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	Number of brushes required in a rotating field type alternator to provide DC excitation. **2**
2	Identify the type of alternator for high speed operations. Non salient pole type alternator
3	Synchronous reactance consists of ________ and _________. Leakage reactance and armature reaction reactance
4	List any two methods to find voltage regulation of alternator. EMF method, MMF method
5	Define the term synchronizing torque in parallel operation of alternators. • It is a component of electrical torque produced by a synchronous generator. • If any one of the alternator in parallel operation is drop out of synchronism synchronizing torque bring it back to synchronism • **Synchronizing Torque ,** $T_{SY} = \frac{P_{SY}}{2\pi N_S/60}$
6	If excitation current is increased in the synchronous motor under lagging power factor load the power factor will __________________. Leading power factor
7	**List any two features of synchronous motors.** It is a constant speed motor Not self starting Double excitation motor
8	Write the equation for synchronous speed of synchronous motor. **Synchronous speed ,** $N_S = \frac{120f}{P}$

<table>
<tr><td>9</td><td>Write any two applications of universal motor.
Food mixer, Portable drilling machine</td></tr>
</table>

PART B

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

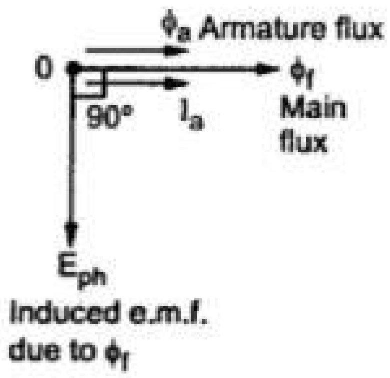
<table>
<tr><td>1.</td><td>Calculate pitch factor of given alternator if the coil span of winding is 150 degree.

Kc= cos ($\frac{\alpha}{2}$)

α = 180 – coil span =180-150 = 30

Kc= cos ($\frac{30}{2}$) = cos 15 =0.9659
</td></tr>
<tr><td>2.</td><td>Describe the effect of armature reaction under leading power factor load in alternators.

- At zero powerfactor leading, I$\boldsymbol{aph}$ **lead** Eph by 90
- armature flux in phase with main flux..
- It strengthens the main flux. Hence emf generated by the alternator increases.



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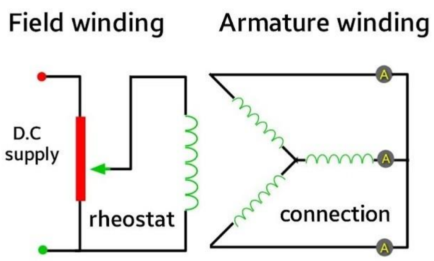
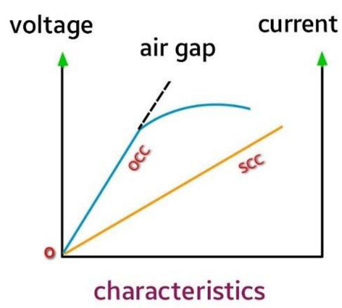
<tr><td>3</td><td>Illustrate the nature of open circuit and short circuit characteristics of alternators.





- OCC is a graph between open circuit voltage and field current .Here load terminals are kept open
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<tr><td></td><td>

- Short circuit characteristics is a graph between field current and short circuit armature current. Here load terminals are short circuited.

