JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR

B.Tech – II Sem

L	T	P	C
3	0	0	3

(19A02201T) Basic Electrical & Electronics Engineering

Part A: Basic Electrical Engineering
(Civil, Mechanical, CSE, CSSE, IT and Food Technology)

Course Objectives:

1. To introduce basics of electric circuits.
2. To teach DC and AC electrical circuit analysis.
3. To explain working principles of transformers and electrical machines.
4. To impart knowledge on low voltage electrical installations

Unit 1 DC & AC Circuits:

Electrical circuit elements (R - L and C) - Kirchhoff laws - Series and parallel connection of resistances with DC excitation. Superposition Theorem - Representation of sinusoidal waveforms - peak and rms values - phasor representation - real power - reactive power - apparent power - power factor - Analysis of single-phase ac circuits consisting of RL - RC - RLC series circuits.

Unit Outcomes: Able to

- Recall Kirchoff laws (L1)
- Analyze simple electric circuits with DC excitation (L4)
- Apply network theorems to simple circuits (L3)
- Analyze single phase AC circuits consisting of series RL - RC - RLC combinations (L4)

Unit 2 DC & AC Machines:

Principle and operation of DC Generator - EMF equations - OCC characteristics of DC generator – principle and operation of DC Motor – Performance Characteristics of DC Motor - Speed control of DC Motor – Principle and operation of Single Phase Transformer - OC and SC test on transformer - principle and operation of Induction Motor [Elementary treatment only]

Unit Outcomes: Able to

- Explain principle and operation of DC Generator & Motor.
- Perform speed control of DC Motor (L2)
- Explain operation of transformer and induction motor. (L2)
- Explain construction & working of induction motor - DC motor

Unit 3 Basics of Power Systems:

Layout & operation of Hydro, Thermal, Nuclear Stations - Solar & wind generating stations – Typical AC Power Supply scheme – Elements of Transmission line – Types of Distribution systems: Primary & Secondary distribution systems.

The D.C machines are classified as d.c generators and d.c motors. The construction of a d.c machine is basically same whether it is a generator or a motor.

D.C. Generators

An electrical machine which converts mechanical energy into an electrical energy is called an electrical generator.

Constructional details of D.C Machines:-

A D.C machine consists of the following parts.

1. Yoke
2. Poles
3. Field winding
4. Armature.
5. Commutator.
6. Brushes and bearings.

1. Yoke:-

Yoke is outer frame.

(i) Yoke provides mechanical support for the poles and acts as a protecting cover for the whole machine.

(ii) It carries the magnetic flux produced by the poles.

For small generators, yokes are made of cast iron. for large machines cast steel or rolled steel is used.

2. Poles:-

Each pole is divided into 2 parts. (i) Pole core (ii) Pole shoe

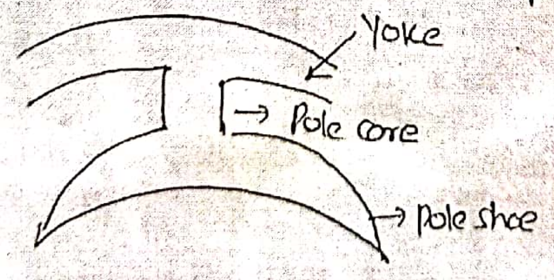


Fig. Pole structure

Functions of Pole core and Pole shoe:-

1. Pole core carries a field winding which is necessary to produce the flux.
2. It directs the flux produced through air gap to armature core and to the next pole.
3. Pole shoe is having a shape such that it increases the area of armature core to come across the flux.

of material:- Poles are made of magnetic material ie cast iron or cast steel. The laminations of required size and shape are stamped together to get a pole which is then bolted to the yoke.

3. Field winding (F1–F2):-

The field winding is wound on the pole core with a definite direction.

Function:- Field windings carry current due to which the pole core on which the field winding is placed behaves as an electromagnet, producing necessary flux.

As it helps in producing the magnetic field i.e. exciting the pole as an electromagnet it's called field winding or Exciting winding.

Choice of material:- Field winding has to carry current. So it is made of conducting material like aluminium or copper. Copper is proper choice as it can bend easily. Field coils are required to take any type of shape and bend about pole core.

Field winding is divided into various coils called field coils. These are connected in series with each other and wound in such a direction around pole cores, such that alternate 'N' and 'S' poles are formed.

4. Armature:- Armature is divided into two parts.
(i) Armature core (ii) Armature winding.

(i) Armature core:- Armature core is cylindrical in shape mounted on the shaft. It consists of slots on its periphery. It has air ducts to permit the air flow through armature and this serves cooling purpose.

