BE8255 Basic Electrical, Electronics and Measurement Engineering

Unit – II

Electrical Machines

Part-B

1.Explain the construction of D.C Machines.

[OR]

Explain the construction of D.C Motor.

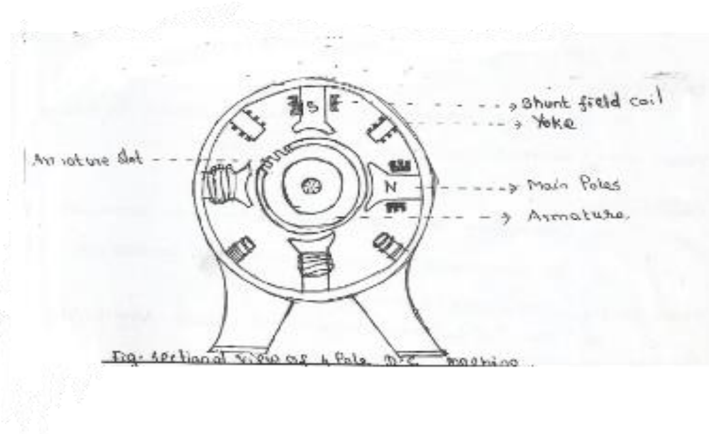
[OR]

Explain the construction of D.C generator. [AU]

Answer:

D.C Machine consists of

1. Magnetic frame or yoke
2. Poles, interpoles, windings
3. Armature.
4. Commutator
5. Brushes, Bearings and shaft.



Magnetic Frame:

The magnetic frame or yoke serves two purposes.

i) It act as protecting cover for the whole machine and provides mechanical support for the poles.

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

Poles:

The poles consist of

i) Pole cores ii) Pole shoes iii) Pole coils.

- The pole cores and pole shoes from the field magnet.
- The end of the pole core towards the armature is often expanded in the form of shoe to reduce the reluctance of the air gap.
- Field winding is wound over the pole core.
- The pole coils are made up of copper wine or strip.
- When the current pass through these coils the pole becomes an electromagnet & start establishing a magnetic field in the machines.
- For very small machines, the poles are made of cast iron.
- For large machine, cast steel is used. To minimize the eddy current pole is laminated.

Interpoles:

- Interpoles are provided to improve commutation.
- It connected in series with the armature since they carry aramature current.
- The coils are made up of fewer turns of thicker conductor to reduce resistance.

Armature:

Armature consists of i) Armature Core
ii) Armature windings

- Armature are contains armature conductors or coils.
- Armature along with the conductors rotates under poles & hence the flux produced by fluid magnet in cut by armature conductor.
- When armature core rotates in the pole flux, eddy current are also produce in it. This produce unnecessary heat which result in heavy power loss.
- To minimize the eddy current losses the armature core is laminated.
- When the conductors rotate, they alternatively come under the influence of north and south poles. This causes high hysteresis losses in the armature core.
- To reduce hysteresis losses, few percentages of silicon is used in the armature.

Commutator:

- The commutator converts the alternating emf into unidirectional or direct emf.
- As it collects current from armature, it is also made up of copper segments.
- It is cylindrical in shape and is made up of wedge-shaped segment of conductivity copper.
- These segments are insulated from each other by thin layer of mica.
- The armature coils leads are soldered to each commutator segment by a riser.

Brushes and Bearings:

- Brushes are made up of carbon or graphite.
- This collects the current from the commutator and convey it to the external load resistance.
- Brushes are rectangular in shape. These brushes are housed in brush holders & brush holders mounted over brush holder stud and brush holder stud mounted on brush yokes.
- Ball bearings are used as they are more reliable for light machine.
- For heavy duty machines, roller bearings are preferred.

2.Explain the working principle of DC generator

[OR]

What is DC generator. Describe the working principle of DC generator, with neat diagrams. [AU]

Answer:

An electrical generator is rotating machine which converts mechanical energy into electrical energy.

Working principle:

It operates on the principle of Faraday's Law of electromagnetic Induction, which states that whenever a current carrying conductor cut the magnetic flux, induced emf is generated.

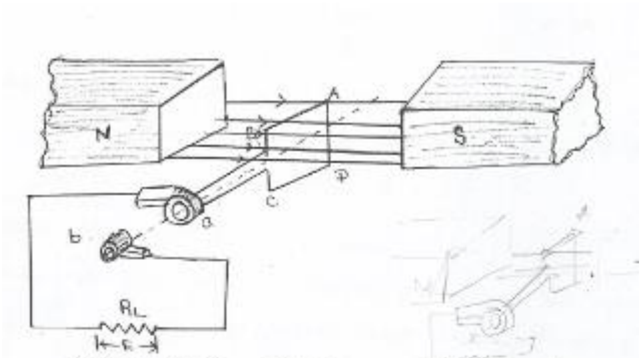


Figure. Working principle of DC generator.

- Let us consider a single turn coil ABCD rotated on a shaft within a uniform magnetic field of flux density. It is an anticlockwise direction.
- Let 'l' be the length and 'b' be the breadth of the coil in meters. When the coil sides AB and CD are moving parallel to the magnetic field, the flux lines are not being cut and no emf is induced in the coil. At this position assume the angle of rotation 'Q' as zero.
- This vertical position of the coil is the starting position. According to Faraday's Law II, the emf induced is proportional to the rate of change of flux linkages.

$$e = -N\frac{d\emptyset}{dt}$$

Where 'N' is the number of turns, ∅ is the flux and "t" is the time.

As N=1, $e = -\frac{d\emptyset}{dx}\ volts.$

Initially, when the coil is moving parallel to the flux lines, no flux line is cut and hence

$$\frac{d\emptyset}{dt} = 0\ and\ e = 0$$

After time "t" secs, the coil would have rotated through an angle "ωt" radians in the anti-clockwise direction. The flux then linking with the coil is $Blb\cos\theta$

$$\therefore\ e = -\frac{d}{dt}(Blb\cos\omega T) = Em\sin\omega t$$

Where

$Em = Blb\omega$

Em = Maximum value of induced emf.

B =Flux density

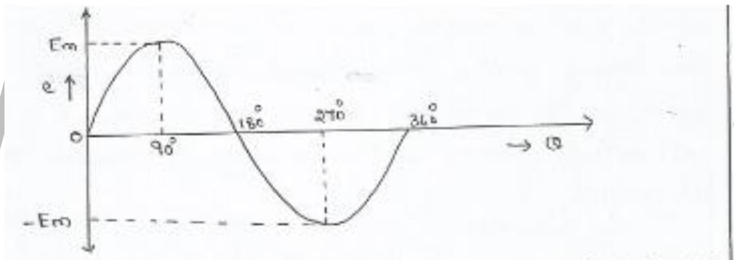


Fig. The changes in voltage, e with respect to the angle

When slip rings are connected, bidirectional current is produced.

- When $\theta = 0,$ coil side is parallel to flux line. No flux line is cut. Emf=0.
- When$\theta = 90^0$, coil moving at right angle to flux line and hence flux are cut at maximum rate. Therefore, maximum e.m.f produced.
- When $\theta = 180^0$, coil again parallel to flux line, emf=0
- When$\theta = 270^0$, coil move to right angle to flux line with position reversed. Hence emf maximum in opposite direction.
- When$\theta = 360^0$, coil is parallel to flux emf=0.[Coil come to starting position].

<u>E.M.F. Induced in Generator:</u>

Let ∅ be the flux per pole in wbers.

Let p be the number of poles.

Let z be the total number of conductors in the armature. All the z conductors are not connected in series. They are divided into groups and let A be the number of parallel paths into which these conductors are grouped.

Each parallel path will have Z/A conductors in series. Let N be the speed of rotation in revolution per minute (rpm).

Consider are conductor on the periphery of the armature. As this conductor makes one complete revolution, it cuts $p\emptyset$ webers. As the speed is N rpm, the time taken for one revolution is 60/N secs.

