DC Generator.

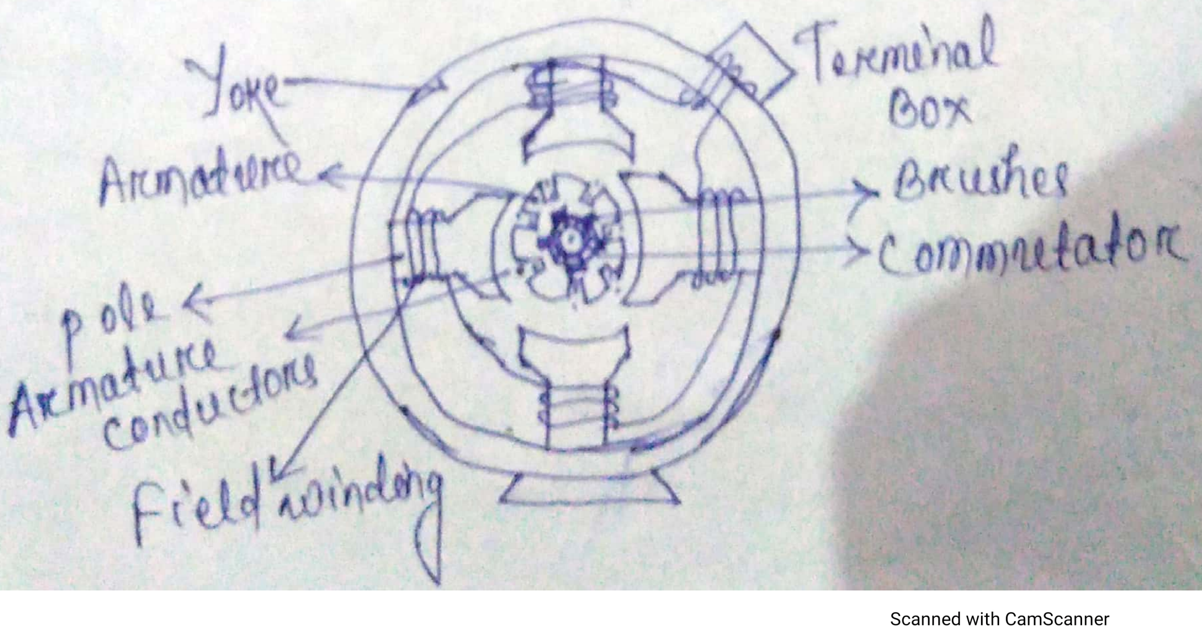
Generator :→ The electrical machine which converts mechanical energy into electrical energy is called generator.

Principle of DC generator :→ It works on the principle of Faraday's law of electromagnetic Induction i.e. whenever any conductor or coil cuts the magnetic lines of force, the emf will be induced in that conductor or coil.

→ The direction of emf generated by the generator can be found by applying Fleming's Right Hand Rule.

I/P Mechanical energy → Generator → O/P Electrical energy

Parts of a DC generator :→



(1) Yoke (Body) :→ It is an outer part of the machine called Yoke or body and made of cast iron or cast steel.

→ It has 2 main functions one is to hold all the other parts of the machine and second to provide magnetic path for the flow of magnetic lines of force.

(2) Field pole :→ It is an internal part of the machine and is fitted with the body with the help of screws or nuts. Every machine has minimum two poles.

→ It consists of two parts called pole cores and pole shoes. Pole cores are made of solid piece of cast iron, cast steel or laminated core but pole shoes are made of laminated core.

→ The electromagnetic coil is fitted in the pole core to provide magnetic lines of force and function of pole shoes are to provide uniform flux.

(3) Armature :→ It is a revolving part of the machine and is made of laminated core having cylindrical shape. The no. of slots are provided on its outer periphery in which suitable winding is done.

(4) Commutator :→ It is cylindrical shaped made of hard drawn copper segments and each segment is insulated by thin layers of mica.

→ Each segment has a raised portion known as riser connection of coil leads.

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→ It is fitted with one side of the armature and its function is to collect current from the coils of armature and converts it into D.C.

(5) Brush :→ To collect the current from the commutator is known as brush.

(6) Cooling Fan :→ It is made of cast iron or aluminium and fitted with the armature shaft opposite to commutator side.

→ Its function is to circulate air and keep the machine cool.

(7) Bearing :→ It is fitted with the side cover and its function is to minimize the friction effect.

(8) Terminal Box :→ Generally it is fixed at one side of the machine having a no. of terminals for armature and field connection.

(9) Shaft and pulley :→ A shaft is made of mild steel which carries the armature, commutator, fan and bearings.

→ The pulley is made of cast iron and is fixed on the shaft by a key stud.

Types of armature windings :→

→ There are two types of armature windings. These are :→

(1) Lap winding

(2) Wave winding

(1) **Lap winding** :→ The winding used to carry more current and less voltage is called lap winding.

→ In this winding the number of poles in the machine is equal to the number of parallel path for current. It is also called parallel winding.

→ The two ends of any armature coil are connected to two adjacent commutator segments.

No. of path = No. of poles	or,	A = P

(2) **Wave winding** :→ The winding used to carry more voltage and less current is called wave winding.

→ In this winding the no. of paths for current are always two, so there are only two carbon brushes irrespective of number of poles.

→ The ends of any coil are connected to commutator segments wide apart.

No. of path = 2	or,	A = 2

No. of path = A and No. of poles = P

comparision between Lap winding and wave winding :→

Lap winding	Wave winding
(1) The parallel paths in the armature are equal in no. of poles (pole) $P = A$(path)	(1) There are only two parallel paths in respective of no. of poles path $(A) = 2$
(2) It is used for high current.	(2) It is used for low current.
(3) It is used for low voltage machines	(3) It is used for high voltage machine.
(4) The number of brush sets is equal to the no. of poles.	(4) The brush sets are used only two..

Emf equation of generator :→

→ As we know that emf generated in the generator is according to laws of Faraday's magnetic induction. So, the emf equation of a generator is as under :→

Let, E = E.M.F induced in generator armature conductor in volt.

P = No. of poles

ϕ = flux per pole in weber (wb)

N = Speed of armature rotation in r.p.m (N/60 in r.p.s)

[r.p.m = Revolution per minute and r.p.s = Revolution per second]

Z = No. of armature conductors
A = No. of parallel paths in armature winding.

Emf generated = Emf generated in one parallel path

cutting of flux per conductor in one revolution = ϕP wb.

cutting of flux per conductor in one second = $\frac{\phi PN}{60}$ wb/sec.

E.M.F generated per conductor = $\frac{\phi PN}{60}$ volts

E.M.F generated per path = $\frac{\phi PN}{60} \times \frac{Z}{A}$ volts

So, the emf generated i.e. Eg is given by,

$$E_g = \frac{\phi ZN}{60} \times \frac{P}{A} \text{ volts}$$

→ In wave winding, The no. of parallel paths (A) are always '2' (A = 2) so,

E.M.F generated per path, $E_g = \frac{\phi ZN}{60} \times \frac{P}{2}$ [∵ A = 2]

$$\Rightarrow E_g = \frac{\phi ZPN}{120} \text{ volts.}$$

→ In lap winding, The no. of parallel paths (A) are equal to the no. of poles (P) i.e. A = P

so, the emf generated per path i.e.

$$E_g = \frac{\phi ZN}{60} \times \frac{P}{P} \quad [∵ A = P]$$

$$\Rightarrow E_g = \frac{\phi ZN}{60} \text{ volts}$$

Example :→ A four pole lap wound shunt generator has 800 armature conductors and runs at the speed of 400 rpm. Find the emf generated. If the flux per pole is 0.05 wb?

