568

April 2024

ELECTRICAL MACHINES – II

PART-A

1. What are the requirements of an alternator? [3 marks]

- For the generation of emf, there should be two basic systems required.
    1. Magnetic field system to produce the magnetic field.
    2. Armature system which houses conductor on which the emf is to be induced.
- In order to induce emf in the conductors, one system must be kept under movement, with respect to the other system which is stationary.
- In alternators, any one of the following methods can be adopted to generate A.C e.m.f.
    1. Stationary armature and rotating field system.
    2. Stationary field and rotating armature system.

2. Why cooling is necessary for alternators? [3 marks]

- The losses produced in the core and conductors of electrical machines are converted into heat.
- It raises the temperature of several parts of the machine.
- Hence to reduce the heat, air or Hydrogen is used as cooling medium.

3. What is meant by effective resistance? [3 marks]

- The effective resistance of the armature is the resistance offered by the armature winding for an alternating current. It is greater than the D. C resistance due to skin effect.
- R_{eff} is usually assumed to be1.6 R_{DC}. the voltage drop due to this resistance (I R_{eff}) is very low compared to other voltage drops

$$R_{eff} = 1.6\ R_{DC}$$

4. What are the advantages of parallel operation of alternators? [3 marks]

- In the event of break down or shut down for the maintenance of an alternator in generating station, it is possible to maintain the continuity of supply.
- Repair and maintenance of individual machines can be carried out one after the other without any deviation from the normal routine work.
- If several small alternators are used, depending upon the load requirement any required number of alternators can be operated and the remaining machines can be put off. It is economical and improves the efficiency of the generating station.
- When the demand increases, new alternators can be installed to operate in parallel. This reduces the initial capital cost of system of purchasing a large size alternator in anticipation of increasing demands.
- It is difficult to manufacture and transport large size alternators. In such cases two or more number of alternators can be connected in parallel to meet the load requirement.

5. Compare squirrel cage and slip ring induction motor. [3 marks]

Cage Induction Motor	Slip ring Induction Motor
• Rotor construction is very simple.	• Rotor construction is not simple as compared to squirrel cage rotor.
• Rotor conductors are made of copper or Aluminum bars and short circuited at either ends.	• Wound rotor having windings similar to stator windings. They are star connected and three leads are connected to three slip rings.
• No provision to add extra resistance in the rotor circuit.	• Extra resistance can be inserted in the rotor circuit.
• High starting current.	• Low starting current.
• Cheaper cost and low maintenance.	• High cost and maintenance are more.
• Higher efficiency.	• Slightly lesser efficiency.
• Speed control by rotor resistance is not possible	• Speed control by rotor resistance is possible.
• No moving contacts in the rotor.	• Carbon brushes, slip rings etc are provided in the rotor circuit.
• Less starting Torque	• High starting Torque.

6. Write down the expression for relationship between slip and slip frequency. [3 marks]

Slip(S):

- The difference between the synchronous speed (Ns) and the actual speed (Nr) of the rotor is known as slip.
- Is always expressed as the percentage.

$$\% \text{ slip} = \frac{Ns - Nr}{Ns} \times 100$$

Slip frequency (f'):

- When the rotor is stationary, the frequency of rotor current is the same as the supply frequency. But when the rotor starts revolving, the frequency of rotor current depends upon the slip speed or the relative speed.
- Let the frequency of rotor current be f '.

$$S = \frac{f'}{f} \Longrightarrow f' = S f$$

7. Write about hunting and its prevention. [3 marks]

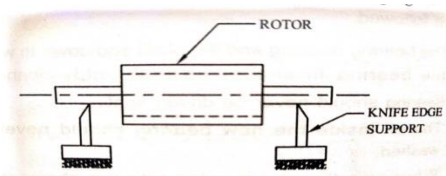
- Hunting is the phenomenon of oscillation of the rotor about its steady state position or equilibrium state in a synchronous motor. Hence, hunting means a momentary fluctuation in the rotor speed of a synchronous motor.
- The damper windings used to prevent hunting.

8. State the application of a split phase motor. [3 marks]

- These type motors are used in
  - ✓ fans,
  - ✓ blowers,
  - ✓ centrifugal pumps,
  - ✓ domestic refrigerators,
  - ✓ oil burners,
  - ✓ washing machines,
  - ✓ Drilling machines and machine tools etc.

9. What is meant by static balancing? [3 marks]

- Balancing is an operation for correcting the weight distribution of the finished rotor assembly. For smooth running without vibrations, the rotor should be mechanically balanced.
- The unequal distribution of weight in the rotor causes centrifugal forces and creates "swinging" of rotor.



Static Balancing
Fig. 5.2

- Static balancing The rotor to be balanced is placed on two knife edges of the balancing rig as shown in Fig.(5.2).
- Here rotor refers to complete rotor including slip rings, coupling etc. The knife edges should be in perfect horizontal plane.
- A well balanced rotor will remain standing in any position when turned about the axis in any direction it will not oscillate.
- If the rotor is unbalanced, then the heavy side will always try to come down and the rotor cannot stay in any position.
- The balancing is achieved by adding weight to lighter portion or drilling out material from heavier portion of the rotor

10. List the classification of cage motor. [3 marks]

- Motors with normal starting torque and normal starting current
- Motors with high starting torque and normal starting current
- High torque and high slip motor

PART-B

11. a (i) Explain the types of armature winding used in alternators. [7 marks]

- Armature winding of alternators is classified in following types.
    1. Single layer winding
    2. Double layer winding
    3. Lap winding
    4. Full pitch winding
    5. Short pitched winding
    6. Concentrated Windings
    7. Distributed Windings

