Transformer Module - III

1. What is transformer?

⇒ Transformer is a static device that transfers electric power from one circuit to another without change of frequency. There is no rotating part in a transformer so it is a static device. Transformers operates on ac supply. In transformer operation two electrical circuits are not connected to each other they are interlinked by common magnetic circuit.

2. Define an ideal transformer.

⇒ An ideal transformer is an imaginary transformer, which has

i) no copper losses (no winding resistance)
ii) no iron loss in core
iii) no leakage flux.

An ideal transformer gives output power exactly equal to the input power. The efficiency of an ideal transformer is 100%. Actually it is impossible to have such a transformer in practice but ideal transformer makes problems easier.

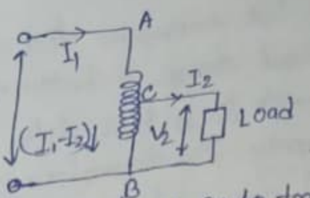
Zero winding resistance:- It is assumed that resistance of Primary as well as secondary winding of an ideal transformer is zero. Both the coils are purely inductive in nature.

No leakage flux:- Leakage flux is a part of magnetic flux which does not get linked with secondary winding. In ideal transformer, it is assumed that entire amount of flux get linked with secondary winding.

100% efficiency:- An ideal transformer does not have any losses like hysterisis loss, eddy current loss etc.

3. Write a short note on Auto Transformer.

⇒ ~~An two~~ winding auto transformer is a single winding transformer in which a part of the winding is common high voltage to low voltage.



step down auto tranformer

The primary winding AB has N_1 number of turns and the secondary winding BC has N_2 number of turns. BC is common to primary and secondary winding

$$\frac{E_1}{E_2} = \frac{N_2}{N_1} = K \quad [\text{K is the turns ratio}]$$

The input current is I_1 and ~~I_2~~ load current is I_2. Then $I_1 N_1 = I_2 N_2$. The output voltage V_2 can be varied.

4. Explain the operating Principle of Transformer.

⇒ Transformer works on principle of inductance between two or more inductively coupled coils. Here one of the winding is called primary which is energized by an alternating voltage source and secondary winding is connected to the load. If ac voltage is supplied to primary winding coil and produce alternating current, alternating magnetic flux in the core of the transformer. Alternating magnetic flux links with primary and secondary coil turns and induces an emf by self induction and mutual induction respectively.

5. & 6 & 7. Derive expressions for the emf induced in the transformer windings?

From Faraday's law

$$E_1 = -N_1 \frac{d\phi}{dt}$$
$$= -N_1 \frac{d}{dt}(\phi_m \sin \omega t)$$
$$= -N_1 \omega \phi_m \cos \omega t$$
$$= N_1 \omega \phi_m \sin(\omega t - \pi/2)$$

ϕ_m = maximum value of flux
f = frequency
N_1 → Primary winding
N_2 → Secondary winding
ϕ → flux

The induced emf lags flux by $\pi/2$. → question → 7

$$E_1 max = N_1 \omega \phi_m$$
$$= N_1 2\pi f \phi_m \quad [\omega = 2\pi f]$$
$$E_1 \cancel{max} = \cancel{\frac{N_1 \omega \phi_m}{\sqrt{2}}} \quad \frac{N_1 2\pi f \phi_m}{\sqrt{2}}$$
$$= \sqrt{2}\pi f N_1 \phi_m$$

$$E_1 = 4.44 f N_1 \phi_m$$ → question-6

Similarly

$$E_2 = 4.44 f N_2 \phi_m$$

$$\frac{E_2}{E_1} = \frac{4.44 f N_2 \phi_m}{4.44 f N_1 \phi_m}$$

$$\Rightarrow \frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$ → question-5

8. Why is a transformer rated in KVA?

⇒ The rated capacity of a transformer is expressed in KVA. Generally the rating of a transformer is determined by its temperature. The temperature is caused by the losses in the machine. Copper loss depends on the value of the load current and iron loss on voltage. Total loss of a transformer depends on volt-Ampere. It is independent of load power factor. A certain amount of current will produce at any value of power factor. The output in kilowatts is proportional to the power factor. The load current increse propotionaly losses and temperature.

