TED(21)-5031 REVISION

2021 Model Question Paper set-I

SYNCHRONOUS MACHINES AND FHP MOTORS

Time: 3 Hour Max.Marks: 75

PART A

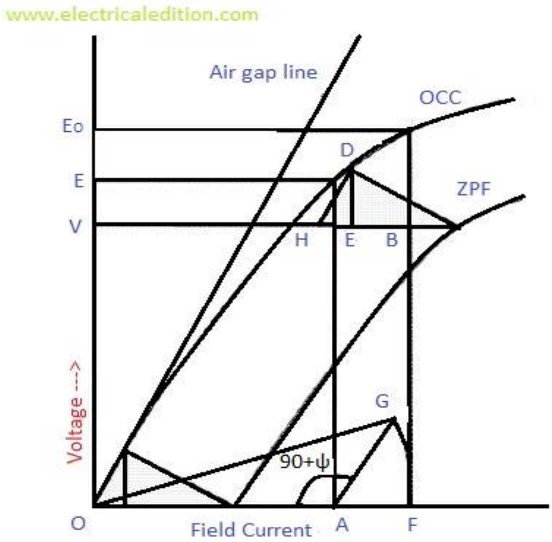
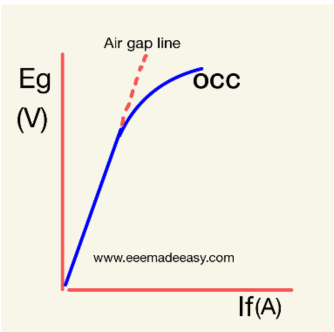
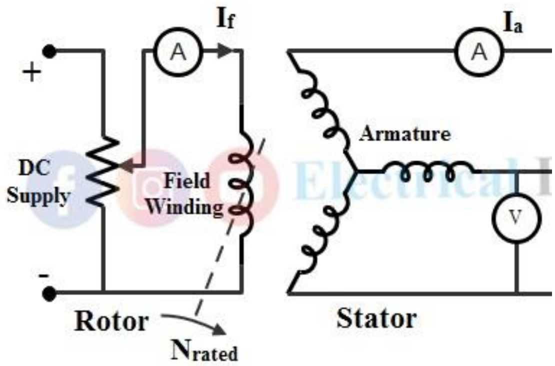
I. Answer all questions in one word or one sentence. Each question carries 1 mark.

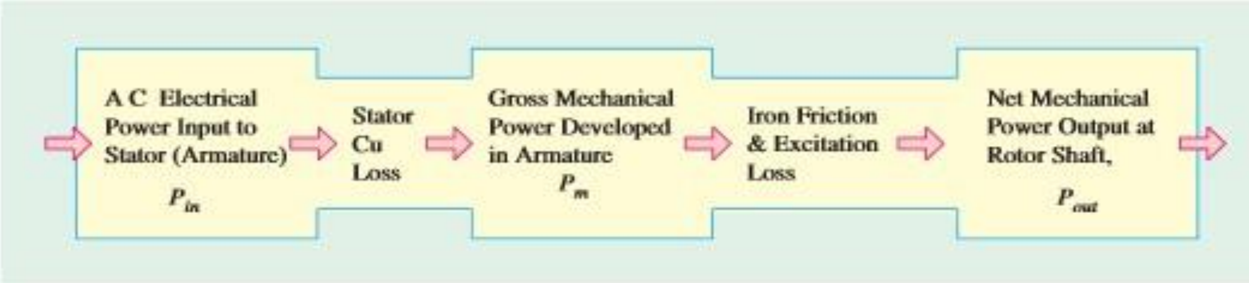
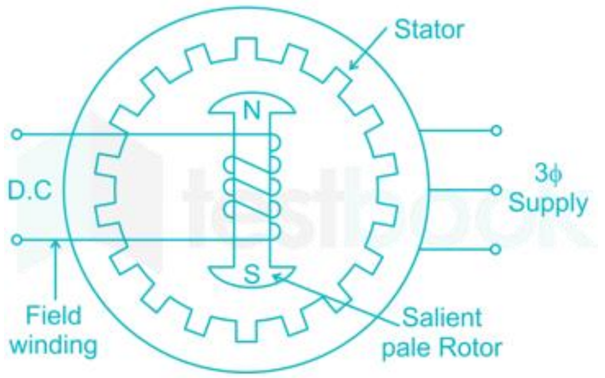
1	Name the alternator which has large axial length and small diameter. **Non salient pole type**
2	Under purely inductive load the armature reaction has _______ effect in alternator. **demagnetising**
3	Load angle is the phase difference between _____ and ______. **V and E_b (phase voltage and back emf)**
4	Identify the voltage regulation method which is known as the pessimistic method used for alternators. **EMF method or synchronous impedance method**
5	Name any two methods to synchronize two alternators. **Three dark lamp and synchroscope method**
6	Write the necessary conditions to operate synchronous motors as synchronous condensers. **When Eb > V**
7	The V curve of a synchronous motor shows the relationship between **Armature current and field current**
8	Describe the method to eliminate the hunting effect on synchronous motors. **By using damper windings**
9	List out the classification of stepper motor based on operation. **Variable Reluctance stepper motor, permanent magnet stepper motor,Hybrid stepper motor**
10	Explain why a synchronous motor is known as a doubly excited machine. **Ac supply is given to stator and dc supply is given to rotor**

