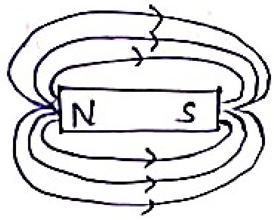
UNIT-3

TRANSFORMERS

Basic Definations :-

Magnetic field :- The area which attracts magnetic materials and iron pieces, that region is called "magnetic field".



Magnetic flux (Ø) :- It is the total number of lines of force existing in a magnetic field is called as "magnetic flux (Ø). Units are "webers".

Magnetic flux density : (B)

The flux per unit area in a magnetic field is called "magnetic flux density (B).

i.e $\boxed{B = \frac{\phi}{A}}$ → Units are "web/m^2"

Magnetic field Strength :(or) Magnetic field intesity (H)

It is the force experienced by unit North pole at particular point in a magnetic field is called "MFI".

Units are AT/web (or). Aamper-Turns/web

Magneto motive force (mmf) :- The force which drives the flux through a magnetic material is called "mmf". units are "AT".

Permeability (μ) :- It is the ability of the medium which allows the magnetic fluxes through it self, is called permeability :

(or)

It is the ratio of flux density (B) to the magnetic field strength

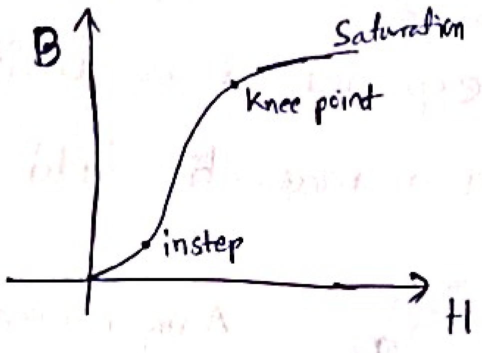
$\mu = B/H$ (or) $\boxed{\mu = \mu_0 \mu_r}$

→ No units

μ_0 = Absolute permeability
= 1 for air
μ_r = relative permeability

· B-H Curve of Magnetic material :-

→ The graph between flux density(B) and field intensity (H) is called B-H Curve.



Transformer :-

The transformer is a static device which transfers electrical power one circuit to another circuit, at constant frequency.

→ The transformer is power constant device

→ The transformer is constant frequency device

→ It can be used for different voltage & current changing values of A.C supply

→ It is used in different stages of electrical systems as generation, transmission, distribution and utilization.

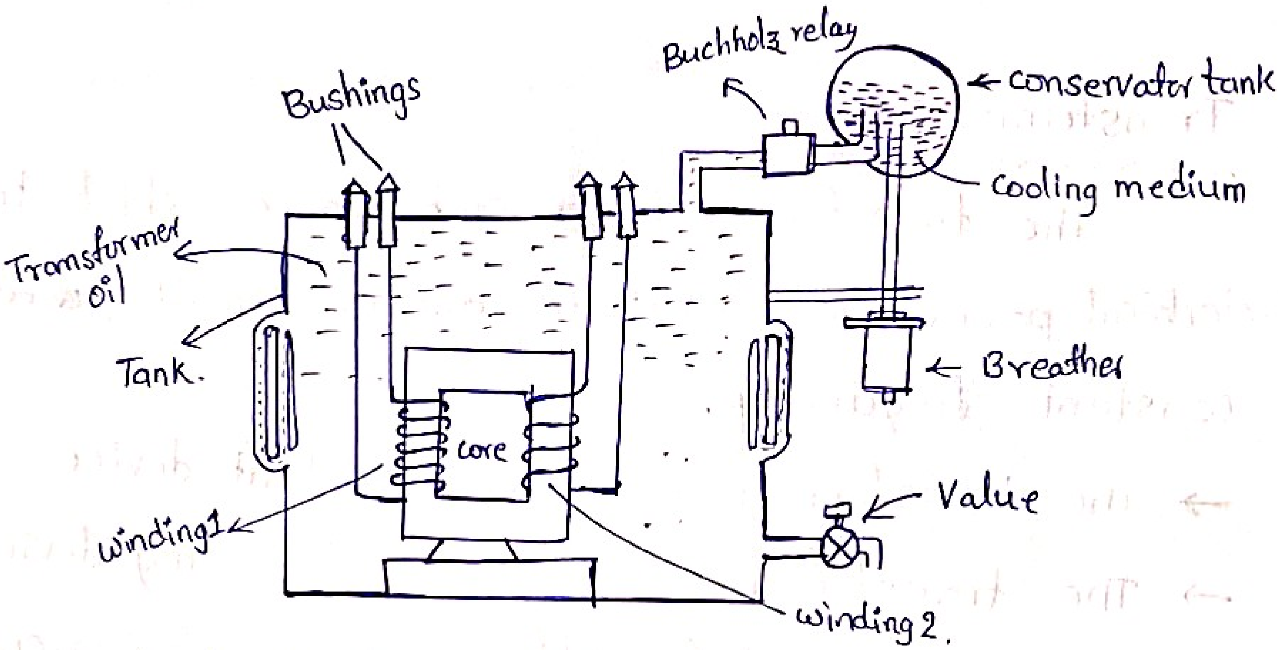
Construction of Transformer

The essential components of the transformer are

1. Magnetic core
2. Two windings, namely primary and secondary windings
3. A time varying magnetic flux.

The constructional diagram of single-phase transformer as shown in below, it having different components as

1. Core
2. Limb
3. Yoke or Tank
4. Windings
5. Conservator Tank.
6. Cooling medium
7. Breather
8. Explosion vent
9. Buchholz relay
10. Bushings.
11. Transformer oil.



constructional diagram of Single-phase Transformer

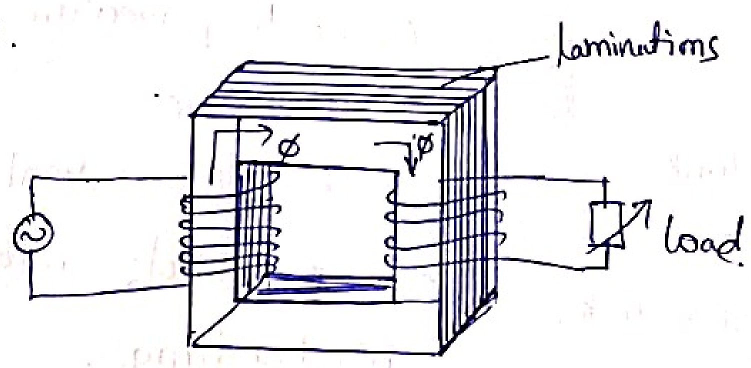
① Transformer core :- The main function of transformer core which gives accomidation for windings transformer. It may be reactangular or square, having limbs. It is made up of cast iron. It is two types

ⓐ core type
ⓑ Shell type

ⓐ Core type transformer :- Inthis transformer rectangular frame laminations are formed to build the core.

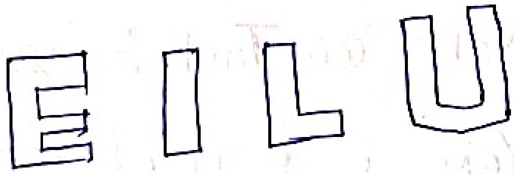
→ It has single magnetic circuit

→ In this transformers windings are surrounded by limbs of core.



