Module 1: Introduction

Role of Mechanical Engineering in Industries and Society

Mechanical engineering is one of the oldest and broadest engineering disciplines, and plays a significant role in enhancing industrial safety, economic strength, societal quality of life throughout the world.

In the previous century, were developed engineering achievements that have contributed to the increase in life expectancy, improved health conditions, increased mobility thanks to the development of the automobile and the airplane, increased productivity of labor as many of the products made available to many people. In the future Mechanical engineering will develop engineering solutions that foster a cleaner, healthier, safer and sustainable world.

Emerging Trends and Technologies in different sectors

Energy Sector: Mechanical engineers in the energy industry design and operate fossil fuel, hydroelectric, conventional, nuclear, and cogeneration power plants. They are involved in all aspects of the production and conversion of energy from one form to another. Mechanical Engineering is directly related to the application and development of equipment to create and transform any kind of energy and use it.

Manufacturing Sector: Here Mechanical Engineer has responsible for all aspect of the design, development, implementation, operation and management of manufacturing system.
The job of manufacturing/production Engineer involves the use of machine tools, materials and human resources in the most effective way to produce any goods.

Automotive Sector: The automotive industry relies heavily on the field of mechanical engineering to improve safety, fuel consumption, and emissions control. Recent advancements in mechanical engineering design, process optimizations enabled engines are quieter, faster, and more fuel efficient. Also Currently, the areas where engineers are focused include enhancing the transmissions, fuel injection systems, creating hybrid vehicles that can run on battery as well as IC Engines.

Aerospace Sector: Aerospace engineering is the primary field of engineering concerned with the development of aircraft and spacecraft. The most important role of the mechanical engineer involves the design of engines, propellers, selection of materials, high precision fabrication processes etc. Air conditioning systems also influences the efficiency of gas turbines as well as the comfort of the personnel in the spacecraft.

Marine Sector: Marine engineering is the engineering of boats, ships, submarines, and any other marine vessel. Marine engineering incorporates many aspects of mechanical engineering. Such as design of shipboard propulsion systems, steering, anchoring, cargo handling, heating, ventilation, air conditioning etc.

Module 1: Energy

Fossil Fuels

- Formed mainly from ancient microscopic plants and bacteria that lived in the ocean and salt water seas. These micro-organisms died and settled to the sea floor, they mixed with sand silt to form organic rich mud which was gradually heated and compressed chemically transforming into petroleum.
- The liquid petroleum which are less dense than water move upwards through earth's crust. It passes through an impermeable layer of rock which traps the petroleum creating a reservoir of petroleum and natural gas.

Types of Fuels: The important fuels are as follows

1) Solid fuels

2) Liquid fuels

3) Gaseous fuels

Solid Fuels

- Coal is the major fuel used for thermal power plants to generate steam. Coal occurs in nature, which was formed by the decay of vegetable matters buried under the earth millions of years ago under pressure and heat. This phenomenon of transformation of vegetable matter into coal under earth's crust is known as Metamorphism.
- The type of coal available under the earth's surface depends upon the period of metamorphism and the type of vegetable matter buried, also the pressure and temperature conditions. The major constituents in coal moisture (5-40%), volatile matter (combustible & or incombustible substances about (50%) and ash (20-50%).
- The chemical substances in the coal are carbon, hydrogen, nitrogen, oxygen and sulphur. In the metamorphism phenomenon, the vegetable matters undergo the transformation from peat to anthracite coal, with intermediate forms of lignite and bituminous coal.

Liquid Fuels

- All types of liquid fuels used are derived from crude petroleum and its by-products. The petroleum or crude oil consists of 80-85% C, 10-15% hydrogen, and varying percentages of sulphur, nitrogen, oxygen and compounds of vanadium.
- The crude oil is refined by fractional distillation process to obtain fuel oils, for industrial as well as for domestic purposes. The fractions from light oil to heavy oil are naphtha, gasoline, kerosene, diesel and finally heavy fuel oil. The heavy fuel oil is used for generation of steam. The use of liquid fuels in thermal power plants has many advantages over the use of solid fuels.

Gaseous Fuels

- For the generation of steam in gas fired thermal plants, either natural gas or manufactured gaseous fuels are used. However, manufactured gases are costlier than the natural gas. Generally, natural gas is used for power plants as it is available in abundance. The natural gas is generally obtained from gas wells and petroleum wells.
- The major constituent in natural gas is methane, about 60-65%, and also contains small amounts of other hydrocarbons such as ethane, naphthenic and aromatics, carbon dioxide and nitrogen. The natural gas is colourless, odourless and non-toxic.The artificial gases are producer gas, water gas coke-oven gas; and the Blast furnace gas.
- Generally, power plants fired with artificial gases are not found. The gaseous fuels have advantages similar to those of liquid fuels, except for the storage problems. The major disadvantage of power plant using natural gas is that it should be setup near the source; otherwise the transportation losses are too high.