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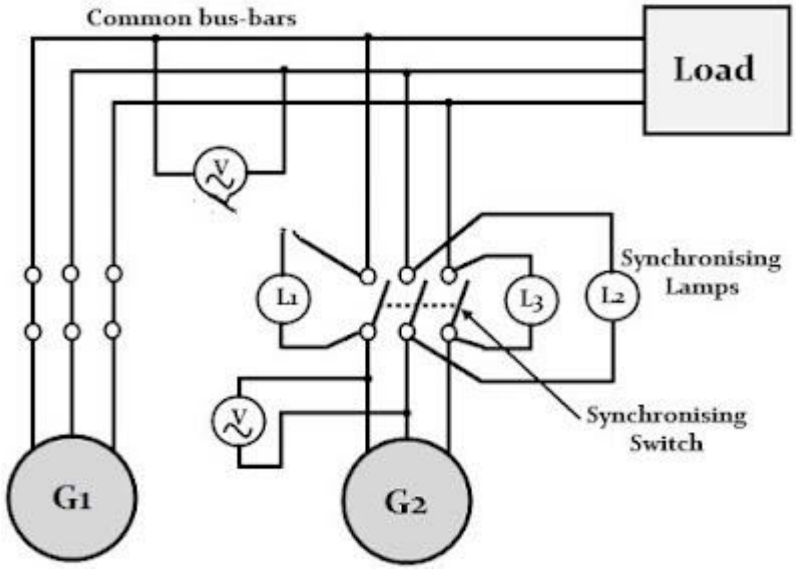
<tr><td>4</td><td>

Draw the layout of parallel operation of two alternators in the dark lamp method.



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<tr><td>5</td><td>

List out any three advantages of parallel operation of alternators.

- Continuity of supply
- High efficiency
- Operating and generation cost can be reduced

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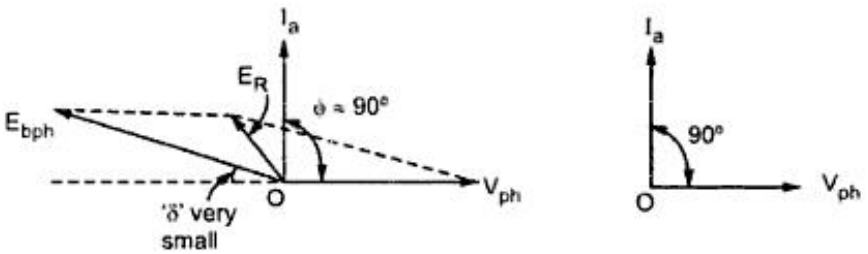
<tr><td>6</td><td>

Describe the operation of a synchronous motor as a synchronous condenser.

- An over excited synchronous motor that runs on no load is called synchronous condensers.
- It draws leading current
- Used for power factor improvement.
- **If this motor is on no load condition, where load angle ‘δ’ is small & Eb > V**



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<tr><td>7</td><td>

Define any three torques in synchronous motors.

Starting torque
Torque produced at the time of starting of synchronous motor is called starting torque
Running torque
Torque produced at running condition of synchronous motor is called starting torque

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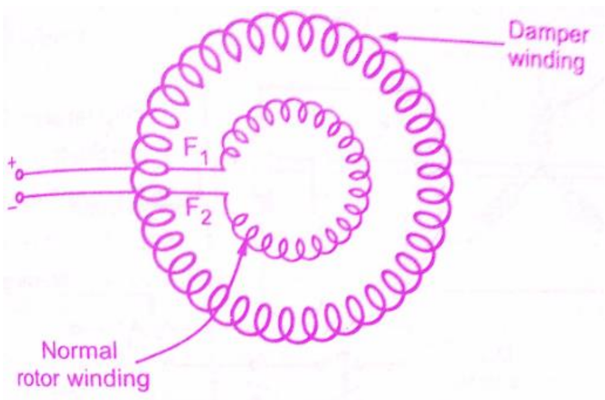
</table>

	Pull in torque The amount of torque required for synchronous motor to pull into synchronism
8	List out any three applications of synchronous motor. • Used in power houses and substations • It can be used as a frequency changer • Used to improve voltage regulation of transmission lines.
9	Describe the nature of capacitors used in capacitor start induction run type single phase induction motors. ✓ C_R – Run capacitor: Used for continuous running of motor. It is paper capacitor. ✓ C_S – Starting capacitor: used at the starting. It is electrolytic type capacitor.
10	Describe how the damper winding helps the self starting of the synchronous motor. ✓ Damper winding consists of low resistance copper bars. ✓ Damper windings are short-circuited at the ends and form as a squirrel cage winding. ✓ When three phase supply is applied, rotating magnetic field is produced which induce current in the damper winding. ✓ And the motor starts as a squirrel cage induction motor. ✓ When motor approaches synchronous speed dc supply is given to rotor ✓ Rotor poles and stator poles interlocked and motor runs at synchronous speed ✓ When motor is running at synchronous speed, there is no emf induced in damper winding. 

