BAPUJI POLYTECHNIC, SHABNUR.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS

TRANSMISSION DISTRIBUTION AND UTALISATION (15EE52T)

UNIT-1

TRANSMISSION SYSTEMS

AC TRANSMISSION AND DISTRIBUTION SYSTEM:

SCHEMATIC LAYOUT DIAGRAM

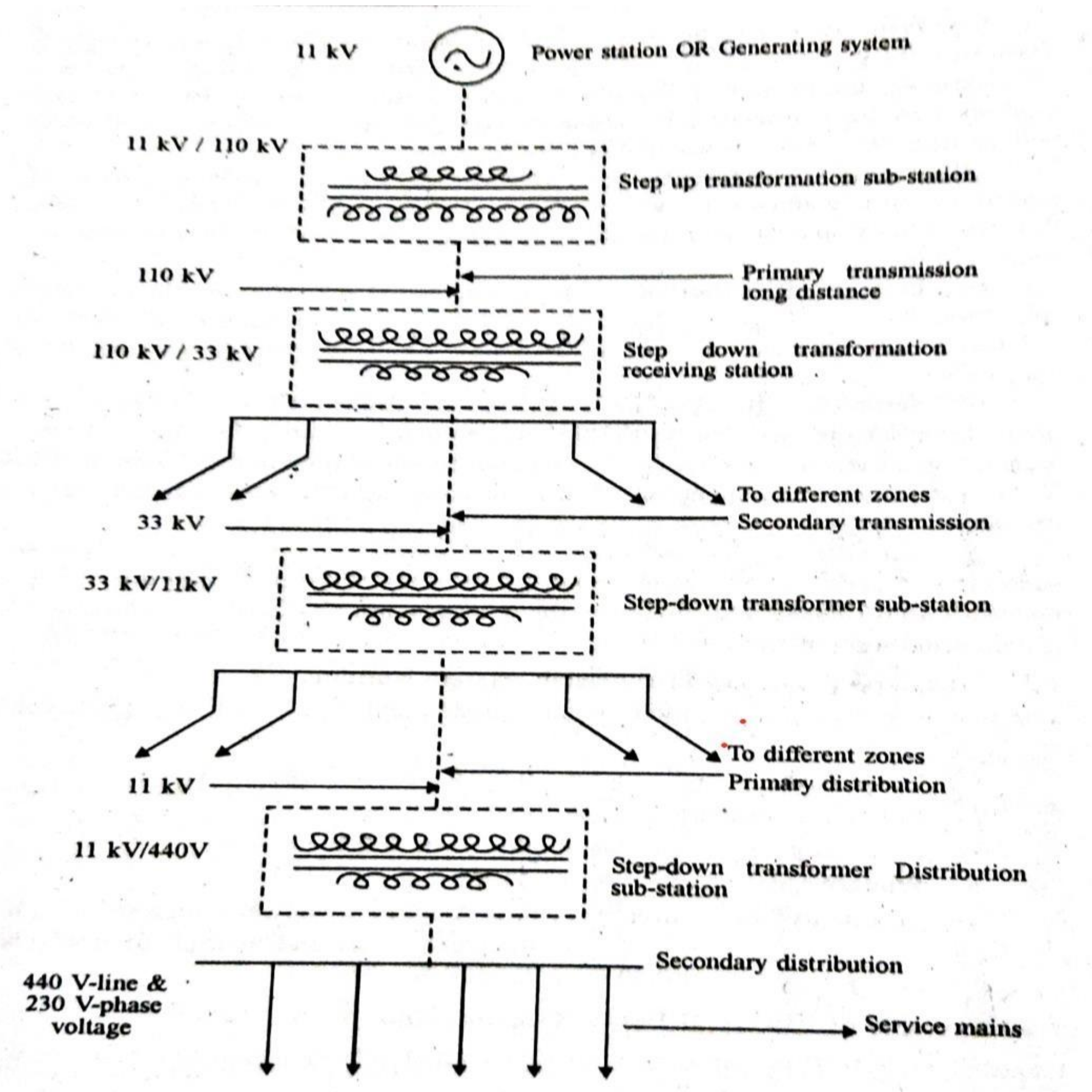


Fig. 1.1 AC Power System Network

STANDARD TRANSMISSION AND DISTRIBUTION VOLTAGES:

The standard voltages used for transmission and distribution are for

1) Generation: 6.6 KV, 11KV, 22KV, 33KV

2) Primary transmission: 110KV, 220KV

3) Secondary transmission: 66KV, 33KV

4) Primary distribution: 11KV

4) Secondary distribution: 440V and 230V for AC. 110V and 220V for DC

ADVANTAGES OF HIGH VOLTAGE TRANSMISSION

The advantages of high voltage transmission are

1) For higher transmission voltage power loss is less
2) Efficiency is high
3) Voltage drop is less
4) Cost is less
5) In high voltage transmission output power will be more for a given input.
6) The stability of the power system is increased with increase in transmission voltages
7) In low voltage transmission line current is more, it is difficult to handle, hence high voltage transmission is preferable.

LIMITATIONS OF HIGH VOLTTAGE TRANSMISSION

1) The high voltage transmission increases the cost of towers, insulators and other supporting structures.
2) The insulation cost of transformer and switchgear is increased
3) Corona loss will be more
4) More radio and television interference.

