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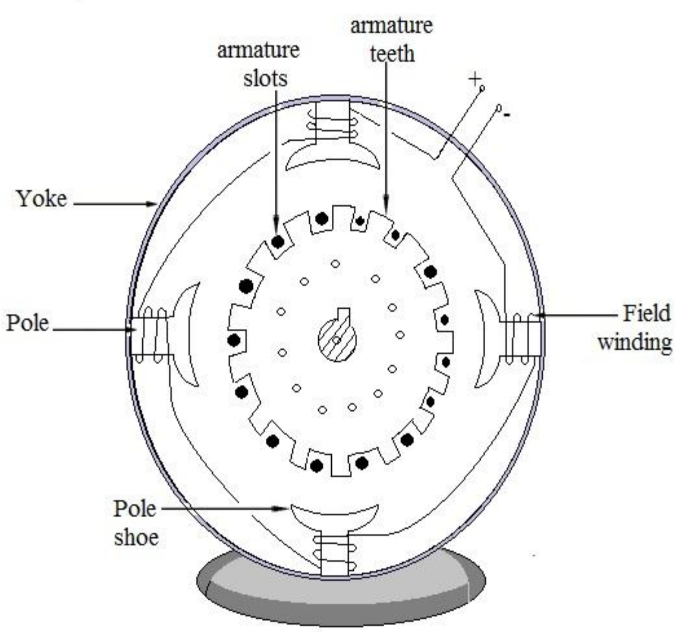
D.C. GENERATOR

- Generator Principle:- An electrical generator is a machine which converts mechanical energy into electrical energy.



- Practical Generator:- the actual generator has following essential parts:

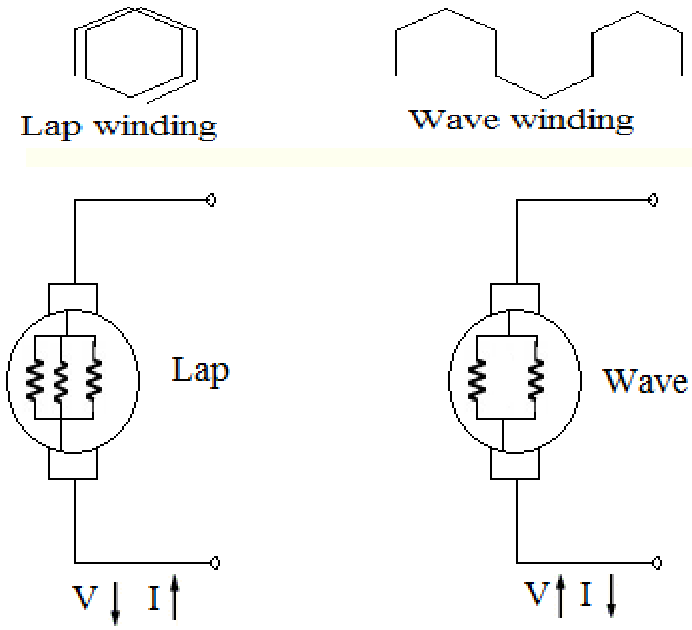
- Magnetic frame OR yoke:- It provides mechanical support for the poles and acts as a protecting cover for the whole machine. It carries the magnetic flux produced by the poles.

- Pole core and pole shoe:- Pole shoe spread out the flux in the air gap and being of larger cross-section, reduce the reluctance of magnetic path. They also support the exciting coils.

- Pole coil OR field coil:- The field coils are made up of copper wire or strip, which are wounded on a rectangular frame for the correct dimension. Then the frame is removed and wounded coil is put into place over the core where current passes through it, they electromagnetise the poles which produce the flux that is cut by revolving armature conductors.

- Armature core:- It houses the armature conductor or coils and causes them to rotate and hence cut the magnetic flux of the field magnets. Tis important function is to provide a path of very low reluctance to the flux through the armature from a N – pole to a S – pole.

