Topic :- Transformer:
Each batch will visit nearby pole mounted sub-station and prepare a report based on the following points:

1. Rating: kV A rating, primary and secondary voltage, connections
2. Different parts and their functions
3. Earthing arrangement
4. Protective devices

ABSTRACT : In day to day life we use electrical device .Most of them cannot even live for a second too. Many of us uses the electrical devices, this electrical devices need energy to run. This is which usually is generated in large amount in power generation plant from where it come to us by stepping down by a electrical device namely, **Transformer**. In this report we will see a transformer at a glance overview as well as in a nutshell .

I. INTRODUCTION

One of the main reasons that we use alternating AC voltages and currents in our homes and workplace's is that AC supplies can be easily generated at a convenient voltage, transformed (hence the name transformer) into much higher voltages and then distributed around the country using a national grid of pylons and cables over very long distances.

The reason for transforming the voltage to a much higher level is that higher distribution voltages implies lower currents for the same power and therefore lower **I^2R** losses along the networked grid of cables. These higher AC transmission voltages and currents can then be reduced to a much lower, safer and usable voltage level where it can be used to supply electrical equipment in our homes and workplaces, and all this is possible thanks to the basic **Voltage Transformer**.

Figure : 1 - Voltage Transformer

II. METHODS AND MATERIAL

The **Voltage Transformer** can be thought of as an electrical component rather than an electronic component. A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of **Faraday's law of induction** by converting electrical energy from one value to another.

The transformer does this by linking together two or more electrical circuits using a common oscillating magnetic circuit which is produced by the transformer itself. A transformer operates on the principals of "**electromagnetic induction**", in the form of Mutual Induction.

What is Mutual induction ?

Mutual induction is the process by which a coil of wire magnetically **induces a voltage** into another coil located in close proximity to it. Then we can say that transformers work in the "magnetic domain", and transformers get their name from the fact that they "transform" one voltage or current level into another.

Transformers are capable of either ***increasing or decreasing the voltage and current levels of their supply***, without modifying its frequency, or the amount of electrical power being transferred from one winding to another via the magnetic circuit.

A **single phase voltage transformer** basically consists of two electrical coils of wire, one called the "**Primary Winding**" and another called the "**Secondary Winding**". For this tutorial we will define the "primary" side of the transformer as the side that usually takes power, and the "secondary" as the side that usually delivers power. In a single-phase voltage transformer the primary is usually the side with the higher voltage.

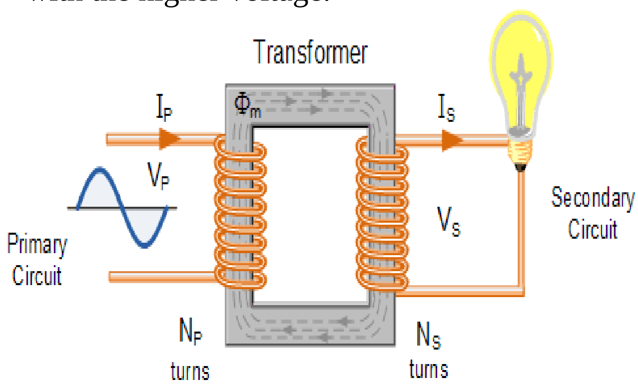
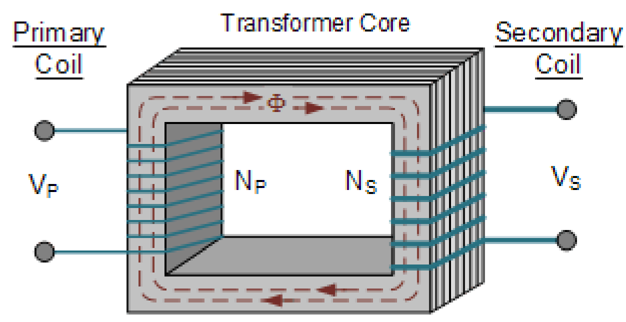


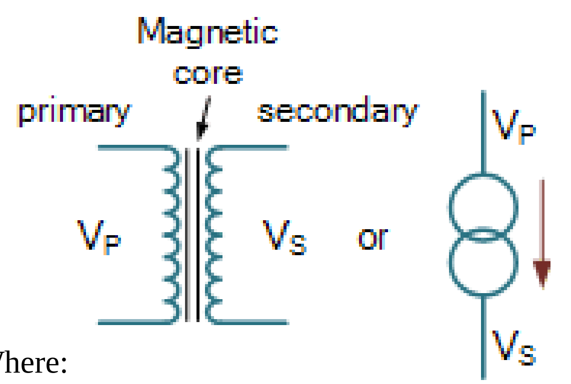
Figure : 2 - Single Phase Voltage Transformer

These two coils are not in electrical contact with each other but are instead wrapped together around a common closed magnetic iron circuit called the "core". This soft iron core is not solid but made up of individual laminations connected together to help reduce the core's losses. The two coil windings are electrically isolated from each other but are magnetically linked through the common core allowing electrical power to be transferred from one coil to the other. When an electric current passed through the primary winding, a magnetic field is developed which induces a voltage into the secondary winding as shown.

In other words, for a transformer there is no direct electrical connection between the two coil windings, thereby giving it the name also of an Isolation Transformer. Generally, the primary winding of a transformer is connected to the input voltage supply and converts or transforms the electrical power into a magnetic field. While the job of the secondary winding is to convert this alternating magnetic field into electrical power producing the required output voltage as shown.

Single Phase Transformer Construction





Where:

V_P - is the Primary Voltage

V_S - is the Secondary Voltage

N_P - is the Number of Primary Windings

N_S - is the Number of Secondary Windings

Φ (phi) - is the Flux Linkage

Notice that the two coil windings are not electrically connected but are only linked magnetically. A single-phase transformer can operate to either increase or decrease the voltage applied to the primary winding. When a transformer is used to "increase" the voltage on its secondary winding with respect to the primary, it is called a Step-up transformer. When it is used to "decrease" the voltage on the secondary winding with respect to the primary it is called a Step-down transformer.

However, a third condition exists in which a transformer produces the same voltage on its secondary as is applied to its primary winding. In other words, its output is identical with respect to voltage, current and power transferred. This type of transformer is called an "Impedance Transformer" and is mainly used for impedance matching or the isolation of adjoining electrical circuits.

The difference in voltage between the primary and the secondary windings is achieved by changing the number of coil turns in the **primary winding (NP)** compared to the number of coil turns on the **secondary winding (NS).**

As the transformer is basically a linear device, a ratio now exists between the number of turns of the primary coil divided by the number of turns of the secondary coil. This ratio, called the ratio of transformation, more commonly known as a transformers **"turns ratio", (TR)**. This turns ratio value dictates the operation of the transformer and the corresponding voltage available on the secondary winding.

