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AC Machine Lab Manual

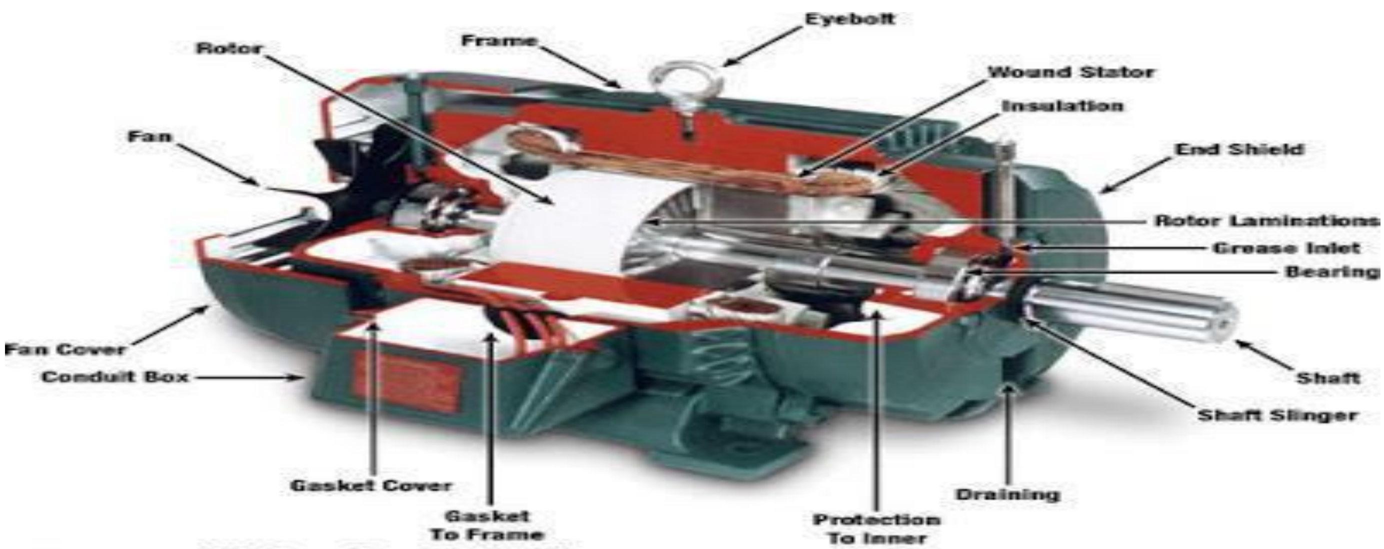


Figure 8 – Motor Construction

Diploma
Vth Semester
Electrical Engineering

List of Experiments

1. To Study the construction of three 3-phase induction motor.
2. To Study the construction of three 3-phase Synchronous Generator (Alternator).
3. To study the different starting methods of 3-phase induction motors & also study how to reverse the direction of rotation in a 3-phase induction motor.
4. To perform no load test on a three phase induction motor to find out its performance parameters with the help of Equivalent circuit
5. To perform blocked rotor test on a three phase induction motor to find out its performance parameters with the help of Equivalent circuit.
6. To conduct the brake load test on a 3-Slip ring Induction motor and to draw its performance Characteristics.
7. To conduct OC (no load) & SC (blocked rotor) tests on the given 1-Induction motor and to Determine its equivalent circuit parameters.
8. To conduct OC & SC test in a 3-Alternator and to Determine its regulation by synchronous impedance method.

Experiment no. 1

Aim of the Experiment:

To Study the construction of three 3-phase induction motor.

Theory: The induction motor essentially consists of two parts:

· Stator

· Rotor.

The supply is connected to the stator and the rotor received power by induction caused by the stator rotating flux, hence the motor obtains its name –induction motor.

The stator consists of a cylindrical laminated & slotted core placed in a frame of rolled or cast steel. The frame provides mechanical protection and carries the terminal box and the end covers with bearings. In the slots of a 3-phase winding of insulated copper wire is distributed which can be wound for 2,4,6 etc. poles.

The *rotor* consists of a laminated and slotted core tightly pressed on the shaft.

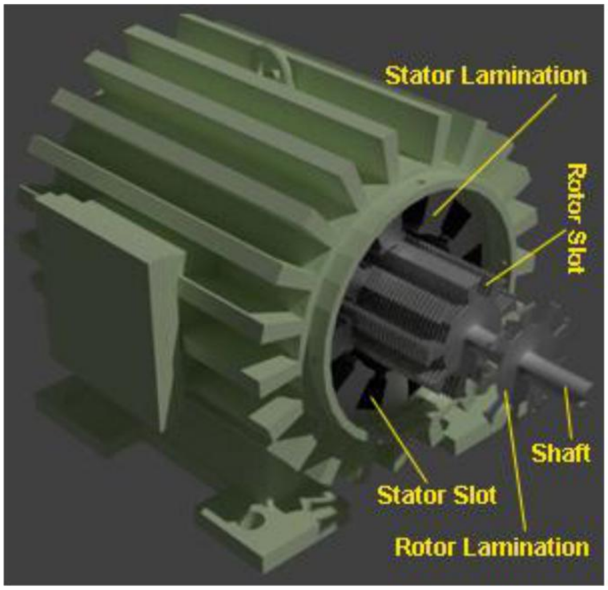
There are two general types of rotors:

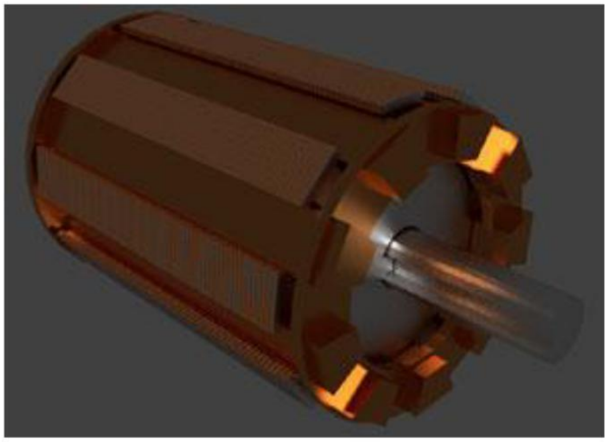
· The squirrel-cage rotor,

· The wound (or slip ring) rotor.

In *the squirrel-cage rotor*, the rotor winding consists of single copper or aluminium bars placed in the slots and short-circuited by end-rings on both sides of the rotor.

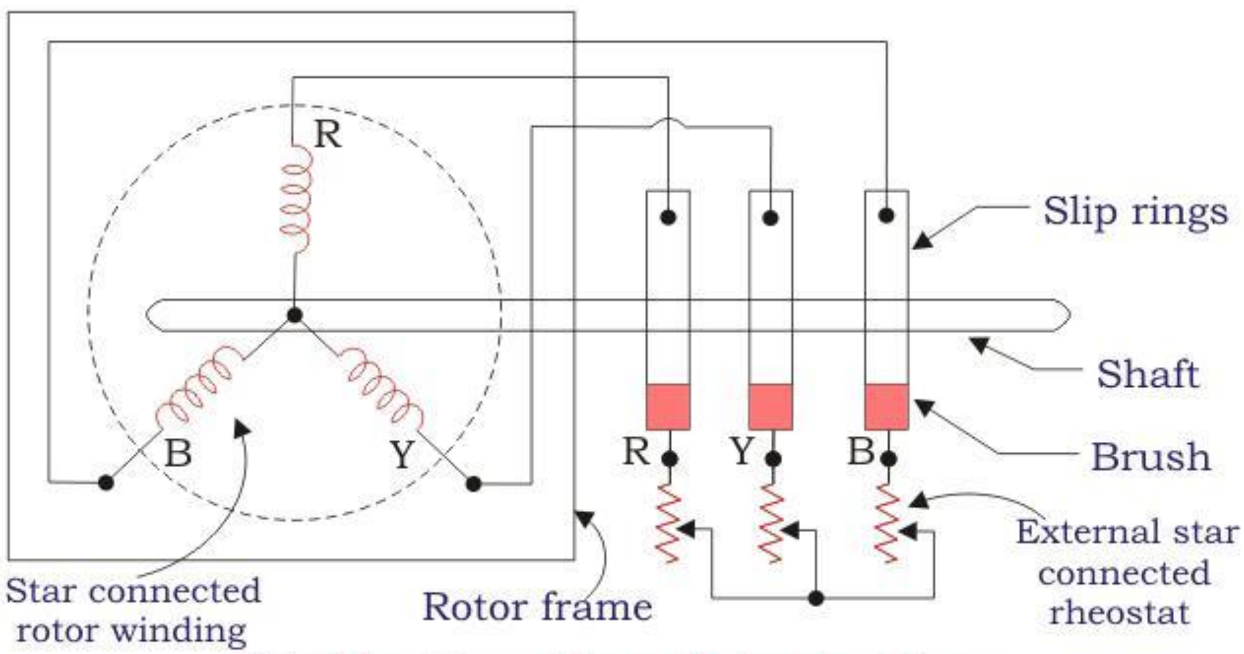
In the *wound rotor*, an insulated 3-phasewinding similar to the stator winding and for the same number of poles is placed in the rotor slots. The ends of the star-connected rotor winding are brought to three slip rings on the shaft so that connection can be made to it for starting or speed control.





