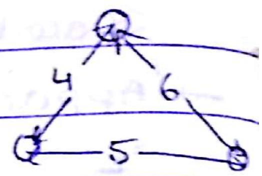
Q Determine the inductance /km of 3ϕ Xmission line using 20mm diameter conductors when conductors are situated at the corners of triangle with spacing of 4, 5, 6 meters. Conductors are regularly transposed.

→ Conductor radius(r) = $\frac{20}{2}$ = 10mm = 1cm.

→ GMR = 0.7788 × r = 0.7788 cm.



→ $L/phase = 2\times10^{-7} \log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r'}$ H/m.

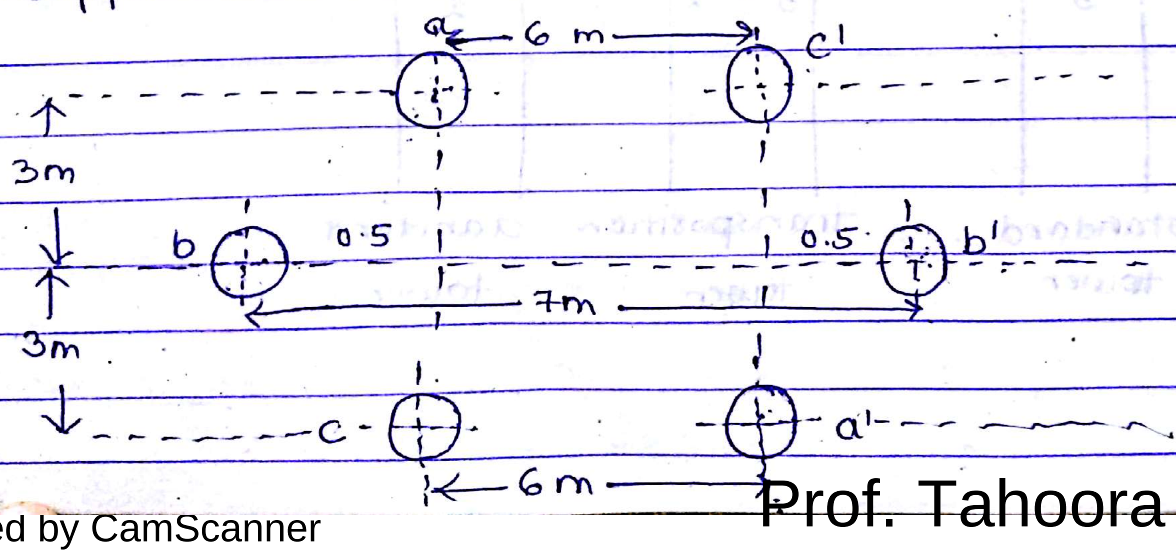
$= \frac{2\times10^{-7}}{10^{-3}\times10^{-3}} \log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r'}$ mH/km.

$= 0.2 \log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r'}$

$= 0.2 \log_e \frac{\sqrt[3]{400\times500\times600}}{0.7788}$

L = 1.29 mH/km.

(Q) A part of the transpositioning cycle of 3ϕ double circuit line is shown. Radius of each conductor is 0.9 cm. The conductors are solid copper. Find L/phase/km of line.



→ GMR of each conductor $= 0.7788 \times r$

$= 0.7788 \times 0.9 \times 10^{-2}$

$= 7.0092 \times 10^{-3}\ m$

→ $d_{aa'} = \sqrt{6^2 + 6^2} = 8.4852\ m$

$d_{bb'} = 7\ m$

$d_{cc'} = 8.4852\ m$

~~$d_{ab'} = d_{cb} = d_{b'c} = d_{ba'} = \sqrt{3^2 + 7.5^2} =$~~

→ GMR of conductors of phase A;

