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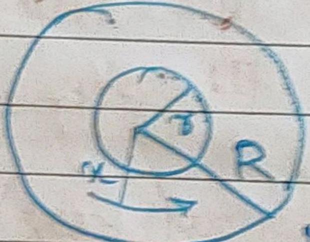
Q1. Derive eqn for fictious radius of
(1) hollow conductor
inner radius: r
outside radius: R

(2) Determine value of inductance of single phase line ($r = 3cm$, $R = 7cm$) distance = 4m apart. Find fictious radius.

Ans. Internal Inductance:



$$B_x 2\pi x = \mu_0 I \left(\frac{x^2 - r^2}{R^2 - r^2}\right)$$ By ampere's law.

$$B_x = \frac{\mu_0 I}{2\pi x}\left(\frac{x^2 - r^2}{R^2 - r^2}\right)$$

$$d\phi = B_x \, l \, dx.$$

$$d\lambda_{int} = d\phi \times \left(\frac{x^2 - r^2}{R^2 - r^2}\right).$$

$$= \frac{\mu_0 I}{2\pi x} l \left(\frac{x^2 - r^2}{R^2 - r^2}\right)^2 dx.$$

$$= \frac{\mu_0 I l}{2\pi (R^2 - r^2)^2}\left[x^3 - 2r^2 x + \frac{r^4}{x}\right] dx.$$

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$$\lambda_{int} = \int_{r}^{R} d\lambda_{int}$$

$$= \int_{r}^{R} \frac{\mu_0 I l}{2\pi(R^2-r^2)^2}\left(x^3 - 2r^2 x + \frac{r^4}{x}\right)dx$$

$$= \frac{\mu_0 I l}{2\pi(R^2-r^2)^2}\left(\frac{R^4-r^4}{4} - r^2(R^2-r^2) + r^4 \ln r\right)$$

L_{int} (per unit length) $= \dfrac{\lambda_{int}}{R}$.

$$= \frac{\mu_0 I}{2\pi(R^2-r^2)^2}\left(\frac{1}{4}(R^4-r^4) + r^4 \ln(R/r) - r^2(R^2-r^2)\right) \text{ H/m}$$

external inductance

As all current = linked inductance from surface to distance D.

$$L_{ext} = \frac{\mu_0}{2\pi} \ln\left(D/R\right) \text{ H/m}.$$

Total inductance = Lext + Lint.

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let fictious radius $= r'$

total inductance $= \frac{\mu_0}{2\pi} \ln(D/r')$

$\{$int. inductance $= 0\}$.

$$\therefore \frac{\mu_0}{2\pi} \ln\left(\frac{D}{r'}\right) = \frac{\mu_0}{2\pi} \ln\left(\frac{D}{R}\right) + \frac{\mu_0}{2\pi(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} + r^4 \ln(R/r) - r^2(R^2-r^2)\right].$$

$$\ln\left(R/r'\right) = \frac{1}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} + r^4 \ln(R/r) - r^2(R^2-r^2)\right].$$

$$\therefore \boxed{r' = R \cdot e^{-\frac{1}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} - r^2(R^2-r^2) + r^4 \ln(R/r)\right]}}$$

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$r = 3cm \quad R = 7cm \quad d = 4m$
$= 0.03m \quad = 0.07m$

$$r' = R e^{\frac{1}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} - r^2(R^2-r^2) + r^4 \ln(R/r)\right]}$$

$$\cancel{r' = 0.07 \times e}^{-\left[\frac{1}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} - r^2(R^2-r^2)\right] - (\ldots)\right]}$$

$$r' = R \times \left(\frac{r}{R}\right)^{r^4/(R^2-r^2)^2} \times e$$

$$0.07 \times \left(\frac{3}{7}\right)^{3^4/(7^2-3^2)^2} = 0.07 \times \left(\frac{3}{7}\right)^{3^4/4^2 10^2}$$

