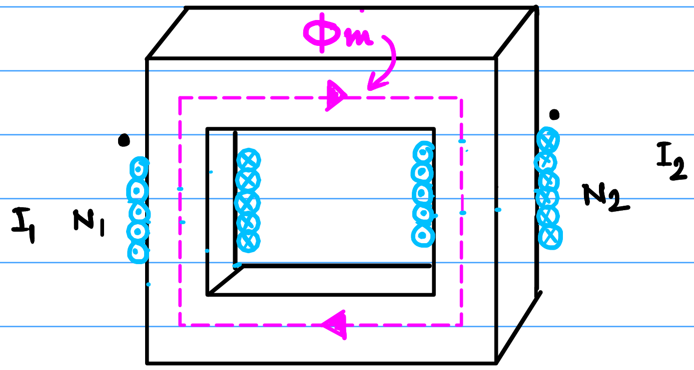



According to Amperes circuital law

$$\oint \vec{H} \cdot \vec{dl} = Ni \qquad \mathcal{R} = \text{Reluctance}$$

$$\Rightarrow N_1 i_1 - N_2 i_2 = H \cdot l$$

$$\Rightarrow N_1 i_1 - N_2 i_2 = \phi \mathcal{R}$$

$$\Rightarrow N_1 i_1 - N_2 i_2 = \phi \frac{l}{A \mu_0 \mu_r}$$

Now for practical T/F $\mu_r$ is finite, Therefore

$$N_1 i_1 - N_2 i_2 = N_1 i_\psi$$

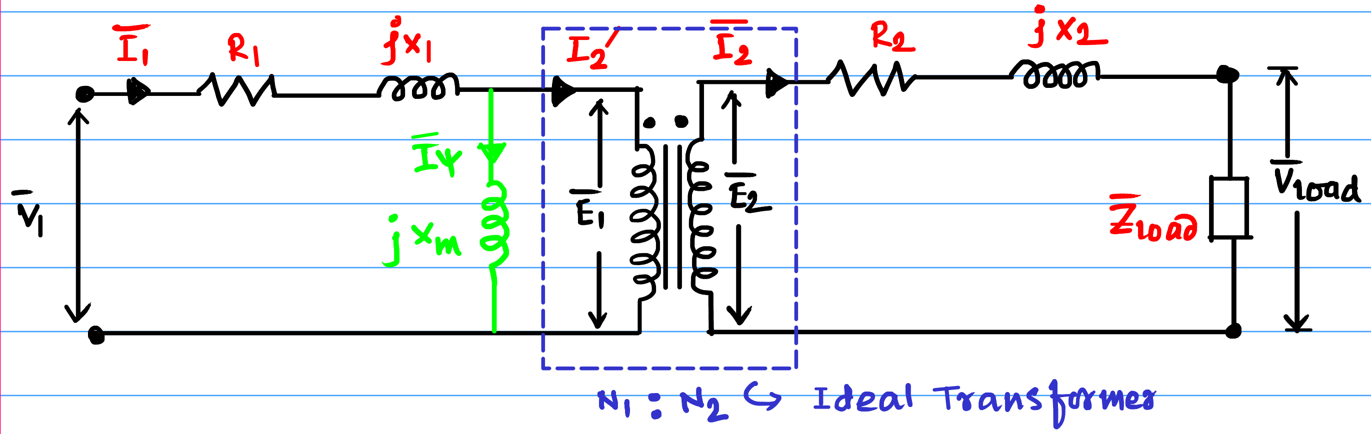
$$\Rightarrow N_1 i_1 = N_2 i_2 + N_1 i_\psi$$

$$\Rightarrow i_1 = \frac{N_2}{N_1} i_2 + i_\psi$$

$$\Rightarrow \bar{I}_1 = \frac{N_2}{N_1} \bar{I}_2 + \bar{I}_\psi \quad \text{[ Phasor Representation ]}$$

$$\Rightarrow \boxed{\bar{I}_1 = \bar{I}_2' + \bar{I}_\psi}$$

$I_\psi$ = Magnetizing current.

