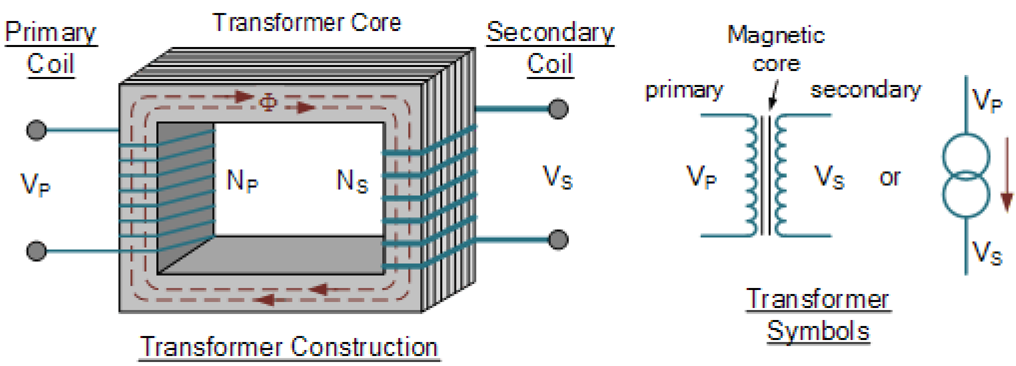
Pavuluri Rajeshwari

1.)State the principle of a transformer.

A.) 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.




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

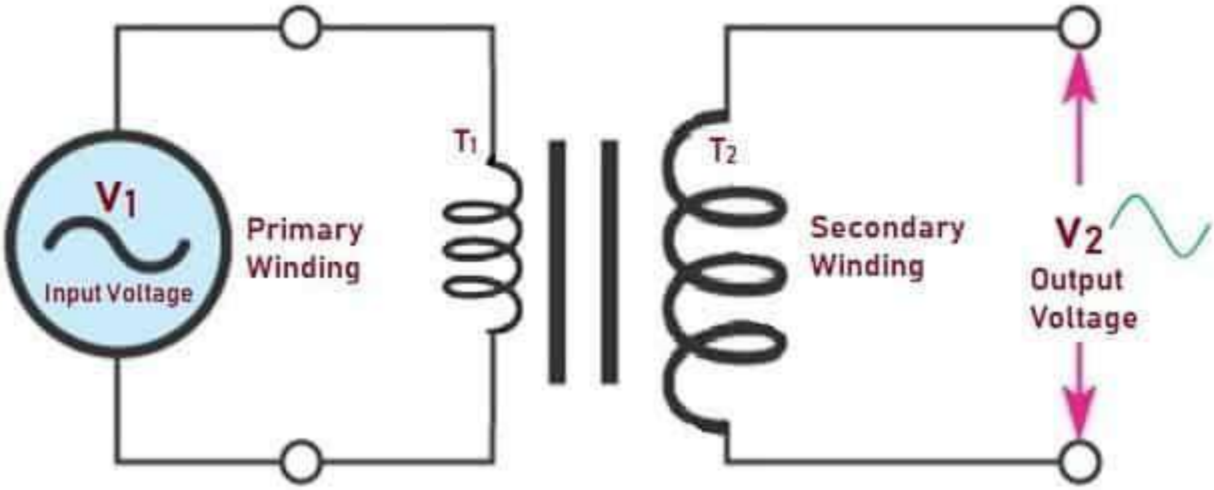
Φ (phi) – is the Flux Linkage

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**

2.)What are the applications of step-up & step-down transformer?

At the most basic level, step-up transformers increase voltage while step-down transformers decrease it

A transformer that is used to step up the output voltage by maintaining the flow of current stable without any variation is known as a step-up transformer. This kind of transformer is mainly used in the applications of power transmitting and power generating stations applications. This transformer includes two windings like primary and secondary. The primary winding has fewer turns as compared with the secondary winding




The uses of Step-up Transformers include the following.

These transformers are applicable in electronic devices like Inverters & Stabilizers to stabilize the voltage from low to high.

It is used for distributing electrical power.

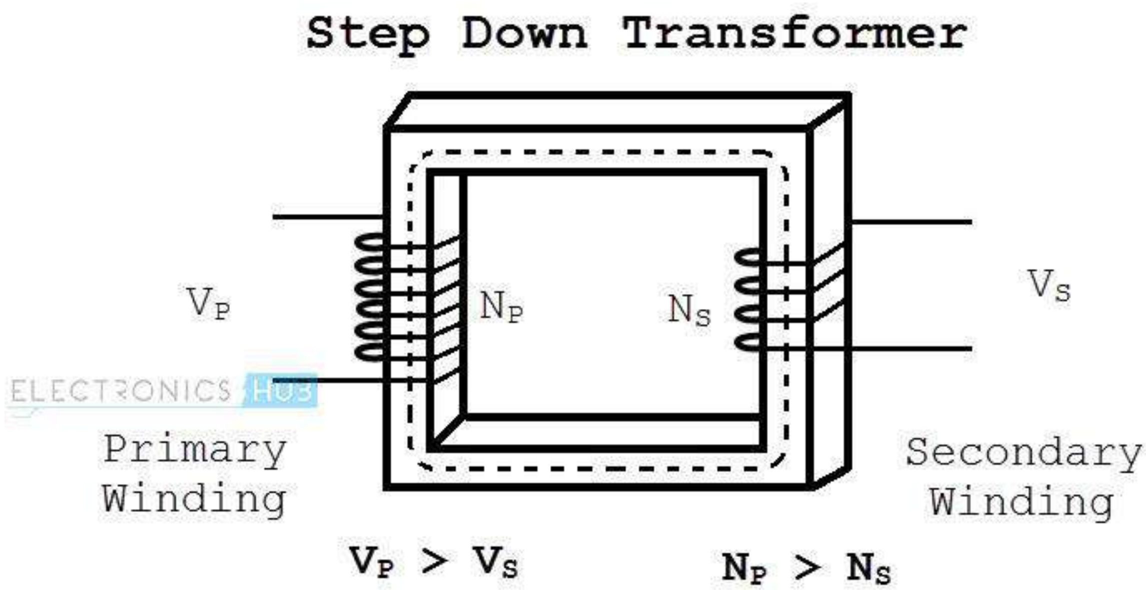
This transformer is used to change the high voltage in transmission lines which is generated from the alternator.

This transformer is also used to make an electric motor run, X-ray machines, microwave oven, etc.

It is used to boost electrical and electronic devices

A Step down Transformer is a type of transformer, which converts a high voltage at the primary side to a low voltage at the secondary side.

If we speak in terms of the coil windings, the primary winding of a Step down Transformer has more turns than the secondary winding. The following image shows a typical step down transformer.




All the street transformers which we see near our homes are step down transformers. They take a 11kV alternating voltage at the primary and convert it to 230V for distributing it to our homes.