Sol^n :→ Given Data :→

Here, $P = 4$

$Z = 800$

$N = 400$ rpm.

$A = 4$ [∵ Lap wound $A = P$]

$\phi = 0.05$ wb

The generated emf, $E_g = \frac{\phi Z N}{60} \times \frac{P}{A}$.

$= \frac{0.05 \times 800 \times 400}{60} \times \frac{4}{4}$

$= 266.6$ Volts (Ans)

Home Work :→

① Q :→ A four pole wave wound shunt generator has 800 armature conductors and runs at the speed of 400 r.p.m. Find the emf generated. If the flux per pole is 0.05 wb ?

② Q :→ A 8 pole generator armature with 400 conductors runs at 1000 rpm. Find the emf generated when flux per pole is 0.06 wb.

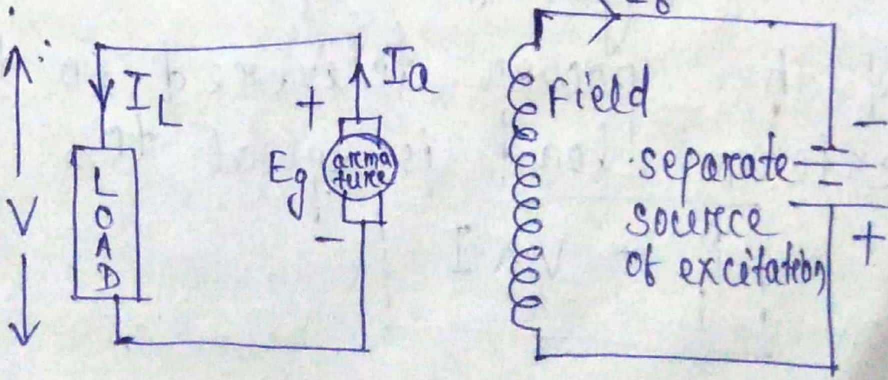
Find :→ ⓐ In case of Lap wound. and ⓑ In case of Wave wound.

Classification of DC generators :→

- DC generators
  - separately excited DC generator
  - self excited DC generator
    - shunt DC generator
    - series DC generator
    - compound DC generator
      - Long shunt compound DC generator
      - Short shunt compound DC generator

separately excited DC generator :→

→ These are the generators whose field magnets are energized by some external DC source, such as a battery.



[separately excited DC generator]

→ In separately excited DC generator,

I_a = Armature current

I_L = Load current

V = Terminal voltage

E_g = Generated EMF.

→ The voltage drop in the armature,

$$V = I_a \times R_a$$

$$\Rightarrow \boxed{V = I_a R_a}$$

Here, $I_a = I_L = I$ (say)

and the voltage across the load,

$$\boxed{V = I R_a}$$

Where, R_a = armature resistance

Power generated is given by,

$$\boxed{P_g = E_g \times I_a}$$

And the power delivered to the external load is equal to,

$$\boxed{P_L = V \times I}$$

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Self excited DC generators :→

→ These are the generators whose field magnets are energized by the current supplied by themselves.

→ In these type of machines, the field coils are internally connected with the armature.

→ Due to residual magnetism, some flux is always present in the poles. When the armature is rotated, some emf is induced. Hence some induced current is produced.

→ This small current flows through the field coil as well as the load and thereby strengthening the pole flux.

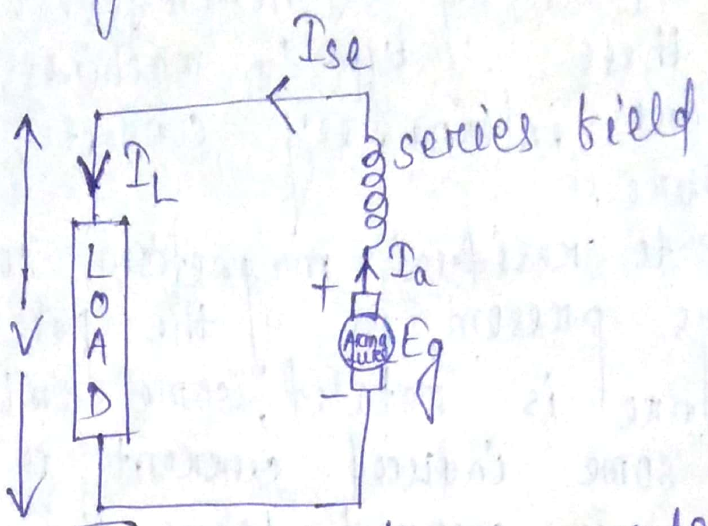
→ As the pole flux strengthened, it will produce more armature emf, which cause the further increase of current through the field. This increased the field current further raises the armature emf and this cumulative phenomenon continues until the excitation reaches the rated value.

→ According to the position of the field coils, self-excited DC generators may be classified as :-

(1) series wound DC generators
(2) shunt wound DC generators
(3) compound wound DC generators.

(1) Series wound DC generators :→

→ In these type of generators, the field windings are connected in series with the armature conductors.



[Series wound DC generator]

→ Here, the whole current flows through the field coils as well as the load. As the series field winding carries the full load current it is designed with relatively few turns of thick wire. The electrical resistance of the series field winding is therefore very low (nearly 0.5Ω).

→ Here, R_{se} = series winding / series field resistance.

I_{se} = series field current / the current flowing through the series field.

R_a = Armature resistance

I_a = Armature current

I_L = Load current

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V = Terminal voltage

E_g = Generated EMF

Then, $I_a = I_{se} = I_L = I$ (say)

voltage across the load is,

$$V = E_g - I_a R_a$$

$$\Rightarrow E_g = V + I_a R_a$$

power generated is given by,

$$P_g = E_g \times I$$

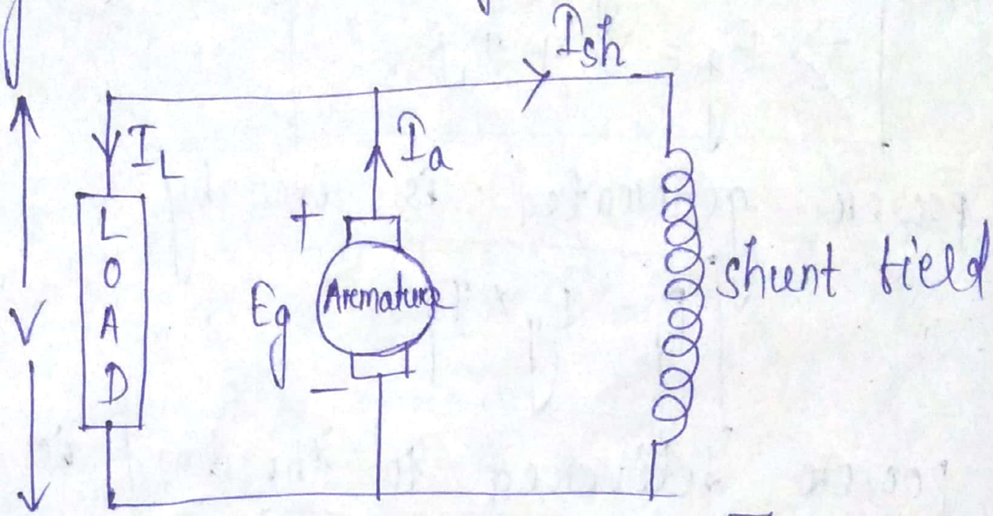
power delivered to the load is given by,

$$P_L = V \times I = VI$$

(2) Shunt wound DC generators :→

→ In these type of DC generators, the field windings are connected in parallel with the armature conductors.