VARIOUS SYSTEMS OF POWER TRANSMISSION AND DISTRIBUTION

1) DC 2 wire system: It consists of 2 wires one is positive and other is negative. The positive is outgoing while negative is return wire. The below figure shows schematic and symbolic representation of Dc 2 wire system

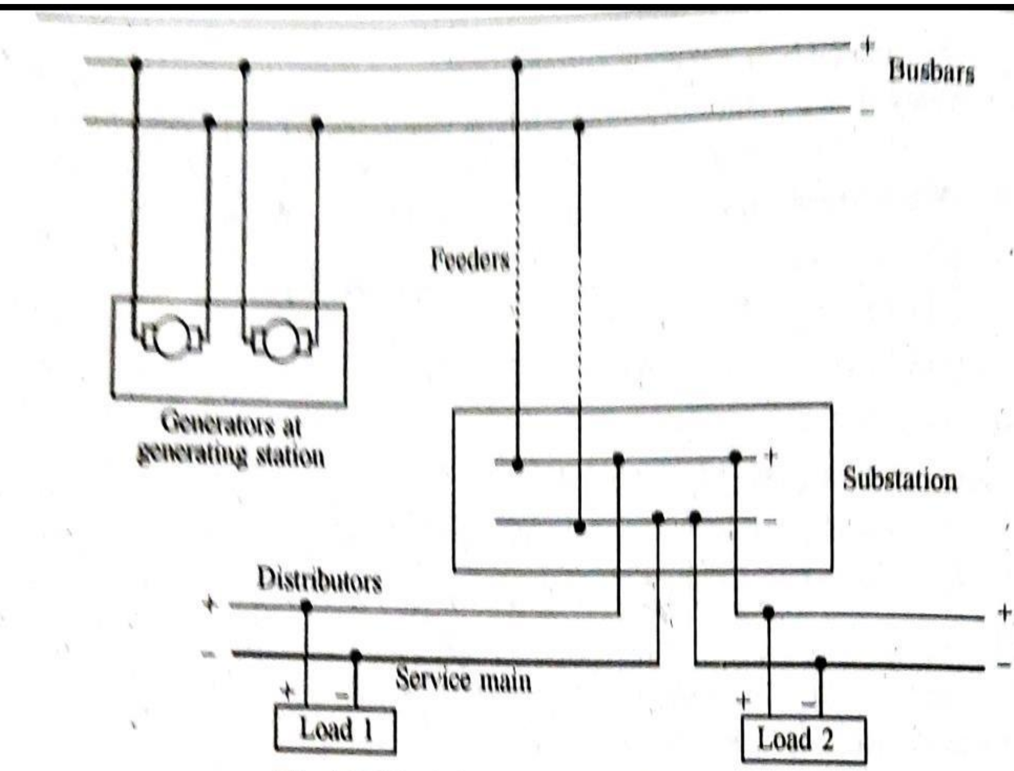


Fig. 1.2 Schematic arrangement of DC 2-wire system

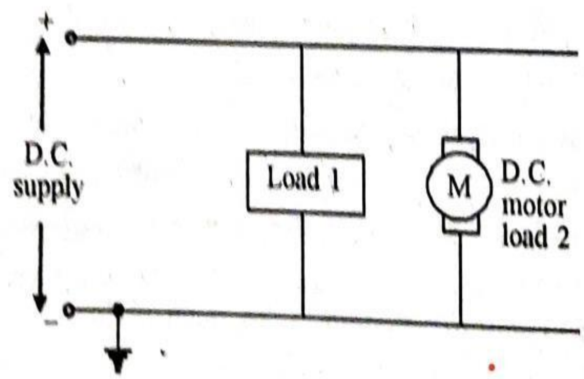


Fig. 1.3 Symbolical representation of DC 2-wire system

Applications of DC 2-wire System :

- For distribution of DC power.
- For electric traction system.
- For emergency lighting system.
- Charging of batteries in UPS (Uninterruptable Power Supplies).

2) SINGLE PHASE TWO WIRE AC SYSTEM:

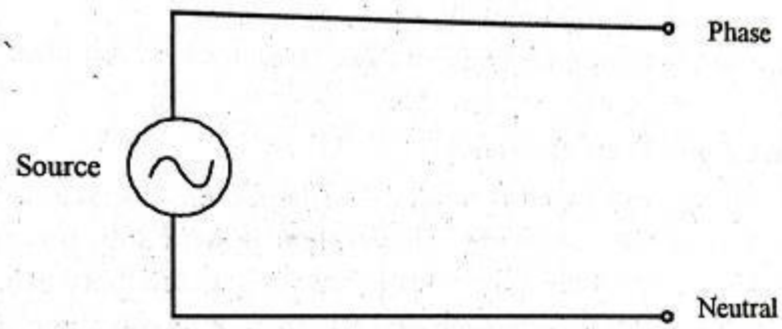


Fig. 1.4 Single phase two wire system

Applications of single phase 2-wire system :

1 ➢ For domestic supply connection.

2 ➢ For domestic and industrial lighting connection.

3 ➢ For street lighting connection.

3) THREE PHASE THREE WIRE AC SYSTEM:

The three phase three wire system may be star or delta connected. If it is star connected, then its neutral is grounded. The Fig. 1.5 shows the scheme of three phase three wire system for the primary distribution. The large consumers like factories

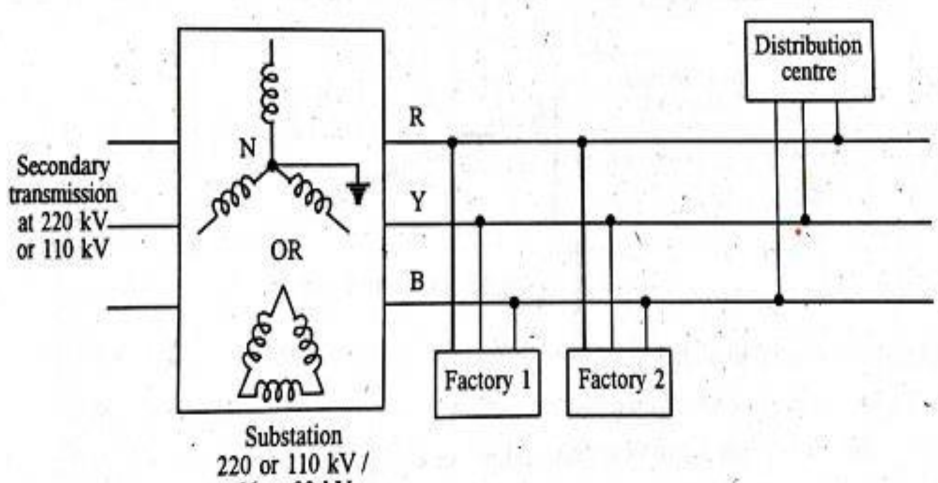


Fig. 1.5 Three phase three wire system

which need bulk supply are directly supplied from the substations. The power is also distributed to other substations and distribution centres.