9) What will happen if a transformer is operated in DC?

⇒ Transformers works on Faraday's Law of Electromagnetic Induction which current in coil must change. If DC is applied current will no change and transformer will not work.

winding resistance is very small. For DC, inductive reactance is zero and frequency is zero. Therefore impedence is low. Winding ~~more~~ draws more current which may damage the winding.

10) Why will a Transformer not operate under DC supply?

⇒ We know that transformer operation principle is based on Faraday's law of Electromagnetic Induction.

We state that whenever there is a change of flux linkage in coil and EMF is induced in the coil. When DC is applied in the primary coil of transformer there will be no change of flux in the coil. So no EMF will be induced in the primary coil there.

11) Why is the core of a transformer laminated? Transformer core is made up of which material?

⇒ The core is not designed to have any currents flow through it. However a conducting loop that experience a changing magnetic field. It is small current induced in it. These called eddy current.

The core is laminted to reduce these currents to a minimum interfere with the efficent transfer of energy from the primary coil to secondary coil.

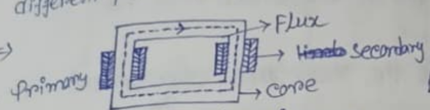
Transformer core is made up soft iron.

12) Explain with reasons as to why transformer core is made up of Silicon steel lamination

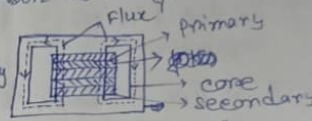
⇒ A transformer core is made up of silicon steel lamination because
1. It helps to reduce energy losses through eddy currents
2. The laminations stack together to form an efficent magnetic circuit, reducing the core size and weight.
3. Silicon steel is a good electrical conductor and has a high magnetic permeablity. which helps to increase the transformer's efficency.
4. The laminations also act as insulation between the turns of the transformer's winding.

13. Draw a core type and shell type transformer. mention their different parts and make a comparison the two types of transformers

⇒



Core type transformer



Shell type Transformer

Core type	Shell types
i) two limbs two jokes	i) three limbs and two jokes.
ii) single magnetic circuit	ii) Two magnetic circuits
iii) more copper loss	iii) Less copper loss
iv) Percentage impedence lower	iv) percentage impedence higher

14) Distinguish between core type and shell type transformer?

Core type	Shell type
i) Easy in design and construction.	i) Comparatively complex.
ii) Reduction of leakage reactance is not easily possible.	ii) Reduction of leakage reactance is highly possible.
iii) The assembly can be easily dismantted for repair work.	iii) It Cannot be easily dismantled for repair work.

15) Why is the low voltage winding placed near the core?

→ The winding and core are both made of metals so an insulation have to be placed in between them. The thickness of insulation depends on the voltage rating of the winding.

If HV winding is placed near to the transformer core more insulation is required to insulate them. the result increase in the cost of insulation material and also size of transformer increses. Reduce the cost of insulation the low voltage winding placed near the core.

16) What are the ideal conditions of a transformer operation?

⇒ i) The two windings of this transformer have no resistance.

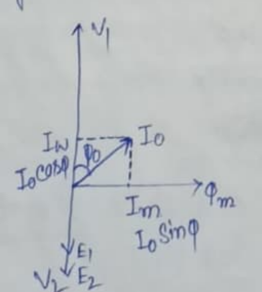
ii) There are no losses, to the resistance, eddy current and hysteresis.

iii) The efficency of the transformer is 100%.

iv) The total flux generated in the transformer is confined to the core and leakage flux is zero.

17) Draw and explain the no load phasor diagram of an ideal single-phase transformer.

