PROBLEM SOLUTIONS: Chapter 2

Problem 2.1
At 60 Hz, $\omega = 120\pi$.

$$\text{primary:} \quad (V_{\rm rms})_{\rm max} = N_1 \omega A_{\rm c} (B_{\rm rms})_{\rm max} = 2755 \quad {\rm V, rms}$$

$$\text{secondary:} \quad (V_{\rm rms})_{\rm max} = N_2 \omega A_{\rm c} (B_{\rm rms})_{\rm max} = 172 \quad {\rm V, rms}$$

At 50 Hz, $\omega = 100\pi$. Primary voltage is 2295 V, rms and secondary voltage is 143 V, rms.

Problem 2.2

$$N = \frac{\sqrt{2} V_{\rm rms}}{\omega A_c B_{\rm peak}} = 167 \quad \text{turns}$$

Problem 2.3

$$N = \sqrt{\frac{75}{8}} = 3 \quad \text{turns}$$

Problem 2.4
Resistance seen at primary is $R_1 = (N_1/N_2)^2 R_2 = 6.25\Omega$. Thus

$$I_1 = \frac{V_1}{R_1} = 1.6 \quad {\rm A}$$

and

$$V_2 = \left(\frac{N_2}{N_1}\right) V_1 = 40 \quad {\rm V}$$

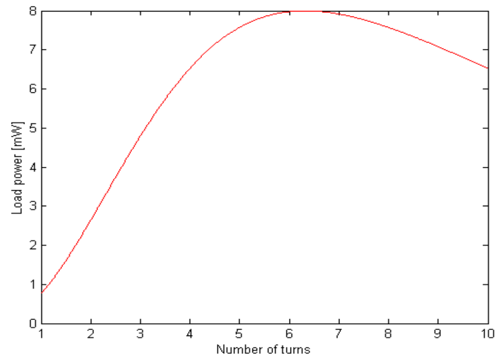
Problem 2.5
The maximum power will be supplied to the load resistor when its impedance, as reflected to the primary of the ideal transformer, equals that of the source (2 kΩ). Thus the transformer turns ratio N to give maximum power must be

$$N = \sqrt{\frac{R_{\rm s}}{R_{\rm load}}} = 6.32$$

Under these conditions, the source voltage will see a total resistance of $R_{\rm tot} =$ 4 kΩ and the current will thus equal $I = V_{\rm s}/R_{\rm tot} = 2$ mA. Thus, the power delivered to the load will equal

$$P_{\rm load} = I^2 (N^2 R_{\rm load}) = 8 \quad {\rm mW}$$

Here is the desired MATLAB plot:



Problem 2.6

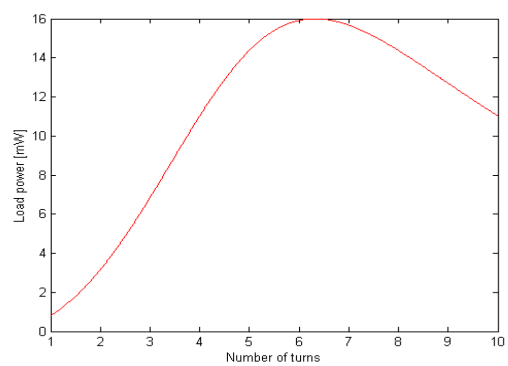
The maximum power will be supplied to the load resistor when its impedance, as reflected to the primary of the ideal transformer, equals that of the source (2 kΩ). Thus the transformer turns ratio N to give maximum power must be

$$N = \sqrt{\frac{R_{\mathrm{s}}}{R_{\mathrm{load}}}} = 6.32$$

Under these conditions, the source voltage will see a total impedance of $Z_{\mathrm{tot}} = 2 + j2$ kΩ whose magnitude is $2\sqrt{2}$ kΩ. The current will thus equal $I = V_{\mathrm{s}}/|Z_{\mathrm{tot}}| = 2\sqrt{2}$ mA. Thus, the power delivered to the load will equal

$$P_{\mathrm{load}} = I^2(N^2 R_{\mathrm{load}}) = 16 \quad \mathrm{mW}$$

Here is the desired MATLAB plot:



Problem 2.7

$$V_2 = V_1 \left(\frac{X_{\rm m}}{X_{\rm l_1} + X_{\rm m}} \right) = 266 \quad {\rm V}$$

