BEE

MODULE-5

PART-A

1. **What the application of motor?**
The **applications** of electrical **motor** include the following. The **applications** of electrical **motor** mainly include blowers, fans, machine tools, pumps, turbines, power tools, alternators, compressors, rolling mills, ships, movers, paper mills.

2. **What do you mean by AC three-phase induction motor?**
The **three-phase AC induction motor** is a rotating electric machine that is designed to operate on a **three-phase** supply. This **3 phase motor** is also called as an asynchronous **motor**. These **AC motors** are of two types: squirrel and slip-ring type **induction motors**.

3. **On what principle does the induction motor work?**
The motor which works on the principle of electromagnetic induction is known as the induction motor. The electromagnetic induction is the phenomenon in which the electromotive force induces across the electrical conductor when it is placed in a rotating magnetic **field**.

4. **What are the types of induction motors?**
The types of induction motors can be classified depending on whether they are a single phase or **three** phase induction motor.

Single Phase Induction Motor

- Split Phase **Induction Motor**.
- Capacitor Start **Induction Motor**.
- Capacitor Start and Capacitor Run **Induction Motor**.
- Shaded Pole **Induction Motor**.

Depending upon the type of rotor used the three-phase induction motor is classified as:

- Squirrel Cage **Induction Motor**.
- Slip Ring **Induction Motor** or Wound Rotor **Induction Motor** or **Phase** Wound **Induction Motor**.

5. **What are the main parts of AC three-phase induction motor?**
The A.C. Induction Motor has three main parts, **rotor**, **stator** and enclosure.
The **stator** and **rotor** do the work and the enclosure protects the **rotor** and **stator**. **STATOR CORE**: The **stator** is the stationary part of the motor's electromagnetic circuit and is made up of thin metal sheets, called laminations.

6. **The starting torque of a three-phase induction motor can be increased by increasing what?**
There are **three** ways to **improve the starting torque** of **induction Motor**.
Internal Rotor Resistance: The across the line **starting torque** at low speed **can be increased by increasing** the rotor resistance. This **will** decrease the efficiency of the **motor**, and the heat on the rotor.

External Rotor Resistance: If you have access to the rotor winding circuit separate resistors can be used to temporarily increase the starting resistance and torque and at running speed, the resistor can be shorted to improve efficiency.
Variable Voltage/Frequency: variable frequency drive (VFD) can control the torque of the induction motor by changing the applied frequency. By doing this, the motor can start at a low frequency, corresponding to the lip frequency of the motor. This allows full torque at zero, or any, speed. This is an expensive but most elegant solution.

7. **How in a poly phase squirrel-cage induction motor, increased starting torque can be obtained ?**
When **motor** attains its rated speed the rotor resistance is short-circuited and **motor** functions like a **squirrel cage induction motor**. The **starting torque** of the **squirrel cage induction motor** can be improved if the rotor resistance is **increased**.

(OR)

A wound rotor **induction motor can** have variable **starting torque**. a) less conductor material used. Explanation: A **squirrel**-**cage induction motor** is **more** efficient than a wound rotor **induction motor**. Explanation: **Squirrel cage induction motor** has lesser **starting torque**.

8. **The ratio among rotor input, rotor output and rotor Cu losses are?**
$\boldsymbol{rotor\ gross\ output, Pm/\ rotor\ input, P2} = \mathbf{1} - \boldsymbol{s} = \boldsymbol{N/\ Ns}$;
$\boldsymbol{Pm/\ P2} = \boldsymbol{N\ /Ns}$
$\therefore \boldsymbol{rotor\ efficiency} = \boldsymbol{N/\ Ns}$
$\boldsymbol{rotor\ copper\ loss/\ rotor\ gross\ output} = \boldsymbol{s\ /1 - s}$
$\therefore \boldsymbol{P2:Pm:Pc} :: \mathbf{1}: \mathbf{1} - \boldsymbol{s} : \boldsymbol{s}$

9. **How a rotor rotates in an Induction motor? Explain**
In a three-phase **induction machine**, alternating current supplied to the stator windings energizes it to create a **rotating** magnetic flux. ... The **rotor** circuit is shorted and current flows in the **rotor** conductors. The action of the **rotating** flux and the current produces a force that generates a torque to start the **motor**.

10. **Discuss about slip in an Induction motor.**
"**Slip**" in an **AC induction motor** is defined as:
As the speed of the rotor drops below the stator speed, or synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the rotor's windings and creating more torque.

11. **What are the part of the alternator?**
The **alternator** consists of several **components—**stator (armature), rotor (rotating magnetic field), and a bridge rectifier. Each has their own dedicated function.

12. **Explain the principle of alternator**.
Working **Principle of Alternator**. All the **alternators** work on the **principle** of electromagnetic induction. According to this law, for producing the electricity we need a conductor, magnetic field and mechanical energy. Every machine that rotates and reproduces Alternating Current.

13. **Explain the synchronous method of an alternator**.
The armature of the **alternator** or **synchronous generator** is connected to TPST switch. The three terminals of the switch are short circuited by an ammeter. The voltmeter is connected between two line terminals to measure o.c voltage of the **alternator**. For the purpose of excitation, a DC supply is

connected field winding.

14. **Why almost all large size Synchronous machines are constructed with rotating field system type?**
The relatively small amount of power, about 2%, required for field system via slip-rings and brushes. For the same air gap dimensions, which is normally decided by the kVA rating, more space is available in the stator part of the machine for providing more insulation to the system of conductors, especially for machines rated for 11kV or above. Insulation to stationary system of conductors is not subjected to mechanical stresses due to centrifugal action.
Stationary system of conductors can easily be braced to prevent deformation. It is easy to provide cooling arrangement for a stationary system of conductors.
Firm stationary connection between external circuit and system of conductors enable he machine to handle large amount of volt-ampere as high as 500MVA.

15. **How are alternators classified?**
Another way to **classify alternators** is by the number of phases of their output voltage. The output can be single phase, or polyphase. Three-phase **alternators** are the most common, but polyphase **alternators** can be two phase, six phase, or more.

16. **What is the equation for frequency of emf induced in an Altenator?**
Frequency of emf induced in an Alternator,f ,expressed in cycles per second or Hz, is given by the following F = (PN)/120 Hz
Where
P- Number of poles
N-Speed in rpm

17. **What are the advantages of salient pole type construction used for Synchronous machines?**
Advantages of salient-pole type construction are : They allow better ventilation
The pole faces are so shaped that the radial air gap length increases from the pole center to the pole tips so that the flux distribution in the air-gap is sinusoidal in shape which will help the machine to generate sinusoidal emf
Due to the variable reluctance the machine develops additional reluctance power which is independent of excitation

18. **Why is the stator core of Alternator laminated?**
The stator core of Alternator is laminated to reduce eddy current loss.

