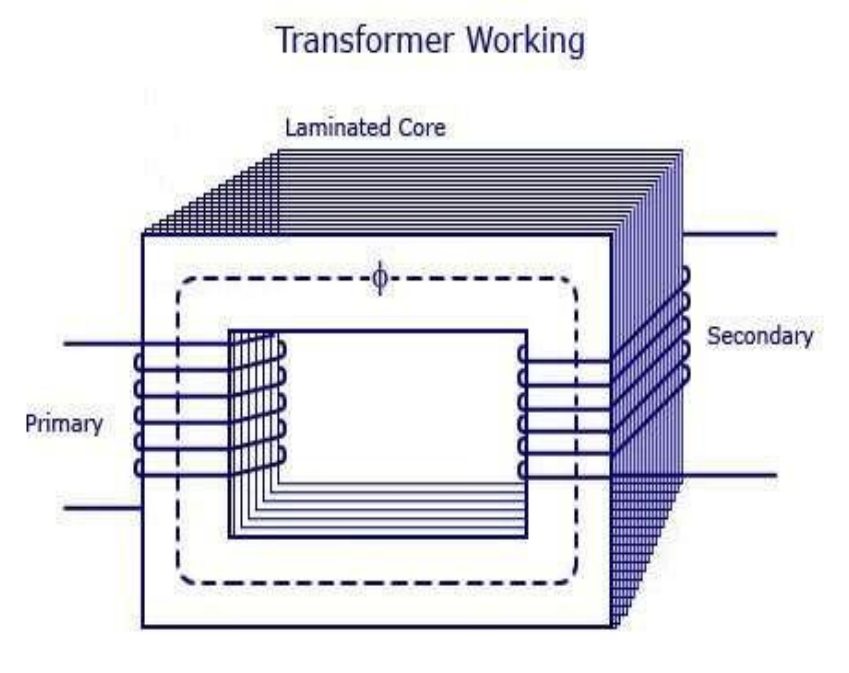
TRANSFORMER

Transformer

- A transformer is a static device.
- The word ‘transformer’ comes form the word ‘transform’.
- Transformer is not an energy conversion device, but it is device that changes AC electrical power at one voltage level into AC electrical power at another voltage level through the action of magnetic field but with a proportional increase or decrease in the current ratings., without a change in frequency.
- It can be either to step-up or step down.

Principle

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below



As shown above the transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips you can see that there are some narrow gaps right through the cross-section of the core. These staggered joints are said to be 'imbricated'. Both the coils have high mutual inductance. A mutual electro-motive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage. Most of the alternating flux developed by this coil is linked with the other coil and thus produces the mutual induced electro-motive force. The so produced electro-motive force can be explained with the help of Faraday's laws of Electromagnetic Induction as

$$e=M*dI/dt$$

If the second coil circuit is closed, a current flows in it and thus electrical energy is transferred magnetically from the first to the second coil.

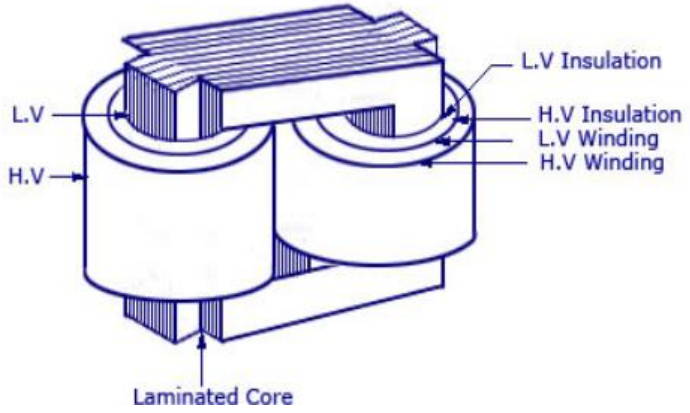
The alternating current supply is given to the first coil and hence it can be called as the primary winding. The energy is drawn out from the second coil and thus can be called as the secondary winding.