→ The laminations are pressed or punched out from the steel sheets, we can ~~desi~~ manufacture the core of Transforma

→ These laminations sheets are assemble as letter

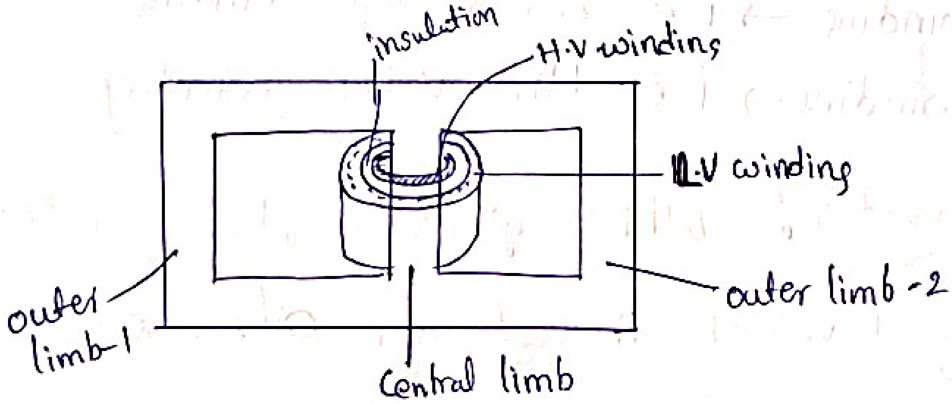
E, I, L, U as 

→ In this type of core, interleaving windings is used which reduces leakage fluxes.

ⓑ **Shell type transformer** :- In this shell type windings are surrounded by core of transformer.

→ It has double magnetic circuit.

→ It has a central limb and two outer limbs, as



→ For construction of this type core, we use E & I shape lamination sheets.

→ It require less insulation for designing it

→ Cooling mechanism is easy.

2. Limb :- Limb is a part of core, which gives accomidation for winding and protect the winding for physical stress.

3. Yoke (or) Tank :- ~~It is a total cover~~

Yoke is part of transformer which protects transformer winding from physical stress and gives accomidation for transformer oil.

4. Windings :- We have two windings in transformer

→ Primary winding → which is connected with supply
&
→ Secondary winding → which is connected with load.

(or)

L.V winding → i.e Low voltage winding
H.V winding → i.e High Voltage winding.

5. conservator :- Which gives a place for increasing decreasing levels of transformer oil i.e cooling medium

6. Breather :- Which is protects the transformer oil from all weather condition problems.

7. Buchholz relay :- The relay which rings the alaram when fault is occured in transformer.

8. **Bushings** :- Which provides insulation between winding terminals to the transformer tank.

9. **Transformer oil** :- The main function of T/F oil is to provide cooling of windings and insulation between windings

10. **Explosion Vent** :- It is a Valve for ~~when~~ realising oil from the tank when sudden explosion is occures.

Faradays Law:-

Faraday Frist law :- " whenever a conductor cuts the flux then an "emf" induces in that conductor.

Faraday's Second Law :- The induced emf in a conductor is directly proportional to the rate of change of flux linkages

i.e $\boxed{e = -N\frac{d\phi}{dt}}$ i.e $e \propto \frac{d\phi}{dt}$

Self induced emf :- It is induced emf in a coil when it's own flux links with it self.

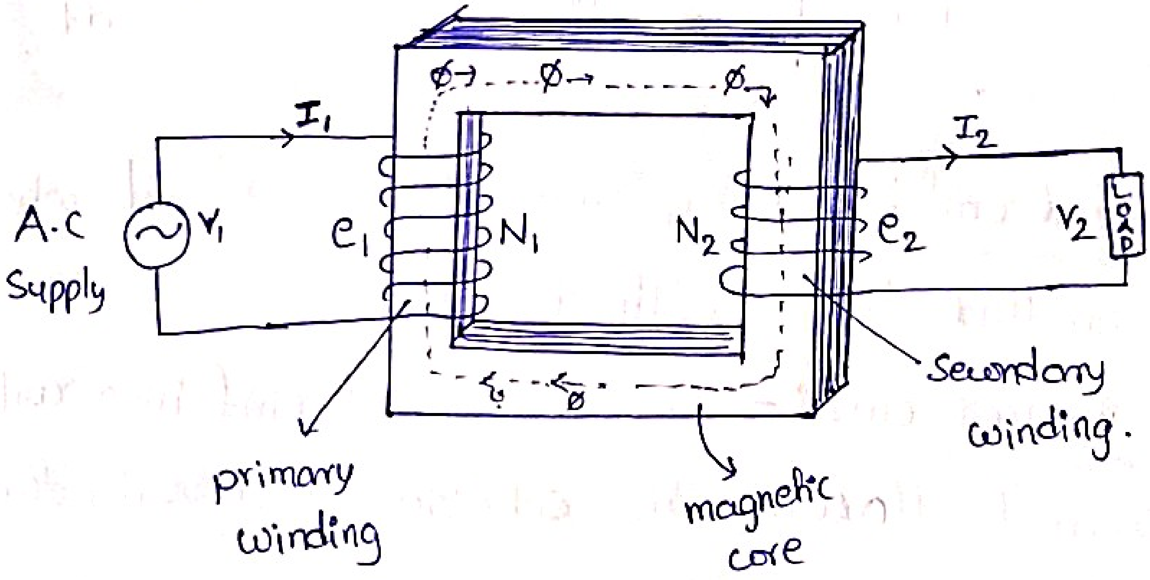
Mutual induced emf :- It is induced emf in a coil due current flowing in beside coil & it's flux linkages.

Working Principle of Transformer

The transformer works on the principle of Fraday's Laws of ~~mutual~~ ~~ind~~ electromagnetic mutual induction principle, which states that when two coils are magnetically coupled, then current in one coil changes uniformely and induces ~~or~~ developes the emf in other coil.

In a transformer the coil which is connected with supply is called primary winding and the coil which is connected with load is called secondary winding.

Consider a basic transformer, ~~pri~~ which is having N_1 no. of turns in primary and N_2 no. of turns in secondary as shown in below.



→ When primary winding is connected with AC-source, then current "I_1" flows through the winding and produces an alternating flux (ϕ).

→ This alternating flux passes through magnetic core and links with secondary winding.

→ According to faradays law of electromagnetic mutual induction principle, an emf (i.e mutual induced emf(e_2)) is induceds in the secondary winding.

→ This secondary induced emf causes the current "I_2" and drives the load.

Like this, transformer transfers the power from one circuit other circuit without electrical connection.

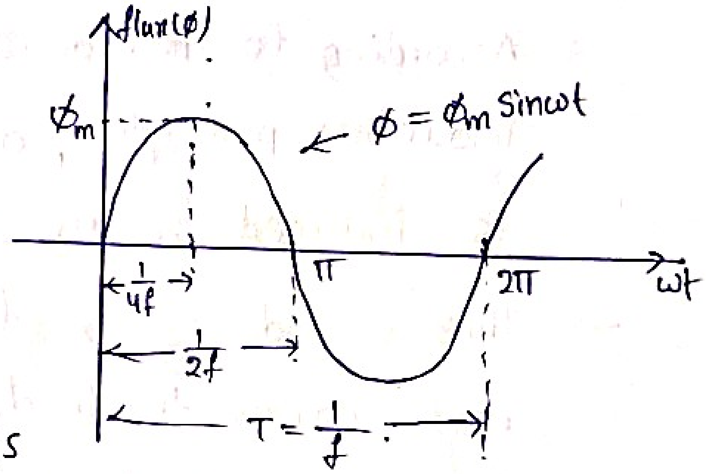
Q:- Explain why the transformer will not works for d.c supply?

A:- If d.c supply is given to the primary of transformer, then their is no transformer action, why because "d.c supply having frequency zero, so their is no alternating fluxes, and no-leakage reactance." if d.c supply is given then primary winding draws very high current, then transformer burn-out (or) exploision will be takes place.

EMF- equation of Transformer

When the primary winding is excited by an alternating voltage 'V_1', it circulates alternating current producing an alternating flux 'ϕ'.

The waveform for alternating flux 'ϕ' can drawn as for time period '2π'.



Let ϕ = alternating flux

ϕ_m = maximum flux

N_1 = No. of primary turns

N_2 = No. of Secondary turns

E_1 = primary induced emf in RMS

E_2 = Secondary induced emf in RMS

f = frequency of supply.

→ According to Faraday's law of electromagnetic induction the average emf induced ~~por~~ in each turn is proportional to the average rate of change of flux.

