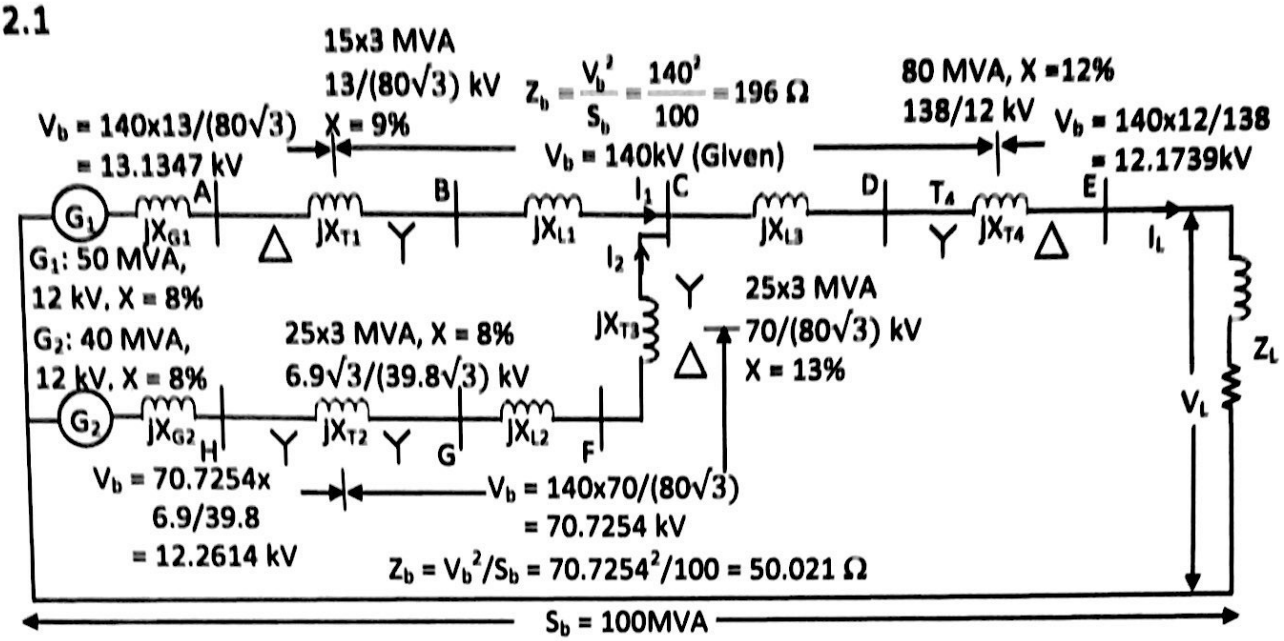
EE3015 Tutorial #2

2.1



(a)

$$X_{G1} = X_{G1,old} x \left[\frac{V_{b,old}}{V_{b,new}}\right]^2 x \left[\frac{S_{b,new}}{S_{b,old}}\right]$$

$$= 0.08x\left[\frac{12}{13.1347}\right]^2 x\frac{100}{50} = 0.1335\ \text{pu}$$

$$X_{T1} = 0.09x\left[\frac{13}{13.1347}\right]^2 x\frac{100}{45} = 0.1959\ \text{pu}$$

$$X_{L1} = \frac{X_{L1,actual}}{Z_b} = \frac{30}{196} = 0.1531\,\text{pu}$$

$$X_{L3} = \frac{50}{196} = 0.2551\,\text{pu}$$

$$X_{T4} = 0.12x\left[\frac{138}{140}\right]^2 x\frac{100}{80} = 0.1457\ \text{pu}$$

$$X_{T3} = 0.13x\left[\frac{80\sqrt{3}}{140}\right]^2 x\frac{100}{75} = 0.1698 \text{ pu}$$

$$X_{L2} = \frac{30}{50.021} = 0.5998 \text{ pu}$$

$$X_{T2} = 0.08x\left[\frac{\sqrt{3}x6.9}{12.2614}\right]^2 x\frac{100}{75} = 0.1013 \text{ pu}$$

$$X_{G2} = 0.08x\left[\frac{12}{12.2614}\right]^2 x\frac{100}{40} = 0.1916 \text{ pu}$$

