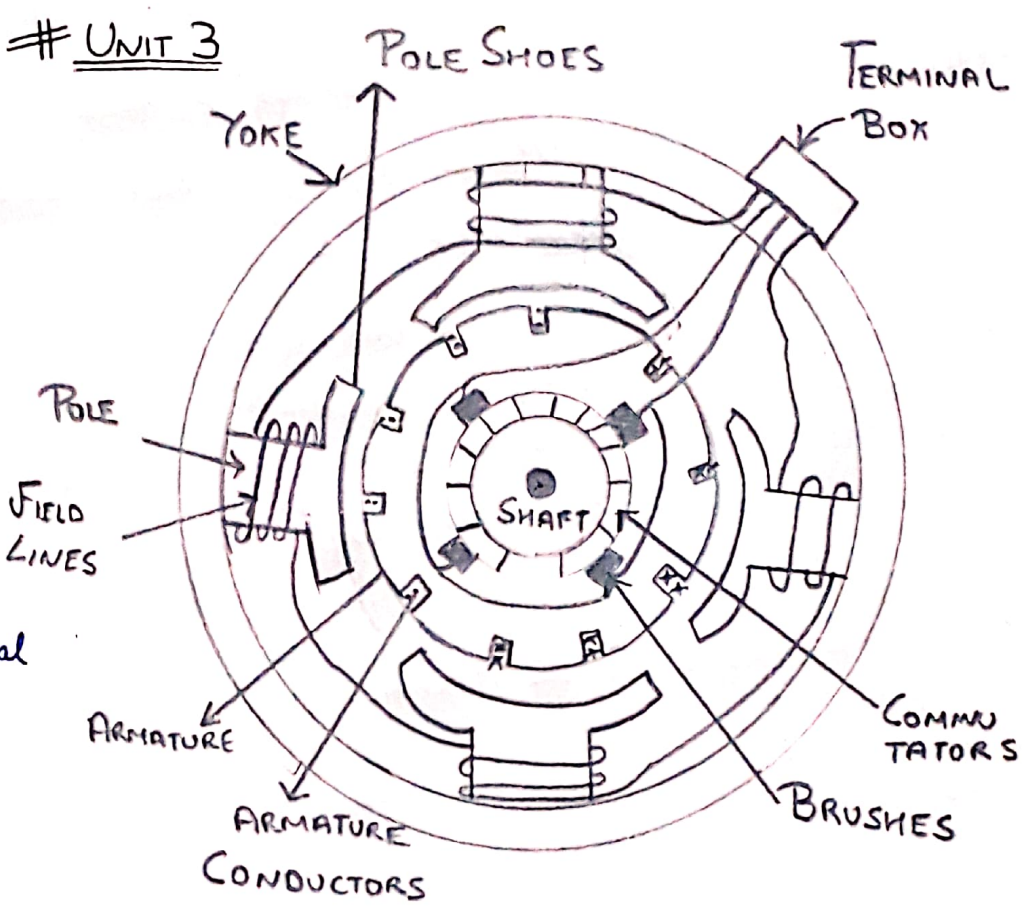
UNIT 3

→ D.C MACHINES

CONSTRUCTION

TWO PARTS → STATOR
TWO PARTS → ROTOR



- **YOKE**

→ Protects machine from external conditions.
→ Low reluctance

- **POLE**

→ Induce EMF
→ Laminated pole core to reduce eddy current losses.

- **FIELD WINDINGS**

→ Used to regulate flux density / Magnetic field intensity.

- **BRUSH**

→ Carbon / Graphite
→ Consists of a spring for tension to prevent airgap
→ Acts as a point of contact

- **ARMATURE**

→ Laminated core (Mica)
→ Copper wirdings around conductor slots
→

- **COMMUTATOR**

→ Commutar plates (Al / Cu) seperated by mica sheets
→ Transfers supply in/out of the machine

→ Faradays Law

- $\mathcal{E} = +N\frac{d\phi}{dt}$

- When a conductor is placed in a varying magnetic field, an EMF is induced. In closed circuit, an Induced current flows through it.