$$= 0.07 \left(\frac{3}{7}\right)^{0.050625}$$

$$= \underline{0.06706}$$

$$e^{-\frac{1}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} - r^2(R^2-r^2)\right]}$$

$$= e^{-\frac{1}{(40)^2}\left[\frac{7^4-3^4}{4} - 3^2(40)\right]}$$

$\frac{7^4-3^4}{4} \rightarrow 580 \qquad 3^2(40) \rightarrow 360$

$$= e^{-0.1375}$$

$$= \underline{0.87153}$$

$$r' = 0.87153 \times 0.06706$$
$$= 0.05844\, m$$

$$\underline{r' = 5.844\, cm}$$

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$$L = \frac{2\times10^{-7}}{(R^2-r^2)^2}\left[\frac{R^4-r^4}{4} - r^2(R^2-r^2) + r^4\ln(R/r)\right] + \ln(D/r_2).$$

$$L = 2\times10^{-7}\left[\left(0.1395 + \frac{1}{40^2}\left(3^4\log\left(\frac{7}{3}\right)\right) + \log\left(\frac{400}{7}\right)\right)\right]$$

$$L = 2\times10^{-7}\left[0.1375 + \frac{1}{40^2\times10^{-4}}\left(81(0.3679)\times10^{-4}\right) + 1.7569\right).$$

$$\cancel{L = 3.8189\ 3.5718\ (0.8104)\times10^{-7}\ H/m}$$

$$\cancel{L = 0.3104\ mH/km}.$$

$$L = 2\times10^{-7}(0.1375 + 0.0186 + 1.7569).$$

$$\underline{L = 3.826\times10^{-7}\ H/m}.$$

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[illegible]
/ /

Q2. 3 single phase transformers are given with their name plate ratings. Determine reactance diagram for STAR-DELTA and DELTA-DELTA.

11 MVA, 11/33 kV, $X_l = 0.11$ pu, $X_m = 39$ pu

Ans

$$Z_{B1} = \frac{(kV)^2_{B1}}{(MVA)_B} \; ; \; Z_{B2} = \frac{(kV)^2_{B2}}{(MVA)_B}$$

$(MVA)_B = 11$; $(kV)_{B1} = 11$ kV ; $(kV)_{B2} = 33$ kV.

$Z_{B1} = 11^2/11 = 11\,\Omega$

$Z_{B2} = 33^2/11 = 99\,\Omega$.

actual reactances reffered to primary side:-

$x_1 = 0.11 \times Z_{B1}$
$= 1.21\,\Omega$

$x_2 = 39 \times Z_{B1} = 429\,\Omega$.

(a) STAR-DELTA:

$(MVA)_{B3\phi} = 3 \times 11 = 33$.

$(kV)_{B1, L-L} = \sqrt{3} \times 11 = 19.053$ kV.

$$Z_{B1} = \frac{(kV)^2_{B1, L-L}}{(MVA)_{B,3\phi}} = 11\,\Omega.$$

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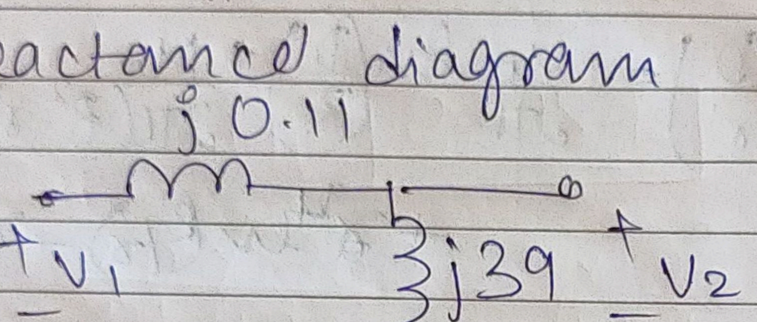
$x_1 = \frac{1.21}{11}$ pu $= 0.11$ pu.

$x_2 = \frac{429}{11}$ pu $= 39$ pu.

Reactance diagram STAR-DELTA:



(b) DELTA - DELTA.

