CHAPTER

PART-4 1. Transformer.

Introduction.

- A Transformer is a static device that Transfer energy from one circuit to another circuit through medium of magnetic Field and without change in frequency.
- winding which are connected to the power supply is known as Primary winding.
- winding which are connected to the Load is known as Secondary winding.
- both winding are electrically isolated but magnetic coupled.

Construction.

(i) core :-

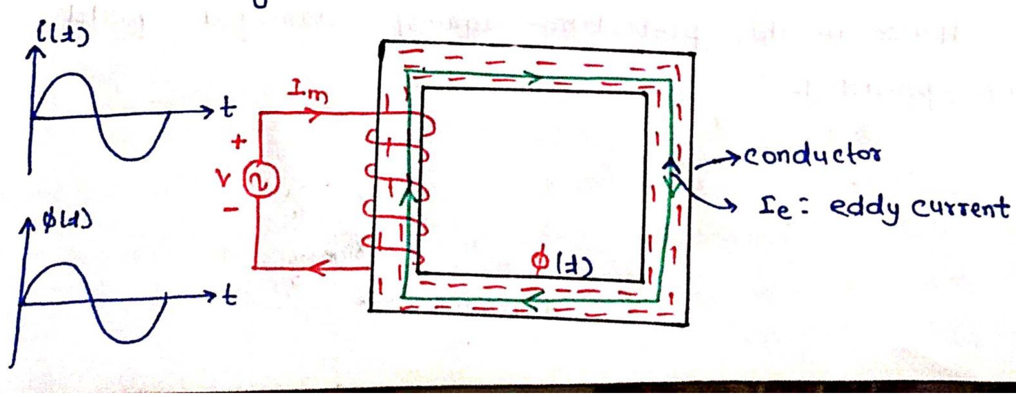
- It is used to provide Low reluctance path to the Field.
- Silicon to added in steel in order to increase the resistivity of material. and permeability also Increases & magnetostiction decreases.

Resistivity ↑ , Permeability ↑ , magnetostriction ↓.

CRGOSS :- Cold Rolled Grain oriented silicon steel.

- Permeability ↑
- Hystresis & eddy current loss ↓

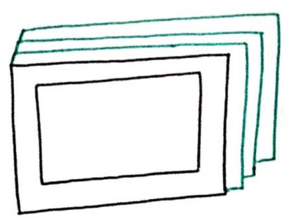
- rolling is done in the direction of magnetization.



- In order to provide low reluctance, core should be made up of magnetic material such as steel, which is also conductor.
- when flux linkage changes with steel (i.e core) so their is an induced emf and current flows which is known as eddy current. The Losses due to this is known as Eddy current loss.

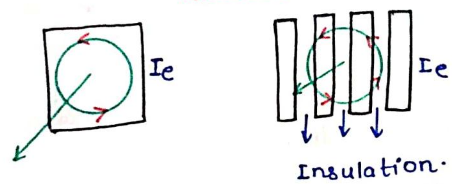
  - By addition of silicon in steel, resistivity increases hence Eddy current decreases.

- Lamination are done in order to reduce eddy current loss.

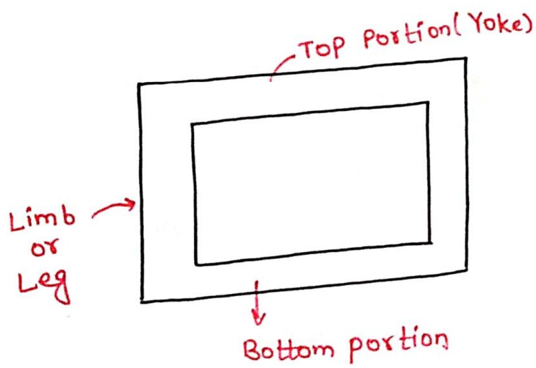


- Lamination are isolated using coating of Varanish.

Cross sectional view of core.

