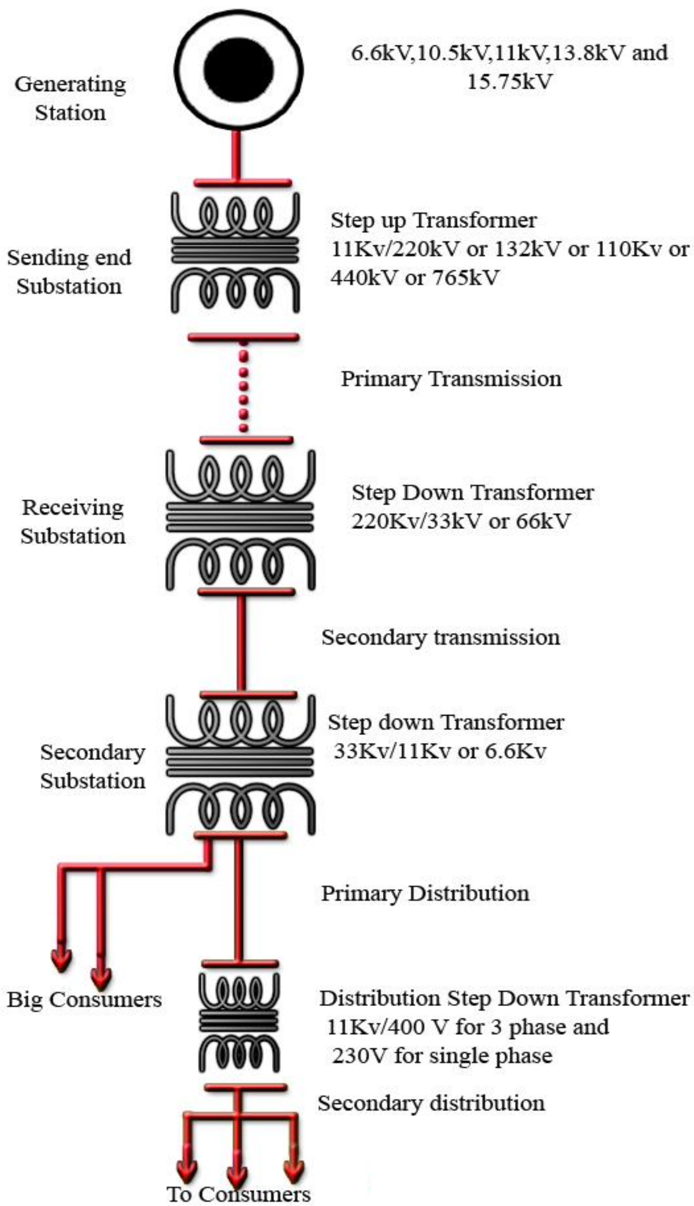
MODULE 3

ELECTRICAL POWER TRANSMISSION

Typical AC Power Supply Scheme



(1) Generating station

Electric power is produced in generating station by 3-phase alternators operating in parallel. The usual generation voltage is **11 kV**. This 11 kV is stepped up to **110kv** or **132kV** or **220kV** or **440kV** or **765kV** at the generating station with the help of 3-phase transformers.

(2) Primary transmission

The electric power at **110kv** or **132kV** or **220kV** or **440kV** or **765kV** is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. This forms the primary transmission.

(3) Secondary transmission

The primary transmission line terminates at the **receiving station (RS)** where the voltage is reduced to **33kV or 66kV** by step-down transformers. From receiving station, electric power is transmitted to various sub-stations (SS) and this forms secondary transmission.

(4) Primary distribution

At **sub-station (SS)** voltage is reduced to **11kV** using step-down transformers. The 11 kV lines run along the important road sides of the city. It may be noted that big consumers (having demand more than 50 kW) are generally supplied power at 11 kV for further handling with their own sub-stations.

(5) Secondary distribution

Primary distribution line (11 kV) terminates at distribution sub-stations (*DS*) or distribution transformer. These sub-stations are located near the consumers' localities and step down 11kV to 400V which is distributed to the consumers using 3-phase, 4-wire system (440 V between phases and 230 V between any phase and neutral)

Comparison of D.C. and A.C. Transmission

D.C. transmission

Advantages

1) Requires only two conductors
2) No inductance, capacitance, phase displacement and surge problems
3) Better voltage regulation - due to the absence of inductance, the voltage drop in a D.C. Transmission line is less than the A.C. Line.
4) No skin effect - therefore, entire cross-section of the line conductor is utilised.
5) D.C. Line requires less insulation - the potential stress on the insulation is less in case of D.C system than that in A.C. System.
6) Less corona loss and reduced interference with communication circuits
7) No stability problems and synchronising difficulties

Disadvantages

1) Electric power cannot be generated at high D.C. voltage due to commutation problems.
2) The D.C. voltage cannot be stepped up for transmission of power at high voltages.
3) The D.C. switches and circuit breakers have their own limitations

A.C. transmission

Advantages

1) Power can be generated at high voltages.
2) The maintenance of D.C. Sub-stations is easy and cheaper.
3) The D.C voltage can be stepped up or stepped down by transformers with ease and efficiency.
4) This permits high voltage transmission and distribution at safe voltage levels.

