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Assi 2

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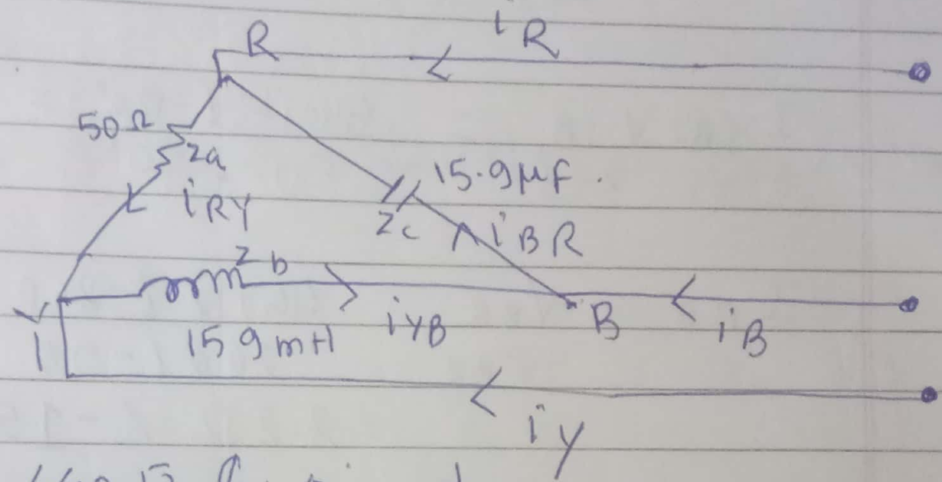
1. A 440V, 50 Hz three phase supply has delta-connected load having 50 Ω between RED(R) and YELLOW(Y), & 159 mH between YELLOW (Y) and BLUE (B), and 15.9 μF between B & R. Assuming RYB sequence, calculate the line current. & Also calculate the total power ~~calculation~~ consumed in the load.

=)



$V_{RY} = 440\sqrt{2} \angle 0°$ volts

$V_{YB} = 440\sqrt{2} \angle -120°$ volts

$V_{BR} = 440\sqrt{2} \angle -240$.

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times 15.9 \times 10^{-6}}$$

$$= \frac{1}{100\pi \times 159 \times 10^{-7}}$$

$$= \frac{1}{159\pi} \times 10^{5}$$

$$= \frac{1}{16 \times \pi} \times 10^{4} \approx 200$$

125
~~250~~
$\frac{\cancel{10}^5}{\cancel{16} \times 3.14}$ ×~~1000~~
8
$= 125 \times 1.5$
$= 132.5$

6.3×8 2
50.4

$X_L = 2\pi f L = 2 \times 3.14 \times 50 \times 159 \times 10^{-3}$

$= 6.28 \times 5 \times 160 \times 10^{-2}$

$= 6.28 \times 5 \times 1.6$

$6.28 \times 8.0 = \boxed{50.3}$

Step1

$\therefore Z_{BY} = j50 \angle 90^\circ \,\Omega = 50j \quad 2\pi f L$

$Z_{RY} = 50 + j0 \ \Omega$.

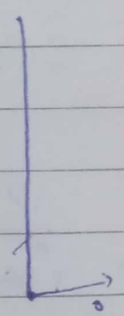
$Z_{RB} = -j200 = 200 \angle -90^\circ \to \frac{-j}{2\pi f C}$

Step2

$I_{RY} = \frac{V_{RY}}{Z_{RY}} = \frac{440\sqrt{2}}{50} = 8.8\sqrt{2} \angle 0 \ A$

$I_{YB} = \frac{V_{YB}}{Z_{YB}} = \frac{440\sqrt{2} \angle -120^\circ}{50 \angle 90^\circ} = 8.8\sqrt{2} \angle -210^\circ \ A$

$I_{BR} = \frac{V_{BR}}{Z_{BR}} = \frac{440\sqrt{2} \angle -240}{200 \angle -90}$
$= 2.2\sqrt{2} \angle -150 \ A$



