Chapter-3 Transformer

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o.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-
					Transform

UNIT- 3 Transformers

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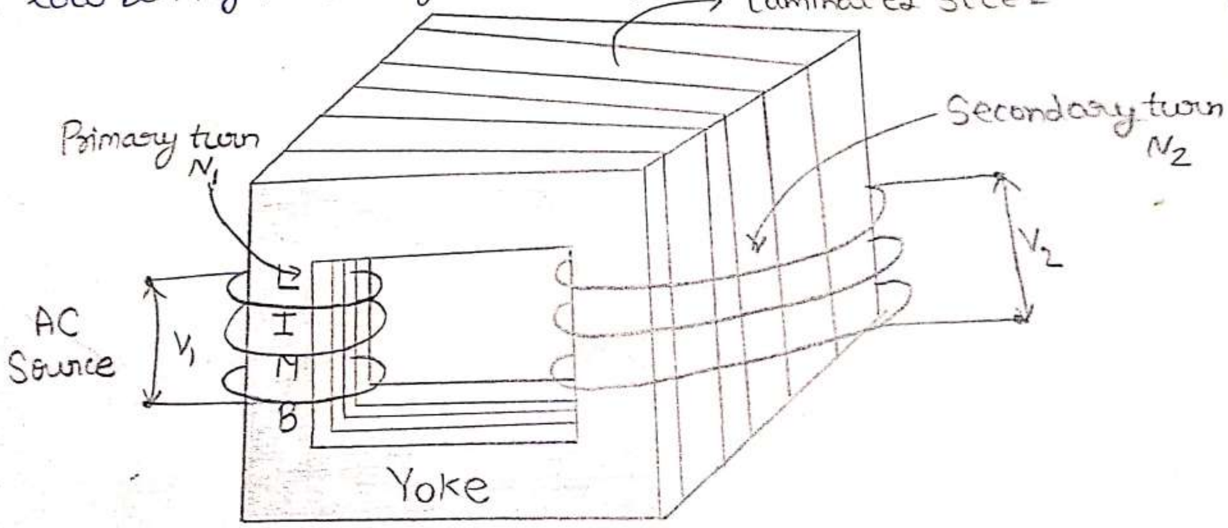
☆ Construction of transformers ⟶

- The single phase transformer consist of magnetic core & two windings.
- By construction two windings are called as high voltage (H.V.) & low voltage (L.V).
- The core of transformer is constructed from Sheet Steel to provide a continuous magnetic Path.
- It is laminated to minimize eddy current loss.
- Silicon is added with Steel lamination to reduce loss.
- The lamination are insulated by each other by light coating or varnes or an offside layer.
- The thickness of lamination are varies from 0.35mm to 0.5mm from a frequency of 50Hz.
- The low & High voltage windings are wound



Main Ideas, Questions & Summary:

Acc^r to core construction & manner in which primary & Secondary windings are phase arround it, the transformer are classified as:

(i). Core type

(ii). Shell type

In the core type transformer windings surround are considerable portion of core whereas shell type considerable portion of shell.

(i). Core type transformer ⟶ In this type core is generally stacked by L shaped laminations.

- This type of transformer as single magnetic curcuit But it has two legs (limbs).
- Initially some part of low voltage windings is wrapped arround the two legs then some part of high voltage windings is wrapped over.
- The connection point is overlapped each other (H.V & L.V) i.e. it is called as concentric wiring or cylindrical windings.

(ii). Shell type transformer ⟶ In this type of transformer, the laminations are used to stack the shell.

- This type of transformer has double magnetic circuit & there legs.
- Along with it's these legs it generally require only one critical leg for winding.
- To reduce the lekage flux to minimum, increase the amount of leakage flux to maximum.
- The low voltage & high voltage windings are alternatively put in the for most

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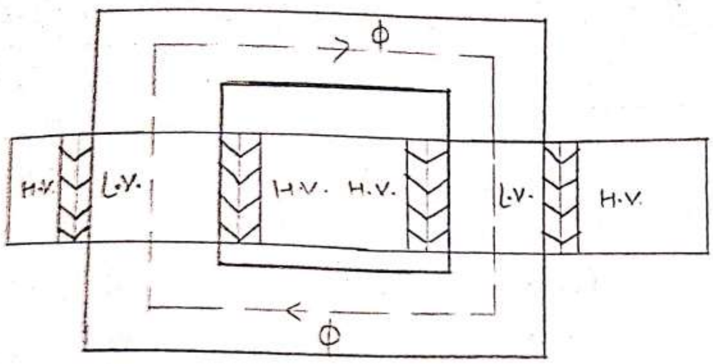
. Such arragements of winding is called as Sandwich or Disc winding.



(i). core type transformer

☆ Comparision b/w Core Type Transformer & Shell Type Transformer →

Core Type Transformer	Shell Type Transformer
①. The winding Surround a considerable part of the core.	① The Core Surround are considerable Portion of the winding.
②. More Suitable for high Voltage transformer.	②. More economically for low voltage transformers.
③. Windings are of cylindrical type	③. Winding are of disc or Stagged type.
④ Core is either circular or rectangular.	④. core is of Spiral type.
⑤. Mean length of coil term is Shoter.	⑤. Mean length of coil is larges

Main Ideas, Questions & Summary:

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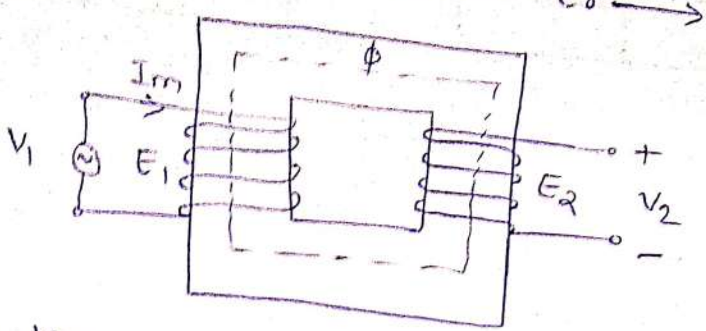
✯ EMF equation of transformer →



As we know that the working principle of transformer is based on faraday's law of electro magnetic induction. This is also known as mutual inductance law & fundamental and represented as

$$e = -N\frac{d\phi}{dt} \quad \text{—— (1)}$$

As we know that the emf generated is denoted or represented by sinosudial wave along with this the flux is also represented as sinosudual wave.

So, $\phi = \phi_m \sin\omega t$ —— (2)

$$e = -N\frac{d\,\phi_m \sin\omega t}{dt}$$

$$e = -\omega\phi_m N\cos\omega t$$

$$e = -N\omega\phi_m \cos\omega t$$

$$e = \underbrace{-N\omega\phi_m}_{E_m} \sin(\omega t - \pi/2)$$

$$\boxed{E = E_m \sin(\omega t - \pi/2)} \qquad \because E_m = -N\omega\phi_m$$

$$\because E_{rms} = \frac{E_m}{\sqrt{2}}$$

$$= \frac{N\cdot\omega\cdot\phi_m}{\sqrt{2}}$$

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$$= \frac{N(2\pi f)\phi_m}{\sqrt{2}}$$

$$= \frac{2\pi}{\sqrt{2}}(Nf \cdot \phi_m)$$

$$= \sqrt{2}\,\pi\,(Nf \cdot \phi_m)$$

$$\boxed{E_{rms} = 4.44(N \cdot f \cdot \phi_m)}$$

(No. of turns)

(frequency) (maximum flux in transformer circuit)

$$E_1 = 4.44(N_1 \cdot f \cdot \phi_m)$$
$$E_2 = 4.44(N_2 \cdot f \cdot \phi_m)$$

★ Voltage transformation Ratio :-

- It is the ratio of secondary voltage to primary voltage & represented as K.
- For an ideal transformer terminal voltages are equal to induced voltage. So,

$$V_1 = E_1$$
$$V_2 = E_2$$

Transformation ratio $K = \frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{4.44(N_2 f \phi_m)}{4.44(N_1 f \phi_m)}$

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

Case I. if the value of K is more than Unity $(N_2 > N_1)$, the transformation is said to be step-up transformer.

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Case-II if the value of K is less than unity ($N_1 > N_2$), the transformation is said to be Step-down transformer.

For ideal transformer input power must be equal to output power. So,

$$V_1 I_1 = V_2 I_2$$

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} \Big/ \frac{V_2}{V_1} = \frac{I_1}{I_2}$$

(Current transformation ratio)

☆ Ideal Transformer →

- An ideal transformer is an imaginary transformer which as following properties. The resistance of primary & secondary winding are negligible. Therefore, Copper loses in the transformer is zero.
- In this transformer the likage of flux is zero & efficiency is high & 100 %.
- There are no losses due to hystris & eddy current.
- The Core has infinite Permiability & core losses reduce to zero.
- In this transformer their is no ohmic losses exist has ohmic resistance is zero.

☆ Difference b/w Practical & ideal transformers →

Practical Transformers	Ideal Transformers
① There are Copper	① There
② There is leakage of flux.	② There is no leakage of flux.
③ Windings of this transformers as ohmic resistance.	③. No ohmic resistance.

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④ Efficiency is varied from 70 percent to maximum.

⑤ All concentrated transformers are Practical transform.

④. Efficiency is 100 percent.

⑤. It is impossible to design ideal transformer.

★ Losses in transformers →

There are no. of losses exist in transformer & they are known as (i). Core loss
(ii). Ohmic loss → Stray loss
→ Dielectric loss

(i). Core loss → The core losses is represented by P_c in transformers. Generally this type/core loss consist two components (i). loss (P_h) & (ii). eddy Current loss (P_e)

The mathematical expression for this is given by

$$P_c = P_h + P_e$$

(ii). Ohmic loss → It is also known as Copper loss or I^2R loss. Ohmic loss is generally occur in both primary & Secondary loss.

Note → In addition to ohmic & core losses the following two losses are also present in transformer

(a). Stray load loss → As leakage field is present in transformer, induces eddy current in conductor, tanks, channels etc. these eddy current gives rise to stray load loss.

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(b). Dielectric loss → This loss occurs in insulating material i.e. in Solid insulation of H.V. transformers & in the transformer oil.

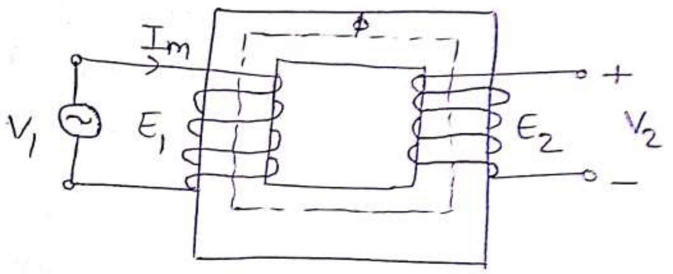
Note → The stray load loss & dielectric losses are very small & therefore neglected.

✯ Phasor of Ideal transformer at no load →

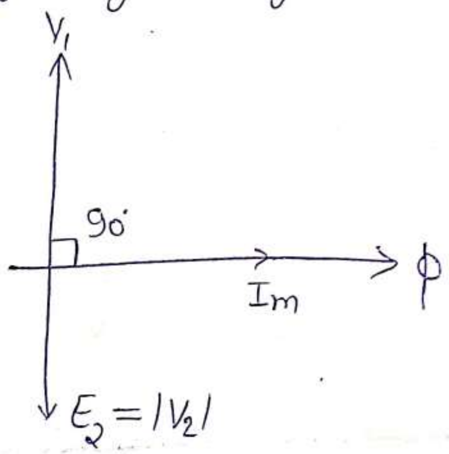
→ At no load condition output current is zero ($I_2 = 0$).

→ V_1 is applied across the primary winding of the transformer.

→ This voltage application draws are magnetizing current I_m.



In the case of no load transformer the current legs the voltage by an agle of 90°.



Phasor for transformer at No load

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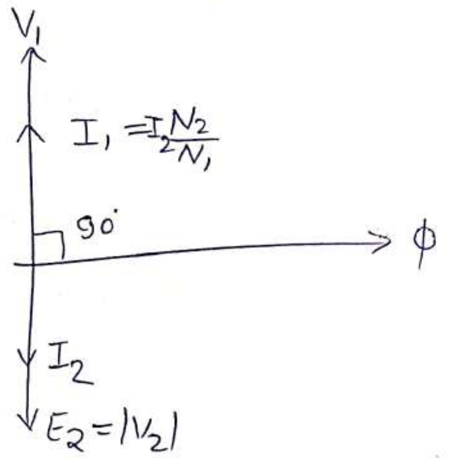
The magnetizing current I_m, setup a flux ϕ in the common magnetic circuit. Acc^r. to the formula $\phi = \frac{N_1 I_m}{R}$

Since, N_1 & R are constant the flux is in phase with I_m.

