CHAPTER 12

TRANSMISSION & DISTRIBUTION OF ELECTRIC POWER

12.1 Introduction

The electric energy is generated at the power stations which are far away from the urban areas. There is a large network of conductors between generating station and the consumers. The network is called transmission and distribution system. The transmission system is to deliver power from generating stations to the load centers. Distribution system is to deliver power from substations to the various consumers. Electrical power can be transmitted and distributed by either A.C or D.C. But in practice 3 phase, 3 wire A.C. system is universally adopted for transmission of large blocks of power and 3- phase, 4 wire A.C. system is usually adopted for distribution of electric power.

12.2 Various Systems of Power Transmission

The various Systems of Power Transmission are

(A) D.C. Systems

(i) D.C. two wire

(ii) D.C. two wire with mid point earthed.

(iii) D.C. three wire system

(B) Single Phase A.C. systems

(i) Single Phase two –wire

(ii) Single Phase two-wire with mid point earthed.

(iii) Single Phase Three-wire.

(C) Two Phase A.C. systems

(i) Two Phase Four-wire

(ii) Two Phase Three –wire

(D) Three Phase A.C. Systems.

(i) Three Phase 3-wire

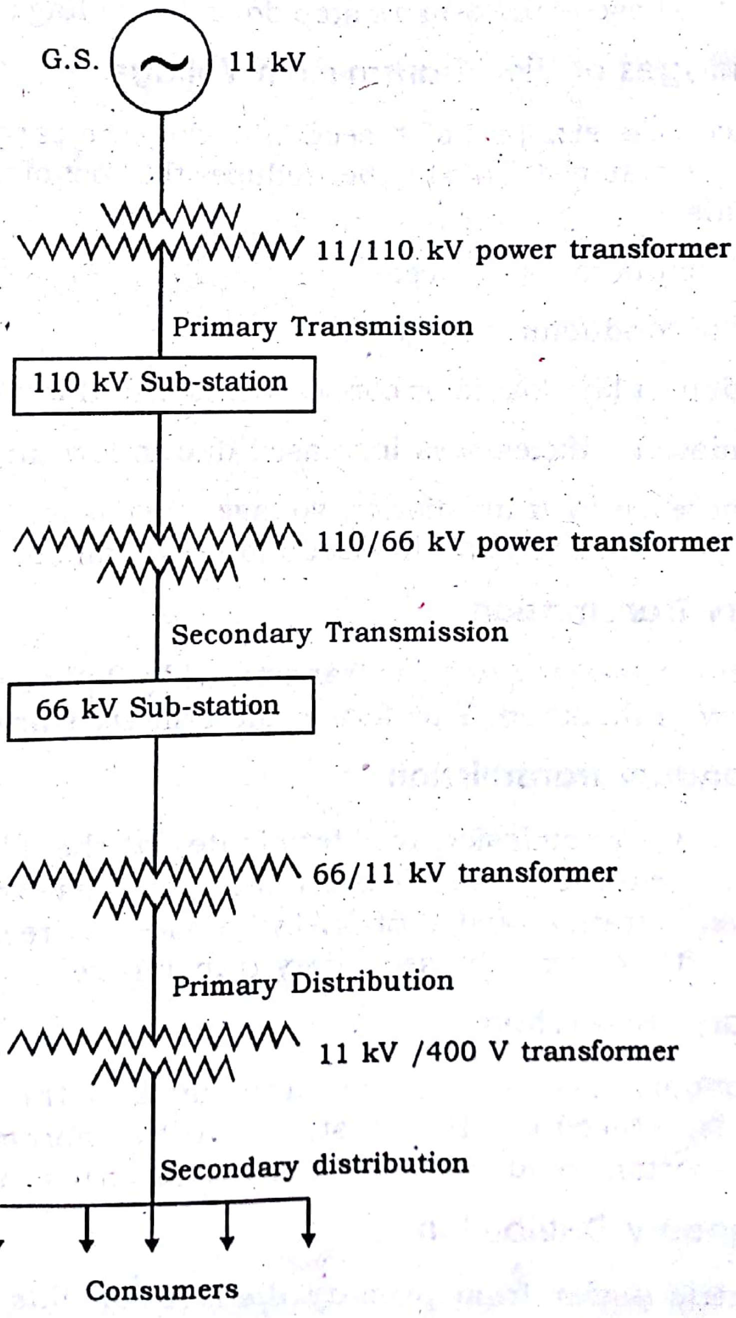
(ii) Three Phase 4-wire.

