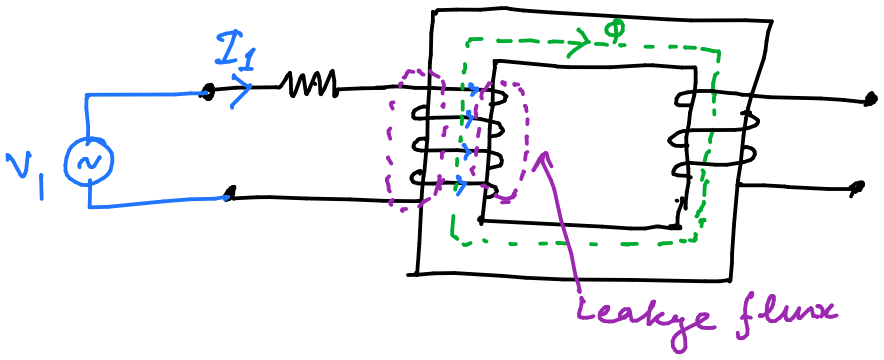
→ Include the winding resistance

→ Include the leakage flux

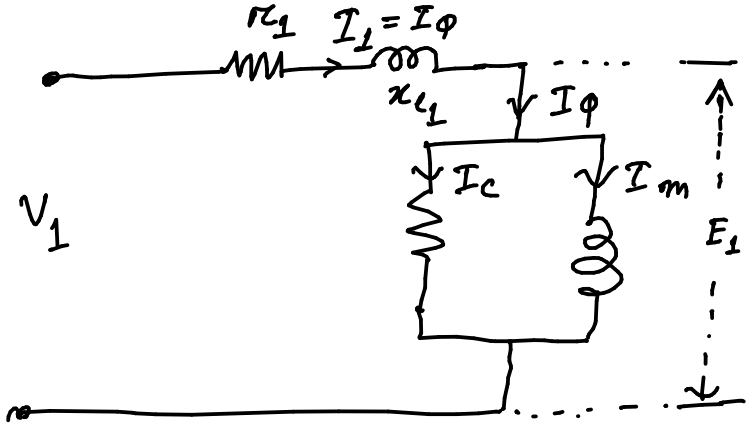


I_1 →
- I_m : Magnetizing current, which is responsible to establish flux Φ in the core
- I_c : Core-loss component of exciting ↓ Hysteresis loss + eddy current loss

The exciting current I_ϕ ($\equiv I_1$ at no-load)

$$I_\phi = I_m + I_c$$

(I_1 at no-load)



No load in secondary side.

r_1 : Resistance of the primary winding

Assume that the leakage flux in primary side is Φ_{l_1} →

↓

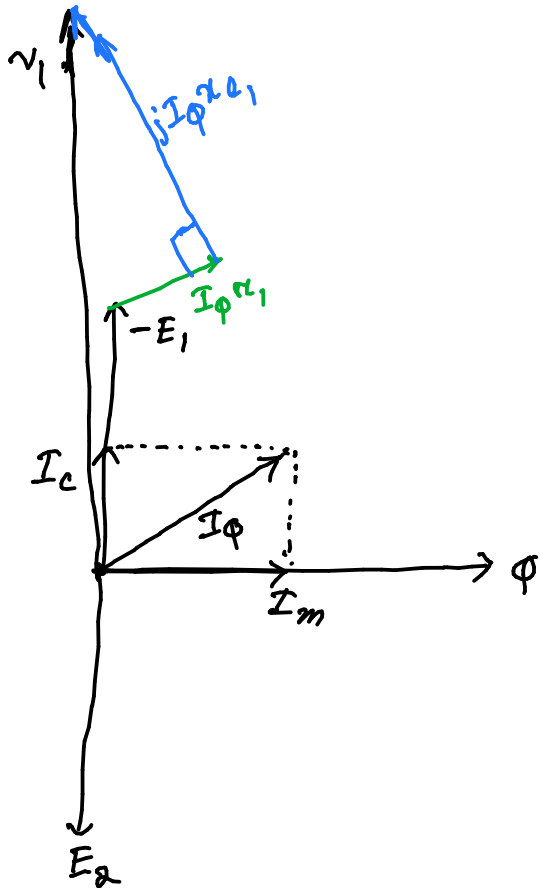
Primary side leakage inductance L_{l_1}

↓

Primary side leakage reactance

$$x_{l_1} = 2\pi f L_{l_1}$$

$$V_1 = I_\phi (r_1 + j x_{l_1}) + E_1$$



- When transformer connected to a load.

↓

I_2 current.

↓

ϕ' flow to oppose the existing ϕ

↓

Draw more current I_1' from primary to counteract ϕ' & to maintain ϕ in the core.