Disadvantages

1) An A.C Line requires more copper (3 conductors) than a D.C Line (2 conductors).
2) The construction of A.C Transmission line is more complicated than a D.C. Transmission line.
3) Skin effect increases the effective resistance of the line.
4) Due to line capacitance there is a continuous loss of power due to charging current even when the line is open.

From the above comparison, it is clear that high voltage d.c. transmission is superior to high voltage a.c. transmission. The present day trend is towards a.c. for generation and distribution and high voltage d.c. for transmission.

High Voltage Transmission

Advantages

1) Reduces volume of conductor material
2) Increases transmission efficiency
3) Decreases percentage line drop

Limitations

1) Cost of insulating the conductors increases
2) Cost of transformers, switchgear and other terminal apparatus increases

Various Systems of Power Transmission

1. D.C. system

(*i*) D.C. two-wire.
(*ii*) D.C. two-wire with mid-point earthed.
(*iii*) D.C. three-wire.

2. Single-phase A.C. system

(*i*) Single-phase two-wire.
(*ii*) Single-phase two-wire with mid-point earthed.
(*iii*) Single-phase three-wire.

3. Two-phase A.C. system

(*i*) Two-phase four-wire.
(*ii*) Two-phase three wire.

4. Three phase A.C. system

(*i*) Three-phase three-wire.
(*ii*) Three-phase four-wire.

Out of all the above systems universally adopted system for transmission of electric power is 3-phase, 3-wire a.c. system

Main components of overhead line

1) Conductors
2) Supporting structures - poles or towers and keep the conductors at a suitable level above the ground.
3) Insulators - attached to supports and insulate the conductors from the ground
4) Cross arms - provide support to the insulators
5) Miscellaneous items - phase plates, danger plates, lightning arrestors, anti-climbing wires

Conductor Material

Properties of a good conductor material are:

1) High electrical conductivity
2) High tensile strength to with stand mechanical stress
3) Low cost
4) Low specific gravity

Commonly Used Conductor Materials are:

1. Copper

- High conductivity
- High Tensile strength
- High current density
- homogenous, durable, high scrap value
- Cu is the ideal material that transmission & distribution but due to high cost it is used rarely

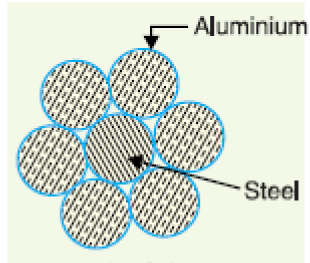
2. Aluminium

- Cheap and light compare to Cu
- Low conductivity
- Low tensile strength & high coefficient of linear expansion – causes greater sag
- for same resistance :
    - conductivity = 60% of cu
    - diameter = 1.26 of cu
    - weight of Al is almost 1/2 of cu - due to less weight, high swings occur, hence larger cross arms are required

- Aluminium is widely used as a conductor material for heavy-current transmission

3. Steel Cored Aluminium (ACSR)

- ACSR – Aluminium conductor steel reinforced
- Due to low tensile strength Al conductor produces greater sag, since it is unsuitable for long distance transmission
- To increase tensile strength, Al conductor is reinforced with a core of galvanised steel wire.



- Central core of galvanised steel is surrounded by number of Al strands. Diameter of both steel and Al wires are same cross-section of two metals generally in the ratio of 1:6 or 1:4.
- Reinforcement with steel
    - increases tensile strength,
    - keep the conductor light
    - causes smaller sag - suitable for long distance transmission
        - Towers of smaller height can be used.

4. Galvanised Steel

A protective layer of Zinc is applied to steel to prevent rusting & corrosion.

Advantages

- Very high tensile strength
- Suitable of small power transmission over small distance
- Suitable for rural area

Disadvantages

- Poor conductivity due to high resistance of steel
- Not suitable for large power transmission over long distance.