Before the wide usage of switching power supplies, almost all low voltage wall adapters use step down transformers.

And are **used** in the main adapters and chargers for cell phones, CD players and stereos.
It **can** be **used** to **step down** the voltage level in transmission line. In welding machines it is **used** in reducing voltage and increasing current.

3.)What types of cores are used for transformers?

## Solid iron or steel

Steel and iron have been one of the most common materials used for constructing cores. They serve as an excellent pathway for magnetic flux, allowing the magnetic field to be very high without saturating the material. They provide sturdy magnetic fields and generate enough heat required, thus boosting the overall performance of the transformer.

## Laminated silicon steel

These cores have thin silicon alloy laminations stacked one over the other. These alloys provide great magnetic pathways but, don’t conduct electric current. Instead of a solid piece of iron or steel, these thin layers result in reduced eddy currents and electrical pathways. Thus, the efficiency of transformers using these alloys increases greatly.

## Amorphous steel

Amorphous steel cores are made up of many layers of paper-thin metallic tapes stacked together. They work on the same idea as laminated silicon steel but, with better efficiency. This is because the super thin strips reduce the flow of eddy currents even further, due to which there are lower losses and higher operating efficiency even at higher frequencies. These cores are commonly used in medium frequency and high efficiency transformers.

These three different types of cores are used to build different types of transformers like step-up, step-down, auto, three-phase, rectifier and many others

4.)Define the voltage regulation of a transformer and write its expression.

**Voltage Regulation** of single-phase transformers is the percentage (or per unit value) change in its secondary terminal voltage compared to its original no-load voltage under varying secondary load conditions. When there is no-load connected to the transformers secondary winding, that is its output terminals are open-circuited, there is no closed-loop condition, so there is no output load current ($I_L = 0$) and the transformer acts as one single winding of high self-inductance.

A transformers voltage regulation change between its secondary terminal voltage from a no-load condition when $I_L = 0$, (open circuit) to a fully-loaded condition when $I_L = I_{MAX}$ (maximum current) for a constant primary voltage is given as:

Transformer Voltage Regulation as a Fractional Change

$$\text{Regulation} = \frac{\text{Change in Output Voltage}}{\text{No-load Output Voltage}}$$

$$\therefore \text{Regulation} = \frac{V_{(\text{no-load})} - V_{(\text{full-load})}}{V_{(\text{no-load})}}$$

## Transformer Voltage Regulation as a Percentage Change:

$$\%Reg_{(down)} = \frac{V_{(no\text{-}load)} - V_{(full\text{-}load)}}{V_{(no\text{-}load)}} \times 100\%$$

$$\%Reg_{(up)} = \frac{V_{(no\text{-}load)} - V_{(full\text{-}load)}}{V_{(full\text{-}load)}} \times 100\%$$

5.)On what size the construction of bushings in a transformer depend?

……

6.)Discuss about copper losses in a transformer?

**Copper loss** is the term often given to heat produced by electrical currents in the conductors of **transformer** windings, or other electrical devices. **Copper losses** are an undesirable transfer of energy, as are core **losses**, which result from induced currents in adjacent components.

These losses occur due to ohmic resistance of the transformer windings. If $I_1$ and $I_2$ are the primary and the secondary current. $R_1$ and $R_2$ are the resistance of primary and secondary winding then the copper losses occurring in the primary and secondary winding will be $I_1^2R_1$ and $I_2^2R_2$ respectively.

Therefore, the total copper losses will be

$$P_c = I_1^2R_1 + I_2^2R_2$$

These losses varied according to the load and known hence it is also known as variable losses. Copper losses vary as the square of the load current.

7.)Discuss about Eddy current loss in transformer?

When the flux links with a closed circuit, an emf is induced in the circuit and the current flows, the value of the current depends upon the amount of emf around the circuit and the resistance of the circuit.

Since the core is made of conducting material, these EMFs circulate currents within the body of the material. These circulating currents are called **Eddy Currents**. They will occur when the conductor experiences a changing magnetic field. As these currents are not responsible for doing any useful work, and it produces a loss ($I^2R$ loss) in the magnetic material known as an **Eddy Current Loss**.
The eddy current loss is minimized by making the core with thin laminations.

The equation of the eddy current loss is given as:

$$P_e = K_e B_m^2 t^2 f^2 V \qquad \text{watts}$$

Where,

$K_e$ – coefficient of eddy current. Its value depends upon the nature of magnetic material like volume and resistivity of core material, the thickness of laminations

$B_m$ – maximum value of flux density in $wb/m^2$

T – thickness of lamination in meters

F – frequency of reversal of the magnetic field in Hz

V – the volume of magnetic material in $m^3$

8.)Discuss about Hysteresis loss in a transformer?

The core of the transformer is subjected to an alternating magnetizing force, and for each cycle of emf, a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss and given by the equation shown below:

$$P_h = K\eta B_{max}^{1.6} f V \quad \text{watts}$$

Where

Kɳ is a proportionality constant which depends upon the volume and quality of the material of the core used in the transformer,

f is the supply frequency,

Bmax is the maximum or peak value of the flux density.

The iron or core losses can be minimized by using silicon steel material for the construction of the core of the transformer.

9.)Discuss all day efficiency?

**Definition:** All day efficiency means the power consumed by the transformer throughout the day. It is defined as the **ratio of output power to the input power** in kWh or wh of the transformer over 24 hours. Mathematically, it is represented as

$$\text{All day efficiency, } \eta_{\text{all day}} = \frac{\text{output in kWh}}{\text{input in kWh}} \quad \text{(for 24 hours)}$$

All-day efficiency of the transformer depends on their load cycle. The load cycle of the transformer means the repetitions of load on it for a specific period.The ordinary or commercial efficiency of a transformer is defined as the ratio of the output power to the input power.

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

10.)State the principle of a transformer?

Same as 1st question

11.) Classify the different types of losses in a transformer.

