Unit - IV	Biomass Energy

Syllabus

Introduction-Bio mass resources-Energy from Bio mass: conversion processes-Biomass Cogeneration-Environmental Benefits. Geothermal Energy: Basics, Direct Use, Geothermal Electricity. Mini/micro hydro power : Classification of hydropower schemes, Classification of water turbine, Turbine theory, Essential components of hydroelectric system.

Contents

4.1 Introduction

Biomass is the material derived from plants that use sunlight to grow which include plant and animal material such as wood from forests, material left over from agricultural and forestry processes, and organic industrial, human and animal wastes. Biomass energy is a type of renewable energy generated from biological (such as, anaerobic digestion) or thermal conversion (for example, combustion) of biomass resources.

In nature, if biomass is left lying around on the ground it will break down over a long period of time, releasing carbon dioxide and storing energy slowly. By burning biomass, its stored of energy is released quickly and often in a useful way. So converting biomass into useful energy imitates the natural processes but at a faster rate.

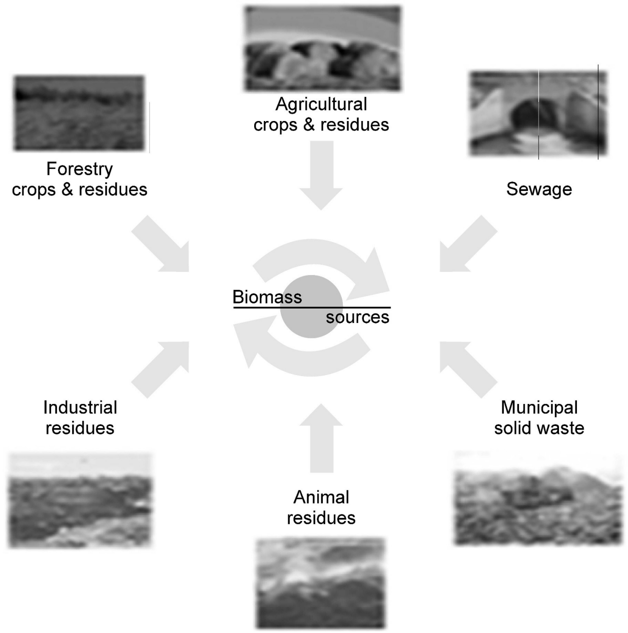


Fig. 4.1.1 : Biomass sources

Biomass can be transformed into clean energy and/or fuels by a variety of technologies, ranging from conventional combustion process to advanced biofuels technology. Besides recovery of substantial energy, these technologies can lead to a substantial reduction in the overall biomass waste quantities requiring final disposal, which can be better managed for safe disposal in a controlled manner while meeting the pollution control standards.

Biomass conversion systems reduce greenhouse gas emissions in two ways. Heat and electrical energy is generated which reduces the dependence on power plants based on fossil fuels. The greenhouse gas emissions are significantly reduced by preventing methane emissions from decaying biomass. Moreover, biomass energy plants are highly efficient in harnessing the untapped sources of energy from biomass resources and helpful in development of rural areas.

4.2 Biomass Resources

Biomass comes from a variety of sources which include :

- Woody Fuels
- Forestry Residues
- Mill Residues
- Agricultural Residues
- Urban Wood and Yard Wastes
- Chemical Recovery Fuels
- Animal Wastes
- Dry Animal Manure

Woody Fuels

Wood wastes of all types make excellent biomass fuels and can be used in a wide variety of biomass technologies. Combustion of woody fuels to generate steam or electricity is a proven technology and is the most common biomass-to-energy process. Different types of woody fuels can typically be mixed together as a common fuel, although differing moisture content and chemical makeup can affect the overall conversion rate or efficiency of a biomass project.

Forestry Residues

Forestry residues have been the focus of many recent biomass studies and feasibility assessments due to increasing forest management and wildfire prevention activities under the National Fire Plan. The USDA Forest Service and the Bureau of Land Management have been tasked with reducing the hazardous fuel loading within the forests and the urban wild land interface.

Forestry residues are typically disposed of by on-site (in-forest) stacking and burning. This results in substantial air emissions that affect not only the forest lands and nearby

populations, but the overall regional air quality as well. Open burning can also cause water quality and erosion concerns. The Forest Service and other public and private land management entities would like to have viable alternatives for disposing of their forestry residues in a more environmentally benign manner. An ideal situation, from the perspective of forest managers, would be the creation of a market for the forestry residues. The market they envision would generate revenues for the forest managers, which in turn would allow much needed expansion of the forest management programs.

Mill Residues

Mill residues are a much more economically attractive fuel than forestry residues, since in forest collection and chipping are already included as part of the commercial mill operations. Biomass facilities collocated with and integral to the mill operation have the advantage of eliminating transportation altogether and thus truly achieve a no-cost fuel. Mill residues have long been used to generate steam and electricity.

Agricultural Residues

Agricultural residues can provide a substantial amount of biomass fuel. Similar to the way mill residues provide a significant portion of the overall biomass consumption in the Pacific Northwest, agricultural residues from sugar cane harvesting and processing provide a significant portion of the total biomass consumption in other parts of the world. One significant issue with agricultural residues is the seasonal variation of the supply.

Urban Wood and Yard Wastes

Urban wood and yard wastes are similar in nature to agricultural residues in many regards. A biomass facility will rarely need to purchase urban wood and yard wastes, and most likely can charge a tipping fee to accept the fuel. Many landfills are already sorting waste material by isolating wood waste. This waste could be diverted to a biomass project, and although the volume currently accepted at the landfills would not be enough on its own to fuel a biomass project, it could be an important supplemental fuel and could provide more value to the community in which the landfill resides through a biomass project than it currently does as daily landfill cover.

Chemical Recovery Fuels

Chemical recovery fuels are responsible for over 60 percent of the total biomass energy consumption of the United States, and therefore must be mentioned in any analysis of biomass. By and large, the chemical recovery facilities are owned by pulp and paper facilities and are an integral part of the facility operation.

Animal Wastes

Animal wastes include manures, renderings, and other wastes from livestock finishing operations. Although animal wastes contain energy, the primary motivation for biomass processing of animal wastes is mitigation of a disposal issue rather than generation of energy. This is especially true for animal manures. Animal manures are typically disposed of through land application to farmlands. Tightening regulations on nutrient management, surface and groundwater contamination, and odor control are beginning to force new manure management and disposal practices. Biomass technologies present attractive options for mitigating many of the environmental challenges of manure wastes. The most common biomass technologies for animal manures are combustion, anaerobic digestion, and composting. Moisture content of the manure and the amount of contaminants, such as bedding, determine which technology is most appropriate.

Dry Animal Manure

Dry animal manure is produced by feedlots and livestock corrals, where the manure is collected and removed only once or twice a year. Manure that is scraped or flushed on a more frequent schedule can also be separated, stacked, and allowed to dry. Dry manure is typically defined as having a moisture content less than 30 percent. Dry manure can be composted or can fuel a biomass-to-energy combustion project.

4.3 Energy from Biomass

4.3.1 Fixed Dome Plant

A fixed-dome plant consists of a digester with a fixed, non-movable gas holder, which sits on top of the digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas stored and the height difference between the slurry level in the digester and the slurry level in the compensation tank. The costs of a fixed-dome biogas plant are relatively low. It is simple as no moving parts exist. There are also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The plant is constructed underground, protecting it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labour-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and

cracks). A fixed-dome plant comprises of a closed, dome-shaped digester with an immovable, rigid gas-holder and a displacement pit, also named 'compensation tank'. The gas is stored in the upper part of the digester. When gas production commences, the slurry is displaced into the compensating tank. Gas pressure increases with the volume of gas stored, i.e. with the height difference between the two slurry levels. If there is little gas in the gas-holder, the gas pressure is low. The digesters of fixed-dome plants are usually masonry structures, structures of cement and ferro-cement exist.

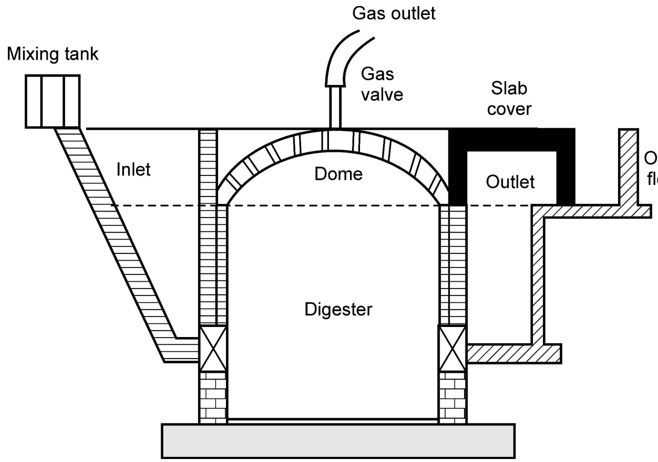


Fig. 4.3.1 : Fixed dome type

Advantages

- It has no corrosion trouble
- It requires less cost compared to a floating drum type
- It does not need maintenance
- Heat insulation is better and temperature will be constant.

Disadvantages

- It produces variable gas pressure
- It requires skilled masons
- Gas production of the digester volume is also less.

4.3.2 Floating Gas Holder Type

In a floating gas holder type digester, the gas holder is separated from the digester. In this type, gas collector is a cylindrical dome fabricated from mild steel plates. The floating gas collector dome slides vertically up and down in the main digester in accordance with the pressure and volume of biogas. Initially the gas holder is at the lower level. The biogas is produced in the digester and it rises naturally into the floating dome collector. The gas pressure in the dome increases and the dome rises to accommodate the gas volume. As the floating dome rises, the volume of the gas in the floating dome increases.

The gas outlet pipe is connected to the upper most point of the floating dome. The axis of the fixed digester and the floating dome collector are in one line. A central guide rod passing through the dome gives a proper alignment. The seating arrangement and guide arrangement are designed to provide leak proof and smooth operation.

