University Institute of Engineering & Technology CSJMU KANPUR

Department of Electronics & Communication Engineering

Course Name- Electrical Machine (ECE S 204)

Branch ECE

UNIT 2: Network Theory & Concept

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Single Phase Transformers

After studying this unit, the student will be able to understand

• state the purpose of a transformer.

• explain the principle of mutual induction. ·

• determine the output voltage of a transformer if the input voltage and turns ratio are known.

• determine the full-load current of a transformer given the kVA and voltages of the primary and secondary windings.

• identify the common types of transformers from their schematic diagrams.

• read transformer winding diagrams and connect a transformer for the desired primary and secondary voltage.

• choose the proper transformer taps to obtain the desired output voltage.

• connect buck and boost transformers to obtain desired voltage for a single-phase application.

• choose the correct transformer kVA for the application, given the voltage, current, and phase requirement of a load.

Introduction

Transformers have been an essential component in electrical and electronic circuits since the 1830s and although new technologies in some electronic circuits have reduced the need for transformers, they are still essential in many applications.

A transformer uses the principles of electromagnetism to change one A.C. voltage level to another. Faraday's work in the 19th century showed that a changing current in a conductor (e.g. a transformer primary winding) sets up a changing magnetic field around the conductor. If another conductor (secondary winding) is placed within this changing magnetic field a voltage will be induced into that winding.

Turns Ratio.

Faraday also calculated that the voltage induced into the secondary winding would have a magnitude that depends on the TURNS RATIO of the transformer. i.e. If the secondary winding has half the number of turns of the primary winding, then the secondary voltage will be half the voltage across the primary winding. Likewise, if the secondary winding has twice the number of turns of the primary winding, the secondary voltage will be double the primary voltage.

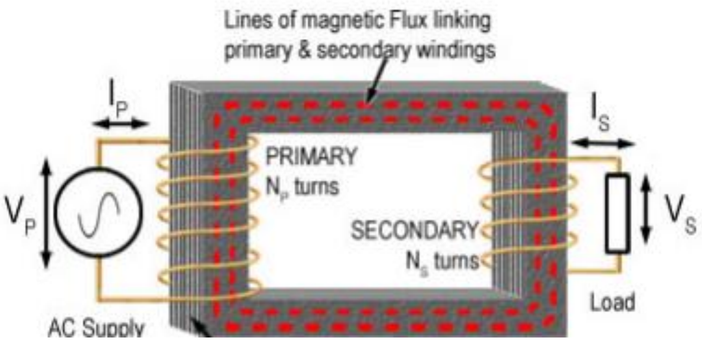
Power ratio

Because the transformer is a passive component, (it has no external power supply) it cannot produce more power out from its secondary than is applied to its primary. Therefore if the secondary voltage is greater than the primary voltage by a particular amount, the secondary current will be smaller than the primary current by a similar amount, i.e. If the voltage is doubled the current will be halved.

Transformation Ratio.

Basic Transformer operation can be described by two formulae relating the transformation ratio to the turns ratio of the transformer windings.

- V_P = the primary voltage.
- I_P = the primary current.
- V_S = the secondary voltage.
- I_S = the secondary current.
- N_P = the number of turns in the primary winding.
- N_S = the number of turns in the secondary winding.



$$\frac{\text{The number of primary turns } N_P}{\text{The number of secondary turns } N_S} = \frac{\text{The primary voltage } V_P}{\text{The secondary voltage } V_S}$$

$$\frac{\text{The number of secondary turns } N_S}{\text{The number of primary turns } N_P} = \frac{\text{The primary current } I_P}{\text{The secondary current } I_S}$$

Transformer Losses.

The formulae in Fig. 1.1 relate to an ideal transformer, i.e. a transformer with no power losses, in which, Primary volt amperes = Secondary volt amperes. While practical transformers can be extremely efficient, some losses will occur because not all of the magnetic flux produced by the primary winding will link with the secondary winding. The power losses that occur in a transformer are of three type:

1. Copper Losses.

These losses can also be called winding losses or I^2R losses, because they can occur in windings made from metals other than copper. The losses become evident as heat, generated in the (copper) wire windings as they dissipate power due to the resistance of the wire.

The power loss in a transformer winding can be calculated by using the current in the winding and its resistance, in formula for power, $P = I^2R$. This formula is the reason copper losses are sometime called I^2R losses. To minimise the losses the resistance of the winding must be kept low, using wire of suitable cross sectional area and low resistivity.

2. Hysteresis losses.

Each time the alternating current reverses (once each cycle), tiny "magnetic domains" within the core material are reversed. These are physical changes within the core material and take up some energy. The amount of energy used depends on the "reluctance" of the core material; in large cores of power transformers where hysteresis loss maybe a problem it is largely overcome by using special low reluctance "grain oriented" steel as the core material.

3. Eddy Current losses.

Because the iron or steel core is an electrical conductor as well as a magnetic circuit, the changing current in the primary will tend to set up an EMF within the core as well as in the secondary winding. The currents induced into the core will oppose the changes of magnetic field taking place in the core. For this reason these eddy currents must be kept as small as possible. This is achieved by dividing the metal core into thin sheets or "laminations", each one insulated from the others by an insulating coat of lacquer or oxide. Laminated cores greatly reduce the formation of eddy currents without affecting the magnetic properties of the core.

In high frequency transformers eddy current losses are reduced by using a core made of a ceramic material containing a large proportion of tiny metal particles, iron dust or manganese zinc. The ceramic insulates the metal particles from each other, giving a similar effect to laminations, and performing better at high frequencies.

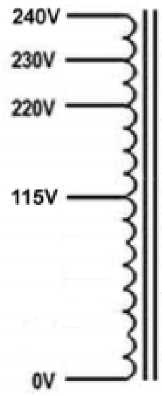
Due to the ways of reducing losses described above, practical transformers closely approach the ideal in performance. In large power transformers, efficiencies of about 98% can be achieved. Therefore for most practical calculations, it can be assumed that a transformer is "Ideal" unless its losses are specified. The actual secondary voltages in a practical transformer will be only slightly less than those calculated using the theoretical transformation ratio.

Off Load Current.

Because the action of a transformer is nearly perfect, the power in both primary and secondary windings is the same, so when no load is put on the secondary, no secondary current flows and the power in the secondary is zero ($V \times I = 0$). Therefore, although a voltage is applied to the primary no current will flow, as the power in the primary must also be zero. In practical transformers the "Off Load Current" in the primary is actually very low.

Autotransformers.

This is a special type of transformer that has only one winding. It is often used for conversion between different mains (line) voltages, allowing electrical equipment to be used internationally. The single continuous winding is divided into a number of "tappings" as shown in Fig. 11.3.5 to produce different voltages. An appropriate number of turns are provided between each tapping to produce the required voltage, based on the turns ratio between the complete winding and the tapping. A useful method of calculating unknown voltages on an autotransformer, if the number of turns on the various tappings is known, is to use the volts per turn method described on the Basic Transformer Operation page. Unlike a conventional transformer with primary and secondary windings, the autotransformer does not provide any isolation between input and output.



Autotransformers are also used to provide the very high voltages need for such applications as automobile ignition systems and cathode ray tube drives in CRT TVs and monitors.