PART C

Answer ALL questions. Each question carries 7 mark

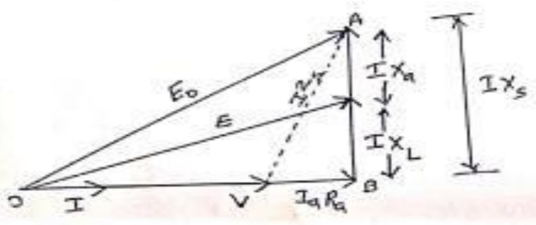
III	Calculate speed and open circuit phase voltage of a 4 pole 3 phase 50 Hz star connected alternator with 36 slots and 30 conductor per slot full pitched winding. The flux per pole is 0.05 web sinusoidally distributed.
	OR
IV	A 3 phase 8 pole 750 rpm star connected alternator has 72 slots on armature. Each slot has 12 conductors and winding is short chorded by 2 slots. Find induced emf between lines, given flux per pole is 0.06 web. **Answer:** No of poles ,P = 8 Flux/pole ϕ = 0.06 wb Conductor/slot =12 No.of slots = 72 n=slots/pole = 72/8 =9 m=slots/pole/phase = 9/3 =3 Speed, N =750 rpm ($N_s = \frac{120f}{P}$) $f = \frac{PN}{120} = \frac{8X\,750}{120} = 50Hz$ $Zph = \frac{\text{No.of slots x (conductor/slot)}}{3} = \frac{72\ X\ 12}{3} = 288$ $Tph = \frac{Zph}{2} = \frac{2888}{2} = 144$ $\beta = \frac{180}{n} = = \frac{180}{9} = 20$ Short chorded by 1 slot , α = β x no.of slots by short pitched = 20 x 2 =40 $Kc = \cos\left(\frac{\alpha}{2}\right) = \cos\left(\frac{40}{2}\right) = \cos 20 = 0.939$ $Kd = \frac{\sin\left(\frac{m\beta}{2}\right)}{m \sin\left(\frac{\beta}{2}\right)} = \frac{\sin\left(\frac{3x20}{2}\right)}{3\sin\left(\frac{20}{2}\right)} = \frac{\sin(30)}{3\sin(10)}$ **= 0.959**

	Induced emf ,Eph = 4.44 fϕ Tph Kc Kd volt = 4.44 x 50 x 0.06 x 144 x 0.939 x 0.959 = 1727.23 V Line voltage ,$E_L = \sqrt{3}$ X Eph = $\sqrt{3}$x1727.23=2991.65 V
V	Derive the equation for generated EMF in synchronous generators. Let, Z_{ph} = Number of conductor / phase = 2T T = Turns /Phase Φ = flux per pole N= speed Kc =Pitch factor Kd = distribution factor Kf = form factor =1.11 for sine wave Total flux cut in one revolution = PΦ webber Time taken $= \frac{60}{N}$ second Average emf induced $= \frac{\text{Total flux cut}}{\text{Time taken}}$ $= \frac{P\Phi}{\frac{60}{N}}$ $= \frac{P\Phi N}{60}$ volt Where N = 120f /P $= \frac{P\Phi}{60} \times \frac{120f}{P} = 2f\phi$ Average emf induced / phase = 2fϕ x Z_{ph} = 2fϕ x 2T = 4fϕ T RMS value of induced emf /phase = Average value x Form factor = 4fϕ T x 1.11 =4.44 fϕ T volt **Actual emf induced /phase = 4.44 fϕ T Kc Kd volt**