1. Single layer winding:

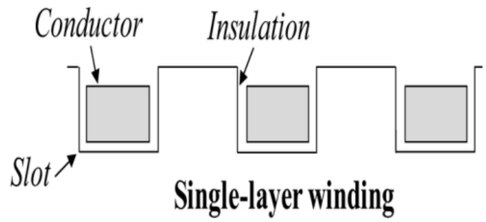


Fig. 1.1

- Single- layer winding One coil-side occupies the total slot area shown in fig. 1.1
- Single- layer winding Used only in small ac machines
- The three most common types of single layer windings are
    1. Concentric windings (Unequal coil span)
    2. Chain windings (Equal coil span)
    3. Mush windings (Equal coil span)

2. Double layer winding:

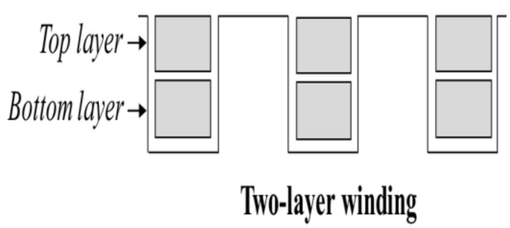


Fig. 1.12

- Slot contains even number (may be 2,4,6 etc.) of coil-sides in two layers shown in fig.1.12
- Double-layer winding is more common above about 5kW machines

3. Lap winding:

- In a lap winding the finish of one coil side is connected to the start of the adjoining coil.
- lap winding shown in fig.1.13

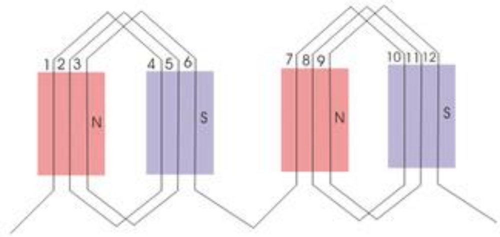


fig.1.13

4. Full pitch winding:

- If the coils pan is equal to the pole pitch, then the winding is called full pitch winding.

5. Short pitched winding:

- If the coil span is less than the pole pitch, then the winding is said to be short pitched winding

6. Concentrated Windings:

- All the winding turns are wound together in series to form one multi-turn coil.
- All the turns have the same magnetic axis Examples of concentrated winding are field windings for salient-pole synchronous machines.

7. Distributed Windings:

- All the winding turns are arranged in several full-pitch or fractional-pitch coils.
- These coils are then housed in the slots spread around the air-gap periphery to form phase Examples of distributed winding are Stator and rotor of induction machines.

11. a (ii) State the differences between salient pole rotor and cylindrical rotor. [7 marks]

S.No	Salient Pole Rotor	Cylindrical Rotor
1	Rotor is having projecting pole	Rotor is having no projecting pole
2	Rotor causes speed fluctuation	Rotor causes no speed fluctuation
3	Damper winding is provided	No need for damper winding
4	Suitable for low and medium speed operation	Suitable for high speed operation
5	Large diameter and short axial length	Small diameter and long axial length
6	Windage loss is more	Windage loss is less
7	Air gap is non-uniform	Air gap is uniform due to smooth cylindrical periphery
8	Prime mover used are water turbine, I.C engines	Prime movers used are steam turbines, Electric motors.

11. b (i) Derive an expression for the EMF equation of an alternator. [10 marks]

Let

$Z_p = 2T$ = Number of armature conductors in series per phase.
P = Number of poles.
ϕ = Useful flux per pole in Weber.
N = Rotational speed in rpm.
F = Frequency in hertz and is equal to $\frac{120}{NP}$

- The flux cut by any conductor while passing from the centre of one inter polar gap to the centre of the next is ϕ Weber and since during the movement, the emf wave completes half cycle.
- I.e. the time taken is $\frac{1}{2f}$ seconds.
- Therefore, the average rate of cutting the flux $\frac{d\emptyset}{dt} = \frac{\emptyset}{1/2f}$

  $= 2\,\phi\,f$ we/sec.

  Hence average emf induced in each conductor $= 2\,\phi\,f$ volt.

- Average emf per phase,

  $E_{av\,/\,phase}$ = *number of conductors in series / phase* **X** *average induced emf per conductor*

  $= Z_p * 2\,\phi\,f = 2T * 2\,\phi\,f = 4\,\phi\,f\,T$ volt.

- For distributed winding the average value of emf per phase will be k_d time above the value

  i e $E_{av\,/\,phase} = k_d\ 4\,\phi\,f\,T$ volt

- For short pitched winding the true average value of emf per phase will be k_p time above the value

  i e $E_{av\,/\,phase} = k_d\,k_p\ 4\,\phi\,f\,T$ volt

  And $E_{rms\,/\,phase}$ = form factor(k_f)* $k_d\,k_p\ 4\,\phi\,f\,T$ volt

  if $k_f = 1.11$

  $\therefore\ E_{rms\,/\,phase} = 1.11 * k_d\,k_p\ 4\,\phi\,f\,T$ volt

$$\boldsymbol{E_{rms\,/\,phase} = 4.44\ k_d\ k_p\ \phi\ f\ T\ \text{- volt}}$$

- If the alternator is star-connected, as is usually the case, the line voltage is √3 times the phase value. So, the line induced emf,

$$\boldsymbol{E_L = \sqrt{3}\ 4.44\ k_d\ k_p\ \phi\ f\ T\ \text{- volt}}$$

11. b (ii) Derive an expression to find the relationship between frequency speed and number of poles. [4 marks]

- In a four pole alternator, two cycles will be completed during one revolution of the rotor.
- Similarly in a six pole machine, three cycles are completed in one revolution.

  Let

  P - Total number of magnetic poles.

  N - Speed of rotor in rpm.

  F - Frequency of generated EMF.

  Number of cycles per revolution = $\frac{P}{2}$

  Rotor revolution per second = $\frac{N}{60}$

  But cycles/sec = frequency = f

Frequency (f) = $\frac{\textbf{Number of cycles}}{\textbf{revolution}} * \frac{\textbf{revolution}}{\textbf{second}}$

$$f = \frac{P}{2} * \frac{N}{60}$$

$$f = \frac{PN}{120} \text{ Hz or cycles / second}$$

$$N = \frac{120F}{P} \text{ rpm, } P = \frac{120F}{N}$$

12. (a) Explain the effect of armature reaction of alternators for various power factor loads.

