Problem-1:-

Given:- 25 KVA 1-Phase transformer

$$a = \frac{2400}{240} = 10$$

Measurement of open-circuit test are taken at the Secondary side.

$V_{ocs} = 240\,V$ $\quad I_{ocs} = 3.2\,A$ $\quad P_{ocs} = 165\,W$

$$PF = \frac{P_{ocs}}{V_{ocs} I_{ocs}} = \frac{165}{240 \times 3.2} = 0.2148$$

$$\Rightarrow \theta_{oc} = \cos^{-1}(0.2148) = 77.59^\circ$$

Shunt excitation admittance

$$|Y_{ocs}| = \frac{I_{ocs}}{V_{ocs}}$$

$$= \frac{3.2}{240} = 0.01333\ \mho$$

$$\therefore\ Y_{ocs} = 0.01333\angle{-77.59^\circ}\ \mho$$

$$\Rightarrow Y_{ocs} = 0.002865 - j\,0.0130021$$

$$\Rightarrow R_{cs} = \frac{1}{0.002865} = 349.65\,\Omega$$

$$X_{ms} = \frac{1}{0.0130021} = 76.796\,\Omega$$

The excitation elements are now referred to the primary side as

$$R_{cp} = a^2 R_{cs} = (10)^2 (349.65) = 34.904\ k\Omega$$

$$X_{mp} = a^2 X_{ms} = (10)^2 (76.796) = 7.6796\ k\Omega$$

The measurement of short-circuit test are taken on the primary side.

$P_{scp} = 375\ W$ $\quad V_{scp} = 55\ V$ $\quad I_{scp} = 10.4\ A$

Compute I_p rated

$$I_{prated} = \frac{S_{rated}}{V_p} = \frac{25 \times 10^3}{2400} = 10.4\ A$$

Hence the short-circuit test is carried on full-load primary current.

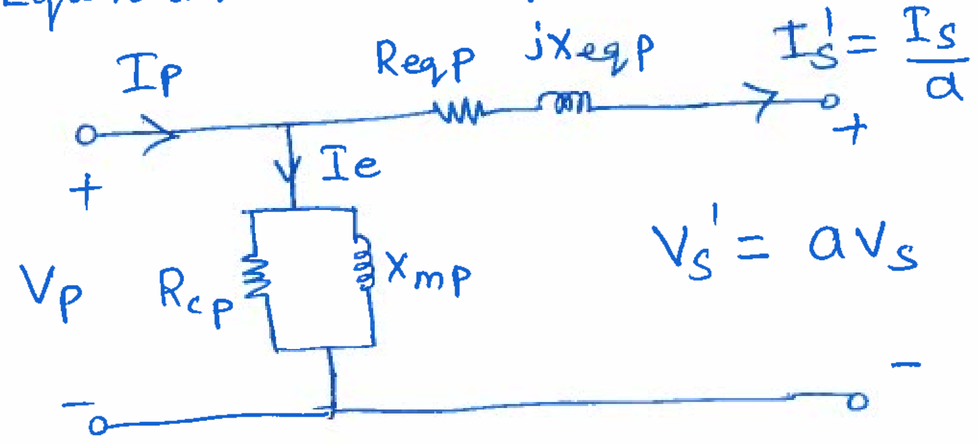
Now $$PF = \frac{P_{scp}}{V_{scp} \cdot I_{scp}} = \frac{375}{55 \times 10.4} = 0.65559$$

$$\Rightarrow \theta = \cos^{-1}(0.65559) = 49.035^\circ$$

$$Z_{scp} = \frac{V_{scp} \angle \theta}{I_{scp}} = \frac{55 \angle 49.035^\circ}{10.4}$$

$$Z_{scp} = 3.467 + j\,3.993\ \Omega$$

Equivalent circuit referred to the primary side



(b) $\cos\theta = 0.85$ lagging

$P_{out} = 25 \times 0.85 = 21.25 \text{ kW}$

$\theta_s = \cos^{-1}(0.85) = 31.788^\circ$

Now $I_s = \dfrac{P_{out} (= P_s)}{V_s \cos\theta_s}$

$= \dfrac{21.25 \times 10^3}{240 \times 0.85}$

$I_s = 104.166 \text{ A}$

$\therefore \quad \bar{I}_s = 104.166 \angle -31.788^\circ \text{ A}$

Now, $\bar{V}_p = \bar{V}_s' + \bar{I}_s' (R_{eq\,p} + jX_{eq\,p})$

$$= aV_s + \frac{I_s}{a}\left(R_{eqp} + jX_{eqp}\right)$$

$$= (10)(240\angle 0^\circ) + \frac{104.166}{10}\angle -31.788^\circ \left(3.467 + j3.993\right)$$

