

## Lecture 4: Electrical Energy

Energy exists in different forms in nature but the most important form is the electrical energy. The modern society is so much dependent upon the use of electrical energy that it has become a part of our life.

### 4.1 Importance of Electrical Energy

Electrical energy is superior to all other forms of energy due to the following reasons:

- I. **Convenient form.** Electrical energy is a very convenient form of energy. It can be easily converted into other forms of energy. For example, if we want to convert electrical energy into heat, the only thing to be done is to pass electrical current through a wire of high resistance e.g., a heater. Similarly, electrical energy can be converted into light (e.g. electric bulb), mechanical energy (e.g. Electric motors) etc.
- II. **Easy control.** The electrically operated machines have simple and convenient starting, control and operation. For instance, an electric motor can be started or stopped by turning on or off a switch. Similarly, with simple arrangements, the speed of electric motors can be easily varied over the desired range.
- III. **Greater flexibility.** One important reason for preferring electrical energy is the flexibility that it offers. It can be easily transported from one place to another with the help of conductors.
- IV. **Cheapness.** Electrical energy is much cheaper than other forms of energy. Thus, it is overall economical to use this form of energy for domestic, commercial and industrial purposes.
- V. **Cleanliness.** Electrical energy is not associated with smoke, fumes or poisonous gases. Therefore, its use ensures cleanliness and healthy conditions.
- VI. **High transmission efficiency.** The consumers of electrical energy are generally situated quite away from the centres of its production. The electrical energy can be transmitted conveniently and efficiently from the centres of generation to the consumers with the help of overhead conductors known as transmission lines.

### 4.2 Generation of Electrical Energy

The conversion of energy available in different forms in nature into electrical energy is known as generation of electrical energy.

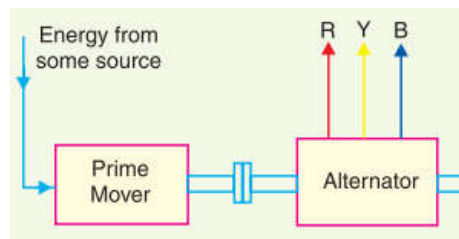


Figure 4.1

### 4.3 Sources of energy

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. These sources of energy are:

- (i) The Sun
- (ii) The Wind
- (iii) Water
- (iv) Fuels
- (v) Nuclear energy.

Out of these sources, the energy due to Sun and wind has not been utilized on large scale due to a number of limitations. At present, the other three sources viz., water, fuels and nuclear energy are primarily used for the generation of electrical energy.

I. **The Sun.** The Sun is the primary source of energy.

There are two main types of solar energy technology: photovoltaics (PV) and solar thermal. Solar PV is the rooftop solar you see on homes and businesses - it produces electricity from solar energy directly.

Solar thermal technologies use the sun's energy to generate heat, and electricity is generated from that. The heat energy radiated by the Sun can be focused over a small area by means of reflectors. This heat can be used to raise steam and electrical energy can be produced with the help of turbine-alternator combination. However, this method has limited application because:

- It requires a large area for the generation of even a small amount of electric power.
- It cannot be used in cloudy days or at night, it is an uneconomical method.

Nevertheless, there are some locations in the world where strong solar radiation is received very regularly and the sources of mineral fuel are scanty or lacking. Such locations offer more interest to the solar plant builders.

II. **The Wind.** This method can be used where wind flows for a considerable length of time.

The wind energy is used to run the windmill, which drives a small generator. In order to obtain the electrical energy from a windmill continuously, the generator is arranged to charge the batteries.

These batteries supply the energy when the wind stops. This method has the advantages that

maintenance and generation costs are negligible. However, the drawbacks of this method are (a) variable output, (b) unreliable because of uncertainty about wind pressure and (c)

power generated is quite small.

(iii) Water. When water is stored at a suitable place, it possesses potential energy because of the head created. This water energy can be converted into mechanical energy with the help of water turbines. The water turbine drives the alternator, which converts mechanical energy into electrical energy. This method of generation of electrical energy has become very popular because it has low production and maintenance costs.