✲ Phasor of Ideal transformer at load →
when a load is connected to the output terminals there will be a phase difference betⁿ voltage & current, decided by nature of load.

i). Resistive load When the load applied is resistive in nature the phase difference betⁿ voltage & current is zero.
→ There will be a phase difference of 90° b/w generated flux & applied voltage.



Phasor for transformer at Resistive load

ii). Inductive load → In case of inductive load current legs behind from voltage by an angle of θ.
→ And Current legs the flux by angle of 90 − θ

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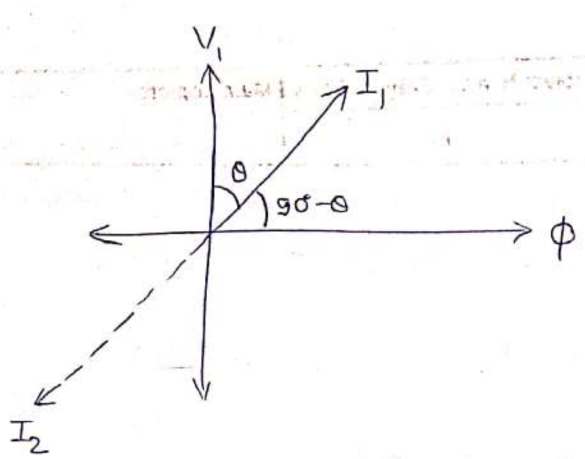
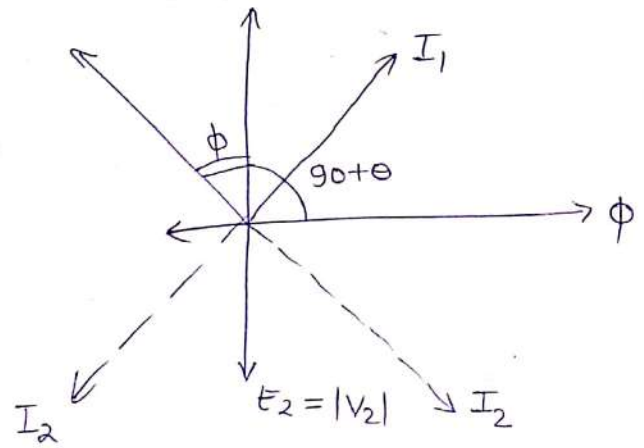


iii). ~~In Case~~ In case of Capacitive load, the Current legs the voltage by angle θ.

→ And Current also legs the flux by angle of $90+\theta$.



✱ Voltage Regulation →

$$\text{Percentage Regulation} = \frac{\text{Terminal voltage at no load} - \text{Terminal voltage at on load}}{\text{Terminal voltage at no load}}$$

$$= \frac{\text{Voltage drop in transformer at load}}{\text{no load rated voltage}}$$

✱ Efficiency of transformer →

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} = \frac{\text{Input Power} - \text{losses}}{\text{Input Power}}$$

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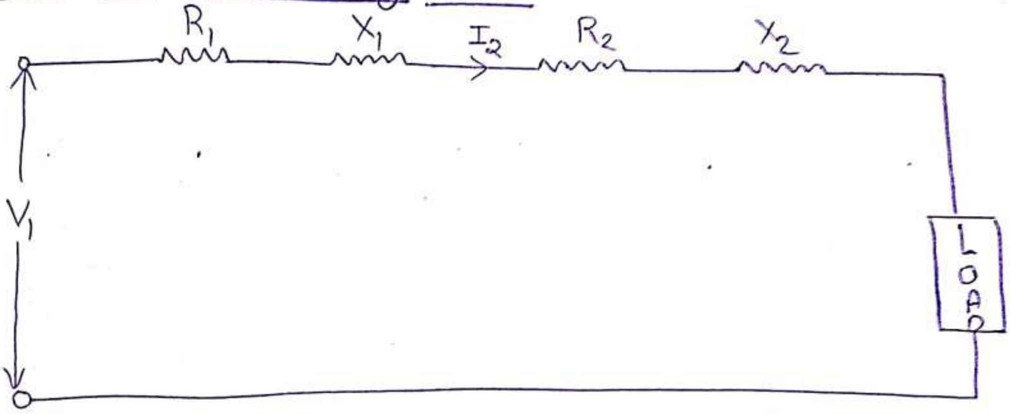
$$= 1 - \frac{\text{losses}}{\text{Input Power}}$$

✲ Equivalent circuit of transformer →

Two independent circuit of a transformer can be resolved into an equivalent Circuit. There are two methods availble to refer transformer equivalent circuit.

1). Refer to Secondary side
2). Refer to Primary side

1). Refer to Secondary Side



- The Resistive drop in Secondary winding $= I_2R_2$
- The reactive drop in Seondary winding $= I_2X_2$
- The Resistive drop in Primary winding $= I_1R_1$
- The reactive drop in Primary winding $= I_1X_1$

As transformation ratio is K, primary resistance & reactive drops as refered to secondary will be K times, So KI_1R_1 & KI_1X_1 respectively.

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if I_1 is Substituted as KI_2, Primary resistive & reactive drops refered to Secondary Side will be $K^2I_2R_1$ & $K^2I_2X_1$

Total resistive drop in a transformer $= K^2I_2R_1 + I_2R_2$

$$= I_2(K^2R_1 + R_2)$$

$$= I_2R_{02}$$

reactive drop $= K^2I_2X_1 + I_2X_2$

$$= I_2(K^2X_1 + X_2)$$

$$= I_2X_{02}$$

2). Refer to Primary →

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✩ Transformer Rating →

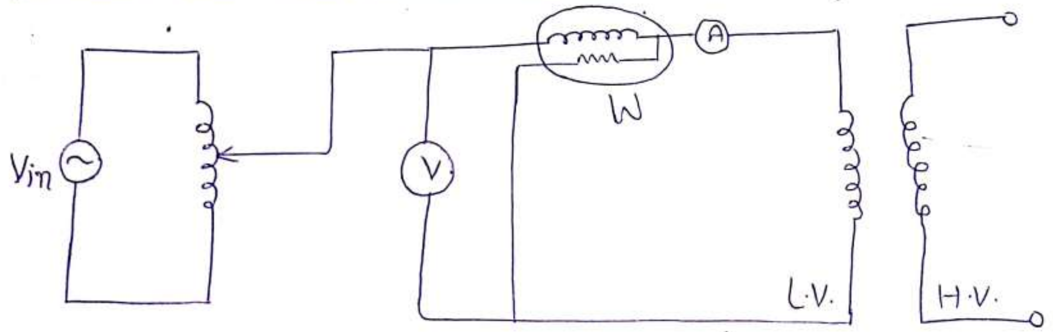
→ Typical nameplate rating of transformer is given as 10 KVA, 3300/220V, 50 Hz.

→ Here, 10 KVA is rated output at secondary terminals which is expressed as Kilo-Volt-Ampere rather than Kilo-watt.

→ This is due to that the output is limited by Heating & hence by the losses in the transformer.

→ These losses depends upon the voltage (core loss) & current (I^2R loss) & are unaffected by the load Powerfactor.

✩ Open circuit Test for transformer :-



The connection diagram for open circuit test is given with voltmeter, wattmeter & Ammeter. These meters are connected with low voltage side.

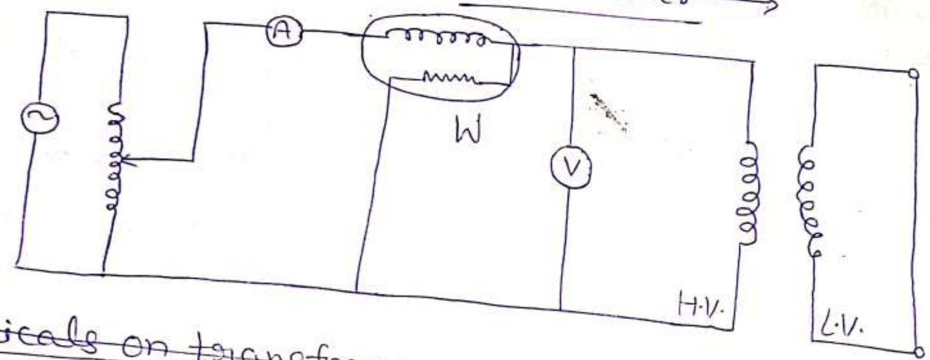
The voltage at rated frequency is applied to that low voltage side with the help of Auto variable transformer.

The high voltage side of the transformer is kept open.

Main Ideas, Questions & Summary:

With the help of variac(auto transformer), applied voltage gets slowly increase until the voltmeter gives reading equal to rated voltage to the low voltage side.
After reaching at rated L.V. Side Voltage all three instruments reading are recorded

✲ Short Circuit Test for transformer →



~~Numericals on transformer →~~

~~Q→ The flux ϕ linked with coil depends~~ on time t is

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* Numericals on transformer ⟶

Q→ The flux ϕ depends on t is $\phi = (3t^2+t+5)$, $t = \phi$..

Solⁿ→ $\frac{d\phi}{\partial t} = 6t+1 = 7$

Q→ A single phase 3300/220 V, 50 Hz transformer has secondary has full load current of 180 Ampere. It has 50 turns on its secondary side. Calculate (i). voltage per turn
(ii). No. of ~~primary~~ turn N
(iii). The full load Primary Current
(iv). KVA output of transformer

Solⁿ→

$V_1 = 3300V$
$V_2 = 220V$
$f = 50Hz$
$I_2 = 180A$
$N_2 = 50$

(i). Voltage Per turn

$$\frac{V_2}{N_2} = \frac{220}{50} = 4.4 \text{ turn}$$

(ii). No. of primary turn

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow \frac{3300}{220} = \frac{N_1}{50} \Rightarrow N_1 = \frac{3300 \times 50}{220} \Rightarrow N_1 =$$

(iii). The full load Primary Current

$$\frac{V_2}{V_1} = \frac{I_1}{I_2}$$

$$\frac{220}{3300} = \frac{I_1}{180} \Rightarrow I_1 = \frac{18\cancel{0} \times 22\cancel{0}}{33\cancel{00}} = 12A$$

Main Ideas, Questions & Summary:

(iv). KVA Output of transformer

$$V_1 I_1 = V_2 I_2$$
$$3300 \times 12 = 220 \times 180$$
$$39600 = 39600$$

Q→ A 6 KVA, 110 V/500 V Single phase transformer has Secondary terminal voltage of 487.5 when loaded. Determine the regulation of transformer.

Sol^n→

$$\frac{V_2}{V_1} = \frac{E_2}{E_1}$$

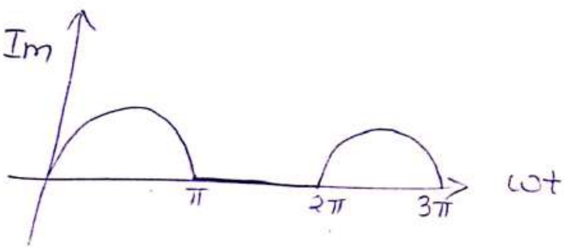
$$\frac{500}{110} = \frac{487.5}{E_1}$$

$$E_1 = \frac{487.5 \times 110}{500}$$

$$E_1 = 1072.5 \text{ V}$$

☆ Numerical on Wave form →

Q→ Find the Average, effective value & formfactor of a half rectifier current wave.



Sol^n→ Average $= I_{av} = \frac{1}{2\pi} \int_0^{2\pi} i \, d(\omega t)$

$$i = \begin{cases} I_m \sin \omega t & 0 < \omega t \leq \pi \\ 0 & \pi < \omega t \leq 2\pi \end{cases}$$

$$= \frac{1}{2\pi} \int_0^{\pi} I_m \sin \omega t \, d(\omega t)$$

$$= -\frac{1}{2\pi} \Big[I_m \cos \omega t \, d(\omega t) \Big]_0^{\pi} = \frac{2 I_m}{2\pi} = \frac{I_m}{\pi}$$

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$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi}\int_0^{\pi} i_m^2 \sin^2 \omega t \, d(\omega t) + \int_{\pi}^{2\pi} 0 \cdot d(\omega t)}$$

$$=$$

Chapter-4 Electrical Machine

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09/10/18	4		Mr. Mohit Bajpai	BEE		Electrical Machines

✫ Introductions →

The two types of voltage & current sources are available, for the same two types of rotating electrical energy conversion machines are available.

1). A Direct Current (D.C.) Machine

2). The Alternating current (A.C.) Machines

The Word machine is commonly used for the feature that are common to both the motor & the generator.

✫ D.C Machines →

The D.C. Machines are the electro mechanical energy conversion device. The DC Machines are of two types:

i). D.C. Motor

ii). D.C. Generator

The Machine which converts mechanical energy into D.C. electrical energy is known as D.C. Generator.