PART B

II. Answer any eight questions from the following, each question carries 3 marks.

1.	Calculate distribution factor of a three phase distributed winding of alternator. The alternator has 2 poles and 18 slots. Kd = $\dfrac{\mathbf{sin}\left(\frac{m\beta}{2}\right)}{\mathbf{m\ sin}\left(\frac{\beta}{2}\right)}$

	Slot angle $(\beta) = \frac{180}{n}$ $n = \frac{\text{slots}}{\text{pole}} = \frac{18}{2} = 9$, $\beta = \frac{180}{9} = 20$, $m = \frac{n}{\text{phase}} = \frac{9}{3} = 3$ $Kd = \frac{\sin\left(\frac{3 \times 20}{2}\right)}{3 \sin\left(\frac{20}{2}\right)} = \frac{\sin(30)}{3 \sin(10)} = 0.959$
2.	List out any three advantages of stationary armature over rotating armature. • Output current can be easily collected • Stationary armature coils can be insulated easily • Cooling of the armature winding is easy 3. Describe the ZPF characteristics of a synchronous generator.  • It is a curve of armature terminal voltage (V) and field current(If) • Zero power factor characteristics is also called potier characteristics. • Here the machine is operated with rated armature current and lagging power factor.
4	Explain the necessary conditions to be satisfied for parallel operation of alternators. • Terminal voltage should be same • Frequency should be same • Phase sequence should be same.
5	Describe the experimental method to plot the open circuit characteristics of the alternator.  • Graph between open circuit voltage and field current

	• Keep load terminals open • Run alternator at rated speed • Increase filed current up to 125 % of rated voltage is obtained.
6	Define the term synchronizing current in parallel operation of alternators. When emf of any one alternator in synchronism is falls back by an angle δ ,there is a current flow known as synchronising current. • **Synchronizing Current ,** $I_{SY} = \frac{E_R}{Z_S}$
7	Develop the power flow diagram of a synchronous motor. 
8	Identify the basic features of synchronous motors. • It is a constant speed motor • Can be operated under lagging ,leading, and unity power factor • Not self starting • Need both AC and DC supply • Also called double excitation motor • Runs either at synchronous speed or not at all
9	Describe the necessary conditions to be satisfied to self start a single phase induction motor • It require a 2 phase supply to produced rotating magnetic field • An additional winding called starting is provided during starting. • Starting winding and main winding produce a 90 degree phase shift • It is explained by double field revolving theory
10	Explain why a synchronous motor is known as a doubly excited machine.  • Ac supply is given to stator • Rotor is excited with dc supply • Both stator and rotor require separate supply for the operation of

