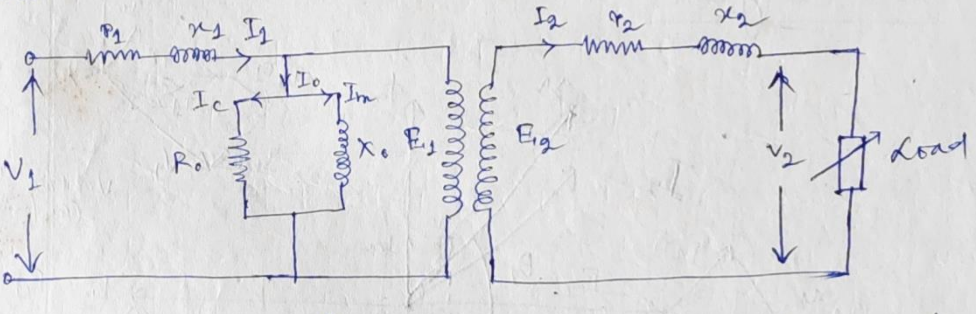
Equivalent Circuit :-

Equivalent circuit is the electrical representations of the equations that describe the behaviour of an electrical device.



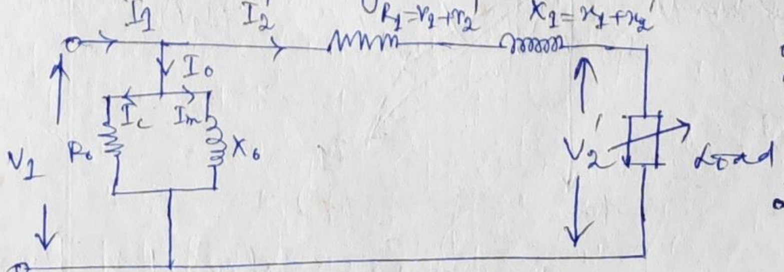
Here, r_1 and x_1 represent the primary resistance and leakage reactances.

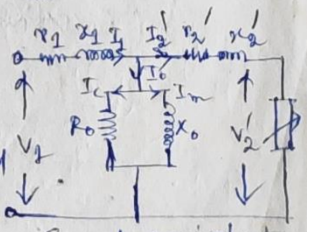
r_2 and x_2 are secondary winding impedances.

R_0 = Core loss component of resistance.

X_0 = reactance corresponding to magnetising component.

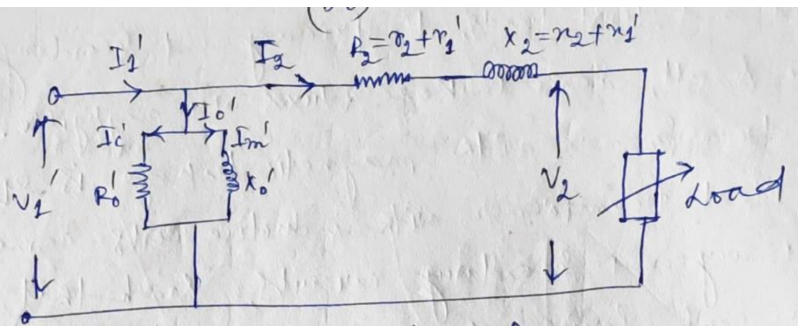
The equivalent circuit can be modified and redrawn by referring the winding impedances to either the primary side or the secondary side of the transformer.





Exact equivalent circuit referred to primary.

Approximate equivalent circuit referred to primary.