$$V_p = 2452.66 \angle 0.381^\circ \text{ V}$$

$$\therefore \; V_{regulation} = \frac{|V_p| - |V_s'|}{|V_s'|} \times 100$$

$$= \frac{2452 - (10)(2400)}{(10)(2400)} \times 100$$

$$= 2.194\ \%$$

Efficiency :

$$\eta = \frac{P_{out}}{P_{in}} \times 100\ \%$$

$$= \frac{P_{out}}{P_{out} + P_{cu} + P_{core}} \times 100\ \%$$

$$P_{core} = \frac{|V_P|^2}{R_{CP}} = \frac{(2452.66)^2}{34.904 \times 10^3} = 172.345\,W$$

$$P_{cu} = {I_s'}^2 \cdot R_{eqP}$$

$$= \left(\frac{104.166}{10}\right)^2 \cdot 3.47$$

$$P_{cu} = 376.188\,W$$

$$P_{in} = 376.188 + 172.343 + 21250$$

$$= 21798.53\,W$$

$$\eta = \frac{21250}{21798.53} \times 100$$

$$\eta = 97.48\,\%$$

c. Condition for max. efficiency, $P_{core} = P_{cu}$ & PF = 1

$$P_{core} = P_{cu} = 165\,W = I_s^2 R_{eqs}, \quad R_{eqs} = \frac{3.467}{100} = 0.03467$$

$$I_s = \sqrt{\frac{165}{0.03467}} = 68.98\,A$$

Power output at η_{max}

$$P_{out} = V_s I_s \underbrace{\cos\theta_s}_{1}$$

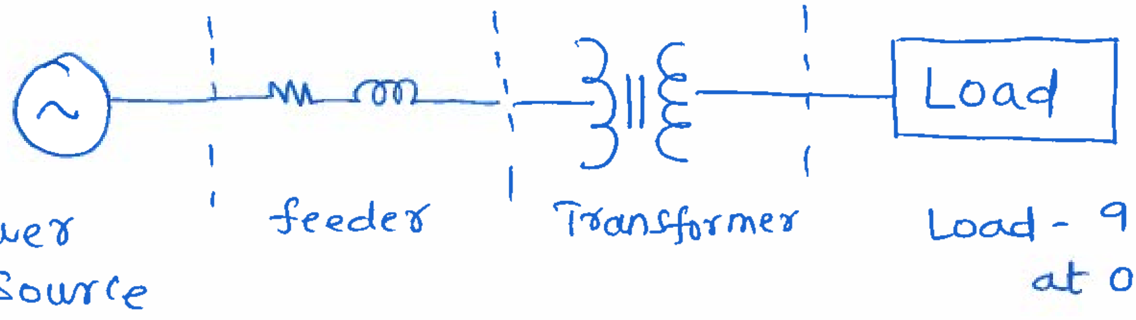
$$= 240 * 68.98 = 16.556\,kW$$

$$\eta_{max} = \frac{P_{out}}{P_{out} + 2P_c} = \left(\frac{16.556\,kW}{16.556\,kW + 2(165)}\right) * 100\%$$