It is necessary to know the ratio of the number of turns of wire on the primary winding compared to the secondary winding. The turns ratio, which has no units, compares the two windings in order and is written with a colon, such as 3:1 (3-to-1). This means in this example, that if there are 3 volts on the primary winding there will be 1 volt on the secondary winding, 3 volts-to-1 volt. Then we can see that if the ratio between the number of turns changes the resulting voltages must also change by the same ratio, and this is true.

Transformers are all about "ratios". The ratio of the primary to the secondary, the ratio of the input to the output, and the turns ratio of any given transformer will be the same as its voltage ratio. In other words for a transformer: **"turns ratio = voltage ratio".** The actual number of turns of wire on any winding is generally not important, just the turns ratio and this relationship is given as:

A Transformers Turns Ratio

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = n = \text{Turns Ratio}$$

Assuming an ideal transformer and the phase angles:

$$\Phi P \equiv \Phi S$$

Note that the order of the numbers when expressing a transformers turns ratio value is very important as the turns ratio 3:1 expresses a very different transformer relationship and output voltage than one in which the turns ratio is given as: 1:3.

This ratio of 3:1 (3-to-1) simply means that there are three primary windings for every one secondary winding. As the ratio moves from a larger number on the left to a smaller number on the right, the primary voltage is therefore stepped down in value as shown.

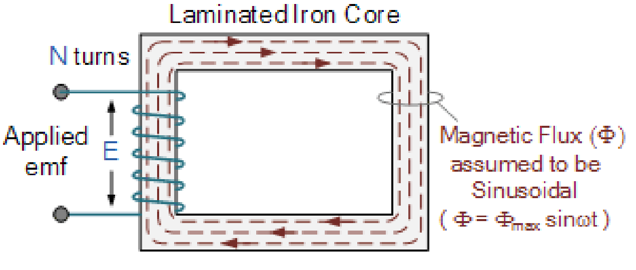
Then the main purpose of a transformer is to transform voltages at preset ratios and we can see that the primary winding has a set amount or number of windings (coils of wire) on it to suit the input voltage. If the secondary output voltage is to be the same value as the input voltage on the primary winding, then the same number of coil turns must be wound onto the secondary core as there are on the primary core giving an even turns ratio of 1:1 (1-to-1). In other words, one coil turn on the secondary to one coil turn on the primary.

If the output secondary voltage is to be greater or higher than the input voltage, (step-up transformer) then there must be more turns on the secondary giving a turns ratio of 1:N (1-to-N), where N represents the turns ratio number. Likewise, if it is required that the secondary voltage is to be lower or less than the primary, (step-down transformer) then the number of secondary windings must be less giving a turns ratio of N:1 (N-to-1).

Transformer Action

We have seen that the number of coil turns on the secondary winding compared to the primary winding, the turns ratio, affects the amount of voltage available from the secondary coil. But if the two windings are electrically isolated from each other, how is this secondary voltage produced ?

We have said previously that a transformer basically consists of two coils wound around a common soft iron core. When an alternating voltage (VP) is applied to the primary coil, current flows through the coil which in turn sets up a magnetic field around itself, called mutual inductance, by this current flow according to Faraday's Law of electromagnetic induction. The strength of the magnetic field builds up as the current flow rises from zero to its maximum value which is given as $d\Phi/dt$.



As the magnetic lines of force setup by this electromagnet expand outward from the coil the soft iron core forms a path for and concentrates the magnetic flux. This magnetic flux links the turns of both windings as it increases and decreases in opposite directions under the influence of the AC supply.

However, the strength of the magnetic field induced into the soft iron core depends upon the amount of current and the number of turns in the winding. When current is reduced, the magnetic field strength reduces.

When the magnetic lines of flux flow around the core, they pass through the turns of the secondary winding, causing a voltage to be induced into the secondary coil. The amount of voltage induced will be determined by: $N.d\Phi/dt$ (Faraday's Law), where N is the number of coil turns. Also this induced voltage has the same frequency as the primary winding voltage.
Then we can see that the same voltage is induced in each coil turn of both windings because the same magnetic flux links the turns of both the windings together. As a result, the total induced voltage in each winding is directly proportional to the number of turns in that winding. However, the peak amplitude of the output voltage available on the secondary winding will be reduced if the magnetic losses of the core are high.

If we want the primary coil to produce a stronger magnetic field to overcome the cores magnetic losses, we can either send a larger current through the coil, or keep the same current flowing, and instead increase the number of coil turns (NP) of the winding. The product of amperes times turns is called the "ampere-turns", which determines the magnetising force of the coil.

So assuming we have a transformer with a single turn in the primary, and only one turn in the secondary. If one volt is applied to the one turn of the primary coil, assuming no losses, enough current must flow and enough magnetic flux generated to induce one volt in the single turn of the secondary. That is, each winding supports the same number of volts per turn.

As the magnetic flux varies sinusoidally, $\Phi = \Phi_{max} \sin\omega t$, then the basic relationship between induced emf, (E) in a coil winding of N turns is given by:

e.m.f. = turns * rate of change

$$E = N\frac{d\Phi}{dt}$$

$$E = N \times \omega \times \Phi_{max} \times \cos(\omega t)$$

$$E_{max} = N\omega\Phi_{max}$$

$$E_{rms} = \frac{N\omega}{\sqrt{2}} \times \Phi_{max} = \frac{2\pi}{\sqrt{2}} \times f \times N \times \Phi_{max}$$

$$\therefore E_{rms} = 4.44 f N \Phi_{max}$$

Where:

f - is the flux frequency in Hertz, $= \omega/2\pi$
N - is the number of coil windings.
Φ - is the flux density in webers

This is known as the Transformer EMF Equation. For the primary winding emf, N will be the number of primary turns, (NP) and for the secondary winding emf, N will be the number of secondary turns, (NS).

Also please note that as transformers require an alternating magnetic flux to operate correctly, transformers cannot therefore be used to transform or supply DC voltages or currents, since the magnetic field must be changing to induce a voltage in the secondary winding. In other words, transformers DO NOT operate on steady state DC voltages, only alternating or pulsating voltages.

If a transformers primary winding was connected to a DC supply, the inductive reactance of the winding would be zero as DC has no frequency, so the effective impedance of the winding will therefore be very low and equal only to the resistance of the copper used. Thus the winding will draw a very high current from the DC supply causing it to overheat and eventually burn out, because as we know I = V/R.