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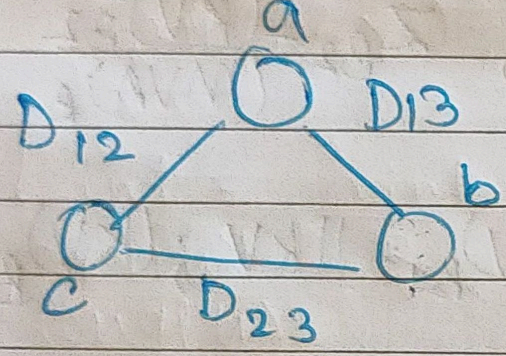
Q3. Find capacitance of phase to neutral per km of a three phase line having conductors of 1cm radius placed at corners of a triangle with sides ~~4cm~~, 4m, 3m and 5m. Assume line is transposed and carried balanced load.

Ans



$D_{12} = 4\,m$
$D_{13} = 3\,m$
$D_{23} = 5\,m$

$r = 1cm = 0.01\,m$

$$D_{eq} = (D_{12}D_{13}D_{23})^{1/3}$$
$$= 60^{1/3} = 3.91487\ m$$

Capacitance of phase to neutral.

$$C_{an} = \frac{2\pi\varepsilon_0}{\ln\left(\frac{D_{eq}}{r}\right)}\ \mu F/km$$

$$= \frac{0.0242}{\log\left(\frac{3.91487}{0.01}\right)} = \frac{0.0242}{2.5927}$$

$= 0.0093338\ \mu F/km$

$$= \boxed{9.3338 \times 10^{-3}\ \mu F/km}$$

Ans

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Q4. From a load duration curve;
Max. demand on system 44MW.
Load supplied by 2 generating units = 28 MW and 24 MW.
Unit-1 is base unit and works for all time. Unit-2: peak load unit, works for 44% time.
Energy produced annually (unit-1) = 2×10^8 units and (unit-2) = 15×10^6 units.
Find (a) plant capacity factor
(b) plant use factor of both units
(c) load factor
(d) load factor of total plant.

(a) 44 MW = max. demand
Generating units → 28 MW (Unit 1), 24 MW (Unit 2, 44%)
annual → 2×10^8 units, 15×10^6 units.

Plant capacity factor

$$= \frac{2\times10^8 + 15\times10^6}{28\times10^3\times8760 + 24\times10^3\times8760}$$

$$= \frac{215\times10^6}{(876\times52)\times10^4} = \frac{215}{876\times52}\times10^2.$$

plant capacity factor $= \boxed{0.47199}$

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(b). Plant use factor

UNIT-1

$$= \frac{2\times10^8}{28\times10^3\times8760} = \frac{2\times10^4}{28\times876}$$

$$\boxed{= 0.8154}$$

UNIT-2

$$= \frac{15\times10^6}{24\times10^3\times8760\times0.44}$$

$$= \frac{15\times10^4}{24\times876\times44}$$

$$= \boxed{0.16215}$$

combined plant use factor $= \dfrac{2\times10^8 + 15\times10^6}{28\times10^3\times8760 + 24\times10^3\times8760\times0.44}$

$$= \frac{215\times10^6}{8760(28+24(0.44))\times10^3}$$

$$= \frac{215\times10^2}{876\times(38.56)} = \boxed{0.6365}$$

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(c) load factor = $\dfrac{\text{avg load}}{\text{peak load}}$

UNIT-1

$$= \frac{2\times10^8/8760}{44\times10^3} = \frac{10^4}{19272}$$

$$LF_1 = \boxed{0.5189}$$

UNIT-2

$$= \frac{15\times10^6/8760}{44\times10^3} = \frac{15\times10^2}{38544}.$$

$$LF_2 = \boxed{0.03892}$$

(d) Total plant load factor $= \dfrac{(2\times10^8+15\times10^6)/8760}{44\times10^3}$

$= LF_1 + LF_2$

$= \cancel{0.0084}\ \boxed{0.55782}$