1)

a)

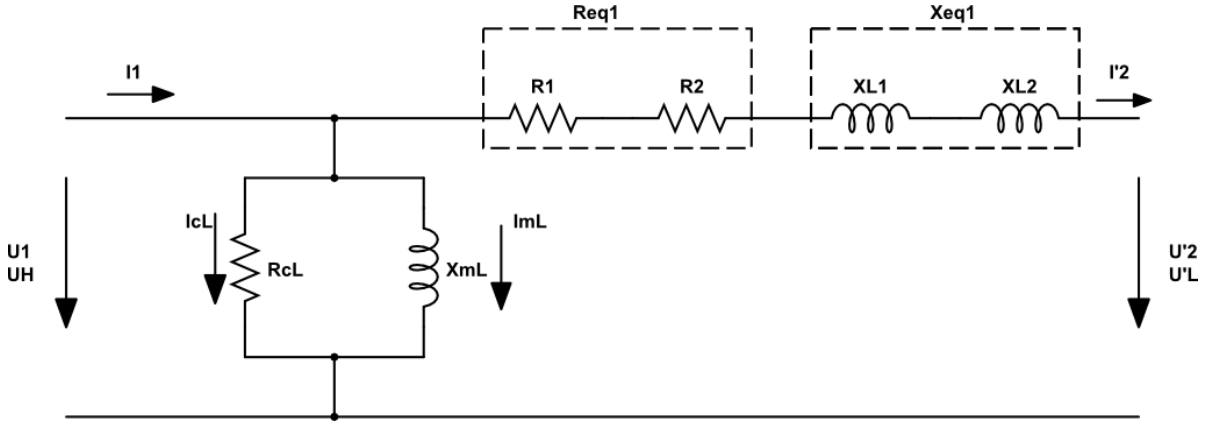
$$a = \frac{U_1}{U_2} = \frac{1000}{100} = 10$$

$$S_n = U_{1n} I_{1n} = U_{2n} I_{2n}$$

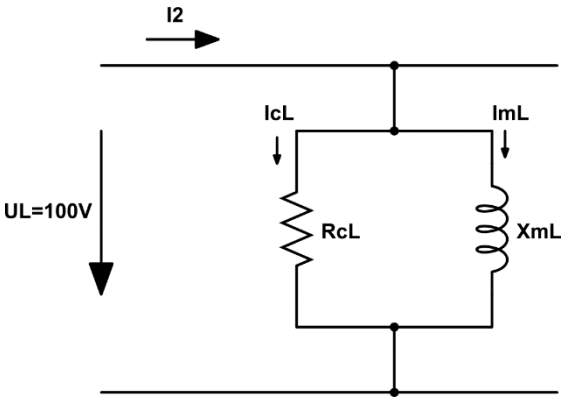
$$I_{1n} = \frac{S_n}{U_{1n}} = \frac{100000}{1000} = 100A$$

$$I_{2n} = \frac{S_n}{U_{2n}} = 1000A$$

b)



No Load



$$P_0 = I_{cL}^2 R_{cL} = \frac{U_{cL}^2}{R_{cL}} \Rightarrow R_{cL} = \frac{U_{cL}^2}{P_0} = 25\Omega$$