Electrical Power Ratings in a Transformer

Another one of the transformer basics parameters is its power rating. The power rating of a transformer is obtained by simply multiplying the current by the voltage to obtain a rating in **Volt-amperes, (VA).** Small single phase transformers may be rated in volt-amperes only, but much larger power transformers are rated in units of **Kilo volt-amperes, (kVA)** where **1 kilo volt-ampere is equal to 1,000 volt-amperes**, and units of **Mega volt-amperes, (MVA)** where **1 mega volt-ampere is equal to 1 million volt-amperes.**

In an ideal transformer (ignoring any losses), the power available in the secondary winding will be the same as the power in the primary winding, they are constant wattage devices and do not change the power only the voltage to current ratio. Thus, in an ideal transformer the Power Ratio is equal to one (unity) as the voltage, V multiplied by the current, I will remain constant.

That is the electric power at one voltage/current level on the primary is “transformed” into electric power, at the same frequency, to the same voltage/current level on the secondary side. Although the transformer can step-up (or step-down) voltage, it cannot step-up power. Thus, when a transformer steps-up a voltage, it steps-down the current and vice-versa, so that the output power is always at the same value as the input power. Then we can say that primary power equals secondary power, (PP = PS).

Transformer Basics – Efficiency

A transformer does not require any moving parts to transfer energy. This means that there are no friction or windage losses associated with other electrical machines. However, transformers do suffer from other types of losses called “copper losses” and “iron losses” but generally these are quite small.

Copper losses, also known as I2R loss is the electrical power which is lost in heat as a result of circulating the currents around the transformers copper windings, hence the name. Copper losses represents the greatest loss in the operation of a transformer. The actual watts of power lost can be determined (in each winding) by squaring the amperes and multiplying by the resistance in ohms of the winding (I2R).

Iron losses, also known as hysteresis is the lagging of the magnetic molecules within the core, in response to the alternating magnetic flux. This lagging (or out-of-phase) condition is due to the fact that it requires power to reverse magnetic molecules; they do not reverse until the flux has attained sufficient force to reverse them.

Their reversal results in friction, and friction produces heat in the core which is a form of power loss. Hysteresis within the transformer can be reduced by making the core from special steel alloys.

The intensity of power loss in a transformer determines its efficiency. The efficiency of a transformer is reflected in power (wattage) loss between the primary (input) and secondary (output) windings. Then the resulting efficiency of a transformer is equal to the ratio of the power output of the secondary winding, PS to the power input of the primary winding, PP and is therefore high.

An ideal transformer is 100% efficient because it delivers all the energy it receives. Real transformers on the other hand are not 100% efficient and at full load, the efficiency of a transformer is between 94% to 96% which is quiet good. For a transformer operating with a constant voltage and frequency with a very high capacity, the efficiency may be as high as 98%. The efficiency, η of a transformer is given as:

Transformer Efficiency

$$\text{efficiency, } \eta = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

$$= \frac{\text{Input Power - Losses}}{\text{Input Power}} \times 100\%$$

$$= 1 - \frac{\text{Losses}}{\text{Input Power}} \times 100\%$$

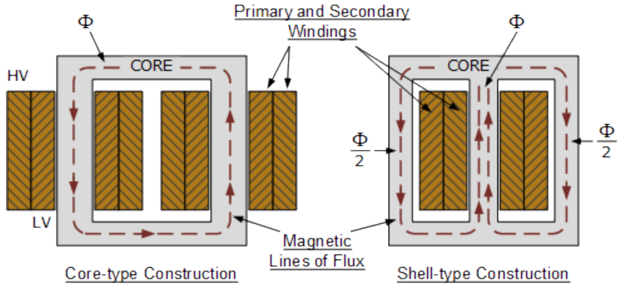
where: Input, Output and Losses are all expressed in units of power.

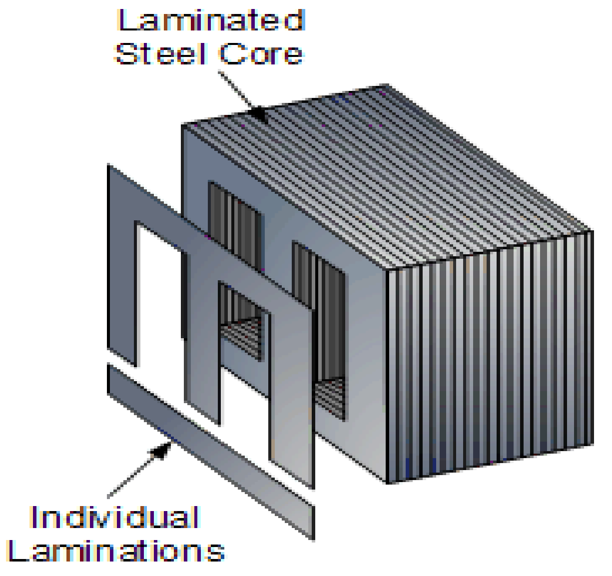
Generally when dealing with transformers, the primary watts are called “volt-amps”, VA to differentiate them from the secondary watts. Then the efficiency equation above can be modified to:

$$\text{Efficiency, } \eta = \frac{\text{Secondary Watts (Output)}}{\text{Primary VA (Input)}}$$

η

Transformer Construction





The construction of a simple two-winding transformer consists of each winding being wound on a separate limb or core of the soft iron form which provides the necessary magnetic circuit

This magnetic circuit, know more commonly as the “transformer core” is designed to provide a path for the magnetic field to flow around, which is necessary for induction of the voltage between the two windings.

However, this type of transformer construction were the two windings are wound on separate limbs is not very efficient since the primary and secondary windings are well separated from each other. This results in a low magnetic coupling between the two windings as well as large amounts of magnetic flux leakage from the transformer itself. But as well as this “O” shapes construction, there are different types of “transformer construction” and designs available which are used to overcome these inefficiencies producing a smaller more compact transformer.

The efficiency of a simple transformer construction can be improved by bringing the two windings within close contact with each other thereby improving the magnetic coupling. Increasing and concentrating the magnetic circuit around the coils may improve the magnetic coupling between the two windings, but it also has the effect of increasing the magnetic losses of the transformer core.

As well as providing a low reluctance path for the magnetic field, the core is designed to prevent circulating electric currents within the iron core itself. Circulating currents, called “eddy currents”, cause heating and energy losses within the core decreasing the transformers efficiency.

These losses are due mainly to voltages induced in the iron circuit, which is constantly being subjected to the alternating magnetic fields setup by the external sinusoidal supply voltage. One way to reduce these unwanted power losses is to construct the transformer core from thin steel laminations.