5. Cadmium Copper

- cu alloyed with cadmium(cd)
- High tensile strength (An addition of 1% or 2% cadmium to copper increases the tensile strength by about 50% and the conductivity is reduced by 15% below that of pure copper)
- can be used for exceptionally long spans
- high cost of Cadmium

Line Supports

Supporting structures for OH lines are of various types:

1. Wooden pole

- made of seasoned wood
- May rot below ground level - foundation failure (to prevent this, portion of the pole below ground level is impregnated with preservative compounds like Creosote oil.
- smaller life(20 to 25 years)
- less mechanical strength
- Require periodic inspection
- cannot be used for voltages higher than 20 kV
- used for distribution purposes at low voltages upto 11 kV

2. Steel pole

- ✓ used as substitute for wooden poles
- ✓ Greater mechanical strength
- ✓ suitable for long span
- ✓ used for distribution purpose in cities
- ✓ longer life - Need to be galvanised or painted to prolong its life
- ✓ used for distribution purposes at low voltages upto 11 kV
- ✓ there are three types:
  1. Rail pole
  2. Tubular pole
  3. Rolled steel joints

3. RCC Pole

- ✓ Great mechanical strength
- ✓ Longer life
- ✓ Permit longer spans than steel poles
- ✓ Required little maintenance
- ✓ Good insulating property
- ✓ used for distribution purposes at low voltages upto 11 kV
- Heavy weight & High cost of transportation

4. Steel Towers

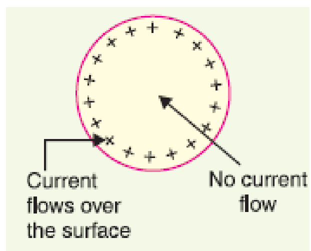
- ✓ Used for Long distance transmission at higher voltage
- ✓ permit the use of longer spans

- ✓ Can with stand most serve climatic condition
- ✓ Tower act as lightning controller - Tower footings are usually grounded by driving rods into the earth
- ✓ Two types
    - ➢ Single controller tower
    - ➢ Double controller tower - Ensure the continuity of supply

Skin Effect

- ✓ Tendency of AC current to concentrate near the surface of a conductor is known as skin effect.
- ✓ When a conductor carries DC current, current is uniformly distributed over the entire cross section of the conductor but when a conductor carries AC current it doesn't distribute uniformly, rather it has tendency to concentrate near the surface of conductor.

Causes for skin effect



- ➢ A solid conductor can be considered as made of large number of stands, each carries a small part of current
- ➢ Inductance "L" of each strand will vary according to its position. Strands near the centre are surrounded by greater magnetic flux and so they have larger L (=NΦ/I) & X_L (= $2\pi f L$) than the stands near the surface. High reactance of inner strands causes AC current to flow near the surface of conductor.
- ➢ Due to skin effect, the effective area of cross-section of conductor through which current flows is reduced consequently resistance of conductor is slightly increased when AC current flows.

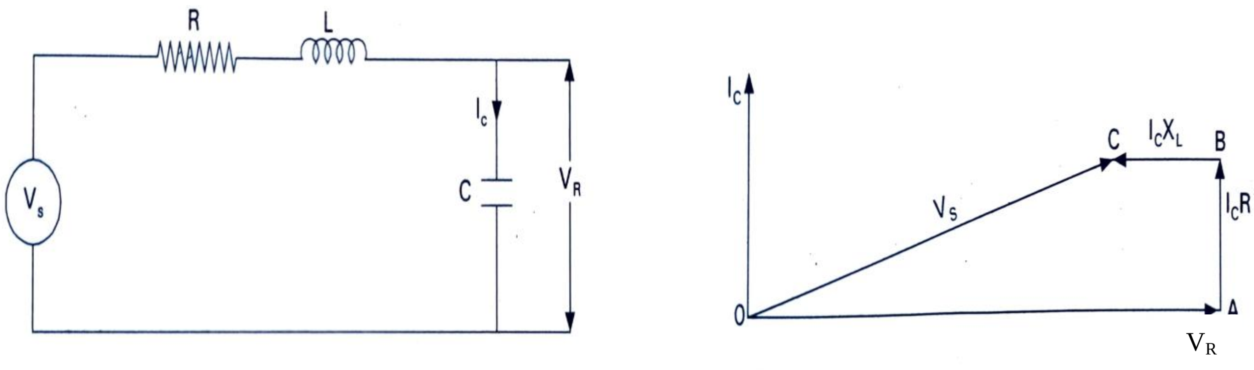
Skin Effect depends upon

1) Nature of material
2) Diameter of wire - increases with diameter
3) Frequency of supply - increases with frequency
4) Permeability - increase with increase in permeability.
5) Shape of conductor - more for solid, less for stranded
6) Skin effect is negligible when $\begin{cases} \text{current is low (f <50 Hz)} \\ \text{conductor diameter is small (d<1cm).} \end{cases}$

Ferranti Effect

When a medium or long transmission line is open circuited or lightly loaded then receiving end voltage (V_R) will be more than Sending end voltage V_S. This phenomenon is known as Ferranti Effect.

