Unit - 2

1) A 100 KVA, 3300V / 240V, 50 HZ, single phase transformer has 990 turns on the primary. calculate the number of turns on secondary and the approximate value of primary and secondary full load currents.

Data : 100 kVA, $E_1 = 3300V$, $E_2 = 240V$, $N_1 = 990$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \Rightarrow \frac{3300}{240} = \frac{990}{N_2} \Rightarrow N_2 = 72$$

$$I_1(FL) = \frac{VA}{E_1} = \frac{100\times10^3}{3300} = 30.303A$$

$$I_2(FL) = \frac{VA}{E_2} = \frac{100\times10^3}{240} = 416.67A$$

2) The e.m.f per turn of a single-phase, 6.6kV, 440V, 50Hz transformer is approximately 12V. calculate number of turns in the HV and LV windings and the net cross-sectional area of the core for a maximum flux density of 1.5 T

Data : $E_1 = 6.6$ kV, $E_2 = 440V$, $f = 50HZ$, e/turn = 12V,
$B_m = 1.5T$

$$E_1 = \left[\frac{e.m.f}{turn}\right] \times N_1 \Rightarrow 6.6\times10^3 = 12N_1 \Rightarrow N_1 = 550$$
... turn on HV side

$$E_2 = \left[\frac{e.m.f}{turn}\right] \times N_2 \Rightarrow 440 = 12N_2 \Rightarrow N_2 = 36.666 \approx 37$$
... turn on LV side

$$E_1 = 4.44\phi_m f N_1$$

$$6.6\times10^3 = 4.44 \times \phi_m \times 50 \times 550$$

$$\phi_m = 0.054 \text{ Wb}$$

$$B_m = \frac{\phi_m}{A}$$

$$A = \frac{\phi_m}{B_m} = \frac{0.054}{1.5} = 0.0360 \text{ m}^2 = 360 \text{ cm}^2$$

3) A single phase, 50 HZ, 1000 KVA transformer for 1200/240V ratio has a maximum flux density of 1.2 wb/m² and an effective cross section of 300 cm², the magnetising current (RMS) is 0.2A. Estimate the inductance of each wire on open circuit.

Data: $f = 50 Hz$, $B_m = 1.2\ wb/m^2$, $a = 300 cm^2$, $I = 0.2A$

$E_1 = 4.44\, \phi_m f N_1$

$\phi_m = B_m a = 1.2 \times 300 \times 10^{-4} = 0.036\ wb$

$12000 = 4.44 \times 0.036 \times 50 \times N_1$

$N_1 = 1501.5 \approx 1502$

$\frac{E_2}{E_1} = \frac{N_2}{N_1} \Rightarrow \frac{240}{12000} = \frac{N_2}{1502} \Rightarrow N_2 = 30.04 \approx 30$

$L_1 = \frac{N_1 \phi}{I} = \frac{1502 \times 0.036}{0.2} = 270.36 H$

$L_2 = \frac{N_2 \phi}{I} = \frac{30 \times 0.036}{0.2} = 5.4 H$

4. The voltage per turn of a single phase transformer is 1.1 volt, when the primary winding is connected to a 220 volt, 50 Hz AC supply the secondary voltage is found to be 550 volt. find the primary and secondary turn and core area if maximum flux density is 1.1 tesla.

Data: $E/_{turn} = 1.1 V$, $E_1 = 220 V$, $f = 50 Hz$, $E_2 = 550 V$,

$B_m = 1.1 T$

$E_1 = \left[\frac{e.m.f}{turn}\right] \times N_1 \Rightarrow \cancel{1.1 \times 110 = 550 N_1}\ 220 = 1.1 N_1$

