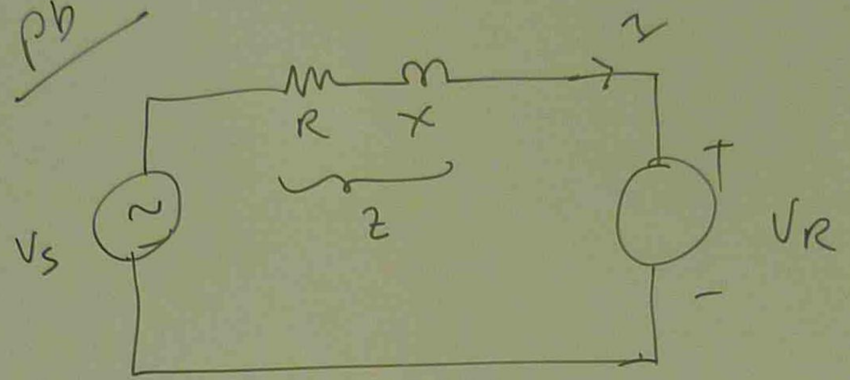
POWER TRANSMISSION LINE

pb



IN ABOVE CIRCUIT, THE LOAD CONSUMES 1500 WATT AT POWER FACTOR OF 0.8 AND VOLTAGE OF 460V. THE TRANSMISSION LINE IMPEDANCE $Z = 2 + j5\ \Omega$

CALCULATE SENDING END VOLTAGE FOR

(a) LAGGING POWER FACTOR

(b) LEADING POWER FACTOR.

$V_R = 460V$

$$I = \frac{\text{power}}{V \times \cos\phi}$$

$$= \frac{1500}{460 \times 0.8} = 4.08 \angle{-36.8} \text{ Amp} \quad \text{LAGGING PF}$$

$$\overline{V_S} = \overline{V_R} + I\,Z$$

$$= 460 \angle 0 + 4.08 \angle{-36.8} \; (2 + j5)$$

$$= 460 + 4.08 \angle{-36.8} \left(\sqrt{2^2 + 5^2} \; \angle \tan^{-1}\frac{5}{2} \right)$$

$$= 460 + 4.08 \angle{-36.8} \times 5.39 \angle 68.2$$

$$= 460 + 22 \angle 31.4$$

$$= 460 + 22 \left(\cos 31.4 + j \sin 31.4 \right)$$

$$= 479 + j11.4$$

$$= \sqrt{479^2 + 11.4^2} \; \angle \tan^{-1}\frac{11.4}{479} = 479 \angle 1.4 \, V$$

LEADING PF

$$\bar{V_S} = \bar{V_R} + IZ$$

$$= 460\angle 0 + 4.08\angle +36.8 \times (2 + j5)$$

$$= 460 + 4.08\angle 36.8 \times 5.39\angle 68.2$$

$$= 460 + 22\angle 105.1$$

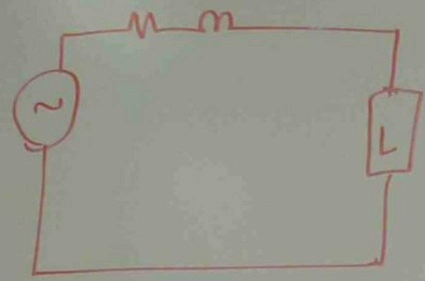
$$= 460 + 22(\cos 105.1 + j\sin 105.1)$$

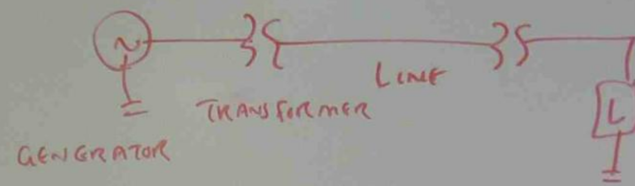
$$= 454 + j21.2$$

$$= \sqrt{454^2 + 21.2^2}\ \angle \tan^{-1}\frac{21.2}{454}$$

$$= 455\angle 2.7^{\circ}\ V$$

PER UNIT REPRESENTATION OF POWER LINE EQUIPMENTS





LINE IMPEDANCE

$$Z(pu) = \frac{Z(\Omega)}{Z(BASE)} = \frac{Z(\Omega) \times VA(BASE)}{(BASE\ VOLTAGE)^2}$$

