UNIT - II

TRANSFORMER.

Transformer is a static device, which transforms the electrical power from one circuit to another circuit at the same frequency.

It operates on the principle of mutual induction.

TRANSFORMER CONSTRUCTION:

The essential elements of a transformer core.

* Primary winding : The winding which is connected to AC supply is called 1° winding.
* secondary winding : The winding which is connected to load is called 2° winding.
* Transformer core : The two windings of the transformer core magnetically coupled through the core.

- The core is constructed of transformer sheet steel laminations to provide continuous magnetic path with a minimum air gap.
- The core is made up of silicon steel to reduce hysterisis loss.
- The laminations are insulated from each other by light coat of varnish (or) oxide layer on the surface.
- The thickness of the lamination varies from 0.35 mm for 50 Hz and 0.5mm for 25 Hz.

Other necessary parts are,

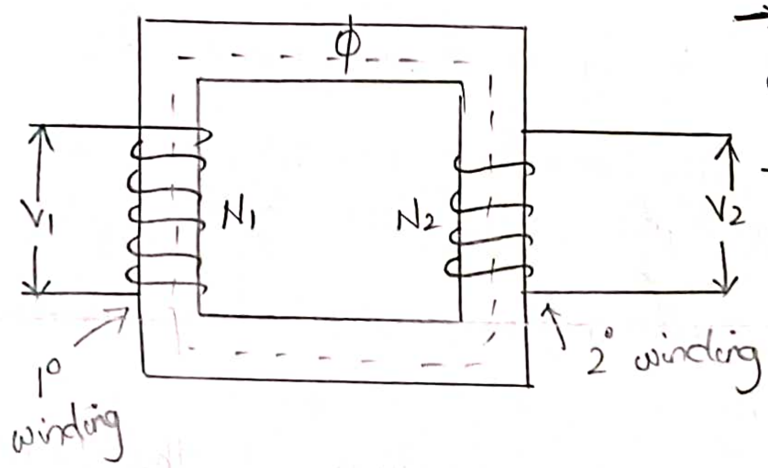
→ A suitable container for the assembled core windings.

→ A suitable medium for insulating the core and windings from each other and from the container.

The two basic types of transformer construction are:

* Core type   * Shell type.

→ CORE TYPE TRANSFORMER :-



→ There are two limbs in a core type transformer.

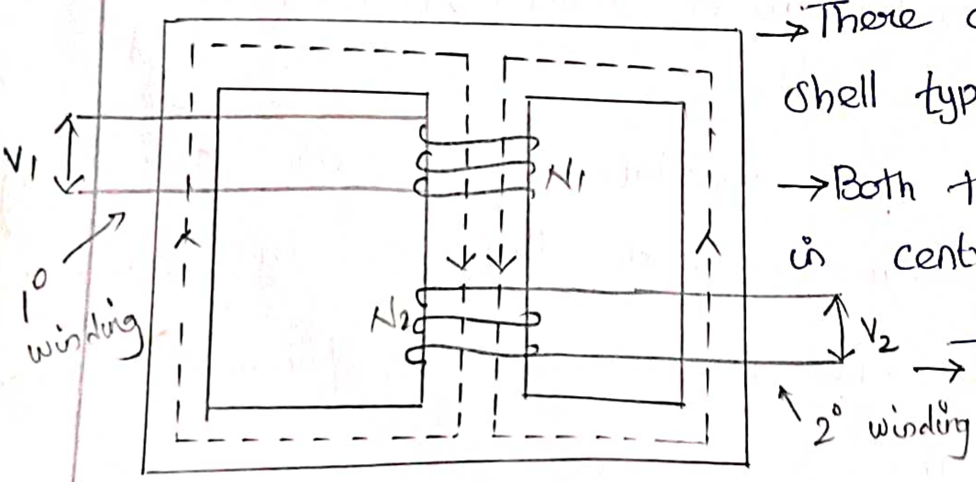
→ The two windings are placed in each limb.

→ There is only one path for magnetic flux.

→ The individual laminations are cut in L shape.

→ In order to minimize the air gap in the joints b/w the strips, the layers are stacked alternatively.

→ SHELL TYPE TRANSFORMER.

