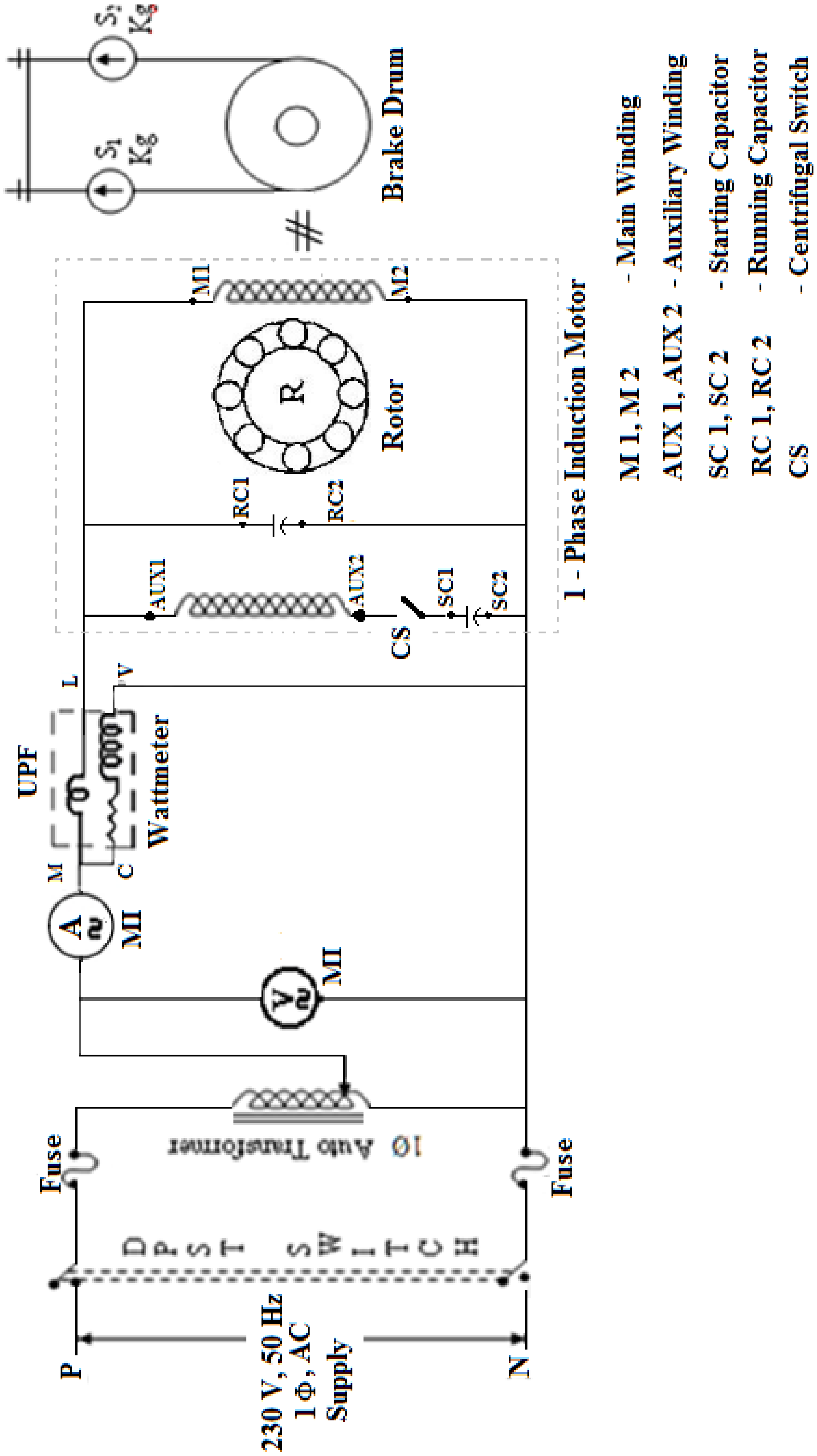
CIRCUIT DIAGRAM:



EX.NO.1 **Date:**

LOAD TEST ON SINGLE PHASE INDUCTION MOTOR

AIM:

To determine the performance characteristic of a given single phase capacitor start induction motor by conducting load test.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Autotransformer			
6.	Connecting wires			

THEORY:

In the single phase induction motor, single phase a.c. supply is given to the stator winding. The stator winding carries an alternating current which produces the flux which is also alternating in nature. This flux is called main flux. This flux links with the rotor conductors and due to transformer action e.m.f. gets induced in the rotor. The induced e.m.f. drives current through the rotor as rotor circuit is closed circuit. This rotor current produces another flux called rotor flux required for the motoring action. Thus second flux is produced according to induction principle due to induced e.m.f. hence the motor is called induction motor. As against this in d.c. motor a separate supply is required to armature to produce armature flux. This is an important difference between d.c. motor and an induction motor. The single phase induction motors are not self-starting, to make a single-phase induction motor self-starting, the following methods are used

(i) Split-phase motors
(ii) Capacitor motors
(iii) Shaded-pole motors

Capacitor-Start Capacitor-Run Motor

In these method two capacitors C_1 and C_2 are used in the starting winding .The smaller capacitor C_1 required for optimum running conditions is permanently connected in series with the starting winding. The much larger capacitor C_2 is connected in parallel with C_1 for optimum starting and remains in the circuit during starting. The starting capacitor C_1 is disconnected when the motor approaches about 75% of synchronous speed. The motor then runs as a single-phase induction motor.