In all types of transformer construction, the central iron core is constructed from of a highly permeable material made from thin silicon steel laminations assembled together to provide the required magnetic path with the minimum of losses. The resistivity of the steel sheet itself is high reducing the eddy current losses by making the laminations very thin.

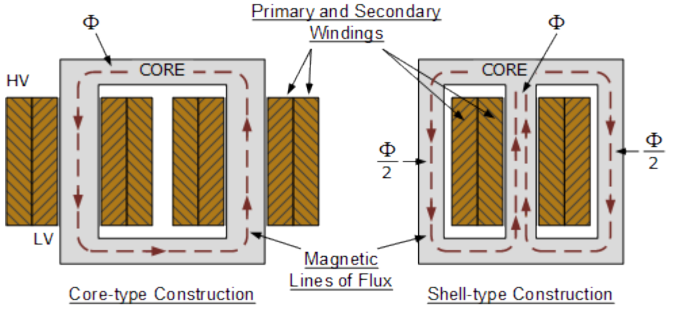
These steel transformer laminations vary in thickness’s from between 0.25mm to 0.5mm and as steel is a conductor, the laminations are electrically insulated from each other by a very thin coating of insulating varnish or by the use of an oxide layer on the surface.

Transformer Construction of the Core

Generally, the name associated with the construction of a transformer is dependant upon how the primary and secondary windings are wound around the central laminated steel core. The two most common and basic designs of transformer construction are the Closed-core Transformer and the Shell-core Transformer.

In the **"closed-core" type (core form)** transformer, the primary and secondary windings are wound outside and surround the core ring. In the **"shell type" (shell form)** transformer, the primary and secondary windings pass inside the steel magnetic circuit (core) which forms a shell around the windings as shown below.

Transformer Core Construction



In both types of transformer core design, the magnetic flux linking the primary and secondary windings travels entirely within the core with no loss of magnetic flux through air. In the core type transformer construction, one half of each winding is wrapped around each leg (or limb) of the transformers magnetic circuit as shown above.

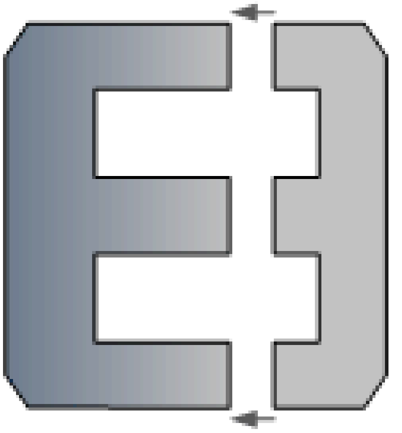
The coils are not arranged with the primary winding on one leg and the secondary on the other but instead half of the primary winding and half of the secondary winding are placed one over the other concentrically on each leg in order to increase magnetic coupling allowing practically all of the magnetic lines of force go through both the primary and secondary windings at the same time. However, with this type of transformer construction, a small percentage of the magnetic lines of force flow outside of the core, and this is called "leakage flux".
Shell type transformer cores overcome this leakage flux as both the primary and secondary windings are wound on the same centre leg or limb which has twice the cross-sectional area of the two outer limbs. The advantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils on both left and right hand sides before returning back to the central coils.
This means that the magnetic flux circulating around the outer limbs of this type of transformer construction is equal to $\Phi/2$. As the magnetic flux has a closed path around the coils, this has the advantage of decreasing core losses and increasing overall efficiency.

Transformer Laminations

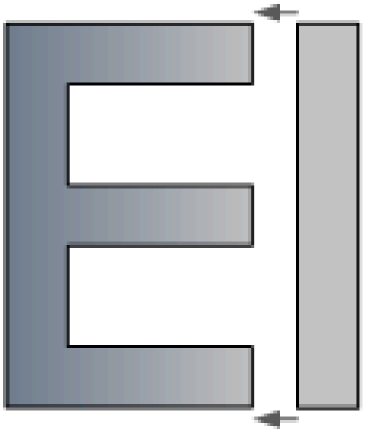
But you may be wondering as to how the primary and secondary windings are wound around these laminated iron or steel cores for this types of transformer constructions. The coils are firstly wound on a former which has a cylindrical, rectangular or oval type cross section to suit the construction of the laminated core. In both the shell and core type transformer constructions, in order to mount the coil windings, the individual laminations are stamped or punched out from larger steel sheets and formed into strips of thin steel resembling the letters "E's", "L's", "U's" and "I's" as shown below.

Transformer Core Types

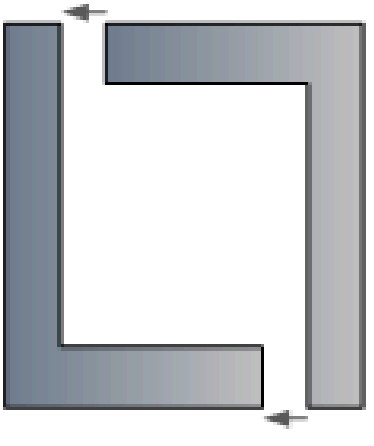
These lamination stampings when connected together form the required core shape. For example, two “E” stampings plus two end closing “I” stampings to give an E-I core forming one element of a standard shell-type transformer core. These individual laminations are tightly butted together during the transformers construction to reduce the reluctance of the air gap at the joints producing a highly saturated magnetic flux density.
Transformer core laminations are usually stacked alternately to each other to produce an overlapping joint with more lamination pairs being added to make up the correct core thickness. This alternate stacking of the laminations also gives the transformer the advantage of reduced flux leakage and iron losses. E-I core laminated transformer construction is mostly used in isolation transformers, step-up and step-down transformers as well as auto transformers.



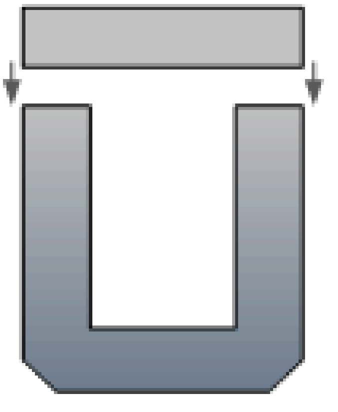
"E-E" Laminations



"E-I" Laminations



"L" Laminations



"U-I" Laminations

Winding

Two sets of winding are made over the transformer core and are insulated from each other. Winding consists of several turns of copper conductors bundled together, and connected connected in series.