Since the emf induced in the conductor

= rate of change of flux cut.

$$e\ \alpha\ \frac{d\emptyset}{dt} = \frac{p\emptyset}{60/N}$$

$$e = \frac{NP\emptyset}{60}\ volts$$

Since there are Z/A conductors in series in each parallel path the emf induce d.

$$E_g = \frac{NP\emptyset}{60}\frac{Z}{A}$$

$$E_g = \frac{\emptyset NZ}{60}\frac{P}{A}\ volts$$

The armature conductors are generally connected in two different ways, viz, lap winding and wave winding. For lap wound armatures, the number of parallel paths is equal to the number of poles. [i.e. A=P]. In wave wound machines, A=2.

3.Calculate the speed if the armature is lap connected. A wave connected armature winding has 19slots with 54 conductors per slot. If $\emptyset = 0.025wb, p = 8$. Calculate the speed at which the generator should be run to give 513v. [OR]

A wave connected armature winding has 19slots with 54 conductors per slot. If the flux per pole is 0.025wb and number of poles is 8. Find the speed at which the generator should be run to give 513v. Also find the speed if the armature is lap connected.

Solution:

Given

P =8

$\emptyset = 0.025wb$

Z = 19 x 54 = 1026

E_g= 513 volts.

For wave wound

$$E_g = \emptyset \frac{ZN}{60} \frac{P}{A}$$

$$N = \frac{60 \ x \ E_g \ x \ A}{\emptyset \ Z \ N \ P}$$

$$= \frac{60 \ x \ 513 \ x \ 2}{0.025 \ x \ 19 \ x \ 54 \ x \ 8}$$

$$N = 300 \ rpm$$

For lap wound, A=P=8

$$\therefore \ N = \frac{60 \ x \ 513 \ x \ 8}{0.025 \ x \ 1026 \ x \ 8}$$

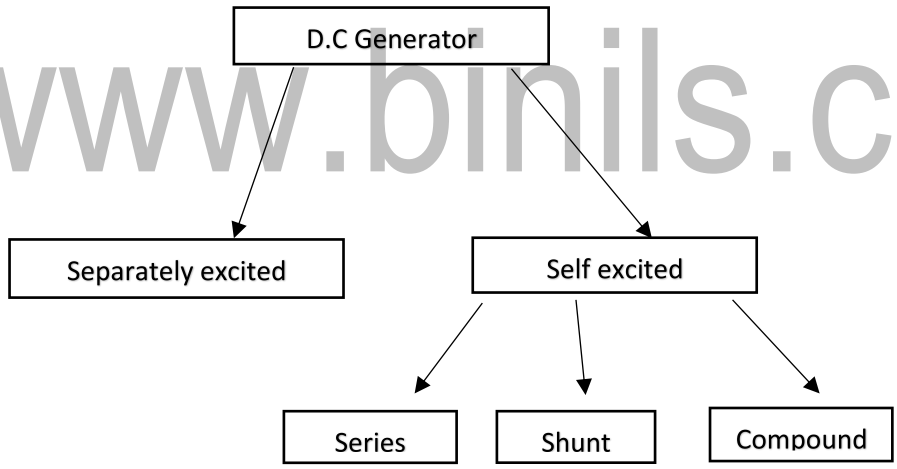
$$N = 1200 \ rpm$$

4. Describe all the types of D.C generators in detail.

[OR]

Draw the circuit model of separately & self-excited generator and write the relationships among the current & voltage.

<u>Types of DC Generators:</u>



<u>i) Separately excited DC generator:</u>

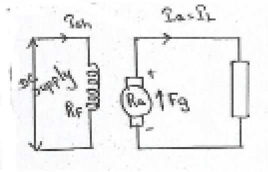
The required power for exciting the field windings is obtained from power developed in armature of DC generator.

The field winding has large number of turns of thin wire.

Terminal Voltage

$V = E_g - I_a R_a - V_{brush}$

$V_{brush} = Voltage\ drop\ at\ the\ contacts\ of\ the\ brush.$



Generally V_{brush} is neglected because of very low values.

$$Generated\ emf\ E_g = V + I_aR_a + V_{brush}$$

Electric power developed = E_gI_a

Power delivered to load = VI_a

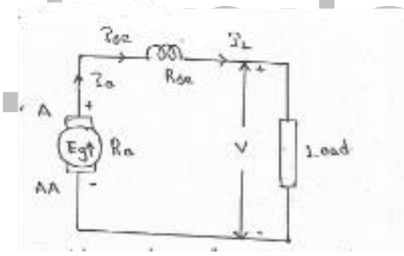
Self-excited Generators:

If in a d.c generator field winding is supplied from the armature of the generator itself, then it is called a self-excited d.c generator.

There are three types,

1. Series generator 2. Shunt generator 3. Compound generator

1. Series Generator:



The field winding is connected in series with the armature. This type of D.C. generator is called D.C series generator.

The field winding has less number of turns of thick wire. If has low resistance.

Here, armature, field and load are all in series. So they carry the same current.

$$\therefore\ I_a = I_{se} = I_L$$

Generated emf

$$E_g = V + I_aR_a + I_aR_{se} + V_{brush}$$

Where,

V=terminal voltage in volts

I_aR_a $= Voltage\ drop\ in\ the\ armature\ resistance.$

I_aR_{se} $= Voltage\ drop\ in\ the\ series\ field\ winding\ resistance.$

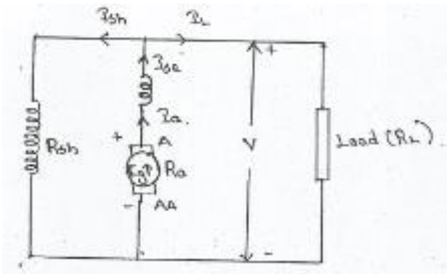
$V_{brush} = brush\ drop$

$$\therefore\ Terminal\ voltage\ V = E_g - I_a R_a - I_a R_{se} - V_{brush}$$

$Power\ developed\ in\ the\ armature = E_g I_a$

$Power\ delivered\ to\ load = V I_a (or) V I_L$

2. Shunt Generator:



- In d.c shunt generator, field winding and load are connected across the armature.
- The shunt field winding has more number of turns of thin wire. It has high resistance.

$$Terminal\ voltage\ V = E_g - I_a R_a$$

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

$$Armature\ current I_a = I_L + I_{sh}$$

$$Power\ developed\ by\ armature = E_g I_a$$

$$Power\ delivered\ to\ load = V I_L$$

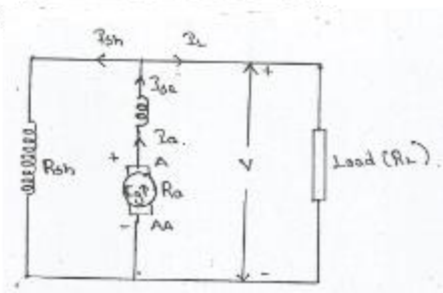
3. Compound Generator:

The compound generator consists of both shunt field winding and series field windings. One winding is in series and other winding is in parallel with the armature. Compound generator can be classified as,

a) Long shunt compound generator.
b) Short shunt compound generator.

a) Long shunt compound generator:

- Shunt field winding is connected between both series field and armature winding.



Series field current $I_{se} = I_a = I_L + I_{sh}$

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

Generated emf $E_g = V + I_a(R_a + R_{se}) + V_{brush}$

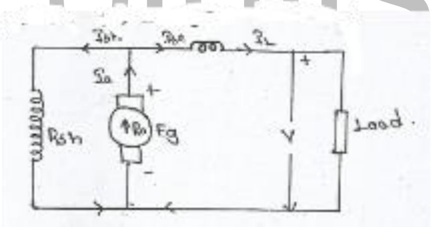
Terminal voltage $V = E_g - I_a(R_a + R_{se}) - V_{brush}$

Power developed in armature= $E_g I_a$

Power delivered to load $= VI_L$

b) Short shunt compound Generator:

- Shunt field winding is connected in parallel with the armature and this combination is connected in series with series field winding.