⇒



No load primary current I_0 is called the ~~exitei~~ exciting current of the transformer

1. one in phase with V_1 is known ~~as~~ iron loss component I_W because it supplies the iron loss

$$I_W = I_0 \cos\varphi_0$$

2. The other component is in quardrature V_1 and is known as magnetizing component I_μ

$$I_\mu = I_0 \sin\varphi_0$$

When the transformer is no load, primary current lags V_1 and an angle ϕ_0

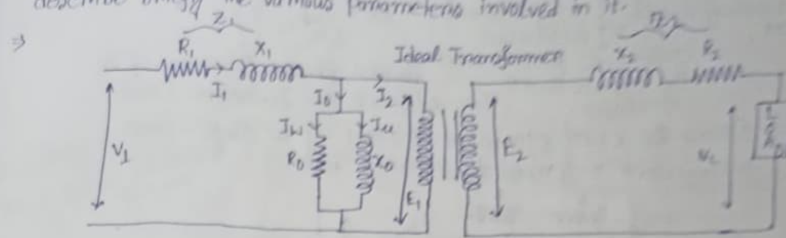
$W_0 = V_1 I_0 \cos\phi_0$

It is principle the core loss which is responsible for the shift in current vector from 90° position, angle ϕ_0 is known as hysteresis angle.

$$I_0 = \sqrt{I_w^2 + I_\mu^2}$$

18) Draw the exact equivalent circuit of a transformer and describe briefly the various parameters involved in it.

⇒



a) leakage flux is present at primary and secondary sides. The leakage reactance are denoted as X_1 and X_2 respectively

b) The primary and secondary winding resistance denoted as R_1 and R_2 respectively. These resistances cause voltage drop as I_1R_1 and I_2R_2 and also copper losses $I_1^2R_1$ and $I_2^2R_2$

c) Permeability of the core cannot be infinite. magnetizing current is ~~m~~ needed. Mutual flux also causes core loss in iron parts of the transformer.

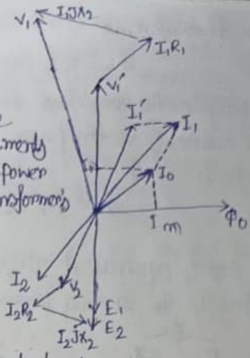
d) The no load current I_0 is divided pure inductance X_0 and non inductive resistance R_0 which are connected into parallel across the primary.

The voltage transformation ratio,

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = K$$

19. Explain the principle of operation of a transformer under loaded condition.

⇒ Under loaded conditions, a transformer operates by transferring electrical energy from the primary winding to the secondary winding. Primary winding is connected to the source and the secondary winding delivers power to the load. the transformers ** adjusts the current and voltage levels to match the load requirements maintaining the power balance. Transformer's core flux and magnetizing current are still present. Additional currents flow to meet the efficient power transfer. **



~~loaded~~ phasor Diagram of the Transformer on Inductive Load.

20) Draw the exact equivalent circuit of a single-phase transformer referred to primary side.

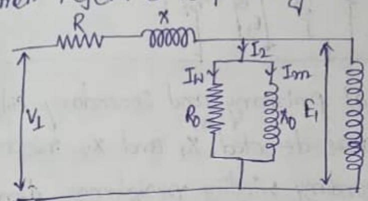


fig:- Primary side at equivalent side

21) Draw the exact equivalent circuit of a single-phase transformer under lagging p.f load and describe briefly the various parameters involved in it.

⇒

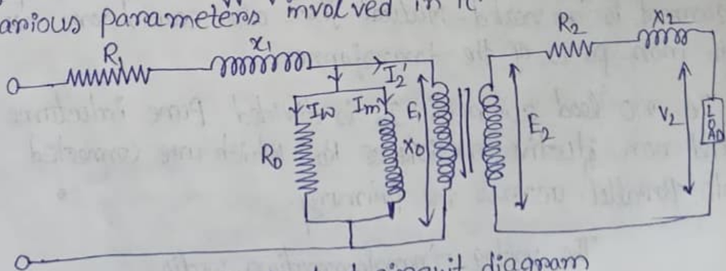


fig:- Equivalent circuit diagram

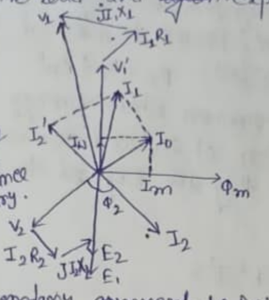
Where
R_1 = Primary winding Resistance I_W = Working component
R_2 = Secondary winding Resistance
I_0 = No-load current
I_μ = Magnetizing component

This I_μ and I_w are connected in parallel across the primary circuit. The value of E_1 (Primary e.m.f) is obtained by subtracting vectorially $I_1 Z_1$ from V_1. The value of $X_0 = E_1/I_0$ and $R_0 = \frac{E_1}{I_w}$, we know that

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = K$$

23) Draw the phasor diagram of a Transformer of a Transformer with capacitive load and ~~again~~ explain.