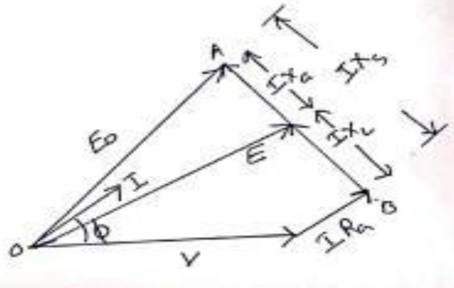
OR

VI

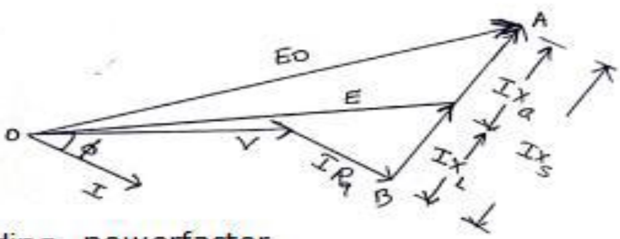
Develop the phasor diagrams of alternators under lag lead and unity power factor loads.



UPF



Leading power factor



Leading powerfactor

VII

A three phase star connected 1000 KVA,11000V alternator has rated current of 52.5A. the ac resistance per phase is 0.45 ohm.The test result are given below
OC test : field current = 12.5 A voltage between line = 422 V
SC test : field current = 12.5 A line current = 52.5 A
Determine full load voltage regulation at 0.8 pf lead.

OR

VIII

The following are the test details obtained on a 6600V alternator

Open circuit voltage	3100	4900	6600	7500	8300
Field current	16	25	37.5	50	70

A field current of 20 A is necessary to circulate a full load current on a short circuit. Calculate the full load regulation at 0.8 pf lagging by MMF method.

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IX

Describe the different starting methods used in synchronous motors.

1.Using Pony Motor

- A small induction motor is called pony motor.

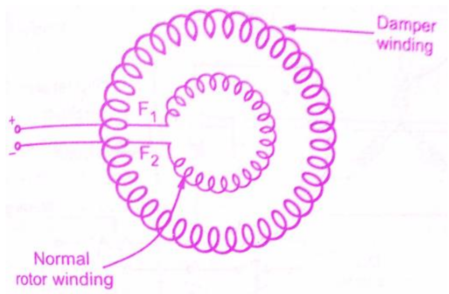
- Pony motor is coupled to the synchronous motor which bring the rotor of synchronous motor to synchronous speed.
- Then switch on DC supply to rotor
- Rotor pole lock with rotating magnetic field and rotates in synchronous speed
- Once rotor attains synchronous speed, pony motor can be decoupled.

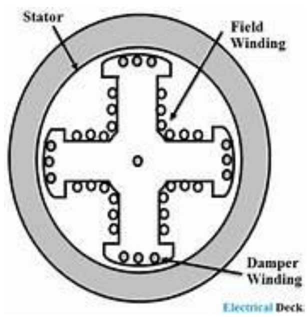
2. Using small DC machine

- A dc machine is coupled to the synchronous motor
- The DC machine works as a dc motor initially and bring the synchronous motor in to synchronous speed.
- When achieve Ns, DC machine works as a dc generator and supply dc to the rotor of synchronous motor.

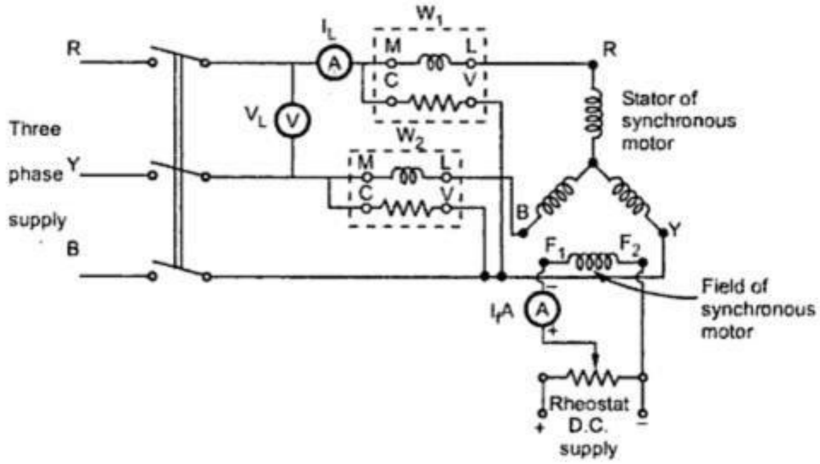
3.**Using Damper winding**

- Damper winding consists of low resistance copper bars
- Damper windings are short-circuited at the ends and form as a squirrel cage winding.
- It is placed in the pole faces of salient poles
- When three phase supply is applied, rotating magnetic field is produced which induce current in the damper winding
- And the motor starts as a squirrel cage induction motor.
- When motor approaches synchronous speed dc supply is given to rotor
- Rotor poles and stator poles interlocked and motor runs at synchronous speed
- When motor is running at synchronous speed, there is no emf induced in damper winding





