\# $\eta = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + \text{iron-loss} + \text{Cu-loss}}$

\# $p.f = \frac{kW \rightarrow \text{active}}{kVA \rightarrow \text{apparent}}$

$P_{out} = VI\cos\phi$

iron loss = constant at any load

Cu-loss = $x^2 \times$ Cu-loss

$P_{out} = x \times P_{out}$

$\therefore \quad \eta = \frac{x P_{out}}{x P_{out} + x^2 \text{Cu-loss} + \text{ironloss}}$

For max $\eta$ = iron loss = Cu-loss

$\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$

can be $\cancel{\frac{I_2 R_{02}}{V_2}}$ $I_2 X_{02}$

also for all VR

$V_{reg}$ at lag p.f $= \frac{I_1 R_{01}\cos\phi_1 + I_1 X_{01}\sin\phi_1}{V_1} \times 100\%$

$V_{reg}$ at unity p.f $= \frac{I_1 R_{01}}{V_1} \times 100\%$

$V_{reg}$ at leading pf $= \frac{I_1 R_{01}\cos\phi_1 - I_1 X_{01}\sin\phi_1}{V_1} \times 100\%$

For max $\eta$ =

kVA

load = full load $\times \sqrt{\dfrac{\text{iron loss}}{\text{F.L Cu-loss}}}$

at max $\eta$ = kVA ma aaucha

A $3\phi$ transformer

load ko

3-phase power $\rightarrow$ $P_2 = \sqrt{3}\, V_2 I_2 \cos\phi$

Cu-loss for 3-phase

$$= 3 \times (I_{1p})^2 \times R_1 + 3 \times (I_{2p})^2 \times R_2$$

primary    secondary

$$k = \frac{1}{\sqrt{3}} \frac{V_2}{V_1}$$

① The O.C and S.C test data are given below for a single phase 5kVA, 200V/400V and 50Hz transformer.

O.C test from LV side : 200V 1.25A 150W
S.C test from HV side : 20V 12.5A 175W

Calculate the equivalent ckt parameters referred to primary and secondary ckt and draw the equivalent ckt.

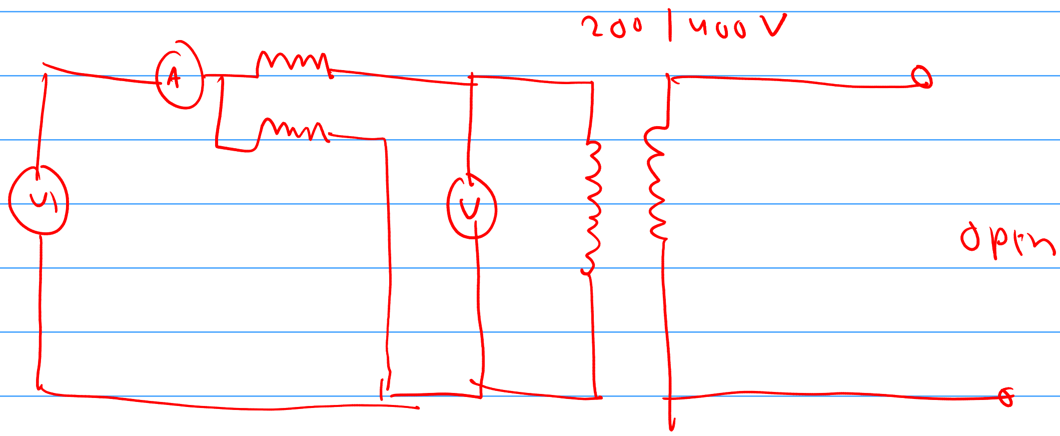
soln:- Transformer is step-up (LV - HV)

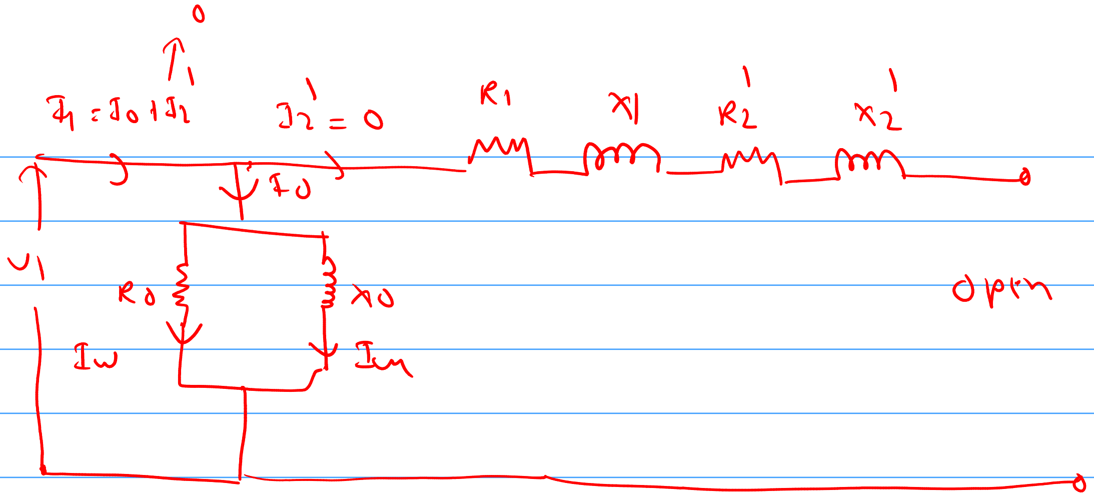
Part - I O/C test

$$V_0 = 200V, \quad W_0 = 150W, \quad I_0 = 1.25\ A$$

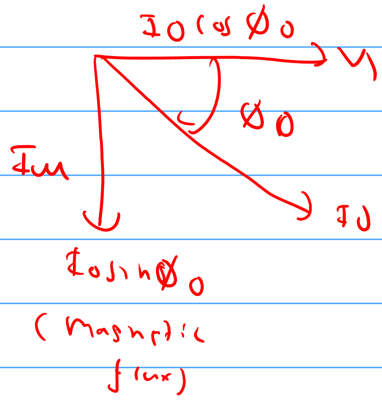
(i) HV side opened

(ii) all equipments connected to LV side and supplied by a rated voltage.






$I_0 = 1.25A$, $W_0 = 150W$, $V_0 = 200V = V_1$ $I_w$ ( iron loss)




