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Power System Analysis (I), EE 0903481,   *Second Term 2016/2017*
Date: 20/03/2017   *Time: 1 hour*

Problem 1 (5 pts):
The single line diagram of a power system is shown in the figure below. The ratings and parameters of all components are as follows
G: 40MVA, 20kV, X=0.2p.u.
T_1: 25MVA, 22/132kV, X=0.10 p.u.
T_2: 25MVA, 132/11.5kV, X=0.10 p.u.
Line (short transmission line): $Z = 0 + j10\ \Omega$
Load (constant impedance): 10MW with 0.707 lagging power factor at 11 kV.
Draw the equivalent impedance diagram marking all the reactance/impedance of all components including the load in p.u., to a **base of 22 kV, 100 MVA at the generation side** (Neglect transformer phase shifts)

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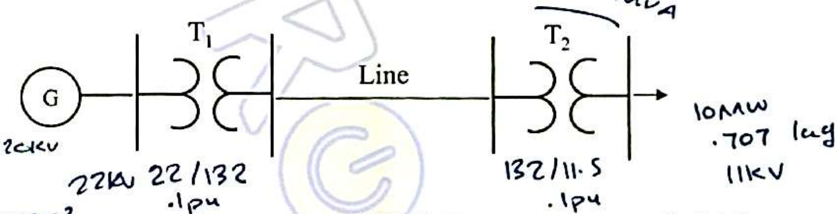


132kV   11.5kV

$Z_G = 0.2 * \left(\frac{100}{40}\right)\left(\frac{20}{22}\right)^2$
$= 0.41\ pu$

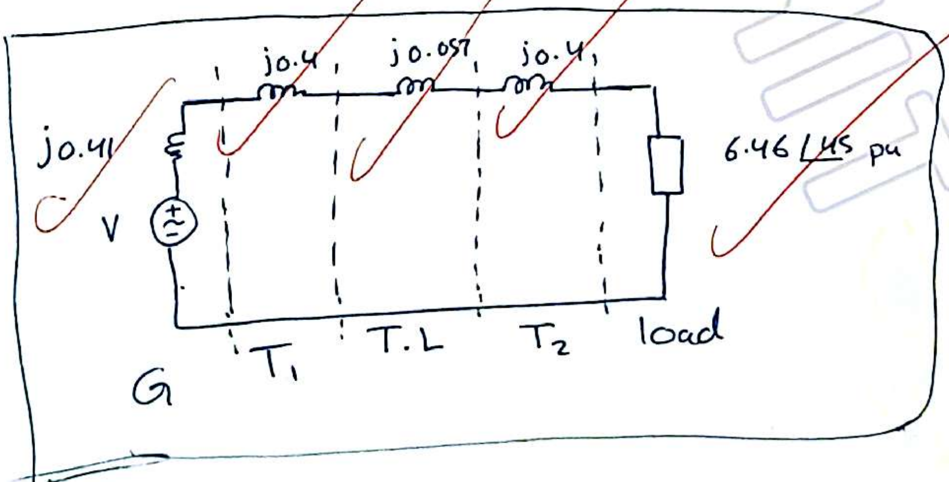
$Z_{T_1} = 0.1 * \left(\frac{100}{25}\right)$
$= 0.4 pu$

$Z_{Line} = \frac{10}{(132)^2/100}$
$= 0.057 pu$

$Z_{T_2} = 0.1 * \frac{100}{25}$
$= 0.4 pu$

$Z_L = \frac{V^2}{S} \angle \cos^{-1} .707$
$= \frac{(11)^2}{10/.707} = 8.55\,\Omega$

$Z_{Lpu} = \frac{8.55}{(11.5)^2/100}$
$= 6.46 \angle 45$



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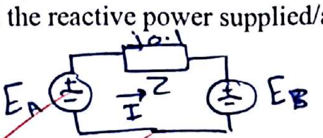
Problem 2 (5 pts):

A short lossless transmission line with leakage reactance of 0.1 p.u is used to connect two zones together (Zone-A and Zone-B). Zone-A supplies positive active power while it consumes positive reactive power. The voltage magnitudes at both ends of the transmission line are either 1.0 p.u. or 1.05 p.u., and the phase angles are either 5^{O} or 0^{O}. (All the quantities given in p.u. are by using a common base)

(a) Determine the voltages (p.u.) at each side of the transmission line?