	OR
X	Illustrate the experimental method to plot the V and inverted V curves of a synchronous motor.

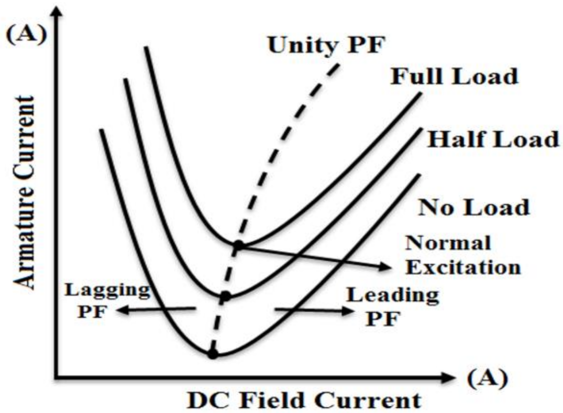


W1 &W2 are power factor meters

1. Connections are given as per the circuit diagram.
2. By adjusting the auto transformer rated supply is given to the motor. The motor starts as an induction motor.
3. In order to give the excitation to the field winding, for making it to run as synchronous motor, DC is applied
4. By varying the field current with the help of field rheostat from under excitation to over excitation, note down the excitation current, armature current and the power factor.
5. The same process has to be repeated for loaded conditions.
6. Later reduce the load and the motor is switched off

V curve

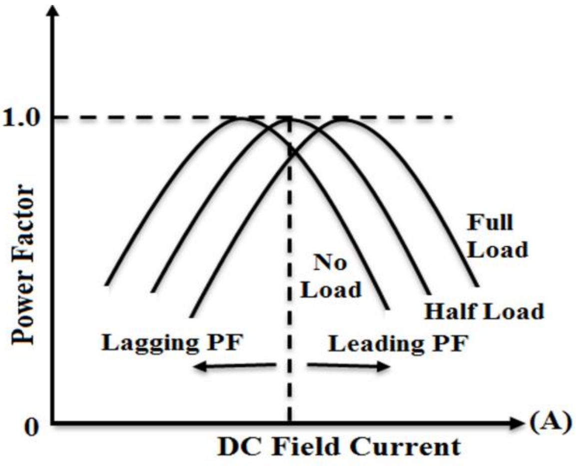
- V curve is a plot of the armature current versus field current for different constant loads.
- Assume the motor is running at constant load.
- If the field current is increased from small value, the armature current decreases until the minimum value where motor operates at UPF
- In this region, the motor operates at a lagging power factor.
- If the field current is increased further, the armature current increases and the motor starts operating at the leading power factor



Inverted V curve

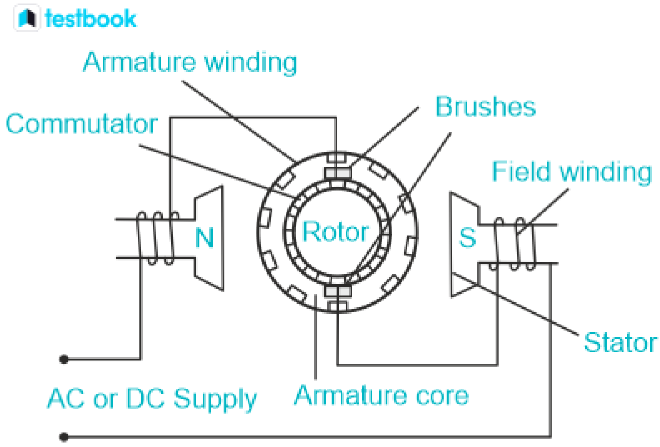
- **Inverted V curve** is a plot of power factor versus field current for different constant loads.
- The motor is running at constant load.
- If the field current is increased from small value, the power factor changes from lagging to unity power factor.

