Transformer Tutorial

1. Primary side : 15000 V
Secondary side : 240V

$$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{15000}{240} = \underline{62.5}$$

2. $$\frac{R_1}{R_2} = \left(\frac{N_1}{N_2}\right)^2 \Rightarrow \left(\frac{400}{N_2}\right)^2 = \frac{2000}{6}$$

$$\underline{N_2 = 22 \text{ turns.}}$$

3. $$V_2 = \frac{N_2}{N_1} V_1 = \frac{500}{2000} \times 1200\angle 0^\circ$$

$$\underline{V_2 = 300\angle 0^\circ \quad V}$$

$$I_2 = \frac{N_1}{N_2} I_1 = \frac{2000}{500} \times 5\angle -30^\circ$$

$$\underline{I_2 = 20\angle -30^\circ \quad A}$$

$$Z_2 = \frac{V_2}{I_2} = \frac{300\angle 0^\circ}{20\angle -30^\circ}$$

$$\underline{Z_2 = 15\angle 30^\circ \quad \Omega}$$

$$Z_2' = \left(\frac{N_1}{N_2}\right)^2 Z_2 = \left(\frac{2000}{500}\right)^2 \times 15\angle 30^\circ$$

$$\underline{Z_2' = 240\angle 30^\circ \quad \Omega}$$

4. Reflect all impedance to the source side. In this case, there will be two conversion stages due to two transformers.

$$R'_{mid} = \left(\frac{N'_2}{N_3}\right)^2 R_{right} = \left(\frac{1}{2}\right)^2 \times 8 = 2\,\Omega$$

$$R_{mid} = R + R'_{mid} = 3+2 = 5\,\Omega$$

$$R'_{left} = \left(\frac{N_1}{N_2}\right)^2 R_{mid} = \left(\frac{3}{1}\right)^2 \times 5 = 45\,\Omega$$

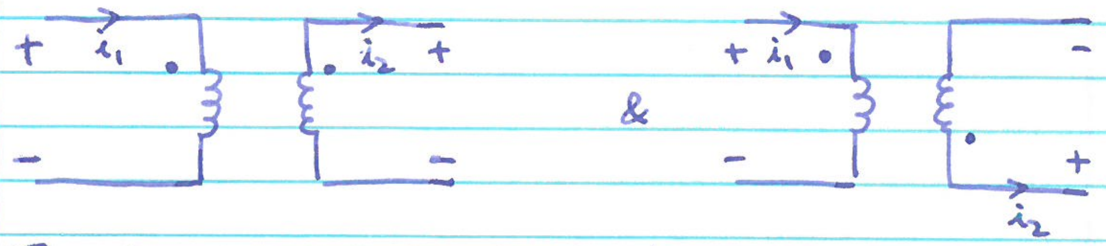
$$\Rightarrow R_{tot} = 45+5 = 50\,\Omega$$

$$I_1 = \frac{V_1}{R_{tot}} = \frac{200\angle 90^\circ}{50} = \underline{4\angle 90^\circ\ A}$$

$$I_2 = \left(\frac{N_1}{N_2}\right) I_1 = \frac{3}{1} \times 4\angle(90^\circ+180^\circ) = \underline{12\angle 270^\circ A}$$

$$I_3 = \left(\frac{N'_2}{N_3}\right) I_2 = \frac{1}{2} \times 12\angle 270^\circ = \underline{6\angle 270^\circ A}$$

Note. The dot on the transformer coil indicates the direction of current flowing out of the coil.



Flip of coil current due to load connection results to 180° phase shift.

5. 38.1 kV (Y) – 3.81 kV (Δ) Transformer.

38.1 kV is phase voltage ⇒ line (rated) voltage is

$\sqrt{3} \times 38.1\ \text{kV} = \underline{66\ \text{kV}}$.