$D_{sa} = \sqrt[4]{d_{aa} \cdot d_{aa'} \cdot d_{a'a'} \cdot d_{a'a}}$

$= \sqrt[4]{(7.0092 \times 10^{-3})(8.4852)(7.0092 \times 10^{-3})(8.4852)}$

$= 0.2437\ m$

~~→ GMR of conductors of phase B;~~

$D_{sb} = \sqrt[2]{d_{bb} \cdot d_{bb'}}$ ~~$\cdot d_{b'b'} \cdot d_{b'b}$~~

$= \sqrt[2]{(7.0092 \times 10^{-3})(7)}$ ~~$(7.0092 \times 10^{-3})(7)$~~

$= 0.22150\ m$

$D_{sc} = \sqrt[2]{d_{cc} \cdot d_{cc'}}$

$= \sqrt[2]{(7.0092 \times 10^{-3})(8.4852)}$

$= 0.2437\ m$

$D_s = \sqrt[3]{D_{sa} D_{sb} D_{sc}} = 0.2360\ m$

→ $d_{ab} = \sqrt{3^2 + 0.5^2} = 3.04138\ m$

$d_{ab'} = \sqrt{6.5^2 + 3^2} =$ ~~8.07...~~ $7.1589\ m$

→ GMD.

$D_{ab} = \sqrt[4]{d_{ab} \cdot d_{ab'} \cdot d_{a'b'} \cdot d_{a'b}}$

$= \sqrt[4]{(3.04138)(7.1589)(3.04138)(7.1589)}$

$= 4.6661\ m$

$$D_{bc} = \sqrt[4]{d_{bc} \cdot d_{bc'} \cdot d_{c'b} \cdot d_{c'b'}}$$
$$= \sqrt[4]{(3.041)(7.159)(7.159)(3.041)}$$
$$= 4.666 \text{ m.}$$

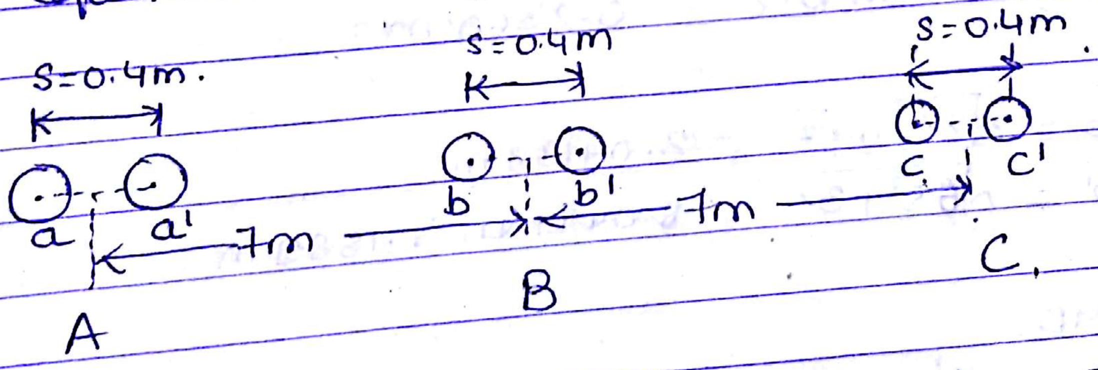
$$D_{ca} = \sqrt[4]{d_{ca} \cdot d_{ca'} \cdot d_{c'a} \cdot d_{c'a'}}$$
$$= \sqrt[4]{(6)(6)(6)(6)}$$
$$= 6 \text{ m.}$$

$$D_m = \sqrt[3]{D_{ab} D_{bc} D_{ca}} = 5.0739 \text{ m}$$

→ $L/\text{phase} = 0.2 \log_e \frac{D_m}{D_s}$ mH/km.

$$L = 0.2 \log_e \frac{5.0739}{0.236} = 0.6136 \text{ mH/km}$$

(Q) Find the inductive reactance of 3ϕ bundle conductor line with 2 conductor/phase with spacing of 40cm. Phase to phase seperation is 7m in horizontal configuration. All conductors are ACSR with dia 3.5cm. Compare the above value with that of equivalent single conductor line.



→ Radius of each sub-conductor $r = \frac{3.5}{2} = 1.75$ cm

$= 1.75 \times 10^{-2}$ m

→ GMR of each conductor $= 0.7788 \times 1.75 \times 10^{-2}$
$= 1.363 \times 10^{-2}$ m.

→ GMR $D_s = \sqrt{r' s} = 0.0738$ m.

→ $D_{ab} = D_{bc} = \sqrt[4]{d_{ab}\, d_{ab'}\, d_{a'b}\, d_{a'b'}}$
$= \sqrt[4]{7 \times 7.4 \times 6.6 \times 7} = 6.994$ m.

