Single-phase Transformer

Construction

Acknowledgement: *The materials presented in this lecture has been taken from open source, reference books etc. This can be used only for student welfare and academic purpose.*

Recap

- Magnetization curve
- Hysteresis Loop/ B-H Curve
- Magnetic Circuit losses and its types
- Fringing effect and stacking factor
- Properties of magnetic materials

Lecture-4 Objectives

- Transformer definition and its need
- Constructional details
- Its classifications and applications
- Its cooling
- Induced EMF in secondary and primary winding

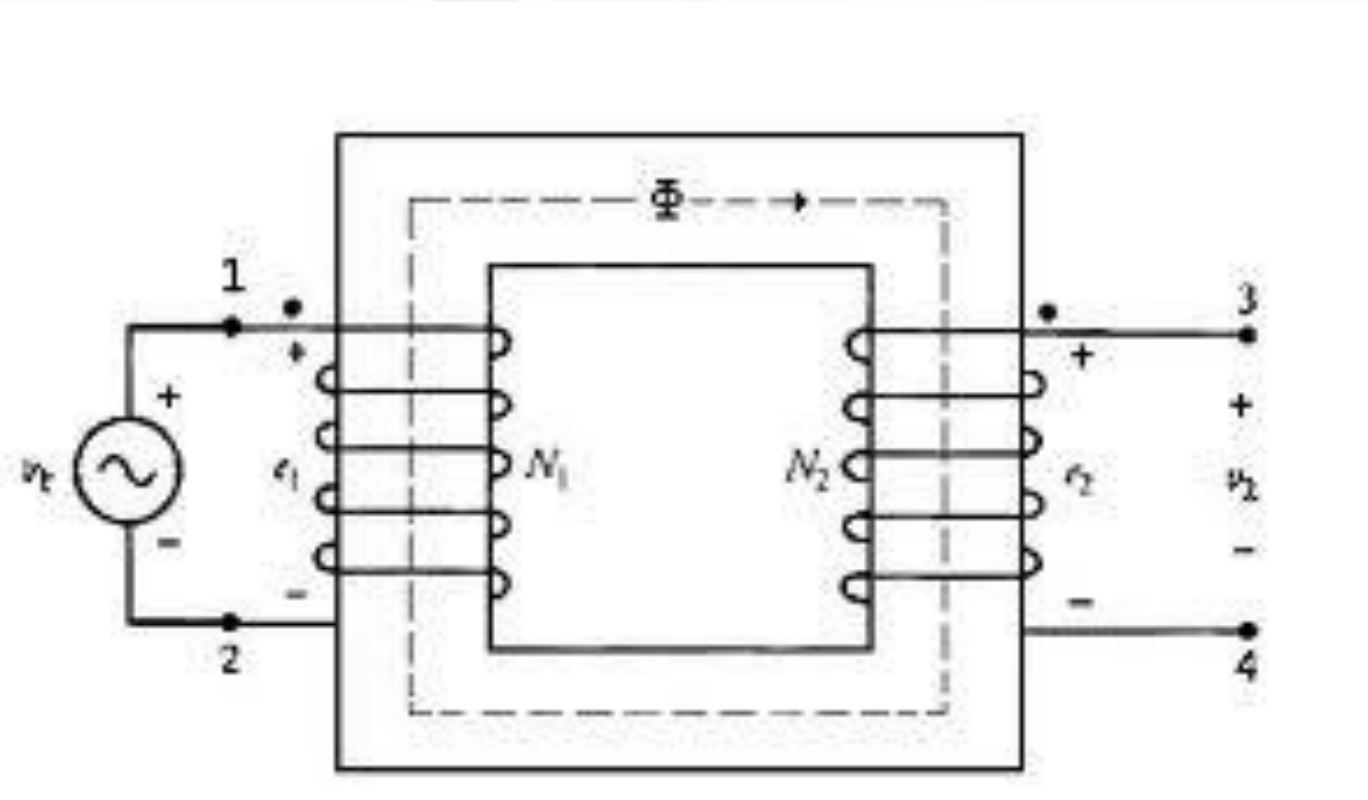
What is a Transformer?

- A transformer is a static electrical machine which transfers electrical energy from one circuit to another without changing the frequency.
- A transformer is a static electrical machine which raises or lowers voltage or current at the same frequency.
- It works on the principle of MUTUAL INDUCTION.

