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Fundamentals Of Power Generation

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42. FUNDAMENTALS OF POWER GENERATION

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INTRODUCTION

The objective of this fundamentals of power generation article is to create an awareness of various method of power generation to students. This paper aims to highlight proven technologies that are being used worldwide.

ENERGY CAN EXIST IN VARIOUS FORMS

Radiation energy: The radiation from the sun contains energy, and so does the radiation from a light or a fire. More solar energy is available when the radiation is more intense and when it is collected over a larger area. Light is the visible part of radiation.

Chemical energy: Wood and oil contain energy in a chemical form. The same is true for all other materials that can burn. The larger the content of chemical energy, the larger the heating value (calorific value) of the material is and, of course, the more material we have. Also, animate energy (delivered by bodies of human beings and animals) is, in essence, chemical energy. Furthermore, batteries contain chemical energy.

Potential energy: This is the energy possessed by an object because of its position relative to other objects. For example, the energy of water stored in a reservoir at a certain height. The water has the potential to fall, and therefore contains a certain amount of energy. More potential energy is available when there is more water and when it is at a higher height.

Kinetic energy: This is the energy an object possesses due to its movement, as in wind or in a water stream. The faster the stream flows and the more water it has, the more energy it can deliver. Similarly, more wind energy is available at higher windspeeds, and more of it can be tapped by bigger windmill rotors.

Thermal energy or heat: This is the energy that is generated and measured by heat. Heat in turn is indicated by temperature. The higher the temperature, the more energy is present in the form of heat.

Mechanical energy or rotational energy: Also called shaft power, this is the energy of a rotating shaft. The amount of energy available depends on the flywheel of the shaft, i.e. on the power which makes the shaft rotate.

Electrical energy: This is the energy made available in the form of electricity or electric power. A dynamo (generator) and a battery can deliver electrical energy. Electrical energy is supplied by the combination of electric voltage and current. The higher the voltage and the current, the more electrical energy is made available.

Before getting into the different types of power generation, it is important to understand about the two different types of Energy resources – Renewable and Non-Renewable.

RENEWABLE ENERGY RESOURCES

Renewable energies generate power using natural sources that can be replaced over a relatively long time frame. Examples of renewable energies include solar, wind, hydro, geothermal and biomass.

Advantages: Because renewable energies are not burned like fossil fuels, they do not release pollutants into the atmosphere and provide a cleaner, healthier environment. Sources of renewable energy are found everywhere in the world and are not fully utilized.

Disadvantages: Initial costs for setting up renewable energy plants are often quite high and require careful planning and implementation. Building dams, for example, for hydroelectric power requires high initial capital and relocating villages is a major challenges. Renewable energies like solar and wind require large tracts of land to produce energy quantities competitive with fossil fuel burning. Renewable sources of energy generation are also affected by weather, reducing their availability. For example, wind turbines only rotate it there is enough wind at a given speed.

NON-RENEWABLE ENERGY RESOURCES

Non-renewable energies come from resources that are not replaced or are replaced only very slowly by natural processes. The primary sources for nonrenewable energies in the world are fossil fuels -- coal, gas and oil. Nuclear energy is also considered nonrenewable because there is a limited availability of thorium or uranium in the Earth's crust.

Advantages: Fossil fuels are the world's traditional energy sources and electrical power plants, vehicles and various industrial plants are built around using them. Many nonrenewable energies are more reliable than most renewables and are not subject to weather conditions. They provide continuous 24 x7 dependent energy.

Disadvantages: Fossil fuels are in a limited supply and one day it will be depleted. Processes

releases harmful greenhouse gases into the atmosphere, primarily CO2. Nuclear power plants do not release CO2, but pose other risks such as potential radiation leaks and waste storage problems. The costs for building new nuclear power plants have also risen sharply making them less economical than other types of power.