Applications of three phase three wire system :

- For primary and secondary transmission system.
- For primary distribution system.
- For large or big consumer like factories, industries which need bulk power supply.

4) THREE PHASE FOUR WIRE AC SYSTEM:

1.4.4 Three Phase Four Wire System

The fourth wire in this system is neutral and hence the transformer secondary in such system is always star connected. This system is generally preferred for the secondary distribution. The single phase loads are connected between one of the three lines and a neutral while the three phase loads can be given three phase supply directly, along with the provision of neutral for the internal distribution. The Fig. 1.6 shows the three phase four wire system. The voltage between any of the lines and a neutral is 230 V while the voltage between any two lines is 440 V.

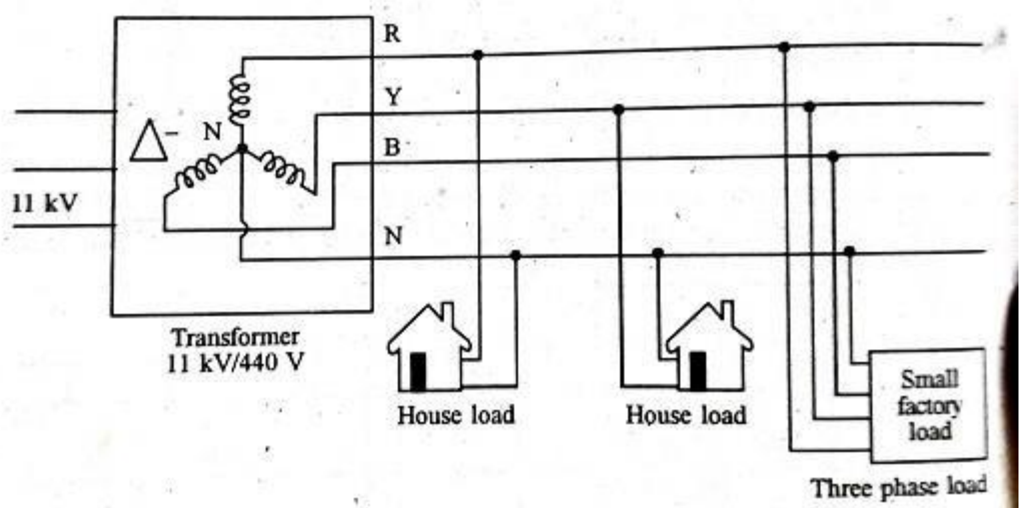


Fig. 1.6. Three-phase four wire system

Applications of three phase four wire system :

- For secondary distribution system.
- For small scale factories, industries supply connection.
- For three phase load connection

COMPARE HVAC AND HVDC TRANSMISSION SYSTEM

SL.NO.	REFERENCE	HVAC	HVDC
1	Conductor requirement	It requires 3 or 4 conductors	It requires only2 conductors
2	Construction	Complicated	Easy
3	Corona effect	Corona effect is more	Corona effect is less
4	Skin effect	There is Skin effect	No skin Skin effect
5	Voltage drop	Voltage drop is more	Voltage drop is less
6	Voltage transmission	Voltage transmission is easy by stepping up or by stepping down the voltage using transformers	DC voltage can not be stepped up or stepped down easily

7	Maintenance	Maintenance AC substation is easy and cheaper	Maintenance of DC substation is difficult and costly
8	Generation of power	Generation of power at high voltage is easy	Generation of power at high voltage is difficult
9	Inductance and capacitance effect	Inductance and capacitance effect is more	Inductance and capacitance effect is less
10	Long distance transmission	For very Long distance transmission cost is more	For very Long distance transmission cost is less

OVERHEAD TRANSMISSION LINES

COMPARE OVERHEAD AND UNDERGROUND TRANSMISSION SYSTEM

SL. NO.	Reference	Overhead	Underground
1	Initial cost	Low	High
2	Maintenance cost	High	low
3	Safety	Less	More
4	Chances of fault	More	Less
5	Chances of accidents	More	Less
6	Fault location	Easy	Difficult
7	Repairing	Repairing is easy	Repairing is difficult
8	Jointing	Jointing is easy	Jointing is difficult
9	Voltage drop	Voltage drop is more	Voltage drop is less
10	Appearance	Looks bad	Beautiful appearance

MAIN COMPONENTS OF OVERHEAD TRANSMISSION LINES

Main components of overhead transmission lines are:

- Conductors: Depending upon current carrying capacity proper size of conductor should be used. For single ckt. 3 conductor and for double ckt. 6 conductors are used, generally ACSR conductors are used.
- Insulators: For mechanical support to conductor and for isolation between conductor and supporting structure insulators are required.
- Towers: for supporting the line conductors suspended in the overhead air, towers are required.
- Transformers: For stepping up and stepping down the voltage Transformers are required, Transformers permits power to be transmitted at higher efficiency.
- Protective devices: to protect the transmission system and for reliable operation various
  Protective devices are required like circuit breaker, lightening arrestor , relays, earthing wire. Guy wire, Guy wire insulator ext.

CLASSIFICATION OF TRANSMISSION LINES BASED ON DISTANCE

According to the distance the transmission lines are classified as follows
1) Short transmission lines
2) Medium transmission lines
3) Long transmission lines

1. **Short transmission lines:** In this the transmission distance is about 80KM and the voltage range is around 20KV

2. **Medium transmission lines:** In medium transmission distance is about 80KM to 250KM and the voltage range is up to 100KV
3. **Long transmission lines:** In Long distance transmission distance is more than 250KM and the voltage range is more than 100KV

LINE CONSTANTS

The electrical power is transmitted through a transmission lines, generally ACSR or Aluminum conductors are used and these conductors have parameters i.e resistance, inductance and capacitance, these parameters are called line constants. The resistance, inductance and capacitance which effects on transmission line.