Nuclear Power Plant

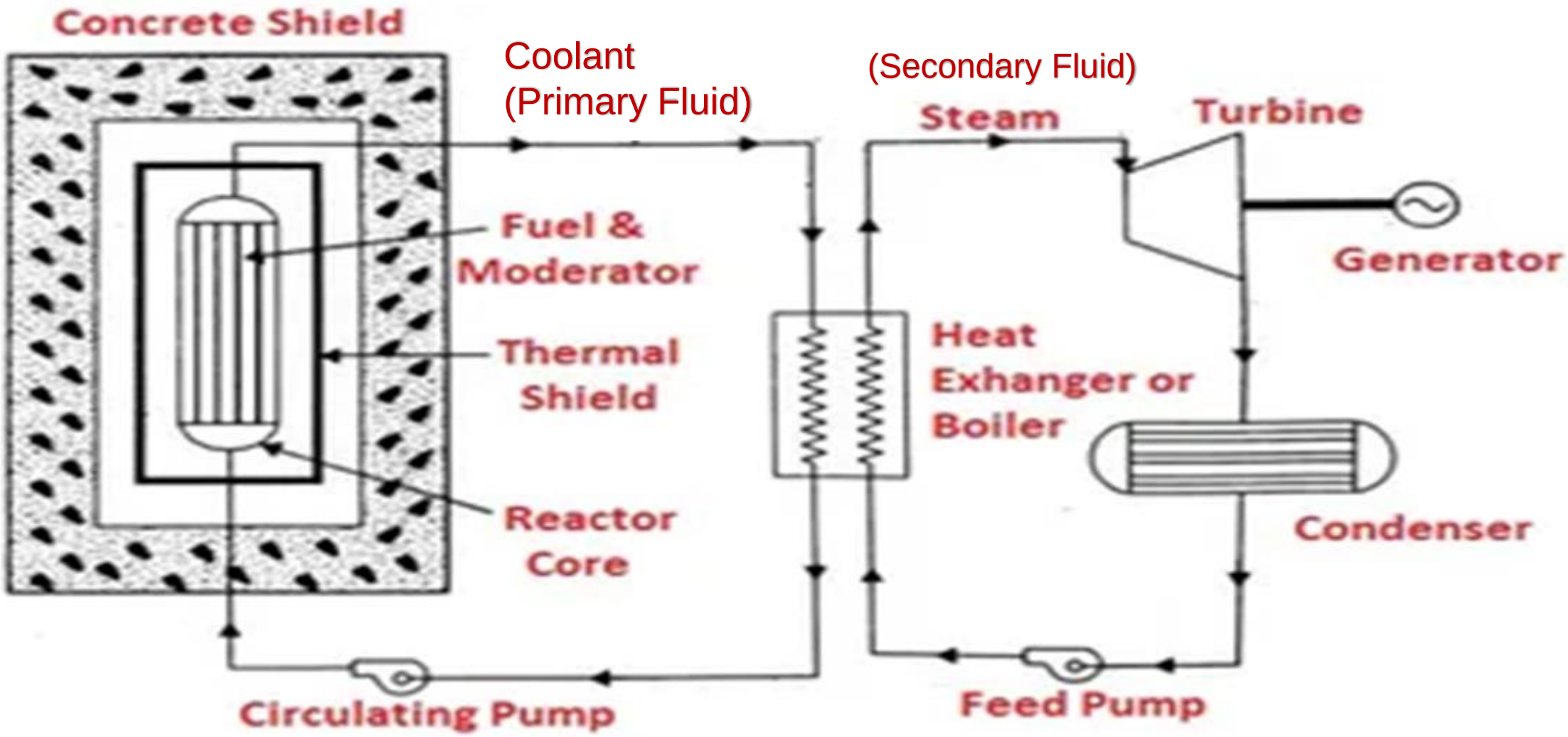


Figure: Schematic Representation of Nuclear Power Plant

Components of Nuclear Power Plant

- **Nuclear Reactor:** The reactor has following components
  - ✓ **Moderator:** It reduces the kinetic energy of the neutron to control the chain reaction. Generally graphite is used as moderator.
  - ✓ **Thermal Shield:** This concrete structure avoids leakage of radiation to the outer atmosphere.
  - ✓ **Coolant:** Coolant absorbs heat from the nuclear reactor that keeps the reactor cooled. This heat further exchanged to secondary liquid in heat exchanger.

- **Heat Exchanger(Boiler):** It is a heat exchanger, where coolant from nuclear reactor will transfer heat to water. After absorbing heat, water converts into super heated steam.