$$V_L = \frac{11}{V_b} = \frac{11}{12.1739} = 0.9036\angle 0^\circ \text{ pu}$$

$$S_L = \left(\frac{P_L}{pf_L}\angle +\text{Cos}^{-1}0.9\right)/S_b = \left(\frac{60}{0.9}\angle 25.84^\circ\right)/100 = 0.667\angle 25.84^\circ \text{ pu}$$

$$I_L = \left(\frac{S_L}{V_L}\right)^* = \left(\frac{0.667\angle 25.84^\circ}{0.9036\angle 0^\circ}\right)^* = 0.7378\angle -25.84^\circ \text{ pu}$$

$$Z_L = \frac{V_L}{I_L} = \frac{0.9036\angle 0^\circ}{0.7378\angle -25.84^\circ} = 1.2247\angle 25.84^\circ = 1.1022 + j\,0.5338 \text{ pu}$$

The impedance diagram is shown in the figure of the previous page.

(b)

$V_C = j(X_{L3} + X_{T4})\, I_L + V_L = 0.2957\angle 64.16^\circ + 0.9036 = 1.0325 + j0.2661 =$
$1.0662\angle 14.45^\circ$ pu

$I_1 = I_2 = I_L/2 = 0.3689\angle -25.84^\circ$ pu

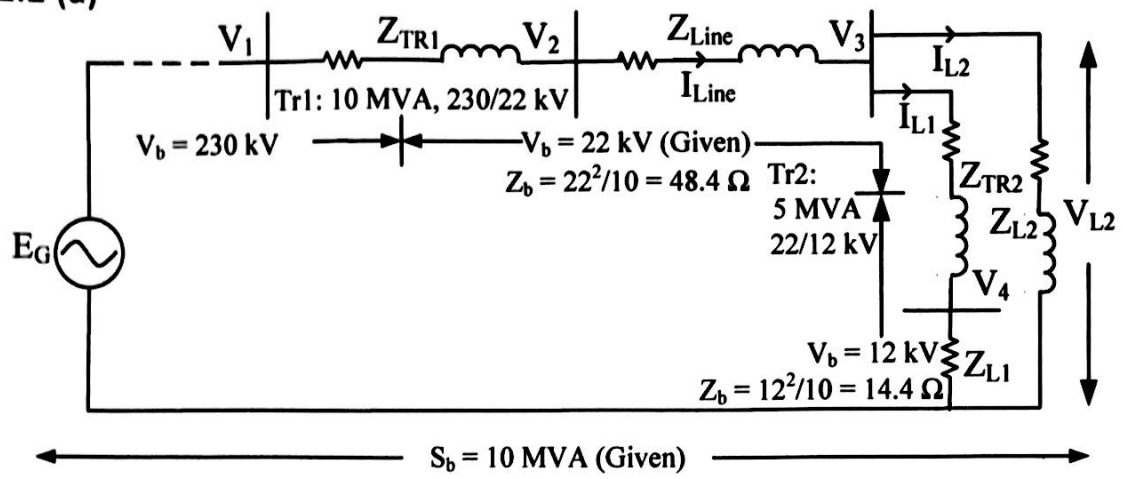
$V_{t,\,G1} = V_A = j(X_{T1} + X_{L1})\, I_1 + V_C = 0.1287\angle 64.16^\circ + 1.0662\angle 14.45^\circ =$
$(0.05611 + j0.1159) + (1.0325 + j0.2661) = 1.1536\angle 19.34^\circ$ pu

Actual $|V_{t,\,G1}| = 1.1536 \times V_{b,\,G1} = 1.1536 \times 13.1347 = 15.1527$ kV

$V_{t,\,G2} = V_H = j(X_{T2} + X_{L2} + X_{T3})\, I_2 + V_C = 0.3213\angle 64.16^\circ + 1.0662\angle 14.45^\circ$
$= (0.14 + j0.2891) + (1.0325 + j0.2661) = 1.2973\angle 25.34^\circ$ pu

Actual $|V_{t,\,G2}| = 1.2973 \times V_{b,\,G2} = 1.2973 \times 12.2614 = 15.9066$ kV