Resistance: The resistance in a transmission line is to oppose the flow of current, it is distributed uniformly along the length of the conductor

The resistance in the conductor is given by ohms law $R=\rho^{l}/a\ \Omega$

Where R=Resistance in ohms

P=Specific resistance in ohm-meter

^{l} = length of conductor in meters

A= area of cross section in mtr-sqr

Inductance: When AC is supplied to the transmission lines, a changing flux is sets up which link the conductor, due to these flux linkages the conductor posse's inductance.

The inductance of AC circuit is defined as flux linkages per unit ampere.

Inductance L= Flux linkage/Current

L=øN/I Henry

Capacitance: In transmission lines two conductors are separated as spacing in which air is acting as dielectric. It is similar to that two conductors are separated by insulator to which potential difference is applied. Hence capacitance is exist between two lines and between line and earth.

- **C=charge on capacitor / P.D. applied**
  C=Q /V Farad

2.6 Voltage Drop and Losses in Transmission Line

When the transmission line is loaded, current flows in a line, due to presence of line constants i.e., Resistance Inductance and Capacitance Voltage drop and losses takes place in the line. According to Ohms law.

(i) Voltage drop in transmission line is $\bar{I}\,\bar{Z}$

(ii) Line losses in transmission is I^2R.

2.7 Voltage Regulation and Efficiency of Transmission Line

When the transmission line is loaded, the load current flows in a line due to which Voltage drop takes place i.e.,

$$\text{Voltage Drop} = \text{Current} \times \text{Impedance}$$
$$= I \times (R + jX)$$

Because of this Voltage drop the receiving end Voltage will be generally less than the sending end Voltage ($V_R < V_S$). The actual Voltage drop is the difference between sending end Voltage and receiving Voltage ($V_S - V_R$). This Voltage drop in a transmission line is expressed as a percentage of receiving end Voltage and is known as Voltage regulation.

The Voltage regulation of a transmission line is defined as change of Voltage at the receiving end when load is thrown off from full load, the Voltage at sending end being constant. It is expressed as a percentage of the receiving end Voltage.

$$\therefore \%\ \text{of regulation} = \frac{V_S - V_R}{V_R} \times 100$$

Where, V_S = Sending end Voltage.

V_R = Receiving end Voltage.

Efficiency of a Transmission Line :

When the transmission line is loaded, the load current flows in a line due to presence of resistance, resistive losses i.e., I^2R losses takes place and receiving end power will be less than sending end power.

Generally the ratio of output power to the input power is called efficiency. Similarly in a transmission line. The ratio of receiving end power to the sending end power is called transmission efficiency.

$$\therefore \text{ \% Transmission efficiency } = \frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

$$\% \eta_T = \frac{V_R I_R \cos \phi_R}{V_S I_S \cos \phi_S} \times 100$$

Where, V_S = Sending end Voltage

I_S = Sending end current.

V_R = Receiving end Voltage

I_R = Receiving end current

$\cos \phi_R$ = Receiving end power factor

$\cos \phi_S$ = Sending end power factor.

2.8 Performance of short Transmission Lines

As the distance is less in this line effect of capacitance is neglected. The effect of resistance, and inductance is considered as lumped at one side. The equivalent circuit diagram is shown in the fig. 2.13 considering a single phase circuit.

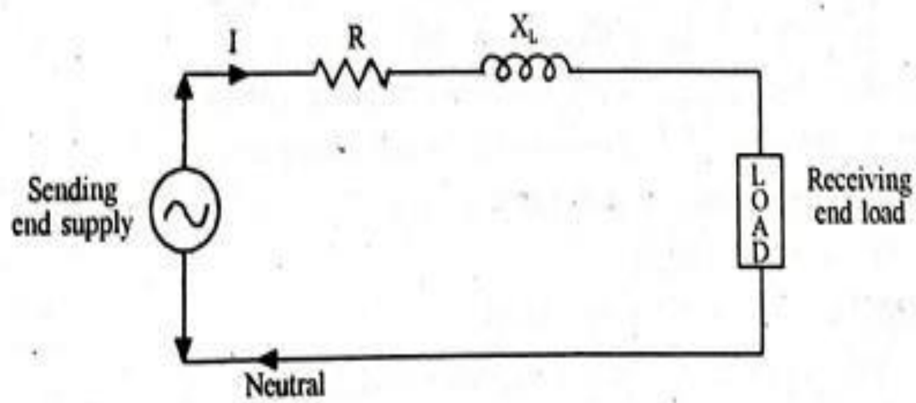


Fig. 2.13

Here, V_S = Sending end Voltage/phase

V_R = Receiving end Voltage/phase

I = Load current

R = Loop resistance.
(Resistance of 2 conductors
i.e., both phase and neutral)

X_L = Loop reactance/phase.

$\cos \phi_s$ = Sending end power factor.

$\cos \phi_R$ = Receiving end power factor.

The vector diagram for above circuit is drawn for lagging power factor as shown in Fig. 2.14.