$N_1 = 200$

... turns on HV side

$E_2 = \left[\frac{e.m.f}{turn}\right] \times N_2 \Rightarrow 550 = 1.1 N_1$

$N_2 = 500$

$E_1 = 4.4\, \phi_m f N_1$

$220 = 4.4 \times \phi_m \times 50 \times 200$

$\phi_m = 5 \times 10^{-3}$

$B_m = \frac{\phi_m}{A} \Rightarrow A = \frac{\phi_m}{B_m}$

$A = \frac{5 \times 10^{-3}}{1.1} = 45.04\ cm^2$

5) A 1-phase transformer has 360 turns and 180 turns respectively in the secondary and primary windings. The respective resistance are 0.233 and 0.067. calculate the equivalent resistance of

1) The primary in terms of the secondary winding
2) the secondary in terms of the primary winding
3. The total resistance of the transformer in terms of the primary

Data: $N_2 = 360$, $N_1 = 180$, $R_2 = 0.233\,\Omega$, $R_1 = 0.067\,\Omega$

$$K = \frac{N_2}{N_1} = \frac{360}{180} = 2$$

as secondary turns are more, secondary winding is high voltage side, Hence the secondary the resistance values are high.

1) $R_1' = K^2 R_1 = 4 \times 0.067 = 0.268\,\Omega$

2) $R_2' = \dfrac{R_2}{K^2} = \dfrac{0.233}{4} = 0.05825\,\Omega$

3) $R_{1e} = R_1 + R_2' = 0.067 + 0.05825 = 0.12525\,\Omega$

6) A 100 KVA, 1100/200 volt single phase transformer has the following parameters. $r_1 = 0.1\,\Omega$, $x_1 = 0.3\,\Omega$, $r_2 = 0.004\,\Omega$ $x_2 = 0.012\,\Omega$. find equivalent resistance and leakage reactance as referred to high voltage winding.

Data: $V_1 = 1100V$, $V_2 = 200V$, $r_1 = 0.1\,\Omega$, $x_1 = 0.3\,\Omega$, $r_2 = 0.004\,\Omega$, $x_2 = 0.012\,\Omega$

$$K = \frac{V_2}{V_1} = \frac{200}{1100} = 0.1818$$

On high voltage side the impedance is high

$$r_2' = \frac{r_2}{K^2} = \frac{0.004}{(0.1818)^2} = 0.121\,\Omega,$$

$$R_{1e} = r_1 + r_2' = 0.1 + 0.121 = 0.221\,\Omega$$

$$x_2' = \frac{x_2}{K^2} = \frac{0.012}{(0.1818)^2} = 0.363\,\Omega$$

$$X_{1e} = x_1 + x_2' = 0.3 + 0.363 = 0.663\,\Omega$$

7) A single phase transformer with 10.1 turns ratio and rated at 50 KVA, 24000/240 V, 50 Hz is used to step down the voltage of a distribution system. The low tension voltage is kept constant at 240V. find the value of load impedance on the low tension side so that the transformer will be loaded fully. find the value of maximum flux inside the core if the low tension side has 23 turns

Data: $V_2 = 240V$, $VA = 50\ KVA$; $f = 50\ Hz$, $N_2 = 23$

$$I_2(F.L) = \frac{VA}{V_2} = \frac{50 \times 10^3}{240} = 208.333\ A$$

$$Z_L(F.L) = \frac{V_2}{I_2(F.L)} = \frac{240}{208.333} = 1.152\Omega$$

$$V_2 = 4.44\ f\ \phi m\ N_2$$

$$240 = 4.44 \times 50 \times \phi m \times 23$$

$$\phi m = 0.047\ wb$$

8) A single phase transformer takes 10A and on no-load at 0.2 p.f lagging. the turns ratio 4:1 (step down). If the load on the secondary is 200 A at p.f of 0.85 lagging, find the primary current and power factor. neglect the voltage drop in the winding. Also draw the phasor diagram:

data: $I_0 = 10A$, $\cos\phi_0 = 0.2$, $\frac{N_1}{N_2} = \frac{4}{1}$, $I_2 = 200A$, $\cos\phi_2 = 0.85$