Winding can be classified in two different ways:

1. Based on the input and output supply
2. Based on the voltage range

Within the input/output supply classification, winding are further categorized:

1. Primary winding - These are the winding to which the input voltage is applied.

2. Secondary winding - These are the winding to which the output voltage is applied.

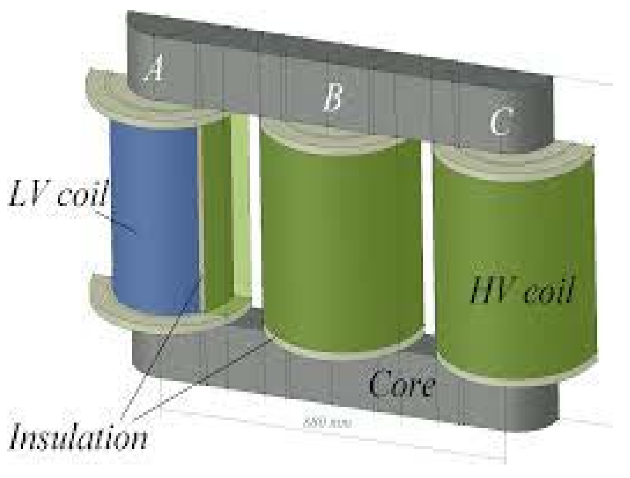
Within the voltage range classification, winding are further categorized:

1. High voltage winding - It is made of copper conductor. The number of turns made shall be the multiple of the number of turns in the low voltage winding. The conductor used will be thinner than that of the low voltage winding.
2. Low voltage winding - It consists of fewer number of turns than the high voltage winding. It is made of thick copper conductors. This is because the current in the low voltage winding is higher than that of high voltage winding.

Input supply to the transformers can be applied from either low voltage (LV) or high voltage (HV) winding based on the requirement.

Insulating Materials

Insulating paper and cardboard are used in transformers to isolate primary and secondary winding from each other and from the transformer core.
Transformer oil is another insulating material. Transformer oil performs two important functions: in addition to insulating function, it can also cool the core and coil assembly. The transformer's core and winding must be completely immersed in the oil. Normally, hydrocarbon mineral oils are used as transformer oil. Oil contamination is a serious problem because contamination robs the oil of its dielectric properties and renders it useless as an insulating medium.



Conservator Tank of a Transformer

This is a cylindrical tank mounted on supporting structure on the roof the transformer main tank. The main function of conservator tank of transformer is to provide adequate space for expansion of oil inside the transformer.

Function of Conservator Tank of a Transformer

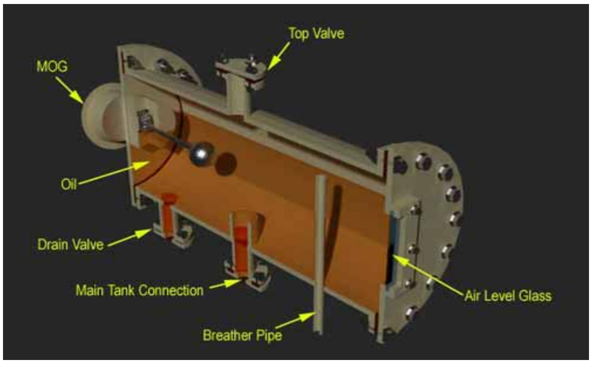
When transformer is loaded and when ambient temperature rises, the volume of oil inside transformer increases. A conservator tank of transformer provides adequate space to this expanded transformer oil. It also acts as a reservoir for transformer insulating oil.

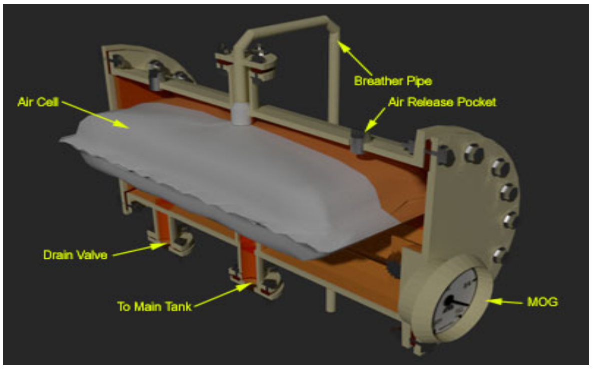
Construction of Conservator Tank

This is a cylindrical shaped oil container closed from both ends. One large inspection cover is provided on either side of the container to facilitate maintenance and cleaning inside of the conservator.
Conservator pipe, i.e. pipe comes from main transformer tank, is projected inside the conservator from bottom portion. Head of the conservator pipe inside the conservator is provided with a cap. This pipe is projected as well as provided with a cap because this design prevent oil sludge and sediment to enter into main tank from conservator. Generally silica gel breather fixing pipe enters into the conservator from top. If it enters from bottom, it should be projected well above the level of oil inside the conservator. This arrangement ensure that oil does not enter the silica gel breather even at highest operating level.

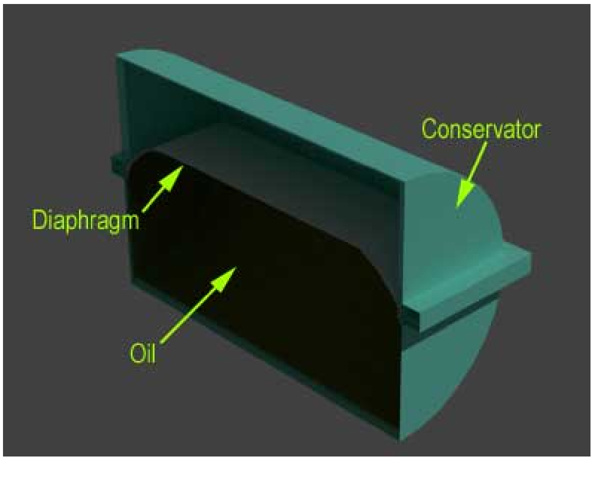
Working of Conservator Tank

When volume of transformer insulating oil increases due to load and ambient temperature, the vacant space above the oil level inside the conservator is partially occupied by the expanded oil. Consequently, corresponding quantity of air of that space is pushed away through breather. On other hand, when load of transformer decreases, the transformer is switched off and when the ambient temperature decreases, the oil inside the transformer contracts. This causes outside air to enter in the conservator tank of transformer through silica gel breather.