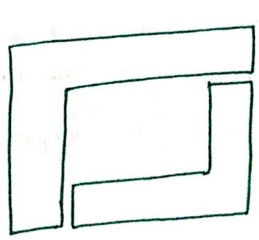


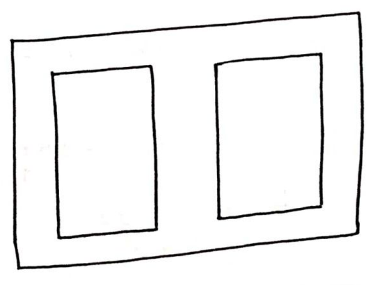
- Eddy current loss reduces by using Insulation.



Two Legged core.

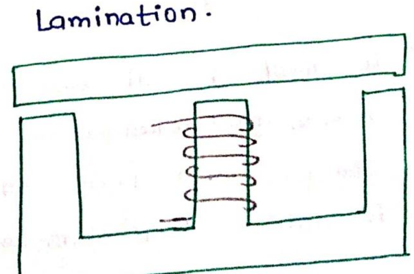
- made up of L shape Laminations.





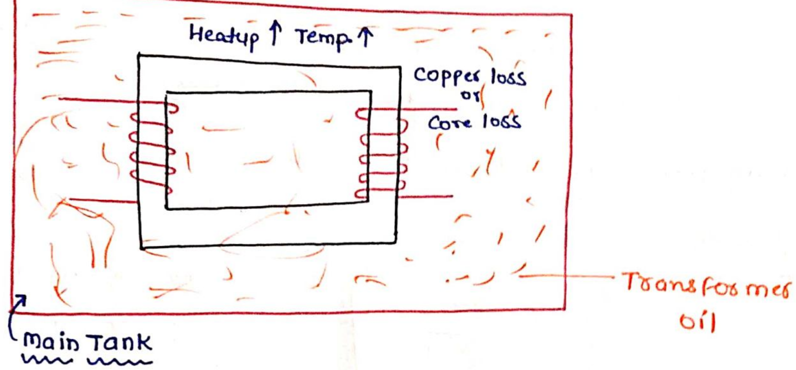
Three Legged Core.

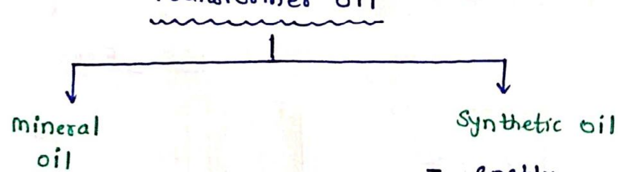
- Made up of E & I Shaped Lamination.



(ii) winding :- made up of Solid or Standard copper or Aluminium Conductor.

(iii) Transformer oil :- Due to copper loss & core loss, winding and core heatup. Hence temp. increases. So, T.F oil used, which act as coolant as well as ~~[struck out]~~ Insulation.

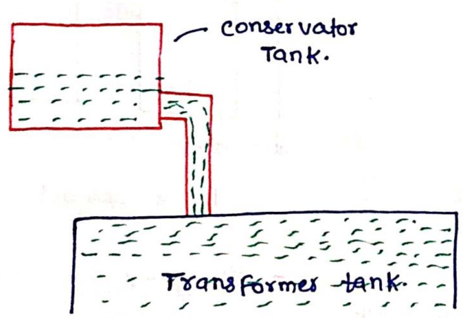




- costly.

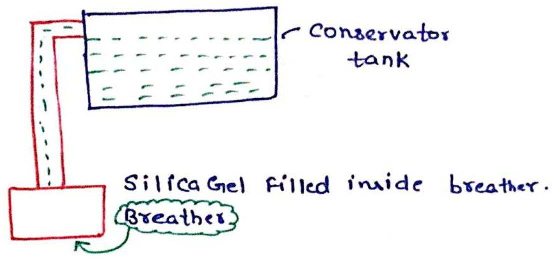
- Product of crude petrolium
- Problem of fire hazard.