- Lens Law

$$\mathcal{E} = -N\frac{\delta\phi}{\delta t}$$

- Methods of Varying M.F:
  1) Mouing Magnet
  2) Mouing Coil
  3) Rotating Coil

→ EMF Equations of DC Machine

a) Flux linked with one revolution made by one conductor in one parallel path, $= P\phi$

b) Time taken by one conductor for one revolution $= \frac{60}{N}$

c) EMF induced in one revolution $= \frac{P\phi N}{60}$

No. of conductors in each Parallel Path, $= \frac{Z}{A}$

∴ EMF induced in all conductors in one parallel path in one revolution

$$\Rightarrow \mathcal{E} = \frac{\phi PN}{60}\cdot\frac{Z}{A}$$

P → No. of Poles
Z → No. of Conductors
A → No. of Parallel Path
N → Revolutions / Minute
ϕ → Flux per Pole

* Lap Winded System
→ A = P

* Wave Winded System
A = 2

- For DC Generator

$$\mathcal{E}_g = \frac{\phi ZNP}{60A}$$

- For DC Motor

$$\mathcal{E}_B = \frac{\phi ZNP}{60A}$$

$\mathcal{E}_B$ → Back EMF

Unit 3

- DC Motor

→ Electromechanical device that converts electrical energy to mechanical energy.

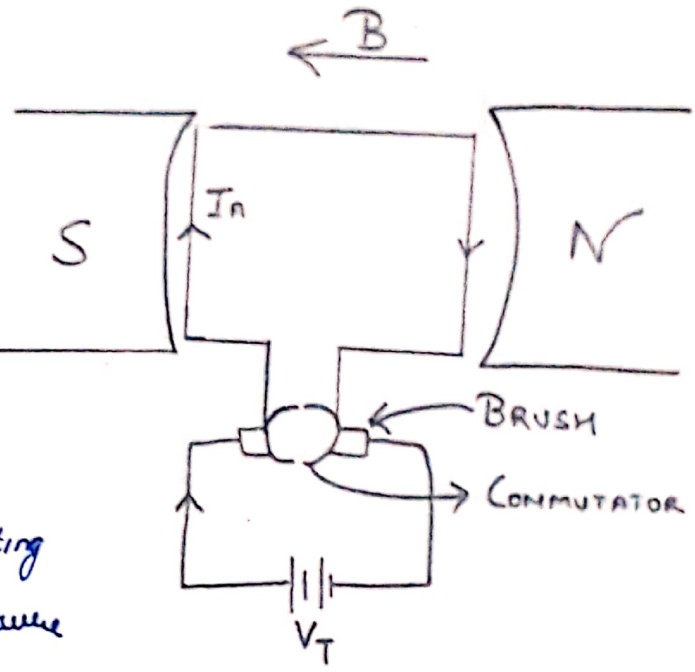
* The induced EMF is called Back EMF (E_B)

Using ohms law,

$$I_A = \frac{V_T - E_B}{R_A}$$

I_A → Armature Current

R_A → Armature Resistance



Significance of Back EMF

- Enables a DC motor to become self regulating
- Enables DC motor to draw as much armature current as required.