The Machine which converts D.C. electrical energy into mechanical energy is known as D.C. Motor.

✫ Working Principal of D.C. Machines →

① It is based on the Principal of Electromechanical energy conversion.

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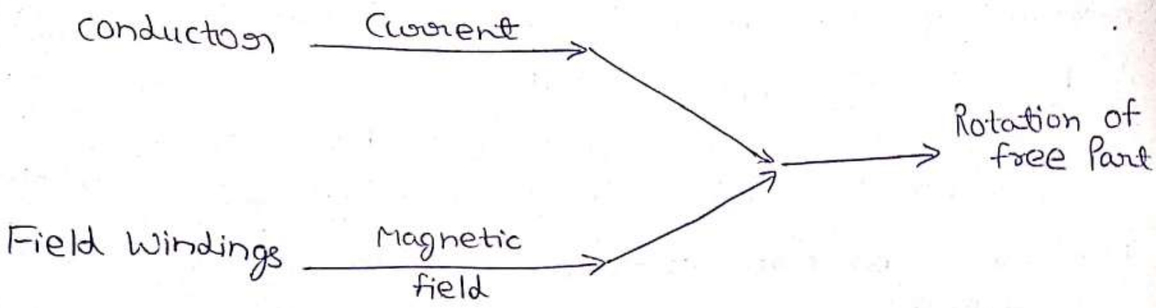
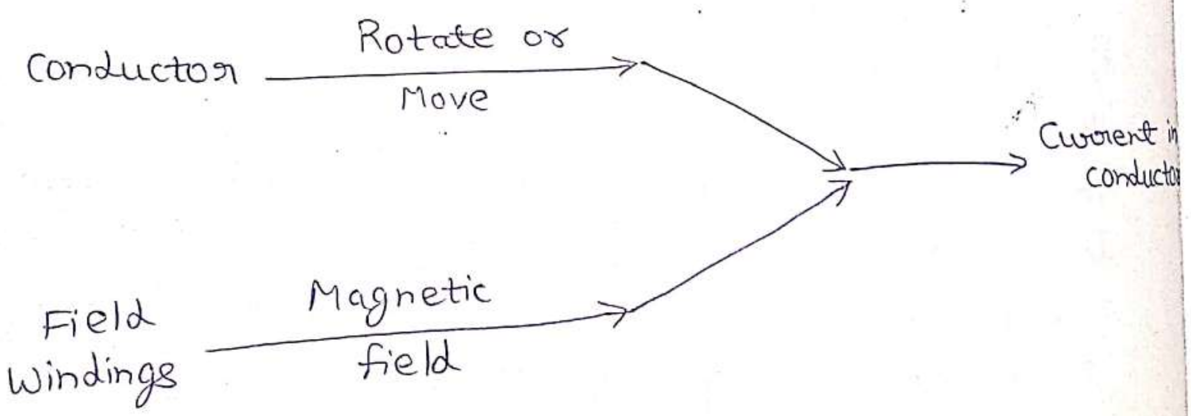
(3). This conversion & principle is represented as "When a current carrying conductor is placed in a Magnetic field, It experiences a force that move as such that electrical energy is converted to mechanical energy. (Fig.1)



(Fig. 1) <u>Line Diagram For D.C. Motor</u>



(Fig. 2) <u>Line Diagram For D.C. Generator</u>

If an extenal applied force makes the Conductor to move in the Current Starts to flow in conductor i.e. M.E. into Electrical energy. (Fig. 2)

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In Both principle the magnetic field is the medium for energy conversion.

★ Parts of D.C. Machines ⟶

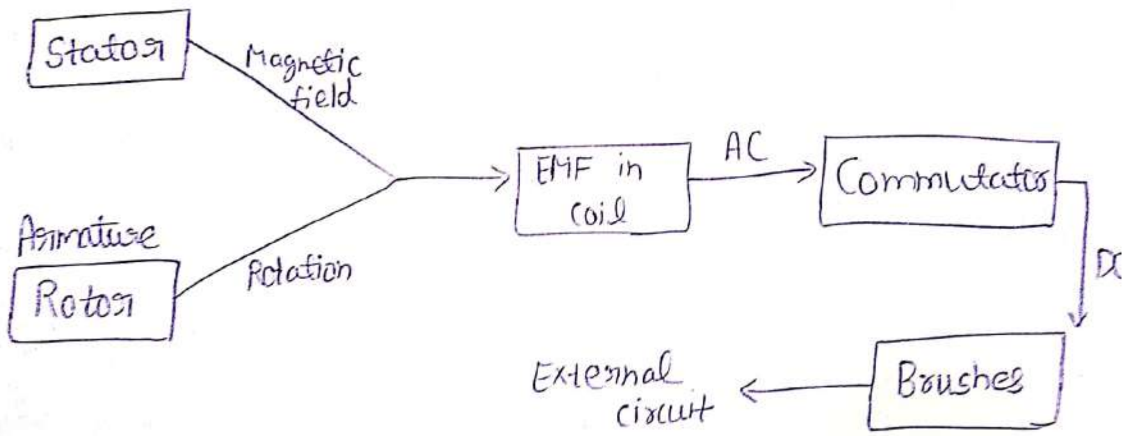
Any electrical machine has mainly two parts:

(1). Rotor ⟶ It is free to move & normally it is inner part of machine.

(2). Stator ⟶ It is fixed such that cannot move & normally outer part of the machine.

Along with the Stator & Rotor dc machines has following other parts

(i). Magnetic field System (Stator)
(ii). Armature (Rotor)
(iii). Coil System
(iv). Commutator (use to convert A.C. into D.C)
(v). Brushes



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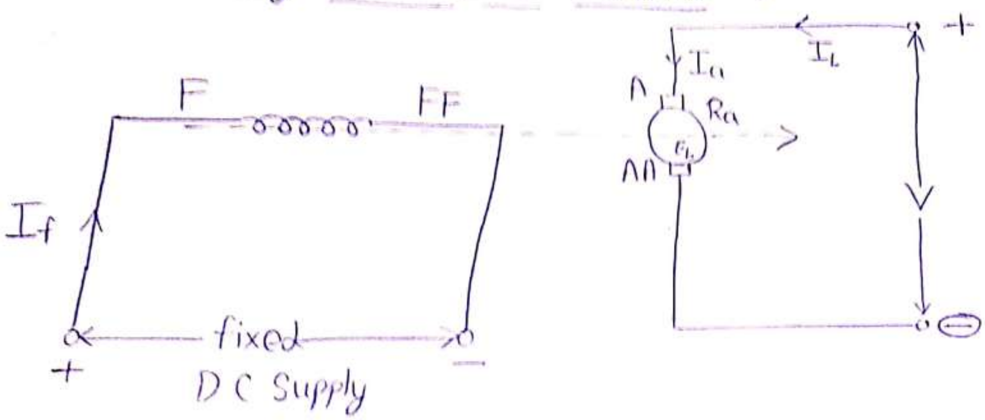
✯ Types of D.C. Machines →

On the basis of Excitation Method there are two types of DC Machines available -

1. Separately Excited DC Machine
2. Self Excited DC Machine
   - a → Shunt type
   - b → Series type
   - c → Compound type
     - Long Shunt
     - Short Shunt

1. Separately Excited DC Motor →



When Separately exited dc machine the exitation source is used Separately to excited the device.

In case of Separately excited dc moter their will be a it self generated emf called as back Em.f (E_b).

The relation between terminal voltage V & back Emf (E_b) is given by

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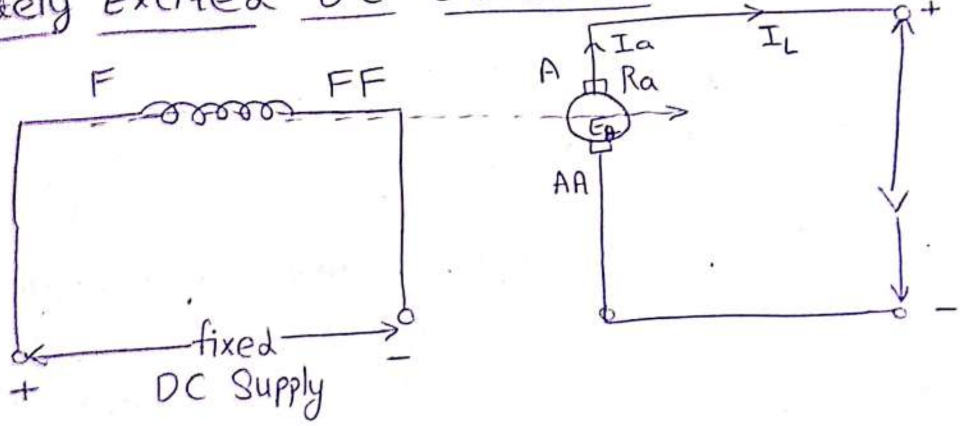
$$\boxed{V = E_b + I_a \times R_a} \qquad V > E_b$$

where, V is terminal voltage
E_b is back emf
I_a Armmeture Current
R_a Armmeture Resistance

* Separately Excited D.C. Generator →



$$\boxed{V = E_g - I_a \times R_a} \qquad V < E_g$$

In Separately exicted d.c. Generator, a generated emf called as E_g.
The Current I_a & I_L both are equal so, $I_a = I_L$.
& Current must be reaching to the output terminal from the device.

Main Ideas, Questions & Summary:

EMF Equation of DC Machines →

$$\boxed{E = \frac{N \times P \times \phi \times Z}{60 \times A}}$$

Where, $E \rightarrow$ Generated Emf
$N \rightarrow$ Speed in RPM
$P \rightarrow$ No. of Poles
$\phi \rightarrow$ Flux
$Z \rightarrow$ No. of conductors
$A \rightarrow$ No. of parallel paths

∴ for lap winding $A = P$
∴ for wave winding $A = 2$

Characteristics of Separetly Exicited DC Mortor →

i). In Separately exicited DC Moter, the field is supplied from a constant voltage so that the field Current is constant. The two moter therefore as similar characterstic

Characterstic is a graph betn two dependent quantities
In Case of Separately Exicied DC motor, there are following two characterstics exist:

(a). Speed (N) – Armature Current (I_a) Characterstics

$$\boxed{N \propto \frac{V - I_a R_a}{\phi}}$$

In design of characterstics between N & I_a we kept voltage V is constant.
As the result flux is also constant at low load condition. The flux lightly decreases due to Armature reaction.
If the effect of armature reaction is neglacted the flux ϕ remains constant. The motor Speed is given as

The dependcy ... on voltage ... This equation ... so, speed N ... increase in ...

(b). Torque ... If the ... consta...

This ... thr...

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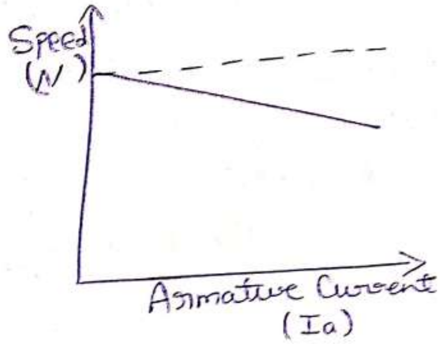
The dependcy of Speed shown by formula given & its depeands on voltage, armature.

This equation is of a straight line with negative slope. so, speed N of the moter decreases linearly with increase in armature current.

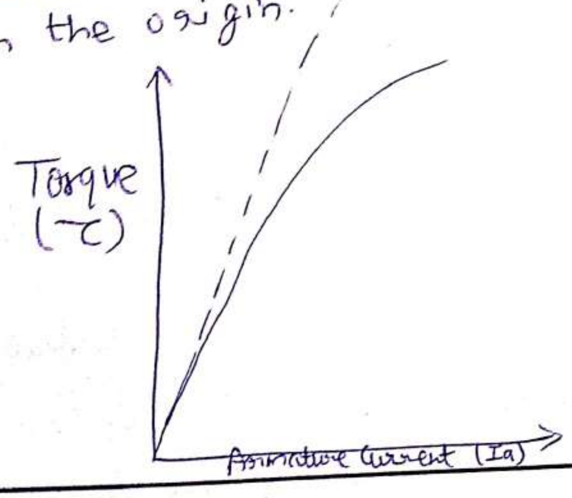


(b). Torque - Armature Current characterstics →
If the effect of Armature rxn is neglacted. ϕ is nearly constant & relation of τ with Ia is represented from

$\tau \propto \phi . Ia$

$\boxed{\tau \propto Ia}$

This relation is also Straight line relation which Passes through the origin.



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★ Speed Control of Separetly excited DC Motor →

Speed of DC motor is given by

$$\boxed{N = \frac{V - I_a R_a}{K\phi}}$$

As the relation of speed shows that it depends upon the supply voltage V, the armature resistance R_a & field flux ϕ which is produced by the field current.