→



jx_1 = leakage reactance primary.
jx_2 = leakage reactance secondary.

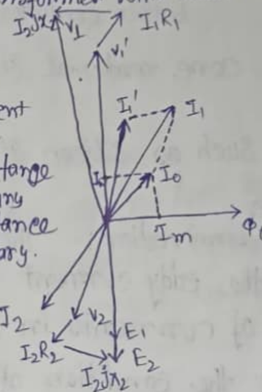
V_1 = the supply voltage.
E_1 = the induced voltage at primary.
$V_1' = -E_1$ (the primary side in the phasor diagram)
I_0 = the no load current at primary ($I_w + I_m$)
E_2 = the secondary induced voltage.
V_2 = the output voltage at the secondary
I_2 = the secondary load current
ϕ = the p.f. angle

I_2' = secondary current to primary.

22) & 24) 25) Draw the phasor diagram of a Transformer with inductive load and explain?

→ V_1 = Supply voltage
E_1 = the induced voltage at primary
$V_1' = -E_1$ (the primary side in the phasor diagram)
I_0 = the no load current at primary

I_2 = Secondary load current
ϕ = the p.f. angle.
jX_1 = leakage reactance primary
jX_2 = leakage reactance secondary.



E_2 = the secondary induced voltage.
V_2 = the output voltage at the secondary.

26) & 27) Explain the energy losses in a transformer. Process to overcome these losses.

→ Copper Losses (ohmic Losses) :-

These losses occur due to the ohmic resistance of the transformer windings and dissipated a heat if I_1 and I_2 is primary and secondary resistance then the copper losses will be $I_1^2 R_1$ and $I_2^2 R_2$

~~copper loss~~ is ~~minimized~~ by using ~~thicker wire~~ on better conductor.

Iron Losses :-

Iron losses are caused by the alternating flux in core of the transformer as this loss occurs in the core. It is divided into hysteresis and eddy current loss.

Hysteresis loss :- The core of the transformer is subjected to an alternating magnetizing force and cycle of emf, a hysteresis loop is traced out. Power is dissipted of heat as known as hysterisis loss. $P_h = K_h f B_m^K$

eddy loss:- This is a phenomenon where energy is lost as heat due to the production of induced currents in conductive material when they are exposed to changing magnetic fields.

$$P_e = K_e B_m^2 f^2 T^2 V$$

- copper loss is minimized by using thicker wire on better conductor.

1. Core material selection :-

Core materials with low hysteresis loss, such as silicon steel, reduce the energy magnetic cycles.

2. Lamination:- The core ~~laminationing~~ laminated to reduce the eddy current by preventing circulation of currents in core material.

28) Derive the condition of maximum efficency in a single-
29) phase transformer.

→

$$\eta = \frac{\text{output}}{\text{input}}$$

$$= \frac{\text{output}}{\text{output} + \text{loss}}$$

$$= \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + W_i + I_2^2 R_{02}}$$

$$\frac{d\eta}{dI_2} = \frac{(V_2 I_2 \cos\phi_2 + W_i + I_2^2 R_{0e})\, V_2\cos\phi_2 - (V_2 I_2 \cos\phi_2 + 2 I_2 R \ldots}{(V_2 I_2 \cos\phi_2 + W_i + I_2^2 R_{0e})^2}$$

For get max efficiency

$(V_2 I_2 \cos\phi_2 + \omega i + I_2^2 R_0 e) V_2 \cos\phi_2 - V_2 I_2 \cos\phi_2 (V_2 \cos\phi_2 + 2 I_2 R_0 e) = 0$

$\Rightarrow V_2 \cos\phi_2 (V_2 I_2 \cos\phi_2 + \omega i + I_2^2 R_0 e - V_2 I_2 \cos\phi_2 - 2 I_2^2 R_0 e) = 0$

$\therefore \omega i = I_2^2 R_0 e$

Iron loss = copper loss

This is the condition for max efficiency.