(iv) Conservator tank or Expansion tank



- The level of oil. also when Load changes, when Load increases, oil expands and when Load decreases, oil contracts so the oil level changes with Load hence Conservator tank or expansion tank is used to keep main tank full of oil.

(V.) Breather



- when temp. increases, the oil expands. the gas at the top of the oil level expelled out. when temp. decreases, the oil contructs. so it will draw air from out side. This air may certain moisture. So breather is used to restrict moisture, which consist of silica Gel.

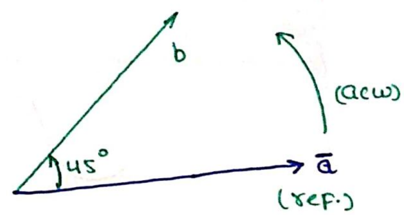
(6.) Bucholz relay

- It is used to detect internal fault of Transformer.
- It is connected in between conservator tank and main Tank.
- when Fault occurs, the temperature increases, the oil decomposed into gaseous bubbles. These gases bubble moves from main tank to Conservator tank through bucholz relay. These gaseous bubbles disturb mercury Float. So mercury Float send signal to Alarm and circuit Breaker.

Phasor :-

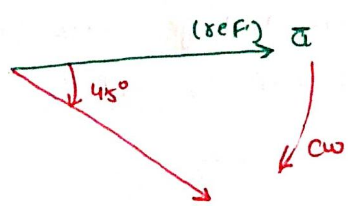
(i) $\bar{a}$ $\bar{b}$

$\bar{a} = a\angle 0$, $\bar{b} = b\angle +45°$



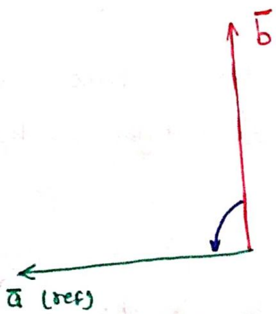
- $\bar{b}$ lead $\bar{a}$ by 45°
- $\bar{a}$ lag $\bar{b}$ by 45°

(ii) $\bar{a} = a\angle 0$, $\bar{b} = b\angle -45°$



- $\bar{b}$ lags $\bar{a}$ by 45°

(iii)

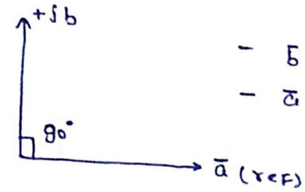


- $\bar{b}$ lags $\bar{a}$ by 90°.