→ In shunt wound generators the voltage in the field winding is same as the voltage across the terminal.



[Shunt wound generator]

Here, R_{sh} = shunt field / shunt winding resistance.

I_{sh} = shunt field current or the current flowing through the shunt field.

R_a = armature resistance

I_a = armature current.

I_L = Load current.

V = Terminal voltage

E_g = Generated EMF

→ Here, the armature current I_a is dividing in two parts :- One is shunt field current 'I_{sh}' and another is the load current 'I_L'.

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

→ The effective power across the load will be maximum when 'I_L' will be maximum. So, it is required to keep shunt field current as small as possible. For this purpose the resistance of the shunt field winding generally kept high (100 Ω) and large no. of turns are used for the desired EMF.

→ The shunt field current is equal to,

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

→ Voltage across the load is given by,

$$V = E_g - I_a R_a$$
$$\Rightarrow E_g = V + I_a R_a$$

→ power generated is, $P_g = E_g \times I_a$

→ power delivered to the load is,

$$P_L = V \times I_L$$

(3) Compound Wound DC generator :→

→ In series wound generators, the output voltage is directly proportional with the load current. In shunt wound generators, the output voltage is inversely proportional with load current.

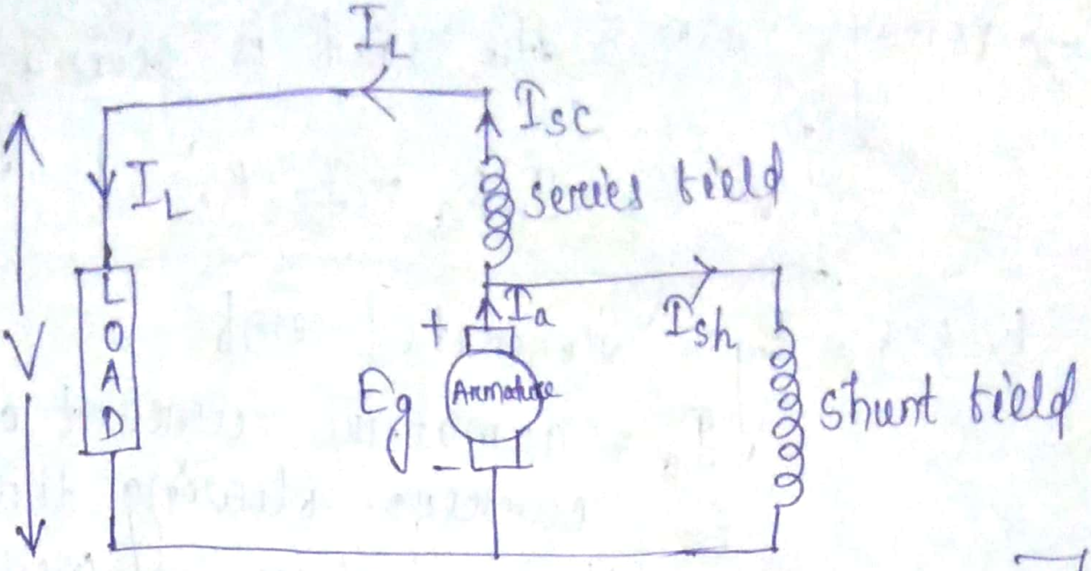
→ A combination of these two types of generators can overcome the disadvantages of both. This combination of windings is called compound wound DC generator.

→ Compound wound generators have both series field winding and shunt field winding. One winding is placed in series with the armature and the other is placed in parallel with the armature. This type of DC generators may be of 2 types :-

(1) short shunt compound wound generator and (2) Long shunt compound wound generator.

(1) short shunt compound wound DC generator :→

→ These are the generators where only the shunt field winding is in parallel with the armature winding, and both are in series with the series field winding as shown in the figure below.



[short shunt compound wound generator]

→ The series field current is given by,

$$I_{se} = I_L$$

Where, I_{se} = Series field current

I_L = Load current.

→ The shunt field current is given by,

$$I_{sh} = \frac{(V + I_{se} R_{se})}{R_{sh}}$$

Where, I_{sh} = shunt field current

V = Terminal voltage

R_{se} = series field resistance

R_{sh} = shunt field resistance

I_{se} = series field current

→ voltage across the load is given by,

$$V = E_g - I_a R_a - I_{se} R_{se}$$

Where, E_g = Generated emf

I_a = armature current or the current flowing through the armature winding.

R_a = armature Resistance.

→ The power generated is given by,

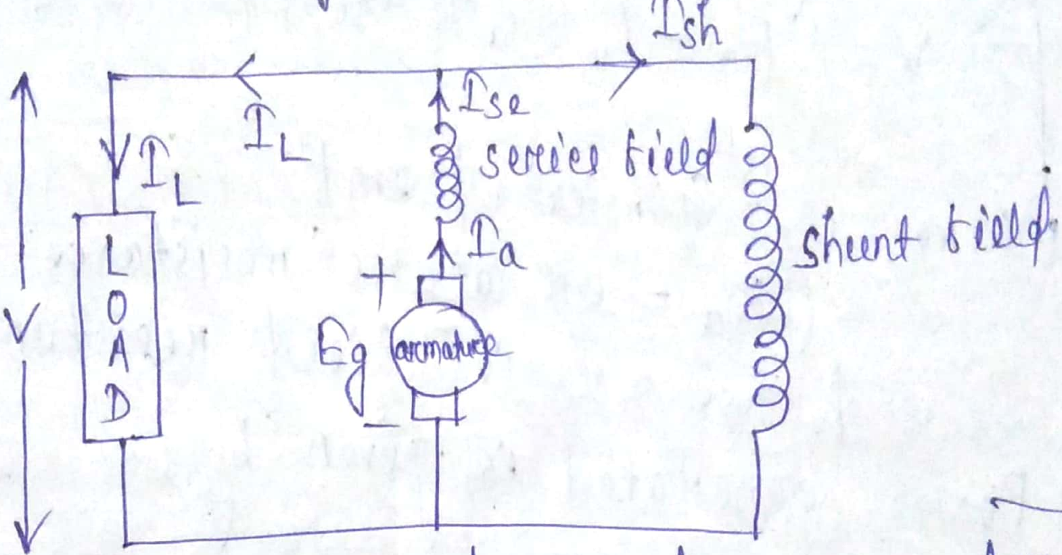
$$P_g = E_g \times I_a$$

→ Power delivered to the load is given by,

$$P_L = V \times I_L$$

(2) Long shunt compound wound DC generator :→

→ Long shunt compound wound DC generator are the generators where the shunt field winding is in parallel with both the series field winding and the armature winding.