TABULAR COLUMN FOR WITHOUT CAPACITOR:

Observation Tabulation:

S.No.	Line Voltage V_L (V)	Line Current I_L (A)	Input Power P_i (Watts)		Speed (N) rpm	Spring Balance Reading		($S_1 \sim S_2$) Kg
			Observed	Actual		S_1 Kg	S_2 Kg	

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque N-m	%Slip	Input Power P_i (W)	Output Power (W)	% η

FORMULA USED:

1. Input power, P_i = W (in watts)
2. Torque = $(S_1 \sim S_2) \times R \times 9.81$

   Where, R = Radius of brake drum of motor in meter

   S_1, S_2 = spring balance reading in kg

3. Output Power, P_o = $\frac{2\pi NT}{60}$ Watts
4. % Efficiency, η = $\frac{Outputpower}{Inputpower} \times 100$
5. Synchronous speed, $N_S = \frac{120f}{P}$ (rpm)

   Where, f = frequency in Hz

   P = no. of poles

6. % Slip, s = $\frac{N_S - N}{N_S} \times 100$

   Where, N_s=synchronous speed in rpm

   N_r=speed of the rotor in rpm

7. Power factor = $\cos\phi = \frac{P_{in}}{V_L I_L}$

TABULAR COLUMN FOR WITH CAPACITOR:

Observation Tabulation:

S.No.	Line Voltage V_L	Line Current I_L	Input Power P_i		Speed (N)	Spring Balance Reading		$(S_1 \sim S_2)$
			Observed M.F=	Actual		S_1	S_2	
	V	A	W	W	rpm	Kg	Kg	Kg

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque	Slip	Input Power P_i	Output Power	η
	No unit	N-m	%	W	W	%

PRECAUTION:

1) Before switching on the supply the autotransformer is kept in minimum position.
2) There should be no load while starting the motor.

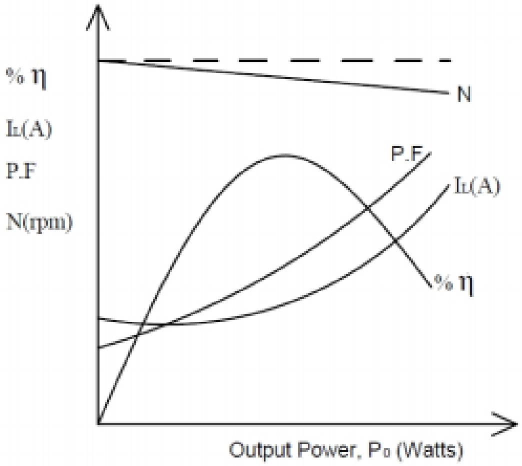
PROCEDURE:

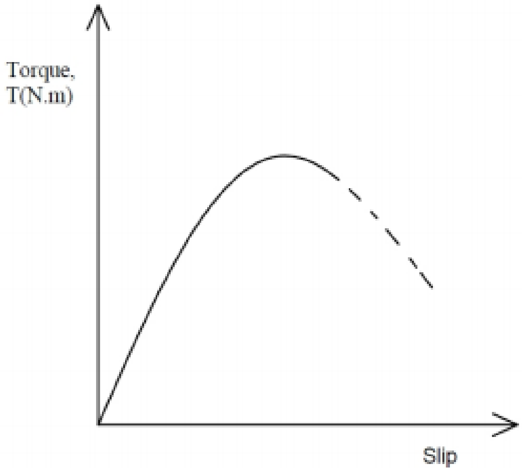
1. Connections are given as per the circuit diagram.
2. Switch on the supply at no load condition.
3. Apply the rated voltage to the motor by adjusting autotransformer.
4. The no load readings are taken.
5. Vary the load in suitable steps and note down all the readings till rated current is reached.

GRAPHS:

1. Output Power Vs speed
2. Output power Vs Torque
3. Output power Vs Effecting
4. Output power Vs slip
5. Output power Vs Power factor

MODEL GRAPHS:





MODEL CALCULATION:

1. Input power = 480 W

2. Torque = ($S_1 \sim S_2$) × R × 9.81 Where, R = 0.11 m
 = 2 × 0.11 × 9.81
 = 2.15 Nm

3. Output Power = $\frac{2\pi NT}{60}$

 $= \frac{2\pi \times 1470 \times 2.15}{60}$

 = 330.79 Watts

4. % η = $\frac{Output}{Input} \times 100$

 $= \frac{330.79}{480} \times 100$ = 68.91 %

5. Slip = $\frac{N_S - N}{N_S} \times 100$

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

 $N_S = \frac{120 \times 50}{4} = 1500$

 Slip = $\frac{1500 - 1470}{1500} \times 100 = 2\%$

6. Power factor = $\cos\phi = \frac{P_{in}}{V_L I_L}$

 $= \frac{480}{218 \times 7.5} = 0.202(no unit)$

VIVA QUESTION:

1. **A single phase induction motor is not self-starting. Why?**
   When a single phase supply is connected across a single phase winding, a pulsating magnetic field is produced. The force experienced by the upper conductors of the rotor will be downward and the force experienced by the lower conductors will be directed upward. The two sets of force will cancel and the rotor will experience no torque. Hence the rotor will not rotate.
2. **How will you change the direction of rotation of a single phase induction motor?**
   The direction of rotation of a single phase induction motor can be changed by changing the direction of current either in the starting winding or in the running winding.
3. **What type of motor is used for ceiling fans?**
   Permanent magnet capacitor motor is used for ceiling fans.
4. **Why single phase induction motor has low power factor?**
   The current through the running winding lags behind the supply voltage by a very large angle. Hence the power factor is low in single phase induction motor.
5. **Why are centrifugal switches provided on single phase inductions motor?**
   The centrifugal switches are provided on single phase induction motors, because when the motor is running at 75% of the synchronous speed, the centrifugal switch connected in the auxiliary winding operates and disconnect the auxiliary winding from the supply.
6. **What is the function of capacitor in a single phase induction motor?**
   Capacitor is used to improve the power factor of the motor. Due to the capacitor connected in series with the auxiliary winding, the capacitive circuit draws a leading current which increases the split phase angleα between the two current Im and Ist.
7. **What are the classifications of single phase induction motor based on the method of starting?**
   a) Split phase motor
   b) Capacitor start motor
   c) Capacitor start Capacitor run motor
   d) Shaded pole motor

APPLICATIONS:

Single-phase induction motors are used extensively for smaller loads such as centrifugal pump, fan and compressor.