(iv) $\bar{a} = a\angle 0$ (ref) $\quad j = +90^\circ$

$\bar{b} = jb$

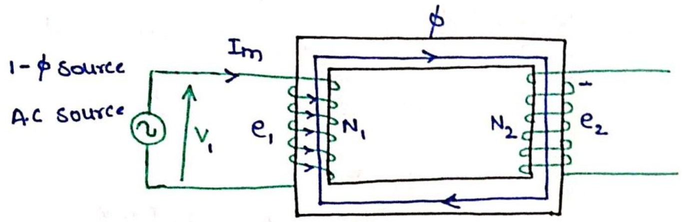
$= b\angle +90^\circ$

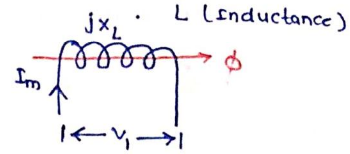


- $\bar{b}$ leads $\bar{a}$ by 90°
- $\bar{a}$ lags $\bar{b}$ by 90°

$j = 90^\circ \qquad 1/j = -j = -90^\circ$

Induced Emf in Transformer :-

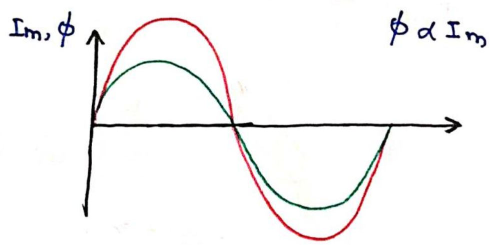




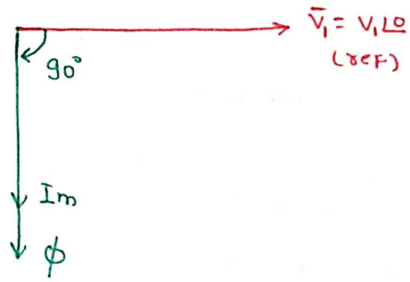
$\bar{I}_m = \frac{V_1\angle 0}{jX_L} = \frac{|V_1|}{|X_L|}\angle -90^\circ$

Im = magnetizing current.

- magnetizing current ~~supp~~ lags supply Voltage by 90° $\qquad$ Im lags V_1 by 90°



$\phi \propto I_m$



ϕ = space-phasor $\qquad \cdot\ \phi \propto I_m$

I = time-phasor $\qquad I_m = I_{max}\sin\omega t$

$\phi = \phi_{max}\sin\omega t$

- As flux is time varring so when flux linkage with coil ① and coil ② changes so there is an induced emf e_1 and e_2.

$\phi = \phi_m \sin\omega t$

↓

peak value.

$e_1 = -N_1 \frac{d\phi}{dt} \qquad e_2 = -N_2 \frac{d\phi}{dt}$

$$e_1 = -N \frac{d}{dt}(\phi_m \sin\omega t)$$

$$e_1 = -N_1 \phi_m \omega \cos\omega t$$

$$e_1 = -N_1 \phi_m \omega \sin(90^\circ - \omega t)$$

$$e_1 = N_1 \phi_m \omega \sin(\omega t - 90^\circ)$$

$$e_2 = -N_2 \frac{d}{dt}(\phi_m \sin\omega t)$$

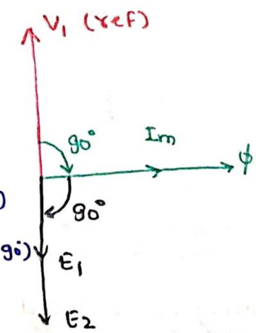
$$e_2 = -N_2 \phi_m \omega \cos\omega t$$

$$e_2 = -N_2 \phi_m \omega \sin(90 - \omega t)$$

$$e_2 = N_2 \phi_m \omega \sin(\omega t - 90^\circ)$$

but $\phi = \phi_m \sin\omega t$

– both e_1 & e_2 lags ϕ by 90°.



$E_1 = N_1 \phi_m \omega \sin(\omega t - 90^\circ)$

$e_1 = E_{m_1} \sin(\omega t - 90^\circ)$

$E_{m_1} = N_1 \phi_m \omega$

$E_{m_1} = 2\pi f N_1 \phi_m$

$E_2 = N_2 \phi_m \omega \sin(\omega t - 90^\circ)$

$e_2 = E_{m_2} \sin(\omega t - 90^\circ)$

$E_{m_2} = N_2 \phi_m \omega$

$E_{m_2} = 2\pi f N_2 \phi_m$

Rms Value :- $E_1 = \frac{E_{m1}}{\sqrt{2}} = \sqrt{2}\pi f N_1 \phi_m$ $\qquad E_2 = \frac{E_{m2}}{\sqrt{2}} = \sqrt{2}\pi f N_2 \phi_m$

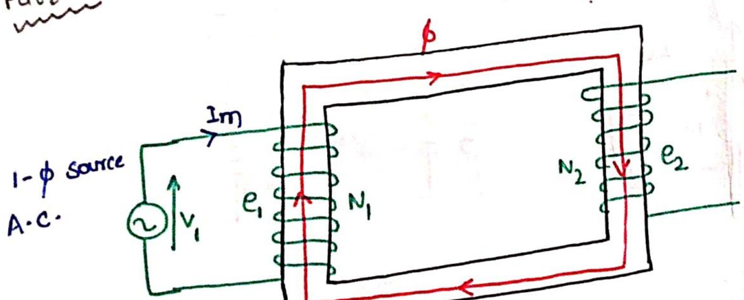
$$\boxed{E_1 = 4.44 f \phi_m N_1}$$ Imp. result

$$\boxed{E_2 = 4.44 f \phi_m N_2}$$ Imp. result.

$$\boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1} = K = \text{Transformation Ratio.}}$$ Imp. Result.