PART C

Answer ALL questions. Each question carries 7 mark

III	Find phase and line voltages of star connected three phase 6 pole alternator which runs at 1200 RPM having flux per pole of 0.1 webber sinusoidal distributed, its stator has 54 slots. 2 conductors per slot each coil short pitched by one slot. **Answer:** No of poles ,P = 6 Flux/pole ϕ = 0.1 wb Conductor/slot =2 No.of slots = 54 n=slots/pole = 54/6 =9 m=slots/pole/phase = 9/3 =3 Speed, N =1200 rpm ($N_s = \frac{120f}{P}$) $f = \frac{PN}{120} = \frac{6 X 1200}{120}$ = 60Hz Zph = $\frac{\text{No.of slots x (conductor/slot)}}{3} = \frac{54 x 2}{3}$ = 36 Tph =$\frac{Zph}{2} = \frac{36}{2}$ = 18 $\beta = \frac{180}{n} = = \frac{180}{9}$ =20 Short chorded by 1 slot , α = β x no.of slots by short pitched = 20 x 1 =20 Kc= cos ($\frac{\alpha}{2}$) = cos ($\frac{20}{2}$) =cos 10 = 0.984 Kd = $\frac{\sin\left(\frac{m\beta}{2}\right)}{m \sin\left(\frac{\beta}{2}\right)} = \frac{\sin\left(\frac{3x20}{2}\right)}{3 \sin\left(\frac{20}{2}\right)} = \frac{\sin(30)}{3 \sin(10)}$ **= 0.959** **Induced emf ,Eph = 4.44 fϕ Tph Kc Kd volt** = 4.44 x 60 x 0.1 x 18 x 0.984 x 0.959 = 451.08V Line voltage ,$E_L = \sqrt{3}$ X Eph = $\sqrt{3}$x451.08 =781.30 V
	OR
IV	Calculate the RMS value of induced EMF per phase of a 10 pole three phase 50 Hz alternator with 2 slots per pole per phase and 4 conductor per slot. The coil span is 150 degrees. Flux per pole is 0.12 web.

	Answer: Datas Given: No of poles,P = 10 Frequency, f= 50Hz Slots/pole/phase, m = 2 n = m x phase = 2x3=6 Conductor/slot=2 No of conductors , Zph = slots/pole/phase x conductor/slot x no of poles =m x P x conductor/slot =10x2x 4 = 80 Tph = $\frac{Zph}{2}$ = 80/2 = 40 Coil span = 150 α = 180-150 =30 Flux/pole=0.12wb Pitch factor, Kc= $\cos\left(\frac{\alpha}{2}\right) = \cos\left(\frac{30}{2}\right) = \cos 15 = 0.965$ Distribution factor, Kd = $\frac{\sin\left(\frac{m\beta}{2}\right)}{m \sin\left(\frac{\beta}{2}\right)}$ $\beta = \frac{180}{n} = \frac{180}{6} = 30$ $= \frac{\sin\left(\frac{2x30}{2}\right)}{2 \sin\left(\frac{30}{2}\right)} = \frac{\sin\left(\frac{60}{2}\right)}{2 \sin(15)} = \frac{\sin(30)}{2 \sin(15)} = 0.965$ **Induced emf ,Eph = 4.44 fϕ Tph Kc Kd volt** = 4.44x 40x0.965x0.965x50x0.12 = 992.3V
V	Compare the salient pole and cylindrical rotor type synchronous generators.

Salient pole type rotor	**Non-salient pole type rotor**
Rotor poles are projected	Rotor poles are not projected
More number of poles are present	2 or 4 poles are present
Have large diameter and small axial length	Have small diameter and large axial length
Used for low and medium speed applications	Used for large speed applications

	Used with hydraulic turbines	Used with steam turbines
	Construction is difficult	Construction is easy
	Windage loss is more	Windage loss is less
	Air gap is present between poles	No airgap is present between poles
	Flux is not uniform	Flux is uniform
	OR	

VI List out the advantages of short pitched and distributed type windings in alternators.

