

CONDUCTOR RESISTANCE

Conductor Resistance is a measure of the difficulty to the pass an electrical current through it. Higher the resistance, lesser the current will flow though the conductor. Resistance of a conductor is influenced by conductor dimension, construction and conditions like temperature and resistivity.

It is normally expressed as ohms per km.

D.C. Resistance:

Conductor resistance at 20°C (R_{20})

$$R_{20} = (4A/n\pi d^2) K_1 K_2 K_3$$

Where,

R_{20} = Maximum resistance at 20°C in Ω/km

A = Volume resistivity at 20°C of the conductor metal in $\Omega\text{mm}^2/\text{km}$.

S No.	Name of the Material	Resistivity (A) at 20°C
1	Annealed Copper Conductor	17.241
2	Aluminium Conductor	28.264

n = number of wires in the conductor

d = nominal diameter of the wires in the conductor in mm

K_1 = factor depending on the diameter of the wires and the metal, as given in the following table

Maximum Diameter of wires in conductor		K_1			
Above mm	Upto and including mm	Solid Conductor		Stranded Conductor	
		Plain Copper	Metal Coated Copper	Plain Copper	Aluminium or aluminium alloy
0.05	0.10	-	-	1.07	1.12
0.10	0.31	-	-	1.04	1.07
0.31	0.91	1.03	1.05	1.02	1.04
0.91	3.60	1.03	1.04	1.02	1.03
3.60	4.50	1.03	1.04	-	-
4.50	-	1.03	1.03	-	-

K_2 = factor depending on conductor formation, as follows.

i) 1.00 for solid conductors

ii) 1.02 for stranded class 2 conductors if the nominal wire dia. exceeds 0.6 mm

iii) 1.04 for stranded or flexible conductors if the nominal wire dia. not exceeds 0.6 mm.

K_3 = factor depending upon whether the conductor has frequent use in multicore cables, making allowance for the lay of the cores, or is of a size generally used for single core cables. Values of K_3 are as follows.

i) 1.00 for conductors of cables for fixed installations of nominal cross-sectional areas 500 mm² and above and for flexible conductors of 630 mm²

ii) 1.02 for conductors of cables for fixed installation of nominal cross-sectional areas up to and including 400 mm²

iii) 1.05 for flexible conductors of nom. cross-sectional areas up to and including 500 mm².

The D.C resistance (Ω/km) at temperature t is

$$R_t = R_{20}[1 + \alpha_{20}(t - 20)]$$

The temperature coefficient per degree Celsius at 20°C (α_{20}) for copper is 0.00393 and for aluminium is 0.00403.

Where,

R_t = conductor resistance at $t^\circ\text{C}$ (Ω/km)

R_{20} = conductor resistance at 20°C (Ω/km)

α_{20} = temperature coefficient of resistance of the conductor material at 20°C

t = conductor temperature ($^\circ\text{C}$)

A.C Resistance:

If a conductor is carrying high alternating currents, the distribution of current is not evenly disposed throughout the cross-section of the conductor. This is due to two independent effects known as the 'skin effect' and 'proximity effect'.