Problem 2.8

part (a): Referred to the secondary

$$L_{\rm m,2} = \frac{L_{\rm m,1}}{N^2} = 150 \quad {\rm mH}$$

part(b): Referred to the secondary, $X_{\rm m} = \omega L_{\rm m,2} = 56.7\,\Omega$, $X_{\rm l_2} = 84.8$ mΩ and $X_{\rm l_1} = 69.3$ mΩ. Thus,

$$\text{(i)} \quad V_1 = N \left(\frac{X_m}{X_m + X_{\rm l_2}} \right) V_2 = 7960 \quad {\rm V}$$

and

$$\text{(ii)} \quad I_{\rm sc} = \frac{V_2}{X_{\rm sc}} = \frac{V_2}{X_{\rm l_2} + X_m || X_{\rm l_1}} = 1730 \quad {\rm A}$$

Problem 2.9

part (a):

$$I_1 = \frac{V_1}{X_{\rm l_1} + X_{\rm m}} = 3.47 \quad {\rm A}; \qquad V_2 = N V_1 \left(\frac{X_{\rm m}}{X_{\rm l_1} + X_{\rm m}} \right) = 2398 \quad {\rm V}$$

part (b): Let $X'_{\rm l_2} = X_{\rm l_2}/N^2$ and $X_{\rm sc} = X_{\rm l_1} + X_{\rm m}||(X_m + X'_{\rm l_2})$. For $I_{\rm rated} =$ 50 kVA/120 V = 417 A

$$V_1 = I_{\rm rated} X_{\rm sc} = 23.1 \quad {\rm V}$$

$$I_2 = \frac{1}{N} \left(\frac{X_{\rm m}}{X_{\rm m} + X_{\rm l_2}} \right) I_{\rm rated} = 15.7 \quad {\rm A}$$

Problem 2.10

$$I_{\rm L} = \frac{P_{\rm load}}{V_L} = 55.5 \quad {\rm A}$$

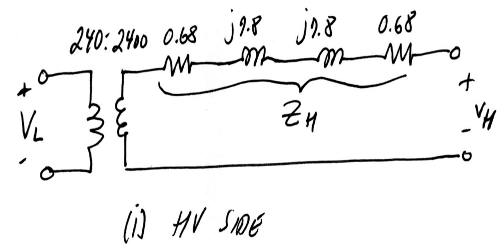
and thus

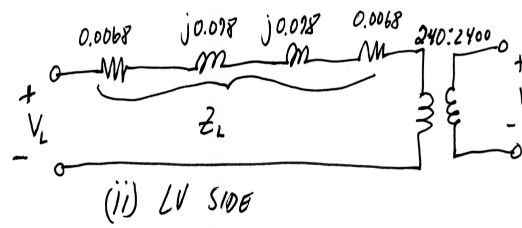
$$I_{\rm H} = \frac{I_{\rm L}}{N} = 10.6 \quad {\rm A}; \qquad V_{\rm H} = N V_{\rm L} + j X_{\rm H} I_{\rm H} = 2381\angle 9.6^\circ \quad {\rm V}$$

The power factor is $\cos(9.6^\circ) = 0.986$ lagging.

Problem 2.11

part (a):





part (b):

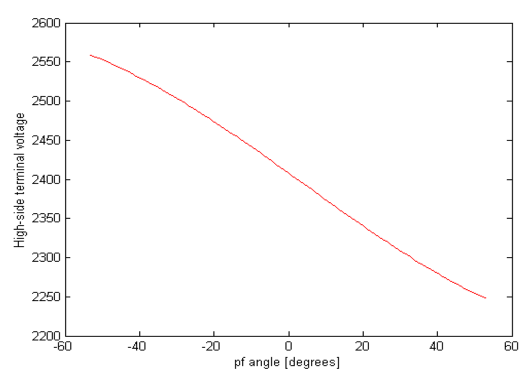
$$\hat{I}_{\text{load}} = \frac{30 \text{ kW}}{230 \text{ V}}\, e^{j\phi} = 93.8\, e^{j\phi} \quad \text{A}$$

where ϕ is the power-factor angle. Referred to the high voltage side, $\hat{I}_{\text{H}} = 9.38\, e^{j\phi}\text{A}$.

$$\hat{V}_{\text{H}} = Z_{\text{H}} \hat{I}_{\text{H}}$$

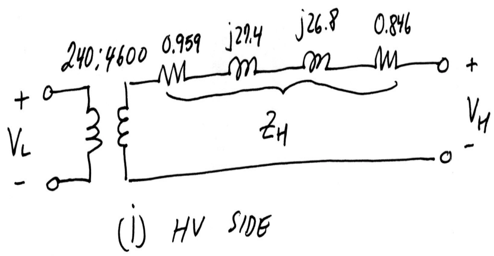
Thus, (i) for a power factor of 0.85 lagging, $V_{\text{H}} = 2413$ V and (ii) for a power factor of 0.85 leading, $V_{\text{H}} = 2199$ V.