(OR)

Conversely, as the magnetic field of our energized rotor passes through our **stator core**, it creates a perpendicular flow of current through the **stator**. ... Simply stated a **stator core** is **laminated** and insulated in order to reduce induced circulating currents and associated heat down to a manageable level.

19. **What are the causes of changes in voltage in Alternators when loaded?**
Variations in terminal voltage in Alternators on load condition are due to the following three causes:

Voltage variation due to the resistance of the winding,R

Voltage variation due to the leakage reactance of the winding, Xt

20. **What steps are to be taken before disconnecting one Alternator from parallel operation?**
The following steps are to be taken before disconnecting one Alternator from parallel operation
The prime-mover input of the outgoing generator has to be decreased and that of other generators has to be increased and by this the entire active-power delivered by the outgoing generator is transferred to other generators.
The excitation of the outgoing generator has to be decreased and that of other generators have to be increased and by this the entire re active-power delivered by the outgoing generator is transferred to other generators.
After ensuring the current delivered by the outgoing generator is zero,it has to be disconnected from parallel operation.

Module - 5

Part - B

3) Torque equation:

Torque produced by induction motor depends upon the following three factors:

1) Magnitude of rotor current (I_2).

2) Flux which interact with the rotor of induction motor (ϕ).

3) Power factor induction motor ($\cos\theta_2$).

Combining all these factors, we get

$T \propto \phi I_2 \cos\theta_2$; where T is the torque produced by induction motor.

The flux ϕ produced by the stator is proportional to stator emf E_1.

i.e., $\phi \propto E_1 \rightarrow ①$

we know that transformation ratio, $K = \frac{E_2}{E_1}$

$K = \frac{E_2}{\phi}$ (∵ from ①)

$E_2 = \phi$

Rotor current I_2 is defined as the ratio of rotor induced emf under running condition, sE_2 to total impedance, Z_2 of rotor side,

i.e., $I_2 = \frac{sE_2}{Z_2} \rightarrow ②$

and total impedance Z_2 on rotor side is given by,

$Z_2 = \sqrt{R_2^2 + (sX_2)^2} \rightarrow ③$

Substituting eq ③ in eq ② we get,

$$I_2 = \frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}} \text{ ; } s \text{ is the slip of}$$

We know that power factor is defined as ratio of resistance to that of impedance.

$$\cos\theta_2 = \frac{R_2}{Z_2} = \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

Substituting flux, rotor current and power factor in torque equation, we get,

$$T \propto E_2 \cdot \left(\frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}}\right) \cdot \left(\frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}\right)$$

$$T \propto sE_2^2 \cdot \left(\frac{R_2}{(\sqrt{R_2^2 + (sX_2)^2})^2}\right)$$

$$\boxed{\therefore\ T = K \cdot sE_2^2 \cdot \left(\frac{R_2}{(\sqrt{R_2^2 + (sX_2)^2})^2}\right)} \qquad \left[\text{Constant } K = \frac{3}{2\pi n_s}\right]$$

where, n_s is synchronous speed in r.p.s, $n_s = N_s/60$

So, finally the equation of torque becomes,

$$\boxed{T = sE_2^2 \times \left(\frac{R_2}{(\sqrt{R_2^2 + (sX_2)^2})^2}\right) \times \frac{3}{2\pi n_s} \text{ N-m}}$$

The torque will be maximum when slip $s = \frac{R_2}{X_2}$

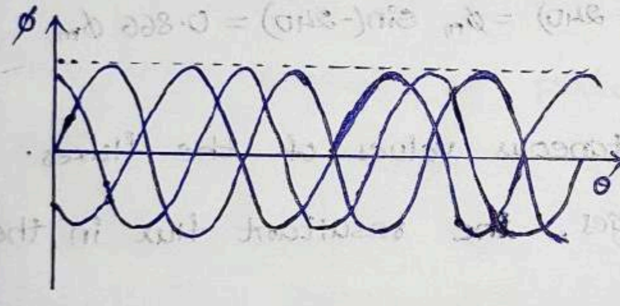
$$T = \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$$

$$\boxed{T_{max} = K \cdot \frac{E_2^2}{2X_2} \quad N-m}$$

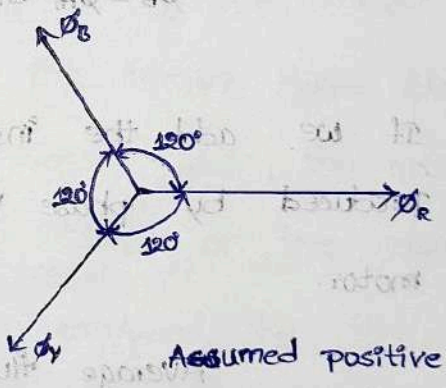
4) <u>Rotating magnetic field in an induction motor</u>:-

The stator of an induction motor consists of a number of overlapping windings offset by an electrical angle of 120°. When the primary winding or stator is connected to a three phase alternating current supply, it establishes a rotating magnetic field which rotates at a synchronous speed.

The wave form of the three fluxes is,



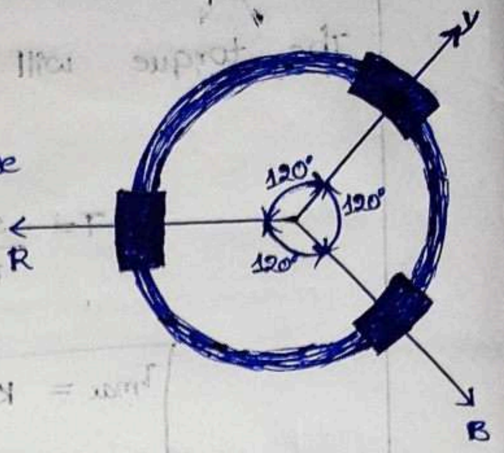
Waveforms of three fluxes



Assumed positive directions.

The three phase winding carry the balance current if the applied sinusodial voltage is balanced and the impedance of each winding is also balanced. The stator winding is physically placed 120° appart.

If the phase sequence is R, Y, B; the Y phase current lags the R phase current by 120° and B phase current lags the Y phase current by 120° or leads the R phase current by 120°.