$Z_1(\Omega)$ AT VA_1, V_1

TO FIND Z_1 AT VA_2 AND V_2

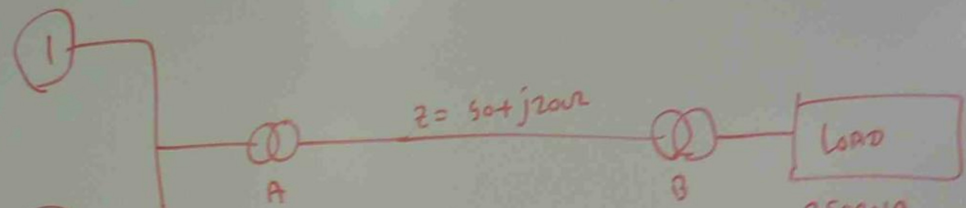
$$Z_2(pu) = Z_1(pu) \times \frac{V_2^2}{V_{BASE}^2} \times \frac{VA\ BASE}{VA_2}$$

VA = VOLT AMP (APPARENT POWER)

VA (BASE) = BASE VOLT AMP.

Pb

1000 VA
250V
$Z = j0.2$ pu



2000 VA
250V
$Z = j0.3$pu

A
4000 VA
250/800 V
$Z = j0.1$pu

B
8000 VA
800/400 V
$Z = j0.08$pu

2500 VA
400V

CALCULATE P.U IMPEDANCE REFERRED TO BASE 5000 VA, 250V

BASE 5000 VA , 250V (BASE) (BASE VOLTAGE AT PRIMARY

RESPECTIVE BASE VOLTAGE AT SECONDARY IS 800V

GENERATOR (1)

$$Z_{pu(5000)} = j0.2 \times \frac{250^2}{250^2} \times \frac{5000}{1000} = j1.0 \text{ pu}$$

GENERATOR (2)

$$Z_{pu(5000)} = j0.3 \times \frac{250^2}{250^2} \times \frac{5000}{2000} = j0.75 \text{pu}$$

TRANSFORMER (A)

$$Z_{pu}(5000) = j0.1 \times \frac{250^2}{250^2} \times \frac{5000}{4000} = j0.125\ pu$$

TRANSFORMER (B)

$$Z_{pu}(5000) = j0.1 \times \frac{400^2}{250^2} \times \frac{5000}{8000} = j0.128\ pu$$

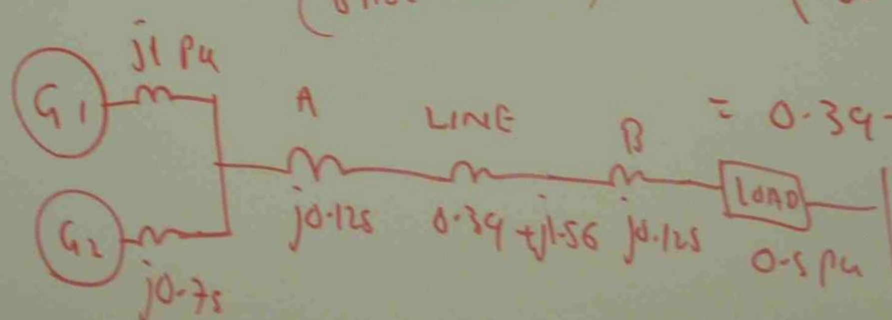
LOAD

$$\frac{VA}{VA\,BASE} = \frac{2500}{5000} = 0.5\ pu$$

LINE

$$Z(pu) = \frac{Z(\Omega) \times VA\ BASE}{(BASE\ VOLTAGE)^2} = \frac{(50 + j20) \times 5000}{(800)^2}$$

$$= 0.39 + j1.56$$



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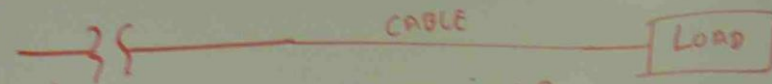


2600V

λ/λ

15000 VA

3000/280V

$Z = j0.06$ pu

$Z = 0.4 + j0.6\ \Omega$

Δ CONNECTED

$Z = 50 + j20\ \Omega$

TAKE BASE VOLTAGE 2600V, 20000 VA.

FIND EQUIVALENT DIAGRAM.