→ $D_{ca} = \sqrt[4]{d_{ac}\, d_{a'c}\, d_{ac'}\, d_{a'c'}}$
$= \sqrt[4]{14 \times 14.4 \times 13.6 \times 14} = 13.997$ m.

→ $D_m = \sqrt[3]{D_{ab} D_{bc} D_{ca}} = 8.814$ m.

→ D_m by considering center to center distances of the bundle.
$D_m = \sqrt[3]{7 \times 7 \times 14} = 8.819$ m.

→ Inductance of bundle conductor line
$L = 0.2 \log_e \dfrac{D_m}{D_s}$ mH/km.

$= 0.2 \log_e \dfrac{8.814}{0.0738} = 0.9565$ mH/km.

→ Inductive reactance of bundle conductor
$X_L = 2\pi f L = 2\pi (50)(0.9565 \times 10^{-3}) = 0.3$[illegible] Ω/km

→ Equivalent radius of the conductor considering single conductor/phase.

$r_1 = \sqrt{\dfrac{n \pi r^2}{\pi}}$ $n \rightarrow$ no of subconductors in bundle.

$= \sqrt{n r^2} = \sqrt{2 \times (1.75 \times 10^{-2})^2} = 0.0247 m$

→ GMR of each conductor:

- $r_1' = 0.7788 r_1 = 0.01927 m$.
- $Dm_1 = \sqrt[3]{7 \times 7 \times 14} = \sqrt[3]{D_{ab} D_{bc} D_{ka}} = 8.819 m$
- Inductance $L_1 = 0.2 \log_e \frac{Dm_1}{r_1'}$

$= 0.2 \log_e \frac{8.819}{0.01927}$

$= 1.22522 \ mH/km$.

- $X_{L1} = 2\pi f L_1$

$= 2\pi (50)(1.22522 \times 10^{-3})$

$= 0.38491 \ \Omega/km$.

Comments : The inductance of the bundle conductor line is significantly less than that of the line with one solid conductor/phase.

Q. Calculate the capacitance of 100km long 3φ, 50Hz overhead transmission line consisting of 3 conductors, each of diameter 2cm & spaced 2.5m at the corners of equilateral triangle.

→ $d = 2.5m = 250 cm$.

→ $r = \frac{2 cm}{2} = 1 cm$.

$$C = \frac{2\pi\epsilon_0}{\log_e d/r} \text{ F/m} = \frac{2\pi\epsilon_0}{\log_e (250/1)}$$

$$= 10.075 \times 10^{-2} \text{ F/m}.$$

→ Capacitance of 100km long line $= 100 \times 1000 \times 10.075 \times 10^{-12}$

$= 1.0075 \times 10^{-6}$ F/km.

1 km → 1000 m
1000 → ?

Q The 2cm diameter conductors of a 3φ, 3 wire xmission line are situated at the corners of a triangle of sides 3.5 m, 5 m & 8 m. Find capacitance/conductor/km if the line is transposed.

→ $r = \frac{2\text{cm}}{2} = 1\text{cm} = 1 \times 10^{-2}$ m.

→ $d_1 = 3.5$ m ; $d_2 = 5$ m ; $d_3 = 8$ m.

→ Capacitance/conductor/km $= \frac{2\pi\epsilon_0}{\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}}$

$$= \frac{2\pi\epsilon_0}{\log_e \frac{\sqrt[3]{3.5 \times 8 \times 5}}{1 \times 10^{-2}}}$$

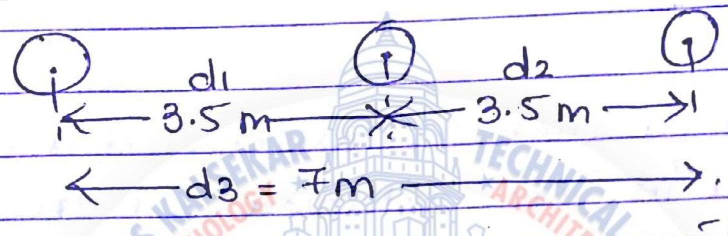
$$= 8.8978 \times 10^{-2} \text{ F/m}.$$

→ Capacitance/conductor/km $= 8.8978 \times 10^{-2} \times 1000$

$= 0.0088978 \times 10^{-6}$ F/km

Prof. Tahoora Qureshi

Q. A 3ϕ, 50Hz transmission line has flat horizontal configuration with 3.5m between adjacent conductors. The conductors are of no 2/0 hard drawn seven strand copper (outside conductor diameter = 1.05cm). The voltage of the line is 110KV, find the capacitance to neutral & the charging current/km.