Transformer

- It consists of two windings insulated from each other and wound on a common core made up of a magnetic material.
- AC voltage is connected across one of the windings called primary winding.
- Load is connected to the other winding called the secondary winding.
- In both windings, EMF is induced by electromagnetic induction.

Single-phase Transformer Construction



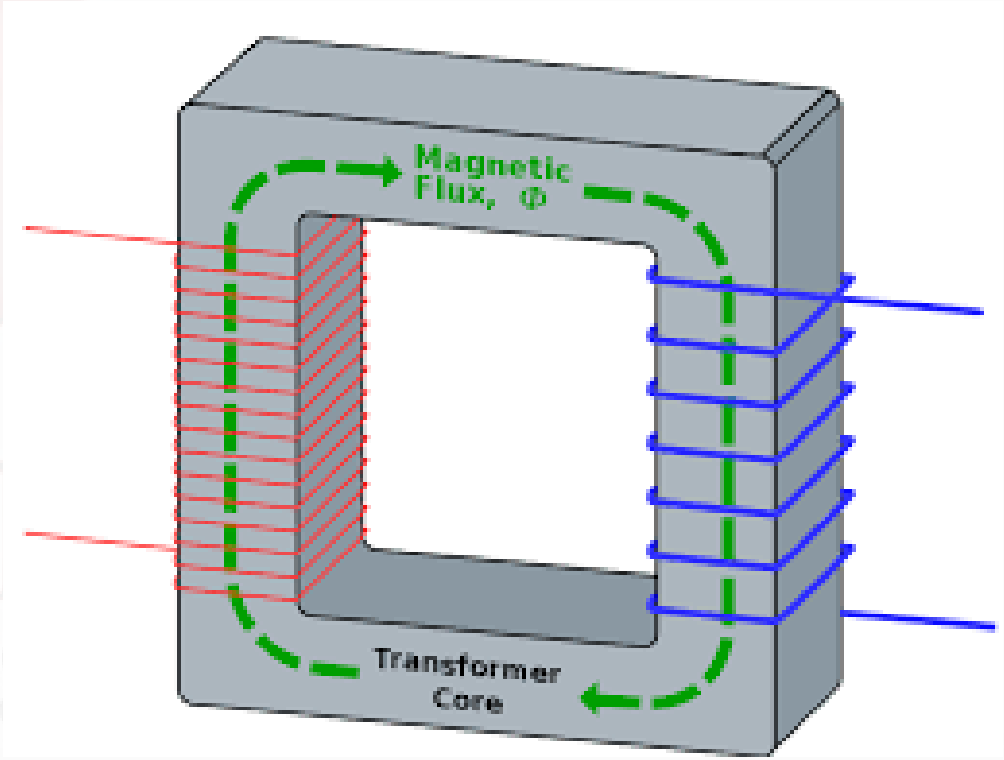
Single-phase Transformer Construction

Constructional details

- Main Components of a Transformer are,
  - Magnetic core
  - Primary & Secondary windings
  - Insulation of windings
  - Conservator tank & Explosion vent
  - Bushings
  - Buchholz relay
  - Breather
  - Cooling arrangements

