Transmission Lines Parameters

- » Introduction to transmission lines (T.L)
- » Types of Overhead line Conductors.
- » Resistance Calculation.
- » Inductance Calculation.
- » Capacitance Calculation.

☑ Overhead transmission System

1. Although underground AC transmission would present a solution to some of environmental and aesthetic (جمالي) problems in overhead transmission lines, there are technical and economic reasons that make the use of underground ac transmission not preferable.

2. The overhead transmission System is mostly used at high voltage level mainly because it is much cheaper Compared to underground system.

3. The selection of an economical voltage level for the T.L is based on the amount of power and the distance of transmission.

   ⟹ The economical voltage between lines in 3ϕ is given by :-

$$V = 5.5 \sqrt{0.62 L + \frac{P}{100}}, \text{ where}$$

V = line voltage in kV.
L = Length of T.L in km.
P = Peak real power in kW.

4. Standard transmission voltages are established
   - → HV (30 – 230) kV
   - → EHV (230 – 765) kV
   - → UHV (765 – 1500) kV

Types of overhead line conductors

based on → Conducting material
based on → the strength

1. The material to be chosen for conduction of power should be such that it has the lowest resistance. This would reduce the transmission losses.

(a) *

1) Silver resistivity $1.6\ \mu\Omega cm$
2) Copper resistivity $1.7\ \mu\Omega cm$
3) gold resistivity $2.35\ \mu\Omega cm$
4) aluminium resistivity $2.65\ \mu\Omega cm$

Problems: cost, theft, supply is quit limitted

(b) *

The weight of material (density)

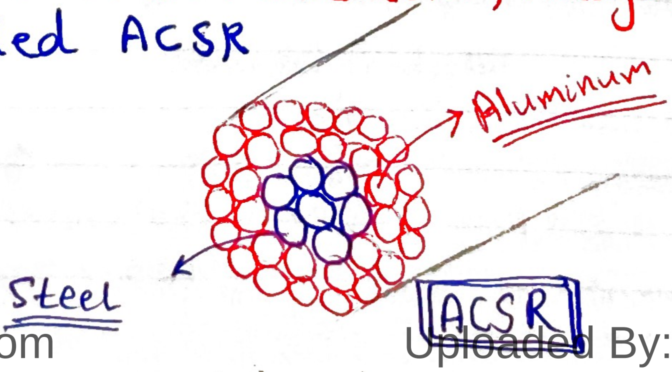
1) aluminium
2) Copper
3) Silver
4) gold

note: The weight the aluminium condu... having the same resis... as that of copper is roughly 60% less t... of copper.

2. In the early days of the transmission of electric power, conductors where usually copper, but aluminum conductors have completly replaced copper for overhead lines because of the much lower cost and lighter weight of an aluminum conductor compared with a copper conductor of the same resistance.

3. The most commonly used conductors for high voltage transmission lines are:-

* AAC — ALL-Aluminum Conductors
* AAAC — All-Aluminum-Alloy Conductors (سبائك الألمنيوم)
* ACSR — Aluminum Conductor, Steel-Reinforced (معزز، مقوى)
* ACAR — Aluminum Conductor, Alloy-Reinforced.
* Expanded ACSR



» Aluminum-alloy conductors have higher tensile (قوة الشد) strength than the ordinary aluminum.

» ACSR consists of a central core of steel strands surrounded by layers of aluminum strands.

» ACAR has a central core of higher-strength aluminum surrounded by layers of aluminum.

» Expanded ACSR has a filler such as (paper, fiber) separating the inner steel strands from the outer aluminum strands. The filler gives a larger diameter (and hence, lower corona) for a given conductivity and tensile strength. Expanded ACSR is used for some extra-high voltage lines.

Stranded Conductors

» To increase the area stranded conductors are used. This increase the flexibility and the ability of the wire or cable to be bent.