The phase current I_r, I_y and I_B set up flux in the core the resultant magnitude of the average flux can be calculated by adding the magnetic flux produced by individual current

Let us first take the case when the R phase current at zero position of the waveform. The flux produced by the R phase current is ϕ_r.

$$\phi_r = \phi_m \sin(0) = 0$$

$$\phi_y = \phi_m \sin(0-120) = \phi_m \sin(-120) = -0.866\,\phi_m$$

$$\phi_b = \phi_m \sin(0-240) = \phi_m \sin(-240) = 0.866\,\phi_m$$

If we add the instantaneous values of the fluxes produced by phase voltages, the resultant flux in the motor.

Average flux = 1.5 x maximum flux.

The average flux of constant magnitude rotates in the same way as the input three supply phases rotate.

5) a) Torque in an induction motor is created by the interaction between the rotating magnetic field produced by the alternating current in the stator windings and the magnetic field produced by the induced current in the rotor assembly.

17th que Repeat

The speed of the rotating magnetic field is dependent on the applied frequency and is described by the equation S,

$$S = \frac{120F}{P}$$; where S is the speed of the field in RPM

F is the frequency of applied Voltage

P is the number of poles.

so, as long as the rotor is turning at a different speed than the magnetic field, the lines of flux will cut through the ~~condo~~ conductive rotor assembly and induce current, which will produce another magnetic field. The two fields interact by producing the torque. Since the motor stator is fixed by being bolted down, the rotor attempts to turn. As long as the torque on the rotor shaft is less than the torque produced by the interaction between the two fields, the rotor will accelerate. when the torque matches the load, the shaft speed will stabilize

b) The squirrel cage induction motor has very low starting torque due to it's rotor resistance of very low value. So to provide a higher value of rotor resistance the double cage rotor is used in induction motor.

The motive is to provide higher value of rotor resistance in such a manner that the rotor with its higher valued resistance provides higher torque and more efficiency.

6) 14th que Repeat

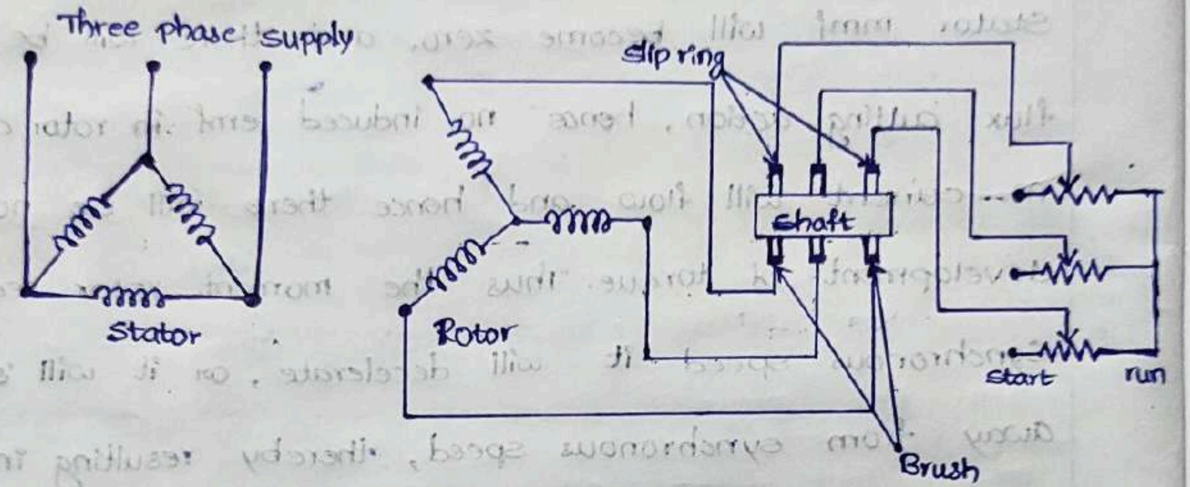
In an induction motor balanced poly-phase supply is given to balanced polyphase stator winding. This produces a rotating magnetic field in the air gap of the induction motor. This rotating magnetic field interacts with rotor conductors; cutting them. Thus an emf is induced in the rotor conductors and since they are closed at both ends by end rings and current starts flowing in the rotor conductors. Thus a rotor mmf is developed and by interaction of rotor mmf with stator mmf a torque is produced. By Lenz's law the effect opposes the cause which produces it. Here the effect is rotation of the rotor and the cause is induced emf, so the rotor rotates in a way so as to oppose the induced emf which caused the rotation, i.e. the rotor starts to rotate in the direction of rotating field which minimizes flux cutting action of the air gap mmf thereby reducing the induced emf in the rotor conductors.

Now for an on load operation of induction motor this electromagnetic torque developed by the interaction of stator mmf and rotor mmf will accelerate until it reaches load torque to be supplied. In this process the rotor will always try to catch synchronous speed, but the moment it reaches synchronous speed, the relative velocity between rotor conductors and rotating stator mmf will become zero, and there will be no flux cutting action, hence no induced emf in rotor conductors, no current will flow and hence there will be no development of torque. Thus the moment rotor reaches synchronous speed it will decelerate, or it will 'slip' away from synchronous speed, thereby resulting in relative velocity between rotating air gap mmf and rotor again, leading to the development of induced emf and thus the rotor will settle at a constant speed less than synchronous speed to supply the load torque. When operated at no load, the rotor will settle at a speed slightly less than the synchronous speed at which the frictional torque is supplied.

7) slip ring motor:

15th que repeat

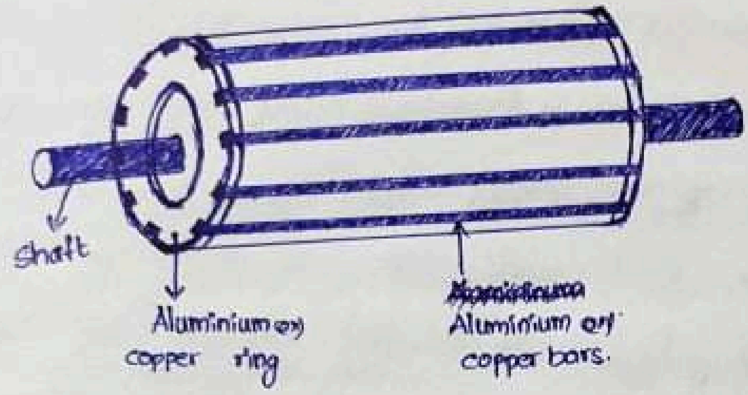
The motor which employing the wound rotor is known as slip ring induction motor (or) phase wound motor. It consists laminated cylindrical core which has a semi-closed slot, at the outer periphery and carries three-phase insulating winding. The rotor is wound for the same number of poles as that of the stator.