III. **Fuels.** The main sources of energy are fuels viz., solid fuel as coal, liquid fuel as oil and gas

fuel as natural gas. The heat energy of these fuels is converted into mechanical energy by suitable prime movers such as steam engines, steam turbines, internal combustion engines etc. The prime mover drives the alternator, which converts mechanical energy into electrical energy. Although fuels continue to enjoy the place of chief source for the generation of electrical energy, yet their reserves are diminishing day by day. Therefore, the present trend is to harness water power, which is more or less a permanent source of power.

IV. **Nuclear energy.** Towards the end of Second World War, it was discovered that large amount of heat energy is liberated by the fission of uranium and other fissionable materials. It is estimated that heat produced by 1 kg of nuclear fuel is equal to that produced by 4500 tonnes of coal. The heat produced due to nuclear fission can be utilized to raise steam with suitable arrangements. The steam can run the steam turbine, which in turn can drive the alternator to produce electrical energy. However, there are some difficulties in the use of nuclear energy. The principal ones are

- High cost of nuclear plant
- Problem of disposal of radioactive waste and dearth of trained personnel to handle the plant.

The chief sources of energy used for the generation of electrical energy are water, fuels and nuclear energy. Below is given their comparison in a tabular form:

S.No.	Particular	Water-power	Fuels	Nuclear energy
1.	<i>Initial cost</i>	High	Low	Highest
2.	<i>Running cost</i>	Less	High	Least
3.	<i>Reserves</i>	Permanent	Exhaustable	Inexhaustible
4.	<i>Cleanliness</i>	Cleanest	Dirtiest	Clean
5.	<i>Simplicity</i>	Simplest	Complex	Most complex
6.	<i>Reliability</i>	Most reliable	Less reliable	More reliable

#### 4.4 Unit of electrical energy

Electrical energy. The unit of electrical energy is watt-sec or joule and is defined as follows:

One watt-second (or joule) energy is transferred between two points if a p.d. of 1 volt exists between them and 1 ampere current passes between them for 1 second i.e.,

Electrical energy in watt-sec (or joules)  
= voltage in volts  $\times$  current in amperes  $\times$  time in seconds

Joule or watt-sec is a very small unit of electrical energy for practical purposes. In practice, for the measurement of electrical energy, bigger units viz., watt-hour and kilowatt-hour are used.

1 watt-hour = 1 watt  $\times$  1 hr.

= 1 watt  $\times$  3600 sec = 3600 watt-sec

1 kilowatt hour (kWh) = 1 kW  $\times$  1 hr. = 1000 watt  $\times$  3600 sec =  $36 \times 10^5$  watt-sec.

#### 4.5 Types of fuels

Solid Fuel: Example, coal.

Liquid Fuel: Example, Diesel, Petrol.

Gaseous Fuel: Example, Natural gas, Coal gas.

#### 4.6 Advantages of Liquid Fuels over Solid Fuels

- I. The handling of liquid fuels is easier and they require less storage space.
- II. The combustion of liquid fuels is uniform.
- III. The solid fuels have higher percentage of moisture and consequently they burn with great difficulty. However, liquid fuels can be burnt with a fair degree of ease and attain high temperature very quickly compared to solid fuels.
- IV. The waste product of solid fuels is a large quantity of ash and its disposal becomes a problem.
- V. However, liquid fuels leave no or very little ash after burning.
- VI. The firing of liquid fuels can be easily controlled. This permits to meet the variation in load demand easily.

#### 4.7 Advantages of Solid Fuels over Liquid Fuels

- I. In case of liquid fuels, there is a danger of explosion.
- II. Liquid fuels are costlier as compared to solid fuels.
- III. Sometimes liquid fuels give unpleasant odours during burning.
- IV. Liquid fuels require special types of burners for burning.
- V. Liquid fuels pose problems in cold climates since the oil stored in the tanks is to be heated in order to avoid the stoppage of oil flow.

## 4.6 Electrical transmission

Electrical transmission is the process of delivering generated electricity - usually over long distances - to the distribution grid located in populated areas.