Series field current $= I_{se} = I_L$

Load current $= I_L$

Shunt field current $I_{sh} = \frac{V + I_{se}R_{se}}{R_{sh}}$

Generated emf E_g $= V + I_a R_a + I_{se} R_{se} + V_{brush}$

Terminal voltage V $= E_g - I_a R_a - I_{se} R_{se} - V_{brush}$

Power developed in armature $= E_g I_a$

Power delivered to load $= VI_L$

4. A 25KW, 250V dc shunt generator has armature and field resistance of 0.06ohm and 125ohm respectively. Calculate the total power developed by the armature when it delivers full load output. [OR]

Find the total power developed by the armature when it delivers full load output. The dates are P=25kw, V=250v, R_a =0.06ohm, R_{sh}=125ohm.

To find:

Total power developed by the armature when it delivers full load output.

$Load\ current\ I_L = \frac{P}{V} = \frac{25\ x\ 10^3}{250} = 100A$

Field current, $I_{sh} = \frac{V}{R_{sh}} = \frac{250}{125} = 2A$

$\therefore Armature\ current I_a \ = I_L + I_{sh}$

$I_a \ = 100 + 2 = 102A$

Generated emf $E_g = V + I_a R_a$

= 250+102x0.06

= 256.12V

Power developed by armature = $E_g I_a$

= 256.12x102

= 26.12KW.

5. List the application of DC generator.

[OR]

What are the application of D.C generator?

1. DC shunt Generator
   - Electroplating
   - Battery charging
2. DC series Generator
   - Used for series arc lighting
   - Used for series incandescent lighting
3. DC compound Generator
   - Used for welding purpose
   - Used to supply power to railway circuits, elevator motors etc.
4. Separately excited Generator
   - Used in places where wide range of DC voltage is required for testing purpose.

6. With neat diagram explain the working principle of D.C Motor and derive its torque,

equation. (OR)

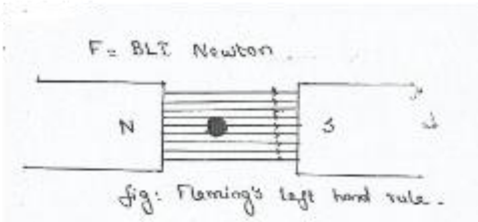
What is a back emf in DC Motor? Explain the principle of DC Motor.

Answer:

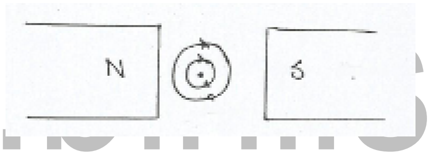
DC Motor converts Electrical energy into Mechanical Energy.

Principle of Operation:

Whenever a current carrying conductor is placed in a magnetic field, a mechanical force is produced on the conductor. The direction of force is given by Fleming's left-hand rule.

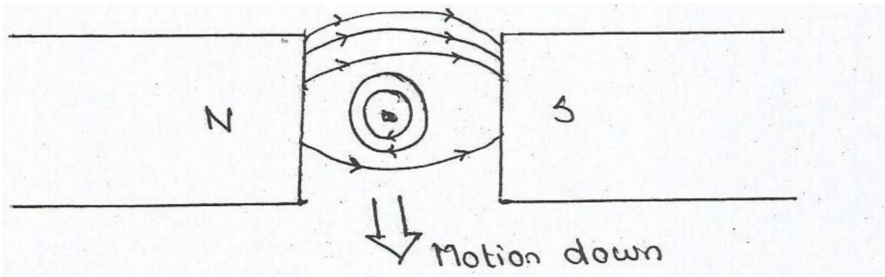


- In a uniform magnetic field in which a straight conductor carrying no current is placed. The direction of magnetic flux line is from North to South pole.

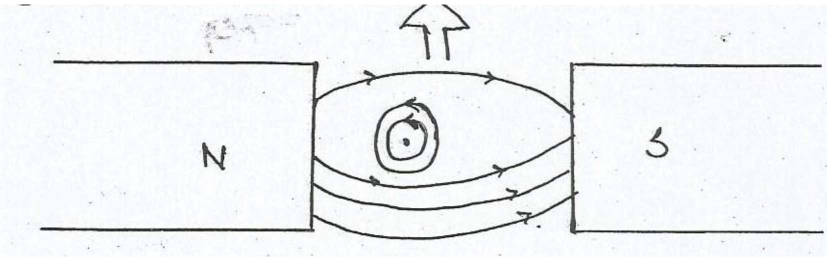


There is no movement of the conductor during the above condition.

- If the current carrying conductor is placed in the magnetic field. The field is due to the current in the conductor aiets the main field above the conductor, but opposes the main field below the conductor. Hence the flux strengthens above the conductor and weakens below the conductor. It is found that a force acts on the conductor, trying to push the conductor downwards.



- If the current in the conductor is reversed, the strengthening of flux lines occurs below the conductor and the conductor will be pushed, upwards.



Back EMF:

When the machine working as a motor, voltages are induced in the conductors. This emf is called the back emf or counter emf, since the cause for this is the rotation, which in turn, is due to the supply voltage.

The back emf

$$E_b = \frac{\emptyset ZN}{60} \; x \; \frac{P}{A} \; volts$$

$\emptyset - flux\ per\ pole\ in\ wb.$

Z – No.of conductors in the armature

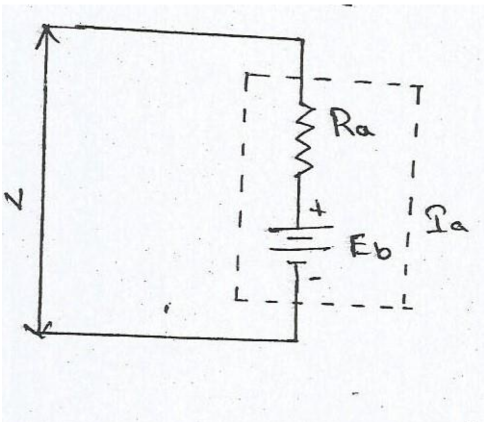
P – No.of poles

A – No.of parallel paths.

V – Supply voltage to the motor

$I_a - Armature\ current$

$R_a - Armature\ resistance\ in\ ohm$



The voltage equation of this DC Motor is

$$V = E_b + I_a R_a \; volts$$

The armature current

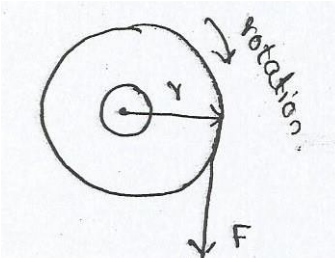
$$I_a = \frac{V - E_b}{R_a} \; Amps.$$

Torque Equation:

Torque is nothing but turning or twisting force about an axis,

Torque is measured by the product of force and the radius at which the force acts. Consider a wheel of radius "r" metres acted on by a circumferential force "F". Let the force "F" cause the wheel to rotate at "N" rpm. The angular velocity of the wheel is

$$\omega = \frac{2\pi N}{60} \ rad/sec.$$



Torque $T = F \ x \ r \ \ N - m$

Work done per revolution = F x distance moved

= F x 2πr joules

Power developed, P $= \frac{Work\ done}{time}$

$$= \frac{F \ x \ 2\pi r}{time\ for\ 1\ rev} = \frac{F \ x \ 2\pi r}{60/_N}$$

[rpm=60; rps=N/60; time for one rev =60/N]

$$P = (F \ x \ r)\frac{2\pi N}{60}$$

$$P = T\omega \ watts$$

Where T=torque in N-m, ω = angular speed in rad/sec

The torque developed by a DC Motor is also called as armature torque.

The gross mechanical power developed in the armature in $E_b I_b$

Power in armature = Armature torque x ω

$$E_b I_a = T_a \ x \ \frac{2\pi N}{60}; \quad E_b = \frac{\emptyset PNZ}{60A}$$

$$\frac{\emptyset PNZ}{60A} \ I_a = T_a \ x \ \frac{2\pi N}{60}; \ T_a = \frac{\emptyset I_a}{2\pi} \ \frac{PZ}{A}$$

$$T_a = 0.159\emptyset \ I_a \frac{PZ}{A} \ N - m$$

The above equation is torque equation of a DC Motor.