On the basis of speed dependency there are three methods to control speed:

① Variation of Resistance in Armature Circuit
This method is also called as Armature resistance controlled (Rehostatic Controll)

② Variation of field flux
This is called as field flux Controlled.

③ Variation of Applied voltage
This is called Armature voltage controlled

① Variation of Resistance in Armature Circuit
Armature resistance controll (Reshostatic control)

In this method variable series resistor R_{se} is put in series with armature circuit.

The speed are control while varing the resistance which varied the current.

In variation of current the flux is affected & hence the speed is varied or control.

The Resistance R_{se} reduce and result to reduce in voltage applied to armature & hence speed is reduce.

This method suffers from the following draw back:

① A large amount of power is wasted in external resistance R_{se}.

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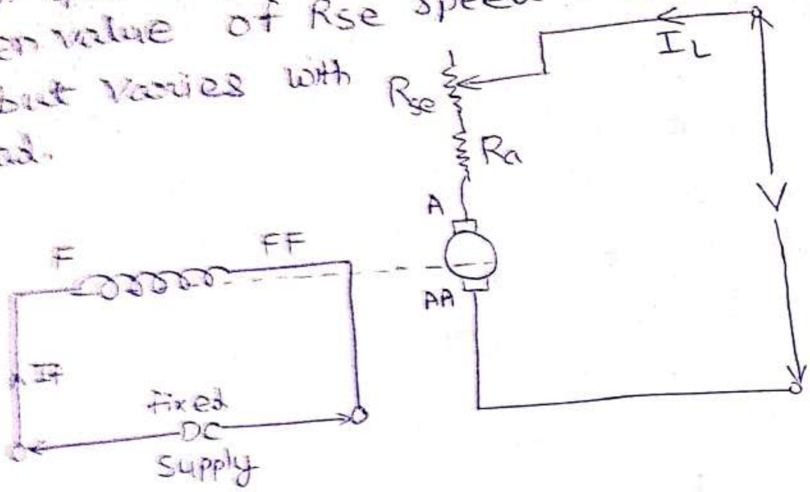
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

2) Control is limited to given speed normal rating & increases of speed cannot be opp by this method.

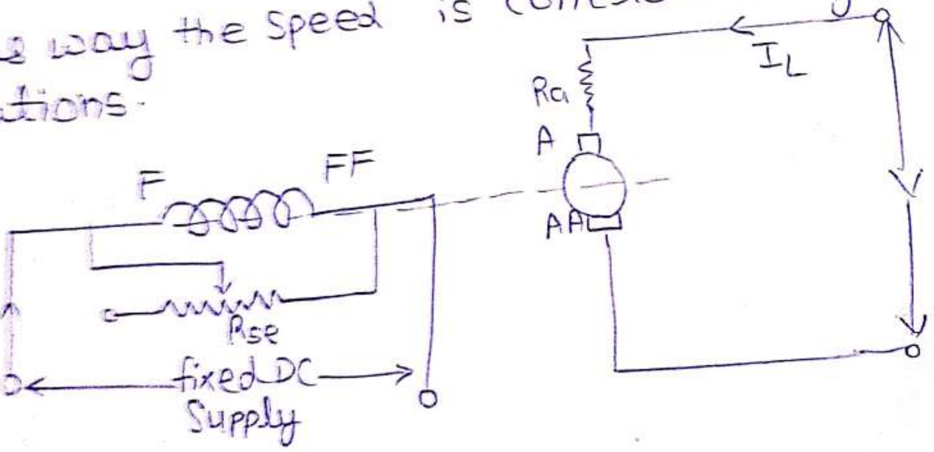
3) For a given value of Rse speed reduction is not constant but varies with motor load.



2) Variation of field flux (ϕ)
(Field Flux Controlled)

Weakning of field causes increase in speed of the motor while strengthning the field causes decrease the speed. Here, the variable resistance is connected in series with the field coil.

In this way the speed is controlled by means of flux variations.



Main Ideas, Questions & Summary:

Library / Website Ref.:-

Relactance control envolve variation of Relactance of magnetic circuit of moter. Field Voltage control by variying the voltage at field circuit. While keeping Armeture terminal voltage constant.

(3). Speed Controlled by Variaying the Armature terminal Voltage →

If the Armature terminal voltage (V) is varying, counter emf ($V - I_aR_a$) or E_V changes almost proportionaly.

For a constant flux moter the speed varied accordingly with the change in input voltage.

DC Moter speed control by this method is obtained in three following methods:

i). Ward leonard System
ii). Controled Rectifiers
iii). Series Parallel armature Control

☆ A.C. Machines →

→ Generation & Utilization of electricity are generally in A.C. & Machines which works on A.C. Supply are called as A.C. Machines.

→ A.C. Machine are more popular than D.C. Machine Because available supply is AC.

→ AC. Machines are basically of two types:

i). Induction Machines → These Machines are Singly excited machine which works on the principle of mutual induction. These are classified into two categories:

(a). Single phase induction Machine
(b). Three phase induction Machine

(ii). Synchronous Machines → These Machines are doubly excited machine & basically used to generate large amount of power at power generating Stations.

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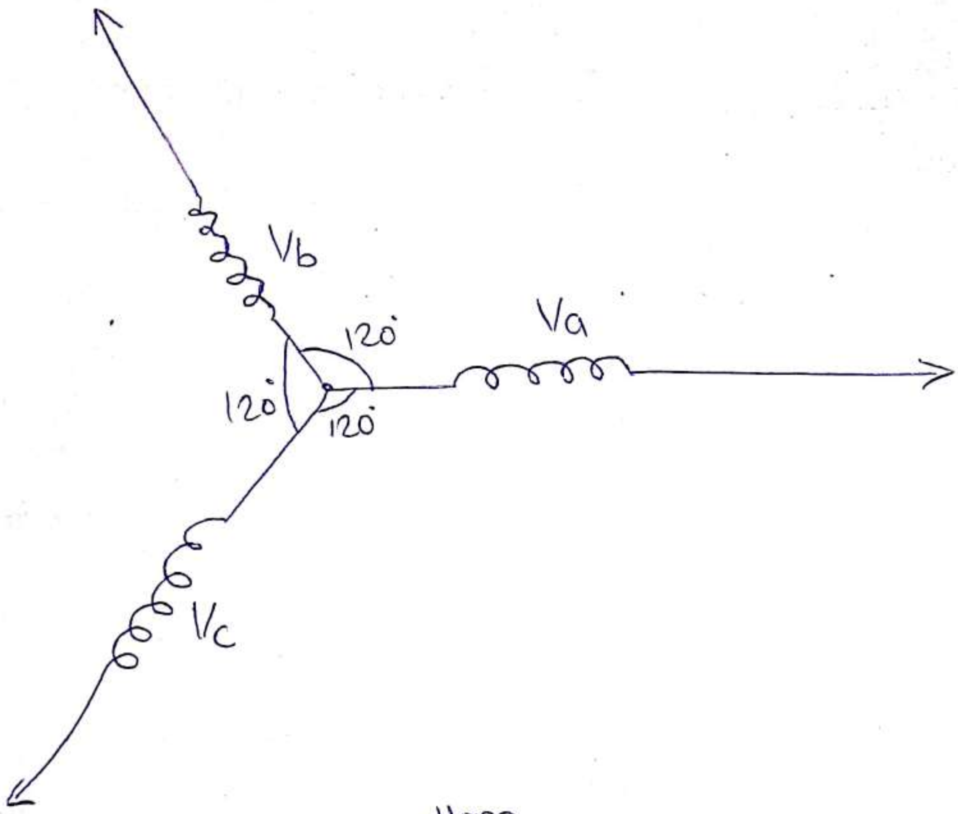
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

★ Generation of Rotating Magnetic field →

- The Generation of Electricity is always in 3-ϕ Such that we are using 3-ϕ Generators at generating power plants.
- In three Phase Generators the three windings are used & utilized at 120° Separation as Given in diagram



- The Voltage developed in three windings is denoted by

$$V_a = V_m \sin \omega t$$
$$V_b = V_m \sin(\omega t + 120^\circ)$$
$$V_c = V_m \sin(\omega t + 240^\circ)$$

Main Ideas, Questions & Summary:

→ As all three windings are apart from each other at 120° the supply or magnetic field is also generated with same separation.
→ In such a way the generated / developwed magnetic field is also of rotating in nature.

☆ Three Phase induction Machine (Motor) →

Principle → The working principle of induction motor based upon the principle of mutual inductance b/w Stator & rotor.
→ This mutual inductance principle is related with Faraday's law of eletromagnetic induction.
→ Faraday's law of electromagnetic induction is given in two parts:
(a).
(b).

Working of Three Phase induction Moter →
Stater of an induction moter is stationary Part which is fixed in nature.
→ 3-ϕ Supply is fed to in induction Moter, which is wound by three phase balanced windings.
→ As Stater is excited by 3-ϕ balance current, there is a mmf is developved (Magnetive Motive Force).
→ This mmf is equal to the product of no. of turns in windings & the current flow in that windings.

$$F = N \cdot I$$

→ As this mmf is rotating in nature i.e. magnetic field develops around the winding. But 3-ϕ windings are not Physicaly rotating.

So, we can say Stator field is rotating with respect to Stator & Speed of Stator field is given by

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

$$\boxed{N_S = \frac{120 \times f}{P}}$$

Where, $N_S \longrightarrow$ Stator field Speed / Synchronous Speed
$f \rightarrow$ Frequency of Supply
$P \rightarrow$ No. of Stator poles

→ This rotating MMF is transfered to rotor side with the help of mutual inductance.

→ Now, the rotor starts to rotate at less speed w.r.t to the synchronous speed.

→ This MMF is received by rotor winding & it starts to rotate. The rate at which the rotor behind the synchronous speed is called slip (S).

$$\boxed{S = \frac{N_S - N_r}{N_S}}$$

Where $N_r \longrightarrow$ Speed of rotor

$$\boxed{\text{Percentage Slip}(S) = \frac{N_S - N_r}{N_S} \times 100}$$

Construction of Induction Machine & Types of Induction Machine →

An induction machine as basically two main parts

1). Stator
2). Rotor

Stator & Rotor are non attached basically & electrically there is a small 0.4mm to 4mm.

Main Ideas, Questions & Summary:

Library / Website Ref.:-

1). Stator → It is the stationary part of the machine which consist of Stator frame & Stator winding.

→ Stator frame is made up of from a Speed or iron which enclosed are follow, cylindrical core made up from thin laminated silicon steel.

→ laminations are used to reduced the eddy current losses.

→ Stator winding are wound in inner surface part of Stator, to increase the mechanical strength of winding a no. of evenly space slots are provided & windings are wounds in provided slots.

→ Three phase windings are wound for definite no. of Poles, which is according to the speed of machine. The Speed is inversely proportional to the no. of Poles as given by equation

→ Poles are always multiples of two Such that 2, 4, 8, ---. & Frequency is 50 hz.

2). Rotor → It is rotating part of machine which comprises cylindrical laminated iron core on a Shaft.

→ The Core is also laminated Speed of iron But they are thicker than Stator core.

→ Rotor Consist of rotor winding & Shaft.

→ Acc to rotor windings & constructional feature, rotor is classified into two categories:

(i). Squirrel case rotor

(ii). Wound rotor

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

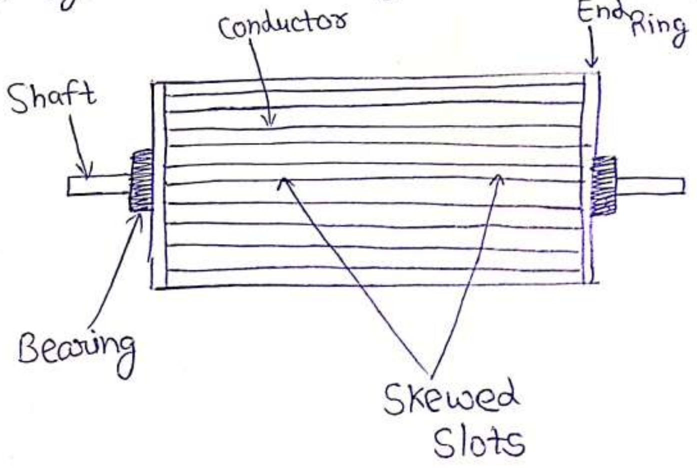
★ Types of Induction Machine →
On the basis of rotor classification machine is of two types:

1). Squirrel case induction machine → In this machine the rotor type is commonly used and allmost 85% machines are made up of with this rotor.

→ This rotor consist of slots like stator But no. of slots in stator & rotor differs, to avoid magnetic locking.

→ In these slots rotor winding are wound which is made up from copper bars.

→ All Copper bars are join at more ends to each other by metal ring.



2). Wound Rotor or Slipring Induction Machine →

→ It Consist of laminated cylindrical core which has slots like stator & squirrel case induction machine.