The primary current.

$$\boxed{I_1 = I_\phi + I_1'}$$

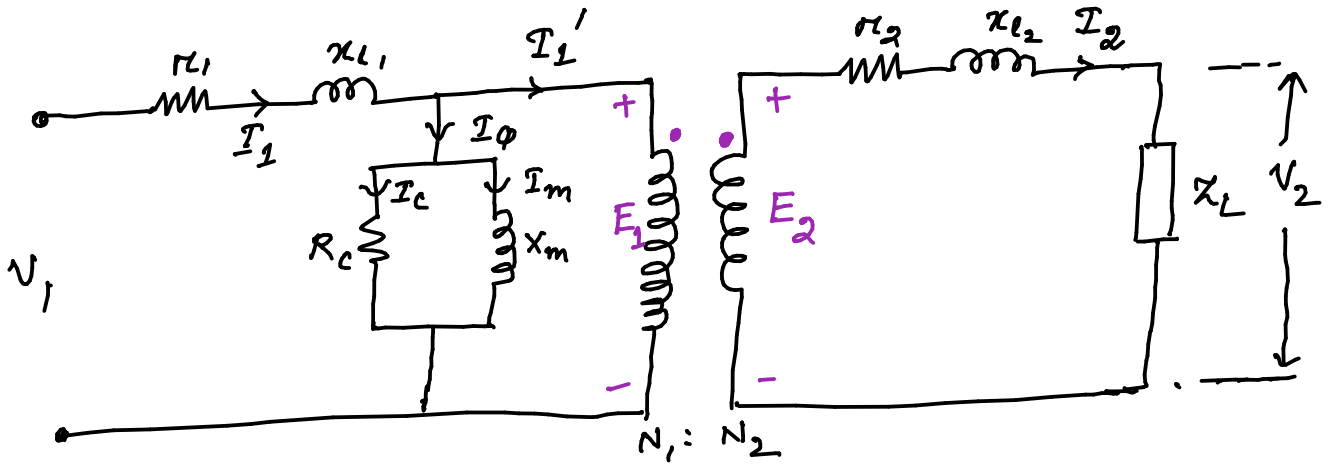
I_ϕ : No load excitation current which is responsible for establishing ϕ in the core & take into the account of core - loss

$$I_\phi = I_m + I_c$$

I_1' : Load component of primary current.

- r_2 : resistance of the secondary winding

x_{l_2} : leakage reactance of secondary side.



- The secondary side impedance referred to primary side $Z_2' = \left(\frac{N_1}{N_2}\right)^2 Z_2$

- Leakage impedance of primary side

$$Z_{l_1} = r_1 + jx_{l_1}$$

- Leakage impedance of secondary side

$$Z_{l_2} = r_2 + jx_{l_2}$$

→ When Z_{l_2} is transferred to primary side or referred to primary side

$$\boxed{Z_{l_2}' = \left(\frac{N_1}{N_2}\right)^2 Z_{l_2}}$$

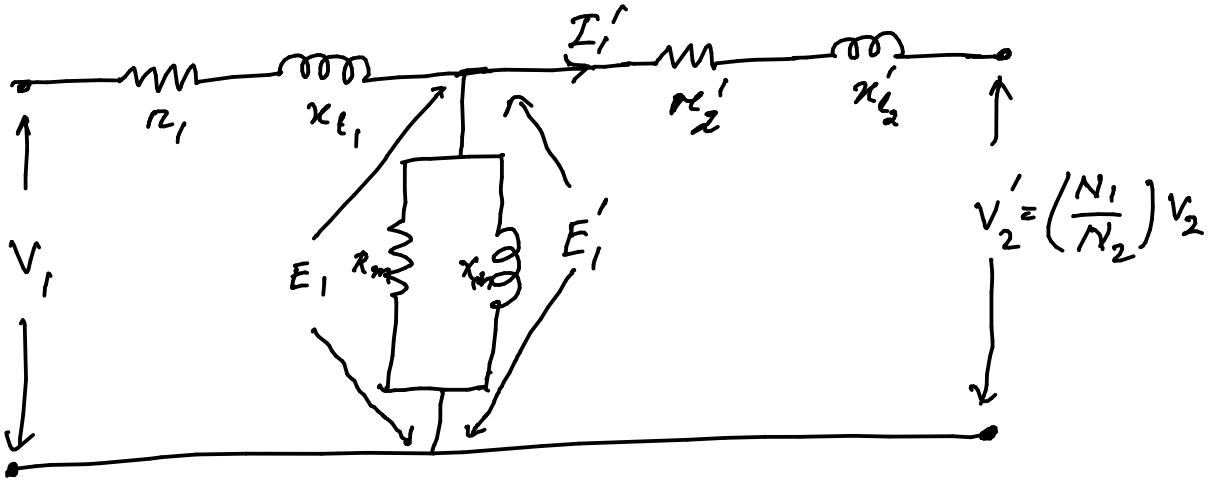
$$\boxed{r_2' = \left(\frac{N_1}{N_2}\right)^2 r_2} \qquad \boxed{x_{l_2}' = \left(\frac{N_1}{N_2}\right)^2 x_{l_2}}$$

- The secondary quantities referred to primary side :

$$Z_{l_2}' = \left(\frac{N_1}{N_2}\right)^2 Z_{l_2}$$

$$E_1' = \left(\frac{N_1}{N_2}\right) E_2$$

$$I_1' = \left(\frac{N_2}{N_1}\right) I_2 \qquad (I_1' N_1 = I_2 N_2)$$



Equivalent T- circuit of transformer.