TYPES OF POWER GENERATION

The traditional proven forms of power generation that are being utilized today are listed below:

→ Thermal power generation
→ Nuclear Power generation
→ Hydro Power generation
→ Solar Power generation
→ Wind power generation

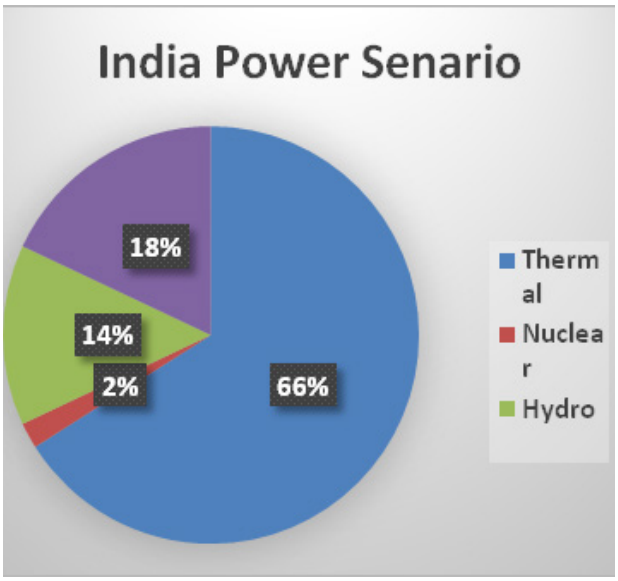


Figure -1 India Installed Power

Thermal Power Generation

A thermal power station is a power station in which heat energy isconverted to electric power. High pressure water is heated by a boiler and turned to steam. The boiler uses Coal, Oil or Gas as fuel to heat the water. During combustion in the boiler or steam generator, the heat is exothermicallyreleased and high pressure water absorbs the heat and converts into high pressure steam. The boiler efficiency is typically 85-90%.

The high pressure steam is used to spin a steam turbine. Thesteam turbine is a mechanical device that extracts thermal energy from high pressuresteam and converts it tomechanical work on a rotating output shaft. The efficiency of the steam turbine is 50-55%. The steam turbine is coupled to an Electrical generator, which converts mechanical energy obtained from the steam turbine into electricity. The generator uses the turning motion of the turbine shaft to rotate a rotor which has oppositely charge magnets and is surrounded by copper wire loops. Electromagnetic induction is created by the rotor spinning around the inside of the core, generating electricity.

After the steam passes through the steam turbine, the steam is condensed in a condenser and recycled to where it was heated (Boiler). This cycle is known as a Rankine cycle (see below).

Chemical Energy (Coal,Oil &Gas)- -Heat Energy (Steam Generator)-Mechanical Energy (Steam turbine)---Electrical Energy (Generator)

The electricity generated is transmitted for long distances via high voltage transmission lines. The transmission lines branch of into sub-stations where the voltages are stepped down via transformers and fed via low voltage transmission lines to consumers.

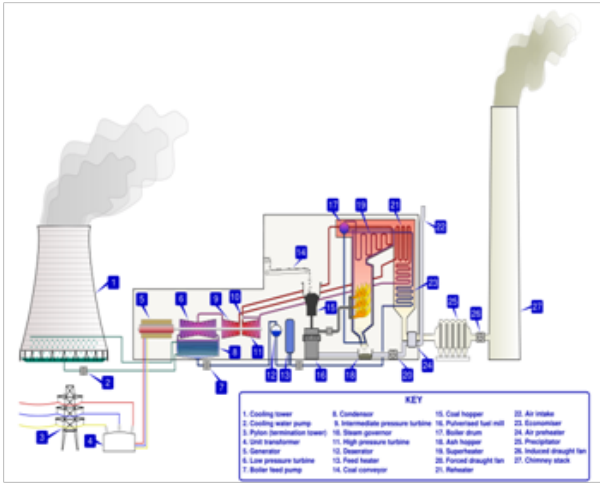


Figure - 2 A Typical Thermal Power Plant

A typical thermal power plant picture can be seen in Figure - 2.The overall power plant cycle efficiency ranges from 35-48%. The capital cost of the thermal power plant is Rs 4-6 Crores/ MW. India's thermal power installed capacity is 66% (218,960 MW) as shown in Figure - 1. This is partly due to the abundance of coal/lignite in India. Some of the gaseous by products of burning coal/lignite are Carbon dioxide (CO2), Sulphur dioxide (SO2) and Nitrogen dioxide (NO2). Technologies have been put in place at Thermal Power plants to minimize if not eliminate the release of these gases into the atmosphere.