[Diagram -7 marks, Explanation -7 marks]

- The armature winding of an alternator carries current only when the alternator is loaded. At no-load, there will be no current flowing through the armature winding. In alternators under loaded condition, there are two fluxes present in the air-gap.

  They are

  - ✓ Flux due to the field ampere turns
  - ✓ Flux due to the current flowing through the armature winding
- That is, when the armature carries the load current, an armature flux (ϕa) is produced in the armature winding and is also present in the air gap.
- There is already another flux due to field current that is also present in the air-gap. Now there are two fluxes present in the air gap.
- But actually the machine needs only the fluxes due to field ampere turns only.
- **The effect of armature flux due to armature current over the main field flux is called armature reaction.**

This effect can be in the following forms:

They are

- ✓ The armature flux will produce a distortion over the field flux
- ✓ The armature flux will oppose the main field flux (or) will aid the main flux.
- ✓ The above said armature reaction effects depends upon the p.f of the load.

Armature reaction of unit power factor:

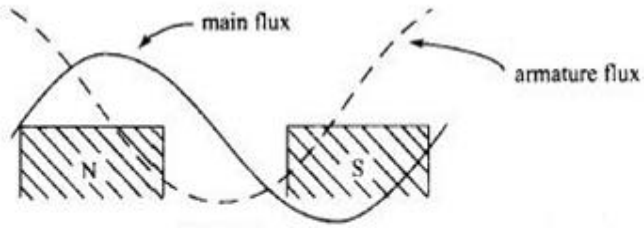


Fig 2.2 Unity p.f

- Consider the load of the alternator as resistive and for which the p.f is unity.
- That is the load current is in phase with the terminal voltage V.
- at unity p.f, armature flux cross magnetizing.
- at unity p.f of the load, the main flux and the armature flux are as shown in Fig 2.2 The result is that the flux at the leading pole tips of the pole is reduced.
- While it is increased at the trailing pole tips.
- Hence these two effects are more or less off set each other. Hence the field strength is constant. Under unity p.f load, the **armature reaction is distortional.**

Armature reaction of zero power factor lagging :

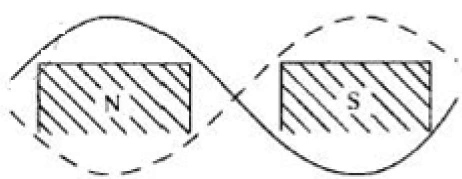


Fig 2.3 Zero p.f lagging

- Consider the load of the alternator as pure inductive, and for which the p.f is zero lagging.
- That is the load current lags the terminal voltage by an angle 90˚
- At zero p.f lagging load, the armature flux is in direct opposition to the main flux as shown in Fig 2.3.
- So the main flux is decreased. For zero p.f lagging, **the armature reaction is demagnetizing.**
- It weakens the main flux. So less emf is generated.
- To keep the generated emf constant, field excitation has to be increased, in order to compensate the weaken flux.

Armature reaction of zero power factor leading:

- Consider the load of the alternator is pure capacitive, and for which the p.f is zero leading.
- That is the load current leads the terminal voltage V by an angle 90˚.
- At zero p.f leading, the armature flux is in phase with the main flux as shown in Fig 2.4.

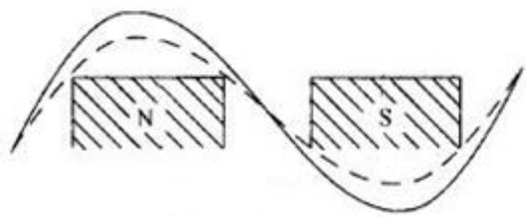


Fig 2.4 Zero p.f leading

- The armature flux added with the main flux and hence the flux is increased.
- Here the **armature reaction effect is magnetizing**.
- Due to increasing of flux, the generated emf is increased.
- Hence to keep the generated emf constant, the field excitation has to be reduced in order to compensate the increasing flux.

Armature reaction of Intermediate power factor:

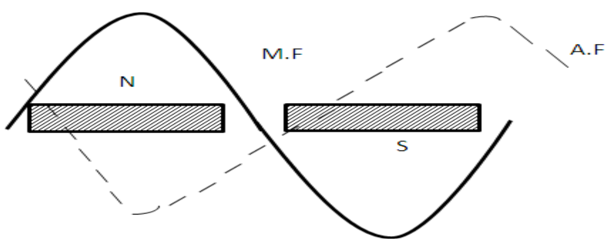


Fig 2.5 Intermediate power factor

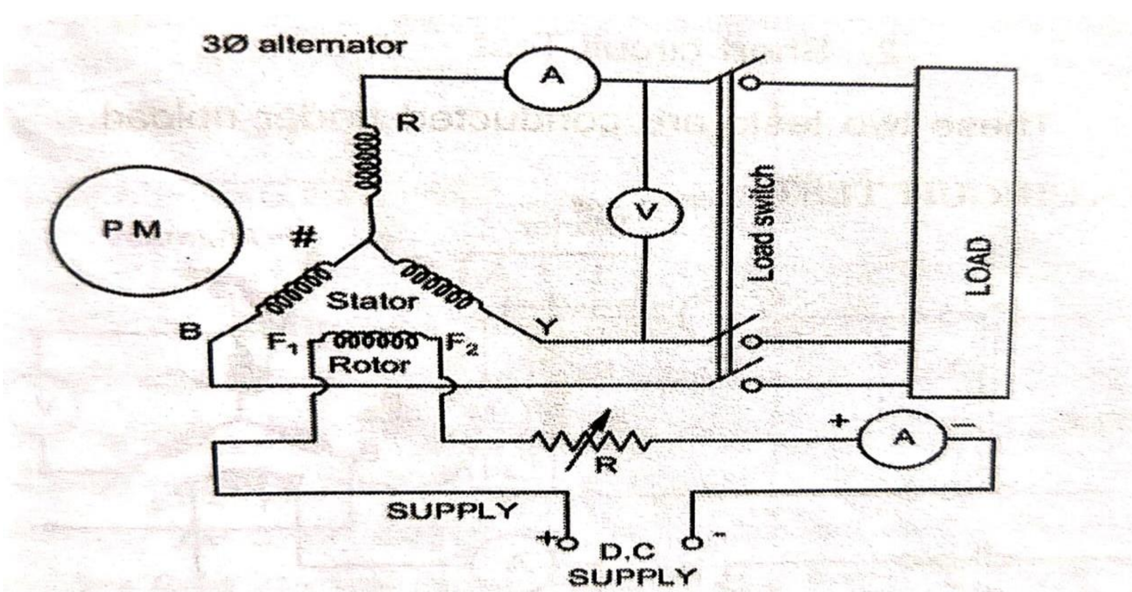
- If the p.f the load is intermediate (say 0.7 p.f lagging) the armature reaction effect is partly distortion and partly demagnetizing. The effect is shown in Fig 2.5

12. (b) Explain how regulation of alternator is determined by conducting direct load test.

[Diagram -7 marks, Explanation -7 marks]

- In case of small machines, the regulation may be found by direct loading.

Diagram:



The procedure is as follows:

- ✓ The alternator is driven by means of a prime-mover.
- ✓ The speed is adjusted to synchronous speed by adjusting the speed of prime-mover.
- ✓ The terminal voltage is adjusted to rated value at any power factor by varying the field current.
- ✓ Note the no load terminal voltage (E).
- ✓ Then close the load switch. Vary the load step by step and tabulate the terminal voltage (V) and load current (I) as shown in the tabulator column.
- ✓ The readings are taken up to full load current.

SL. No	Load current (I1)	Terminal voltage (V) in volts	No load terminal Voltage (E)	% Regulation $= \frac{E-V}{V}$ x100 V

- ✓ Then the load is reduced to zero and switch off the supply.
- ✓ Calculate the regulation by using the formula.

$$\% \text{ Regulation} = \frac{E-V}{V} \times 100$$

13. **(a) Explain the following with a neat sketch: (i) star delta starter, (ii) auto transformer starter.** **[star delta starter -7 marks, auto transformer starter-7 marks]**

i) Star Delta Starter:

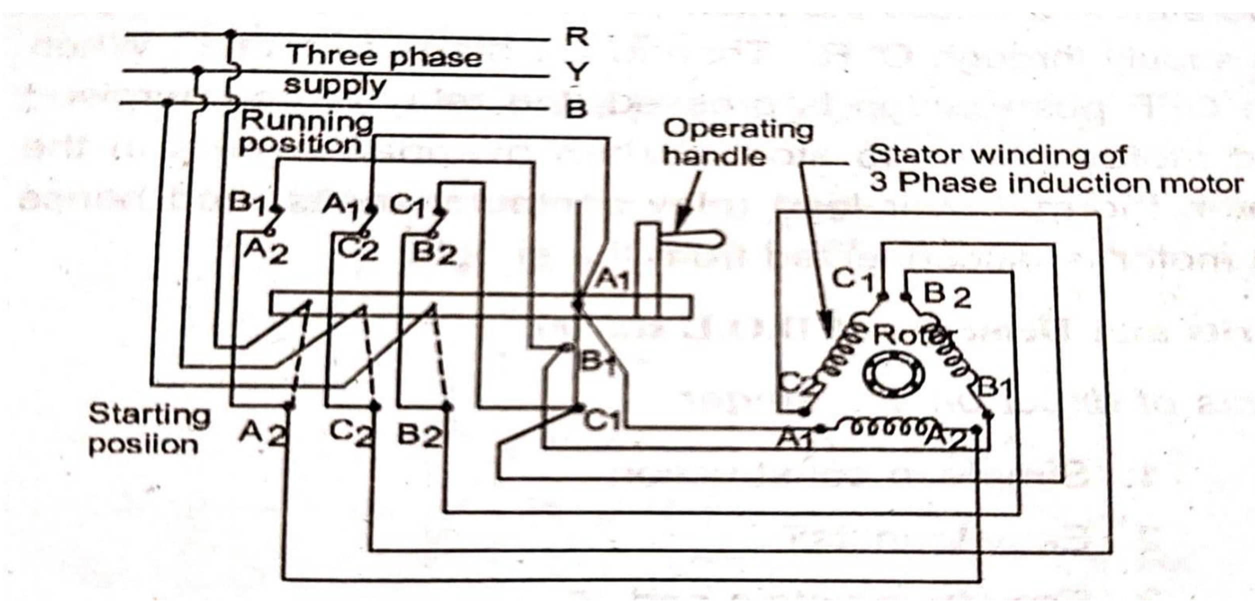


Fig.3.1

- At starting the star delta starter connects the three stator windings in star across the supply voltage.
- After motor attains speed, the same windings are connected in delta across the same supply through a change over switch.
- The connection diagram for star-delta starter is shown in Fig.3.1.
- The starter is provided with mechanical inter locking device to prevent the handle in "run" position first.
- Since at starting, the stator windings are connected in star, the voltage across each phase winding is reduced $1/\sqrt{3}$ of line voltage (since in star $V_p = V_L/\sqrt{3}$)
- Therefore the starting current is reduced to $1/\sqrt{3}$ times that of current taken with direct starting.
- The starting torque is also reduced to $1/3^{rd}$ of starting torque obtained with direct switching.

No volt release:

- If the supply fails (or) voltage drops in the line below a certain level the iron piece inside the relay is demagnetized and hence relay contactor and supply return to their original position. So the motor is disconnected from the supply.