Functions:-
1. Armature core provides place for armature winding.
2. It provides a path of low reluctance to the magnetic flux produced by the field winding.

...e of material:- It has to provide a low reluctance path ... the flux. It is made of cast iron or cast steel. It is made up of laminated construction to reduce eddy current loss.

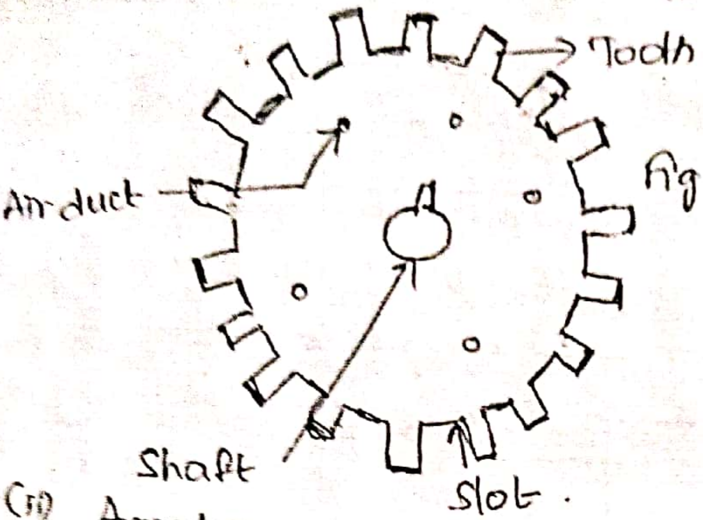


Fig. Single circular lamination of armature core.

(ii) Armature winding :- Armature winding is interconnection of the armature conductors, placed in the slots provided on the armature core periphery. When the armature is rotated in case of generator, magnetic flux gets cut by armature conductors and e.m.f gets induced in them.

Function :-

1- Generation of emf takes place in the armature winding in case of generators.

2. To carry the current supplied in case of d.c motors.

3. To do the useful work in the external circuit.

Armature windings are made of copper.

5. Commutator :-

The function of a commutator are :-

(i) To facilitate the collection of current from armature conductors.

2. The basic nature of emf induced in the alternating conductors is alternating. The internally developed alternating emf is converted to d.c emf. This is possible by commutator in case of generators.

3. It produces uni-directional torque in case of dc motors.

Commutator is made of copper segments as it collects current from armature. It is cylindrical in shape and is made up of wedge shaped segments and each commutator segment is insulated from each other by thin layer of mica.

...es and bearings:-

Brushes collect current from commutator and make it available to the ~~stia~~ external circuit. Brushes are made of soft material like carbon.

Brushes are rectangular in shape and are made to press on the commutator surface.

The function of the bearings is to reduce friction between rotating and stationary parts of the machine. Ball-bearings are used as they are more reliable. The following fig. shows a cross-section of d.c machine with its constructional details.