Long shunt compound wound DC generator

→ Here, the shunt field current is given by,

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

Where, I_{sh} = shunt field current
V = Terminal voltage
R_{sh} = shunt field resistance

Here, the armature current, (I_a) = the series field current, (I_{se})

$$\Rightarrow I_a = I_{se}$$

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

where, I_L = Load current

→ Voltage across the load is equal to,

$$V = E_g - I_a R_a - I_{se} R_{se}$$

$$\Rightarrow V = E_g - I_a (R_a + R_{se}) \quad [\because I_a = I_{se}]$$

where, E_g = Generated emf

R_a = armature resistance

and R_{se} = series field resistance.

→ Power generated is given by,

$$P_g = E_g \times I_a$$

→ Power delivered to the load is given by,

$$P_L = V \times I_L$$

→ In a compound wound generator, the shunt field is stronger than the series field. When the series field assists the shunt field, generator is said to be cummulatively compound wound generator.

→ On the other hand, if the series field opposes the shunt field, the generator is said to be differentially compound wound generator.

Characteristics of DC generator :→

→ The characteristic curves of a dc generator are discussed below :→

(i) Open circuit characteristic curve (OCC) :→

→ Sometimes, it is also called as no load or magnetic characteristic curve. This curve gives the relation between the emf generated (E_g) in the armature and the field current (I_f) at the rated speed.

(ii) Internal characteristic curve (ICC) :→

→ This curve is also known as the total characteristic curve and gives the relation between the emf generated (E_g) and the armature current (I_a) of the generator.

(iii) External characteristic curve (ECC) :→

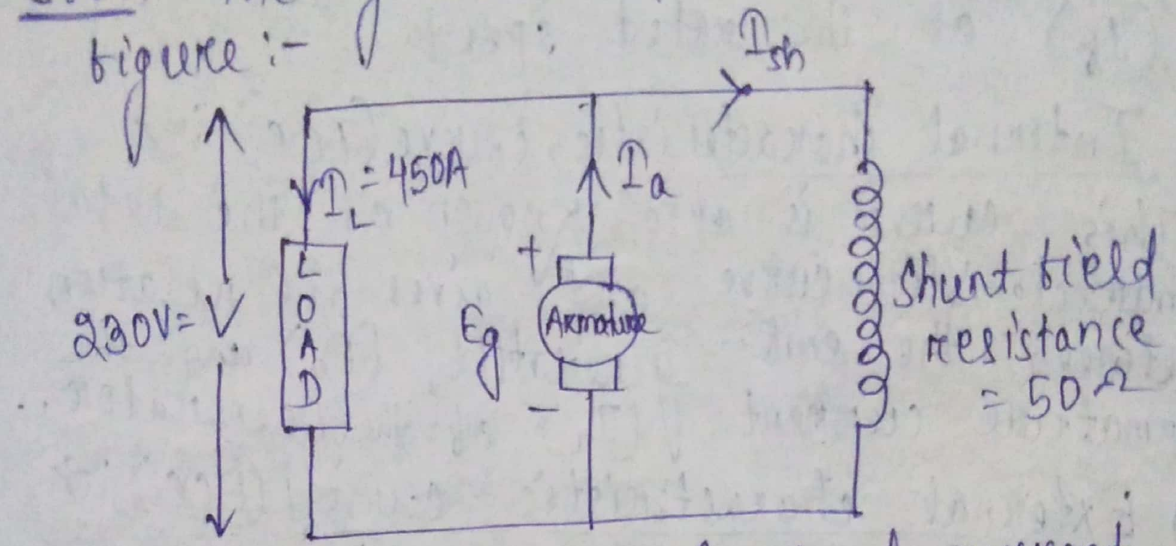
→ This curve gives the relation between the load current (I_L) and the terminal voltage (V).

DC generator

PROBLEMS :→

(1) Q:→ A shunt generator delivers 450 A at 230 V and the resistance of the shunt field and the armature are 50 Ω and 0.03 Ω respectively. Calculate the generated emf?

Sol^n:→ The generator ckt is as shown in the figure :-



Given Data :→ I_L = 450 A = Load current.

Terminal voltage = V = 230 V

Shunt field resistance = R_{sh} = 50 Ω

armature resistance = R_a = 0.03 Ω

generated emf = E_g = ?

Sol^n :→

We know, $E_g = V + I_a R_a$

Here, the value of 'V' and 'R_a' is known are given to us. But we don't know the value of 'I_a'.

↳ These are not necessary for exam. But for your understanding I'm writing that part.

We know that,

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

Here, $I_{sh} = \frac{V}{R_{sh}} = \frac{230}{50} = 4.6\ A$.

Now, $I_a = 450 + 4.6 = 454.6\ A$.

The armature voltage drop,

$I_a R_a = 454.6 \times 0.03 = 13.6\ V$

Now, Generated emf is,

$E_g = V + I_a R_a$

$= 230 + 13.6 = 243.6\ V$.

$\Rightarrow \boxed{E_g = 243.6 V}$ (Ans)

Questions :→

① A shunt generator supply 240 V and delivers 96 A. is having the armature resistance is 0.15 Ω and the shunt field resistance is 60 Ω. find the armature current and the generated emf ?

② A shunt generator supplies a load of 10 KW at 250 V through a pair of feeders of total resistance 0.07 Ω. The resistance of the armature and shunt field windings are 0.05 and 63.2 Ω respectively. Find :→ (a) The terminal voltage ?

(b) the emf generated in the armature

Hints given:-> Here the load current,

$$I_L = \frac{W}{V} = \frac{Power}{voltage} = \frac{10KW}{250V}$$

and 1KW = 1000 watt.

and 10 KW = 10 × 1000 Watt.

$$so, \; I_L = \frac{10KW}{250V} = \frac{10 \times 1000}{250} = 40A$$

$$\Rightarrow \boxed{I_L = 40A}$$

(3) Q:-> A short-shunt compound DC generator supplies 80A at 200V. If the field resistance, $R_{sh} = 40\Omega$, the series resistance, $R_{se} = 0.02\Omega$ and the armature resistance, $R_a = 0.04\Omega$ determine the e.m.f generated?

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DC Motor.

DC Motor :→ The electrical machine which converts the DC electrical energy in to a mechanical energy.

I/p → Motor → O/p

Electrical energy → Motor → Mehanical energy

Principle of DC Motor :→

→ When a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. In other words, when a magnetic field and an electric field interact, a mechanical force is produced.

→ The DC motor ore direct current motor works on the principle is known as the motoring action.

→ The direction of rotation of a DC motor is given by Fleming's left hand Rule.

→ structurally and construction wise a DC Motor is exactly similar to a DC generator, but electrically it is just the opposite of the generator.