A.)Copper,eddy current and hysteresis losses in que 6,7,8

## a.)Iron Losses

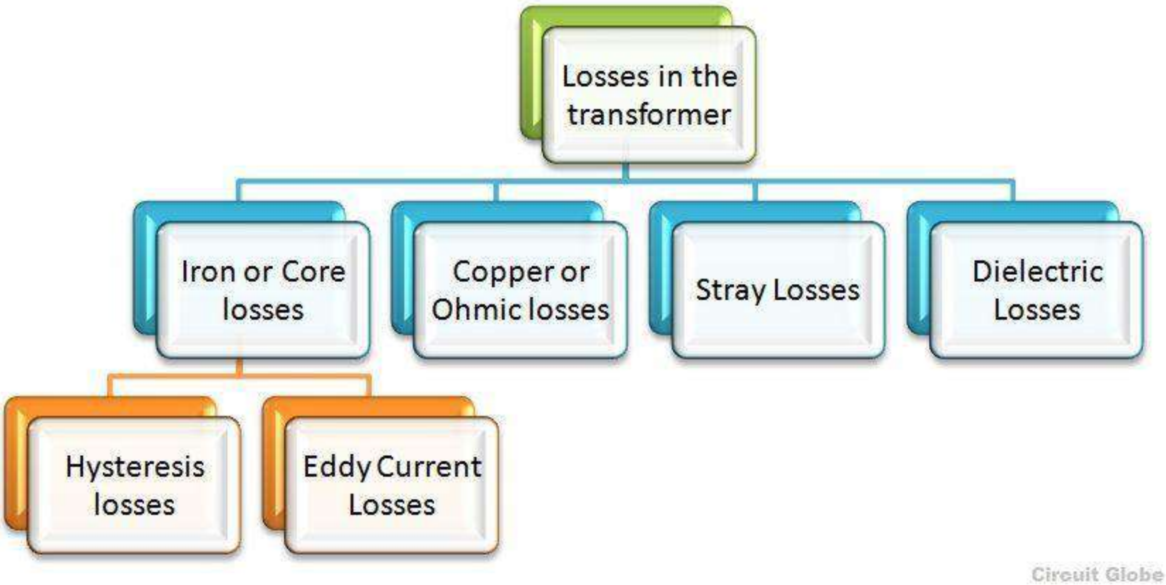
Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as **Core loss**. Iron loss is further divided into hysteresis and eddy current loss.

## Stray Loss

The occurrence of these stray losses is due to the presence of leakage field. The percentage of these losses are very small as compared to the iron and copper losses so they can be neglected.

## Dielectric Loss

Dielectric loss occurs in the insulating material of the transformer that is in the oil of the transformer, or in the solid insulations. When the oil gets deteriorated or the solid insulation gets damaged, or its quality decreases, and because of this, the efficiency of the transformer gets affected.




12.)same as 7th question

13.)Describe an ideal transformer.?

A.)An **ideal transformer** is an imaginary transformer which does not have any loss in it, means no core losses, copper losses and any other losses in transformer. Efficiency of this transformer is considered as 100%.

14.) Define transformation ratio.

A.)It is actually defined for a transformer.

Transformation Ratio (K) is defined as the ratio of the EMF in the secondary coil to that in the primary coil.

K = E2/E1 = (4.44(Φm)fN2)/(4.44(Φm)fN1)

Therefore,

K = E2/E1 = N2/N1….(1)

Now,

V1 = E1 + voltage drop

E2 = V2 + voltage drop

Due to the resistance in the windings and some leakage flux, there is some loss in voltage. This is called as Voltage Drop.

But, in ideal case, voltage drop can be neglected.

Hence,

$V1 = E1$

$E2 = V2$

Hence,

$E2/E1 = V2/V1$…..(2)

Also, in a transformer, the power across the primary as well as the secondary winding is same. Hence,

$V1.I1 = V2.I2$

$V1/V2 = I2/I1$……..(3)

Now, combining (1), (2) & (3), we get,

$K = E2/E1 = N2/N1 = V2/V1 = I2/I1$

Where,

1 represents the primary coil

2 represents the secondary coil

E is emf in the respective coil

V is the voltage in the respective coil

I is the current in the respective coil

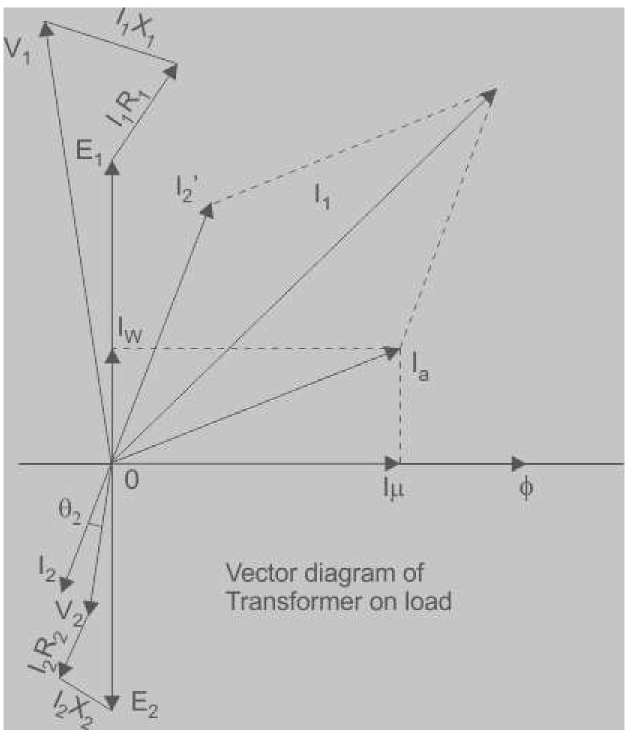
N is number of turns of the respective coils

Φm is the mutual flux in the core.

15.)Explain why a transformer is rated in KVA

A.)**Transformers** are **rated** in **kVA** because the losses occurring in the **transformers** are independent of power factor. **KVA** is the unit of apparent power. It is a combination of real power and reactive power. **Transformers** are manufactured without considering the load being connected.

16.)Draw the equivalent circuit of a transformer referred to primary side.




17.) What is a Transformer?

A.)A **transformer** is an **electrical** device that trades voltage for current in a circuit, while not affecting the total **electrical** power. This means it takes high-voltage electricity with a small current and changes it into low-voltage electricity with a large current, or vice versa.

18.)What is Two winding transformer?

A.)The **two-winding transformer** is one in which **two windings** are linked by a common time-varying magnetic flux. ... In these **transformers**, the core is magnetized in the direction of rolling, thus making for lower core loss and lower exciting current than when the magnetization is in a direction across that of rolling.

19.)What is Three winding transformer?

A.)Sometimes in high rating **transformer**, the third **winding** is constructed in addition to the primary and the secondary **windings**. The third **winding** is called the tertiary **winding**, and because of the **three windings**, the **transformer** is called the **three winding transformer**.

20.)What is Six winding transformer?

The three phase transformer have six windings ,three primary and three secondary,the six windings are connected by the manufacturer as either delta or wye.The primary primary winding and secondary windings may each be connected in a delta or wye configuration .They do not have to be connected in the same transformer .The actual configurations used depend upon application.

11.3.2021

## Module-4

### Part-B

1. Give the concept of single phase ideal transformer. Describe Performance with the help of neat phasor diagram.

Ans: Def: The transformer which is free from all types of losses is known as an ideal transformer. It is an imaginary transformer that has no core loss, no ohmic resistance, and no leakage flux. The ideal transformer has the following important characteristic.

→ The resistance of their primary & secondary winding becomes zero.
→ The core of the ideal t/f is has infinite permeability.
→ The leakage flux of t/f becomes zero.
→ The ideal t/f has 100% efficiency; the t/f is free from hysteresis & eddy current loss.