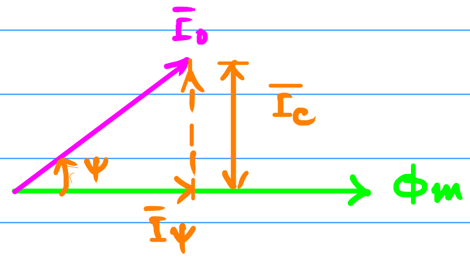



$$\boxed{\bar{I}_\psi = \frac{\bar{E}_1}{jx_m}}$$

$x_m$ = Inductive Reactan that represents the mutual flux

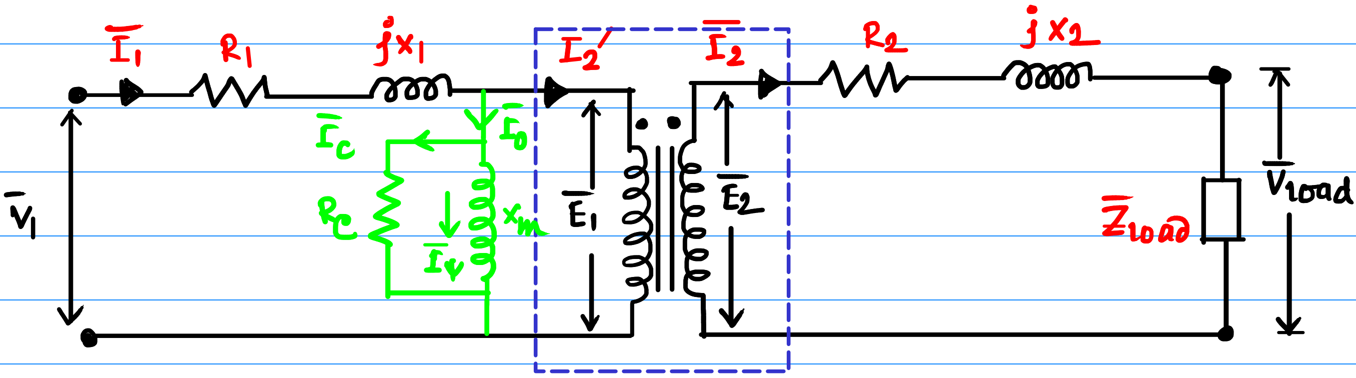
$\bar{I}_\psi$ creates the mutual flux $\phi_m$. So we can say $\phi_m$ and $\bar{I}_\psi$ are at same phase.

However according to Hysteresis curve the current leads the flux

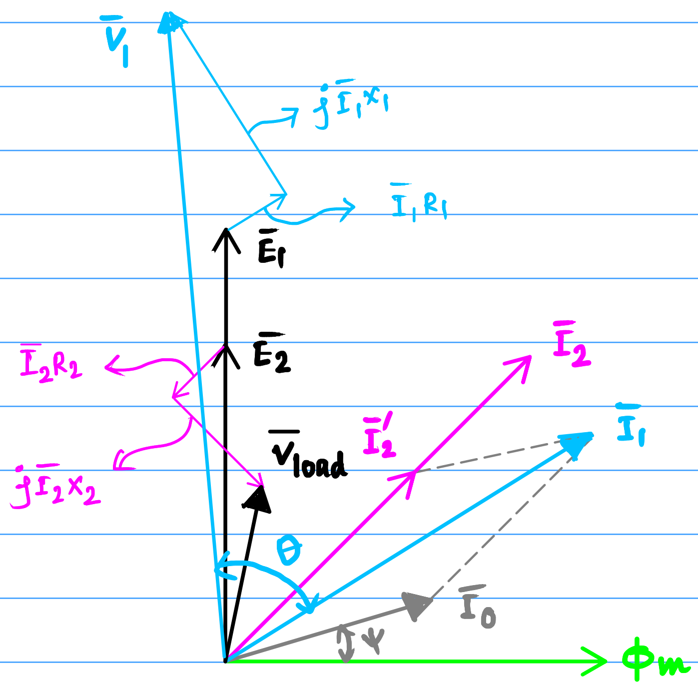



The component of $\bar{I}_0$ which is along $\phi_m$ creates the flux. The component of $\bar{I}_0$ perpendicular to $\phi_m$ represents the core loss component.

