UNIT-4

Sabyasachi
DATE / /

TRANSFORMER

upto 11KV

Generation ⟷ Transmission ⟶ Distribution.

Step up
Step down

Efficiency – 96 – 97%.
principle – based on faraday laws of

Principal

Transformer is based on the principle of Electromagnetic induction or mutual induction (Faraday law)
Fig. shows the principle diagram for transformer.
For transformer Action it is necessary to supply alternating voltage at primary side. This voltage gives the Exciting current or no load current to the primary binding. This current sets up the working flux or magnetising flux in the core which links to both the binding. Now by the Faradays law of EMI, Emf is induced in both the bindings let e_1 is induced in primary binding.

and is given by ψ = total flux linked with the primary binding = $N_1\phi$

N_1 = No. of primary turns

Φ = ϕ per turn in weber.

Since flux (ϕ) is due to alternating supply it is given by

$$e_1 = \frac{-d\psi}{dt}.$$

$$\psi = N_1 \phi.$$

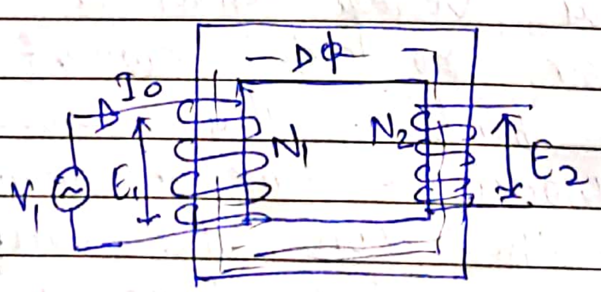
$$e_1 = -N_1 \frac{d\phi}{dt}.$$

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

$$e_1 = -N_1 \frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -N_1 \omega \phi_m \cos\omega t = N_1 \omega \phi_m \sin(\omega t - \frac{\pi}{2}).$$

So Induced Emf lags the flux by 90°. The maxm value of Emf is E_1 =



$E_m = \frac{E_{rm}}{\sqrt{2}}$

$$E_1 max = N_1 \omega \phi_m.$$

But $\omega = 2\pi f$, where f = frequency in Hz

$$(E_1) = E_1 \frac{2\pi f N_1 \phi_m}{\sqrt{2}} = 4.44 f N_1 \phi_m.$$

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ϕ_m = Maxm flux in the core.

Similarly the induced emf in secondary binding is

$E_2 = 4.44 f N_2 \phi_m$

rms

$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$ (transformer relation)

A single phase transformer has 400 primary and 1000 secondary turns. The net cross sectional area of the core is 60 cm². If the primary binding be connected to a 50 Hz supply at 500 Volt Calculate the a) peak value of ϕ density in the core. b) voltage Induce in the secondary binding.

$N_1 = 400$ $N_2 = 1000$ Area $= 60 cm^2 \times 10^{-2}$

$f = 50 Hz$ $V_1 = 500$

a) $E_1 = N_1 \omega \times \phi_m$.

$500 = 500 \times 2 \times 3.14 \times 50 \times \phi_m$.

$\phi_m = \frac{1}{2 \times 3.14} = 0.159$

$\phi = B.A$ — $0.159 = B \times 60 \times 10^{-2}$

$B = 0.265$

$500 = 4.44 \times 50 \times 500$

$\frac{E_2}{E_1} = \frac{1000}{500}$ = $E_2 = 2 \times 500 =$

No. 2. $E_1 = 4.44 \times 50 \times 500 \times \phi_m = 500$

$$\phi_m = \frac{\cancel{500}}{4.44 \times 50 \times \cancel{400}} =$$

$$\phi_m = 0.00563 \text{ Wb}.$$

$$\phi_m = BA$$

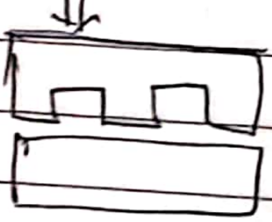
$$B_m = \frac{0.00563}{0.006}$$

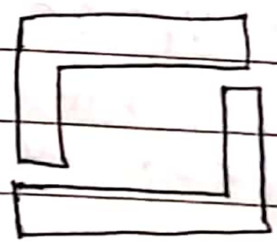
$$= 0.938 \text{ W}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$$E_2 = 500 \times \frac{1000}{4} = 1250 \text{ V}$$