Speed and Torque Equation:

For a DC Motor, the speed equation is

W.K.T

$$E_b = V - I_a R_a = \frac{\emptyset ZN}{60} \frac{P}{A}$$

$$V - I_a R_a = \frac{\emptyset ZN}{60} \ x \ \frac{P}{A}$$

$$\therefore N = \frac{V - I_a R_a}{\emptyset Z} \ x \ \frac{60A}{P}$$

Z, A &P are constants,

$$N = \frac{K(V - I_a R_a)}{\emptyset}$$

Where K is a constant

Therefore, Speed equation becomes

$$N \ \alpha \ \frac{V - I_a R_a}{\emptyset}$$

Or $N \propto \frac{E_b}{\emptyset}$

By varying the flux and voltage, the motor speed can be changed.

The torque equation of a DC motor is given by

$$T \propto \emptyset I_a$$

Here the flux ∅ directly proportional to the current flowing through the field winding.

i.e.

$$\emptyset \propto I_f$$

For DC shunt motor, the shunt field current I_{sh} is constant as long as input voltage is constant.

Therefore, flux is also constant.

Hence $T \propto \emptyset I_a$ becomes

$$T \propto I_a$$

For DC series motor, the series field current is equal to the armature current I_a. Here the flux ∅ is proportional to the armature current I_a.

$$\emptyset \propto I_a$$

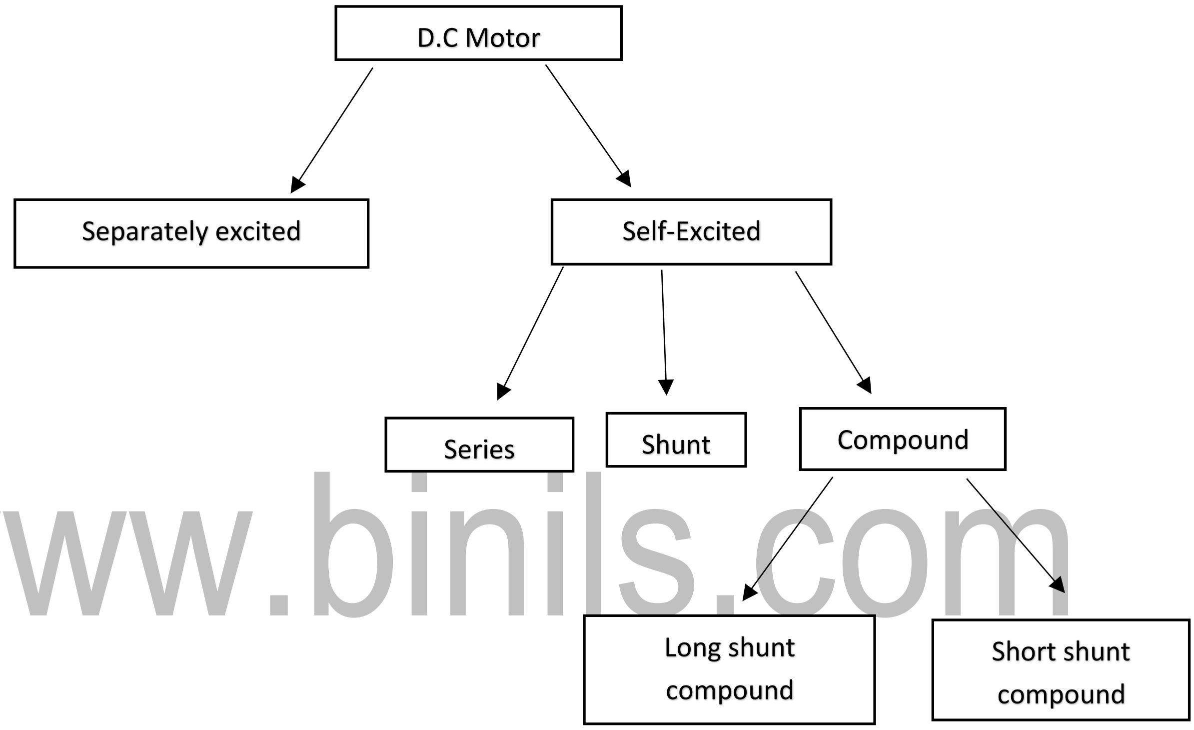
Hence $T \propto \emptyset I_a$ becomes

$$\therefore T \propto I_a^2$$

7. Explain the types of DC Motor

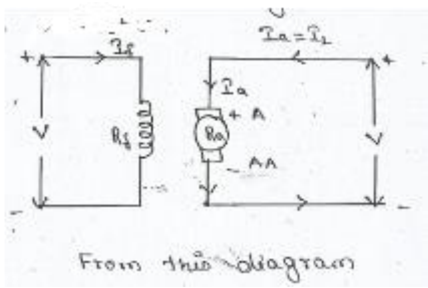
[OR]

Draw the circuit diagram of self and separately excited motor and write the relationship among the current & voltage.



<u>i) Separately excited DC Motor:</u>

Here the field winding and armature are separated. The field winding is excited by a separate DC source. That is why it is called as separately excited DC Motor.



Armature current $I_a = line\ current\ I_L$

Back emf $E_b = V - I_aR_a - V_{brush}$

V_{brush} is very small and therefore it is neglected.

ii) Self excited Motor:

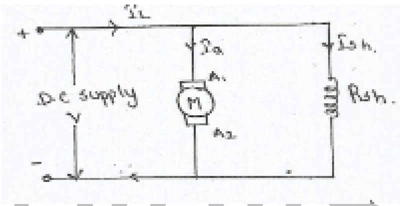
The required power for exciting the field winding is obtained from the power supplies to the armature of the DC Motor.

It is further classified as

1. DC shunt Motor
2. DC series Motor
3. DC compound Motor

1. DC shunt Motor:

- The field winding is connected is parallel with the armature.
- The field winding has a large number of turns and smaller cross section area.
- Since the field current is small, the field power loss is also small.



- The line current is divided into two paths, one through the field winding and second through the armature. i.e.,

$$I_L = I_a + I_{sh}$$

$$I_{sh} = \frac{V}{R_{sh}}$$

Voltage equation of a DC shunt motor is given by,

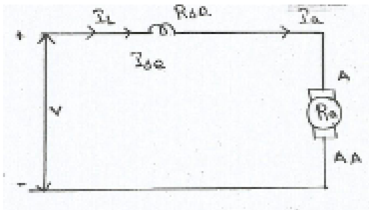
$$V = E_b + I_a R_a + V_{brush}$$

In shunt motor, flux produced by field winding is proportional to the field current I_{sh}.

i.e., $\emptyset \propto I_{sh}$

Here the input voltage is constant and so the flux is also constant. Therefore, DC shunt motor is also called as constant flux motor or constant speed motor.

2. DC Series motor:



- The field winding is connected in series with armature. The field winding should have less number of turns of thick wire.

$$I_a = I_{se} = I_L$$

The voltage Equation is given by

$$V = E_b + I_a(R_a) + I_{se}$$

Where $I_a = I_{se}$

$$\therefore\ V = E_b + I_a(R_a + R_{se}) + V_{brush}$$

V_{brush} – neglected

Hence

$$\therefore\ V = E_b + I_a(R_a + R_{se})$$

In a DC series motor, full armature current flows through the series field winding. Therefore, flux produced is directly proportional to the armature current. i.e.,

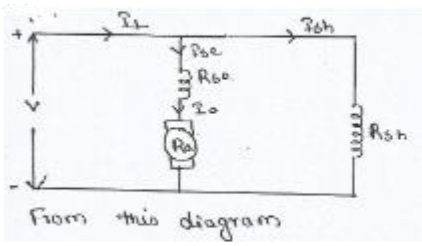
$$\emptyset \propto I_{se} \propto I_a$$

3. DC compound Motor:

The DC compound motor consists of both series and shunt field windings.

a) Long shunt compound Motor:

In this motor, the shunt field winding is connected across both armature and series field winding.