In an ideal transformer, there is no power loss. Therefore, the output Power is equal to the input power.

$E_2 I_2 \cos\phi = E_1 I_1 \cos\phi$ or $E_2 I_2 = E_1 I_1$

or $\frac{E_2}{E_1} = \frac{I_1}{I_2}$

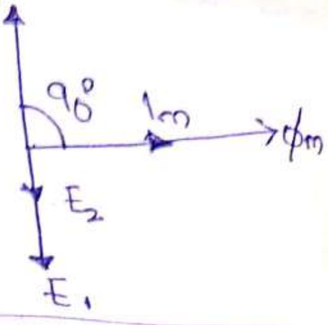
∴ Transformer ratio will be given by the eq$^n$

$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K.$$

Phasor Diag. of Ideal Transformer

The phasor diagram of the ideal T/f is shown in fig below. As the coil of the primary transformer is purely inductive the magnetising Current induces in the t/f lag 90° by the input voltage $V_1$.

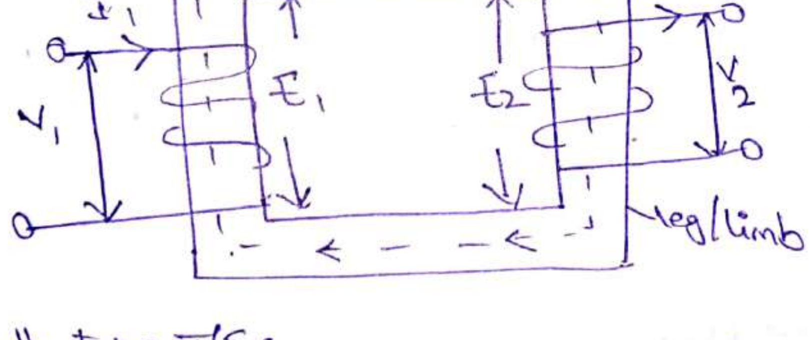
The $E_1$ & $E_2$ are the emf induced in the primary & secondary winding of the t/f. The direction of the induced emf is inversely proportional to the applied voltage.




2. Explicate in detail with a neat diagram about the constructional details of single phase transformers.

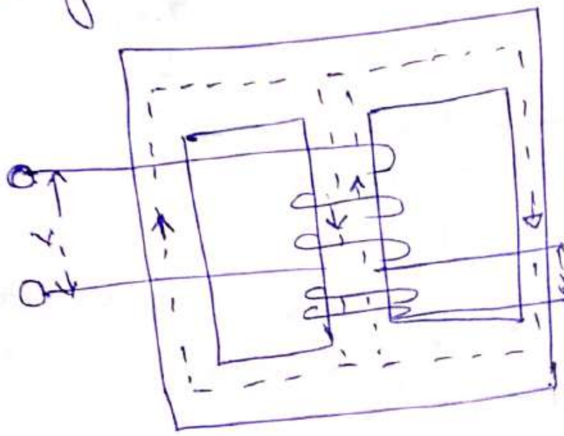
Ans Based on how the windings are wound around the central steel laminated core, the t/f construction is divided into two types.

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 fig below. This type of construction ensures that magnetic lines of force flow across both the windings simultaneously. The main disadvantage of the core-type t/f is the leakage flux that occurs due to the flow of a small proportion of magnetic lines of force outside the core.

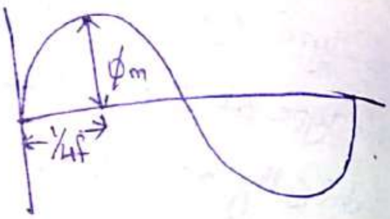



Shell-type T/F:
In this type of t/f construction, the primary and secondary windings are positioned cylindrically on the center limb reaching resulting in twice the cross-sectional area than the outer limbs.

There are two closed magnetic path in this type of construction and the outer limb has the magnetic flux $\phi/2$ flowing. shell type t/f overcomes leakage flux, reduces core losses and increases efficiency.



3. Derive the EMF equation of t/f? Hence derive the voltage ratio



Ans: EMF eqn of a t/f

let

$N_1$ = No. of turns in Primary

$N_2$ = No. of turns in secondary.

$$B_m = \frac{\phi_{max}}{A}$$

∴ Average rate of change of flux

$$E = \frac{d\phi}{dt}$$

$$d\phi = \phi_{max} - 0$$

$$dt = \frac{T}{4} = 1/4f.$$

$$\frac{d\phi}{dt} = \frac{\phi_{max}}{1/4f} = 4f\phi_{max}$$

∴ Avg emf induced per turn =

$4f\phi_{max}$ V/t.

f flux varies sinusoidally, then r.m.s value of induced emf is obtained by multiplying the average value with form factor.

Now

R.M.S value of emf = formfactor × Avg. value

$= 1.11 \times 4f\phi_m$

$= 4.44f\phi_m$

$E_1 = 4.44 f N_1 \phi_{max} = 4.44 f N B_m A$ (v)

$E_2 = 4.44 f N_2 \phi_{max} = 4.44 f N_2 B_m A$ (v).

In an ideal t/f or no load

$V_1 = E_1$ & $V_2 = E_2$.

Voltage Transformation Ratio (K)

$$\frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = K.$$

$N_2 > N_1$ ; $K > 1$ - step up t/f

$N_2 < N_1$ ; $K < 1$ - step down t/f

for an ideal t/f

Input VA = Output VA

$V_1 I_1 = V_2 I_2$

or $\frac{I_1}{I_2} = \frac{V_2}{V_1} = K$.

K is defined as the ratio of turns of wire in the secondary winding to the no. of turns of ~~of~~ wire in the primary winding.

$$\boxed{\frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K}$$

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4. What is the efficiency of t/f? How the efficiency of t/f be calculated?

Ans. Efficiency of Transformer.

It can be defined as output power divided by the input power

$$\text{efficiency} = \frac{\text{output}}{\text{input}} = \frac{\text{input-losses}}{\text{input}} = 1 - \frac{\text{losses}}{\text{input}}$$

Condition for Max efficiency.

Copper loss $= I^2 R_1$

Iron loss $= W_i$

$$\text{efficiency} = 1 - \frac{\text{losses}}{\text{input}} = 1 - \frac{I_1^2 R_1 + W_i}{V_1 I_1 \cos\phi_1}$$

$$\eta = 1 - \frac{I_1 R_1}{V_1 \cos\phi_1} - \frac{W_i}{V_1 I_1 \cos\phi_1}$$

diff above eqn with respect to $I_1$

$$\frac{d\eta}{dI_1} = 0 - \frac{R_1}{V_1 \cos\phi_1} + \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

$$\eta_{max} \text{ at } \frac{d\eta}{dI_1} = 0$$

$$\eta_{max} = \frac{R_1}{V_1 \cos\phi_1} = \frac{W_i}{V_1^2 I_1^2 \cos\phi_1}$$

$$\frac{I_1^2 R_1}{V_1 I_1^2 \cos\phi_1} = \frac{W_i}{V_1 I_1^2 \cos\phi_1}$$

$$I_1^2 R_1 = W_i$$

Hence, efficiency of a t/f will be max when Copper loss and iron losses are equal.