- **Steam Turbine:** Turbine is work producing device. It converts kinetic energy of the steam into mechanical energy when steam is made to expand on the turbine blades. The expanded steam is in binary state of vapour and liquid. This expanded steam enters into condenser.

- **Generator:** Generator is a electric device, which converts mechanical energy into electric energy. Thus produced electric energy is transmitted to electric grids.

- **Condenser:** Condenser is a heat exchanger. Here steam from turbine enters into condenser tubes and loses heat to the cold water. After losing heat, the steam converted into liquid state.

- **Pump:** Pump is a work absorbing device. The liquid water is fed back to boiler with help of feed water pump. It will regulate the flow of water in boiler so as to generated the steam at desired quantity and pressure levels.

Working of Nuclear Power Plant

- The nuclear power plant utilizes the heat energy generated during the fission reaction to convert liquid water into super heated steam in heat exchanger. During the fission reaction enormous heat energy is generated. This heat is absorbed by a coolant while passing through the thermal shield. This heat is further transmitted secondary liquid (water).

- After absorbing heat liquid water becomes super heated steam at very high pressure. This high pressure is converted into kinetic energy with the nozzle. This expanded steam is then passed over the steam turbine blades. Where, high kinetic energy of steam is converted into mechanical energy.

- Thus produced mechanical energy is converted into electrical energy with help of generator. This electric energy transmitted to electric grids. The steam expanded in turbine is further cooled in condenser. After condensation vapor is converted into liquid water. This water is pumped back to boiler with the help of feed water pump.

Advantages:

- Well suited for large scale power generation.
- It has very high energy density compared all other power plants.
- Less fuel consumption and no fuel handling compared to thermal power plants.

Disadvantages:

- High initial cost.
- The danger of radioactivity hazards is always persisting.
- The disposal of fission products is a big problem.
- Working condition is always harmful to the health of the workers.