$$K = \frac{N_2}{N_1} = \frac{1}{4} = 0.25$$

$$I_2' = KI_2 = \frac{1}{4} \times 2000 = 50A$$

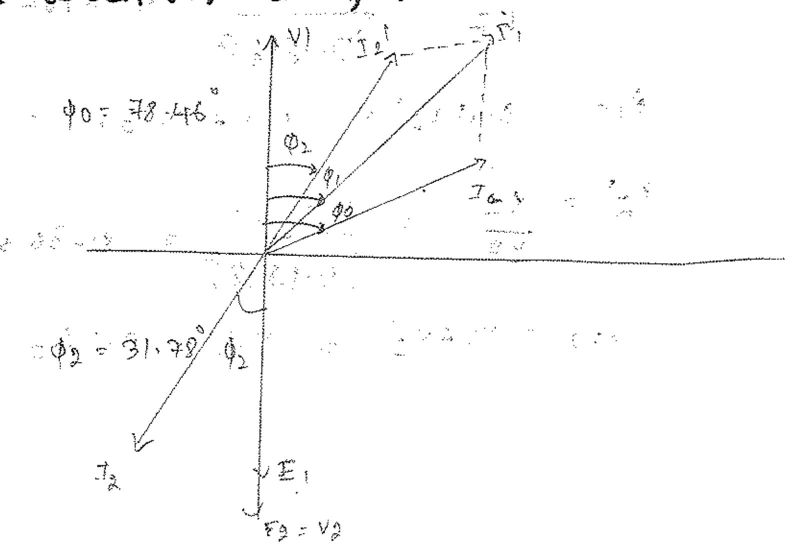
$$\phi_2 = \cos^{-1} 0.85 = 31.788'$$

I_2' is in anti phase with I_2 which lags E_2 by $31.788'$

$\cos\phi_0 = 0.2$

$\phi_0 = 78.463°$

$\bar{I_1} = \bar{I_2}' + \bar{I_0}$



Resolve I_2' and I_0 into two components, along ϕ and in quadrature with ϕ

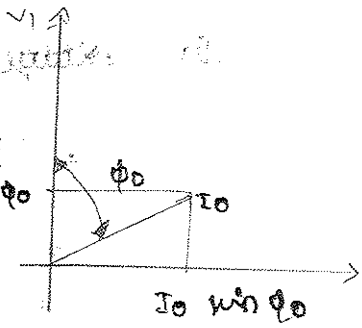
Horizontal component of $I_0 = I_0 \sin\phi_0 = 9.798$

Vertical component of $I_0 = I_0 \cos\phi_0 = 2$

Horizontal component of $I_2' = I_2' \sin\phi_2 = 26.3388$

Vertical component of $I_2' = I_2' \cos\phi_2 = 42.5$

$\bar{I_1} = \bar{I_2'} + \bar{I_0}$

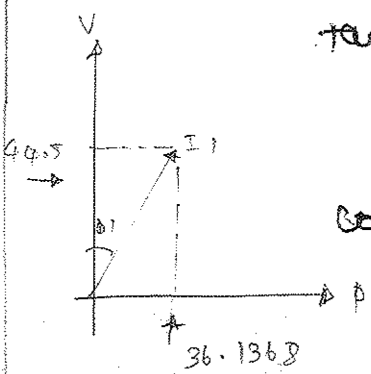


Horizontal component of $I_1 = 9.798 + 26.3388$
$= 36.1368$

Vertical component of $I_1 = 2 + 42.5 = 44.5$

$$|I_1| = \sqrt{(36.1368)^2 + (44.5)^2} = 57.3246$$

As ϕ_1 is the angle made by I_1 with V_1 which is y-axis



$$\tan\phi = \frac{36.1368}{44.5}$$

$\phi_1 = 39.078'$

$\cos\phi_1 = \cos(39.078) = 0.7762$ lagg

9) The parameters of ~~app~~ approximate equivalent circuit of a 4KVA, 200/400 V, 50Hz, 1ϕ transformer are: $R_p = 0.15\Omega$, $X_p' = 0.37\Omega$, $R_0 = 600\Omega$, $X_m = 300\Omega$. When a rated voltage of 200V is applied to primary, a current of 10A at lagging power factor of 0.8 flows in the secondary winding. Calculate

i) The current in the primary I_P

ii) The terminal voltage at the secondary side

Data: $I_2 = 10\,A$, $\cos\phi = 0.8$ lagg, $K = \frac{V_2}{V_1} = \frac{400}{200} = 2$