- <u>Lap and Wave winding</u>:-



→ The wave winding gives more e.m.f than the lap winding for the same e.m.f lap winding would require large number of conductors which will result in higher winding cost and less efficient utilization of space in the armature slot.

→ In wave winding equalizing connection are not necessary whereas in a lap winding they are necessarily needed

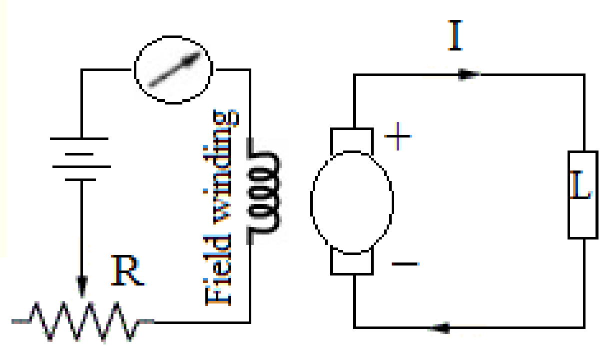
→ When large currents are required, it is necessary to use lap winding, because it gives more parallel paths.

→ Lap winding is suitable in the system where low voltage and high current is required

- <u>Types of generator:</u>

Generators are usually classified in two parts as follows:

(a) <u>Separately –excited generator</u>: These are the generators whose field magnets are energized from an independent external source of D.C. current



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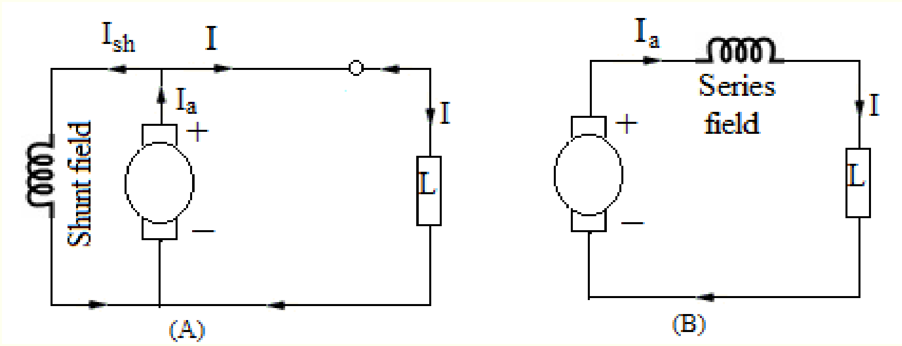
(b) Self- excited generator: The generator whose field magnets are energized by the generator's induced e.m.f itself.

Both type of generator further are divided into following types:

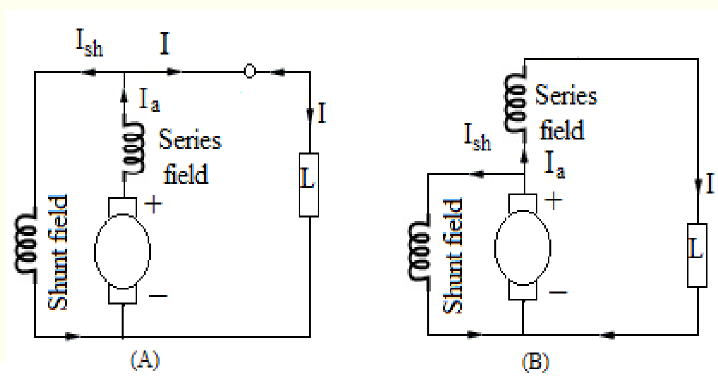


→ Shunt wound: The field windings are connected across or in parallel with the armature conductors and have the full voltage of the generator applied across them is called shunt wound D.C. generator.

→ Series wound: The field windings are joined in series with armature conductors are called series wound D.C generator.

→ Compound wound: It is a combination of a series and a few shunt windings and can be either short – shunt or long – shunt given as below.