2.2 (a)



$$Z_{Line} = \frac{Z_{Line,\,actual}}{Z_b} = \frac{1.5 + j7.2}{48.4} = 0.1519\angle 78.23^\circ = 0.0309 + j0.1488\,pu$$

$$Z_{Tr1} = Z_{Tr1,old} x \left[\frac{V_{b,old}}{V_{b,new}}\right]^2 x \left[\frac{S_{b,new}}{S_{b,old}}\right]$$

$$= (0.02 + j0.08) x \left[\frac{230}{230}\right]^2 x \frac{10}{10} = 0.02 + j0.08\ pu$$

$$Z_{Tr2} = (0.012 + j0.06) x \frac{10}{5} = 0.024 + j0.12\ pu$$

$$Z_{L1} = \frac{32}{14.4} = 2.2222\ pu$$

$$S_{L2} = \left(\frac{P_{L2}}{pf_{L2}} \angle +\text{Cos}^{-1}0.8\right) / S_b = \left(\frac{4}{0.8}\angle 36.87^\circ\right) / 10 = 0.5\angle 36.87^\circ\ pu$$

$$V_{L2} = \frac{22}{V_b} = \frac{22}{22} = 1\angle 0^\circ\ pu;\ 0^\circ \text{ is our reference angle.}$$

$$I_{L2} = \left(\frac{S_{L2}}{V_{L2}}\right)^* = \left(\frac{0.5\angle 36.87^\circ}{1\angle 0^\circ}\right)^* = 0.5\angle -36.87^\circ\ pu$$

$$Z_{L2} = \frac{V_{L2}}{I_{L2}} = \left(\frac{1\angle 0^\circ}{0.5\angle -36.87^\circ} \right)^* = 2\angle 36.87^\circ \text{ pu}$$

(b)

$$V_3 = V_{L2} = 1\angle 0^\circ \text{ pu}$$

$$I_{L1} = \frac{V_3}{Z_{Tr2} + Z_{L1}} = \frac{1\angle 0^\circ}{2.2462 + j0.12} = \frac{1\angle 0^\circ}{2.2494\angle 3.058^\circ} = 0.4446\angle -3.058^\circ \text{ pu}$$

$$I_{Line} = I_{L1} + I_{L2} = 0.4446\angle -3.058^\circ + 0.5\angle -36.87^\circ = 0.904\angle -20.985^\circ$$

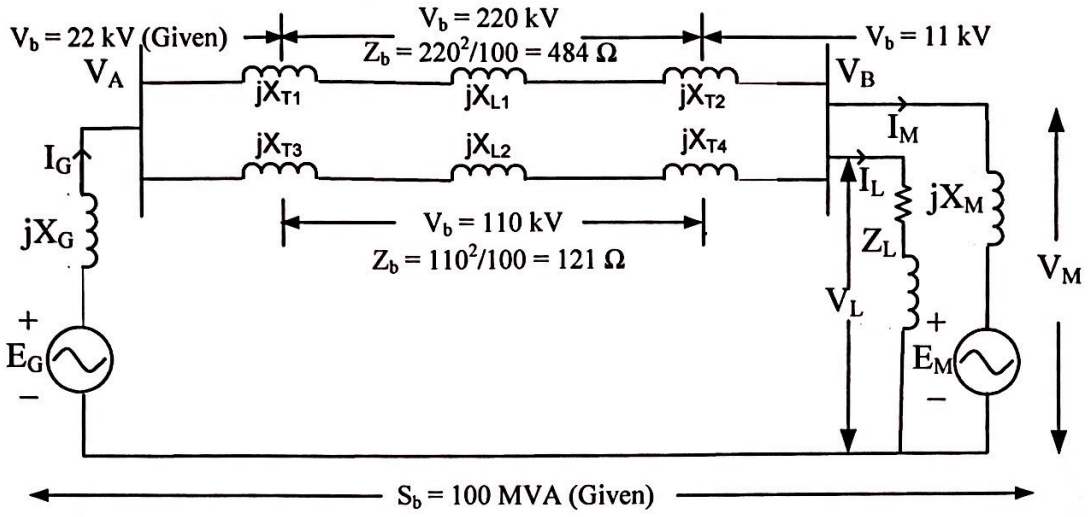
$$V_2 = Z_{Line} \times I_{Line} + V_3 = 0.1519\angle 78.23^\circ \times 0.904\angle -20.985^\circ + 1\angle 0^\circ = 1.0805\angle 6.134^\circ$$