** $\boxed{a = \frac{N_1}{N_2}}$ ** turns Ratio

Part -5



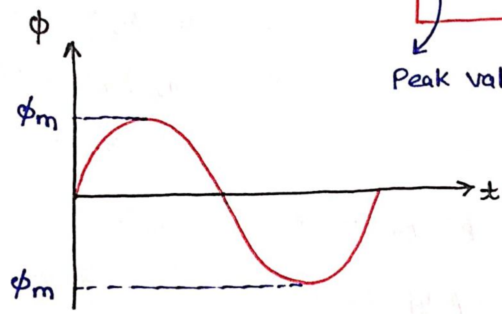
$V \approx E_1 = 4.44 f \phi_m N$

If voltage drop of primary winding is Neglected.

$\phi_m \simeq \frac{V_1}{4.44 f N_1}$

$\phi_m \propto \frac{V_1}{f}$ — Ratio of supply voltage and frequency.

ϕ_m → Peak value of flux.

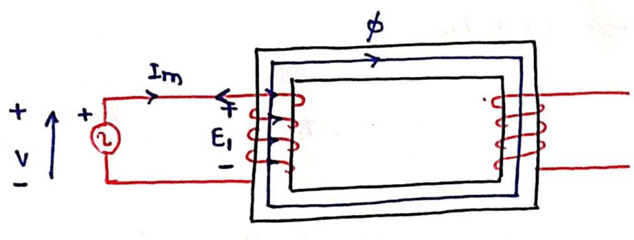


- If ratio of supply voltage & frequency remains constant, so ϕ_m (i.e peak of flux) remains constant.

