UNIT V POWER PLANT

Introduction to Power Plant Engineering

The whole world is in the grip of energy crisis and the pollution manifesting itself in the spiraling cost of energy and uncomforted due to increase in pollution as well as the depletion of conventional energy resources and increasing curve of pollution elements. It is commonly accepted that the standard of living increases with increasing energy consumption per capita.

The government of India has laid down the policy "it is imperative that we carefully utilize our renewal (*i.e.,* non-decaying) resources of soil water, plant and animal live to sustain our economic development" our exploration or exploitation of these is reflected in soil erosion, salutation, floods and rapid destruction of our forest, floral and wild life resources. The depletion of these resources often tends to be irreversible since bulk of our population depends on these natural resources. Depletion of these natural resources such as fuel, fodder, and housing power plant;

A power plant is assembly of systems or subsystems to generate electricity, *i.e.*, power with economy and requirements. The power plant itself must be useful economically and environmental friendly to the society. The present book is oriented to conventional as well as non-conventional energy generation.

CLASSIFICATION OF POWER PLANTS



A power plant may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated. The type of prime move determines, the type of power plants. The major power plants, which are discussed in this book, are,

- 1. Steam power plant
- 2. Diesel power plant
- 3. Gas turbine power plant
- 4. Nuclear power plant
- 5. Hydro electric power plant

The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plants are called **THERMAL POWER PLANT**, because these convert heat into electric energy.

Sources of Energy

There are mainly two types of sources of energy

- 1. Conventional Sources of Energy (Non-Renewable Sources of Energy)
- 2. Non-conventional Sources of Energy (Renewable Sources of Energy).

CONVENTIONAL SOURCES OF ENERGY

These resources are finite and exhaustible. Once consumed, these sources cannot be replaced by others. Examples include coal, timber, petroleum, lignite, natural gas, fossil fuels, nuclear fuels etc.

The examples are (i) fossil fuel (ii) nuclear energy (iii) hydro energy

Have you not seen the filling of fuel in automobiles? What are the fuels that are being used in automobiles? What type of sources of energy are they? Are they non-conventional? Fossil fuel is an invaluable source of energy produced due to chemical changes taking place in the absence of oxygen, in plants and animals that have been buried deep in the earth's crust for many million years. Fossil fuels like coal, petroleum and natural gas are formed in this manner. These are conventional sources of energy. For example, energy from, Petroleum, natural gas, coal, nuclear energy, etc

NON-CONVENTIONAL SOURCES OF ENERGY

These sources are being continuously produced in nature and are not exhaustible.

Examples include wood, geothermal energy, wind energy, tidal energy, nuclear fusion, gobar gas, biomass, solar energy etc.

The examples are (*i*) Solar energy (*ii*) wind energy (*iii*) geothermal energy (*iv*) ocean energy such as tidal energy,

wave energy (v) biomass energy such as gobar gas.

It is evident that all energy resources based on fossil fuels has limitations in availability and will soon exhaust. Hence the long term option for energy supply lies only with non-conventional energy sources. These resources are in exhaustible for the next hundreds of thousands of years. The sources which are perennial and give energy continuously and which do not deplete with use are the Non conventional sources of energy. For example, energy from, solar energy, bio-energy, wind energy, geothermal energy, wave, tidal and OTEC.

STEAM TURBINE POWER PLANT

The conversion from coal to electricity takes place in three stages :

Stage 1

The first conversion of energy takes place in the boiler. Coal is burnt in the boiler furnace to produce heat. Carbon in the coal and Oxygen in the air combine to produce Carbon Dioxide (CO2) and heat.



Stage 2

The second stage is the thermodynamic process :

- a) The heat from combustion of the coal boils water in the boiler to produce steam. In modern power plant, boilers produce steam at a high pressure and temperature.
- b) The steam is then piped to a turbine.
- c) The high pressure steam impinges and expands across a number of sets of blades in the turbine.
- d) The impulse and the thrust created rotate the turbine.
- e) The steam is then condensed and pumped back into the boiler to repeat the cycle.