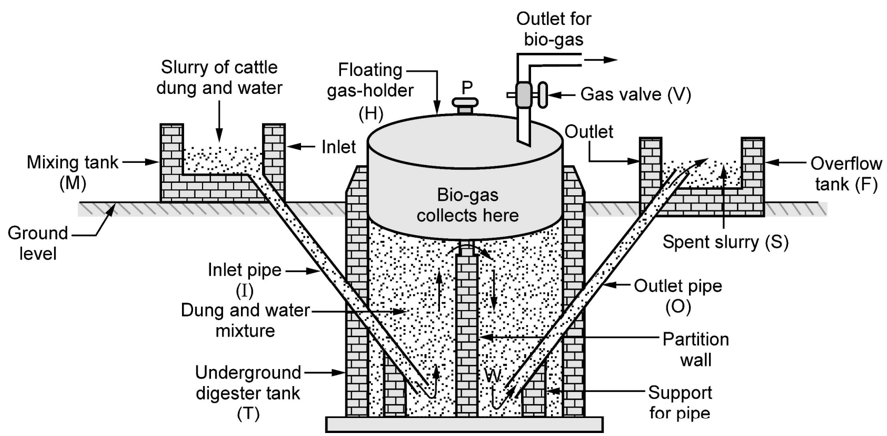


Fig. 4.3.2 : Floating gas holder type

Advantages

- It has less trouble because solids are constantly submerged.
- It has no problem of gas leakage.
- Danger of mixing oxygen with the gas is minimized.
- No separate pressure device is needed when the fresh waste is added to the tank.
- Constant gas pressure is obtained.

Disadvantages

- It has higher cost.
- It is not suitable for colder regions because of heat lost through the metal holder.
- It requires maintenance in flexible pipe joining area and main gas pipe.

4.4 Conversion Process

Biomass can be converted into different forms of energy by using various processes. Many factors affect the choice of the process like quantity of biomass feedstock, desired energy form, environmental standards, economic conditions, and project specific factors. Biomass can be converted into three main products : power or heat generation, transportation fuels and chemical feedstock.

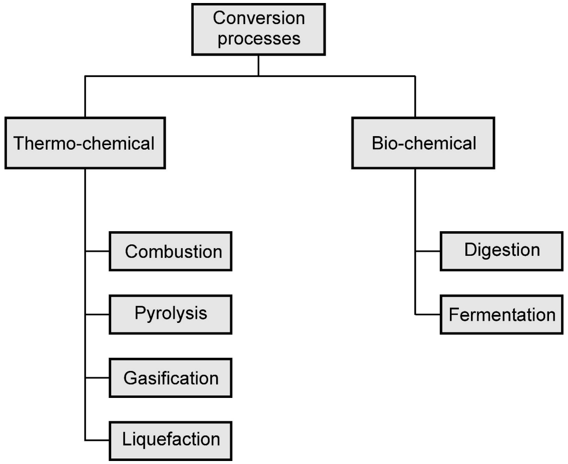


Fig. 4.4.1 : Flowchart for biomass conversion technologies

4.4.1 Thermo-chemical Conversion

In thermo-chemical conversion, energy is produced by applying heat and chemical processes. There are four thermo-chemical conversion processes, which are given below.

4.4.1.1 Combustion Process

Combustion is an exothermic chemical reaction, in which biomass is burned in the presence of air. In this process chemical energy which is stored in the biomass is converted into the **mechanical** and **electrical** energies. This process is suitable for dry biomass containing moisture less than 50 %. Biomass is burned at the temperature of 800-1000 °C. This process is used for domestic applications as well as commercially in biomass power plants inorder to produce electricity. The typical efficiencies for stand-alone biomass combustion power plants (using wood and forest residue as a fuel) range between 20-50 MW, with the related electrical efficiencies in the range of 25-30 %. These power plants are suitable where fuels are available at low costs. In recent years advanced combustion technology is being used. The application of fluid bed system and advanced gas cleaning allows for production of electricity from biomass, on scale of 50-80 MW, with 30-40 % electrical efficiencies.

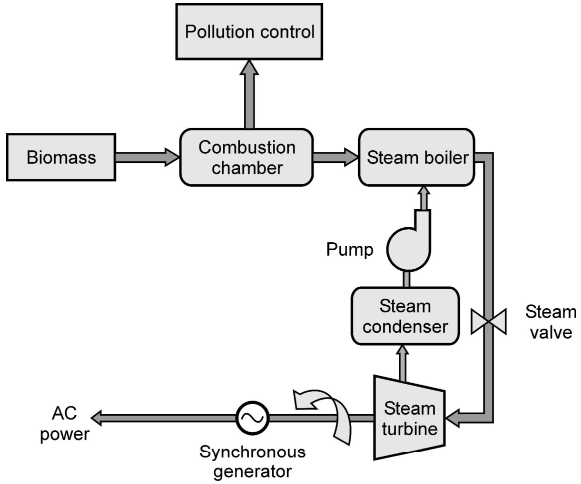


Fig. 4.4.2 : Production of electricity by combustion of biomass

4.4.1.2 Pyrolysis Process

It is the process of conversion of biomass to liquid (bio-oil), solid (charcoal) and gaseous (fuel gases) products by heating in the absence of air at 500 °C. There are three types of pyrolysis : Fast pyrolysis, conventional (Carbonization) pyrolysis and slow pyrolysis.

Fast pyrolysis process has high heating value and heat transfer rate and completes within seconds. Fast pyrolysis yields 60 % bio-oil, 20 % bio-char and 20 % biogas. Conventional pyrolysis process is the process in which mostly carbon (35 %) is left as residue. Slow pyrolysis takes more time than fast pyrolysis, it also has low temperature and heating values. Flash pyrolysis is the type of fast pyrolysis, in which 80 % bio-oil is obtained at keeping temperature low. If flash pyrolysis is used for converting biomass to bio-crude, it has up to 80 % efficiency.

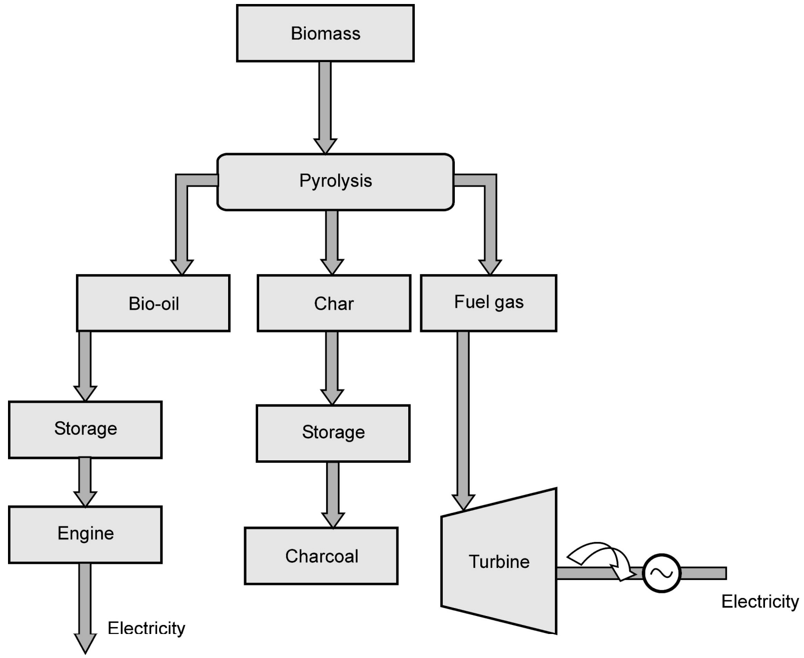


Fig. 4.4.3 : Production of electricity by pyrolysis of biomass

4.4.1.3 Gasification Process

In biomass gasification, charcoal, wood chips, energy crops, forestry residues, agricultural waste and other wastes are transformed into flammable gases at high temperature (800-1000 °C). In this process fuel (biomass) reacts with a gasifying medium such as oxygen enriched air, pure oxygen, steam or a combination of both. The product gas composition and energy content depends upon the gasifying media's nature and amount of it. Low Calorific Value (CV) gas obtained by gasification about 4-6 MJ/N m^3. The product gas can be used as a feedstock (syngas) in the production of chemicals like methanol. One promising concept is the biomass integrated gasification/ combined cycle (BIG/CC), in which gas turbines convert the gaseous fuel to electricity with a high overall conversion efficiency. The integration of gasification and combustion/ heat recovery ensures 40-50 % conversion efficiency for a 30-60 MW. The syngas can be converted into hydrogen gas, and it may have a future as fuel for transportation.

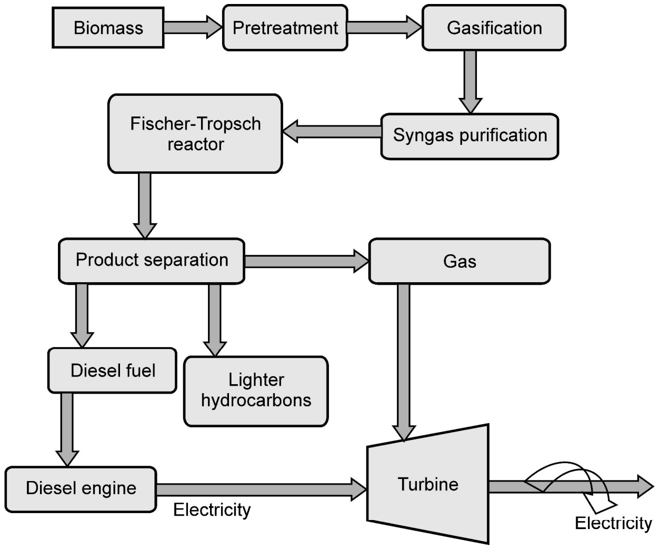


Fig. 4.4.4 : Production of electricity by gasification of biomass

4.4.1.4 Liquification Process

It is the process in which biomass is converted into liquid phase at low temperatures (250-350 °C) and high pressures (100-200 bar), usually with a high hydrogen partial pressure and catalysts to increase the rate of reaction. This process is used to get maximum liquid yields with higher quality than from the pyrolysis process. The product has higher heating value and lower oxygen content which makes the fuel chemically stable. The main purpose of the liquefaction is to obtain high H/C ratio of the product oil

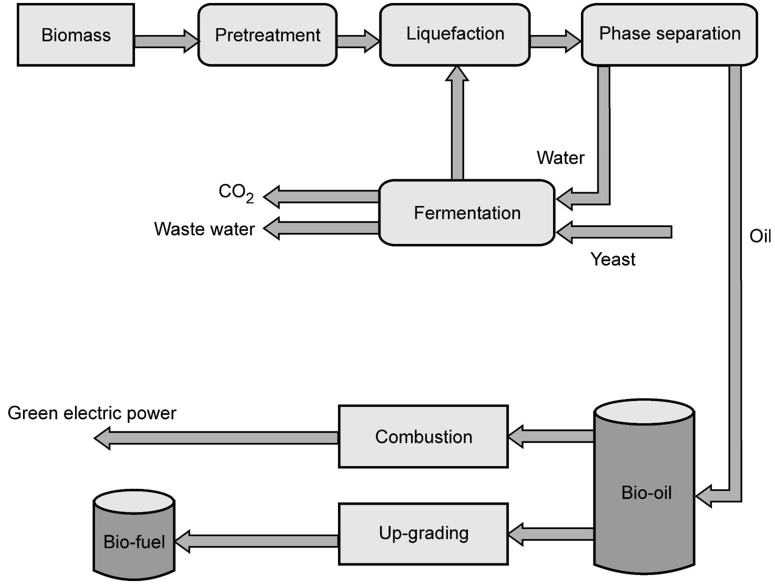


Fig. 4.4.5 : Liquefaction process of biomass

4.4.2 Bio-chemical Conversion

Biochemical conversion makes use of the enzymes of bacteria and other living organisms to break down biomass and convert it into fuels. This conversion process includes anaerobic digestion and fermentation.

