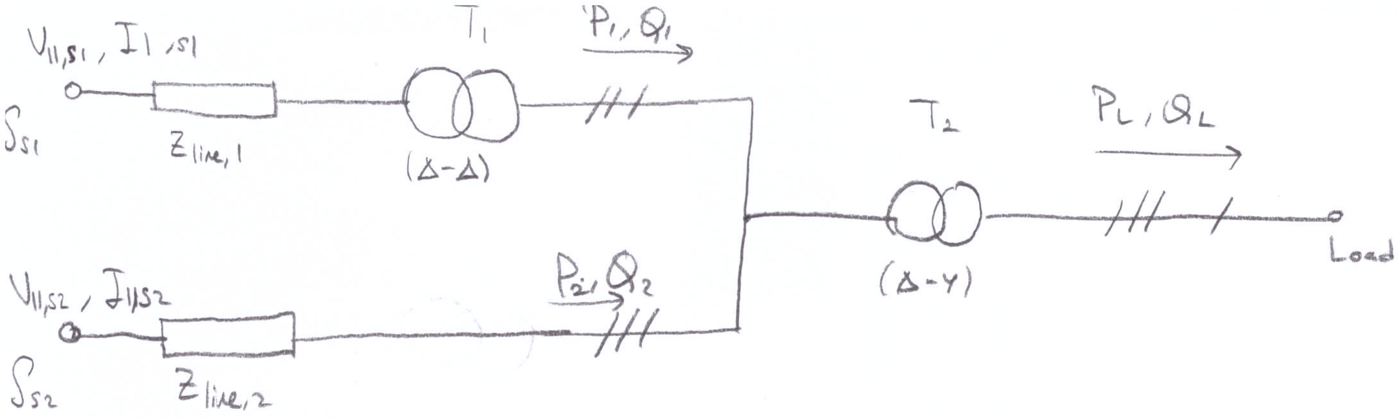


a) $\Delta - Y$ connection is selected for T_2 in order to provide neutral connection to the load.

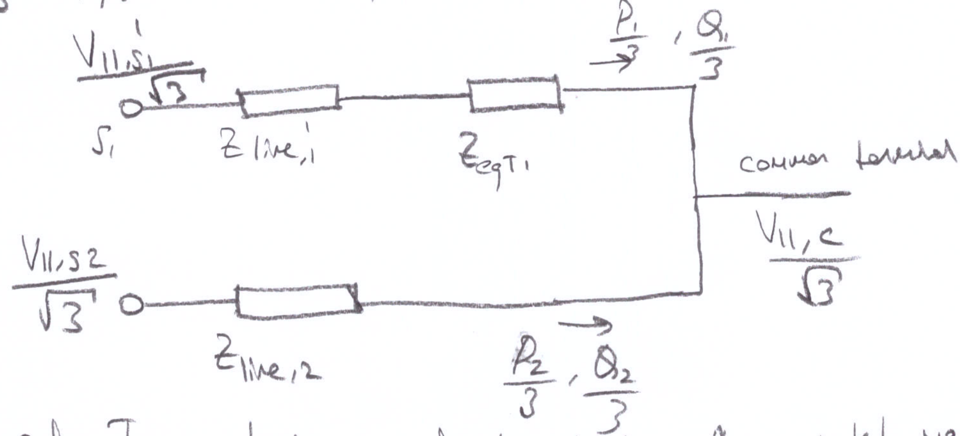
b) Let us first refer the left side of T_1 to the right side.

$$V_{ll,S1}' = V_{ll,S1}\,\frac{6.9}{15} \qquad Z_{line,1}' = Z_{line}\left(\frac{6.9}{15}\right)^2$$

$$Z_{T_1-HV}^{(Y)} = \frac{Z_{T_1-HV}}{3} \qquad Z_{T_1-LV}^{(Y)} = \frac{Z_{T_1 LV}}{3}$$

