(a) \[ \frac{E_1}{N_1} = \frac{E_2}{N_2} = \frac{2400}{240} = 2300 \text{ V} \]

(b) \[ \bar{E}_2 = \bar{E}_2 \bar{I}_2 \quad \bar{I}_2 = \left( \frac{E_2}{E_1} \right) = \left( \frac{2400}{220} \right) = 10.907 \text{ A} \]

\[ \bar{Z}_2 = \frac{\bar{E}_2}{\bar{I}_2} = \frac{220 \angle 0^\circ}{10.907 \angle -36.87^\circ} = 20.907 \angle -36.87^\circ = 0.6613 \angle 36.87^\circ - \bar{Z}_2 = 0.529 + j 0.397 \Omega \]

(c) \[ \bar{Z}_1 = \left( \frac{N_1}{N_2} \right)^2 \bar{Z}_2 = 100 \bar{Z}_2 = 66.13 \angle 36.87^\circ \Omega \]

(d) \[ P_1 = P_2 = 80 (0.8) = 64 \text{ kW} \]

\[ Q_1 = Q_2 = 64 \text{ kvar (36.87\(^\circ\))} = 48 \text{ kvar} \]
Neglecting the series impedance:

\[ \bar{E}_1 = \frac{N_1}{N_2} \bar{E}_2 = \frac{N_1}{N_2} \bar{V}_2 = (\frac{2400}{240}) \cdot 240/\angle 0^\circ = 2400/\angle 0^\circ \ V \]

\[ \frac{N_2}{N_1} \frac{I_2}{I_1} = \left( \frac{240}{2400} \right) (5.97) = 0.597 \ A \]

\[ G_C = \frac{P_2}{E_1^2} = \frac{213}{(2400)^2} = 3.698 \times 10^{-5} \ s \]

\[ Y_C = \left( \frac{N_2}{N_1} \frac{I_2}{I_1} \right) / E_1 = 0.597 / 2400 = 2.4875 \times 10^{-7} \ s \]

\[ B_m = \sqrt{Y_C^2 - G_C^2} = \sqrt{(2.4875 \times 10^{-7})^2 - (3.698 \times 10^{-5})^2} \]

\[ B_m = 2.460 \times 10^{-7} \ s \]

\[ Y_C = G_C - j B_m = 3.698 \times 10^{-5} - j 2.460 \times 10^{-7} = 2.4875 \times 10^{-7} / 81.45^\circ S \]
\[ R_{eq1} = \frac{P_1}{|I_1|^2} = \frac{750}{(20.8^2)} = 1.734 \, \Omega \]

\[ Z_{eq1} = \frac{V_1}{|I_1|} = \frac{60}{20.8} = 2.885 \, \Omega \]

\[ X_{eq1} = \sqrt{Z_{eq1}^2 - R_{eq1}^2} = \sqrt{(2.885)^2 - (1.734)^2} = 2.306 \, \Omega \]

\[ Z_{eq1} = R_{eq1} + jX_{eq1} = 1.734 + j2.306 = 2.885 \angle 33.06^\circ \, \Omega \]

\[
\begin{align*}
    Z_1 &= \frac{R_{eq1/2}}{Z_{eq1/2}} + \frac{jX_{eq1/2}}{Z_{eq1/2}} \quad \text{(c)} \\
    V_1 &= G_c = 3.678 \times 10^{-5} \\
    E_m &= -j2.046 \times 10^{-5} \\
    \text{Equivalent T circuit referred to high voltage side} \\
\end{align*}
\]

3.8.

\[ \bar{V}_1 = 2400/0^\circ \]

Using voltage division:

\[ E_1 = \left(2400/0^\circ\right) \frac{36000}{j(6000+1)} = 2399.6 \angle 0^\circ \, V \]

\[ \bar{V}_2 = \bar{E}_2 = \left(\frac{N_1}{N_2}\right) \bar{E}_1 = 239.96 \angle 0^\circ \, V \]
(a) \[
\alpha = \frac{2400}{240} = 10
\]
\[
R'_2 = \alpha^2 R_2 = \left(\frac{2400}{240}\right)^2 \times 0.0075 = 0.75 \Omega
\]
\[
x'_2 = \alpha^2 x_2 = (10)^2 \times 0.01 = 1.0 \Omega
\]

Refered to the HV-side, the exciting branch conductance and susceptance are given by

\[
\left(\frac{1}{\alpha^2}\right) \times 0.003 = \left(\frac{1}{100}\right) \times 0.003 = 0.03 \times 10^{-3} \text{ S}
\]

And

\[
\left(\frac{1}{\alpha^2}\right) \times 0.02 = \left(\frac{1}{100}\right) \times 0.02 = 0.2 \times 10^{-3} \text{ S}
\]

The equivalent circuit referred to the high-voltage side is shown below:

(b) \[
R'_1 = R_1 / \alpha^2 = 0.0075 \Omega
\]
\[
x'_1 = x_1 / \alpha^2 = 0.01 \Omega
\]

The equivalent circuit referred to the low-voltage side is shown below:
\[
\begin{align*}
\bar{V}_{1p} & = 1.0 \angle 0^\circ \\
\bar{V}_{2p} & = \frac{j 52.083}{j (0.02083 + 8.6806 \times 10^{-3})} \approx 0.9998 \angle 0^\circ \text{ pu} \\
\bar{V}_2 & = \bar{V}_{2p} \times V_{\text{base}} = (0.9998 \angle 0^\circ)(240) = 239.95 \angle 0^\circ \text{ V}
\end{align*}
\]

S_{\text{base1}} = 50 \text{ kVA} \\
V_{\text{base1}} = 2400 \text{ V} \\
Z_{\text{base1}} = \frac{(2400)^2}{50 \times 10^3} = 115.2 \Omega \\
S_{\text{base2}} = 50 \text{ kVA} \\
V_{\text{base2}} = 240 \text{ V} \\
Z_{\text{base2}} = \frac{(240)^2}{50 \times 10^3} = 1.152 \Omega

Using voltage division:

Using voltage division:
SELECT A COMMON BASE OF 100 MVA AND 22 kV (NOT 23 kV PRINTED WRONGLY IN THE TEXT) ON THE GENERATOR SIDE;

BASE VOLTAGE AT BUS 1 IS 22 kV; THIS FIXES THE VOLTAGE BASES FOR THE REMAINING BUSES IN ACCORDANCE WITH THE TRANSFORMER TURNS RATIOS.

USING EQUATION 3.3.11, PER-UNIT REACTANCES ON THE SELECTED BASE ARE GIVEN BY

\[ G: \begin{align*}
\frac{X}{100} &= 0.15 \left( \frac{100}{50} \right) = 0.2 \\
T_1: \frac{X}{20} &= 0.1 \left( \frac{100}{20} \right) = 0.25
\end{align*} \]

\[ T_2: \frac{X}{20} = 0.06 \left( \frac{100}{20} \right) = 0.15 \]

\[ T_3: \frac{X}{20} = 0.064 \left( \frac{100}{20} \right) = 0.16 \]

\[ T_4: \frac{X}{20} = 0.00 \left( \frac{100}{20} \right) = 0.25 \]

\[ M: \frac{X}{20} = 0.185 \left( \frac{100}{20} \right) \left( \frac{10.45}{10} \right)^2 = 0.25 \]

FOR LINE 1, \[ Z_{BASE} = \frac{280^2}{100} = 484 \] AND \[ X = \frac{48.4}{484} = 0.1 \]

FOR LINE 2, \[ Z_{BASE} = \frac{110^2}{100} = 121 \] AND \[ X = \frac{65.43}{121} = 0.54 \]

THE LOAD COMPLEX POWER AT 0.6 LAGGING PF IS \[ S_L(34) = 57/53.15 \] MVA.

\[ V^2_L = \frac{(10.45)^2}{57/53.15} = \frac{V^2_{LL}}{S_L(34)} \]

\[ = 1.1495 + j 1.53267 \] M.

THE BASE IMPEDANCE FOR THE LOAD IS \[ \frac{(11)^2}{100} = 1.21 \]

\[ \text{LOAD IMPEDANCE IN PU} = \frac{1.1495 + j 1.53267}{1.21} = 0.95 + j 1.2667 \]

THE PER-UNIT EQUIVALENT CIRCUIT IS SHOWN BELOW:

![Per-Unit Impedance Diagram](image-url)
With a base of 15 MVA and 66 kV in the primary circuit, the base for secondary circuit is 15 MVA and 13.2 kV, and the base for tertiary circuit is 15 MVA and 2.8 kV. Note that $X_{ps}$ and $X_{pt}$ need not be changed.

$X_{st}$ is modified to the new base as follows:

$$X_{st} = 0.08 \times \frac{15}{10} = 0.12$$

With the bases specified, the per-unit reactances of the per-phase equivalent circuit are given by

$$X_p = \frac{1}{2} (j0.07 + j0.09 - j0.12) = j0.02$$
$$X_s = \frac{1}{2} (j0.07 + j0.12 - j0.09) = j0.05$$
$$X_t = \frac{1}{2} (j0.09 + j0.12 - j0.07) = j0.07$$
(a) The autotransformer connection is shown below:

\[ I_1 = \frac{90,000}{80} = 1125 \text{A} \quad ; \quad I_2 = \frac{90,000}{120} = 750 \text{A} \]

\[ V_1 = 80 \text{kv} \quad ; \quad V_2 = 120 + 80 = 200 \text{ kv} \]

\[ I_{in} = 1125 + 750 = 1875 \text{A} \]