4.4.2.1 Anaerobic Digestion Process

This is a process in which organic material directly converted to a gas which is termed as biogas. It is mixture of methane, carbon dioxide and other gases like hydrogen sulphide in small quantities. Biomass is converted in anaerobic environment by bacteria, which produces a gas having an energy of 20-40 % of lower heating value of the feedstock. This process is suitable for organic wastes having high moisture about 80-90 %. This biogas can be directly used in spark ignition gas engines and gas turbines and can be upgraded to higher quality natural gas by removing carbon dioxide. The overall conversion efficiency of this process is 21 %. Waste heat from engines and turbines can be recovered by using combined heat and power system.

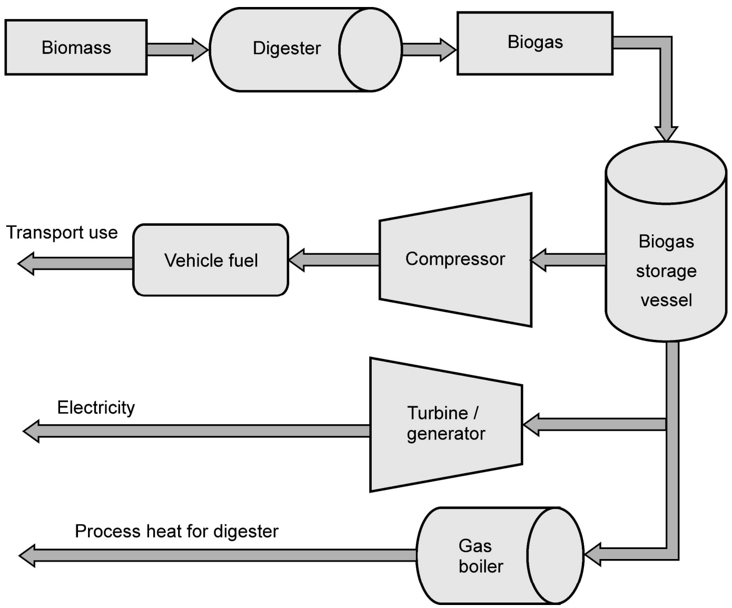


Fig. 4.4.6 : Anaerobic digestion process

4.4.2.2 Fermentation Process

Fermentation is an anaerobic process that breaks down the glucose within organic materials. It is a series of chemical reactions that convert sugars to ethanol. The basic fermentation process involves the conversion of a plant's glucose (or carbohydrate) into an alcohol or acid. Yeast or bacteria are added to the biomass material, which feed on the sugars to produce ethanol and carbon dioxide. The ethanol is distilled and dehydrated to obtain a higher concentration of alcohol to achieve the required purity for the use as automotive fuel. The solid residue from the fermentation process can be used as cattle-feed and in the case of sugar cane; the bagasse (the dry pulpy residue left after the extraction of juice from sugar cane) can be used as a fuel for boilers or for subsequent gasification.

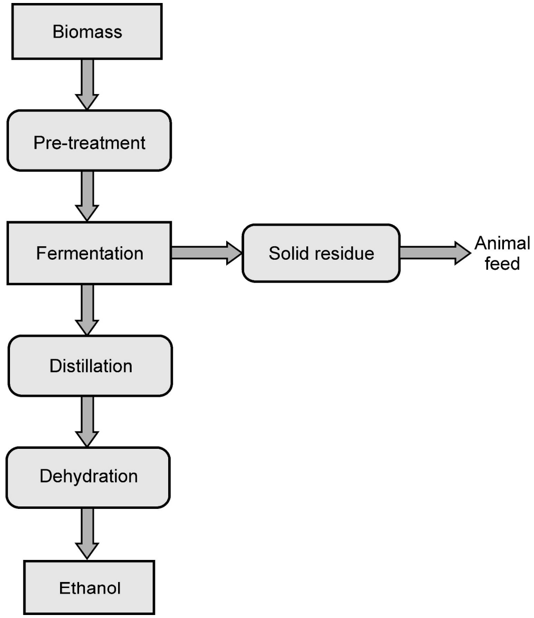


Fig. 4.4.7 : Fermentation process

4.5 Biomass Cogeneration

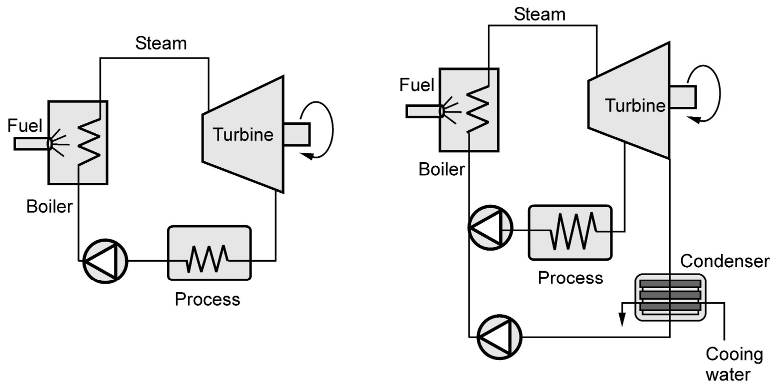
Cogeneration or Combined Heat and Power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. Mechanical energy may be used either to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan for delivering various services. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryer or chilled water for process cooling. Cogeneration provides a wide range of technologies for application in various domains of economic activities. The overall efficiency of energy use in cogeneration mode can be up to 85 percent and above in some cases.

4.5.1 Cogeneration Technology

Cogeneration technologies that have been widely commercialized include extraction/back pressure steam turbines, gas turbine with heat recovery boiler (with or without bottoming steam turbine) and reciprocating engines with heat recovery boiler.

4.5.1.1 Steam Turbine Cogeneration Systems

The two types of steam turbines most widely used are the backpressure and the extraction another variation of the steam turbine topping cycle cogeneration system is the extraction-back pressure turbine that can be employed where the end-user needs thermal energy at two different temperature levels. The full-condensing steam turbines are usually incorporated at sites where heat rejected from the process is used to generate power. The specific advantage of using steam turbines in comparison with the other prime movers is the option for using a wide variety of conventional as well as alternative fuels such as coal, natural gas, fuel oil and biomass. The power generation efficiency of the demand for electricity is greater than one MW up to a few hundreds of MW. Due to the system inertia, their operation is not suitable for sites with intermittent energy demand.



Back-pressure turbine **Extraction-condensing turbine**

Fig. 4.5.1 : Steam turbine cogeneration

4.5.1.2 Gasturbine Cogeneration Systems

Gas turbine cogeneration systems can produce all or a part of the energy requirement of the site, and the energy released at high temperature in the exhaust stack can be recovered for various heating and cooling applications though natural gas is most commonly used, other fuels such as light fuel oil or diesel can also be employed. The typical range of gas turbines varies from a fraction of a MW to around 100 MW. Gas turbine cogeneration has probably experienced the most rapid development in the recent years due to the greater availability of natural gas, rapid progress in the technology, significant reduction in installation costs, and better environmental performance.

Furthermore, the gestation period for developing a project is shorter and the equipment can be delivered in a modular manner. Gas turbine has a short start-up time and provides the flexibility of intermittent operation. Though it has a low heat to power conversion efficiency, more heat can be recovered at higher temperatures. If the heat output is less than that required by the user, it is possible to have supplementary natural gas firing by mixing additional fuel to the oxygen-rich exhaust gas to boost the thermal output more efficiently.

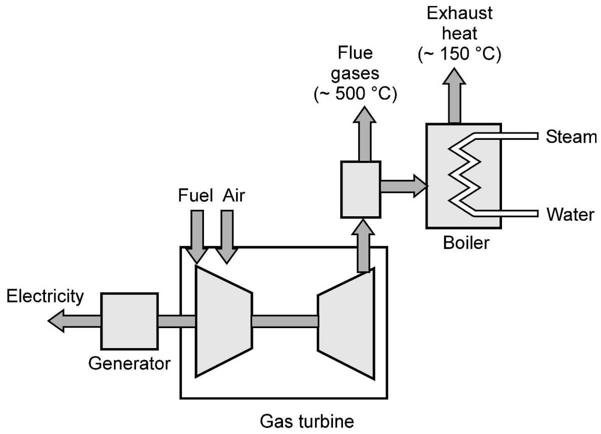


Fig. 4.5.2 : Gas turbine cogeneration

On the other hand, if more power is required at the site, it is possible to adopt a combined cycle that is a combination of gas turbine and steam turbine cogeneration. Steam generated from the exhaust gas of the gas turbine is passed through a backpressure or extraction-condensing steam turbine to generate additional power. The exhaust or the extracted steam from the steam turbine provides the required thermal energy.

4.5.1.3 Reciprocating Engine Cogeneration Systems

Reciprocating Engine Cogeneration Systems also known as Internal Combustion (I.C.) engines, these cogeneration systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat for recovery : exhaust gas at high temperature and engine jacket cooling water system at low temperature As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high, e.g. low pressure steam or hot water.

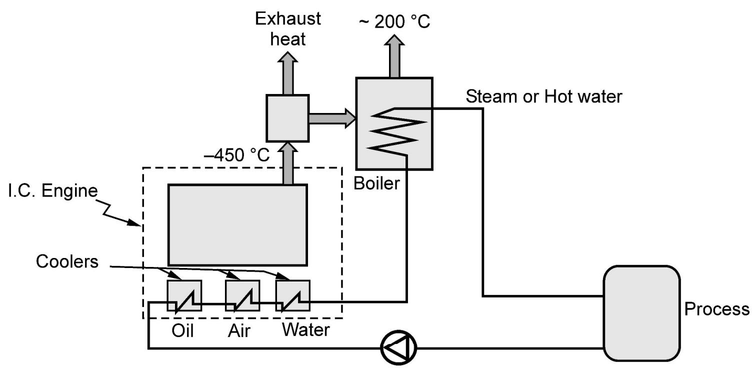


Fig. 4.5.3 : Reciprocating cogeneration

Though diesel has been the most common fuel in the past, the prime movers can also operate with heavy fuel oil or natural gas. These machines are ideal for intermittent operation and their performance is not as sensitive to the changes in ambient temperatures as the gas turbines. Though the initial investment on these machines is low, their operating and maintenance costs are high due to high wear and tear.