Consider a long transmission line:



(a) OH transmission line

(b) Vector Diagram ($V_R > V_S$) of Ferranti Effect

C = capacitance assumed to be concentrated (lumped) at receiving end

I_c = charging current leads V_S
R = Resistance
L = Inductance
Rise in voltage=OA-OC (neglecting I_cR)

$= I_c X_L$

Rise in voltage is due to emf induced in line inductance ($I_c X_L$) due to capacitance charging current I_c.

Hence both inductance and capacitance are necessary to cause Ferranti effect

CORONA

The phenomenon of violet glow, hissing noise and production of ozone gas in an overhead transmission line is known as **corona.**

Theory of Corona formation

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, then the air surrounding the conductors is subjected to electrostatic stresses and ionization starts. The voltage at which the ionization starts is known as critical disruptive voltage. When the voltage is gradually increased beyond ***critical disruptive voltage***, a faint luminous glow of violet colour appears around the conductors with a hissing noise. This phenomenon is called visual corona and the voltage at which it occurs is known as ***visual critical voltage***.

- In case of AC, if the conductors are polished and smooth the corona is same throughout the length of the conductor otherwise the rough points will appear brighter.

- In case of DC, the positive conductor has uniform glow and negative conductor has spotty glow
- If the spacing between the conductors is not very large compared to their diameter, spark over takes place due to insulation break down of air before corona is observed.

Power loss due to corona

$$\boxed{P = 242{\cdot}2\left(\frac{f+25}{\delta}\right)\sqrt{\frac{r}{d}}\left(V-V_c\right)^2 \times 10^{-5}\ \text{kW / km / phase}}$$

f = supply frequency in Hz

V = phase-neutral voltage (r.m.s.)

V_c = disruptive voltage (r.m.s.) per phase

δ = air density factor (Under standard conditions, δ = 1)

Effect of Corona

(1) A violet glow is observed around the conductor

(2) Produces hissing noise

(3) Produces ozone

(4) At rough surfaces glow will be more

(5) It involves energy loss in the form of light, heat sound and chemical action

Factors Affecting Corona

Atmosphere - As corona is formed due to ionization of air surrounding the conductors, therefore, it is affected by the physical state of atmosphere. In *stormy weather*, number of ions is more than normal so corona occurs at much less voltage.

Conductor size - The corona effect depends upon the shape and conditions of the conductors. The *rough and irregular surface* will give rise to more corona because unevenness of the surface decreases the value of breakdown voltage. Corona is more in *stranded conductor* than in a solid conductor

Spacing between conductors - If the spacing between the conductors is made very large as compared to their diameters, corona does not appear. It is because larger distance between conductors reduces the electro-static stresses at the conductor surface, thus avoiding corona formation.

Line voltage - If line voltage it is low, condition of air around the conductors does not change and no corona is formed. If the line voltage high, electrostatic stresses developed at the conductor surface causes ionization of air, then corona is formed.

Advantages

(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 stresses between the conductors.

(2) Corona reduces the effects of transients produced by surges

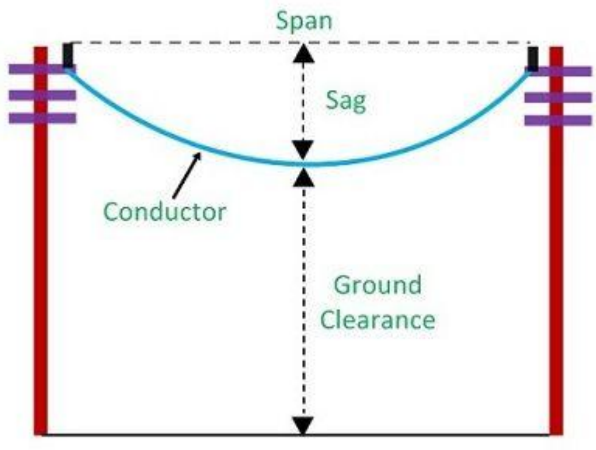
Disadvantages

1) It causes power loss and reduces transmission efficiency
2) The effective capacitance of the conductors is increased due to increased diameter
3) Charging current increases
4) Corrosion due to ozone formation
5) Interference with neighboring communication lines

Sag in Overhead Lines

While erecting an overhead line, if the conductors are too much stretched between supports to save conductor material, conductor may break due to excessive tension. In order to have a safe tension in the conductors, they are not fully stretched but are allowed to have a dip or **sag**.