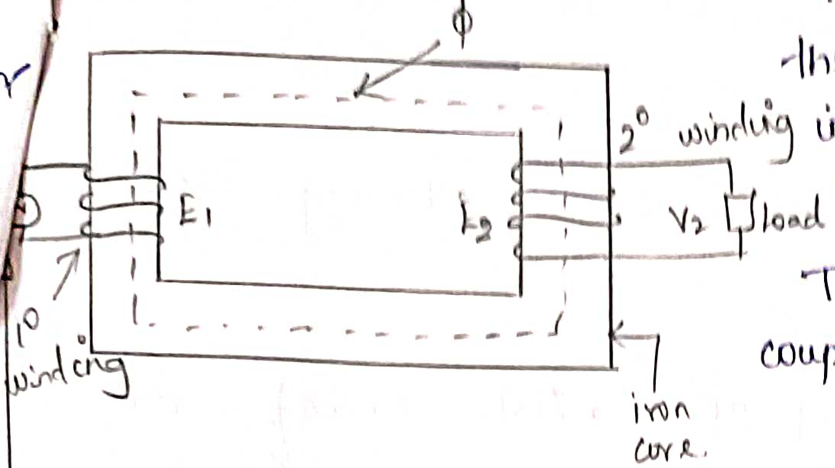


→ There are three limbs in shell type transformer.

→ Both the windings are placed in central limb.

→ The Laminations are of E and I type cores.

WORKING PRINCIPLE OF A TRANSFORMER.



A transformer operates on the principle of mutual inductance b/w two inductively coupled coils.

The two windings are coupled by magnetic induction.

One of the winding called primary is energized by sinusoidal voltage.

The second winding called 2° feeds the load.

The alternating current in the 1° winding set up an alternating flux ϕ in the core.

The 2° winding is linked by most of this flux and emf's are induced in the two windings.

The emf induced in the 2° winding drives current through the load connected to the winding.

"Energy is transferred from the 1° to 2° through the medium of magnetic field".

A transformer is a device that,

transfers electric power from one circuit to another

It does so without changing the frequency

It accomplishes this by electromagnetic Induction (mutual inductance).

CLASSIFICATION OF TRANSFORMER.

It is classified on the basis of

* Construction
  - Core type
  - Shell type
  - Berry type
* Voltage output
  - Step down
  - Step up
  - Auto-transformer.
* Duty they perform.
  - Current transformer
  - Potential
  - Power
* Application
  - Welding transformer
  - Furnace
  - Ratio
* Input supply.
  - Single phase transformer
  - Three phase transformer
* Cooling.
  - Dry type (Air natural or Air blast)
  - Oil immersed transformer.

EQUATION OF A TRANSFORMER.

ϕ = Flux

ϕ_m = Max Value of flux

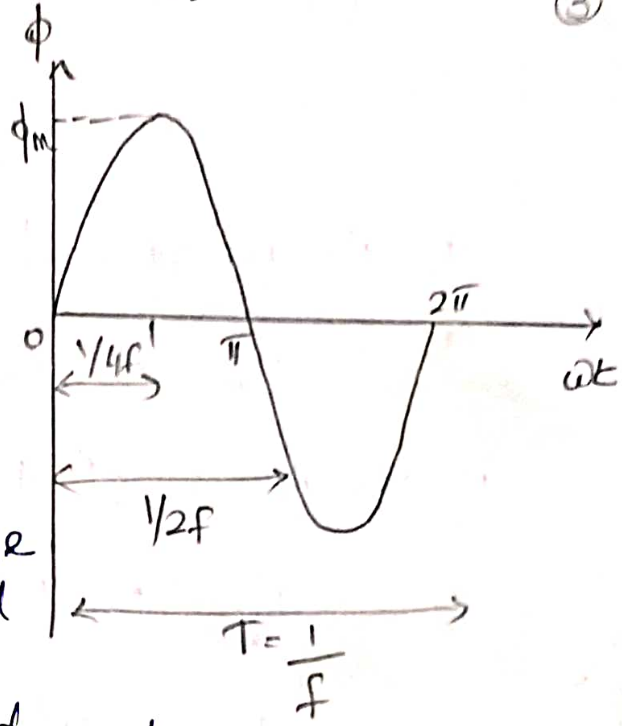
N_1 = No. of 1° turns

N_2 = No. of 2° turns

f = frequency of Supply Voltage

E_1 = RMS Value of 1° induced emf

E_2 = Rms Value of 2° induced emf.