- If the field current is increased further, the power factor reduces and the motor starts operating at leading power factor.



XI

Describe the construction and working of universal motors.



- A universal motor is runs on both AC and DC power.
- Universal motors are series-wound.
- The series connection allows them to generate high torque.
- run at a higher speed on DC supply than AC

Manufactured in two ways.

(i) Concentrated pole, non-compensated type (low power rating)

(ii) Distributed field compensated type (high power rating)

CONSTRUCTION

- Similar to the construction of a DC series motor
- It has stator and rotor.
- Field poles are mounted on stator
- Field coils are wound on the field poles.
- stator field circuit and armature is laminated to minimize the eddy currents loss
- The rotor is of wound type having straight or skewed slots
- It has commutator and brushes

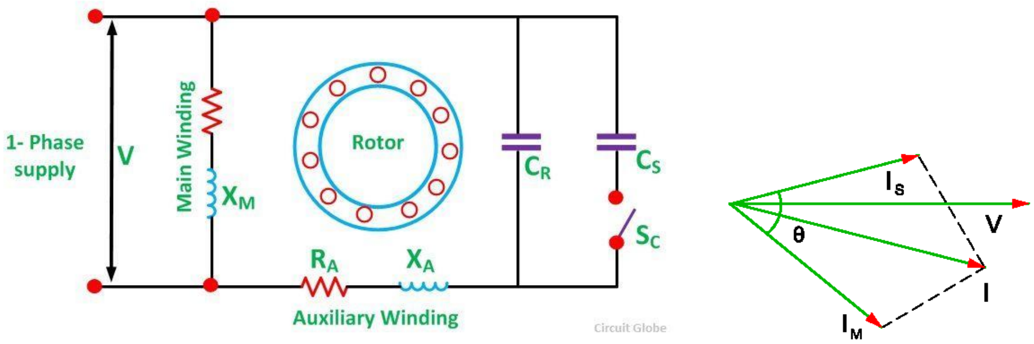
Working of universal motor

• When DC current flows in the field winding, it produces an electromagnetic field.
• The same current also flows from the armature conductors.
• When a current carrying conductor is placed in an electromagnetic field, it experiences a mechanical force.
• Due to this mechanical force, or torque, the rotor starts to rotate.
• The direction of this force is given by Fleming's lefthand rule.
• When fed with AC supply, it still produces uni directional torque.
• Because, armature winding and field winding are connected in series, they are in same phase.
• Hence, as polarity of AC changes periodically, the direction of current in armature and field winding reverses at the same time.

OR

XII Describe the construction and working of capacitor start capacitor run type induction motors.