From the above possible systems of transmission it is difficult to select the best system without comparison. The basis of comparison between the various systems is usually economy, i.e., the volume of conductor required. Therefore, the volume of the conductor material required is minimum.

While comparing the amount of conductor material required for different systems of transmission, the following assumptions are to be made.

(a) The Power to be transmitted is same
(b) The distance over which power is transmitted remains the same.
(c) The line losses are same.
(d) The maximum voltage to earth is same.

12.3 Power Transmission Scheme



The figure shows the layout of a typical a.c. power supply scheme by a single line diagram. The G.S. represents the generating station where the electric power is produced. The generation voltage is 11kV. For economy in the transmission, the generation voltage is stepped up to 110 kV at the generating station with the help of power transformer. The electric power at 110 kV. is transmitted through overhead lines.

The 110kV line terminates at the 110 kV substation. At the substation, the voltage is reduced to 66kV by step-down transformer. From this station, electric power is transmitted at 66 kV by 3-phase, 3-wire overhead system. The 66 kV line terminates at the 66 kV substation. Here the voltage is reduced to 11kV using stepdown transformers. The 11kV lines run along the important road sides of the city. The big consumers are supplied power at 11kV for further handling with their own sub-stations. The power at 11kV is delivered to distribution transformers. These transformers step down the voltage to 400V.

12.4 Advantages of High Transmission Voltage

(i) It reduces the size (are of X-section of the core carrying the current) of the conductor material. This further reduces the cost of the supporting structure materials.

(ii) Cost of conductor is reduced.

(iii) Weight of conductor is reduced.

(iv) Reduction in line losses or copper losses (I^2R) due to reduced current.

(v) Transmission efficiency is increased due to low line losses.

(vi) With increase in transmission voltage, the current is reduced and voltage drop in the lines is low. This leads to better voltage regulation.

12.5 Primary Transmission

The electric power at 110 kV is transmitted by 3 phase-3 wire overhead system to the 110 kV. substation. This forms the primary transmission.

12.6. Secondary Transmission

The primary transmission line terminates at the 110 kV sub station. Here the voltage is reduced to 66 kV by step-down transformers. From this station, electric power is transmitted at 66 kV by 3 phase-3 wire overhead system to other sub-stations. This forms the secondary transmission.

12.7 Primary Distribution

The secondary transmission line terminates at the 66 kV substation. Here the voltage is reduced to 11kV by step down transformers. The 11 kV lines run along the important road sides of the city. This forms the primary distribution.

12.8 Secondary Distribution

The electric power from primary distribution line (11 kV) is delivered to distribution transformers. Here the voltage is reduced to 400V. From the distribution transformers, electric power is transmitted at 400V, 3 phase 4 wire overhead system to the low voltage consumers.

This forms the secondary distribution

12.9 Substation

The main functions of a substation are

(i) To receive energy transmitted at high voltage form the generating stations.

(ii) To reduce the voltage to a value appropriate for local distribution.

(iii) To provide facilities for switching

Substations have some additional functions. They provide points where safety devices may be installed to disconnect equipment or circuit in the event of fault. Voltage on the outgoing feeders can be regulated at a substation.

12.10 Classification of Substations

The substation may be classified in numerous ways.

1. According to service requirement

Substations are used for the following purposes.

(i) For changing the voltage level

(ii) For improving the power factor

(iii) For converting a.c. power in to d.c. power.

According to the service requirement, sub stations may be classified in to

(a) Transformer Substations. Substations which change the voltage level of electric supply are called transformer sub-stations. The main component of these sub-stations are transformers.

Most of the sub-stations in the power system are transformer substations.

(b) Switching sub-stations. These substations perform the switching operations of the power lines. Switching sub stations do not change the voltage level. The incoming and the outgoing lines have the same voltage.

(c) Power factor correction sub stations. Substations which improve the power factor of the system are called power factor correction sub-stations. These are generally located at the receiving end of transmission line.

(d) Frequency changer sub-stations. Substations which change the supply frequency are called frequency changer sub-stations.

(e) Converting substations. Sub-stations which change a.c. power in to d.c. power are called converting sub-stations. These sub-stations are used for traction purposes, electroplating and electric welding.