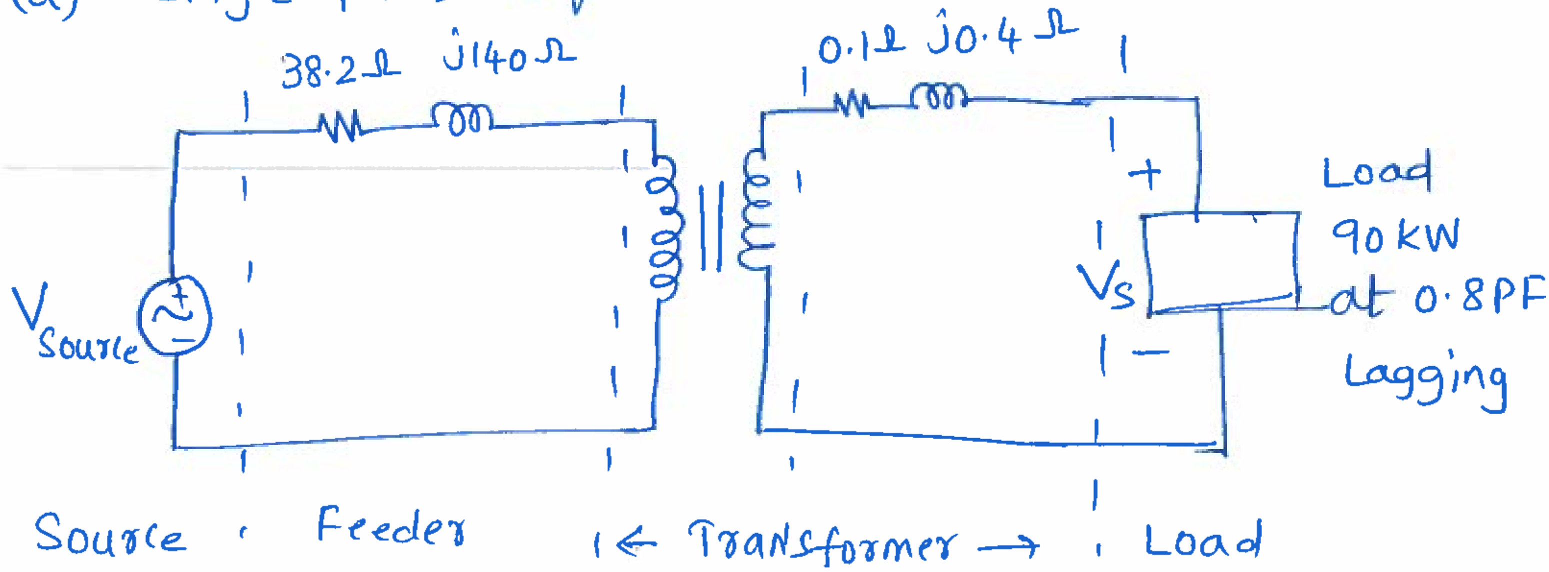
$$= 98.04\%$$

Problem-2 :-

Single-phase distribution system



(a) Single-phase equivalent circuit of the power-system



(b) To solve this problem, we will refer the circuit to the secondary (low-voltage) side.

The feeder impedance referred to the secondary side is

$$Z_{line} = (38.2 + j140)\ \Omega$$

$$a = \frac{14\,kV}{2.4\,kV}$$

$$Z'_{line} = \frac{(38.2 + j140)\,\Omega}{a^2}$$

$$Z'_{line} = (1.12 + j4.11)\,\Omega$$

To compute the secondary current $\cdot I_s$

$$P_s = V_s I_s \cos\theta_s$$

$$I_s = \frac{P_s}{V_s \cos\theta_s}$$

$$= \frac{90 \times 10^3}{(2400)(0.8)} = 46.88\ A$$

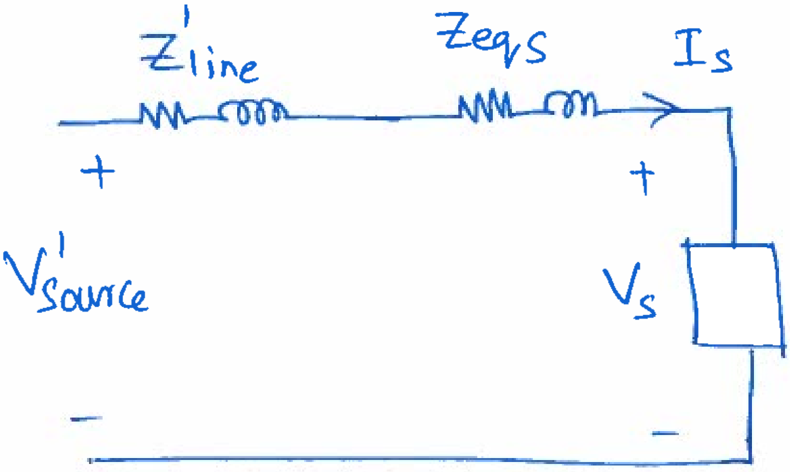
$$\therefore \quad \bar{I}_s = 46.88 \angle -\cos^{-1}(PF)$$

$$\bar{I}_s = 46.88 \angle -36.87^\circ\ A$$

The voltage at the power source of this system (referred to the secondary side) is

$$V'_{source} = V_s + I_s Z'_{line} + I_s Z_{eq_S}$$

Taking $V_s = 2400 \angle 0^\circ\ V$ as reference



$$V'_{source} = V_s + I_s(Z'_{line} + Z_{eqs})$$

$$= 2400\angle 0^\circ + 46.88\angle -36.87^\circ \left(1.12 + j4.11 + 0.1 + j0.4\right)$$

$$V'_{source} = 2576\angle 3.0^\circ \text{ V}$$

$\therefore$ The voltage at the power source is

$$V_{source} = V'_{source} \cdot a$$

$$= (2576\angle 3.0^\circ)\left(\frac{14\text{ kV}}{2.4\text{ kV}}\right)$$

$$V_{source} = 15.5\angle 3.0^\circ \text{ kV}$$

(c) To find the voltage regulation of the transformer we must find the voltage at the primary side of the transformer (referred to the secondary side).

