Unit-3

DC

* Motor:- Converts electrical energy to mechanical energy.
Generator:- Converts mechanical energy to electrical energy.

* DC machine advantages
→ Lower speed → Less complexity → Easy designs
→ High power range isn't required

* Motor and Generator Construction
1) Yoke:- Protects machine from external conditions
→ Low reluctance path and are strong.
2) Pole:- Induce EMF and laminated pole core to reduce eddy current losses.
3) Pole shoes:- Distribute magnetic field uniformly.
4) Field windings:- Used to regulate flux density/magnetic field density Or produce uniform $\vec{B}$ within which armature rotates
5) Armature:- Laminated soft iron core and copper windings around conductor slots. Protect from eddy currents.
6) Commutator:- Transfer supply in/out of machine
Commutator plates (Al/Cu) separated by mica sheets.
7) Brushes:- Carbon/Graphite. Consists of a spring for tension to prevent air gap. Acts as a point of contact.

* EMF equation.

ϕ = Flux per pole in wb.
Z = total no. of armature conductors.
P = no. of poles.
A = no. of parallel paths: $A = 2$ (wave winded system), $A = P$ (lap winded system)
N = speed of armature in rpm
E_g = EMF of generator.

- Flux linked with one revolution made by one conductor in one parallel path = $P\phi$
- Time taken by one conductor for one revolution = $\frac{60}{N}$
- 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 = $\frac{\phi P N}{60} \frac{Z}{A}$

For DC generator	For DC motor
$E_g = \frac{\phi Z N P}{60 A}$	$E_B = \frac{\phi Z N P}{60 A}$ $E_B \rightarrow$ Back Emf.

★ DC Generator

→ Principle - Works on the principle of Faraday's law of EMI which states that a change in magnetic field around the conductor induces an emf in conductor

→ Working.
- According to Faraday's law of EMI, whenever a conductor is placed in varying magnetic field, an emf gets induced in conductor.
- If conductor is provided with a closed path, the induced current will circulate within the path.
- In DC generator, field coils produce an electromagnetic field and armature conductors are rotated into field. Thus, electromagnetically induced emf is generated in armature conductors.
- Direction of induced current is given by Fleming's Right hand rule
- Acc. to Fleming right hand rule, direction of induced current changes whenever direction of motion changes.
- Let's consider an armature clockwise an a conductor at left moving upward. When armature completes half rotation, the direction of motion of that conductor will be reversed to downward. Hence direction of current in every armature conductor will be AC.
- But with split ring commutator, connections of armature conductors also gets reversed when current reversal occurs. And therefore, we get unidirectional current at terminals.

★ D.C Motor.

→ Principle :- When current carrying conductors is placed in a magnetic field, it experiences a mechanical force
- Fleming Left Hand Rule.

$F = BIL$

→ Working.
- When armature windings are connected to DC supply, an electric current ~~setsup~~ sets up in the winding.
- Magnetic field may be provided by field winding or by permanent magnets.
- So, current carrying armature conductors experience a force due to magnetic field
- Commutator is made segmented to achieve unidirectional torque. Otherwise, direction of force would have reversed every time when direction of movement of conductor is reversed in Magnetic field.

★ Back emf :- When armature of DC motor rotates under influence of Torque, magnetic field is produced & hence emf is induced.

The induced emf acts in opp. direction to applied voltage is known as back emf

$I_A = \frac{V_T - E_B}{R_A}$ I_A = Armature Current. R_A = Armature resistance

→ Significance of back emf :
- Enables DC Motor to become self regulating & draw as much armature current as required to develop torque.
- based on Lenz Law

★ DC series motor
- Field windings are connected in series with armature
- Designed in Fewer no. of turns as compared to shunt motor
- Small no. of turns
- Thick wire
- low resistance.
- Since torque is directly proportional, hence for increase in torque, increase in motor current is relatively less.
- Ideal for i) High starting Torques ii) Torque overloading.
- Machine runs at larger speed at light load, produces huge torque

→ Advantages :- ① High starting Torque ② Simple construction ③ Easy to Design ④ Easy to maintain.

→ Disadvantages :- ① Poor speed regulation ② Torque & speed, so it drops sharply

→ Applications

① Drill machine ② Sewing machine ③ Winch ④ Vacuum Cleaners.

$$\phi \propto I_A ,\ \phi = K_F I_A$$
$$\tau = K_e \phi I_A$$
$$\tau = K_e K_F I_A^2$$

→ Speed Control in DC series motor :-
- Need :- For controlling operation of apparatus, Cost effectiveness For Higher efficiency and performance, Reliability.

$$N \propto \frac{E_B}{\phi}$$
$$N = K\frac{(V_T - I_A R)}{\phi}$$
$$\boxed{N = \frac{[V_T - I_A(R_A + R_{SA})]\,60A}{\phi Z P}}$$

① Flux control :-

$$N \propto \frac{1}{\phi} \text{ as } E_B = \frac{\phi N Z P}{60A}$$
$$I_A \propto \frac{1}{\phi}$$

- Increasing Resistance will increase A.C I_A, thus flux is reduced. This increases speed of system.
- Control is independent of load.