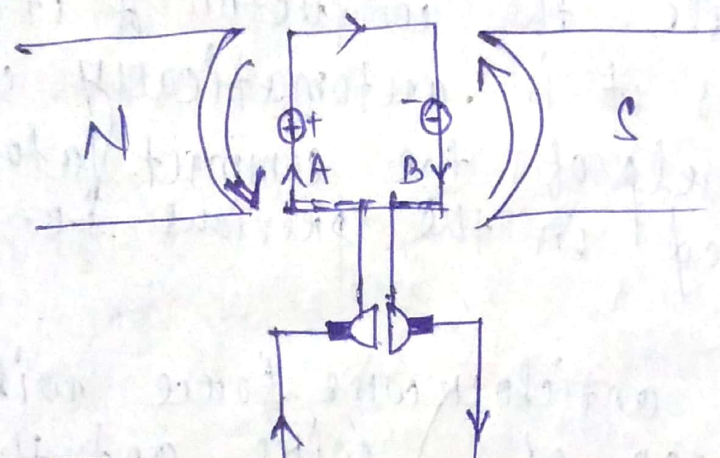
→ Here we unlike a generator we supply electrical energy to the input port and derive the mechanical energy from the output port.

→ So, we can well understand that motor is just opposite to the phenomenon of a DC generator, and we can derive both motoring and generating operation from the same machine by simply reversing the ports of the machine.

DC MOTOR

Working principle of a DC Motor:→

→ The working of a DC Motor depends upon the principle that when a current carrying conductor is kept in a magnetic field, a force acts on the conductor which tends to rotate it. How this force acts and produces a contineous motion is explained below:-



Force acting on a current carrying conductor

→ A sectional view of a loop of wire is shown under the north and south poles. The current in conductor 'A' is shown inward while in conductor B it is outward. A force will act on both conductors A and B which will tend to rotate the loop in the anticlockwise direction as given by the Fleming's Left Hand Rule.

→ This force will act till the conductors are in the magnetic field. Therefore to obtain a continuous motion, many conductors are placed such that if one leaves the magnetic field, another enters it.

→ When loop AB starts rotating, after a very short time, conductor 'B' will come under the north pole and conductor A under the south pole.

→ Now, the current in conductor B is inward, while the conductor A it is outward as it is automatically changed with the help of the commutator as explained in the previous i.e. DC generator.

→ Again an anticlockwise force will act on the loop of wire and thus a continuous motion in the anticlockwise direction will be obtained in this case. The dc motors are usually partial or complety enclosed as they are ~~operate~~ required to operate on rough work such as four mills, saw mills etc.

DC MOTOR

Terms used in DC MOTORS :→

Back emf or counter emf :→ When the armature of a motor (carrying a conductor) rotates in a magnetic field, an emf is generated in its conductor according to the Faraday's laws of electromagnetic induction. This emf generated in the conductor acts in opposition to the applied voltage (V), and is therefore called the back emf or counter emf represented by 'E_b'. Its value is always less than the applied voltage.

→ The back emf is induced due to the motion of the conductors in the magnetic field, and therefore its value is determined by the emf equation of the generator i.e. given by,

$$E_b = \frac{\phi Z N}{60} \times \frac{P}{A} \; V$$

Here, E_b = Back emf or counter emf

ϕ = flux per pole in weber (wb)

P = No. of poles

N = speed of armature rotation in r.p.m. [revolution per minute].

Z = No. of armature conductors.

A = No. of parallel paths in the armature winding.

→ This equation is also called as the emf equation of a DC Motor. The procedure is also same as the equation of DC generator.

→ The back emf (E_b) is always less than the applied voltage (V) because if it becomes equal to it, no current will flow through the armature and thus the motor action will stop. The current through the armature is due to the net emf acting on the armature. Therefore:-

$$E_b = V - I_a R_a$$

$$\Rightarrow V = E_b + I_a R_a$$

and $$I_a R_a = V - E_b$$

$$\Rightarrow I_a = \frac{V - E_b}{R_a}$$

Where, E_b = Back emf

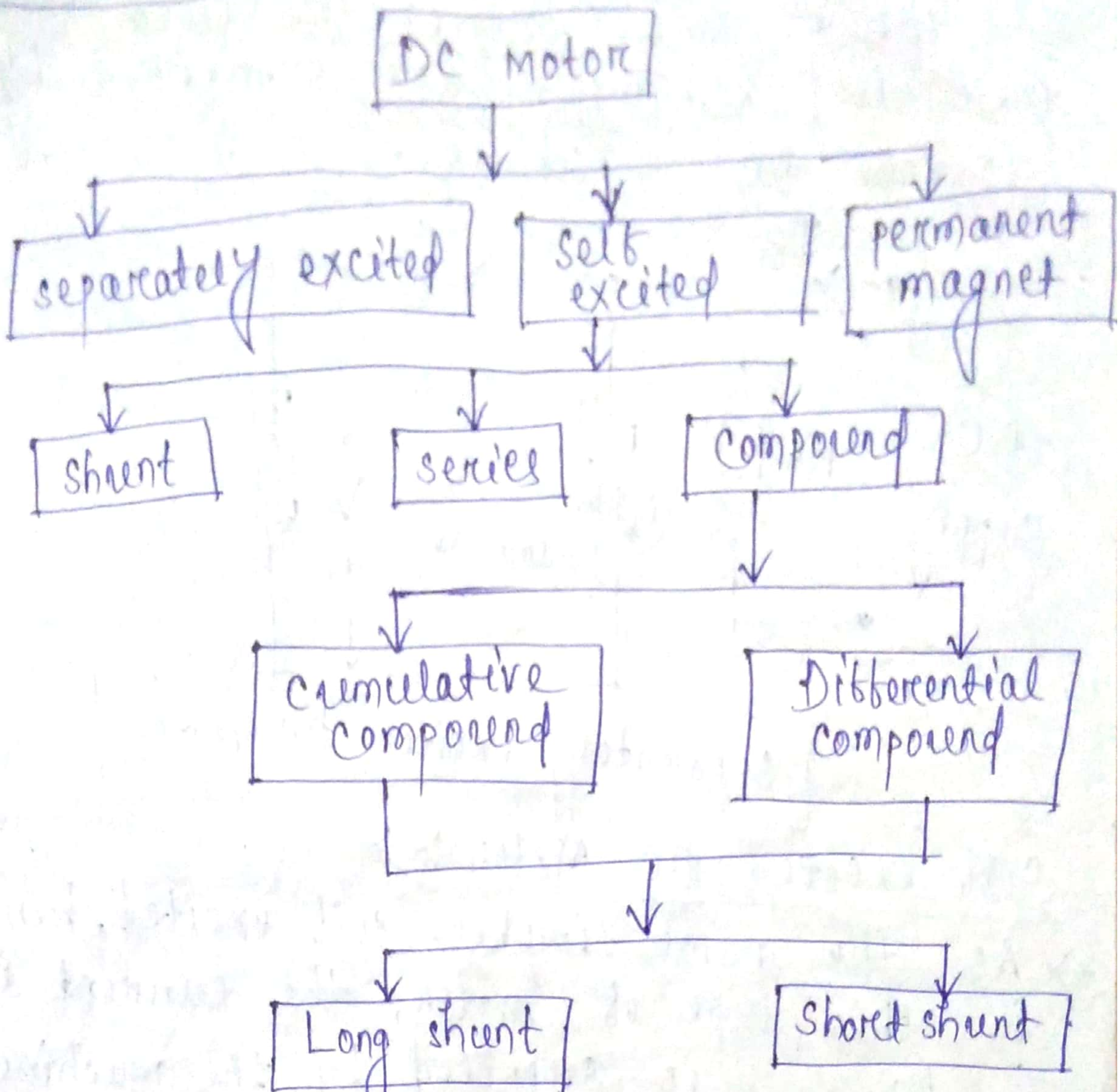
V = applied voltage

I_a = armature current.