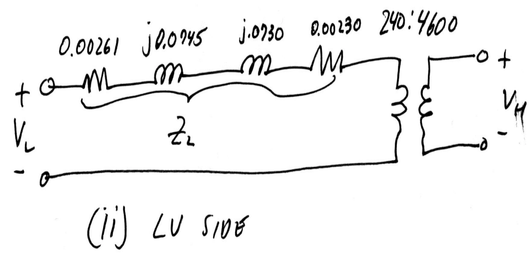
part (c):



Problem 2.12

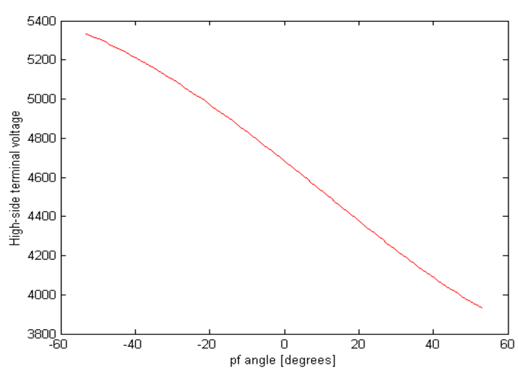
part (a):





part (b): Following methodology of Problem 2.11, (i) for a power factor of 0.85 lagging, $V_{\mathrm{H}} = 4956$ V and (ii) for a power factor of 0.85 leading, $V_{\mathrm{H}} = 4000$ V.

part (c):



Problem 2.13

part (a): $I_{\mathrm{load}} = 160\,\mathrm{kW}/2340\,\mathrm{V} = 68.4$ A at $\angle = \cos^{-1}(0.89) = 27.1°$

$$\hat{V}_{\mathrm{t,H}} = N(\hat{V}_{\mathrm{L}} + Z_{\mathrm{t}} I_{\mathrm{L}})$$

which gives $V_{\mathrm{H}} = 33.7$ kV.

part (b):

$$\hat{V}_{\mathrm{send}} = N(\hat{V}_{\mathrm{L}} + (Z_{\mathrm{t}} + Z_{\mathrm{f}}) I_{\mathrm{L}})$$

which gives $V_{\text{send}} = 33.4$ kV.

part (c):

$$S_{\text{send}} = P_{\text{send}} + jQ_{\text{send}} = \hat{V}_{\text{send}}\hat{I}^*_{\text{send}} = 164 \text{ kW} - j64.5 \text{ kVAR}$$

Thus $P_{\text{send}} = 164$ kW and $Q_{\text{send}} = -64.5$ kVAR.

Problem 2.14

Following the methodology of Example 2.6, efficiency = 98.4 percent and regulation = 1.25 percent.

Problem 2.15

part (a):

$$|Z_{\text{eq,L}}| = \frac{V_{\text{sc,L}}}{I_{\text{sc,L}}} = 107.8 \text{ m}\Omega$$

$$R_{\text{eq,L}} = \frac{P_{\text{sc,L}}}{I^2_{\text{sc,L}}} = 4.78 \text{ m}\Omega$$

$$X_{\text{eq,L}} = \sqrt{|Z_{\text{eq,L}}|^2 - R^2_{\text{eq,L}}} = 107.7 \text{ m}\Omega$$

and thus

$$Z_{\text{eq,L}} = 4.8 + j108 \text{ m}\Omega$$

part (b):

$$R_{\text{eq,H}} = N^2 R_{\text{eq,L}} = 0.455\ \Omega$$

$$X_{\text{eq,H}} = N^2 X_{\text{eq,L}} = 10.24\ \Omega$$

$$Z_{\text{eq,H}} = 10.3 + j0.46 \text{ m}\Omega$$

part (c): From the open-circuit test, the core-loss resistance and the magnetizing reactance as referred to the low-voltage side can be found:

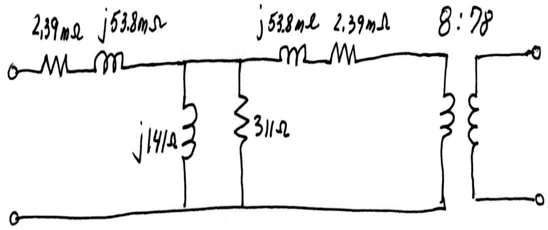
$$R_{\text{c,L}} = \frac{V^2_{\text{oc,L}}}{P_{\text{oc,L}}} = 311\ \Omega$$

$$S_{\text{oc,L}} = V_{\text{oc,L}} I_{\text{oc,L}} = 497 \text{ kVA}; \quad Q_{\text{oc,L}} = \sqrt{S^2_{\text{oc,L}} - P^2_{\text{oc,L}}} = 45.2 \text{ kVAR}$$

and thus

$$X_{\mathrm{m,L}} = \frac{V_{\mathrm{oc,L}}^2}{Q_{\mathrm{oc,L}}} = 141\ \Omega$$

The equivalent-T circuit for the transformer from the low-voltage side is thus:



part (d): We will solve this problem with the load connected to the high-voltage side but referred to the low-voltage side. The rated low-voltage current is $I_{\mathrm{L}} = 50$ MVA/8 kV = 6.25 kA. Assume the load is at rated voltage. Thus the low-voltage terminal voltage is

$$V_{\mathrm{L}} = |V_{\mathrm{load}} + Z_{\mathrm{eq,L}} I_{\mathrm{L}}| = 8.058\ \mathrm{kV}$$

and thus the regulation is given by (8.053-8)/8 = 0.0072 = 0.72 percent.

The total loss is approximately equal to the sum of the open-circuit loss and the short-circuit loss (393 kW). Thus the efficiency is given by

$$\eta = \frac{P_{\mathrm{load}}}{P_{\mathrm{in}}} = \frac{50.0}{50.39} = 0.992 = 99.2\ \text{percent}$$

part (e): We will again solve this problem with the load connected to the high-voltage side but referred to the low-voltage side. Now, $\hat{I}_{\mathrm{L}} = 6.25\angle 25.8°$ kA. Assume the load is at rated voltage. Thus the low-voltage terminal voltage is

$$V_{\mathrm{L}} = |V_{\mathrm{load}} + Z_{\mathrm{eq,L}} \hat{I}_{\mathrm{L}}| = 7.758\ \mathrm{kV}$$

and thus the regulation is given by (7.758-8)/8 = -0.0302 = -3.02 percent. The efficiency is the same as that found in part (d), $\eta = 99.2$ percent.

Problem 2.16

The core length of the second transformer is is $\sqrt{2}$ times that of the first, its core area of the second transformer is twice that of the first, and its volume is $2\sqrt{2}$ times that of the first. Since the voltage applied to the second transformer is twice that of the first, the flux densitities will be the same. Hence, the core loss will be proportional to the volume and

$$\mathrm{Coreloss} = 2\sqrt{2}3420 = 9.67 \quad \mathrm{kW}$$

The magnetizing inductance is proportional to the area and inversely proportional to the core length and hence is $\sqrt{2}$ times larger. Thus the no-load magnetizing current will be $\sqrt{2}$ times larger in the second transformer or

$$I_{\text{no-load}} = \sqrt{2}\,4.93 = 6.97 \quad \text{A}$$

Problem 2.17

part (a): Rated current at the high-voltage side is 20 kVA/2.4 kV = 8.33 A. Thus the total loss will be $P_{\text{loss}} = 122 + 257 = 379$ W. The load power is equal to $0.8 \times 20 = 16$ kW. Thus the efficiency is

$$\eta = \frac{16}{16.379} = 0.977 = 97.7 \text{ percent}$$

part (b): First calculate the series impedance ($Z_{\text{eq,H}} = R_{\text{eq,H}} + jX_{\text{eq,H}}$) of the transformer from the short-circuit test data.

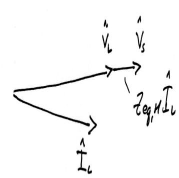
$$R_{\text{eq,H}} = \frac{P_{\text{sc,H}}}{I_{\text{sc,H}}^2} = 3.69\,\Omega$$

$$S_{\text{sc,H}} = V_{\text{sc,H}} I_{\text{sc,H}} = 61.3 \times 8.33 = 511 \; kVA$$

Thus $Q_{\text{sc,H}} = \sqrt{S_{\text{sc,H}}^2 - P_{\text{sc,H}}^2} = 442$ VAR and hence

$$X_{\text{eq,H}} = \frac{Q_{\text{sc,H}}}{I_{\text{sc,H}}^2} = 6.35\,\Omega$$

The regulation will be greatest when the primary and secondary voltages of the transformer are in phase as shown in the following phasor diagram



Thus the voltage drop across the transformer will be equal to $\Delta V = |I_{\text{load}}||Z_{\text{eq,H}}| =$ 61.2 V and the regulation will equal 61.2 V/2.4 kV = 0.026 = 2.6 percent.