4.6 Environmental Benefits

Biomass energy is a renewable source of energy that is produced from things like wood, crops waste, animal matter and living crops. Biomass is used as fuel to produce electricity and other energy forms. These fuels can be in form of liquid , gas or solid. The use of biomass energy has various benefits and those are mostly environment friendly and economic. Biomass energy has become a great alternative nowdays to use fossil fuels for energy production.

Reducing Carbon Footprint

Biomass energy produces less carbon footprint compared to fossil fuels. This is because new plants grow to replace the old ones that were used to produce biomass energy before. The use of fossil fuel reduces when biomass energy is produced and this lowers the carbon dioxide levels in the atmosphere. The only disadvantage is that fossil fuels are usually used to harvest and manipulate biomass.

Reducing Methane Levels

With the introduction of biomass energy, methane levels in the atmosphere reduce. Methane is responsible for the greenhouse effect and with the production of biomass

energy, the gas levels are lowered. Methane is usually produced when organic matter decomposes therefore by lowering it; the greenhouse effect is reduced as well.

Preventing Forest Fires

Virgin wood is one of the biomass plant materials that are used to produce **biomass energy** and this material is usually obtained from forests. Cutting trees may not seem like a sensible thing to reduce forest fires but this actually works. Harvesting trees from forests can help to prevent fire breakouts as a result of dense growth. If there are too many trees in the forest, there is a high risk of a forest fire and this is not good for the environment because it means that a lot of carbon dioxide will be released into the atmosphere.

Improved Air Quality

When biomass energy replaces fossil fuels, it helps to improve air quality because there is less pollution. The use of fossil fuels has also been blamed for causing acid rain and this is one of the benefits of biomass energy. Biomass does not produce sulphur emissions when it is being burned and this reduces any chances of acid rain. The atmospheric carbon is recycled with the use of biomass and this is an advantage because human civilization therefore ends up with less pollution.

Reliability

There is an increased demand for power and this means that people need a source of energy that can be relied upon. Biomass energy is reliable because the plant materials and animal matter that are in use to produce it are in constant supply. Biomass is a reliable source of electricity therefore; people do not have to worry about power blackouts. It is also cheap to produce and this results in lower electric bills.

Recycling

Some of the sources of biomass energy include industrial waste and co-products and this is a big advantage because it means that nothing will go to waste. All the waste products that human get from industries can be used to produce biomass energy.

4.7 Geothermal Energy

Geothermal energy refers to heat energy stored under the ground for millions of years through the earth formation. It utilizes a rich storage of unutilized thermal energy that exists under the earth's crust. Geothermal energy is site specific but can be very cheap especially when used for direct heating. It is a challenge to estimate power from this source since it occurs underground at extremely high temperatures. The earth's crust has immense heat (thermal) energy stored over millions of years. There exists a huge temperature difference between the earth's crust and the surface. The temperature difference is known as **geothermal gradient.** This energy is sufficient to melt rock. The molten rock, called **magma,** at times erupts through cracks on earth surface as volcanoes. Geothermal energy is converted to produce electricity. The presence of geothermal deposits in form of hot geothermal fluid is a sign of a good site. The site should have a shallow aquifer to allow injection of water. The inherent geothermal product should be about 300 °F.

4.7.1 Geothermal Resources

Basic kinds of geothermal sources are as follow

- Hydrothermal
- Geopressured
- Hot dry rock
- Magma resources
- Volcanoes.

4.7.2 Direct use of Geothermal Energy

- Hot springs for bathing.
- Cooking food.
- Heating swimming pools and baths or therapeutic use.
- Space heating and cooling.
- Agriculture (mainly greenhouse heating, crop drying, and some animal husbandry).
- Aquaculture (heating mainly fish ponds and raceways).
- Providing heat for industrial processes and heat pumps (for both heating and cooling).

4.7.3 Working Principle of Direct Usage

- Direct sources function by sending water down a well to be heated by the earth's warmth.
- Then a heat pump is used to take the heat from the underground water to the substance that heats the house.
- Then the cold water is injected back into the earth.

4.8 Power Generation from Geothermal Energy

4.8.1 Dry Steam Geothermal Power Plant

The Geysers dry steam power plant in Northern California, depend on high temperature steam formations to directly provide the energy to drive power generator turbines. This type of formation is called a "**dry steam**" power plant because the steam is released from the pressure of a deep reservoir, through a rock catcher, and then past the power generator turbines.

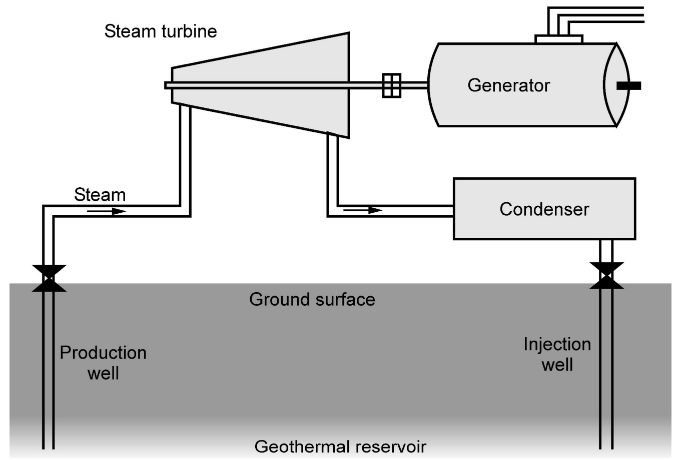


Fig. 4.8.1 : Dry steam system

Dry steam reservoirs use the water in the earth's crust, which is heated by the mantle and released through vents in the form of steam. The dry steam power plant is suitable where the geothermal steam is not mixed with water. Production wells are drilled down to the aquifer and the superheated, pressurised steam (180°- 350 °C) is brought to the surface at high speeds, and passed through a steam turbine to generate electricity. In simple power plants, the low pressure steam output from the turbine is vented to the atmosphere, but more commonly, the steam is passed through a condenser to convert it to water. This improves the efficiency of the turbine and avoids the environmental problems caused from the direct release of steam into the atmosphere. The waste water is then reinjected into the ground with reinjection wells. The underground water reservoirs that feed such a system are refilled when rain falls on the land. The rainwater eventually soaks back into the crust of the earth. Because this occurs on a continuous basis, geothermal energy is considered a renewable resource. This is the oldest type of geothermal power plant. It was first used at Lardarello in Italy where it has powered electric railroads since 1904. About 6 percent of the energy used in northern California is produced at 28 dry steam reservoir plants found at The Geysers dry steam fields in northern California. At peak production, these dry steam geothermal power plants are the world's largest single source of geothermal power producing up to 2,000 megawatts of electricity an hour. That is about twice the amount of electricity a large nuclear power plant can produce. These dry steam power plants emit only excess steam and very minor amounts of gases.

4.8.2 Liquid-Dominated Geothermal Power Plant

In the liquid dominated reservoir, the water temperature is above the normal boiling point 100 °C. However, it does not boil but it remains in liquid state because the water in the reservoir is under pressure. When the water comes to the surface, the pressure is reduced, then rapid boiling occurs and the liquid water flashes into a mixture of hot water steam. The steam can be separated and used to generate electric power or to provide space and process heat or it may be distilled to yield the purified water. There are two important methods of liquid-dominated systems as follows,

- Flash- steam system
- Binary- cycle system.

4.8.2.1 Flash-steam System

Flash steam power plants force water down into an injection well by a groundwater pump. The well must be sunk deep enough to reach subterranean rocks at a temperature higher than the boiling point of water. The water filters through the rocks where it becomes heated and rises back up through the nearby production well. The hot water from the production well enters a flash tank where the reduced pressure causes the water to boil rapidly or "flash" into vapour. Water that remains liquid in the flash tank is returned to the groundwater pump to be forced down into the earth again.

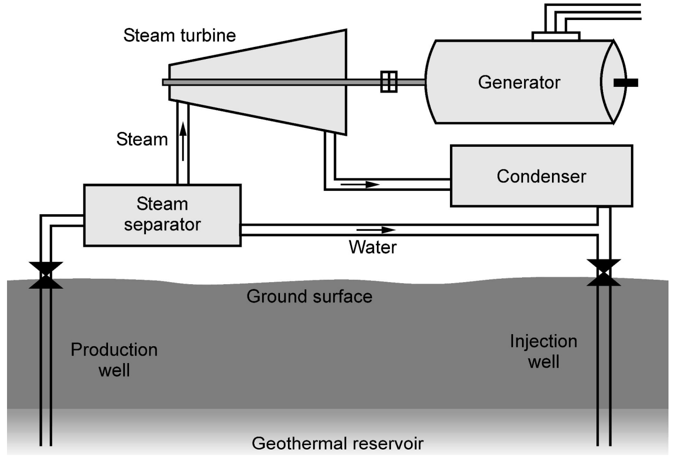


Fig. 4.8.2 : Flash steam system

The vapour from the flash tank drives a steam turbine, which turns the shaft of an electric generator. After passing through the turbine, the steam is cooled in a condenser. This returns the water vapour to the liquid state, and this liquid is forced by the groundwater pump back down into the earth along with the diverted water from the flash tank. Some of the condensed vapour can be used for drinking and irrigation because it is, in effect, distilled. The flash tank must be periodically flushed and cleaned to get rid of mineral build up. If the water from the production well has high mineral content, the flushing must be done more freqently. Flash steam stations pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines. They require fluid temperatures of atleast 180 °C, usually more. This is the most common type of station in operation today. Flash steam plants use geothermal reservoirs of water with temperatures greater than 360 °F (182 °C). The hot water flows up through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Any leftover water and condensed steam may be injected back into the reservoir, making this a potentially sustainable resource.

4.8.2.2 Binary Cycle System

Binary cycle power plants use a two-step process to extract power from geothermal water that is not hot enough produce steam to spin a turbine by itself. The water from the geothermal reservoir never comes into direct contact with the blades of the turbine generator and it uses water-based geothermal resources of approximately 200 to 360 °F. In the binary cycle system, warm geothermal water is pumped to the surface and passed through a heat exchanger that contains a fluid such as a butane or pentane hydrocarbon with a much lower boiling point than water. The heat from the geothermal water causes this secondary or 'binary' fluid to flash into vapour. The vapour created by heating the pentane spins the turbine powering the generator, while the cooled steam from the geothermal source is injected back into the formation where it heats up again and is available to eventually re-circulate through the heat exchanger. That is why geothermal is considered a renewable resource, as a properly managed formation can potentially produce power indefinitely.