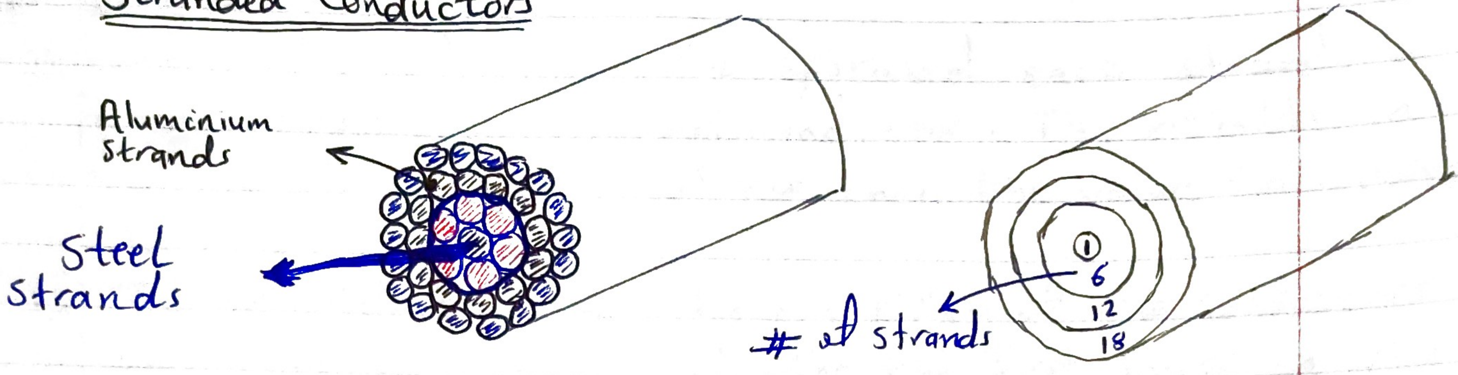
» Generally the circular conductors of the same size are used for spiralling.

» Each layer of strands is spiraled in the opposite direction of its adjacent layer. This spiraling holds th strands in place (can't open up easily)

Stranded Conductors

- ⓐ easier manufacturing (larger sizes)
- ⓑ better mech. strength, as well as better handling, much more flexible

Stranded Conductors



Total # of strands → 1, 7, 19, 37, 61, 91

Line Resistance :-

- R_{ac} ~
- R_{dc} –

» The dc resistance of a solid round conductor at a specified temperature is given by :-

$$R_{dc} = \frac{\rho^{T} l}{A} \ \Omega \qquad (*)$$

where

- $\rho \equiv$ conductor resistivity at temp T (°C)
- $l \equiv$ conductor length (m)
- $A \equiv$ Conductor cross-sectional area (m²)

» Conductor resistance depends on the following factors :-
[1] Temperature [2] Spiraling [3] Frequency

[1] Temperature

Resistivity of conductor metals varies linearly over normal operating temperatures according to

$$\rho^{T_2} = \rho^{T_1}\left(\frac{T_2 + T}{T_1 + T}\right)$$

⇒ The conductor resistance increase as temp increases.

$$R_2 = R_1\left(\frac{T_2 + T}{T_1 + T}\right)$$

(R_2 or R^{T_2}; R_1 or R^{T_1})

T ≜ temperature constant that depends on the conductor material.

⊙ For Aluminum
T ≅ 228

2 Spiraling

» Since a stranded conductor is spiraled, each strand is longer than the finished conductor. This results in a slightly higher resistance than the value calculated using equation (*).

» The spiralling increase the resistivity of the conductors to an extent about 2% for the first layer on the centre conductor, about 4% for the second layer, and so on.

3 Frequency "skin effect"

» When ac flows in a conductor, the current distribution is not uniform over the conductor cross-sectional area and the current density is greatest at the surface of the conductor. This causes the ac resistance to be somewhat higher than the dc resistance. This behavior is known as skin effect.

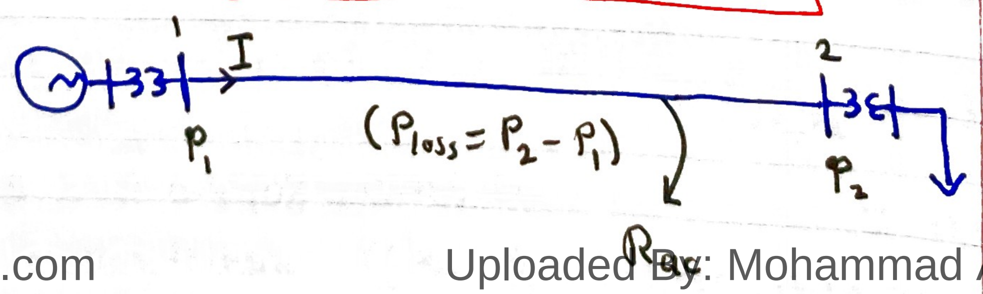
» This uneven distribution does not assume large proportion at 50 Hz up to a thickness of about 10 mm.