Part-5

Polarity of Induced Emf

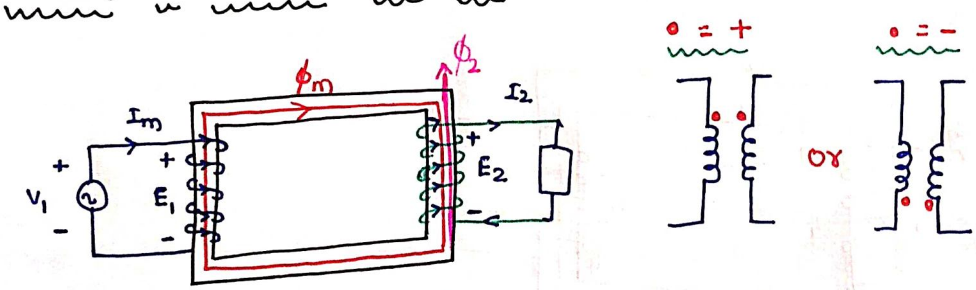
Polarity of induced emf E_1:-

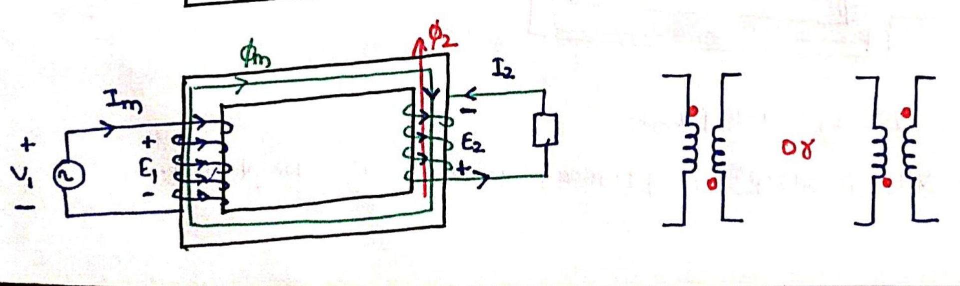


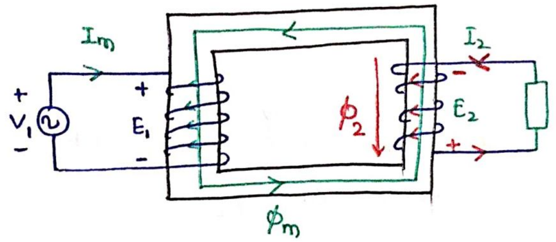
Primary winding.

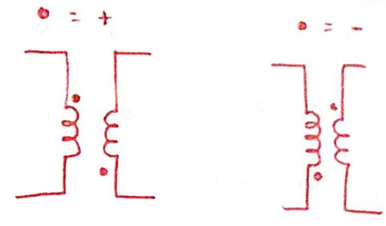
- When time varring flux links with primary winding, their is an induced emf in coil (i). According to Lenzs Law, the polarity of induced emf E_1 such that. if current would flow due to E_1, it should oppose the Im current.

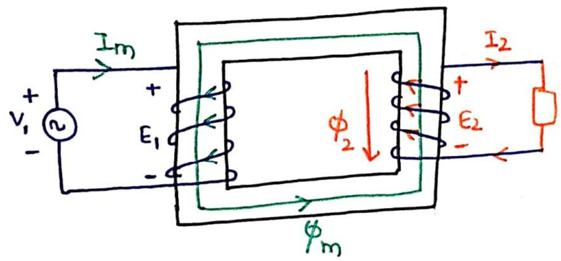
Polarity of induced emf E_2:-



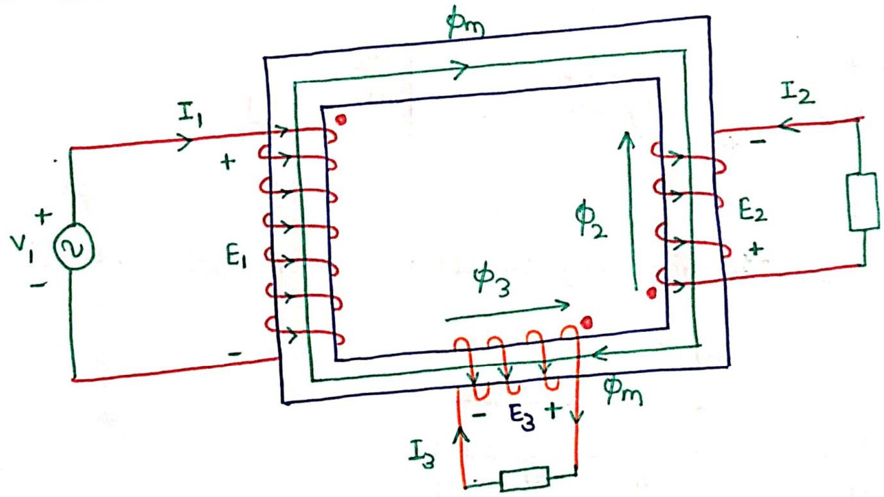


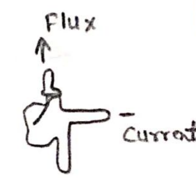




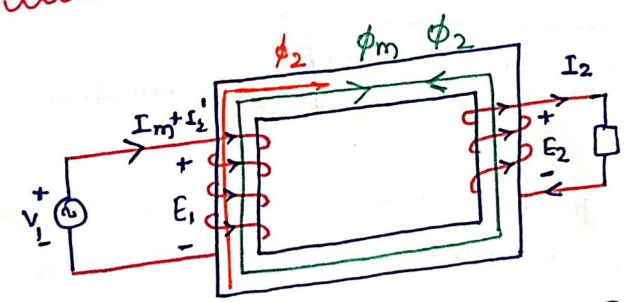


Three phase winding DoT convension :-





Transformer on Load :-



- When Transformer ON No Load.