Hydel Power Plant

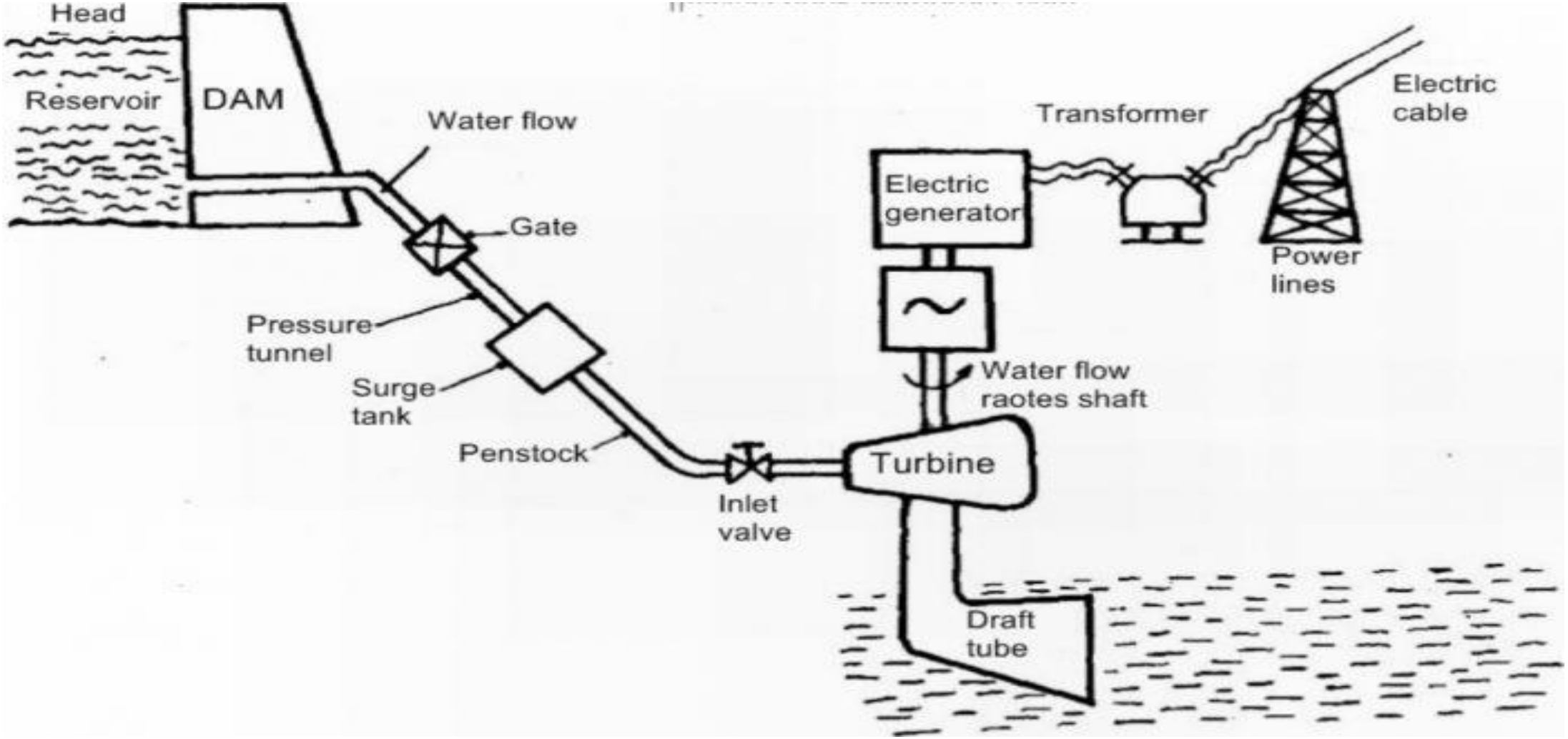


Figure: Schematic Representation of Hydro Power Plant

Components of Hydro Power Plant

1. **Reservoir:** It stores large amount of water behind the dam. The energy stored in reservoir is potential energy. The height of the water stored in reservoir will determine the potential energy stored in water.
2. **Surge Tank:** A surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the turbine inlet. When there is sudden reduction in load on the turbine, the governor closes the gates of the turbine to reduce the water flow. This causes pressure to increase abnormally in the penstock. This is prevented by using a surge tank, in which the water level rises to reduce the pressure. On the other hand, the surge tank provides excess water needed when the gates are suddenly opened to meet the increased load demand.
3. **Penstock:** A penstock is a huge steel pipe which carries water from the reservoir to the turbine. Potential energy of the water is converted into kinetic energy as it flows down through the penstock due to gravity.
4. **Water Turbine:** It converts high kinetic energy into mechanical energy once the water flows over the turbine blades.
5. **Generator:** The generator shaft is coupled to turbine shaft. In generator, mechanical energy is converted into electrical energy. This electric energy is further transmitted to grids.
6. **Draft Tube:** It is pipe through which water discharged into river.

Working of Hydro Power Plant

Hydroelectric power plant (Hydel plant) utilizes the potential energy of water stored in a dam built across the river. The potential energy of the stored water is converted into kinetic energy by first passing it through the penstock pipe. The kinetic energy of the water is then converted into mechanical energy in a water turbine. The turbine is coupled to the electric generator. The mechanical energy available at the shaft of the turbine is converted into electrical energy by means of the generator.

Advantages:

- No fuel is required as potential energy is stored water is used for electricity generation
- Neat and clean source of energy
- Very small running charges - as water is available free of cost
- Comparatively less maintenance is required and has longer life
- Serves other purposes too, such as irrigation

Disadvantages:

- High construction cost is required due to construction of dam.
- long transmission line is required to transmit this hydroelectric power.
- It doesn't supply constant hydroelectricity due to the availability of water.