$W_0 = V_1 I_w$

iron loss $\quad w_0 = V_1 \times I_0 \cos \phi_0$

or $\quad 150 = 200 \times 1.25 \times \cos \phi_0$

$$\phi_0 = \cos^{-1}\left(\frac{150}{200 \times 1.25}\right)$$

$$= 53.13^\circ$$

$I_m = I_0 \sin \phi_0 = 1 \text{ A}$

$I_w = I_0 \cos \phi_0 = 0.75 \text{ A}$

$$R_0 = \frac{V_1}{I_w} = \frac{200}{0.75} = 266.667 \Omega$$

$$X_0 = \frac{V_1}{I_m} = \frac{200}{1} = 200\Omega$$

$$k = \frac{V_2}{V_1} = \frac{400}{200} = 2$$

$R_0' = R_0 \times K^2 = 266.667 \times 2^2 = 1066.668\,\Omega$

$X_0' = X_0 \times K^2 = 200 \times 2^2 = 800\,\Omega$

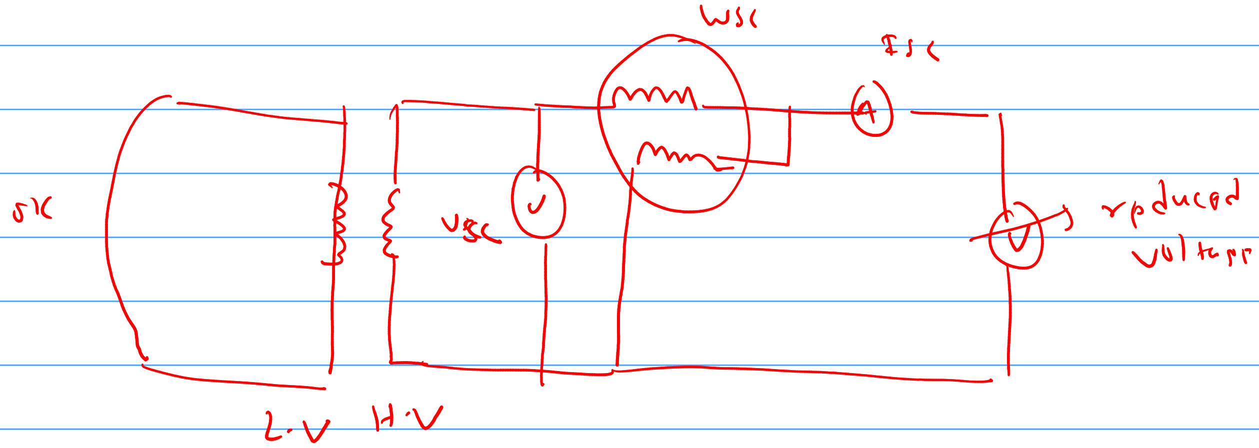
$V_0' = V_0 \times K = 200 \times 2 = 400\,V$

$I_0' = \frac{1}{K} I_0 = \frac{1}{2} \times 1.25 = 0.625\,A$

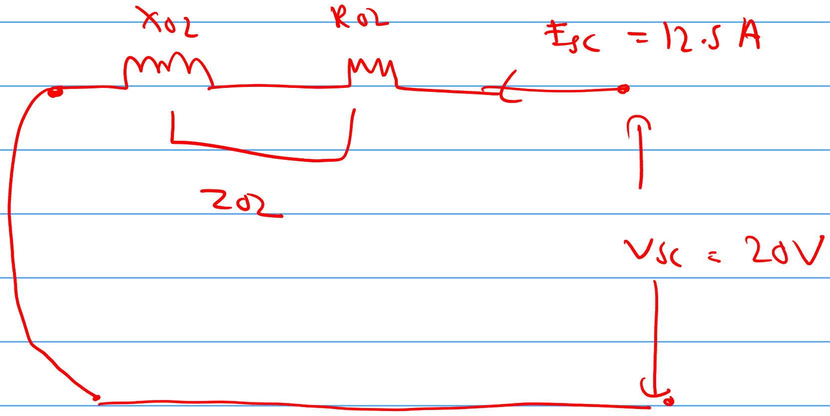
part -2 (S/C test)

① LV side is S/C

(ii) all component to HV side




Ckt referred to secondary side




$W_{sc} = 175\,W$ = copper loss

$$V_{sc} = I_{sc} \times Z_{02}$$

or $$Z_{02} = \frac{V_{sc}}{I_{sc}} = \frac{20}{12.5} = 1.6\,\Omega$$

$$W_{sc} = I_{sc}^2 \times R_{02}$$ (cu-loss) resistance

or, $$175 = (12.5)^2 \times R_{02}$$

$$\therefore \quad R_{02} = 1.12\,\Omega$$

$$X_{02} = \sqrt{Z_{02}^2 - R_{02}^2} = \sqrt{1.6^2 - 1.12^2}$$
$$= 1.14\,\Omega$$

$$Z_{01} = \frac{Z_{02}}{k^2} = \frac{1.6}{2^2} = 0.4\,\Omega$$

$$R_{01} = \frac{R_{02}}{k^2} = 0.28\,\Omega$$

$$X_{01} = \frac{X_{02}}{k^2} = 0.285\,\Omega$$

---

(step-down)

\# A 100 kVA, 11 kV/220V, 50 Hz single transformer produced the following results.

iron

O.C test : 220V , 45A , 2kW

S.C test : 500V , 9.09 A , 3kW → copper

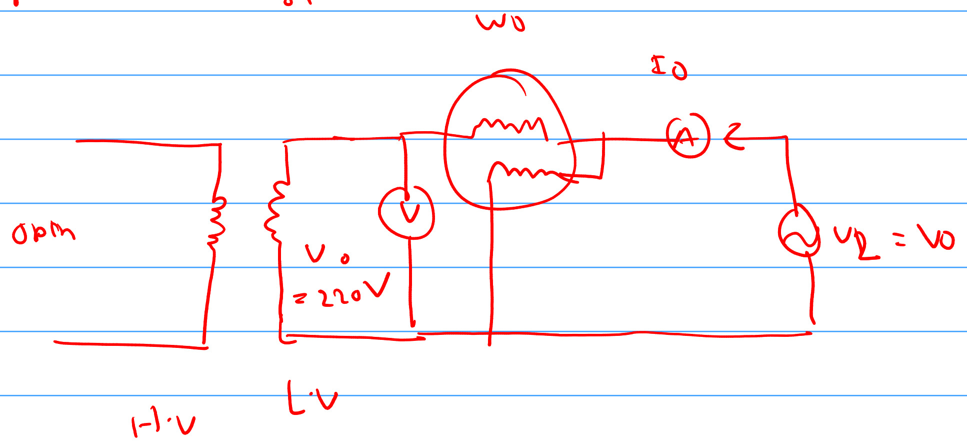
Solve :

Part I O/C test

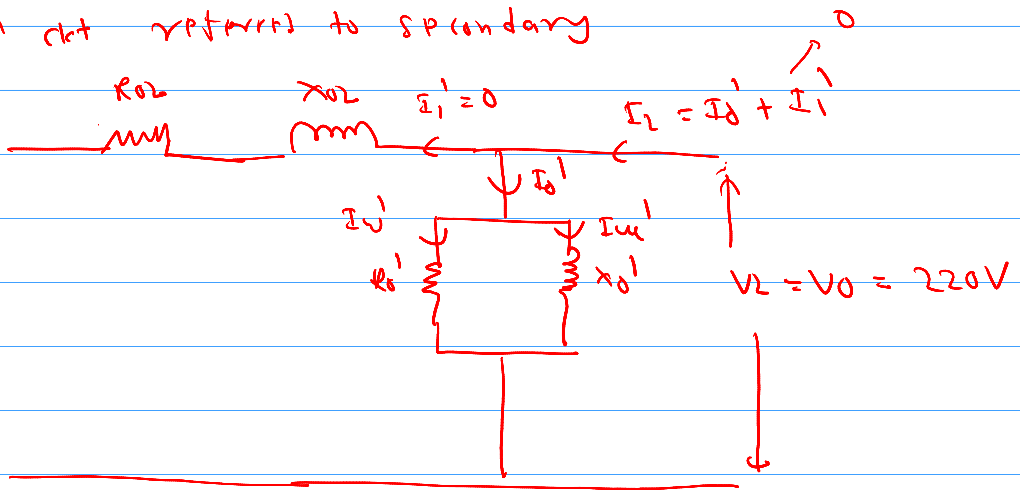
$V_0 = 220V$ , $I_0 = 45A$ , $W_0 = 2kW$

(i) HV side open

(ii) all equipments in LV ~~stride~~ side and supplied by rated voltage.




eqn ckt referred to secondary




$V_2 = 220V$ , $W_0 = 2 \times 10^3 W$ , $I_2 = 45A$

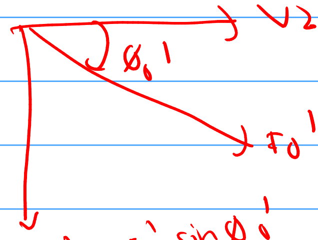
( give in question)

now

$W_0 = 2kW = 2\times10^3\ W$ (iron)

iron loss

$I_w' = I_0' \cos\phi_0'$




$I_\mu' = I_0' \sin\phi_0'$

(mag flux)