λ | λ TRANSFORMER

$$Z(20000) = j0.06 \times \frac{3000^2}{2600^2} \times \frac{20{,}000}{15000}$$

$$= j0.107 \text{ pu}$$

CABLE

$$Z(\text{pu}) = \frac{Z(\Omega) \times \text{VA BASE}}{(\text{BASE V})^2} = \frac{(0.4 + j0.6) \times 20{,}000}{(2600)^2}$$

$$= 0.136 + j0.204 \text{ pu}$$

LOAD $\Delta \rightarrow Y$ CONVERSION

$$Z_{pu} = \frac{50+j20}{3} \times \frac{20,000}{(V_{BASE})^2}$$

3000V ⟶ 280V

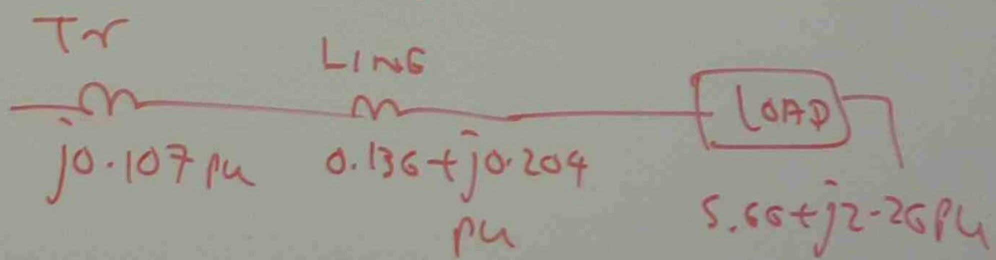
2600V ⟶ ? $= 280 \times \frac{2600}{3000}$

BASE

$= 242.7$

$$Z_{pu} = \frac{50+j20}{3} \times \frac{20,000}{(242.7)^2}$$

$= 5.66 + j2.26$ pu



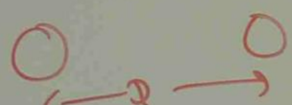
CALCULATION OF LINE INDUCTANCE AND LINE CAPACITANCE

LINE RESISTANCE $R = \frac{\rho L}{A}$

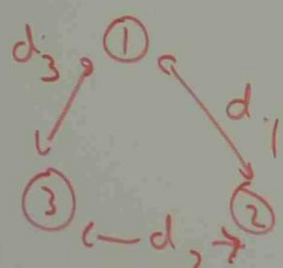
LINE INDUCTANCE $L = 2 \times 10^{-7} \ln \frac{GMD}{GMR}$ H/m

GMD = GEOMETRIC MEAN DISTANCE BETWEEN LINE CONDUCTORS

GMR = GEOMETRIC MEAN RADIUS OF LINE CONDUCTOR



GMD = D



$GMD = \sqrt[3]{D_1 \times D_2 \times D_3}$

GMR = RADIUS " R "

LINE CAPACITANCE

$$C = \frac{2\pi\varepsilon}{\ln\frac{GMD}{GMR}} \quad F/m$$

$$= \frac{2\pi \times \frac{10^{-9}}{36\pi}}{\ln\frac{GMD}{GMR}} = \frac{\frac{1}{18} \times 10^{-9}}{\ln\frac{GMD}{GMR}} \quad F/m$$

LINE INDUCTIVE REACTANCE

$$X_L = 2\pi f L \quad (\Omega)$$

LINE CAPACITIVE REACTANCE

$$X_C = \frac{1}{2\pi f C} \quad (\Omega)$$

$$L = 0.741 \times 10^{-3} \log_{10} \frac{GMD}{GMR} \quad H/mile$$

$$C = \frac{0.0388}{\log_{10} \frac{GMD}{GMR}} \quad \mu F/mile$$

Pb DETERMINE THE CONSTANTS IN π MODEL SINGLE PHASE LINE HAVING THE FOLLOWING SPECIFICATIONS.

OUTSIDE DIAMETER = 0.629 in

SPACING = 12 ft

GEOMETRIC MEAN RADIUS = 0.01987 ft

RESISTANCE/mile = 0.1966 Ω

LINE LENGTH = 25 miles.