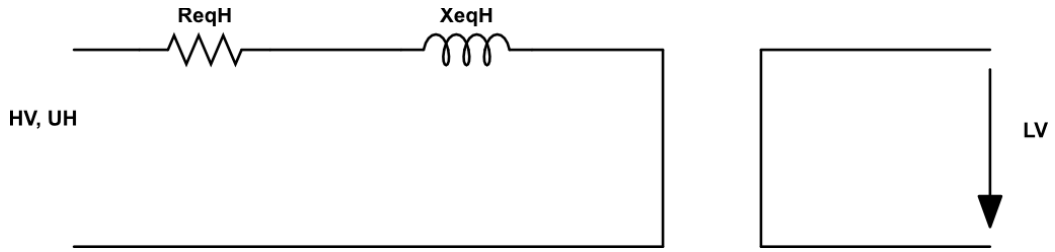
$$I_{cL} = \frac{U_L}{R_{cL}} = 4A$$

$$I_{mL} = \sqrt{I_L^2 - I_{cL}^2} = 4.47A$$

$$X_{mL} = \frac{U_L}{I_{mL}} = 22.37\Omega$$

$$R_{cH} = a^2 R_{cL} = 2500\Omega \qquad X_{mH} = a^2 X_{cL} = 2237\Omega$$

Short Circuit

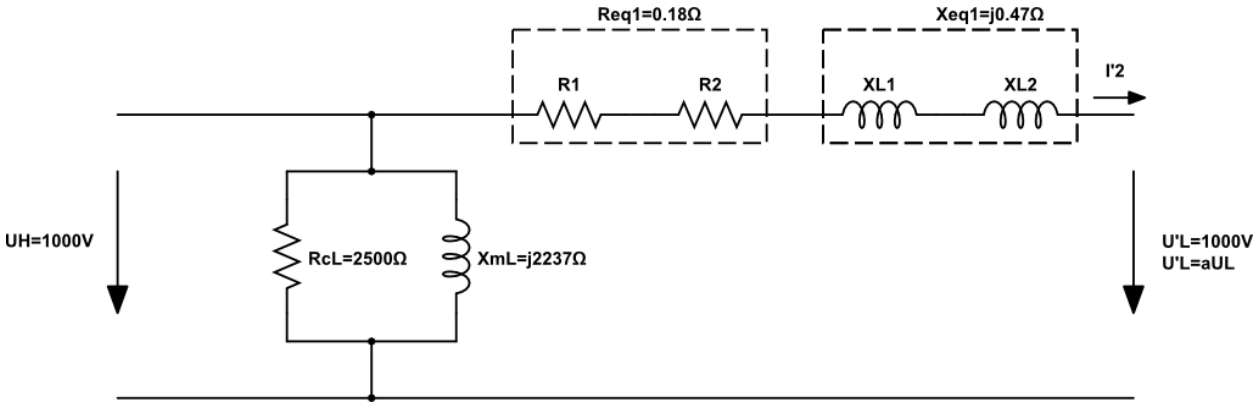


$$P_{sc} = R_{eqH} I_H^2 \Rightarrow R_{eqH} = \frac{P_{sc}}{I_H^2} = 0.18\Omega$$

$$Z_{eq} = \frac{U_H}{I_H} = 0.5\Omega$$

$$Z_{eq} = R_{eqH}^2 + X_{eqH}^2$$

$$X_{eqH} = \sqrt{Z_{eq}^2 - R_{eqH}^2} = j0.47\Omega$$



c)

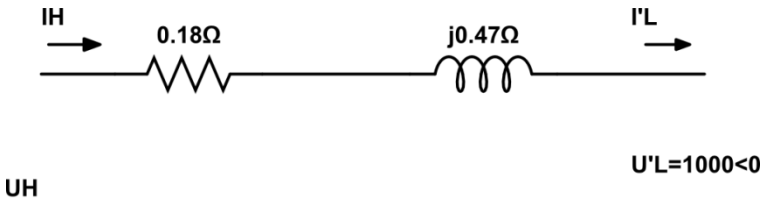
$$VR = \frac{|U_1| - |U'_2|_{rated}}{|U'_2|_{rated}} \cdot 100\%$$