$W_0 = V_2 \times I_w'$

$2\times10^3 = 220 \times I_0' \cos\phi_0'$

$(I_2 = I_0')$
ammeter reading

or $2\times10^3 = 220 \times 45 \cos\phi_0'$

or $\cos\phi_0' = \dfrac{2\times10^3}{220\times45}$

$\therefore \phi_0' = 78.34^\circ$

$I_w' = I_0' \cos\phi_0' = 9.09\ A$

$I_\mu' = I_0' \sin\phi_0' = 44.07\ A$

Then $X_0' = \dfrac{V_2}{I_\mu'} = \dfrac{220}{44.07} = 4.992 A$

$R_0' = \dfrac{V_2}{I_w'} = \dfrac{220}{9.09} = 24.20 A$

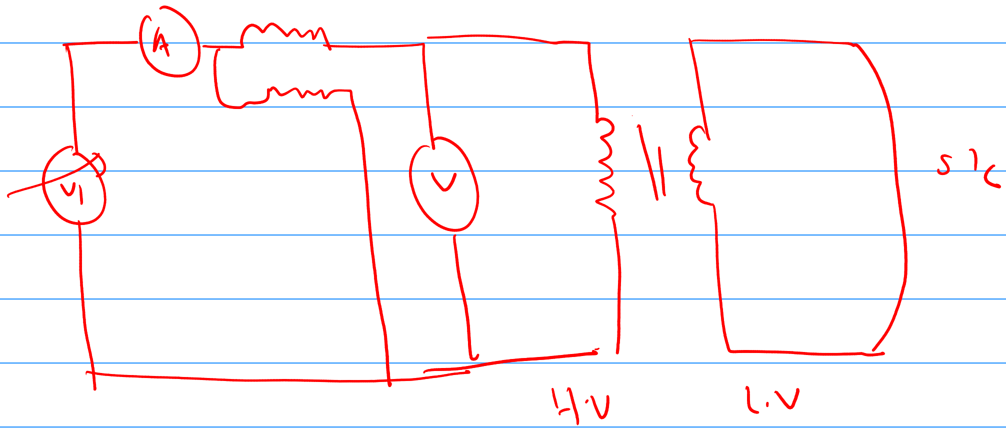
$k = \dfrac{V_2}{V_1} = \dfrac{220}{11\times10^3} = 0.02$

$R_0 = \dfrac{R_0'}{k^2} = 60500\,\Omega$ | $X_0 = \dfrac{X_0'}{k^2} = 12480\,\Omega$

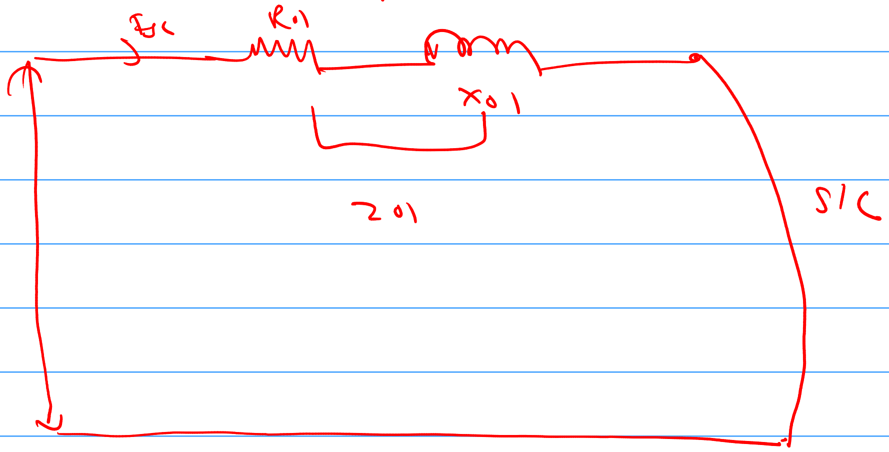
part - II s/c test

$V_{sc} = 500V$ , $I_{sc} = 9.09 V$ , $W_{sc} = 3kW$

① LV is s/c
② H.V all e connected with reduced rated voltage supply.




ckt with respect to primary side




$$Z_{01} = \frac{V_{sc}}{I_{sc}} = \frac{500}{9.09} = 55\Omega$$

$W_{sc} = I_{sc}^2 \times R_{01}$ (Cu-loss)

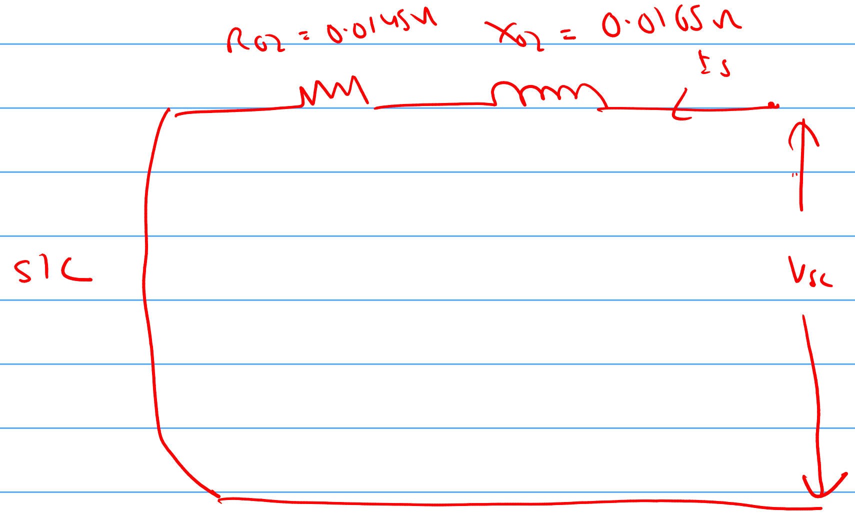
$$R_{01} = \frac{W_{sc}}{(I_{sc})^2} = \frac{3\times10^3}{(9.09)^2} = 36.307\ \Omega$$

$$X_{01} = \sqrt{(Z_{01})^2 - (R_{01})^2} = 41.31\,\Omega$$

$$R_{02} = K^2 R_{01} = (0.02)^2 \times 36.307 = 0.014\ \Omega$$

$$K = \frac{V_2}{V_1} = 0.02$$

$$X_{02} = K^2 X_{01} = (0.02)^2 \times 41.31 = 0.0165\,\Omega$$




eq ckt referred to LV side #

# A transformer is rated at 100 kVA. At full load it's copper loss is 1200W and its iron loss is 960W. Calculate

capacity

(i) $\eta$ at full load, unity p.f

(ii) $\eta$ at half load, 0.8 p.f

Soln ÷

100 kVA - Transformer

Cu-loss = 1200 W

iron-loss = 960W

(i) $p.f = \frac{kW}{kVA}$ $\quad$ $P_{out} = kVA \times pf$

$= 100 \times p.f \quad kW$

at full load $(x=1)$ $\quad p.f = 1$

$P_{out} = 100 \times 1 = 100 \text{ kW}$

$$\eta = \frac{x \times P_{out}}{x \times P_{out} + x^2 \times Cu\text{-loss} + iron\text{-loss}}$$

$$= \frac{1 \times 100 \times 10^3}{1 \times 100 \times 10^3 + 1^2 \times 1200 + 960}$$

$= 0.978 = 97.88\%$

(ii) at half load $(x = 0.5)$ with $p.f = 0.8$, $\cos\phi = 0.8$

$P_{out} = VI\cos\phi$
$= 100 \text{ kVA} \times 0.8 = 80 \text{ kW}$

$2. \quad \eta = \dfrac{0.5 \times 80}{0.5 \times 80 + (0.5)^2 \times 1.2 + 0.96}$

$= 0.9674$
$= 96.74\ \%$

\# A $1\phi$ 500 kVA transformer working at unity p.f has an efficiency of 90% at half load and iron loss of 2000W. Determine $\eta$ at full load.