- Power Input at Motor Terminal

$$P_{MT} = V_T I_A$$

Mechanical Power

- Electromagnetic Power

$$P_E = E_A I_A$$

Electrical Power

- Electromagnetic Torque

$$T = \frac{P_E}{\omega_m}$$

$\omega_m = \frac{2\pi N}{60}$

$T \propto \phi I_A$

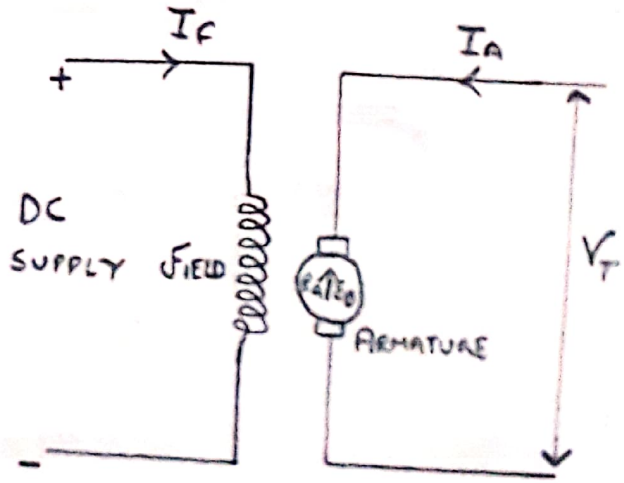
- Rotational Speed

$$n = n_0\left(\frac{E_A}{E_{A_0}}\right)$$

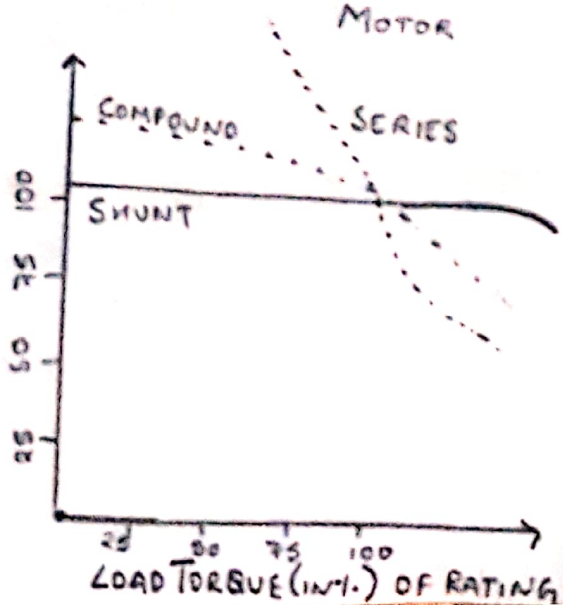
n_0 → rated speed

E_{A_0} → Rated Voltage

$$I_A = \frac{\text{Power}}{\text{Terminal Voltage } (V_T)}$$



a) Seperately Excited Motor



DC - SERIES MOTOR

$E = K_e \phi \omega_m$ — (I)

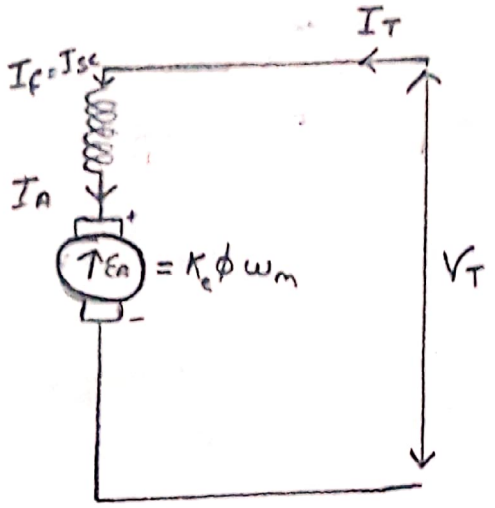
$V = E + R_A I_A$ — (II)

$t = K_e \phi I_A$ — (III)

from (I), (II) & (III)

$$\omega_m = \frac{V}{K_e \phi} - \frac{R_A}{K_e \phi} I_A$$

$$= \frac{V}{K_e \phi} - \frac{R_A}{(K_e \phi)^2} t$$



In series motor, flux is a func^n of armature current,

$\Rightarrow \quad \phi \propto I_A \quad \Rightarrow \quad \phi = K_f I_A$

$\Rightarrow \quad \boxed{T = K_e K_f I_A^2}$ [from (III)]

$\Rightarrow$

$$\omega_m = \frac{V}{\sqrt{K_e K_f t}} - \frac{R_A}{K_e K_f}$$

ADVANTAGE
- → HIGH STARTING TORQUE (AT LOW SPEEDS)
- → SIMPLE CONSTRUCTION
- → EASY TO DESIGN
- → EASY TO MAINTAIN

DISADVANTAGE
- → POOR SPEED REGULATION (REQUIRES LOAD BEFORE STARTING)
- → TORQUE ∝ SPEED, SO TORQUE DROPS SHARPLY

APPLICATIONS
- → DRILL MACHINE
- → SEWING MACHINE
- → WINCH
- → VACCUM CLEANERS

R_A is the sum of armature and field winding resistances

Since the torque is directly proportional, hence for increase in torque increase in motor current is relatively less.

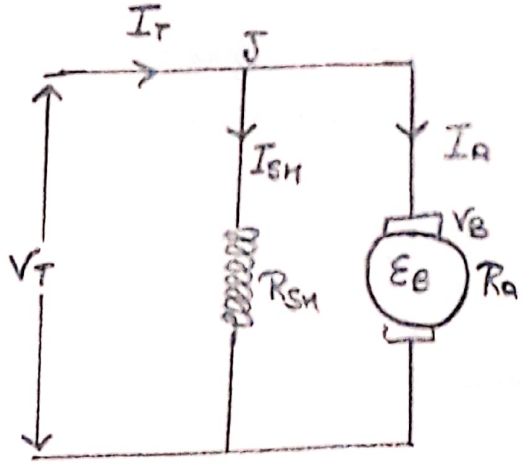
Series motors are hence ideal for 1) High Starting Torques
2) Torque Overloading

Machine runs at larger speed at light load, produces huge torque.

Should be avoided when there is a possibility of load torque dropping to cause double the rated speed.

DC Shunt Motor

$R_{SH} \gg R_A$



- Shunt field windings are made up of higher number of turns & lower gauge as compared to series motor.
- Higher conductor turns provides stronger mag. field.
- Lower gauge provides higher resistance
- When voltage is provided to terminals, armature & field draw sufficient current & rotation is produced.

$E_B \propto N$

$\tau \propto I_A$

$\phi_{SH} \propto I_{SH}$

- If load is increased, speed reduces which thereby reduces back EMF and increases armature current & torque
- Thus causing the speed to return to original and compensate for load.