An important part of this process includes transformers, which are used to increase voltage levels to make long distance transmission feasible.

The electrical transmission system is used in combination with power plants, distribution systems, and sub-stations to form what is known as the electrical grid. The grid is designed to meet all of society's electricity needs, and is what gets the electrical power from its beginning to its end use. Since power plants are most often located outside of densely populated areas, the transmission system must be large.



Figure 4.2. High voltage power lines are used for the transmission of electricity over long distances.

### Power Lines

Power lines or transmission lines, such as those in Figure 1, are used to transport electricity from place to place. This electricity is in the form of alternating current and begins at step-up transformers, and typically span a distance of 500 kilometers or less. There are 3 types of lines:

- Overhead lines are very high voltage, between 100 kV and 800 kV, and do the majority of long distance transmission. They must be high voltage in order to minimize power losses to resistance.
- Underground lines are used to transport power through populated areas, underwater, or anywhere that overhead lines cannot be used. They are less common than overhead lines due to heat-related losses and higher cost.
- Sub transmission lines carry lower voltages (26 kV - 69 kV) to distribution stations, and can be overhead or underground.

## 4.7 Electrical Power Supply

The power supply system is mainly classified into two types,

- Single phase
- Three-phase system.

The single phase is used in a place where less power is required and for running the small loads. The three phases are used in large industries, factories and in the manufacturing unit where a large amount of power is required.

One of the major difference between the single phase and the three phase is that the single phase consists one conductor and one neutral wire whereas the three-phase supply uses three conductors and one neutral wire for completing the circuit.

### Definition of Single phase

The single phase requires two wires for completing the circuit, i.e., the conductor and the neutral. The conductor carries the current and the neutral is the return path of the current. The single phase supplies the voltage up to 230 volts. It is mostly used for running the small appliances like a fan, cooler, grinder, heater, etc.

### Definition of Three Phase

The three-phase system consist four wires, three conductors and one neutral. The conductors are out of phase and space  $120^\circ$  apart from each other. The three-phase system is also used as a single-phase system. For the low load, one phase and neutral can be taken from the three-phase supply.

### Key Differences Between Single Phase and Three Phase

1. In single-phase supply, the power flows through one conductor whereas the three-phase supply consists three conductors for power supply.
2. The single-phase supply requires two wires (one phase and one neutral) for completing the circuit. The three phase requires three phase wires and one neutral wire for completing the circuit.
3. The single phase supplies the voltage up to 230V whereas the three-phase supply carries the voltage up to 415V.
4. The maximum power is transferred through three phases as compared to single-phase supply.
5. The single phase has two wire, which makes the network simple whereas the three-phase network is complicated as it consists four wires.

6. The single-phase system has only one phase wire, and if the fault occurs on the network, then the power supply completely fails. However, in three-phase system, the network has three phases, and if the fault occurs on any one of the phases, the other two will continuously supply the power.
7. The efficiency of the single-phase supply is less as compared to three-phase supply. Because the three phase supply requires less conductor as compared to single-phase supply for the equivalent circuit.
8. The single-phase supply requires more maintenance and become costly as compared to three-phase supply.
9. The single-phase supply is mostly used in the house and for running the small loads. The three-phase supply is used in large industries and for running the heavy loads.

### **Benefits and Uses of a Single Phase AC Power Supply**

Single-phase power supply units have a broad array of applications. Units that have a limited power need up to 1000 watts typically make the most efficient use of a single-phase AC power supply. Generally, benefits of selecting a single-phase system include:

- Broad array of application uses
- Most efficient AC power supply for up to 1000 watts
- Fewer design costs
- Less complex designs

### **Benefits and Uses of a Three Phase AC Power Supply**

Typical applications for 3 phase systems include data centers, mobile towers, power grids, shipboard and aircraft, unmanned systems, and any other electronic with a load greater than 1000 watts. Three phase power supplies offer a superior carrying capacity for higher load systems. Some of the benefits include:

- Reduction of copper consumption
- Fewer safety risks for workers
- Lower labor handling costs
- Greater conductor efficiency
- Ability to run higher power loads