(b) Determine the real and the reactive power supplied/absorbed by Zone-B in p.u.?

$\alpha = 0$ $\quad Z = 0.1 pu$



$S_A = -P + jQ$
leads but less magnitude

a) $V_A = 1 \angle 5^\circ$ pu

$V_B = 1.05 \angle 0^\circ$ pu

b) $S_B = V_B I^*$

$V_B = 1.05 \angle 0^\circ$

$I = \frac{V_A - V_B}{j0.1} = \frac{1\angle 5 - 1.05\angle 0}{j0.1}$, $I^* = 1.024 \angle -31.68^\circ$

$S_B = 0.915 - 0.565j$

Consumes +ve Real power & supplies +ve Reactive power

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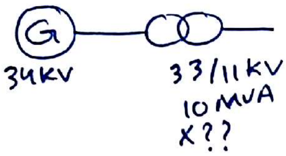
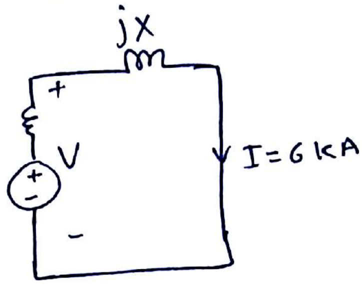
Problem 3 (5 pts):
A 10 MVA, 33/11 kV three-phase transformer is connected to an ideal 34 kV voltage source. The three-phase short circuit current at the LV side of the transformer is 6 kA. Determine the per unit reactance of the transformer on its own base.



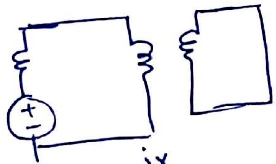


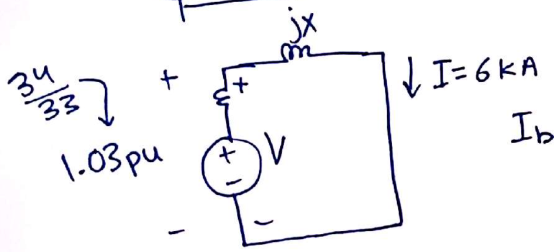
$Z_{base} = \frac{V^2}{S} = \frac{(33)^2}{10} = 108.9\,\Omega$

$-34k + 6k * jX = 0$

$jX = \frac{34}{6}$

$X = 5.667\,\Omega$





$I_{base} = \frac{S}{\sqrt{3} * V_L}$ | $I_L = \frac{10}{\sqrt{3} * 11}$

$= 524.86\,A$

$I_{pu} = 11.43$ pu

$-1.03 + jX * 11.43 = 0 \Rightarrow$ $X = 0.09$ pu

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Problem 4 (5 pts):
Three single-phase transformers, each rated 15MVA, 33/6.35 kV with leakage reactance of 15% are connected Δ/Y. Three 60 Ω Δ-connected resistors are connected to the LV side of the three-phase transformer.
(a) Find the Y-equivalent impedance seen from HV side of the three-phase transformer.
(b) Find the power consumed by the resistors at rated voltage operating condition.

$S_{3\phi} = 45\text{MVA}$, 33 / 11 KV
$X = .15\,\text{pu}$

a) $R_{Y_{LV}} = \frac{60}{3} = 20\,\Omega$

$R_{Y_{HV}} = R_{Y_{LV}} *$ transformation ratio
$= 20 * \left(\frac{33}{11}\right)^2$
$R_{Y_{HV}} = 180\,\Omega$

b) ~~$P = |S|\cos\theta$~~ ~~$I_L = \frac{S_{3\phi}}{\sqrt{3} V_L} = \frac{45M}{\sqrt{3} * 11}$~~ $P = \frac{V^2}{R}$

~~$S = \sqrt{3} V_L I_L = 45\text{MVA}$~~

~~$P = 45\text{MW}$~~

b) $P = \frac{V_{LL}^2}{R_Y} = \frac{3V_{LN}^2}{R_Y}$

$P_{3\phi} = 6.05\,\text{MW}$

$P = \frac{V_{LL}^2}{R_Y + 0.15j}$

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Problem 5 (5 pts):
The ratings of a three-winding transformer are as follows:

Primary: 33kV, Y-connected, 60 MVA
Secondary: 11kV, Y-connected, 40 MVA
Tertiary (t): 3.3kV, Δ-connected, 20 MVA

- With measurement made on the primary side with secondary short circuited and tertiary open, the leakage reactance is 1.3 Ω. $Z_{ps} = 1.3\,\Omega$
- With measurement made on the secondary side with tertiary short circuited and primary open, the leakage reactance is 0.242 Ω. $Z_{st} = 0.242\,\Omega$
- With measurement made on primary side with the tertiary short circuited and secondary open, the leakage reactance is 2.5 Ω. $Z_{pt} = 2.5\,\Omega$

Calculate the per unit impedance of the equivalent circuit based on the rated MVA and voltage of the primary?