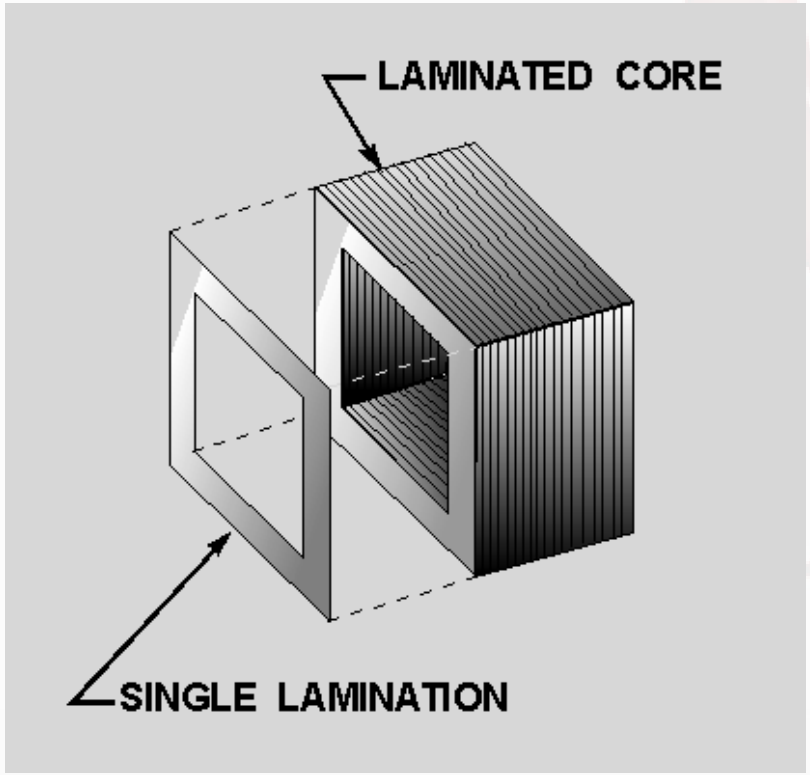
Magnetic Core

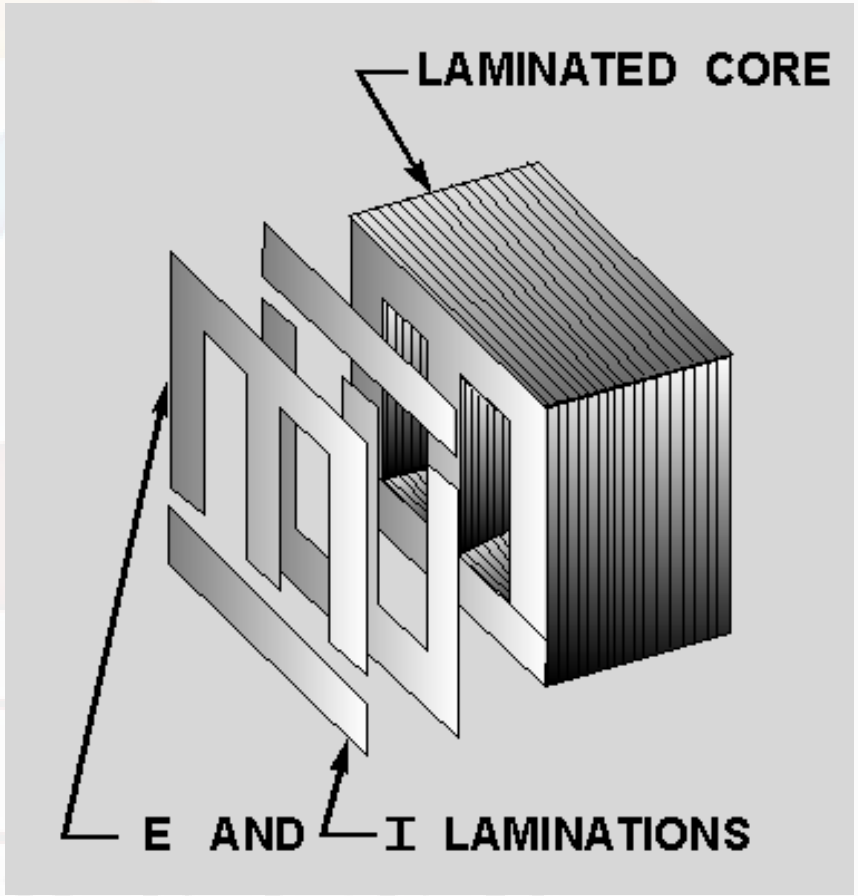
- Magnetic circuit consists of an iron core.
- Core is made up of stacks of thin laminations (0.35mm thickness) of **C**old **R**olled **G**rain **O**riented (CRGO) silicon steel.
- These laminations are lightly insulated with varnish.
- Two types of magnetic circuit are core type and shell type.