The difference in level between points of supports and the lowest point on the conductor is called sag.



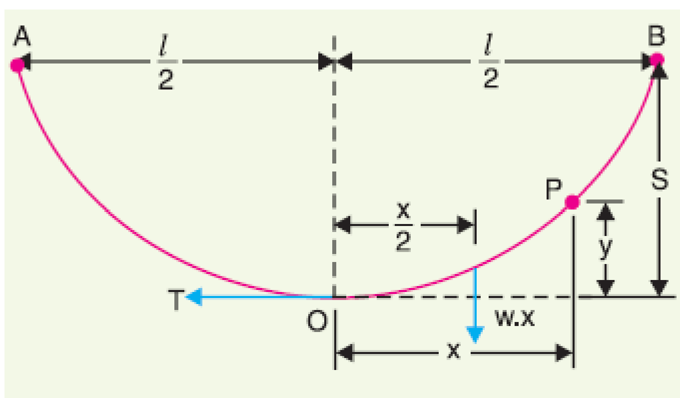
The factors affecting the sag in an OH line

1) **Weight of the conductor -** Heavier the conductor, greater will be the sag. In cold places where ice coating takes place, the conductor weight increases and hence Sag increases.
2) **Length of the span -** As the span increases the sag also increases i.e., Sag is directly proportional to span.
3) **Tensile strength -** The Sag is inversely proportional to the tensile strength.
4) **Temperature -** As the temperature increases, the length of the conductor also increases and so the Sag increases.
5) **Wind pressure -** Greater is the wind pressure more will be the swing and hence sag.
6) **Ice weight -** Ice will be deposited on the conductor and increases the conductor weight. Hence sag increases.

Calculation of Sag

1) When supports are at equal levels

Consider a conductor between two equilevel supports A and B with O as the lowest point as shown in Figure.



Let

l = Length of span
w = Weight per unit length of conductor
T = Tension in the conductor.

Consider a point P on the conductor. Taking the lowest point O as the origin, let the co-ordinates of point P be x and y. Assuming that the curvature is so small that curved length is equal to its horizontal projection (i.e., OP = x), the two forces acting on the portion OP of the conductor are :

(a) The weight wx of conductor acting at a distance x/2 from O.

(b) The tension T acting at O.

Equating the moments of above two forces about point O, we get,

$$T\,y = w\,x \times \frac{x}{2}$$

$$y = \frac{w\,x^2}{2\,T}$$

The maximum sag (S) is represented by the value of y at either of the supports A and B.

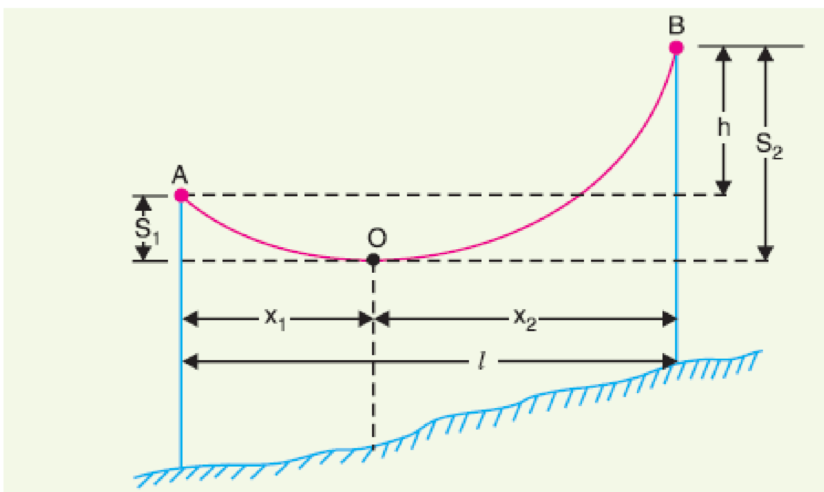
At support A,

$$x = l/2 \quad \text{and} \quad y = S$$

$$\text{Sag,} \quad S = \frac{w(l/2)^2}{2T} = \frac{w\,l^2}{8\,T}$$

2) When supports are at unequal levels

In hilly areas, we generally come across conductors suspended between supports at unequal levels. Figure shows a conductor suspended between two supports A and B which are at different levels. The lowest point on the conductor is O.