Procedure:

1) Design the rotor according to the define ratings of the machine with proper lamination & skewing slots.
2) Make sure the rotor must be closed with end rings ifit is a squirrel cage rotor.
3) Properly design the 3-phase rotor winding as similar to the stator with each phase 120 mechanically apart if it is a slip ring rotor.
4) Design the stator periphery with internal slots.
5) Make sure the construction of stator & rotor are in such a way that there must be an air gap between the stator & rotor for the rotation of RMF.



Slip Ring Three Phase Induction Motor

Precaution:
Make sure there must be proper lamination in all the part & also in the winding in order to reduce the losses.

Result:
We studied the construction of three-phase induction motor.

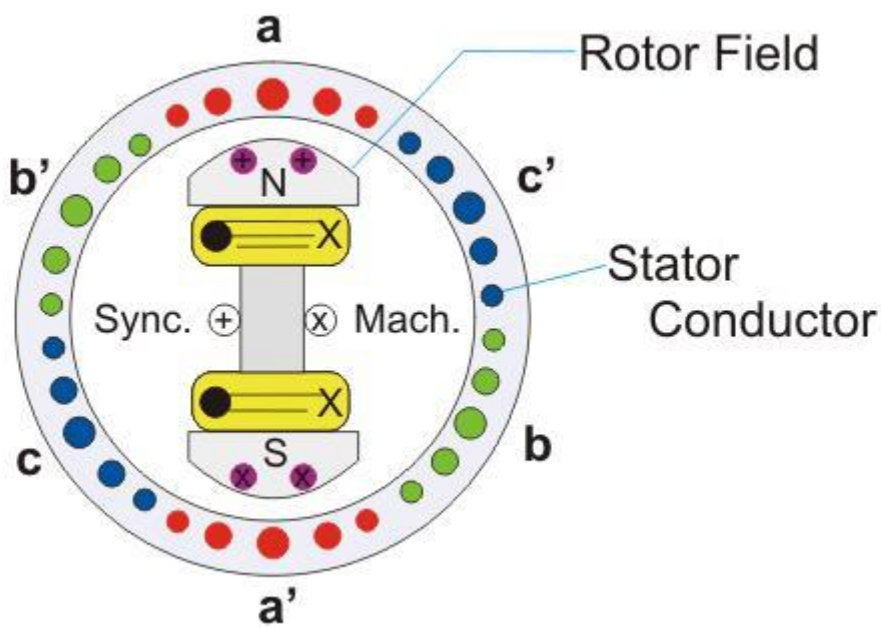
Experiment no. 2

Aim of the Experiment:

To Study the construction of three 3-phase Synchronous Generator(Alternator).

Theory: Construction wise, an alternator generally consists of field poles placed on the rotating fixture of the machine i.e. rotor as shown in the figure above. Once the rotor or the field poles are made to rotate in the presence of armature conductors housed on the stator, an alternating 3φ voltage represented by aa' bb' cc' is induced in the armature conductors thus resulting in the generation of 3φ electrical power. All modern day electrical power generating stations use this technology for generation of 3φ power, and as a result the alternator or synchronous generator has become a subject of great importance and interest for power engineers.

An alternator is basically a type of AC generator which is also known as synchronous generator, for the simple reason that the field poles are made to rotate at synchronous speed $N_S = 120\ f/P$ for effective power generation. Where, f signifies the alternating current frequency and the P represents the number of



poles.

In most practical **construction of alternator**, it is installed with a stationary armature winding and a rotating field unlike in the case of DC generator where the arrangement is exactly opposite. This modification is made to cope with the very high power of the order of few 100 Megawatts produced in an AC generator contrary to that of a DC generator. To accommodate such high power the conductor weigh and dimension naturally has to be increased for optimum performance. And for this reason is it beneficial to replace these high power armature windings by low power field windings, which is also consequently of much lighter weight, thus reducing the centrifugal force required to turn the rotor and permitting higher speed limits.

There are mainly two types of rotor used in **construction of alternator**,

1. Salient pole type.
2. Cylindrical rotor type.

Salient Pole Type

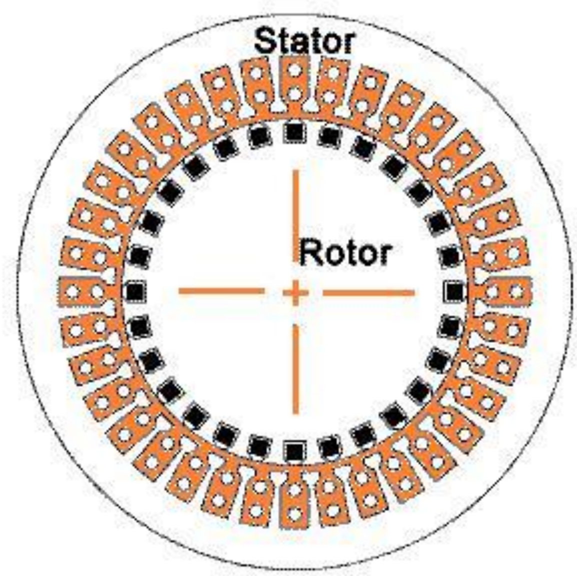
The term salient means protruding or projecting. The salient pole type of rotor is generally used for slow speed machines having large diameters and relatively small axial lengths. The pole in this case are made of thick laminated steel sections riveted together and attached to a rotor with the help of joint. An alternator as mentioned earlier is mostly responsible for generation of very high electrical power. To enable that, the mechanical input given to the machine in terms of rotating torque must also be very high. This high torque value results in oscillation or hunting effect of the alternator or synchronous generator. To prevent these oscillations from going beyond bounds the damper winding is provided in the pole faces as shown in the figure. The damper windings are basically copper bars short circuited at both ends are placed in the holes made in the pole axis's. When the alternator is driven at a steady speed, the relative velocity of the damping winding with respect to main field will be zero. But as soon as it departs from the synchronous speed there will be relative motion between the damper winding and the main field which is always rotating at synchronous speed. This relative difference will induce current in them which will exert a torque on the field poles in such a way as to bring the alternator back to synchronous speed operation.

The salient features of pole field structure has the following special feature-

1. They have a large horizontal diameter compared to a shorter axial length.
2. The pole shoes covers only about $^{2}/_{3}$rd of pole pitch.
3. Poles are laminated to reduce eddy current loss.
4. The salient pole type motor is generally used for low speed operations of around 100 to 400 rpm, and they are used in power stations with hydraulic turbines or diesel engines.

Salient pole alternators driven by water turbines are called hydro-alternators or hydro generators.