$I_2' = KI_2 = 2 \times 10 = 20A$ at 0.8 lagging

$I_2' = 20\angle -\cos^{-1}0.8 = 20\angle -36.869° = 16 - j12\,A$

$$I_m = \frac{V_1}{X_m} = \frac{200}{300} = 0.666A$$

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$$I_C = \frac{V_1}{R_0} = \frac{200}{600} = 0.333\,A$$

$$\bar{I_0} = \bar{I_C} + j\,\bar{I_m} = 0.333 + j0.666\,A$$

$$\bar{I_P} = \bar{I_2} + \bar{I_0} = 16 - j12 + 0.333 + j0.666$$

$$= 16.333 - j\,12.666\,A$$

$$= 20.67 \angle -37.79^\circ A$$

(ii) voltage drop in primary $= I_2' [R_p' + jX_p']$

$$= (30 \angle -36.869^\circ)\,[0.15 + j0.37] = (20 \angle -36.869^\circ)(0.399 \angle 67.93^\circ)$$

$$= 7.98 \angle 31.06^\circ V$$

$$= 6.836 + j\,4.117\,V$$

$$V_2' = V_1 - \text{voltage drop}$$

$$= (200 + j0) - (6.836 + j\,4.117)$$

$$= 193.164 - j\,4.117\,V$$

$$V_2' = 193.2 \angle -1.22\,V$$

$$V_2 = K V_2' = 2 \times 193.2 \angle -1.22^\circ$$

$$V_2 = 386.4 \angle -1.22^\circ V$$

10) A 100 kVA, 6.6 kV/415 V single-phase transformer has an effective impedance of $(3+j8)\,\Omega$ referred to HV side. Estimate the full load voltage regulation at 0.8 pf lagging and 0.8 pf lagging

Data: The primary is HV side, $Z_{1e} = 3 + j8\,\Omega$, $R_{1e} = 3\,\Omega$, $X_{1e} = 8\,\Omega$

$$K = \frac{415}{6.6 \times 10^3} = 0.06287$$

$$(I_1)_{FL} = \frac{VA}{V_1} = \frac{100 \times 10^3}{6.6 \times 10^3} = 15.1515\,A$$

$$(I_2)_{FL} = \frac{VA}{V_2} = \frac{100 \times 10^3}{415} = 240.9638\,A$$

$$R_{2e} = K^2 R_{1e} = 0.01185\,\Omega$$

$$X_{2e} = K^2 X_{1e} = 0.03162\,\Omega$$

(i) $\cos\phi = 0.8$ lagging full load, $\sin\phi = 0.6$

$$\%R = \frac{(I_1)_{FL}\,[R_{1e}\cos\phi + X_{1e}\,\cancel{\cos}\sin\phi]}{V_1} \times 100 = +1.652\%$$

$$\% R = \frac{(I_2)_{FL}\,[R_{2e}\cos\phi + X_{2e}\sin\phi]}{V_2}\times 100 = 1.652$$

ii) $\cos\phi = 0.8$ leading, full load; $\sin\phi = 0.6$

$$\% R = \frac{15.1515\,[3\times 0.8 - 8\times 0.6]}{6.6\times 10^3}\times 100 = -0.5509\%$$

(8) A 20 kVA, 2500/500 V, single-phase transformer has the following parameter:

HV winding: $r_1 = 8\Omega$ and $x_1 = 17\Omega$

LV winding: $r_2 = 0.3\Omega$ and $x_2 = 0.7\Omega$

Find the voltage regulation and the secondary terminal voltage at full load for a pf of 0.8 lagging and 0.8 leading. The primary voltage is held constant at 2500 V.

