ME0048 – ALTERNATIVE SOURCES OF ENERGY

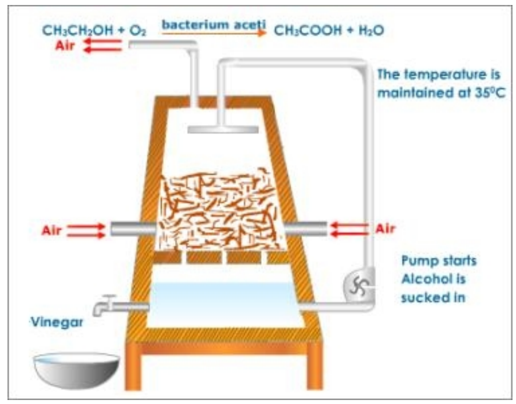
UNIT-1 BIOMASS

BIOMASS

The biomass is the agricultural waste, animal waste or by-products in the crop field or industrial wastes. The energy conversion from biomass can be bio-chemical or thermo-chemical methods.

FERMENTATION

The process of bio-chemical degradation of materials is called fermentation. This process is done with the help of micro-organisms (bacteria/yeast).

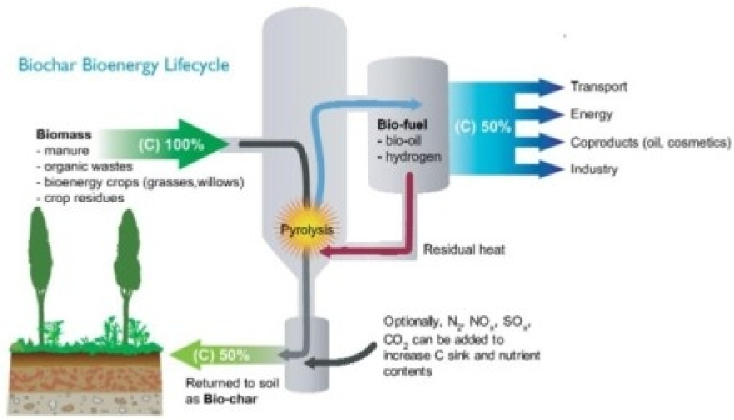


PYROLYSIS

Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen. It is the fundamental chemical reaction that is the precursor of both the combustion and gasification processes and occurs naturally in the first two seconds.

The products of biomass pyrolysis include biochar, bio-oil and gases including methane, hydrogen, carbon monoxide, and carbon dioxide. Depending on the thermal environment and the final temperature, pyrolysis will yield mainly biochar at low temperatures, less than 450 0C, when the heating rate is quite slow, and mainly gases at high temperatures, greater than 800 0C, with rapid heating rates. At an intermediate temperature and under relatively high heating rates, the main product is bio-oil.

Pyrolysis can be performed at relatively small scale and at remote locations which enhance energy density of the biomass resource and reduce transport and handling costs. Heat transfer is a critical area in pyrolysis as the pyrolysis process is endothermic and sufficient heat transfer surface has to be provided to meet process heat needs. Pyrolysis offers a flexible and attractive way of converting solid biomass into an easily stored and transported liquid, which can be successfully used for the production of heat, power and chemicals.



PYROLYSIS OF BIOMASS

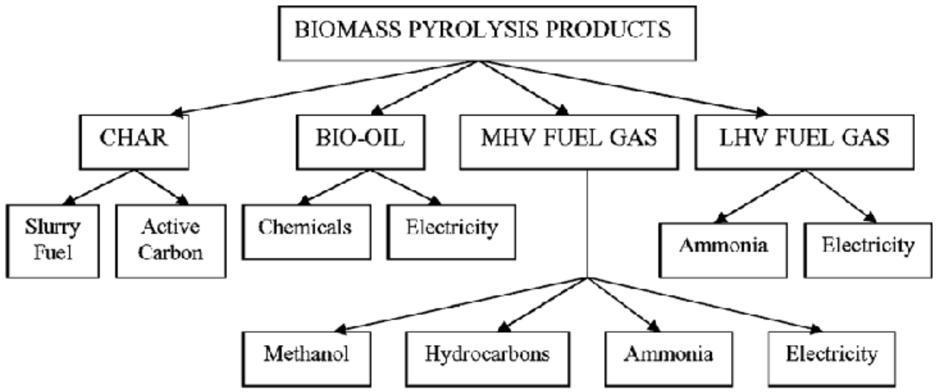
Feedstock for Pyrolysis

A wide range of biomass feedstocks can be used in pyrolysis processes. The pyrolysis process is very dependent on the moisture content of the feedstock, which should be around 10%. At higher moisture contents, high levels of water are produced and at lower levels there is a risk that the process only produces dust instead of oil. High-moisture waste streams, such as sludge and meat processing wastes, require drying before subjecting to pyrolysis. The efficiency and nature of the pyrolysis process is dependent on the particle size of feedstocks. Most of the pyrolysis technologies can only process small particles to a maximum of 2 mm keeping in view the need for rapid heat transfer through the particle. The demand for small particle size means that the feedstock has to be size-reduced before being used for pyrolysis.

Pyrolysis processes can be categorized as slow pyrolysis or fast pyrolysis. Fast pyrolysis is currently the most widely used pyrolysis system. Slow pyrolysis takes several hours to complete and results in biochar as the main product. On the other hand, fast pyrolysis yields 60% bio-oil and takes seconds for complete pyrolysis. In addition, it gives 20% biochar and 20% syngas. Fast pyrolysis processes include open-core fixed bed pyrolysis, ablative fast pyrolysis, cyclonic fast pyrolysis, and rotating core fast pyrolysis systems.

The essential features of a fast pyrolysis process are:

- Very high heating and heat transfer rates, which require a finely ground feed.
- Carefully controlled reaction temperature of around 500°C in the vapour phase
- Residence time of pyrolysis vapours in the reactor less than 1 sec
- Quenching (rapid cooling) of the pyrolysis vapours to give the bio-oil product.