Single-phase Transformer Construction

Magnetic Core

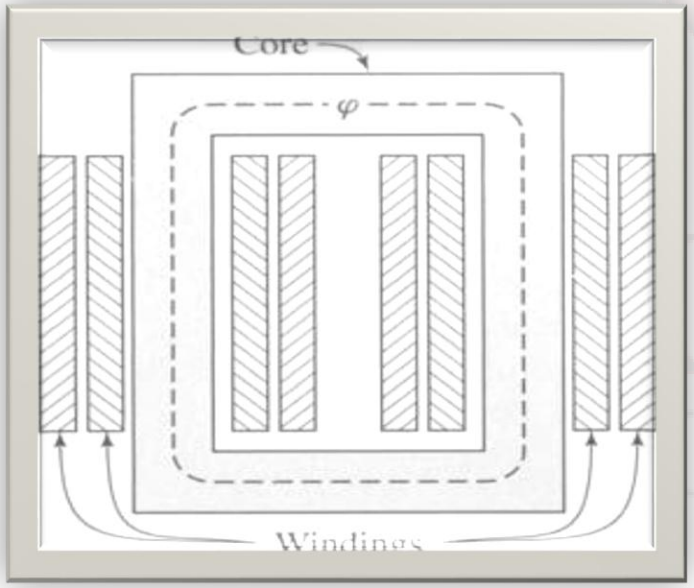


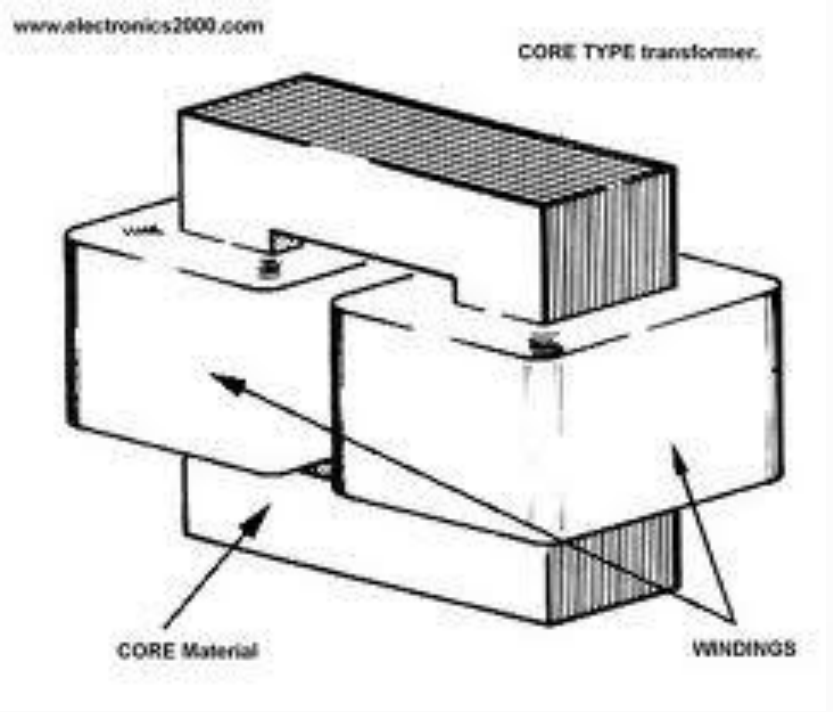


Single-phase Transformer Construction

Core type construction

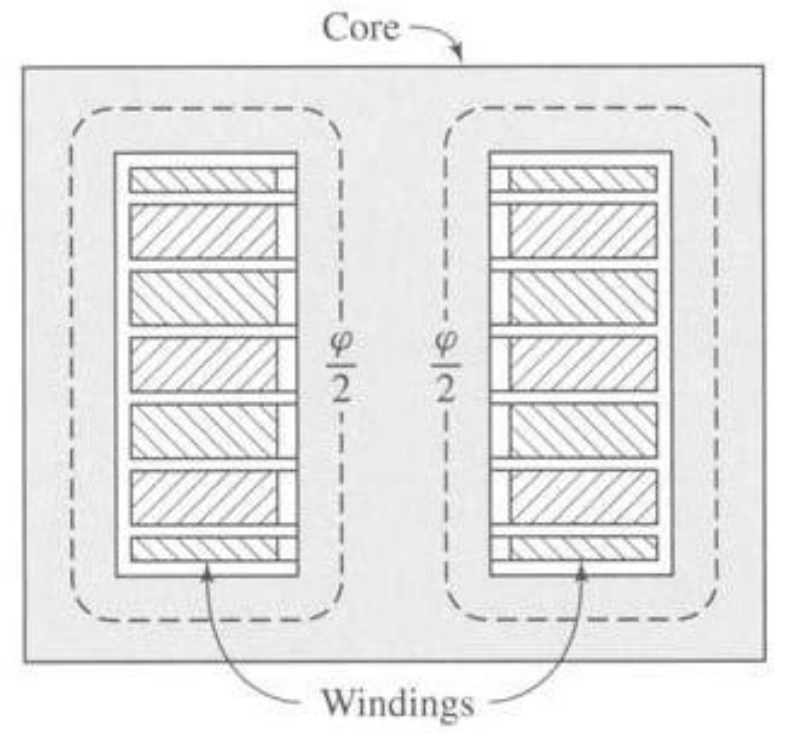
- In the *core type*, the windings are wound around two legs of a rectangular magnetic core.
- Windings surround the core & it has only one magnetic path.