$i_R + i_{BR} = I_{RY}$

$\Rightarrow i_R + 2.2\sqrt{2} \angle -150 = 8.8\sqrt{2} \angle 0$

$\Rightarrow \boxed{i_R = 8.8\sqrt{2} - 2.2\sqrt{2} \angle -150}$

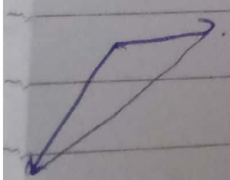
Also,

$i_{YB} + I_B = I_{BR}$

$\Rightarrow 8.8\sqrt{2} \angle -210 + I_B = 2.2\sqrt{2} \angle -150$

$\Rightarrow \boxed{I_B = 2.2\sqrt{2} \angle -150 + 8.8\sqrt{2} \angle -210}$

Also,



$I_Y + I_{RY} = I_{YB}$

$\boxed{I_Y = 8.8\sqrt{2} \angle -210 - 8.8\sqrt{2}}$

$i_R = 8.8\sqrt{2} - 2.2\sqrt{2}\left[\cos(-150) + j\sin(-150)\right]$

$= 8.8\sqrt{2} - 2.2\sqrt{2}\left[-\sin 60^\circ - j\cos 60\right]$

$= 8.8\sqrt{2} + 2.2\sqrt{2}\left[\frac{\sqrt{3}+j}{2}\right]$

$= 8.8\sqrt{2} + 1.1\sqrt{2}(\sqrt{3}+j)$

$= 8.8\sqrt{2} + 1.1\sqrt{6} + 1.1\sqrt{2}j$

$=$

$i_B = 2.2\sqrt{2}\left[\cos 150 - j\sin 150\right] + 8.8\sqrt{2}\left[\cos 210 - j\sin 210\right]$

$\frac{88\times88}{4}$ 704 704 7744

$$P_{RY} = I_{RY}^2 \times 50 \quad (\text{RMS})$$

$$= \left(\frac{8.8\sqrt{2}}{\sqrt{2}}\right)^2 \times 50$$

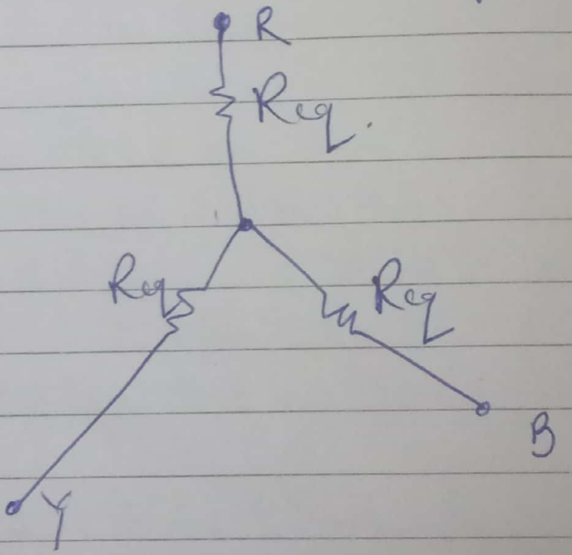
$$= (8.8)^2 \times 50.$$

$$= 77.44 \times 50 = 3872.00 = 3872 \text{ watt}$$

P_{BR} & $P_{BY} = 0.$

$\therefore$ Total Power $= (8.8)^2 \times 50$ watt.

2. For the case considered in prob 1, calculate the values of the equivalent star-connected balanced resistors for the same amount of consumed power.