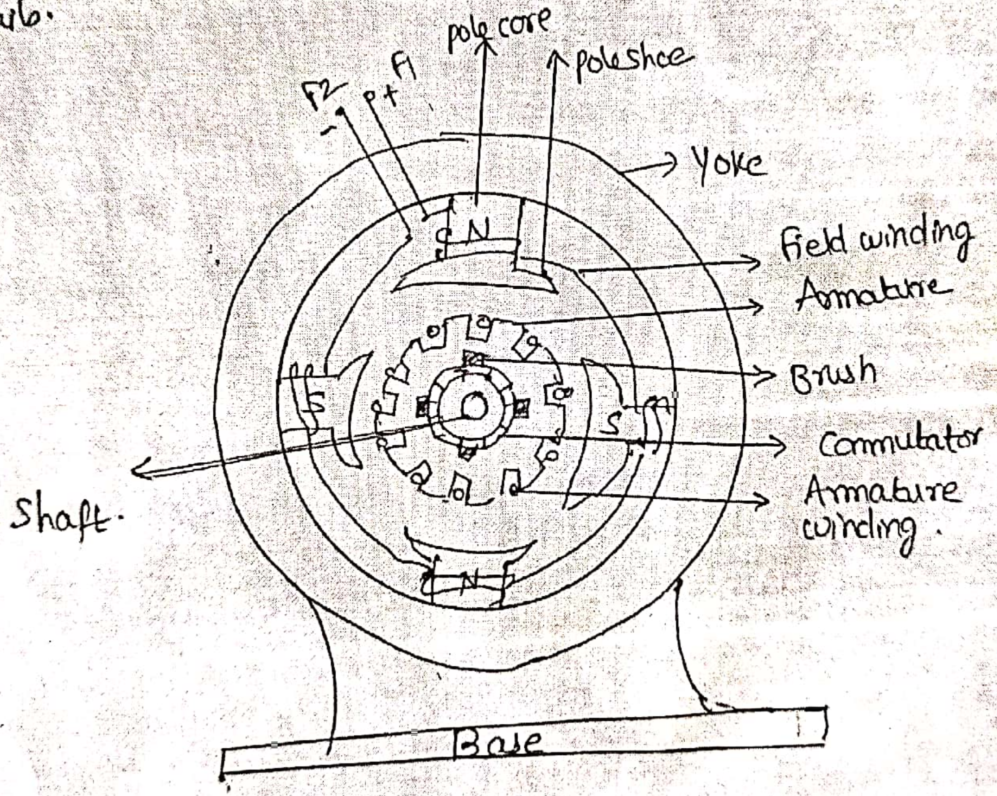


Fig. Construction details of D.C Machine.

Principle of operation of D.C Generators:-

All generators work on the principle of Faraday's law of electromagnetic induction. Whenever a conductor cuts magnetic flux, dynamically induced e.m.f is produced in it according to Faraday's law of electromagnetic induction. This e.m.f causes a current to flow if the conductor circuit is closed.

A Voltage is generated in a conductor as long as there exists a relative motion between conductor and the flux. This voltage is called dynamically induced e.m.f. So the main requirements in a generator are: (i) The conductor or coil.
(ii) The flux.
(iii) The relative motion between conductor and flux.

Fig.

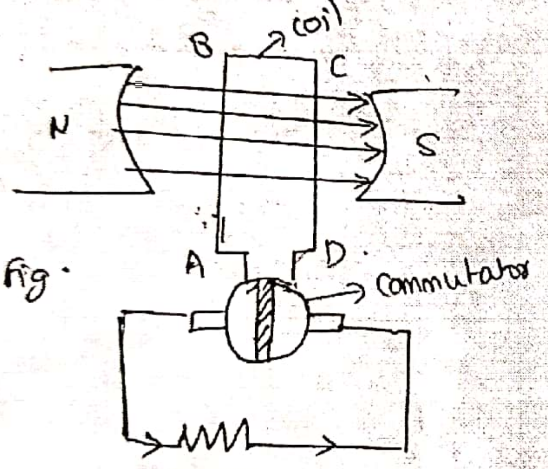


Fig. Principle of operation of D.C Generator

In a generator, the conductors are rotated to cut the magnetic flux which is stationary.

- For large voltage as output, the number of conductors are connected to form a winding. This winding is called armature winding kept on armature.
- Primemover is the external device used to rotate the armature. Ex:- Engines and turbines.

The necessary magnetic flux is produced by current carrying winding called "field winding". The direction of induced emf can be obtained by using Flemings Right hand Rule.

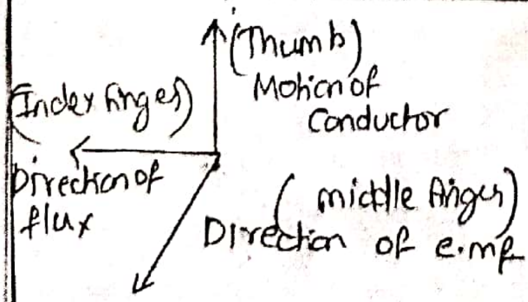


Fig. Fleming's Right hand Rule.

" Fleming's Right hand rule:- If thumb, index finger and middle finger of right hand are mutually perpendicular to each other and index finger is made to point in the direction of lines of flux, thumb in the direction of the relative motion of the conductor with respect to flux, then the middle finger gives the direction of the e.m.f induced in the conductor."

magnitude of the induced emf is given by (6)

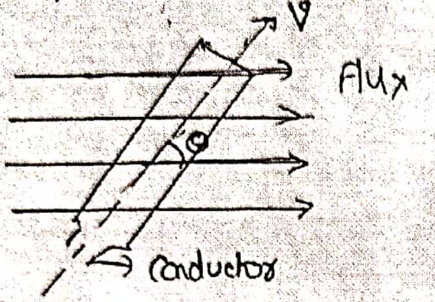
$$\boxed{E = Bl(v\sin\theta)}$$ where

B is flux density of the magnetic field. (units of B are Tesla)

l is length of conductor in m.

v is relative velocity of the conductor. (m/s)

θ is angle between the plane of rotation and the plane of flux.