Solar Power Plant

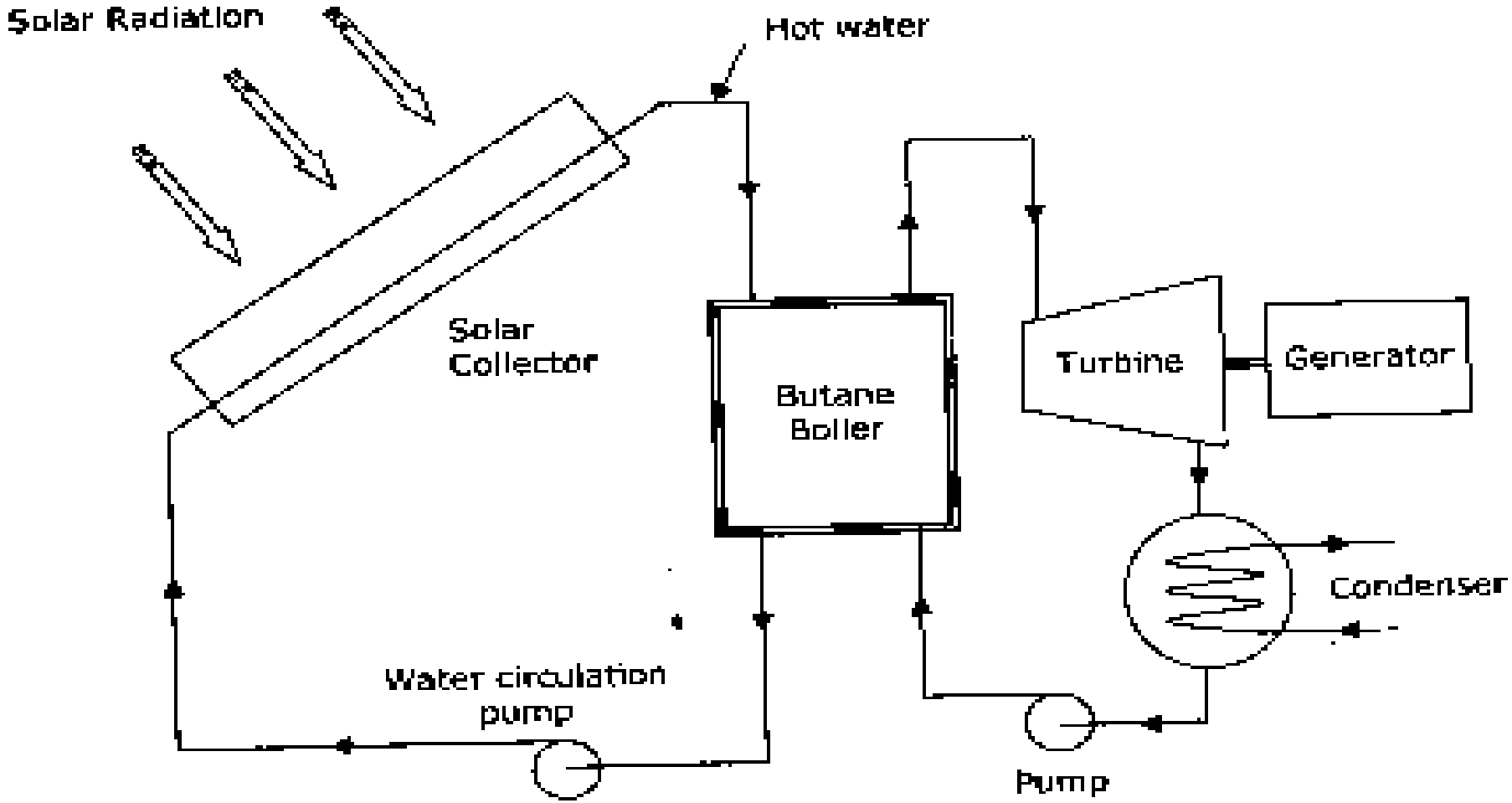


Figure: Schematic Representation of Solar Power Plant

Components of Solar Power Plant

- **Solar Collector:** A solar collector is a heat exchanger, where it transmits the heat from sun radiation to water. After absorption of heat, water density reduces and high density cold water pushes the hot water away from the collector. The
- **Heat Exchanger (Butane Boiler):** It is a heat exchanger, where hot water from solar collector will transfer heat to butane. After absorbing heat, butane converts into super heated vapour. Butane is selected as working fluid as it boils at low temperature.
- **Turbine:** Turbine is work producing device. It converts kinetic energy of the butane vapour into mechanical energy when vapour is made to expand on the turbine blades. The expanded vapour is in binary state of vapour and liquid. This expanded steam enters into condenser.
- **Generator:** Generator is a electric device, which converts mechanical energy into electric energy. Thus produced electric energy is transmitted to electric grids.
- **Condenser:** Condenser is a heat exchanger. Here vapour from turbine enters into condenser tubes and loses heat to the cold water. After losing heat, the steam converted into liquid state.
- **Pump:** Pump is a work absorbing device. The liquid butane is fed back to boiler with help of feed pump. It will regulate the flow of butane in heat exchanger so as to generated the vapour at desired quantity and pressure levels.

Working of Solar Power Plant

The solar power plant utilizes the heat energy from the solar radiations to heat liquid water in solar collector. This water, after absorbing heat, enter into heat exchanger. In heat exchanger hot water transmits heat to butane in liquid state. After absorbing heat, the liquid butane turns into vapour at high pressure. As the temperature of water will be as low as upto $80\,^{0}C$, it need a working fluid that boils at low temperature like butane.

This high pressure vapour is converted into kinetic energy with the help of nozzle. This expanded steam is then passed over the turbine blades. Where, high kinetic energy of steam is converted into mechanical energy. Thus, produced mechanical energy is converted into electrical energy with help of generator. This electric energy transmitted to electric grids. The vapour expanded in turbine is further cooled in condenser. After condensation vapor is converted into liquid butane. This butane is pumped back to heat exchanger with the help of feed pump.

Advantages:

- Endless amounts of energy, free of cost.
- Modern systems work efficiently even in winter
- Solar power is pollution-free and causes no greenhouse gases to be emitted after installation
- Reduced dependence on import of foreign oil and fossil fuels like coal based plant etc.
- Plant can be installed at remote locations. Hence, power transmission losses are low.