➢ Generated E.M.F equation: The amount of electromotive force in the armature conductor can be calculated as follows:



Let ϕ = magnetic flux/pole in Wb (Weber)

Z = total number of armature conductor

= No. of slots × No. of conductor per slot

P = No. of generator poles

A = No. of parallel paths in armature

N = armature rotation in revolutions per minute

E = e.m.f induced in any parallel path in armature.

Generated e.m.f E_g = e.m.f generated in anyone of the parallel paths

Average e.m.f generated/conductor = $\frac{d\phi}{dt}$ volts

Flux cut/conductor in one revolution $d\phi = \phi P$ wb

No. of revolution/second = N/60

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

⇨ For a simplex wave-wound generator :

No. of parallel paths = 2

No. of conductors in one path = $\frac{Z}{2}$

E.M.F generated / paths = $\frac{\phi PN}{60} \times \frac{Z}{2} = \frac{\phi PNZ}{120}$ volts

⇨ For simplex lap wound generator:

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

- Iron loss in armature:

→ Hysteresis loss(W_h): This loss is due to the reversal of magnetization of the armature core. The core undergoes one complete cycle of magnetic reversal after passing under one pair of poles.

According to steinmetz formula,

$$W_h = \eta B_{max}^{1.6} f \text{ volts}$$

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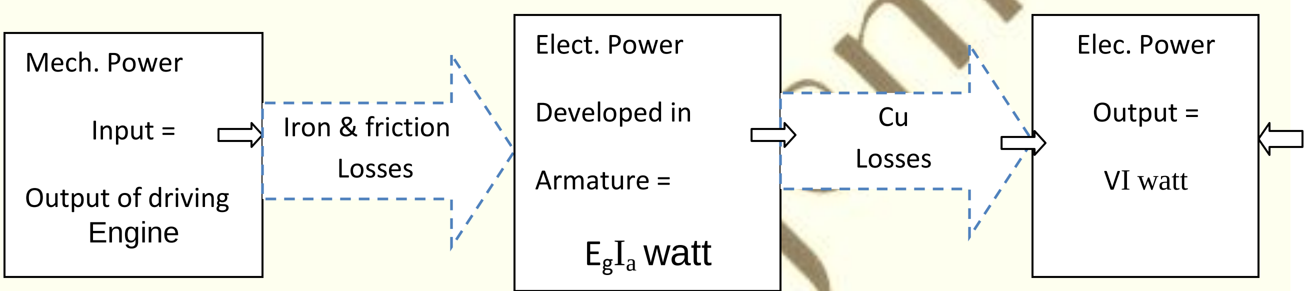
→ Eddy current loss: When the armature core rotates, it also cuts the magnetic flux. An e.m.f is induced in the body of the core according to the law of electromagnetic induction. The e.m.f though small, sets up large current in the body of the core due to its small resistance. This current is known as eddy current. The power loss due to the flow of this current is called eddy current loss

Eddy current loss is given by,

$$W_e = Kf^2t^2V^2B_{max}^2 \text{ watt}$$

- Power stages:



1. Mechanical efficiency

$$\eta_m = \frac{B}{A} = \frac{total\ watt\ generated\ in\ armature}{mechanical\ power\ supplied}$$

$$= \frac{E_g I_a}{output\ of\ driving\ engine}$$

2. Electrical efficiency:

$$\eta_e = \frac{C}{B} = \frac{watt\ availabe\ in\ load\ circuit}{total\ watt\ generated}$$

$$= \frac{VI}{E_g I_a}$$

3. Overall r combined efficiency:

$$\eta_c = \frac{C}{A} = \frac{watt\ availabe\ in\ load\ circuit}{mechanical\ power\ supplied}$$