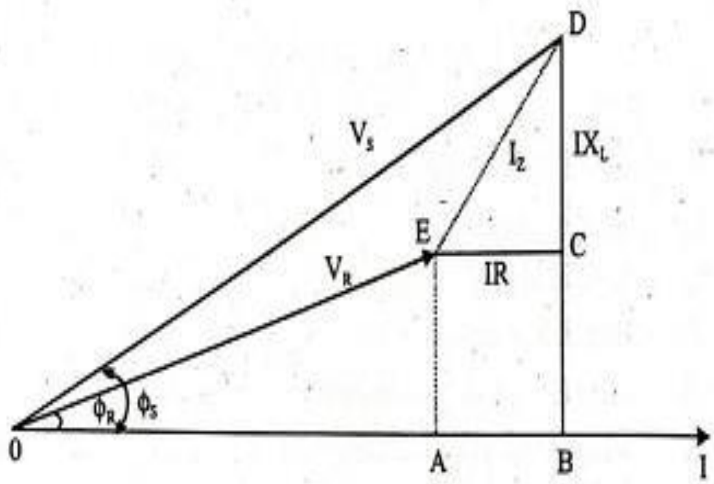


Fig. 2.14 Vector diagram of short transmission line

In a vector diagram, current is taken as reference vector.

ϕ_R = Phase angle at the receiving end.

ϕ_s = Phase angle at the sending end.

EC=IR = Voltage drop due to resistance in phase with I.

CD=IX_L = Voltage drop due to reactance quadrature with I.

From right angle triangle OBD, we get.

$$(OD)^2 = (OB)^2 + (BD)^2$$

$$(OD)^2 = (OA + AB)^2 + (BC+DC)^2$$

$$Vs^2 = (V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R + IX_L)^2$$

$$\therefore \quad V_S = \sqrt{(V_R \cos \phi_R + IR)^2 + (V_R \sin \phi_R \pm IX_L)^2}$$

–ve sign is for leading power factor

$$\% \text{ Regulation} = \frac{V_S - V_R}{V_R} \times 100$$

$$\text{Sending end power factor, } \cos \phi_s = \frac{OB}{OD}$$

$$= \frac{V_R \cos\phi_R + IR}{V_S}$$

Sending end power = Line input = $V_S I_S \cos\phi_S$

Receiving end power = Line output = $V_R I_R \cos\phi_R$

$$\therefore \text{ \% Transmission efficiency} = \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S}$$

If line losses is I^2R per phase, then

$$\text{\% Transmission efficiency} = \frac{\text{Line output}}{\text{Line output + Line losses}} \times 100$$

$$= \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_R + I^2R} \times 100$$

CORONA

Definition: The phenomenon of violet glow of light, hissing noise and the production of ozone gas in an overhead transmission line is known as corona

THEORY OF CORONA FORMATION:

Some ionization is always present in the air due to cosmic rays, UV rays and radio activity; therefore under normal condition air around the conductor contains some ionized particles (free electrons and positive ions) and neutral molecules. When a potential difference is applied between the conductors, potential gradient is set up in the air which will have maximum value at the conductor surface, under the influence of potential gradient free electrons acquire a greater velocity. The Greater the applied voltage, more is the potential gradient and more is the velocity of free electrons

When the potential gradient at the conductor surface reaches about 30KV/cm, the velocity acquired by the free electrons is sufficient to strike a neutral molecule with enough force to dislodge one or more free electrons and another ion, these free electrons again accelerated and collide with neutral molecule, this produces more free electrons and ions. This process of ionization is cumulative, the result of this ionization is that either a corona is formed or spark takes place between the conductor.

FACTORS EFFECTIG CORONA

1) <u>Atmosphere:</u> In the stormy weather condition , number of free electrons and positive ions are more than the normal fair weather condition, therefore corona occurs at much less voltage in stormy weather condition.
2) <u>Shape of the conductor:</u> The rough and irregular shape of the conductor will give rise to more corona because rough surface decrease the value of break down voltage.
3) <u>Spacing between conductors:</u> The large distance between the conductor reduces the electrostatic stress between the conductors.
4) <u>Line voltage:</u> The line voltage directly effects on corona loss, for lower line voltage corona may be absent but for voltage higher than the disruptive critical voltage corona begins,more is the line voltage more corona loss occurs.
5) <u>Clearance from ground:</u> The smaller the clearance between line conductor from ground, more is the corona loss.
6) <u>Frequency :</u> It can be observed that higher the supply frequency higher is the corona loss.

ADVANTAGES OF CORONA:

1) Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electrostatic stress between the conductors
2) The increased diameter reduces the effect of transients produced by the surges.

DISADVANTAGES OF CORONA:

1) Corona is accompanied by loss of energy, this effect on the transmission efficiency of the line.
2) Ozone gas is produced by corona and may cause corrosion of the conductor due to chemical action.
3) Current drawn by the line due to corona is non sinusoidal and hence non sinusoidal voltage drop is occur in the line, this may cause inductive interference with neighboring communication lines

METHODS TO REDUCE CORONA EFFECT

1) **By increasing conductor size:** By increasing the size of the conductor the voltage at which corona occurs is reduced and hence corona occurs can be considerably reduced.
2) **By increasing conductor spacing:** By increasing the spacing between the conductor the voltage at which corona occurs can be raised, hence corona effects can be eliminated.

<u>SKIN EFFECT</u>

The tendency of alternating current to concentrate near the surface of the conductor is known as skin effect

When a conductor is carrying direct current, this current is uniformly distributed over the whole cross sectional area of the conductor, however when alternating current is passed, current does not distributed uniformly, rather it has the tendency to concentrate near the surface of the conductor.

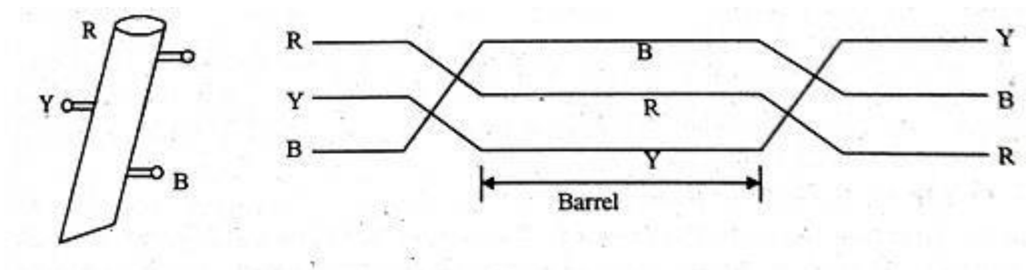
FERRANTI EFFECT

In case of long distance transmission line at no load or lightly loaded the voltage at receiving end will be more than the sending end voltage i.e. rise of voltage occur at receiving end which is called Ferranti effect.