Problem 2.18

For a power factor of 0.87 leading, the efficiency is 98.4 percent and the regulation will equal -3.48 percent.

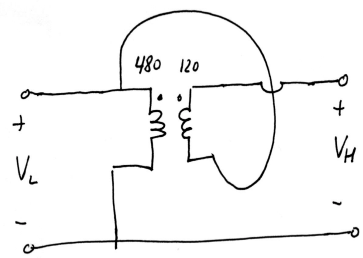
Problem 2.19

part (a): The voltage rating is 2400 V:2640 V.

part (b): The rated current of the high voltage terminal is equal to that of the 240-V winding, $I_{\text{rated}} = 30 \times 10^3/240 = 125$ A. Hence the kVA rating of the transformer is $2640 \times 125 = 330$ kVA.

Problem 2.20

part (a):



part (b): The rated current of the high voltage terminal is equal to that of the 120-V winding, $I_{\text{rated}} = 10^4/120 = 83.3$ A. Hence the kVA rating of the transformer is $600 \times 83.3 = 50$ kVA.

part (c): The full load loss is equal to that of the transformer in the conventional connection, $P_{\text{loss}} = (1 - 0.979)\ 10$ kW $= 210$ W. Hence as an autotransformer operating with a load at 0.85 power factor ($P_{\text{load}} = 0.85 \times 50$ kW $=$ 42.5 kW), the efficiency will be

$$\eta = \frac{42.5 \text{ kW}}{42.71 \text{ kW}} = 0.995 = 99.5 \text{ percent}$$

Problem 2.21

part (a): The voltage rating is 78 kV:86 kV. The rated current of the high voltage terminal is equal to that of the 8-kV winding, $I_{\text{rated}} = 50 \times 10^6/8000 =$ 6.25 kA. Hence the kVA rating of the transformer is 86 kV $\times$ 6.25 kA $=$ 537.5 MVA.

part (b): The loss at rated voltage and current is equal to 393 kW and hence the efficiency will be

$$\eta = \frac{537.5 \text{ MW}}{538.1 \text{ MW}} = 0.9993 = 99.93 \text{ percent}$$

Problem 2.22

No numerical result required for this problem.

Problem 2.23

part (a): 7.97 kV:2.3 kV; 191 A:651 A; 1500 kVA
part (b): 13.8 kV:1.33 kV; 109 A:1130 A; 1500 kVA
part (c): 7.97 kV:1.33 kV; 191 A:1130 A; 1500 kVA
part (d): 13.8 kV:2.3 kV; 109 A:651 A; 1500 kVA

Problem 2.24

part (a):

(i) 23.9 kV:115 kV, 300 MVA
(ii) $Z_{\text{eq}} = 0.0045 + j0.19\,\Omega$
(iii) $Z_{\text{eq}} = 0.104 + j4.30\,\Omega$

part (b):

(i) 23.9 kV:66.4 kV, 300 MVA
(ii) $Z_{\rm eq} = 0.0045 + j0.19\,\Omega$
(iii) $Z_{\rm eq} = 0.0347 + j1.47\,\Omega$

Problem 2.25

Following the methodology of Example 2.8, $V_{\rm load} = 236$ V, line-to-line.

Problem 2.26

The total series impedance is $Z_{\rm tot} = Z_{\rm f} + Z_{\rm t} = j11.7 + 0.11 + j2.2\,\Omega = 0.11 + j13.9\,\Omega$. The transformer turns ratio is $N = 9.375$. The load current, as referred to the transformer high-voltage side will be

$$I_{\rm load} = N^2 \left(\frac{325\ \text{MVA}}{\sqrt{3}\,24\ \text{kV}}\right) e^{j\phi} = 7.81 e^{j\phi}\ \text{kA}$$

where $\phi = -\cos^{-1} 0.93 = -21.6°$. The line-to-neutral load voltage is $V_{\rm load} = 24\sqrt{3}$ kV.