The a.c. resistance at temperature t is

$$R_{ac} = R_t (1 + y_s + y_p) \quad \dots (\Omega/\text{km})$$

Where

R_t - D.C. resistance (Ω/km) at temperature at $t^\circ\text{C}$

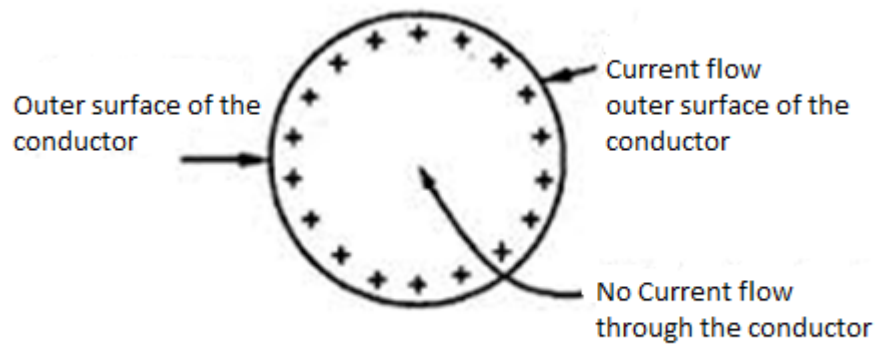
y_s - The skin effect

y_p - proximity effect factor

R_{ac} - A.C. resistance (Ω/km) at temperature $t^\circ\text{C}$

Skin Effect:

When an alternating current flows to a circuit the outer surface of the conductor carries more current compare to the inner surface of the conductor. This leads to high resistance to ac and it is mainly depends on high frequency of the circuit. This effect is known as skin effect.



Skin Effect Factor (y_s):

At power frequencies of 50-60Hz the skin effect factor is small for conductors whose diameter is smaller than 150 mm². If the cable size is greater than 150 mm², we have to consider the skin effect factor.

$$y_s = \frac{x_s^2}{192 + 0.8x_s^2}$$

$$x_s^2 = \frac{8\pi f}{R_t} \times 10^{-7} k_s$$

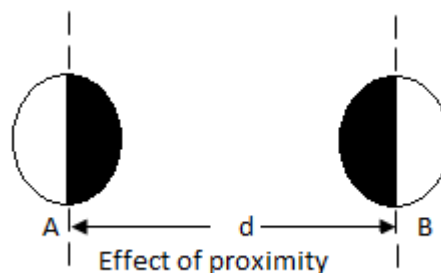
Where,

f - Frequency

k_s - Factor determined by conductor construction 1 for circular, stranded, compacted and sectored these formulae are accurate provided that X_s does not exceed 2.8

Proximity Effect:

When the conductor carries ac power, due to constantly varying the magnetic field induces eddy current in the nearby conductor such as loop or wound coil of a wire. In conductor where the current flows in the same directions, this results in high current density in the nearby loops due to current distribution across the cross section of a conductor. This effect is called Proximity effect. (where d is the spacing between the conductor)



Proximity Effect Factor (y_p):

The proximity effect also increases the effective resistance and is associated with the magnetic fields of two conductors which are close together. If each carries a current in the same direction, the halves of the conductors in close proximity are cut by more magnetic flux than the remote halves.

1) For two core cables:

$$y_p = \frac{x_p^4}{192 + 0.8x_p^4} \times \left(\frac{d_c}{s}\right)^2 \times 2.9$$

$$x_p^2 = \frac{8\pi f}{R_t} \times 10^{-7} k_p$$

Where,

f = Frequency (Hz)

k_p = Factor determined by conductor construction 1 for circular, stranded, compacted and sector 0.8 if above conductors are dried and impregnated

d_c = Diameter of conductor (mm)

R_t = D.C. resistance (Ω/km) at temperature at $t^\circ\text{C}$

S = Spacing between conductor centres (mm)

2) For three core cables:

$$y_p = \frac{x_p^4}{192 + 0.8x_p^4} \times \left(\frac{d_c}{s}\right)^2 \times \left[0.312 \times \left(\frac{d_c}{s}\right)^2 + \frac{1.18}{\frac{x_p^4}{(192 + 0.8x_p^4) + 0.27}}\right]$$

$$x_p^2 = \frac{8\pi f}{R'} \times 10^{-7} k_p$$

Where

f = Frequency (Hz)

k_p = Factor determined by conductor construction 1 for circular, stranded, compacted and sector 0.8 if above conductors are dried and impregnated

d_c = Diameter of conductor (mm)

R' = D.C. resistance (Ω/km) at temperature at $t^\circ\text{C}$

S = Spacing between conductor centres (mm)

For cables in flat formation $S = \sqrt{S_1 \times S_2}$, where S_1, S_2 are the distances between conductors.