Biomass Pyrolysis Products

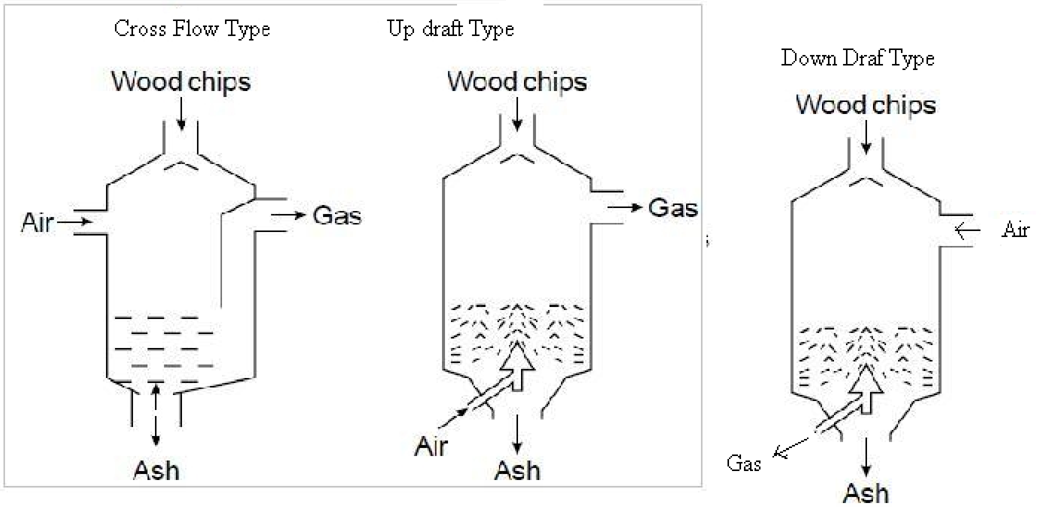
Gasification & combustion

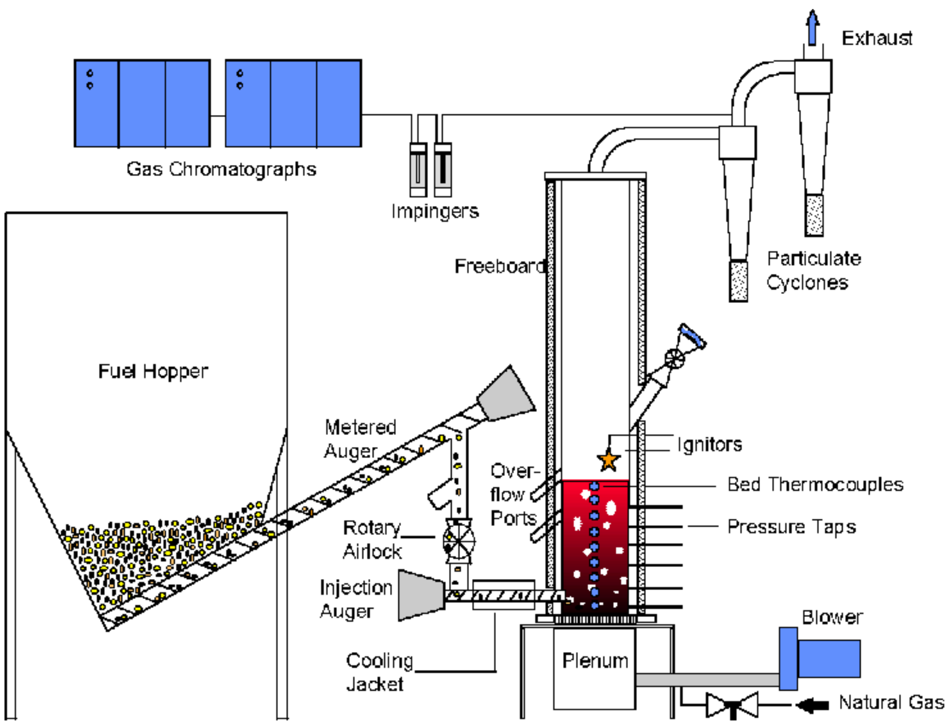
The gasification is the process of converting biomass into gaseous fuels. The combustion of biomass through gasification can be done. The gasifier is the equipment used to gasify the biomass fuel. It's a thermo-chemical conversion of biomass.

The types of gasifiers

The gasifiers are classified based on the gas flow direction in the bed. The gas flow is upward in the up-draft, downward in down-draft, perpendicular in the cross flow type. In the fluidized bed concept, the biomass particles are gasified and burnt in the floating condition by supplying air with the fluidization velocity. The fluidized bed can be operated as atmospheric or pressurized bed conditions.

1. Up-draft gasifier 2. Down-draft gasifier 3. Cross flow gasifier 4. Fluidised Bed Gasifier





Fluidised Bed Gasification/Combustion

Biogas

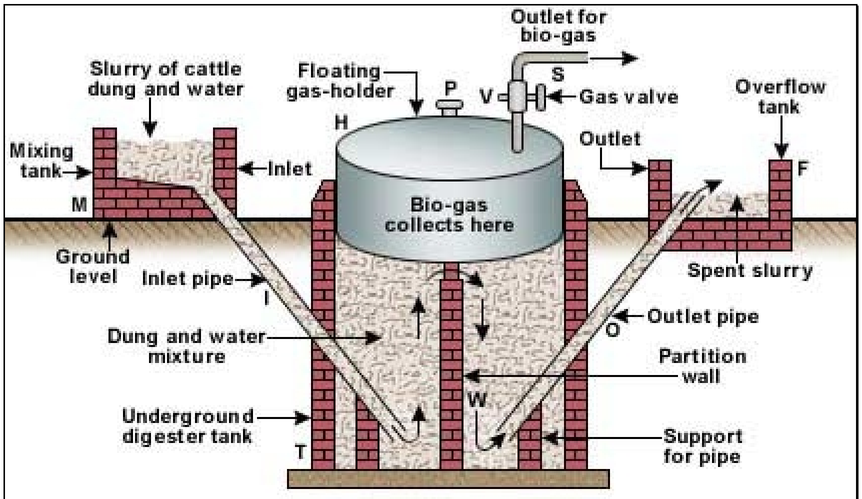
The biogas power plant works on fermentation concept. The feed is mixed with water and supplied to the digester and allowed there several days. The combustible gas contains methane comes out of it. The cobar gas is cleaned by supplying through water and then used in cooking or heating applications.

Types of Biogas plants: 1. Fixed Dome Digester plant

2. Floating Dome Digester plant

Floating gas-holder type of plant

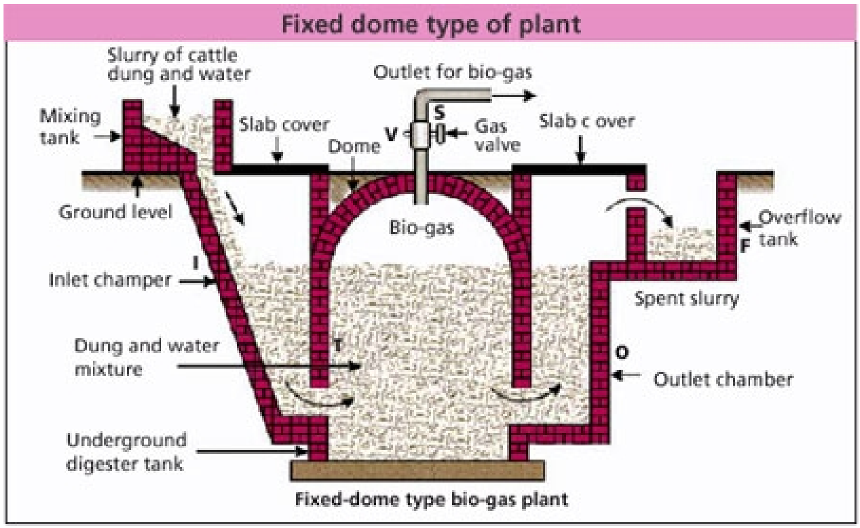
A well is made out of concrete called the digester tank T, which is divided into two parts. One part is an inlet, from where the slurry is fed to the tank. The cylindrical dome H of the tank is made out of stainless steel that floats on the slurry and collects the gas generated. Hence it is called floating gas-holder type of bio gas plant. The slurry is fermented for about 50 days. As more gas is made by the bacterial fermentation, the pressure inside H increases. The gas can be taken out from outlet pipe V. The decomposed matter expands and overflows into the next chamber in tank T, which is removed by the outlet pipe to the overflow tank and used as manure for cultivation purposes.



Floating gas-holder type bio-gas plant.

Fixed dome type of plant

A well and a dome are made out of concrete called the digester tank T. This dome is fixed and thus it is called fixed dome type of bio gas plant. The function of the plant is similar to the floating holder type bio gas plant. The used slurry expands and overflows into the overflow tank F.