$\theta = 0$, $E = 0$

$\theta = 90°$, $E = E_m$ where $E_m = Blv$

$\theta = 180°$, $E = 0$

$\theta = 270°$, $E = -E_m$

$\theta = 360°$, $E = 0$

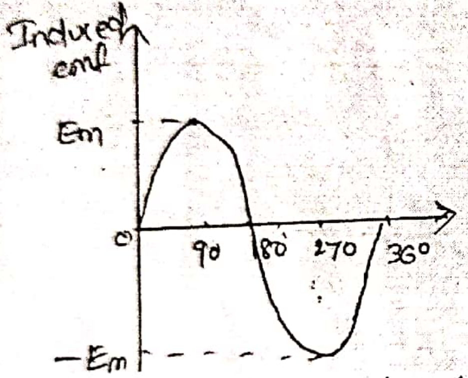


fig. Graphical representation of induced e.m.f.

The induced e.m.f in a d.c generator is purely sinusoidal i.e., alternating. To have d.c voltage, a device called "Commutator" is used. A commutator converts internally generated alternating e.m.f to an unidirectional e.m.f.

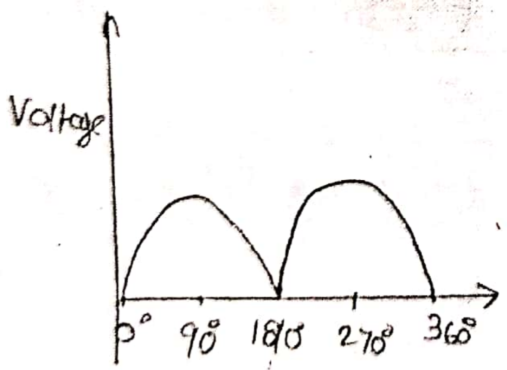


fig. Unidirectional Voltage

Thus the working of a d.c generator is based on faraday's law of electromagnetic induction, which states that if there is a relative motion between a conductor placed in a magnetic field and the field, a dynamically induced emf is produced in the conductor. The direction of the induced emf is given by fleming's right hand rule.

...ltage and current relations:-

$I_a = I_{se}$

$I_a = I_{sh} + I_L$

Voltage across shunt field winding is V_t, Resistance of shunt field winding is R_{sh}, Resistance of series field winding is R_{se}.

Shunt field current $I_{sh} = \frac{V_t}{R_{sh}}$

Voltage equation, $E = V_t + I_a R_a + I_{se} R_{se} + V_{brush}$

2. Short shunt compound generator :-

The shunt field winding is connected only across the armature.

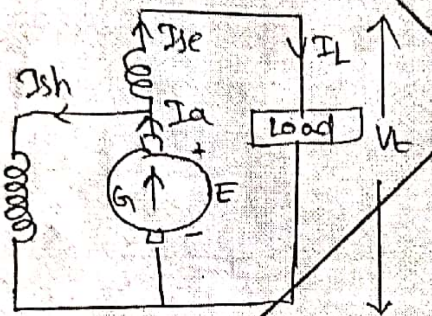


fig. Short shunt compound generator

The voltage and current relations are:

$I_a = I_{sh} + I_L$

and $I_{se} = I_L$.

The voltage Equation is

$E = V_t + I_a R_a + I_L R_{se} + V_{brush}$

Shunt field current (Neglect V_{brush})

$I_{sh} = \frac{V_t + I_L R_{se}}{R_{sh}} = \frac{E - I_a R_a}{R_{sh}}$

In all the above voltage equations for different generators, the voltage drop at the contacts of the brush can be neglected as it is of negligible value.

E.M.F Equation of D.C Generator :-

Let P = Number of poles of the generator

ϕ = Flux produced by each pole in webers.

N = Speed of armature in r.p.m.

Z = Total number of armature conductors.

A = Total number of parallel paths in which the 'z' number of conductors are divided.

$A = P$ for lap winding

$A = 2$ for wave winding.

According to Faraday's law of electromagnetic induction,

EMF generated / conductor $= \frac{d\phi}{dt}$.
e_g

revolution, conductor will cut total flux produced by all the poles.

$$\therefore d\phi = \phi P$$

Time required to complete one revolution as speed is N rpm

is $dt = \frac{60}{N}$

$$\therefore E = \frac{d\phi}{dt} = \frac{\phi P N}{60}.$$

This is the emf induced in one conductor. There are total Z conductors with A parallel paths.

The conductors in one parallel path are always in series. Hence $\frac{Z}{A}$ number of conductors are always in series and e.m.f remains same across all the parallel paths.

$$\therefore \text{Total Emf} = \frac{\phi P N}{60} \times \frac{Z}{A}$$

$\therefore$ E.m.f Equation of a d.c generator: $\boxed{E = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)}$

For Lap winding type, $A = P \Rightarrow E = \frac{\phi Z N}{60}$

For wave winding type, $A = 2 \Rightarrow E = \frac{\phi Z N P}{120}$

O.C.C. of a DC Shunt Generator :-

O.C.C means open circuit characteristics. The characteristics is the graph of generated no load voltage E_0 on Y-axis and field current I_f on X-axis when speed of generator is maintained constant. It is plotted without load with open output terminals. These characteristics are also called No load characteristics (or) magnetization characteristics.