Overload release:

- Due to overload, the motor may get heated up. Due to this heat, the overload relay contactor melts thereby disconnecting the motor from the supply. Thus overload relay protects the motor from overload,

ii) Auto Transformer Starter:

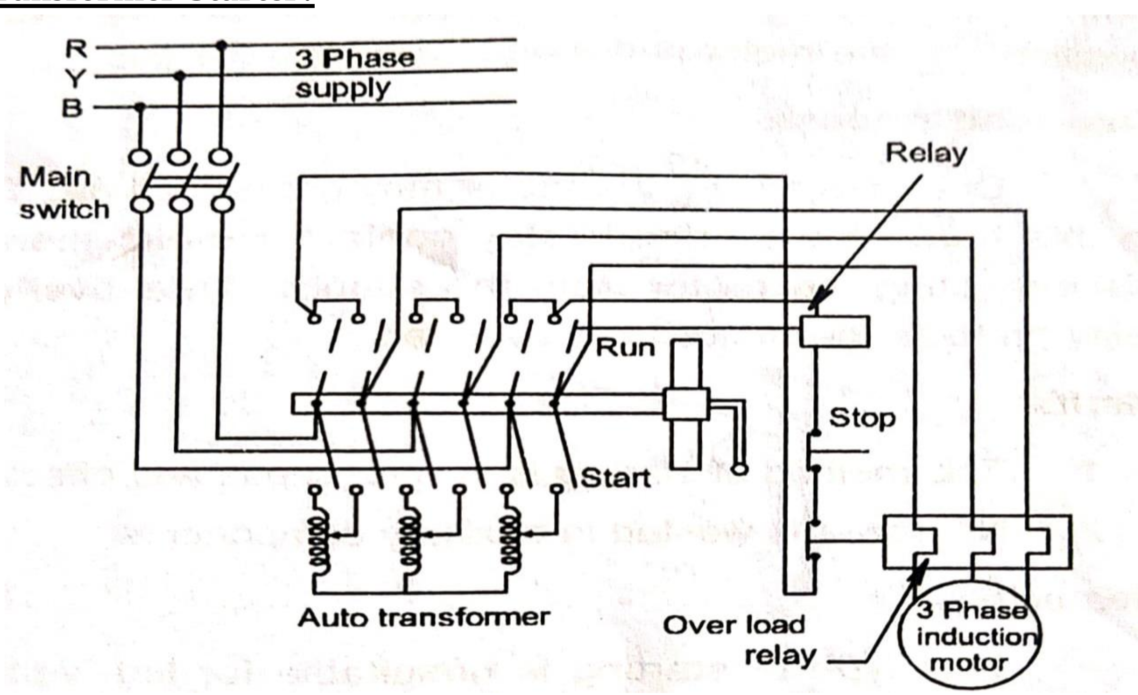


Fig.3.2

- This method of starting is suitable for cage motors.
- Auto transformer starter consists of 3 phase auto transformer with the provision of taps, in order to give reduced voltage.
- The auto transformers are generally tapped at 50%, 60%, 80% points.
- The adjustment at these voltages made proper requires starting torque. At about 80% of normal speed of the motor, the connections are so changed that the auto transformer is removed from the circuit.
- Then the rated voltage is applied across the motor. The arrangements for making the changes from start to run may be having manually or magnetically operated.
- For small motors, the change over arrangement may be of air break. For larger motors this arrangement may be of oil immersed type, in order to reduce the sparking during change over.
- The manually operated type is having a multiple double throw switch as shown in Fig.3.2
- During start, the switch is thrown to 'start' position. The motor is applied with reduced voltage, through tappings of auto transformers.
- After the motor reaches about 80% of rated speed, the switch is changed over to 'run' position and the motor is applied with full voltage from the mains.
- The starter is provided with 'no volt release' and 'over load release' as protective devices.

No volt release:

- If the supply fails (or) voltage drops in the line, below a certain level, the iron piece inside the relay is de magnetized, and hence the relay contactor and supply contactor return to their original position. So the supply given to the motor is disconnected.

Overload release:

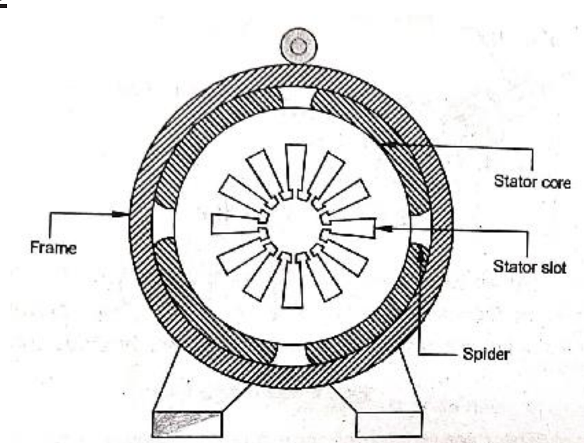
- Due to overload, the motor may get heated up. Due to this heat, the overload relay contactor melts thereby disconnecting the motor from the supply. Thus overload relay protects the motor from overload

13. (b) Explain with neat sketches the construction details of slip ring induction motor.

[Diagram -7 marks, Explanation -7 marks]

- An Induction motor consists of mainly two parts:
  - ✓ **Stator**
  - ✓ **Rotor**

STATOR CONSTRUCTION:



Stator Frame:

- It is in the form of cylinder. This is used for supporting the stator.
- To fix the terminal box, provision is arranged at the outer surface.
- At the circular portions on both ends of the frame, provision is made to fit the end cover with frame.
- Eye bolt is fitted at the top of the frame.