$$V_P' = V_S + I_S Z_{eqs}$$

$$= 2400\angle 0^\circ + (46.88\angle -36.87^\circ)(0.1 + j0.4)$$

$$V_P' = 2415\angle 0.3^\circ \text{ V}$$

$\therefore$ Voltage regulation is

$$VR = \frac{|V_P'| - |V_S|}{|V_S|} \times 100$$

$$= \frac{2415 - 2400}{2400} \times 100$$

$$VR = 0.63\ \%$$

(d) The overall efficiency of the power system will be the ratio of the output power to the input power.

The output power = power supplied to the load

$= 90\text{kW}$.

input power $P_{in} = P_{out} + P_{loss}$

$$P_{in} = P_{out} + P_{loss}$$

$$= P_{out} + I^2 R$$

$$= (90 \times 10^3) + (46.88)^2 (1.22)$$

$$P_{in} = 92.68\ kW$$

There fore the efficiency of the power system is

$$\eta = \frac{P_{out}}{P_{in}} \times 100\ \%$$

$$= \frac{90 \times 10^3}{92.68 \times 10^3} \times 100\ \%$$

$$\eta = 97.1\ \%$$

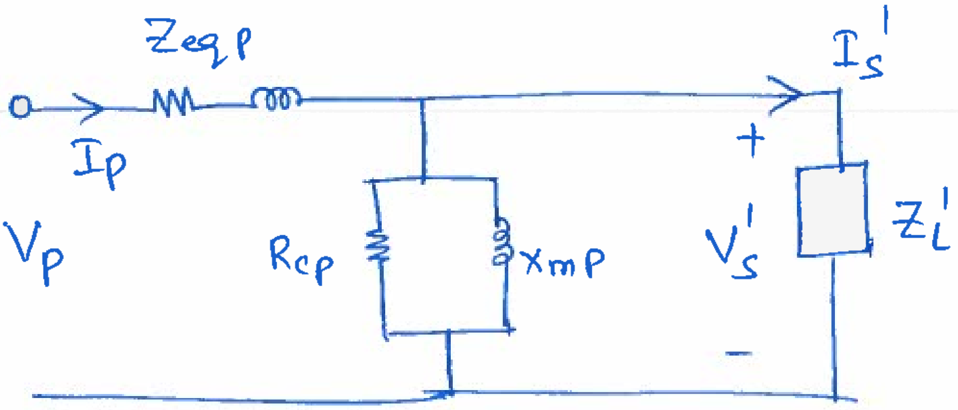
Problem-3:-

$$\text{Turns ratio } a = \frac{8000}{230} = 34.78$$

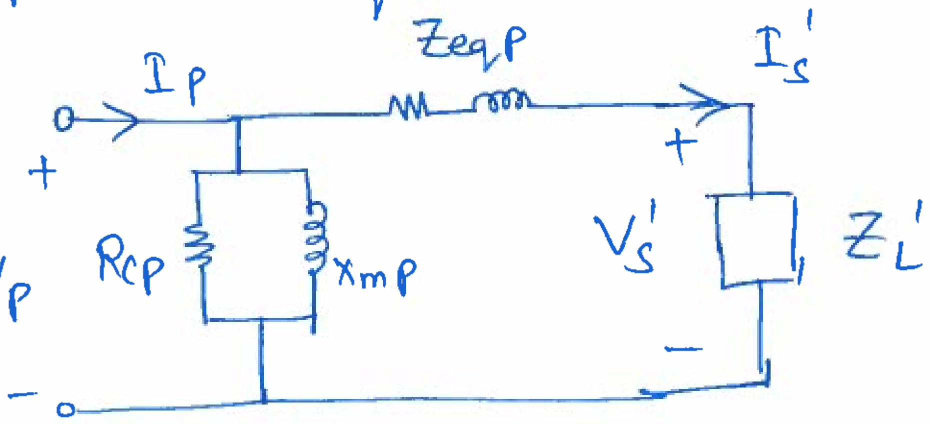
$$Z_{eqp} = (20 + j100)\ \Omega$$

$$R_{cp} = 100\ k\Omega \qquad X_{mp} = 20\ k\Omega$$

(a) Equivalent circuit referred to the primary side



Approximate equivalent circuit,



The load impedance referred to the primary side,

$$Z_L' = a^2 Z_L$$

$$Z_L' = (34.78)^2 (2.0 + j0.7) = 2419 + j847 \, \Omega$$

The referred secondary current,

$$I_s' = \frac{V_P}{Z_{eqp} + Z_L'}$$

$$= \frac{7967\angle 0^\circ}{(20 + j100) + (2419 + j847)}$$

$$I_s' = 3.045 \angle -21.2^\circ \text{ A}$$

The refered secondary voltage is,

$$V_s' = I_s' Z_L' = (3.045 \angle -21.2^\circ)(2419 + j847)$$

$$V_s' = 7804 \angle -1.9^\circ \text{ V}$$

The actual secondary voltage is

$$V_s = \frac{V_s'}{a} = \frac{7804 \angle -1.9^\circ}{34.78} = 224.4 \angle -1.9^\circ \text{ V}$$

The voltage regulation is

$$VR = \frac{|V_P| - |V_S'|}{|V_S'|} \times 100\ \%$$

$$= \frac{7967 - 7804}{7804} \times 100\ \%$$

$$VR = 2.09\%$$

(b) Now the load is disconnected. Connect a capacitor with $Z_L = -j3.0\,\Omega$ as load.