CORE TYPE / SHELL TYPE Read





Comparision b/w CORE TYPE / CELL TYPE

* voltage, current and impedence transformation.

$$K = \frac{V_2}{V_1} = \frac{\text{secondary binding voltage}}{\text{primary binding voltage}}$$

$$= \frac{N_2}{N_1} \quad \frac{\text{No. of turns in secondary binding}}{\text{No. of turns in primary binding}}.$$

current transformation

$$V_1 I_1 = V_2 I_2$$

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{1}{K} = \frac{N_1}{N_2}$$

$\phi \times S = NI$

mmf

Impedence Transformation:-

$$\frac{V_2}{I_2} = Z_2 \qquad \left(\because \frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1} \right)$$

$$V_2 = \left(\frac{N_2}{N_1}\right) V_1$$

$$I_2 = (N_1/N_2) I_1$$

$$Z_2 = \frac{(N_2/N_1) V_1}{\left(\frac{N_1}{N_2}\right) I_1}$$

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

$$= Z_2'.$$

$$Z_2' = \left(\frac{1}{K}\right)^2 Z_2 \qquad \left\{ Z_1' = \left(\frac{N_2}{N_1}\right)^2 Z_1 = K^2 Z_1 \right\}$$

Where Z_2' is secondary impedance referered ~~to~~ to the primary, Similarly it can be shown that primary impedance referered to secondary

* Transformer phrasal diagram.

Ideal Transformer:-

A transfomer is said to be ideal if

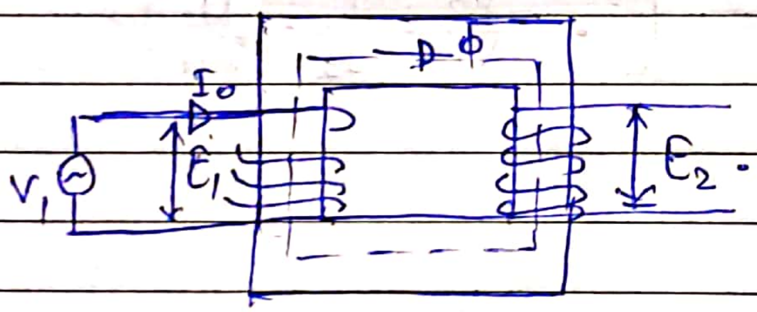
1) If binding resistance is negligible so there is no copper loss (I^2R) loss.

2) There is no leakage of flux in air.

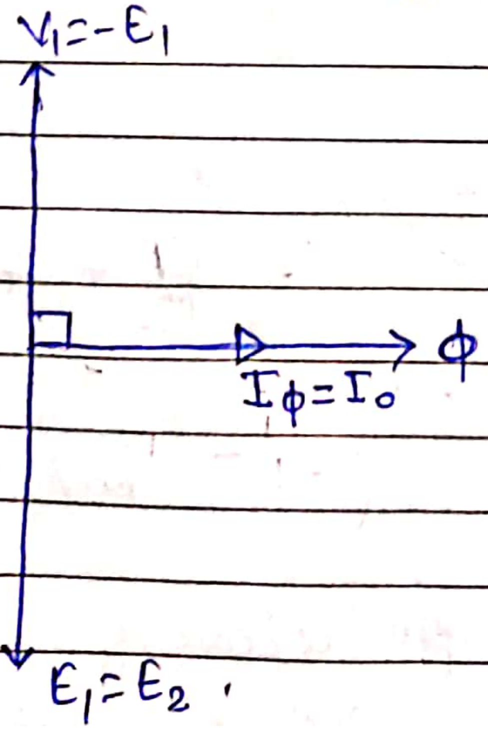
3) Magnetic material is ideal & there will be no Core loss (Iron loss in it).
↳ ohmic losses.