TRANSPOSITION OF CONDUCTORS

The most common system used for over head transmission is three phase three wire system. When the conductors of three phase over head system are unsymmetrical spaced, then the constants inductance and capacitance are not the same in different phases. Due to interchange of power between the phases there is a wide difference in the resistance of conductor.

As the constants of three lines are not equal, the voltage drop i.e. IZ will be different in each line, which may result unbalanced voltage at receiving end even if the sending end voltage is balanced. Therefore practically such lines are interchange at particular distance called transposition of conductors as shown in fig. below



UNDERGROUND TRANSMISSION LINES

In highly populated areas like metropolitan cities over head transmission and distribution is impracticable and considered as hazards. For safe transmission and distribution cables can be laid under the ground called underground cable system.

Classification of UG cables:

Cables are classified in different ways.

1) According to the no. of conductors, it can be classified as
   - Single core
   - Two core
   - Three core
   - Multi core

2) According to the voltage rating it can be classified as
   - Low voltage (LT) cable operating vg up to 1kv
   - High voltage (LT) cable operating vg up to 11kv
   - Super tension (ST) cable operating vg from 22kv to 33 kv
   - Extra High voltage (EHT) cable operating vg from 33kv to 66kv
   - Extra Super tension (ST) cable operating vg is 132kv and above

3) According to the nature of application of insulation and lead sheath.
   - Belted type cable
   - H-type cable
   - SL- type cable
   - HSL- type cable
4) According to the method of improving dielectric strength.
   - Solid type cable
   - Oil filled cable
   - Gas pressure type cable
   - External oil pressure type cable.

GENERAL CONSTRUCTION OF UG CABLE

The below fig. shows general construction of cable used for under ground system. The UG cable consists of core, paper insulation, lead sheath, bedding and serving

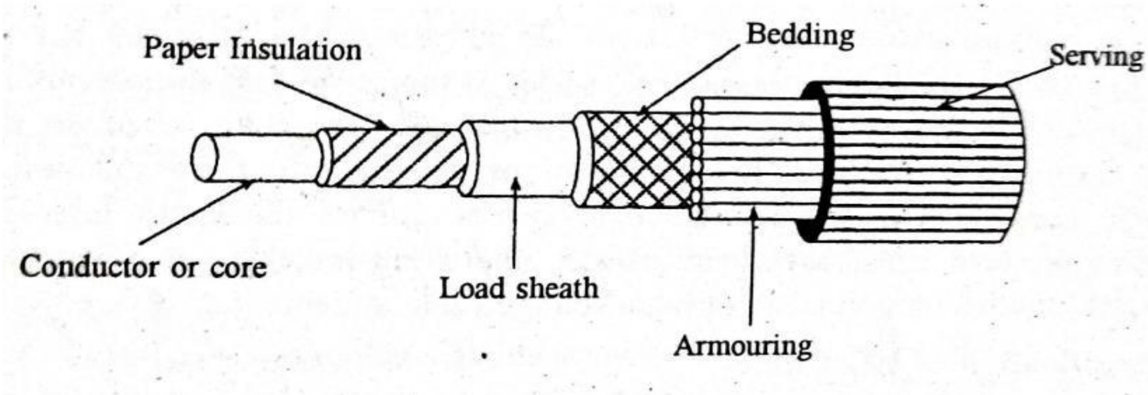


Fig. 3.1 Construction of UG cable

Conductor or core: The conductor is placed at the centre and it is made up of copper or aluminum, the cable may have one or more conductors depends upon service requirements

Paper insulation: Each core or conductor is coated with insulation of impregnated paper, varnish or rubber mineral compound. The thickness of insulation depends upon voltage rating.

Lead sheath or metallic sheath: A metallic sheath of lead or aluminum is provided over paper insulation, this sheath protects the cable from moisture, acids, alkalies.

Bedding: bedding is the layer provided over the lead sheath. It consists of fibrous material like jute or hessian tape. The bedding is provided to protect the lead sheath against corrosion and mechanical injury.

Armouring: Armouring is a layer of galvanized steel wire or tape, which protects cable from mechanical injury during laying and handling.

Serving: serving is a layer of fibrous material like jute similar to that of bedding. Serving protects armouring from atmospheric conditions