The three terminals of a rotor and three start terminals connecting through slip rings are connected to a shaft. The aim of the shaft is to transmit mechanical power.

Squirrel cage motor:-

The motor which employing the squirrel cage type rotor is known as the squirrel cage induction motor. The construction of the rotor is rugged and simple. The rotor of the motor consists the cylindrical laminated core having semiclosed circular slots. and short circuit at each end by copper or Aluminium ring, called short circuiting ring. It is not possible to add any external resistance in the rotor of the circuit



Squirrel cage induction motors

Merits:-

1) The rotor of slip ring motor has a cylindrical core with parallel slots and each slot consists each bar, whereas the slot of the squirrel cage motor is not parallel to each other.

2) Squirrel cage motor has high power factor as compared to slip ring motor

3) The efficiency of squirrel cage motor is high whereas the slip ring motor has low efficiency.

4) The starting torque of slip ring motor is high whereas in squirrel cage motor it is low.

5) The copper loss in slip ring motor is high as compared to squirrel cage motor.

6) The cost of the slip ring motor is high, because it consists of brushes. The squirel cage motor is cheap.

[Diagrams are optional]

q) Phasor Diagram:

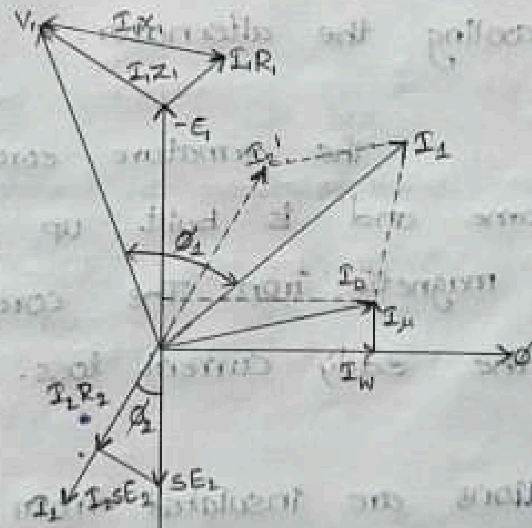
Let us take the mutual flux ϕ between the stator and rotor windings as the reference phasor. This flux induces emfs in the stator and rotor. These emfs under running conditions are E_1 and sE_2 respectively lagging 'ϕ' by 90°. Since the rotor winding is a short circuit, the voltage sE_2 sets up the rotor current I_2 lagging behind by an angle ϕ_2 and sE_2 will be equal to the rotor impedance drop.

$$\phi_2 = \tan^{-1}\left(\frac{sX_2}{R_2}\right)$$

and

$$sE_2 = I_2(R_2 + jsX_2)$$

From the above equation, the phasor diagram of induction motor on load condition can be drawn as.



The current flowing in the stator winding i.e., Stator Current

$$I_0 = I_0 + I_2'$$

where; I_0 = No load current in I.M

I_2' = Rotor current referred to the stator.

The phasor sum of E_1, I_1, R_1 and $I_1 X_1$ gives the applied voltage V_1. $\cos\phi_1$ is the p.f of the stator and $\cos\phi_1$ is the p.f of the rotor circuit.

$$V_1 = E_1 + I_1 (R_1 + jsX_1).$$

10) <u>Construction of an alternator</u>:-

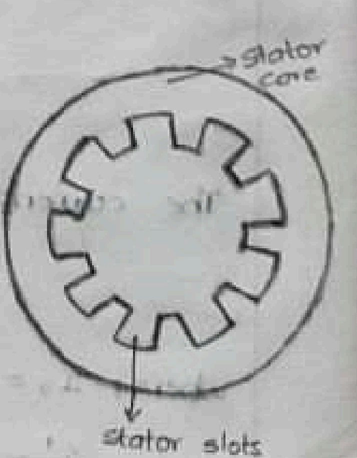
Rotor and stator are two main parts in the construction of an alternator.

<u>Stator</u>:-

The stator consists of stator frame and stator core. The stator frame is used for holding the armature stampings and windings in position. Ventilation is maintained with the help of holes cast in the frame itself, which assist in cooling the alternator.

The armature core is supported by the stator frame and is built up of laminations of steel alloys (or) magnetic iron. The core is laminated to minimize the eddy current loss.

The laminations are insulated from each other and have spaces in between them for allowing the cooling air to pass through. The stator is made up of number of slots on it's inner periphery as shown in the fig. The slots are used for holding the armature windings.



Rotor:-

there are two types of rotors : 1) Smooth cylindrical type ;

2) Salient pole type. "

smooth cylindrical type :

The rotor consists of a smooth solid steel cylinder, having a number of slots along its outer periphery for hosting the field coils. They do not have projected poles, instead, it has a uniform length in all directions, giving a cylindrical shape to the rotor.

The pole areas are unslotted, as shown in the figure below. Here, the rotor has 4 poles. The pole areas are surrounded by the field winding placed in slots.

The winding are placed so that the flux density will be maximum on the polar central line and gradually falls away on either side.

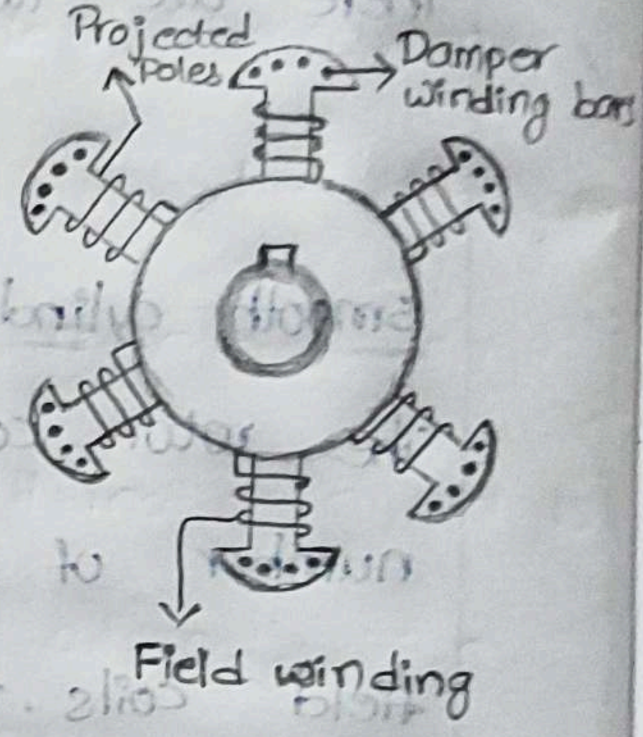
It has very long axial length but small diameters. The construction of the rotor gives better balance, quiter operation and less windage loss.

salient pole type:-

The term salient means projecting. The poles are made of thick laminated steel sections pivoted together.