4. Condition for maximum efficiency:

Generator output = VI

Generator input $= VI + I_a^2R_a + W_c$

$= VI + (I + I_{sh})^2R_a + W_c$ $(\because I_a = I + I_{sh})$

If I_{sh} is neglecyed as compared to load current,

Then $I_a = I$

$$\eta = \frac{output}{input} = \frac{VI}{VI + I_a^2R_a + W_c} = \frac{1}{1+(\frac{IRa}{V}+\frac{W_c}{VI})}$$

Now, efficiendy is maximum when denominator is minimum, when

$$\frac{d}{dI}\left(\frac{IR_a}{V} + \frac{W_c}{VI}\right) = 0 \quad \text{OR} \quad \frac{R_a}{V} - \frac{W_c}{VI^2} = 0$$

Or $I^2R_a = W_c$

Hence, generator efficiency is maximum when

Variable loss = constant loss

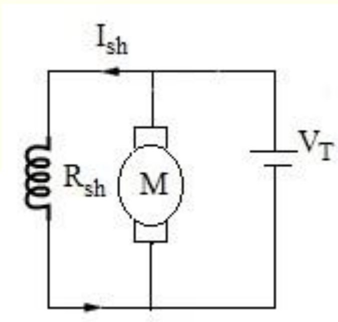
D.C. Motors

Motor's principle: it converts electrical energy into mechanical energy "whenever a current carring conductor is placed into magnetic field, it experiences a force and due to this force, torque is developed in it.

→ Now in motor current is supplied to armature and to field winding both i.e. in shunt motor from a battery source.

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

Now, this battery will make current to flow in the magnetic field and at the same time armature conductors will also have current in it.



Anand Panchbhai
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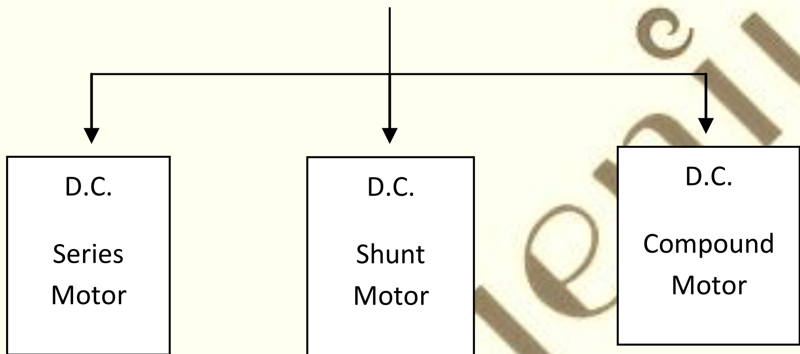
→ Now, field current will generate or produce the flux in the magnetic circuit and at the same time armature conductor contains flow of current i.e. current carrying conductors kept into magnetic field will experience force and torque is developed and motor starts rotating.

- Classification of D.C. Motor:

The D.C. Motor is classified same as D.C. Generator.

Self – excited

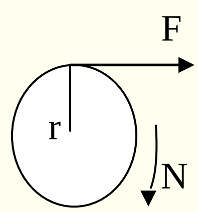


- Torque equation of D.C. Motor:

We know that

Torque = force × perpendicular distance

$= F \times R$



Work done by this force in one direction revolution

$= \text{force} \times \text{distance}$

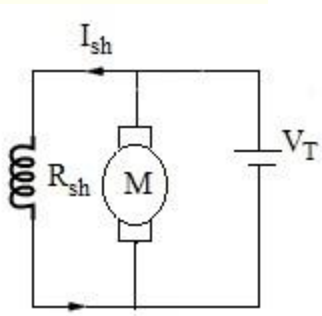
$= F \times 2\pi r$

Power developed $= \frac{work}{time}$

$= F \times 2\pi r \times N$ [N = rpm per sec. $= \frac{1}{dt}$]

$P = F \times r \times 2\pi N$

$P = \tau \times \frac{2\pi N}{60}$ [$\frac{N}{60}$ = rps]



$$P = \tau \times \omega$$

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- Motor equation:

$E_g = \frac{\phi ZNP}{60\ A}$ => $E_g \ \alpha \ \phi N$

$\Phi \ \alpha \ I_f$ [flux α field current]

$E_b = V_T - I_a R_a$

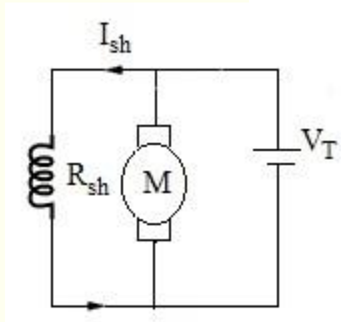
$T = \frac{P}{\omega} = \frac{E_b I_a}{2\pi \frac{N}{60}} = \frac{\frac{\phi NPZ}{60a} \times I_a}{2\pi \frac{N}{60}}$

$T \ \alpha \ I_a$

- Characteristic of D.C. shunt motor:

[note: there are three characteristic for shunt and series motor
(i) $T \longrightarrow I_a$,
(ii) $N \longrightarrow I_a$,
(iii) $N \longrightarrow T$]

$I_{sh} = \frac{V_T}{R_{sh}}$ } constant

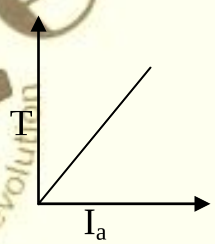


i.e. $I_{sh} = I_f$ = constant

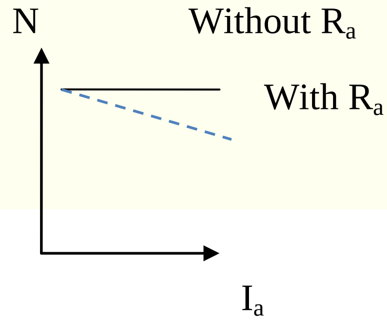
∴ $\phi \ \alpha \ I_f$ = constant

(i) $T \longrightarrow I_a$

$T \ \alpha \ \phi \ I_a$



$T \alpha \ I_a$ (ϕ = constant)



(ii) $N \longrightarrow I_a$

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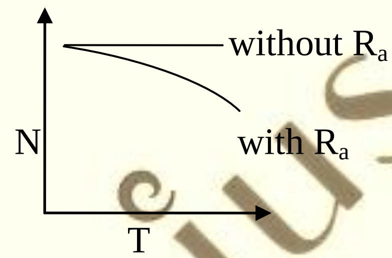
$E_b \alpha \phi N$
E_b α N
$V - I_aR_a$ α N
If R_a is considered we get some dropping characteristic

(iii) N ⟶ T

We know that,
T α I_a ---(1)
Also,
N α $V_T - I_aR_a$
∴ N α $V_T - T.R_a$

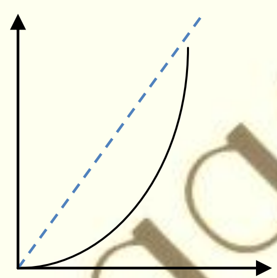


- Characteristic of D.C. series Motor:

As from figure it is clear that
$I = I_{sh} = I_a$

(i) T ⟶ I_a

T α ϕ I_a

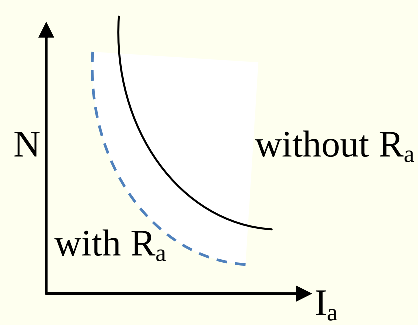


Tα I_f.Ia

T α I^2_a [unsaturated parabolic curve]

T α I_a [saturated straight line]

(ii) N ⟶ I_a



$E_b \alpha \phi N$
E_b α N
$V - I_aR_a$ α I_a N
N α $\frac{V_T}{I_a}$ - R_a
Neglecting R_a
N α $\frac{1}{I_a}$