Data: 20 kVA, $V_1 = 2500$ V, $V_2 = 500$ V, $K = \frac{V_2}{V_1} = 0.2$

$$R_{2e} = r_2 + K^2 r_1 = 0.3 + (0.2)^2\times 8 = 0.62\Omega$$

$$X_{2e} = X_2 + K^2 X_1 = 0.7 + (0.2)^2\times 17 = 1.38\Omega$$

$$I_2(FL) = \frac{VA}{V_2} = \frac{20\times 10^3}{500} = 40A$$

i) $\cos\phi = 0.8$ lag

$$\% R = \frac{I_2(FL)\,[R_{2e}\cos\phi + X_{2e}\sin\phi]}{V_2}\times 100 = 10.592\%$$

$$V_2 = 500 - I_2(FL)\,[R_{2e}\cos\phi + X_{2e}\sin\phi]$$

$$V_2 = 447.04\ \%$$

(ii) $\cos\phi = 0.8$ ~~lead~~

$$\% R = \frac{I_2(FL)\,[R_{2e}\cos\phi - X_{2e}\sin\phi]}{V_2}\times 100 = -2.65\%$$

$$V_2 = 500 - I_2(FL)\,[R_{2e}\cos\phi - X_{2e}\sin\phi]$$

$$= 513.28\text{ V}$$

(9) A single phase transformer on full loads has an impedance drop of 10V. calculate the value of power factor when its regulation will be zero.

For zero voltage regulation

$E_2 = V_2$ and $\% R = 0$

power factor is leading for zero voltage regulation

$$\% R = \frac{I_1 R_{1e}\cos\phi - I_1 X_{1e}\sin\phi}{V_1}\times 100 = 0$$

$I_1 R_{1e} \cos\phi - I_1 X_{1e} \sin\phi = 0$

$I_1 R_{1e}$ = Resistive drop = $V_R = 10V$

$I_1 Z_{1e}$ = Impedance drop = $V_Z = 20V$

$I_1 X_{1e} = \sqrt{(I_1 Z_{1e})^2 - (I_1 R_{1e})^2} = \sqrt{(20)^2 - (10)^2} = 17.3205\,V = V_X$

$\tan\phi = \frac{V_R}{V_X} = \frac{10}{17.3205} = 0.5773$

$\phi = 30^\circ$

$\cos\phi = 0.866$ lagging

This is the power factor for zero voltage regulation

13) The primary and secondary windings of 500 kVA transformer have resistance of 0.4Ω and 0.001Ω respectively. The primary and secondary voltages are 6600 V and 400V respectively. The iron loss is 3kW. Calculate the efficiency on full load, the load power factor being 0.8 lagging.

Data: 500 kVA, $R_1 = 0.4\Omega$, $R_2 = 0.001\Omega$, $V_1 = 6600V$, $V_2 = 400V$

P_i = iron loss = 3kW

$I_1(FL) = \frac{VA}{V_1} = \frac{500 \times 10^3}{6600} = 75.7575A$

$k = \frac{V_2}{V_1} = \frac{400}{6600} = 0.0606$ $\quad R_2' = \frac{R_2}{k^2} = \frac{0.001}{(0.0606)^2} = 0.27225\,\Omega$

$R_{1e} = R_1 + R_2' = 0.4 + 0.27225 = 0.67225\,\Omega$

$(P_{cu})_{FL}$ = copper loss on full load $= [I_1(FL)]^2 R_{1e}$

$= (75.7575)^2 \times 0.67225$

$= 3858.1764\,W$

$\%\eta(FL) = \frac{VA\cos\phi}{VA\cos\phi + P_i + P_{cu}(FL)} \times 100$

$= \frac{500 \times 10^3 \times 0.8}{500 \times 10^3 \times 0.8 + 3 \times 10^3 + 3858.1764} \times 100$

$= 98.3143\,\%$ Full load efficiency

(4) A 600 KVA, single phase transformer when working at U.P.f has an efficiency of 92% at full load and also at half load. Determine the efficiency when it operates at unity P.f and 60% of full load.