The poles are also laminated to minimize the eddy current losses. The salient pole type of rotors are characterized by their large ~~dia~~ diameters and relatively short axial lengths

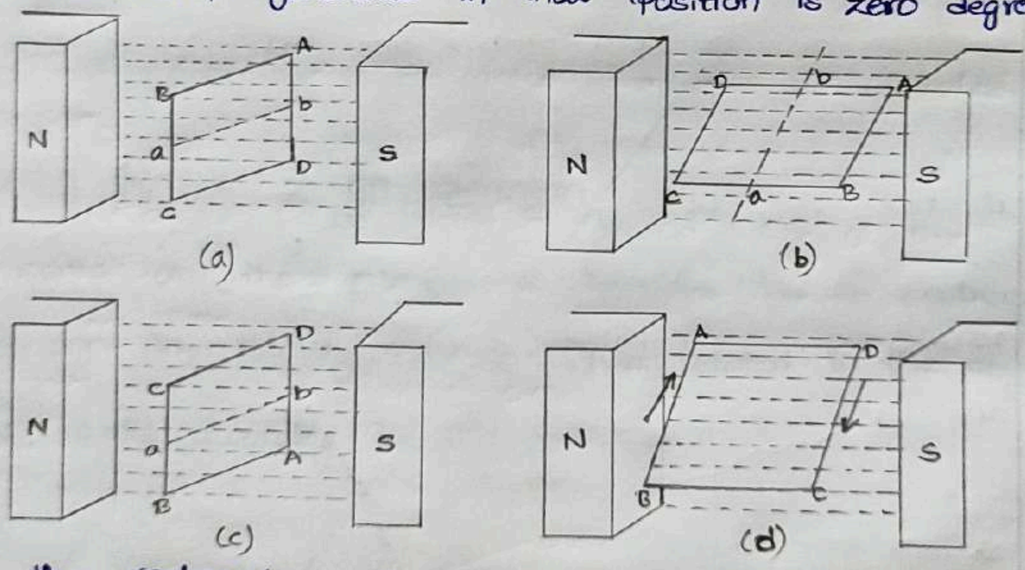
It is generally used for low and medium speed operations, mainly employed in engine driven alterantors.



Salient pole type rotor.

11) <u>Working principle of an alternator</u>:-

All the alternators works on the principle of electromagnetic induction. According to this law, for producing the electricity we need a conductor, magnetic field and mechanical energy. Every machine that rotates and reproduces Alternating current. To understand the working principle of the alternator, consider two opposite magnetic poles north and south and the flux is travelling between these two magnetic poles. In the figure (a), rectangular coil is placed between the north and south magnetic poles. The position of the coil is placed in such a way that the coil is parallel to the flux, so no flux is cutting and therefore no current is induced. So that the waveform generated in that position is zero degrees.



If the rectangular coil rotates in a clockwise direction at an axis a and b, the conductor side a and b, the conductor side A and B, comes infront of the south pole and C and D come in-front of a north pole as shown in fig. b. So, now we can say that the motion of the conductor is perpendicular to the flux lines from N to S pole and the conductor cuts the magnetic flux. At this position, the rate of flux cutting by the conductor is maximum because the conductor and flux are perpendicular to each other and therefore the current is induced in the conductor and this will be in maximum position.

The conductor rotates ~~this~~ one more time at 90° in a clockwise direction then the rectangular coil comes in the vertical position. Now the position of the conductor and magnetic flux line is parallel to each other as shown in fig.c. In this figure, no flux is cutting by the conductor and therefore no current is induced. In this position the waveform is reduced to zero degrees because the flux is not cutting

In this second half cycle, the conductor is continued to rotate in a clockwise direction for another 90° so here the rectangular coil comes to a horizontal position in such a way that the conductor A-B comes infront of north pole and C-D comes infront of south pole, as shown in fig. D. The rectangular coil again rotates in another 90° then the coil reaches the same position from where the rotation is started and therefore, the current will drop again to zero.

In this complete cyclic process, this is the process of producing the current and EMF of a single phase. The displacement between three phases is 120°. This is the working principle of an alternator.

19) The synchronous Impedance Method or EMF Method is based on the concept of replacing the effect of armature reaction by an imaginary reactance. The method requires following data to calculate the regulation.

19th que repeat

1) open circuit characteristic (o.c.c)

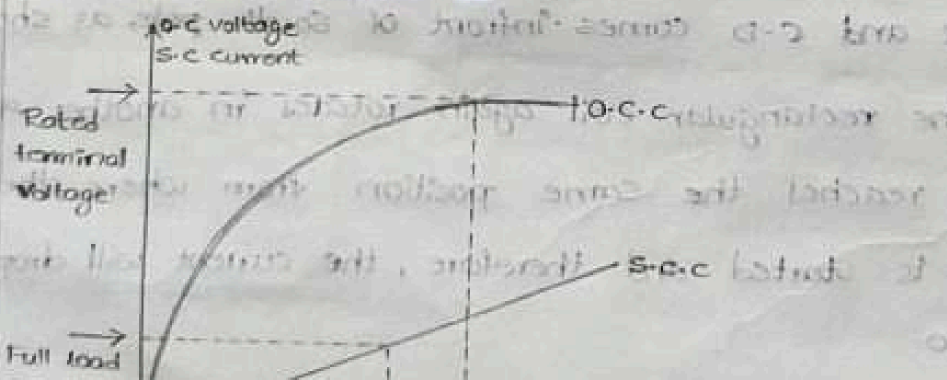
⇒ The occ is a plot of the armature terminal Voltage as a function of field current with a symmetrical 3-phase short circuit applied cross the armature terminals with the machine running at rated speed.

⇒ At any Value of field current, if E_i is the open circuit Voltage and I_{sc} is the short circuit current then for this Value of excitation.

$$Z_c = E/_{S_{Ic}}$$

⇒ The Value of Z's calculated for the unsaturated region.

⇒ The o.cc is called the unsaturated value of the synchronous impedance.



2) Short circuit characteristic (S.C.C)

⇒ The S.CC is a plot of short circuit armature current Versus the field current.

⇒ The current range of the insturment should be about 25 - 50% more than the full load current of the alternator.