$\frac{d}{dI_2}\left(I_2 R_{02} + \frac{P_i}{I_2}\right) = 0$

$R_{02} - \frac{P_i}{I_2^2} = 0$

$P_i = I_2^2 R_{02}$

30) 31) 32) Define voltage regulation of a transformer.

$\Rightarrow \left[\frac{\text{secondary no voltage} - \text{secondary full load voltage}}{\text{Secondary no load voltage}}\right] \times 100\%$

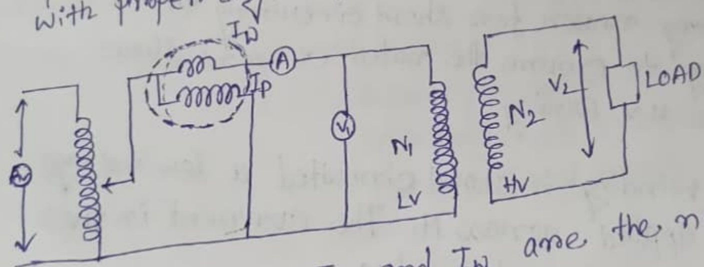
E_2 = the secondary no load voltage.

V_2 = the terminal voltage at secondary.

$$\frac{E_2 - V_2}{E_2} \times 100$$

33) Explain the open circuit test of single phase transformer with proper diagram?

$\Rightarrow$



I_m and I_W are the no load components.

R_0 = core loss Resistance

X_0 = magnetizing Reactance

N_1 = Primary winding

N_2 = Secondary winding

V_1 = primary voltage

V_2 = secondary voltage

$$P_i = W_0 - \frac{V_1^2}{r_p} - I_0^2 r_1$$

$\frac{V_1^2}{r_p}$ and $I_0^2 r_1$ are very small, so.

$$P_i = W$$

$$\therefore W = V_1 I_0 \cos\theta.$$

$$\cos\theta = \frac{W}{V_1 I_0}$$

34) Explain why the open test gives core loss and short circuit test gives copper loss.

→ The open circuit is conducted to the ~~iron~~ core loss in a transformer. When the secondary winding is kept open, the primary winding is connected to the rated voltage. In this condition the core loss includes hysteresis and eddy current losses in the transformer.

The short circuit test is performed to detmine the copper losses in a transformer. When the secondary winding is short-circuited and the rated voltage is applied to the primary winding. ~~I~~ Secondary winding represents the total current to magnetize the core and the current flowing through the copper winding. by subtracting you can obtain the copper loss.

35) Explain why L.V. winding is short circuited and H.V. winding is excited for the short circuit test of single phase transformer.

L.V. winding short-circuited

The primary reason for short circuiting the L.V. winding to ensure the rated current flows through the H.V. winding.

The L.V. winding is short circuited a low voltage ~~sight~~ is applied across it. The current in the H.V. winding to its rated value.

H.V. winding short circuited

A rated voltage apply the H.V. winding to helps the determineng the copper losses in the transformer.

The short-circuited L.V. winding allows for a practical and safe measurement of the current.

38) A Single-Phase transformer with a 2KVA rating has a 480 V Primary and a 120 V secondary. Determine the primary and Secondary full - load currents of the transformer.

→ Single phase transformer VA rating = 2 KVA

$= 2 \times 1000$

$= 2000$ V

Primary voltage $(V_1) = 480$ V

Primary load currents $= \frac{2000}{480}$

$= 4.16$ A

Secondary voltage $(V_2) = 120$ V

Secondary load currents $= \frac{2000}{120}$

$= 16.66$ A

39) A Single phase 50 Hz transformer ~~with a 2KVA~~ has 30 Primary turns and 350 secondary turns. The net cross - Sectional area of the core is 250 cm². The primary winding is connected to the 230 V, 50 HZ supply. calculate a) the peak value of flux density in the core b) the primary current when the secondary current is 100 A.