Stator core:

- Stator core is made of laminated steel stampings and has slots and teeth on its inner Periphery to house stator windings.
- The stampings are 04.to 0.5 mm thick.
- Stator carries a 3-phase winding having space displacement of 120° electrical
- The 3-phase winding is either star or delta connected and is fed from 3-phase supply
- The radial ventilating ducts are provided along the length of the stator core

ROTOR CONSTRUCTION:

- Rotor comprises a cylindrical laminated iron core, with slots on outer periphery
- Like stator, rotor lamination are punched in one piece for small Machine
- In larger machine the lamination are segmented
- If there are ventilating ducts on the stator core, an equal number of such ducts is provided on rotor core
- According to windings rotor are of two types
  - ✓ Squirrel cage rotor
  - ✓ Slip ring or wound rotor

Slip ring rotor construction:

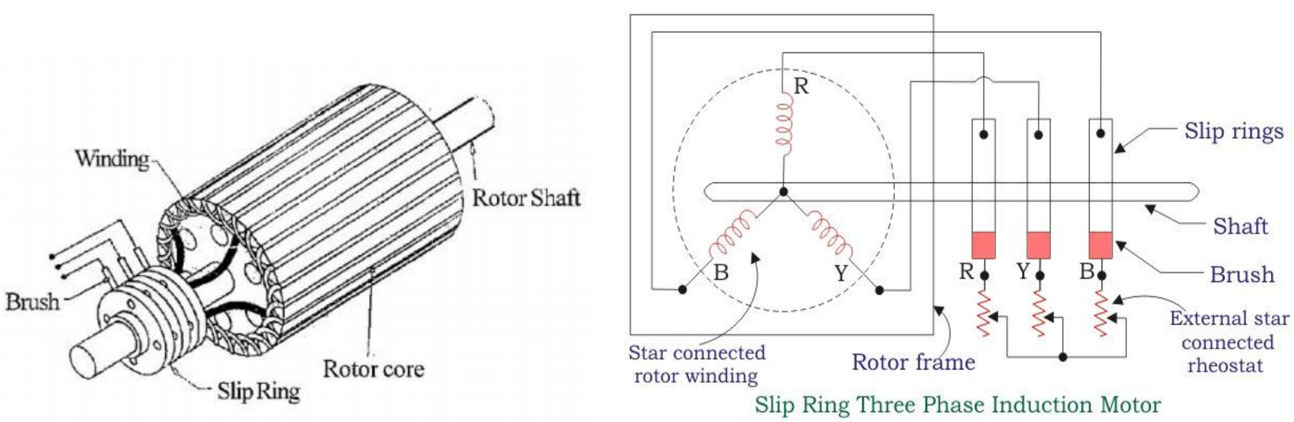


Fig.3.3

- The slip ring rotor is also made of steel laminations.
- This type of rotor is provided with three phase double layer distributed winding.
- The three phase winding is accommodated in the rotor slots.

- Each end of the three phase windings is connected in star, the remaining three terminals are brought out and they are connected to three slip rings.
- These slip rings are mounted on the shaft with insulation provided between each other.
- The brushes are so arranged to rest on three slip rings.
- External star connected rheostat is connected to these slip rings as shown in Fig.3.3
- At starting, the external resistances are connected in series with the rotor and hence the starting torque of the motor is high. (Since $T \propto R_2$).
- Under normal working condition of the motor, the three slip rings are short circuited by means of a metal collar and acts like the squirrel cage rotor.
- During short circuiting the slip rings, the brushes are automatically lifted from the surface of slip rings.
- This arrangement reduces the frictional losses wear and tear of the slip rings and brushes. For slip rings high quality phosphor bronze is used.

Air gap:

- The air gap between the stator and rotor is always very small.
- It is normally kept as small as possible in order to have minimum air gap reluctance.
- For small rating machines, the air gap is from 0.35mm to 0.65mm.
- For large rating machines, the air gap is from 1.00mm to 1.5 mm

End shield:

- The function of the two end shields is to support the rotor shaft.
- They are fitted with bearings and attached to the stator frame with the help of studs and bolts.

14.(a) Explain the construction, working and speed torque characteristics of a capacitor start and capacitor run induction motor.

[Construction -7 marks, working and characteristics -7 marks]

Construction:

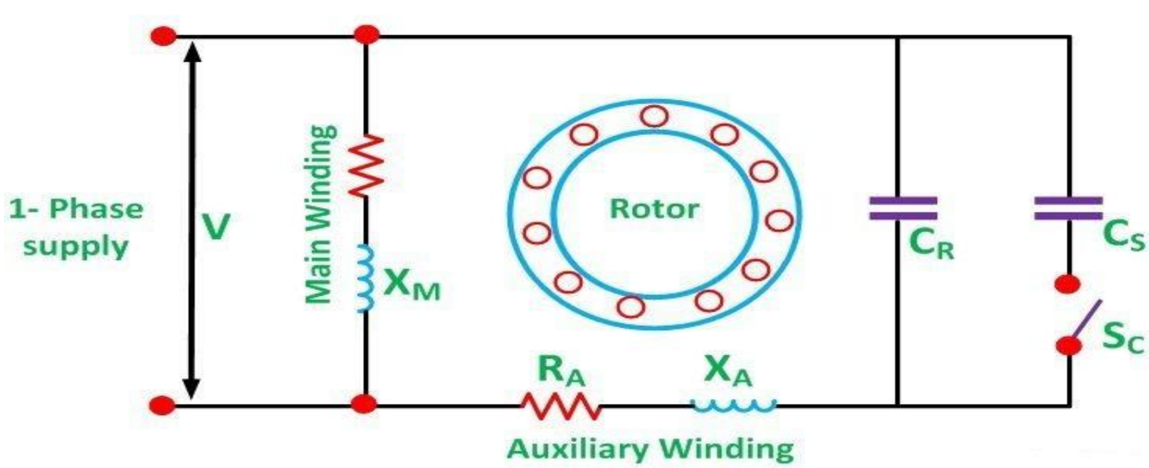


Fig.4.1

- It is an improved form of split phase motor.
- Two windings are provided in the stator. They are main winding and auxiliary winding.
- The main winding has low resistance and high reactance.
- The auxiliary winding has high resistance and low reactance.
- Two parallel connected capacitor, C_R and C_S are series with the auxiliary winding as shown in Fig.4.1
- A centrifugal switch is connected in series with the capacitor C_S as shown in Fig.4.1.
- When the motor picks up 75% of rated speed, the centrifugal switch disconnects the capacitor C_S from the circuit. The capacitor C_S carries current only at starts and is of electrolytic type with high capacity.
- Capacitor C_R is in the circuit while the motor runs, and is a paper or oil type with low capacity.
- The rotor is of squirrel cage type. (Short circuited copper bar).