⇒ 38.1 kV is the base of HV side when line-neutral.

$$Z_{base}^{LV} = \frac{(V_{LV,B})^2}{MVA_B} = \frac{(3.81\ \text{kV})^2}{75\ \text{MVA}} = 0.1935\ \Omega$$

$$R_L = \frac{0.6}{0.1935} = \underline{3.10\ \text{p.u.}}$$

$$Z_{base}^{HV} = \frac{(V_{HV,B})^2}{MVA_B} = \frac{(66\ \text{kV})^2}{75\ \text{MVA}} = 58.1\ \Omega$$

$$R_L = 0.6 \cdot \left(\frac{66}{3.81}\right)^2 = \underline{180\ \Omega}$$

$$\Rightarrow R_L = \frac{180}{58.1} = \underline{3.10\ \text{p.u.}}$$

Ans: R_L is same in per unit when reflected to HV and LV.

6. $R_{e,LV} = 0.121\ \Omega$.

Using 400 MVA as its base:

$$R_e = 0.121 \Big/ \frac{(22kV)^2}{400MVA} = \underline{0.10\ p.u.}$$

$$R_e' = 0.1 \left(\frac{220}{230}\right)^2 \times \frac{100}{400} = \underline{0.0228\ p.u.}$$

⇒ change from one base to another base.

7. LV side: $VA_B = 100MVA$, $V_B = 7.97kV$

$$\Rightarrow R_B^{LV} = X_B^{LV} = \frac{(V_B)^2}{VA_B} = \frac{(7.97kV)^2}{100MVA} = 0.635\ \Omega.$$

HV side: $VA_B = 100MVA$, $V_B = 79.7kV$

$$\Rightarrow R_B^{HV} = X_B^{HV} = \frac{(79.7kV)^2}{100MVA} = 63.5\ \Omega.$$

$$\Rightarrow X_L = \frac{0.040\ \Omega}{0.635\ \Omega} = \underline{0.0630\ p.u.}$$

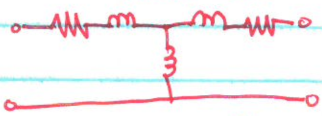
$$X_H = \frac{3.75\ \Omega}{63.5\ \Omega} = \underline{0.0591\ p.u.}$$

$$X_m = \frac{114\ \Omega}{0.635\ \Omega} = \underline{180\ p.u.}$$

$$R_L = \frac{0.76\ m\Omega}{0.635\ \Omega} = \underline{0.0012\ p.u.}$$

$$R_H = \frac{0.085\ \Omega}{63.5\ \Omega} = \underline{0.0013\ p.u.}$$

Remove ideal transformer.



Note. Normalize turn ratio to transformer base: $\left(\frac{7.97kV}{7.97kV}\right) : \left(\frac{79.7kV}{79.7kV}\right) = 1 : 1$

8. LV side: $Z_B^{LV} = \dfrac{(460\,V)^2}{250\,kVA} = 0.846\ \Omega.$

But the common base is 100 kVA at 460 V

$$Z_{B,100kVA}^{LV} = \frac{460^2}{100 \times 10^3} = 2.12\ \Omega$$

* Need to convert to transformer base then to common base.

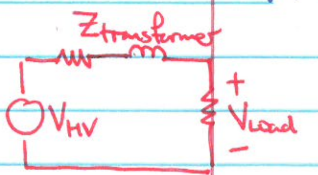
$\Rightarrow$ $Z_{transformer} = (0.026 + j0.12) \cdot \left(\dfrac{0.846}{2.12}\right)$

$= 0.0106 + j0.0489$ p.u. (at 100kV base).

$$V_{Load} = \frac{438\,V}{460\,V} = 0.952\angle 0^\circ \text{ p.u.}$$

$$I_{Load} = \frac{P}{V} = \frac{95\,kVA / 100\,kVA}{0.952\angle 0^\circ} = 0.998\angle 0^\circ \text{ p.u.}$$

HV side: $V_{HV} = V_{Load} + I_{Load} Z_{transformer}$



$= 0.952\angle 0^\circ + 0.998\angle 0^\circ \times (0.0106 + j0.0489)$

$V_{HV} = 0.963 + j0.0488$

$= 0.964 \angle 29.0^\circ$ p.u.

$\Rightarrow$ $V_{HV}^{act} = 0.964\angle 29.0^\circ \times 2400 = \underline{2313\ V}$ (rated l-l.)