⇒ Single phase transformer,

Primary turns $(n_1) = 30$

Secondary " $(n_2) = 350$

Cross sectional area $(A) = 250\ cm^2$

$= 250 \times 10^2\ m^2$

voltage $(E) = 230$ V

frequency $(f) = 50$ Hz

We Know,

$\phi_m = B_m \times A$

$= B_m \times 250 \times 10^2\ Wb/m^2$

again,

1.38×10^{-6}

$E = 4.44\, \phi_m f n_1$

$\frac{E}{4.44 f n_1}$

$\Rightarrow 230 = 4.44 \times B_m \times 250 \times 10^2 \times 50 \times 30$

$\Rightarrow B_m = \frac{230}{4.44 \times 250 \times 10^2 \times 1500}$

$= 1.38 \times 10^{-6}\ Wb/m^2$

ii) We know,

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

$$\Rightarrow \frac{I_1}{100} = \frac{35\cancel{0}}{3\cancel{0}}$$

$$\Rightarrow I_1 = \frac{3500}{3}$$

$$= 1166.6\ A$$

The primary current is 1166.6A.

40) The primary of a 50 Hz, Step down transformer has 480 turns and is fed from 6400V supply. Find a) the peak value of the flux produced in the core b) the voltage across the secondary winding if it has 20 turns.

→ a)

$$f = 50\ Hz$$

$$n_1 = 480$$

$$E_1 = 6400V$$

$$E_1 = 4.44\,\phi\,f\,n_1$$

$$\Rightarrow 6400 = 4.44 \times \phi \times 50 \times 480$$

$$\Rightarrow \phi = \frac{640\cancel{0}}{4.44 \times 5\cancel{0} \times 48\cancel{0}}$$

$$= 0.06\ Wb$$

b)

$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$

$$\Rightarrow \frac{6400}{E_2} = \frac{\cancel{480}^{24}}{2\cancel{0}}$$

$$= 24$$

$$\Rightarrow E_2 = \frac{6400}{24}$$

$$= 266.6\ V$$

41) A 5KVA, 440/220 V Single phase transformer has a Primary and secondary winding resistances are 2 ohms and 0.8 ohms respectively and the corresponding leakage resistances are 10 ohms, and 1.5 ohms respectively. Find the secondary terminal

voltage at full load. 0.8 power factor lagging

voltage rating = 5 KVA
= 5×1000
= 5×10^3 A
voltage (I_1) = $\frac{220}{440}$ V
resistance (R_2) = 2 Ω
leakage resistance

voltage rating = 5 KVA = 5×10^3 A
current (I_1) = $\frac{220}{440}$ V
Primary resistance (R_1) = 2 Ω
secondary " (R_2) = 0.8 Ω

lagging power factor ($\cos\theta$) = 0.8
$\sin\theta = \sqrt{1-(0.8)^2}$
$= \sqrt{1-0.64}$
$= \sqrt{0.36}$
$= 0.6$

leakage resistance,
Primary resistance (R_1) = 10 Ω
Secondary " (R_2) = 1.5 Ω

$R_{02} = 2\times\left(\frac{220}{440}\right)^2 + 0.8$
$= 0.5 + 0.8$
$= 1.3\ \Omega$

$X_{02} = 10\times\left(\frac{220}{440}\right)^2 + 1.5$
$= 2.5 + 1.5$
$= 4\ \Omega$

$I_2 = \frac{5\times10^{-3}}{220}$
$= 22.73$ A

We know,
$E_2 = V_2 + I_2 R_{02}\cos\theta_2 + I_2 X_{02}\sin\theta_2$
$V_2 = E_2 - I_2 R_{02}\cos\theta_2 + I_2 X_{02}\sin\theta_2$
$= 220 - 22.73\times1.3\times0.8 + 22.73\times4\times0.6$
$= 220 - 22.73(1.04 + 2.4)$
$= 220 - 78.19$
$= 141.81$ V

4) A 200 KVA single phase transformer has 1000 turns in the primary and secondary winding resistances are 2 ohms and 0.8 ohms respectively and the corresponding leakage resistances are 10 ohm and 1.5 ohms respectively.

Find the secondary terminal voltage at full load. 0.8 power factor lagging.