Cylindrical Rotor Type



Cylindrical Rotor Alternator.

The cylindrical rotor is generally used for very high speed operation and employed in steam turbine driven alternators like turbo generators. The machines are built in a number of ratings from 10 MVA to over 1500 MVA. The cylindrical rotor type machine has uniform length in all directions, giving a cylindrical shape to the rotor thus providing uniform flux cutting in all directions. The rotor in this case consists of a smooth solid steel cylinder, having a number of slots along its outer periphery for hosing the field coils. The cylindrical rotor alternators are generally designed for 2-pole type giving very high speed of 3000rpm or 4-pole type running at a speed of 1500 rpm Where, f is the frequency of 50 Hz. The cylindrical rotor synchronous generator does not have any projections coming out from the surface of the rotor, rather central polar area are provided with slots for housing the field windings as we can see from the diagram above. The field coils are so arranged around these poles that flux density is maximum on the polar central line and gradually falls away as we move out towards the periphery. The cylindrical rotor type machine gives better balance and quieter-operation along with lesser windage losses.

$$N_s = \frac{(120 \times f)}{P} = \frac{(120 \times 50)}{2} = 3000\ rpm$$

$$N_s = \frac{(120 \times f)}{P} = \frac{(120 \times 50)}{4} = 1500\ rpm$$

Procedure:

1) Design the rotor according to the define ratings of the machine with proper lamination & skewing slots.
2) Make sure that the rotor must be designed according to the specification.
3) Properly design the 3-phase stator windingwith each phase 120 mechanically apart if it is a slip ring rotor.
4) Design the stator periphery with internal slots.
5) Make sure the construction of stator & rotor are in such a way that there must be an air gap between the stator & rotor them.

Precaution:

Make sure there must be proper lamination in all the part & also in the winding in order to reduce the losses.

Result:

We studied the construction of three-phase synchronous machine.

Experiment no. 3

Aim of the Experiment:

To study the different starting methods of 3-phase induction motors& also study how to reverse the direction of rotation in a 3-phase induction motor.

Theory: The most usual methods of starting 3-phase induction motors are:

1. For slip-ring motors
- rotor resistance starting

2. For squirrel-cage motors
- direct-on -line starting
- star-delta starting
- Autotransformer starting.

There are two important factors to be considered in starting of induction motors:

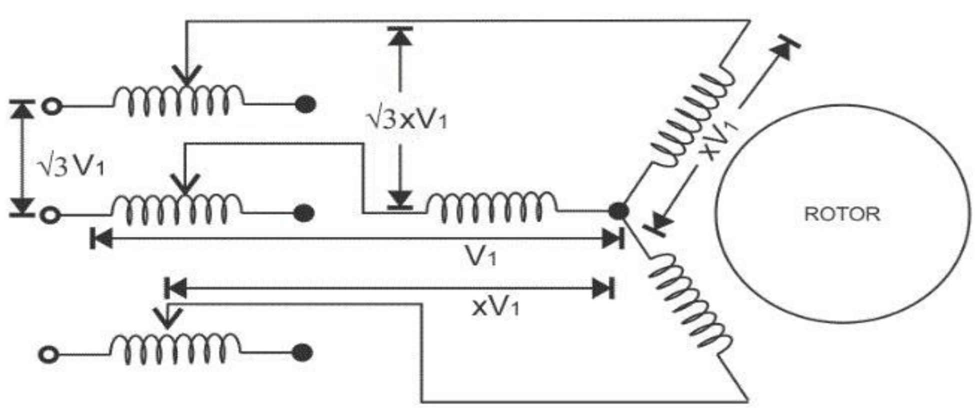
¨ the starting current drawn from the supply, and

¨ The starting torque.

The starting current should be kept low to avoid overheating of motor and excessive voltage drops in the supply network. The starting torque must be about 50 to 100% more than the expected load torque t ensure that the motor runs up in a reasonably short time.

a. **Rotor resistance starting**

By adding eternal resistance to the rotor circuit any starting torque up to the maximum torque can be achieved; and by gradually cutting out the resistance a high torque can be maintained throughout the starting period. The added resistance also reduces the starting current, so that a starting torque in the range of 2 to 2.5 times the full load torque can be obtained at a starting current of 1 to 1.5 times the full load current.



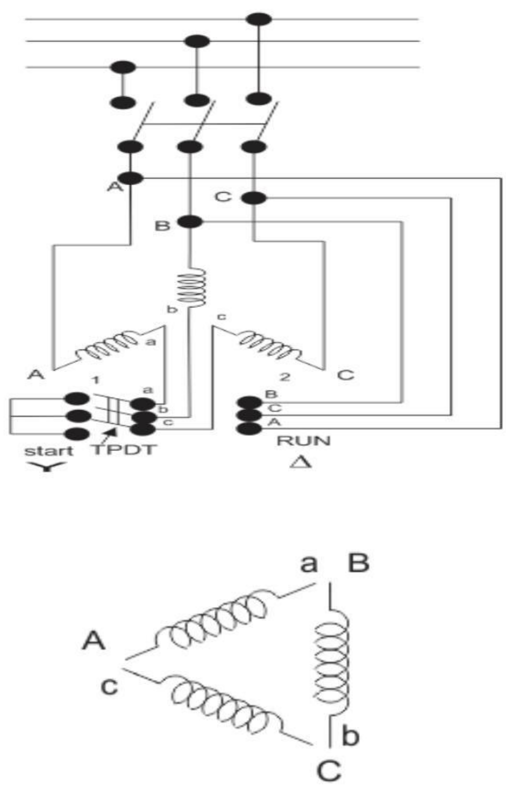
b. **Direct-on-line starting**

This is the most simple and inexpensive method of starting a squirrel cage induction motor. The motor is switched on directly to full supply voltage. The initial starting current is large, normally about 5 to 7 times the rated current but the starting torque is likely to be 0.75 to 2 times the full load torque. To avoid excessive supply voltage drops because of large starting currents the method is restricted to small motors only. To decrease the starting current cage motors of medium and larger sizes are started at a reduced supply voltage. The reduced supply voltage starting is applied in the next two methods.

c. **Star-Delta starting**

This is applicable to motors designed for delta connection in normal running conditions. Both ends of each phase of the stator winding are brought out and connected to a 3-phase change -over switch. For starting, the stator windings are connected in star and when the machine is running the switch is thrown quickly to the running position, thus connecting the motor in delta for normal operation. The phase voltages & the phase currents of the motor in star connection are reduced to 1/Ö3 of the direct -on -line values in delta. The line current is 1/3 of the value in delta.

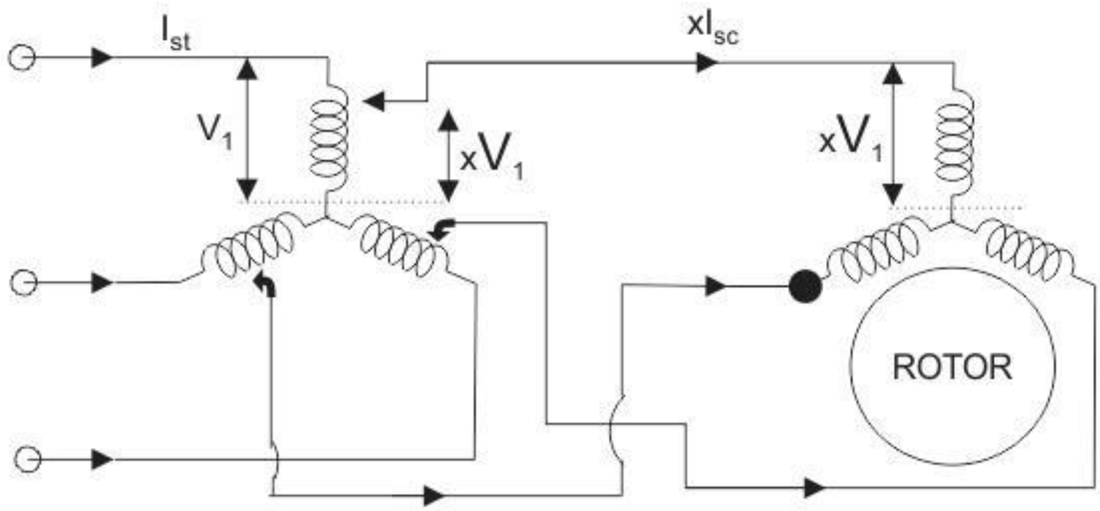
A disadvantage of this method is that the starting torque (which is proportional to the square of the applied voltage) is also reduced to 1/3 of its delta value.