2. According to constructional features:

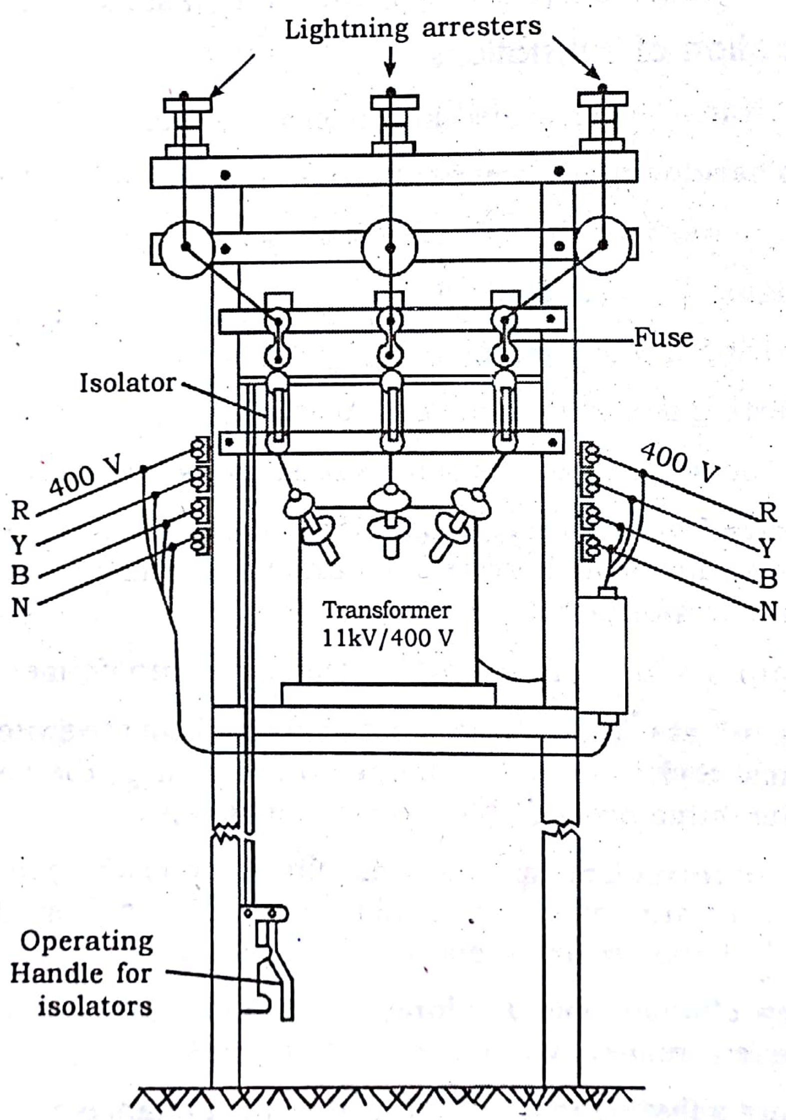
According to the constructional features, the sub-stations are classified as

(a) Indoor sub-stations. The equipment of the sub-station is installed indoor up to 11 kV. voltage. If the atmosphere is contaminated with impurities, these can be erected up to 66 kV

(b) Outdoor sub-stations. For voltages beyond 66kV, equipment is invariably installed outdoor. The outdoor substations are further subdivided in to pole mounted substations and foundations mounted substations.

(c) Underground substations. In thickly populated areas, there is scarcity of land as well as the prices of land are very high. This has led to the development of underground substation. In such substations,, the equipment is placed underground.

12.11 Pole Mounted Substation



Layout of polemounted sub-station

Such substations are erected for mounting distribution trans formers of capacity up to 250kVA. These substations are of outdoor type and the equipments are mounted on the supporting structure of H.T line. Triple pole mechanically operated switch is used for switching "on" and "off" of H.T transmission line. H.T fuse unit is installed for protection of H.T. side. To control L.T. side iron clad low tension switch of suitable capacity with fuses is installed. Lightening arresters are installed over the H.T. line to protect the transformer from the surges. Substation is earthed at two or more places. Transformers upto 100 kVA are mounted on double pole structure and for transformers of capacity above 100kVA but not exceeding 250 kVA, 4 pole structure with suitable platform is used.