∴ Average emf per turn = Average rate of change of flux

i.e $$\frac{d\phi}{dt} = \frac{\text{change in flux}}{\text{Time required for change in flux}}$$

In above ~~above~~ figure initial flux ($\phi = 0$) and after "1/4th" cycle the fluxes are maximum i.e 'ϕ_m', so

i.e $$\frac{d\phi}{dt} = \frac{\phi_m - 0}{(1/4f)} = 4f\,\phi_m \text{ wb/sec}$$

So, Average emf per turn $= 4f\,\phi_m$ Volts. i.e $\text{emf}/\text{turn} = 4f\phi_m$

→ The RMS value of induced emf per turn

$$\text{emf}/\text{turn} = 1.11 \times 4.f\,\phi_m$$

i.e $$= 4.44\,f\,\phi_m$$

→ If primary winding has 'N_1' of no. of turns, then RMS value of induced emf in primary

i.e $\boxed{E_1 = N_1 \times 4.44 f\,\phi_m}$ volts

Simillarly, in secondary

$\boxed{E_2 = N_2 \times 4.44\,f\,\phi_m}$ volts.

Transformation ratio (K)

If transformer having primary induced emf (E_1) and secondary induced emf (E_2), then

i.e $K = \frac{E_2}{E_1}$ $\quad \because E_2 \propto N_2 \;\&\; E_1 \propto N_1$

and $K = \frac{N_2}{N_1}$ $\quad \because E_2 = V_2 \;\&\; E_1 = V_1$

and $K = \frac{V_2}{V_1}$ i.e * $\boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{V_2}{V_1} = K = \frac{I_1}{I_2}}$

problems:- ① The maximum flux density in the core of 250/3000 volts, 50 Hz single phase transformer is 1.2 webor per square meter. If the emf per turns is 8 volts determine primary and secondary turns and area of the core.

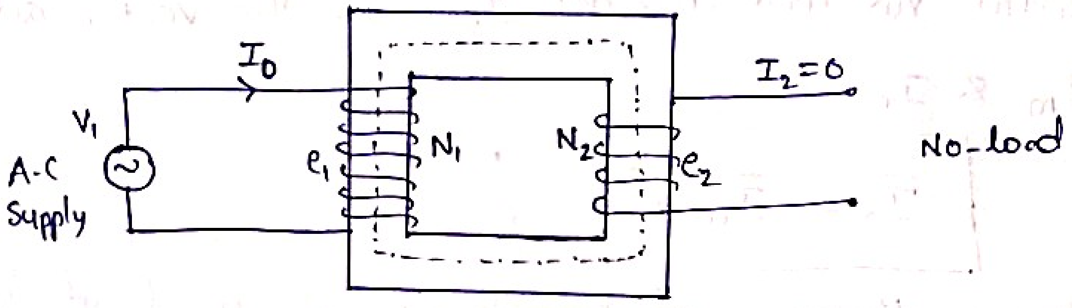
P② The number of turns on the primary and secondary windings of a single phase transformer are 350 and 35 respectively. If the primary is connected to a 2.2KV, 50 HZ, determine the secondary voltage.

Comparision between core type and shell-type transformer

Core type transformer	Shell-type transformer
1. The windings surround the core and placed on the side limbs	1. The core surrounds the winding and is placed on central limb.
2. Laminations is in L, I, U strips formatts.	2. Laminations sheet is in long strips in shape of E & I
3. Two limbs exist	3. Three limbs exist
4. Requires more copper material	4. Requires less copper
5. Requires more insulation	5. Less insulation require
6. Equal distribution of flux on the limbs	6. Unequal flux distribution of flux in the limbs.
7. More loss exists	7. Less loss exists
8. High output achived	8. Less output can be achieved
9. Easy to maintain	9. Difficult to maintain
10. Natural cooling possible	10. Cooling mechanism exists

Practical Transformer on No-load

The practical transformer with no-load is shown in figure.



When transformer is on No-load, then secondary current is zero, but practical transformer has hysteresis and eddy current loss because it is excited by AC-Source which causes alternating flux. Due to small internal resistance in winding of transformer it ~~have~~ causes a small amount of primary copper loss. At this the current drawn by primary is called No-load current (I_0).

→ This no-load input current has two components

→ Wattless component :(I_m) : The magnetizing current (I_m) is the purely reactive component of I_0, that lags V_1 by 90°, which is produce the magnetic flux.

i.e $I_m = I_0 \sin \phi_0$

→ Wattful component :-(I_c) :- The power component (I_c) which supplies the total losses of transformer under no-load condition

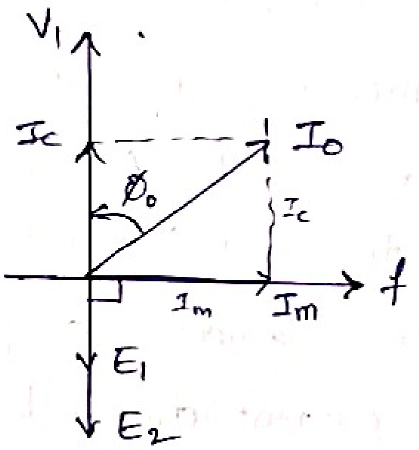
i.e $I_c = I_0 \cos\phi_0$

This I_c is in phase with 'V_1'

→ The total no-load current 'I_0' is the vector addition of I_m & I_c

$$\boxed{\bar{I_0} = \bar{I_m} + \bar{I_c}}$$

→ The phasor diagram of transformer at no-load is



→ From the above phasor diagram, magnitude of no-load current

$$I_0 = \sqrt{I_m^2 + I_0^2}$$ & "$\cos\phi_0$" is No-load power factor

→ The total power input on no-load is

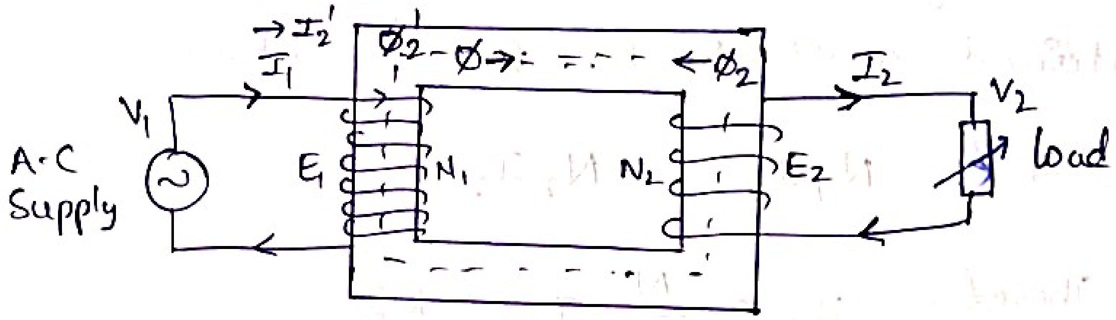
$$W_0 = V_1 I_0 \cos\phi_0 = V_1 I_c = P_i \text{ (Iron losses)}$$

→ Where 'I_0' is very small, hence primary copper loss is negligible.

→ Hence power input 'W_0' on no-load always reprecent the iron losses as copper loss is negligible.

Transformer ON-load :-

The practical transformer connected with load is shown as below figure.



When primary winding of the transformer is connected to AC Source, then V_1 induces emf E_2 in Secondary by transformer action. When secondary winding is connected with load then 'I_2' flows in winding.

→ The current I_2 flowing through secondary winding produces flux "ϕ_2", which opposes ϕ.

→ Then main flux 'ϕ' is decreases, then E_1 decreases then current drawn by primary is "I_2'", which producess additional flux 'ϕ_2'' which opposes ϕ_2

→ This I_2' neutralizes ϕ_2, the flux is maintained constant, hence transformer is flux constant machine.