Stage 3

In the third stage, rotation of the turbine rotates the generator rotor to produce electricity based of Faraday's Principle on electromagnetic induction.

Gas Turbine Power Station

The schematic arrangement of a gas turbine power plant is shown in Figure 1.8. The main components of plants are :

- Compressor
- Regenerator
- Combustion Chamber
- Gas Turbine
- Alternator
- Starting motor



Compressor

The compressor used in the plant is generally of rotatory type. The air at atmospheric pressure is drawn by the compressor via the filter which removes the dust from the air. The rotatory blades of the compressor pushthe air between stationary blades to raise its pressure. Thus air at high pressure is available at the output of the compressor.

Regenerator

A regenerator is a device which recovers heat from the exhaust gases of the turbine. The exhaust is passed through the regenerator before wasting to atmosphere. A regenerator consists of a nest of tubes contained in a shell. The compressed air from the compressor passes through the tubes on its way to the combustion chamber. In this way compressor is heated by the hot exhaust gases. *Combustion Chamber*

The air at high pressure from the compressor is led to the combustion chamber via the regenerator. In the combustion chamber, heat is added to the air by burning oil. The oil is injected through the burner into the chamber at high pressure ensure atomisation of oil and its thorough mixing with air. The result is that the chamber attains a very high temperature. The combustion gases are suitably cooled and then delivered to gas turbine.

Gas Turbine

The products of combustion consisting of a mixture of gases at high temperature and pressure are passed to the gas turbine. These gases in passing over the turbine blades expand and thus do the mechanical work. The temperature of the exhaust gases from the turbine is about 900oF. *Alternator*

The gas turbine is coupled into the alternator. The alternator converts the mechanical energy of the turbine into electrical energy. The output of the alternator is given to the bus-bars through transformers, isolators and circuit breakers.

Starting Motor

Before starting the turbine, compressor has to be started. For this purpose, an electric motor is mounted on the same shaft as that of the turbine. The motor is energised by the batteries. Once the unit starts, a part of the mechanical power of the turbine drives the compressor and there is no need of the motor now.

Internal Combustion Engines Plant

It is a plant in which the prime mover is an internal combustion engine. An internal combustion engine has one or more cylinders in which the process of combustion takes place, converting energy released from the rapid burning of a fuel-air mixture into mechanical energy. Diesel or gasfired engines are the principal types used in electric plants. The plant is usually operated during periods of high demand for electricity.

NUCLEAR ENERGY

In a universe, energy and matter have a common origin.

None the energy nor the matter can be created or destroyed; instead they just change their state. As well, they are convertible to each other.

Albert Einstein was the first man who explained this relation by the well known formula :

E = mC2

This equation defines :

E (Energy) equals to m (mass) times C2 (C stands for speed of light).

By looking in close, we may find the enormous energy exist in a small piece of material.

The name of atom comes from Greek language, referring to smallest part of nature. Nowadays we have a better knowledge on atom structure, and we know a nucleus, surrounded by electrons, form the atoms. This structure is somehow similar to our solar system.

Nuclear Fission

Any try for splitting a part a nucleus will cause a tremendous energy be released. This energy would be released in both forms of heat and light. In a harnessed, controlled way of doing this, a useful energy for producing electricity is possible. Doing this at once would result to a big explosion, as seen in an automatic bomb.

In a nuclear power plant, uranium is the element used as fuel. Uranium is found in many parts of the world but in a low quantity. It is loaded in to the reactor in a tiny pallet form inside long rods.

Fission meaning splitting a part is what happens in a reactor. Here uranium atoms are split in a paced controlled chain of reactions.

Inside a reactor the intensity of crashes are harnessed by inserting-taking of control roads.

In an atomic bomb a different process occurs, by using almost pure pieces of elementsuranium 235 or plutonium, in a precise mass and shape, burning them together in a great force. As we see there is no requisite like this in a reactor.