Case - I

p.f = 1

$\eta = 90\% = 0.9$

$x = 0.5$

iron = 2000 W = 2kW

$P_{out} = VI\cos\phi$ (p.f)

$= 500 \times 1 = 500 \text{kW}$

$$\eta = \frac{x \times P_{out}}{x \times P_{out} + x^2 \times \text{Cu-loss} + \text{iron-loss}}$$

or $\quad 0.9 = \dfrac{0.5 \times 500}{0.5 \times 500 + (0.5)^2 \times \text{Cu-loss} + 2}$

$\therefore$ Cu-loss $= 103.11$ kW

(ii) $\eta = ?$

$x = 1$

$$\eta = \frac{1 \times 500}{1 \times 500 + 1^2 \times 103.111 + 2}$$

$= 0.8262 = 82.62\ \%$ (full load)

# A 20 kVA, 250V / 2500 V, 50 Hz $1\phi$ transformer has the following parameters; $R_0 = 600\Omega$, $X_0 = 180\Omega$, $R_{01} = 0.05\Omega$ and $X_{01} = 0.15\Omega$

(i) Calculate iron loss

(ii) Calculate the primary current at which the $\eta$ of transformer will be maximum and also calc maximum $\eta$.

soln ÷

20 kVA → capacity

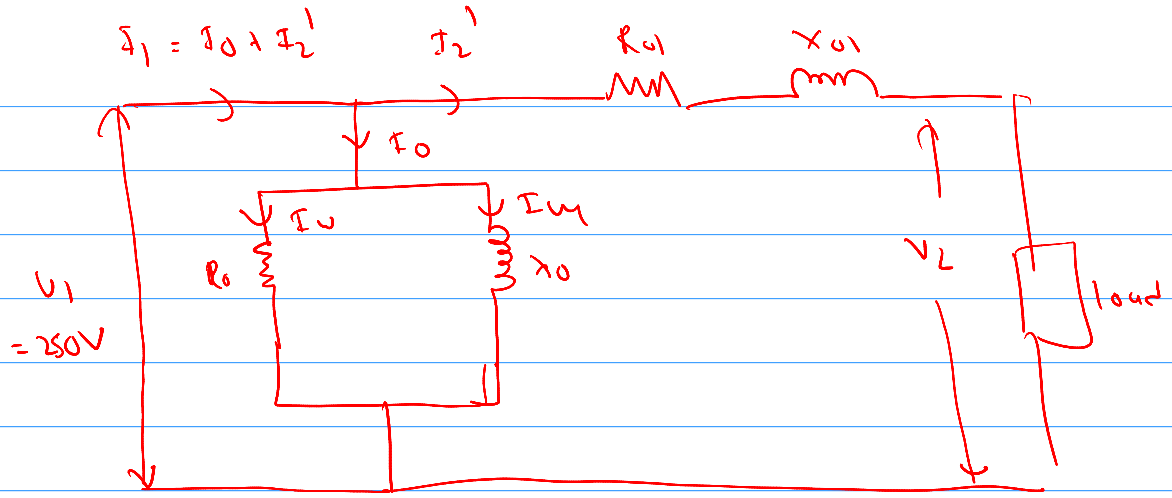
250 | 2500 V, 50Hz, $1\phi$

↑

Step-up (L.V - H.V)

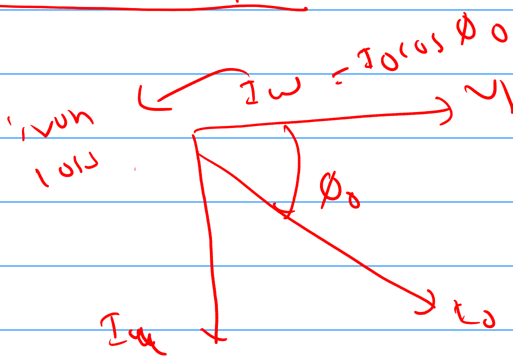
$R_0 = 600\Omega$, $X_0 = 180\Omega$ $R_{01} = 0.05\Omega$ $X_{01} = 0.15\Omega$

Drawing eqn ckt of transformer referred to primary




$I_w$ responsible for iron-loss

$$\text{Iron-loss} = V_1 I_w$$
$$= V_1 I_0 \cos\phi_0$$




$= I_0 \sin\phi_0$ → mag flux

Here,

$$V_1 = I_w \times R_0$$
$$I_w = \frac{V_1}{R_0} = \frac{250}{600} = \frac{5}{12} \text{ A}$$

$$I_\mu = \frac{V_1}{X_0} = \frac{250}{180} = \frac{25}{18} \text{ A}$$

$$\text{Iron-loss} = V_1 \times I_w = 250 \times \frac{5}{12} = 104.167 \text{ W}$$
$$= 0.10416 \text{ KW}$$

For max $\eta$

iron-loss = Cu-loss

Cu-loss due to heat (resistance)

or $\quad 0.10416 \,(W) = (I_2')^2 \times R_{01}$

or, $\quad 0.10416 \times 10^3 = (I_2')^2 \times 0.05 \,(\Omega)$

$\therefore \quad I_2' = 45.64\text{ A}$

$$\eta_{max} = \frac{P_{out}}{P_{out} + 2 \times \text{iron-loss}} \quad (\text{iron} = \text{Cu loss})$$

$$\eta_{max} = \frac{VI\cos\phi}{VI\cos\phi + 2 \times 0.10416\text{ kW}}$$

$$= \frac{20\text{ kVA} \times 1}{20\text{ kVA} \times 1 + 2 \times 0.10416\text{ kW}}$$

$$= \frac{20\text{ kW}}{20\text{ kW} + 2 \times 0.10416\text{ kW}}$$

$$= 0.9896$$

$$= 98.96\,\% \quad \#$$

---

\# The no-load current of a transformer is 10 A at a p.f of 0.3 lagging when connected to a 400V, 50Hz power supply. If the primary winding has 500 turns. Calculate

(a) The magnetizing and working comp of no-load current ($I_w$ and $I_\mu$)

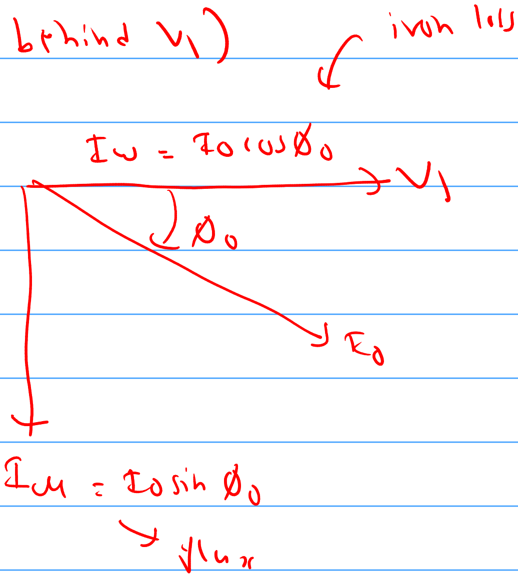
(b) iron - loss

(c) max and rms value of $\phi$ in core

soln:

$I_0 = 10A \quad V_1 = 400V \quad N_1 = 300$

p.f = 0.3 lag ( $I_0$ lags behind $V_1$)




p.f = $\cos\phi_0$ = 0.3

$\phi_0 = 75.542^\circ$

$I_\mu = I_0 \sin\phi_0$

$= 9.537$ A

$I_w = I_0 \cos\phi_0$

$= 10 \times 0.3$

$= 3A$

iron loss $= V_1 \cdot I_w$

$= 400 \times 3 = 1200W$

$E = 4.44 f \phi_m N_1$

in ideal

$E_1 = V$

$V = 4.44 f N_1 \phi_m$

$400 = 4.44 \times 50 \times 500 \times \phi_m$

$\therefore \phi_m = 3.6036 \times 10^{-3}$ wb

$$\phi_{rms} = \frac{\phi_m}{\sqrt{2}} = 2.5481 \times 10^{-3} \text{ wb}$$

---

# A 50 kVA, 200 / 2200, 50 Hz 1ø transformer has the following parameters: $R_0 = 600\Omega$, $X_0 = 200\Omega$ refer to primary and $R_{02} = 2\Omega$ and $X_{02} = 4\Omega$ refer to secondary side. Calculate $\eta$ of transfer when supplying a power at 40kW to the load with 0.65 pf lagging at rated voltage. Is the transformer over-loaded or under loaded? Calculate the % by which it is overloaded or underloaded.

soln:

50 kVA → capacity

200 / 2200V, 50Hz, 1ø → step-up

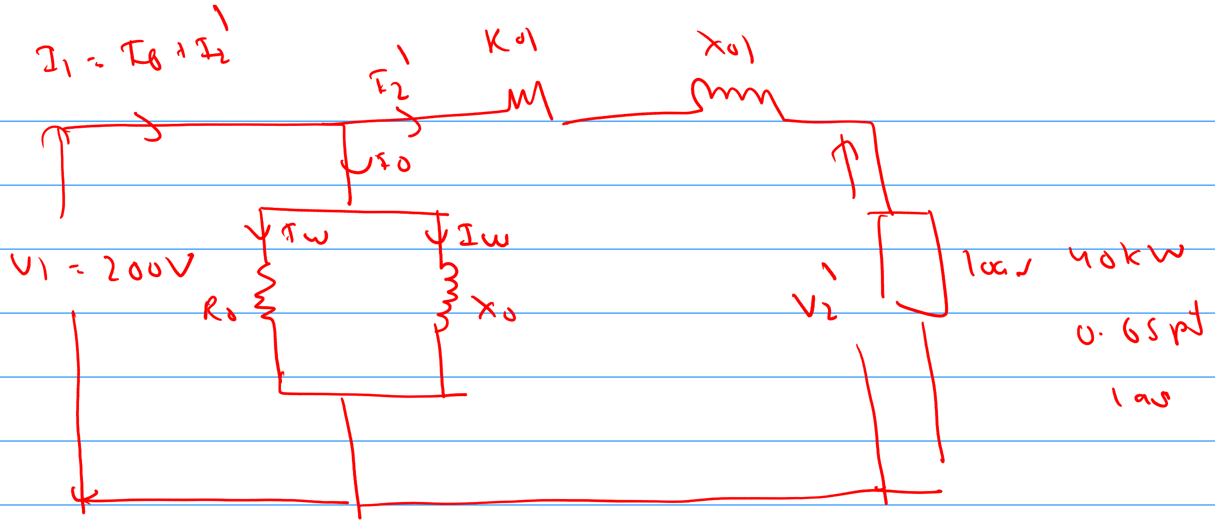
$R_0 = 600\Omega$, $X_0 = 200\Omega$

$R_{02} = 2\Omega$, $X_{02} = 4\Omega$

$$K = \frac{V_2}{V_1} = \frac{2200}{200} = 11$$

$$R_{01} = \frac{R_{02}}{K^2} = 0.01625\Omega \qquad X_{01} = \frac{X_{02}}{K^2} = 0.03305\Omega$$

eq$^n$ ckt referred to primary




To find if it is overloaded or not

capacity = 50 kVA

load = 40 kW (0.65 pf lag)

$$p.f = \frac{kW}{kVA}$$

$$\text{required kVA for load} = \frac{kW}{p.f} = \frac{40}{0.65} = 61.53\ kVA$$

but our capacity is 50 kVA so it is overloaded

$$\%\ \text{overload} = \left(\frac{61.53 - 50}{50}\right) \times 100\ \%$$

$$= 23.06\ \%$$

$$\eta = \frac{x\ P_{out}}{x\ P_{out} + \text{iron} + \cancel{\text{Cu-loss}}\ x^2\ \text{Cu-loss}}$$

$P_{out} = VI\cos\phi = 50\,kVA \times 0.65$

$= 32.5\,kW$

$I_w = \frac{V_1}{R_0} = \frac{200}{600} = \frac{1}{3}\,A$

$\text{iron-loss} = V_1 I_w = 200 \times \frac{1}{3} = 66.66\,W$

$\text{Cu-loss} = (I_2')^2 \times R_{01}$

40kW load 0.65

$40 \times 10^3 = V_2' \times I_2' \cos\phi$

$40 \times 10^3 = 200 \times 0.65 \times \cancel{\cos\phi}\; I_2'$

$\therefore I_2' = 307.69\,A$

$\text{Cu-loss} = (307.69)^2 \times 0.01652$

$= 1564.023\,W$

how logic

$$\boxed{x = \frac{\text{required kVA}}{\text{given kVA}} = \frac{61.53}{50} = 1.23}$$

$$\eta = \frac{x\,P_{out}}{x\,P_{out} + \text{Cu-loss} \times x^2 + \text{iron loss}}$$

$$= \frac{1.23 \times 32.5 \times 10^3}{1.23 \times 32.5 \times 10^3 + (1.23)^2 \times 1564.023 + 66.66}$$

$= 0.9425 = 94.25\,\%$

A 200 kVA single phase transformer is in circuit continuous for 8 hrs in a day the load is 160 kw at 0.8 Pf, for 6 hrs, the load is 80kw kw at unity power factor & for the remaining period of the day in runs on no load.

Given that the full load copper loss = 3.02 kw and iron loss = 1.6 find the all day efficiency of the transformer. [2070]

Full load O/p = 200 kVA

Full load Cu-loss = 3.02 kw

full load iron loss = 1.6 kw

O/p energy = 160×8 + 80×6 + 0×10

= 1760 kWh

iron loss = 1.6 kw×24

= 38.4 kwh

(a) Cu-loss 160kw 0.8 pf in 8 hrs

here

$p.f = \frac{kW}{kVA}$ $0.8 = \frac{160}{kVA}$

required kVA for load = $\frac{160}{0.8}$ = 200 kVA

$W_{cu} = \left(\frac{200}{200}\right)^2 \times W_{cu}$ $= x^2 W_c$

= 3.02 kW

in 8 hrs

$W_{cu}$ = 3.20×8 = 24.16 kwh

Cu-loss for load at 80kW at 1 p.f in 6hr

required kVA for load $= \frac{kW}{p.f} = \frac{80}{1} = 80$ kVA

$$W_c = \left(\frac{80}{200}\right)^2 \times W_{cu}$$

$$= \frac{4}{25} \times 3.02 = 0.4832 \text{ kW}$$

$W_{cu}$ in 6 hrs $= 0.4832 \times 6 = 2.899$ kWh

I/p energy = O/p energy + iron loss + copper loss (8) + copper loss (6) hrs

$= 1760 + 38.4 + 24.16 + 2.899$ kWh

$= 1825.4593$ kWh

$\therefore \eta_{all\ day} = \frac{P_{out}}{P_{in}} \times 100\%$

$$= \frac{1760}{1825.4593} \times 100\%$$

$$= 96.41\%$$

# A 25 KVA, 6000 V / 250 V single phase transformer has the following parameters $R_1 = 8\Omega$, $X_1 = 15\Omega$, $R_2 = 0.02\Omega$, $X_2 = 0.05\Omega$ calculate the full voltage regulation at power factor.