Construction of single core UG cable

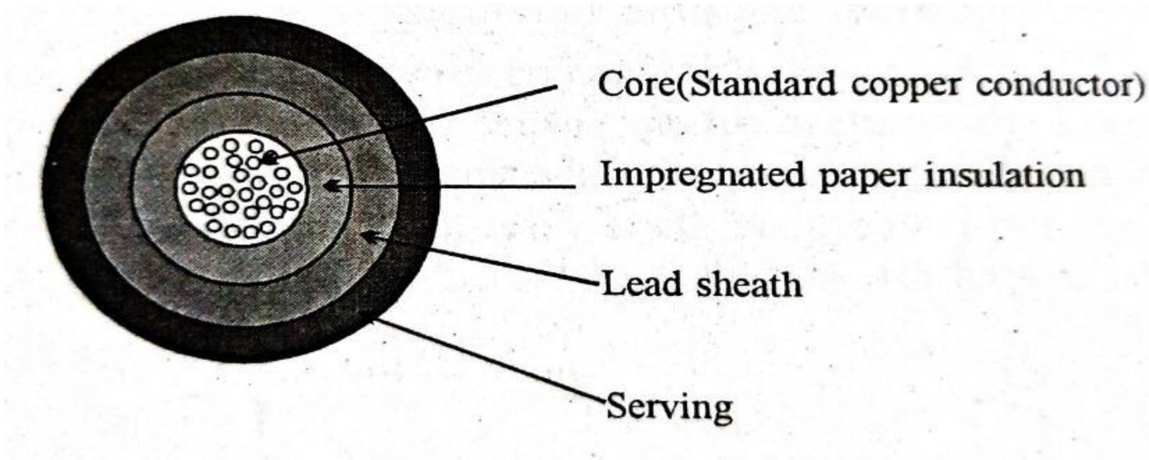
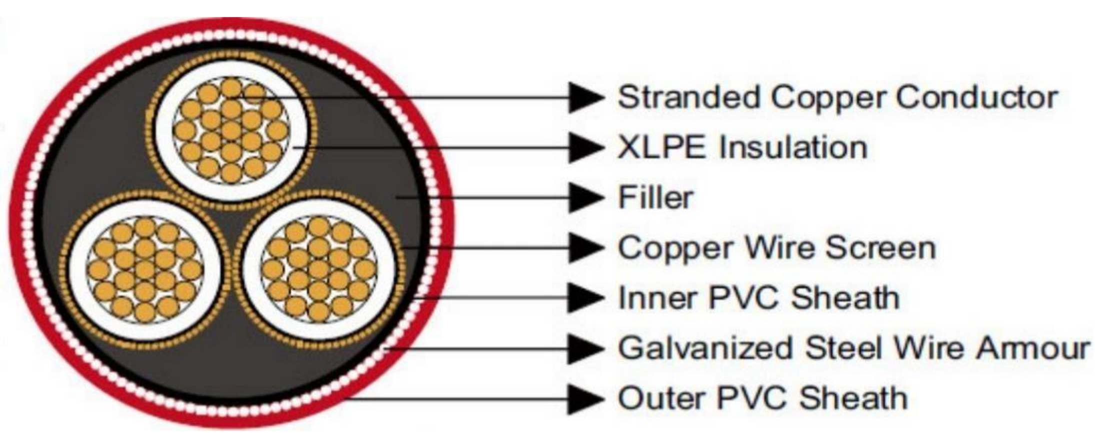


Fig. 3.3 Single core LT cable.

This cable is designed for low voltage capacity, hence electrostatic stresses developed are small and thermal conductivity is not so important. Therefore special construction is not required in low voltage cables. The cable may be single core or multicore. Fig shows single core low voltage cable.

The cable consist of stranded copper or aluminum conductor, insulated by a layers of impregnated paper or varnished cambric, to protect the cable from moisture and from mechanical handling lead sheath is provided over insulation paper. To protect lead sheath from corrosion serving of compounded material is provided over lead sheath, the single core low voltage cable is not generally armored in order to avoid excessive sheath loss.

Construction of 3 core XLPE cable



XLPE is a crossed linked polyethylene. XLPE is produced from polyethylene under high pressure with organic peroxide as additives. The application of heat and pressure is used to effect the cross linking, this causes individual molecular changes to link with one another.XLPE cable carrying large current under normal condition(90 degree)to short circuit conditions(250 degrees).For voltage up to 66 kv three core or multicore cable is preferred.

Fig shows 3 core XLPE cable, it consists of 3 stranded conductors surrounded by cross linked polyethylene as insulation, again these are surrounded by copper tape screen. All the 3 conductors are covered by armouring to protect against mechanical injury. Finally PVC sheath is used to protect the cable from corrosion, acids and alkalies.

LAYING OF UNDERGROUND CABLES

The laying of underground cables classified into three types:

1) Direct laying method
2) Draw-in method
3) Solid system method.

1)**Direct laying method:**

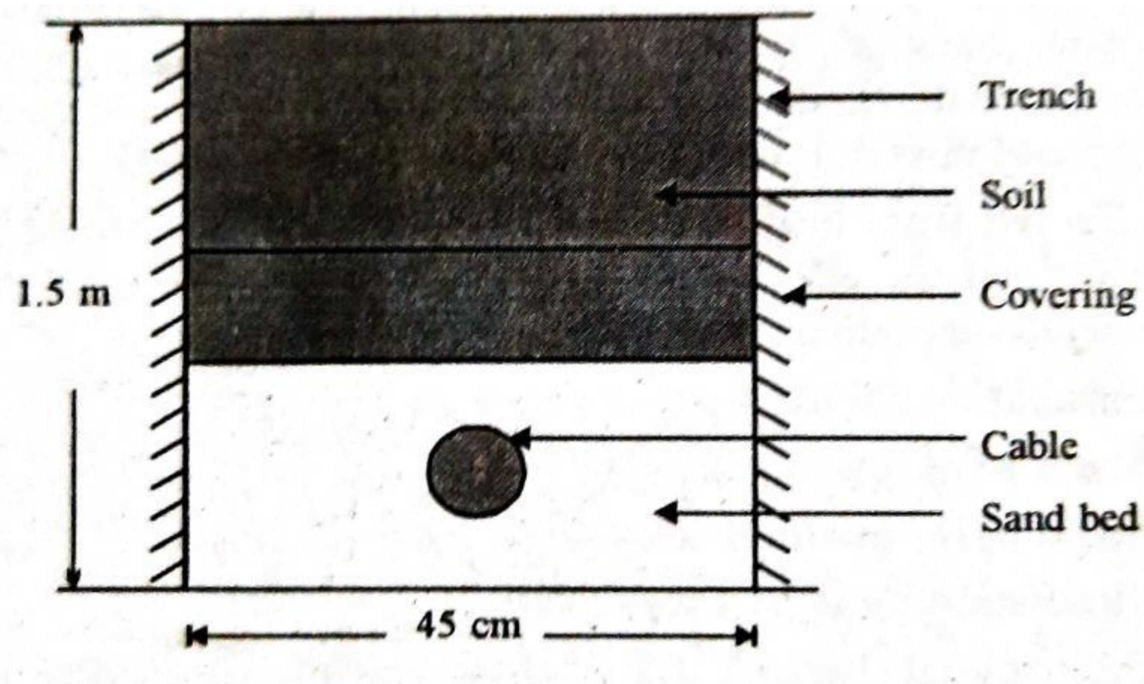


Fig. 3.7 Direct laying system

This method is very simple and cheap, a trench of about 1.5 mtr height and 45 cm width is dug, it is covered by a fine sand of about 10 cm thickness to form a sand bed. A cable is kept on this bed then again cable is covered with a another layer of sand bed and then covered with bricks and concrete to protect from mechanical injury.