Byproducts of such reactions are radioactive materials. If released, they would be gravely harmful. Knowing this, strong structures must keep the materials in the case of any accident.

The released heat energy would be used for boiling water in the core of reactor. So instead of burning fuel, we may use the heat of reactor core.

By sending the hot water around the nuclear to the heat exchanger section, water filled pipes produce steam needed for steam turbine.

Nuclear Fusion

In another form of nuclear reaction, joining of smaller nuclei makes a larger nucleus. Such a process in sun changes the hydrogen atoms to helium. The result heat and light we receive in earth.

In a more detailed explanation, two different types of atoms, deuterium and tritium, combine to make a helium plus and extra particle called neutron.

There has been a fierce competition among scientists, but to their frustration, they have yet trouble in controlling reaction in a closed space. The advantage of fusion is its abundance of supply (hydrogen) as well as its less radioactive material than fission.

HYDROELECTRIC

Man has utilised the power of water for years. Much of the growth of early colonial industry can be attributed to hydropower. Because fuel such as coal and wood were not readily available to inland cities, settlers were forced to turn to other alternatives. Falling water was ideal for powering sawmills and grist mills. As coal became a better-developed source of fuel, however, the importance of hydropower decreased.

Theory

Hydroelectric systems make use of the energy in running water to create electricity. In coal and natural gas systems, a fossil fuel is burned to heat water. The steam pressure from the boiling water turns propellers called turbines. These turbines spin coils of wire between magnets to produce electricity. Hydro powered systems also make use of turbines to generate electrical power; however, they do so by using the energy in moving water to spin the turbines.

Water has kinetic energy when it flows from higher elevations to lower elevations. The energy spins turbines like as shown in Figure.

In larger scale hydroelectric plants, large volumes of water are contained by dams near the generator and turbines. The "forebay" is a storage area for water that must be deep enough that the penstock is completely submerged. The water is allowed to flow into the electricity-generating system through a passage called the penstock. The controlled high-pressure water spins the turbines, allowing the generator to produce an electric current. The powerhouse contains and protects the equipment for generating electricity. The high-pressure water exits the system through a draft tube. The fish ladder attempts to minimise the environmental impact of hydroelectric systems by providing a path for migrating fish to take.



Types of Hydroelectric Power Plants Micro-Scale

As their name implies, micro-hydroelectric plants are the smallest type of hydroelectric energy systems. They generate between one kilowatt and one megawatt of power. The main application for these hydro systems is in small, isolated villages in developing countries. They are ideal for powering smaller services such as the operation of processing machines.

Small-Scale

Small hydropower systems can supply up to 20 megawatts of energy. These systems are relatively inexpensive and reliable. They have the potential to provide electricity to rural areas in developing countries throughout the world. Small systems are especially important to countries that may not be able to afford the costs of importing fossil fuels such as petroleum from other countries.

Run-of-the-River

In some areas of the world, the flow rate and elevation drops of the water are consistent enough that hydroelectric plants can be built directly in the river. The water passes through the plant without greatly changing the flow rate of the river. In many instances a dam is not required, and therefore the hydroelectric plant causes minimal environmental impact on its surroundings. However, one problem with run-of-the-river plants is the obstruction of fish and other aquatic animals. This and other problems are discussed in the next section.

Problems with Hydroelectric Power

Although hydroelectric power is admittedly one of the cleanest and most environmentallyfriendly sources of energy, it too has the capability to alter or damage its surroundings. Among the main problems that have been demonstrated by hydroelectric power is significant change in water quality. Because of the nature of hydroelectric systems, the water often takes on a higher temperature, loses oxygen content, experiences siltation, and gains in phosphorus and nitrogen content.

Another major problem is the obstruction of the river for aquatic life. Salmon, which migrate upstream to spawn every year, are especially impacted by hydroelectric dams. Fortunately, this problem has been dealt with by the production of fish ladders. These structures provide a pathway for fish to navigate past the hydroelectric dam construction.