→ In Wound rotor the rotor is wound with insulated copper winding like stator But with lesser no. of slots then Stat

Main Ideas, Questions & Summary:

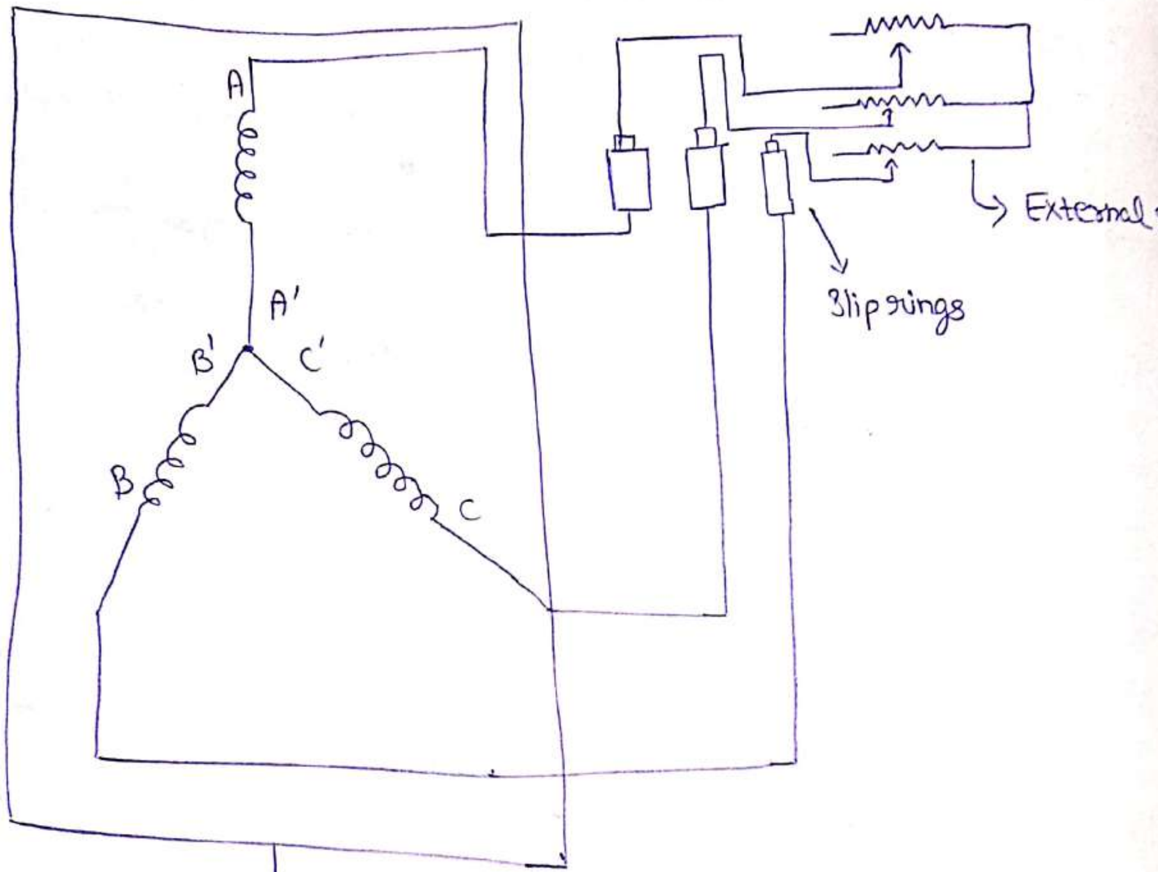
Library / Website Ref.:

→ Generally winding is star connected whose one end is short circuited at common point & at other end external resistance is connected with sliprings.

→ External resistance increases the starting torque of machine as well as reduces starting current.

→ Construction of slip ring & wound rotor is complicated & expensive.

→ It is used where large starting torque is required like cranes, lifts



Rotor Winding

★ Comparision of Squirrel case induction motor & slip ring induction motor →

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Squirrel Case Induction Moters	Slip rings Induction Moters
①. They are simple in construction.	①. They are complicated in Construction
②. No external resistance is required.	② External resistance is required & connected with slip rings.
③. They are economicaly cheap.	③. They are costly.
④. They have low starting torque.	④. They have high starting torque.
⑤. They are used in water pump, fan, miles etc.	⑤. They are used in lift, cranes, traction etc.

* Numericals on Induction Machine →

Q-①. Find the running speed of a 4 poles induction moter working on 50 H_z Supply having 4% slip.

Soln →

$$N_S = \frac{120 \times f}{P}$$

$$N_S = \frac{120 \times 50}{4} = 1500\ RPM$$

$$\%\ S = \frac{N_S - N_r}{N_S} \times 100$$

$$4 = \frac{1500 - N_r}{1500} \times 100$$

$$60 = 1500 - N_r$$

$$N_r = 1440\ RPM$$

Q-②. A three phase induction moter has 4 pole & is connected to 400 volt, 50 H_z Supply. Calculate the actual roter Speed & Roter frequency when the slip is 3%.

Main Ideas, Questions & Summary:

Sol^n →

$$N_S = \frac{120 \times f}{P}$$

$$N_S = \frac{120 \times 50}{4} = 1500 \text{ RPM}$$

$$\% S = \frac{N_S - N_r}{N_S} \times 100$$

$$3 = \frac{1500 - N_r}{1500} \times 100$$

$$45 = 1500 - N_r$$

$$N_r = 1455 \text{ RPM}$$

$$\boxed{f' = S \times f}$$

Rotor frequency   Supply frequency

$$f' = \frac{3}{100} \times 50$$

$$f' = \frac{15}{10} = \frac{3}{2} = 1.5 \, Hz$$

Q → A 3-ϕ, 50Hz, 6 pole induction moter runs at Its full load with Speed 960 RPM. Calculate the slip of moter at full load.

Sol^n →

$$S = \frac{N_S - N_r}{N_S}$$

$$N_S = \frac{120 \times 50}{6} = 1000$$

$$S = \frac{1000 - 960}{1000} = \frac{40}{1000} = \frac{4}{100}$$

$$\% S = \frac{40}{1000} \times 100 = 4 \%$$

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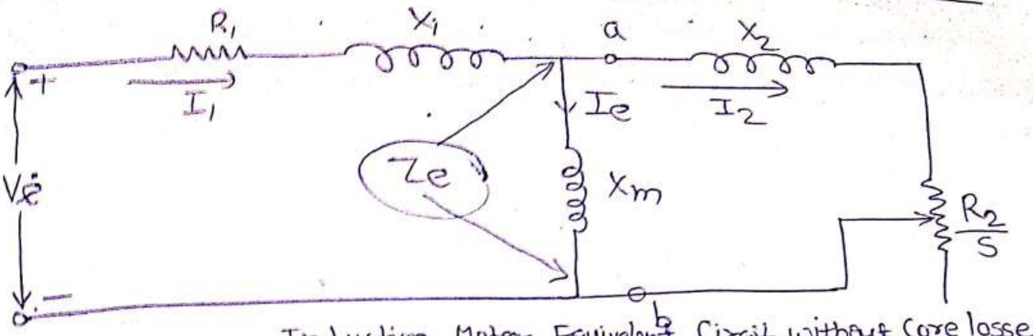
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

✱ Torque Slip Characteristics of 3-φ Induction Moter→



Induction Moter Equivalent Circuit without Core losses

→ For torque slip characteristics of 3-φ induction moter, the application of thevinin's theorem is required.

→ The Equivalent circuit of 3-φ induction moter reduces the Computation work.

→ In this equivalent circuit R_1 & X_1 represent primary winding (Stator Circuit) resistance & reactance respectively & R_2 & X_2 represent Secondary winding (Rotor circuit) & reactance respectively.

→ For appling Thevenin's theorem to this equivalent circuit, consider two points a & b as giver.

→ From these two points view towards the voltage Source VI & circuit considered R_1, X_1, X_m & Voltage Source VI.

→ According to the thevinins' theorem the Circuit is replaced by eq. source voltage (Ve) & eq. impedence (Ze) as given below.

$$Ve = \frac{V_1(jX_m)}{R_1 + j(X_1 + X_m)}$$

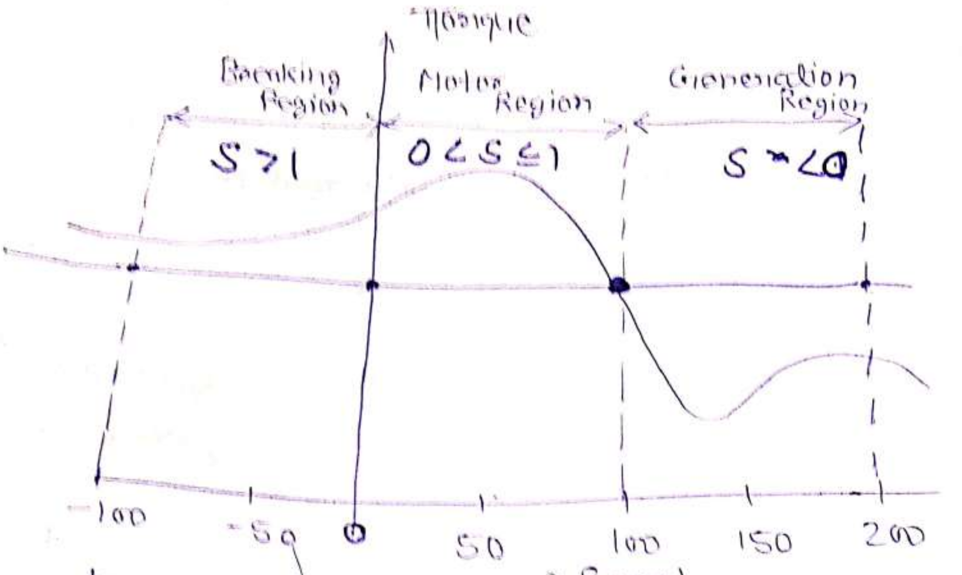
Main Ideas, Questions & Summary:

Library / Website Ref.:-

$$Z_e = \frac{(R_1 + jX_1)(jX_m)}{R_1 + j(X_1 + X_m)}$$

→ Here, Ve is the Voltage appearing across terminal a & b with the rotor circuit is disconnected from these two points.

→ Equivalent Stator circuit Ze is the impedence view from terminals a & b towards the voltage source.



★ Torque Slip characteristic Curve in region of bracking motor & generation

★ Significance torque slip characterstics

IMP

① Motoring mode

→ For motoring mode the slip is defined as $0 < S \leq 1$

→ Under normal operation, rotor revolves in the direction of rotating field produces by Stator.

→ As slip varies from 1 to 0 at synchronus speed the region is utilizes for motor.

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② Generator mode →

→ For these mode the slip is negative & defined as $S<0$

→ An Induction motor will operate in this region only. use its stator terminal are connected to frequency voltage & its rotor is d above Synchronous Speed.

→ The Connection of stator terminal to voltage source. Is design in order to estiblish the rotating gap at Synchronous speed.

③. Breaking Mode →

→ For this mode the slip is $S>1$

→ A slip more than one can we obtained by driving the rotor opposite to the direction of rotating field.

→ A Practically utility as $S>1$ obtained by making the rotor to a quick stop by Breaking action. Called as plugging.

→ Plugging condition can be obtained by inter the leads of stator.

★ Starting of Induction Motor →

Induction motor, when direct supply take 5-7 times there full load Current & developed only 1.5 to 2.5 times full load torque.

Main Ideas, Questions & Summary:

Library / Website Ref.:-

The intial excensive Current is objectionable Because this will produce large line voltage drop which will affect operation of other electric equipment connected to same line.

Direct on line Starting :→

→ In this method as the name indicates the motor is started by connecting it directly to 3-ϕ

→ The motor is connected directly to supply directly the Starting Current will be high that 5 to 7 times full load Current

→ Hence this method of starting is suitable for relatively Small machines.

The method of starting induction motor are given as

(i) Squarrel case moter

- Stator resistance starting or primary resistance starting
- Auto transformer starting
- Star-Delta starting

(ii) Slip ring Moter

- Rotor resistance starting.

