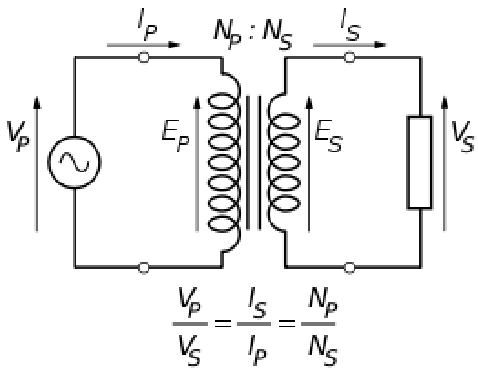
CHAPTER 4 TRANSFORMER

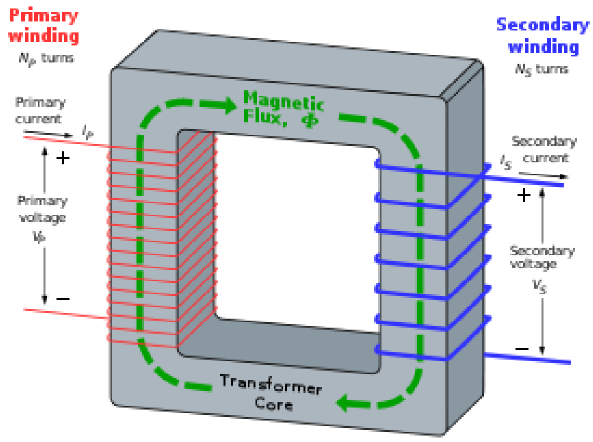
Introduction

Transformer is the most efficient static device among all electrical machines. It has no moving parts, rugged and durable in construction. It has very high efficiency and only used for AC applications.

Definition:

Transformer is a static device which transfers the electrical power from one circuit to another inductively without change of frequency. It works on the principle of mutual induction.





Principle of operation

A transformer works on the principle of mutual induction. It has two windings primary and secondary, wound on the same laminated iron core as shown in fig. An AC voltage is applied to the primary winding. In an ideal transformer (without losses) the primary acts like a pure inductance and draws a current lagging behind the applied voltage by 90^0. This current sets up an alternating flux in the core. This flux links both the primary and secondary windings. Thus the flux linking with the secondary changes with time and hence an emf is induced in the secondary of the transformer. This is the principle of operation of a transformer on no load. If a load is connected to the secondary, a current flows both in the primary and secondary and power is transferred from primary to secondary.

Transformer on load

When an ac source V1 (RMS value) is applied to the primary an EMF E1 is induced in the primary by the alternating flux Φ set up in the core. By Lenz's law E1 should be equal and opposite to V1. Hence as long as V1 is constant

Construction of a transformer

1. Core
2. Windings
3. Transformer tank
4. Bushings
5. Relay

Core:

Core of a transformer is made up of grain oriented silicon steel laminations or nickel alloy laminations. The thickness of the lamination is 0.3 to 0.6 mm each insulated with varnish / enamel or oxide film. These laminations are tightly stacked together to form the core of the required thickness. The purpose of using laminations is to reduce eddy current loss. The use of silicon steel in the core is to reduce the hysteresis loss.

Windings of transformer:

The limbs of the transformer are wound with the windings. The primary and the secondary windings are made of copper . The primary winding is connected to the ac supply and the secondary connected to the load. The conductors can be circular, square or flat in cross section.

Transformer tank

The core is wound with the windings and the entire setup is placed inside the transformer tank. The transformer tank houses the transformer and the transformer oil. The tank also protects the transformer from dust, dirt and the mechanical damages. The cooling of the windings is done by the transformer oil. There are several ways of cooling like forced air cooling, forced oil cooling , air cooling etc. The cooling exchanges the heat generated from the winding to the surrounding medium.

Bushings:

The windings of the transformers place inside the transformer tank are taken outside through ceramic bushings for the external connections.

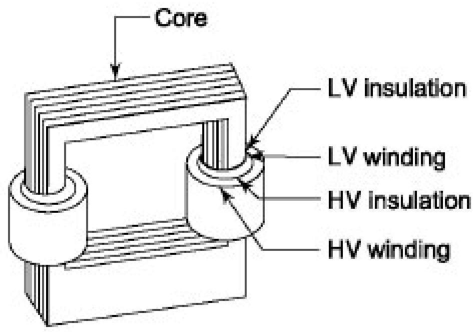
Relay:

The oil level reduces due to the heat generated in the winding; a particular level is maintained using relays.

Types of the Transformer:

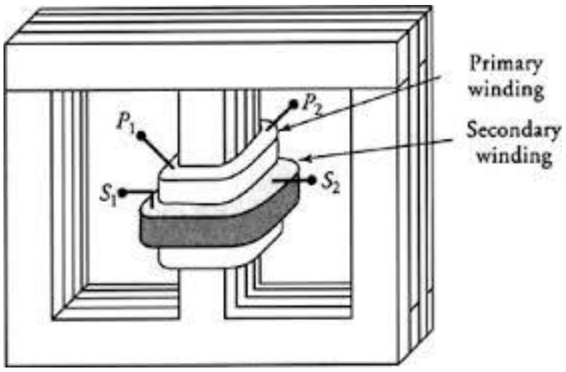
1) Core type of transformer:

In core type a large part of core is surrounded by the windings. Primary and secondary windings are wound on opposite limbs The coils used are of cylindrical type and are form wound in Helical layers. In general coils may be circular or oval or rectangular. Usually half of the primary and half the secondary windings are placed side by side on each limb so as to reduce the leakage flux. The layers are insulated from each other

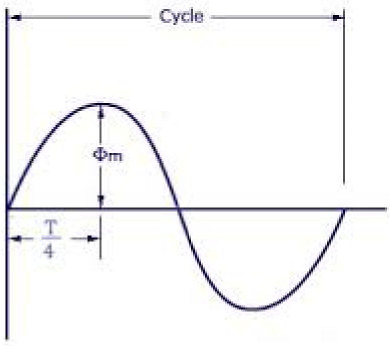


2) Shell type of transformer

In shell type both the primary and secondary winding are placed on the central limb. The coils are wound to form layer.



Derivation for the EMF equation



Let N_1 = No. of turns in primary
N_2 = No. of turns in secondary
Φ_m = Maximum flux in core in webers = B_m x A
f = Frequency of a.c. input in Hz.

Since Φ is due to AC supply $\Phi = \Phi_m \text{Sin}(wt)$

The flux increases from it's zero value to maximum value Φ_m in one quarter of the cycle i.e. in 1/4 f second.
The average value of emf /turn = rate of change of flux linkage
The average value of emf /turn = $(\Phi_m - 0) / T/4$
$= 4 \Phi_m f$
Therefore, r.m.s value of e.m.f./turn = $4.44 \Phi_m f$ volts
Now, r.m.s value of induced e.m.f in the whole primary winding
= (induced e.m.f. / turn) x No. of primary winding

$E_1 = 4.44 f N_1 \Phi_m$ ------------------- (i)

Similarly, r.m.s. value of e.m.f. induced in secondary is,

$E_2 = 4.44 f N_2 \Phi_m$ ------------------- (ii)