Advantages of short chorded or short pitched winding

1. Copper can be saved because end connection length is reduced
2. The generated emf waveform shape will be improved. Ie, emf waveform become sinusoidal shape
3. Due to short coding, high frequency harmonics can be eliminated.
4.It helps to reduce eddy current loss and hysteresis loss in alternator

Advantages of distributed winding

- It reduces harmonics emf so waveform improved
- Distribution of conductors helps for better cooling
- It reduces armature reaction effects

VII From the following test results determine the voltage regulation of a 2000 V single phase alternator delivering a current of 100 A at 0.8 pf leading. The results: full load Current of 100 A is produced on short circuit by a field excitation of 2.5 A and EMF of 500 V is produced on open circuit by the same field current. The armature resistance is 0.8 ohm.

OR

VIII A 200 KVA 3000 V 50 Hz three phase alternator has effective armature resistance of 0.6 ohm per phase. A field current of 45 A produces a short circuit current of 240 A on short circuit and open circuit voltage of 1040 V between lines. Calculate percentage voltage regulation at 0.8 pf lag.

Answer :

Datas Given

Ra = 0.6 ohm

Field current, If = 45A

Isc=240A

Ia $=\frac{KVA\ X\ 10^3}{\sqrt{3}V_L} = \frac{200\ X\ 10^3}{\sqrt{3}\ X\ 3000}$ =38.4A

Voc =1040V

Voc/phase = $\frac{1040}{\sqrt{3}}$ =600.4 V

V_L = 3000V

Vph $=\frac{V_L}{\sqrt{3}} = \frac{3000}{\sqrt{3}} =$ 1732.05 V

Synchronous impedance , Zs= $\frac{Voc/phase}{Isc/phase} = \frac{600.4}{240}$ = 2.5ohm

Synchronous reactance, $X_S = \sqrt{Z_S{}^2 - R_a{}^2} = \sqrt{2.5\ ^2 - 0.6\ ^2}$ = 2.42ohm

At 0.8 lag

$E_0 = \sqrt{[(V_{ph} \cos\phi + I_a R_a)^2 + (V_{ph} \sin\phi + I_a X_S)^2]}$

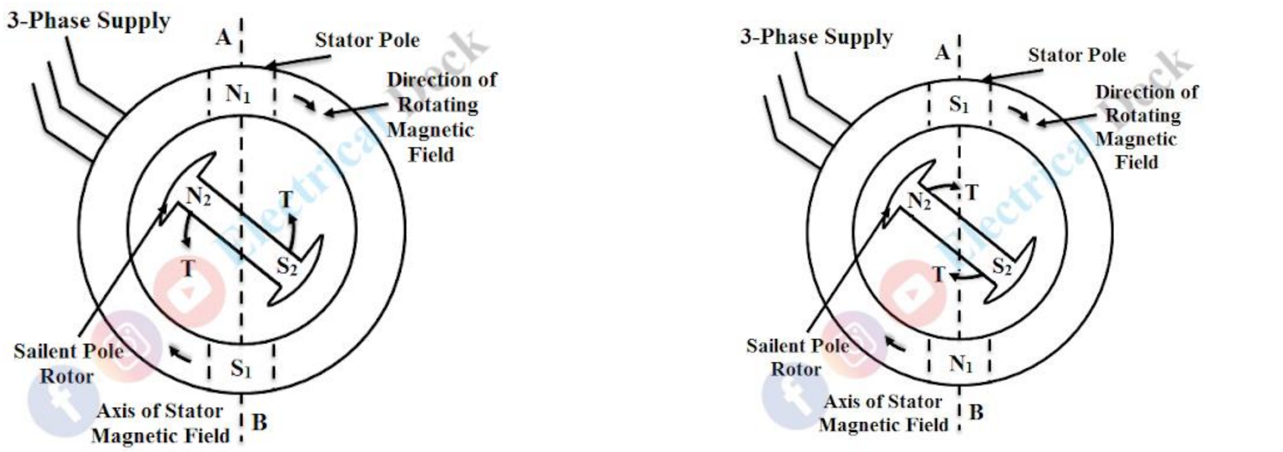
$= \sqrt{[(1732.05 \text{ x } 0.8 + 38.4 \text{ x } 0.6)^2 + (1732.05 \text{x } 0.6 + 38.4 \text{ x } 2.42)^2]}$