## Complete equivalent ckt diagram of T/F :-




The core loss $= \dfrac{|\bar{E}_1|^2}{R_c} = P_{core}$




$$\boxed{\begin{aligned} \bar{V}_1 &= \bar{I}_1R_1 + j\bar{I}_1x_1 + \bar{E}_1 \\ \bar{E}_2 &= \bar{I}_2R_2 + j\bar{I}_2x_2 + \bar{V}_{load} \\ N_1\bar{I}_2' &= N_2\bar{I}_2 \\ \bar{I}_1 &= \bar{I}_0 + \bar{I}_2' \end{aligned}}$$

The equivalent circuit of a real T/F accounts for ⇒

i) ohmic losses and voltage drops.

[ Primary (coil-1) and Secondary (coil-2) resistances]

ii) Leakage flux [ weak coupling ]

[ Primary (coil-1) and Secondary (coil-2) reactances ]

iii) Finite permiability

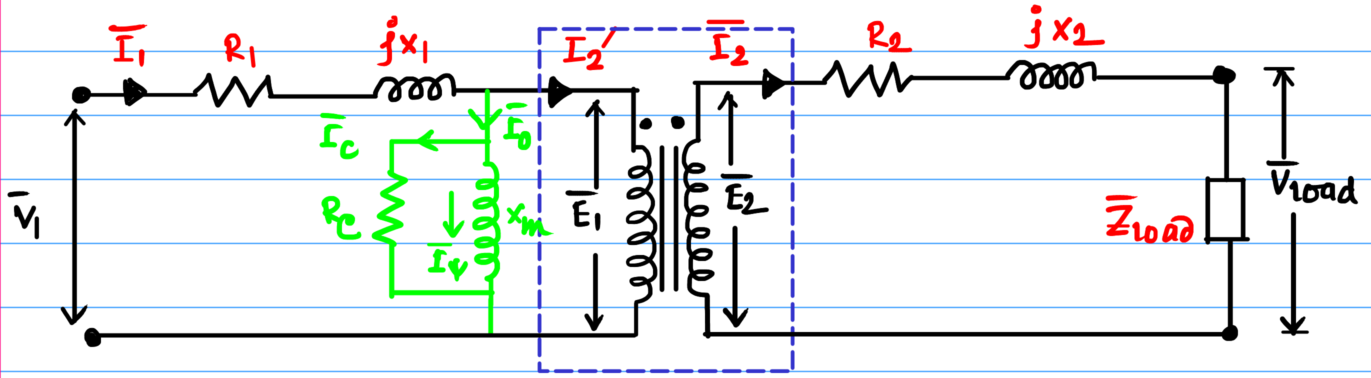
[ $I_m$ is introduced and so the $jX_m$]

iv) Core losses

[ $R_c \rightarrow I_c$]

$R_c$ is the resistance that represents the core loss.

## T/F equivalent ckt referred to primary side :-




$N_1 : N_2 \hookrightarrow$ Ideal Transformer

Secondary equations of the T/F is as follows

$$\bar{E}_2 = \bar{V}_{load} + \bar{I}_2 (R_2 + jx_2)$$

$$\frac{\bar{E}_1}{N_1} = \frac{\bar{E}_2}{N_2}$$

$$\bar{E}_1 = \frac{N_1}{N_2}\bar{E}_2$$

$$\Rightarrow \frac{N_2}{N_1}\bar{E}_1 = \bar{V}_{load} + \bar{I}_2 (R_2 + jx_2)$$

$$\Rightarrow \bar{E}_1 = \frac{N_1}{N_2}\bar{V}_{load} + \frac{N_1}{N_2}(R_2 + jx_2)\bar{I}_2$$