Let

l = Span length

h = Difference in levels between two supports

x_1 = Distance of support at lower level (i.e., A) from O

x_2 = Distance of support at higher level (i.e. B) from O

T = Tension in the conductor

If *w* is the weight per unit length of the conductor, then,

$$\text{Sag } S_1 = \frac{w\,x_1^{2*}}{2T}$$

$$\text{Sag } S_2 = \frac{w\,x_2^{2}}{2T}$$

Also $\quad x_1 + x_2 = l \quad \ldots(i)$

Now $\quad S_2 - S_1 = \frac{w}{2T}[x_2^2 - x_1^2] = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$

$\therefore \quad S_2 - S_1 = \frac{w\,l}{2T}(x_2 - x_1) \quad [\because x_1 + x_2 = l]$

But $\quad S_2 - S_1 = h$

$\therefore \quad h = \frac{w\,l}{2T}(x_2 - x_1)$

or $\quad x_2 - x_1 = \frac{2\,Th}{w\,l} \quad \ldots(ii)$

Solving exps. (*i*) and (*ii*), we get,

$$x_1 = \frac{l}{2} - \frac{T\,h}{w\,l}$$

$$x_2 = \frac{l}{2} + \frac{T\,h}{w\,l}$$

Having found x_1 and x_2, values of S_1 and S_2 can be easily calculated.

Transmission line constants

Transmission lines are basically electrical circuits with uniformly distributed constants along the length. These constants are:

- Resistance (R)
- Capacitance (C)
- Inductance (L)

Resistance

It is the property of every material due to which it offers opposition to the flow of current.

$R = \frac{\rho l}{A}$ $\quad$ ρ = Resistivity (Ωm)

l = length (m)

A = area of cross section (m^2)

Let R_1 & R_2 be the resistance of conductor at t_1°C & t_2°C

$$R_2 = R_1 [1 + \propto_1 (t_1 - t_2)]$$

Where $\propto_1 =$ temperature coefficient of resistance at t_1°C

$$\propto_1 = \frac{\propto_0}{1 + \propto_0 \ t_1}$$

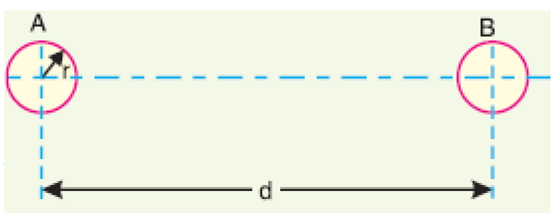
Where $\propto_0$ = temperature coefficient of resistance at 0°C

Inductance

A current carrying conductor is always surrounded by concentric circles of magnetic flux. In case of A.C. supply this flux setup around the conductor will be varying in magnitude and links with the same conductor as well as with other conductors. Due to these flux linkages the line possesses inductance.

$$L = \frac{Flux\ linkage}{Current} = \frac{N\phi}{I} \qquad \text{(weber per turns or Henry)}$$

Inductance of a Single Phase Line



Consider a single phase overhead line consisting of two parallel conductors *A* and *B* spaced *d* metres apart. Let the radius of each conductor be r

Inductance of conductor A, $L_A = \left[\frac{1}{2} + 2log_e \frac{d}{r}\right] \times 10^{-7}$ H/m

Loop inductance = $2L_A$ $= \left[1 + 4log_e \frac{d}{r}\right] \times 10^{-7}$ H/m

If relative permeability μ_r is to be considered then

Inductance of conductor A, $L_A = \left[\frac{1}{2}\mu_r + 2log_e \frac{d}{r}\right] \times 10^{-7}$ H/m

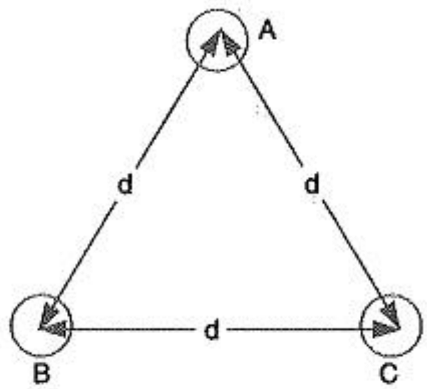
Loop inductance = $2L_A$ $= \left[\mu_r + 4log_e \frac{d}{r}\right] \times 10^{-7}$ H/m

Inductance of 3-Phase Line

a) Symmetrical spacing

Consider a 3-phase overhead transmission line with symmetrical spacing ie, three conductors are equally spaced

d = spacing (distance) between conductors.
R = radius of each conductor



Inductance of each conductor is same

$$L_A = L_B = L_C = \left[\frac{1}{2} + 2log_e\,\frac{d}{r}\right] \times 10^{-7} \quad \text{H/m}$$

b) Unsymmetrical spacing (transposed line)

Consider a 3-phase overhead transmission line irregularly spaced as shown in figure.