Working and speed torque characteristics:

- When single phase supply is given to the stator winding a rotating magnetic field is produced in the stator.
- This rotating magnetic field cuts the short circuited rotor conductors a magnetic field is set up in the rotor.
- Due to interaction of two stator and rotor magnetic field, a torque is developed in the rotor and continues to rotate.
- At start the two capacitances C_R and C_S and are in parallel hence the total capacitance is sum of individual capacitance.
- When the motor attains about 75% of rated speed, the centrifugal switch, disconnects the capacitor. C_S, while running and the auxiliary winding improved the power factor of the motor.

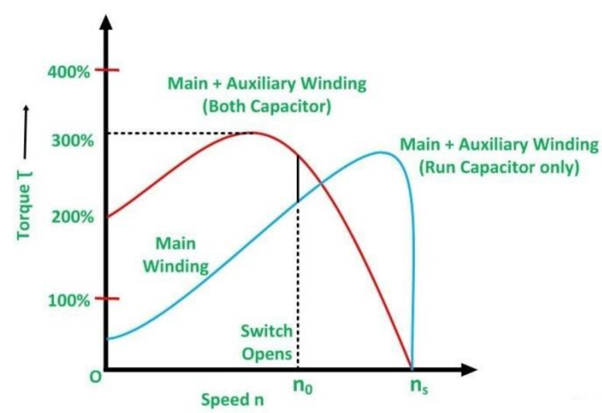


Fig.4.2

- The speed torque characteristics of capacitor start run motor are shown in Fig.4.2
- The direction of rotation of motor is reversed by reversing the terminal connection of any one winding.

14. (b) Explain the principle of operation of a synchronous motor.

[Diagram -7 marks, Explanation -7 marks]

Introduction:

- A synchronous motor is a machine which converts electrical energy into mechanical energy that rotates at a constant speed equal to synchronous speed.
- An alternator can run as a synchronous motor if A.C supply is given to armature winding and D.C supply is given to the field winding. Such type of motor is known as synchronous motor.
- Some important features of synchronous motor are, given below.
  - ✓ It runs at synchronous speed at all. It runs at constant speed. The only way to change the speed is to change the supply frequency (Since Ns= 120 f / P) It cannot be self started.
  - ✓ It is capable of being operated under a wide range of power factors both lagging and leading.

Principle of operation of a synchronous motor:

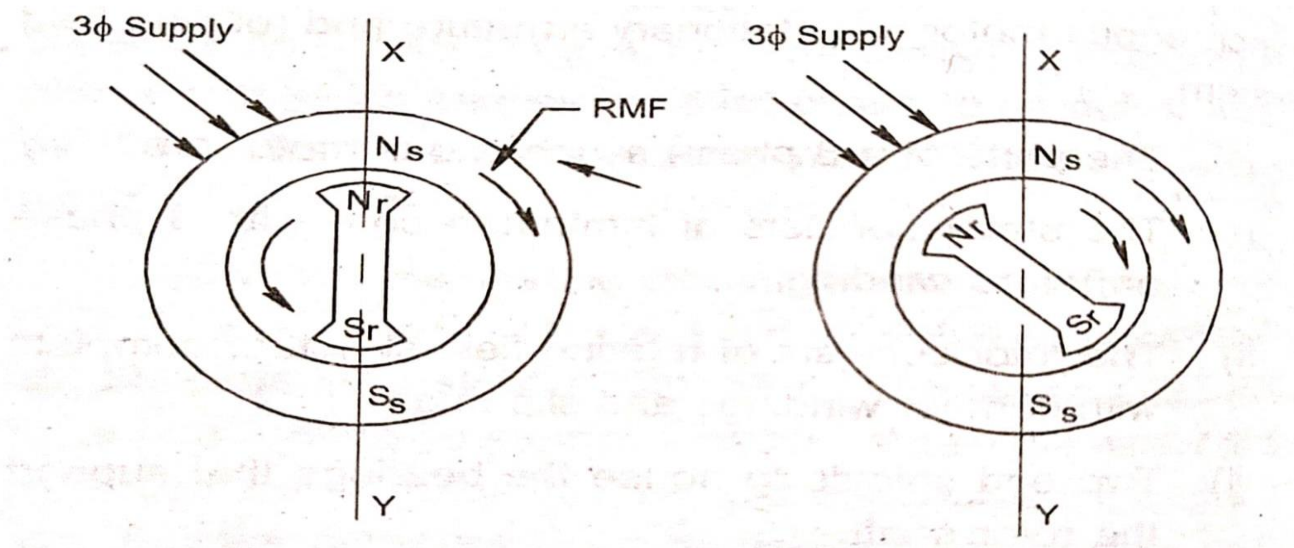


Fig 4.12(a) Fig 4.12(b)

- When a balanced 3 phase A.C supply is given to a 3phase stator winding of synchronous motor, it produces a rotating magnetic field.
- The speed of rotating magnetic field is synchronous speed Ns = 120f / P
  - f - Supply frequency,
  - P - Number of poles in the stator.
- This rotating field can be considered as a north (Ns) and south pole (Ss) at the stator as shown in Fig.4.12(a)
- Assume the rotating magnetic field is rotated in clockwise direction. D.C. excitation to the rotor also forms the rotor poles Nr and Ss as shown in Fig.4.12 (a).
- For the rotor position shown in Fig.4.12. (a), the stator poles are at points X and Y (ie, Ns at X and Ss at Y).
- Like poles Ns of stator and Nr of rotor repel each other. Similarly Ss of stator and Sr of rotor also repel each other.
- Now the rotor will begin to rotate in anticlockwise direction as shown in Fig.4.12(b)