$$\bar{I}_2' N_1 = \bar{I}_2 N_2$$

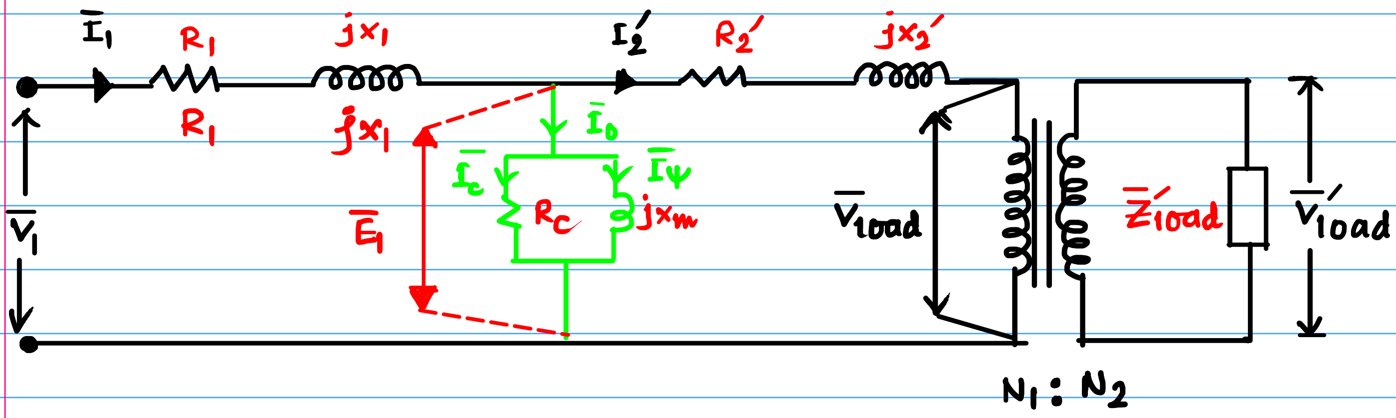
$$\Rightarrow \bar{I}_2 = \left(\frac{N_1}{N_2}\right)\bar{I}_2'$$

$$\Rightarrow \bar{E}_1 = \bar{V}_{load}' + \left(\frac{N_1}{N_2}\right)^2 \bar{I}_2' (R_2 + jx_2)$$

$$\Rightarrow \bar{E}_1 = \bar{V}_{load}' + \bar{I}_2' (R_2' + jx_2')$$

where
$$\boxed{\begin{aligned} R_2' &= R_2\left(\frac{N_1}{N_2}\right)^2 \\ x_2' &= x_2\left(\frac{N_1}{N_2}\right)^2 \end{aligned}}$$
Secondary impedance referred to primary.

and
$$\boxed{\bar{V}_{load}' = \left(\frac{N_1}{N_2}\right)\bar{V}_{load}}$$
Secondary terminal voltage referred to primary.




we also can refer the load to the primary side.

$$\bar{V}_{load} = \bar{I}_2 \bar{Z}_{load}$$

$$\Rightarrow \left(\frac{N_2}{N_1}\right) \bar{V}'_{load} = \bar{I}_2 Z_{load}$$

$$\Rightarrow \bar{V}'_{load} = \left(\frac{N_1}{N_2}\right) \bar{I}_2 Z_{load} \qquad \text{as } \left[\bar{I}_2 = \left(\frac{N_1}{N_2}\right) \bar{I}_2'\right]$$