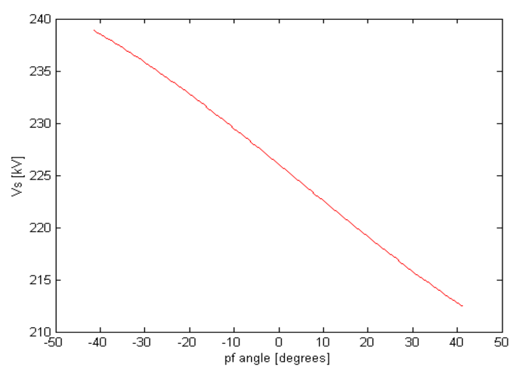
part (a): At the transformer high-voltage terminal

$$V = \sqrt{3}\,|NV_{\rm load} + I_{\rm load}Z_{\rm t}| = 231.7 \quad \text{kV, line-to-line}$$

part (b): At the sending end

$$V = \sqrt{3}\,|NV_{\rm load} + I_{\rm load}Z_{\rm tot}| = 233.3 \quad \text{kV, line-to-line}$$

Problem 2.27



Problem 2.28

First calculate the series impedance ($Z_{\rm eq,H} = R_{\rm eq,H} + jX_{\rm eq,H}$) of the transformer from the short-circuit test data.

$$Z_{\rm eq,H} = 0.48 = j1.18\,\Omega$$

The total imedance between the load and the sending end of the feeder is $Z_{\rm tot} = Z_{\rm f} + Z_{\rm eq,H} = 0.544 + j2.058\,\Omega$. The transformer turns ration is $N = 2400{:}120\sqrt{3} = 11.6$.

part (a): The referred load voltage $V_{\rm load}$ and current $I_{\rm load}$ will be in phase and can be assumed to be the phase reference. Thus we can write the phasor equation for the sending-end voltage as:

$$\hat{V}_{\rm s} = V_{\rm load} + I_{\rm load} Z_{\rm tot}$$

We know that $V_{\rm s} = 2400/sqrt3 = 1386$ V and that $I_{\rm load} = 100\,{\rm kVA}/(\sqrt{3}2.4\,{\rm kV})$. Taking the magnitude of both sides of the above equation gives a quadradic equation in $V_{\rm load}$

$$V_{\rm load}^2 + 2R_{\rm tot}I_{\rm load}V_{\rm load} + |Z_{\rm tot}|^2 I_{\rm load}^2 - V_{\rm s}^2$$

which can be solved for $V_{\rm load}$

$$V_{\rm load} = -R_{\rm tot}I_{\rm load} + \sqrt{V_{\rm s}^2 - (X_{\rm tot}I_{\rm load})^2} = 1.338 \quad {\rm kV}$$

Referred to the low-voltage side, this corresponds to a load voltage of $1.338\,{\rm kV}/N = 116$ V, line-to-neutral or 201 V, line-to-line.

part (b):

$$\text{Feeder current} = \left|\frac{2400}{\sqrt{3}Z_{\rm tot}}\right| = 651 \quad {\rm A}$$

$$\text{HV winding current} = \frac{651}{\sqrt{3}} = 376 \quad {\rm A}$$

$$\text{LV winding current} = 651N = 7.52 \quad {\rm kA}$$

Problem 2.29

part (a): The transformer turns ratio is $N = 7970/120 = 66.4$. The secondary voltage will thus be

$$\hat{V}_2 = \frac{V_1}{N}\left(\frac{jX_{\rm m}}{R_1 + jX_1 + jX_m}\right) = 119.74\angle 0.101^\circ$$

part (b): Defining $R_{\rm L}' = N^2 R_{\rm L} = N^2 1$ k$\Omega = 4.41$ MΩ and

$$Z_{\rm eq} = jX_{\rm m}||(R_2' + R_{\rm L}' + jX_2') = 134.3 + j758.1 \quad {\rm k}\Omega$$

the primary current will equal

$$\hat{I}_1 = \frac{7970}{R_1 + jX_1 + Z_{\rm eq}} = 10.3\angle - 79.87^\circ \text{ mA}$$

The secondary current will be equal to

$$\hat{I}_2 = N\hat{I}_1 \left(\frac{jX_\text{m}}{R'_2 + R'_\text{L} + j(X_\text{m} + X_2)} \right) = 119.7\angle 0.054^\circ \quad \text{mA}$$

and thus

$$\hat{V}_2 = R_\text{L}\hat{I}_2 = 119.7\angle 0.054^\circ \quad \text{V}$$

part (c): Following the methodology of part (b)