⟹

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

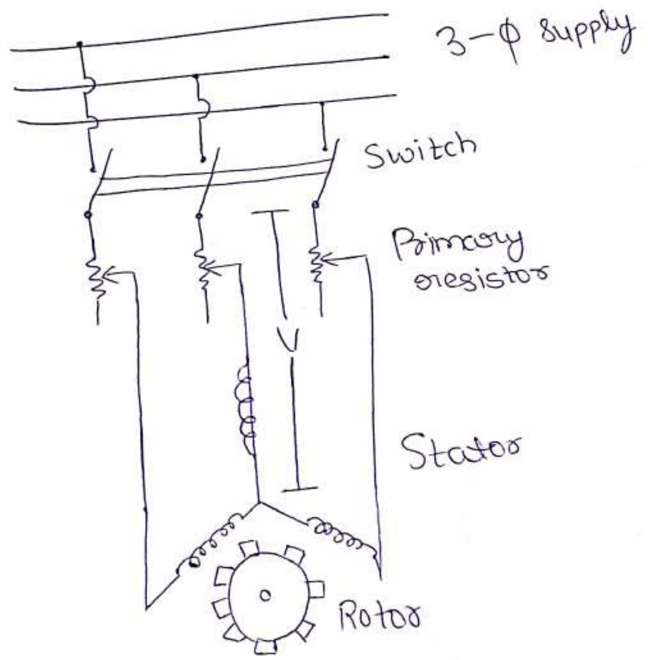
- Stator resistance Starting →

→ In this method the external resistances are connected in Series with each phasor of Stator winding.

→ The Purpose of resistor connector is to drop some Voltage.

→ Therefore, the initial Current drawn by the motor is reduced & this is the drawback of this method also.

→ Drawback is also depend as current varies directly with the square of applied voltage.



Connection Diagram of Primary resistor

→ If the voltage applied across the motor is reduced by 50%, Torque is reduced by 50% & Starting Current is reduced by 25%

Main Ideas, Questions & Summary:

Library / Website Ref.:-

in
each phase of so that maximum resistance offered in element & rotor circuit this reduces the starting
current & increases the starting torque.
As the motor picks up the speed the external resistance is gradually cut out in each phase of the circuit.

Speed control of induction Motor →

The speed of induction Motor can be expressed as

$$N_r = N_s(1-s)$$
$$N_r = \frac{120f}{P}(1-s)$$

Acc to the formula the speed of moter depends on frequency, no. of poles & slip (S).

Generally the methods of speed control are distinguised according to the action of moter i.e. ① from the Stator Side
② from the rotor side

① Various methods of speed control from the stator are:
(i). change in no. of poles
(ii). Varying the line frequency
(iii). Varieying the appling voltage

② Various methods of Speed Control from the rotor side are:
(i). Varying the rotor circuit resistance
(ii). Injecting Voltage of suitable frequency into rotor circuit.

① (i). change in no. of poles → A change in no. of poles, changes the synchronus speed of moter & therefore the operating speed or rotor speed is controlled.

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Since the no. of poles can be change only by even numbers, the speed controlled is not continuous But a stepped L.

(ii). Varying of line frequency

The synchronous speed of induction motor is depends on frequency. & By varying the line varying the line frequency Speed can be controlled But this method is rarely used.

(iii). Varying of the appling voltage

By Varying the applied voltage to induction motor the speed of the motor can be changed. This method is very easy & also cheap to control the motor speed.

(2) (i). The Slip on wound rotor motor speed is reduced by introducing an external resistance in series with an rotor circuit change the rotor resistance, rotor starter may be use, the disadvantage of this method is that with the increase in rotor resistance i^2r losses will increase.

(ii). The Speed of induction motor is controlled by injecting a voltage in the rotor circuit.

The injected voltage should have the same frequency as the rotor frequency.

When injected voltage, which has phase opposition to the rotor induced emf, it decreases the speed of motor.

When injected voltage, which has phase same to the rotor induced emf, it increases the speed of motor.

Main Ideas, Questions & Summary:

✳ Synchronous Generator (Alternator) →

→ Synchronous generator is known as Double exited AC generator which induces AC supply.

→ Double exited means it require an external DC supply to excite field coil.

→ Alternator are universaly addopted for generation of large 3-φ power. Alternator ex, can deliver AC Power

→ But field winding always takes Power from a external source.

→ Alternator is designed to operate with minium slip as its Synchronus & rotor speed are same.

→ The speed of Alternator given as

$$\boxed{N = \frac{120f}{P}}$$

✳ Working & Construction →

→ In 3-φ Alternator armature winding always wound on Stator & field winding is wound on rotor.

→ Because Asfield winding as two terminals & it require only two slip rings, which shapes the cost of insulation

→ Armatture winding as four terminals which required four slip rings, 3 for phases & 1 for neutral.

→ Alternators are design for large Power generation But & economical Complicated & expensive for small power generation.

→ The amount of insulation between slip ring & Shaft is kept high Because voltage rating of generation is in order of 11 KV.

→ Construction wise rotor of Synchronous machine are of two types:

(i). cyclindrical rotor

(ii). Salient pole rotor

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According to the contructional ~~[illegible]~~ feature of rotor Alternator are two types :

(1). Hydro Alternator

(2). Turbo Alternator

(1). Hydro Alternator

→ Hydro Alternator are designed with Salient pole rotor, which operates best at low Speed

→ Salient pole rotor as large no. of poles for generation at 50 Hz with low Speed.

→ For e.g. → if alternator is rotate at 300 RPM & generates Supply at 50Hz then no. of poles required are

$$N = \frac{120f}{P}$$

$$P = \frac{120 \times 50}{300} = 20 \text{ Poles}$$

→ The Salient Pole the diameter is Small & length of rotor is high.

(2). Turbo Alternator

→ Turbo Alternator are designed with cylindrical rotor, which operates best at high Speed.

→ Cylindrical rotor as Small no. of poles for generator at 50Hz with High Speed.

Main Ideas, Questions & Summary:

Library / Website Ref.:-

CHAPTER – 5
Power Convertor

★ Semiconductor material →
The material whose properties lies in between conductor & insulator materials.

Semiconductor are of two types:
(i). Intrensic Semiconductor (Pure)
(ii) Extrensic Semiconductor (Impure)

Doping → Adding some impurities to pure semiconductor is known as doping.

There exist two types of doping process:
(i). Trivalent
(ii). Pentavalent

By appling the Process of Doping the Extrensic Semiconductor are of two types:
(i). N-type (Pentavalent Doping)
(ii). P-type (Trivalent Doping)

With the Combination of P-type & N-type Semiconductors, various electronic devices can be design like
(i). P-N Junction diode
(ii). Transistor (PNP or N-P-N)
(iii). IGBT
(iv). SCR
(v). JFET etc.

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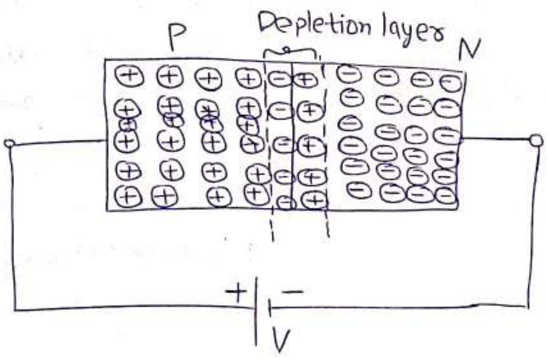
☆ P-N Junction Diode →

In N-type Semiconductor majority charge carrier is equal to electrons & minority charge carrier is equal to holes.
In P-type Semiconductor majority charge carrier is equal to holes & minority charge carrier is equal to electrons



→ PN Junction diode is the two terminal device having a single junction. The two terminals are known as Anode and cathode.

→ At the joining of p-type & n-type Semiconductor with Special febrication process So called as junction.

→ The working PN diode

Main Ideas, Questions & Summary:

Library / Website Ref.:-

① When Positive terminal af battery is connected with P type & negative terminal of battery is connected with N type, the Connection Is called Forward baised.

① Forward baised → In this baising as the positive voltage is Increased no. of holes at P terminal & no. of electrons at N terminal increase accordingly.

→ This increment in charge carriers at both terminals will allow to move holes & electrons through junction.

→ In this regards the depletion layer (which exist at junction) decrease by increasing the voltage continuously

→ As the voltage crosses the line thrshold limit we will get movement of electrone across the junction

→ This movement of electrons is taking place from n to p terminal & current will flow from P to n.

→ The Current will increase as the increase in voltage up to a limit only afterwords there will be a break down.

② Reverse baised → when Positive terminal of battey is Connected to N type & negative terminal of battery is Connected with ptype, the connection is called Reverse baised.

→ In this baising as the positive voltage is increased no. of holes at n terminal & no. of electrons at p terminal increase accordingly.

→ The increment in charge carrier at both terminals will allow to move holes & electrons through junction

→ In this regards the depletion layer (which exist at junction)

→ As the voltage increase

→ This movement of electrons is taking place from p to n terminal & current will flow from n to p.

→

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

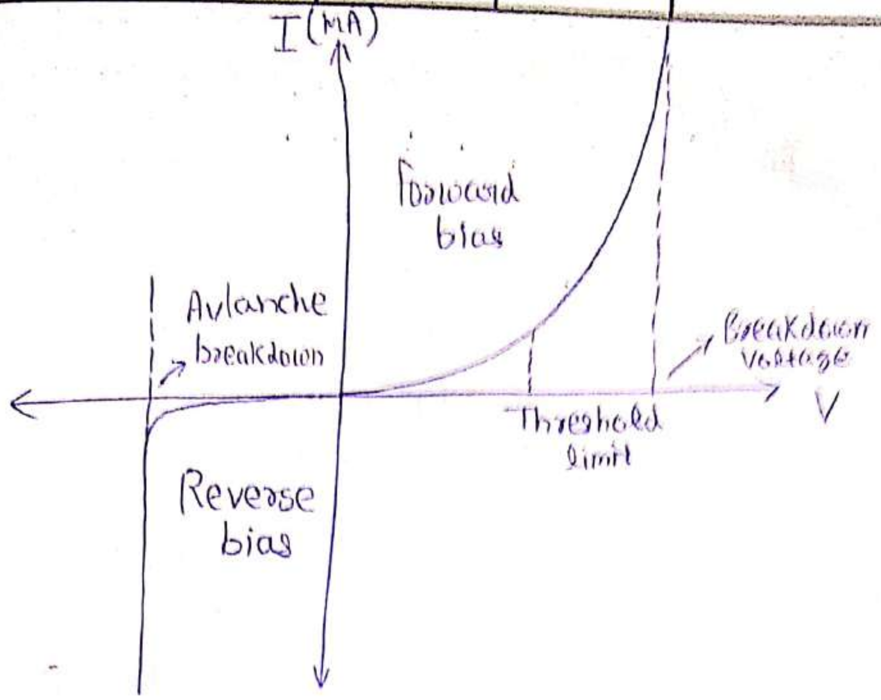


Fig. → V−I characterstics of an P-N Junction

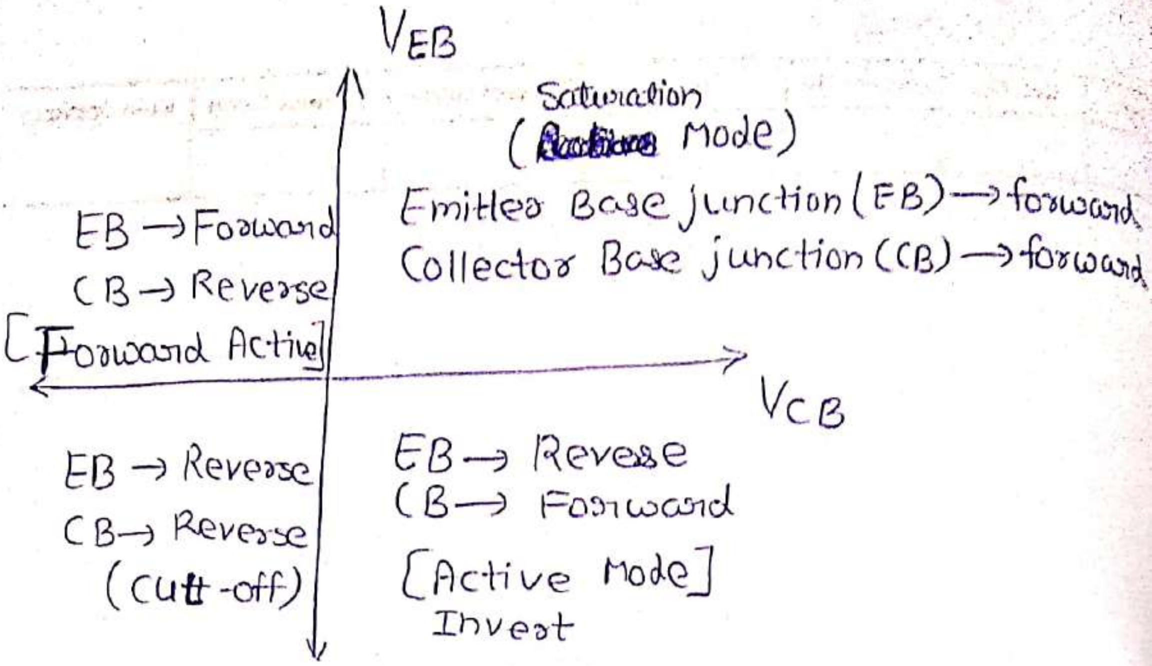
Note → PN Junction diode is usually known as diode. It is a unidirectional divice which is allow flow of I in one direction. which is forward baised.
they are generally used in rectifier.