Advantages and Disadvantages Advantages

- Inexhaustible fuel source
- Minimal environmental impact
- Viable source--relatively useful levels of energy production
- Can be used throughout the world

Disadvantages

- Smaller models depend on availability of fast flowing streams or rivers.
- Run-of-the-River plants can impact the mobility of fish and other river life

SOLAR

The name solar power is actually a little misleading. In fact, most of the energy known to man is derived in some way from the sun. When we burn wood or other fuels, it releases the stored energy of the sun. In fact, there would be no life on earth without the sun, which provides energy needed for the growth of plants, and indirectly, the existence of all animal life. The solar energy scientists are interested in energy obtained through the use of solar panels. Although the field of research dealing with this type of solar power is relatively new, one should bear in mind that man has known about the energy of the sun for thousands of years. **Theorv**

The energy of the sun can be used in many ways. When plants grow, they store the energy of the sun. Then, when we burn those plants, the energy is released in the form of heat. This is an example of indirect use of solar energy. The form we are interested in is directly converting the sun's rays into a usable energy source : electricity. This is accomplished through the use of "solar collectors", or, as they are more commonly known as, "solar panels".

There are two ways in which solar power can be converted to energy. The first, known as "solar thermal applications", involve using the energy of the sun to directly heat air or a liquid. The second, known as "photoelectric applications", involve the use of photovoltaic cells to convert solar energy directly to electricity.

There are two types of solar thermal collectors. The first, known as flat plate collectors, contain absorber plates that use solar radiation to heat a carrier fluid, either a liquid like oil or water, or air. Because these collectors can heat carrier fluids to around 80oC, they are suited for residential applications. The second type of solar collectors is known as concentrating collectors. These panels are intended for larger-scale applications such as air conditioning, where more heating potential is required. The rays of the sun from a relatively wide area are focused into a small area by means of reflective mirrors, and thus the heat energy is concentrated. This method

has the potential to heat liquids to a much higher temperature than flat plate collectors can alone. The heat from the concentrating collectors can be used to boil water. The steam can then be used to power turbines attached to generators and produce electricity, as in wind and hydroelectric power systems.

Photovoltaic cells depend on semiconductors such as silicon to directly convert solar energy to electricity. Because these types of cells are low-maintenance, they are best suited for remote applications.

Solar power has an exciting future ahead of it. Because solar power utilizes the sun's light, a ubiquitous resource (a resource that is everywhere), solar panels can be attached to moving objects, such as automobiles, and can even be used to power those objects. Solar powered cars are being experimented with more and more frequently now.

Problems with Solar Power

Solar power is actually one of the cleanest methods of energy production known. Because solar panels simply convert the energy of the sun into energy that mankind can use, there are no harmful byproducts or threats to the environment.

One major concern is the cost of solar power. Solar panels (accumulators) are not cheap; and because they are constructed from fragile materials (semiconductors, glass, etc.), they must constantly be maintained and often replaced.

Further, since each photovoltaic panel has only about 40% efficiency, single solar panels are not sufficient power producers. However, this problem has been offset by the gathering together of many large panels acting in accord to produce energy. Although this setup takes up much more space, it does generate much more power.

Advantages and Disadvantages

Advantages

- Inexhaustible fuel source.
- No pollution.
- Often an excellent supplement to other renewable sources.
- Versatile is used for powering items as diverse as solar cars and satellites.

Disadvantages

- Very diffuse source means low energy production large numbers of solar panels (and thus large land areas) are required to produce useful amounts of heat or electricity.
- Only areas of the world with lots of sunlight are suitable for solar power generation.

WIND

Mankind has made use of wind power since ancient times. Wind has powered boats and other sea craft for years. Further, the use of windmills to provide power for the accomplishment of agricultural tasks has contributed to the growth of civilization. This important renewable energy source is starting to be looked at again as a possible source of clean, cheap energy for years to come.