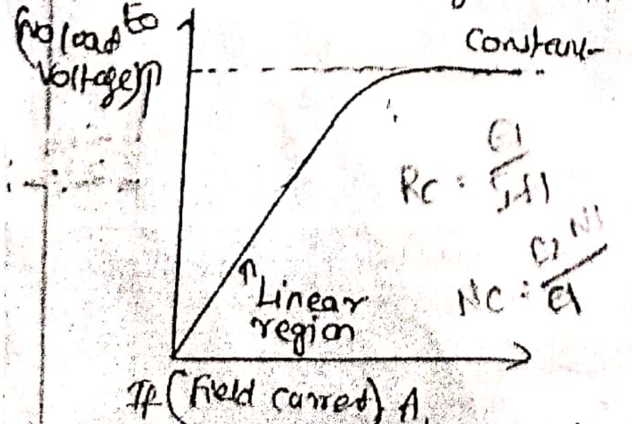


Fig: Open Circuit Characteristics

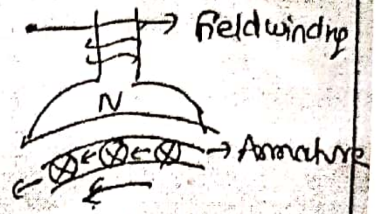
The characteristics is linear till saturation and after that bends such that voltage remains constant though I_f increases. Induced emf varies with speed. ($E \propto N\phi$) Magnetization characteristics for various speeds can be plotted.

D.C Motors

D.C Motor is a machine which converts electrical energy into mechanical energy.

Principle of operation of a D.C Motor :-

When a current carrying conductor is placed in a magnetic field, it experiences a mechanical force.

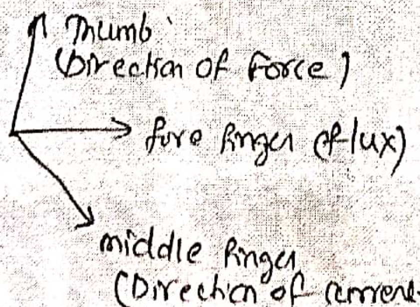


The magnitude of the force experienced by the conductor in a motor is given by,

$$\boxed{F = BIL}$$

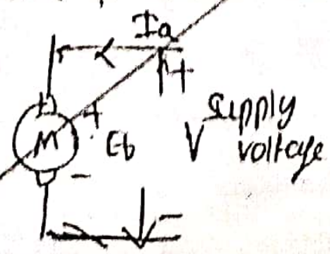
F is force in Newtons.
B is flux density due to flux produced by the field winding.
l is length of the conductor.
Fleming's Left hand Rule is used to find the direction of force.

Fleming's left hand Rule :- If index finger, middle finger and thumb are placed mutually perpendicular to each other, index finger points the direction of magnetic field, middle finger in the direction of current then thumb gives the direction of force experienced by the conductor.



~~**Significance of Back E.M.F :-** In a DC motor, after motoring action and According to Faraday's law of electromagnetic induction there is an induced emf in the rotating armature conductors. This induced emf in the armature always acts in the opposite direction of the supply voltage. This is according to Lenz's law.~~

~~Lenz's law states that the induced emf opposes the supply voltage. This emf is called Back EMF E_b.~~



~~Voltage Equation of a D.C Motor:~~

~~$V = E_b + I_a R_a$ + Brush drop.~~

~~On neglecting brush voltage drop,~~

$$\boxed{V = E_b + I_a R_a} \quad \text{where } E_b = \frac{\phi Z N}{60}\left(\frac{P}{A}\right)$$

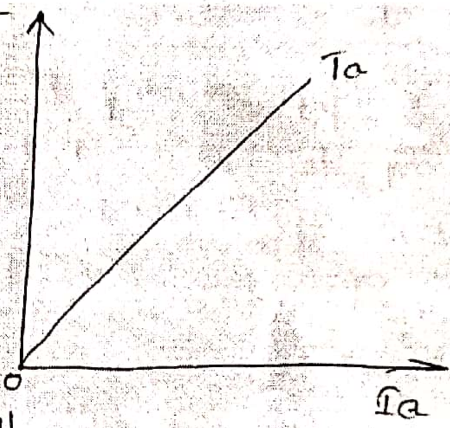
Performance characteristics of DC motors:-

The performance of a dc motor under various conditions can be judged by the following characteristics.