$= \sqrt{1408.68^2 + 1132.158^2}$

=1807.25 V

% Regulation $= \frac{E_0 - V_{ph}}{V_{ph}}$ **x100** $= \frac{1807.25 - 1732.05}{1732.05}$ **x100 = 4.34 %**

IX Explain the working principle of synchronous motors with the help of neat diagrams.



- When three phase supply is applied to stator, a rotating magnetic field produced.
- The speed of rotating magnetic field is called synchronous speed (Ns)
- In fig 1 ,When N1 and N2 are at position A and S1 and S2 at position B. They repel each other
  Rotor tries to rotate in anticlockwise
- In fig 2, stator pole position changed.
- N1 is at position B and S1 is at A
- N1 attracts S2 and S1 attracts N2
- Rotor tries to rotate in clockwise direction.
- So torque is not unidirectional
- Due to large inertia of rotor, it does not respond quickly with the change in torque.
- Therefore, synchronous motor is not self-starting.

	• When rotor is rotated to synchronous speed by external starting methods, rotor and stator poles magnetically locked and continue to run in synchronous speed.
	OR
X	Compare three phase induction motor and synchronous motor.

Synchronous Motor	**Induction motor**
Double excitation motor	Single excitation motor
AC to stator and DC to rotor	AC to stator only
Runs at synchronous speed	Always runs less than synchronous speed
Not self starting	Self starting
Suitable for lagging, leading and UPF	only lagging power factor
More efficient than induction motor	Efficiency is less than that of the synchronous motor
Cost is higher than induction motor	Cost less than synchronous motor

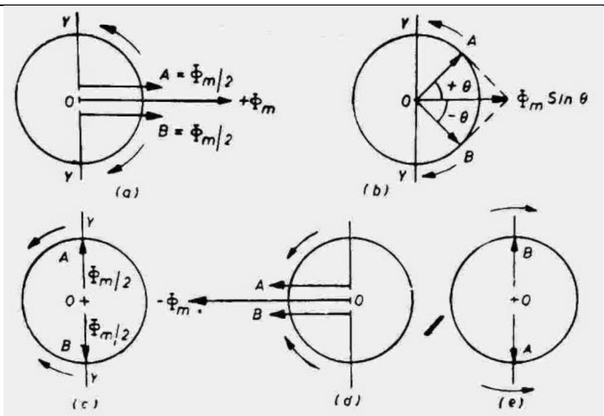
XI

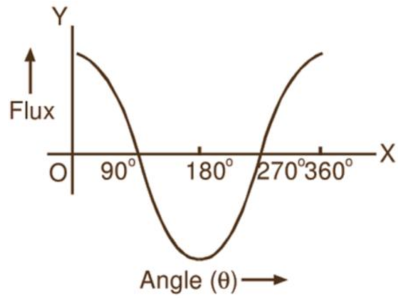
Explain with the help of double field revolving theory that the single phase induction motor is not a self starting motor.

- Single phase IM consists of only one stator winding.
- The rotor is a squirrel cage rotor.
- When single phase supply given to stator an alternating flux produced.
- This flux crosses the air gap and links with the rotor conductors.
- The rotor forms a closed circuit, current is induced in the rotor bars and a torque is produced.
- The torque developed on the upper half of rotor tends to rotate rotor in one direction and torque produced on the lower half of the rotor tends to rotate in opposite direction.
- Hence net torque on the rotor is zero.
- Hence single phase induction motor is not self-starting.