Fixed dome type of plant

Fixed-dome type bio-gas plant

Advantages and disadvantages

In the floating gas-holder type of plant, the floating chamber is made of stainless steel. This is expensive and needs continuous maintenance and supervision for non-rust. This does not rise in the fixed dome type of bio gas plant as everything is made of concrete. The volume of fixed dome type of biogas is fixed. So if the gas pressure increases inside, it may cause damage to the concrete dome. This does not happen in the floating holder type of bio gas plant.

UNIT-2 SOLAR ENERGY

SOLAR RADIATION

The solar radiation can be beam or direct radiation and diffuse or scattered radiation. The direct radiation reaches the earth from sun directly but diffuse radiation is due to scattered effect of atmosphere and the particles in the air. Global radiation means the total radiation of beam and diffuse types. The sun's surface temperature is around 5000° C. The solar radiation from the sun is around 178 TW. The solar energy potential or intensity on earth surface is around 0-1 kW/m^2 (night to noon).

SOLAR RADIATION MEASUREMENTS

1. Pyranometer : To measure global radiation (both beam and diffuse radiation)
2. Pyrheliometer : To measure beam radiation
3. Pyrgeometer: To measure IR and long wave radiation
4. Sunshine recorder : To measure the actual sunshine daily hours

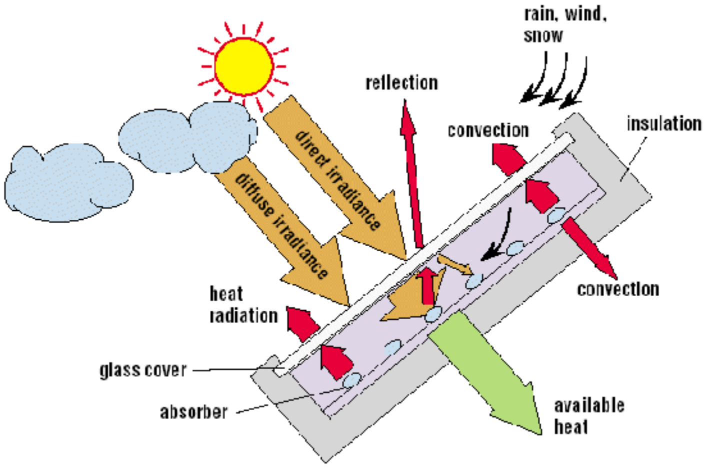
SOLAR ENERGY TECHNOLOGIES

1. Solar thermal Energy /Power – Flat plate, Parabolic or concentrated, central tower plant
2. Solar Photovoltaic Energy – SPV Cells

Solar thermal energy application includes drying, power generation, hot water applications etc. The solar photovoltaic system is the direct electric power generation from solar energy.

SOLAR FLAT PLATE COLLECTORS

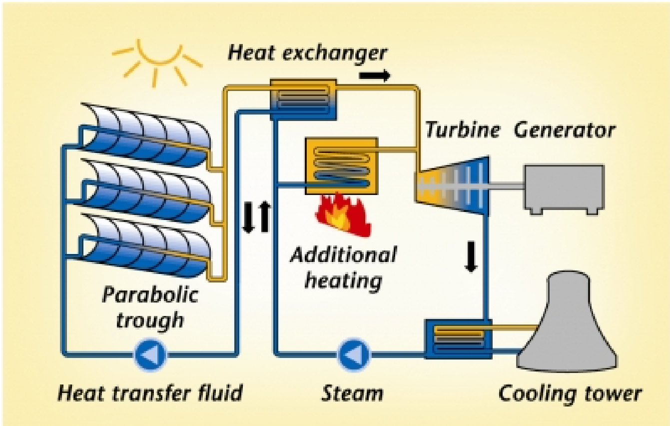
The flat plate collectors contains absorber plate , absorber tube to carry the heat transfer fluids, insulation, glass cover to absorb the income solar radiation etc. The temperature range is around 60-90 C. Its suitable for domestic thermal applications.



SOLAR FLAT PLATE COLLECTOR

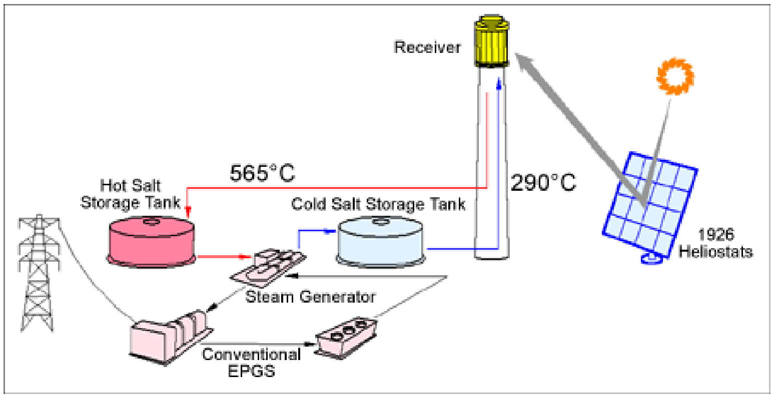
SOLAR PARABOLIC TROUGH POWER GENERATION

An array of parabolic troughs is used to achieve high temperature around 400 C and an additional firing involved to run during non-solar times as well as lean solar rays. The working principle is simple steam power cycle (Rankine cycle).

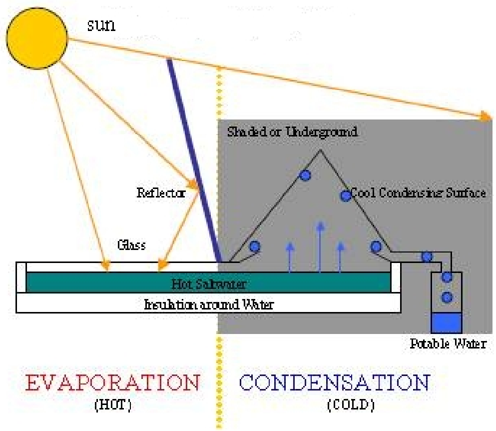


SOLAR CENTRAL RECEIVER POWER PLANT

The boiler is placed centrally in the large mirrors field. Array of helio-stat mirrors are used to focus the solar rays towards central receiver to produce high temperature more than 500 C to produce steam out of water and the steam is used to run a steam turbine and then the water is condensed in condenser and pumped back to the boiler.



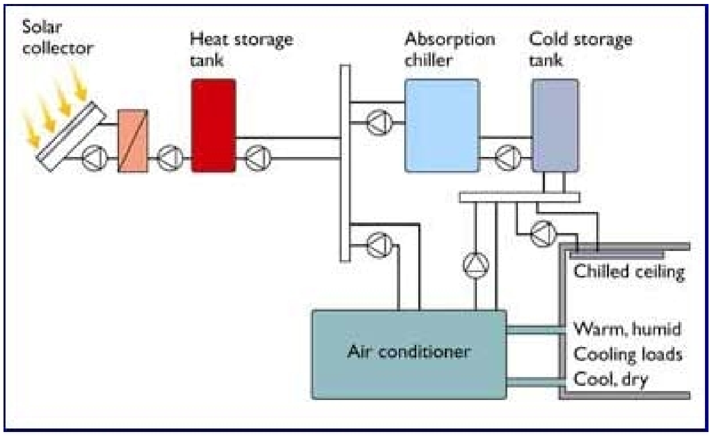
SOLAR STILLS



The working principle of Solar stills is similar to rainfall. The evaporation and condensation of saline or sea water is used in the solar stills to produce potable water. The solar energy is used to produce vapour from the salt water and the condensation of that vapour takes place in the shaded or underground place. The condensed water is collected.