12.12 Substation Equipments

The main equipments required for substations are given below.

1. Bus-bars: Bus-bar is a term used for a main bar or conductor carrying an electric current to which many connection may be made. The bus-bars operate at constant voltage. The bus-bars are usually of aluminium. The incoming and outgoing lines in a substain are connected to the bus-bars.

2. Insulators: The insulators serve as supports and insulation of the bus-bars. The most commonly used material for the manufacture of insulators is porcelain. There are several types of insulators. Pin type, suspension type and shackle insulator. The use of the insulators in the substain will depend upon the service requirement.

3. Isolators: An isolator or disconnecting switch is used to open a circuit under no load. In other words, isolator switches are operated only when the lines in which they are connected carry no current. There are two types of isolators. Single pole isolator and three pole isolator.

4. Circuit Breaker: A circuit breaker is an equipment which can open or close a circuit under any condition, i.e.. no load, full load or fault conditions. The function of the circuit breaker is to isolate the plant and lines rapidly and safely by automatic means under fault conditions. Since fault current in a power system are very high in magnitude, therefore, the construction of a circuit breaker should be mechanically very strong.

5. Power transformer: Power transformer is used to step-up or step-down the voltage. Usually naturally cooled oil immersed, two winding, three phase transformers are used up to the rating of 10 MVA. The transformers of rating higher than 10MVA are usually air blast cooled.

6.Current transformer : The function of the current transformer is to transfer current in the power line to a value which is convenient for the operation of measuring instruments and relays. The measuring instruments and protective devices are designed for low voltages (110 V) and currents (5A). They will not work satisfactorily if mounted directly on the power lines.

7. Potential transformer : The function of the potential transformer is to transfer voltage in the power line to a value which is convenient for the operation of measuring instruments and relays. It is a step-down transformer and steps down the voltage in a known ratio. The primary winding of the potential transformer is connected to the main bus-bars and to the secondary windings, various indicating and metering equipments are connected.

8. Protective relays : The function of the protective relay to sense the dangerous conditions and based on this sensing, to isolate the circuit. When the fault occurs the relay operates to complete the trip coil circuit which results in the opening of the circuit breaker and therefore isolation of the faulty section from the rest of the system. The relay thus ensures the safety of the circuit equipment from damage and normal working of the health portion of the system.

9. Lightning arrester: The function of the lightning arrester is to protect the equipment against electric surges. A lightning arrester should be installed as near the transformer as possible because it is the most costly equipment of the sub-station.

10. Carrier-Current Equipment: This equipment is required for communication, relaying and telemetering. This equipment is connected to the line through coupling capacitor and a wave trap. Wave traps are connected at the line entrance vertically or horizontally. Coupling Capacitors are installed on the line side of a wave trap and are normally base mounted.

12.13 Advantages of Underground system over Overhead System of Power Distribution

1. More safe
2. Low maintenance cost
3. Very few chances of fault
4. Few chances of accidents
5. Good appearance
6. Free from lightning effects
7. No interference with communication circuits

12.14 Disadvantages of Underground System over Overhead System

1. More expensive
2. Difficult to locate the fault
3. Cannot be worked above 66kV due to insulation difficulties

12.15 Distribution System

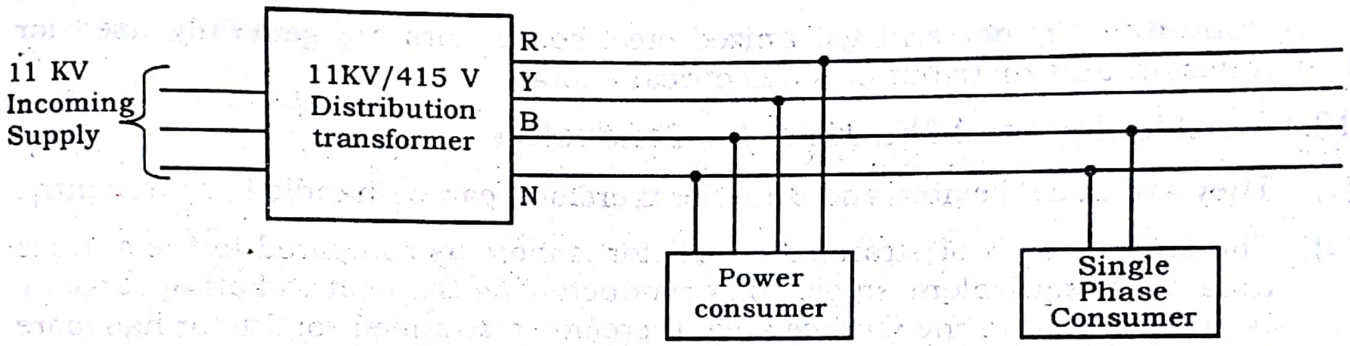
The following systems are used for distributing power to the consumers

