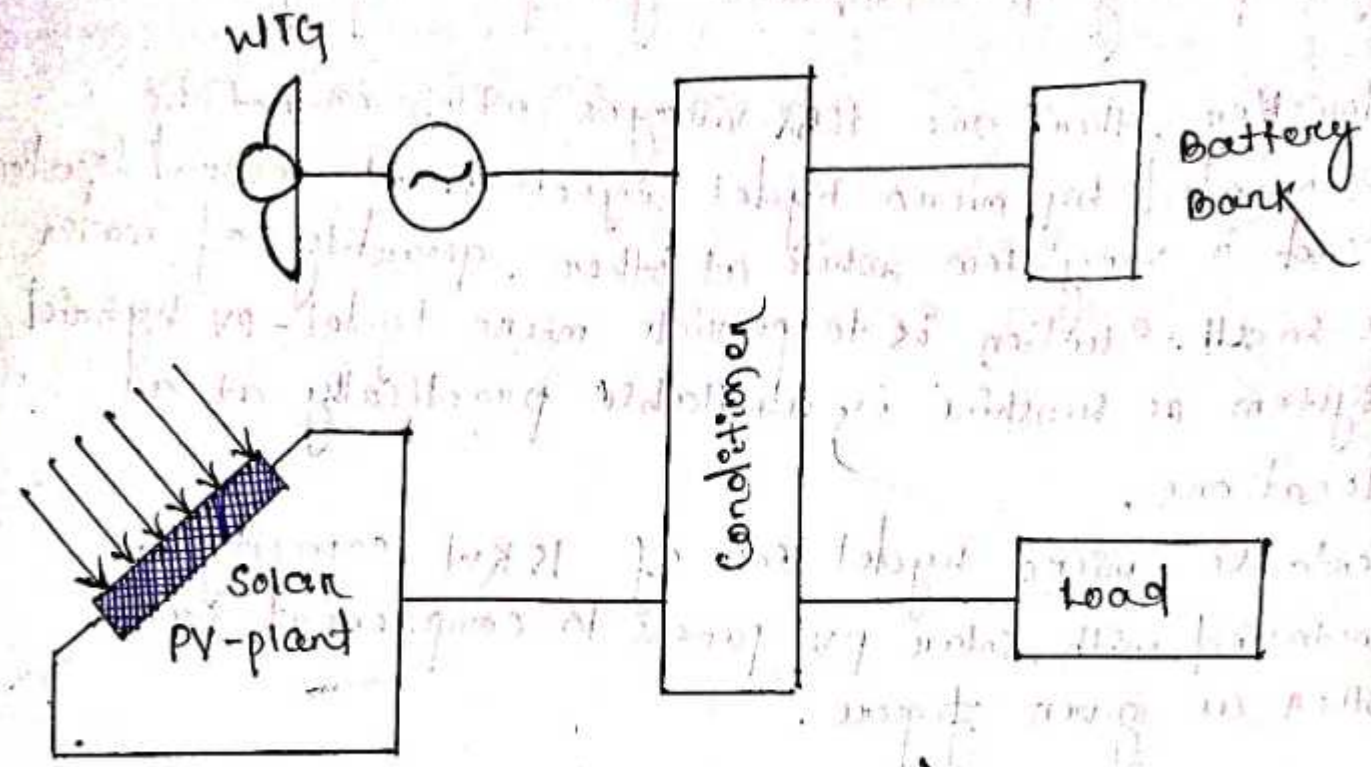
(Block diagram of PV + Diesel hybrid power plant)

- Several experiments have been carried out to find where 10% diesel fuel would be required with given solar PV array area to replace 90% of diesel that would be consumed for a diesel system only.

★ Wind - PV Hybrid System:

- Wind and solar hybrid energy system are located in open terrains away from multistorey building and forests. Locations are selected in those areas where the sunshine and wind are favorable for more than 8 months during a year.
- A schematic wind-PV hybrid system is shown in figure. During the day when sun shines, the solar photovoltaic plant generate dc electric energy conditioner provided,

converts dc to ac and supplies power to the load.