RESULT:

Thus the load test on single phase induction motor was performed and the respective graphs were drawn.

S.No.	Parameters	Without Capacitor	With Capacitor
1.	Maximum efficiency		
2.	Maximum slip		
3.	Maximum power factor		
4.	Maximum torque		

INFERENCE:

The load test helps to determining the operational limits, efficiency, and performance characteristics of the single-phase induction motor. By analyzing the results, engineers can make decisions regarding motor selection, system design, and maintenance schedules, ensuring the motor operates efficiently under its expected load conditions.

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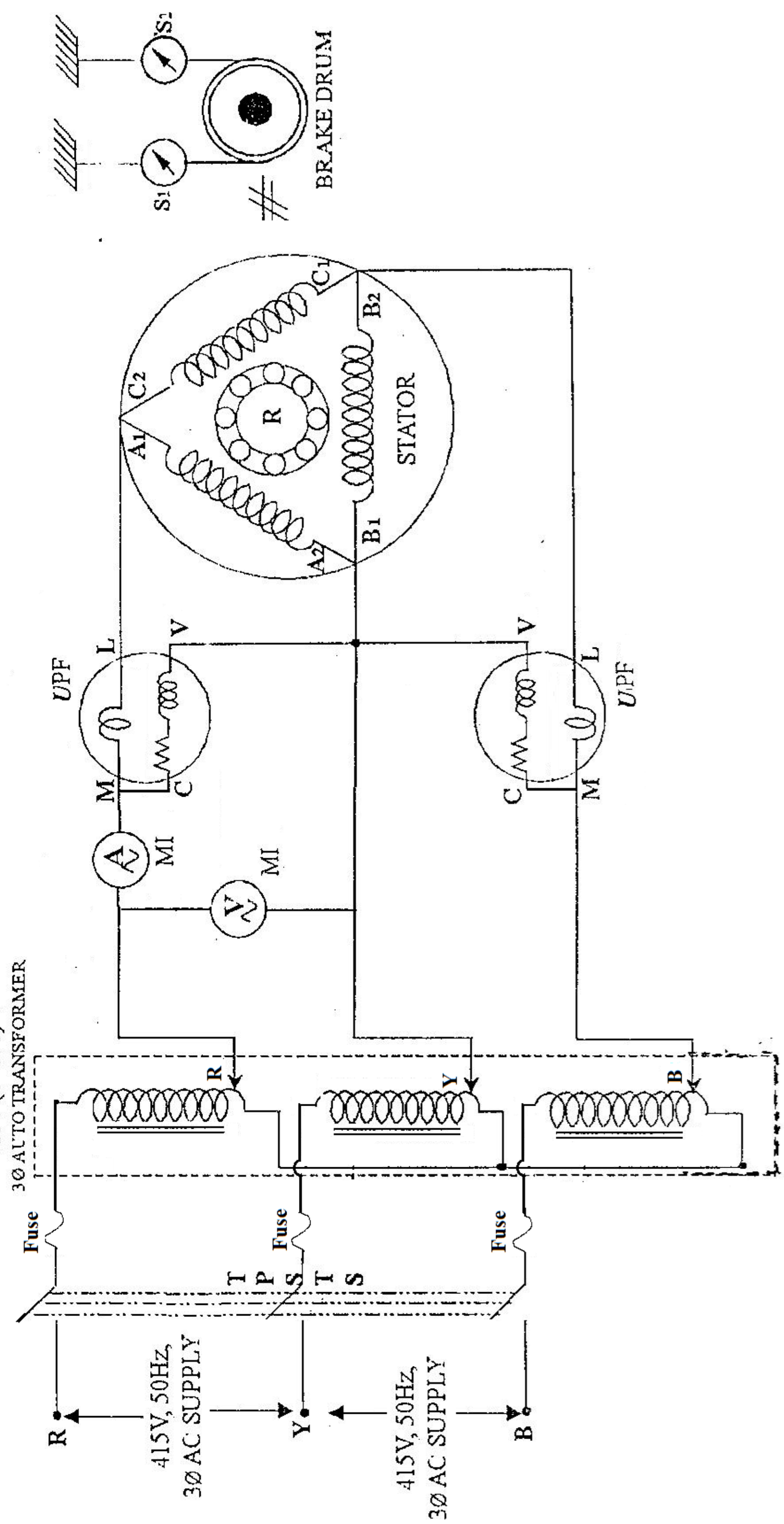
CIRCUIT DIAGRAM

LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR



EX.NO.2 **Date:**

LOAD TEST ON 3-PHASE SQUIRREL CAGE INDUCTION MOTOR

AIM :

To determine the performance characteristics of 3-phase squirrel cage induction motor by direct loading.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

Basically the induction motor consists of two main parts, namely

1. The part i.e. three phase windings, which is stationary called stator.
2. The part which rotates and is connected to the mechanical load through shaft called rotor.

The two typed of rotor constructions which are used for induction motors are,

(i) Squirrel cage rotor and
(ii) Slip ring wound rotor

Squirrel Cage Rotor

The rotor core is cylindrical and slotted on its periphery. The rotor consists of uninsulated copper or aluminium bars called rotor conductors. The bars are placed in the slots. These bars are permanently shorted at each end with the help of conducting copper ring called end ring. The bars are usually brazed to the end rings to provide good mechanical strength. The entire structure looks like a cage, forming a closed electrical circuit. So the rotor is called squirrel cage rotor.