$$R = 0.1966 \times 25 = 4.92\ \Omega$$

$$L = 0.741 \times 10^{-3} \log_{10} \frac{12}{0.01987}$$

$$= 2.06 \times 10^{-3}\ H/\text{mile}$$

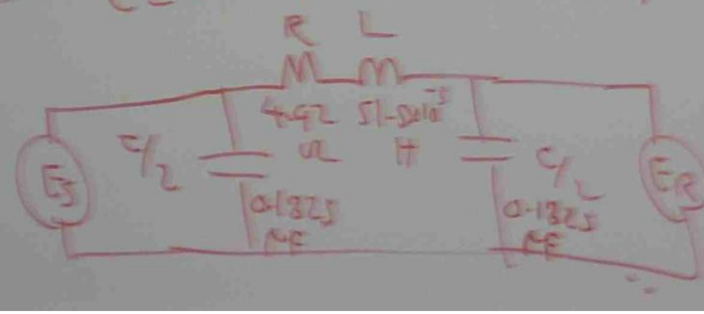
25 miles $L = 2.06 \times 10^{-3} \times 25 = 51.5 \times 10^{-3}\ H$

$$C = \frac{0.0388}{\log_{10} \frac{GMD}{GMR}} = \frac{0.0388}{\log_{10} \frac{12}{0.01987}}$$

$$= 0.0146\ \mu F/\text{mile}.$$

25 miles

$$C = 0.0146 \times 25 = 0.365\ \mu F$$



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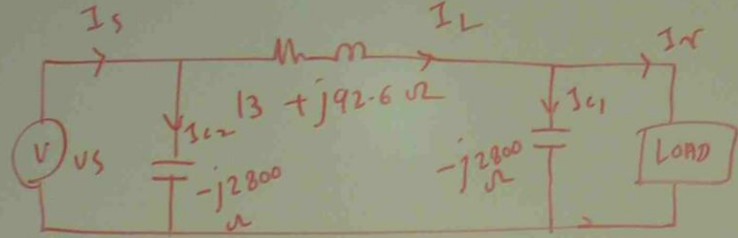


LOAD = 120 kV

If LOAD ON GIVEN LINE IS 12 000 kW, UNITY P.F SUPPLIED AT 120 kV. CALCULATE I_s, V_s, POWER SUPPLIED BY GENERATOR.

$$\bar{V}_r = 120{,}000 \angle 0\ \text{V} \qquad \bar{I}_r = \frac{P}{V_r \cos\phi} = \frac{12000 \times 10^3}{120 \times 10^3} = 100\ \text{A} = 100 \angle 0\ \text{A}$$

$$I_{c_1} = \frac{V}{-jX_{c_1}} = \frac{120{,}000}{-j2800} = j42.9\ \text{A}$$

$$I_L = I_r + I_{c_1} = 100 + j42.9\ \text{A} = \sqrt{100^2 + 42.9^2} \angle \tan^{-1}\frac{42.9}{100} = 109 \angle 23.2^\circ\ \text{Amp.}$$

$$\bar{V}_s = \bar{V}_r + \bar{I}_L Z = 120{,}000 + 109 \angle 23.2 \times (13 + j92.6)$$

$$= 120{,}000 + (100 + j42.9) \times (13 + j92.6)$$

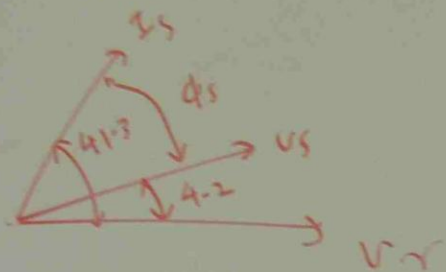
$$= 120{,}000 - 2670 + j9820$$

$$= 117300 + j9820 = 117700 \angle 4.2^\circ\ \text{V}$$

$$I_{c2} = \frac{\bar{V_S}}{-jX_{c2}} = \frac{117300 + j9820}{-j2800} = -3.52 + j41.9 \text{ A}$$

$$\bar{I_S} = \bar{I_{c2}} + \bar{I_L} = -3.52 + j41.9 + 100 + j42.9 = 96.5 + j84.8$$

$$= 128.5 \angle 41.3 \text{ A}$$



$$\phi_S = 41.3 - 4.2 = 36.5^\circ$$

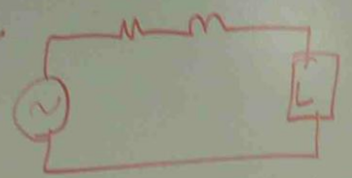
$$P = V_S I_S \cos \phi_S$$

$$= 117700 \times 128.5 \times \cos 36.5$$

$$= 12160{,}000 \text{ W}$$

$$\approx 12160 \text{ kW}$$

pb



IN ABOVE CIRCUIT, THE LOAD CONSUMES 4000 W AT PF 0.8 LAGGING. THE SENDING END VOLTAGE IS 600 V AND THE IMPEDANCE $Z = 1 + j4\ \Omega$. DETERMINE LOAD VOLTAGE