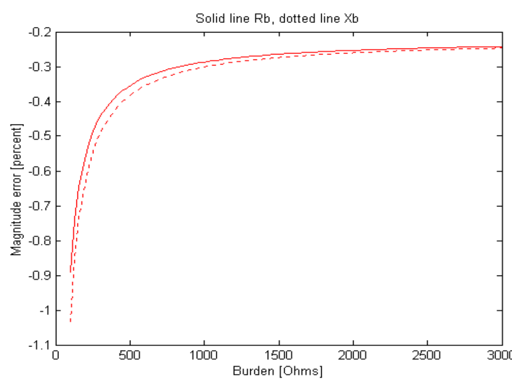
$$\hat{V}_2 = 119.6\angle 0.139^\circ \quad \text{V}$$

Problem 2.30

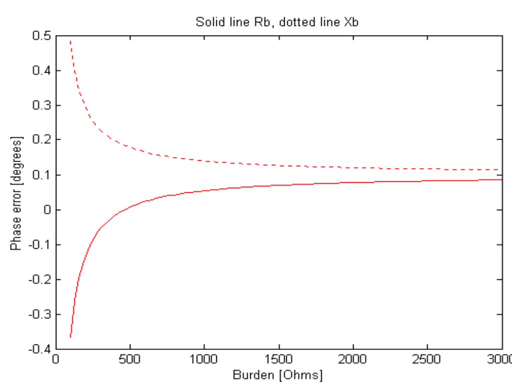
This problem can be solved iteratively using MATLAB. The minimum reactance is 291 Ω.

Problem 2.31

part (a):



part (b):



Problem 2.32

part (a): The transformer turns ratio $N = 200/5 = 40$. For $I_1 = 200$ A

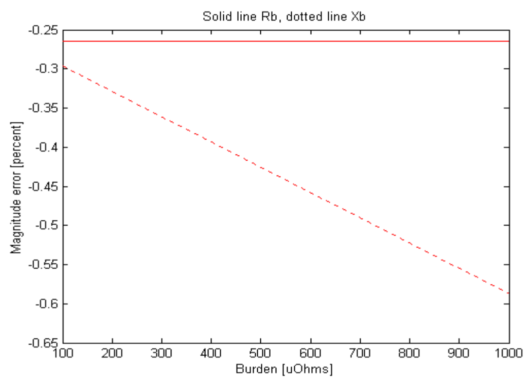
$$I_2 = \frac{I_1}{N}\left(\frac{jX_\mathrm{m}}{R_2' + j(X_\mathrm{m} + X_2')}\right) = 4.987\angle 0.024°$$

part (b): Defining $R_\mathrm{L}' = N^2 250\mu\Omega = 0.4\,\Omega$

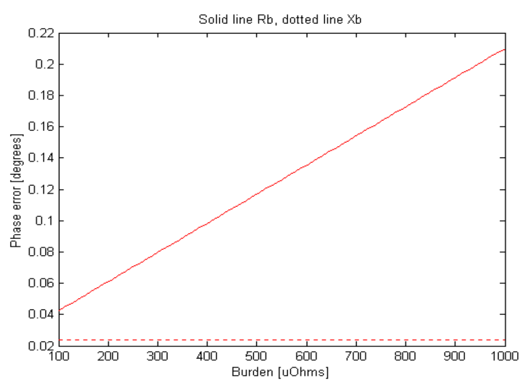
$$I_2 = \frac{I_1}{N}\left(\frac{jX_\mathrm{m}}{R_2' + R_\mathrm{L}' + j(X_\mathrm{m} + X_2')}\right) = 4.987\angle 0.210°$$

Problem 2.33

part (a):



part (b):



Problem 2.34

$$Z_\mathrm{base,L} = \frac{V^2_\mathrm{base,L}}{P_\mathrm{base}} = 1.80\,\Omega$$

$$Z_\mathrm{base,H} = \frac{V^2_\mathrm{base,H}}{P_\mathrm{base}} = 245\,\Omega$$

Thus

$$R_1 = 0.0095 Z_{\text{base,L}} = 17.1\ \text{m}\Omega; \quad X_1 = 0.063 Z_{\text{base,L}} = 113\ \text{m}\Omega$$

$$X_{\text{m}} = 148 Z_{\text{base,L}} = 266\ \Omega$$

$$R_2 = 0.0095 Z_{\text{base,H}} = 2.33\ \Omega; \quad X_2 = 0.063 Z_{\text{base,H}} = 15.4\ \Omega$$