Star Delta

d. **Auto-transformer starting**

This method also reduces the initial voltage applied to the motor and therefore the starting current and torque. The motor, which can be connected permanently in delta or in star, is switched first on reduced voltage from a 3-phase tapped auto -transformer and when it has accelerated sufficiently, it is switched to the running (full voltage) position. The principle is similar to star/delta starting and has similar limitations. The advantage of the method is that the current and torque can be adjusted to the required value, by taking the correct tapping on the autotransformer. This method is more expensive because of the additional autotransformer.



Pertaining to Auto-Transfer Starting

Reversing:

Reversing the connections to any two of the three motor terminals can reverse the direction of rotation of 3-phase induction motor

Procedure

1. For rotor resistance starting, connect the slip-ring motor as shown in FIG.1. Start the motor with full starting resistance and then decrease the resistance in steps down to zero. Take observations of the stator & rotor currents
2. For direct-on -line starting , connect the cage motor as shown in FIG.2
3. For star-delta starting , connect the cage motor to the terminals of the stardeltaswitch (FIG.3)
4. For autotransformer starting, connect the cage motor as shown in FIG.4. Take care at starting that the "Run" switch is open and that it is not closed before the "Start" switch is opened.

5. In each case observe the starting currents by quickly reading the maximum indication of the ammeters in the stator circuit.
6. Reverse the direction of rotation of the motor by reversing of two phases at the terminal box. The reversal has to be made when the motor is stopped and the supply switched off.

Result:
We studied the different starting methods& how to revere the direction of rotation of a 3-phase induction motor.

Experiment no. 4

Aim of the Experiment:

To perform no load test on a three phase induction motor to find out its performance parameters with the help of Equivalent circuit.

THEORY:

The no load test is similar to the open circuit test on a transformer. It is performed to obtain the magnetizing branch parameters (shunt parameters) in the induction machine equivalent circuit. In this test, the motor is allowed to run with no-load at the rated voltage of rated frequency across its terminals. Machine will rotate at almost synchronous speed, which makes slip nearly equal to zero. This causes the equivalent rotor impedance to be very large (theoretically infinite neglecting the frictional and rotational losses). Therefore, the rotor equivalent impedance can be considered to be an open circuit which reduces the equivalent circuit diagram of the induction machine (Fig. 1) to the circuit as shown in Fig. 2. Hence, the data obtained from this test will give information on the stator and the magnetizing branch. The connection circuit diagram of no load test is shown in Fig. 3. The no load parameters can be found from the voltmeter, ammeter, and wattmeter readings obtained when the machine is run at no load as shown below:

Readings Obtained:

Line to line voltage at stator terminals: V_{nl} volts

Stator Phase Current : I_{nl} amps

Per phase power drawn by the stator : P_{nl} watts

Calculations:

$$Z_{nl} = \frac{(V_{nl} / \sqrt{3})}{I_{nl}} \text{ ohms}$$

$$r_{nl} = \frac{P_{nl}}{I_{nl}^2} = r_1 + r_c \text{ ohms}$$

$$X_{nl} = \sqrt{Z_{nl}^2 - R_{nl}^2} = X_1 + X_m \text{ ohms}$$

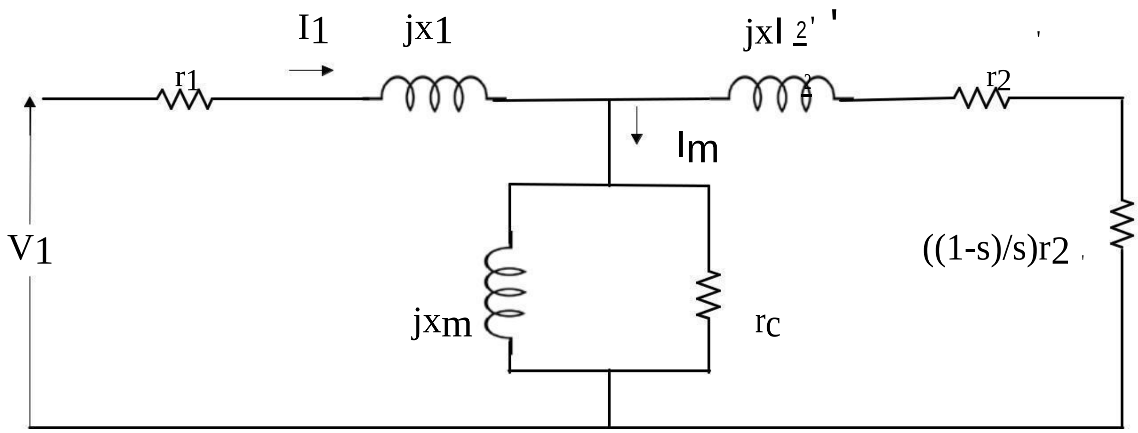


Fig. 1. Per phase equivalent circuit of 3-phase induction motor

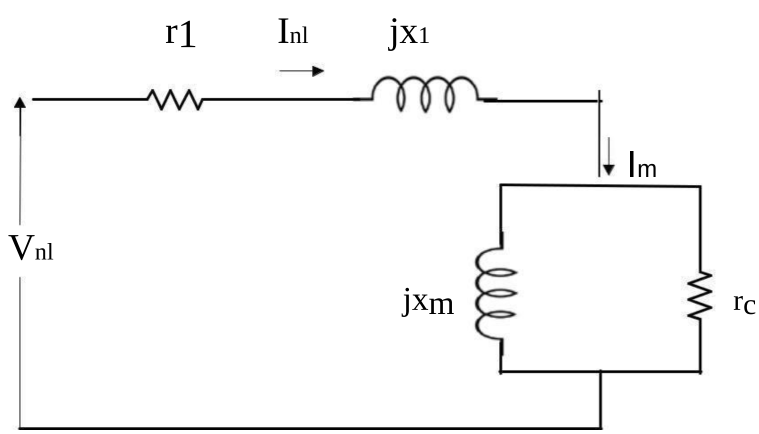


Fig. 2. Approximate Equivalent Circuit for No-Load Test

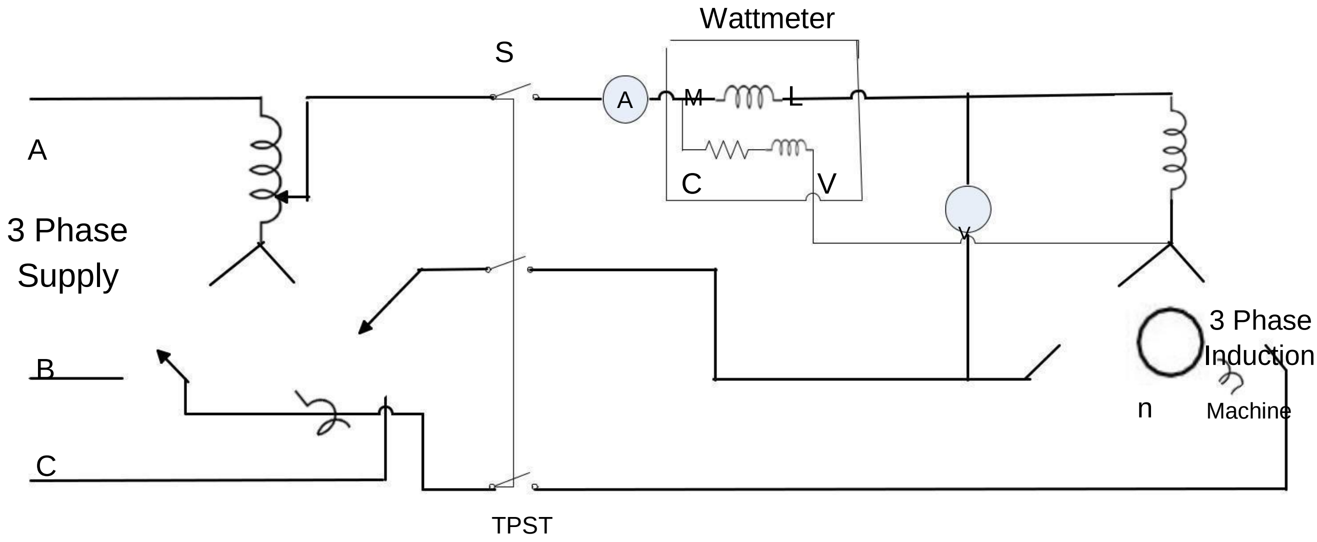


Fig. 3. Connection diagram for performing No-load and Blocked Rotor tests on 3 phase Induction machine