Disadvantages:

- Cost of power generation is high.
- Needs thermal power storage system for uninterrupted working during when sun is unavailable.
- Needs very large solar collector area for installation.
- Cannot supply continuous electric power.
- Only suitable where favorable sun-shine conditions are available.
- Low thermal efficiency.

Wind Power Plant

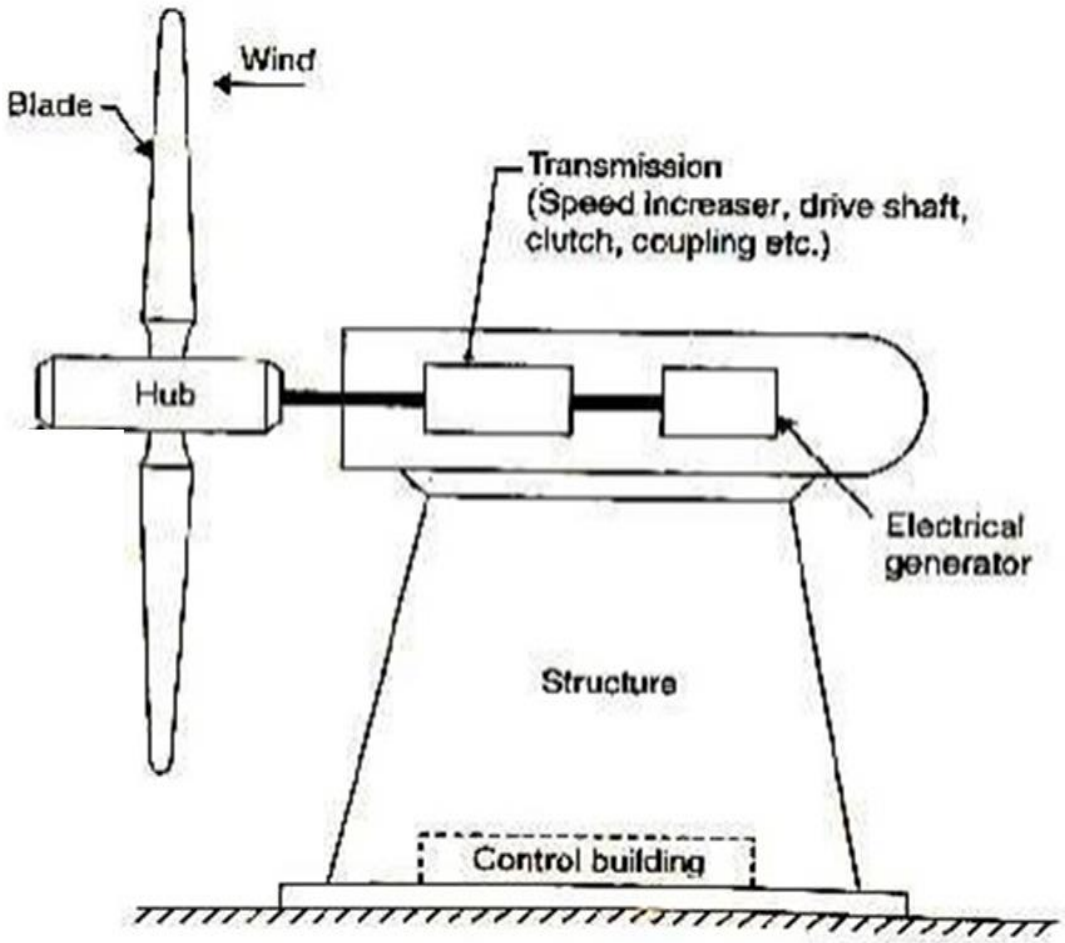


Figure: Horizontal Axis Wind Turbine

Components of Wind Power Plant

- **Turbine Blades:** It is propellers with two, three or five blades mounted on the horizontal shaft (this gives higher output than when they are mounted on the vertical shaft) and made of a lightweight material such as carbon fiber, fiberglass or wood, that is strong enough to resist wind forces. It is built with aero foil structure due to which kinetic energy of the wind is converted into rotary motion of the turbine shaft.
- **Gear Box:** A Mechanical gearbox is used to increase the rotational speed of the generator.
- **Generator:** An Electrical generator is used to produce the electrical power which is coupled on gear shaft.
- **Support Structure:** It supports the rotors, gearbox, generator and axillary equipment.