$$I_L = I_{se} + I_{sh}$$

$$I_{se} = I_a$$

Therefore, $I_L = I_a + I_{sh}$

$$I_{sh} = \frac{V}{R_{sh}}$$

The voltage equation of this motor is given by

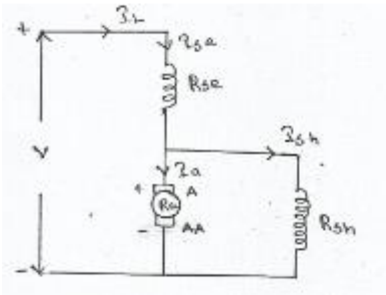
$$V = E_b + I_a R_a + I_{se} R_{se} + V_{brush}$$

Where, $I_a = I_{se}$

$$\therefore \; V = E_b + I_a (R_a + R_{se}) + V_{brush}$$

b) Short shunt compound Motor:

- In this motor, the shunt field winding is across the armature and series field winding is connected in series with this combination.



$$I_L = I_{se}$$

$$I_L = I_a + I_{sh}$$

$$\therefore \; I_L = I_{se} = I_a + I_{sh}$$

The voltage across the shunt field winding can be found out from the voltage equation.

$$V = E_b + I_a R_a + I_{se} R_{se} + V_{brush}$$

$$I_{se} = I_L$$

$$V = E_b + I_a R_a + I_L R_{se} + V_{brush}$$

Voltage drop across the shunt field winding is $= V - I_L R_{se}$

$$V_{sh} = E_b + I_a R_a + V_{brush}$$

$$\therefore \; I_{sh} = \frac{V - I_L R_{se}}{R_{sh}}$$

3. List the application of DC Motor

[OR]

What are the application of D.C Motor?

Shunt Motor:

- Centrifugal pups
- Conveyors
- Machine tools
- Printing presses etc.

Series Motor:

- Praction
- Hoists
- Crane
- Battery-powered vehicles etc.

Compound Motor:

- Rolling Mill etc.

9. What are the different methods of speed control in DC Motor? Explain it.

[OR]

Explain in detail about various methods of speed control in D.C Motor.

Speed Control of DC shunt Motor:

The speed of a dc motor is given by

$$N = \frac{V - I_a R_a}{Z\emptyset}\left(\frac{A}{P}\right)$$

$$N = \frac{K(V - I_a R_a)}{\emptyset}$$

Where,

V = applied voltage

I_a = armature current

R_a =armature resistance

$\emptyset = flux\ per\ pole$

K = Constant

From the above equation, three methods of speed controls are possible.

1) By varying the resistance in the armature circuit [Rheostatic Control]

2) By varying the flux [Flux control]

3) By varying the applied voltage [voltage control]

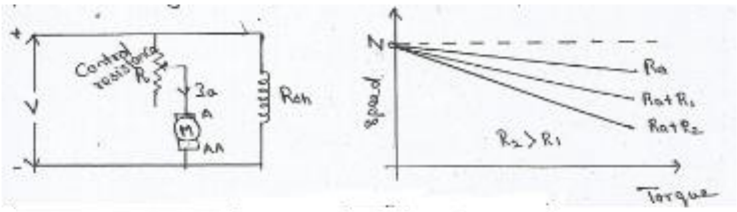
1. By varying the resistance in the armature circuit:

- A variable resistance R is connected in series with armature circuit. Here input voltage V is constant. The speed of the motor can be controlled by varying the resistor R.

So, the equation becomes

$$N = \frac{[V - I_a(R_a + R)]K}{\emptyset}$$

- By increasing the controller resistance R, the potential drop across the armature is decreased. Therefore, the motor speed also decreases. This method of speed control is applicable only for speed less than no load speed.



From the above graph, by increasing the armature circuit resistance the speed can be decreased.

Advantage:

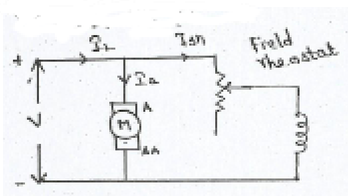
i) Simple method of speed control.

Disadvantage:

i) Here input in constant. The output power in becomes less. Therefore for lower speeds, more and more power is wasted in this controller resistance. Hence this method of speed control is highly inefficient.

ii) Change in speed with the change in load becomes large.

2. By varying the flux:



- The speed is inversely proportional to flux, i.e.,

$$N \propto \frac{1}{\emptyset}$$

- By varying the flux, the motor speed can be varied. The flux of a dc motor can be changed by changing the field currents (I_{sh})
- By varying the field circuit resistance, the shunt field current can only be decreased, i.e., the flux will be decreased. Thus motor speed can be increased by decreasing the flux. This method of speed control can be used for increasing the speed of the motor above its rated speed.(base speed)

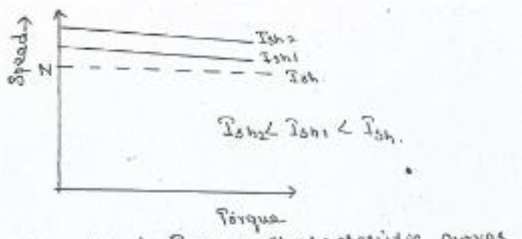
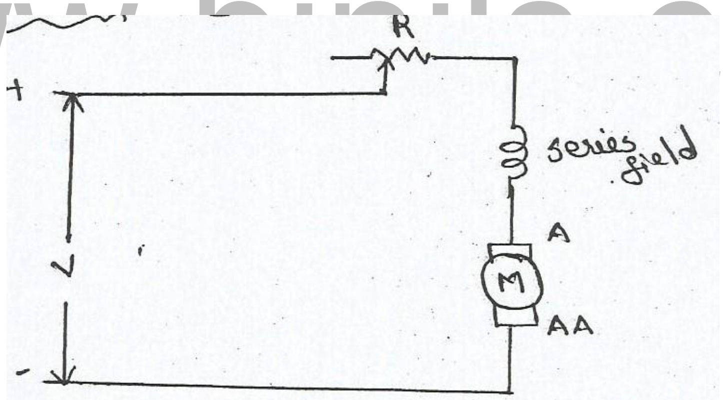


fig: Speed - Torque characteristic curves of dc shunt motor.

Speed Control of DC series Motor:

Variable resistance in series with motor:



- By increasing the resistance, the voltage applied across the armature terminal can be decreased.
- By reducing the voltage across the armature, the motor speed also decreases. Because the applied voltage is directly proportional to the speed,

$$N \propto E_b, \quad E_b \propto V$$

$$\therefore \quad N \propto V$$

- Here, the full motor current passes through this resistance. Due to this, more power loss occurs in this resistance.

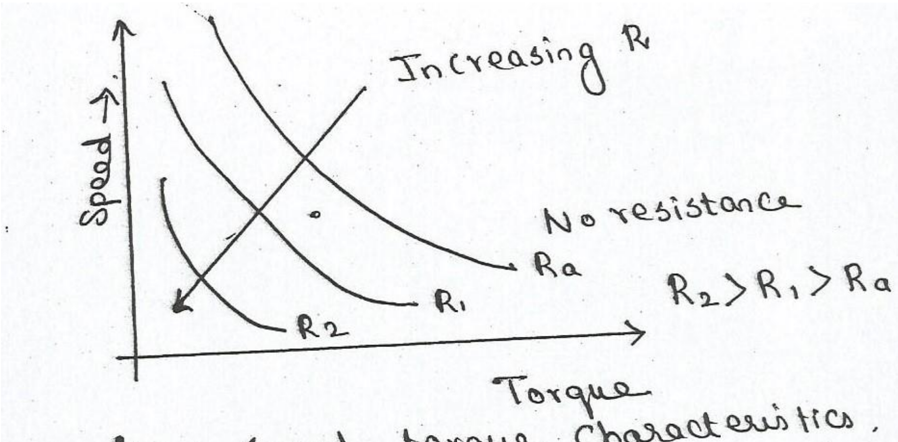
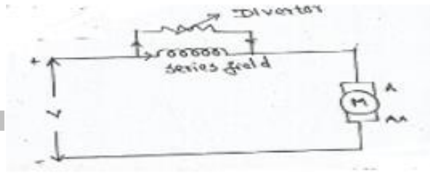


fig: Speed-torque characteristics.