1) Torque - Armature current characteristics
2) speed - Armature current characteristics
3) speed - Torque characteristics.

1) Torque - Armature current characteristics :- (T Vs I_a)

=> The graph showing the relationship between the Torque and the Armature current is called a Torque - Armature current characteristics.



=> These are also called electrical characteristics

for a dc motor $T \propto \phi I_a$

$$\boxed{T_a \propto I_a.}$$

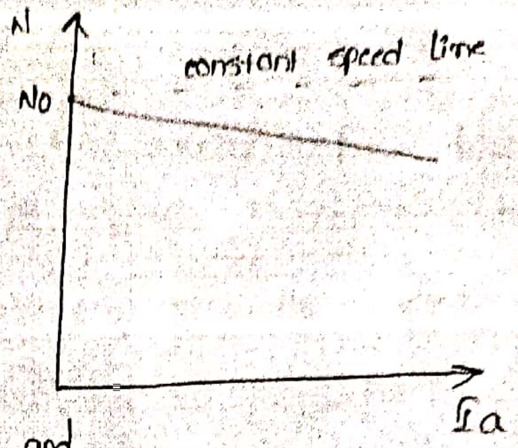
2) speed - Armature current characteristics :- (N Vs I_a)

=> A graph showing the relationship between the speed and Armature current characteristics.

speed

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

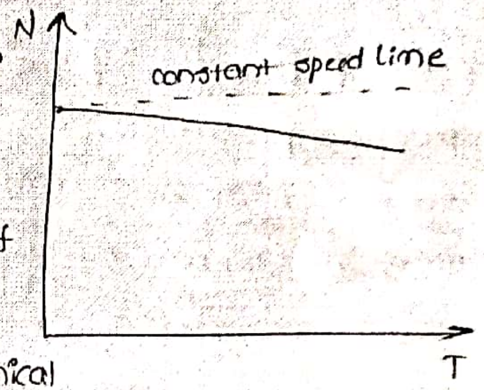
$N \propto V - I_a R_a$



so as load Increases, the armature current Increases and hence drop $I_a R_a$ also Increases.

3) speed - Torque characteristics (N Vs T) :—

⇒ The graph showing the relation ship between the speed and the torque of the motor is called speed - Torque characteristics of the motor.



⇒ These are also called mechanical characteristics.

speed control of DC motor :—

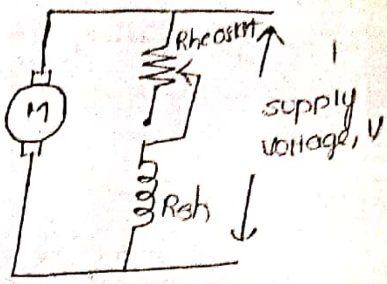
There are two methods of speed control are.

i) field flux control method

ii) Armature voltage control method.

i) flux control :—

⇒ from Emf equation $N \propto \frac{1}{\phi}$ i.e; speed is inversely proportional to the flux.

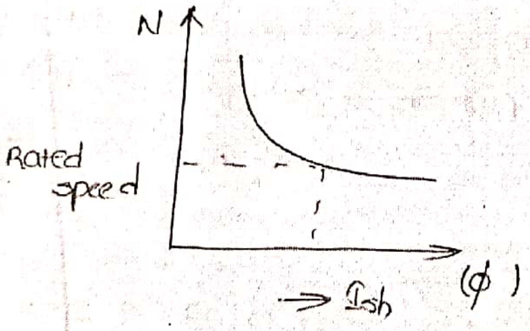


⇒ flux is dependent on the current through the shunt field winding.

⇒ flux can be controlled by adding a rheostat (variable resistance) in series with the shunt field winding.

⇒ When the Resistance R of Rheostat is increased, the shunt field current I_{sh} decreases. So the flux produced decreases due to which speed of the motor increases $(N \propto \frac{1}{\phi})$

By this method, speed control above rated value is possible.

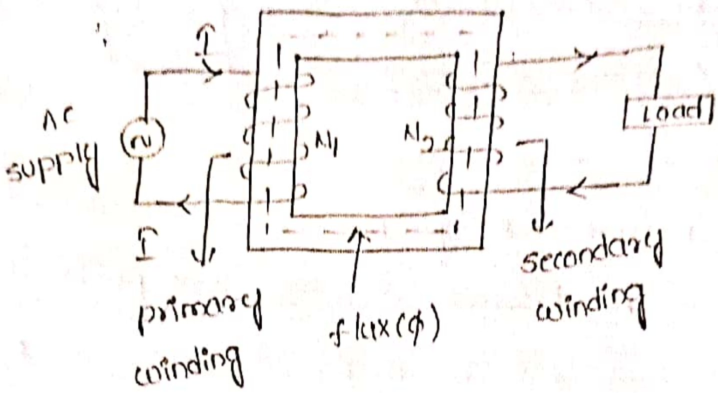


ii) Armature voltage control method :-

⇒ the speed is directly proportional to the voltage applied across the Armature. The voltage across the armature can be controlled by adding a variable resistance in series with the armature.