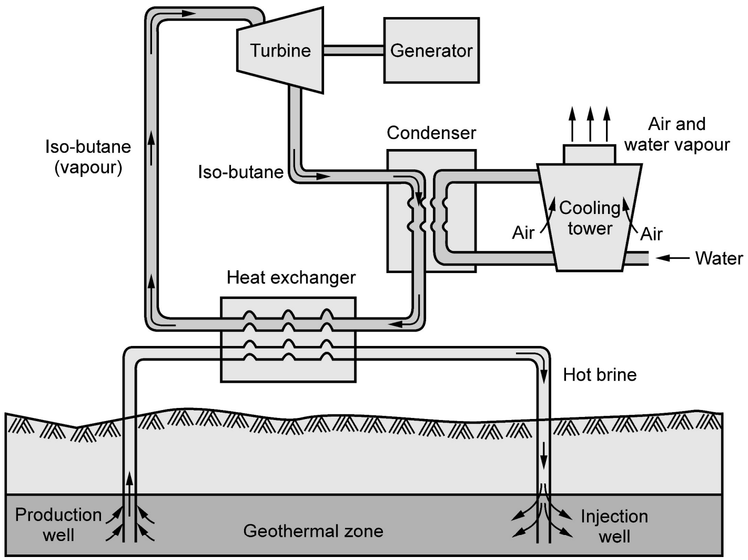


Fig. 4.8.3 : Binary cycle geothermal power system

The vapour created by heating the pentane drives the turbine on the power generator, while the cooled steam from the geothermal source is injected back into the formation where it heats up again and is available to eventually re-circulate through the heat exchanger. That is why geothermal is considered a renewable resource, as a properly managed formation can potentially produce power indefinitely.

Moderate-temperature geothermal water is much more common than high-temperature water and many areas have been identified as having geothermal reservoirs with water that is below 400 °F (204 °C). The US department of energy predicts that most geothermal power plants built in the future will be binary cycle power plants that can take advantage of this slightly cooler water.

4.9 Classifications of Water Turbine

Water turbines/hydraulic turbines are rotary prime movers which convert the potential or kinetic energy of water into mechanical energy in the form of rotational energy. A water turbine when coupled with an electrical generator produces electrical energy. It is one of the most suitable means of electric power generation system. It is estimated that about 20 % of the total electric power in the world comes from hydro power plants. The only limitation is that it can be operated through the turbine, if there is a continuous flow of water. In the areas which are surrounded by hills and mountains known as catchment area, water turbine systems can be installed. The small rivers form a big river to flow. By constructing a machinery dam across flowing rivers, a water reservoir can be formed. The water is carried from the reservoir to water turbine by a long pipe known as penstock and the hydraulic energy possessed by water is converted into mechanical energy and then to electrical energy. Depending upon the head of water and available discharge, different types of water turbines are classified.

They are basically of two types :

- Impulse turbine and
- Reaction turbine.

4.9.1 Impulse Turbine

In an impulse turbine, the total potential energy available with water is fully converted into kinetic energy by means of nozzle. The turbine is quite suitable for high head and low discharge available with it.

In this type of turbine, there is a water nozzle which converts the total potential energy available with water into kinetic energy. Water is discharged from the nozzle in the form of water jet and high kinetic energy. The high kinetic energy jet is made to strike, on a series of curved buckets or blades mounted on the periphery of a wheel which is placed on the turbine shaft. This is the type of impulse turbine which requires high head and less water availability. Pelton wheel is one of the most commonly used impulse turbines.

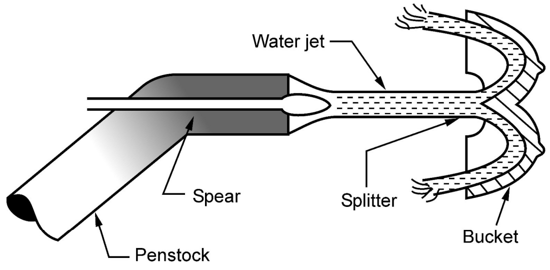


Fig. 4.9.1 : Discharge of water from the nozzle

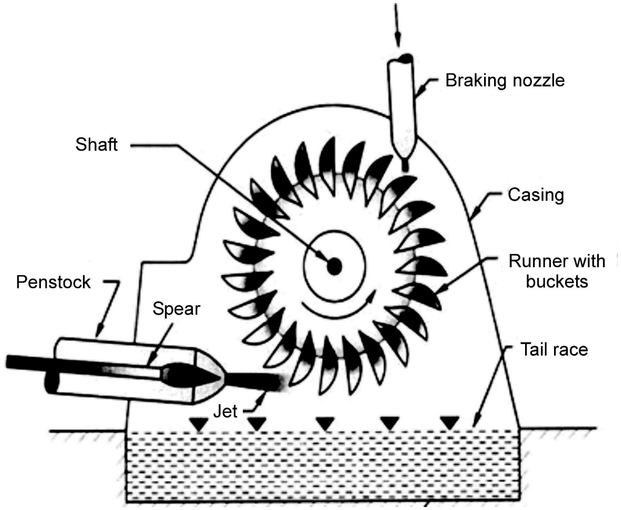


Fig. 4.9.2 : Pelton turbine with single jet

It shows the installation of Pelton wheel. The wheel, so called runner, consists of a circular wheel mounted with large number of buckets or blades fixed on the periphery. The buckets which are used are known as **double hemispherical buckets .** The buckets are made of cast iron, bronze, or stainless steel. The flow of water through nozzle is controlled by the to-and-fro movement of spear.

The impulsive force, which acts tangentially, imparted on a series of buckets one after the another is made to rotate the runner in the direction of water jet impingement. The entire combination is put inside a casing to prevent the scattering of water. The pressure energy is fully converted to kinetic energy through nozzle. The high velocity of jet gives impingement over the bucket. The impulsive force given by the jet rotates the wheel. The pressure inside casing remains atmospheric.

4.9.2 Reaction Turbine

Reaction turbine is quite suitable for low head and high discharge. The water supplied to the reaction turbine possesses both pressure as well as kinetic energy. The total pressure energy is not fully converted to kinetic energy initially, as it happens in impulse turbine. The water flows first of all to guide blades which supply water in a proper direction and then it is passed through moving blades which are mounted on the wheel. A part of the pressure energy of water, when flowing through the moving blades, is converted into kinetic energy which is absorbed by the turbine wheel. The water leaving the moving blades is at low pressure. Thus, there is a difference in pressure between the entrance and exit of the moving blades. Due to this difference in pressure, there is an increase in kinetic energy and hence a reaction is developed in opposite direction which acts on the moving blades. The rotation of the wheel is set up in opposite direction. In case of reaction turbine, the water is discharged at the tail race through draft tube.

4.9.2.1 Francis Turbine

Francis turbine is also called medium head turbine. In this turbine, water flows radially and finally discharges axially. Hence, this turbine is also called **mixed flow** turbine. It consists of a spiral casing inside which there are large numbers of stationary guide blades/guide vanes. They are fixed all around the circumference of an inner ring of moving vanes called **runner** (Fig. 4.9.3). The runner is fixed on the turbine shaft.

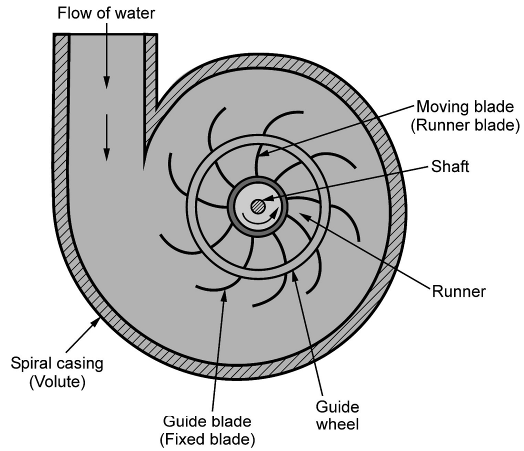


Fig. 4.9.3 : Francis turbine component

The runner consists of a series of curved blades numbering 16-24. The runner vanes are so well-designed in shape that water enters the runner radially and leaves the runner axially. Water with pressure energy enters through the passage into the casing radially through the guide vanes. It flows from the outer periphery of the runner in the radial direction over the moving vanes and finally it is discharged at the center axially at low pressure.

The kinetic energy is imparted to the runner when it flows over the moving vanes which produce rotation to the shaft. Water is then discharged at lower pressure through a diverging conical tube known as **draft tube,** which is fitted at the center of the runner.

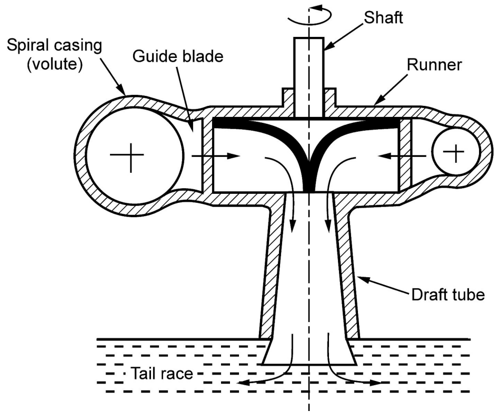


Fig. 4.9.4 : Francis turbine installation

The draft tube converts kinetic energy into pressure energy and hence the pressure available at the exit of draft tube is the atmospheric pressure. The other end of the tube is immersed in water known as tail race.