Data: 600 KVA, $\cos\phi = 1$, $\eta_{FL} = 92\%$, $\eta_{HL} = 92\%$.

$$\%\eta_{FL} = \frac{(KVA \times 10^3)\cos\phi}{(KVA \times 10^3)\cos\phi + (P_{cu})_{F.L.} + P_i} \times 100$$

$$0.92 = \frac{600 \times 10^3}{600 \times 10^3 + (P_{cu})_{F.L} + P_i}$$

$$(P_{cu})_{FL} + P_i = 52173.913 \rightarrow (1)$$

For half load, $n = \frac{1}{2} = 0.5$

$$\%\eta_{HL} = \frac{n \times (KVA \times 10^3) \times \cos\phi}{n \times (KVA \times 10^3) \times \cos\phi + n^2 (P_{cu})_{F.L} + P_i} \times 100$$

$$0.92 = \frac{0.5 \times 600 \times 10^3}{0.5 \times 600 \times 10^3 + 0.25 (P_{cu})_{F.L} + P_i}$$

$$0.25 (P_{cu})_{F.L} + P_i = 26086.9565 \rightarrow (2)$$

Solving equation (1) & (2)

$$P_{cu\,F.L} = 34782.608\,W$$

$$P_i = 17391.304\,W$$

To find η at 60% of full load at $\cos\phi = 1$, n = fraction of load = 0.6

$$\%\eta = \frac{n \times (KVA \times 10^3)\cos\phi}{n \times (KVA \times 10^3)\cos\phi + n^2 (P_{cu})_{FL} + P_i}$$

$$= \frac{0.6 \times 600 \times 10^3 \times 1}{0.6 \times 600 \times 10^3 \times 1 + 0.36 \times 34782.608 + 17391.304} \times 100$$

$$\%\eta = 92.3282\%$$

(5) Calculate the efficiency at half, full load of a 100 KVA transformer for power factor of unity and 0.8. The copper loss is 1000 W at full load, and iron loss is 1000 W

Data: 100 KVA, $(P_{cu})_{F.L.} = 1000\,W$, $P_i = 1000\,W$

(i) $\cos\phi = 1$, full load

$$\% \eta_{FL} = \frac{VA\cos\phi}{VA\cos\phi + (P_{cu})FL + P_i} \times 100$$

$$= \frac{100 \times 10^3 \times 1}{100 \times 10^3 \times 1 + 1000 + 1000} \times 100$$

$$= 98.04\%$$

(ii) $\cos\phi = 0.8$, full load

$$\% \eta_{FL} = \frac{100 \times 10^3 \times 0.8}{100 \times 10^3 \times 0.8 + 1000 + 1000} \times 100$$

$$= 97.56\%$$

For half load, copper loss $= n^2 (P_{cu}).FL$ where $n = 0.5$

$$\% \eta_{HL} = \frac{n\,VA\cos\phi}{n\,VA\cos\phi + n^2 (P_{cu})F.L + P_i} \times 100$$

(i) $\cos\phi = 1$, half load

$$\% \eta_{HL} = \frac{0.5 \times 100 \times 10^3 \times 1}{0.5 \times 100 \times 10^3 + 1 + (0.5)^2 \times 1000 + 1000} \times 100$$

$$= \cancel{96.96\%}\ 97.56\%$$

(ii) $\cos\phi = 0.8$, half load

$$\% \eta_{HL} = \frac{0.5 \times 100 \times 10^3 \times 0.8}{0.5 \times 100 \times 10^3 \times 0.8 + (0.5)^2 \times 1000 + 1000} \times 100$$

$$= 96.96\%$$

6. A 200 KVA, single phase transformer has an efficiency 98% at full load, 0.8 P.f. lag. If the maximum efficiency occur at three quarters full load, calculate the iron loss and full load copper loss.