$$\cdot\ I = \frac{440\sqrt{2}}{3R_{eq}}$$

$$P_T = 3 \times \left(\frac{440}{\sqrt{3}R_{eq}}\right)^2 \times R_{eq}$$

$$= \frac{(440)^2}{3R_{eq}} = \frac{440\times440}{3\times50\times50} = \frac{8.8\times8.8}{3}$$

$$= \frac{77.44}{3}$$

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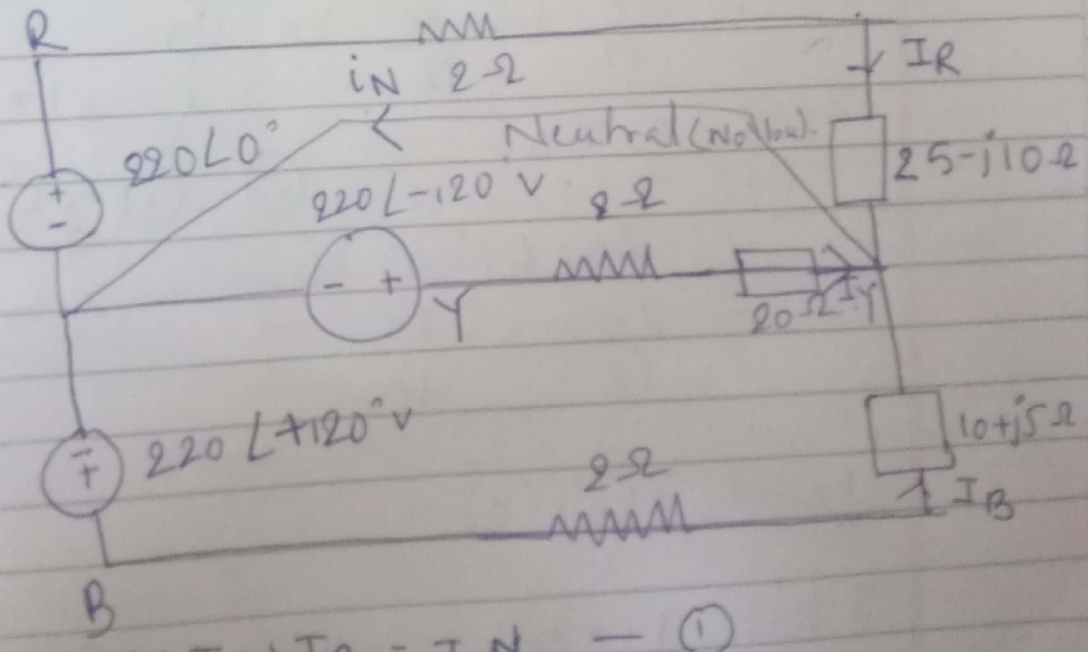
$$P_T = \left(\frac{440}{\sqrt{3}R_{eq}}\right)^2 \times R_{eq} = \frac{3872}{3}$$

$$\Rightarrow \frac{440 \times 440}{3R_{eq}} R_{eq} = \frac{3872}{3}$$

$$\Rightarrow R_{eq} = \frac{\cancel{440}^{10} \times \cancel{440}\ \cancel{110}\ \cancel{10}\ 5}{\cancel{3872}\ \cancel{968}\ \cancel{88}\ \cancel{44}\ 2}$$