That is Copper loss = Iron loss.

5. Discuss the effect of variable frequency and supply voltage on iron loss and performance of the t/f?

Ans: Power t/f's are not ordinarily subjected to frequency variations and usually are subject to only modest voltage variations, but it's interesting to consider the effects thereof.

Variations in voltage and/or frequency affects the iron losses in a t/f. As long as the flux variations are sinusoidal w.r.t time, hysteresis loss & eddy current loss varies according to the following relations

$P_h \propto f(\phi_{max})^x \Rightarrow P_e \propto f^2(\phi_{(max)})^2$

If the t/f is operated with the frequency & voltage changed in the same proportion, the flux density will remain unchanged as obvious & apparently the no-load current will also remain unaffected.

The t/f can be operated safely at frequency less than rated one with correspondingly reduced voltage. In this case iron losses will be reduced. But if the t/f is operated with increased voltage & ~~f~~ frequency in the same proportion, the core losses may increase to an intolerable level. Increase in frequency with constant supply voltage will cause reduction in hysteresis loss and leave the eddy current losses unaffected. Some increase in voltage could, therefore, be tolerated at higher frequencies, but exactly how much depends on the relative magnitude of the hysteresis and eddy current losses and the grade of iron used in the transformer core.

6. Define voltage regulation of a t/f & enumerate the factors which influence the magnitude of this change?

Ans: Def: The voltage regulation is defined as the change in the magnitude of receiving & sending voltage of the t/f. The voltage regulation determines the ability of the t/f to

Provide the constant voltage for variable loads.

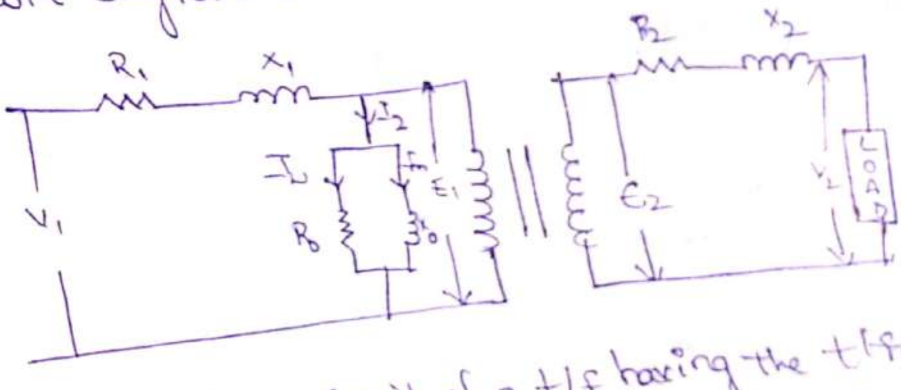
$$\text{voltage Regulation} = \frac{E_2 - V_2}{E_2}$$

$$\%\ \text{voltage Regulation} = \frac{E_2 - V_2}{E_2} \times 100.$$

when the t/f is loaded with continuous supply voltage, the terminal voltage of t/f varies. The variation of voltage depends on the load & its power factor.

7. Draw the exact equivalent circuit of a transformer & describe briefly the various parameters involved in it?

Ans: The simplified equivalent circuit of a t/f is drawn by representing all the parameters of the t/f either on the secondary side or on the primary side. The equivalent circuit diagram of the t/f is shown below.




let the equivalent circuit of a t/f having the t/f ratio $K = \frac{E_2}{E_1}$. The induced emf $E_1$ is equal to the primary applied voltage $V_1$ less primary voltage drop. This voltage causes current $I_0$ no-load current in the primary winding of the t/f. The value of no-load current is very small, & thus it is neglected. Hence, $I_1 = I_1'$. The no load current is further divided into two components called magnetizing current ($I_M$) & working current ($I_W$).

hese two components of no-load current are due to the current drawn by a non-inductive resistance $R_0$ & pure reactance $X_0$ having voltage $E_1$ or $V_1$ (Primary voltage drop).

The secondary current $I_2$ is

$$I_2 = \frac{I_1'}{k} = \frac{I_1 - I_0}{k}$$

The terminal voltage $V_2$ across the load is equal to the induced emf $E_2$ in the secondary winding less voltage drop in the secondary winding.

3) Distinguish btw core type and shell type transformer. Why the low voltage winding is placed near the core? Why the core of a t/f is laminated?

Ans: One of the major difference btw the core & shell type t/f is that in core type transformer, the winding encircles the core, whereas, in shell type t/f, the core encircles the winding of the t/f.

In core type t/f's, the LV winding of the t/f is placed near the core in order to reduce the cost of insulation and the size of the t/f. If the HV winding of the t/f is placed near the core, the insulation would have to be thicker leading to higher cost.

The core of the t/f is laminated to reduce these to a minimum as they interfere with the efficient t/f to energy from the primary coil to the secondary one. The eddy currents cause energy to be lost from the t/f as they heat up the core - meaning that electrical energy is being wasted as heat.

9. Define a t/f. Explain the principle of operation of transfo

Ans: A transformer can be defined as a static device which helps in the transformation of electric power in one circuit to electric power of the same frequency in another circuit.

The main principle of operation of a t/f 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.

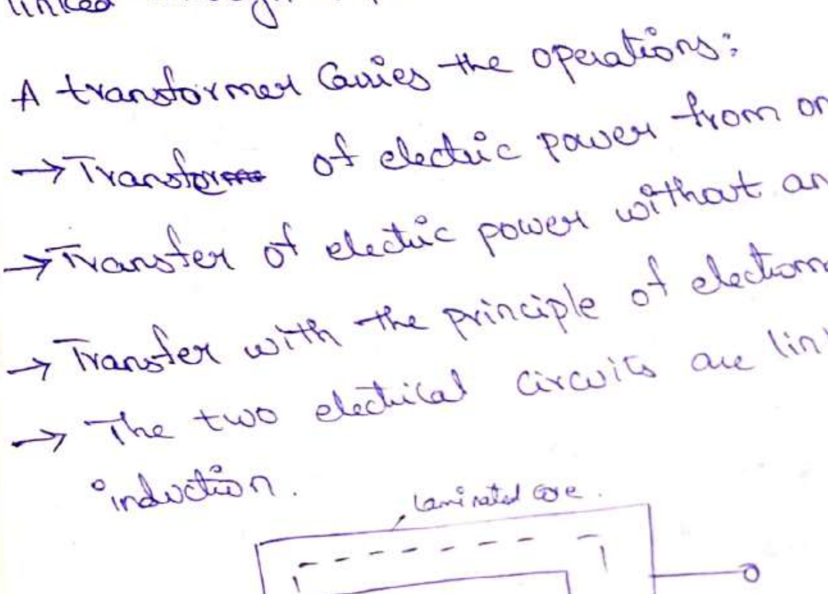
A transformer carries the operations:

→ Transform 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.