$$PF = 0.6 \Rightarrow \cos\theta_2 = 0.6 \text{ leading}$$

$$\Rightarrow \theta_2 = +53.13°$$

$$I_H = I'_L = 100\angle 53.13° = 100(\cos 53.13° + j\sin 53.13°)A$$

$$I_H = 60 + j80A$$

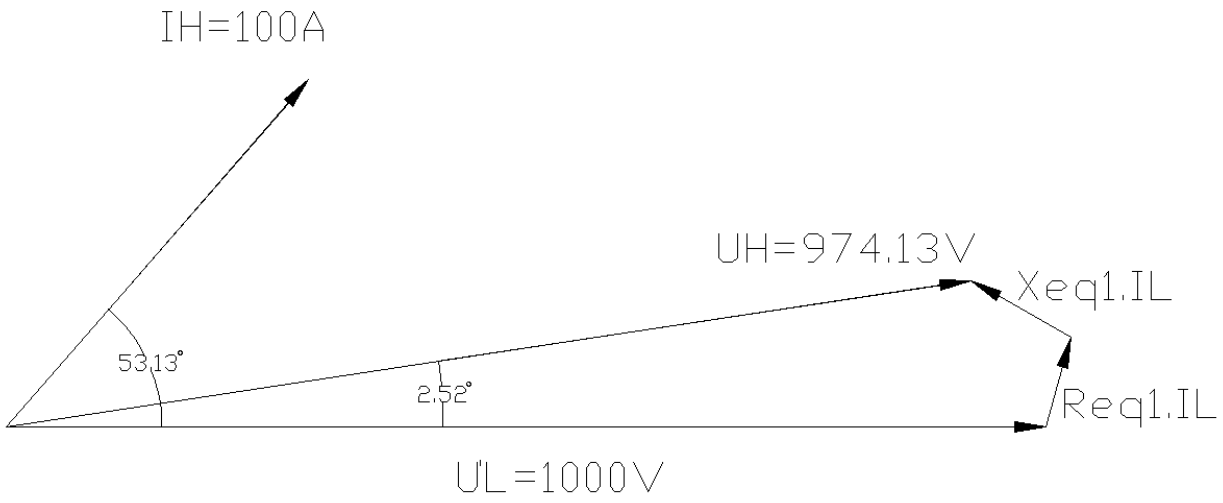


$$\dot{U}_H = \dot{U}'_L + \dot{I}'_L + \dot{Z}_{eqH} = 1000 + (60 + j80)\cdot(0.18 + j0.47)$$

$$\dot{U}_H = 973.2 + j42.8 = 974.13\angle 2.52°$$

$$VR = \frac{974.13 - 1000}{1000}\cdot 100\% = -2.59\%$$

d)



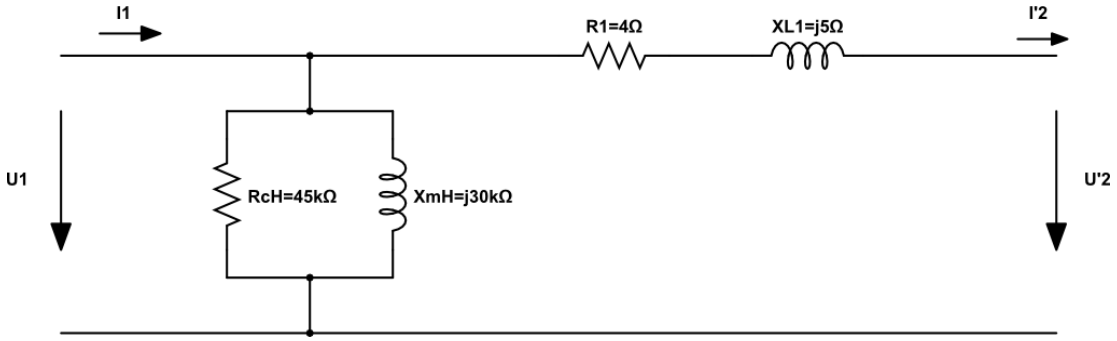
2) a)

$$a = \frac{2300}{230} = 10$$

$$\cos\phi = 0.85 \text{ lagging} \Rightarrow \phi = -31.8°$$

$$R_{cH} = a^2 R_{cL} = 45000\Omega$$

$$X_{mH} = a^2 X_{mL} = j30000\Omega$$



$$I_n = \frac{S_n}{U_n} = \frac{25000}{230} = 108.7A$$

$$\dot{I}_L = 108.7\angle -31.8° = \dot{I}_2$$

$$I'_2 = \frac{I_2}{a} = 10.87A$$

$$U'_2 = aU_2 = 2300V$$

$$\dot{U}_1 = \dot{U}'_2 + \dot{I}'_2 \dot{Z}_{eqH} = 2300\angle 0° + (10.87\angle -31.8°)\cdot(4 + j5)$$
$$= 2300\angle 0° + (9.23 - j5.73)\cdot(4 + j5)$$