$$\Rightarrow \boxed{R_{eq} = 50\ \Omega}$$

3. For the unbalanced three phase system shown below, Calculate the numerical value of the current in neutral line.



$$I_Y + I_R + I_B = I_N \quad \text{— (1)}$$

(1) $\frac{220\angle 0}{2+25-j10\Omega} = i_R$

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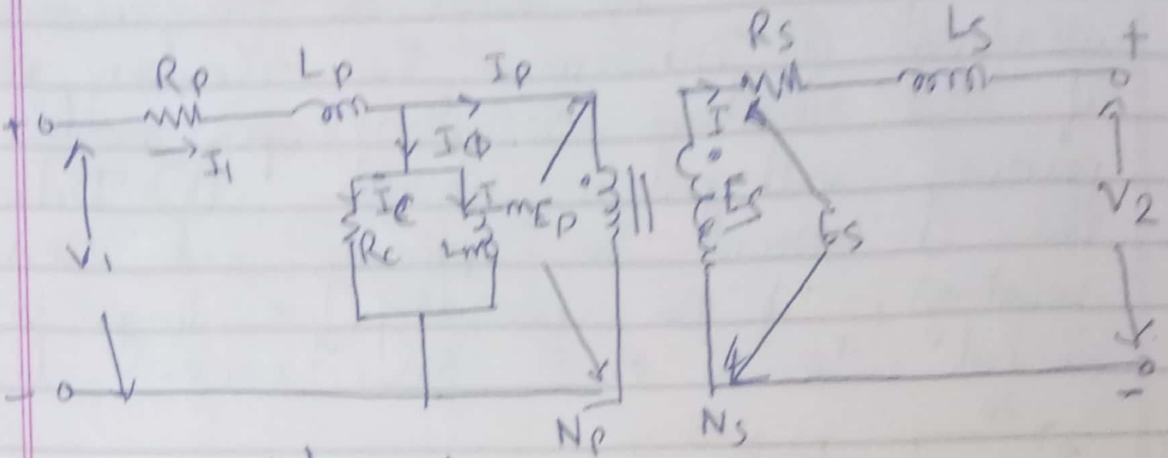
An approximate equivalent circuit of a Transformer



V_1 = Input voltage

V_2 = Output voltage

I_1 = Input current

$I_2 = I_s$ = Output current

N_p = No. of turns on Primary

N_s = No of ~~on~~ turns on Secondary.

E_p = EMF induced in primary.

E_s = EMF induced in secondary

$$a = \frac{N_p}{N_s} \quad -(1)$$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} = a = \frac{I_s}{I_p} \quad -(2)$$

$$I_c + I_m = I_\Phi \quad -(3)$$

where, $I_\Phi \rightarrow$ excitation current

$I_c \rightarrow$ Core loss current

$I_m \rightarrow$ ~~core magnetic current~~. Core magnetisation current.

Dot convention → If both dots are on to P_1 it means E_p and E_s are in same phase & I_p and I_s in same direction.

EMF equations → Assumes that the magnetic flux generated in core is given by

$$\Phi(t) = \Phi_m \cos(\omega t) \quad —(1)$$

Using faraday's Law

Peak value → $E_p(t) = -N_p \frac{d\Phi}{dt} \quad —(2)$

$$= N_p \Phi_m (2\pi f) \sin \omega t \quad —(3)$$

$$E_p(RMS) = \frac{N_p \Phi_m (2\pi f)}{\sqrt{2}} \text{ volts}$$

$$\simeq 4.443\, N_p \Phi_m f \text{ volts} \quad —(4)$$

we write,

$$\Phi_m = B_m A \quad —(5)$$

where B_m = Magnetic flux Density in core, (Max. value) in Wb/m^2

and A = Area of Cross section of Core.

$$\therefore \boxed{E_p \simeq 4.443\, f N_p B_m A} \quad —(6)$$

In a similar manner, it can be shown that $\boxed{E_s \simeq 4.443\, f N_s B_m A} \quad —(7)$

◦ B_m is measured in (Webers)/m^2. Thus it is also known as Tesla (T)

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$$\frac{E_P}{E_S} \simeq \frac{N_P}{N_S} = a \quad -8.$$

Prob1. A step down transformer has a turns ratio of 4 to 1. If the transformer secondary voltage is 120 V, calculate the primary voltage. If a 100 Ω load is connected to secondary, how much current would flow in (a) Primary (b) Secondary.

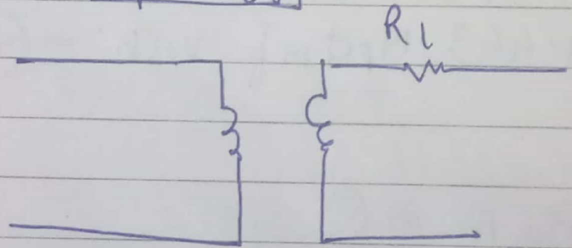
$$a = \frac{4}{1} = 4.$$

$$V_s = 120.$$

$$\frac{E_P}{E_S} = a$$

$$\Rightarrow E_P = 4 \times 120$$

$$\Rightarrow \boxed{E_P = 480V}$$



$$i_s = \frac{E_S}{R_L} = \frac{120}{100} = 1.2\,A.$$

$$i_p = \frac{i_s}{a} = \frac{1.2}{4} = 0.3\,A.$$

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Q. A single phase, transformer with 2 KVA has a 400 V primary and a 120V secondary. Determine the primary and secondary full-load currents.