4.9.2.2 Kaplan Turbine

Kaplan turbine is also called as **low head reaction** turbine which is suitable for comparatively low discharge and is known as axial flow reaction turbine. It is similar to Francis turbine. It consists of a spiral casing in which there are large numbers of stationery guide vanes. They are fixed all around the circumference of an inner ring of moving vanes called **runner.** High-pressure water enters the turbine casing and enters into the guide vanes. The water strikes the runner and flows axially through guide vanes and imparts kinetic energy to the runner which produces rotation. The water is then discharged at the center of the runner in axial direction into the draft tube. The outlet of the draft tube is immersed in water. The construction of Kaplan turbine is just similar to Francis turbine except the shape of runner. The runner of Kaplan turbine runner has only 3, 4, or 6 blades, either fixed or adjustable on hub. The latter is known as **propeller turbine.**

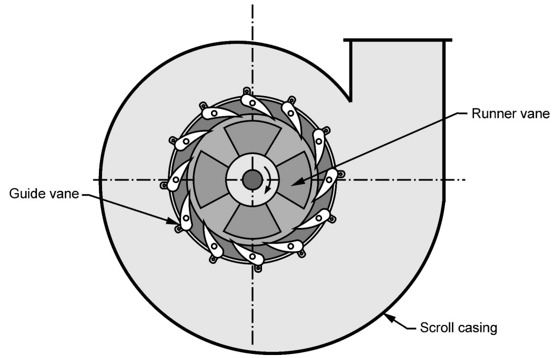


Fig. 4.9.5 : Components of Kaplan turbine

4.10 Essential Components of Hydroelectric Systems

A hydroelectric plant consists of a reservoir for storage of water, a diversion dam, an intake structure for controlling and regulating the flow of water, a conduit system to carry the water from the intake to the waterwheel, the turbines coupled with generators, the draft tube for conveying water from waterwheel to the tailrace, the tailrace and a power house i.e., the building to contain the turbines, generators, the accessories and other miscellaneous items. The size, location, and type of each of these essential elements depend upon the topography and geological conditions and the amount of water to be used. The height to which the dam may be built is usually limited by the extent of flowage damage. Pondage may have great value, particularly for peak load power plants, warranting the purchase of extensive flowage rights. The spillway section of the dam must be long enough to pass safely the maximum amount of water to be expected. Likewise the abutments and other short structures must be built to withstand successfully the greatest freshet conceivable on the river.

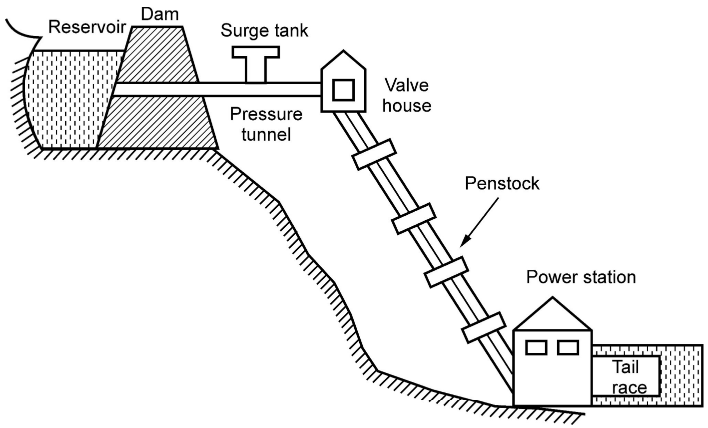


Fig. 4.10.1 : Components of hydro electric system

Storage Reservoir :

It is the basic requirement of a hydroelectric plant. Its purpose is to store water during excess flow periods (i.e., rainy season) and supply the same during lean flow periods (i.e., dry season) and thus it helps in supplying water to the turbines according to the load on the power plant.

A reservoir can be either natural or artificial. A natural reservoir is a lake in high mountains and an artificial reservoir is made by constructing a dam across the river. Low head plants require very large storage reservoir. The capacity of reservoir depends on the difference between runoffs during high and lean flows.

Dam :

The function of dam is not only to raise the water surface of the stream to create an artificial head but also to provide the pondage, storage or the facility of diversion into conduits. A dam is the most expensive and important part of a hydro-project. Dams are built of concrete or stone masonry, earth or rock fill.

The type and arrangement depends upon the topography of the site. A masonry dam may be built in a narrow canyon. An earth dam may be best suited for a wide valley. The choice of dam also depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards.

Forebay :

The forebay serves as a regulating reservoir storing water temporarily during light load period and pro-viding the same for initial increase on account of increasing load during which water in the canal is being accelerated. In short, a forebay may be considered as an enlarged body of water just above the intake to store water temporarily to meet the hourly load fluctuations. This may either be a pond behind the diversion dam or an enlarged section of a canal spread out to accommodate the required widths of intake.

Where the hydroelectric plants are located just at the base of the dam, no forebay is required because the reservoir itself serves the purpose of the forebay. However, where the plants are situated away from the storage reservoir a forebay is provided.

Spillway :

This is constructed to act as a safety valve. It discharges the overflow water to the down-stream side when the reservoir is full, a condition mainly arising during flood periods. These are generally constructed of concrete and provided with water discharge opening shut off by metal control gates. By changing the degree to which the gates are opened, the discharge of the head water to the tailrace can be regulated inorder to maintain the water level in the reservoir.

Intake :

The intake includes the head-works which are the structures at the intake of conduits, tunnels, or flumes. These structures include booms, screens or trash racks, sluices to divert and prevent entry of debris and ice into the turbines. Booms prevent the ice and floating logs from going into the intake by diverting them to a bypass chute. Screens or trash racks are fitted directly at the intake to prevent the debris from going into the lake. Debris cleaning devices should also be fitted on the trash racks. Intake structures can be classified into high pressure intakes used in case of large storage reservoirs and low pressure intakes used in case of small ponds provided for storing small amount of water for daily or weekly load variations.

Surge Tank :

A reduction in load on the generator causes the governor to close the turbine gates and thus create an increased pressure in the penstock. This may result in water hammer phenomenon and may need pipe of extraordinary strength to withstand it otherwise the penstock may burst. To avoid this positive water hammer pressure, some means are required to be provided for taking the rejected flow. This may be accomplished by providing a small storage reservoir or tank (open at the top) for receiving the rejected flow and thus relieving the conduit pipe of excessive water hammer pressure. This storage reservoir, called the surge tank is usually located as close to the power station as possible, preferably on ground to reduce the height of the tower.

A decrease in load demand causes a rise in water level in the surge tank. This produces a retarding head and reduces the velocity of water in the penstock. The reduction in flow velocity to the desired level makes the water in the tank to fall and rise until damped out by friction. Increase in load on the plant causes the governor to open the turbine gates inorder to allow more water to flow through the penstock to supply the increased load and there is a tendency to cause a vacuum or a negative pressure in the penstock. This negative pressure in the penstock provides the necessary accelerating force and is objectionable for very long conduits due to difficult turbine regulation. Again under such conditions, the additional water flows out of the surge tank. As a result the water level in the surge tank falls, an accelerating head is created and flow of water in the penstock is increased. Thus surge tank helps in stabilising the velocity and pressure in the penstock and reduces water hammer and negative pressure or vacuum.

Though by providing a relief valve at the turbine inlet rejected flow can be dealt in a better manner, but it cannot provide excess water required by the turbine when the load demand increases. Open conduits leading water to the turbine require no protection but when closed conduits are employed, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, close conduits are always provided with a surge tank. A forebay also serves the function of a surge tank. The ideal location of a surge tank is at the turbine inlet but in the case of medium and high head power plants, the height of the surge tank will become excessive. Because of this reason, the surge tanks are usually provided at the junction of the pressure tunnel and the penstock. Several designs of surge tanks have been adopted in hydroelectric power plants, the important considerations, being the amount of water to be stored, the magnitude of pressure to be relieved of and the availability of space at the construction site. Surge tanks may be simple surge tank, restricted orifice surge tank or differential surge tank. Simple surge tank is very sluggish in action and needs the largest volume. So this is the most expensive and is seldom used, except in special cases.

The restricted orifice surge tank is more efficient and economical than the first one, but its main drawback is that the desirable sudden creation of accelerating and retarding heads in the conduits also results in correspondingly sudden fluctuations of head on the turbine, which the governors may have difficulty to accommodate. Differential surge tank is the compromise between the simple surge tank and the restricted orifice surge tank.

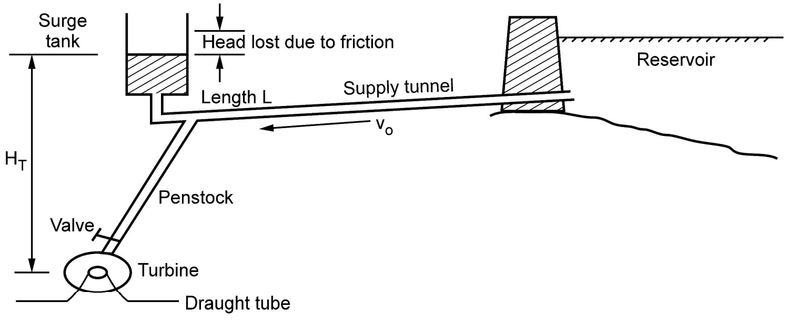


Fig. 4.10.2 : Surge tank

Penstock :

It is a closed conduit which connects the forebay or surge tank to the scroll case of the turbine. In case of medium head power plants each unit is usually provided with its own penstock. In case of high head plants, a single penstock is frequently used, and branch connections are provided at the lower end to supply two or more units. Penstocks are built of steel or reinforced concrete. Steel penstocks are almost always welded on the longitudinal seam. The circumferential seam may be welded also. In long penstocks great care must be taken to protect the conduit against water hammer. The thickness must be adequate to withstand both the normal hydrostatic pressure and also the sudden surges both above and below normal caused by fluctuations in load and by emergency conditions.

Valves and Gates :

In low head plants gates at the entrance to the turbine casing are usually all that is needed to shut off the flow. Individual hoist-operated gates are provided in cases where frequent shutdowns may be called for and where the time available for inspection is limited. Other plants employ stop gates or stop logs which are placed in sections by means of travelling crane. For installations employing medium or longer length penstocks or employing a common penstock for more than one unit, it is necessary to install valves at or near the entrance to the turbine casing. These are usually of the butterfly or pivot type for low and medium heads.

Trash Racks :

These are built up from long, flat bars set vertically or nearly so and spaced in accordance with the minimum width of water passage through the turbine. The clear space between the bars varies from 25 mm or 40 mm to 150 or 200 mm on very large installations. These are to prevent the ingress of floating and other material to the turbine. In some cases where large diameter turbines are employed, the racks are omitted, but provision is usually made for skimmer walls or booms to prevent ice and other material from entering the unit.

Tailrace :

The water after having done its useful work in the turbine is discharged to the tailrace which may lead it to the same stream or to another one. The design and size of tailrace should be such that water has a free exit and the jet of water, after it leaves the turbine, has unimpeded passage.

Draft Tubes :

An airtight pipe of suitable diameter attached to the runner outlet and conducting water down from the wheel and discharging it under the surface of the water in the tailrace is known as **draft tube.**

If there is no draft tube and the water discharges freely from the turbine exit, then the turbine operates under a head equal to the height of the headrace water level above the runner exit. By installing draft tube, the operating head is increased by an amount equal to the height of the runner outlet above the tailrace. This creates a negative pressure head at the runner exit. This makes it possible to install the turbine above the tailrace without loss of head. By installing the draft tube and increasing its section from runner exit to the tailrace, some of the kinetic energy possessed by the water leaving the runner outlet is converted into pressure energy and the water leaves at the tailrace at a much reduced velocity. This results again in the kinetic head which increases the negative pressure at the runner exit. This in turn increases the operating head on the turbine increasing its output and efficiency. The height and type of tube used depends upon two factors. The pressure at the turbine exit or inlet of the draft tube should not be less than one-third of the atmospheric pressure. This is essential to avoid cavitation. Also to maintain continuity of flow without vaporisation, the pressure at any point in the tube should not fall below the vapour pressure of water. Further, to avoid separation of flow, the included angle should not exceed 10°.