In short, a transformer carries the operations shown below:

- Transfer of electric power from one circuit to another.
- Transfer of electric power without any change in frequency.
- Transfer with the principle of electromagnetic induction.
- The two electrical circuits are linked by mutual induction.

Transformer Construction

A transformer consists of two inductive windings and a laminated steel core. The coils are insulated from each other as well as from the steel core. A transformer may also consist of a container for winding and core assembly (called as tank), suitable bushings to take out the terminals, oil conservator to provide oil in the transformer tank for cooling purposes. And all types of transformers, core is constructed by assembling (stacking) laminated sheets of steel, with minimum air-gap between them (to achieve continuous magnetic path). The steel used is having high silicon content and sometimes heat treated, to provide high permeability and low hysteresis loss. Laminated sheets of steel are used to reduce eddy current loss. The sheets are cut in the shape as E, I and L. To avoid high reluctance at joints, laminations are stacked by alternating the sides of joint.



Classification of Transformer

- **As per phase**

1. **Single phase**
2. **Three phase**

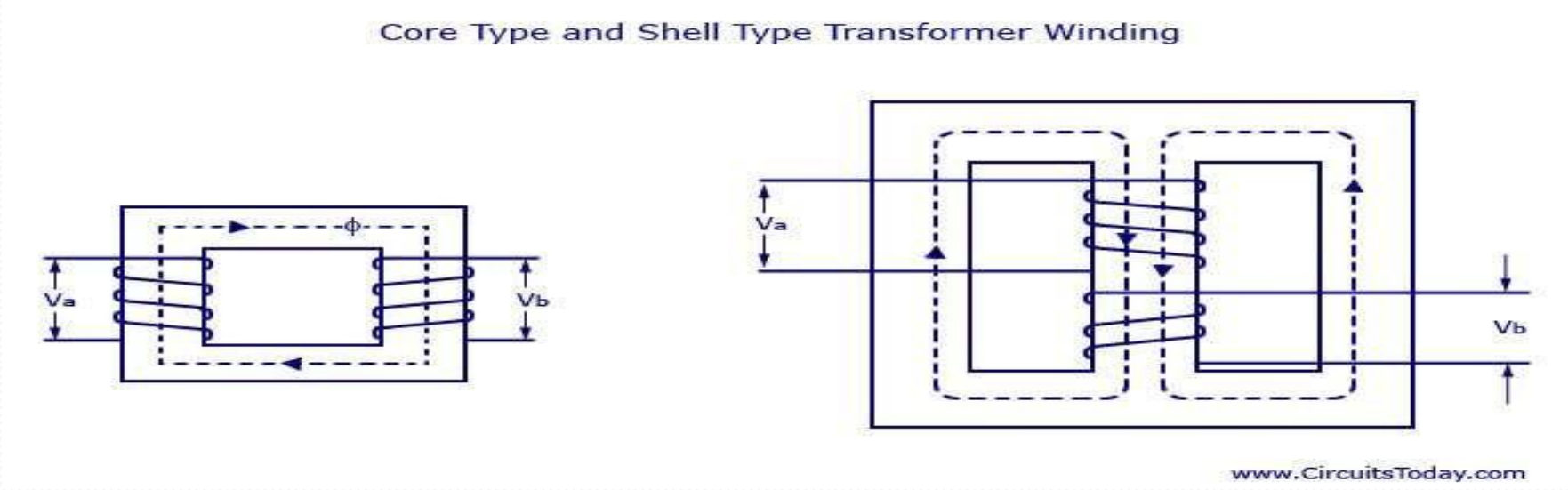
- **As per core**

1. **Core type**
2. **Shell type**

Transformer Classified as per Core

CORE TYPE & SHELL TYPE TRANSFORMER

The core-type transformer has two limbs, whereas the shell type transformer has three limbs. In core type transformer, both the primary and secondary windings are placed on the side limbs whereas in shell type transformer, the windings are placed on the central limbs on the transformer.