$E_p = 400\,V$

$E_s = 120\,V$

Rep = 2 KVA.

$a = \frac{E_p}{E_s} = \frac{400}{120}$

$\Rightarrow \boxed{a = \frac{10}{3}}$

$S_{max} = 2 \times 10^3$ VA.

If nothing is given, we will assume purely resistive circuit.

$\therefore S = 2000$ VA $= 0$

(i) $E_p i_p = 2000$

$\Rightarrow i_p = \frac{2000}{400} = 5$

$\Rightarrow \boxed{i_p = 5}$

$i_s = \frac{2000}{120} = \frac{50}{3}$ A

$\boxed{i_s = \frac{50}{3}\,A}$

$120 \times i_c = 2000$

$i_c = \frac{200}{12} = \frac{50}{3}$

Prob 3. A single phase transformer has 480 turns on primary and 90 turns on secondary. The maximum value of the magnetic flux density in the core is 1.1 T. when 2200 volts, 50 Hz is applied to primary. Calculate the cross-section area of the core.

Sol^n

$$E_p = 4.443 f N_p B_m A$$

$$\Rightarrow 2200 = 4.443 \times 50 \times 480 \, B_m A$$

$$\Rightarrow A = \frac{2200}{4.443 \times 50 \times 480 \times 1.1}$$

$$= \frac{22}{4.443 \times 240 \times 1.1}$$

$$= \frac{2}{4.443 \times 24\,12}$$

$$= \frac{1}{53.28}$$

$$\boxed{A = 0.0187 \, m^2 = 187 \, cm^2}$$

$$\phi_m = B_m A$$

$$= 1.1 \times 0.0187 \text{ weber}$$

$$= .02057$$

$$= 2.057 \text{ mweber}$$

$$E_S = E_P \times a^2$$

$$E_S = \frac{\cancel{2200}^{\cancel{550}\ 275} \times \cancel{90}^{3}}{\cancel{480}_{\cancel{12}\ \cancel{6}\ 2}}$$

$$= \frac{825}{2}$$

$$= 412.5$$

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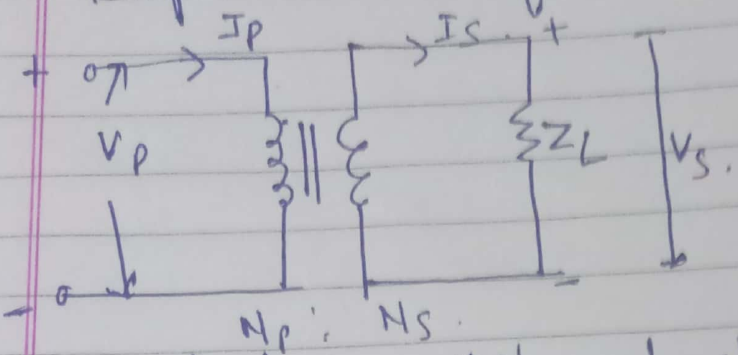
Impedence Transformation in a transformer



Ideal lossless Voltage transformer.

Turns ratio, $a = \frac{N_p}{N_s}$ —(1)

Also, $\frac{V_p}{V_s} = a = \frac{I_s}{I_p}$

Additionaly, $V_s = I_s Z_L$ —(3)

Input impedence

$Z_{in} \triangleq \frac{V_p}{I_p}$ —(4)

$= \frac{a V_s}{I_s/a}$

$= a^2 \frac{V_s}{I_s}$

$= a^2 Z_L$ —(5)

Probl. An ideal transformer has a 150-turn primary and a 750 turns secondary. The primary is connected to a 240 V, 50 Hz source. The secondary winding supplies a load of 4 Amperes at a lagging ~~power winding supplies a load of 4 Amperes~~ factor of 0.8.