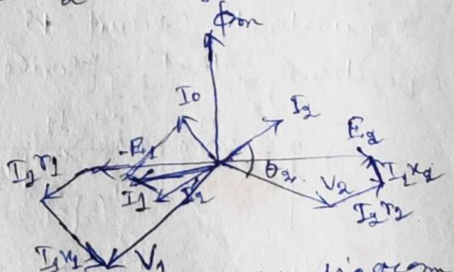
Approximate Equivalent circuit referred to Secondary

$$K = \text{Turns ratio} = \frac{N_2}{N_1} = \frac{\text{No. of Secondary turns}}{\text{No. of primary turns}}$$

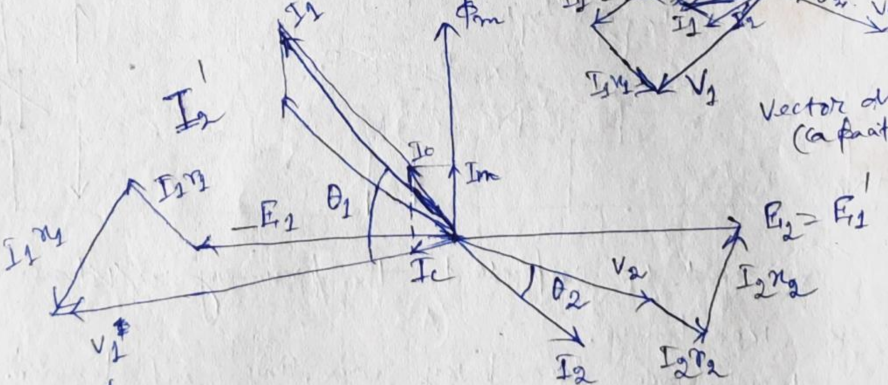
$$R_1 = r_1 + \frac{r_2}{K^2}, \quad R_2 = r_2 + K^2 r_1$$

$$X_1 = x_1 + \frac{x_2}{K^2}, \quad X_2 = x_2 + K^2 x_1.$$

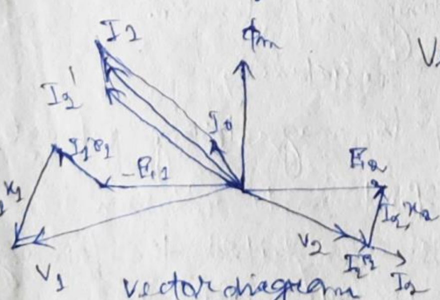
Vector diagram:



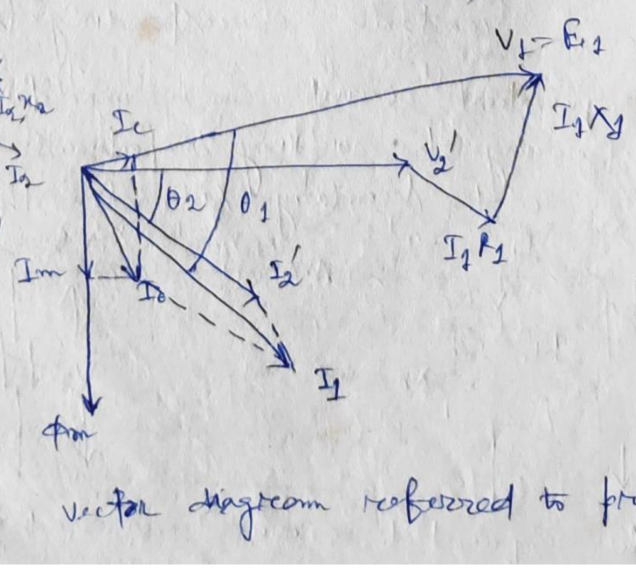
Vector diagram (capacitive load)



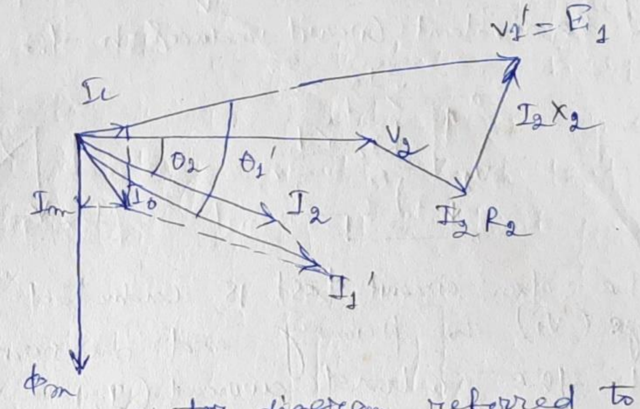
Vector diagram of a transformer (inductive load)



vector diagram (Resistive load)



vector diagram referred to primary



Vector diagram referred to Secondary

① A single phase transformer has 400 primary and 1,000 secondary turns. The net cross sectional area of the core is 60 cm², If the primary winding is to be connected to a 50 c/s supply at 500V., calculate the value of maximum flux density in the core and the e.m.f. induced in the ~~core.~~ secondary winding.