Data: 200 KVA, $\% \eta = 98\%$, $\cos\phi = 0.8$ lag

$$\% \eta = \frac{KVA\cos\phi}{KVA\cos\phi + P_i + (P_{cu})F.L} \times 100$$

$$0.98 = \frac{200 \times 10^3 \times 0.8}{200 \times 10^3 \times 0.8 + P_i + (P_{cu}).F.L}$$

$$P_i + (P_{cu})F.L = 3265.3061 \rightarrow (1)$$

KVA at $\eta_{max} = \frac{3}{4}$ full load KVA

but KVA at η_{max} = KVA rating $\times \sqrt{\frac{P_i}{(P_{cu})F.L}}$

$$\frac{3}{4} \times KVA = KVA \times \sqrt{\frac{P_i}{P_{cu}\,F.L}} \Rightarrow (0.75)^2 = \frac{P_i}{(P_{cu})\,F.L}$$

$$(P_{cu}) \cdot F.L = 1.7778\, P_i \rightarrow (2)$$

subs in (1), $P_i + 1.7778\, P_i = 3265.306$

$$P_i = 1175.51\,W$$

$$P_{cu}(F.L) = 2089.8\,W$$

17. A 500 KVA transformer has core loss of 2200 volts and a full load copper loss of 7500 watts. If the power factor of the load is 0.9 lagging, calculate the full load efficiency and the KVA load at which maximum efficiency occurs

Data : 500 KVA, $P_i = 2200\,W$, $P_{cu}(FL) = 7500\,W$, $\cos\phi = 0.9$

$$\%\,\eta_{FL} = \frac{VA\cos\phi}{VA\cos\phi + P_i + P_{cu}(FL)} \times 100$$

$$= \frac{500 \times 10^3 \times 0.9}{500 \times 10^3 \times 0.9 + 2200 + 7500} \times 100 = 97.89\%$$

KVA for η_{max} $= KVA \times \sqrt{\frac{P_i}{P_{cu}(F.L)}}$

$$= 500 \times \sqrt{\frac{2200}{7500}}$$

$$= 270.801\ KVA$$

18. The maximum efficiency of a single phase 250 KVA, 2000/250 V transformer occurs at 80% full load and is equal to 97.5% at 0.8 p.f. Determine the efficiency and regulation on full load at 0.8 p.f. lagging if the impedance of the transformer is 9 percent

Data : 250 KVA, 2000/250 V, n = fraction of load = 80%

$\eta_{max} = 95.8\%$, $\cos\phi = 0.8$

At η_{max}, $P_i = P_{cu}$

$$\%\,\eta_{max} = \frac{n\,KVA \times 10^3 \cos\phi}{n\,KVA \times 10^3 \cos\phi + 2P_i} \times 100$$

$$0.975 = \frac{0.8 \times 250 \times 10^3 \times 0.8}{0.8 \times 250 \times 10^3 \times 0.8 + 2P_i}$$

$P_i = 4102.5641\ W =$ Iron losses

At 80% load

$P_{cu} = n^2 (P_{cu})_{F.L} = P_i$ As $\eta = \eta_{max}$

$(0.8)^2 (P_{cu})_{F.L} = 4102.5641$

$(P_{cu})_{F.L} = 6410.2564\ W$

$$\%\eta_{F.L} = \frac{KVA \times 10^3 \times \cos\phi}{KVA \times 10^3 \times \cos\phi + (P_{cu})_{F.L} + P_i} \times 100$$

$$= \frac{250 \times 10^3 \times 0.8}{250 \times 10^3 \times 0.8 + 6410.2564 + 4102.5641} \times 100$$