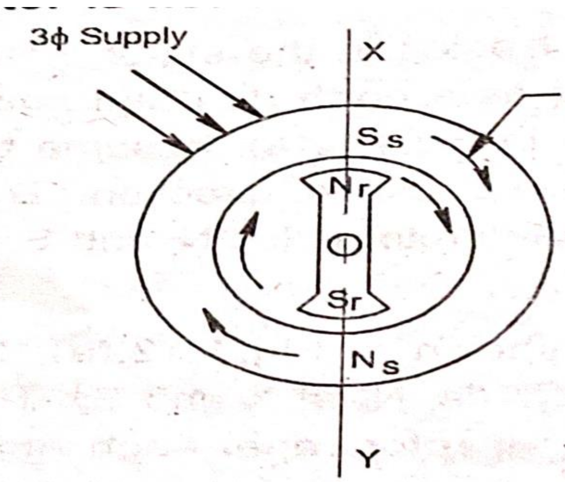


Fig 4.12(c)

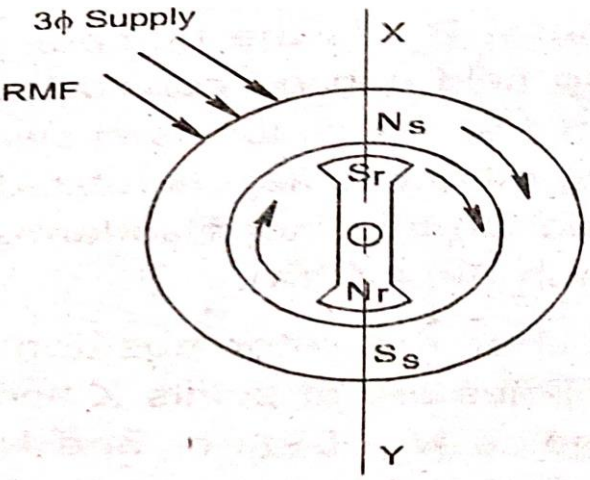


Fig 4.12(d)

- Half a cycle later, the position of the stator poles inter changed Ns is at point Y, and Ss is at point X, Now Ns attract Sr and Sr attracts Nr.
- Hence the rotor tends to rotate in clockwise direction as shown in Fig.4.12(c). Since the repulsion and attraction take place in every half a cycle alternatively, the rotor is stationary. Therefore synchronous motor is not self starting.
- Now let us consider the positions of stator and rotor as shown in Fig.4.12 (c). The stator and rotor poles attract each other.
- Suppose if the rotor is rotating clockwise with such a speed that it turns through one pole pitch by the time of stator poles inter change, their positions are as shown in Fig.4.12(d).
- Now also there is attraction between the stator and rotor poles. By this magnetic coupling the motor will continue to run at synchronous speed.

15.(a) Discuss the points to be attended during annual maintenance of induction motors.

[14- Marks]

- When an electric motor has been properly installed, it requires little attention; later on to keeps it working properly.
- If the motor is kept clean and dry and properly lubricated periodically, it will give trouble free service for a long time.
- All maintenance works should be done correctly under the supervision of an experienced electrician.
- The annual maintenance works to be carried out are as follows.
    1. Check all high speed bearings and renew if necessary.
    2. All motor windings should be thoroughly blown out with clear dry air.
    3. Renew switch and fuse contacts, if damaged
    4. Check the insulation resistance value (I.R.Value) between the phases of motor windings, Control gear and wiring.
    5. Check the earth connection and measure earth resistance.
    6. Check the air gap.
    7. Check the oil level

8. Renew oil in starters subjected to damp or corrosive elements.
9. Overhaul the motors which have been subjected to severe operating conditions.
10. Clean dirty varnish and oily windings.

- A register should be maintained for each motor and the important maintenance works which are carried out should be noted in the register.
- These records should have the following data.
  1. Past Performance
  2. Normal insulation level
  3. Air gap measurements
  4. Nature of repairs
  5. Time of previous repair works
- These records will be helpful for good maintenance and good performance.

15. (b) Explain the causes for the troubles that occur in an induction motor. [14 marks]

- The following causes for the troubles that occur in an induction motor

1. <u>Causes for motor Failing to Start :</u>

- ✓ Burnt out fuse
- ✓ Worn-out bearing
- ✓ Overload
- ✓ Open phase
- ✓ Loose rotor bars
- ✓ Magnetic locking

2. <u>Causes for Motor runs slowly:</u>

- ✓ Short in coil groups
- ✓ reversed coils
- ✓ Worn out bearing
- ✓ Overload
- ✓ Loose rotor bars
- ✓ Low voltage
- ✓ Low Frequency

3. <u>Causes for motor Excessive heating:</u>

- ✓ Over load
- ✓ Worn out bearings and tight bearings
- ✓ Short in coil groups
- ✓ Single phasing
- ✓ Low voltage

4. **<u>Causes for Motor starts in wrong direction:</u>**

- ✓ Reverse phases
- ✓ Wrong connection

5. **<u>Causes for Motor produce excessive noise:</u>**

- ✓ Single phasing
- ✓ Load unbalanced
- ✓ Air gap not uniform
- ✓ Loose coupling
- ✓ Rotor rubbing on stator

6. **<u>Causes for Wound the rotor runs the half speed:</u>**

- ✓ Open circuit in rotor

7. **<u>Causes for motor Bearings hot:</u>**

- ✓ Bent shaft
- ✓ Defective bearing
- ✓ Wrong grade of grease
- ✓ Misaligned bearing

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