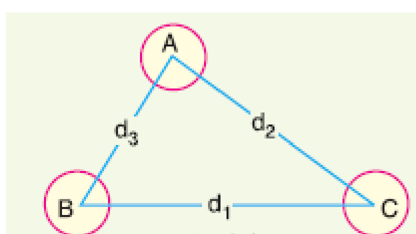


Fig. 9.8

$$L_A = L_B = L_C = \left[\frac{1}{2} + 2\log_e\,\frac{D_{eq}}{r}\right] \times 10^{-7} \quad \text{H/m}$$

$D_{eq} = \sqrt[3]{d_1 d_2 d_3}$ = *equivalent equilateral spacing or* GMD (*geometrical mean distance*)

Capacitance

Any two conducting surfaces or plates separated by some dielectric medium (may be air) and between which a p.d. is applied forms a capacitor.

$$\text{Capacitance, } C = \frac{Q}{V} \quad \text{farad.}$$

In case of the overhead line the two conductors form the two plates of a capacitor. The air acts like a dielectric medium. This capacitance is uniformly distributed over the entire length of the line as shown in Fig. 3.9. When AC supply is given to this line, it draws a leading current and is known as charging current.

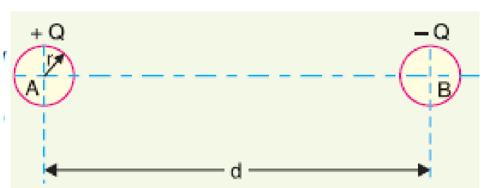
$$\text{Charging current, } I_C = \frac{V}{X_c} = \frac{V}{\frac{1}{2\pi f C}} = 2\pi f C V$$

If the line capacitance is more it draws more charging current I_C, which compensates the lagging component of line current. Hence net current in the line is reduced. The advantages of reduction in line current are :

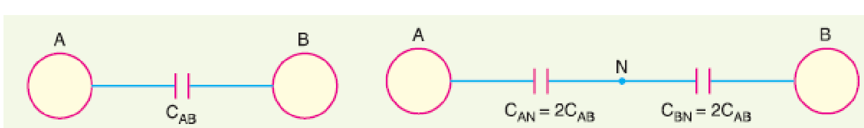
- ✓ line losses are reduced.
- ✓ voltage drop is reduced, hence voltage regulation is improved.
- ✓ power factor improves.
- ✓ line efficiency increases.
- ✓ load capacity increases.

Capacitance of a 1ϕ Transmission Line

Consider a 1-phase overhead transmission line as shown in figure



Since potential of the mid-point between the conductors is zero, this midpoint is the neutral plane. Thus the ***capacitance*** **to neutral** for the two wire line is twice the **line-to-line capacitance**.



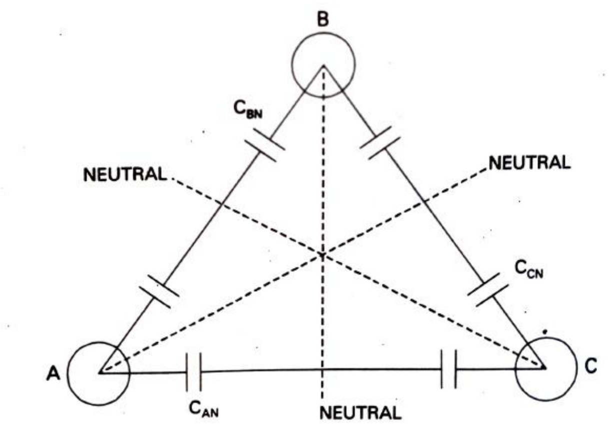
Capacitance to neutral	$C_{AN} = C_{BN} = \dfrac{2\pi\varepsilon_0}{\log_e \frac{d}{r}}$	F/m

Line-to-line capacitance	$C_{AB} = \dfrac{\pi\varepsilon_0}{\log_e \frac{d}{r}}$	F/m

Capacitance of a 3ϕ Transmission Line

a) **Symmetrical Spacing**

Consider a 3-phase overhead transmission line with symmetrical spacing ie, three conductors are equally spaced



Capacitance of each conductor w.r.t neutral is same

$$\mathbf{C_{AN} = C_{BN} = C_{CN} = \frac{2\pi\varepsilon_0}{\log_e \frac{d}{r}} \quad F/m}$$

b) **Unsymmetrical spacing**

$$\mathbf{C_{AN} = C_{BN} = C_{CN} = \frac{2\pi\varepsilon_0}{\log_e \frac{D_{eq}}{r}} \quad F/m}$$

$D_{eq} = \sqrt[3]{d_1 d_2 d_3}$ = equivalent equilateral spacing or GMD (geometrical mean distance)

Transposition

- ✓ In case of transmission lines with unsymmetrical conductors (unequal spacing) inductance, capacitance and resistance of each phase are not the same. This results in an equal voltage drop in three phases. Therefore, the receiving end voltage (V_R) is not same in all phases.
- ✓ In order to make the voltage drop equal in all conductors, position of conductors are interchanged at regular intervals along the line. This is known as **transposition**. Thus three possible arrangement of conductor exist for one third of the total length of transmission line.
- ✓ When communication line run parallel with overhead line high voltages are induced in communication line. To reduce this induced voltage communication line is also transposed.