CO2 is one of the greenhouse gases that protect the earth by keeping it warmer than normal. But, a continuous increase in the amount of greenhouse gases would lead to an increase in the earth's surface temperature, leading to global warming and climate change. This huge

concern has slowly started to shift the tide from generating electricity from Thermal Power plants to other renewable means (Hydro, Solar and Wind).

NUCLEAR POWER GENERATION

Nuclear poweruses nuclear energy to generate heat as opposed to coal/oil/gas in Thermal power. Nuclear energy originates from the splitting of enriched uranium atoms – a process called fission(refer to Figure-3).

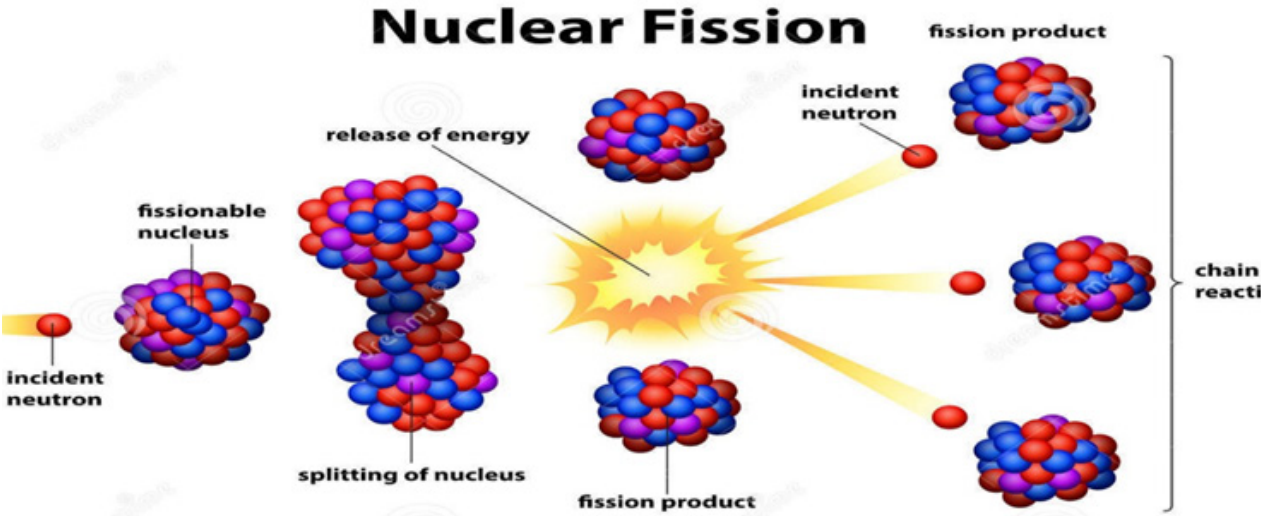


Figure -3 Nuclear Fission – Using Enriched Uranium

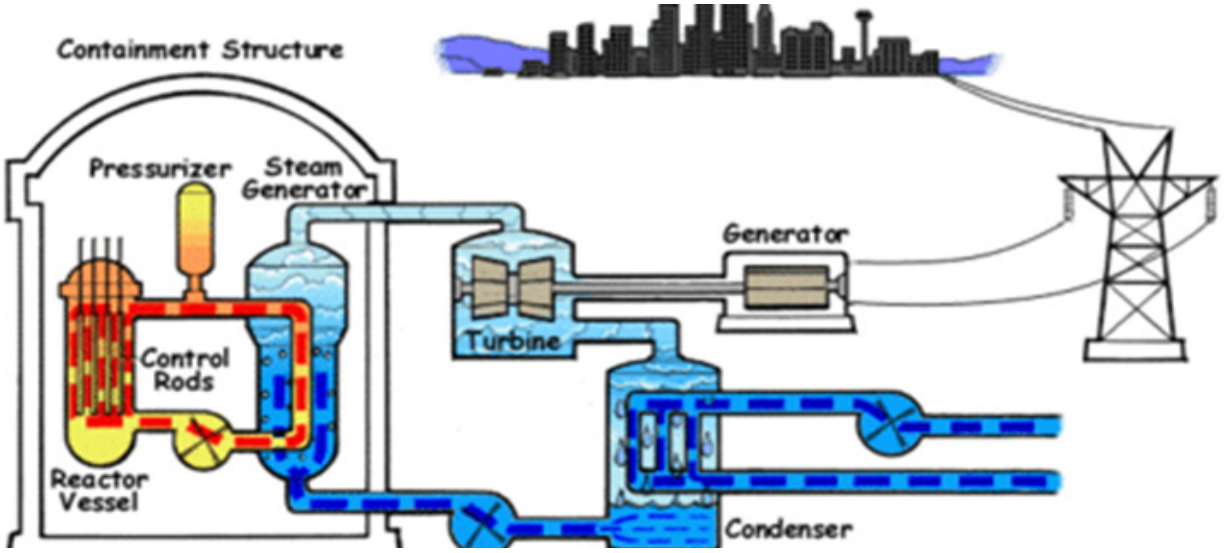


Figure - 4 A Typical Nuclear Power Plant

The nuclear reactor vessel is the heart of the Nuclear power station (refer to Figure-4). In its central part, the reactor core is heated up by controlled nuclear fission with uranium rods. With this heat, a coolant (typically heavy water) is heated as it is pumped through the reactor. The heavy water absorbs the heat from the reactor and is converted to high pressure steam. Similar to a Thermal power plant, the high pressure steam is used to spin a turbine generator, which in turn produces electricity.

Nuclear power installed capacity in India is about 2% (6,780 MW). Becausenuclear power plants do not burn fuel, they do not produce any greenhouse gas emissions. Nuclear power is considered to be reliable. However, because of the excessive safety requirements, the capital costs to build a Nuclear power plant are very high (Rs. 15-20 Crores/MW).

Availability of enriched uranium is limited in India, safe nuclear waste disposal is a major challenge and concerns about safety continue to make Nuclear power a less popular choice.

HYDRO POWER GENERATION

Hydropower is a form of renewable energy. Water stored in a damfalls by gravity through a tube called penstock and is used to spin water turbines located below the dam (refer to Figure-5). The potential energy of standing water is converted to kinetic energy by moving it, then converted to mechanical energy by

spinning a turbine.The turbine is coupled to a generator, which produces electricity.