⇒ Starting with zero field current, increase the field current gradually and cautiosly till rated current flows in the current

3) Resistance of the armature winding:-

⇒ the measure the D.C resistance of the armature circuit of the alternator.

⇒ the effective a.c resistance may be taken to be 1.2 times the D.C resistance.

Regulation calculation:-

⇒ From O.C.C, S.C.C [redacted] Z_s can be determined for any load condition.

⇒ Applying D.C known voltage across the two terminals and measuring current. so the value of R_a per phase is known

$$X_s = \sqrt{Z_s^2 - R_a^2}$$

So synchronous speed per phase can be determined.

⇒ No load induced emf per phase, E_{Ph} can be determined by the mathematical expression delivered earlier.

$$E_{Ph} = \sqrt{(V_{Ph}\cos\phi + I_aR_a)^2 + (V_{Ph}\sin\phi + I_aX_s)^2}$$

Where V_{Ph} = Phase value of rated voltage ; I_a = Phase value of current

⇒ Finally the voltage regulation of alternator can be determined from the formula,

$$\text{Voltage regulation} = \frac{E_{Ph} - V_{Ph}}{V_{Ph}}$$

13) There are two types of losses occur in three phase induction motor. These losses are;

2nd Que repeated

1) Constant or fixed losses.

2) Variable losses

Constant (or) fixed losses:-

Constant losses are those losses which are considered to remain constant over normal range of induction motor. The fixed losses can be easily obtained by performing no-load test on the three phase induction motor. These losses are further classified as:

1) Iron (or) core losses
2) Mechanical losses.
3) Brush friction losses.

Iron (or) core losses:

Iron or core losses are furthe divided into hysteresis and eddy current losses. Eddy current losses are minimized by using lamination on core. since by laminating the core, area decreases and hence resistance increases, which results in decrease in eddy currents. Hysteresis losses are minimized by using high grade silicon steel. The core losses depends upon the frequency of the supply Voltage.

Mechanical and Brush Friction losses

Mechanical losses occur at the bearing and brush friction loss occurs in wound rotor induction motor. These losses are zero at start and with increases in speed these loses increases. In three phase induction motor the speed usually remains constant. Hence these losses almost remains constant.

Variable losses :-

These losses are also called copper losses. These losses occur due to the current flowing in stator and rotor windings. As the load changes, the current flowing in rotor and stator winding also changes and hence these losses also change. Therefore these losses are called variable losses. The copper losses are obtained by performing blocked rotor test on 3-phase I.M. The main function of I.M is to convert an electrical power into mechanical power. During this conversion of electrical energy into mechanical energy the power flows through different stages.

Effect of slip of I.M:

Slip increases with increase in load, providing a greater torque. It is common to express the slip as the ratio between the shaft rotation speed and the synchronous magnetic field speed.

$$s = \left(\frac{n_s - n_a}{n_s}(100)\right)\%$$

where ; s = slip ; n_a = shaft rotating speed
n_s = synchronous speed of magnetic field

Where the rotor is not turning the slip is 100%

18) Differences between Induction and synchronous generator.

S.NO	Synchronous motor	Induction motor.
1.	The electromagnetic motor which converts electrical energy into mechanical work at constant speed is called Synchronous motor.	The electromagnetic motor which converts electrical energy into mechanical work at variable speed is called as Induction motor.
2.	The Synchronous motor runs at the synchronous speed	Induction motor runs at the Non-Synchronous speed.
3.	Works on the principle of 'Magnetic locking'	Works on the principle of 'Electromagnetic induction.
4.	It has two parts, Stator and rotor. Stator connects with 3-Phase AC supply and rotor connect with D.C supply.	Similarly it also consists of two parts, the stator and rotor. Here, only stator connects with 3-phase AC supply.
5.	It requires the DC excitation to start the motor.	Induction motor does not require an excitation system to start the motor.
6.	Relative motion is not required between the rotor and stator.	Relative motion is required between the stator and rotor.
7.	Zero slip occurs in the Synchronous motor	Different slip occurs in the induction motor.
8.	It has more power efficiency due to the leading power factor.	It has less efficiency than the synchronous motor
9.	It is used for power factor correction, Voltage regulation of transmission line etc.,	It is mostly used in the industries.
10.	Maximum maintenance is required	Minimum maintenance is required

20) Advantages of AC Generators:

⇒ A.C is very easy and efficient to transmit over a long distance rather that D.C.

⇒ The design of the AC generator is fairly simpler than DC generator type.

⇒ No need for matching a Voltage.

⇒ Cost of maintenance is less.

⇒ They have a quiet operation.

⇒ An AC generator allows users to convert it's current to other voltage with the use of transformers.

⇒ AC generator is compatible only with an AC generator and no with a DC generator

⇒ AC motors do not have a smell that is very typical of DC motors, in the latter, this is caused by and also these are compatible with an AC Generator and not with a DC generator type.

Disadvantages:-

⇒ This poses a challenge when it comes to handling because of the greater Voltages needed to supply a fixed level of power.

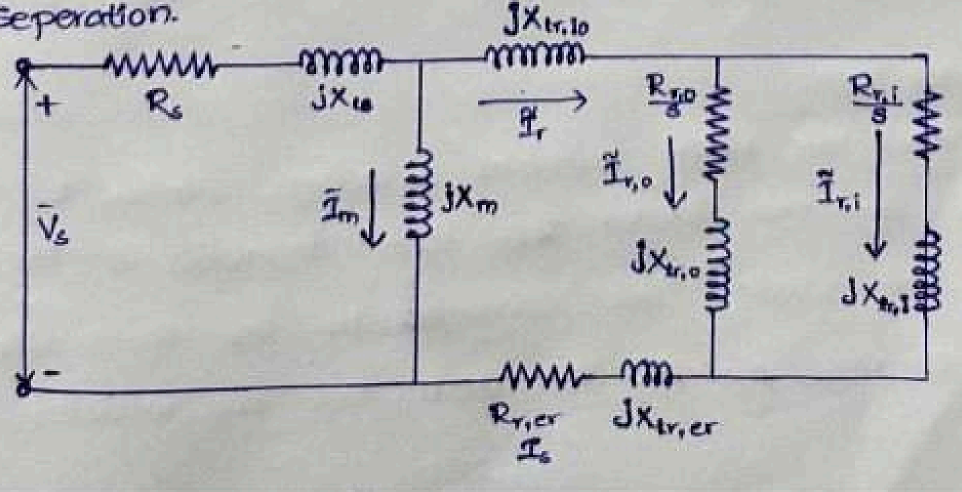
⇒ In these systems require additional insulation because of the greater voltages and needed to supply a fixed level of power.

