ASSIGNMENT NO 2

PARTH JOHRI

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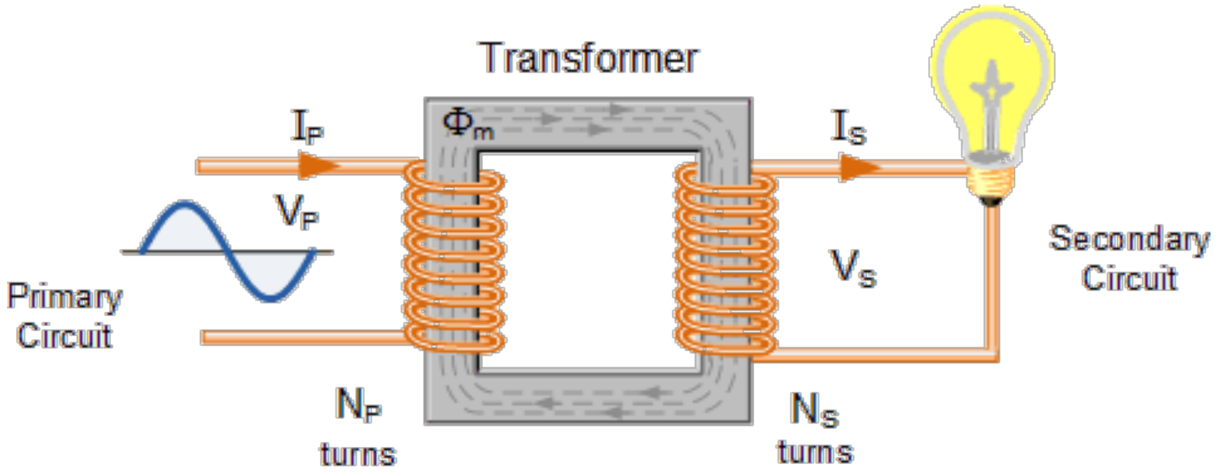
SINGLE PHASE TRANSFORMER



A single-phase transformer is a type of power transformer that utilizes single-phase alternating current, meaning the transformer relies on a voltage cycle that operates in a unified time phase.

EMS is used to study a single-phase transformer. AC Magnetic module of **EMS** coupled to thermal solver both are utilized to compute and generate magnetic fields, electromagnetic losses including *core loss*, excess *loss*, *hysteresis loss*, *eddy loss*, and temperature evolution of the studied transformer.

SOLIDWORKS model of a Single-phase transformer

The model of a single-phase transformer consists of a *core, an inner coil and an outer coil*.

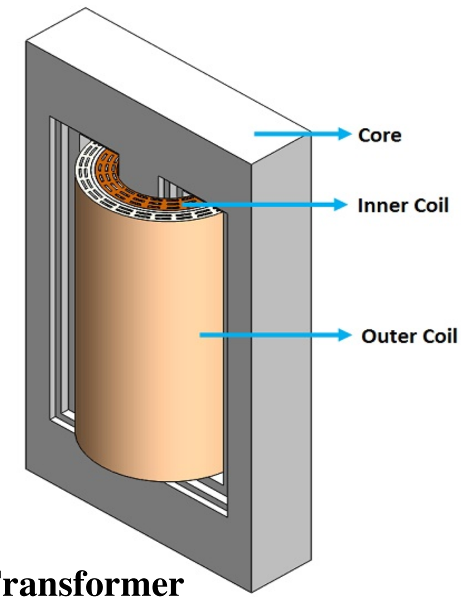


Figure 1 - 3D model of a Single phase Transformer

Construction of Single Phase Transformer

A simple single-phase transformer has each winding being wound cylindrically on a soft iron limb separately to provide a necessary magnetic circuit, which is commonly referred to as **"transformer core"**. It offers a path for the flow of the magnetic field to induce voltage between two windings.