Advantages:

1)This method is simple and cheap.

2) This method is free from external disturbance like traffic variations.

3) good heat dissipation condition.

Disadvantages:

1) It requires more maintenance.
2) Fault location is very difficult.
3) Alteration of work is difficult.

2)Draw-in method:

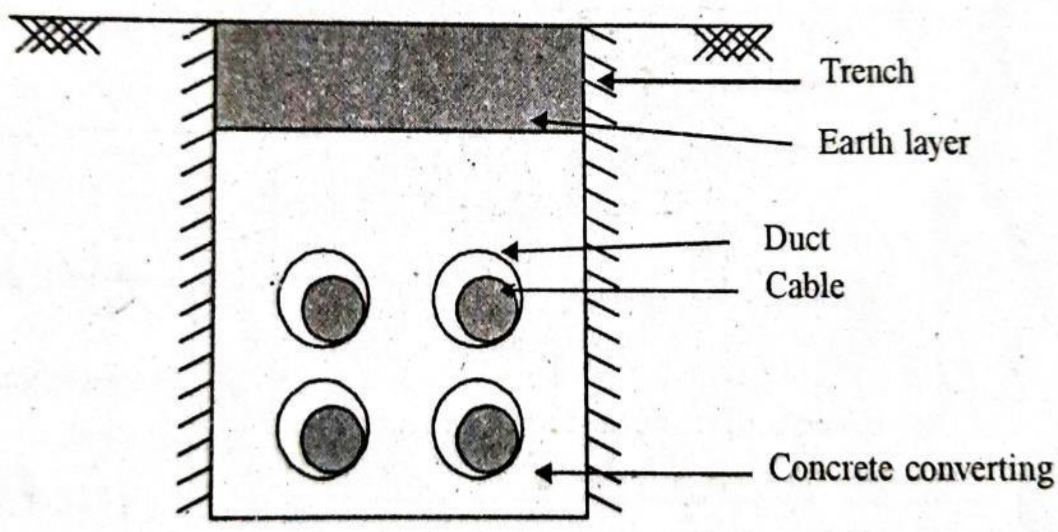


Fig. 3.8 Draw-in-system.

In this method ducts are made of either cast iron or cement concrete or glazed stone are laid in trenches side by side, a separate pipes or ducts are provided for each cable. The pipes are covered with bricks and concrete and the remaining dug out soil is filled again in the trench.

The cables are pulled into the conduit from manholes provide at suitable distances along the cable route, this metod of cable laying is used in cities where excavation is expensive and inconvenient, this method is generally used for short distances like road crossing, workshops etc. where once the conduits have been laid repairs and alteration of work can be easily done through manholes without opening the ground.

Advantages:

1) Repairing and maintenance cab be done easily without opening the ground.
2) Addition and alteration of work is possible.
3) Jointing is easy.
4) Chances of fault are less.

Disadvantages:

1) Initial cost is very high
2) The current carrying capacity of cable is reduced because of close grouping of cables.

1) **Solid system method**

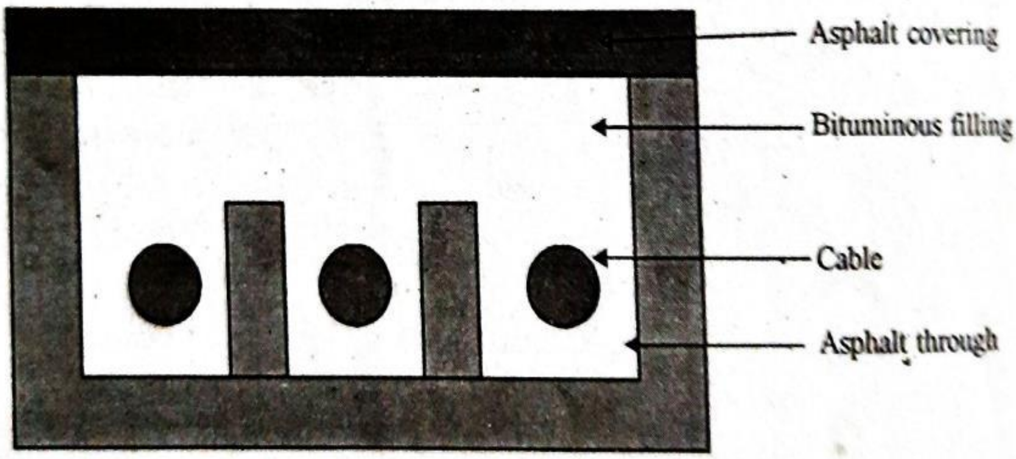


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Fig. 3.9 Solid system using Asphalt through

In this system of cable laying, cable is laid in a throughs or open pipe placed in earth along the cable route. The throughs are made up of treated wood or cast iron or stone core. After laying the cable gap is filled with asphalt or bituminous. This method of laying is rarely used because of more expensive and poor heat dissipation.

Faults in UG cables

The faults commonly occur in UG cables are

1) **Open circuit faults**: This fault is due to conductor breaking or conductors being pulled out from the joint.
2) **Short circuit fault:** This kind of fault occur when the insulation between two cable or between two multicore cables get damaged. In this case current will not flow through main core which is connected to the load but will flow directly from one conductor to another or from one core to multicore. The load is short circuited.
3) **Ground or Earth fault**: This type of fault occurs when the insulation of the cable gets damaged. During this fault current flowing from faulty cable to earth or or to sheath of the cable, current will not flow to the load.

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