$= 95\%$

$$(I_1)_{F.L} = \frac{KVA \times 10^3}{V_1} = \frac{250 \times 10^3}{2000} = 125\ A$$

R_{1e} = equivalent resistance referred to primary

$$= \frac{(P_{cu})_{F.L}}{[(I_1)_{F.L}]^2} = \frac{6410.2564}{(125)^2} = 0.4102\ \Omega$$

$$\%\ \text{Resistance} = V_R = \frac{(I_1)_{F.L}\, R_{1e}}{V_1} \times 100 = \frac{125 \times 0.4102}{2000} \times 100$$

$= 2.563\%$

% impedance = 9% = given

$$\%\ \text{Reactance} = V_X = \sqrt{(9)^2 - (2.563)^2} = 8.6273\%$$

$$\%\ \text{Regulation} = [V_R \cos\phi + V_X \sin\phi] \times 100$$

$= [0.02563 \times 0.8 + 0.086273 \times 0.6] \times 100$

$= 7.2267\%$

19). A 100 KVA 1000/10 kV, 50 Hz, single phase transformer has an iron loss of 1100 W. The copper loss with 5A in the high voltage winding is 400 W. Calculate the efficiency at i) 25% (ii) 50% (iii) 100% of normal load for power factor of 1.0 and 0.8. The output terminal voltage being maintained at 10 kV. Find also the load for maximum efficiency at both power factors.

Data: 100 KVA, $V_1 = 1000\ V$, $V_2 = 10\ kV$, $P_i = 11000\ W$

$P_{cu} = 400\ W$ with $I = 5A$ in high voltage winding

$$I_1(F.L) = \frac{VA}{V_1} = \frac{100\times10^3}{1000} = 100A$$

$$I_2(F.L) = \frac{VA}{V_2} = \frac{100\times10^3}{10\times10^3} = 10A$$

$$P_{cu} \propto I^2 \qquad \frac{(P_{cu})'}{P_{cu}(F.L)} = \frac{(I')^2}{[I_2.(F.L).]^2}$$

$$\frac{400}{P_{cu}(F.L)} = \left(\frac{5}{10}\right)^2$$

$$P_{cu}(F.L) = 1600\ W$$

i) 25% load, $n = 0.25$

$$P_{cu} = n^2 \times P_{cu}(FL) = (0.25)^2 \times 1600 = 100W$$

$$\%\eta = \frac{nVA\cos\phi}{nVA\cos\phi + P_i + P_{cu}} \times 100 \quad \text{where } P_{cu} = n^2 P_{cu}(F.L)$$

a) $\cos\phi = 1$ $\quad \%\eta = \frac{0.25\times100\times10^3\times1}{0.25\times100\times10^3\times1 + 1100 + 100}\times100 = 95.42\%$

b) $\cos\phi = 0.8$ $\quad \%\eta = \frac{0.25\times100\times10^3\times0.8}{0.25\times100\times10^3\times0.8 + 1100 + 100}\times100$

$= 94.34\%$

(ii) 50% load, $n = 0.5$

a) $\cos\phi = 1$ $\quad \%\eta = \frac{0.5\times100\times10^3\times1}{0.5\times100\times10^3\times1 + 1100 + 400}\times100$

$= 97.087\%$

b) $\cos\phi = 0.8$ $\quad \%\eta = \frac{0.5\times100\times10^3\times0.8}{0.5\times100\times10^3\times0.8 + 1100 + 400}\times100$

$= 96.385\%$

(iii) 100% load $n = 1$

a) $\cos\phi = 1$ $\quad \%\eta = \frac{1\times100\times10^3\times1}{1\times100\times10^3\times1 + 1100 + 1600}\times100 = 97.37\%$

b) $\cos\phi = 0.8$ $\quad \%\eta = \frac{1\times100\times10^3\times1}{1\times100\times10^3\times0.8 + 1100 + 1600}\times100$

$= 96.735\%$