SOLAR COOLING AND REFRIGERATION

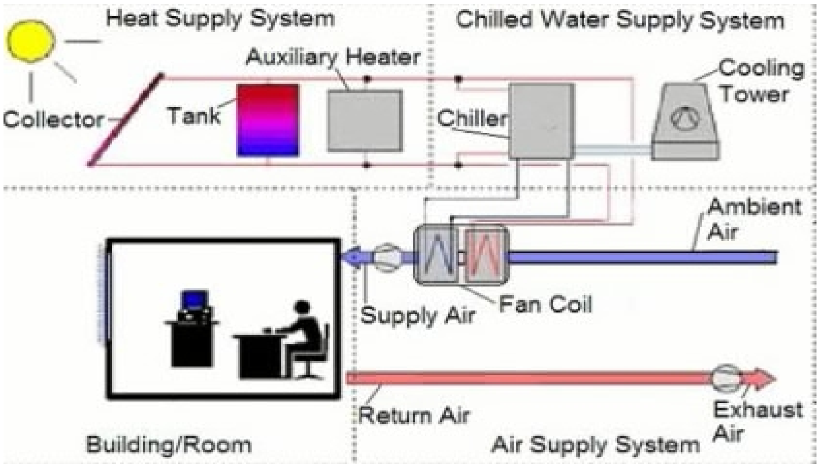
The solar cooling and refrigeration system operates based on vapour absorption refrigeration principle. Solar energy is used to run the vapour generator of the system.



Schematic of an absorption solar cooling system.

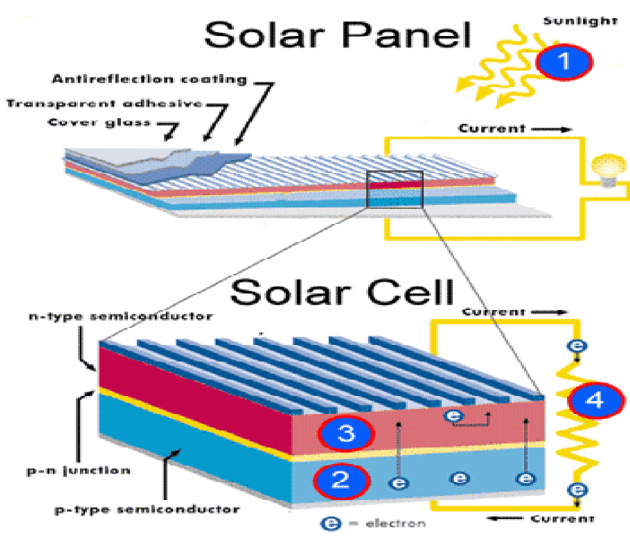
SOLAR AIR-CONDITIONING SYSTEM

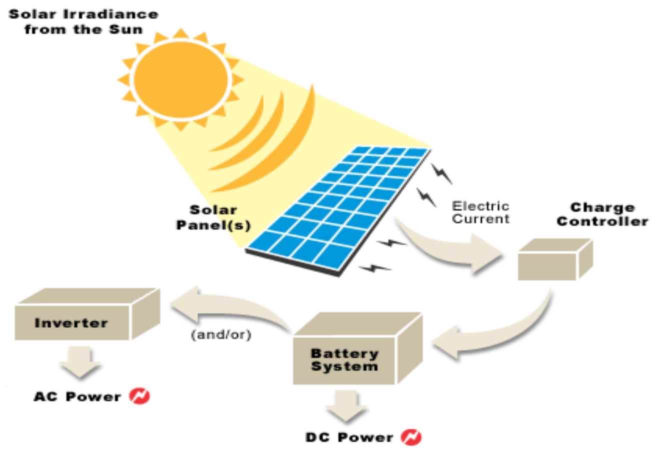
This solar HVAC consists of heat supply system, chilled water supply system, air-conditioned space. The chiller operates on vapour absorption principle.



SOLAR PHOTOVOLTAIC SYSTEMS (SPV)

SPV Cells uses semi-conductor materials which is capable of free the electrons by use of light energy (Photon-light or sun rays into Electrons – electricity). The arrangement of solar panels (multiple solar cells) will give the desired electric power.





SPV SYSTEM

Limitations of solar energy

1. Availability – intermittent, during day time
2. Dilute source – very low concentration of energy potential
3. Susceptible to climatic changes – clouds, rain etc.

Advantages of Solar Energy

1. Renewable sources of energy
2. Free of energy cost
3. No pollution
4. No fuel transport
5. No ash/waste disposal

UNIT-3 WIND ENERGY

The Wind turbines convert wind movement (K.E.) into mechanical energy. **Most modern wind turbines are used to create electricity**. That is what is referred to as a wind generator. If the mechanical energy is used only for mechanical movement, it is a *windmill*. In the commonly used wind generator, the wind turns the blades, which turn the shaft. The shaft spins in a generator and electromagnetism in the generator produces electricity.

TERMS USED IN WIND ENERGY

1. Wind speed: The speed at which the wind is flowing.
2. Cut-in speed: The minimum speed of turbine at which the turbine starts developing power. e.g. 5 m/s
3. Cut-off (Furling) speed: The maximum speed of turbine at which the turbine stops developing power. e.g. 30 m/s .Its for safe operation of wind turbine.
4. Power of wind, $P = 0.5\ \rho\ A\ V^3$. Where A – Swept area of rotors, V-Velocity of wind , ρ – Density of air
5. Betz' limit or law: The theoretical maximum possible power can be extracted from the wind energy. Its value is 59.3% of power available in the wind.
6. Power co-efficient is the ratio of power output of the turbine to the power available in the wind.

WIND DATA AND ITS ENERGY ESTIMATION

The wind data includes wind speed, speed variation along the altitude, wind direction over the long term, air density and turbulence intensity. The energy estimation can be done based on the wind data.

FACTORS INVOLVED IN SITE SELECTION FOR WIND MILLS

1. The availability of wind with sufficient kinetic energy.
2. The magnitude of wind velocity should be high

3. The wind availability should be throughout the year
4. The site should be free from obstacles
5. Availability of vast open land on a flat terrain at a lower land cost
6. The construction materials should be available and cheaper
7. Availability of skilled workers
8. Away from the populated places but not away from load centre.
9. No possibility of storms, floods, earthquakes, volcanoes, etc.