⇒ for a given load, when Resistance is added to the armature, I_aR_a drop increases. Due to this voltage across Armature decreases, this decreases speed below rated value.

principle and operation of Single phase Transformer :-



Single phase Transformer

principles :-

The principle of mutual Induction states that when two coils are inductively coupled and if current in one coil is changed uniformly then an e.m.f gets induced in the other coil. The emf can drive a current, when closed path is provided to it.

operation :-

One of the two coils is connected to a source of alternating voltage. This coil in which electrical energy is fed with the help of source is called "primary winding". The other winding is connected to load. The electrical energy transformed to this winding is drawn out to the load.

This winding is called secondary winding. The primary winding has N_1 number of turns while the secondary winding has N_2 number of turns.

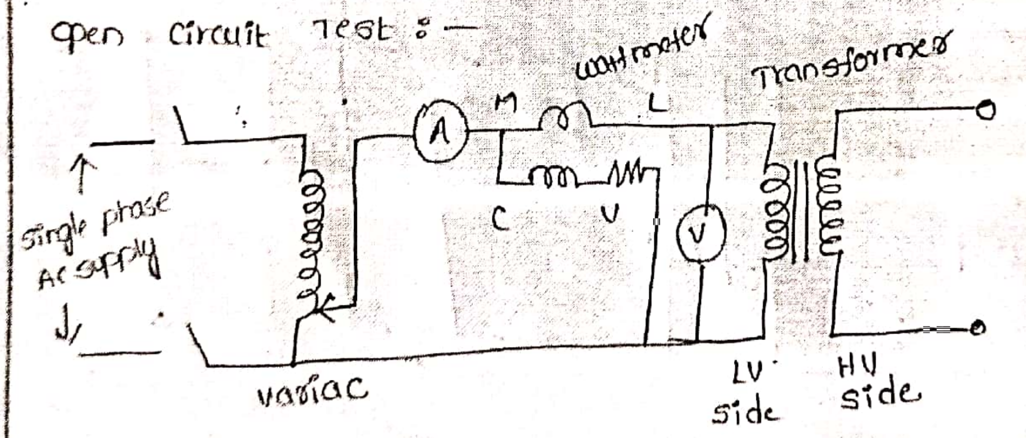
When primary winding is excited by an alternating voltage, it circulates an alternating current. (It circulates an alternating)

This current produces an alternating flux(ϕ) which completes its path through common magnetic core as drawn dotted in figure. Thus an alternating flux links with secondary winding. As the flux is alternating, according to faraday's law of an electromagnetic Induction, mutually induced emf gets developed in the secondary winding. If now load is connected to the secondary winding, this emf drives a current through it.

Thus though there is no electrical contact between the two windings, an electrical energy gets transferred from primary to the secondary.

OC and SC Test on Transformer :—

open circuit Test :—



The secondary side (HV) of transformer is kept open. By using variac rated voltage i/p is applied to the primary (LV).

Wattmeter measures input power, Ammeter measures input current and voltmeter measures primary voltage. As transformer secondary is open, it is on no load. So current drawn by the primary is no load current I_0.

wattmeter in oc test gives Iron losses.