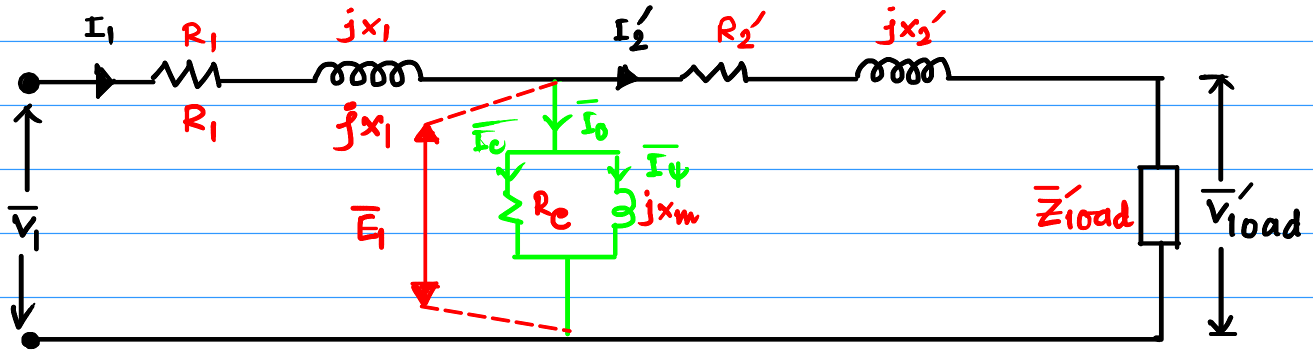
$$\Rightarrow \bar{V}'_{load} = \left(\frac{N_1}{N_2}\right)^2 \bar{I}_2' \bar{Z}_{load}$$

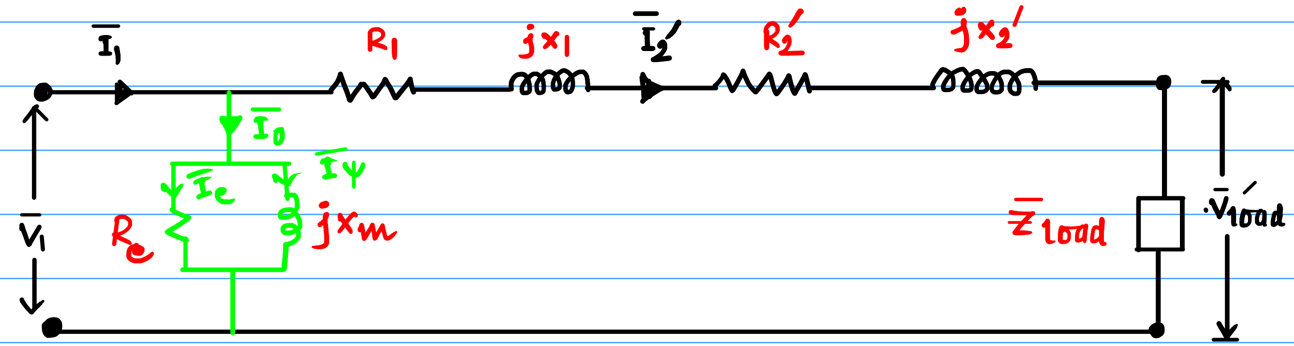
$$\Rightarrow \boxed{\bar{V}'_{load} = \bar{I}_2' \bar{Z}'_{load}} \qquad \boxed{Z'_{load} = \left(\frac{N_1}{N_2}\right)^2 Z_{load}}$$

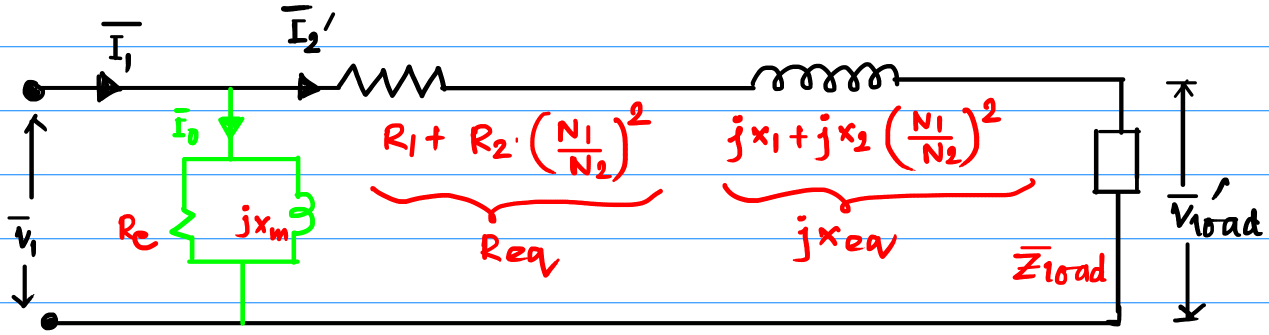
Now draw the equivalent ckt of T/F referred to the secondary