ADVANTAGES OF WIND MILLS : Free of energy cost, No pollution, No water required, low operating costs etc. **Disadvantages:** Fluctuation in wind speed, occupies more land, Noisy

TYPES OF WIND MILL Based on no. of rotor blades: 1. Single blade 2. Multi-blade rotors

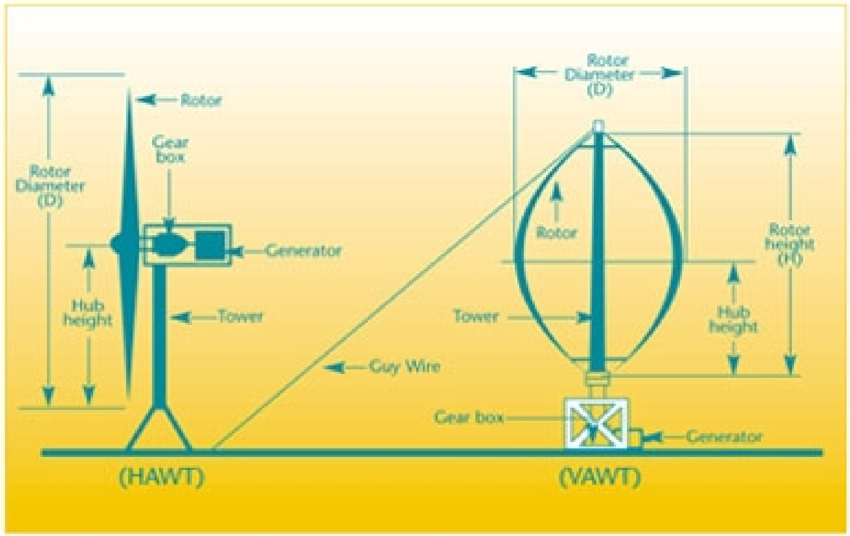
Based on axis of rotation : 1. Horizontal Axis (HWAT) 2. Vertical Axis (VWAT)

HORIZONTAL AXIS WIND TURBINE (HWAT)

The Rotor blades are fitted on the main shaft in a horizontal hub. This direction of wind is parallel to the axis of rotation of rotor blades. The horizontal hub is connected to a gearbox and generator, which are located inside the nacelle. The nacelle houses the electrical components and is mounted at the top of the tower. There is a supporting tower to withstand the rotor and nacelle as well as wind kinetic energy.

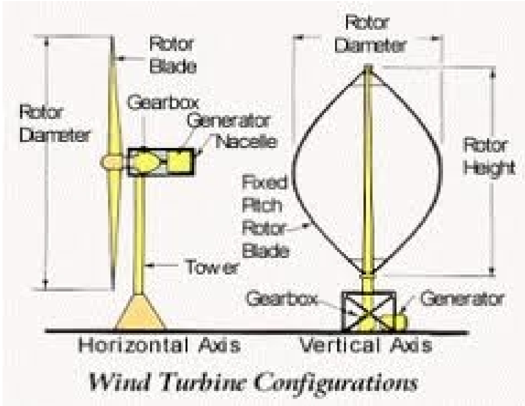
VERTICALAL AXIS WIND TURBINE (VWAT)

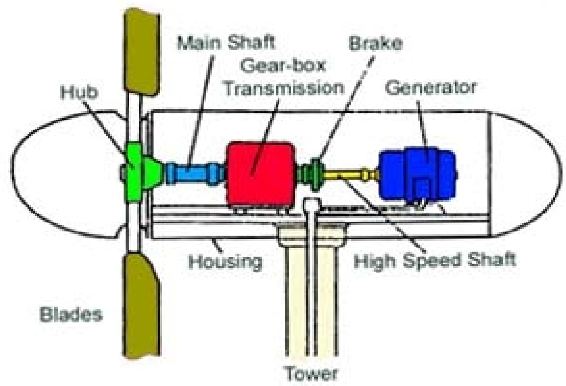
The Rotor blades are fitted on the main shaft in a vertical hub. This direction of wind is perpendicular to the axis of rotation of rotor blades. The main shaft is connected to a gearbox and generator. There is a supporting wire to withstand the rotor as well as wind kinetic energy.



Rotor diameters on modern turbines can be more than 80 meters. The turbines rotor diameter determines its swept area. The swept area is the area through which the rotors of a wind turbine rotate. Larger swept areas usually translate to higher output machines. Machine capacity can range anywhere from a few hundred kilowatts to 5 megawatts. Currently, 1.5-2 MW machines are quite popular. The blades rotate at a speed of 10-30 revolutions per minute at constant rate although an increasing number of machines operate at a variable speed. The amount of power produced is a direct result of the wind speed. Excessive wind speeds, though, require the temporary shutdown of turbines to protect internal components. Most wind turbines have gearboxes, even though an increasing number of modern turbines operate using direct drive systems. The **yaw** mechanism turns the turbine (horizontal motion) so that it faces the wind. Sensors are used to monitor wind direction and the tower head is turned to be in line with the wind. Towers are mostly cylindrical and made of steel, generally painted light grey. Lattice towers are used in some locations. Towers range from 25 to 75 meters in height.

There are many different turbine designs, with plenty of scope for innovation and technological development. The dominant wind turbine design is the up-wind, three bladed, **stall controlled**, constant speed machine. The next most common design is similar, but is **pitch controlled**. Gearless and variable speed machines follow, again with three blades. A smaller number of turbines have 2 blades, or use other concepts, such as a vertical axis.





Three mechanical controls of HWAT

1. **Pitch Control:** Tilting of rotor blade angles from 0 -30° to absorb more energy from the wind. The pitch angle is the angle between the direction of wind and the direction perpendicular to the planes of blades.

2. **Teethering Control:** The up and down movement (swinging motion like see-saw) of nacelle in the vertical direction. Higher wind speed, the nacelle is inclined.

3. **Yaw Control:** The horizontal movement of nacelle to face the wind. Its orientation or steering control for the axis of wind turbine in the direction of wind.

DESIGN CONSIDERATIONS IN HWAT

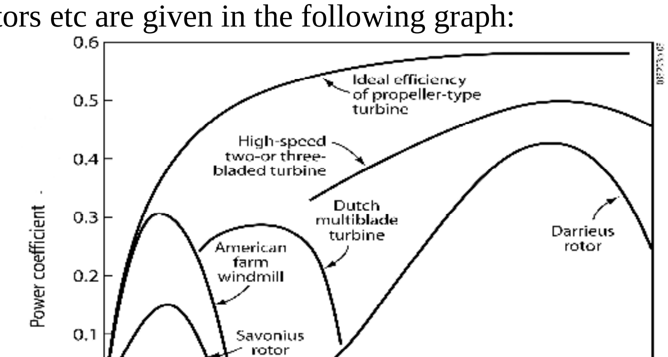
1. The height of the wind energy converter (WEC) should be more than 30 m altitude. There only the wind velocity is higher

2. Few Narrow long blades to withstand the extreme winds

3. The structural dynamics to be studied completely to avoid fatigue failures of rotors

PERFORMANCES OF WIND TURBINES

The ideal efficiency of 59.3% is based on Betz's limit. And the various turbine configurations like single rotor, Darrius rotor, multi-blade rotors etc are given in the following graph:



The range of speed ratio with the power co-eff is compared. The three blade rotor machine performs better in the speed ratio as well as power developed. The Savonius rotor works at lower speed ratio but the power co-efficient is also very low.

WIND TURBINE PHYSICS: FACTORS AFFECTING PERFORMANCE

The efficiency of wind turbines depends on various factors such as location, geographical factors, mechanics, rotor shape/ size, etc. Output can be regulated by a constant or variable rotational speed, as well as adjustable and non-adjustable blades.

POWER IN THE WIND The importance of accurate wind speed data becomes clear when one understands how the speed affects the power. Let A – Swept area of rotors, V-Velocity of wind. **Power of wind, $P = 0.5 \rho A V^3$**

AERODYNAMICS OF BLADES

A careful choice of the shape of the blades is crucial for maximum efficiency. Initially, wind turbines used blade shapes, known as airfoils, based on the wings of airplanes. Today's wind turbines still use airfoils, but they are now specially designed for use on rotors. Airfoils use the concept of lift, as opposed to drag, to harness the wind's motion. The idea behind lift is that when the edge of the airfoil is angled very slightly out of the direction of the wind, the air moves more quickly on the downstream (upper) side creating a low pressure that essentially lifts the airfoil upward. The amount of lift for a given airfoil depends heavily on the angle that it makes with the direction of the relative wind, known as the angle of attack,?. With a certain range, an increased angle of attack means increased lift, but also more drag, which detracts from the desired motion.