Transformer Classified as per Phase

Single Phase Transformer

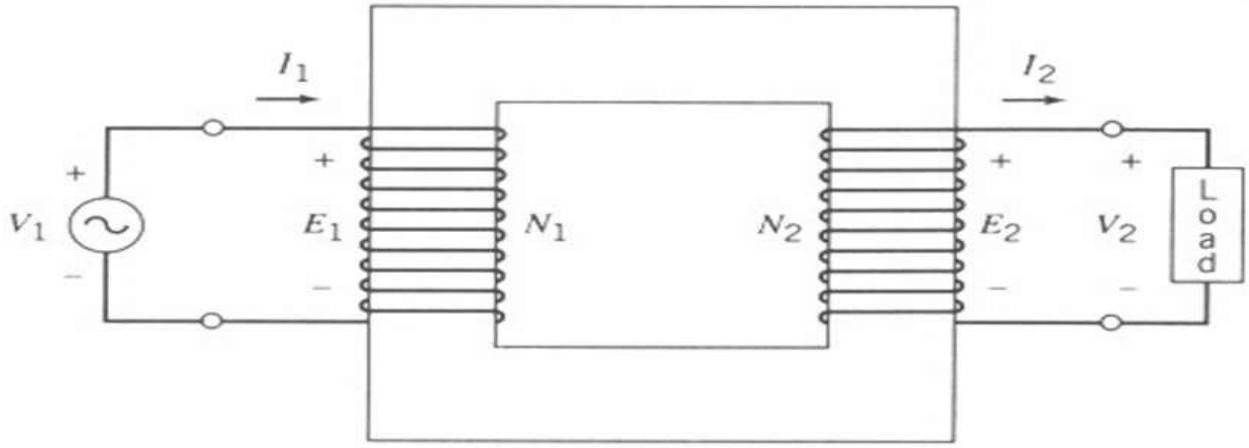
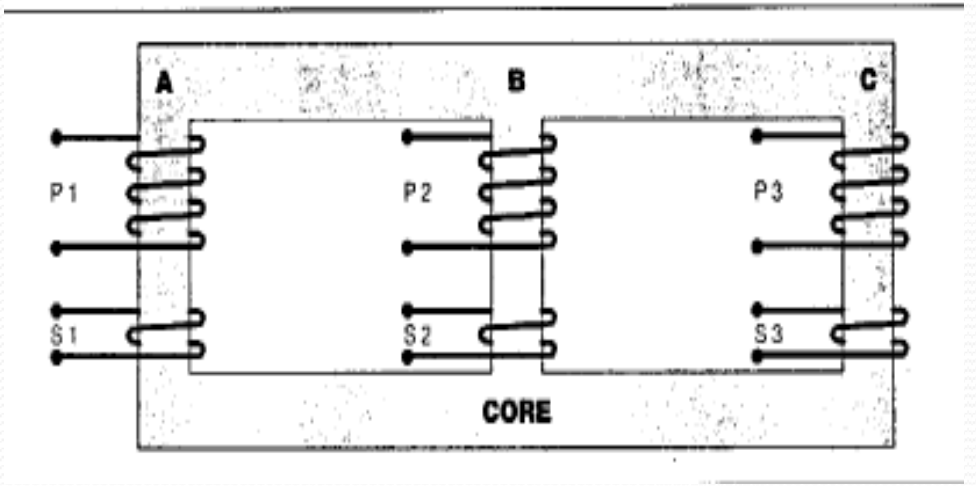


FIGURE 4.8 A transformer circuit.