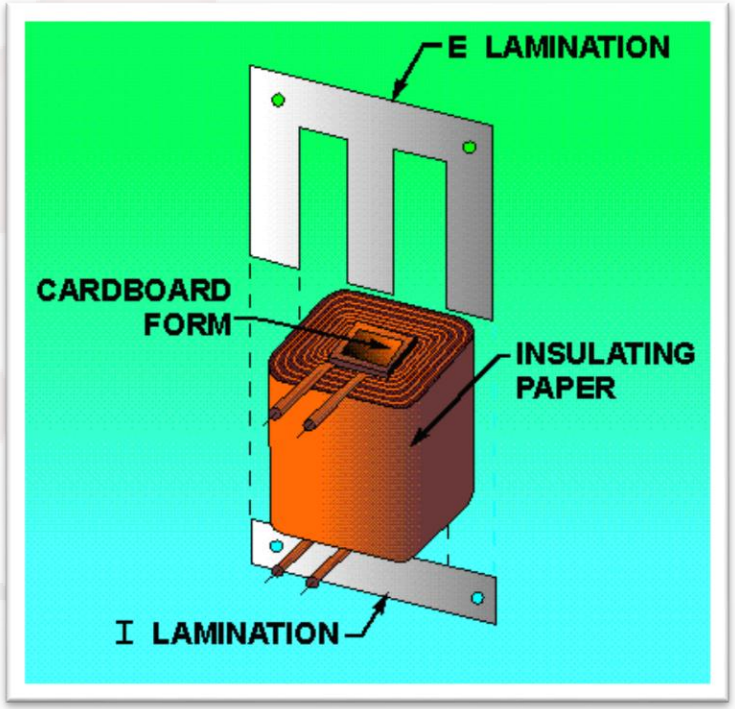




Shell type construction

- In shell type, the windings are wound around the center leg of a three-legged core
- Core surrounds the windings.





