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Power Systems Study Material

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Power System: It is a system which deals with principles of power generation, transmission, distribution in order to supply electrical energy to consumers on economical basis.

Transmission lines

Transmission lines are made of conductors and the material used is aluminum because it's is cheaper and lighter.

Transmission line conductor configurations are of two types i.e., solid and stranded conductors.

The disadvantages of solid conductors include skin effect and reduced flexibility.

Skin effect:

It is the no uniform distribution of current flowing through a conductor.

Effects:

Effective radius of the conductor decreases thereby decreasing the effective area of the conductor, which results in increase of resistance and losses.

Skin effect increases with increase in conductor size, increase in relative permeability of the conductor material, and increase in frequency of current flowing through the conductor.

Skin effect is not mutual effect and for DC supply skin effect is zero.

Proximity effect:

It is a mutual effect.

When two conductors carrying current in same/opposite direction are placed near to each other, then there will be non-uniform distribution of current flow in both the conductors. This phenomenon is called proximity effect.

Proximity effect decrease with increase in distance between the two conductors.

Proximity effect is more in underground cables.

Stranded conductors:

Stranded conductor is formed by bundling and twisting a group of small conductors.

The advantages of bundled conductors includes decrease in skin effect and increased flexibility.

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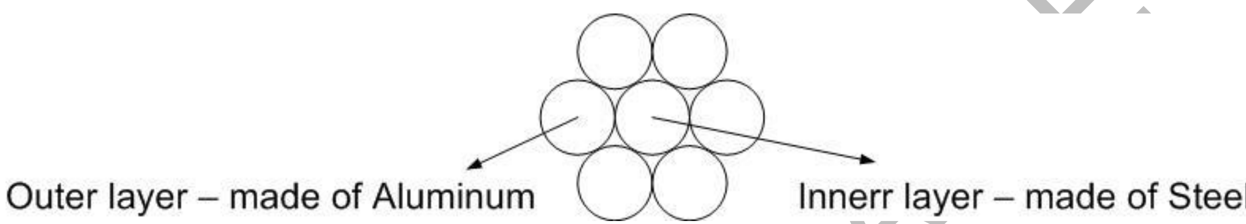
The disadvantage of stranded conductor made of single material includes increased sag. To overcome this composite (made of more than one material) stranded conductors are used.

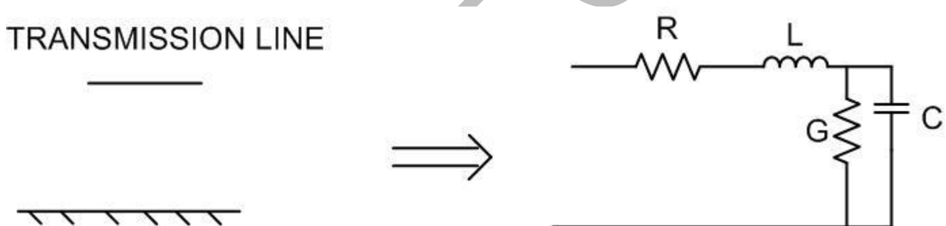
The example of composite stranded conductors is ACSR (aluminum conductor steel reinforced) in which steel is inner layer and aluminum is outer layer.

The below figure shows a two layer ACSR conductor having 7 strands. For a n layer conductor total number of strands are $3N^2 - 3N + 1$.



Line parameter calculations:

Figure below shows a transmission line and its equivalent circuit.



Inductance Calculations.

1) Inductance of a single conductor:

The flux produced by single conductor is split into internal and external flux i.e.,

$\phi = \phi_{internal} + \phi_{external}$, similarly flux linkages are given by $\lambda = \lambda_{internal} + \lambda_{external}$.

Now inductance is given by $= \frac{\lambda}{I}$, where I is the current flowing through the conductor.

Internal flux linkage ($\lambda_{internal}$):

Consider a straight round (cylindrical) conductor, the cross-section of which is shown in Fig below.

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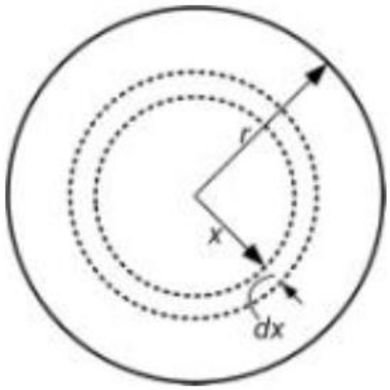

The conductor has a radius of *r* and carries a current *I*. Ampere's law states that the magneto motive force (mmf) in ampere-turns around a closed path is equal to the net current in amperes enclosed by the path. We then get the following expression

$$mmf = \oint H.ds = I. - (1)$$

where *H* is the magnetic field intensity in At/m, *s* is the distance along the path in meter and *I* is the current in ampere. Let us denote the field intensity at a distance *x* from the center of the conductor by H_x. It is to be noted that $H_x$is constant at all points that are at a distance *x* from the center of the conductor. Therefore H_x is constant over the concentric circular path with a radius of *x* and is tangent to it. Denoting the current enclosed by I_x we can then write

$$\oint H_x dx = I_x \rightarrow H_x = \frac{I_x}{2\pi x} \text{ - (2)}$$

If we now assume that the current density is uniform over the entire conductor, we can write

$$\frac{I}{\pi r^2} = \frac{I_x}{\pi x^2} \rightarrow I_x = \frac{\pi x^2}{\pi r^2} I \text{ - (3)}$$

Substituting (3) in (2) gives

$$H_x = \frac{I}{2\pi r^2} x.$$

Assuming a relative permeability of 1, the flux density at a distance of *x* from the center of the conductor is given by

$$B_x = \mu_o H_x = \frac{\mu_o I}{2\pi r^2} x$$

where μ_0 is the permeability of the free space and is given by $4\pi \text{ X } 10^{-7}$ H/m. Now the flux along the circular strip dx is given by