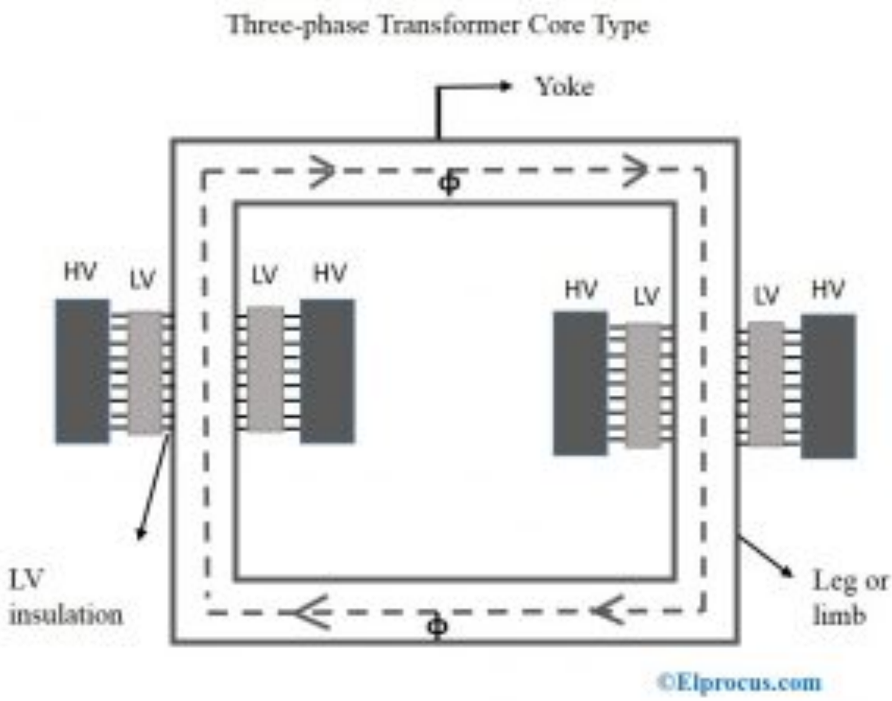
As seen in the figure above, the two windings are not close enough to have an efficient magnetic coupling. Thus, converging and increasing the magnetic circuit near the coils can enhance the magnetic coupling between primary and secondary windings. Thin steel laminations shall be employed to prevent power losses from the core.

Based on how the windings are wound around the central steel laminated core, the transformer construction is divided into two types

Core-type Transformer

In this type of construction, only half of the windings are wound cylindrically around each leg of a transformer to enhance magnetic coupling as shown in the figure below. This type of construction ensures that magnetic lines of force flow across both the windings simultaneously. The main disadvantage of the core-type transformer is the leakage flux that occurs due to the flow of a small proportion of magnetic lines of force outside the core.

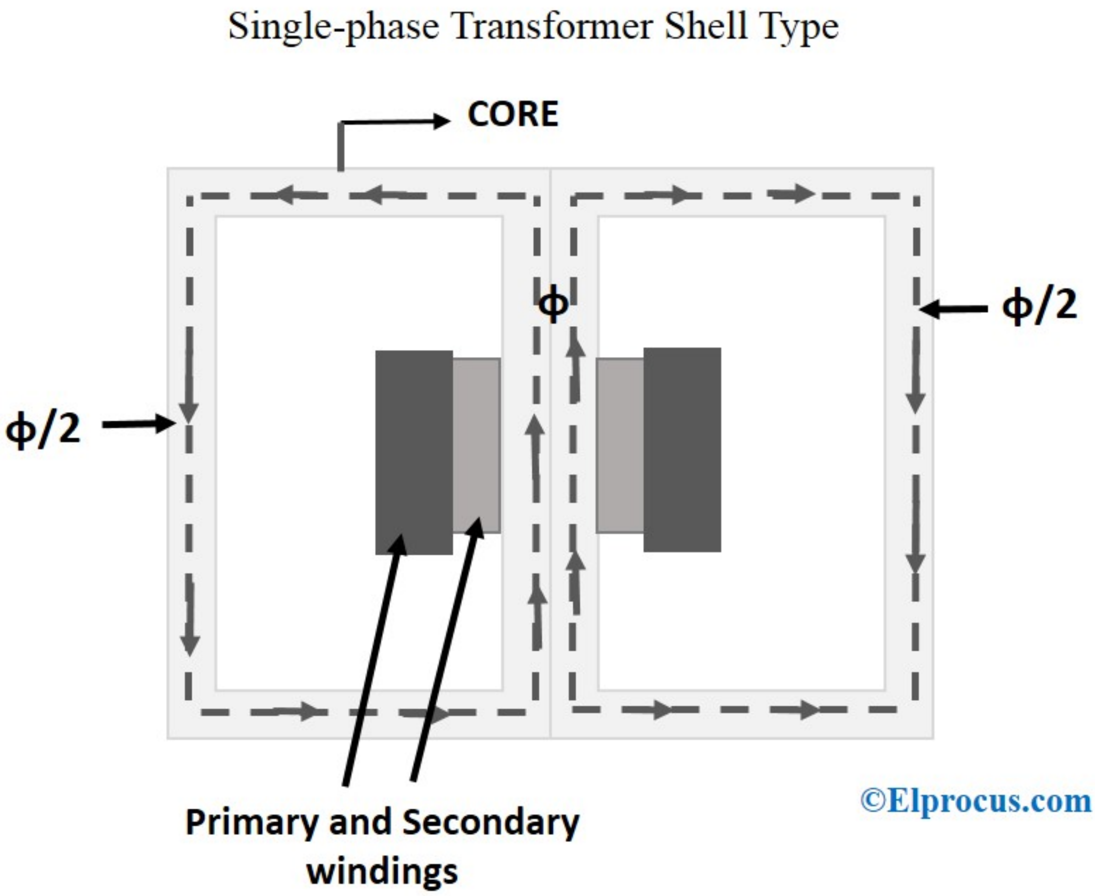
Single-phase Transformer Core-type



Shell-type Transformer
In this type of transformer construction, the primary and secondary windings are positioned cylindrically on the center limb resulting in twice the cross-sectional area than the outer limbs.

There are two closed magnetic paths in this type of construction and the outer limb has the magnetic flux **ϕ/2** flowing.

Shell type transformer overcomes *leakage flux*, reduces *core losses* and ***increases*** *efficiency*.



Principle of Single Phase Transformer

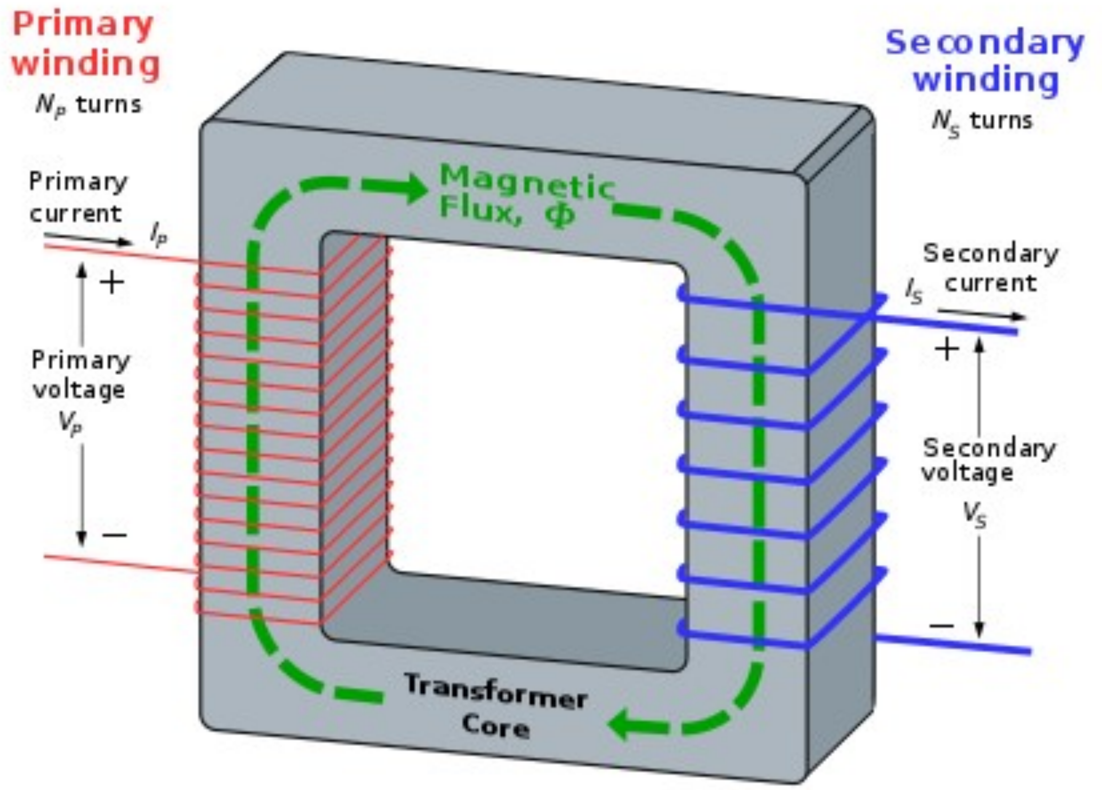
The single-phase transformer works on the principle of Faraday's Law of Electromagnetic Induction. Typically, mutual induction between primary and secondary windings is responsible for the transformer operation in an electrical transformer.

Working of Single Phase Transformer

A **transformer** is a static device that transfers electric power in one circuit to another circuit of the same frequency. It consists of *primary* and *secondary* windings.

This **transformer** operates on the principle of **mutual inductance**.
When the primary of a transformer is connected to an AC supply, the current flows in the coil and the magnetic field build-up. This condition is known as mutual inductance and the flow of current is as per the ***Faraday's Law of electromagnetic induction.*** As the current increases from **zero** to its **maximum** value, the magnetic field strengthens and is given by **dϕ/dt.**

This **electromagnet** forms the magnetic lines of force and expands outward from the coil forming a path of magnetic flux. The turns of both windings get linked by this magnetic flux. The strength of a magnetic field generated in the core depends on the number of turns in the winding and the amount of current. *The **magnetic flux** and **current** are **directly proportional** to each other.*



As the magnetic lines of flux flow around the core, it passes through the secondary winding, inducing voltage across it.
The **Faraday's Law** is used to determine the voltage induced across the secondary coil and it is given by:

$$N. d\phi/dt$$

where,

'**N**' is the number of coil turns

The **frequency** is the **same** in **primary** and **secondary windings**.

Thus, we can say that the voltage induced is the same in both the windings as the same magnetic flux links both the coils together.

Also, the total voltage induced is **directly proportional** to the number of turns in the coil.

Let us assume that the **primary** and **secondary** windings of the transformer have single turns on each. Assuming no losses, the current flows through the coil to produce magnetic flux and induce voltage of one volt across the secondary.

Due to AC supply, magnetic flux varies sinusoidally and it is given by,

$$\boldsymbol{\phi = \phi_{max} \sin \omega t}$$

The relationship between the induced emf, E in the coil windings of N turns is given by,

$$\mathbf{E} = N*(d\phi)/dt$$

$$\mathbf{E} = N*\omega*\phi_{max}*\cos\omega t\phi$$

$$\mathbf{Emax} = N*\omega*\phi_{max}$$

$$\mathbf{Erms} = N*\omega/\sqrt{2}*\phi_{max}=2*\pi/(\sqrt{2}*f*N*\phi_{max})$$

$$\mathbf{Erms} = 4.44*f*N*\phi_{max}$$

Where,

'**f**' is the frequency in **Hertz**, given by **ω/2π.**

'**N**' is the number of coil windings

'**ϕ**' is s the amount of flux in **Weber**

The above equation is the **Transformer EMF Equation**.

For emf of a primary winding of a transformer **E**,

N will be the number of primary turns (**NP**),

while for the emf,

E of a secondary winding of a transformer,

the number of turns, **N** will be (**NS**).

2

AUTOTRANSFORMER

Autotransformer is a *single winding transformer* that works on the principle of **Faraday's Law of electromagnetic induction.** Mostly used in low voltage range, for industrial, commercial and laboratory purposes. Also known as *variac , dimmer stat,* etc.

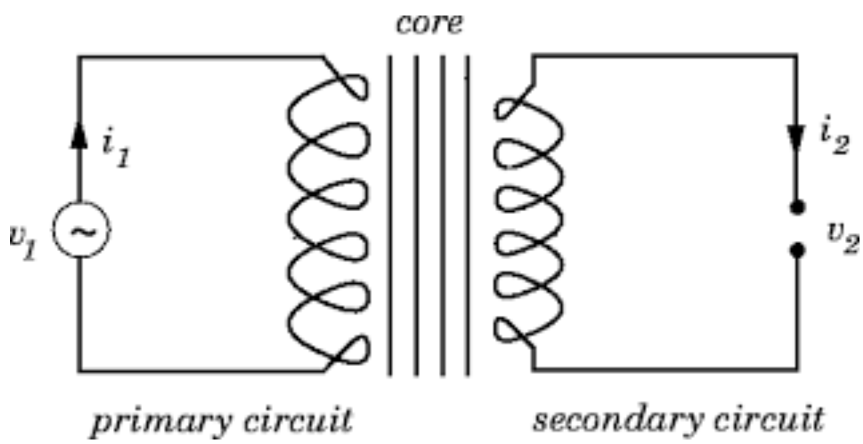
Autotransformer can be **single** and **three**-phase.

Due to single winding, **autotransformers** have fewer losses, **more efficient** and **robust**. By taking tapping on the secondary side, a wide range of voltage can be obtained.

In some applications, they are also connected to converters for *rectifying* the output **AC** voltage.

What is Autotransformer?

The principle of the autotransformer is the same as two winding transformers. It works on the principle of Faraday's Law of electromagnetic Induction, according to which whenever there is a relative change in magnetic field and conductors, an emf is induced in the conductors. Consider a two winding transformer shown below

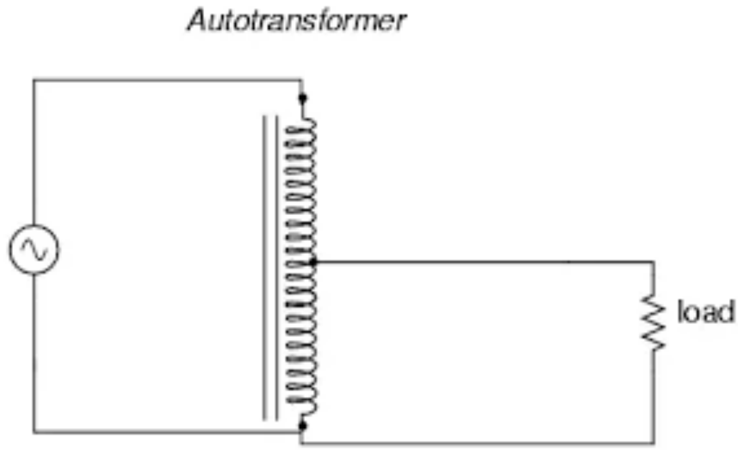


Autotransformer

Working Principle

Now consider the autotransformer circuit diagram shown below. As compared to two winding transformers as shown in Figure 1, Autotransformer has single winding. When an alternating supply is given to the primary circuit, because of **Faraday's Law of electromagnetic Induction**, an emf is induced in the primary part.

Since the **magnetic field** is **alternating** in nature, and conductors are **stationary**.



The induced emf in primary produces a flux, which is called as primary winding flux. This flux links the secondary winding and induces an emf on secondary winding due to mutual induction. Hence emf is transferred in the secondary winding. Based on a number of turns on the secondary side, the magnitude of induced emf is determined.

Autotransformer Working

The emf equation of induced emf is given as

$$E = 4.44 * \emptyset * N * f$$

This can be generalized for both **primary winding emf** and **secondary winding emf**.

If we take ratio we get as

$$E1/E2 = N1/N2 = k$$

It could be seen that the magnitude of induced emf is directly proportional to a number of turns. If a number of turns are greater on the secondary side, it is called a step-up autotransformer. If several turns are less, it is called a step-down autotransformer. It is also observed that, in two winding transformers, flux links the secondary winding through the core of the transformer. There is no electrical link between primary and secondary. For that reason, the transformer is called as electrically isolated but magnetically coupled device. But for an autotransformer, there is electrical isolation. There is only one winding. For this reason, autotransformer is called as electrically and magnetically coupled device.

The nature emf induced as shown in above is statically induced emf. If the source is alternating and conductors are constant, in that case, nature induced emf is statically induced emf. If conductors are rotating and the magnetic field is constant in that case emf induced is dynamically induced emf. In the transformer and autotransformer, induced emf is statically induced emf. In the case of DC generators, induced emf is dynamically induced emf. For statically induced emf, the direction of currents is given by Lenz's Law. In the case of dynamically emf, it is given by Fleming's Right Hand Rule. Hence in autotransformer, the direction of induced emf is given by Lenz's Law.

Properties of Autotransformer

The properties are

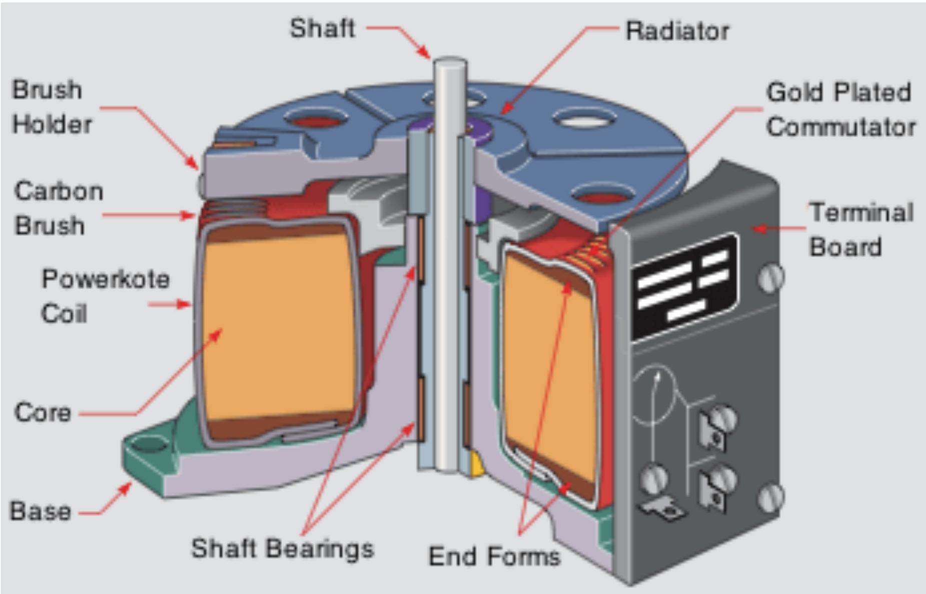
1. Auto Transformer is electrically and magnetically coupled device
2. In Autotransformer, power is constant
3. In autotransformer, overall flux is constant
4. In autotransformer, frequency is constant
5. Voltage and current vary based on a number of turns.
6. Autotransformer is also called a phase-shifting device
7. The losses are less in autotransformer as compared to two winding transformer due to single winding
8. The efficiency of the autotransformer is more as compared to two winding transformers
9. Both iron and copper losses are less an autotransformer.

Auto Transformer Construction

A transformer basically consists of **two** parts

1. Conductors
2. Core

The conductors in the autotransformer are made up of **copper**. They are of low resistance. The copper conductors are insulated with each other. The material used for insulation is impregnated paper, mica, etc. The insulation also helps in reducing eddy current losses. The winding is wound around the core. For a single winding transformer, the requirement of copper is less as compared to two winding transformers.



To transfer flux from primary to the secondary, core is used. The core is made up of magnetic material like silicon steel, CRGO steel, etc.
CRGO steel is the most **efficient** material for core, as it has the least hysteresis losses. The role core is to transfer flux from one part of winding to other parts. Other important parts as shown in figure 3 are bearings, brushes, terminal boards, etc. The parts shown are used for dimmer stat basically used for laboratory purposes.

Advantages and Disadvantages of Autotransformer

The **advantages** are

Losses in Autotransformer are less
The efficiency of the autotransformer is more
Copper Requirement is less
The core requirement is less

The **disadvantages** are

Autotransformers cannot be used for high voltages. Since any discontinuity in the primary winding would result in complete primary voltage on the secondary side, therefore it cannot be used for high voltages
The insulation requirement is more. Since autotransformer is both electrically and magnetically coupled, the requirement of insulation is more.
Because of common winding, a neutral connection is difficult.

Applications of Autotransformers

The following are the applications of autotransformers.

1. Autotransformers are used for starting induction motors
2. Auto Transformers are used for voltage regulation
3. Autotransformers are used for laboratory purposes.
4. Autotransformers are used in many industrial applications like paper mills, factories, etc.