10. what are taps and when are they used? what is the diff btw "insulating", "isolating", and "shielded winding" of single phase transformers?

Ans Taps are provided on some transformers on the high voltage winding to correct for high or low voltage conditions, and still deliver full rated output voltage at the Secondary terminals

Standard tap arrangements are at 2.5% and 5% of the rated primary voltage for both high and low voltage conditions.

Insulating and isolating transformers are identical. These terms are used to describe the isolation of the primary and secondary windings, or insulation between the two.

A Shielded transformer is designed with a metallic shield between the primary and secondary windings to alternate transient noise.

Module-4

(10) A

Taps:

Actually tap is a direct connection to a term on a transformer winding at a voltage other than nominal rated voltage.

we know that the power supply will be fluctuating when it is sent by the powerstation so there will be huge differences in the secondary terminal voltage. to overcome this a tap is fixed to the primary windings of the transformer. Then for example (take 2:1 transformer) if 240V is sents 120V but if 480V comes up then it sends 240V then due to this the appliance will gets damaged. so this tap is used to normalized the secondary voltage

(b)

Actually Insulating and Isolating transformers are identical. these terms are used to describe the isolation of primary and secondary windings con Insulation b/w two. A shielded transformer is which in it having a shield b/w primary and secondary winding these are generally used in computers, music players, etc.

All the ~~ge~~ transformers are of Insulating (or) Isolating except a few are of different type

~~(i) (or) single~~

11A) In some cases single phase transformers can be operated at the voltage's less than there name plate voltages.. But they will provide the less voltage (or) power. But in any circumstances the transformer shouldn't be operated above the name plate voltage (or) rated voltage. But if the taps are provided then there will no problem in high voltage cases also..

(b) yes, 60HZ transformers can be operated at 50HZ

(12A)
(a) Actually transformers are used ||el to produce the voltages in primary and secondary circuits. connecting transformer with same parameters results in equal load sharing.

(b) Yes, a single phase transformer can be used in three phase transformer by connecting the primary with the other two wires of 3-phase circuit (or) By taking 3-single phase transformers and connecting them in Delta-Delta position.

(13A)

No, three phase power can be developed from single phase transformer. But it is of one ...

But it is possible only when three single phase transformers are connected in a delta or Y-than or by connecting two wires of three phase transformer to single phase to primary.

(b) to select the transformers first we should know the primary and secondary voltages. The faster the change in voltage. the high is frequency and the high is the heat produced

(14A)

voltage regulation is the ratio of percentage of voltage output to that of input.

$$\boxed{\text{Regulation} = \frac{V_{out}}{V_{in}} = \frac{V_{no\,load} - V_{full\,load}}{V_{no\,load}},}$$

All the electric devices or appliance will release so part of electricity as in the form of Heat. In transformers this heat is released from the coils and due to the temperature rise occurs.

the highest the temperature in which the material can with stand than it's higher the class of insulation. If the higher it the class of insulation the material can withstand without causing any degradation.

5A) Transformer works on the principle of mutual Induction.

Mutual Induction:

The principle of mutual Induction states that when two coils are inductively connected if the current flowing in one coil changes then it induces the ~~neg~~ emf.

5b) There are mainly two types of losses in transformer:

(i) Ironloss
(ii) copper loss

(i) Ironloss: this occurs due to the loss of magnetic field when passed through the iron core. this loss is furtherly divided into two types.

(a) eddy current loss
(b) Hysteresis loss.

(ii) copperloss: this occurs due to the loss of current wastage as the heat ~~or~~ electric current from the coils of the form of heat transformer.

(16)

Actually in real life it is hard to calculate the Resistance and Reactance of the transformer.

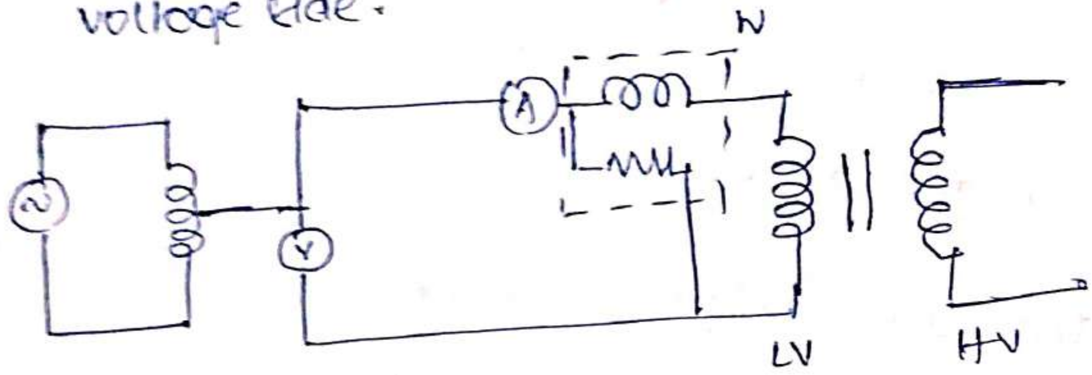
So, some tests are to perform are

(i) open circuit tests (OC)

(ii) short circuit tests (SC)

(i) open circuit test: (oc test)

This type of test is usually done for a step transformer. As this test is done on the low voltage side.




Autotransformer.

In this we measure

$V_0$ (no load primary voltage)

$I_0$ (no load primary current) [very low value]

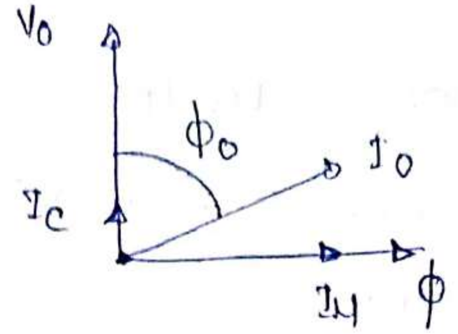
$W_0$ (No load losses) [ core losses]

As $I_0$ is low the 'cu' loss value will also be very low.

So, from this test we calculate.