→ $r = \frac{1.05}{2} = 0.5025 \text{ cm} = 0.5025 \times 10^{-2} \text{ m}$.

→ $d_1 = 3.5\text{m}$; $d_2 = 3.5\text{m}$; $d_3 = 7\text{m}$.

→ Capacitance to neutral $C_N = \frac{2\pi\epsilon_0}{\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}}$ F/m.

$$= \frac{2\pi\epsilon_0}{\log_e \frac{\sqrt[3]{3.5 \times 3.5 \times 7}}{0.5025 \times 10^{-2}}}$$

$$= 8.2088 \times 10^{-2} \text{ F/m}.$$

→ Capacitance/km $= 8.2088 \times 10^{-2} \times 1000$.

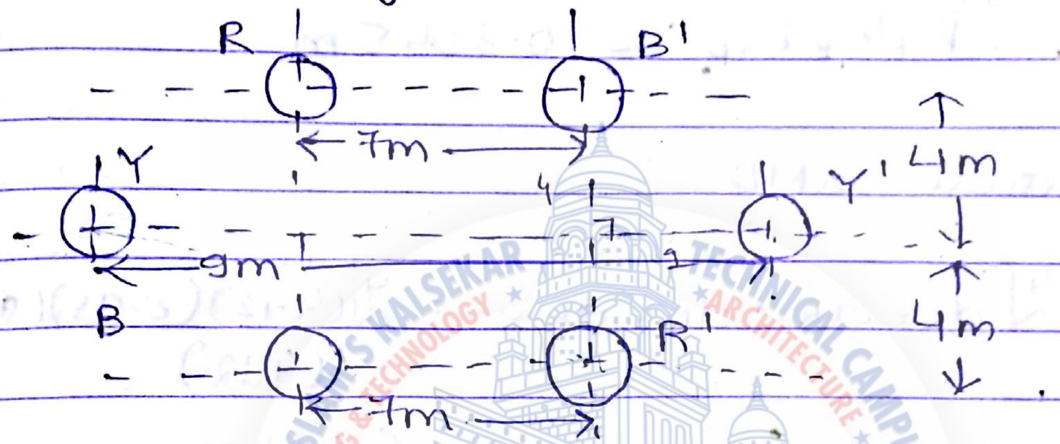
$$= 0.00820 \times 10^{-6} \text{ F/km}.$$

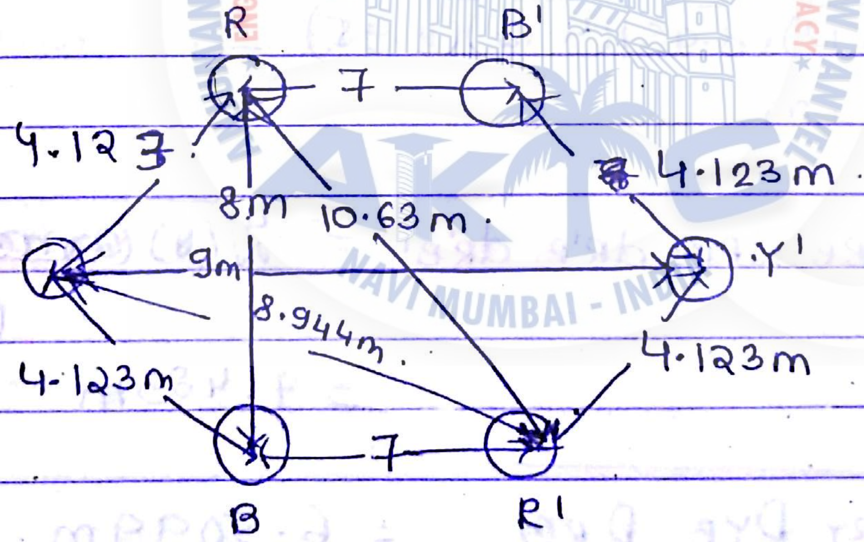
→ Charging current/km (I_c) $= 2\pi f C_N V_{ph}$