The load impedance referred to the primary side is

$$Z_L' = a^2 Z_L = (34.78)^2(-j3.0) = -j3629\,\Omega$$

The reffered Secondary current is

$$I_S' = \frac{V_P}{Z_L' + Z_{eqP}}$$

$$= \frac{7967\angle 0^\circ}{(-j3629) + (20+j100)}$$

$$I_S' = 2.258\angle 89.7^\circ\ A$$

The referred Secondary voltage is

$$V_s' = I_s' Z_L' = (2.258\angle 89.7^\circ)(-j3629)$$

$$V_s' = 8194\angle -0.3^\circ \text{ V}$$

The actual Secondary voltage is

$$V_s = \frac{V_s'}{a} = \frac{8194\angle -0.3^\circ}{34.78} = 235.6\angle -0.3^\circ \text{V}$$

The voltage regulation is

$$VR = \frac{|V_P| - |V_s'|}{|V_s'|} \times 100\%$$

$$= \frac{7967 - 8194}{8194} \times 100\%$$

$$VR = -10.6\%$$

Problem 4

Turns ratio, $a = \dfrac{2200}{220} = 10$

a- $R_{esp} = R_p + a^2 R_s = 4 + 10^2 * 0.04 = 8\ \Omega$

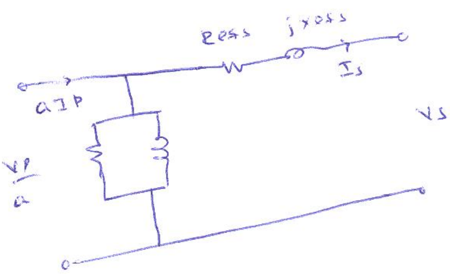
$X_{esp} = X_p + a^2 X_s = 5 + 10^2 * 0.05 = 10\ \Omega$

$Z_{esp} = (8 + j10)\ \Omega$ - Total series impedance referred to HV side

$Z_{ess} = (0.08 + j0.1)\ \Omega$ - Total series impedance referred to LV side

b- $I_s = \dfrac{10{,}000}{220} = 45.45$, $\theta = -\cos^{-1} 0.8 = -36.87^\circ$

$I_s = 45.45 \angle -36.87^\circ$



$\dfrac{V_P}{a} = V_s + I_s (R_{ess} + jX_{ess})$

$= 220 \angle 0^\circ + 45.45 \angle -36.87 [0.08 + j0.1] = 225.64 \angle 0.36\ V$

Voltage Regulation $VR = \dfrac{\frac{V_P}{a} - V_s}{V_s} * 100\%$

$= \dfrac{225.64 - 220}{220} * 100\% = 2.56\%$

c. $\dfrac{V_P}{a} = 220 \angle 0 + 45.45 \angle 36.87 \left(0.08 + j0.1 \right) = 220.258 \angle 1.51$

$VR = \dfrac{220.258 - 220}{220} * 100\% = 0.1173\%$

d - $P_c = 80\ w$

$P_{cu} = I_s^2 R_{efs} = 45.45^2 \times 0.08$

$= 165.25\ w$

$P_{out} = 10 \times 0.8 = 8\ kw$

$$\eta = \frac{P_{out}}{P_{out} + P_{cu} + P_{cu}} = \frac{8000\ w}{8000w + 80w + 165.25w} \times 100\%$$

$= 97.025\%$

It will be the same, because the magnitude of the load current is the same.