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$\theta_1 = 0.8$.

Determine → $\cos\phi = .8$

(a) Turns ratio
(b) Current in primary
(c) The AWG size of wire to be used in primary
(d) The current in secondary
(e) The AWG size of wire to be used in secondary
(f) The consumed power in the load.
(g) The relative power in the load.
(h) The flux in the core.

$\cos\phi = .8$.

lagging power factor $= \sin\phi$
$= -0.6$.

↳ $a = \frac{N_P}{N_S} = \frac{150}{75} = 0.2$

↳ $I_S = 4$

$I_P = \frac{I_S}{a} = \frac{40}{.2} = 20\ A$.

↳ ~~$P = V_{RMS} I_{RMS}$~~

AWG size, 8 (for primary.

↳ $I_s = 4A$.

↳ AWG size, for secondary 15

↳ $P = V_s I_s \cos\phi$.

~~$= 240 \times 4 \times 0.8$~~

~~$= 192 \times 4$~~

~~$= 768$ watt~~

$= 1200 \times 4 \times 0.8\ W$.

3

3↳ $Q = -V_s I_s \sin\phi$ VAR

3

~~$= -240 \times 4 \times 0.6$ VAR~~

~~$= 144 \times 4$~~

2

~~$= 576$ VAR.~~

↳ $S = V_s I_S = \cancel{240 \times 4} = 960\ VA$.

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L) $E_s \simeq 4.443\, f N_s \Phi_{max}$.

$\Rightarrow 1200 \simeq 4.443 \times 50 \times 750\, \Phi_{max}$

$\Rightarrow \Phi_{max} = \dfrac{1200}{4.443 \times 50 \times 750}$ weber

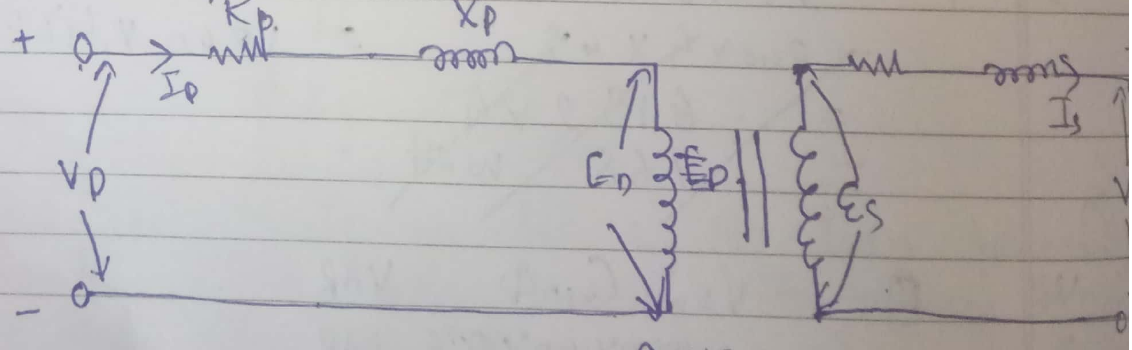
$= \dfrac{12}{4.443 \times 375}$ Weber.

Q2 A 23 kVA, 2300/230-V, 60 Hz, step-down transformer has the following resistance and leakage reactance parameters.

$R_p = 4\,\Omega,\ R_s = 0.04\,\Omega,\ X_p = 12\,\Omega,$
$X_s = 0.12\,\Omega$

The transformer is operating at 75% of its rated load. If the power factor of the load is 0.866 leading, determine the efficiency of the transformer.

Soln



$a = 10$

I_p(full load) $= 10\,A$.
I_s (full load) $= a \times I_p = 100\,A$.