PROCEDURE:

1. Determine the meters and their ratings based on the name plate readings of the machine and requirement.

2. Connect the circuit as shown in Fig. 3.

3. Set/check the variac to be at zero output.

4. First switch on the 3ϕ supply.

5. Close the TPST.

6. Gradually increase the voltage applied to the machine to the rated voltage. Motor runs at a speed quite close to its synchronous speed.

7. Take the reading of voltmeter, ammeter ,wattmeter& speed on that particular voltage on the variac and make a table.

TABLE:

Sl no.	V_{nl}(volt)	I_{nl}(amp)	P_{nl}(watt)	N(rpm)

DISCUSSION:

1. What machine parameters can be obtained from No-Load test?
2. What is the power factor of the machine? Comment on its value.
3. What should be the no load current of an induction motor?
4. Even though there is no-load, why wattmeter reading is not zero?
5. Comment on the slip of the machine when operated at rated voltage.
6. How to obtain the no-load input power to an induction motor when two-wattmeter method of measuring power used?
7. Can a three phase induction motor be started from a single phase supply?
8. No load test is conducted at (a)rated current, (b)rated voltage, (c)high voltage, (d)high current
9. What is the nameplate reading on the machine? What inferences can be drawn from it?
10. What is the real and reactive power consumed in this test?
11. What are the different losses that are present in an induction machine?
12. Which loss in the machine is significant in no load test and why?

CONCLUSIONS:

Hence the parameters found :

Experiment no. 5

Aim of the Experiment:

To perform blocked rotor test on a three phase induction motor to find out its performance parameters with the help of Equivalent circuit.

THEORY: Blocked rotor test is similar to the short circuit test on a transformer. It is performed in the to calculate the series parameters of the induction machine i.e., its leakage impedances. The rotor is blocked to prevent rotation and balanced voltages are applied to the stator terminals at a frequency of 25 percent of the rated frequency at a voltage where the rated current is achieved. Under the reduced voltage condition and rated current, core loss and magnetizing component of the current are quite small percent of the total current, equivalent circuit reduces to the form shown in Fig. 4.

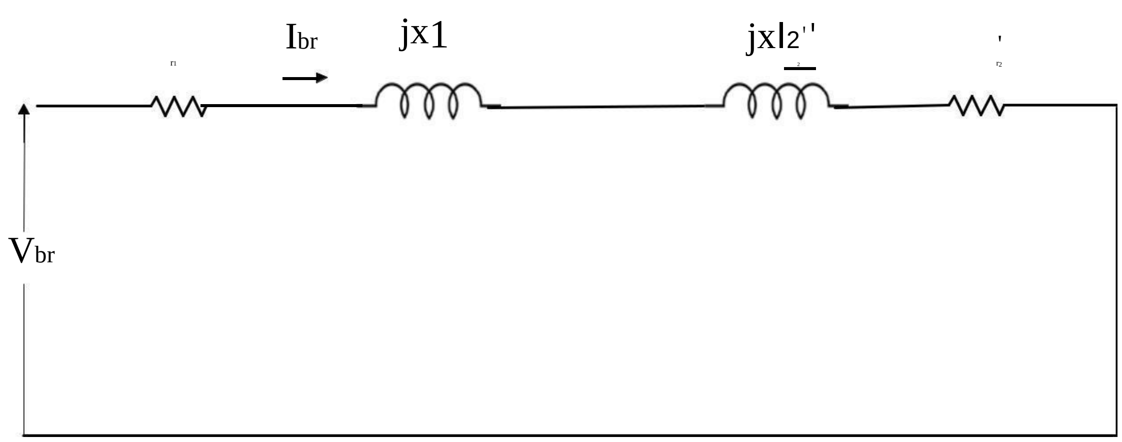


Fig. 4. Equivalent Circuit for Blocked Rotor

Test The slip for the blocked rotor test is unity since the rotor is

stationary.

The resulting speed-dependent equivalent resistance **r_2'{(1/s)-1}** goes to zero and the resistance of the rotor branch of the equivalent circuit becomes very small. Thus, the rotor current is much larger than current in the excitation branch of the circuit such that the excitation branch can be neglected. Voltage and power are measured at the motor input.

Readings Obtained:

Line to line voltage at stator terminals : V_{br} volts

Stator Phase Current : I_{br} amps

Per phase power drawn by the stator : P_{br} watts

Calculations:

$$Z_{br} = \frac{(V_{br}/\sqrt{3})}{I_{nl}} \text{ ohms}$$

$$r_{br} = \frac{P_{br}}{I_{br}^2} = r_1 + r_2' \text{ ohms}$$

$$X_{br} = \sqrt{Z_{br}^2 - R_{br}^2} = X_1 + X_2' \text{ ohms}$$

If it is assumed that $X_1 = X_2'$, then $X_1 = X_2' = \frac{X_{br}}{2}$ ohms

PROCEDURE:

1. Determine the meters and their ratings based on the name plate readings of the machine and requirement.
2. Connect the circuit as shown in Fig. 3.
3. **Set/check the variac to be at zero output**.
4. First switch on the 3ϕ supply.
5. Close the TPST.
6. Now, keeping the rotor still (block the rotor from running), slowly increase the autotransformer output until rated current flows (Typically, this happens at 25% of the rated voltage).
7. Take the ammeter, voltmeter, and wattmeter readings and tabulate.
8. Repeat the procedure for other values stator phase current less than the rated value

TABLE:

Sl no	**I_{br} (Amps)**	**V_{br}(volt)**	**P_{br}(watt)**

DISCUSSION:

1. Why block rotor test of an induction motor is carried out?

2. When r_2/s is split into a series connection of r_2' and $r_2'\{(1/s)-1\}$ in the rotor equivalent circuit of an induction machine, what do the power absorbed by the individual resistors physically represent?

3. How does the equivalent circuit of an induction motor simplify to under blocked rotor conditions? Justify.

4. What is the power factor of the machine?

5. Which loss in the machine is significant in blocked rotor test and why?

CONCLUSION:

Hence the parameters found:

Experiment no. 6

Aim of the Experiment:

To conduct the brake load test on a 3-Slip ring Induction motor and to draw its performance Characteristics.