When the angle of attack gets too large, turbulence develops and drag increases significantly, while lift is lost. The angle of attack on wind turbine blades can be changed either by creating a specific geometry for the blades along the longitudinal axis/ span, also known as pitch control, or by allowing them to rotate around the axis perpendicular to their cross sections (along the span). This movement of turning the wind turbine rotor against the wind is known as the yaw mechanism. The wind turbine is said to have a yaw error, if the rotor is not perpendicular to the wind. Changing the angle of attack is important to maintain a precise amount of lift so the rotor turns at a constant speed.

LOADS, STRESS, AND FATIGUE

Aside from optimizing the blade shape and the yaw direction, a vital consideration in the construction of a wind turbine is the lifetime of the machine. Wind turbines are currently designed to last at least 20 years. The blades must be strong enough to withstand all the loads and stresses from gravity, wind, and dynamic interactions. Blades are carefully manufactured and then extensively tested to make sure they can achieve the desired lifespan.

Types of loads are static, steady, cyclic, transient, impulsive, stochastic, and resonance induced. Static loads are constant and occur even with a non-moving turbine. These include steady wind and gravity. Steady loads are constant when the turbine is in motion and are caused by a steady wind. Cyclic loads are periodic, usually due to the rotation of the rotor. They occur from gravity, wind shear, yaw motion, and vibration of the structure. Transient loads are time varying with occasional oscillation. Braking by the inner gears and mechanics will cause this type of load. Impulsive loads are time varying on short scales, such as a blade being shadowed when passing the tower. Stochastic loads are random, usually around a constant mean value, and are primarily caused by turbulence. Resonance-induced loads, which are to be avoided as much as possible, occur when parts of the wind turbine are excited at their natural frequencies and then vibrate and can induce other parts to vibrate also, putting considerable stress on the turbine.

POWER CONTROL AND AERODYNAMIC BRAKING SYSTEM

As the angle of attack is one of the most important variables in determining the performance of a wind turbine, both in terms of power output and over-speed induced stress protection, it is important to understand the rotor pitch behavior.

An increasing number of larger wind turbines (1 MW and up) are being developed with an active stall power control mechanism. Technically the active stall machines resemble pitch controlled machines, since they have pitch able blades. In order to get a reasonably large torque (turning force) at low wind speeds, the machines will usually be programmed to pitch their blades much like a pitch controlled machine at low wind speeds. On a pitch controlled wind turbine, the turbine's electronic controller checks the power output of the turbine several times per second. When the power output becomes too high, it sends an order to the blade pitch mechanism which immediately pitches (turns) the rotor blades slightly out of the wind. This is actually the aerodynamic braking system, which is the primary braking system for most modern wind turbines. This essentially consists of turning the rotor blades about 90 degrees along their longitudinal axis. Conversely, the blades are turned back into the wind whenever the wind drops again. The rotor blades thus have to be able to turn around their longitudinal axis/ span (to pitch).

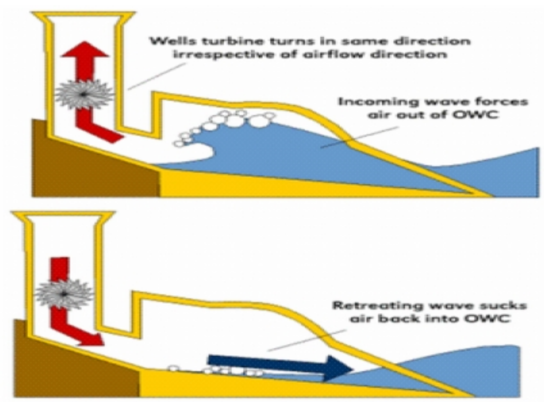
UNIT-4 OCEAN ENERGY

The ocean energy types: 1. Wave Energy 2. Tidal Energy 3. Ocean Thermal Energy

WAVE ENERGY

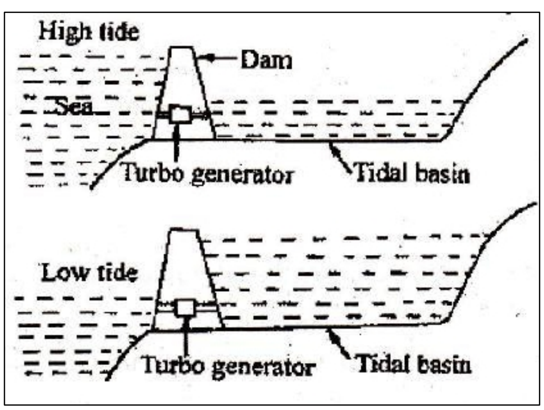
The wave energy is the waves developed by the KE of wind passing on the surface of sea and around 5-15% wind KE is imparted to sea surface water. The waves are smaller amplitude around 2 m.

OSCILLATING WATER COLUMN (OWC)



Oscillating Water Column (OWC) is one of the power generation method used to harvest wave energy by running an aero-turbine. The oscillating water pushes air out and absorbs in during the movement of wind. The power is generated due to the flow of air.

TIDAL ENERGY

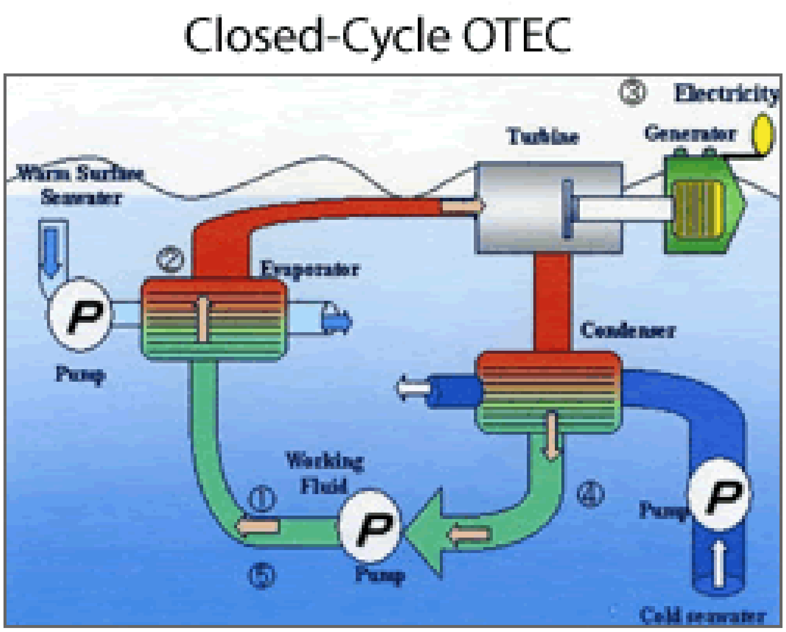


The tidal energy is due to moon's attraction on the earth. Normally lesser tidal waves occur per day (around 2 tides). The amplitude of tidal waves is around 10 m. The tidal energy is harvested by tidal power plants where the high tides are allowed to run an axial turbine during water flows from sea to tidal basin as well as water flows from basin to sea due to the water level difference between the sea and basin.