## Approximate equivalent circuit of T/F :-

The equivalent circuit of a Transformer referred to primary side is ⇒

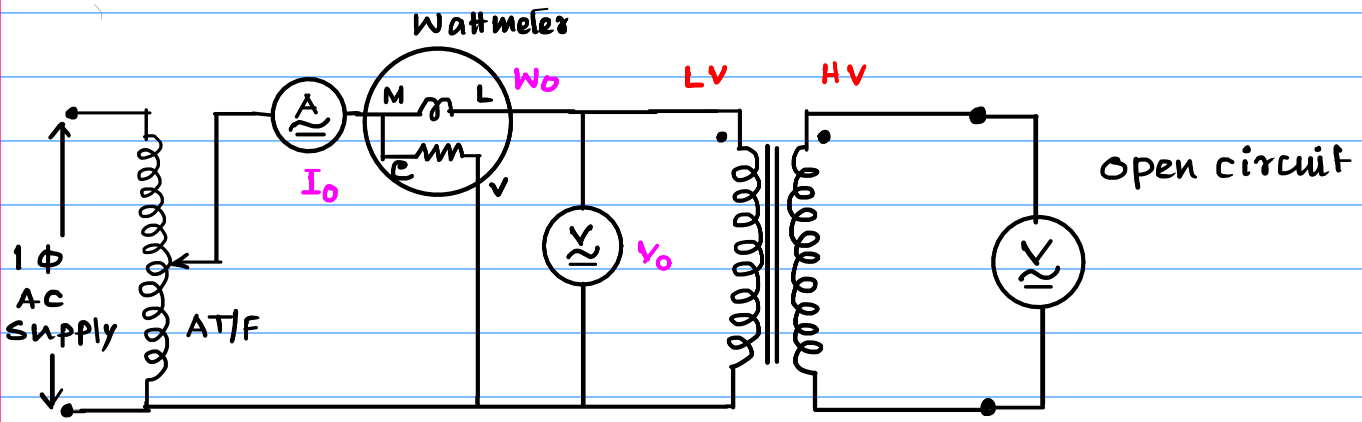


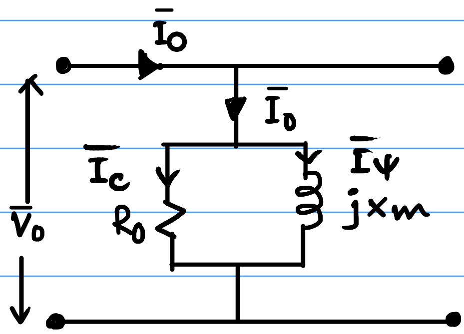



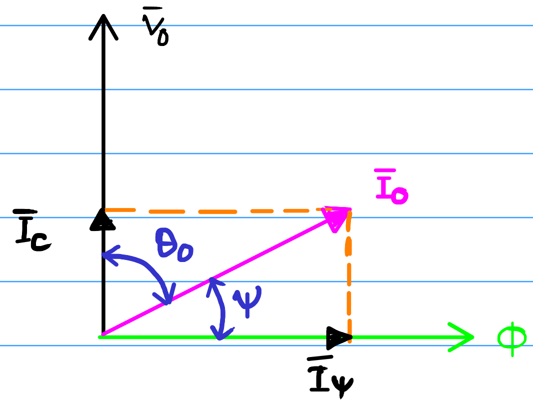



## Tests on T/F to find out circuit parameter :-

### OC Test :-




### ☐ calculation of oc test :-

We have the readings $V_0$, $I_0$, $W_0$

$$\cos\theta_0 = \frac{W_0}{V_0 I_0}$$

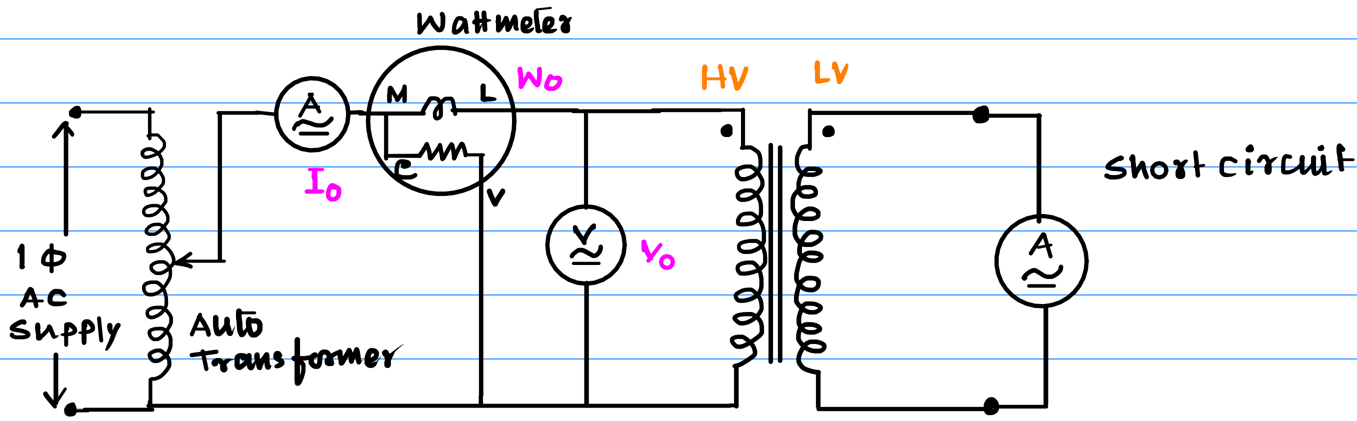
$$\boxed{\theta_0 = \cos^{-1}\frac{W_0}{V_0 I_0}}$$

$I_c = I_0\cos\theta_0$ and $I_\psi = I_0 \sin\theta$

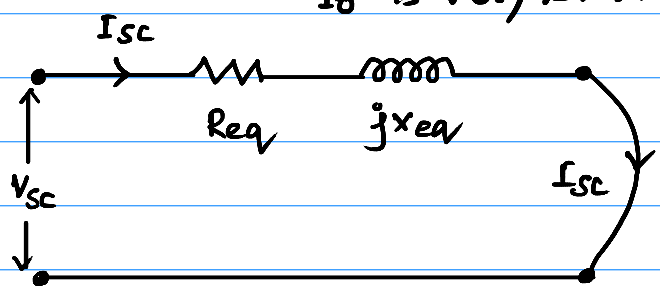