→ The secondary flux ϕ_2 is developes the mmf is '$N_2 I_2$'

and ϕ_2' flux produces mmf "$N_1 I_2'$" these mmf are get balanced, the flux in transformer is maintained constant for load condition

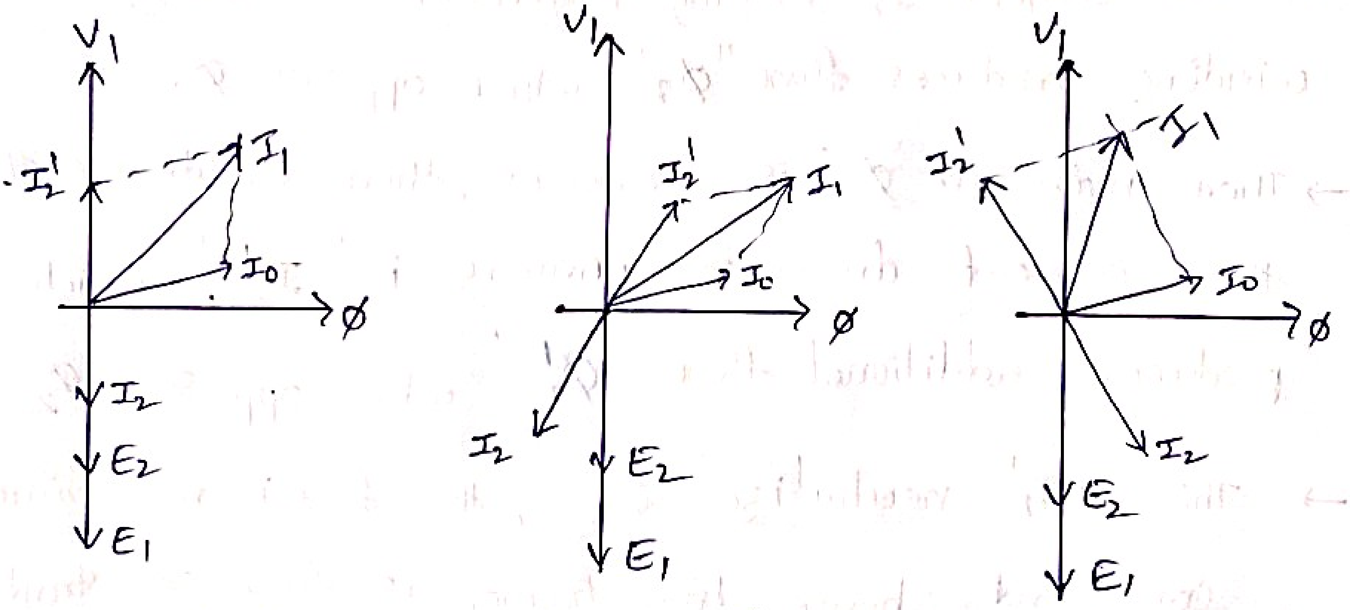
i.e $N_1 I_2' = N_2 I_2$

Therefor $I_2' = \frac{N_2}{N_1} I_2 = k I_2$

→ When a transformer is loaded, the primary current I_1 has two components

i.e $\bar{I}_1 = \bar{I}_0 + \bar{I}_2$

→ It is different for different loads, as in phasor diagram



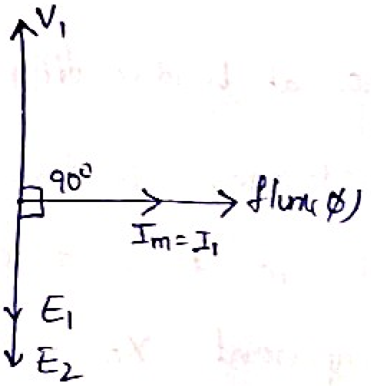
Resistive-load   Inductive-load   Capacitive-load

Ideal Transformer

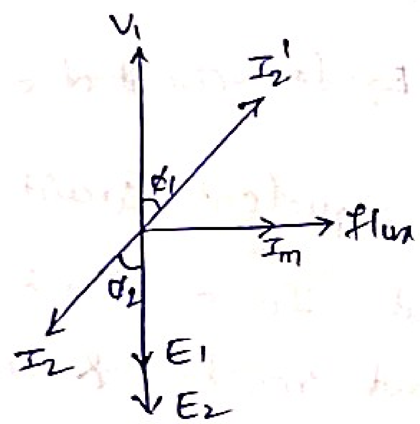
A transformer is said to be ideal transformer if it satisfies following properties

→ It has "no losses
→ Its windings (i.e primary & Secondary) have "zero resistance
→ Leakage flux is zero i.e 100% flux produced by primary links with the secondary.
→ Permeability of core is so high.
→ It has 100% efficiency.
→ Magnetic coupling (K) = 1

Phasor diagrams for ideal transformer



Ideal transformer at No-load



Ideal transformer at load.

In ideal transformer voltage drops in primary and Secondary are zero, because resistance is zero. and E_2 is equal to V_2.

Equalent Circuit of Transformer :-

The equalent circuit of a transformer is a circuit with the combination of various resistances and reactances of the primary and secondary windings, which exactly ~~perp~~ perform like a transformer. It can be drawn a) below.

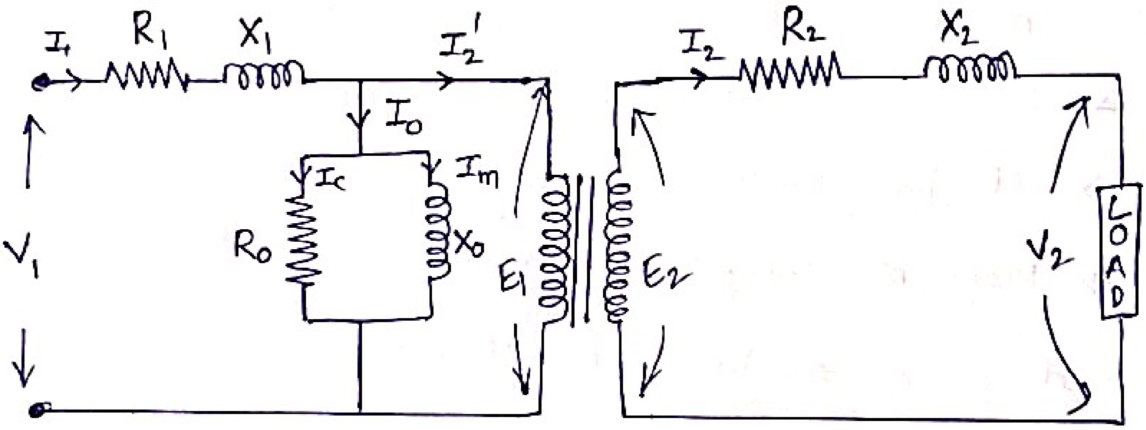


Fig :- Equalent Circuit of a Transformer at Load condition

→ In equalent circuit of transformer, it has no-load current I_o are I_m & I_c which are flows through no-load reactive & active components X_o & R_o

where $R_o = \frac{V_1}{I_c}$ and $X_o = \frac{V_1}{I_m}$

→ In equalent circuit of transformer has leakage reactances X_1 & X_2 w.r.to primary & secondary windings, which represent leakage flux

→ Winding resistance R_1 & R_2 to represent the copper losses $I_1^2 R_1$ & $I_2^2 R_2$ in the primary and secondary windings. respectively.

→ When load is connected, I_2 current ~~then~~ flows and it causes voltage drop across R_2 & X_2, then additional current $I_2' = I_2 K$.