② Armature control
- It is closed loop system
- Torque remains same & constant
- Offers more accuracy
- Speed control in both direction.

★ DC shunt motor
- Field windings are connected in parallel with armature
- Current through shunt field is not same as Armature current
- Large no. of turns
- Current is relatively small as compared to armature current

$$I_{Sh} = \frac{V_T}{R_{Sh}} ,\ I_A = I_T - I_{Sh},\ I_A = \frac{V_T - E_B}{R_A}$$

- If load is increased, speed reduces which reduces back emf and increases armature current and torque

Thus causing speed to return to original and compensate for load

→ Applications :- ① Water Pumps ② Lathe Pump ③ Conveyer belt
→ Advantages - ① Constant speed ② Speed can be pre determined ③ speed Regulation.
→ Disadvantages - ① High installation & Manufacturing cost ② Low starting Torque ③ No variable speed for varying load

AC

* Single Phase Induction Motor.
→ Also known as Asynchronous motors as it always runs at a speed lower than synchronous speed. ~~To~~ Synchronous speed means speed of rotating magnetic field in stator

→ Construction
- Stator :- Stationary part of motor that contains primary winding. Laminated core constructed from stack of thin steel sheets. Laminated core is used to reduce eddy currents.
- Rotor :- Rotating part of motor, placed inside a stator. Cylindrical laminated core constructed from. stack of thin sheets of iron or steel

Two types
① Squirrel cage :- Consists of series of Cu or Al bars that are arranged in cylindrical shape and connected by short circuiting rings at each end.
② Wound rotor :- 3 phase winding similar to stator winding. Rotor winding is connected to slip rings that make contact with brushes.
Brushes are connected to var. resistor, to control speed of motor

→ Principle :- It is based on interaction b/w magnetic fields of stator and rotor winding.

→ Working -
- AC is supplied to stator winding so alternating flux is produced. This flux revolves with synchronous speed. Revolving flux is called RMF
- Then an emf is generated in stator due to Faraday's law of EMI.
- The rotor conductors are ~~also~~ short circuited, hence rotor current is produced due to Induced emf
- Now, induced current in rotor will also produce alternating flux. But this flux is less than that of stator flux.
- ~~So,~~ As there is relative velocity b/w rotating stator flux and rotor, rotor will try to catch up with stator RMF. Thus rotor rotates in same direction as that of stator flux to minimize relative velocity
- However, rotor never catches synchronous speed

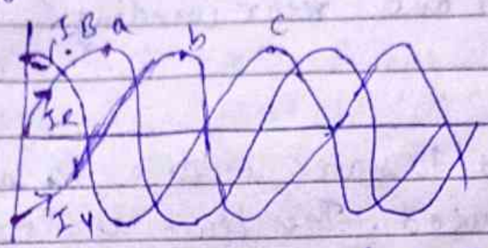
$$N_s = \frac{120 \times f}{P} \ (RPM)$$ f: frequency, P = no. of poles

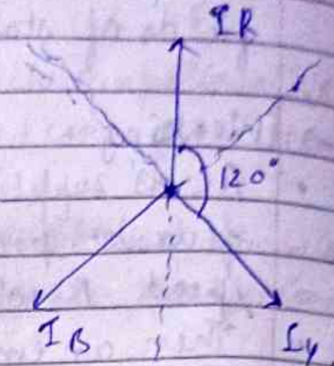
→ Slip :- If rotor catches up stator speed, then there will be no relative velocity b/w stator & rotor, hence no induced rotor current & no torque is produced to maintain rotation. Then rotor will slow down due to lost of torque, then torque will again be created due to relative speed

Diff b/w synchronous speed & Actual speed of rotor is called slip

$$\% \text{slip} = \frac{N_s - N}{N_s} \times 100$$

* Revolving Magnetic field.





At point 'a', flux is along I_R.
At point 'b', " " " I_y
At point 'c', " " " I_B.
Hence, flux moves in clockwise direction.

* Starting of Induction motor.

At time of starting, slip is unity. Starting current is very large.

(i) A starter is hence used to:
- → Reduce heavy starting current.
- → Provide overload & undervoltage Protection

* Types of Starter

Direct on Line	Star Delta
(1) One contactor with no starting circuit to lower high starting current	(1) Uses Two contactors, one to lower voltage in stator & one to run at higher voltage in delta.
(2) Does not decrease starting current	(2) Lowers starting current to $\frac{1}{3}$ times
(3) Connects directly to motor with supply	(3) Connect motor in star at start and then in delta
(4) Poor Power quality	(4) Good Power Quality
(5) Low Efficiency.	(5) High efficiency.
(6) Low Cost	(6) High Cost
(7) Small motors	(7) Large Motors.