1. Single phase A.C Supply using 2 wire. (One phase and one neutral)
2. Three phase A.C. supply using 4 wire. (Three phase wires and one neutral)

Large consumers with heavy motor loads are provided with a 3 phase, 4 wire supply. The voltage between any phase wire and the neutral wire is called phase voltage. The voltage between any two phase wire is called line voltage.

The standard voltage of single phase and three phase are 240 V and 415 V respectively. The voltage between any two of the phase wire in 3-phase system is $\sqrt{3}$ times the voltage between any phase and the neutral.

Three phase 4 wire distribution scheme is shown in figure.



R,Y,B are the phase wires and N is the neutral wire. The 11kV supply from the substation is delivered to the distribution transformer. Here the voltage is reduced to 415V. From the distribution transformers, electric power is transmitted to 415V, 3 phase, 4 wire overhead system to the low voltage consumers. Consumers with high connected load receive power 415/250V where they can use both three phase and single phase supply. Very small domestic and commercial consumers are often provided with single phase supply at 240V.

Distribution system may further be divided into feeders, distributors and service mains.

(a) Feeders. Feeders are the conductors which connect the substations and the distribution transformers. Therefore, current loading of feeder remains the same along its length. Feeders are designed mainly from the point of view of its current carrying capacity.

(b) Distributors. Distributors are the conductors from which numerous tapings for the supply to the consumers are taken. The current loading of a distributor varies along its length. Distributors are designed from the point of view of the voltage drop in them.

(c) Service Mains. Conductors which deliver electric power from the supply pole to the consumer's premises upto the metering apparatus. It may be overhead or underground.

12.16 Conductor Materials

The conductor material used for transmission and distribution of electrical energy must have the following characteristics

1. It should have low cost.
2. It should be light in weight
3. It should have high conductivity.
4. It should not be brittle
5. It should have high tensile strength to withstand mechanical stresses.
6. Low specific gravity in order to give low weight for unit volume.

Aluminium, Copper and galvanized steel conductors are generally used for transmission and distribution of electrical energy.

12.17 Advantages of Stranding the Conductors

(1) They are more flexible and durable, therefore, can be handled conveniently.

(2) The surface area of stranded conductor is more as compared to the surface area of an equivalent single solid conductor. As the heat radiating capacity is proportional to the surface area, therefore, a stranded conductor has more heat radiating capacity as compared to a single solid conductor.

The conductor materials are,

(i) Copper. The resistively of annealed high conductivity copper is 0.01724 W-m/mm^2 at 20^{0}C. The electrical resistance of copper varies with temperature. High conductivity copper is available in the form of fully annealed or the hard drawn state depending on the properties required for the items under manufacture. Hard drawn copper is having double the tensile strength of annealed copper. Insulated cables consists of annealed copper whereas overhead lines consists of hard drawn copper. The busbars for heavy current conductors of relatively short length are made of hard drawn copper.

(ii) Aluminium. Aluminium is replacing copper in many of its applications. It has a conductivity of 62% that of copper. In high voltage transmission lines aluminium is used as supports, conductors and conductor accessories. Aluminium is also used as the conductor for distribution cable.

(iii) Aluminium Conductor Steel Reinforced (A.C.S.R). These conductors are used for long distance high voltage overhead transmission lines. A.C.S.R. consists of a core of galvanized steel strand surrounded by a number of aluminium strands. The core is galvanized steel to prevent rusting and electrolytic corrosion. The steel core takes a greater percentage of mechanical stresses and the aluminium carries the current. A.C.S.R. conductors have high tensile strength.

(iv) Cadmium copper alloys. Cadmium copper alloy contain 0.6 to 1% cadmium when cadmium copper is hard drawn. Its tensile strength is 50% greater than that of hard drawn copper. It is used for overhead lines and for contact wires for overhead lines.