As the bars are permanently shorted to each other through end ring, the entire rotor resistance is very small. Hence this rotor is also called short circuited rotor. As rotor itself is short circuited, no external resistance can have any effect on the rotor resistance. Hence no external resistance can be introduced in the rotor circuit. So slip ring and brush assembly is not required for this rotor. Hence the construction of this rotor is very simple. Induction motor works on the principle of electromagnetic induction.

TABULATION:

Observation Tabulation:

S.No.	Line Voltage V_L (V)	Line Current I_L (A)	Input Power P_i (Watts)				Speed (N) rpm	Spring Balance Reading		$(S_1 \sim S_2)$ Kg
			W_1		W_2					
			Obs.	Act.	Obs.	Act.		S_1 Kg	S_2 Kg	

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque N-m	%Slip	Input Power P_i (W)	Output Power (W)	% η

FORMULA:

1. Torque = ($S_1 \sim S_2$) × 9.81 × R N-m

   Where, R = Radius of brake drum of motor in meter

   S_1, S_2 = spring balance reading in kg

2. Input Power, (P_i) = ($W_1 + W_2$) (Watts)

3. Output Power, (P_o) = $\frac{2\pi NT}{60}$ (Watt)

4. % Efficiency $\eta = \frac{Output}{Input} \times 100$

5. Synchronous speed, $N_S = \frac{120f}{P}$ (rpm)

   Where, f = frequency in Hz

   P = no. of poles

6. % Slip, s = $\frac{N_S - N}{N_S} \times 100$

   Where, N_s=synchronous speed in rpm

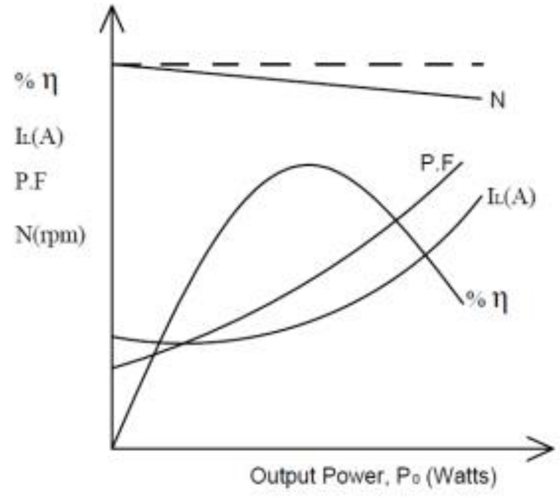
   N_r=speed of the rotor in rpm

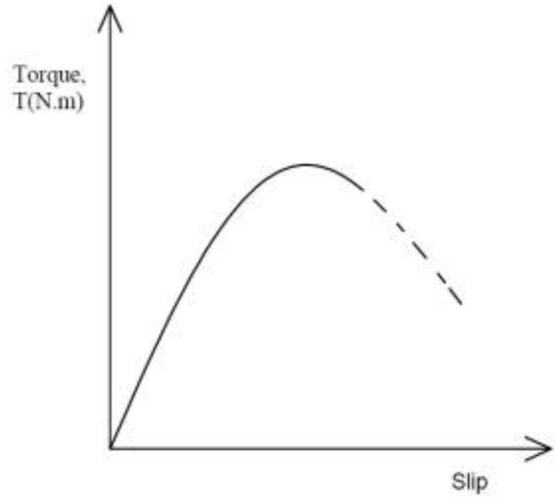
   Where, R = Radius of brake drum of motor in meter

   S_1, S_2 = spring balance reading in kg

7. Power factor = $\cos\phi = \frac{P_{in}}{\sqrt{3}V_L I_L}$

MODEL GRAPHS:





MODEL CALCULATION:

1. Torque = $(S_1 \sim S_2) \times 9.81 \times R$ N-m

   $= 13 \times 9.81 \times 0.098$

   $= 12.49$ Nm

2. Input Power = $W_1 + W_2$

   = 2000 Watts

3. Output Power = $\frac{2\pi NT}{60}$

   $= \frac{2\pi \times 1465 \times 12.49}{60}$

   = 1916.146 Watts

4. % $\eta = \frac{Output}{Input} \times 100$

   $= \frac{1916.14}{2000} \times 100$ = 95.80 %

5. Slip = $\frac{N_S - N}{N_S} \times 100$

   $= \frac{1500 - 1465}{1500} \times 100 = 2.3\%$

6. Power factor = $\cos\phi = \frac{P_{in}}{\sqrt{3} V_L I_L}$

   $= \frac{1916.146}{\sqrt{3} \times 410 \times 5.6} = 0.48$

PRECAUTION:

1. 3-phase autotransformer should be at minimum voltage position.
2. There should be no-load at the time of starting.

PROCEDURE:

1. Connections are given as per the circuit diagram.
2. Switch on the supply at no load condition.
3. Apply the rated voltage to the motor by adjusting autotransformer.
4. If any Wattmeter shows negative reading then interchange M and L connections.
5. The no load readings are taken.
6. Vary the load in suitable steps and note down all the readings till rated current is reached.

GRAPHS:

7. Output Power Vs Efficiency
8. Output Power Vs Torque
9. Output Power Vs Speed
10. Output Power Vs %s

VIVA QUESTIONS:

1. **Why an induction motor is called as rotating transformer?**

   The rotor receives same electrical power in exactly the same way as the secondary of a two winding transformer receiving its power from primary. That is why induction motor is called as rotating transformer.

2. **What are the fundamental characteristics of a rotating magnetic field?**

   (i). The resultant of three alternating fluxes separated from each other by 120 degree has constant amplitude of 1.5 Φ_m, where Φ_m is maximum amplitude of an individual flux due to any phase.