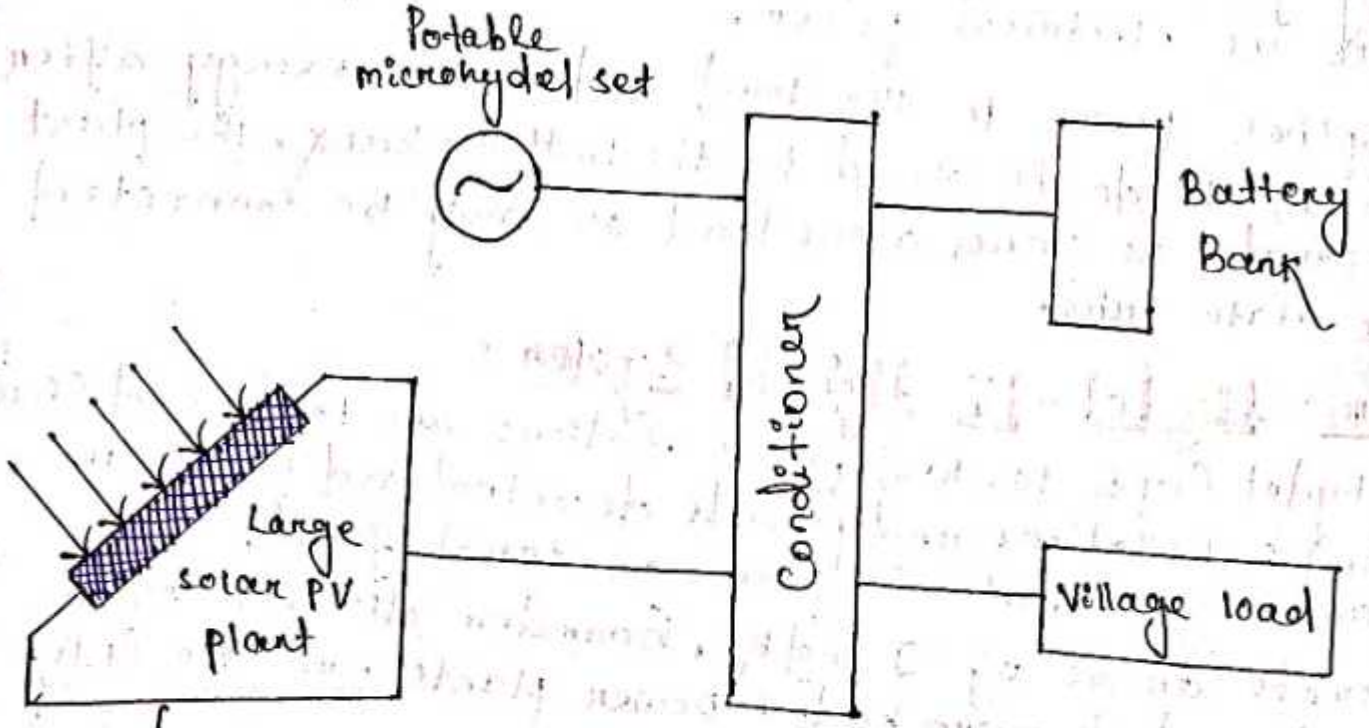
(wind - PV system)

- During favourable wind speed, wind turbine generator produce ac electrical power.
- It supplies power to the load and excess energy after conversion to dc is stored by the battery bank. The plant may operate as stand alone load or may be connected to the state grid.

* **Micro Hydel - PV Hybrid system:**

- Micro hydel (upto 100 KW) power stations are low head (less than 3m) installations and provide decentralised power in mountain regions, also in plains on canal falls.
- In remote areas of J and K, boarder districts of Arunachal pradesh micro hydro power plants are the only source of energy.
- With the help of micro hydro power, rural electrification can be achieved besides providing power for pumped irrigation and grinding mills.

- In Arunachal pradesh, 425 village are being electrified by completing 46 small/micro hydro power projects.
- However, there are 1058 villages which cannot be illeminated by micro hydel projects as at several locations head is very low, while at other, quantity of water is small. Solution is to provide micro hydel-PV hybrid system as sunshine is available practically at all locations.
- Portable micro hydel sets of 15 KW capacity are installed with solar PV panels to complement each other as given figure.



(Diagram of microhydel-PV hybrid system)

- Micro hydel systems are provided with small dam store water to be used during night when solar PV panels stops supply.
- A battery bank may be provided for emergency power supply.

- A battery bank may be provided for emergency power supply whenever required. Load management is carried out to maintain continuity of supply for 24 hours matching with the capacity of generating equipment.