⇒ AC generator is not as durable as a DC generator.

⇒ Working with AC system has some ~~dista~~ distinct risk and difficulties as compared to what can be expected from DC motor.

⇒ In addition to all these risks, an AC generator is not durable as a DC generator type.

8) The equivalent circuit of three phase double cage induction motors with common end rings can be derived as shown in the figure. In the circuit, subscripts i, o and er represent the inner and outer cage and end ring of the rotor respectively and $X_{lr,io}$ represents the mutual leakage inductance between the inner and outer cages. $X_{lr,i}$, $X_{lr,o}$ represent the leakage inductances of the inner and outer cage minus the mutal leakage inductance $X_{lr,io}$. The value of $X_{lr,o}$ is very small and assumed to be zero since the most of the outer bar leakage flux links the low reluctance path inner bar and contributes to $X_{lr,er}$ is also very small and neglected in many cases, especially for fabricated rotors due to the physical seperation.



The resistance of the outer cage, $R_{r,o}$ is larger than that of the inner cage, $R_{r,i}$ due to the smaller cross-sectional area and since it is usually made of brass or bronze, which has higher resistivity than copper. The leakage inductance of the inner cage $X_{lr,i}$, is larger than the outer cage, $X_{lr,o}$ since it is less tightly coupled to the stator, and because the inner bar leakage flux crosses the low reluctance path between the two bars. During motor startup when the slip is high ($s \approx 1$), the large value of $X_{lr,i}$ forces most of the rotor current I_r, to be in the high resistance outer cage. This enables double cage motors to have superior starting performance of high starting torque with low starting current. when operating in steady state at low slip ($s \approx 0$), the influence of $X_{lr,i}$ and $X_{lr,o}$ are negligible, and I_r stays mainly in the low resistance inner bar, as can be predicted, resulting in high effeciency operation.

1) Working principle:

Induction motor works on the principle of electromagnetic induction. The relative speed between stator RMF and rotor conductors causes an induced emf in the rotor conductors, according to the faraday's law of electromagnetic induction the rotor conductors are short circuited, and hence rotor current is produced due to induced emf.

Construction:-

The induction motor mainly divided into two main part
1) Stator   2) Rotor.

Stator:- The stator of an induction motor consists of

a) stator frame : It is made up of cast iron and it holds the stator core.

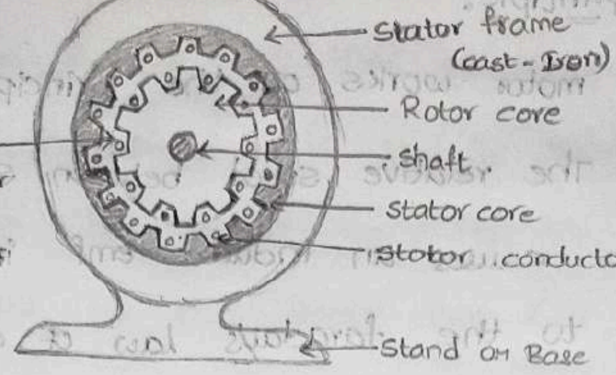
b) Stator core: Made up of thin sheets of steel laminations, stacked together. The stator core has slots for providing three-phase distributed A.C windings in it.

c) stator winding:- consists of insulated copper wire : the windings are three phase distributed winding. The 3-phase are connected in either star (or) delta fashion.

d) End covers: Two end covers made up of cast-iron.

⇒ The stator windings are done for specific number of poles, as per our requirement. Greater is the number of poles, lesser is the speed

$$\therefore N_s = \frac{120f}{P}$$



Construction of Induction motor.

The air-gap between the stator and rotor should be as small as practically possible.

a) It reduces the leakage flux between stator and rotor.

b) It improves the operating power factor of the induction motor.

Rotor:-

Rotor is a hollow laminated core having slots. The rotor core is mounted on the shaft.

Rotor in the induction motor can be classified into two types,

i) Squirrel cage type ii) Wound type or slip ring motor

Squirrel cage type:-

In this type of rotor copper or aluminium bars are placed in the slots on the rotor core and the bars are short-circuited at both ends, using end-rings.

Slip ring type:-

In this, the rotor contains windings similar to that used on the stator. The three terminals of the star-connected windings are connected to the three slip rings. The slip rings are on the shaft, but are insulated from it.

Principle of operation of induction motor.

- Induction motor works on the principle of electro-magnetic induction.

- When a 3-phase ac supply is given to 3-phase distributed winding, a rotating magnetic field is created.

↓

This rotating magnetic field cuts the rotor conductors, inducing an emf in it.

↓

This induced emf causes a current to flow in the rotor, as rotor circuit is short-circuited.

↓

As per lenz's law, the effect opposes the cause.

↓

The effect ~~cause~~ is the :- current in the rotor and the cause is the :- flux cutting by the rotating magnetic field.

↓

So, this cause of flux cutting can be reduced, if the relative speed between the rotating magnetic field and rotor conductors decreases.

⇓

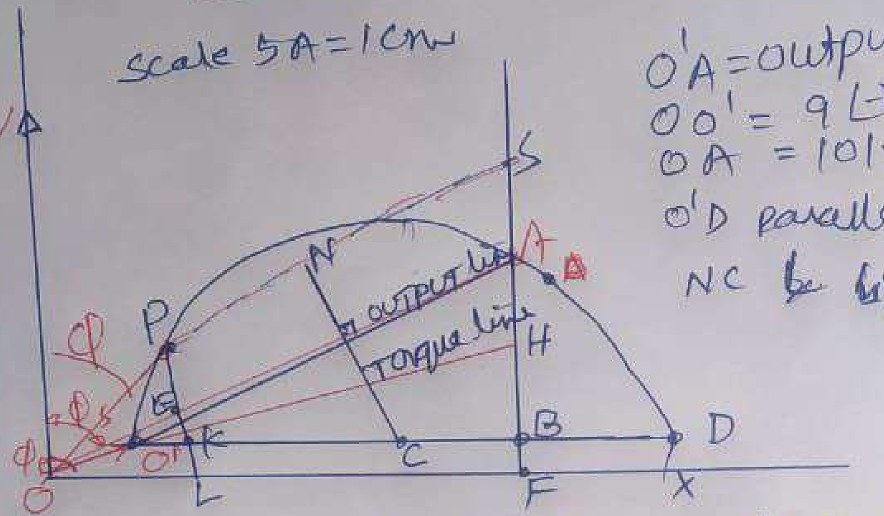
So, a torque is ~~prop~~ produced, which rotates the rotor in the same direction, as that of rotating magnetic field. This reduces the relative flux cutting, as relative speed of flux cutting decreases.