Theory

Differences in atmospheric pressure due to differences in temperature are the main cause of wind. Because warm air rises, when air fronts of different temperatures come in contact, the warmer air rises over the colder air, causing the wind to blow.

Wind generators take advantage of the power of wind. Long blades, or rotors, catch the wind and spin. Like in hydroelectric systems, the spinning movement is transformed into electrical energy by a generator.

The placement of wind systems is extremely important. In order for a wind-powered system to be effective, a relatively consistent wind-flow is required. Obstructions such as trees or hills can interfere with the rotors. Because of this, the rotors are usually placed atop towers to take advantage of the stronger winds available higher up. Furthermore, wind speed varies with temperature, season, and time of day. All these factors must be considered when choosing a site for a wind-powered generator.

Another important part of wind systems is the battery. Since wind does not always blow consistently, it is important that there be a backup system to provide energy. When the wind is especially strong, the generator can store extra energy in a battery.

There are certain minimal speeds at which the wind needs to blow. For small turbines it is 8 miles an hour. Large plants require speeds of 13 miles an hour.

Remote

Remote systems are small, relatively cheap sources of energy. They are best suited for rural environments because they can be left unattended for long periods of time. Further, they can operate under harsh conditions, and thus have potential for powering extremely remote regions **Hybrid**

The very nature of wind-powered generators makes them ideal to use in conjunction with other sources of energy. Wind and solar generators have been extremely successful as supplements to one another. The presence of the wind generator means that the other energy source does not have to be producing as much of the time.

Grid Connected

Grid Connected systems are already in wide use in areas that are already hooked up to a utility grid. Their main use is as a supplement to other forms of energy. This is important because average wind turbines only generate electricity about 25% of the time

Utilities

Because individual wind-powered systems by themselves do not produce a great deal of energy, so-called wind farms have been developed. These collections of many wind generators gathered in one place provide a source of relatively high energy output.

Advantages and Disadvantages

Advantages

- Inexhaustible fuel source.
- No pollution.
- Often an excellent supplement to other renewable sources.

Disadvantages

- Very diffuse source means low energy production large numbers of wind generators (and thus large land areas) are required to produce useful amounts of heat or electricity.
- Only areas of the world with lots of wind are suitable for wind power generation.
- Relatively expensive to maintain.

GEOTHERMAL

The center of the earth can reach **12000** degrees Fahrenheit. Just imagine if we could tap that heat for our own use. Well, geothermal systems do just that. Convection (heat) currents travel quite near the surface in some parts of the world.

Theory

The earth's crust is heated by the decay of radioactive elements. The heat is carried by magma or water beneath the earth's surface. Some of the heat reaches the surface and manifests itself in geysers and hot springs throughout the world.



Geothermal power can be used to directly heat buildings. Further, the pressurised steam from superheated water beneath the earth's surface can be used to power turbines and thus generate electricity.

Although geothermal power seems ideal in that it is naturally occurring and does not require structures to trap or collect the energy (as in solar panels or windmills), it does have limitations. The greatest drawback is that naturally occurring geothermal vents are not widely available. Artificial vents have been successfully drilled in the ground to reach the hot rocks below and then injected with water for the production of steam. However, oftentimes the source of heat is far too deep for this method to work well. Nor can geothermal power realistically generate enough electricity for the entire country or any large industrialised nation. A good-sized hot spring can power at most a moderate sized city of around 50,000 people. And there just isn't enough viable hot springs to power all the cities in any large country.

Advantages and Disadvantages

Advantages

- Theoretically inexhaustible energy source.
- No pollution.
- Often an excellent supplement to other renewable sources.
- Does not require structures such as solar panels or windmills to collect the energy can be directly used to heat or produce electricity (thus very cheap).