TOTAL POWER PROVIDED BY GENERATOR = 4000W

$$I = \frac{P}{V\cos\phi} = \frac{4000}{600 \times 0.8} = 8.32 \angle -\cos^{-1} 0.8$$

$$= 8.32 \angle -36.8^{\circ}\ \text{A}$$

$$\bar{V}_s = \bar{V}_r + I Z$$

$$600 \angle \phi = V_r + 8.32 \angle -36.8\ (1 + j4)$$

$$600\cos\phi + j\,600\sin\phi = V_r + 8.32 \angle -36.8 \times 4.12 \angle 76$$

$$600\cos\phi + j\,600\sin\phi = V_r + 34.3 \angle 39.1$$

$$600\cos\phi + j\,600\sin\phi = V_r + 34.3\,(\cos 39.1 + j\sin 39.1)$$

$$600\cos\phi + j\,600\sin\phi = Vr + 26.6 + j\,21.6$$

$$600\cos\phi = Vr + 26.6$$

$$600\sin\phi = 21.6$$

$$\phi = \sin^{-1}\frac{21.6}{600} = 2.06$$

$$600\cos 2.06 = Vr + 26.6$$

$$Vr = 573\ V$$

$$L = 0.741 \times 10^{-3} \log_{10} \frac{GMD}{GMR} \quad H/mile$$

$$C = \frac{0.0388}{\log_{10} \frac{GMD}{GMR}} \quad \mu F/mile$$

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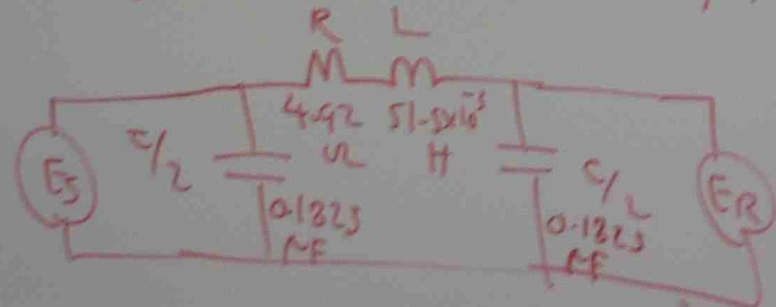

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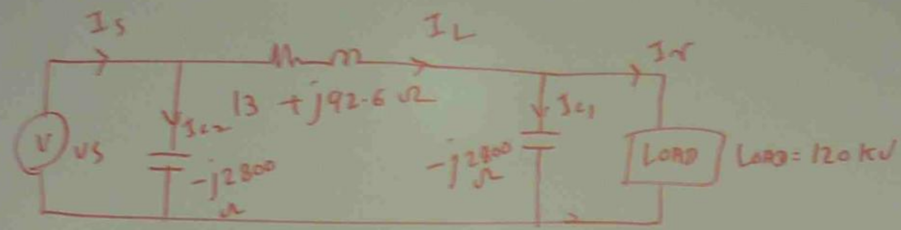

1φ LOAD ON GIVEN LINE IS 12000 KW, UNITY P.F SUPPLIED AT 120 KV. CALCULATE I_s, V_s, POWER SUPPLIED BY GENERATOR.

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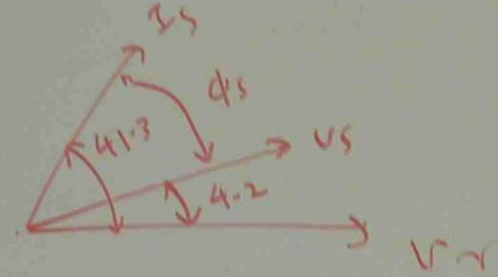

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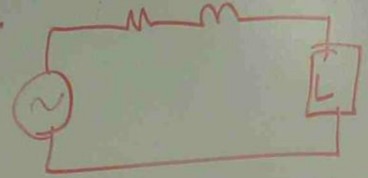

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$600 \sin\phi = 21.6$

$\phi = \sin^{-1} \frac{21.6}{600} = 2.06$

$600 \cos 2.06 = V_r + 26.6$

$V_r = 573\ V$