Working of Wind Power Plant

- The wind power plant utilizes the kinetic energy from the wind to mechanical energy in turn to produce electrical energy. Wind energy is created when the sun heats the earth atmosphere unevenly causing thermosiphon effect. This thermosiphon effect is the cause for formation of the wind. Hence, Wind energy, which is actually a secondary component of solar energy
- When the wind flows over the turbine blade, due to its aero foil shape, the kinetic energy of the wind is converted into rotary motion of the shaft. These blades are connected to a hub. Hub is further connected to gear box. Generally, the speed of the rotor is very low. This isn't enough to produce the high electric power. To increase the speed of the rotor, a gear box is employed.
- This high-speed shaft connects to an electrical generator that converts the mechanical energy from the rotation of the blades into electrical energy. Spinning between 11 and 20 times per minute, each turbine can generate a maximum 1.5 megawatts of electricity enough to power, on average.

Advantages:

- Air as a fuel is free and inexhaustible.
- It is clean source of energy and does note pollute the environment.
- The cost of electricity is too low and wind turbine could be used over more than 20 years
- It's cheap as only the installation and maintenance cost is required.

Disadvantages:

- It takes a lot of research and effort to decide the location where wind power plant has to be installed, due to fluctuating pattern of wind.
- Wind power plant is only useful to the countries with coastal or hilly areas.

BIOFUELS

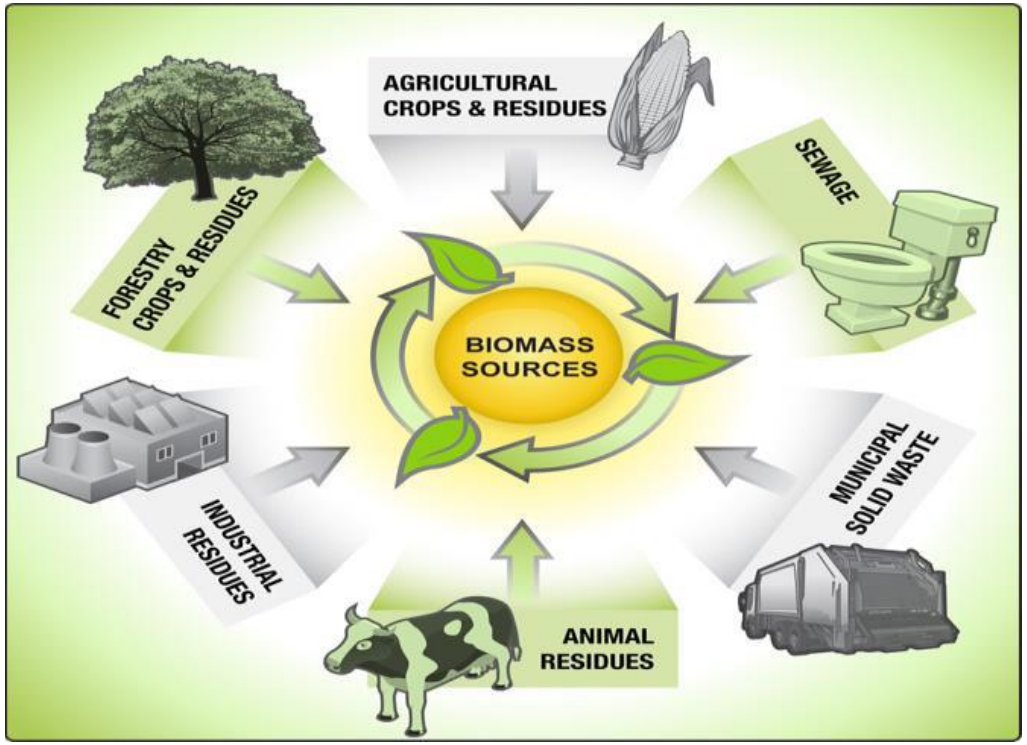
- Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-derived materials which are specifically called lignocelluloses. As an energy source, biomass can either be used directly via combustion to produce heat, or Indirectly after converting it to various forms of biofuel.

- This biomass may be transformed by physical, chemical and biological processes to biofuels. In chemical forms biomass is stored solar energy and can be converted into solid, liquid and gaseous energy carries. Biomass is biological/organic material derived from living, or recently living organisms. (The term is equally applicable to both animal and vegetable derived material, but in the context of energy, it refers to plant based material)

- The term ‘Biofuel’ refers to liquid or gaseous fuels for the transport sector that are predominantly produced from biomass. A variety of fuels can be produced from biomass resources including liquid fuels, such as ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels, such as hydrogen and methane.

- The biomass resource base for biofuel production is composed of a wide variety of forestry and agricultural resources, industrial processing residues, and municipal solid and urban wood residues.

Source of biomass



Examples of various biofuels used in engineering applications: The various bio-fuels are bio-methanol, bio-ethanol, bio-diesel, bio-gas and producer gas.

First-generation biofuels are made from sugar, starch, vegetable oil, or animal fats using conventional technology. The basic feedstock for the production of first-generation biofuels come from agriculture and food processing.