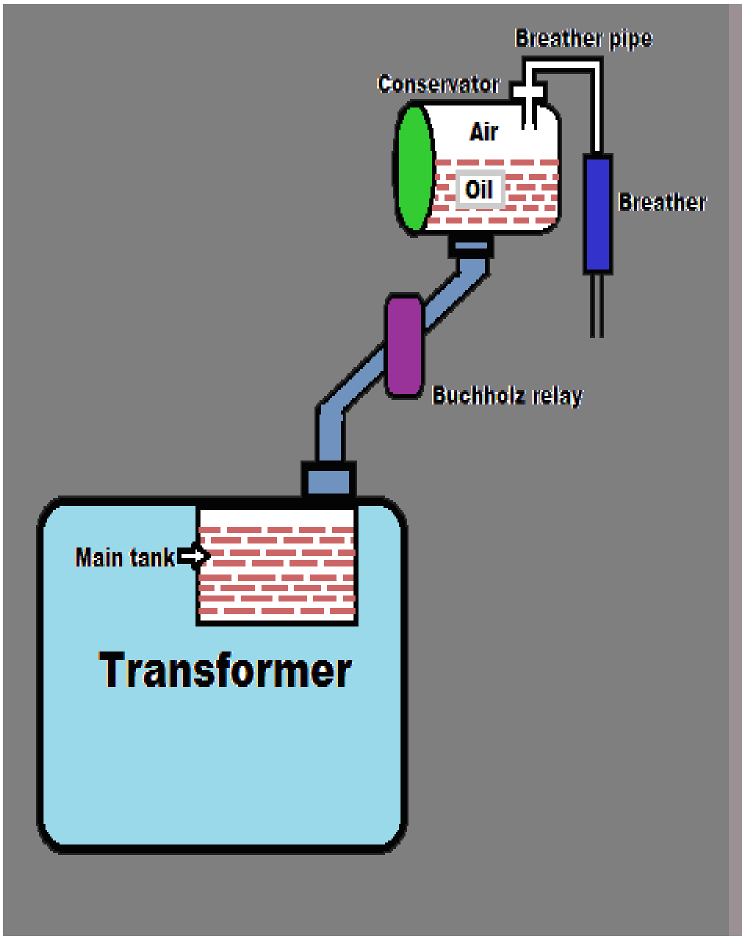


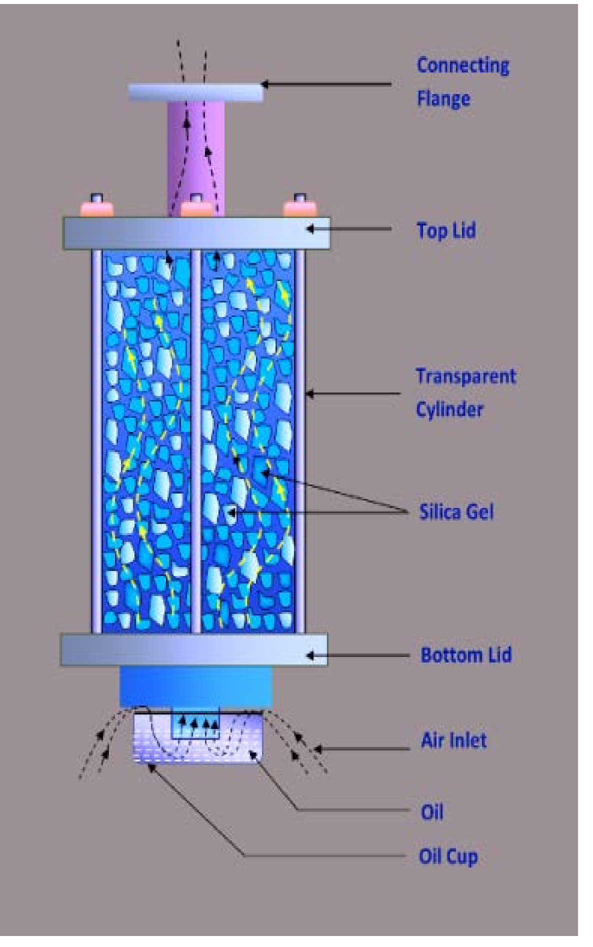


Atmoseal Type Conservator



Diaphragm Sealed Conservator





Transformer **Breatther**

Breather

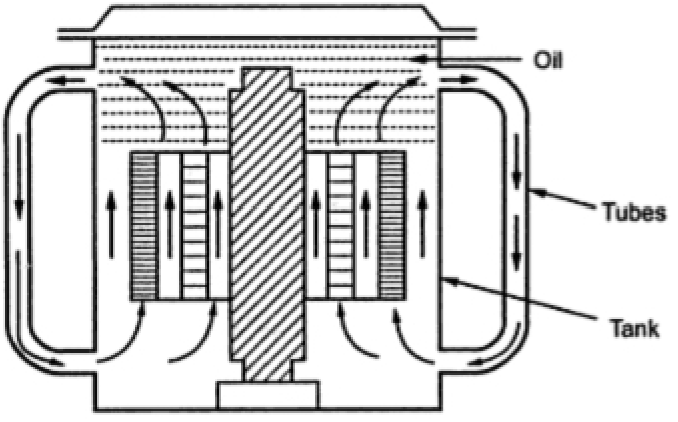
The breather controls the moisture level in the transformer. Moisture can arise when temperature variations cause expansion and contraction of the insulating oil, which then causes the pressure to change inside the conservator. Pressure changes are balanced by a flow of atmospheric air in and out of the conservator, which is how moisture can enter the system.

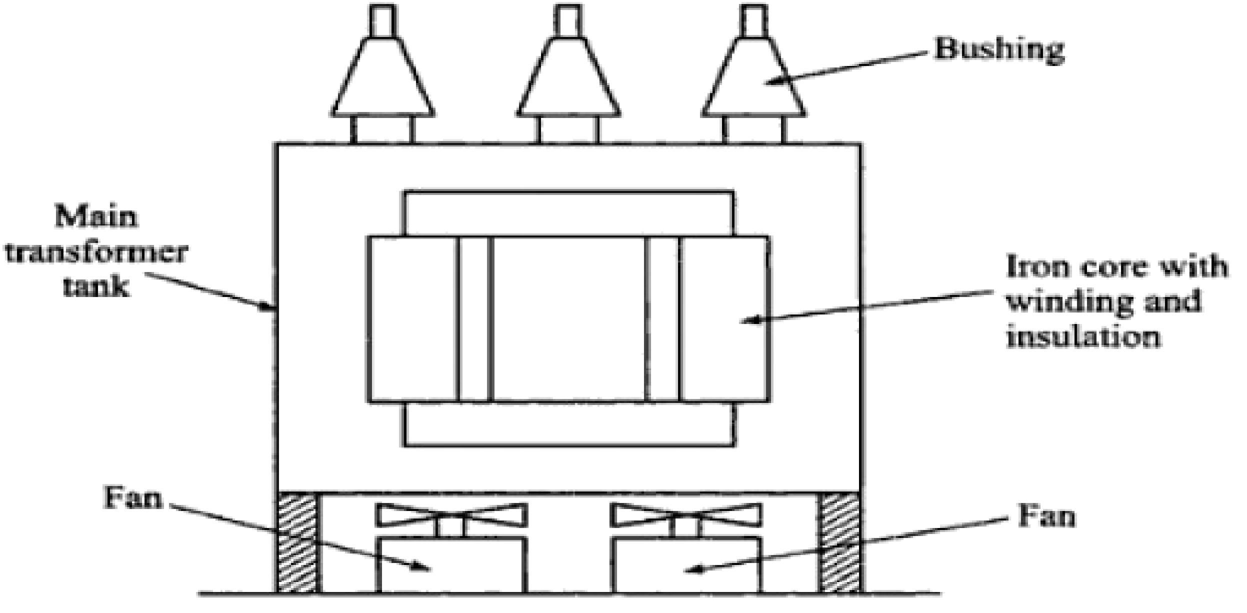
If the insulating oil encounters moisture, it can affect the paper insulation or may even lead to internal faults. Therefore, it is necessary that the air entering the tank is moisture-free.