Soln.:- No. of secondary turns, $N_2 = 1000$

" " primary " , $N_1 = 400$

$V_1 = 500\,V.$

Here, $E_1 = V_1 = 4.44\, f.\, N_1\, \Phi_m$

$\therefore 500 = 4.44 \times 50 \times 400 \times \Phi_m$

$\Rightarrow \Phi_m = 0.563 \times 10^{-2}$ wb.

Cross section of the core, $A = 60\ cm^2$

$\therefore$ Maximum flux density, $B_m = \dfrac{\Phi_m}{A}$

$= \dfrac{0.563 \times 10^{-2} \times 10^{8}}{60} = 9.383$ lines/cm².

Voltage per turn $= \dfrac{500}{400} = 1.25$

$\therefore$ Secondary voltage $= 1000 \times 1.25 = 1250\ V.$

(2) A 50 KVA, 4400/220 V. transformer has $r_1 = 3.45\,\Omega$, $r_2 = 0.009\,\Omega$. The values of reactances are $x_1 = 5.2\,\Omega$ and $x_2 = 0.015\,\Omega$. Calculate for the transformer –

(i) the equivalent resistance as referred to primary.

(ii) the equivalent resistance as referred to secondary

(iii) equivalent reactance referred to both primary and secondary.

(iv) equivalent impedance both referred to primary and secondary and

(v) total copper loss.

Soln. :– Full-load primary current, $I_1 = \dfrac{50,000}{4,400}$ A.

(assuming 100% efficiency) $= 11.36$ A.

Full load secondary current, $I_2 = \dfrac{50,000}{220}$ A. $= 227$ A.

Turns ratio, $K = \dfrac{220}{4400} = \dfrac{1}{20}$.

(i) $R_1 = r_1 + \dfrac{r_2}{K^2} = 3.45 + \dfrac{0.009}{\left(\frac{1}{20}\right)^2} = 7.05\,\Omega$

(ii) $R_2 = K^2 r_1 + r_2 = \left(\dfrac{1}{20}\right)^2 \times 3.45 + 0.009 = 0.0176\,\Omega$.

Also, $R_2 = K^2 R_1 = \left(\dfrac{1}{20}\right)^2 \times 7.05 = 0.0176\,\Omega$ (check).

(iii) $X_1 = x_1 + \dfrac{x_2}{K^2} = 5.2 + \dfrac{0.015}{\left(\frac{1}{20}\right)^2} = 11.2\,\Omega$

$X_2 = K^2 x_1 + x_2 = \left(\dfrac{1}{20}\right)^2 \times 5.2 + 0.015 = 0.028\,\Omega$.

(iv) Also, $X_2 = K^2 X_1 = \left(\dfrac{1}{20}\right)^2 \times 11.2 = 0.028\,\Omega$ (check)

$Z_{01} = \sqrt{R_1^2 + X_1^2} = \sqrt{(7.05)^2 + (11.2)^2} = 13.23\,\Omega$.

$Z_{02} = \sqrt{R_2^2 + X_2^2} = \sqrt{(0.0176)^2 + (0.028)^2} = 0.0331\,\Omega$.

Also, $Z_2 = K^2 Z_1 = \left(\dfrac{1}{20}\right)^2 \times 13.23 = 0.0331\,\Omega$ (check).

(v) Copper loss $= I_1^2 r_1 + I_2^2 r_2 = (11.36)^2 \times 3.45 + (227)^2 \times 0.009$

$= 909$ W.

Also, copper loss $= I_1^2 R_1 = (11.36)^2 \times 7.05 = 910$ W.

$= I_2^2 R_2 = (227)^2 \times 0.0176 = 910$ W.