The most common first-generation biofuels are:

- **Biodiesel:** Extraction with or without esterification of vegetable oils from seeds of plants like soybean, oil palm, oilseed rape and sunflower or residues including animal fats derived from rendering applied as fuel in diesel engines.
- **Bioethanol:** Fermentation of simple sugars from sugar crops like sugarcane or from starch crops like maize and wheat applied as fuel in petrol engines.
- **Bio-oil:** Thermo-chemical conversion of biomass. A process still in the development phase.
- **Biogas:** Anaerobic fermentation or organic waste, animal manures, crop residues an energy crops applied as fuel in engines suitable for compressed natural gas.

Emission of bio-fuels: Biodiesel plays a vital role in reducing emission of many air pollutants. The emission of carbon monoxide (CO), sulphur oxides (SOx), nitrogen oxides (NOx) etc.., is lesser than those of petroleum fuels and thus these are eco-friendly.

Calorific value of bio-fuels: Calorific values of biofuels will be considerably lesser than that of petroleum fuels.

Advantages of biofuel:

- Renewable and inexhaustible (theoretically) source of energy.
- Biomass is very abundant
- Commercial use of biomass may reduce the problem of waste disposal.
- It may also use areas of unused agricultural land and provide jobs in rural communities.

Disadvantages of biofuel:

- A dispersed and land-intensive source.
- Could contribute to global warming and particulate pollution if directly burned.

Global Warming

Radiation from the sun keeps the earth's surface and the atmosphere warm. A major portion of this incoming radiation is absorbed by the earth's surface and small amount by the gases present in the atmosphere. Another small portion is reflected back into the space. Since the radiation absorbed by the earth's surface is re-emitted, equilibrium is established between the radiation absorbed by and that leaving the earth's surface. This accounts for the average temperature of the earth remaining constant. Some gases present in the atmospheric air absorbs a portion of the thermal infrared radiation (wavelength region of 4000 to 5000 nm) and remit to the earth's surface. As a result, the earth's surface becomes warm. This phenomenon is referred to as green house effect.

Greenhouse Gases: The major greenhouse gases in the atmosphere are carbon dioxide, methane, ozone, nitrous oxide, and Chlorofluorocarbons (CFCs). However, the most significant contribution comes from carbon dioxide which is present in the atmosphere in the large quantities. The natural source of carbon dioxide is the biological degradation of vegetable matter which in essence is a reverse of photosynthesis.

There is a rapid increase of greenhouse gases particularly carbon dioxide due to,

1) The combustion of fossil fuels such as coal, oil and natural gas

2) The burning and biodegradation of biomass

3) Deforestation

4) Increase in industrial activities

Global Warming

It is a climatic change that causes due to the emission of greenhouse gases. Global warming leads to raise in temperature of the oceans and the earth surface causing melting of polar ice caps, rise in sea levels and also unnatural patterns of precipitation such as flash floods, excessive snow or desertification.

Causes of Global Warming

1. Emission of Carbon dioxide from the burning fossil fuels in the power plants
2. Emission of Carbon dioxide from burning petroleum products in transportation and industries
3. Deforestation, especially tropical forests for wood, pulp, and farmland
4. Increase in usage of chemical fertilizers on croplands

Effects of Global Warming

1. It is estimated that the earth will warm up by 4 to 5°C more in the 21st century and this may raise the ocean by 2 to 3 feet.
2. The raise in temperature could cause glaciers and the ice caps to melt.
3. The winter will be shorter and warmer while the summer will be longer and hotter.
4. Plant and animal pests such as weeds, insects, rodents thrive better under warm condition leading to massive crop failures
5. Depletion of the ozone layer and hence causes different types of skin diseases

OZONE LAYER DEPLETION

The ozone layer is an invisible layer of protection around the planet that protects us from the sun's harmful rays (ultraviolet radiation). In other words it acts as nature's umbrella against UV radiation. The ozone layer is about 3 mm thick.

Ozone depletion is the thinning of the earth's ozone layer. This is caused due to the presence of greenhouse gases in the atmosphere. Depletion of the Ozone layer is mainly due to the interaction of ozone with chlorine and bromide present in Chlorofluorocarbons (CFCs). Once those toxic gases reach the upper atmosphere, they cause a hole in the ozone layer causing its depletion. This is one of the most important current environmental challenges.

Effects of Ozone Depletion

1. Increases the flux of UV radiation over earth's biosphere
2. Causes skin cancer and eye disorders
3. Decreases the rate of photosynthesis
4. Leads to greenhouse effect
5. It causes decrease in the yield of crops
6. Adversely affects human immunity system and causes genetic abnormalities
7. Causes the degradation of paints, plastics and other polymer materials
8. It effects the marine life