$$\dot{U}_1 = 2365.65 + j23.23 = 2365.75\angle 0.56°$$

$$\eta = \frac{P_2}{P_2 + P_{loss}} = \frac{P_2}{P_2 + P_{cu} + P_c}$$

$$P_2 = U_{2n} I_{2n} \cos\phi = 21.25kW$$

$$P_{cu} = I'^2_{2n} R_{eqH} = 472.6W \qquad (I_{2n} = 10.87)$$

$$P_c = \frac{U_1^2}{R_{cH}} = 124.37W$$

$$\eta = 0.973$$

$$\eta = 97.3\%$$

b) Conditions for maximum efficiency:

$$P_c = P_{cu} \qquad \cos\phi = 1$$

$$P_c = P_{cu} = 124.37W$$

$$P_{cu} = R_{eqH} I_2'^2 \Rightarrow I_2' = \sqrt{\frac{P_{cu}}{R_{eqH}}} = 5.57A$$

$$I_2 = aI'_2 = 55.7A$$

$$P_2 = U_2 I_2 \cos\phi = 230 \cdot 55.7 \cdot 1 = 12811W$$

$$\eta_{\max} = \frac{12811}{12811 + 124.37 + 124.37} = 0.981$$

$$\eta_{\max} = 98.1\%$$

$$X = \frac{I_2}{I_{2n}} = \frac{55.7}{108.7} = 0.512$$

$$X = 51.2\%$$

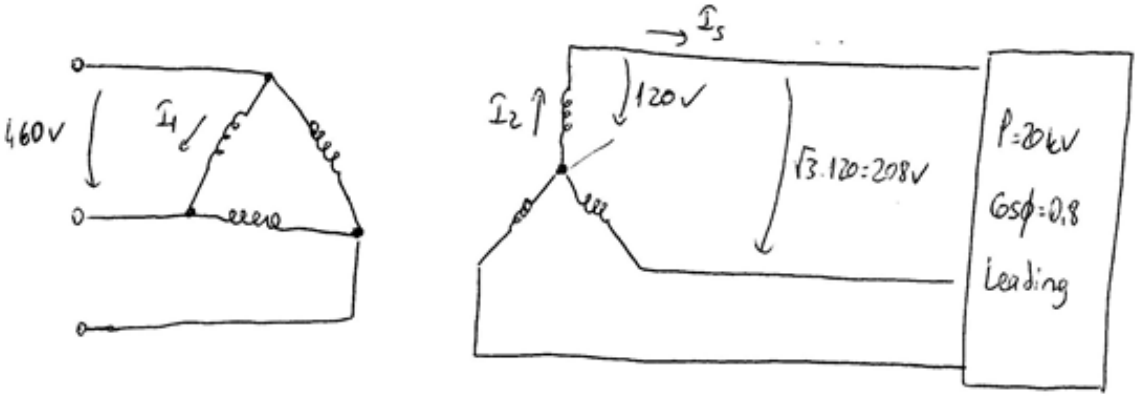
$$\text{if } \cos\phi = 0.85 \Rightarrow P_2 = U_2 I_2 \cos\phi = 10889W$$

$$\eta = \frac{P_2}{P_2 + 2 \cdot P_{cu}} = 0.978$$

$$\eta = 97.8\%$$

3)

a)



b)