$\Rightarrow$

$KVA = 200$
$N_1 = 1000$
$N_2 = 600$

42) A 200 KVA single phase transformer has 1000 turns in the primary and 600 turns on the secondary. The primary winding is supplied from a 440 V, 50 Hz source. Find the i) secondary voltage at no load ii) Primary and secondary currents at the full load.

$\Rightarrow$ Single phase transformer,

voltage rating = 200 KVA
$= 200 \times 10^3 A$

Primary winding $(n_1) = 1000$
Secondary " $(n_2) = 600$
voltage $(E) = 440V$
frequency $(f) = 50 Hz$

i)
$$\frac{E_1}{E_2} = \frac{N_1}{N_2}$$
$$\Rightarrow \frac{400}{E_2} = \frac{10\cancel{00}}{6\cancel{00}}$$
$$\Rightarrow 10E_2 = 2400$$
$$\Rightarrow E_2 = 240$$

ii) Primary current

$$V_1 I_1 F = V_A$$
$$\Rightarrow 440 \times I_1 \times 50 = 200 \times 10^3$$
$$\Rightarrow I_1 = \frac{200 \times 10^3}{440 \times 50}$$
$$= 9.09 A$$

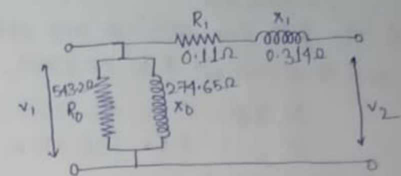
$\frac{2000\cancel{0}}{12\cancel{0}}$

Secondary current.

$$V_2 I_2 f = V_B$$
$$\Rightarrow 240 \times I_2 \times 50 = 200 \times 10^3$$
$$\Rightarrow V_2 = \frac{20\cancel{0} \times 10^3}{24\cancel{0} \times 5\cancel{0}}$$
$$= 166.6 A$$

13) Obtain the equivalent circuit parameters of a 8 KVA, 220/440 V, 50 Hz single phase transformer having following test results are

O.C. test :	Primary voltage 220 V	I = 0.9 A	W = 90 W
S.C " :	" " 20	I = 15 A	W = 100 W



1st case for O.C. test :-

$V = 220V$

$I = 0.9A$

$P = 90W$

We know, $P = VI\cos\theta$

$$\Rightarrow \cos\theta = \frac{P}{VI}$$

$$= \frac{90}{220 \times 0.9} = 0.45$$

$$\sin\theta = \sqrt{1-\cos^2\theta}$$

$$= \sqrt{1-(0.45)^2}$$

$$= \sqrt{1-0.2025}$$

$$= 0.89$$

$$R_0 = \frac{V_1}{I_0\cos\theta_0} = \frac{220}{0.9 \times 0.45}$$

$$= 543.2\ \Omega$$

$$X_0 = \frac{V_1}{I_0\sin\theta_0} = \frac{220}{0.9 \times 0.89} = 274.65\ \Omega$$

2nd case for S.C test

$V = 20V$

$I = 15A$

$P = 100W$

$$R_{OH} = \frac{P}{I^2} = \frac{100}{(15)^2} = 0.44\ \Omega$$

$$Z_{OH} = \frac{20}{15} = 1.33\ \Omega \qquad X_{OH} = \sqrt{(1.33)^2-(0.44)^2}$$

$$= 1.25\ \Omega$$

$R_1 = 0.44 \times \left(\frac{220}{440}\right)^2$

$= 0.11\,\Omega$

$X_1 = 1.25 \times \left(\frac{220}{440}\right)^2$

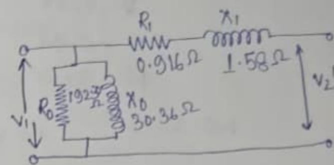
$= 0.314\,\Omega$

44) The following readings are obtained for open circuit and short circuit tests on 8 KVA, 400/120 V, 50 Hz Transformer

OC Test :- 120 V, 4 A, 75 W

SC " :- 9.5 V, 20 A, 110 W

Calculate equivalent circuit parameters referred to high voltage side.