Disadvantages

- Not available in many locations.
- Not much power per vent

Tidal Energy

Tides are caused by the gravitational pull of the moon and sun, and the rotation of the earth. Near shore, water levels can vary up to 40 feet. Only a few locations have good inlets and a large enough tidal range- about 10 feet- to produce energy economically. The simplest generation system for tidal plants involves a dam, known as a barrage, across an inlet. Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides and to empty through the turbine system on the outgoing tide, also known as the ebb tide. There are two-way systems that generate electricity on both the incoming and outgoing tides.



Tidal barrages can change the tidal level in the basin and increase turbidity in the water. It can also affect navigation and recreation. Potentially the largest disadvantage of tidal power is the effect a tidal station can have on plants and animals in the estuaries.

Tidal fences can also harness the energy of tides. A tidal fence has vertical axis turbines mounted in a fence. All the water that passes is forced through the turbines. They can be used in areas such as channels between two landmasses. Tidal fences have less impact on the environment than tidal barrages although they can disrupt the movement of large marine animals. They are cheaper to install than tidal barrages too.

Tidal turbines are a new technology that can be used in many tidal areas. They are basically wind turbines that can be located anywhere there is strong tidal flow. Because water is about 800 times denser than air, tidal turbines will have to be much sturdier than wind turbines. They will be heavier and more expensive to build but will be able to capture more energy

STEAM GENERATOR

The function of a steam generator or a boiler is to convert water into steam at the desired temp. and pressure to suit the turbine which it serves. The basic components of steam generator are furnace and fuel burning equipment, water walls, boiler surface (drum and tubes), superheater surface, air heater (pre-heater) surface, re-superheater surface, economizer surface (feed water heating), and several accessories.

Boiler types: 1- Shell boiler. 2- Fire-tube boiler. 3- Water-tube boiler. Shell boiler: in this type, the close tube or drum contents the water inside. The shell is attached with source of heating (such as electrical heater). Its efficiency and ability to generate the steam are low. It is usually used for simple applications as lab. The electrical boiler is one of this type.

Fire tube boiler: in this type, the hot combustion gases are passed inside the tubes, and the tubes are surrounded with water. The fire-tube boilers may be classified in several ways: 1-Externally or internally fired. 2- Horizontal, vertical or inclined. 3- Direct tube or return rube. In the externally fired boilers, the furnace is places away from the boiler shell, while in the internally forced the furnace is built with the shell.

The horizontal, vertical and inclined designs refer to the arrangement of the drum and fire tubes in it. In a direct through type of fire tube boiler, flue gases flow from the furnace end to the chimney end without changing ther direction, while in the return tube type the gases first flow to the rear and then come to the front through the fire tubes to a smoke box at the front.



Down flow type. Figure shows a sectional view of dawn flow condenser. Steam enters at the top and flows downward. The water flowing through the tubes in one direction lower half comes out in the opposite direction in the upper half Fig. 1.10 shows a longitudinal section of a two pass down-flow condenser.

Central flow condenser. Figure shows a central flow condenser. In this condenser the steam passages are all around the periphery of the shell. Air is pumped away from the centre of the condenser. The condensate moves radially towards the centre of tube nest. Some of the exhaust steams while moving towards the centre meets the undercooled condensate and pre-heats it thus reducing undercooling.





Evaporation condenser. In this condenser steam to be condensed is passed

through a series of tubes and the cooling waterfalls over these tubes in the form of spray. A steam of air flows over the tubes to increase evaporation of cooling water, which further increases the condensation of steam.

ADVANTAGES AND DISADVANTAGES OF A SURFACE CONDENSER

The various advantages of a surface condenser are as follows:

- 1. The condensate can be used as boiler feed water.
- 2. Cooling water of even poor quality can be used because the cooling water does not come in direct contact with steam.
- 3. High vacuum (about 73.5 cm of Hg) can be obtained in the surface condenser. This increases the thermal efficiency of the plant.

The various disadvantages of the surface condenser are as follows:

- 1. The capital cost is more.
- 2. The maintenance cost and running cost of this condenser is high.
- 3. It is bulky and requires more space.