R_a = armature Resistance

$I_a R_a$ = armature drop

Classifications of DC Motor :→

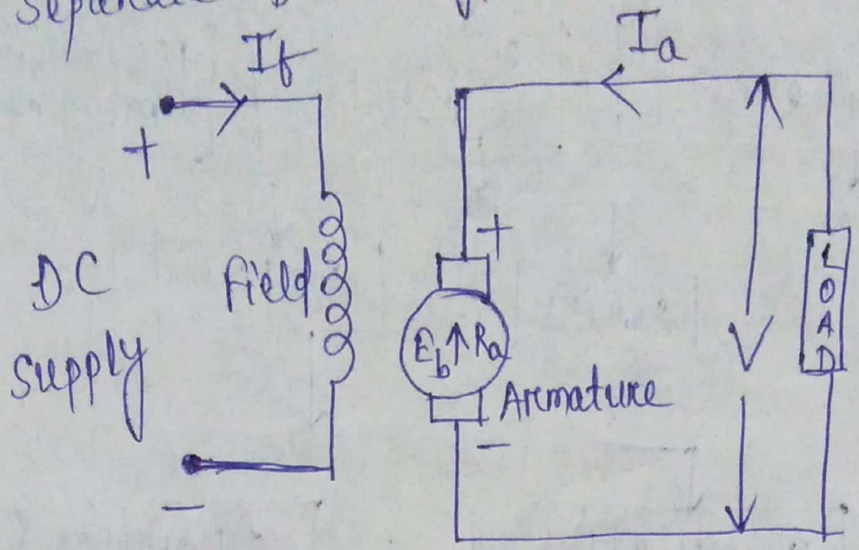


→ A DC motor, DC is named according to the connection of the field winding with the armature. Mainly there are 2 types of DC Motors. First one is separately excited DC Motor and self-excited DC motor.

→ The DC motor is generally used in the location where require protective encloser, for example :- the fire proof etc. according to the requirements.

Separately Excited DC Motor :→

→ As the name signifies, the field coils or the field windings are energized by a separate DC source.



[separately excited DC motor]

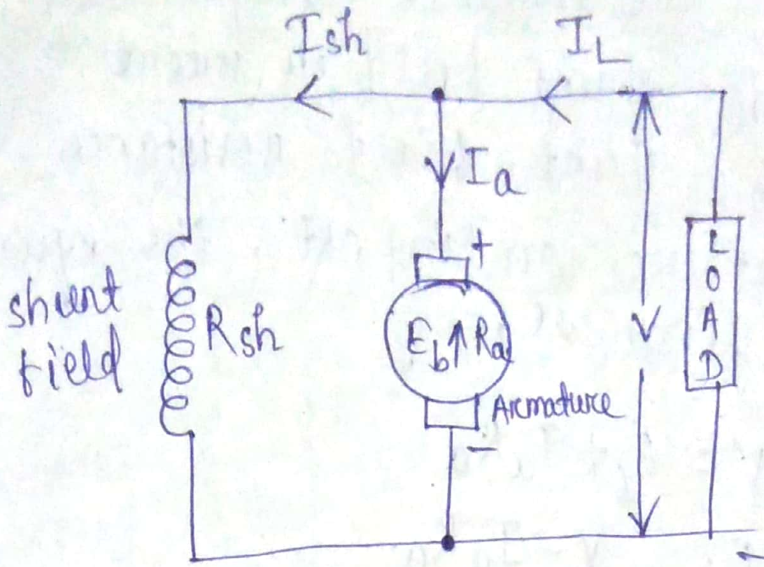
Self excited DC Motor :→

→ As the name implies self-excited, hence, in this type of motor, the current in the windings is supplied by the machine or the motor itself.

→ It is further divided into 3 parts.
These are :→ (1) shunt wound DC Motor
(2) series wound DC motor
(3) compound wound DC motor.

(1) Shunt wound DC Motor :→ This is the most common types of DC motor. Here the field winding is connected in parallel with the armature winding.

Shunt wound DC Motor :→



[shunt wound DC Motor]

→ Here, By applying the KCL at the junction, it is given by,

The sum of the incoming currents at the junction = sum of the outgoing currents at the junction.

So, $\boxed{I = I_a + I_{sh}}$ → This is the current equation.

i.e. $I_L = I_a + I_{sh}$

Where, $I = I_L$ = the input line current or the load current.

I_a = armature current.

I_{sh} = shunt field current or the current flowing through the shunt field winding.

→ The voltage equations are written by using KVL for the field winding ckt,

i.e. $V = I_{sh} \cdot R_{sh}$.

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

Where, V = The terminal voltage
I_{sh} = shunt field current
R_{sh} = shunt field resistance.

→ For armature winding ckt, the equation will be given as,

$$V = E_b + I_a R_a$$
$$\Rightarrow E_b = V - I_a R_a$$

Where, E_b = Back emf
I_a = armature current
R_a = armature resistance.

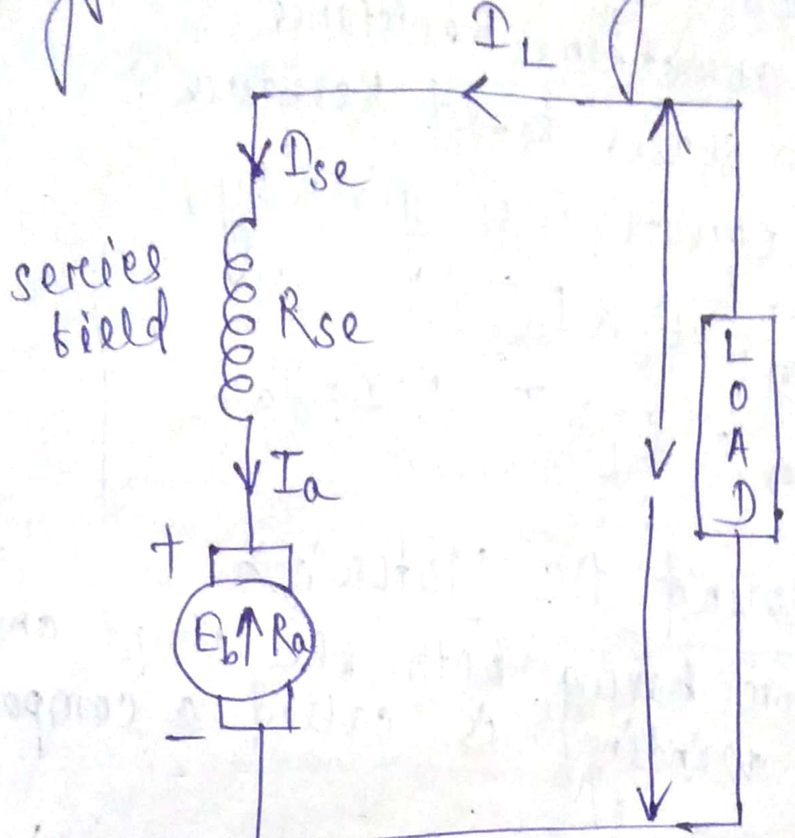
→ The power equation is given by,

$$P_m = E_b \times I_a$$

and "VI_a" is the electrical power supplied to the armature of the motor.