☆ Transistor →
Transistor is a 3-terminal junction device. The three terminals are Emmiter, Base & collector.

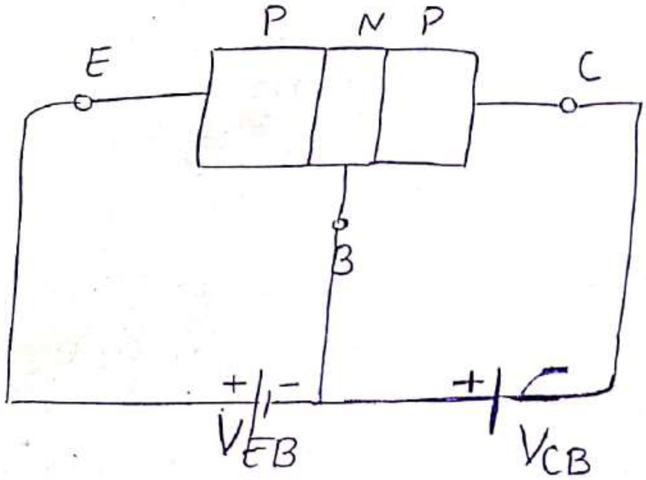
Transistor is of two design :
① PNP
② NPN

Main Ideas, Questions & Summary:

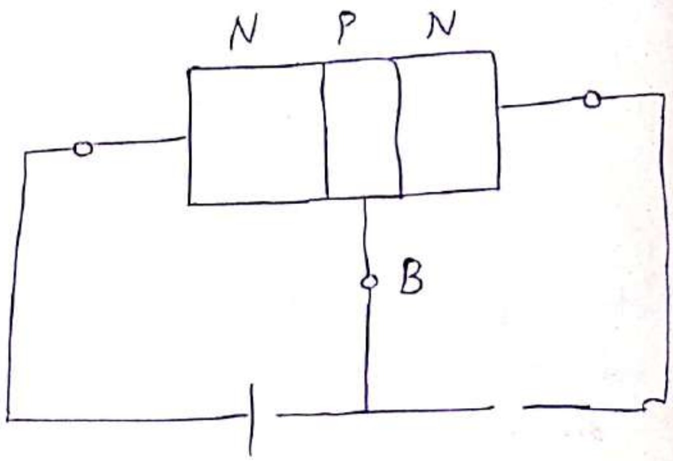
Library / Website Ref.:-


V_{EB}
Saturation
(Mode)
Emitter Base junction (EB) → forward
Collector Base junction (CB) → forward
EB → Forward
CB → Reverse
[Forward Active]
V_{CB}
EB → Reverse
CB → Reverse
(cutt-off)
EB → Revese
CB → Forward
[Active Mode]
Invert

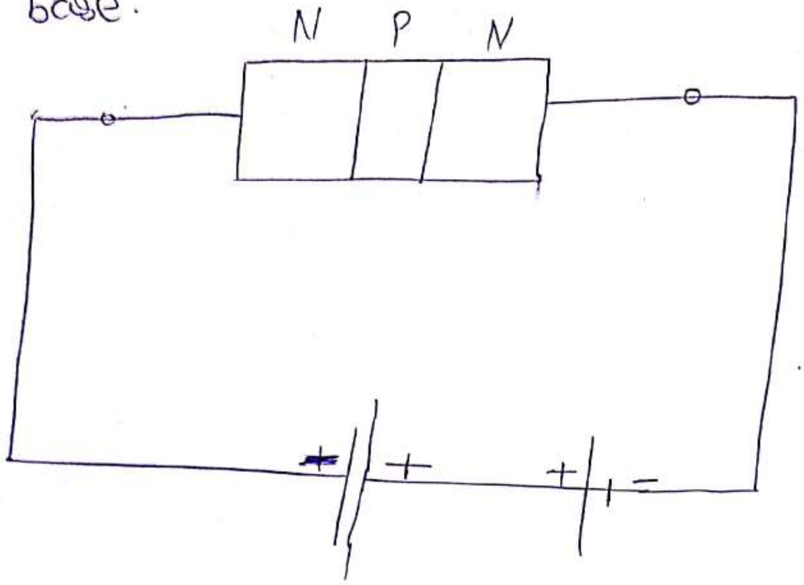
PNP


P N P
E
C
B
+ −
+ −
V_{EB}
V_{CB}

NPN


N P N
B

(B). Saturation mode → In Saturation mode the Ammeter base junction & collector base junction both are forward base.



⇒ Due to the forward base connection the depletion layer at both junctions is reduced to minimum.

⇒ Because of reduction to minimum of depletion layer. The Current will flow across the transistor. But this is not in completely way.

⇒ The Working of transistor in Saturation mode is defined as <u>Closed Switch</u>.

<u>Cutt off mode</u> →

(not in syallabus)

☆ Configuration of Transistor →

There are three configuration available with transistor Known as

1) Common ammeter configuration (CE)
2). Common Base configuration (CB)
3). Common Collector Configuration (CC)

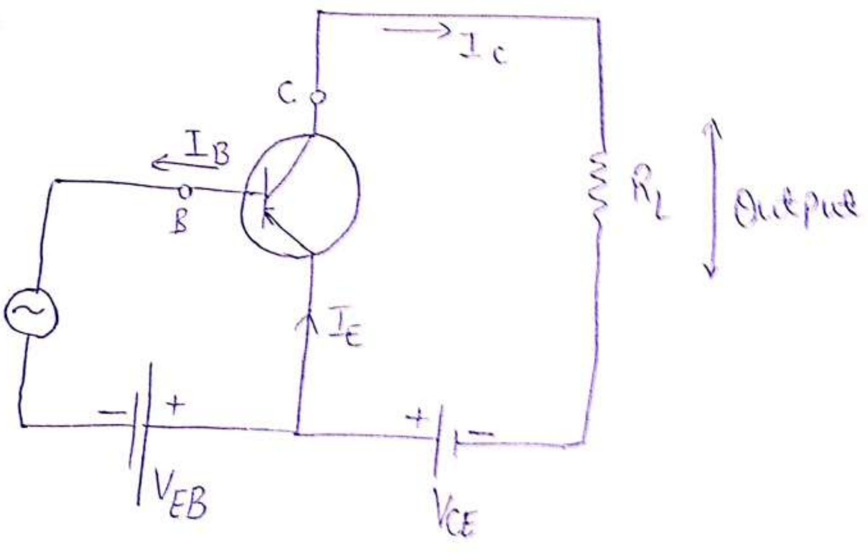
(PNP) 1). Common Emmeter Configuration (CE) →

For CE configuration the emmeter

⇒ Input

⇒ In this configuration the input voltage is equal to V_{EB} & input current is equal to I_B.

Output voltage is equal to V_{CE} & input current is equal to I_C.



Input characterstics →

⇒ Input characterstics is drawn between V_{EB} & I_B at constant V_{CE}.

⇒ It is considered that input characterstics are similar to that of a diode in forward base.

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

$I_B \simeq 0$ below V_γ or Cut in or threhold voltage

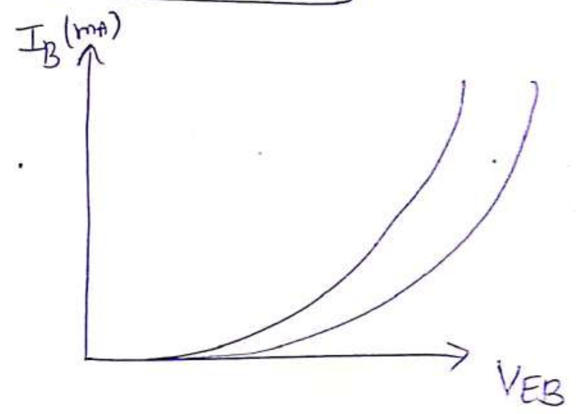
Si, $V_\gamma \simeq 0.7V$

Ge, $V_\gamma = 0.3V$

. After V_γ, I_B increases with small increase in V_{EB}

. Dyanamic input resistance r_i =

$$\boxed{r_i = \frac{\Delta V_{EB}}{\Delta I_B} V_{CE}\,(\text{constant})}$$



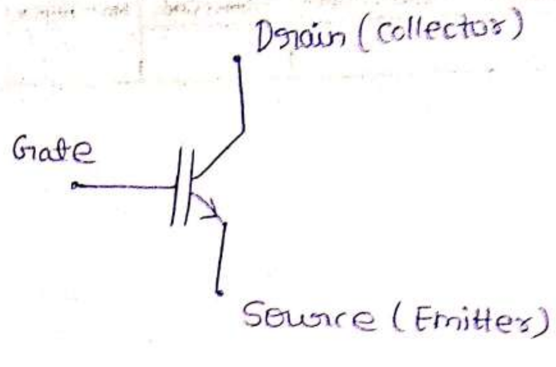
Output characterstics

⇒ Output characterstics is drawn between V_{CE} & I_C.

⇒ It is considered that Output characterstics are in three regions.

Main Ideas, Questions & Summary:

Library / Website Ref.:-



- As it is known that IGBT is the replacement of BJT & MOS & working somewhere related to
- The condition is generated due to regenerative action
- This is not desirable because it means loss of control of drain current by the apply gate voltage.
- The reason for is that a component of hole current travells through the p type body layer
- ① this lateral current causes an voltage drop in the resistance of body layer if this voltage is sufficient to that off transistor turn on voltage, the device (IGBT) will not work.
- ② The steps taken during manufacturing of (IGBT) for avoid condition, (i). to slow down IGBT at turn off so that rate of growth of depletion layer into drift region is slow down.

(ii). To increase current by decreasing the resistance of body layer.

(iii). To use a By pass structure by eliminating One of Source region.

CHAPTER-6. Electrical Installation

POORNIMA

Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:- Electrical Installation
15/11/2018	6			BEE		

* Switch Gear →

It is equipment & apparatus used for the electrical circuit switching, protection & controling.

This is a generate term for wide range of apparatus like Circuit breaker, Switches, Switch fuse units, isolators, fuses etc.

Some devices are only used for switching & not for fault detection. Essential feature of switch gear are the equipment must be completely reliable.

The equipment must be able to discreminate between the fault Section & healthy section.

The equipment must operate very fast to avoid apparatus or device damage.

The equipment must have provifion of manual control

Switch gear can be classified on the basis of voltage level :→

1. Low Voltage (LV) Switch gear (upto 11 kV)
2. Medium Voltage (MV) Switch gear (11kV to 33kV)
3. High Voltage (HV) Switch gear (above 36 kV)

Note → LT → low tension
HT → High tension

Main Ideas, Questions & Summary:

Library / Website Ref.:-

✱ L.V. Switch gear layout →

LV Switch gear covers a wide range of equipment concerned with Switching & interrupting under both normal & abnormal condition. These includes

1. Switches
2. Fuse
3. Circuit breaker
4. Relays

(1) Switches → A Switch is a device used for opening & closing of electrical circuit.
Switch operates on full load or no load condition But not on fault condition.

(2) Fuse → A Short piece of wire or thin Strip which melts when axis current will flow through it.

✱ Fuses are connected in Series with the Circuit.
The melting of fuse elements due to increase in temperature.

(3) Circuit breaker → Circuit breakers are design to operate on all circuit conditions
The circuit breaker are design to operate manually under normal condition & automatecally under fault condition.

(4). Relays → Relays is a device to detect the fault & give the required information to the breaker for circuit interruption.
It is also used to switch the supply from two different for automatic working of equipments.

There are four devices are used in Switch gear :-

1. SFU (Switch Fuse Unit)
2. MCB (Miniature Circuit Breaker)

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Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

(a). Type B
(b). Type C
(c). Type D

(3). ELCB (Earth leakage Circuit Breaker)

(a). Voltage ELCB
(b). Current ELCB

(4). MCCB (Molded Case Circuit Breaker)

(a). Thermal trip unit
(b). Electromagnetic trip unit
(c). Thermal magnetic trip unit
(d). Electronic trip unit
(e). Microprocessor trip unit

★ Elementary Calculations for Energy Consuption →

Appliance	Watts	No.	Hours	Watt × hour	Unit/day
CFL Bulbs	15	8	4	480	0.48
Celing Fans	100	3	8	2400	2.40
TV 32inch LED	40	1	4	160	0.16
Fridge 250L	—	1	24	501/year	1.37
Micro wave	700	1	0.5	350	0.35
Induction Cooker	1200	1	1	1200	1.20
Air Fryer	1500	1	0.5	750	0.75
Other	150	1	3	450	0.45

Main Ideas, Questions & Summary:

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Electrical energy is the most conveneint form of energy In house holds devices the Consumption of electrical energy is measured through energy meter.