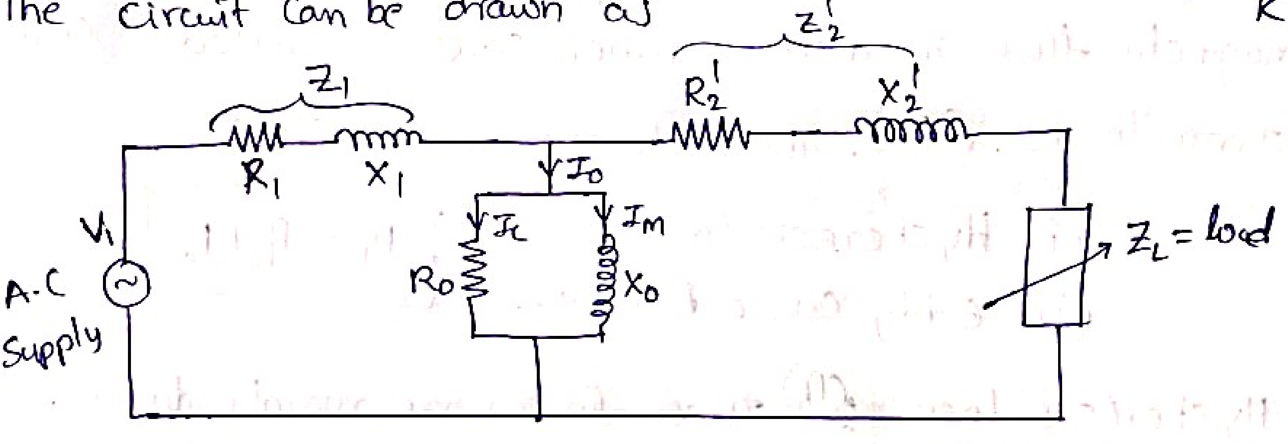
Equalent circuit of transformer when ~~reffered to~~ secondary-parameters reffered to primary side

→ Then

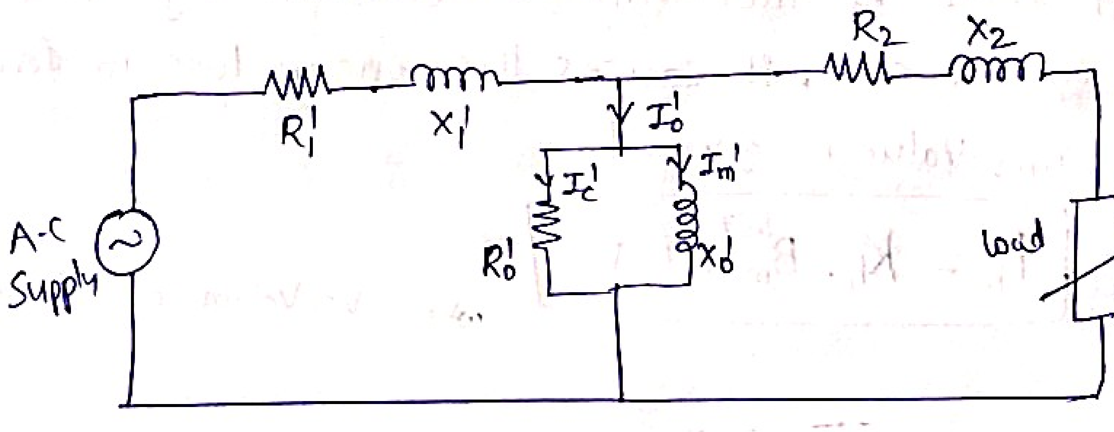
$$R_2' = \frac{R_2}{k^2}, \quad X_2' = \frac{X_2}{k^2}, \quad Z_2' = \frac{Z_2}{k^2} \quad \& \quad I_2' = kI_2$$

$$E_2' = \frac{E_2}{K}$$

The circuit can be drawn as



Equalent circuit of Transformer when primary reffered to secondary side :-



where

$R_1' = K^2 R_1$

$X_1' = K^2 X_1$

$E_1' = KE_1$

Losses in Transformer

→ Losses in transformer can be classified as

Transformer losses

Types

- ① Constant losses
  - i.e Core (or) Iron losses
    - Hysteresis loss
    - Eddy Current loss
- ② Variable losses
  - i.e copper losses
- ③ Stray losses
- ④. Dielectric loss

① Core (or) Iron losses (P_i)

The losses which are produced by alternating magnetic flux in a transformer core is called "core or Iron losses. (P_i). These losses are two types

(i) Hysteresis losses.
(ii) Eddy current losses.

$$\boxed{P_i = P_h + P_e}$$

(i) Hysteresis losses (P_h) :- These losses are mainly due to alternating flux in transformer core when transformer core is magnetization and de-magnetization takes place. The each cycle of alternating flux developes hysteresis loop in transform core, it causes the energy loss in form of heat. This value is given by

$$\boxed{P_h = K_h . B_m^{1.67} . f\ V}$$

where V=Volume of the core.

(ii) Eddy current loss : (P_e)

An induced emf in the core causes the current called eddy current, this eddy current circulates in transformer core and ~~dev~~ causes " I^2R " losses. The losses due to eddy current in transformer core is called Eddy current losses.

i.e $\boxed{P_e = K_e B_m^2 f^2 t^2 v}$ where t = thickness of sheets.

These constant losses can be reduced (or) minimised by using high-grade silicon steel lamination sheets.

(2) Copper Losses (P_c)

The losses due to winding resistances of transformer are called as " copper losses ". The total copper loss.

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

(3) Stray losses :- The losses that occure in the transformer due to the leakage of magnetic flux are called stray losses. Thes losses are very less percentage, so there are negligible

(4) Dielectric loss :- The losses due to ~~o~~ the insulating material for transformer are called as " Dielectric loss ". This loss can be ~~effect the~~ efficieny of transformer.

Efficiency of The transformer

The efficiency of the transformer can be defined as its the ratio of the output power to the input power

i.e $\eta = \frac{\text{output power}}{\text{Input power}}$ (or) $\frac{\text{Power output}}{\text{Power Input}}$

(or) $\eta = \frac{\text{outputo power}}{\text{Output power + Total losses}}$

$$\eta = \frac{\text{Power output}}{\text{Power output} + P_i + P_{cu}}$$

by basis power equations

$$\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_{eq}^2 R_{eq}} \qquad \because P_{cu} = I^2 R$$

If the 'VA' rating of the transformer is $V_2 I_2$ then

$$\eta = \frac{(\text{VA rating}) \cos\phi_2}{(\text{VA rating}) \cos\phi_2 + P_i + I_2^2 R_{eq}}$$

Let $n = \frac{\text{Actual load}}{\text{Full load}}$ i.e fraction of load, then

$$\eta = \frac{n \times (\text{VA rating}) \cos\phi_2}{n(\text{VA rating}) \cos\phi_2 + P_i + n^2 P_{cu}}$$

$$\boxed{\eta\% = \frac{n(\text{VA rating}) \cos\phi_2}{n(\text{VA rating}) \cos\phi_2 + P_i + n^2 P_{cu}} \times 100}$$

Condition for maximum efficiency (η_{max})

In a transformer the output power is less than input power, because it has the losses.

i.e Power output = Power input − Losses

$$P_o = P_i - P_{Loss} \qquad \because P_{loss} = P_i + P_{cu}$$

$$P_i = P_o + (P_i + P_{cu})$$

→ The load current at which efficiency attains maximum value is denoted by 'I_{2max}' and the maximum efficiency denoted as "η_{max}".

→ The efficiency is a function of load i.e load current I_2 assuming $\cos\phi_2$ is constant, and secondary voltage 'V_2' also assumed as constant.