Z_p, Z_s, Z_t

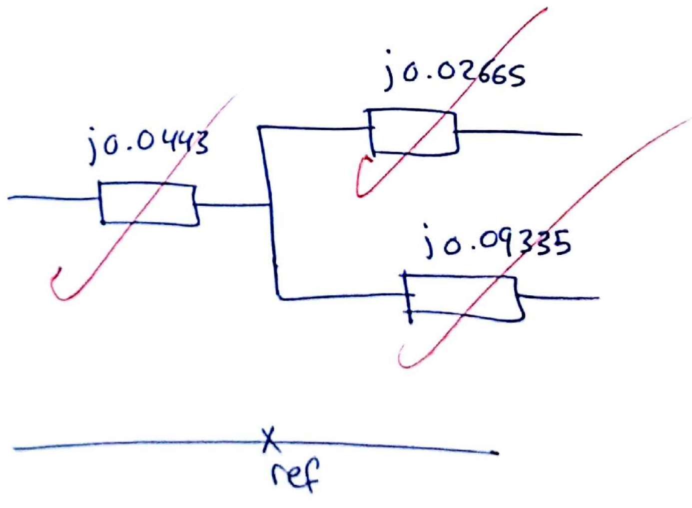
$S_b = 60\,MVA$,

$Z_{ps} = \frac{1.3}{(33)^2/60} = 0.071\,pu$, $Z_{st} = 0.12\,pu$, $Z_{pt} = 0.1377\,pu$

$Z_p = \frac{1}{2}(Z_{ps} + Z_{pt} - Z_{st}) = \frac{1}{2}(0.071 + 0.1377 - 0.12) = 0.0443\,pu$

$Z_s = \frac{1}{2}(Z_{ps} + Z_{st} - Z_{pt}) = \frac{1}{2}(0.071 + 0.12 - 0.1377) = 0.02665\,pu$

$Z_t = \frac{1}{2}(Z_{pt} + Z_{st} - Z_{ps}) = \frac{1}{2}(0.1377 + 0.12 - 0.071) = 0.09335\,pu$



all in pu

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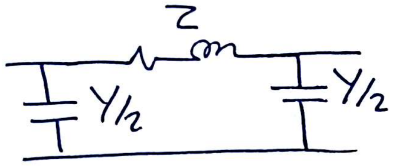
Problem 6 (5 pts):
A three-phase 400kV, 50Hz transmission line is 200 km long. It is found that under no-load condition and with 400kV sending end line voltage, the receiving end line voltage is 440 kV and the sending end per-phase current is $246.6\angle 90^{\circ}$ A. Determine the total shunt admittance of the line?

medium



$l = 200\ km$

@ $I_R = 0$ $V_S = 400kV$, $V_R = 440kV$, $I_S = 246.6\angle 90^{\circ}$ A Y?

$$\begin{bmatrix} 400 \\ 246\angle 90^{\circ} \end{bmatrix} = \begin{bmatrix} 1+\frac{YZ}{2} & Z \\ Y(1+\frac{YZ}{4}) & 1+\frac{YZ}{2} \end{bmatrix} \begin{bmatrix} 440 \\ 0 \end{bmatrix}$$

* نسيت أقسم على $\sqrt{3}$

$$\begin{bmatrix} \frac{400}{\sqrt{3}} \end{bmatrix} = \begin{bmatrix} \ \end{bmatrix} \begin{bmatrix} \frac{440}{\sqrt{3}} \end{bmatrix}$$

$\frac{400}{440} = 1+\frac{YZ}{2} \rightarrow YZ = -\frac{2}{11}$

$246.6j = Y(1+\frac{-2/11}{4})\ 440$

$j0.56 = Y(\frac{21}{22}) \Rightarrow Y = 0.5867\ S$