High & Low Tide Tidal Power Plant

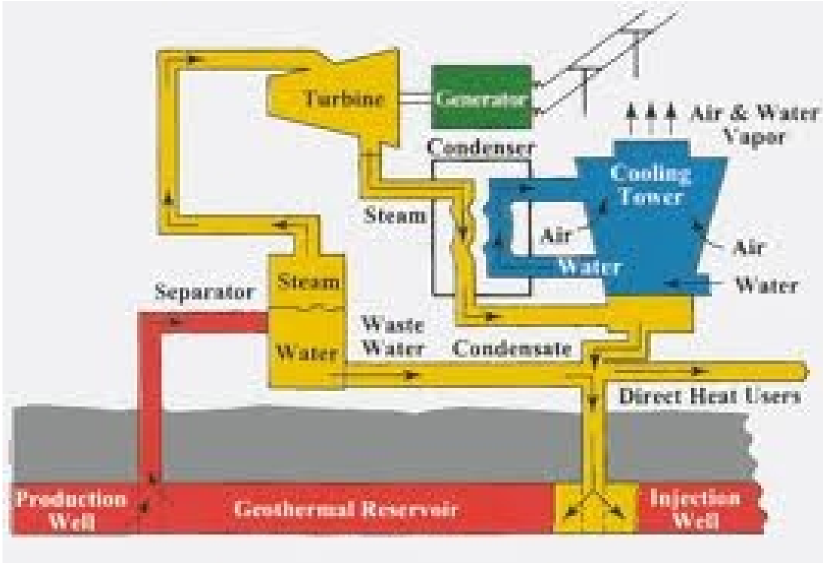
OCEAN THERMAL ENRGY CONVERSION (OTEC)

Ocean Thermal Energy Conversion is working based on the temperature gradient of the sea water. The surface water temperature is around 20-25°C and deep water temperature is around 5-10°C. This small temperature range is capable of operating low temperature power cycle. The organic fluids of low boiling point (e.g. NH3 = - 33°C). The hot surface water is used in the evaporator to generate vapour out of working fluid and it drives a vapor turbine and then its condensed in the condenser which is operated by the deep see cold water.



GEOTHERMAL ENERGY

The geothermal energy is the heat energy available inside the earth. The thermal gradient is 1°C per 40 m depth (**25-30°C/km** depth). The water is sent in the bore wells and the steam out of it used to drive a steam turbine power cycle. The types of this plant can be wet steam and dry steam type.



Geothermal Power plant

Limitations of geothermal energy

Drilling wells and Maintenance of underground piping systems, contaminations of working fluids and treatment of working fluids.

UNIT-5 FUEL CELL AND MHD POWER GENERATION

FUELL CELLS

A fuel cell is a device that electrochemically converts the chemical energy of a fuel and an oxidant to electrical energy. The fuel and oxidant are typically stored outside of the fuel cell and transferred into the fuel cell as the reactants are consumed. The most common type of fuel cell uses the chemical energy of hydrogen to produce electricity, with water and heat as by-products. Fuel cells are unique in terms of the variety of their potential applications; they potentially can provide energy for systems as large as a utility power station and as small as a laptop computer.

Fuel Cell Systems

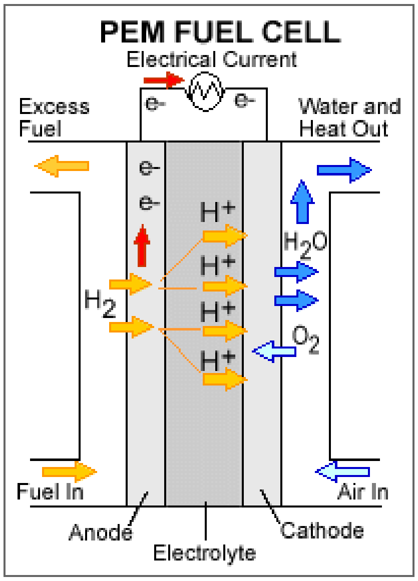
The design of fuel cell systems is complex and can vary significantly depending upon fuel cell type and application. However, most fuel cell systems consist of four basic components: Fuel cell stack, Fuel processor, Current converter, Heat recovery system. Most fuel cell systems also include other components and subsystems to control fuel cell humidity, temperature, gas pressure, and wastewater.

Types of Fuel Cells

1. PEM Fuel Cells or H_2-O_2 Fuel Cell
2. Alkaline Fuel Cells (AFC)
3. Phosphoric Acid Fuel Cell (PAFC)
4. Solid Oxide Fuel Cell (SOFC)

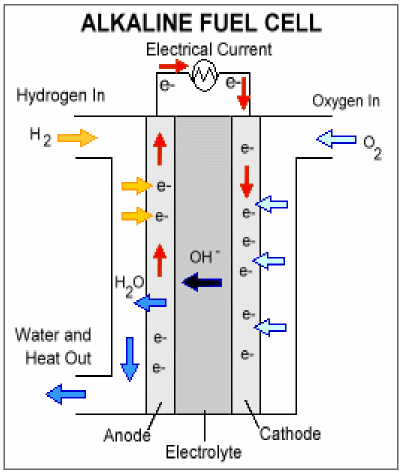
Polymer Electrolyte Membrane (PEM) Fuel Cells

H_2-O_2 Fuel Cell or Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume, compared to other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like some fuel cells. They are typically fueled with pure hydrogen supplied from storage tanks or onboard reformers.



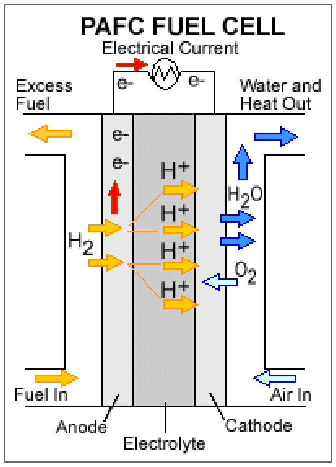
Alkaline Fuel Cells

Alkaline fuel cells (AFCs) were one of the first fuel cell technologies developed, and they were the first type widely used in the U.S. space program to produce electrical energy and water onboard spacecraft. These fuel cells use a solution of potassium hydroxide in water as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. High-temperature AFCs operate at temperatures between 100°C and 250°C (212°F and 482°F). However, newer AFC designs operate at lower temperatures of roughly 23°C to 70°C (74°F to 158°F). AFCs' high performance is due to the rate at which chemical reactions take place in the cell. They have also demonstrated efficiencies near 60 percent in space applications.



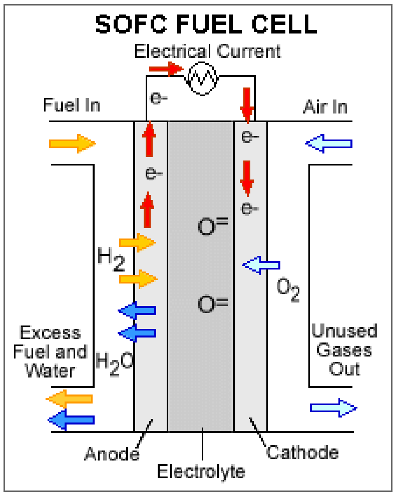
Phosphoric Acid Fuel Cells

Phosphoric acid fuel cells (PAFCs) use liquid phosphoric acid as an electrolyte—the acid is contained in a Teflon-bonded silicon carbide matrix—and porous carbon electrodes containing a platinum catalyst. The chemical reactions that take place in the



cell are shown in the diagram to the right. The phosphoric acid fuel cell is considered the "first generation" of modern fuel cells. It is one of the most mature cell types and the first to be used commercially, with over 200 units currently in use. This type of fuel cell is typically used for stationary power generation, but some PAFCs have been used to power large vehicles such as city buses.

