Underground cable

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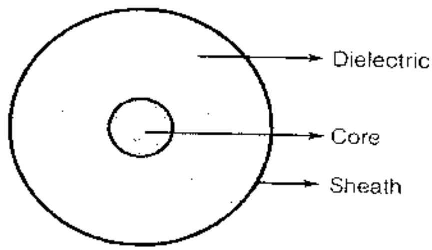
An underground cable consist of three component

(i) **Conductor or core:** It provides conducting path for the current.

(ii) **Dielectric or insulator:** Dielectric withstands operating voltage and isolates conductor from the remaining objects.

(iii) **Sheath:** Sheath does not allow the moisture content and protect conductor from electro chemical factor.



Note:

The most commonly used dielectrics in power cables are impregnated paper, butyl, rubber, PVC, polythene, cross linked polyethylene.

Classification of Cable

1. Based on Voltage

(a) Low voltage (LV) : 1 kV

(b) High voltage (HV) : 11 kV

(c) Super voltage (SV) : 22 kV-33 kV

(d) Extra high voltage (EHV) : 66 kV

(e) Extra super voltage (ESV) : 132 kV and above.

2. Based on Core

(a) Single core

(b) 3-core

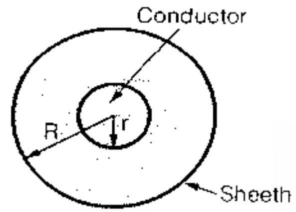
(c) 3.5 core : it is used for secondary distribution purpose.

Parameters of Single Core Cables

Resistance

- Insulation Resistance

$$R_{ins} = \frac{\rho}{2\pi} ln\left(\frac{R}{r}\right) \text{ ohms/metre}$$



where, R_{ins} = Insulation Resistance
ρ = Resistivity of the insulating material
R = Inside radius of sheath
r = Conductor radius

- Resistivity of insulating material at any temperature t

$$\rho_t = \rho_0 e^{-\alpha t}$$

Note:

- In cable, insulation resistance is inversely proportion to length of the cabl

$$R_{ins} \propto \frac{1}{l}$$

- As temperature increases R_{ins} decreases.

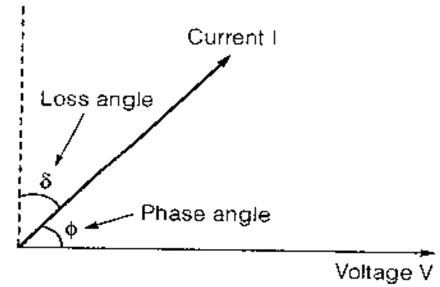
Capacitance

- Capacitance between core and sheath

$$C = \frac{2\pi \epsilon_0 \epsilon_r r}{ln\left(\frac{R}{r}\right)} \text{F/m}$$

where, q = Charge on the surface of the conductor per metre lengt of cable.
ϵ_r = Relative permittivity of dielectric

- Dielectric loss

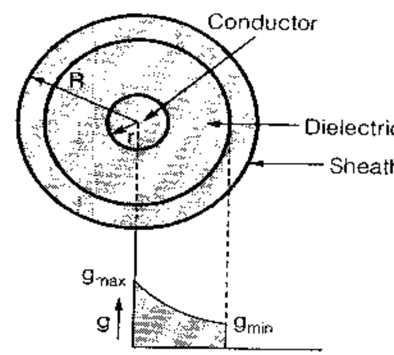


$$P_d = VI \cos\phi = \omega C V^2 \delta$$

where, C = Capacitance of the cable
V = Line to neutral voltage
P_d = Dielectric loss

Electrostatic Stresses

Gradient at a Distance x from the Centre of the Conductor Within the Dielectric Material.



(Electric stress in a single core cable)

$$g = \frac{\lambda}{2\pi \epsilon x} = E$$

where, ϵ = Permittivity of the dielectric
E = Electric field intensity
λ = Charge per unit length

Potential

$$V = \frac{\lambda}{2\pi \in} ln\left(\frac{R}{r}\right)$$

where, r = Radius of conductor

R = Inner radius of the sheath

V = Potential of conductor with respect to the sheath

Gradient is Maximum at the Surface of the Conductor

$$g_{max} = \frac{V}{r\, ln \frac{R}{r}}$$

Gradient is Minimum at the Inner Radius of the Conductor

$$g_{min} = \frac{V}{R\, ln \frac{R}{r}}$$

Note: ....

- The most economical size of the cable is one in which $\frac{R}{r} = e = 2.718$. S that the stress at the surface of core is reduce which will increase the lif of cable.
- Reason of failure of cable is formation of a void between any 2 layer c insulating material. Void near the surface of core will be more serious tha that of the void in other location.
- Characteristic impedance of cable is 40 Ω.
- In overhead transmission line inductor is dominant but in cable capacitanc is more dominant.

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Grading of Cables

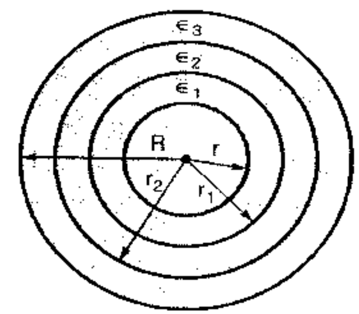
The electrostatic stress in a single core cable has maximum value g_m at the conductor surface and decreases as we move towards sheatl The method of equilising the stress in the dielectric of the cable is know as grading of cable.

1. Dielectric Grading (or) Capacitance Grading

In dielectric grading a homogeneous dielectric is replaced by different dielectrics such that

$$r < r_1 < r_2$$

So, $$\epsilon_1 > \epsilon_2 > \epsilon_3$$



The voltage between conductor and sheath

$$V = V_1 + V_2 + V_3$$

$$V = g_{1max}\, r\, ln\left(\frac{r_1}{r}\right) + g_{2max} r_1\, ln\left(\frac{r_2}{r_1}\right) + g_{3max} r_2\, ln\left(\frac{R}{r_2}\right)$$

For uniform dielectric stress

$$g_{1\,max} = g_{2\,max} = g_{3\,max} = g_{max}$$

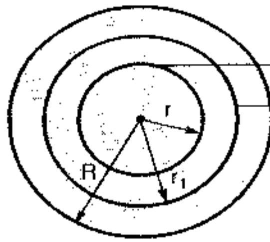
$$V = g_{max}\left[r\, ln\left(\frac{r_1}{r}\right) + r_1\, ln\left(\frac{r_2}{r_1}\right) + r_2\, ln\left(\frac{R}{r_2}\right)\right]$$

Capacitance of the cable

$$C = \frac{2\pi \epsilon_0}{\frac{1}{\epsilon_1} ln\left(\frac{r_1}{r}\right) + \frac{1}{\epsilon_2} ln\left(\frac{r_2}{r_1}\right) + \frac{1}{\epsilon_3} ln\left(\frac{R}{r_2}\right)}$$

2. Intersheath grading

In intersheath grading an identical dielectric material is utilised throughout the total thickness of the cable. It is divided into 2 or more layers by providing intersheath.



- Voltage between conductor and outer sheath (for uniform potential gradient i.e. $g_{1\,max} = g_{2\,(mx)} = g_{max}$

$$V = g_{max}\left[r\,ln\left(\frac{r_1}{r}\right) + r_1\,ln\left(\frac{R}{r_1}\right)\right]$$

- Condition for most economical cable for intersheath grading.

$$V_1 = \frac{V}{e}$$

where, V_1 = Voltage between conductor and intersheath

V = Voltage between conductor and sheath

- Most economical radius of conductor

$$r = \frac{V_1}{g_{max}} = \frac{V}{e g_{max}}$$

- Most economical radius of intersheath

$$r_1 = \frac{V}{g_{max}}$$

- Most economical radius of outersheath

$$R = 1.881\frac{V}{g_{max}}$$

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