   (ii). The resultant always keeps on rotating with certain speed in space, and the speed is given by Ns = 120f / P

3. **Define Synchronous speed in a 3 phase I.M?**

   The speed at which the revolving flux rotates is called synchronous speed Ns and is given by $N_s = 120f / P$

   Where f – Supply Frequency P- Number of poles on the ststor

4. **Define slip and slip speed in an IM?**

   Slip

   The slip of an IM is defined as the ratio of difference between sync. speed (Ns) and rotor speed (N) to the sync. speed.

   $$s = (N_s – N) / N_s$$

   Slip Speed

   The slip speed is defined as the difference in speed between the rotating magnetic field produced by stator (Ns) and rotor speed (N).

5. **Why an induction motor never runs at its synchronous speed?**

   If the motor runs at sync. speed then there would be no relative speed between the two, hence no rotor emf, so no rotor current, then no rotor torque to maintain rotation.

6. **What are the advantages of skewing or why the slots on the induction motors are usually skewed?**

   (a) It reduces magnetic humming.

   (b) It helps in reducing the magnetic locking tendency of the rotor. ie, the tendency of the rotor teeth to remain under the stator teeth due to the magnetic attraction between the two.

7. **The squirrel cage rotor is also known as short circuited rotor. Why?**

   In squirrel cage rotor, the copper bars are placed in the slots. These bars are short circuited at each end with the help of conducting copper ring called end ring. The entire rotor resistance is very small. Hence this rotor is also called as short circuited rotor.

APPLICATIONS:

Three-phase squirrel-cage induction motors are widely used in centrifugal pump, fan and compressor load applications.

RESULT:

Thus the load test on 3-phase squirrel-cage induction motor was performed and the respective graphs were drawn.

INFERENCE:

The load test on a 3-phase squirrel-cage induction motor provides valuable information about the motor's performance under varying load conditions. By analyzing parameters like efficiency, power factor, slip, and losses, engineers can assess the motor's suitability for specific applications, determine the optimal operating conditions, and make decisions related to motor maintenance and replacement.

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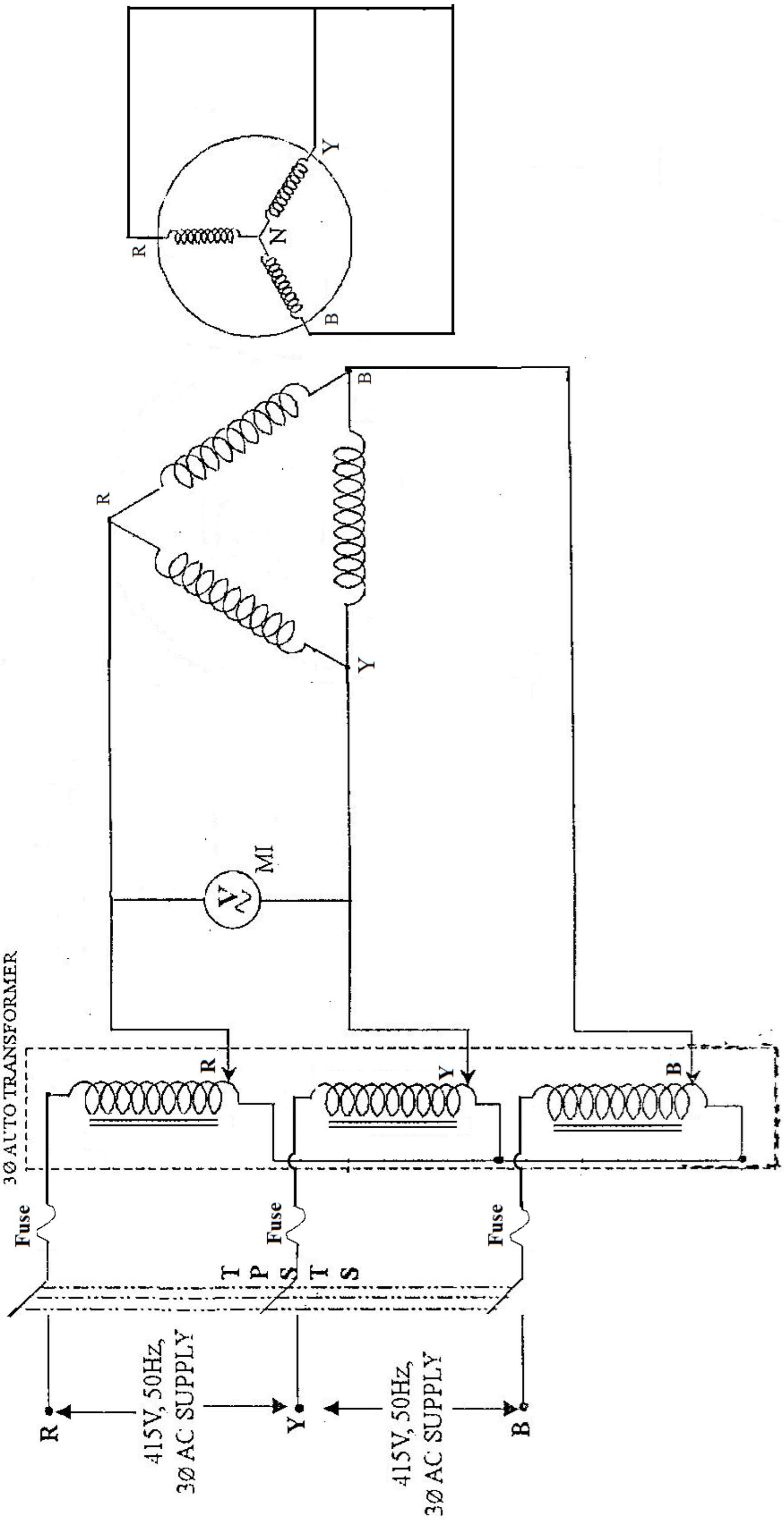
SPEED CONTROL USING STATOR VOLTAGE CONTROL



EXP.NO. 3 **DATE:**

SPEED CONTROL OF 3Φ SLIP RING INDUCTION MOTOR

AIM:

To conduct the experiment for the speed control of 3Φ slip ring induction motor by Stator Voltage Control and Rotor resistance control.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

In case of three phase induction motors it is very difficult to achieve smooth speed control. The speed of the induction motor can be controlled by basically two methods,

Supply (or) Stator Voltage Control

We know that, $T \; \alpha \; (s E_2^2 R_2)/(R_2^2 + (s X_2)^2)$

Now E_2, the rotor induced e.m.f. at standstill depends on the supply voltage V.