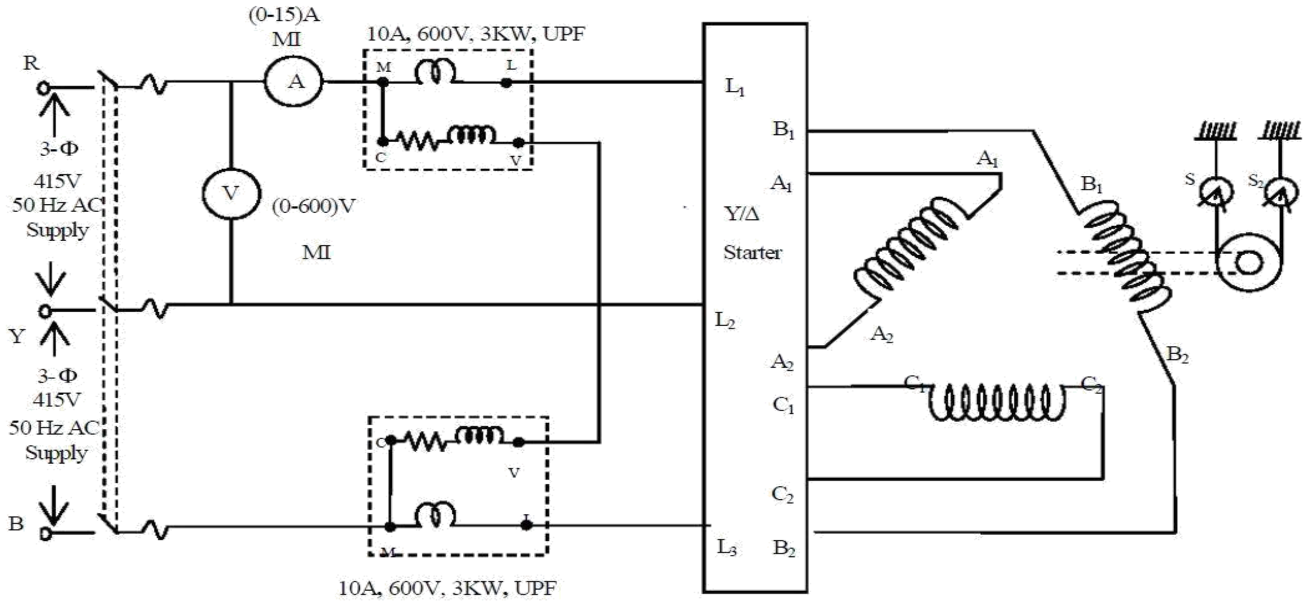
Apparatus Required:

1. 3-Induction Motor
2. Starter
3. Ammeter
4. Voltmeters
5. Wattmeter
6. Fuses
7. Techometer

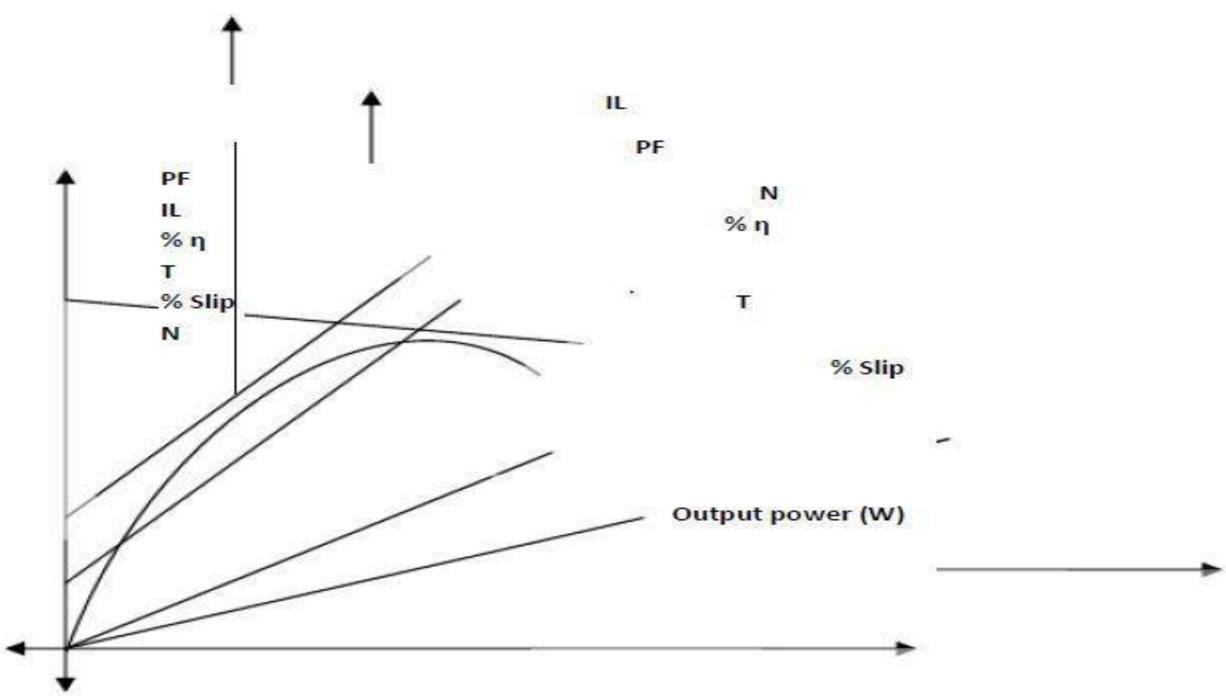
Theory: As a general rule, conversion of electrical energy to mechanical energy takes place in to the rotating part on electrical motor. In DC motors, electrical power is conduct directly to the armature, i.e, rotating part through brushes and commutator. Hence, in this sense, a DC motor can be called as 'conduction motor'. However, in AC motors, rotor does not receive power by conduction but by induction in exactly the same way as secondary of a two winding T/F receives its power from the primary. So, these motors are known as Induction motors. In fact an induction motor can be taken as rotating T/F, i.e, one in which primary winding is stationary and but the secondary is free.

The starting torque of the Induction motor can be increase by improving its p.f by adding external resistance in the rotor circuit from the stator connected rheostat,the rheostat resistance being progressively cut out as the motor gathers speed. Addition of external resistance increases the rotor impedance and so reduces the rotor current. At first, the effect of improved p.f predominates the current- decreasing effect of impedance. So, starting torque is increased. At time of starting, external resistance is kept at maximum resistance position and after a certain time, the effect of increased impedance predominates the effect of improved p.f and so the torque starts decreasing. By this during running period the rotor resistance being progressively cut-out as the motor attains its speed. In this way, it is possible to get good starting torque as well as good running torque.

Procedure:
1) Give all the connections as per the circuit diagram.
2) Switch -ON the supply and press the ON button of the starter.
3) Now put the rotor external resistance switch to run position in steps & slowly.
4) Note the no-load readings of ammeter, voltmeter, wattmeter, speed & loads.
5) Gradually increase the load on the motor by tightening the hand-swivels and note the corresponding meter's readings.
6) Remove the load completely & Switch-Off the power.



Graph: A graph is drawn b/w O/P power in watts (on X-axis) verses speed, torque, current, slip, efficiency & p.f (on Y-axis).



Precautions:

1) There should not be any load on the motor initially.
2) The brake drum should be filled with water to cool it.
3) If the wattmeter shows negative deflection, reverse either pressure coil or current coil and take that reading as negative.
4) The rotor external resistance should be kept at max resistance position initially.

Conclusion:

Experiment no. 7

Aim of the Experiment:

To conduct OC (no load) & SC (blocked rotor) tests on the given 1-Induction motor and to Determine its equivalent circuit parameters.

Apparatus Required:

8. Auto T/F
9. Ammeter
10. Voltmeters
11. Wattmeter
12. Fuses
13. Techometer

Theory: Single phase induction motor also woks on the principle of 'Faraday's laws of electromagnetic induction. The equivalent Circuit of such motor is based on double field revolving theory i.e, an alternating uniaxial quantity can berepresented by two oppositely rotating vectors of half magnitude. So here the single phase motor has been imagined to be made up of one stator winding and two imaginary rotors. Each rotor will be assigned half the actual value of resistance. In order to find the equivalent circuit parameters, it is need to conduct OC & SC tests on it. In OC test, rated voltage will be given to motor with out any load on it. In SC test, the rotor is blocked and a reduced voltage will be given upto the rated load current.

Procedure: **No-load test**:

4) Give all connections as per the circuit diagram.
5) Switch-ON the supply & apply the rated voltage to motor with out any load.
6) Note the readings of voltmeter, ammeter & wattmeter.