Electrical energy is derived from a movement of electric charge, energy i.e. kinetic energy & potential energy.

The Calculation of Energy consuption for different electrical appliances in a given table.

The Calculation of Per day electricity comsuption for any apparatus is done like as for e.g. → Celling fan 100 W each

The daily uses of 3 fans running for 8 hours daily = $100 \times 8 \times 3 = 2400$ W hour = 2.4 KWh

For the fridge the anual consuption of four Star rated 250L capacity is 501 unit in a year running 24 hours daily.

This information is obtaind from Govt. of india, Beuro of energy efficiency.

Per day unit calculated by $\frac{501}{365} = 1.37$ unit/day

Power measurment in d.c. circuits →

The electric Power is calculated in dc circuits with Simple formula $P = V \cdot I$

The Voltage & current calculated with the help of voltmeter & Ammeter as shown in Connection diagram.

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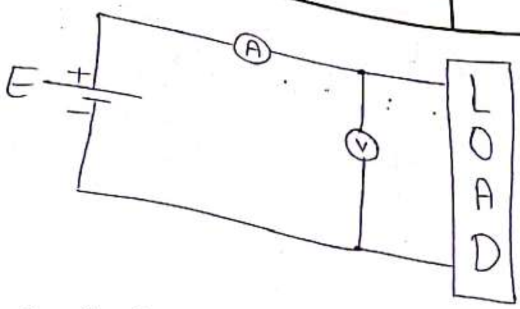
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

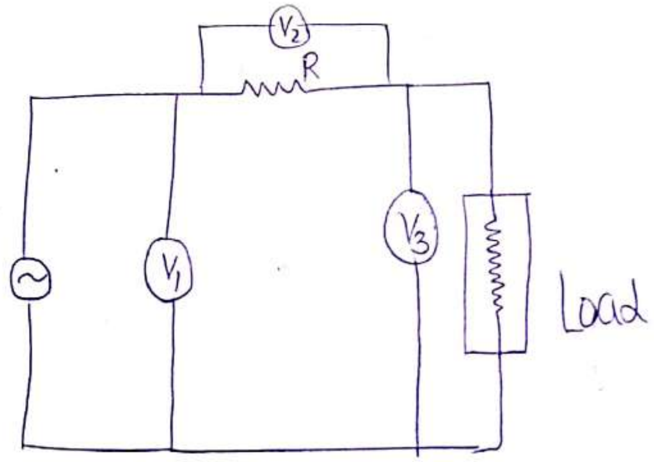


Power Calculation in AC Circircuits →

For AC Circuit the Power is calculated by three methods

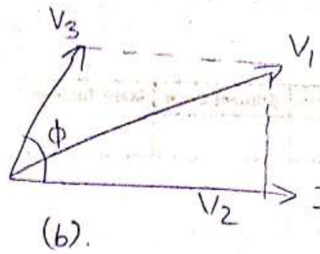
1. Three voltmeter method
2. Three Ammeter method
3. Wattmeter method

(1) Three Voltmeter method →
The Power in a Single phase AC Circuit can be measured using 3 Voltmeter as given in connection diagram



(a) Connection Diagram

Main Ideas, Questions & Summary:



(b).

Assume that load is inductive V_1, V_2, V_3 are load & R is purily non inductive resistance which is connected in series with the circuit.

$$V_1^2 = V_2^2 + V_3^2 + 2V_2V_3\cos\phi$$

$$V_2 = IR$$

$$V_1^2 = V_2^2 + V_3^2 + 2 \cdot P \cdot R$$

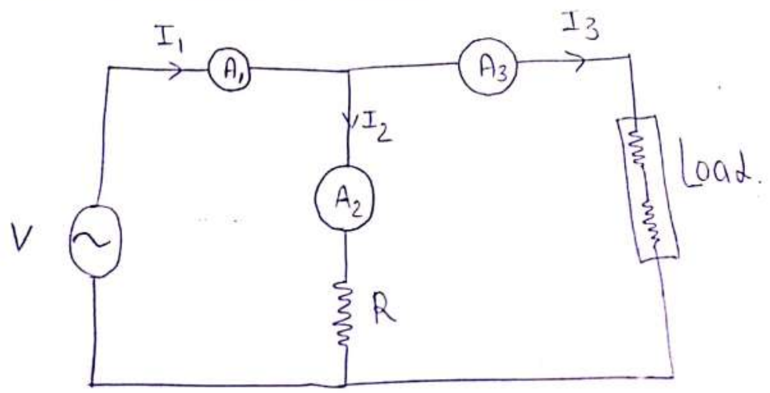
$$P = V_3 I \cos\phi$$

Note → Power calculated in AC Circuit is equal to $P = V \cdot I \cdot$ Power factor

$$\cos\phi = \frac{V_1^2 - V_2^2 - V_3^2}{2V_2V_3} \Rightarrow \boxed{P = \frac{V_1^2 - V_2^2 - V_3^2}{2R}}$$

From the above circuit the voltage V_1 is the vector sum of V_2 & V_3 & represented with phasor diagram

② ✯ <u>Three Ammeter Method</u> →



(a) Connection diagram

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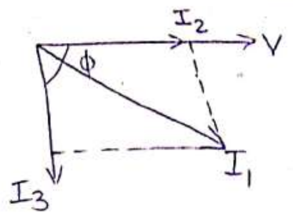
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-



The circuit for measuring single phase power through the three ammeter method is given in connection diagram.
In this method a non inductive resistance R is connected across the inductive load with three Ammeter arrangements.
From the phasor diagram the resistance current I_2 is in phase with the voltage across the circuit.
The current ~~I_3~~ measured by Ammeter A_3 lacks the voltage by an angle of ϕ.

$$I_1^2 = I_2^2 + I_3^2 + 2I_2I_3\cos\phi$$

And $I_2 = \frac{V}{R}$

$$I_1^2 = I_2^2 + I_3^2 + \frac{2VI_3\cos\phi}{R} \qquad \because P = VI_3\cos\phi$$

$$I_1^2 = I_2^2 + I_3^2 + \frac{2P}{R}$$

$$\frac{2P}{R} = I_1^2 - I_2^2 - I_3^2 \qquad \cos\phi = \frac{I_1^2 - I_2^2 - I_3^2}{2I_2I_3}$$

$$\boxed{P = \frac{R(I_1^2 - I_2^2 - I_3^2)}{2}}$$

Main Ideas, Questions & Summary:

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③ Wattmeter method →

In order to measure the power through wattmeter method we use wattmeter in the circuit.

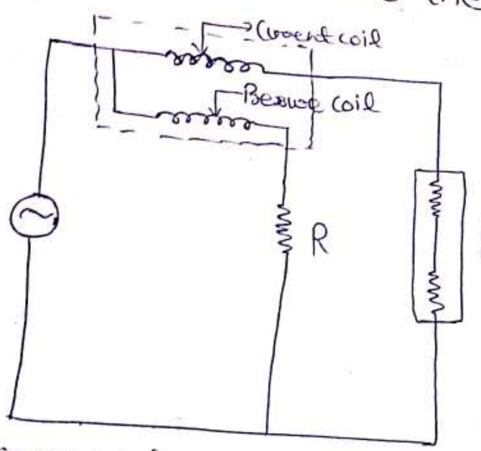
Wattmeter has two coils

① Current coil

② Pressure coil

The load current must passed through the current coil & hence it is connected in series with the load whereas the voltage across the load must appear across the pressure coil & hence it is connected across the load.

Wattmeter also measure the power like $W = P = V \times I \times \cos\phi$



★ Power Measurement

Power can be measured in three phase circuit by wattmeter method.

Following methods are used to measuring the power in 3-ϕ circuit

①. Single wattmeter method

②. Two wattmeter method

③. Three wattmeter method

(i) Single wattmeter method →

As name implies to measure power of single wattmeter requires only one wattmeter

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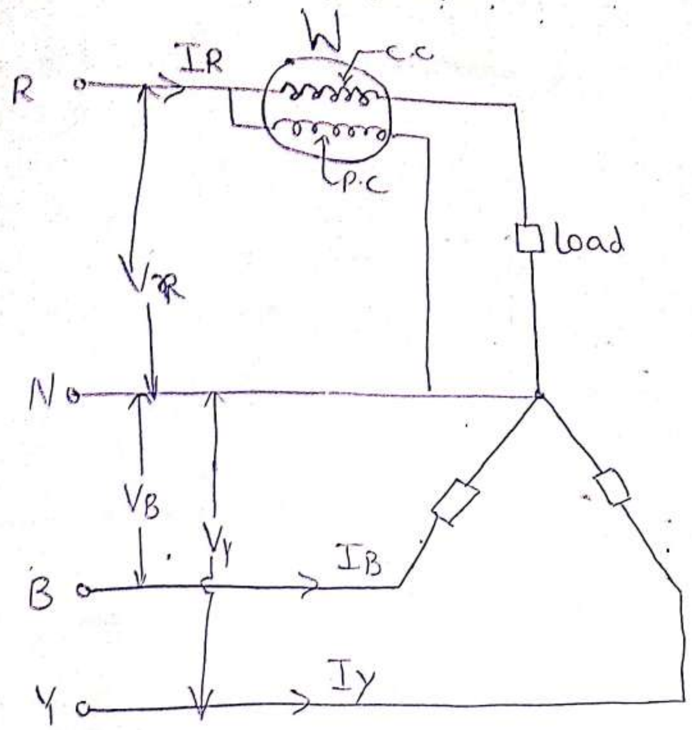
Date	Unit No.	Lecture No.	Faculty	Subject Name	Subject Code	Main Topics:-

This method can be used only if the load is balanced & are connected star connection.



The reading of wattmeter (W) = $P_1 = V_R * I_R \times \cos\phi$

As the load is balanced $\Rightarrow V_R = V_Y = V_B = V_{Ph}$

And $I_R = I_Y = I_B = I_{Ph}$

So $P_1 = V_{Ph} \cdot I_{Ph} \cdot \cos\phi$

And total Power $P = 3P_1$

$$\boxed{P = 3V_{Ph} \cdot I_{Ph} \cdot \cos\phi}$$

Main Ideas, Questions & Summary:

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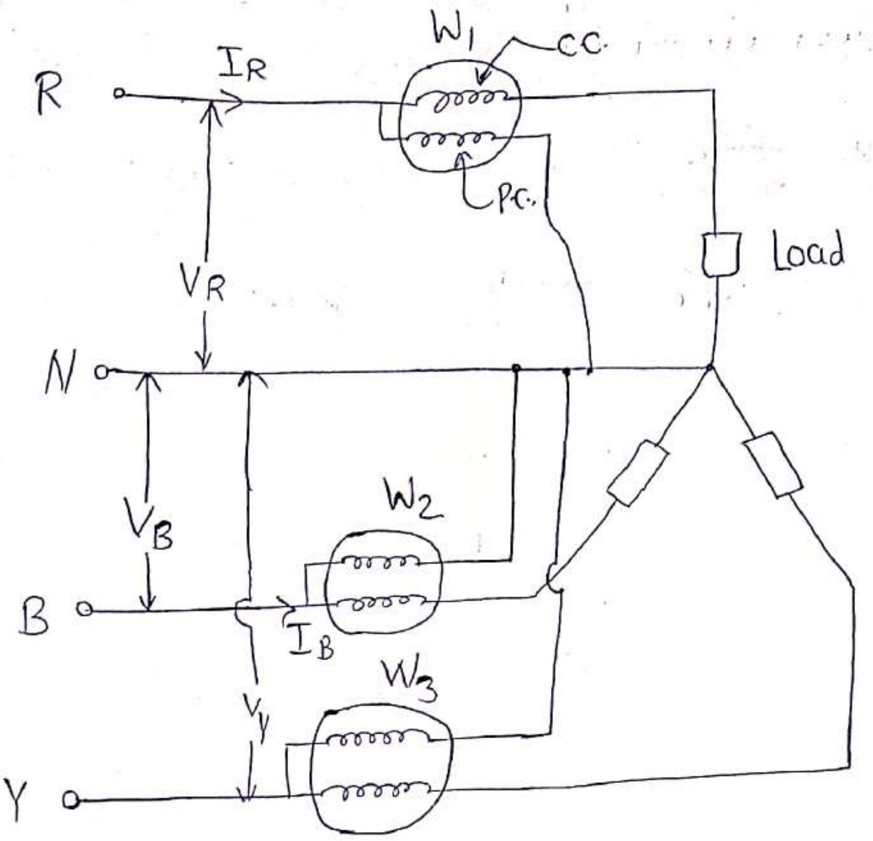
③ Three Wattmeter Method →

This method can be used if the load is balanced as well as Unbalanced when the star Connection is star connected.



Reading of wattmeter $(W_1) = P_1$

V