$$= 2\pi(50)(0.00820 \times 10^{-6}) \times \frac{110 \times 1000}{\sqrt{3}}$$

$$= 0.164 \text{ A/km}.$$

Q Six conductors of a double circuit transmission line are arranged as shown. The dia of each conductor is 2.5 cm. Find the capacitive reactance to neutral and the charging current /km/phase at 132KV & 50Hz assuming that the line is regularly transposed. Neglect effect of earth.





→ GMR of conductors of phase R

$$D_{sR} = \sqrt[4]{d_{RR}\, d_{RR'}\, d_{R'R'}\, d_{R'R}} = \sqrt[4]{(1.25\times10^{-2})(10.63)(1.25\times10^{-2})(10.63)}$$

$$= 0.3645 \text{ m}$$

$$D_{SY} = \sqrt[4]{d_{YY'}\, d_{YY}\, d_{Y'Y}\, d_{Y'Y'}} = \sqrt[4]{(1.25\times10^{-2})(9)(9)(1.25\times10^{-2})}$$

$$= 0.3354\text{m}.$$

$$D_{SB} = \sqrt[4]{d_{BB}\, d_{BB'}\, d_{B'B}\, d_{B'B'}}$$

$$= \sqrt[4]{(1.25\times10^{-2})^2(10.63)^2}$$

$$= 0.3645\ \text{m}.$$

$$D_S = \sqrt[3]{D_{SR} D_{SY} D_{SB}} = 0.3545\text{m}$$

→ Mutual GMD.

$$D_{RY} = \sqrt[4]{d_{RY}\, d_{RY'}\, d_{R'Y}\, d_{R'Y'}} = \sqrt[4]{(4.12)(8.95)(8.95)(4.12)}.$$

$$= 6.072\text{m}.$$

$$D_{YB} = \sqrt[4]{d_{YB}\, d_{YB'}\, d_{Y'B}\, d_{Y'B'}}$$

$$= \sqrt[4]{(4.12)(8.95)(4.12)(8.95)}$$

$$= 6.072\text{m}$$

$$D_{RB} = \sqrt[4]{d_{RB}\, d_{RB'}\, d_{R'B}\, d_{R'B'}} = \sqrt[4]{(8)(7)(8)(7)}.$$

$$= 7.483\text{m}.$$

$$D_m = \sqrt[3]{D_{RY}\, D_{YB}\, D_{RB}} = 6.5099\text{m}.$$

→ Capacitance / phase $= \dfrac{2\pi\epsilon_0}{\log_e \frac{D_m}{D_s}} = 19.1152\times10^{-12}$ F/m.

→ C/p/ km $= 19.1152\times10^{-12}\times1000$

$= 19.1152\times10^{-9}$ F/Km.

→ $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(19.11\times10^{-9})}$

$= 166.567\ k\Omega$.

→ $I_C = 2\pi f C V_{ph}$

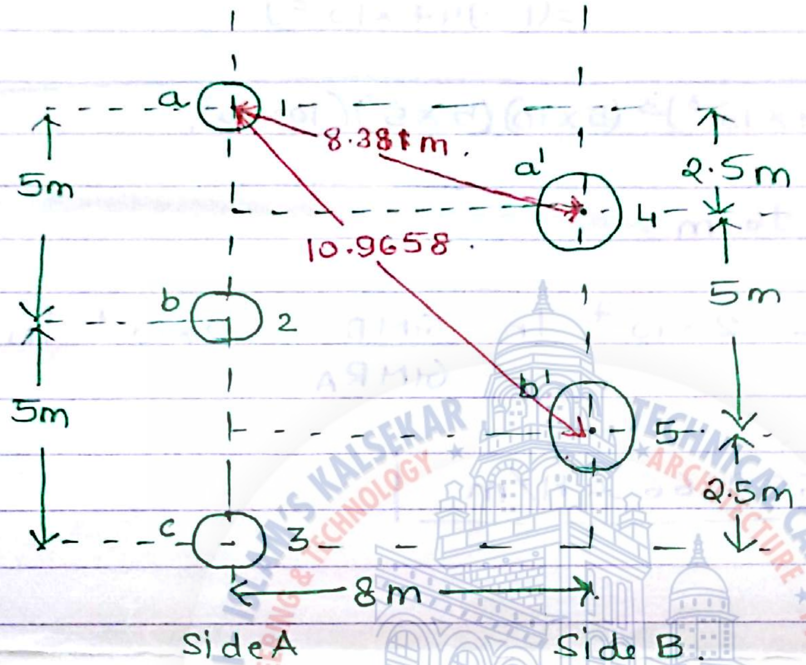
$= 2\pi(50)(19.1152\times10^{-9})\ \frac{132\times10^3}{\sqrt{3}}$.