The above figure shows speed-torque characteristics of a dc series motor with increase in variable resistance in series with armature.

Flux Control Method:

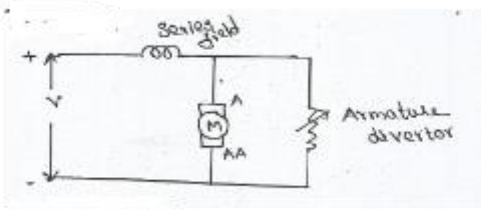
1. Field divertor:



- Field divertor means, a variable resistance connected across the series fielding winding.
- By varying the resistance, the current flowing through the series field changes.
- Due to decrease in field current, the flux can be decreased, the motor speed also increases.

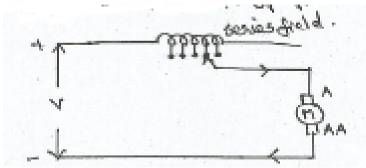
ii) Armature divertor:

- The dc motor speed can be controlled by the armature divertor.
- For constant load torque operation, the armature current I_a is decreased due to armature divertor and flux $\emptyset$ must increase, because the torque is directly proportional to flux and armature current $(T \propto \emptyset I_a)$
- This result is an increase in current taken from the mains. Due to current increase, series field flux also increases. Then the speed of the motor can be decreased. $\left(N \propto \frac{1}{\emptyset}\right)$



iii) Tapped field Control:

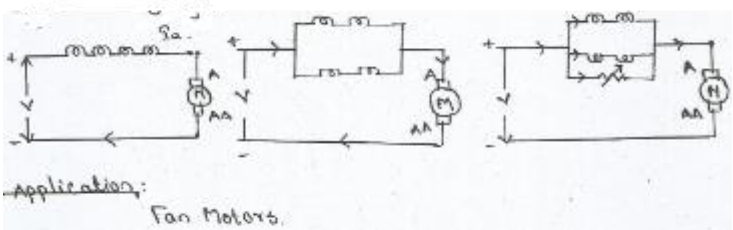
- The speed of the motor is controlled by variation of the number of field turns.



- This method of speed control is applicable where the speed control required is above the base speed.
- By varying the series field turns, the flux can be decreased and motor speed can be increased.

iv) Paralleling field coils:

- In this method speed control is achieved by rearranging the field coils.



3. Explain the construction and working of stepper motors.

[OR]

Describe the construction and the principle of operation of stepper motor.

Stepper motor is basically brushless DC Motor, whose rotor rotates through a fixed angular step in response to input current pulses. That means the full rotation of rotor is divided into equal number of steps and rotor rotates through one step for each current pulse.

Working:

- In this stepper motor the shaft rotates in definite steps, one step being taken each time a command pulse is received.
- The rotor of stepper motor is made of permanent magnet with number of toothed poles on which the field coils are wounded.
- The stator poles are magnetised in appropriate manner by using a microcontroller or by using a microprocessor.
- At the first step first pole is magnetised and second pole is demagnetised, thus cause the rotor to rotate in a fixed angle to align with first pole.
- At the next step, first pole is demagnetised and secan pole is magnetised, this cause the rotor to rotate in a fixed angle to align with second pole and off set with previous pole.

Step Angle:

- Step angle is defined as the angle through which the stepper motor shaft rotates for each command pulse. It is denoted asβ.

$$\beta = \frac{(N_s \sim N_r)}{N_s N_r} \; x \; 360^{\circ}$$

$$\beta = \frac{360^{\circ}}{mN_r}$$

Where,

N_s – Number of stator poles

N_r – Number of rotor poles

m - Number of stator phases

Resolution:

It is defined as the number of steps needed to complete one revolution of the rotor shaft.

$$\therefore \; Resolution = \frac{No.of\ steps}{Revolution} = \frac{360^{\circ}}{\beta}$$

Stepping rate:

The number of steps per second is known as stepping rate. It is also called as stepping frequency.

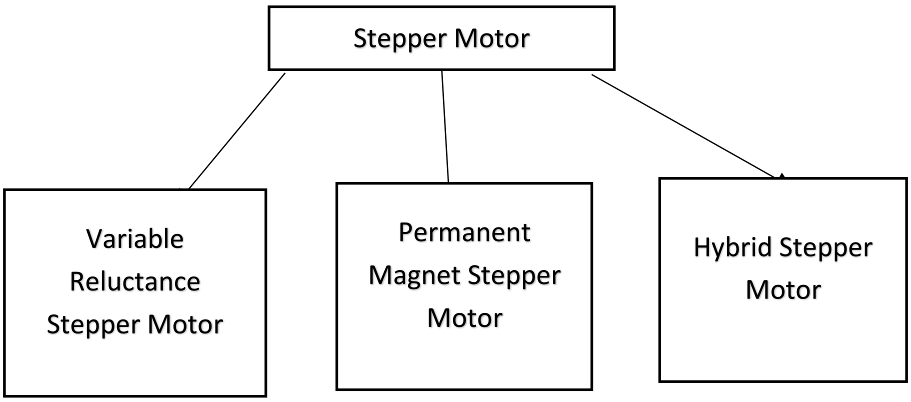
Advantages:

1. It is mechanically simple
2. It requires little or no maintenance
3. It can be driven in open loop without feedback.

Disadvantages:

1. Low efficiency with ordinary controller.
2. Fixed step angle
3. Limited ability to handle large inertia load.
4. Limited power output and sizes available.

Types:



1. Variable Reluctance Stepper Motor:

- The VR stepper motor consists of stator and rotor.
- The stator windings are wound on the stator poles.
- The rotor carries no windings. Rotor poles are made up of ferromagnetic material.
- The rotor is a salient pole type.

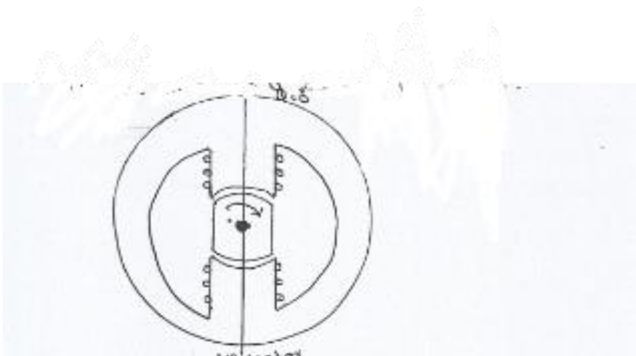


Figure. Variable Reluctance Stepper Motor.

- The motor maybe single stack type and multitask type.
- In this motor, reluctance of the magnetic circuit former by the rotor and stator teeth varies with angular position of the rotor.

2. Permanent Magnet stepper Motor:

- Rotor is permanent magnet. Rotor is cylindrical type.
- Stator windings are wound on the stator poles.
- The motor direction of the rotation depends on the polarity of stator current.
- Application – low manufacturing cost.

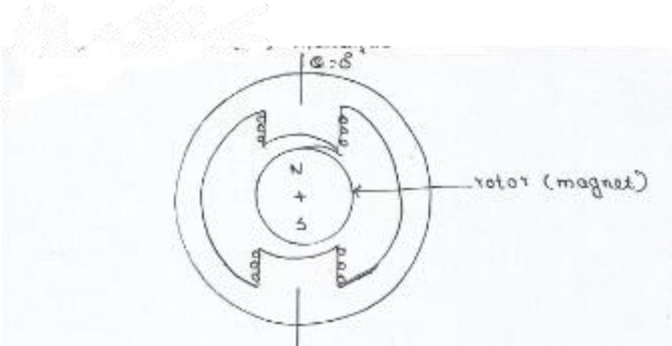


Figure. Permanent magnet P.M motor stepper Motor.

3. Hybrid stepper Motor:

- The rotor is permanent magnet. It is salient pole $\theta = 0^{\circ}$
- The hybrid stepper Motor combines the features of VR stepper motor as well PM stepper Motor.