⇒ OC test :- $V = 120\,V$

$I = 4\,A$

$P = 75\,W$

We know, $P = VI\cos\theta$

or, $\cos\theta = \frac{P}{VI}$

$= \frac{75}{120 \times 4}$

$= 0.156$

$\sin\theta = \sqrt{1-(0.15)^2}$

$= \sqrt{1-0.0225}$

$= \sqrt{0.9775}$

$= 0.988$

$R_0 = \frac{V}{I_0\cos\theta} = \frac{120}{4 \times 0.156} = \frac{120}{0.624} = 192.30\,\Omega$

$X_0 = \frac{V}{I_0\sin\theta} = \frac{120}{4 \times 0.988} = \frac{120}{3.952} = 30.36\,\Omega$

SC test :-

$V = 9.5\,V$

$I = 20\,A$

$P = 110\,W$

$R_{0H} = \frac{P}{I^2} = \frac{110}{20 \times 20} = 0.275$

$Z_{0H} = \frac{V}{I} = \frac{9.5}{20} = 0.475$

$R_1 = 0.275 \times \frac{400}{120}$

$= 0.916\,\Omega$

$X_1 = 0.475 \times \frac{400}{120}$

$= 1.58\,\Omega$

15. The following readings are obtained for open circuit and short circuit tests on 20 KVA, 2000/200 V, 50 Hz single phase Transformer.

OC Test :- 200 V, 1 A, 120 W

SC Test :- 60 V, 10 A, 300 W

a) Find efficiency at half load and 0.8 Power factor lagging.

⇒ For short circuit test,

$$Z_{01} = \frac{60}{10} \Omega = 6\,\Omega$$

$$R_{01} = \frac{300}{(10)^2} = 3\,\Omega$$

$$X_{01} = \sqrt{(6)^2 - (3)^2}$$

$$= \sqrt{36 - 9}$$

$$= \sqrt{27}$$

$$= 5.19$$

i) Rated current on the h.v. side $= \frac{20 \times 10^3}{200} = \frac{20 \times 1000}{200} = 100\,A$

rated copper loss $= 300 \times \left(\frac{100}{10}\right)^2$

$$= 300 \times 100$$

$$= 30000\,W$$

Iron loss = 120 W

Efficiency at half load and 0.8 Power factor lagging is

$$= \frac{20 \times 10^3 \times 0.8 \times 1/2}{20 \times 10^3 \times 0.8 \times 1/2 + (1/2)^2 \times 30000 + 120}$$

$$= \frac{\cancel{1}}{\cancel{1/4 \times 30000 + 120}} = \frac{8000}{8000 + 120 + 75} = 0.9762 = 97.62\%$$

$$= \cancel{1/7620} = \cancel{0.000131} = \cancel{0.0131\%}$$

ii) $P_i = x^2 P_{cu}$

$$\Rightarrow 120 = x^2\, 300$$

$$\Rightarrow x^2 = \frac{120}{300}$$

$$x = \sqrt{2/5} = 0.632$$

$$\eta_{max} = \frac{0.632 \times 20\times10^3 \times 0.8}{0.632 \times 20\times10^3 \times 0.8 + 120 + (0.632)^2 \times 300}$$

$$= \frac{10112}{10112 + 120 + 119.82}$$

$$= 0.9768$$

$$\eta_{max} = 97.68\ \%$$

46) The open circuit test data of a 50 KVA, 2400/120 volts 50 Hz single phase transformer are

o.c test :- Primary voltage 120 V, I = 9.65 A.

W = 396 W

Find equivalent circuit parameters.

$$\Rightarrow \cos\theta = \frac{P_c}{V_n I_c} = \frac{396}{9.65 \times 120} = 0.341$$

$$\therefore \theta = 70$$

$$\sin\theta = 0.93$$

magnetising current $(I_m) = I_m \sin\theta$

$$= 9.65 \times 0.93$$

$$= 9.06\ A$$

core loss " $(I_c) = I_c \cos\theta$

$$= 9.65 \times 0.341$$

$$= 3.29\ A.$$

$$R_{cl} = \frac{V_n}{I_c} = \frac{120}{3.29} = 36.46\ \Omega$$

$$X_{ml} = \frac{V_n}{I_m} = \frac{120}{9.06} = 13.24\ \Omega$$