5.7 Electric and hybrid Electric Vehicle:

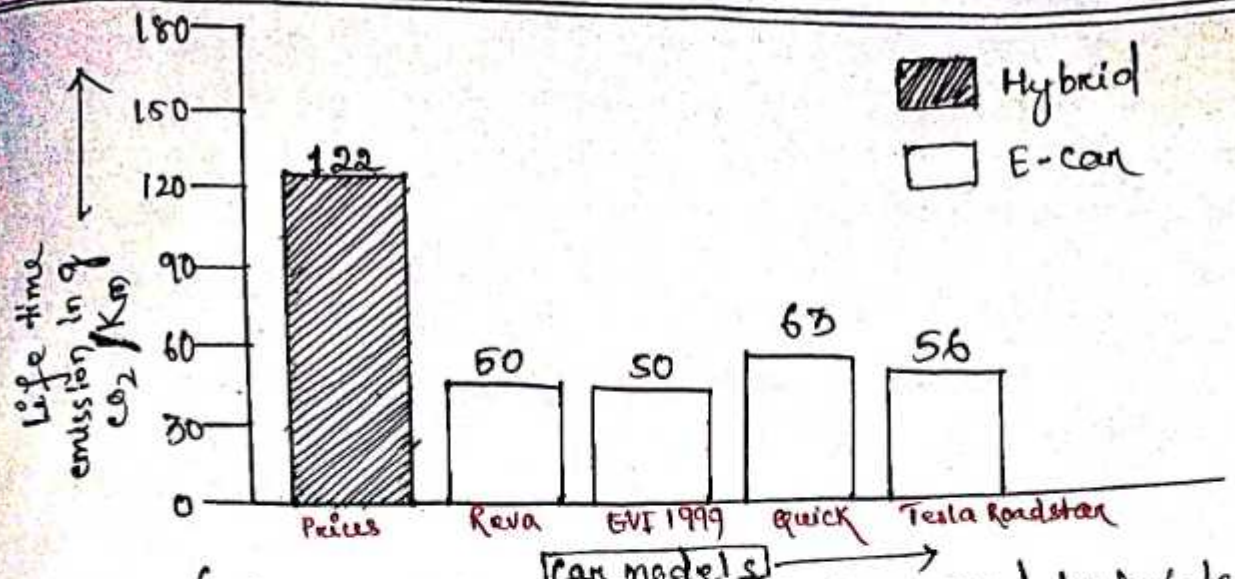
- Electric vehicles are propelled by an electric motor powered by rechargable battery packs. these vehicles need not have internal combustion engines (IEC) system, the drive train and fuel tank.
- Electric motor replace the engine and gets power from rechargable batteries through a controller. The electronic motor controller provides electric power to the motor based on inputs from accelerator.
- Electric power is delivered from battery pack, which is like the fuel tank of an electric (e) vehicle. However, they are slow in speed and move only upto 80Km on a charge. Full battery recharge takes nearly four hours.
- A hybrid electric vehicle combines a conventional internal combustion engine with an electric propulsion system. Presence of electric power train is intended to achieve better fuel economy than conventional vehicle or better performance. Most common of HEV is the hybrid electric car.
- Hybrid vehicles use both petrol and electric propulsion system. In such vehicles, the electric motor provides a boost during starting and recharge during vehicle operations. This cuts emissions significantly and improve fuel economy.

E-Vehicle Need:

- E-Vehicle are gaining popularity concerning to:
  (i) High oil prices.
  (ii) Green house gas emission.
  (iii) Ambient air quality.
- Concern over high oil prices and stringency in pollution and climate regulations have spurred new interest in e-vehicles.
- These are fuel-efficient, as technically conversion of electrical energy into motive power is more efficient than burning fuel in an internal combustion engine.
- According to California Air Resource Board, fuel efficiency of an e-vehicle is three times higher than convention car. As electricity costs less than oil, operating cost per Km falls to a fraction of a petrol car.

Emissions:

- E-vehicles emit nothing from their tail pipe. But the emission from power generation are accounted for in the life cycle assessment of e-vehicle.
- Reva electric car company in UK showed when emission of power stations were included the vehicle emitted 65g CO_2 per Km.
- The best hybrid car gives 104 g per Km.
- A UK study said that life time emission of an e-vehicle is 3 time less than average emission from internal combustion engines CO_2 emission per Km from e-cars and hybrids (emission from power plants and internal combustion engines) accounted for are given in the figure.



(CO_2 emission per Km e-cars and hybrids)

- The other advantage of an e-vehicle is that there are no oil filters, air filters, spark plugs and radiators which needs maintenance.
- **Limitations:**
- Widespread use of battery operated vehicle is constrained by high prices, limited driving range, bar on maximum speed and battery efficiency.
- In India, most e-vehicles run on lead-acid batteries which provides short bursts of power to starter motors in cars. Also, lead is a known environmental hazard with serious health consequences.
- Lead-acid battery will have to give way to lithium-ion batteries that improve performance four times over. Lithium ion is currently a dominant battery technology in portable applications.
- It provides the highest energy density of all rechargable systems. REVA NXR is a new lithium-ion powered e-car claims that a fast charge for 90 minutes would offer a range of 320 Km a day.
- The biggest challenge of e-vehicles industry is to produce batteries that can store large amount of energy that can be released and recharged quickly.

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