$W_0 = V_0 I_0 \cos\phi_0$

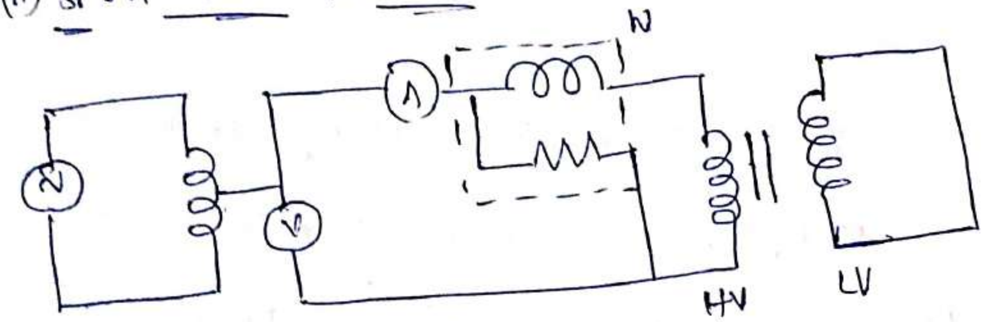
$$\boxed{\cos\phi_0 = \frac{W_0}{V_0 I_0}}$$




* $I_C = I_0 \cos\phi$
* $I_M = I_0 \sin\phi$

$$\boxed{R_0 = R_C = \frac{V_0}{I_C}} \qquad \boxed{X_C = X_0 = \frac{V_0}{I_M}}$$

(ii) <u>short circuit</u> <u>test</u> (sc test)




Auto transformer

In this we measure.

$V_{SC}$ (short ckt voltage) [very low as compared to rated voltage]

$I_{SC}$ (short ckt current [comparable with full current]

$W_{SC}$ (short ckt power) (copper losses)

- wattmeter will read copper losses because of high current passing through windings.

$W_{SC} = I_{SC}^2 R_{2e}$

$$\boxed{Z_{2e} = \frac{V_{SC}}{I_{SC}}}$$

$$\boxed{R_{2e} = \frac{W_{SC}}{I_{SC}^2}} \qquad \boxed{X^2 = Z_{2e}^2 - R_{2e}^2}$$

(18A)

ii) Many of the load testing tools are licensed and charge a good amount of money for the license.

iii) Load test script creation requires scripting knowledge of language supported by tool.

iiii) If any one thing is incorrect total money and time are wasted.

(19A)

In case of no load the secondary terminal of the transformer is open means the circuit is not ~~comple~~ complete on other side. this situation correctly indicates that there is no path available for the current flowing in secondary side, there is no demagnetizing flux generated so there is no need of extra current. so, the primary current would contain only exciting current.

this is done when the load is removed, And the field excitation, speed are kept constant. The value of the open circuit and no load voltage is recorded.

this method is used for small alternators of the power rating less than 5KVA.

(b) out of all the losses like copper loss and core loss core loss is constant because it depends mainly on the magnetic properties of the material used. As for all the transformer soft iron core is used there will be const hysteresis and eddy current loss so there will be const core loss.

# QB Part C Module 4

1) Given,

$\frac{EMF}{turn} = 15V$

(i)

Primary turns $= \frac{440}{15} = 29.3$ turns $\approx 29$ turns

Secondary turns $= \frac{220}{15} = 14.6$ turns $\approx 15$ turns

(ii)

$E_1 = 4.44 f \phi_m N_1$ $\qquad \phi_m = B_m A \qquad B_m = 1 wb/m$

$440 = (4.44)(50)(1)(A)(29)$

$A = 0.0683 m^2$

4) (i) No of turns in each winding:

$\phi_m = B_m A = 1.5 \times \frac{50}{10^4} = 7.5 \times 10^{-3}$ wb

$E_p = 4.44 N_p f \phi_{max} \Rightarrow N_p = \frac{E_p}{4.44 f \phi_{max}}$

$N_p = \frac{2400}{4.44 \times 60 \times 7.5 \times 10^{-3}} = 1201$ turns

$\frac{N_p}{N_s} = 10 \Rightarrow \frac{1201}{N_s} = 10$

$N_s = 120$ turns

(ii) Magnetizing current:

$H = \frac{N_p I_m}{l}$

H = Magnetising field intensity
$N_p$ = turns in primary winding
$I_m$ = Magnetizing current
$l$ = Mean length of core

Scanned with CamScanner

solve for $I_m$

$$I_m = \frac{Hl}{N_p} = \frac{450 \times 0.667}{1201} = 0.25A$$

(iii) The turns ratio

$$\cancel{\frac{N_p}{N_s} = \frac{E_p}{E_s} = \frac{2400}{240}} \quad \frac{N_p}{N_s} = \frac{E_p}{E_s} \approx \frac{V_p}{V_s} = \frac{2400}{240} = 10$$

5) EMF per turn $= 10V$

Primary induced EMF ($E_1 = V_1 = 2200V$)

Secondary induced EMF ($E_2 = V_2 = 220V$)

Supply frequency $f = 50Hz$

$B_{max} = 1.5T$

No of primary turns, $\frac{E_1}{\text{EMF per turn}} = \frac{2200}{10} = 220 = N_1$

No of secondary turns, $\frac{E_2}{\text{EMF per turn}} = \frac{220}{10} = 22 = N_2$

$$\phi_{max} = \frac{\text{EMF per turn}}{4.44f} = \frac{10}{4.44 \times 50} = 0.045\,Wb$$

Net cross sectional area is:

$$A = \frac{\phi_{max}}{B_{max}} = \frac{0.045}{1.5} = 0.03\,m^2$$

2) OC test = open circuit test [gives iron loss of transformer]

SC test = short circuit test [given copper loss]

Given,

$$\frac{V_1}{V_2} = \frac{200}{400}, \quad f = 50\,Hz$$

$$\frac{N_1}{N_2} = \frac{1}{2}$$

$$W_0 = V_1 I_0 \cos\phi_0$$

$$\cos\phi_0 = \frac{W_0}{V_1 I_0} = \frac{80}{200 \times 0.8} = \frac{1}{2}$$

$$\phi_0 = 60^\circ$$

$$I_w = I_0 \cdot \cos\phi_0$$

$$= 0.8 \times \frac{1}{2} = 0.4\,A$$

$$I_m = \sqrt{I_0^2 - I_w^2} = \sqrt{(0.8)^2 - (0.4)^2} = 0.692\,A$$

$$R_0 = \frac{V_1}{I_w} = \frac{200}{0.4} = 500$$

$$X_0 = \frac{V_1}{I_m} = \frac{200}{0.692} = 289.01$$

From SC test:

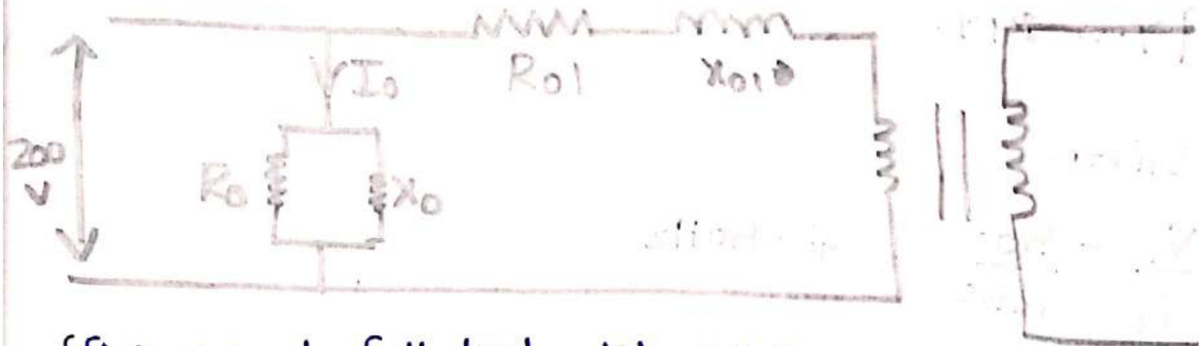
$$Z_{01} = \frac{V_{SC}}{I_{SC}} = \frac{25}{10} = 2.5$$

$$W_{SC} = I_{SC}^2 \cdot R_{01} \Rightarrow R_{01} = \frac{W_{SC}}{(I_{SC})^2} = \frac{90}{100} = 0.9$$

$$\therefore X_{01} = \sqrt{Z_{01}^2 - R_{01}^2} = \sqrt{(2.5)^2 - (0.9)^2}$$

$$= 2.33$$

The Circuit constants referred to LV side;




efficiency at full load with 0.8 lagging Power factor

$W_{SC} = 90W$ $\qquad$ $I_{SC} = I_1 = 10A$

$$I_1(fl) = \frac{6000}{200} = 30A = \frac{\text{KVA rating}}{\text{Primary voltage}}$$

$$W_{cu}(fl) = W_{SC} \times \left(\frac{I_1(fl)}{I_1}\right)^2$$

$$= 90 \times \left(\frac{30}{10}\right)^2$$

$$= 810W$$

$W_{iron} = 80W$ [Primary Power]

$$\eta = \frac{x\,[\text{kva rating}] \times pf}{x\,[\text{kva rating}] \times pf + W_{iron} + x^2 W_{cu}(fl)}$$

$\Rightarrow$ Full load so $x = 1$

$$= \frac{1\,[6000]\,[0.8]}{[6000]\,[0.8] + 80 + 810}$$

$$\frac{4800}{4800 + 890} = 0.8435$$

$\eta\% = 84\%$.

3) Given,

$\frac{V_1}{V_2} = \frac{500}{250}$ , $f = 50Hz$

$\frac{N_1}{N_2} = 2$

$W_0 = V_1 I_0 \cos\phi_0$

$$\cos\phi_0 = \frac{W_0}{V_1 I_0} = \frac{5\cancel{0}}{50\cancel{0} \times 1} = \frac{1}{10} = 0.1$$

$I_w = I_0 \cos\phi_0$

$= 1 \times \frac{1}{10} = 0.1$

$I_m = \sqrt{(I_0)^2 - (I_w)^2} = 0.994$

$= \sqrt{(1)^2 - (0.1)^2} =$

$$R_0 = \frac{V_1}{I_w} = \frac{500}{0.1} = 5000\,\Omega$$

$$X_0 = \frac{V_1}{I_m} = \frac{500}{0.994} = 503.01\,\Omega$$

From sc test:

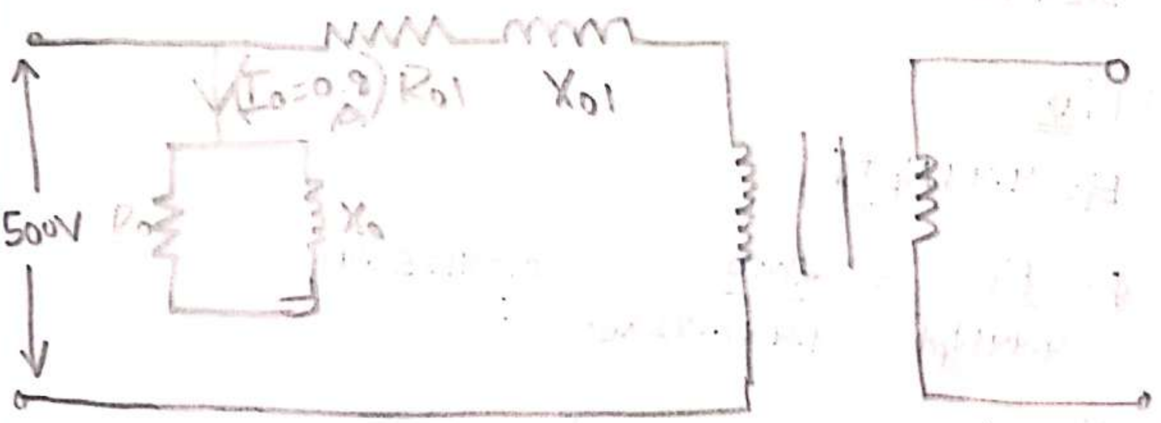
$$Z_{01} = \frac{V_{sc}}{I_{sc}} = \frac{25}{10} = 2.5$$

$$W_{sc} = I_{sc}^2 \cdot R_{01} \Rightarrow R_{01} = \frac{W_{sc}}{I_{sc}^2} = \frac{60}{100} = 0.6$$

$$\therefore X_{01} = \sqrt{(Z_{01})^2 - (R_{01})^2}$$

$$= \sqrt{5.89} = 2.426$$

The circuit constraints referred to L.V side




efficiency at full load with 0.8 lagging power factor:

$W_{sc} = 60W$ $\quad$ $I_{sc} = I_1 = 10A$

$$I_1(fl) = \frac{5000}{500} = 10A$$

$$W_{cu(fl)} = W_{sc} \times \left(\frac{I_{1(fl)}}{I_1}\right)^2$$

$$60 \times \left(\frac{10}{10}\right)^2$$

$$= 60W$$

$$W_{iron} = 50W$$

$$\eta = \frac{[5000][0.8]}{[5000][0.8]+60+50}$$

$$\frac{4000}{4110} = 0.9732$$

$$\eta\% = 97.32\%$$

7) Primary voltage = 2000V

Primary turns = 182

secondary turns = 40

(ii) <u>Flux</u>

$$E_1 = 4.44 N_p f \phi$$

$$\phi = \frac{E_1}{4.44 N_p f} = \frac{2000}{4.44 \times 182 \times 60} = 0.04125\,wb$$

(iii) $\frac{V_1}{V_2} = \frac{N_1}{N_2}$ $\qquad \frac{V_1}{V_2} \approx \frac{E_1}{E_2}$

$$\frac{2000}{E_2} = \frac{182}{40}$$

$$E_2 = \frac{2000 \times 40}{182}$$

$$= \boxed{439.56\,V}$$