Pharasal diagram (Ideal transformer)

1) No Load.



$I_2 = 0$, so $\boxed{V_2 = E_2}$ & $V_1 = E_1$.

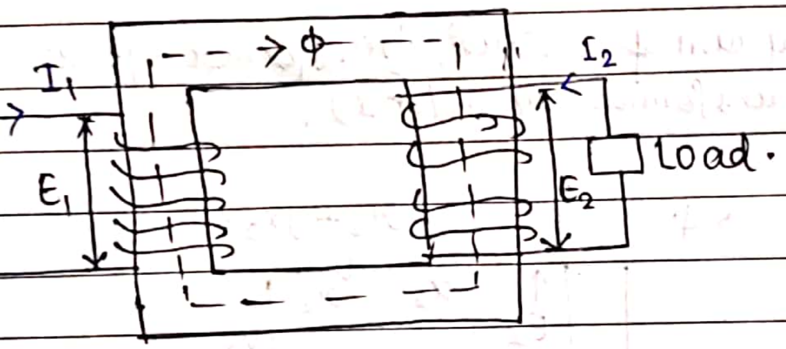


$I_\phi \rightarrow$ Magnetising current

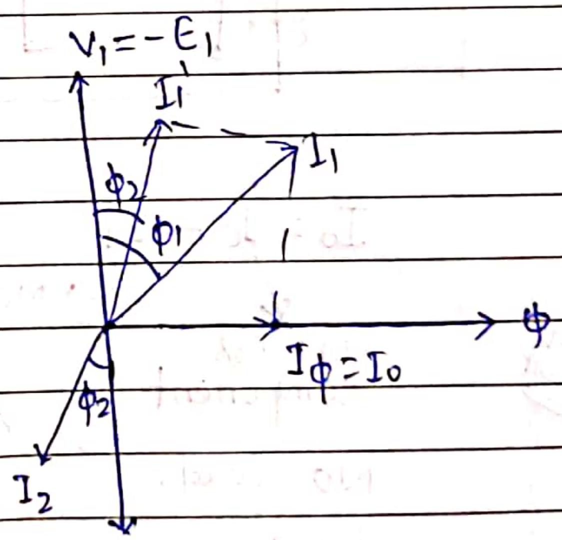
The no load current produces the magnetising ~~current~~ flux (ϕ) which induces the Emf E_1 and E_2 in both the bindings. For convenience we assume $E_1 = E_2$ at 90° lagging behind the flux (ϕ). The applied voltage V_1 is drawn at 90° to ϕ
$V_1 = -E_1$

No load current – Exciting current. (In this case)

Phasor diagram of ideal Transformer on load.



circuit is lagging (Inductive)



$I_1' N_1 = I_2 N_2$

$$\frac{I_2}{I_1'} = \frac{N_1}{N_2}$$

$\bar{I_1} = \bar{I_0} + \bar{I_1'}$

I_0 is only 2 to 6% of the I_1. So it can be neglected.

$I_1 = I_1'$.

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

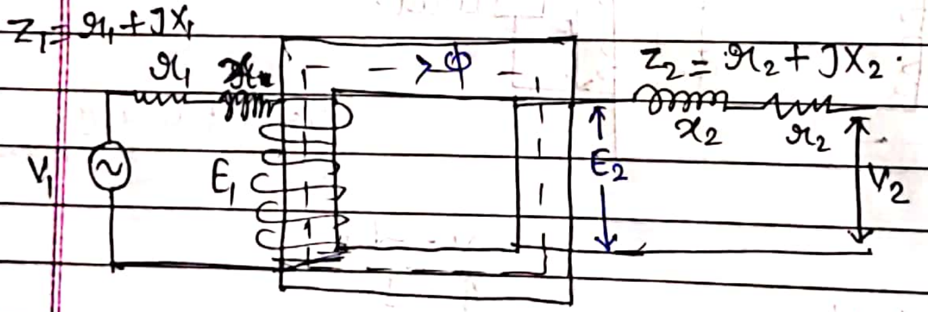
I_1' = This extra primary current is called the load component of primary current. (I_1 component)

$I_1'N_1$ = mmf of primary current to nullify the effect of secondary mmf.