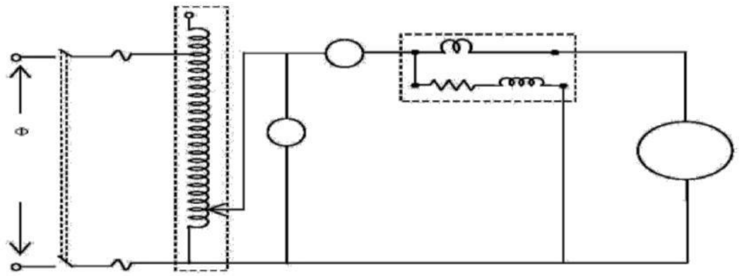
1. Give all connections as per the circuit diagram.
2. Apply a low voltage to motor with auto transformer so that rated load current flows through the stator.

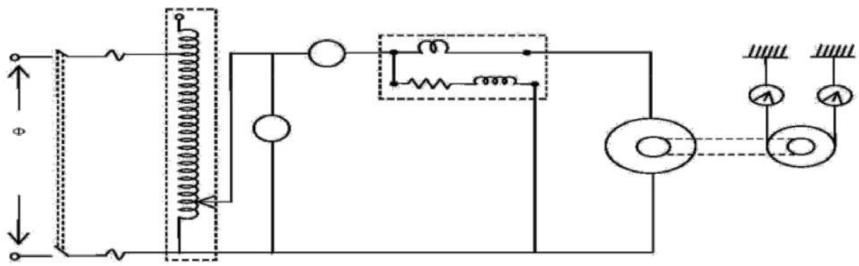
Precautions:

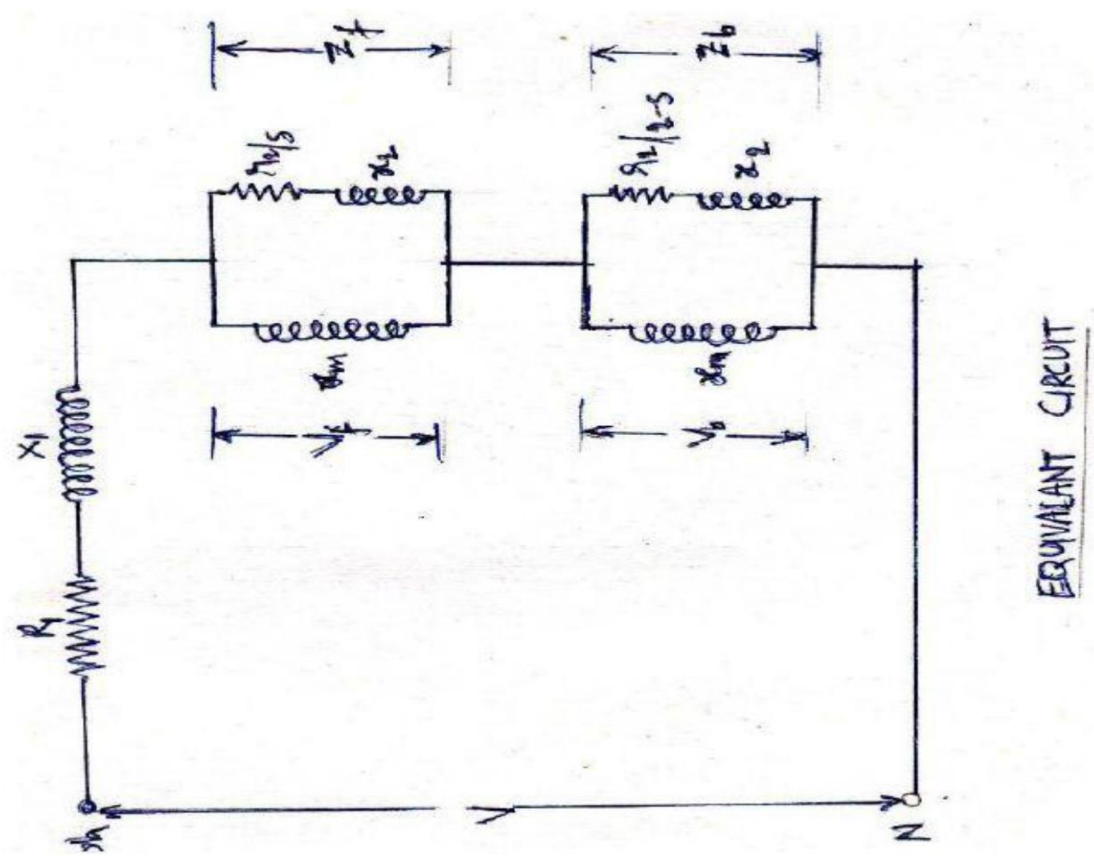
1) The Dimmerstat should be kept at minimum O/ position initially
2) In the rotor-blocked test, the rotor should be blocked firmly.
3) In SC test, the Dimmerstat should be varied slowly such that current should not exceed the rated value.

4) If the wattmeter shows negative deflection, then reverse either pressure coil or current coil & take that reading as negative.

3) Note the readings of voltmeter, ammeter & wattmeter







Observations:

O.C Test:

V_0	I_0	W_0
volt	ampere	watt

S.C Test:

V_{SC}	I_{SC}	W_{SC}
volt	ampere	Watt

Result

Experiment no. 8

Aim of the Experiment:

To conduct OC & SC test in a 3-Alternator and to Determine its regulation by synchronous impedance method.

Apparatus Required:

1. Auto T/F
2. Ammeter
3. Voltmeters
4. Wattmeter
5. Fuses
6. Techometer

Theory: Alternator is a machine, which converts mechanical energy to electrical energy. Regulation of an Alternator can be calculated by synchronous impedance method. In OC test the terminals of the alternator are kept opened and a voltmeter is connected. Keeping speed constant, a relation b/w field current & open circuit voltage are obtained. In SC test, the terminals are short circuited with a suitable ammeter & a relation b/w field current & short circuit Current are obtained.

Voltage regulation:

It is defined as the rise in terminal voltage of an isolated Machine when full load is thrown off w.r.t voltage on the full load, when speed & excitation remaining constant.

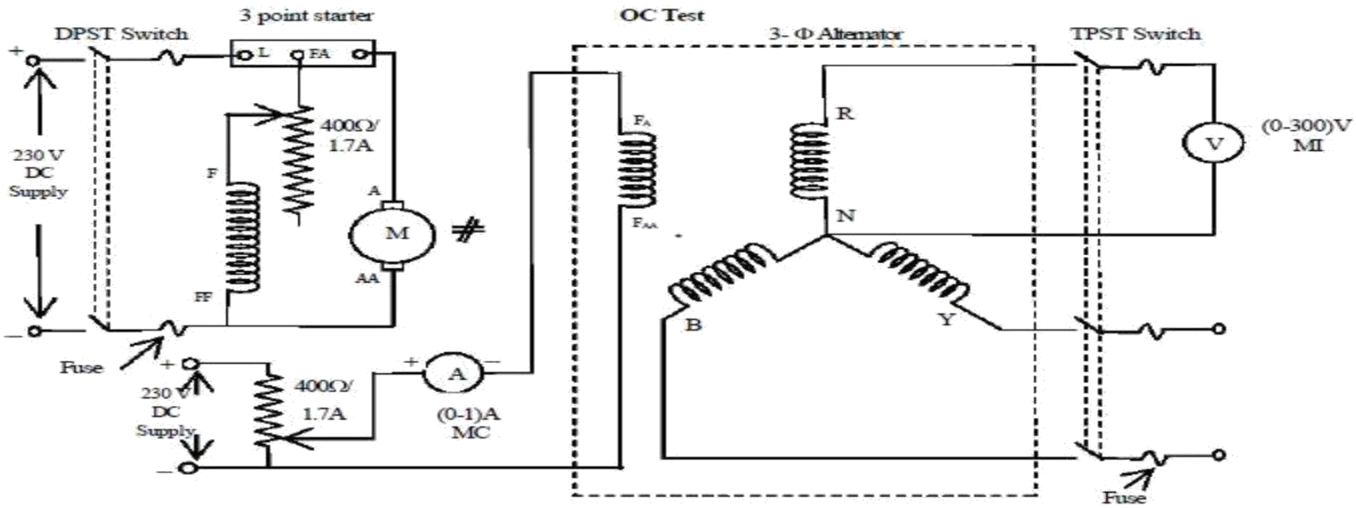
Now, Syn.Impedance (Z_S) = OC voltage / SC current