→ So condition for maximum efficiency is

$$\frac{d\eta}{dI_2} = 0$$

We have $\eta = \dfrac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2}$ $\qquad \because \dfrac{d}{dx}\left(\dfrac{u}{v}\right) = \left(\dfrac{u'v - uv'}{v^2}\right)$

So

$$= (V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_2)(V_2\cos\phi_2) - (V_2 I_2 \cos\phi_2).(V_2\cos\phi_2 + 0 + 2I_2R_2) = 0$$

Let common "$V_2 \cos\phi_2$" and cancel it, then

$\Rightarrow V_2 I_2 \cancel{\cos\phi_2} + P_i + I_2^2 R_2 - V_2 \cancel{I_2 \cos\phi_2} - 2I_2^2 R_2 = 0$

$\Rightarrow \quad P_i - I_2^2 R_2 = 0$

$\boxed{P_i = I_2^2 R_2}$ i.e condition for maximum efficiency

i.e $\boxed{\text{Iron losses} = \text{Copper losses}}$

$\boxed{P_i = P_{cu}}$

Voltage Regulation :-

The voltage regulation of transformer can be defined as ~~change in the~~ ratio of change in secondary voltage when the transformer load is reduced from full load to no-load to the full load secondary voltage

if V_2 = Secondary voltage at full load

V_{02} = Secondary voltage at no-load

$\therefore$ Voltage Regulation $= \dfrac{V_{02} - V_2}{V_2}$

$$\boxed{\%\ \text{Voltage Regulation} = \frac{V_{02} - V_2}{V_2} \times 100}$$

→ If we have $V_2 = I_2 X_{02} \sin\phi$

$V_{02} = I_2 R_{02} \cos\phi$

Then

$$\%\,V.R = \frac{I_2 R_{02}\cos\phi \pm I_2 X_{02}\sin\phi}{V_2}$$

for
inductive load = +Ve
Capacitive load = −Ve

$$= \frac{I_2 R_{02}\cos\phi}{V_2} \pm \frac{I_2 X_{02}\sin\phi}{V_2}$$

→ The Regulation will be zero when power factor angle $\phi = \tan^{-1}\left(-\frac{R_{02}}{X_{02}}\right)$

where '−Ve' indicates that zero regulation occurs at leading power factor..

→ Regulation will be maximum when angle

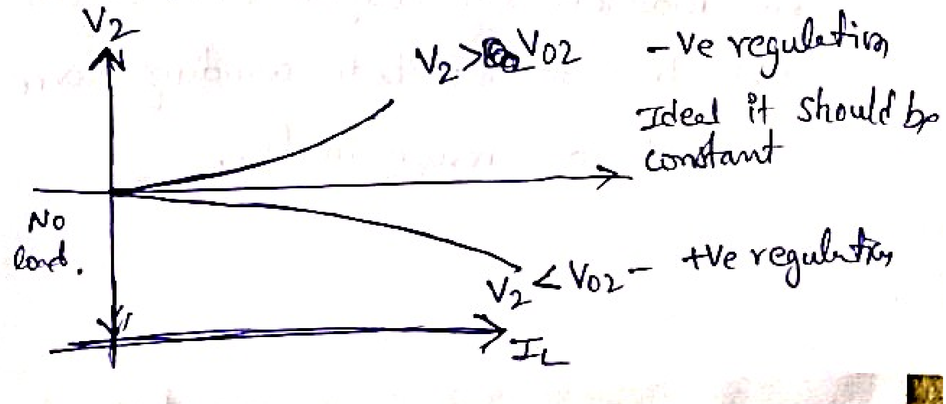
$$\phi = \tan^{-1}\left(\frac{X_{02}}{R_2}\right)$$

Maximum Regulation occurs at " lagging power factor.

→ Voltage Regulation of transformer on an average is about 4%

→ For consumers view Regulation should be kept as possible

→ It can be shown as



Auto-transformer :-

An auto-transformer is a special type of single-phase transformer, consisting of single winding woun-on a laminated core. Here, some part of this single winding acts as the primary winding and some part acts as the secondary winding.

→ The number of turns of the primary and secondary windings can be varied using switch contact. Since the output voltage of the auto-transformer can be varied.

→ So, it also called as VARIAC (VARIable A) (or) Voltage regulator.

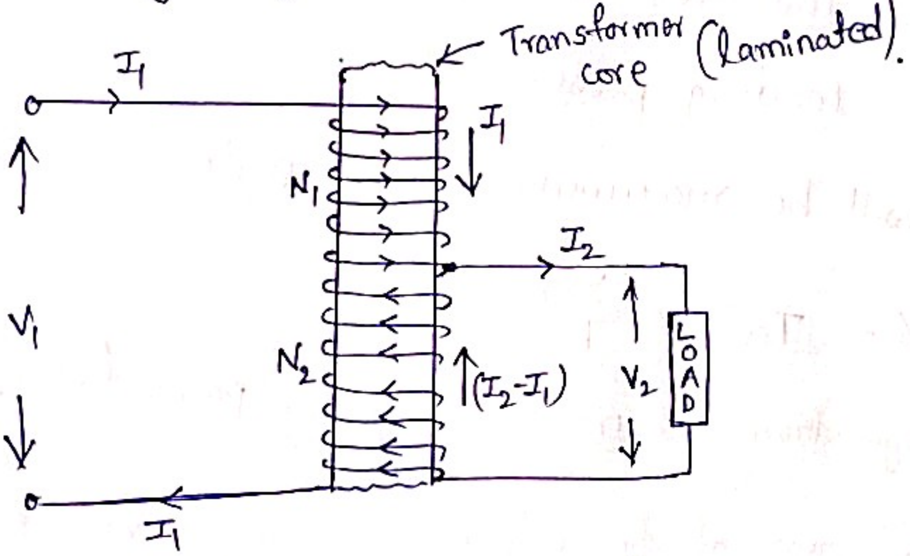


Diagram of Basic Auto-Transformer

→ In two-winding transformer, the windings (primary & secondary) are magnetically coupled and electrically isolated, but in auto transformer both windings are connected electrically as well as magnetically.

→ A part of single continous winding is common to primary and secondary windings. These windings are wound on a silicon steel laminated core.

→ To ~~vary~~ regulate the voltage of the auto-transformer we have a tapping brush which is moving on windings of transformer.

Operation of Single-phase Auto transformer :-

The working of an auto-transformer is similar to ~~that of~~ a two-winding transformer, A-T/F shown below.

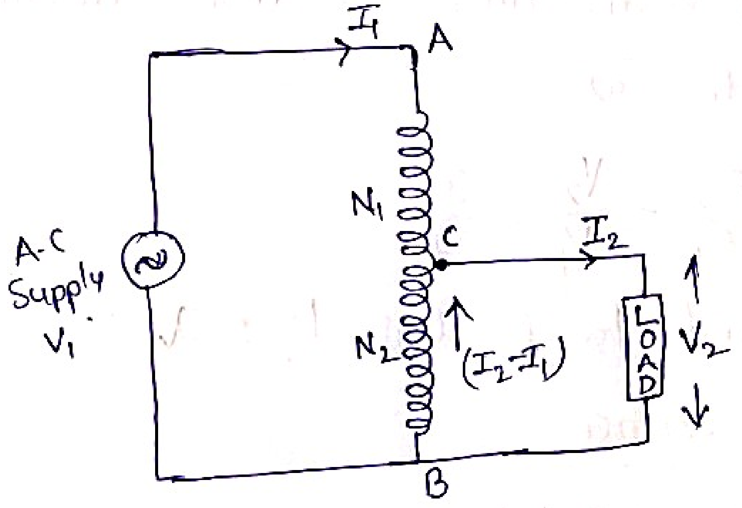


Diagram of Auto-Transformer

In above diagram, the AB is the primary winding of transformer and 'CB' is secondary winding where the tapping is provided.

When a supply voltage V_1 is applied to the primary winding AB, an alternating flux set up in the core due to which an induced emf 'E_1' is devoloped.

Since the secondary winding is a part of the primary winding, a part of the induced emf E_1, is taken in to which the load is connected..

→ Let E_2 be the induced emf in the secondary winding

→ This induced emf drives the current in the secondary winding and hence the load connected to it.

→ As in an ordinary transformer, the transformation ration is turn ratio a)

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

→ The power delivered to load is $P_L = V_2 I_2$

→ But in Auto transformer

$$\boxed{P_{Auto} = V_2 I_2 (1-k)}$$

→ & The ~~con~~ power conducted directly is $\boxed{P = K V_2 I_2}$

→ When $N_1 > N_2$ → is Stepdown Transformer

$N_1 < N_2$ → is Step-up Transformer.