- A single phase transformer
  - Two or more winding, coupled by a common magnetic core

Three Phase Transformer



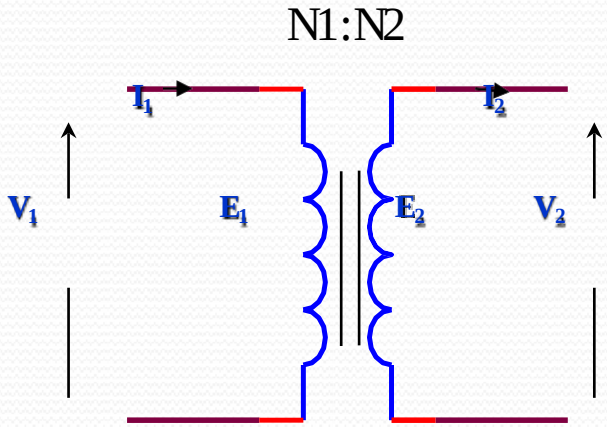
Normally , when three-phase is required, a single enclosure with three primary and three secondary windings wound on a common core is all that is required. However three single-phase transformers with the same rating can be connected to form a three-phase bank. Since each single-phase transformer has a primary and a secondary winding, then 3 single-phase transformers will have the required 3 primary and 3 secondary windings and can be connected in the field either Delta-Delta or Delta-Wye to achieve the required three-phased transformer bank

Ideal Transformer

An ideal transformer is a transformer which has no losses, i.e. it's winding has no ohmic resistance, no magnetic leakage, and therefore no $I^2 R$ and core loses.

However, it is impossible to realize such a transformer in practice.

Yet, the approximate characteristic of ideal transformer will be used in characterized the practical transformer.



V1 – Primary Voltage
V2 – Secondary Voltage
E1 – Primary induced Voltage
E2 – secondary induced Voltage
N1:N2 – Transformer ratio

Transformer Losses

Generally, there are two types of losses;

i. Iron losses :- occur in core parameters

ii. Copper losses :- occur in winding resistance

i. Iron Losses

$$P_{iron} = P_c = (I_c)^2 R_c = P_{opencircuit}$$

ii Copper Losses

$$P_{copper} = P_{cu} = (I_1)^2 R_1 + (I_2)^2 R_2 = P_{short\ circuit}$$

$$or\ if\ referred, P_{cu} = (I_1)^2 R_{01} = (I_2)^2 R_{02}$$

Transformer Efficiency

- The Efficiency of the transformer is defined as the ratio of output power to the input power. Its unit is either in Watts (W) or KW. Transformer efficiency is denoted by η.
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$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\text{output power}}{\text{output power + losses}}$$

$$\eta = \frac{\text{output power}}{\text{output power + iron losses + copper losses}}$$

$$\eta = \frac{V_2 I_2 \text{Cos}\varphi_2}{V_2 I_2 \text{Cos}\varphi_2 + P_i + P_c}$$

Where,

V_2 – Secondary terminal voltage

I_2 – Full load secondary current

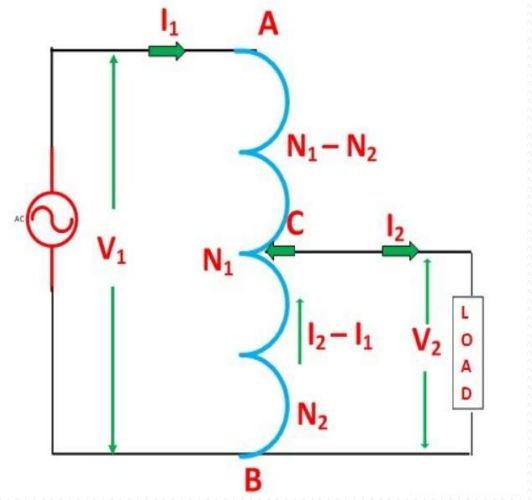
$\text{Cos}\varphi_2$ – power factor of the load

P_i – Iron losses = hysteresis losses + eddy current losses

P_c – Full load copper losses = I_2^2Res

Auto Transformer

An Auto Transformer is a transformer with only one winding wound on a laminated core. An auto transformer is similar to a two winding transformer but differ in the way the primary and secondary winding are interrelated. A part of the winding is common to both primary and secondary sides. On load condition, a part of the load current is obtained directly from the supply and the remaining part is obtained by transformer action. An Auto transformer works as a voltage regulator.



Three Phase Transformer Connections

1.Star-Star connected transformers.
2.Delta-Delta connected transformers.
3.Star-Delta connected transformers.
4. Delta-Star connected transformers.