$\therefore \quad E_2 \; \alpha \; V$

Also for low slip region, which is operating region of the induction motor, $(s X_2)^2 << R_2$ and hence can be neglected.

$\therefore \quad T \; \alpha \; (s E_2^2 R_2)/R_2^2) \; \alpha \; sV^2$ for constant R_2

Now if supply voltage is reduced below rated value, as per above equation torque produced also decreases. But to supply the same load it is necessary to develop same torque hence value of slip increases so that torque produced remains same. Slip increases means motor reacts by running at lower speed, to decrease in supply voltage. So motor produces the required load torque at a lower speed.

But in this method, due to reduction in voltage, current drawn by the motor increases. Large change in voltage for small change in speed is required is the biggest disadvantage.

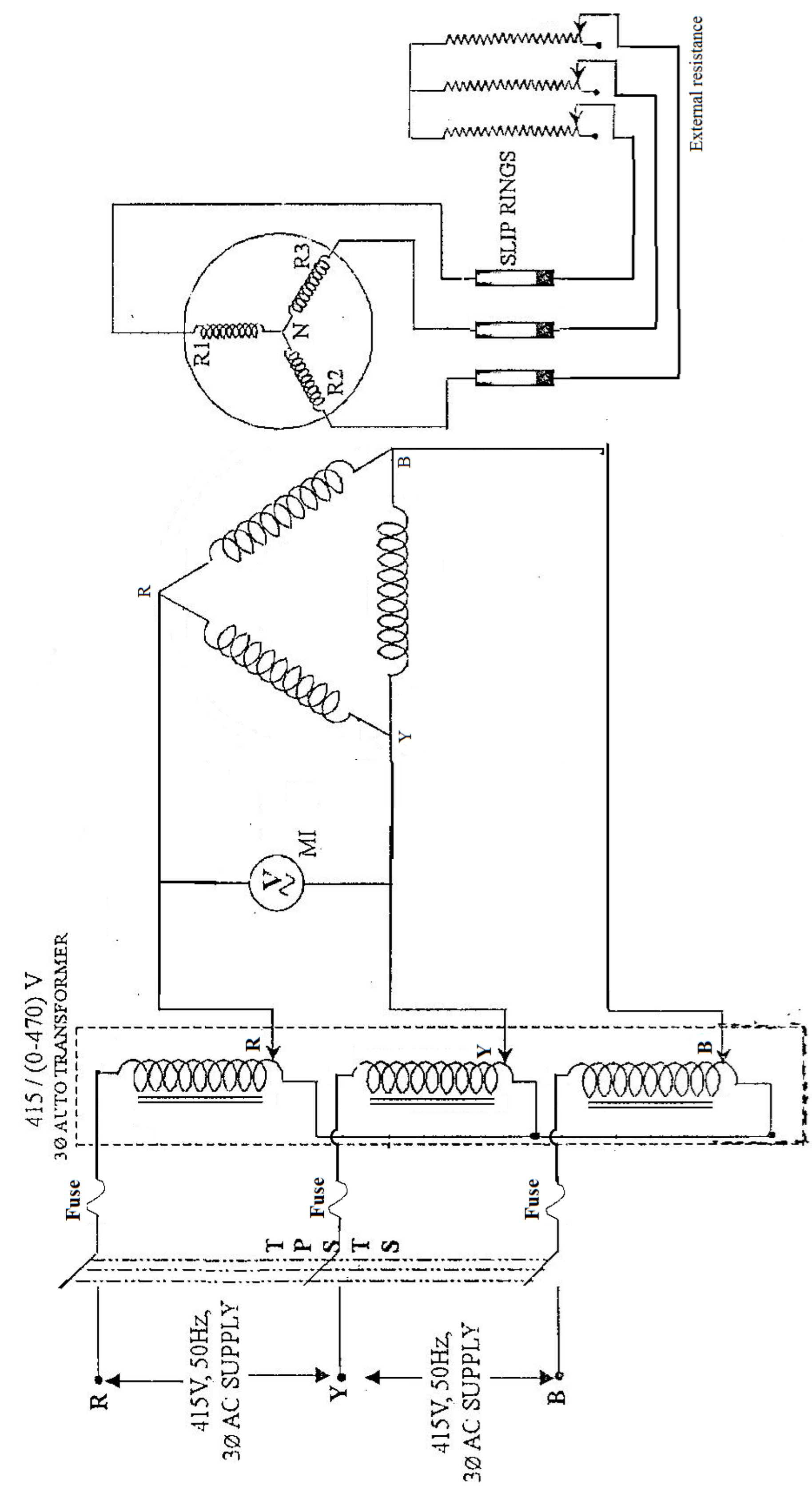
Adding External Resistance in Rotor Circuit

We know, $T \; \alpha \; (s E_2^2 R_2)/(R_2^2 + (s X_2)^2)$

For low slip region $(s X_2)^2 << R_2$ and can be neglected and for constant supply voltage is also constant.