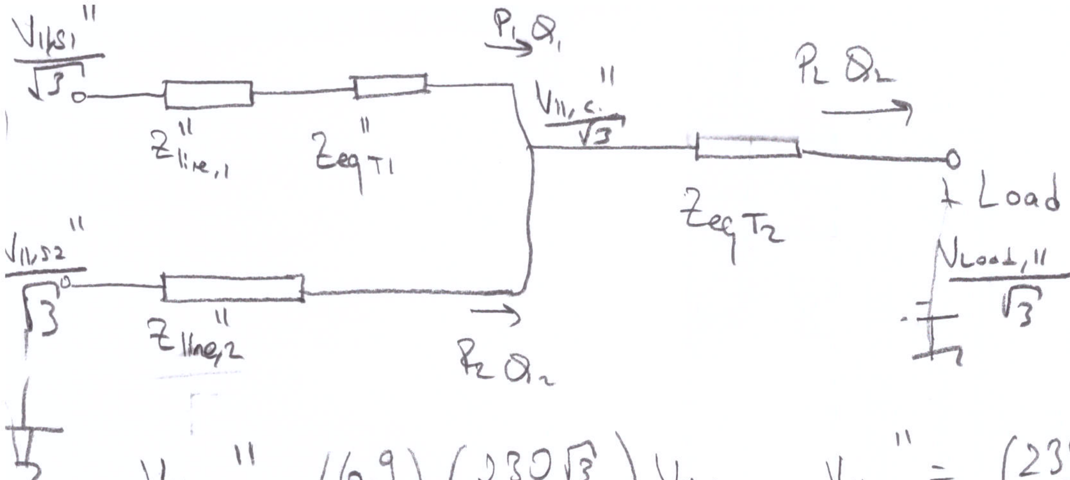
$$Z_{T_1-HV}^{(Y)'} = \frac{Z_{T_1-HV}}{3}\left(\frac{6.9}{15}\right)^2 \qquad Z_{eq_{T_1}} = Z_{T_1-LV}^{(Y)} + Z_{T_1-HV}^{(Y)'}$$

- for upper leg the per-phase circuit
- for lower leg the per phase



For the reference of T_2 let us first find the rated voltage ratio of T_2. Since it is $(\Delta - Y)$ connected ratio is $6.9\,kV : 230\sqrt{3}\,V$.

The line to neutral single phase referred circuit is given as follows;



$$V''_{ll,s1} = \left(\frac{6.9}{15}\right)\left(\frac{230\sqrt{3}}{6.9\times10^3}\right) V_{ll,s1} \qquad V''_{ll,s2} = \left(\frac{230\sqrt{3}}{6.9\times10^3}\right) V_{ll,s2}$$

$$V''_{ll,c} = \left(\frac{230\sqrt{3}}{6.9\times10^3}\right) V_{ll,c} \qquad Z''_{line,1} = \left(\frac{6.9}{15}\right)^2\left(\frac{230\sqrt{3}}{6.9\times10^3}\right)^2 Z_{line,1}$$

$$Z''_{eqT1} = \left(\frac{230\sqrt{3}}{6.9\times10^3}\right)^2 Z_{eqT1} \qquad Z''_{line,2} = \left(\frac{230\sqrt{3}}{6.9\times10^3}\right)^2 Z_{line,2}$$

$$Z_{eq,T_2} = Z^{(Y)'}_{T_2\,HV} + Z_{T2-LV} \qquad Z^{(Y)'}_{T_2\,HV} = \frac{Z_{T_2-HV}}{3}\left(\frac{230\sqrt{3}}{6.9\times10^3}\right)^2$$

so numerically;

$$Z''_{line,1} = 3.5\times10^{-3}(1+j) \qquad Z''_{eqT1} = 7.4\times10^{-3}\,j$$

$$Z''_{line,2} = 3.3\times10^{-3}(1+j) \qquad Z_{eq,T_2} = 6.3\times10^{-3}(1+j)$$

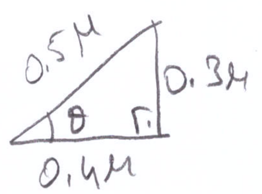
c) Since nominal voltage adjusted to the load; $\frac{V_{Load,ll}}{\sqrt{3}} = 230V$