Scanned with CamScanner

- If we inter-change two supply phases, the direction of rotation of magnetic field reverses and so the rotation of induction motor also reverses.

NOTE :- The rotor of induction motor can never attain synchronous speed, N_s as in that case relative speed will be zero and there will be no flux-cutting. So there will be no induced emf and no developed torque in this case.

(13) contin.. (f) Continu



$O'A$ = output line
$OO' = 9\angle{-78.5^\circ}$
$OA = 101.3\angle{-66.1}$
$O'D$ parallel to OX
NC be bisector to $O'A$

semicircle $O'AD$ is drawn with C as centre
The semicircle is the locus of current vector for all load condition.
AF represents 28440W measure 8.1cm
power 1cm = 28440W/8.1 = 3510W
Full load motor output = 14900W

$pf = \cos\phi = PL/OP = 0.865 \simeq 0.886$

Line current = OP = 30A ($C\theta = 30^\circ$ by measurement)

$$\text{Slip} = \frac{\text{rotor Cu loss}}{\text{rotor input}} = \frac{EK}{PK} = \frac{0.3}{4.5} = 6.7\%$$

(i) $I_{FL} = OP = 30A$ ($\phi = 30^\circ$ by measurement)

(ii) $pf = \cos 30^\circ = 0.886$

(iii) Slip = 6.7%

IARE BEE UNIT-V

(2) A 4 pole, 50 Hz, wound rotor IM has a rotor resistance 0.56Ω/ph and runs at 1430 rpm at full load. Calculate the additional resistance/phase to be inserted in the rotor circuit to lower the speed to 1200 rpm, if the torque remains constant.

$P = 4, f = 50 \quad R_2 = 0.56\Omega$

Case 1

$T = \frac{K S R_2}{R_2^2 + (SX_2)^2}$ but X_2 is not given $(S = \text{slip})$

So $T_1 = \frac{K S_1 R_2}{R_2^2} = \frac{K S_1}{R_2}$

Case 2 $T_2 = \frac{K S_2}{(R_2 + r)}$ (r = external resistance)

$R_2 = 0.56$ rotor resistance

$N_1 = 1430$
$N_2 = 1200$

Since $T_1 = T_2$

$$\boxed{\frac{\cancel{K} S_1}{R_2} = \frac{\cancel{K} S_2}{(R_2 + r)}}$$

$N_s = \frac{120 f}{P}$

$N_s = \frac{120 \times 50}{4}$

$\frac{S_1}{0.56} = \frac{S_2}{0.56 + r}$

$S_1 = \frac{N_s - N_1}{N_s}$

$N_s = \frac{120f}{P} = 1500$ rpm

$S_2 = \frac{N_s - N_2}{N_s}$

$$\frac{\left(\frac{1500 - 1430}{1500}\right)}{0.56} = \frac{\left(\frac{1500 - 1200}{1500}\right)}{(0.56 + r)}$$

$\boxed{S_1 = 0.0466 \quad S_2 = 0.2}$

$r = \left(\frac{0.2}{0.0466}\right) 0.56 - 0.56$

$\boxed{r = 1.84\ \Omega}$

IARE BEE UNIT-V

(4) A 3ϕ 6 pole 50 Hz IM when fully loaded, runs with a slip of of 3%. Find the value of resistance necessary in series/ph of rotor to reduce the speed by 10%. Assume that the resistance of rotor/ph is 0.2 Ω.

(A) Given $P=4$ $f=50$ Hz % Slip$_1 = 3\%$

$R_2 = 0.2$/ph r = external resistance

$$N_S = \frac{120f}{P} = \frac{120\times50}{6} = 1000 \text{ rpm}$$

$$S_1 = 0.03 = \frac{N_S - N_1}{N_S} = \frac{1000-N_1}{1000}$$

$$\boxed{N_1 = 1000-30 = 970 \text{ rpm}}$$

$$\boxed{N_2 = 0.9\times N_1 = 873 \text{ rpm}}$$ (reduced by 10%)

$$\boxed{T_1 = \frac{KS_1}{R_2}} \quad \boxed{T_2 = \frac{KS_2}{R_2+r}} \quad \boxed{S_2 = \frac{1000-873}{1000}, \; S_2 = 0.127}$$

Assume $T_1 = T_2$ (Torque same)

$$\boxed{\frac{KS_1}{R_2} = \frac{KS_2}{R_2+r}} \quad \boxed{S_1 = 0.03, \; S_2 = 0.127}$$

$$r = \left(\frac{S_2}{S_1}\right)R_2 - R_2 = \left(\frac{0.127}{0.03}\right)0.2 - 0.2$$

$$\boxed{r = 0.6466\ \Omega}$$

r = external resistance needed

1

IARE BEE UNIT-V part-C

1. A 3 phase, 400 V Induction motor has the following test readings -

No Load: 400V, 1250W, 9A

short circuit: 150V, 4KW, 38A.

Draw the circle diagram. If the normal rating is 14.9 kW, find from the circle diagram, the full load value of current, power factor and slip.

A) From No. load data

$P_0 = 1250W$, $V_0 = 400V$, $I_0 = 9A$

$P_0 = \sqrt{3}\, V_0 I_0 \cos\phi_0$

$\cos\phi_0 = \frac{P_0(1250)}{\sqrt{3} \times 400 \times 9} = 0.2004$, $\boxed{\phi_0 = 78.5^\circ}$

From S.C. data

$P_s = 4000W$, $V_s = 150V$, $I_s = 38A$

$\cos\phi_s = \frac{P_s}{\sqrt{3} \times V_s \times I_s} = \frac{4000}{\sqrt{3} \times 150 \times 38} = 0.405$

$\boxed{\phi_s = 66.1^\circ}$ $(P_s = \sqrt{3}\, V_s I_s \cos\phi_s)$

Short ckt current with normal voltage

$\boxed{I_{SN} = I_s \left(\frac{400}{150}\right) = 101.3A}$

power taken at normal voltage would be

$\boxed{P_{SN} = P_s \left(\frac{V_N}{V_s}\right)^2 = 4000 \left(\frac{400}{150}\right)^2 = 28.4 KW}$

$I_0 = 9\angle{-78.5^\circ} A$ $I_{SN} = 101.3\angle{66.1} A$