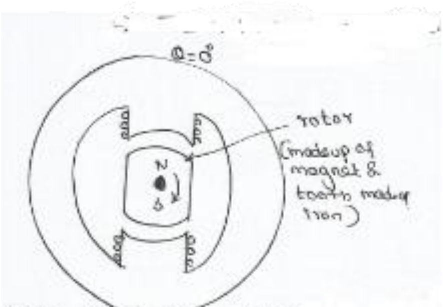


Figure. Hybrid stepper Motor

11. Explain the construction and working principle of Brushless DC Motor. [BL DC]

[OR]

Describes the construction and working principle of BLDC Motor.

Answer:

Construction and Operation:

- The stator of the BLDC Motor is similar to that of a conventional induction motor. The stator has a 3-phase winding which is star connected. The stator core is made up of silicon steel stampings which are stacked together and fixed on the stator frame. The stator windings are supplied through a variable voltage current source inverter(CSI)

- The rotor is salient pole permanent magnet type.
- The stator and rotor fields set locked to each other and remain in synchronism at any and every rotor speed.

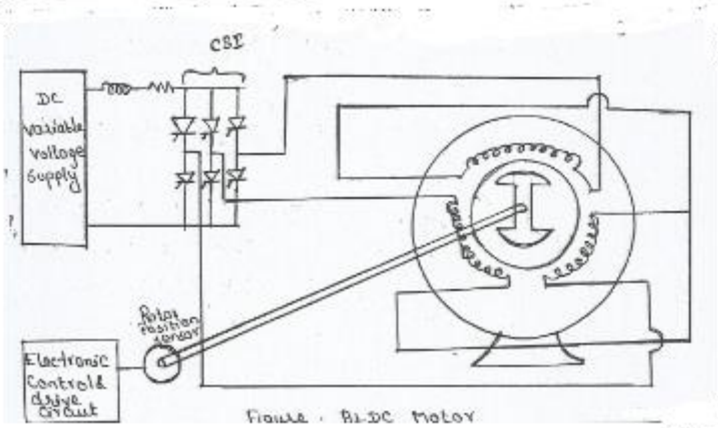


Figure : BLDC motor

- Commonly used rotor position sensors are Hall-effect sensors and optical sensors consisting of LEDS and photo transistors.
- When supply is switched on, current flows through the armature winding.
- Due to the interaction between current and magnetic field, rotor experiences torque, and if this torque is greater than the load torque, rotor starts moving.
- BL DC motor is thus a self-starting motor.
- As the rotor moves, a relative velocity exists between the rotor and the stator. This results in the emf induction in armature winding whose direction is opposite to the applied voltage.
- Due to this back emf, a momentary change 'm' torque and speed will occur.
- The armature draws more current and increases the torque and hence the speed returns to the same value. These changes are very fast and the performance is not affected.

12. What are the advantage and disadvantage of BLDC Motor.

[OR]

Write – Merits and demerits of BLDC Motor.

Advantage:

- There is no field winding so that field copper loss is neglected.
- Better ventilation because of armature accommodated in the stator.
- Small size.
- Regenerative braking is possible.
- Speed can be easily controllable.
- It is possible to have very high speeds.

Disadvantages:

1. Motor field cannot be controlled.

2. It requires a rotor position sensor.

3. It requires a power semiconductor switching circuit.

List the application of BLDC Motor. [2 marks]

What are the application of BLDC Motor.

Application of BLDC Motor

1. Automotive applications.

2. Verticular electric drive motors.

3. Applications in textile and glass industries

4. Computer and Robotics.

5. Small appliances such as fans, mixers etc.

13. Explain the construction and working principle of transformers, with neat diagram. (OR)

Describe in detail about construction & working principle of transformer.

- The transformer works on the principle of electromagnetic induction.
- A transformer is an electrical device, having no moving parts, which by mutul induction transfers electric energy from one circuit to another at the same frequency, usually which change in values of voltage and current.
- It consists of two windings insulated from each other and wound on a common core made up of magnetic material.
- One of the windings called primary is energised by a sinusoidal voltage. The second ending called secondary, feeds the load.

Working principle of a Transformer:

- When the primary winding is connected to an ac source, an exciting current flow through the winding. As the current is alternating, it will produce an alternating flux in the core which will be linked by both the primary and secondary windings.
- The induced emf in the primary winding (E_1) is almost equal to the applied voltage V_1 and will oppose the applied voltage.
- The emf induced in the secondary winding (E_2) can be utilised to deliver power to any load connected across the secondary.
- Thus, power is transferred from the primary to the secondary circuit by electromagnetic induction.
- The flux in the core will alternate at the same frequency of the supply voltage.

Classification of Transformers:

Transformers are classified on the basis of

i) Duty they perform:

1. Power transformer

2. Current transformer

3, Potential transformer.

ii) Construction:

1. Core type transformer
2. Shell type transformer
3. Berry type transformer

iii) Voltage Output:

1. Step down transformer
2. Step up transformer
3. Auto transformer

iv) Application:

1.Welding transformer

2.Furnace transformer

v) Cooling:

1. Duty type transformer.

2.Oil immersed.

vi) Input supply:

1. Single phase transformer.
2. Three phase transformers.

Construction:

The main components of a transformer are

i) The magnetic core

ii) Primary and secondary winding

iii) Insulation of winding

iv) Expansion tank or conservator.

v) Lead and tappings for coils with their supports, terminals and terminal insulators.

vi) Tank oil, cooling arrangement, temperature gauge, oil gauge.

vii) Buchholz relay.

viii) Silica gel breather.

Magnetic Core:

- Magnetic circuit consists of an iron core. The transformer core is generally laminated and is made out of a good magnetic material like silicon steel.
- The thickness of laminations or stampings varies from 0.35 mm to 0.5 mm.
- The lamination is insulated from each other by coating them with a thin coat of varnish.

The two types of transformer cores are

1. Core type

2. Shell type

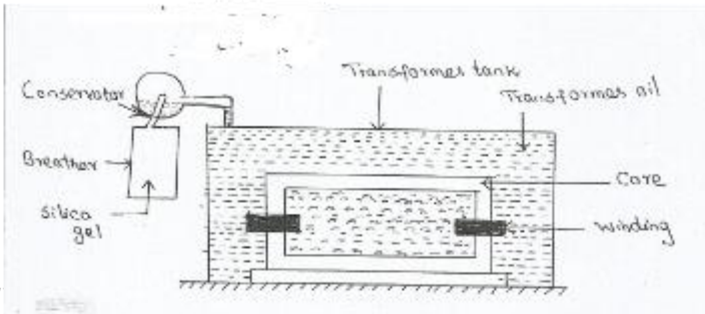


Figure. Transformer.

Windings:

There are two windings in a transformer. They are called primary and secondary windings. Generally, the windings are made of copper.

Insulation:

- Paper is still used as the basic conductor insulation.
- Enamel insulation for low voltage transformer.
- Enamelled copper with paper insulation for power transformers.

Insulating Oil:

- The oil used in transformer protects the paper from dirt and moisture and removes the heat produced in the core and coils.
- It also act as insulating medium.
- The oil must have,
  - i) High dielectric strength
  - ii) Good resistance to emulsion
  - iii) Free from sludging
  - iv) Low viscosity to provide good heat transfer.

Expansion Tank or Conservator:

- A small auxiliary oil tank may be mounted above the transformer and connected to main tank.
- Its function is to keep the transformer tank full of oil despite expansion or contraction of the oil with the changes in temperature.

Temperature Gauge:

- Every transformer is provided with a temperature gauge to indicate hot oil or hottest spot temperature. This indication is done by using alarm contact.

Oil gauge:

- Every transformer is fitted with an oil gauge to indicate the oil level present inside the tank.
- The oil gauge may be provided with an alarm contact which gives an alarm when the oil level has dropped beyond permissible height due to leak or due to any other reason.

Buchholz relay:

- Fault occurred is indicated by the presence of bubble in the oil.
- This gas bubble rise up in pipe.
- Hence an alarm is set in pipe to indicate minor fault.

Breather:

- The breather is filled with some drying agent such as calcium chloride or silica gel. This silica gel absorbs moisture and allow dry ais to enter the transformer tank.