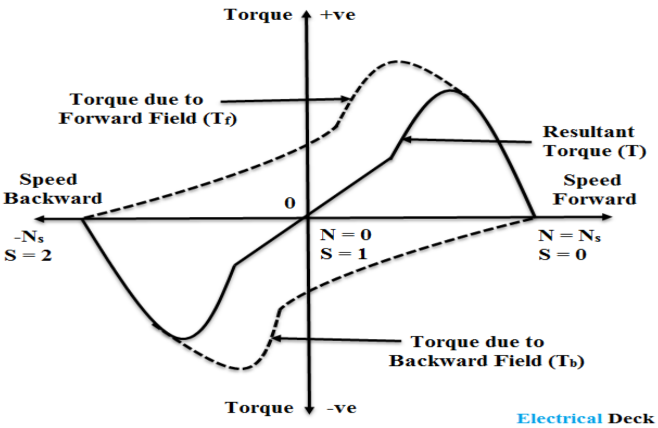
Double Field Revolving Theory

- Let the alternating flux have a maximum value of ϕm.
- ϕm has two components, fluxes A and B.
- A and B are equal in magnitude, ie, $\phi m/2$ but revolving in anti-clockwise and clockwise directions respectively.
- At starting of rotation, $\theta = 0^0$, fluxes A and B, in same direction, the resultant flux is $2 \text{ x } \phi m/ 2 = \phi m$ (Fig a)





- After a quarter cycle of rotation, fluxes A and B in oppositely-direction. so that the resultant flux would be zero.(Fig c)
- After half a cycle, fluxes A and B will have a resultant of -2 x ϕm/ 2 = - ϕm. It is shown in figure below(fig d)
- After three quarters of a cycle, again the resultant is zero, as shown in figure(e)
- If we plot the values of flux from 0 to 360 degree we got a curve as shown.

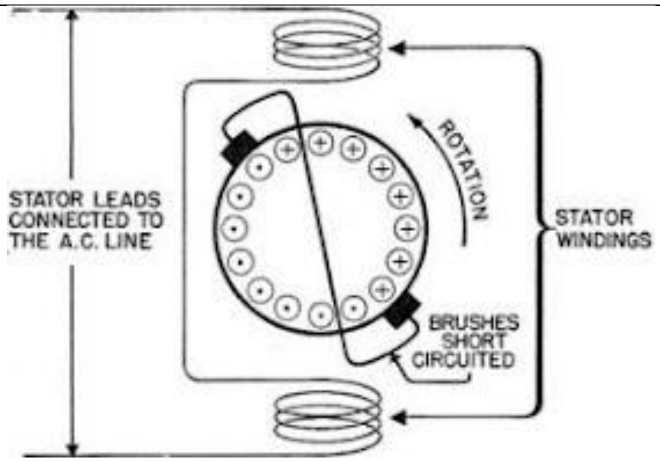


OR

XII Explain the construction and working principle of repulsion type motors.

CONSTRUCTION

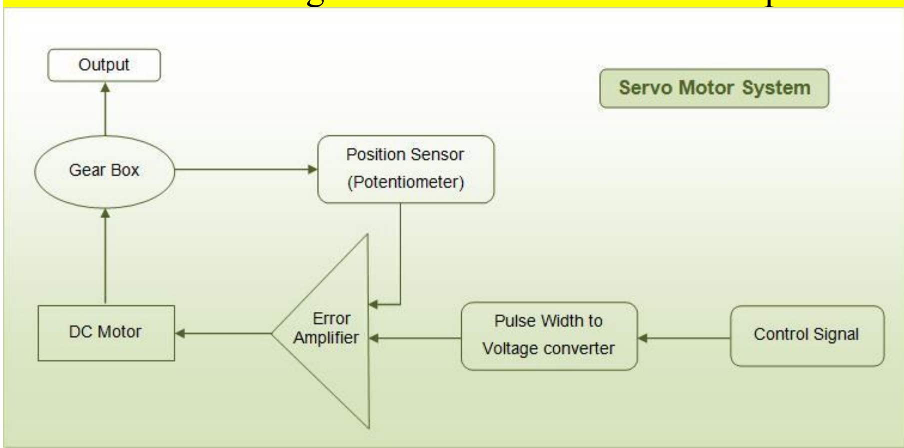
- The stator of the motor is generally cylindrical with slots.
- The rotor windings are distributed type.
- It may be lap winding / wave winding.
- These motors have a commutator.
- Brushes are short circuited and known as brush axis
- Supply is given to stator only.
- Carbon brushes used for conducting current using the armature.
- The main difference between the AC series motor & repulsion motor is how the power supply is supplied in the direction of the armature.