(a) 0.8 lag (b) unity (c) 0.8 lead

Soln ÷

$S = 25\ KVA$ $\qquad V_1 = 6600\ V$

$= 25 \times 10^3\ VA$ $\qquad V_2 = 250\ V$

$R_1 = 8\Omega$ $\qquad R_2 = 0.02\Omega$ $\qquad I_1 = \dfrac{S}{V_1} = \dfrac{25 \times 10^3}{6600}$

$X_1 = 15\Omega$ $\qquad X_2 = 0.05\Omega$

$= 3.78\ A$

$I_2 = \dfrac{S}{V_2}$

$= \dfrac{25000}{250} = 100\ A$

$k = \dfrac{V_2}{V_1} = 0.0378$

Now,

S-P

$$\left( R_2' = \frac{R_2}{k^2} \right)$$

$R_{01} = R_1 + R_2'$

$= 8 + \dfrac{R_2}{k^2}$

$= 8 + \dfrac{0.02}{(0.0378)^2}$

$= 21.997\ \Omega$

$$X_{01} = X_1 + X_2'$$
$$= 15 + \frac{0.05}{(0.0371)^2}$$
$$= 49.99\,\Omega$$

$\cos\phi_1 = 0.8$

$\phi_1 = 36.86^\circ$

$\sin\phi_1 = \frac{3}{5}$

(a) At 0.8 lag

$$V_{reg} = \frac{I_1 R_{01}\cos\phi_1 + I_1 X_{01}\sin\phi_1}{V_1} \times 100\%$$

$$= I_1\left(\frac{R_{01}\cos\phi_1 + X_{01}\sin\phi_1}{V_1}\right) \times 100\%$$

$$= 3.78\left(\frac{21.997 \times 0.8 + 49.99 \times \frac{3}{5}}{6600}\right) \times 100\%$$

$$= 2.72\%$$

(b) At unity p.f

$$V_{reg} = \frac{I_1 R_{01}}{V_1} \times 100\% = \frac{3.78 \times 21.997}{6600}$$

$$= 1.25\%$$

(c) at 0.8 pf lag

$$V_{reg} = I_1\left(\frac{R_{01}\cos\phi_1 - X_{01}\sin\phi_1}{V_1}\right) \times 100\%$$

$$VR_{fs} = 3.78 \left( \frac{21.997 \times 0.8 - 49.99 \times \frac{3}{5}}{6600} \right) \times 100\%$$

$$= -0.71\%$$

---

\# 24 The efficiency of a 1000 KVA, 110/220V, 50 Hz single pha transformer is 98.5% at half [illegible] load at 0.8 p.f. leading & 98.8% full load unity P.F. Determine

(i) iron loss

(ii) full load copper loss

(iii) Maximum efficiency at unity P.F.

Soln:

$V_1 = 110\,V \qquad V_2 = 220\,V \qquad f = 50\,Hz$

$$\eta = \frac{x\,P_{out}}{x\,P_{out} + x^2 W_c + W_i}$$

(i) For half load ($x = 0.5$) p.f $= 0.8$ leading $\cos\phi$ $\quad \eta = 98.5\%$

$$\frac{98.5}{100} = \frac{0.5 \times V_2 I_2 \cos\phi}{0.5 \times V_2 I_2 \cos\phi + (0.5)^2 \times W_c + W_i}$$

$$0.985 = \frac{0.5 \times 1000 \times 0.5}{0.5 \times 1000 \times 0.5 + 0.5^2 W_c + W_i}$$

$$0.985 = \frac{250}{250 + 0.25 W_c + W_i}$$

or $246.25 + 0.24625 W_c + 0.985 W_i = 250$

$\therefore$ $0.24625 W_c + 0.985 W_i = 3.75$ — (i)

at p.f → (i) full load, $\eta = 98.8\%$

$$0.988 = \frac{1000 \times 1}{1000 \times 1 + W_c + W_i}$$

or $1000 + W_c + W_i = 1012.14$

$\therefore$ $W_c + W_i = 12.145$ — (i)

solve (i) and (ii)

$W_c = 11.117$ kW
$W_i = 1.02$ kW

( load = full load $\times \sqrt{\frac{\text{iron}}{\text{cu}} \text{ loss}}$ )

For $\eta$ max

iron = cu-loss

$1.02 = x^2 \times 11.117$

$\therefore x = \sqrt{\frac{1.02}{11.117}} = 0.30$

iron loss = cu-loss

$$\eta = \frac{x \cdot P_{out}}{x \cdot P_{out} + 2 \times W_i} = \frac{0.3 \times 1000 \times 1}{0.3 \times 1000 \times 1 + 2 \times 1.02}$$

$= 99\%$

{

40 hagareko $\eta = \frac{P_{out}}{P_{out} + 2 \times W_i}$

garne hoina

same nai

aaucha #

---

# A 600 KVA, 1 Ø transformer has $\eta$ at 92% both at full load and half load at unity p.f. Determine $\eta$ at 60% at full load at 0.8 p.f lag.

soln ÷

$$\eta = \frac{x \times kVA \times \cos\phi}{x \times kVA \times \cos\phi + W_i + x^2 W_c} \times 100\ \%$$

At F.L unit p.f

$$\eta = \frac{1 \times 600 \times 1}{1 \times 600 \times 1 + W_i + W_c} \times 100$$

$\therefore$ $W_i + W_{cu} = 52.174\ kW$ —— (i)

At half load p.f

$$\eta = \frac{0.5 \times 600 \times 1}{0.5 \times 600 \times 1 + W_i + (0.5)^2 \times W_{cu}} \times 100$$

or, $W_i + 0.25 W_{cu} = 26.087\ kW$

So, $W_i = 17.39\ kW$ , $W_c = 34.78\ kW$

also 60% FL , 0.8 pf $x = 0.6$

$$\eta = \frac{0.6 \times 600 \times 0.8}{0.6 \times 600 \times 0.8 + 17.39 + 0.6^2 \times 34.78} \times 100\ \%$$

$= 90.59\%$

3Ø numericals
given voltage is line voltage

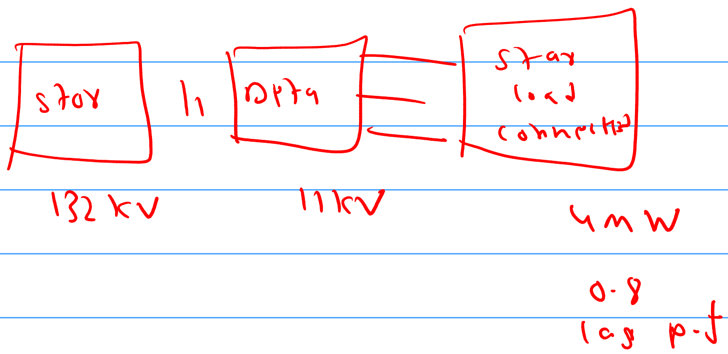
\# A 132 kV / 11 kV star / delta, 3Ø transformer has balanced star connected 3-phase load of 4 MW at p.f of 0.8 lag per phase. The primary winding has resistance and leakage reactance of 10Ω and 30Ω respectively. The secondary winding has resistance and leakage reactance of 0.02Ω and 0.06Ω respectively. Given that iron loss of the transformer is 20 kW