W_0 = Iron losses

W_0 = wattmeter Reading

V_0 : voltmeter Reading

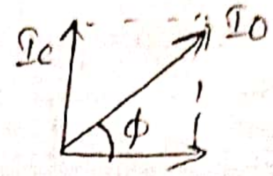
I_0 = Ammeter Reading

No load power factor $\cos\phi_0 = \frac{W_0}{V_0 I_0}$

The two components of current are

$I_c = I_0 \cos\phi_0$

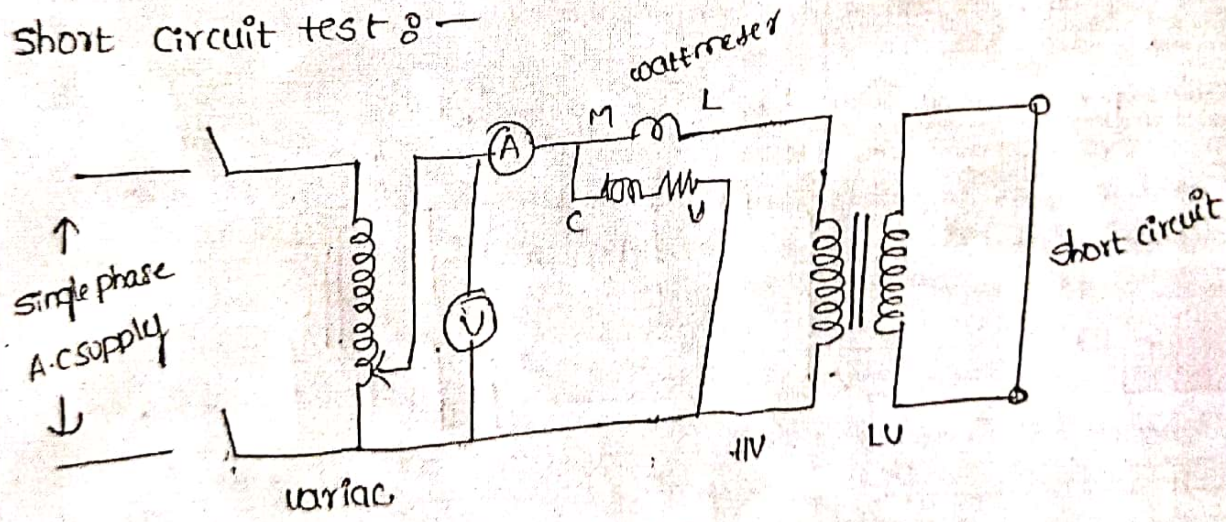
$I_m = I_0 \sin\phi_0$



The exciting circuit parameters are

$R_0 = \frac{V_0}{I_c}$ and $X_0 = \frac{V_0}{I_m}$

Short circuit test :-



The low voltage side is short circuited. The LV winding is connected to ac supply Through variac, ammeter & voltmeter. In short circuit test, low voltage is applied to HV winding such that rated current flows Through it. wattmeter reading is equal to full load copper loss.

W_{sc} = full load copper loss

so short circuit test gives full load copper loss.

~~Three phase~~ Induction Motors.

An induction motor converts electrical energy into mechanical energy

Principle of operation of ~~three phase~~ induction motor :-

Working principle :- Induction motor works on the principle of electromagnetic induction.

When a three phase supply is given to the three phase stator winding, a rotating magnetic field of constant magnitude is produced. The speed of this rotating magnetic field (R.M.F) is synchronous speed N_s rpm.

$$N_s = \frac{120f}{P}$$ where f = supply frequency. P = Number of poles.

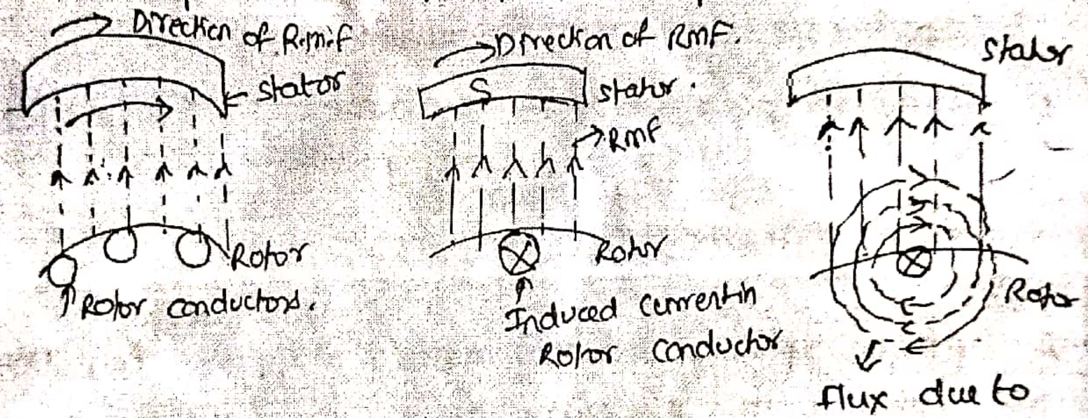


Fig. Working principle of Induction Motor.

Due to relative motion between the rotating magnetic field and rotor conductors, emf gets induced in rotor conductors. This is electro-magnetic induction. As rotor forms closed circuit, induced emf circulates current through rotor called rotor current.

According to Lenz's law, the direction of induced current in the rotor is so as to oppose the cause producing it. The cause of rotor current is the induced emf which is induced because of relative motion present between the rotating magnetic field and the rotor conductors. To oppose the relative motion the rotor experiences a torque in the same direction as that of R.M.F and tries to catch up the speed of rotating magnetic field. The induction motor <u>never</u> rotates at synchronous speed. So it is called asynchronous motor.