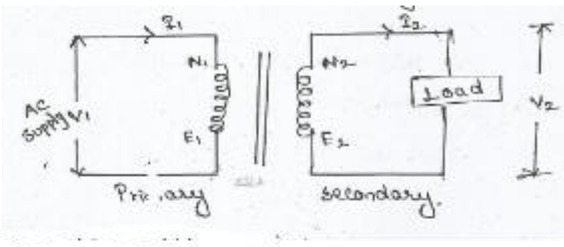
Bushings:

- Connections from the transformer windings are brought out by means of bushing.

14. Derive the expression of Emf induced in a single-phase transformer. [AU]

Write the expression of Emf induced in a transformer.

Consider a transformer arrangement



N_1 – Number of primary turns

N_2 – Number of secondary turns

$\emptyset_m$ – Maximum value of flux in the core in wb

B_m – Maximum value of flux density in the core in wb/m^2

A - Area of the core in m^2

F - Frequency of the AC supply in Hertz

V_1 – Supply voltage across primary in volts.

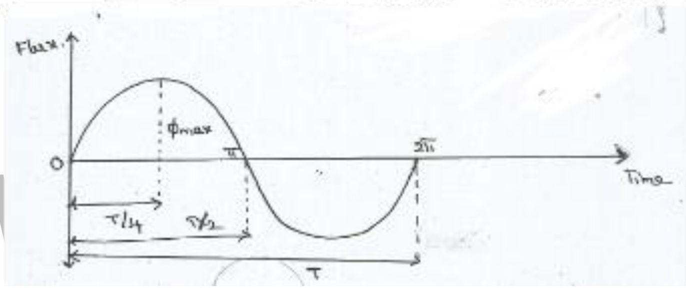
V_2 – Terminal voltage across secondary in volts.

I_1 - Full load primary current in amperes.

I_2 - Full load secondary current in amperes.

E_1 – Emf induced in the primary in volts.

E_2 – Emf induced in the secondary in volts.



We know that $T = \frac{1}{f}$ where f -frequency in HZ.

Average rate of change of flux = $\frac{\emptyset_m}{1/4f}\ wb/seconds$

If we assume single turn coil, the according to Faradays laws of electromagnetic induction, the average value of emf induced/turn = 4f x $\emptyset_m$ volts.

From factor = $\frac{R.M.S\ value}{Average\ value}$ =1.11

Therefore, R.M.S value = Form factor x Average value

Therefore, R.M.S value of emf induced/turn = (1.11) x 4f x $\emptyset_m$

= 4.44 f$\emptyset_m$ volts.

Therefore, R.M.S. value of emf induced in the entire primary winding

$$E_1 = 4.44\ f\emptyset_m\ x\ N_1$$

$$E_1 = 4.44\ f\ B_m\ A\ N_1\ volts$$ ------- (1)

Similarly, R.M.S value of emf induced in the secondary

$E_2 = 4.44\, f\, \emptyset_m N_2\ volts$

$E_2 = 4.44\, f B_m A N_2\ volts$ ------- (2)

Transformation Ratio (K):

For an ideal transformer

$V_1 = E_1;\ \ V_2 = E_2$

and $V_1 I_1 = V_2 I_2$

$\frac{V_2}{V_1} = \frac{I_1}{I_2};\ \frac{E_2}{E_1} = \frac{I_1}{I_2}$ ------ (3)

From equations (2) & (1)

We have

$\frac{E_2}{E_1} = \frac{N_2}{N_1}$ ------- (4)

From equation (3) & (4)

$\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K$ ------- (5)

Where "K" is called transformation ratio

Note:

If $N_2 > N_1$, i.e. K >1 then transformer is a step up transformer.

If $N_2 < N_1$, i.e. K<1, then transformer is a step down transformer.

Voltage ratio = $\frac{E_2}{E_1} = K$

Current ratio = $\frac{I_2}{I_1} = \frac{1}{K}$

15. Mention the simplifying assumptions made to enable a transformer to be treated as an ideal transformer.

[OR]

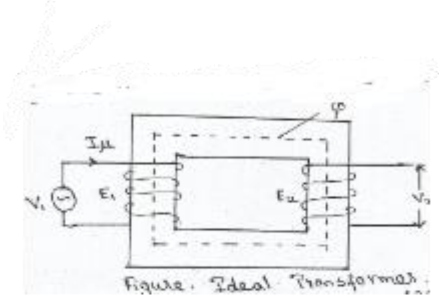
What are the characteristics of an ideal transformer?

Ideal Transformer:

The ideal transformer has the following properties

1. No winding resistance i.e., purely inductive.
2. No magnetic leakage flux.
3. No I^2R loss i.e., no copper loss
4. No core loss

The ideal transformer consists of purely inductive coil loss free core. Windings are wound on core.



Here the ideal transformer secondary is open. The AC supply is connected to the primary winding. A current flow through the primary winding. This current is called magnetising current(I_μ). This current is mainly used to magnetise the core. The value of magnetising current is small. It is lagging V_1 by 90^0.

The current I_μ produces an alternating flux$\emptyset$. I_μ and $\emptyset$ are in phase. This changing flux linking with primary and secondary windings. Due to the alternating flux, a self-induced emf is produced in the primary winding. It is denoted as E_1 and equal to and in opposition to V_1. It is known as counter emf or back emf of the primary windings.

Similarly, an induced emf E_2 is produced in the secondary winding, because the alternating flux in linking with secondary winding. This emf is known as mutually induced emf. This emf E_2 is in opposition to V_1 and its magnitude is proportional to the rate of change of flux and number of secondary turns.

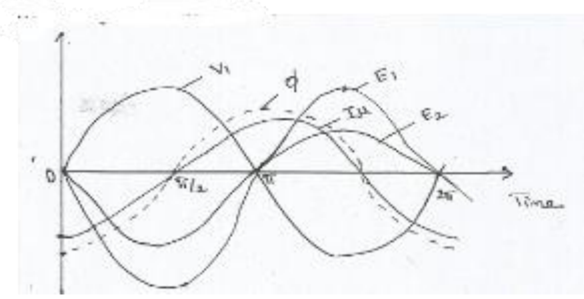


Figure shows input voltage

(V_1) *induced emfs* (E_1, E_2), *flux* $(\emptyset)$ *and magnetising current* (I_u) *wave forms.*

Vector diagram – no load:

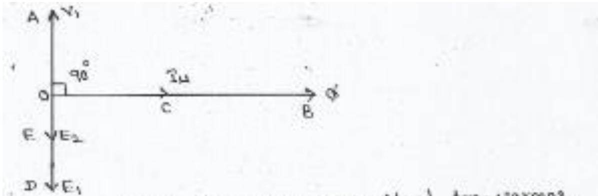


Figure. Phase diagram of an ideal transformer.

Step1: First draw the input voltage line V_1 (OA)

Step2: Draw the flux line ∅ (OB). The angle between V_1

Step3; Draw the magnetizing current I_u (OC). It is in phase with flux.

Step4: Draw the induced emfs E_1 and V_1 is 180^0. i.e., E_1 and V_1 are in opposite directions. (OD and OA)

Step5: Then draw E_2 line. It is in phase with E_1 (OE).

Why is transformer rating given in KVA?

Copper loss depends on current and iron loss depends upon voltage. Hence the total loss in a transformer depends upon volt-ampere (VA) only and not an the phase angle between voltage and current. i.e., it is independent of load power factor. That is why the rating of a transformer is given in KVA and not in KW.

Losses in Transformer:

i) Core or Iron Loss ii) Copper Loss

i) Core or Iron Loss:

- It is caused by the alternating flux in the core.
- It consists of hysteresis loss and eddy current loss.
- Hysteresis loss can be minimized by using steel of high silicon content for the core.
- Eddy current loss can be minimized by using very thin laminations of a transformer core.

ii) Copper Loss:

- This is due to ohmic resistance of the transformer windings.

All-day efficiency:

It is the ratio of energy (in KWh) delivered in a 24 hour period to the energy (in KWh) input for the same interval time.