$= 0.4575\ A/km$.

→ In case of calculations of inductance, determination of self GMD (or GMR) of conductor is necessary because of internal flux linkage of conductor.
But in case of calculation of capacitance, since all charges reside on the surface of the conductor, actual radius of conductor is used.

(4)

The arrangement of conductors of 1φ xmission lines is shown. The forward ckt is composed of 3 solid wires 2.5mm in radius. & return ckt of two wires of r = 5mm placed symmetrically with respect to forward ckt. Find inductance of each side of the line & of the complete line.



~~(i) Side A;~~

~~$r = 2.5\text{ mm} = 2.5\times10^{-3}$ m.~~

~~GMR of each subconductor $(r') = 0.7788\,(2.5\times10^{-3})$.~~

~~$= 1.947\times10^{-3}$ m.~~

~~GMR, $(D_s) = \sqrt{r's} = \sqrt{(1.947\times10^{-3})(5)} = 0.09866$ m.~~

(i) Side A :

$m = 3,\ n' = 2.$

$$GMD = \sqrt[mn']{(D_{aa'}\,D_{ab'})(D_{ba'}\,D_{bb'})(D_{ca'}\,D_{cb'})}.$$

$$= \sqrt[3\times2]{(8.381\times10.9658)(8.381\times8.381)(10.9658\times8.381)}$$

$= 9.16665$ m.

 Prof. Tahoora Qureshi

→ $GMR_A = \sqrt[3\times2]{(D_{aa}\ D_{ab}\ D_{ac})(D_{ba}\ D_{bb}\ D_{bc})(D_{ca}\ D_{cb}\ .}$

$= \sqrt[3\times2]{(r'\ D_{ab}\ D_{ac})(D_{ba}\ r'\ D_{bc})(D_{ca}\ D_{cb}\ r')}$

where $r' = 0.7788\ r = 0.7788 \times 2.5 \times 10^{-3}$ m.
$= (1.947 \times 10^{-3})$

$= \sqrt[6]{(1.947\times10^{-3})^3 (5\times10)(5\times5)(10\times5)}$.

$= 0.27796$ m.

→ 'L' of side A $= 2\times10^{-7} \ln \frac{GMD}{GMR_A} = 2\times10^{-7} \ln \frac{9.1665}{0.27796}$

$L_A = 0.699166\ \mu H/m$.

(ii) Side B

→ $GMD_B = GMD_A = 9.16665$ m.

→ $GMR_B = \sqrt[4]{(D_{a'a'}\ D_{a'b'})(D_{bb'}\ D_{b'a'})}$
$= \sqrt[4]{(r'\ D_{a'b'})(r'\ D_{b'a'})}$.

where; $r' = 0.7788\ r = 0.7788 \times 5 \times 10^{-3}$ m
$= 3.894 \times 10^{-3}$ m

$= \sqrt[4]{(3.894\times10^{-3})^2 \cdot (5)^2} = 0.13953$ m.

→ L_B of side B $= 2\times10^{-7} \ln \frac{GMD}{GMR_B}$

$= 2\times10^{-7} \ln \left(\frac{9.16665}{0.13953}\right)$.

$L_B = 0.8370\ \mu H/m$.

→ Inductance/m is

$L_T = L_A + L_B = 1.536175\ \mu H/m$.

Prof. Tahoora Qureshi