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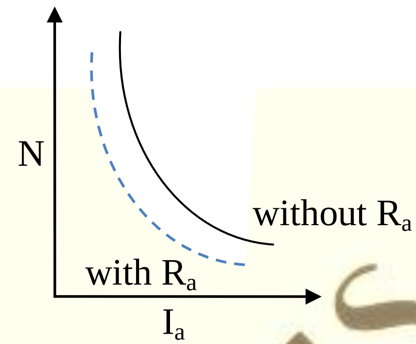
(iii) N ⟶ T

For saturated constant,

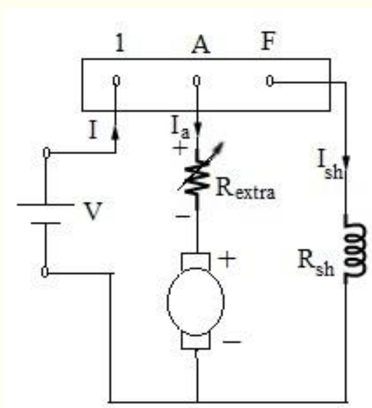
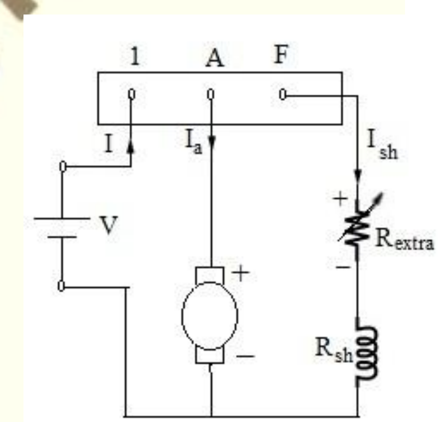
$T \alpha I_a$

$\therefore N \alpha \frac{1}{T}$



- <u>Speed control of D.C. shunt Motor:</u>

There are two methods to control speed of D.C. shunt motor

Armature control	Field control
→ → Rheostat is connected in series with Armature. → If R_{extra} increases I_{extra} increases $\therefore V_T - I_a R_{extra} - I_a R_a = E_b$ $\therefore E_b$ will reduce → We can reduce the speed below the rated speed in this method  	→ Rheostat is connected in series with field winding. → If R_{extra} increases I_{sh} decreases ϕ decrease and N increases → we can increase the speed above the rated speed in this method 

- <u>Speed control of D.C. series Motor</u>

There are four types of method as follows:

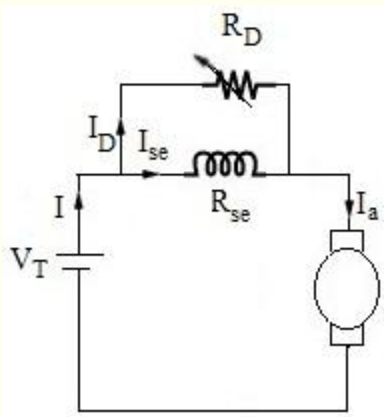
D.C. series Motor

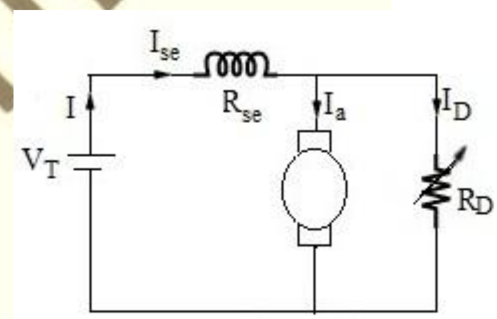
Field Divertor

Armature divertor

→ If R_D increase , I_D increase, I_{se} decreases, then Φ decreases N increases

→ If R_D increases, I_D increases, I_{se} increases then Φ increases and N decreases





Field Tappings

series parallel field