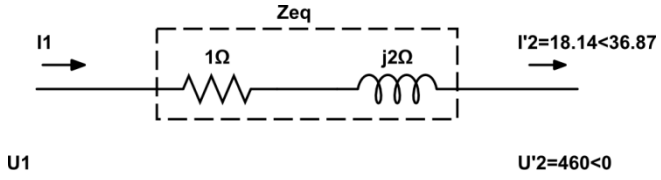
$$P = \sqrt{3} U_{2l} I_{2l} \cos\phi$$

$$I_{2l} = \frac{P}{\sqrt{3} U_{2l} \cos\phi} = 69.47A$$

$$I_1 = \frac{I_2}{a} = 18.14A = I'_2 \qquad (a = \frac{460}{120} = 3.83)$$

$$I_{1l} = \sqrt{3} I_1 = 31.38A$$

c)



$$\cos\phi = 0.8 \Rightarrow \phi = +36.87°$$

$$\dot{U}_1 = \dot{U}_2 + \dot{I}'_2 \dot{Z}_{eq} = 460 + (14.51 + j10.88) \cdot (1 + j2)$$

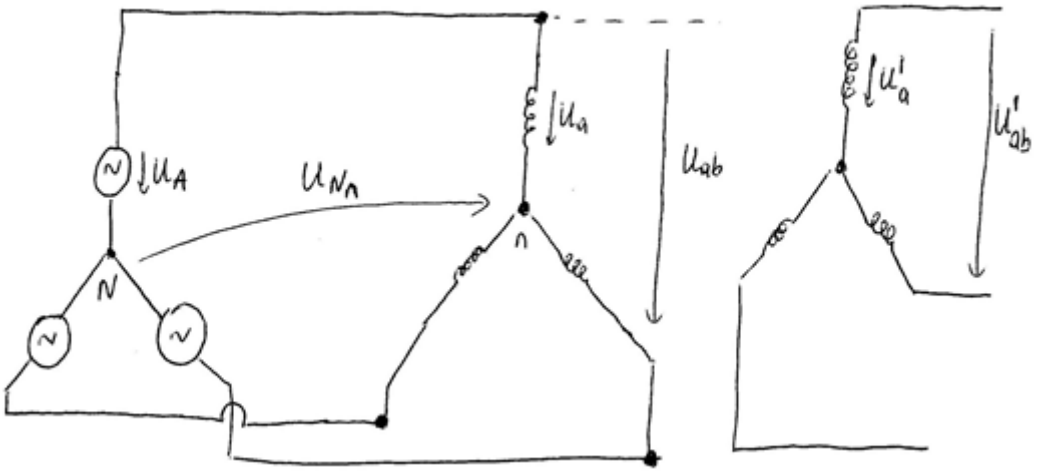
$$\dot{U}_1 = 452.75 + j39.9 = 454.5\angle 5°$$

d)

$$VR = \frac{|U_1| - |U'_2|_{rated}}{|U'_2|_{rated}} \cdot 100 = \frac{454.5 - 460}{460} \cdot 100 = -1.2\%$$

4)

a)



$$U_{Nn} = 1200V \qquad U_{AB} = 4000V \qquad U_A = \frac{4000}{\sqrt{3}} = 2300V$$

$$U_A = \hat{U}_1 \cos wt$$

$$U_a = \hat{U}_1 \cos wt + \hat{U}_3 \cos 3wt$$

$$U_{Nn} = -U_A + U_a = -\hat{U}_1 \cos wt + \hat{U}_1 \cos wt + \hat{U}_3 \cos 3wt$$

$$U_{Nn} = \hat{U}_3 \cos 3wt$$

$$U_{Nn} = \frac{\hat{U}_3}{\sqrt{2}} = 1200V \Rightarrow \hat{U}_3 = \sqrt{2} \cdot 1200V$$

$$U_{Nn} = \sqrt{2} \cdot 1200 \cdot \cos 3wt$$

b) (i)

$$U_a = \sqrt{U_1^2 + U_3^2} = \sqrt{\left(\frac{4000}{\sqrt{3}}\right)^2 + 1200^2} = 2602V$$

$$U'_a = \frac{230}{2300} \cdot 2602 = 260.2V$$

$$\frac{U_a}{U'_a} = \frac{2602}{260.2} = 10$$

(ii)

$$\frac{U_{AB}}{U'_{ab}} = \frac{4000}{400} = 10$$

C)

$$\frac{U_{ab}}{U_a} = \frac{4000}{2602} = 1.537$$

$$\frac{U'_{ab}}{U'_a} = \frac{400}{260.2} = 1.537$$