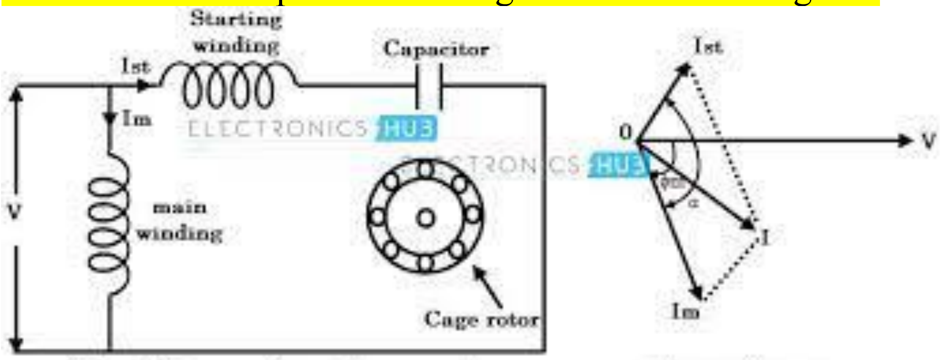
Working

- When magnetic axis and brush axis are parallel and perpendicular, no torque will develop.
- When magnetic axis and brush axis are set at a particular brush shifting angle torque will developed.
- When AC supply is applied to the stator winding, an e.m.f will be induced in the armature.
- The direction of AC will create two poles like north & south
- where a north pole can be formed at the top of the magnetic axis and a south pole can be formed at the bottom of the magnetic axis.
- The induced electromagnetic force direction can be given by Lenz's law. As the force induces the flow of current within the armature conductors
- The current direction will depend on the brushes position.

XIII Describe the working of a servo motor with the help of block diagram.



- The servo has a position sensor, a DC motor, a gear system and control circuit.
- The DC motor run at high speed & low torque when getting power from a battery.
- The speed is lower & torque will be higher than gear and shaft assembly connected to DC motors.
- The position of shaft sense by position sensor

	• The signal is decoded by a control circuit from the position sensor & handles the direction of rotation to get the correct position. • It needs a DC supply of 4.8 V to 6 V. • The gearbox is connected to a shaft which decreases the RPM. • The motor control is through microcontroller by sending PWM signals • The encoder sends the feedback signal to the control circuit. • When the motor reaches to required angle, the control circuit stops the motor accordingly with the help of received signals from an encoder.
	OR
XIV	Explain the working principle of permanent capacitor type single phase induction motor with the help of circuit diagram and vector diagram.  Circuit diagram of capacitor run motor Phasor diagram • Also called capacitor run motor • A low capacitor is connected in series with the starting winding • Capacitor and auxiliary winding are not removed during running condition. • So centrifugal switch is not required. • Capacitor produces more leading phase shift, less total starting current. • Hence, the starting torque produced by these motors will be considerably lower than that of capacitor start motor. • This will result better power factor and efficiency. • When the stator windings are energised from a 1-phase supply, the main winding carries current I_m and the starting winding carries current I_{st}. • The value of the capacitor is chosen such that current I_m is made to lag current I_{st}. These two currents produce a rotating magnetic field which starts the motor. **<u>Advantages</u>** 1. No centrifugal switch is required. 2. As the capacitor is connected permanently to the circuit, the power factor is high. 3. It has a higher pullout torque. 4. Efficiency is high. 5. Noise is less during operation. **<u>Applications</u>** exhaust and intake fans, unit heaters, blowers, etc