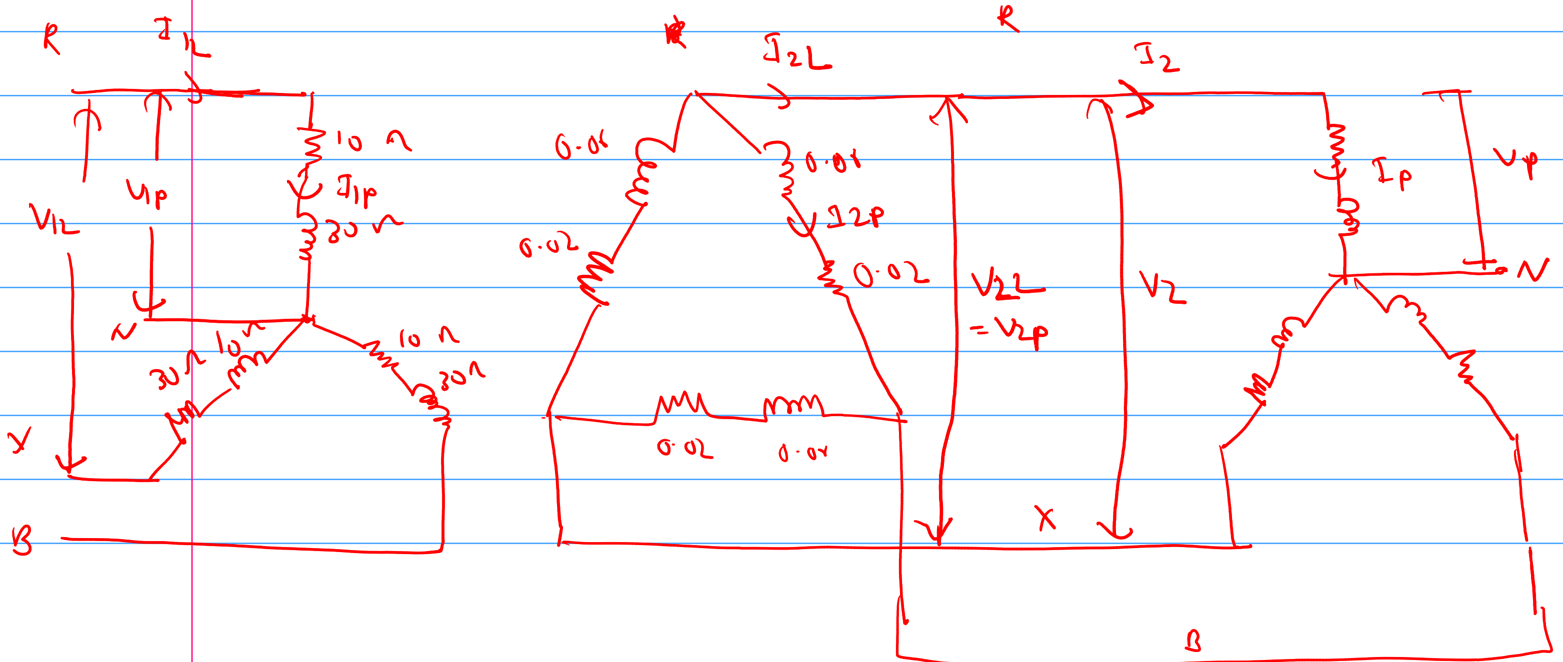
Calculate ÷

① Secondary phase and line current ($I_{2p}$, $I_{2L}$)

② primary line current ($I_{1L}$)

(iii) efficiency of the transformer. ($\eta$)



Now

star

$V_{1L} = 132\,kV$

$V_{1p} = \frac{V_{1L}}{\sqrt{3}}$

$= \frac{132}{\sqrt{3}}$

$= 44\sqrt{3}\,kV$

delta

$V_{2L} = 11\,kV$

$V_{2p} = V_{2L} = 11\,kV$

$I_{2p} = \frac{I_{2L}}{\sqrt{3}}$

load

p.f = 0.8 lag

$P = 4\,MW$

$V_L = V_{2L} = 11\,kV$

$P_L = \sqrt{3}\, V_L I_L \cos\phi$

(3 $\phi$ power)

$P_L = \sqrt{3}\, V_L I_L \cos\phi$

$4 \times 10^6\,W = \sqrt{3} \times 11 \times 10^3 \times I_L \times 0.8$

$\therefore \quad I_L = 262.431\,A$

$\therefore \quad I_L = I_{2L}$

$\therefore \quad \boxed{I_{2L} = 262.431\,A}$

$$\boxed{I_{2p} = \frac{I_{2L}}{\sqrt{3}} = \frac{262.431}{\sqrt{3}} = 151.51\,A}$$

Now,

we know

$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$

or $\dfrac{V_{2p}}{V_{1p}} = \dfrac{I_{1p}}{I_{2p}}$

or $\dfrac{11}{44\sqrt{3}} = \dfrac{I_{1p}}{151.51}$

$\therefore$ $I_{1p} = 21.8685$ A

$\therefore$ $I_{1p} = I_L$

$\therefore$ $\boxed{I_{1L} = 21.8685 \text{ A}}$

$\eta = \dfrac{P_{out}}{P_{out} + \text{iron} + \text{cu-loss}}$

iron-loss $= 20$ kW (const)

Cu-loss $= I^2 R$

for 3-phase

cu-loss $= 3 \times (I_{1p})^2 \times R_1 + 3 \times (I_{2p})^2 \times R_2$

$= 3 \times (21.8685)^2 \times 10 + 3 \times (151.51)^2 \times 0.02$

$= 15724.2557$ W

$= 15.72$ kW

$P_{out} = 4$ mW $= 4 \times 10^6$ W $= 4 \times 10^3$ kW

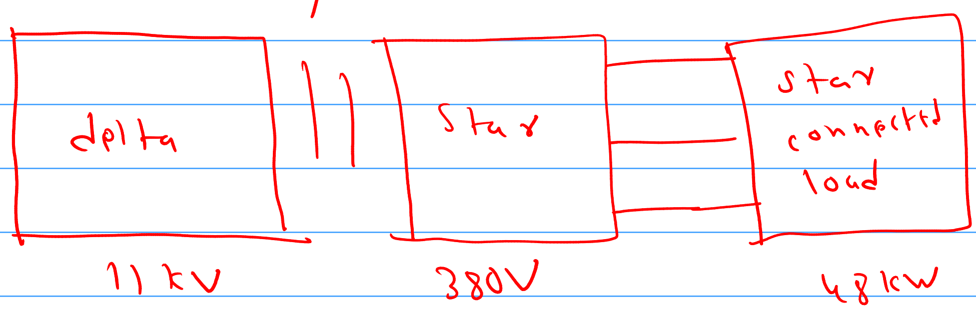
$$\boxed{\eta = \frac{4\times10^3}{4\times10^3 + 20 + 15.72428} = 0.99114 = 99.114\ \%}$$

$V_{L1}$ $\quad$ $V_{L2} \rightarrow$ line voltage

# An 11kV / 380V delta / star 3$\phi$ transformer has balanced star connected 3$\phi$ load of 40kW at p.f at 0.8 lagging per phase. Calculate the primary line current, if the transformer has iron loss of 1.0 kW, calculate the approximate efficiency of the transformer. Given that primary winding resistance and leakage reactance are 25$\Omega$ per phase and 40$\Omega$ per phase respectively. Secondary winding resistance and leakage reactance are 0.01$\Omega$ per phase and 0.02$\Omega$ per phase respectively.