From faraday's law of electromagnetic induction the average emf induced in each turn is ∝ to the average rate of change of flux.

Avg emf per turn = Avg rate of change of flux

$$= \frac{d\phi}{dt}$$

$$\frac{d\phi}{dt} = \frac{\text{change in flux}}{\text{Time required for change in flux}}.$$

$$\frac{d\phi}{dt} = \frac{\phi_m - 0}{\frac{1}{4f}} = 4f\phi_m \text{ wb/sec.}$$

Avg emf per turn = $4f\phi_m$ Volts.

$$\text{Form factor} = \frac{\text{Rms Value}}{\text{Avg Value}} = 1.11$$

RMS Value = 1.11 × Avg Value

$= 1.11 \times 4 f \phi_m = 4.44 f \phi_m.$

If N_1 no. of 1° turns

$$E_1 = N_1 \times 4.44 f \phi_m \text{ Volts.}$$

If N_2 no. of 2° turns

$$E_2 = N_2 \times 4.44 f \phi_m \text{ Volts.}$$

Voltage Transformation Ratio.

It is defined as the ratio of 2° vtg to 1° vtg.

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

$N_2 > N_1$ ie the transformer is called step up.

$N_1 > N_2$ " " " " " " down.

Applications of Transformer.

→ Electrical power engineering for transmission & distribution.

→ As an instrument transformer for measuring current and measuring voltage.

→ As a step down and step up transformer to get reduced or increased output voltage.

→ Radio and TV circuits, telephone circuits., Control & instrumentation circuits.

→ Furnaces and welding transformer.

Losses In a Transformer.

The losses occurring are

* Core (or) Iron loss

* Copper loss.

Iron Loss

It is caused by the alternating flux in the core and consists of hysteresis and eddy current loss. The core flux remains constant for all loads, so it is same for all type of loads.

(hysteresis: reversal of magnetisation; eddy current: change in magnetic field in the conductor)

$$P_h = k_h B_{max} f$$

$$P_e = k_e B_{max}^2 f^2$$

k_h, k_e - Proportionality constant.

B_m - flux density of the core

f - frequency.

..th losses depends upon maximum flux (7)
..ensity and supply frequency.

Hysteresis loss can be minimized by using steel of high silicon content of the core. Eddy current losses can be minimized by using very thin laminations of transformer core.

copper loss.

This loss is due to ohmic resistance of the transformer windings. If I_1, I_2 are 1° & 2° currents and R_1 & R_2 are 1° & 2° resistances, then copper losses will be I^2R.

cu loss at half load = ¼ of full load

$$\text{Total copper loss} = I_1^2 R_1 + I_2^2 R_2.$$

Efficiency of a transformer.

$$\eta = \frac{\text{o/p power}}{\text{i/p power}}$$

$$\eta = \frac{\text{o/p power}}{\text{o/p power} + \text{losses}} = \frac{\text{o/p power}}{\text{o/p power} + \text{iron losses} + \text{copper losses}}$$

$$\text{o/p power} = V_2 I_2 \cos\phi.$$

where

V_2 - 2° Voltage on load

I_2 - 2° current at load

$\cos\phi$ - power factor of the load.

$$\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + P_{cu}}$$

Condition for maximum efficiency.

$$\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + I_2^2 R_2}$$

÷ both num & den by I_2,

$$\eta = \frac{V_2 \cos\phi}{V_2 \cos\phi + \frac{P_i}{I_2} + I_2 R_2} \quad \text{--- (1)}$$

For max. value of efficiency, the denominator must have least value. It can be obtained by differentiating the denominator and equating it to zero.

$$\frac{d}{dI_2} = 0$$

$$\frac{d}{dI_2}\left(V_2 \cos\phi_2 + \frac{P_i}{I_2} + I_2 R_2\right) = 0$$

$$0 - \frac{P_i}{I_2^2} + R_2 = 0$$

$$P_i = I_2^2 R_2 = P_{cu} \quad \text{--- (2)}$$

∴ efficiency of a transformer will be maximum when copper loss = iron loss.

In eq ② Load current can be written as ⑧

$$I_2 = \sqrt{\frac{P_i}{R_2}}$$

If iron loss and copper loss are given, then maximum efficiency

$$= \text{Full load KVA} \times \sqrt{\frac{\text{Iron loss}}{\text{Full load copper loss}}}$$