for 1phase $P_{L\phi} = 0.4MW \quad Q_{L\phi} = 0.3\,MVar$

$$|S| = 0.5MW \qquad = 230\angle 0^\circ \cdot I^*_{Load,line}$$

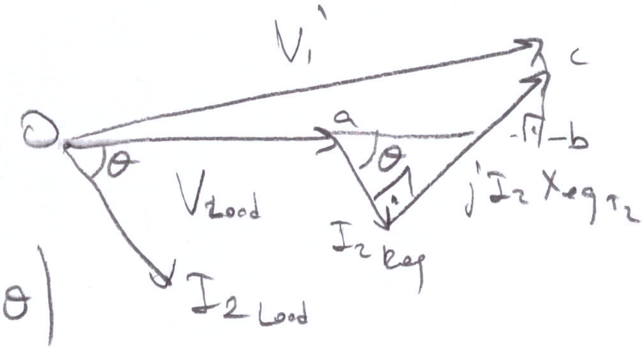
$$I_{load,line} = 2.1739\,kA\angle\alpha \qquad \alpha = \tan^{-1}\left(\frac{0.3}{0.4}\right)$$

$$I_{load,line} = (1.7391 - j\,1.3043)\,kA$$

d) From the power triangle  $\cos\theta = 0.8$

$p.f. = 0.8$ lagging

e) For T_2 line to neutral



assuming $|ob| \cong |oc|$

$$V_1' = V_2 + I_2(R_{eq_{T2}} \cos\theta + X_{eq} \sin\theta)$$

$$|V_1'| = 230 + 2.1739k\,(6.3\times10^{-3})(0.8+0.6)$$

$$|V_1'| = 248.7328 \qquad \text{Regulation} = \frac{248.7328-230}{230}\times100 = 8.1447$$

f) From previous part we know that $\frac{V_{ll,c}''}{\sqrt{3}} = 248.7328\ V$

$$P_{2,\phi} = \frac{0.4MW}{3} \qquad Q_{2,\phi} = 0.1\ MVar$$

$$I_{e,s2}'' \cdot \frac{V_{ll,c}''}{\sqrt{3}} = |S_{2,\phi}| \Rightarrow I_{e,s2}'' = 670.0631\ A$$

$$P_{line,2} = (I_{e,s}'')^2\ 3.3\times10^{-3} \qquad Q_{line,2}'' = (I_{l,s2}'')^2\ 3.3\times10^{-3}$$

$$S_{line,2} = 1481.6\,(1+j)\ VA$$

So; $S_{2,\phi} + S_{line,2} = S_{source2,\phi} \Rightarrow (134.81 + j101.48)\ kVA$

$$P_{1,\phi} = \frac{0.8}{3} MW \qquad Q_{1,\phi} = 0.2\ MVar$$

$$I_{e,1}'' \cdot \frac{V_{ll,c}''}{\sqrt{3}} = |S_{1,\phi}| \Rightarrow I_{e,s2}'' = 1340.1\ A$$

$$P_{line,1} = (I_{e,1}'')^2 (3.5+7.4)\times10^{-3}$$

$$S_{line,1} = 195.76\,(1+j)\ kVA$$

$$S_{1,\phi} + S_{line,1} = S_{source,1\phi} \Rightarrow (462.43 + j335.76)\ kVA$$

So; in 3 phase $\Rightarrow$

$$S_{s1} = (1387.3 + j\,1187.3)\ kVA$$

$$S_{s2} = (404.44 + j\,304.44)\ kVA$$

g) Effriciency $\eta = \frac{P_{out}}{P_{in}} \times 100$

$$\frac{1.2 \times 10^6}{(1387.3 + 404.44) \times 10^3} \Rightarrow \% \, 66.97$$

h) from part f we have power values;

$$\frac{V''_{11,S1}}{\sqrt{3}} \cdot I''_{es1} = |S_{S1}| \Rightarrow \frac{V''_{11S1}}{\sqrt{3}} = 454.1903 \quad V''_{11,S1} = 786.6806$$

$$V_{11,S1} = \left(\frac{15}{6.9}\right)\left(\frac{6.9 \times 10^3}{230\sqrt{3}}\right) V''_{11,S1} \Rightarrow V_{11,S1} = 29621 \text{ V}$$

i) Similarly; from part f we have power values;

$$\frac{V''_{11,S2}}{\sqrt{3}} \cdot I''_{l,s} = |S_{S2}| \rightarrow \frac{V''_{11,S2}}{\sqrt{3}} = 251.8215 \quad V''_{11,S2} = 436.1676$$

$$V_{11,S1} = \left(\frac{6.9 \times 10^3}{230\sqrt{3}}\right) V''_{11,S2} \Rightarrow V_{11,S2} = 7554.6 \text{ V}$$

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