Solid Oxide Fuel Cells



Solid oxide fuel cells (SOFCs) use a hard, non-porous ceramic compound as the electrolyte. Since the electrolyte is a solid, the cells do not have to be constructed in the plate-like configuration typical of other fuel cell types. SOFCs are expected to be around 50-60 percent efficient at converting fuel to electricity. In applications designed to capture and utilize the system's waste heat (co-generation), overall fuel use efficiencies is 80-85 percent.Solid oxide fuel cells operate at very high temperatures—around 1,000°C (1,830°F).

High temperature operation removes the need for precious-metal catalyst, thereby reducing cost. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels and reduces the cost associated with adding a reformer to the system. SOFCs are also the most sulfur-resistant fuel cell type; they can tolerate several orders of magnitude more sulfur than other cell types. In addition, they are not poisoned by carbon monoxide (CO), which can even be used as fuel. This allows SOFCs to use gases made from coal.

Technology Challenges

Cost, Durability and Reliability, System Size, Air, Thermal, and Water Management, Improved Heat Recovery Systems

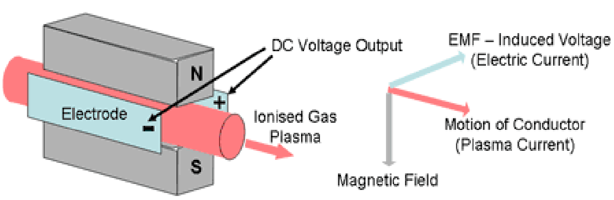
Applications of Fuel Cells Transportation, Stationary power plant, portable power etc.

MAGNETO HYDRODYNAMIC (MHD) POWER GENERATION

Magneto hydrodynamic power generation provides a way of generating electricity directly from a fast moving stream of ionised gases without the need for any moving mechanical parts - no turbines and no rotary generators. MHD power generation has also been studied as a method for extracting electrical power from nuclear reactors and also from more conventional fuel combustion systems

Working Principle of MHD

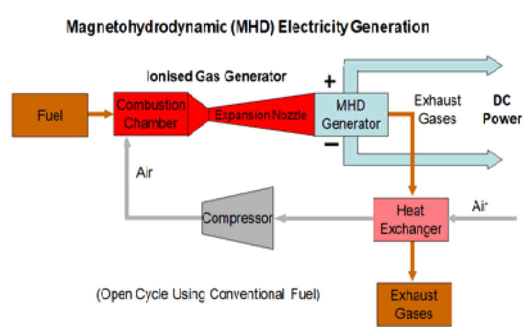
The MHD generator can be considered to be a fluid dynamo. This is similar to a mechanical dynamo in which the motion of a metal conductor through a magnetic field creates a current in the conductor except that in the MHD generator the metal conductor is replaced by a conducting gas plasma. When a conductor moves through a magnetic field it creates an electrical field perpendicular to the magnetic field and the direction of movement of the conductor. This is the principle, discovered by Michael Faraday, behind the conventional rotary electricity generator. Dutch physicist Antoon Lorentz provided the mathematical theory to quantify its effects.



Magnetohydrodynamic Power Generation (Principle)

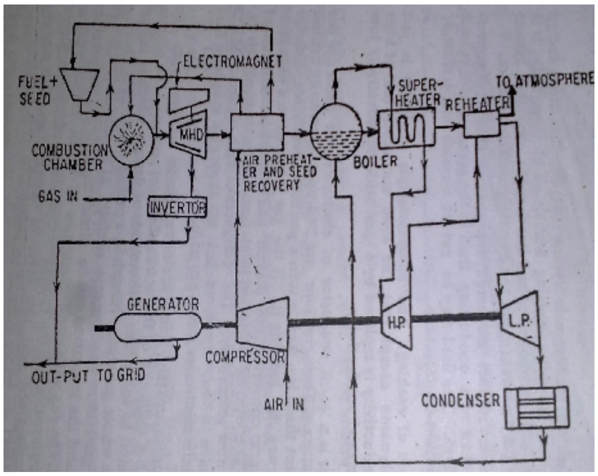
The flow (motion) of the conducting plasma through a magnetic field causes a voltage to be generated (and an associated current to flow) across the plasma , perpendicular to both the plasma flow and the magnetic field according to Fleming's Right Hand Rule. Lorentz Law describing the effects of a charged particle moving in a constant magnetic field can be stated as

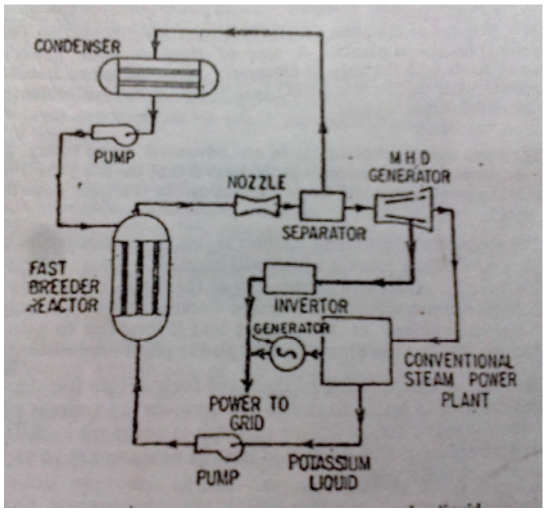
F = Q v B , Where **F** is the force acting on the charged particle, **Q** is charge of particle, **v** is velocity of particle , **B** is magnetic field



The MHD generator needs a high temperature gas source, which could be the coolant from a nuclear reactor or more likely high temperature combustion gases generated by burning fossil fuels, including coal, in a combustion chamber. The diagram below shows possible system components.

The expansion nozzle reduces the gas pressure and consequently increases the plasma speed (Bernoulli's Law) through the generator duct to increase the power output (See Power below). Unfortunately, at the same time, the pressure drop causes the plasma temperature to fall (Gay-Lussac's Law) which also increases the plasma resistance, so a compromise between Bernoulli and Gay-Lussac must be found. The exhaust heat from the working fluid is used to drive a compressor to increase the fuel combustion rate but much of the heat will be wasted unless it can be used in another process. The prime system requirement is creating and managing the conducting gas plasma since the system depends on the plasma having a high electrical conductivity. Suitable working fluids are gases derived from combustion, noble gases, and alkali metal vapours.





Open Cycle MHD Plant

Closed Cycle MHD using liquid metal

An MHD generator produces a DC output which needs an expensive high power inverter to convert the output into AC for connection to the grid. Typical efficiencies of MHD generators are around 10 to 20 percent mainly due to the heat lost through the high temperature exhaust.

Problems encountered in MHD Design

- Achieving High ionization temperature (2000-3000°C),
- Seed materials attack the insulation,
- Corrosion of electrodes by combustion gases,
- Economics-additional investments.

References:

1. **www.renewablenergyworld.com**
2. **www.wikipedia.org**
3. **www.mnre.gov.in**
4. **www.new-energy-portal.com**

Compiled by R.SENTHIL / AP(S.G) – MECH, SRM UNIVERSITY.

****