Actual $|V_2| = 1.0805 \times 22 = 23.77$ kV

$$V_1 = Z_{Tr1} \times I_{Line} + V_2 = (0.02 + j0.08) \times 0.904\angle -20.985^\circ + 1.0805\angle 6.134^\circ = 0.07454\angle 54.98^\circ + 1.0805\angle 6.134^\circ = 1.1310\angle 8.98^\circ$$

Actual $|V_1| = 1.1310 \times 230 = 260.12$ kV

2.3 (a)



$$X_G = X_{G,old} x \left[\frac{V_{b,old}}{V_{b,new}}\right]^2 x \left[\frac{S_{b,new}}{S_{b,old}}\right]$$

$$= 0.18x\left[\frac{22}{22}\right]^2 x\frac{100}{90} = 0.2 \text{ pu}$$

$$X_{T1} = 0.10x\frac{100}{50} = 0.2 \text{ pu}$$

$$X_{L1} = \frac{48.4}{484} = 0.1 \text{ pu}$$

$$X_{T2} = 0.06x\frac{100}{40} = 0.15 \text{ pu}$$

$$X_{T3} = 0.064x\frac{100}{40} = 0.16 \text{ pu}$$

$$X_{L2} = \frac{65.43}{121} = 0.5407 \text{ pu}$$

$$X_{T4} = 0.08x\frac{100}{40} = 0.2 \text{ pu}$$

$$X_M = 0.185x\left[\frac{10.45}{11}\right]^2 x\frac{100}{66.5} = 0.2511 \text{ pu}$$

$$V_M = V_L = V_B = \frac{10.45}{11} = 0.95\angle 0^\circ \text{ pu; } 0^\circ \text{ is our reference angle.}$$

$$S_L = \frac{57}{100}\angle 53.13^\circ = 0.57\angle 53.13^\circ \text{ pu}$$

$$I_L = \left(\frac{S_L}{V_L}\right)^* = \left(\frac{0.57\angle 53.13^\circ}{0.95\angle 0^\circ}\right)^* = 0.6\angle -53.13^\circ \text{ pu}$$

$$Z_L = \frac{V_L}{I_L} = \frac{0.95\angle 0^\circ}{0.6\angle -53.13^\circ} = 1.583\angle 53.13^\circ = 0.95 + j1.267 \text{ pu}$$

(b)

$$S_M = \frac{66.5}{100} = 0.665\angle -36.87^\circ \text{ pu}$$

$$I_M = \left(\frac{S_M}{V_L}\right)^* = \left(\frac{0.665\angle -36.87^\circ}{0.95\angle 0^\circ}\right)^* = 0.7\angle 36.87^\circ \text{ pu}$$

The total current going through the parallel (top and bottom) branches is also the generator current,

$I_G = I_M + I_L = 0.7\angle 36.87^\circ + 0.6\angle -53.13^\circ = 0.9219\angle -3.73^\circ$

where I_L is computed in part 2.3(a).

(i) The voltage at the generator bus is

$V_A = I_G \text{ x } j[(X_{T1} + X_{L1} + X_{T2}) \,||\, (X_{T2} + X_{L2} + X_{T4})] + V_B = 0.9219\angle -3.73^\circ \text{ x } j(0.45 \,||\, + 0.9007) + 0.95\angle 0^\circ = 1.0066\angle 15.917^\circ$

Actual $|V_A| = 1.0066 \times 22 = 22.145$ kV

(ii) The generator internal emf is

$$E_G = jX_G I_G + V_A = 0.2\angle 90^\circ \times 0.9219\angle -3.73^\circ + 1.0066\angle 15.917^\circ$$
$$= 1.0826\angle 25.15^\circ \text{ pu}$$

Actual $|E_G| = 1.0826 \times 22 = 23.817$ kV

The motor internal emf is

$$E_M = V_B - jX_M I_M = 0.95\angle 0^\circ - 0.2511\angle 90^\circ \times 0.7\angle 36.87^\circ$$
$$= 1.065\angle -7.589^\circ \text{ pu}$$

Actual $|E_M| = 1.065 \times 11 = 11.713$ kV