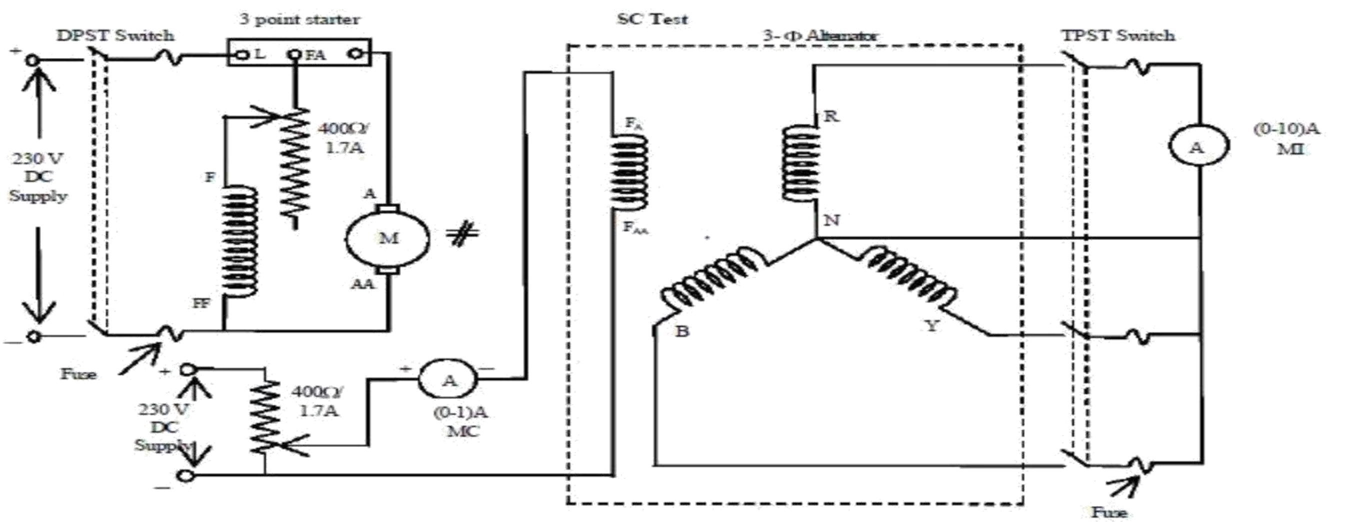
$$X_S = \sqrt{Z^{2S} - R^{2a}}$$

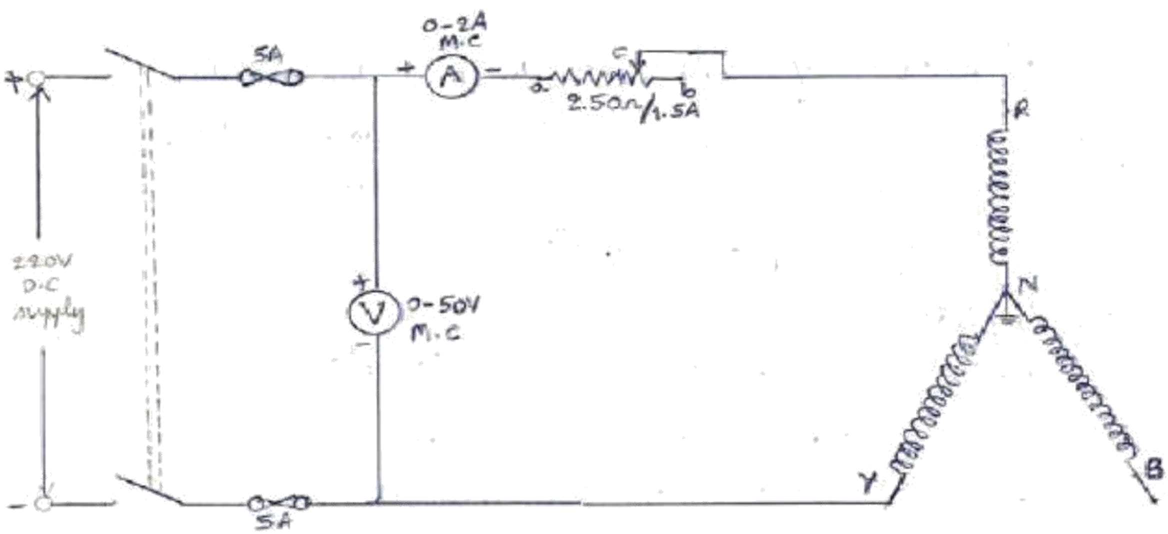
From fig. $E_O = \sqrt{OB^2 + BD^2}$

$$= \sqrt{(V\cos\theta + IR_a)^2 + (V\sin\theta + IX_S)^2}$$

% Regulation = $[(E_0 - V) / V]\ 100$







CIRCUIT DIAGRAM FOR 'Ra'

Procedure: OC test:
1) Give all connections as per the circuit diagram.
2) Switch-ON the supply & by varying the starter, prime mover speed is adjusted to rated.
3) Now keeping the field current at zero, note the induced emf in armature duo to residual Magnetism.
4) By slowly varying the potential divider, field current is increased & corresponding emf Induced is noted up to above 20% of rated voltage.

SC test:
1) Give all connections as per the circuit diagram.
2) Switch-ON the supply & by varying the starter, prime mover speed is adjusted to rated.
3) By slowly varying the potential divider, field current is increased & corresponding short Circuit current is noted up to rated value.

To find armature resistance (R_a):
Give the connections as per diagram and by slowly varying the rheostat, note the values of ammeter & voltmeter up to some value and average them.

Graph:
1) A graph is drawn b/w I_f and V which is known as OC curve, by taking I_f on X-axis and V on Y-axis.
2) A graph is drawn b/w I_f and I_{SC} which is known as SC curve, by Taking I_f on X-axis and I_{SC}V on Y-axis.

Observation:

OC Test: **SCTest:**

Field current I_f	OC voltage	Field current I_f	SC current

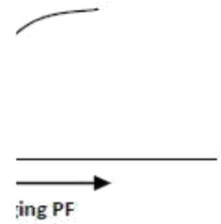
Armature resistance:

voltage	current	Resistance R_a

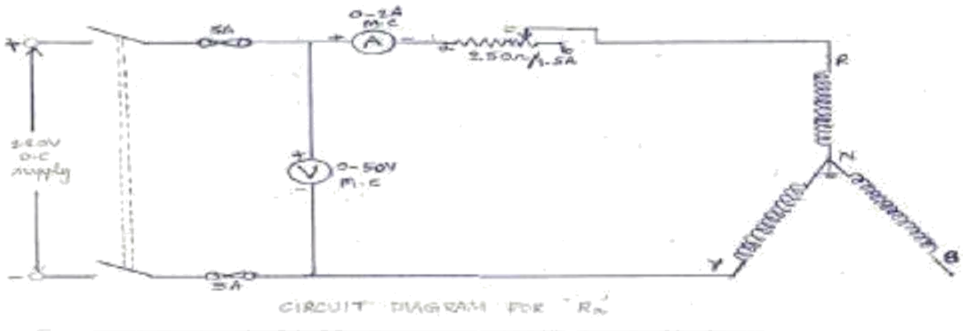
Z.P.F Test:-

If(A)	I Load	V

Model Graph



Circuit Diagram for Ra:-



Ia	V	R in Ω

Result: