

UNIT-4.

A single core cable for 66kV - 3phase system has a conductor diameter of 2cm and sheath of inside diameter 5.3cm. It is required to have two intersheath so that str. r.m.s between the same maximum and minimum values in the three layers of dielectric.

Find the position of intersheath's maximum and minimum stress and voltages on intersheath's. Also find the maximum and minimum stress if the intersheath's are not used.

Rated line voltage $V_L = 66kV$

$$\begin{aligned} \text{Peak value of phase voltage } V_P &= \frac{\sqrt{2} \times 66}{\sqrt{3}} \\ &= 53.9kV. \end{aligned}$$

Diameter of conductor $d = 2\text{cm}$.

Diameter of sheath $D = 5.3\text{cm}$.

- i) Position of intersheath
- ii) Maximum and minimum stress
- iii) Voltage on intersheath
- iv) Maximum and minimum stress if the intersheath are not used.

b) Position of Intersheaths.

d_1 and d_2 of the diameters if two intersheath
 V_1 be voltage between conductor and intersheath 1

V_2 be voltage between intersheath 1 and intersheath 2

V_3 be voltage between intersheath 2 and outer sheath

$$g_{1\text{man}} = \frac{\partial r_1}{d \ln \left(\frac{d_1}{d} \right)}$$

$$g_{2\text{man}} = \frac{\partial r_2}{d_1 \ln \left(\frac{d_2}{d_1} \right)}$$

$$g_{3\text{man}} = \frac{\partial r_3}{d_2 \ln \left(\frac{D}{d_2} \right)}$$

$$g_{1\text{man}} = g_{2\text{man}} = g_{3\text{man}}$$

$$\frac{\partial r_1}{d \ln \left(\frac{d_1}{d} \right)} = \frac{\partial r_2}{d_1 \ln \frac{d_2}{d_1}} = \frac{\partial r_3}{d_2 \ln \frac{D}{d_2}}$$

$$\frac{d_1}{d} = \frac{d_2}{d_1} = \frac{D}{d_2} \rightarrow \textcircled{1}$$

$$\frac{r_1}{d} = \frac{r_2}{d_1} = \frac{r_3}{d_2}$$

equation \textcircled{1}.

$$d_1^2 = d d_2$$

$$d_1^2 = 2 d_2$$

$$d_2 = d_1^2 / 2$$

$$d_1 d_2 = d D$$

$$\frac{d_1 d_1^2}{2} = 2 D$$

$$d_1^3 = 4 D$$

$$d_1^3 = 4 \times 5 \cdot 3 = 21 \cdot 2$$

$$d_1 = (21 \cdot 2)^{1/3}$$

$$d_1 = 2.767 \text{ cm.}$$

$$d_2 = d_1^2 / 2$$

$$= 3.828 \text{ cm.}$$

i) Voltage on the Intershath.

$$V = V_1 + V_2 + V_3$$

$$V_2 = \frac{V_r d_1}{d} \quad V_3 = \frac{V_r d_2}{d}$$

$$V = V_r + \frac{V_r d_1}{d} + \frac{V_r d_2}{d}$$

$$53.9 = V_r \left[1 + 2 \cdot \frac{2.767}{2} + 3 \cdot \frac{2.828}{2} \right]$$

$$V_r + \frac{53.9}{4.2975} = 12.54 \text{ kV.}$$

Voltage on first sheath = $V - V_r$

$$= 53.9 - 12.54$$

$$= 41.36 \text{ kV}$$

$$V_2 = V_r d_1 / d$$

$$= \frac{12.54 \times 2.767}{2}$$

$$= 17.35 \text{ kV.}$$

$$= V - V_r = V_2$$

$$= 53.9 - 12.54 - 17.35 = 24.01 \text{ kV}$$

ii) Maximum and Minimum stress.

$$\text{Maximum stress} = \frac{\partial V}{d \ln \left(\frac{d_2}{d_1} \right)}$$

$$= \frac{24.01 \times 12.54}{2 \ln \left(2 \cdot \frac{2.767}{2} \right)}$$

$$= 38.63 \text{ kN/cm.}$$

$$\text{Minimum stress} = \frac{\partial V}{d \ln \left(\frac{d_1}{d_2} \right)}$$

$$= \frac{24.01 \times 12.54}{2 \cdot 767 \ln \left(2 \cdot \frac{2.767}{2} \right)} = 23.92 \text{ kN/cm.}$$

Maximum and minimum stress if the intershields are not used.

$$g_{\max} = \frac{2V}{d \ln(\frac{D}{d})}$$

$$= \frac{2 \times 66/V_3}{2 \times \ln\left(\frac{5.3}{2}\right)}$$

$$= 39.1 \text{ kV/cm.}$$

The minimum stress if the intershields are not used is given by

$$g_{\min} = \frac{2V}{D \ln(\frac{D}{d})}$$

$$= \frac{2 \times 66/V_3}{5.3 \times \ln\left(\frac{5.3}{2}\right)}$$

$$= 14.75 \text{ kV/cm.}$$

A 2km long 3 core $\delta\phi$ cable has capacitance $0.5 \mu\text{F/km}$ between two conductors bunched with sheath and the third conductor. The capacitance between the conductor is also measured when bunched together and the sheath and found to be $0.25 \mu\text{F/km}$. Determine.

- i) Capacitance between phases.
 - ii) Capacitance between the conductor and the sheath
 - iii) Effective per phase capacitance
 - iv) Capacitance between two conductors connecting a third conductor to the sheath
 - v) Charging current if the supply voltage is 11kV
- So far.

Length of the cable $l = 2 \text{ km}$

Capacitance between two conductors bunched with sheath and third conductor, $C_2 = 0.5 \mu\text{F}/\text{km}$.

Capacitance between Conductors bunched and the Sheath $C_1 = 0.75 \mu\text{F}/\text{km}$.

$$C_1 = 3C_e$$

$$0.75 = 3C_e$$

$$C_e = \frac{0.75}{3}$$

$$\boxed{C_e = 0.25 \mu\text{F}/\text{km}}$$

Capacitance between two bunched conductor (two phases) with sheath and third conductor

$$C_d = 2C_e + C_e$$

$$0.5 = 2C_e + 0.25$$

$$2C_e = 0.5 - 0.25$$

$$2C_e = 0.25$$

$$C_e = \frac{0.25}{2}$$

$$C_e = 0.125 \mu\text{F}/\text{km}.$$

Effective capacitance per phase is given

$$C_n = \frac{3}{2}C_d - \frac{1}{6}C_1$$

$$= \frac{3}{2}(0.5) - \frac{1}{6}(0.75)$$

$$= 0.625 \mu\text{F}/\text{km}.$$

Capacitance between two conductors connecting a third conductor to sheath

$$C = \frac{1}{2} C_n$$

$$= 0.3125 \mu\text{F}/\text{km}$$

Charging Current per phase per km

$$I_c = 2\pi f V_{ph} C_N$$

$$= 2\pi \times 50 \times \frac{11 \times 10^3}{T_3} \times 0.625 \times 10^{-6} = 1.25 \text{ A.}$$

Explain any four insulating materials used in manufacturing of cables.

The following insulating materials are used for underground cables.

1. Rubber
2. Vulcanized Indian Rubber (IR)
3. Impregnated paper
4. Varnished Cambric
5. Poly Vinyl chloride (PVC).

1. Rubber.

Rubber is either natural or synthetic which is obtained from the milky sap of tropical trees or may be produced from alcohol or oil products.

The relative permittivity of rubber is between 2 and 3 and has dielectric strength of about 30kV/mm and the specific resistance is $10^{15} \Omega$.

Pure rubber cannot be used as an insulating material because it absorbs moisture easily and the maximum safe temperature is low of about 38°C . It swells under the action of mineral oils and ages when exposed to light.

2) Vulcanized Indian Rubber (VIR)

It is known for its high durability, greater mechanical strength and good water resistant properties which are far better than pure rubber.

Mineral matter like sulphur (about 3% to 5%) and lead, zinc oxide etc. are mixed with pure rubber to prepare VIR.

Tinned copper conductors have to be employed in cables using VIR insulation as sulphur present in VIR can react very quickly with normal copper conductors, which is a major drawback of VIR.

3. Impregnated Paper.

Impregnated paper is prepared by impregnating chemically pulped paper with some compound like paraffinic or asphaltic material.

Rubber insulation is almost completely replaced by impregnated paper insulation because of its advantages like very low cost, low capacitance, high dielectric strength (30 KV/mm), high thermal conductivity and high insulation resistance.

d. Varnished Cambric.

Varnished Cambric or sometimes referred to as empire tape is prepared by using Cambric a thin white cotton cloth, impregnating and coating it with varnish.

Petroleum jelly is then coated on Cambric surface of the conductor which helps in easy sliding

of conductors inside the cable.

The dielectric strength of the type of insulating material is 45 kV/mm and its dielectric constant ranges between 2.5 and 3.8.

5. Poly Vinyl Chloride (PVC)

PVC is a synthetic materials made from polymerization of acetylene and is in the form of white powder.

Polymer derived from acetylene is used with plasticizers for making thin kind of insulating materials.

Plasticizers are the liquid having very high boiling point.

PVC has certain advantages like offering good dielectric strength of 17 kV/mm , high insulation resistance and good mechanical strength, due to which it is preferred over.

Find the economic size of a single core cable working on a 132 kV three phase system if a dielectric stress of 50kV/cm can be allowed.

Rated line voltage $V_c = 132 \text{ kV}$.

Maximum permissible dielectric stress

$$\sigma_{\max} = 50 \text{ kV/cm.}$$

$$\text{Phase voltage } V_{ph} = \frac{V_c}{\sqrt{3}} = \frac{132}{\sqrt{3}} = \frac{132}{1.73} = 76.210 \text{ kV.}$$

A single and uniformal inner conductor will make the capacitance for 1cm

$$\begin{aligned}V_m &= V_2 \times V_{ph} \\&= V_2 \times 76.210 \\&= 107.78 KV\end{aligned}$$

For most economical size in a cable.

$$g_{man} = \frac{2V_m}{d}$$

$$d = \frac{2V_m}{g_{man}}$$

$$d = \frac{2 \times 107.78}{60}$$

$$d = 3.6 \text{ cm}$$

The most economical conductor diameter
is $d = 3.6 \text{ cm}$

$$\begin{aligned}D &= 2.718 d \\&= 2.718 \times 3.6 \\&= 9.78 \text{ cm.}\end{aligned}$$

Most economical size in a cable, the
diameter of conductor should be 3.6 cm and the
diameter of uniformal sheath should be 9.78 cm.

A single core cable has conductor diameter of 1cm and internal sheath diameter of 1.8cm if impregnated paper of relative permittivity 4 is used as insulation, calculate the capacitance for 1km length of the cable.

conductor diameter $d = 1\text{cm}$

Internal sheath diameter $D = 1.8\text{cm}$

Relative permittivity of

Impregnated paper $\epsilon_r = 4$

Length of cable $l = 1\text{km}$

$$C = \frac{2\pi\epsilon_0\epsilon_r}{\ln\left(\frac{D}{d}\right)} F/m$$

$$= \frac{2\pi \times 8.854 \times 10^{-12} \times 4}{\ln\left(\frac{1.8}{1}\right)} \times 1000$$

$$= 3.785 \times 10^{-7}$$

$$= 0.3785 \times 10^6 F$$

$$= 0.378 \mu F$$

The Capacitance per kilometre of a 3phase belted core cable is 0.2 $\mu F/\text{km}$ between two cores with the third core connected to sheath. Calculate the kva. The supply voltage is 6.6kv and 30 km long.

$$\text{Phase voltage } V_{ph} = \frac{V_L}{r_3}$$

$$= \frac{6.6 \times 10^3}{\sqrt{3}}$$

$$V_{ph} = 3810.512 \text{ V.}$$

The capacitance between two cores with third core connected to shunt is given

$$C_3 = 0.2 \times 30$$

$$C_3 = 6 \mu\text{F}$$

Core to neutral capacitance is given by

$$\begin{aligned} C_N &= 2C_3 \\ &= 2 \times 6 \\ &= 12 \mu\text{F} \end{aligned}$$

The charging current is given by

$$I_C = 2\pi f V_{ph} C_N$$

$$= 2\pi \times 50 \times 3810.512 \times 12 \times 10^{-6}$$

$$= 14.865 \text{ A.}$$

The kVA taken by the cable

$$S = 3V_{ph} I_C$$

$$= 3 \times 3810.512 \times 14.865$$

$$= 164214.0146 \text{ kVA}$$

$$S = 164.214 \text{ kVA.}$$

The insulation Resistance of the single core one-kilometer length cable is $195 \text{ M}\Omega/\text{km}$. If the core diameter is 25cm and resistivity of insulation is $45 \times 10^4 \Omega\text{cm}$. Find insulation thickness.

Outer sheath radius

$$r_2 = r_1 + t \\ = 1.25 \times 10^{-2} + t$$

Insulation resistance

$$R = \frac{\rho}{2\pi L} \ln \left(\frac{r_2}{r_1} \right)$$

$$195 \times 10^6 = \frac{4.5 \times 10^{12}}{2\pi \times 1000} \ln \left(\frac{1.25 \times 10^{-2} + t}{1.25 \times 10^{-2}} \right)$$

$$0.691 = \ln \left[\frac{1.25 \times 10^{-2} + t}{1.25 \times 10^{-2}} \right]$$

$$e^{0.691} = \left[\frac{1.25 \times 10^{-2} + t}{1.25 \times 10^{-2}} \right]$$

$$1.996 = \frac{1.25 \times 10^{-2} + t}{1.25 \times 10^{-2}}$$

$$0.02495 = 1.25 \times 10^{-2} + t$$

$$t = 0.01245$$

$$t = 1.245 \text{ cm}$$

Insulation thickness $t = 1.245 \text{ cm}$.