Advatages of Auto-Transformer

→ It provides continous varying voltage

→ There is ~~lot of~~ Saving in copper requirement

→ It is in Small Size

→ It is more efficient and hase better regulation

→ Has low leakage flux

→ Loss is Low

→ It is mostly used for starter

→ Very cheap and more economical.

Applications of Auto Transformer:-

→ For starting rotating machine like induction motor, synchronous motors.

→ As regulating transformer

→ As voltage booster to raise voltage in an AC-feeder

→ It is used as balance coil in order to provide neutral coil in 3-wire System.

→ For interconnecting Systems which are working with Same voltage.

Three-Phase Transformer Connections (3-ø)

Three-phase transformer :-

The transformer used to supply (or) transfer large amount of power to "three-phase connections, to meet the required demand power economically, is called a "3-ø Transf... In power systems it's used in different stages for stepping up ~~and~~ or stepping down higher voltages.

→ For the construction of 3-ø transformer, we have two methods

① → Using a bank of three single phase transformers

② → Using a single-three phase transformer.

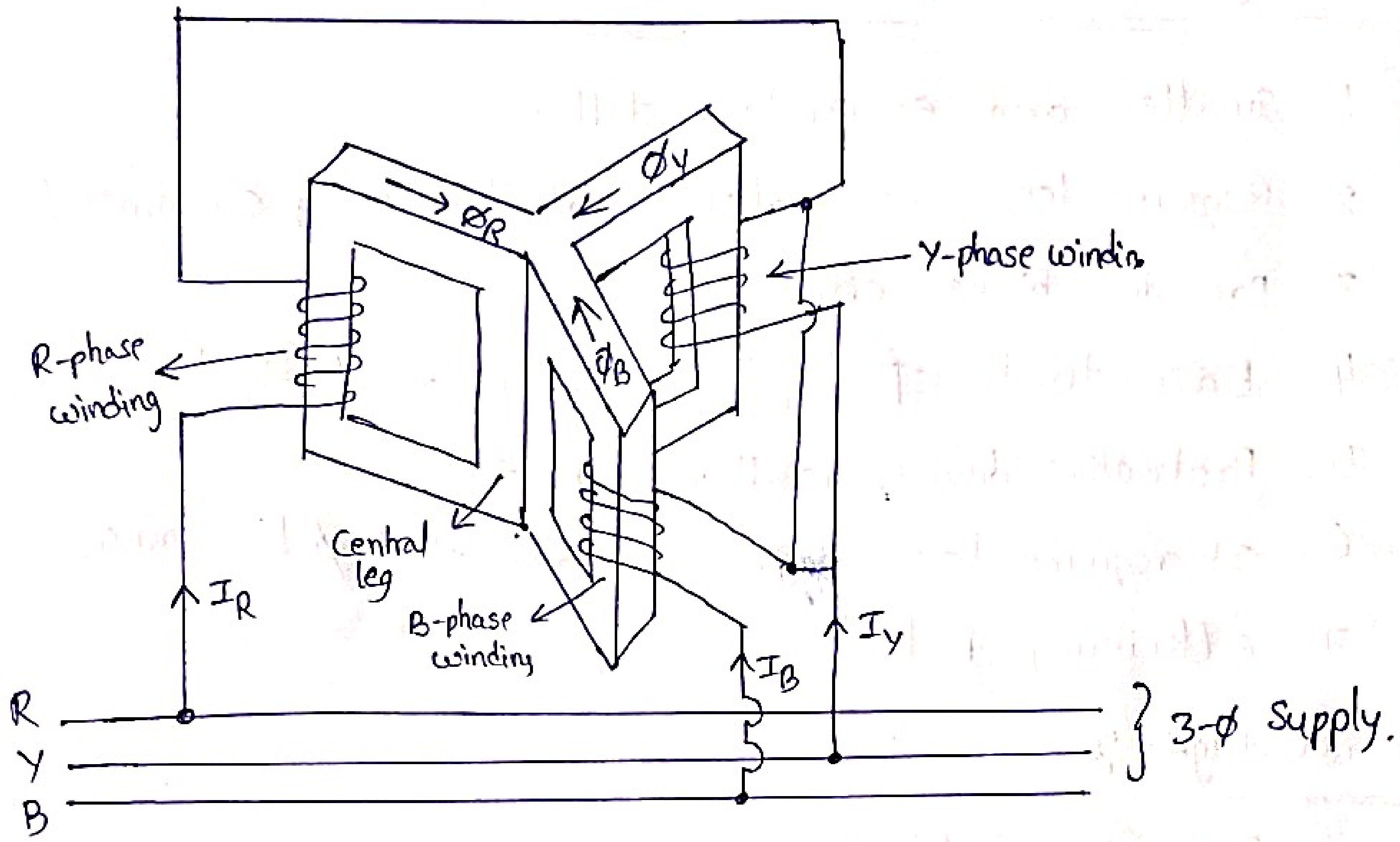
→ By based ~~on~~ on type of the core, we have two types o... 3-ø transformers as

ⓐ Core type three-phase transformer

ⓑ shell type three-phase transformer.

Working of a Three-phase Transformer :-

Consider that the primary of a three-phase transform... are connected in star on the cores, which are displayed by 120°, each other, as shown in figure below. For simplification ~~only~~ purpose, only primary windings are connected to A.C Suppl...



When the primary windings are excited by 3-φ Supply, current I_R, I_Y & I_B flow through its respective windings, which produces the magnetic fluxes ϕ_R, ϕ_Y & ϕ_B in cores. Since centre leg is common for all the cores, the sum of all three fluxes is carried by it. These fluxes induce an emf in primary winding based on the principle of transformer, an emf is induced in ~~r~~ its respective windings. The emf in secondary winding drives the currents to the load connected to it. In this way 3-φ transformer is ~~transform~~ transfer the 3-φ power.

Advatages of Three-phase transformer :-

1. Smaller and easier to install
2. Require less core material and it is more economical
3. Provides higher efficiency
4. Easier to transport, it's weight is relatively less
5. Protective device installation is easier
6. It require less space comparing with 1-ø transformer.
7. Efficiency is high

Dis advatages :-

1. Repairing cost is more
2. When it is self-cooled, it's capacity reduces.

Three-phase Transformer Connections :-

→ The windings of 3-ø transformers may be connected in Star (Y) or Delta (Δ) in the same manner of as three 1-ø transformers.

→ We have 4-ways of connections for 3-ø transforme

① Star (Y) - Star (Y) connection (Y-Y).
② Delta - Delta connection (Δ-Δ)
③ star - Delta connection (Y-Δ)
④ Delta - Star connection (Δ-Y)

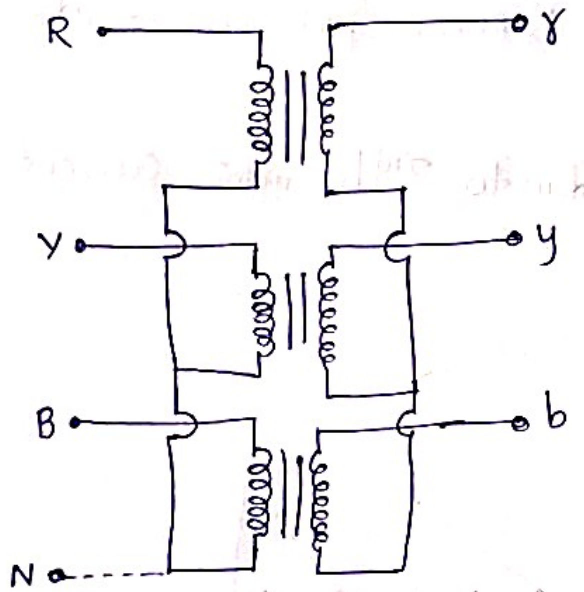
① Star-Star Connection (Y-Y) :-

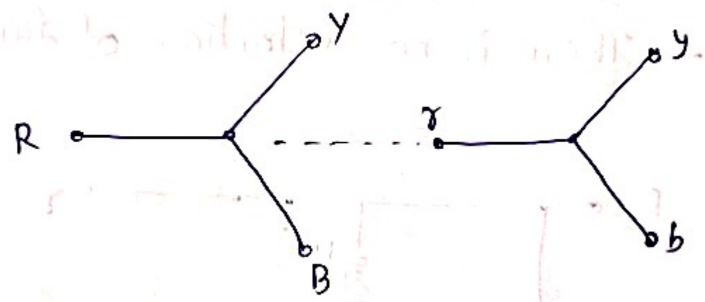
In this connection both the primary and secondary windings are connected in star, as shown below.