Power factor $= \cos\Phi = 0.866$
$\Phi = \cos^{-1}(0.866) = 30°$

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At 75% load →

$I_s = 75\sqrt{2}\ \angle +30^\circ$ → In phasor form

$I_p = 7.5\sqrt{2}\ \angle +30^\circ$ Amp

- $V_s = 230$
  $I_s = 75\sqrt{2}$
  $\cos\phi = 0.866$

$P_{consumed}$ (Load) $= V_s I_s \cos\phi$
$= 230 \times 75\sqrt{2} \times 0.866$
$= 14938.94$ watt

- $E_s = V_s + I_s (R_s + jX_s)$
  $E_p = a E_s$
  $V_p - I_p (R_p + jX_p) = E_p \simeq 2269.58 \angle 4.7^\circ$ volts (RMS)

$I_p = \frac{I_s}{a} = 7.5 \angle +30^\circ$ Amp.

Input power $= V_p I_p \cos\phi_p$

$= 15389.41$ watt.

Efficiency $= \frac{\text{Output Power}}{\text{Input power}}$

$= \frac{14938.94}{15389.41} \times 100$

$= 97\%$

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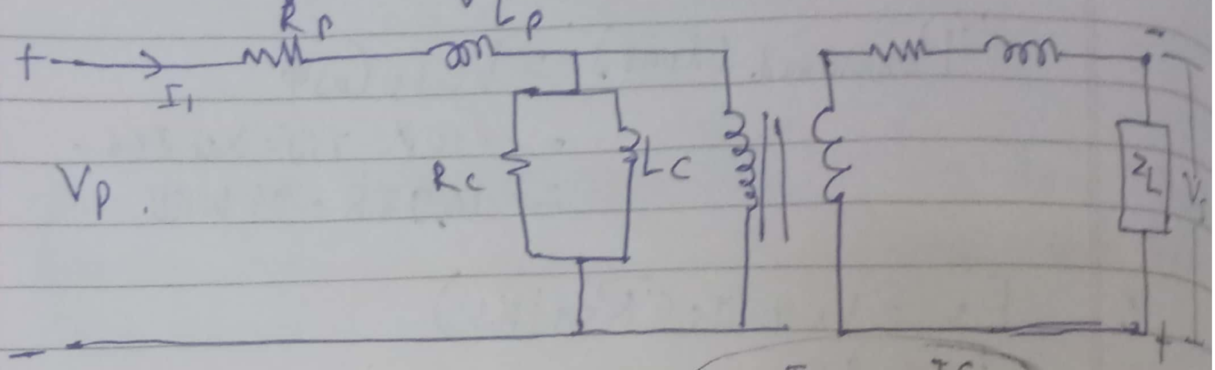
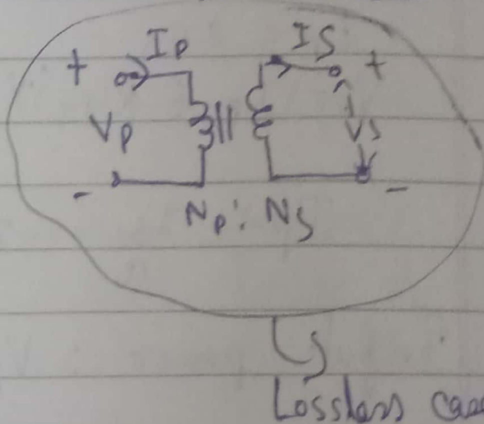
Q. A doorbell requires 0.4 A current at 6V. It is connected to a transformer whose primary contains 2000 turns and is connected to a 110 V household outlet. How many turns should be in the secondary? What is current in primary? How many watts does the bell require from the transformer?