I_2N_2 = secondary mmf

ϕ_1 = primary powerfactor angle.
ϕ_2 = secondary powerfactor angle.

* Phasor diagram of actual transformer (phasor diagram
* of actual transformer on no load).



$I_2 = 0$ $\quad$ $I_1 \simeq I_0$ ⇒ condn for no-load current.

$I_0 = I_c + I_\phi$

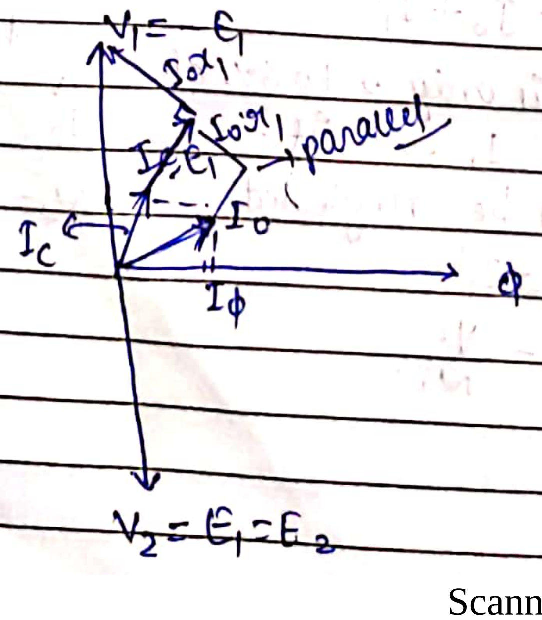
I_ϕ → magnetising component.

I_c → Core loss component

I_0 → no load current

No-load.

$I_2 = 0$



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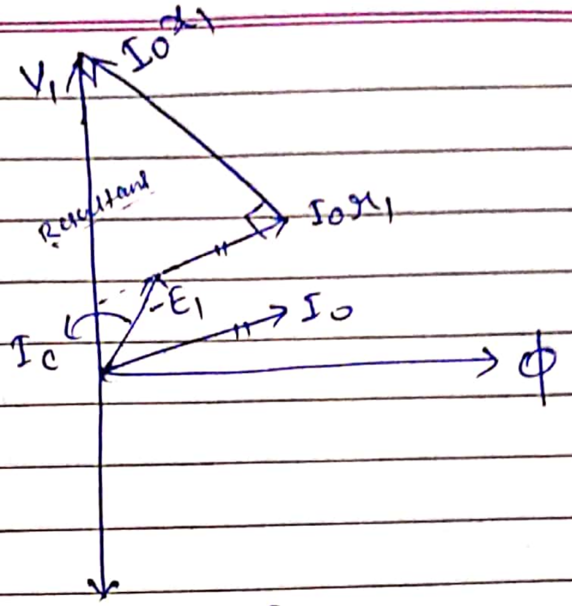

$V_1 = I_1 R_1$.

$V_2 = E_1 = E_2$.

$$\bar{V_1} = -\bar{E_1} + \bar{I_1} r_1 + j\bar{I_1} x_1$$

$[V_1' = -E_1]$

copper loss

effeciency = losses in transformer (core loss,
1) Eddy (circulating current)
~~2) Hysteresis~~

copper loss
(ohmic losses)

$P_{oh} = P_c = I^2 R$

$P_c = I_1^2 R_1 + I_2^2 r_2$.

$$e = \frac{\text{output power in watt}}{\text{Input power in watt}} \times 100$$

$$\frac{\text{output}}{\text{output} + \text{losses}} \times 100.$$

$$\eta = \frac{V_2 I_2 \cos\theta_2}{V_2 I_2 \cos\theta_2 + P_c + P_{oh}}.$$