Problem 2.35

part (a):

(i) $$Z_{\text{base,L}} = \frac{(7.97 \times 10^3)^2}{75 \times 10^3} = 0.940\,\Omega; \quad X_{\text{L}} = 0.12 Z_{\text{base,L}} = 0.113\,\Omega$$

(ii) $$Z_{\text{base,H}} = \frac{(7970)^2}{75 \times 10^3} = 847\,\Omega; \quad X_{\text{H}} = 0.12 Z_{\text{base,H}} = 102\,\Omega$$

part (b):

(i) 797 V:13.8 kV, 225 kVA
(ii) $X_{\text{pu}} = 0.12$
(iii) $X_{\text{H}} = 102\,\Omega$
(iv) $X_{\text{L}} = 0.339\,\Omega$

part (c):

(i) 460 V:13.8 kV, 225 kVA
(ii) $X_{\text{pu}} = 0.12$
(iii) $X_{\text{H}} = 102\,\Omega$
(iv) $X_{\text{L}} = 0.113\,\Omega$

Problem 2.36

part (a): In each case, $I_{\text{pu}} = 1/0.12 = 8.33$ pu.

(i) $I_{\text{base,L}} = P_{\text{base}}/(\sqrt{3}\,V_{\text{base,L}}) = 225\ \text{kVA}/(\sqrt{3}\,797\ \text{V}) = 163\ \text{A}$
$I_{\text{L}} = I_{\text{pu}} I_{\text{base,L}} = 1359\ \text{A}$
(ii) $I_{\text{base,H}} = P_{\text{base}}/(\sqrt{3}\,V_{\text{base,H}}) = 225\ \text{kVA}/(\sqrt{3}\,13.8\ \text{kV}) = 9.4\ \text{A}$
$I_{\text{H}} = I_{\text{pu}} I_{\text{base,H}} = 78.4\ \text{A}$

part (b): In each case, $I_{\text{pu}} = 1/0.12 = 8.33$ pu.

(i) $I_{\text{base,L}} = P_{\text{base}}/(\sqrt{3}\,V_{\text{base,L}}) = 225\ \text{kVA}/(\sqrt{3}\,460\ \text{V}) = 282\ \text{A}$
$I_{\text{L}} = I_{\text{pu}} I_{\text{base,L}} = 2353\ \text{A}$
(ii) $I_{\text{base,H}} = P_{\text{base}}/(\sqrt{3}\,V_{\text{base,H}}) = 225\ \text{kVA}/(\sqrt{3}\,13.8\ \text{kV}) = 9.4\ \text{A}$
$I_{\text{H}} = I_{\text{pu}} I_{\text{base,H}} = 78.4\ \text{A}$

Problem 2.37

part (a): On the transformer base

$$X_{\text{gen}} = \left(\frac{P_{\text{base,t}}}{P_{\text{base,g}}}\right) 1.57 = \left(\frac{800 \text{ MVA}}{850 \text{ MVA}}\right) 1.57 = 1.27 \text{ pu}$$

part (b): On the transformer base, the power supplied to the system is $P_{\text{out}} = 700/850 = 0.824$ pu and the total power is $S_{\text{out}} = P_{\text{out}}/pf = 0.825/0.95 = 0.868$ pu. Thus, the per unit current is $\hat{I} = 0.868\angle\phi$, where $\phi = -\cos^{-1} 0.95 = -18.2°$.

(i) The generator terminal voltage is thus

$$\hat{V}_{\text{t}} = 1.0 + \hat{I} Z_{\text{t}} = 1.03\angle 3.94° \text{ pu} = 26.8\angle 3.94° \text{ kV}$$

and the generator internal voltage is

$$\hat{V}_{\text{gen}} = 1.0 + \hat{I}(Z_{\text{t}} + Z_{\text{gen}}) = 2.07\angle 44.3° \text{ pu} = 53.7\angle 44.3° \text{ kV}$$

(ii) The total output of the generator is given by $S_{\text{gen}} = \hat{V}_{\text{t}} \hat{I}^* = 0.8262 + 0.3361$. Thus, the generator output power is $P_{\text{gen}} = 0.8262 \times 850 = 702.2$ MW. The correspoinding power factor is $P_{\text{gen}}/|S_{\text{gen}}| = 0.926$ lagging.