» At (50-60) Hz, the ac resistance is about 2 percent higher than the dc resistance.

Note:-

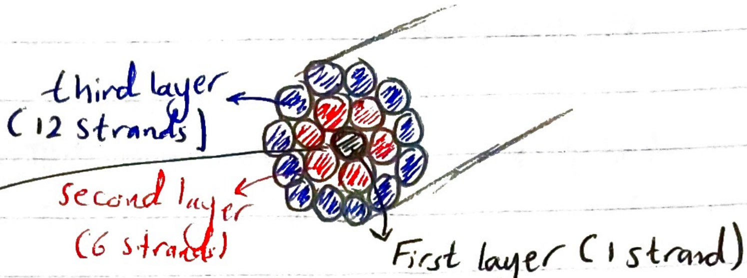
The ac resistance or effective resistance of a conductor is

$$R_{ac} = \frac{P_{loss}}{I^2} \ \Omega$$



example A copper Cable of 19 strands, each strand 2.032 mm in a diameter is Laid over a length of 1km. The temperature rise was found to be 40. Find the value of total R for this cable.

Solution



total # of strands = 19

For 1 strand 

$$A_{1s} = \frac{\pi d^2}{4} = \frac{\pi (0.2032)^2}{4}$$

$$= 0.03243 \ cm^2$$

at 20°C

$$R_{1s} = \frac{\rho l}{A} = \frac{1.7 * 10^{-6} * 100000}{0.03243}$$

$$= 5.24 \ \Omega$$

?!

$$R_{total} = \frac{5.24}{19} = 0.2758 \ \Omega$$

1. Spiraling effect

First layer: $R_{1con} = 5.24$

second layer: $R_{6con} = \frac{5.24}{6} = 0.8733 \ \Omega \xrightarrow{\text{Spir. eff}} R_{6con} = 0.8733 * 1.02$

$$= 0.8908 \ \Omega$$

third layer: $R_{12con} = \frac{5.24}{12} = 0.4367 \ \Omega \xrightarrow{\text{Spir. eff}} R_{12con} = 0.4367 * 1.04$

$$= 0.4541 \ \Omega$$

$$R_{cable} = 5.24 \parallel 0.8908 \parallel 0.4541$$

$$R_{total} = 0.2844 \ \Omega$$

《3.1 % higher when we Consider spiraling effect》

[2] Temperature effect

$$R_2 = R_1 \left(\frac{T + T_2}{T + T_1}\right) = 0.2844 \left(\frac{234.5 + 60}{234.5 + 20}\right)$$

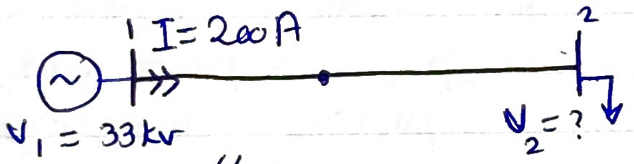
R_2 ← the resistance at new temp.

(for copper ← 234.5)

$$= 0.329\ \Omega$$

$R = 0.2758\ \Omega$ ← compared with (19.3 %)

note: If the cable was carrying a current 200 A, the drop from one end to the other end would be about 65.8 volts due to resistance.



(($V_1 - V_2$ = voltage drop))

[3] frequency effect

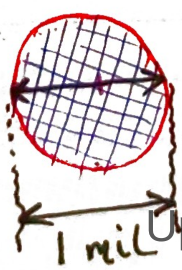
At freq 50 Hz the skin depth in a copper is of the order of 10 mm and hence would not have any significant effect as far as this problem is concerned.

Note:

» In english units, conductor cross-sectional area is expressed in circular mils (cmil)

» A circular mil (cmil) is a unit of area, equal to the area of a circle with a diameter of one mil (one thousandth of an inch)

* one inch = 1000 mils
mil = 0.001 inch
= 0.0254 mm



Area = 1 cmil