$\therefore \quad T \; \alpha \; (s \; R_2)/R_2^2 \; \alpha \; s/R_2^2$

SPEED CONTROL USING ROTOR RESISTANCE CONTROL:



Thus if the rotor resistance is increased, the torque produced decreases. But when the load on the motor is same, motor has to supply same torque as load demands. So motor reacts by increasing its slip to compensate decreases in T due to R_2 and maintains the load torque constant. So due to that additional rotor resistance R_2, motor slip increases i.e. the speed of the motor decreases. Thus by increasing the rotor resistance R_2, speeds below normal value can be achieved. Another advantage of this method is that the starting torque of the motor increases proportional to rotor resistance.

But this method has following disadvantages :

1. The large speed changes are not possible. This is because for large speed change, large resistance is required to be introduced in rotor which causes large rotor copper loss due to reduce the efficiency.
2. The method cannot be used for the squirrel cage induction motors.
3. The speeds above the normal values cannot be obtained.

PRECAUTIONS:

1. The autotransformer should be kept in minimum voltage position.
2. The motor should not be loaded throughout the experiment.
3. The external resistance in the rotor circuit should be kept at maximum value.

PROCEDURE:

1. PROCEDURE FOR STATOR VOLTAGE CONTROL:

1. Connections are given as per the circuit diagram
2. Switch on the supply at no load condition.
3. Apply the rated voltage to the motor by adjusting autotransformer.
4. As speed increases, the external resistance is gradually cut out.
5. By varying the auto transformer and change the voltage then the speed of the motor can be measured.

2. PROCEDURE FOR ROTOR RESISTANCE CONTROL:

1. Connections are made as per the circuit diagram.
2. Switch on the supply at no load condition.
3. Apply the rated voltage to the motor by adjusting autotransformer.
4. By changing the rotor resistance position, the value of resistance will decrease then the speed can be measured.

GRAPHS:

The graph is drawn for,

(1) Stator voltage Vs Speed.

(2) Rotor resistance Vs Speed.

TABULAR COLUMN:

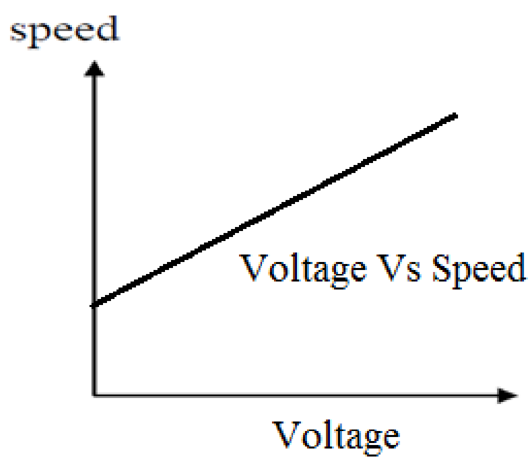
Armature or Stator Voltage Control:

S.No.	Voltage (V)	Speed (RPM)

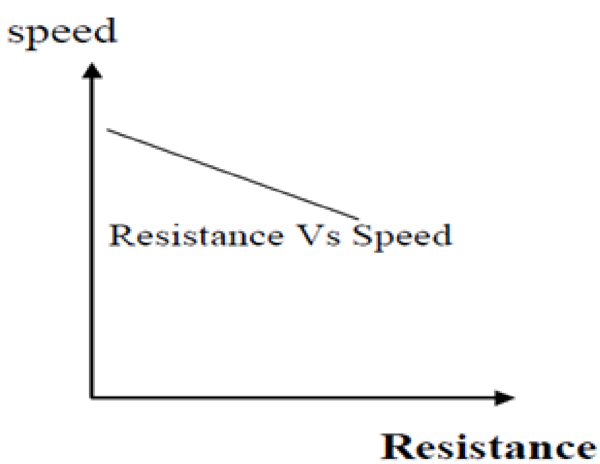
Rotor Resistance Control:

S.No.	Resistance (Ω)	Speed (RPM)

MODEL GRAPHS:



(a). Stator Voltage Control



(b). Rotor Resistance Control

VIVA QUESTIONS:

1. **What are the different methods of speed control of three phase induction motor?**
   a). Control from stator side:
   i).By changing the supply voltage
   ii).By changing the supply frequency
   iii).By changing the number of poles
   b). Control from Rotor side:
   i).Rotor rheostat control
   ii).By operating two motors in cascade or concatenation
   iii).By injecting an emf in the rotor circuit
2. **In which type of motor can resistance be introduced in the rotor circuit? What is the effect of it?**
   Slip ring IM.
   Effects:
   1. starting torque increased
   2. starting current decreased
   3. motor speed can be controlled
2. **What are the adv. of stator voltage control method?**
   - The control circuitry is simple
   - Compact size
   - Quick response time
   - There is considerable savings in energy and thus it is economical method as compared to other methods of speed control.
3. **Mention the application of stator voltage control.**
   This method is suitable for applications where torque demand reduced with speed, which points towards its suitability for fan and pump drives.
4. **What are the advantages and disadvantages of rotor resistance control?**
   Advantage of rotor resistance control is that motor torque capability remains unaltered even at low speeds. Only other method which has this advantage is variable frequency control. However, cost of rotor resistance control is very low compared to variable frequency control.
   Major disadvantage is low efficiency due to additional losses in resistors connected in the rotor circuit.
5. **Where is rotor resistance control used?**
   Where the motors drive loads with intermittent type duty, such as cranes, ore or coal unloaders, skip hoists, mine hoists, lifts, etc. slip-ring induction motors with speed control by variation of resistance in the rotor circuit are frequently used. This method of speed control is employed for a motor generator set with a flywheel (Ilgner set) used as an automatic slip regulator under shock loading conditions.