Classification of Overhead Transmission Lines

Depending upon the length and operating voltage, the overhead transmission lines are classified as

Short transmission lines

- ✓ length of an overhead transmission line is upto about 50km
- ✓ Line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line.
- ✓ Due to smaller length and lower voltage, the capacitance effects are small and hence can be neglected.
- ✓ For studying the performance of a short transmission line, only resistance and inductance of the line are taken into account.

Medium transmission lines

- ✓ Length of an overhead transmission line is about 50-150 km
- ✓ Line voltage is moderately high (>20 kV < 100 kV)
- ✓ Due to sufficient length and voltage of the line, the capacitance effects are taken into account.
- ✓ For purposes of calculations, the distributed capacitance of the line is divided and lumped (concentrated) in the form of capacitors shunted across the line at one or more points.

Long transmission lines

- ✓ Length of an overhead transmission line is more than 150 km
- ✓ Line voltage is very high (> 100 kV)
- ✓ For purposes of calculations, the line constants are considered uniformly distributed over the whole length of the line and rigorous methods are employed for solution.

Performance Characteristics of Single Phase Short Transmission Lines

Effects of line capacitance are neglected for a short transmission line. Therefore, only resistance and inductance of the line are taken into account for studying the performance. The equivalent circuit of a single phase short transmission line is shown in Fig. 10.1 (*i*). Here, the total line resistance and inductance are shown as concentrated or lumped.

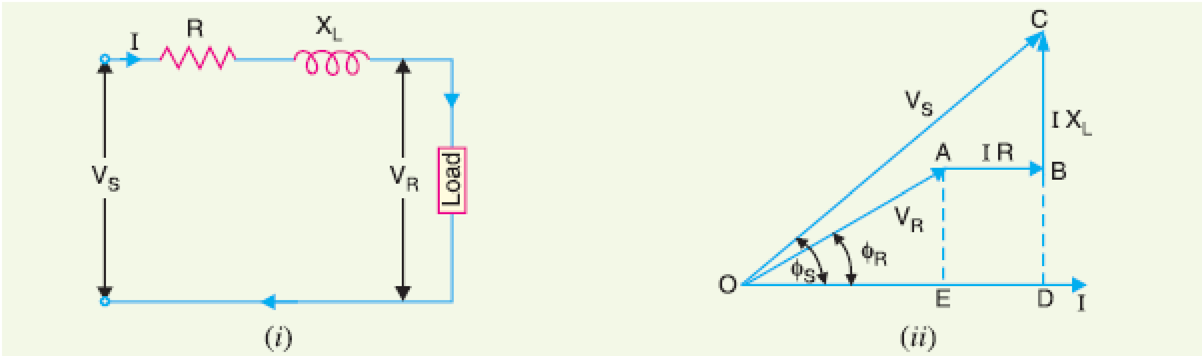


Fig. 10.1

The phasor diagram of the line for lagging load power factor is shown in Fig. 10.1 (*ii*). From the right angled traingle *ODC*, we get,

$$(OC)^2 = (OD)^2 + (DC)^2$$

or

$$V_S^2 = (OE + ED)^2 + (DB + BC)^2$$

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

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

(*i*) %age Voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100$

(*ii*) Sending end *p.f.*, $\cos\phi_S = \dfrac{OD}{OC} = \dfrac{V_R \cos\phi_R + IR}{V_S}$

(*iii*) Power delivered $= V_R I_R \cos\phi_R$

Line losses $= I^2 R$

Power sent out $= V_R I_R \cos\phi_R + I^2 R$

%age Transmission efficiency $= \dfrac{\text{Power delivered}}{\text{Power sent out}} \times 100$

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

Maximum voltage regulation of a distribution line should be

Urban area	– 6%
Suburban area	– 5%
Rural area	– 3%

Maximum voltage regulation of 33kV & 11kV feeders should not exceed the following limits

>33 kV	: –12.5% to + 10%
upto 33 kV	: –9.0% to + 6.0%
LV	: –6.0% to + 6.0%