$R_p = 0$ $R_s = 0$
$L_p = 0$ $L_s = 0$
$R_c \to \infty$
$L_c \to \infty$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$\Rightarrow \frac{110}{6} = \frac{2000}{N_s}$$

$$\Rightarrow N_s = \frac{6 \times 200}{11} = \frac{1200}{11}$$

Lossless Assumption

$N_s = 109$

$I_p = 0.022$ A

$P = 2.4$ W

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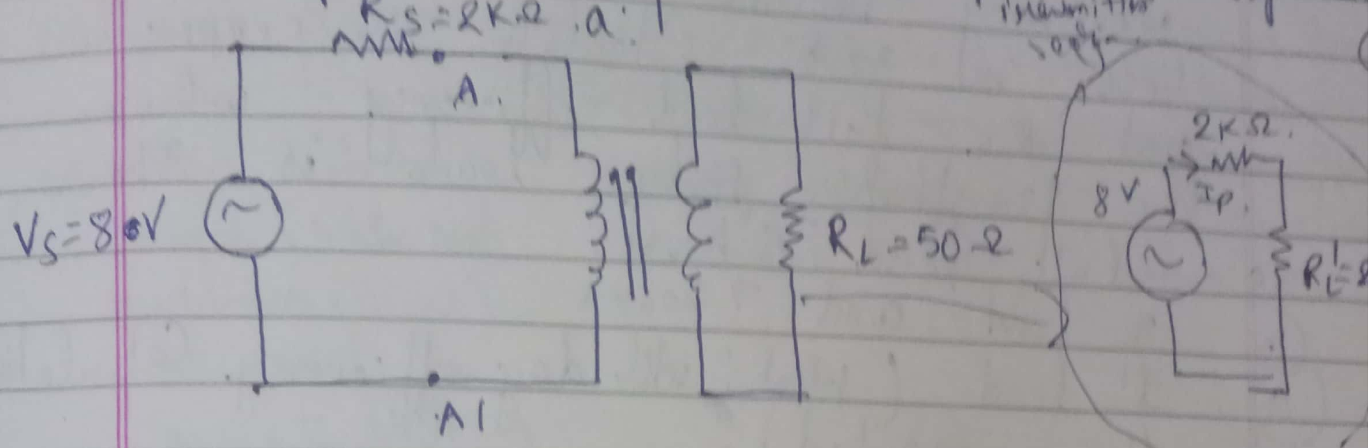
Prob2 A source which can be represented by a voltage source of 8V RMS. in series with an internal resistance of 200 Ω is connected to a 50 Ω load resistor through an ideal transformer. Calculate value of turns ratio for which max. power is supplied to the load, and the corresponding load power.



① $Z_{AA'} = a^2 R_L = R_S$ for max. power transfer.

$$a = \sqrt{\frac{R_S}{R_L}} = \sqrt{\frac{2000}{50}} = 2\sqrt{10} = 2 \times 3.16$$

$\Rightarrow a = 6.32$.

② $P = I_s R_L$.

$q = 0$

$$I_p = \frac{8V}{(2+2)\times 10^3} = 2\times 10^{-3}\ A.$$

$$I_s = 6.32\, I_p = 6.32 \times 2 \times 10^{-3} = 12.64 \times 10^{-3}\ Amp.$$

Power $= I_s^2 R_L$

$= 12.64 \times 50 \times 10^{-3} \times 12.64$

$= 632.00 \times 10^{-3}$.

$= 632$ watt.

2

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$$P = I_s^2 R_L$$
$$= 50 \times (12.64 \times 10^{-3})^2$$
$$= 8 \text{ mWatt}.$$

Q. A 500 KVA, 1 ph, 13.8/4.160 KV, 60 Hz transformer has a primary resistance, $R_p = 0.8\,\Omega$ and secondary resistance $R_s = 0.04\,\Omega$. The iron loss is 3 KW. Calculate the copper loss and the full-load efficiency when the transformer's daily load is 3 hours

(a) full load, 5 hours

(b) $\frac{3}{4}$ load and 7 hours

(c) $\frac{1}{4}$ load (Hint: All day efficiency calculation is expected).

$S = 500$ KVA

$R_p = 0.8$

$R_s = 0.4$.

$$a = \frac{N_p}{N_s} = \frac{13.80}{4.16} = 3.3$$

Energy output over 24 hr period = Energy over 24 hr period − Energy loss over 24 hr period

$$\text{Full load } I_p = \frac{5000\text{KVA}}{13.8\text{KV}} = \frac{5000}{138} = 36.23\text{ A}$$