$\phi_m \propto V/f$ (supply)

Net flux in core = ϕ_m.

- When ϕ_m flux intracts with coil ②, an induced emf E_2 & If Load connected to coil ② I_2 current flows, A/c to Lenz's Law ϕ_2 flux produced by I_2 should oppose ϕ_m. Net flux in core = $\phi_m - \phi_2$

↓Net flux in core = $\phi_m - \phi_2$

but $\phi_m \propto V/f$ (source).

- To keep net flux in core constant (ϕ_m), (coil 1)/ source draws additional current I_2' from source, which produces flux ϕ_2

$$\text{Net flux} = \phi_m - \cancel{\phi_2} + \cancel{\phi_2} = \phi_m$$

Source current / Primary winding current :-

$$I_1 = I_m + I_2' \qquad \phi = \frac{mmf}{Reluctance}$$

$$\phi_2 = \frac{N_1 I_2'}{Reluctance}, \quad \phi_2 = \frac{N_2 I_2}{Reluctance}$$

$$\frac{N_1 I_2'}{\cancel{Reluctance}} = \frac{N_2 I_2}{\cancel{Reluctance}} \qquad \boxed{\frac{N_2}{N_1} = \frac{I_2'}{I_1}}$$

as $I_1 = I_m + I_2'$

as I_m current is very small in comparison to I_2'.

$$I_1 \approx I_2'$$

$$\boxed{\frac{N_2}{N_1} = \frac{I_1}{I_2} = \frac{V_2}{V_1} = \frac{E_2}{E_1} = K}$$

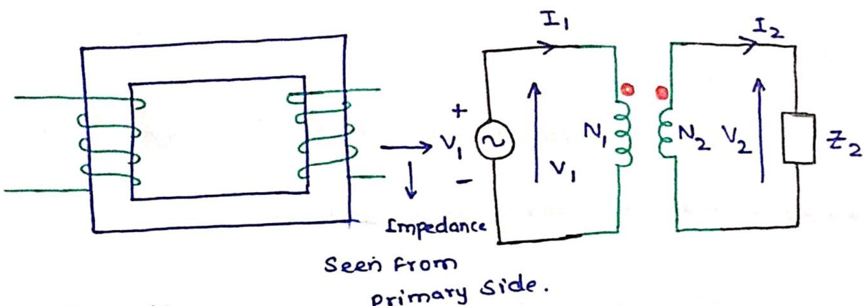
$$V_1 I_1 = V_2 I_2$$

$\boxed{\text{KVA of primary = KVA of secondary}}$ Approximation.

- Load current is always greater than primary magnetizing current. only fault current is greater than Load current in electrical world.

Fault current > Load current >>> magnetizing current.

Impedance Transformation :-



$$Z_2 = \frac{V_2}{I_2}$$

Impedance seen from primary side.

$$= \frac{V_1}{I_1}$$

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

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

$$\frac{V_1}{I_1} = \frac{N_1 V_2 \times N_1}{N_2 \times I_2 \times N_2} = \left(\frac{N_1}{N_2}\right)^2 \frac{V_2}{I_2} = \frac{Z_2}{K^2} \qquad \because \frac{N_2}{N_1} = K \quad \frac{N_1}{N_2} = 1/K$$

***

Impedance Seen from Primary side	$= \frac{Z_2}{K^2} = Z_2' =$	Secondary refer. to primary side.

If Z_1 = Primary impedance.

Primary impedance refer to secondary (Z_1')

***

$$Z_1' = Z_1 * K^2 = Z_1 * \left(\frac{N_2}{N_1}\right)^2 = Z_1\left(\frac{V_2}{V_1}\right)^2$$

$Z = R, \quad Z = jX_L , \quad Z = -jX_C$

Trick :-