$$\boxed{R_0 = \frac{V_0}{I_c} = \frac{V_0}{I_0\cos\theta_0}}$$ and $$\boxed{X_m = \frac{V_0}{I_\psi} = \frac{V_0}{I_0\sin\theta_0}}$$

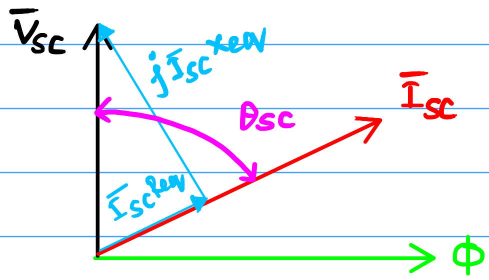
These parameters are referred to (LV) side

## SC Test :-




$I_0$ is very small w.r.t $I_{sc}$ and hence neglected




## Calculation of SC test :-

We have the readings $V_{sc}$, $I_{sc}$, $W_{sc}$

$$\cos\theta_{sc} = \frac{W_{sc}}{V_{sc} I_{sc}} \qquad \theta_{sc} = \cos^{-1}\frac{W_{sc}}{V_{sc} I_{sc}}$$

$$|z| = \frac{V_{sc}}{I_{sc}}$$

$$\boxed{\begin{aligned} R_{eq} &= |z| \cos\theta_{sc} \\ x_{eq} &= |z| \sin\theta_{sc} \end{aligned}}$$

These parameters are referred to (HV) side