Various types of draft tubes are shown in Fig. 4.10.3. The straight conical type draft tube, shown in Fig. 4.10.3 (a), has an efficiency of about 90 % and is employed for low specific speed, vertical shaft Francis turbine. Vertical bell shaped draft tube is shown in Fig. 4.10.3 (b). Where there is a little head room avail-able, the bent draft tubes, shown in Fig. 4.10.3 (c) and Fig. 4.10.3 (d) are used. In Fig. 4.10.3 (d), the horizontal portion of the

tube is gradually bent upwards to lead the water gradually to the tailrace and to prevent entry of air from the outlet end. The exit end of the tube must always be immersed in water.

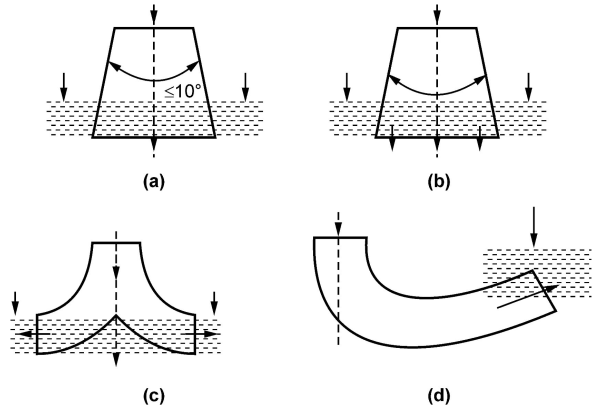


Fig. 4.10.3 : Draft tubes

Prime Movers or Water Turbines :

In hydroelectric power plants, water turbines are used as prime movers and their function is to convert the kinetic energy of water into mechanical energy which is further utilised to drive the alternators generating electrical energy.

4.11 Classification of Hydropower Schemes

The hydroelectric power plants may be classified according to :

- Classification according to the extent of water flow regulation available.
- Classification according to availability of water head.
- Classification according to type of load supplied.
- Classification of hydroelectric power plants based on installed capacity.

Classification according to the extent of water flow regulation available :

According to the extent of water flow regulation available the hydroelectric power plants may be classified into :

- Run-off river power plants without pondage.
- Run-off river power plants with pondage.
- Reservoir power plants.

Run-Off Power Plants without Pondage :

Some hydro power plants are so located that the water is taken from the river directly, and no pondage or storage is possible. Such plants are called the **run-off river power plants** without pondage. Such plants can use water only as and when available; these cannot be used at any time at will or fit any desired portion of the load curve. In such plants there is no control on flow of water.

During high flow and low load periods, water is wasted and during the lean flow periods the plant capacity is very low. As such these plants have a very little firm capacity. At such places, the water is mainly used for irrigation or navigation and power generation is only incidental. Such plants can be built at a considerably low cost but the head available and the amount of power generated are usually very low.

During floods, the tail water level may become excessive rendering the plant inoperative. The main objective of such plants is to use whatever flow is available for generation of energy and thus save coal that otherwise be necessary for the steam plants. During the high flow periods such plants can be employed to supply a substantial portion of base load.

Run-Off River Power Plants with Pondage :

The usefulness of run-off river power plants is increased by pondage. Pondage refers to storage at the plant which makes it possible to cope, hour to hour, with fluctuations of load throughout a week or some longer period depending on the size of pondage. With enough pondage, the firm capacity of the power plant is increased. Such type of power plants can be used on parts of the load curve as required, within certain limitations and is more useful than a plant without pondage. Such power plants are comparatively more reliable and its generating capacity is less dependent on available rate of flow of water. Such power plants can serve as base load or peak load power plants depending on the flow of stream.

During high flow periods these plants may be used as base load and during lean flow periods these plants may be used to supply peak loads only. When providing pondage, tailrace condition should be such that floods do not raise the tailrace water level, thus reducing the head on the plant and impairing its effectiveness. Such plants offer maximum conservation of coal when operated in conjunction with steam power plants.

Reservoir Power Plants :

When water is stored in a big reservoir behind a dam, it is possible to control the flow of water and use it most effectively. Storage increases the firm capacity of the plant and it

can be used efficiently through-out the year. Such a plant can be used as a base load or as a peak load plant as per requirement. It can also be used on any portion of the load curve in a grid system. Most of the hydroelectric power plants everywhere in the world are of this type.

Classification According to Availability of Water Head :

According to availability of water head the hydroelectric power plants may be classified into :

- Low head
- Medium head and
- High head power plants.

Though there is no definite line of demarcation for low, medium and high heads but the head below 30 metres is considered low head, the head above 30 metres and below 300 metres is considered as medium head and above 300 metres is considered as high head.

Low Head Hydroelectric Power Plants :

A typical low head installation on a river consists essentially of a dam across the stream to back up the river and create a fall, the water flowing through the turbines and remerging the river below the dam. A dam or barrage constructed across the river creates the necessary head. The power plant is located near the dam and therefore, no surge tank is required. Either one half of the barrage has regulating gates for discharge of surplus water while the plant is in front of second half or the plant is constructed by the side of the river.

In low head power plants Francis, propeller or Kaplan turbines are employed. Since for given output, large quantity of water is required, head being low, therefore pipes of large diameter and short length are required in low head plants. Structure of such plants is extensive and expensive. Generators employed in such plants are of low speed and large diameter.

Medium Head Hydroelectric Power Plants :

In these power plants, the river water is usually tapped off to a forebay on one bank of the river as in case of a low head plant. From the forebay the water is led to the turbines through penstocks. The forebay provided at the beginning of penstock serves as a water reservoir for such power plants.

In these plants, water is usually carried in open channel from main reservoir to the forebay and then to the turbines through the penstock. The forebay itself serves as the surge tank in this case. In these plants horizontal shaft Francis, propeller or Kaplan turbines are used.

High Head Hydroelectric Power Plants :

If high head is available, a site may be chosen, where a stream descending a steep lateral valley can be dammed and a reservoir for storage of water is formed. A pressure tunnel is constructed between reservoirs to valve house at the start of penstock to carry water from reservoir to valve house.

Surge tank (a tank open from the top) is built just before the valve house so that the severity of water hammer effect on penstock can be reduced in case of sudden closing of fixed gates of the water turbine. Surge tank also serves as a ready reservoir from which the turbine can draw water temporarily when there is sudden increase in demand.

The valve house consists of main sluice valves and automatic isolating valves, which operate on bursting of penstock and cut off further supply of water to penstock. Penstocks are pipes and carry the water from the valve house to the turbines. For heads above 500 m Pelton wheels are used while for lower heads Francis turbines are employed. The generators used are of high speed and small diameter. Penstocks are of large length and comparatively smaller cross section.

Classification According to Type of Load Supplied :

According to the load supplied hydroelectric power stations may be classified into :

- Base load
- Peak load
- Pumped storage plants for the peak load.

Base Load Plants :

The plants, which can take up load on the base portion of the load curve of the power system, are called the base load power plants. Such plants are usually of large capacity. Since such plants are kept running practically on block load (i.e., the load that is practically constant), load factor of such plants is therefore high. Run-off river plants without pondage and reservoir plants are used as base load plants. Plants having large storage can best be used as base load plants and particularly in rainy seasons, when the water level of the reservoir will be raised by rain water. For a plant to be used as base load plant, the unit cost of energy generated by the plant should be low.

Peak Load Plants :

Plants used to supply the peak load of the system corresponding to the load at the top portion of the load curve are called the peak load plants. Runoff river plants with pondage can be employed as peak load plants. If the pondage is enough, a large portion of the load can be supplied by such a plant if and when required. Reservoir plants can of course be used as peak load plants also. Peak load plants have large seasonal storage. They store water during off-peak periods and are operated during peak load periods. Load factor of such plants is low.

Classification of Hydroelectric Power Plants Based on Installed Capacity :

Apart from above classification, hydroelectric power plants can be classified, on the basis of installed capacity, as large, medium, small, mini, and micro hydro power plants. Generally the mini, micro, and pico hydro come under the subcategory of small hydro plants.

4.12 Two Marks Questions with Answers

Part - A

Q.1 What is meant by biomass energy and biomass energy resource ?

Ans. : Organic matters derived from biological organisms are called **biomass.** The energy obtained from biomass is called biomass energy. The raw organic matter obtained from nature for extracting secondary energy is called biomass energy resource.

Q.2 Classify the biomass resources.

Ans. : Biomass resources are broadly classified into two categories :

- Biomass from cultivated fields, crop and forest.
- Biomass derived from waste e.g., municipal waste, animal excreta/dung, forest waste, agricultural waste, bioprocess waste, butcharry waste, fishery waste/processing waste etc.,

Q.3 What do you mean by fossil fuels ?

Ans. : Fossil fuels (coal, petroleum oil and natural gases) are produced from dead, buried biomass under pressure and in absence of air during several millions of years. However; they are considered separately as fossils and are not included in the category of biomass.

Q.4 What are the categories of scope of biomass energy ?

Ans. : The scope of biomass energy is of three categories. They are,

- Rural application of biomass energy
- Urban and industrial applications of biomass energy
- Biomass as a primary source for large scale electrical power generation.

Q.5 List the secondary energy forms of biomass.

Ans. : The biomass can be converted to useful secondary energy forms such as,

- Heat
- Gaseous fuels
- Solid fuels
- Organic chemical
- Liquid fuels.

Q.6 Point out the cultivated biomass.

Ans. : The cultivated biomass (biomass from energy farms) includes :

- Sugar cane crops, sweet sorghum crops, sugar beets.
- Herbaceous crops which are non-woody plants which can be converted into biogas or biochemical fuels.
- Cereals, potatoes and other carbohydrate fruit crops, etc. grown for producing in feeds to the fermentation plants.
- Forests crops of fast growing energy intensive trees specially grown as source of energy.
- Aquatic crops grown in fresh water, sea water, muddy water etc., and these crops include submerged plants, surface plants and include seaweeds, marine algae, water hyacinth, floating kelp etc. algae is considered to be a promising aquatic biomass.

Q.7 List out the biomass energy resources from waste.