Windings

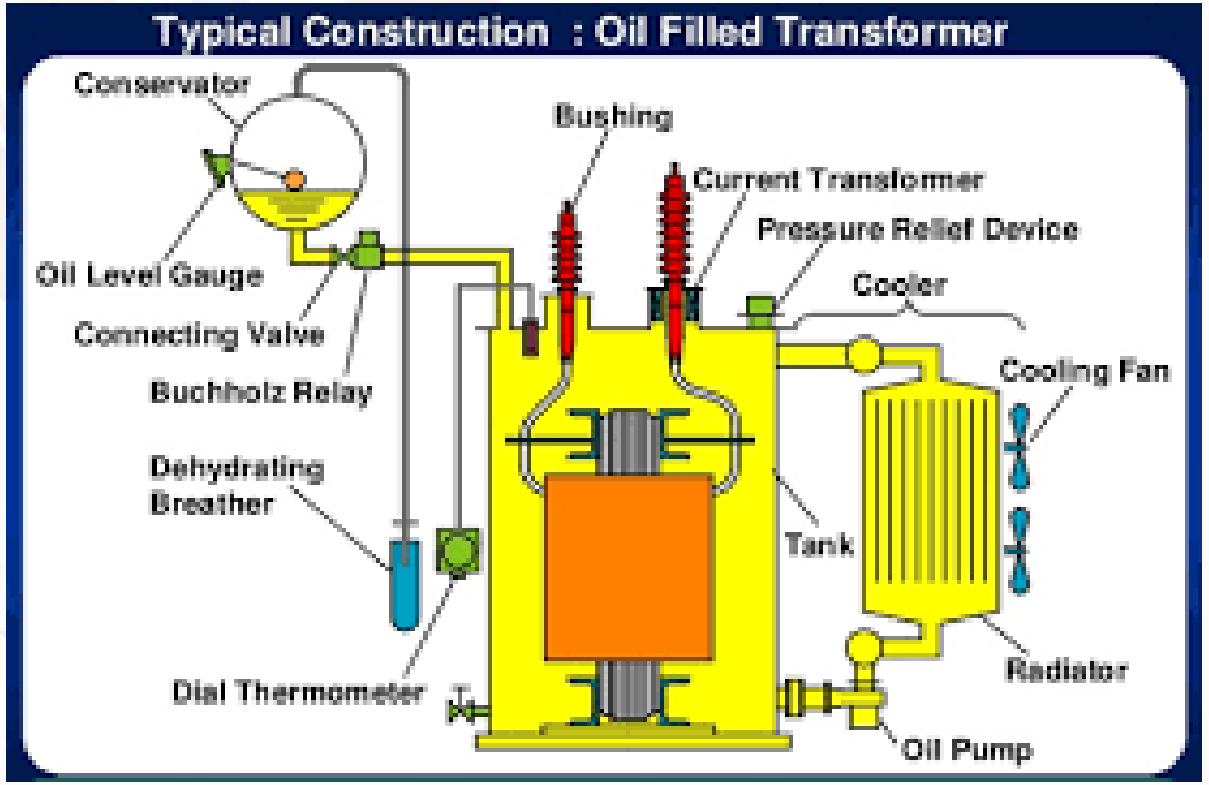
- A transformer has two windings namely primary and secondary.
- These windings consist of a series of turns called coils, wound around the core.
- Transformer windings are made of solid or stranded copper or aluminium strip conductors.

Conservator and Explosion Vent

- Conservator is used to provide adequate space for the expansion of oil when transformer is loaded or when ambient temperature changes.
- Explosion Vent is used to discharge excess pressure developed inside the transformer during loading, to the atmosphere.

Breather

- It sucks the moisture from the air which is taken by transformer so that dry air is taken by transformer.



Single-phase Transformer Construction

Bushings

- Transformers are connected to high voltage lines.
- Extreme care should be taken to prevent the conductors touching the transformer tank.
- So the connections in and out of the transformer are made by the use of bushings.
- Bushings are normally porcelain insulators.

Buchholz Relay

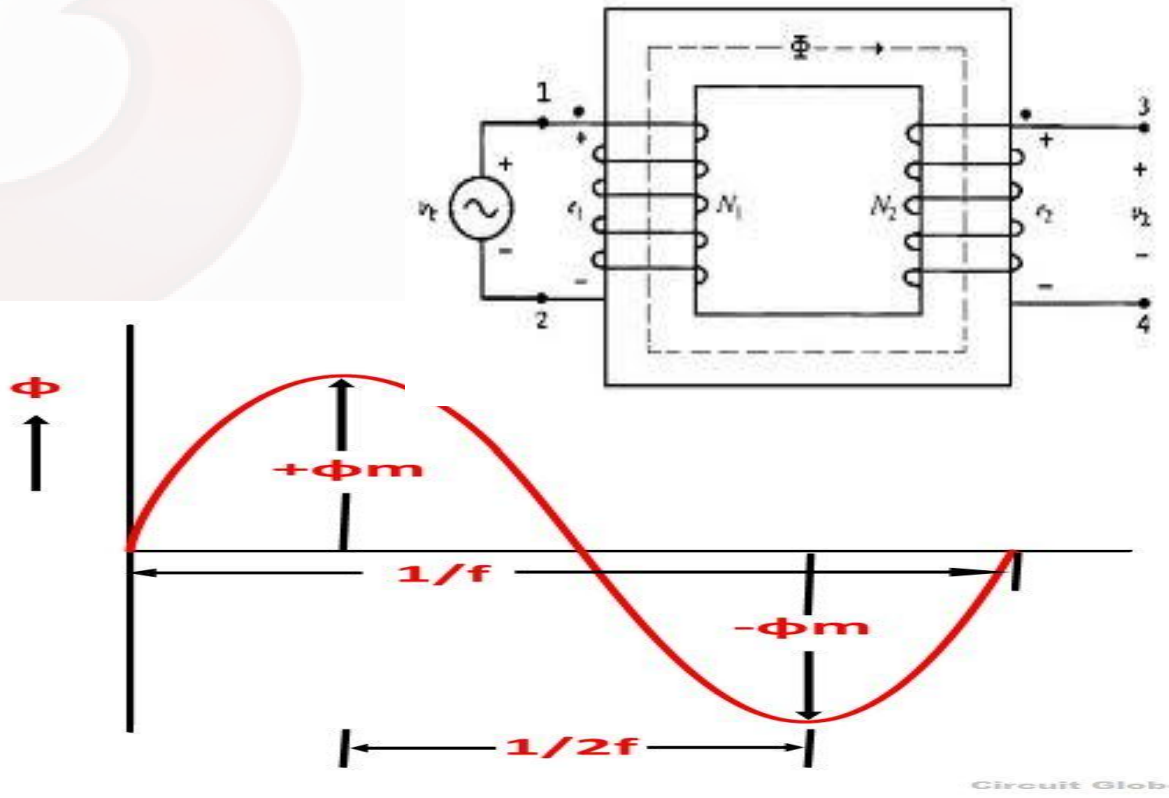
- It is a safety device connected between main tank and conservator tank.
- In case of slow developing faults, it sounds an alarm to alert the operator.
- If serious fault occur in the transformer, it disconnects the transformer to protect it.