→ It gives line voltages $\sqrt{3}$ times phase voltage.

→ In this connection, there is no-phase angle difference between the line voltages of primary and secondary windings.

→ It is economical for small high voltage transformers as the number of turns per phase and the amount of insulation required is less.





0° angular displacement.

Advatages:-

① Requires less number of turns and insulation stress is less.

2. Economical for medium-voltage applications

3. Mechanical strength of the windings is stronger

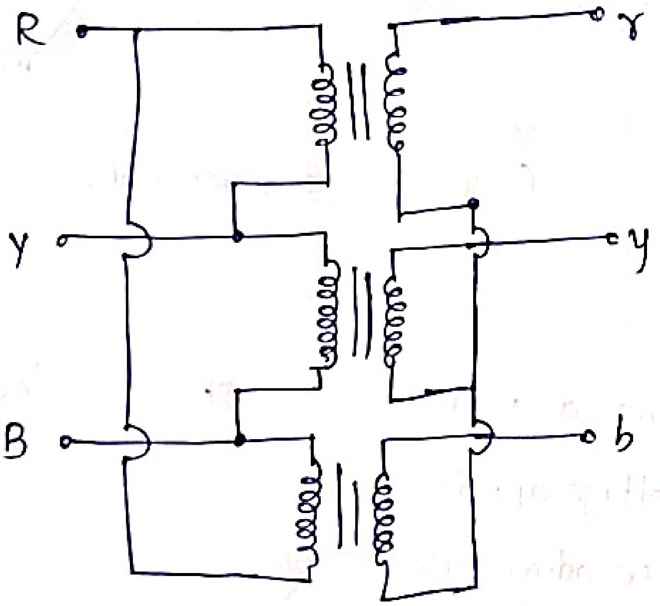
4. Can be used in 3-Ø - 4-wire system, as the neutral point is available.

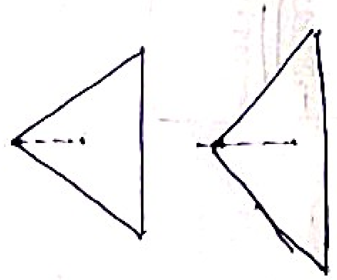
(d) Disadvatages!-

1. If unbalanced load is connected, its performance is poor.
2. When an alternator is connected, then secondary voltage is having the third harmonic ~~presents~~ distortion.

(2). Delta-Delta connection ($\Delta-\Delta$)

→ The primary and secondary windings are connected in delt
→ The number of turns required per phase and the required insulation is more when compared to star-star connection.
→ It is used in "large transformers" for any type of load.
→ There is no-phase displacement between primary and secondary voltages
→ There is no-distortion of flux due to 3rd harmonic currents.





0° angular displacement.

Advatages!-

1. Unbalanced load can be used in this connection.

2) Less windings cross-section and hence it is economical for low voltage transformers

3. Continously supply can be provided, for a bank of three single phase transformers

Dis advatags :-

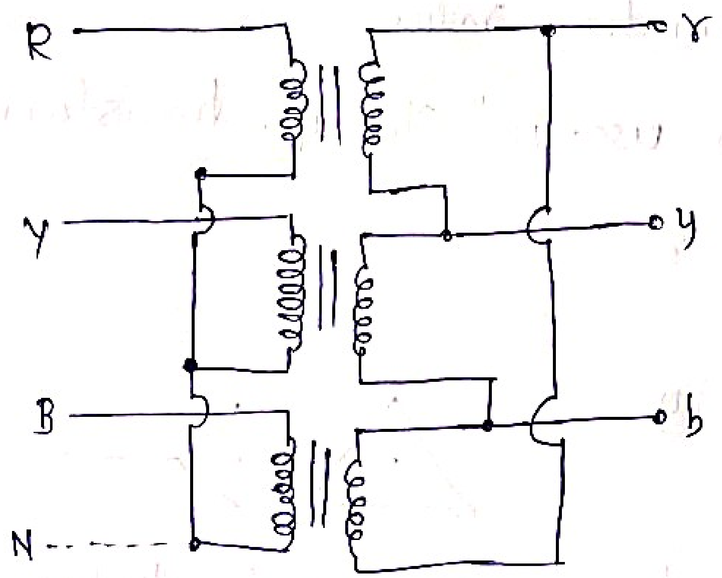
It is not suitable for a three-phase four-wire system due to the absence of neutral point.

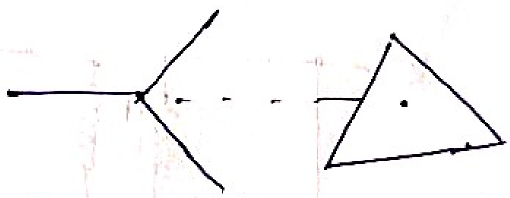
③ Star-Delta Connection :- (Y-Δ)

In this connection primary windings are connected in star with neutral grounded and secondary windings are connected in delta.

→ In this type, the ratio of primary to secondary line voltages is $\sqrt{3}$ times the transformation ratio.

→ This connection is used for "Step-down transformers".





30° angular displacement

Advatages!-

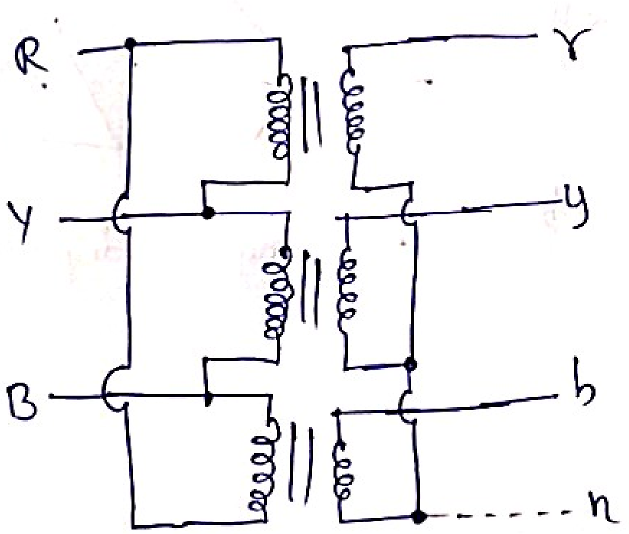
- Requires less no. of turns
- More economical for large and high voltage transformers
- Distortion is avoided
- Unbalanced load can be connected to the transformer

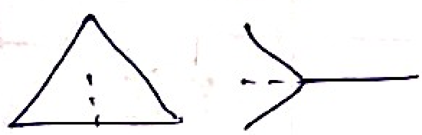
Disadvatages!-

- A phase shift exists between the primary & secondary winding
- It can't be used in parallel with Y-Y & Δ-Δ connection

④ Delta-Star connection (Δ-Y).

- In this connection, the primary windings are connected in delta and the secondary windings are connected in star with neutral ground.
- In this type, the primary to secondary voltages is $\frac{1}{\sqrt{3}}$ times the transformation ratio.
- This type connection used in "Step up-transformers".





30° angular displacement

Advatages :-

→ winding ~~of~~ cross-section area is less in primary side due to delta connection.

→ No-distortion in system.

→ ~~It is~~ can be used in 3-Ø, 4-wire power system.

→ Economical as cost is saved due to less insulation.

→ Unbalanced load can be connected.

Disadvatages :-

→ Phase shifts exists between primary and secondary voltages

→ It cannot be used in parallel with star-star (or) delta-delta connected transformer.

=X=