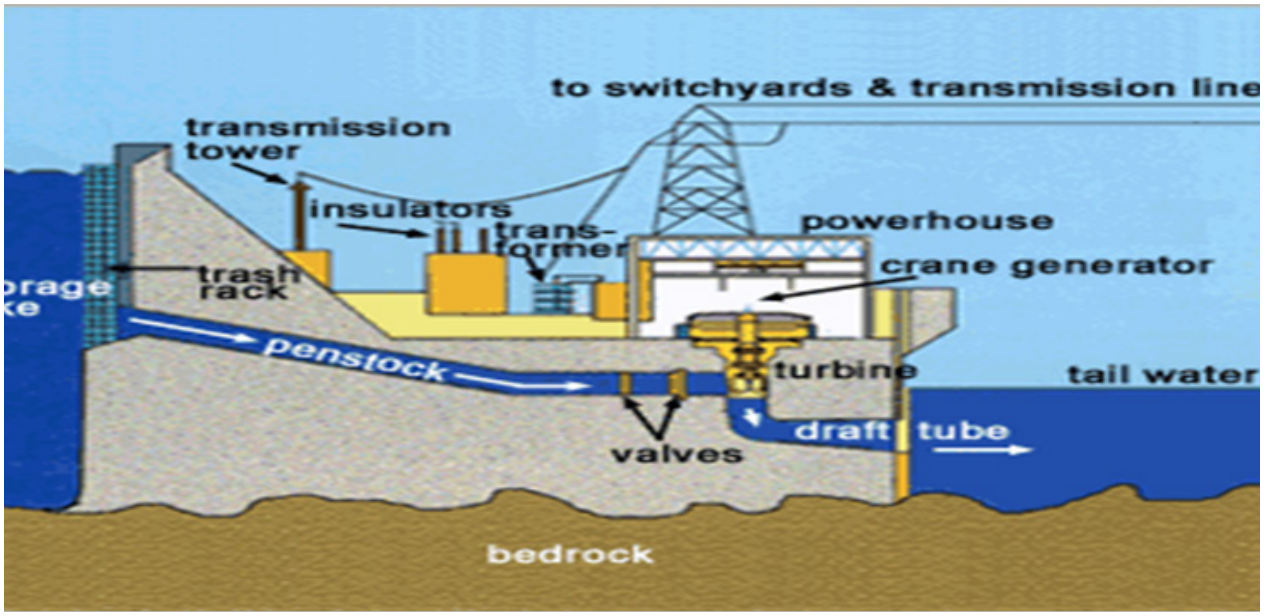


Figure -5 Hydropower Generating Plant

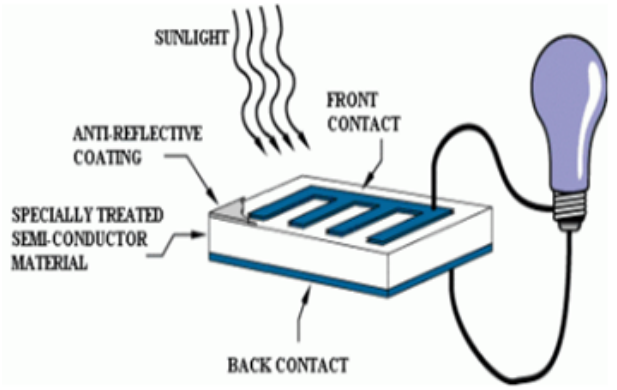
Hydropower does not use any fuel andis environmentally clean. Because of its predictable power output and quick startup times, Hydropower is typically used for catering peak electricity demand.

Due to the vast land area required, the capital cost is Rs 8-10 Crores / MW. The generating cost is about 1/4th of thermal power. Rehabilitation of surrounding landis a major issue. The dam is monsoon dependent and seasonally affected. Hydropower installed capacity in India is about 14% (44,963 MW)

SOLAR POWER GENERATION

Solar power is the conversion of energy from sunlight into electricity using Photovoltaic (PV) cells.

PV cells or Solar cells work by a phenomenon called Photoelectric effect. PV cells use a semiconductor (material that partially acts as a conductor and an insulator). The semiconductor material is specially treated to form an electric field i.e. positive on one side and negative on the other (refer Figure-6 Photovoltaic Cell)



When light energy from the sun or photons strike the solar cell, electrons are knocked loose from the atoms in the semiconductor material. These electrons are captured in the form of electric current by electrical conductors attached to the positive and negative side of the solar cell. The electricity generated from a solar cell is Direct Current (DC). Since most appliances used in homes and businesses are powered by Alternating current (AC), an inverter is used to convert DC to AC (referFigure-7).

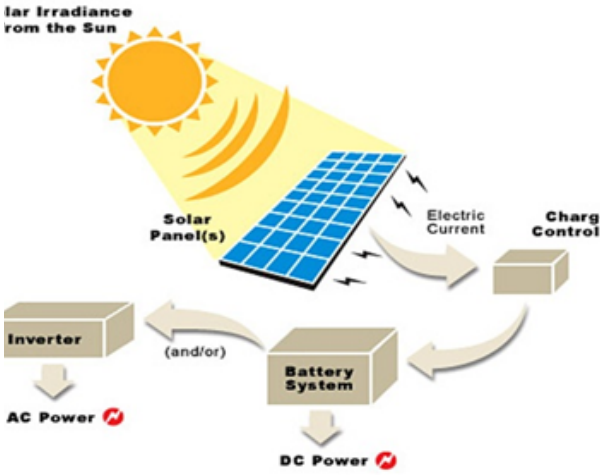


Figure -7 Solar Power Generation

Solar energy can be used to produce electricity in areas without access to the energy grid, to distill water in regions with limited clean water supplies and to power satellites in space.

Some advantages of Solar energy are reduced electricity generating costs because of no fuel cost, can be utilized for diverse applications (power homes or buildings, hot water), low maintenance cost and virtually no greenhouse gases emissions. Solar energy is also available

in abundance.
Disadvantages are require larger land area (4-5 Acres/MW), only available during day time, power generation is poor during winter / cloudy period and relatively higher capital cost (Rs 6.0 to 7.0 Crores / MW). Currently,solar power can be generated 30-33%percent per annum.