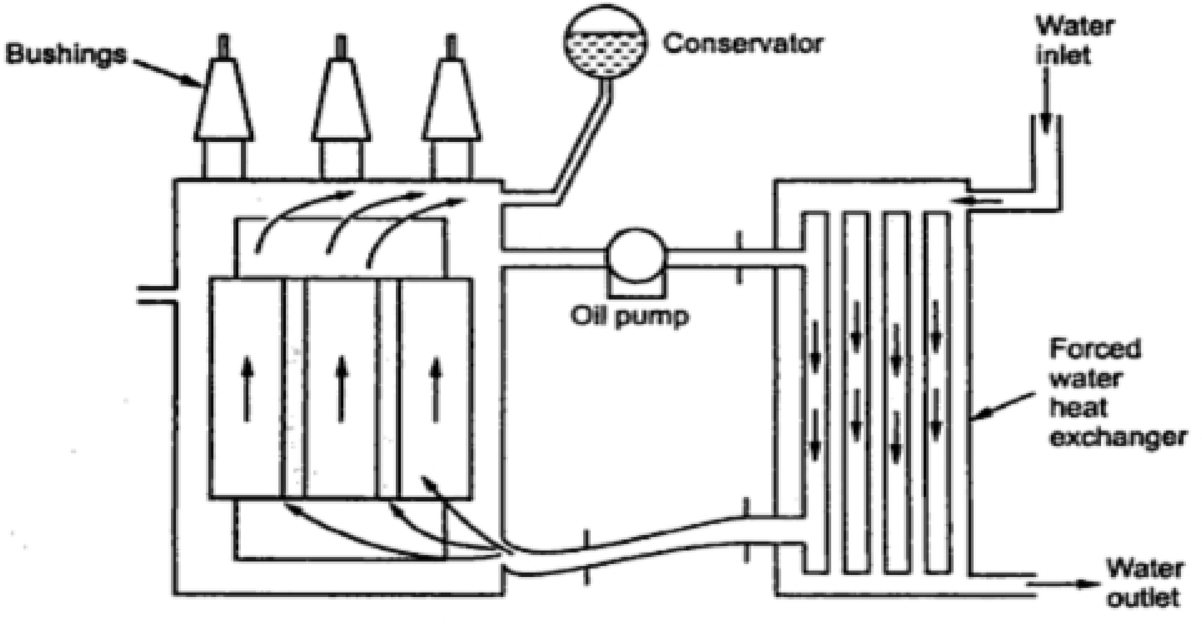
The transformer's breather is a cylindrical container that is filled with silica gel. When the atmospheric air passes through the silica gel of the breather, the air's moisture is absorbed by the silica crystals. The breather acts like an air filter for the transformer and controls the moisture level inside a transformer. It is connected to the end of breather pipe.

Cooling Tubes

Cooling tubes are used to cool the transformer oil. The transformer oil is circulated through the cooling tubes. The circulation of the oil may either be natural or forced. In natural circulation, when the temperature of the oil rises the hot oil naturally rises to the top and the cold oil sinks downward. Thus the oil naturally circulates through the tubes. In forced circulation, an external pump is used to circulate the oil.