soln ÷

3$\phi$




0.8 lagging per phase

$$\eta = \frac{P_{out}}{P_{out} + iron + Cu\text{-}loss}$$

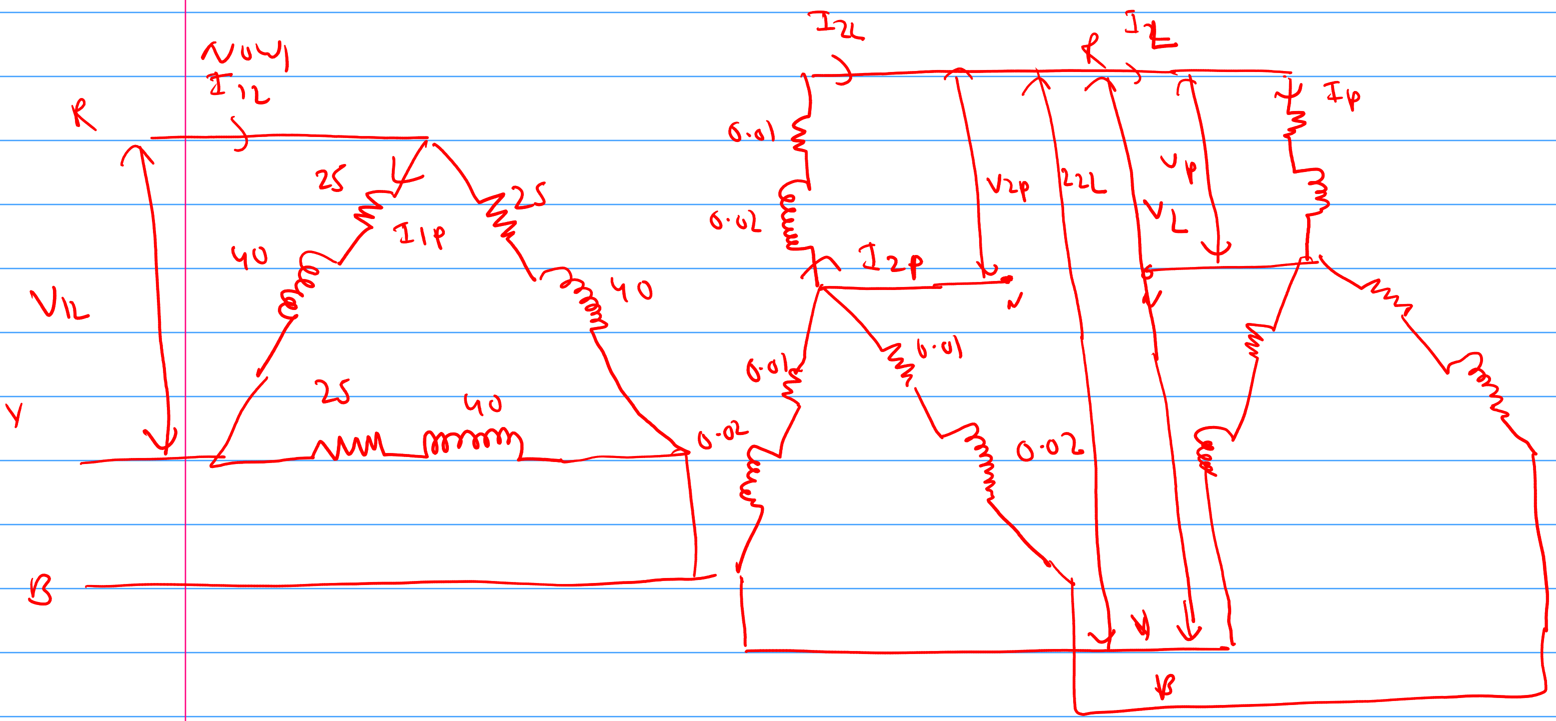
$I_{L1} = ?$

iron loss = 1 kW

$$\text{cu-loss} = 3(I_{1p})^2 R_1 + 3(I_{2p})^2 \times R_2$$

$$P_{out} = \sqrt{3} V_2 I_2 \cos\phi$$

Now,




Now,

$$V_{1p} = V_{1L} = 11\text{ kV}$$

$$I_{1p} = \frac{I_{1L}}{\sqrt{3}}$$

$$V_{2p} = \frac{V_{2L}}{\sqrt{3}}$$

$$V_{2L} = 380\text{ V} = V_L$$

$$V_{2p} = \frac{V_{2L}}{\sqrt{3}} = \frac{380}{\sqrt{3}} = 219.39\text{V} = V_p$$

$$I_{2L} = I_L = I_{2p}$$

Now,

load 40kW 0.8 lag per phase

$P_2 = 40\,kW$

or $P_2 = \sqrt{3} V_2 I_2 \cos\phi$

or $40 \times 10^3 = \sqrt{3} \times 380 \times 0.8 \times I_2$

$\therefore I_2 = 75.96\,A$

$$\boxed{I_2 = I_{2L} = I_{2p} = 75.96\,A}$$

Now,

$$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

$$\frac{V_{2L}}{V_{12}} = \frac{I_{1L}}{I_{2L}}$$

or, $$\frac{380}{11} = \frac{I_{1L}}{75.96}$$

$$\therefore \boxed{I_{1L} = 2.624\,A}$$

$$\eta = \frac{P_{out}}{P_{out} + \text{Iron loss} + \text{Cu-loss}}$$

$\text{Iron-loss} = 10^3\,W$

$\text{Cu-loss} = 3 \times (I_{1p})^2 \times R_1 + 3 \times (I_{2p})^2 \times R_2$

$$\text{cu-loss} = 3 \cdot \left(\frac{2.624}{\sqrt{3}}\right)^2 \times 25 + 3(75.96)^2 \times 0.01$$

$$= 345.2941 \text{ W}$$

$$\eta = \frac{40 \times 10^3}{40 \times 10^3 + 1000 + 345.2941}$$

$$= 0.96746$$

$$= 96.746\%$$

note → if primary and secondary ma all resistance not same

$$\text{cu-loss} = (I_{1p})^2 (R_{11} + R_{12} + R_{13}) + (I_{2p})^2 (R_{21} + R_{22} + R_{23})$$

mathi ko ma all resistance in 3ϕ star and delta same so

$$3 \times (I_{1p})^2 \times R_1 + 3 \times (I_{2p})^2 \times R_2$$

---

\# A 120 kVA, 6000/400 V Y/Y 3ϕ 50 Hz transformer has an iron loss of 1600 W. The maximum efficiency occurs at $\frac{3}{4}$ full load. Find the efficiency of the transformer at

(i) full-load and 0.8 pf

(ii) half-load and unity p.f

soln ÷

For max efficiency

Cu-loss = iron-loss

max $\eta$ occurs at $\frac{3}{4}$ full load

Full load, Cu-los = $3(I_{1p})^2 R_1 + 3(I_{2p})^2 R_2$

Cu-loss at x-load = $x^2$ × Cu-loss at full load

For $\eta$ to be max

Iron loss = $x^2$ × Cu-loss

$x \to \frac{3}{4}$

Iron loss = $\left(\frac{3}{4}\right)^2$ × Cu-loss

or, 1600 = $\left(\frac{3}{4}\right)^2$ × Cu-loss

∴ Cu-loss = 2844.44 W

Iron loss = 1600 W

(i) at full load $(x=1)$ $p.f = 0.8$

$$\eta = \frac{x \times P_{out}}{x \times P_{out} + x^2 \times Cu\text{-}loss + Iron\ loss}$$

$Cu\text{-}loss = 2844.44\ kW$

$Iron\text{-}loss = 1600\ W$

$$P_{out} = \underbrace{\sqrt{3} V_L I_L}_{kVA} \cos\phi \quad (3\text{-phase})$$

$$= 120\ kVA \times 0.8 \rightarrow p.f$$

$$= 96\ kW$$

$$\eta = \frac{1 \times 96 \times 10^3}{1 \times 96 \times 10^3 + 1^2 \times 2844.44 + 1000}$$

$$= 0.9557 = 95.57\ \%$$

(ii) half load $(x=0.5)$ and $p.f = 1$

$$P_{out} = \sqrt{3} V_L I_L \cos\phi$$

$$= 120\ kW$$

$$\eta = \frac{0.5 \times 120}{0.5 \times 120 \times 10^3 + 0.5^2 \times 2844.44 + 1600}$$

$$= 0.9629$$

$$= 96.29\ \%$$