WIND POWER GENERATION

Wind Power is the conversion of Wind energy into electricity. The energy in the wind turns two or three propeller-like blades in a windmill or wind turbine. The blades are connected to a central shaft. The shaft is connected to a gearbox, which in turn is coupled to a generator that produces electricity. The kinetic energy of the wind is converted to mechanical energy and used to rotate the blades and shaft rotor. The mechanical energy of the shaft is converted into electric energy by using a generator.
There are two different types of wind turbines – Horizontal Axis Wind Turbine, where the blades rotate on a horizontal axis and Vertical Axis Wind Turbine (commonly used), where the blades rotate on the vertical axis.
Thegearbox is typically used in a wind turbine to increase rotational speed from a lowerspeedto a higher speed. A common ratio is about 90:1, with a rate of 16.7 rpm input from the rotor to 1,500 rpm output for the generator.The output of a wind turbine depends on the turbine's size and the wind's speed through the rotor.

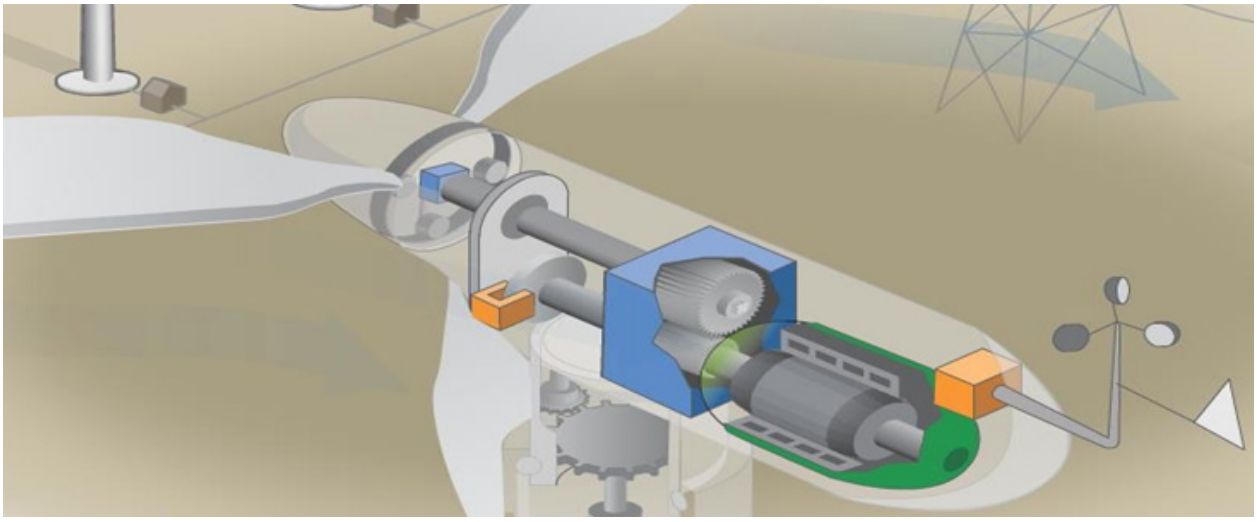


Figure 7 – Wind Turbine Cross Section

Wind energyis a clean fuel source and doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal, oil or natural gasWind is available free of cost and require small land area.
An average onshore wind turbine has a capacity of 2.5–3 MW.The capital cost is slightly higher than thermal power plants but much lower than a solar power plant. A typical capital cost ranges between Rs. 7 - 8 Crores / MW, depending up on the type of turbine, technology, size and location. The total wind installed capacity in Tamil Nadu is 7633 MW (Highest installed capacity) with about a 15% capacity utilization factor.
Some of the disadvantages of Wind turbinesare higher noise and larger land area required to install them.Wind turbinesare also considered a potential threat to wildlife such as birds and bats.

CONCLUSION

It is essential that students understand the different types of energies and fundamentals of power generation including the advantages and disadvantages of the same.The author's intention is to provide an overview of the above to help the reader to better understand and learn the fundamentals of power generation.
The author is taking an opportunity to thank Mr. R. Madhan, Manager, Stock Equipment, USA for supporting this paper.

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