Ans. : The waste to energy processes convert organic wastes to intermediate or secondary energy forms such as heat, biogas, alcohol, fuels, chemicals, etc. The waste is classified as urban (municipal) waste industrial organic waste, process waste agricultural farm waste rural animal waste forest waste fishery, poultry, butcharry waste Animal and human excreta

Q.8 What is meant by biogas plant ?

Ans. : The plant which converts biomass to biogas (methane plus carbon dioxide) by the process of anaerobic digestion is generally called a biogas plant.

Q.9 Mention advantages of biomass energy.

Ans. : It is a renewable source. The energy storage is an in-built feature of it. It is an indigenous source requiring little or no foreign exchange. The forestry and agricultural industries that supply feed stocks also provide substantial economic development opportunities in rural areas. The pollutant emissions from combustion of biomass are usually lower than those from fossil fuels.

Q.10 Mention disadvantages of biomass energy.

Ans. : It is a dispersed and land intensive source. It is often of low energy density. It is also labour intensive and the cost of collecting large quantities for commercial application is significant. Most current commercial large quantities for commercial application are 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. Capacity is determined by availability of biomass and not suitable for varying loads. Not feasible to set up at all locations.

Q.11 What is meant by biomass gasification ?

Ans. : The word gasification (or thermal gasification) implies converting solid fuel into a gaseous fuel by thermo chemical method without leaving any solid carbonaceous residue.

Q.12 Classify the biogas plant.

Ans. : The biogas plant are classified into

- Continuous and batch types
- The dome and drum types.

Q.13 List the factors affecting bio digestion or generation of gas.

Ans. : The factors affecting bio digestion or generation of gas are :

- pH or the hydrogen-ion concentration
- Temperature
- Total sold content of the feed material
- Loading rate
- Seeding
- Uniform feeding
- Nutrients
- Type of feed stocks
- Toxicity due end product

- Pressure
- Acid accumulation inside the digester.

Q.14 Why the biogases are mainly utilized ?

Ans. : Biogases are mainly utilized. The biogas can be utilized effectively for,

- Household cooking
- Lighting
- Operating small engines
- Utilizing power for pumping water
- Chaffing fodder
- Grinding flour.

Q.15 List the feature of continuous plant .

Ans. :

- It will produce gas continuously.
- It requires small digestion chambers.
- It needs lesser period for digestion.
- It has less problems compared to batch type and it is easier in operation.

Q.16 List the features of batch plant.

Ans. :

- The gas production in it is intermittent, depending upon the clearing of the digester.
- It needs several digesters or chambers for continuous gas production, these are fed alternatively.
- Batch plants are good for long fibrous materials.
- This plant needs addition of fermented slurry to start the digestion process.
- This plant is expensive and has problems comparatively; the continuous plant will have less problems and will be easy for operation.

Q.17 Write the advantages of floating drum plant.

Ans. :

- It has scum troubles because solids are constantly submerged.
- In it, the danger of mixing oxygen with the gas to form an explosive mixture is minimized.
- No problem of gas leakage.
- Constant gas pressure.

Q.18 Write the disadvantages of floating drum plant.

Ans. :

- It is costlier since cost is dependent on steel and cement.
- Heat is lost through the metal gas holder, hence it troubles in colder regions and periods
- Gas holder requires painting once or twice a year, depending on the humidity of the location.
- Flexible pipe joining the gas holder to the main gas pipe requires maintenance, as it is damaged by ultraviolet rays in the sun.
- It may be twisted also, with the rotation of the drum for mixing or scum removal.

Q.19 Mention some advantages of fixed dome type plant.

Ans. :

- It is cheaper as compared to floating drum type, as it uses only cement and no steel.
- It has no corrosion trouble.
- Heat insulation is better as construction is beneath the ground.
- Temperature will be constant.
- Cattle and human excreta and long fibrous stalks can be fed.
- No maintenance.

Q.20 Mention some disadvantages of fixed dome type plant.

Ans. :

- This type of plant needs the service of skilled masons, who are rather scarce in rural areas.
- Gas production per cubic meter of the digester volume is also less.
- Scum formation is a problem as no stirring arrangement.
- It has variable gas pressure.

Q.21 What are the techniques or methods of maintaining biogas production ?

Ans. : The methods for maintaining biogas production are,

- Insulating the gas plant
- Composting
- Hot water circulation
- Use of chemicals
- Solar energy systems.

Q.22 What is meant by cogeneration ?

Ans. : A procedure for generating electric power and useful heat in a single installation is known as **cogeneration.** Heat may be supplied in the form of steam, hot water or hot air. The net result is overall increase in the efficiency of fuel utilization.

Q.23 Mention the types and explain the cogeneration principles.

Ans. : Types of cogeneration principles are :

The Topping Cycle : Primary heat is used to generate high pressure and temperature steam for electrical energy generation. The discharged low grade heat, which would otherwise be dispersed to the environment, is utilized in an industrial process or in other ways.

The Bottoming Cycle : Primary heat at high temperature is used directly for industrial process requirements. The remaining low grade heat is then used for electrical power generation, e.g. high temperature cement kiln.

Q.24 What are the three general types of cogeneration systems ?

Ans. : The three general types of cogeneration principles systems are :

- Waste heat utilization,
  - Space heating and cooling
  - Warm water in agriculture
  - Warm water in aquaculture
- Total/Integrated energy system for residential complex
- Total Energy System (TES) for industry.

Q.25 What is meant by incineration ?

Ans. : Organic matter can be burnt in presence of oxygen/air to produce heat and byproducts. This is the well known process called **combustion.** Complete combustion to ashes is called **incineration.**

Q.26 What are the types of gasifiers ?

Ans. : In down draft gasifier fuel and air move in a cocurrent manner.

In update gasifier fuel and air move in a counter current manner. But the basic reaction zones remain the same.

Q.27 What are the types of biomass resources ?

Ans. :

- Forests
- Agricultural crops residues

- Energy crops
- Vegetable oil crops
- Aquatic crop
- Animal waste
- Urban waste
- Industrial waste.

Q.28 What is transesterification ?

Ans. : Process where the raw vegetable oils are treated with alcohol (Methanol or ethanol with a catalyst) to form methyl or ethyl esters.

Q.29 What are the advantages of bio-diesel as engine fuel ?

Ans. :

- Biodegradable produces 80 % less CO_2 and 100 % less SO_2 emissions
- Renewable
- Higher octane number
- It can be used as neat fuel or mixed in any ratio with petro diesel
- It has a higher flash point making it safe to transport.

Q.30 What are the components of cogeneration system ?

Ans. :

- Prime mover
- Generator
- Heat recovery
- Electrical interconnection.

Q.31 What are the types of prime movers ?

Ans. :

- Reciprocating engine
- Combustion of gas functions
- Steam turbines
- Micro turbines
- Fuel cells.

Q.32 Write any two benefits of cogeneration.

Ans. :

- Increased efficiency of energy conversion and use.
- Lower emission to the environment in particular of CO_2, the main greenhouse gas.
- Biomass fuels and some waste materials such as refinery gases, agricultural wastes are used. They serve as fuels for cogeneration schemes increases the cost effectiveness and reduces the need for waste disposal.

Q.33 What are the types of cogeneration system ?

Ans. :

- Steam turbine cogeneration system
- Gas turbine cogeneration system
- Reciprocating engine cogeneration system.

Q.34 What are the types of steam turbine ?

Ans. :

- Back pressure turbine
- Extraction condensing turbine.

Solved Questions

Part - B

Q.1 Describe in detail the construction and working of various types of bio-gas plants. State the merits and demerits of the biogas power plant. **(Refer section 4.3)**

Q.2 Write short notes on : a) Energy from industrial and municipal waste b) Applications of bio-energy. **(Refer section 4.4)**

Q.3 What is the principle involved in the production of biogas and what is the chemical composition of the gas ? What are the various applications of this gas ? Draw a sketch to illustrate the constructional features of a typical biogas plant and describe its operation. **(Refer section 4.5)**

Q.4 a) Compare the advantages and disadvantages of power generation from industrial wastes, municipal waste and agricultural wastes.

b) How do we get energy from various types of wastes ? **(Refer section 4.4)**

Q.5 a) Name the various model of biogas plant.

b) What are the main problems in straw fermentation ? **(Refer sections 4.3 and 4.6)**

Q.6 Sketch and describe any one type of bio-mass gas generation plant. Mention four uses of the biogas produced. **(Refer section 4.3)**

Q.7 How are biogas plant classified ? Explain continuous and batch type plants and compare them with regard to operation and efficiency. **(Refer sections 4.2 and 4.3)**

Q.8 Write short notes on a) Continuous type plant b) Flexible dome type plant. **(Refer section 4.3)**

Q.9 What is community biogas plant ? What is the main problem encountered with operation ? **(Refer section 4.2)**

Q.10 List out the various points to be carried out for selection of site for a biogas plant. **(Refer section 4.6)**

Q.11 Draw schematic diagram of biogas power plant and explain its operation. State and justify the potential of this in satisfying energy demand of our country. **(Refer sections 4.3 and 4.4)**

Q.12 Write briefly on power production from agricultural waste. Draw relevant sketches and point out the relative merits of this technique. **(Refer section 4.4)**

Q.13 What is biomass gasification ? Explain its classification with neat diagram. **(Refer section 4.4)**

Q.14 How ethanol is produced from biomass ? Explain its major classification. **(Refer section 4.4)**

Q.15 What is meant by cogeneration ? How they are classified ? Explain its principles. **(Refer section 4.5)**

Q.16 Explain the following cogeneration systems. a) Steam turbine b) Gas turbine. **(Refer section 4.9)**

Q.17 Explain the following cogeneration systems. a) Reciprocating IC Engine b) Combined cycle. **(Refer section 4.9)**

Q.18 Enumerate the application of the following. a) Cogeneration in utility sector b) Biomass. **(Refer sections 4.2 and 4.5)**

Q.19 Explain the theory of the origin of geothermal energy. Draw the layout of geothermal power plant and explain its operation. **(Refer sections 4.7)**

Q.20 a) Compare tidal power plant with geothermal power plant. b) With relevant diagram, explain the operation of tidal power plant. **(Refer sections 4.7 and 5.2)**

Q.21 Explain in detail any one type of geothermal power plant. Compare its efficiency with tidal power plant. **(Refer sections 4.7 and 5.1)**

Q.22 Draw the schematic and explain the vapour dominated geo thermal plant. **(Refer section 4.8)**

Q.23 Draw the layout of the micro-hydro scheme and explain its components. What are its advantages and disadvantages ? **(Refer section 4.10)**

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