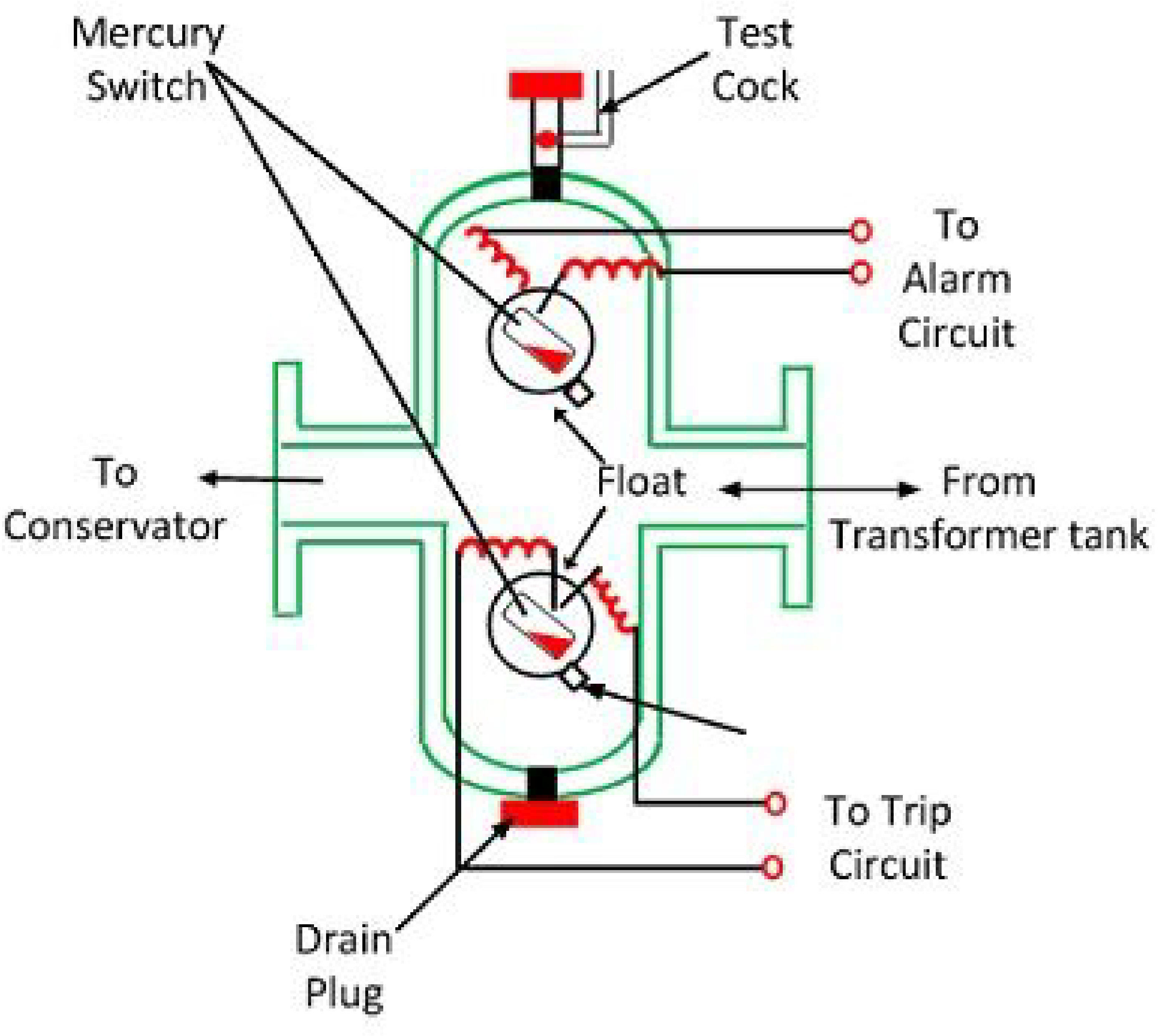


Buchholz Relay

The Buchholz Relay is a protective device container housed over the connecting pipe from the main tank to the conservator tank. It is used to sense the faults occurring inside the transformer. It is a simple relay that is operated by the gases emitted during the decomposition of transformer oil during internal faults. It helps in sensing and protecting the transformer from internal faults.

Explosion Vent

The explosion vent is used to expel boiling oil in the transformer during heavy internal faults in order to avoid the explosion of the transformer. During heavy faults, the oil rushes out of the vent. The level of the explosion vent is normally maintained above the level of the conservatory tank.



III. RESULT AND DISCLUSION

- 1. The output voltage of the transformer across the secondary coil depends upon the ratio (Ns/Np) with respect to the input voltage

- 2. The output voltage of the transformer across the secondary coil depends upon the ratio (Ns/N p) with respect to the input voltage

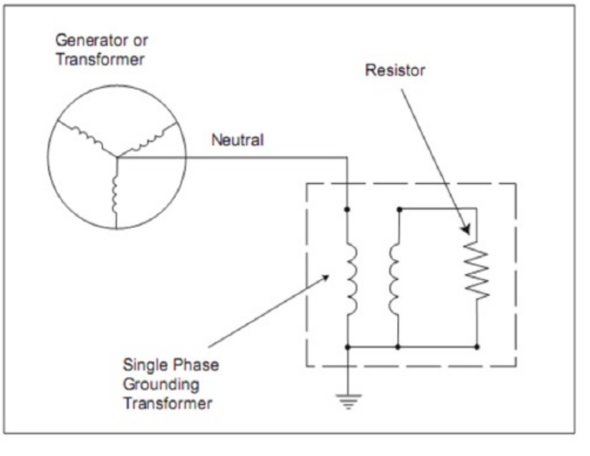
- 3. There is a loss of power between input and output coil of a transformer.

A transformer is an electrical device that transfers electrical energy from one circuit to another by electromagnetic induction (also called transformer action). It is used to step up or step down ac voltage.
These are the basic components of a transformer.

1. Laminated core
2. Windings
3. Insulating materials
4. Transformer oil
5. Tap changer
6. Oil Conservator
7. Breather
8. Cooling tubes
9. Buchholz Relay
10. Explosion vent

Of the above, laminated soft iron core, windings and insulating material are the primary parts and are present in all transformers, whereas the rest can be seen only in transformers having a capacity of more than 100KVA.
Protection Devices :-
1. Buchholz (Gas) Relay
2. Pressure Relay
3. Oil Level Monitor Device
4. Winding Thermometer

Earthing a Transformer :-If the earthing transformer on the Delta Side is outsides the Zone of protection the Earth Fault(E/F) in the delta system outside Current Transformer (CT) locations would produce current distributions as shown which circulate within the differential CT secondaries and is kept out of operating coils. Zig-Zag or inter connected star grounding transformer has normal magnetising impedance of high value but for E/F, currents flow in windings of the same - core in such a manner that the ampere turn cancel and hence offer lower impedance.



IV. CONCLUSION

Where Vs is the instantaneous voltage, Ns is the number of turns in the secondary winding, and dΦ/dt is the derivative of the magnetic flux Φ through one turn of the winding. With turns of the winding oriented perpendicularly to the magnetic field lines, the flux is the product of the magnetic flux density and the core area, the magnetic field varying with time according to the excitation of the primary. The expression dΦ/dt, defined as the derivative of magnetic flux Φ with time t, provides a measure of rate of magnetic flux in the core and hence of EMF induced in the respective winding. The negative sign is described by Lenz's law.

. Although ideal transformer's winding inductances are each infinitely high, the square root of winding inductances' ratio is equal to the turns ratio.

. This also implies the following: Input impedance is infinite when secondary is open and zero when secondary is shorted; there is zero phase-shift through an ideal transformer; input and output power and reactive volt-ampere are each conserved; these three statements apply for any frequency above zero and periodic waveforms are conserved.

. Direction of transformer currents is according to the Right-Hand Rule.

. Windings of real transformers are usually wound around very high permeability ferromagnetic cores but can also be air-core wound.

. Section Leakage factor and inductance of Leakage inductance derives a transformer equivalent in terms of various measurable inductances (winding, self, leakage, magnetizing and mutual inductances) and turns ratio, which are collectively essential to rigorous counter EMF understanding.

. "The turn ratio of a transformer is the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding."

. A step-down transformer converts a high voltage to a lower voltage while a step-up transformer converts a low voltage to a higher voltage, an isolation transformer having 1:1 turns ratio with output voltage the same as input voltage.

. A standardized open-circuit or unloaded transformer test called the Epstein frame can also be used for the characterization of magnetic properties of soft magnetic materials including especially electrical steels.

. ANSI/IEEE Standard C57.13 defines polarity in terms of the relative instantaneous directions of the currents entering the primary terminals and leaving the secondary terminals during most of each half cycle, the word 'instantaneous' differentiating from say phasor current.

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