Series wound DC Motor :→

→ In the series wound DC motor, the field winding is connected in series with the armature winding. The connection diagram is given below:-



[series wound DC Motor]

→ By applying KCL in the above figure we get,

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

where, I_L = Load current.

I_{se} = series field current or the current flowing through the series field winding.

I_a = armature current.

→ The voltage equation can be obtained by applying KVL in the above figure, we get,

$$V = E_b + I(R_a + R_{se})$$

Where, V = Terminal Voltage
E_b = Back emf
R_a = armature Resistance
R_{se} = series field Resistance.

→ The power equation is given by,

$$P_m = E_b \times I_a$$
$$\Rightarrow P_m = E_b \times I \quad \because I = I_a$$

Compound Wound DC Motor :→

→ A DC motor having both the shunt and series field winding is called a compound motor.

→ It is further subdivided as cumulative compound DC Motor and Differential compound DC motor.

→ In cumulative compound motor the flux produced by both the windings is in the same direction i.e.

$$\phi = \phi_{sh} + \phi_{se}$$

→ In Differential compound motor, the flux produced by the series field winding is opposite to the flux produced by the shunt field winding i.e.

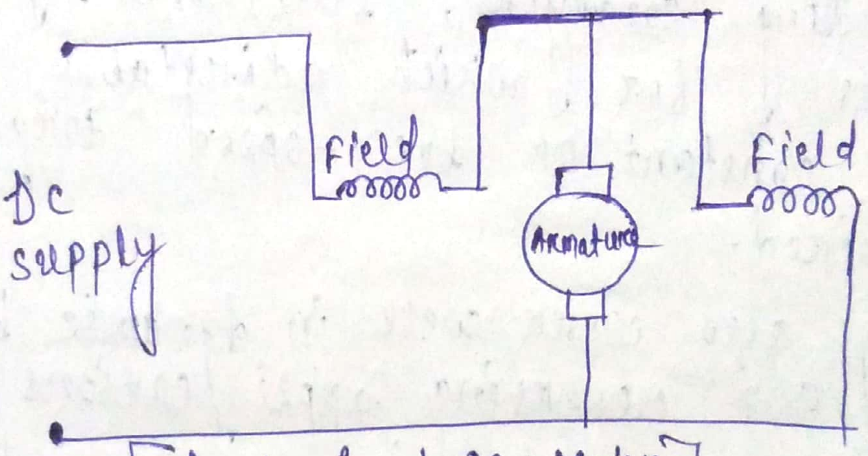
$$\phi = \phi_{sh} - \phi_{se}$$

Compound Wound DC Motor :→

→ Both the cumulative compound and the differential compound DC motor can either be of short shunt or long shunt type depending on the nature of arrangement.

Short Shunt DC Motor :→

→ If the shunt field winding is only parallel to the armature winding and not the series field winding then it is known as short shunt DC Motor or more specifically short shunt type compound wound DC motor.

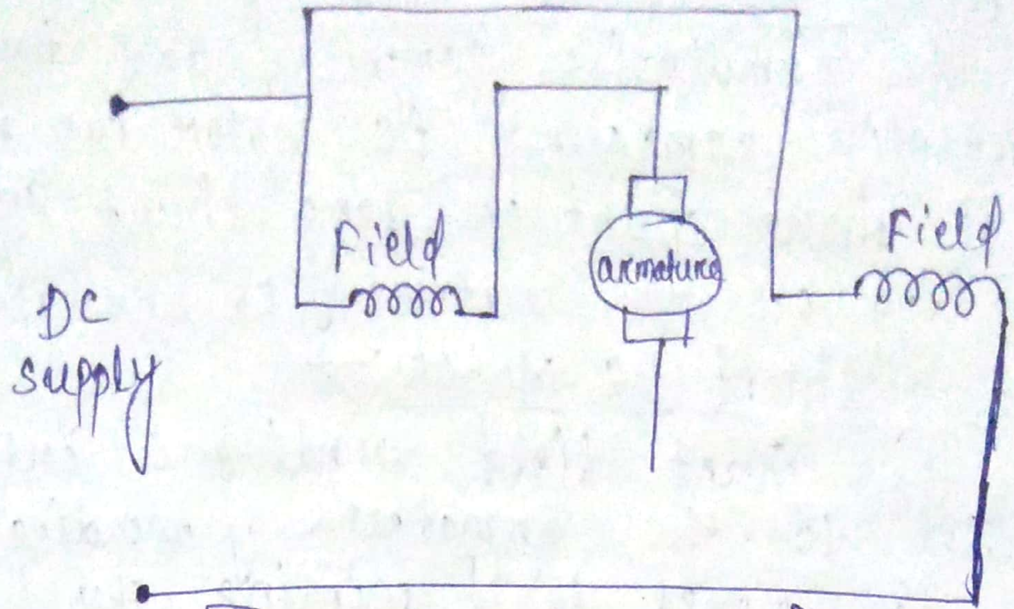


[short shunt DC Motor]

Long shunt DC Motor :→

→ If the shunt field winding is parallel to both the armature winding and the series field winding then it is known as long shunt type compounded wound DC motor or simply long shunt DC motor.

→ The ckt diagram is given below :-



[Long shunt DC Motor]

Applications of DC Motors :→

→ DC motors are suitable for many applications including conveyors, turntables and others for which adjustable speed and constant or low-speed torque are required.

→ They also work well in dynamic barking and reversing applications, which are common in many industrial machines.

Advantages of DC Motor :→ DC motors have the advantage of higher starting torque, quick starting and stopping, reversing, variable speeds with voltage input and they are easier and cheaper to control than AC.

→ AC motor advantages include :- lower power demand on start and minimal maintenance purposes.

Torque in a DC Motor :→ Torque may be defined as the turning or twisting moment of force about an axis. It is measured by the product of force and radius at which the force acts. Therefore,

$$\boxed{\text{Torque} = T = F \times r}$$

Where, F = Force acting in Newtons
r = radius in Meters
T = Torque developed in Newton Meters (Nm).

Armature Torque :→ Every armature conductor of a DC motor lying under a pole produces a torque, which tends to rotate the motor. The sum of all these torque is called the armature torque or the gross torque.

Let, Ta is the armature torque, and the power developed in the armature is also $E_b I_a$.

So, $$E_b I_a = \frac{2\pi T_a N}{60}$$

$$\Rightarrow \boxed{T_a = \frac{E_b I_a \times 60}{2\pi N} = \frac{9.55 \times E_b I_a}{N} \text{ Nm.}}$$

Where, T_a = armature torque
E_b = Back emf
I_a = armature current
N = speed of rotation of the armature in RPM.