Capacitor start and capacitor run induction motor

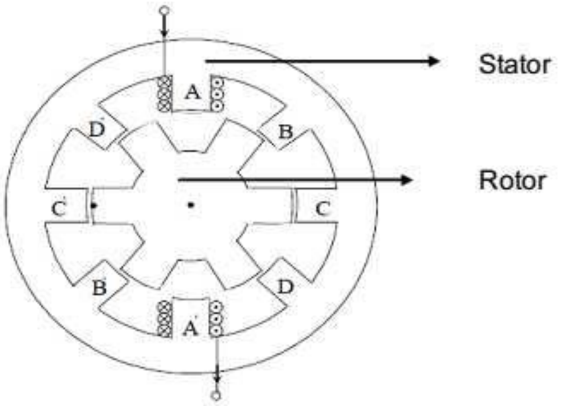


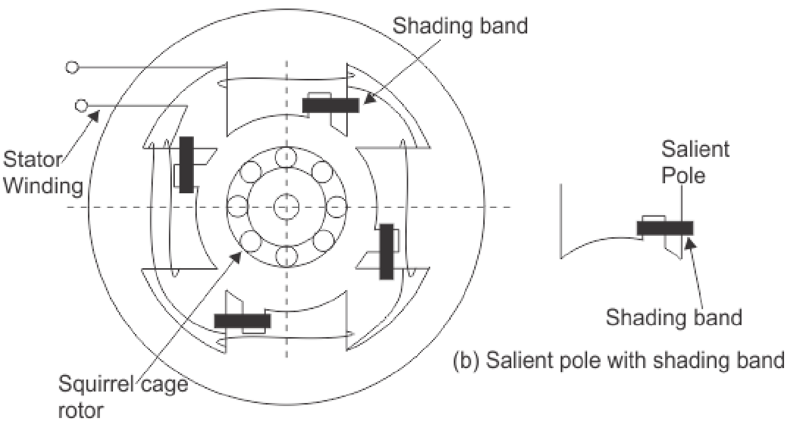
- ✓ It has a cage rotor and stator has two windings known as main and auxiliary winding.
- ✓ Two windings are displaced 90 degrees in space.
- ✓ C_R – Run capacitor: Used for continuous running of motor. It is paper capacitor.
- ✓ C_S – Starting capacitor: used at the starting. It is electrolytic type capacitor.
- ✓ Also known as two value capacitor motor.
- ✓ Two capacitors are connected in parallel at the time of starting.

Advantages:

- Ability to start heavy loads
- Extremely quiet operation
- higher efficiency and power factor
- ability to develop 25 per cent overload capacity

Disadvantages:

	● Cost is higher than capacitor start IM **<u>Applications of Capacitor-Start Capacitor-Run Motor</u>** ✓ Air compressors ✓ Refrigerators ✓ Pumping equipment ✓ Air conditioners ✓ Ceiling fans
XIII	Explain the construction and working of switched reluctance motor **<u>Switched Reluctance Motor</u>** **<u>Construction</u>** • Operates on the same principle of variable reluctance stepper motor. • Stator and rotor have salient poles. • Double saliency is effective for electromagnetic energy conversion. • Opposite pole stator coils are being connected in series. • The laminated rotor has no windings or magnet. • 8 stator pole and 6 rotor pole arrangement are widely used. **<u>Working</u>**  ✓ Stator coils are energised with a single pulse of current at high speed. ✓ At starting and low speeds, a current chopper type control is used to limit the coil current. ✓ Motor rotates in anticlockwise when stator energized in a sequence of ABCD. ✓ Motor rotates in clockwise when stator energized in a sequence of A’B’C’D’. ✓ When stator coil energized, nearest pair of rotor poles is pulled in to alignment with stator poles by reluctance torque. **<u>Advantages</u>** ✓ High efficiency

	✓ High speed up to 30000 rpm ✓ Four quadrant operation is possible appropriate drive circuit. ✓ Self-starting without using additional arrangements. ✓ less expensive because of the nonexistence of permanent magnets **Disadvantages** ✓ High noise level ✓ It uses an external rotor position sensor. ✓ Not well suited for smooth torque production **Application** • Used in electric vehicles. • Food processors • Vacuum cleaners • Washing machines • Industrial drives
	OR
XIV	Explain the construction and working of shaded pole motors. **Shaded Pole Motor**  (a) 4-pole shaded pole construction ➢ It is a self-starting 1-phase induction motor. ➢ It consists of a stator and a squirrel cage type rotor. ➢ The bars of the rotor are skewed at an angle of 60°. ➢ The stator poles are salient poles. ➢ Each stator pole is splitted into two unequal parts, shaded and unshaded. ➢ A copper band is fixed in the smallest portion which is known as shaded portion. **Working**

- When supply is given, an alternating flux is produced in the poles which is known as main flux.
- Due to this flux a current flow through shading coil and a flux produced in the shading coil also
- Shading flux opposes main flux according to lenzs law
- At t= t1, the flux is increasing, so that flux concentrated on unshaded portion
- At t=t2, flux is at its maximum, the flux equally distributed in both shaded and unshaded portion
- At t= t3, Flux is decreasing, the flux concentrated on the shaded portion
- There is a flux shift from unshaded to shaded portion, which produce a torque and rotor rotates in the direction of shaft.