From figure,

$$V_T = I_A R_A + E_B + V_B$$

$$V_T = I_{SH} \cdot R_{SH} \Rightarrow \boxed{I_{SH} = \frac{V_T}{R_{SH}}}$$

V_T is const, R_{SH} is const

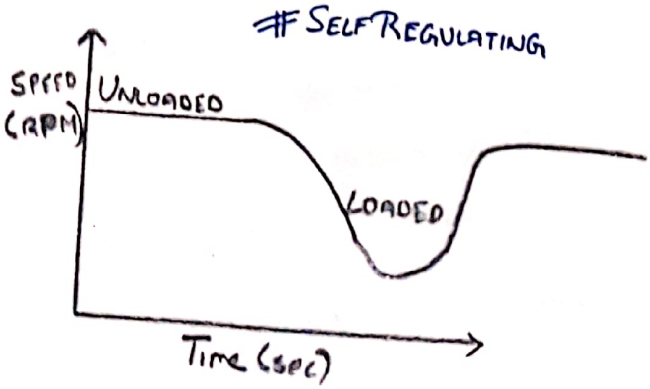
$\Rightarrow$ I_{SH} is CONST

Applying KVL at junc^ J,

$$I_T = I_{SH} + I_A \Rightarrow \boxed{I_A = I_T - I_{SH}}$$

$$\boxed{I_A = \frac{V_T - E_B}{R_A}}$$

Self Regulating



Applications

1) Water Pumps
2) Lathe Pump
3) Conveyer Belts

Advantages

→ Constant Speed

→ Speed can be pre-determined

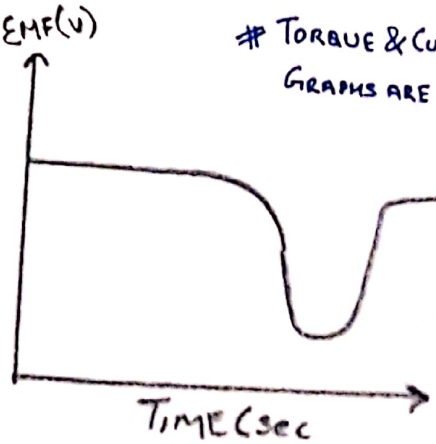
→ Speed Regulation

Disadvantages

→ High Installation & Manufacturing cost

→ Low starting torque, requires low/no starting load

→ No variable speed for variable load



Torque & Current Graphs are Inverted

SPEED CONTROL OF D.C MOTOR

→ Fast controlling operation of apparatus
→ Better performance of machine
→ Higher efficiency
→ System reliability
→ Cost effectiveness.

- SERIES MOTOR

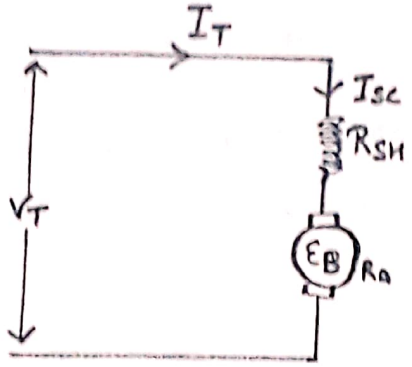
$V_T = E_B + I_A(R_A + R_{SH})$

⇒ Using $E_B = \frac{\phi Z N P}{60A}$

$\Rightarrow V_T = \frac{\phi Z N P}{60A} + I_A(R_A + R_{SH})$

$\therefore$

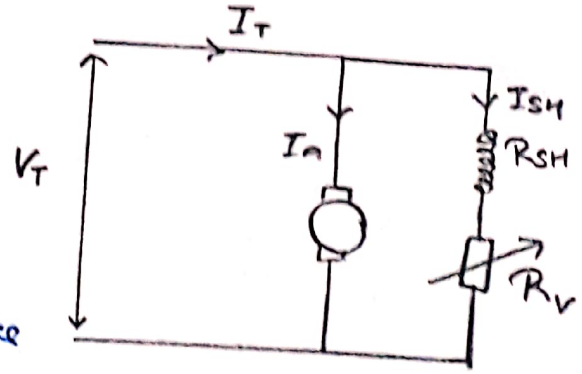
$$N = \frac{(V_T - I_A(R_A + R_{SH}))\,60A}{\phi Z P}$$



→ FLUX CONTROL

$I_A \propto \frac{1}{\phi}$

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



- Increasing variable resistance R_V will increase armature current I_A, thus reducing flux. This will increase speed of system.

⇒ Control is independent of Load.

→ RHEOSTATIC CONTROL

- At point 'a', value of Rheostatic voltage R_c is minimum, hence armature current is max. Thus speed is also maximum. As we move towards point b value of speed drops.