(RPM = Revolution per minute)

Shaft torque :→ The shaft torque (T_{sh}) is the most and the net torque available at the pulley for doing useful work while the armature torque is the total torque developed in the motor.

→ The shaft torque is a little less than the armature torque because some power is used in overcoming the stray losses (i.e. iron loss and friction loss).

$$\boxed{T_a \propto I_a \phi}$$ → Torque eqⁿ of a DC Motor.

where, T_a = armature torque produce in Nm.
I_a = armature current.
ϕ = field flux per pole in wb.

This is called the torque of a DC motor. This means that the torque of a DC motor is directly proportional to the armature current and the field flux. Heavier the load on a motor, greater will be the torque exerted by the armature conductors, and stronger the field flux of the motor, more will be the torque developed.

Speed of a DC Motor :→

speed, $$\boxed{N \propto \frac{E_b}{\phi}}$$

N = speed of the armature rotation in rpm.
E_b = Back emf and ϕ = field flux per pole.

Characteristics of DC Motor :→ The characteristic curves of a motor are the curves which show the relation between the armature current, speed and torque. The following are the characteristic curves of a motor :—

(i) Torque and Armature current characteristic (T/Ia characteristic) :→ This characteristic is also known as the electrical characteristic and shows the relation between torque developed and armature current (Ia) of the motor.

(ii) Speed (N) and Armature current (Ia) characteristic :→ This curve shows the relation between the speed and the armature current (Ia) of the motor.

(iii) Speed (N) and Torque (T) characteristic :→ This characteristic is also known as the mechanical characteristic and it shows the relation between the speed and the torque developed of a motor.

Efficiency of DC Motor :→ The efficiency of a motor is equal to the output developed by the motor divided by the electrical input of the motor i.e. the input minus the losses divided by the input. The efficiency can be calculated in the same way as for the generator.

$$\text{Efficiency} = \eta = \frac{\text{output}}{\text{input}} = \frac{\text{input} - \text{losses}}{\text{input}}$$

$$\%\ \text{efficiency} = \frac{\text{output}}{\text{input}} \times 100\ \%$$

→ Efficiency in the case of motors can also be classified as in the case of generators as follows :→ (i) Mechanical efficiency
(ii) electrical efficiency
and (iii) commercial efficiency.

(i) Mechanical efficiency $(\eta_m) = \dfrac{\text{motor output}}{\text{mechanical power developed}}$.

(ii) Electrical efficiency (η_e) is,

$$\eta_e = \frac{\text{mechanical power developed}}{\text{electrical power input}} = \frac{E_b I_a}{V_L I_L}$$

(iii) commercial efficiency (η_c) is,

$$\eta_c = \frac{V}{I} = \frac{\text{motor bhp}}{\text{electrical power input}}$$

hp = horse power 1 hp = 746 Watt.

The value of bhp $= \dfrac{2\pi T_a N}{60}$ Watt

Applications of DC Motors :→

→ Series motors are used where high starting torque is required such as in electric trains, trams, cranes, lifts, conveyors etc.

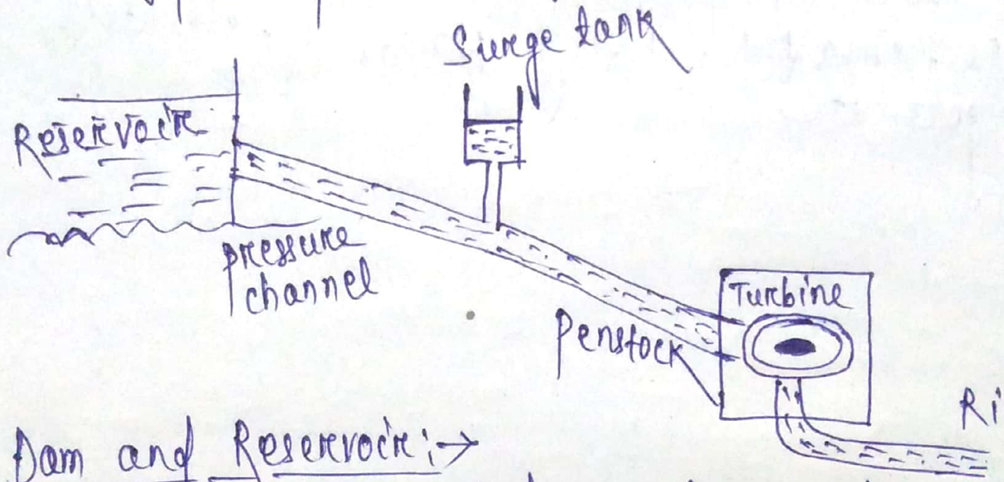
→ Shunt motors are used where constant speed is required at low starting torque, such as in wood working machines, water pumps, blowers, lathes etc.

→ DC cumulative compound motor is used where intermittent high starting torque is required as rolling mills, heavy tool machines, big presses, printing machines, punches, shears, heavy planners, elevators, conveyors etc.

Hydroelectric power plant : Layout, Working & Types

→ Generation of electricity by hydro-power (potential energy in stored water) is one of the cleanest methods of producing electric power. In 2012, hydroelectric power plants contributed about 16% of total electricity generation of the world. Hydroelectricity is the most widely used form of renewable energy. It is a flexible source of electricity and also the cost of electricity generation is relatively low.

Layout and Working of Hydroelectric powerplant :→



Dam and Reservoir :→
The dam is constructed on a large river in hilly areas to ensure sufficient water storage at height. The dam forms a large reservoir behind it. The height of water level (called as water head) in the reservoir determines how much of potential energy is stored in it.

Control gate :→ Water from the reservoir is allowed to flow through the penstock to the turbine. The amount of water which is to be released in the penstock can be controlled by a control gate. When the control gate is fully opened, maximum amount of water is released through the penstock.

Penstock :-> A penstock is a huge steel pipe which carries water from the reservoir to the turbine. Potential energy of the water is converted into kinetic energy as it flows down through the penstock due to gravity.

Water Turbine :-> Water from the penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator. Kinetic energy of the water drives the turbine and consequently the generator gets driven. There are two main types of water turbine ; (i) impulse turbine and (ii) Reaction turbine. Impulse turbines are used for large heads and reaction turbines are used for low and medium heads.

generator :-> A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

Surge Tank :-> Surge tanks are usually provided in high or medium speed or head powerplants when considerably long penstock is required. A surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the power house. The water level in the surge tank rises or falls to reduce the pressure swings in the penstock. When there is sudden reduction in load on the turbine, the governer closes the gates of the turbine to reduce the water flow. This causes pressure to increase abnormally in the penstock. This is prevented by using a surge tank, in which the water level rises to reduce the pressure. On the other hand, the surge tank provides excess water needed when the gates are suddenly opened to meet the increased load demand.

Advantages of a hydroelectric power plant:→

(i) No fuel is required as potential energy is stored water is used for electricity generation.
(ii) Neat and clean source of energy.
(iii) Very small running charges- as water is available free of cost.
(iv) Comparatively less maintenance is required and has longer life.
(v) Serves other purposes too, such as irrigation.

Disadvantages:→

(i) Very high capital cost due to construction of dam.
(ii) High cost of transmission- as hydroplants are located in hilly areas which are quite away from the consumers.