Methods of Cooling of Transformers

- Air natural
- Air Blast
- Oil natural
- Oil blast
- Forced circulation of oil
- Oil and water cooled
- Forced oil and water cooled

EMF Equation of a Transformer

- When a sinusoidal voltage is applied to the primary winding of a transformer, alternating flux ϕ_m sets up in the iron core of the transformer. This sinusoidal flux links with both primary and secondary winding. The function of flux is a sine function.
- ϕ_m be the maximum value of flux in Weber
- f be the supply frequency in Hz
- N_1 is the number of turns in the primary winding
- N_2 is the number of turns in the secondary winding
- Φ is the flux per turn in Weber
- As shown in the above figure that the flux changes from + ϕ_m to – ϕ_m in half a cycle of 1/2f seconds.



Single-phase Transformer Construction

- By Faraday's Law $E_1 = -\frac{d\psi}{dt} \ldots\ldots\ldots (1)$
- Let E_1 be the emf induced in Therefore, $E_1 = -N_1 \frac{d\varphi}{dt}$ .....(2)

Where $\Psi = N_1\phi$,

Since ϕ is due to AC supply $\phi = \phi_m \text{Sin}(wt)$

$$E_1 = -N_1 \frac{d}{dt} (\varphi_m \text{Sin}wt)$$

$$E_1 = -N_1 w\varphi_m \text{Cos}wt$$

$$E_1 = N_1 w\varphi_m \text{Sin}(wt - \pi/2) \ldots\ldots\ldots (3)$$

So the induced emf lags flux by 90 degrees.

Maximum valve of emf

$$E_1 max = N_1 w\varphi_m \ldots\ldots\ldots (4)$$

But $w = 2\pi f$

$$E_1 max = 2\pi f N_1 \varphi_m \ldots\ldots\ldots (5)$$

Single-phase Transformer Construction

- Root mean square RMS value is

$$E_1 = \frac{E_{1max}}{\sqrt{2}} \ldots\ldots\ldots (6)$$

- Putting the value of E_1max in equation (6) we get

$$E_1 = \sqrt{2}\pi f N_1 \varphi_m \ldots\ldots\ldots (7)$$

- Putting the value of $\pi = 3.14$ in the equation (7) we will get the value of E_1 as

$$E_1 = 4.44 f N_1 \varphi_m \ldots\ldots\ldots (8)$$

- Similarly

$$E_2 = \sqrt{2}\pi f N_2 \varphi_m$$

Or

$$E_2 = 4.44 f N_2 \varphi_m \ldots\ldots\ldots (9)$$

- Now, equating the equation (8) and (9) we get

$$\frac{E_2}{E_1} = \frac{4.44 f N_2 \varphi_m}{4.44 f N_1 \varphi_m}$$

Or

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

- Where, term K is called turn ratio.

Single-phase Transformer Construction

Summary

- Transformer definition and its need
- Constructional details
- Its classifications and applications
- Its cooling
- Induced EMF in secondary and primary winding