APPLICATIONS:

Slip ring induction motors are widely used where high starting is necessary say lifts, hoist and cranes.

RESULT:

Thus the speed control of 3-phase slip ring induction motor was performed and the respective graphs were drawn.

INFERENCE:

The **speed control of a 3-phase slip ring induction motor** using rotor resistance control and stator voltage control provides insights into motor performance under different conditions. Rotor resistance control is effective but inefficient, especially at higher resistance values. Stator voltage control provides better efficiency but limits the motor's torque capacity at lower speeds. Both methods demonstrate the speed control, efficiency, torque, and power consumption, and the choice of method depends on the specific application requirements.

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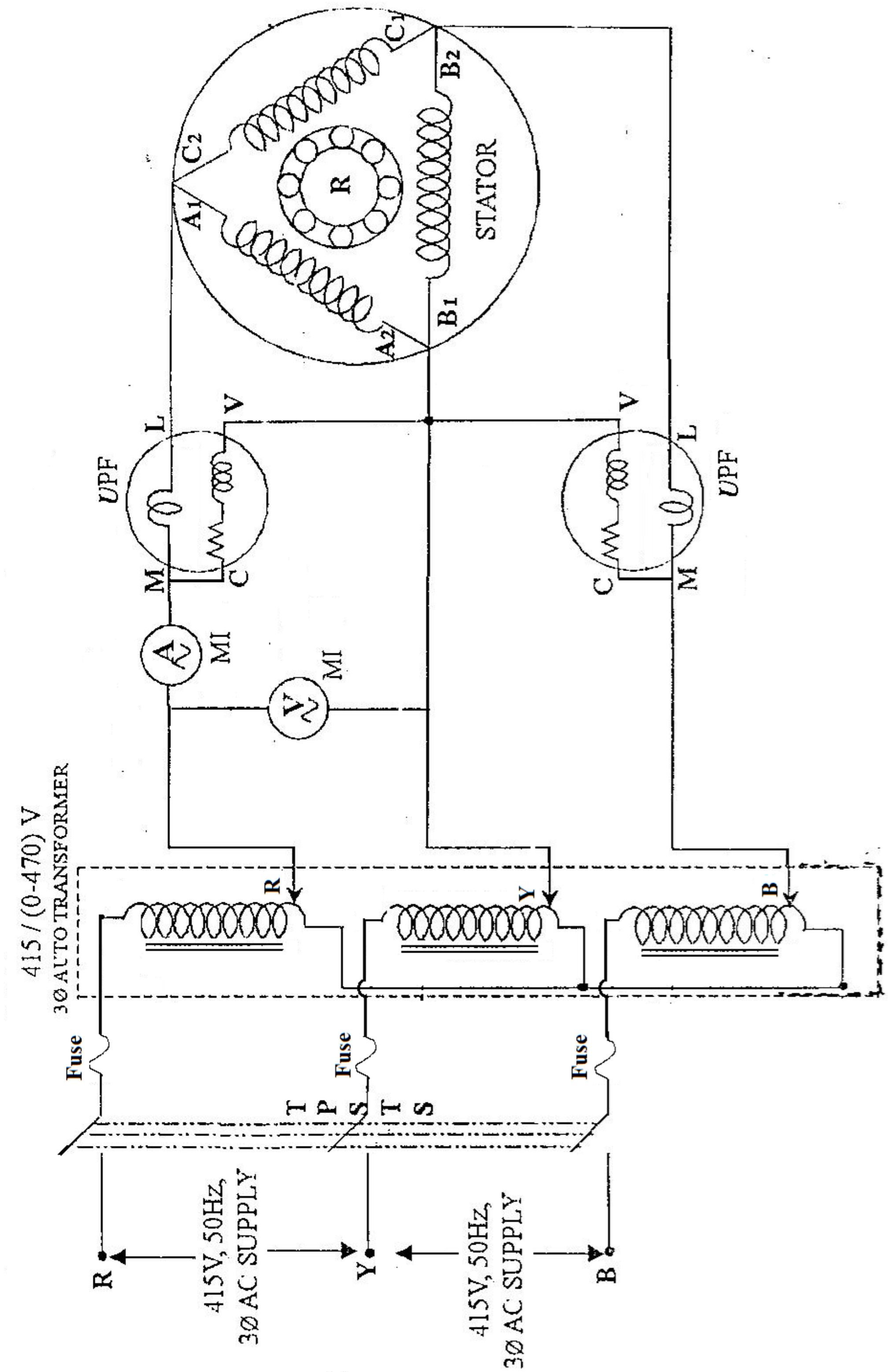
SEPERATION OF NO LOAD LOSSES ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR



EXP.NO.4 **DATE:**

SEPARATION OF LOSSES IN THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

AIM:

To separate the no load losses of a 3 phase squirrel cage induction motor as iron losses and mechanical losses.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

The no load losses are the constant losses which include core loss and friction and windage loss. The separation between the two can be carried out by the no load test conducted from variable voltage, rated frequency supply.

When the voltage is decreased below the rated value, the core loss reduces as nearly square of voltage. The slip does not increase significantly the friction and windage loss almost remains constant.

The voltage is continuously decreased, till the machine slip suddenly begins to increase and the motor tends to stall. At no load this takes place at a sufficiently reduced voltage. The graph showing no load losses versus voltage is extrapolated to V =0 which gives friction and windage loss as iron or core loss is zero at zero voltage.

FORMULA:

1. Input power, (P_i) =(W_1+W_2)in watts
2. Stator copper loss = $3I_{0ph}^2 R_S$ in watts
3. Constant loss/phase $W_C = W - 3I_{0ph}^2 R_S$ in watts
4. Core loss/phase (Wi) = (Constant loss/phase) - Mechanical loss

$$W_i = (W_C - W_m) \text{ Watts}$$

TABULATION:

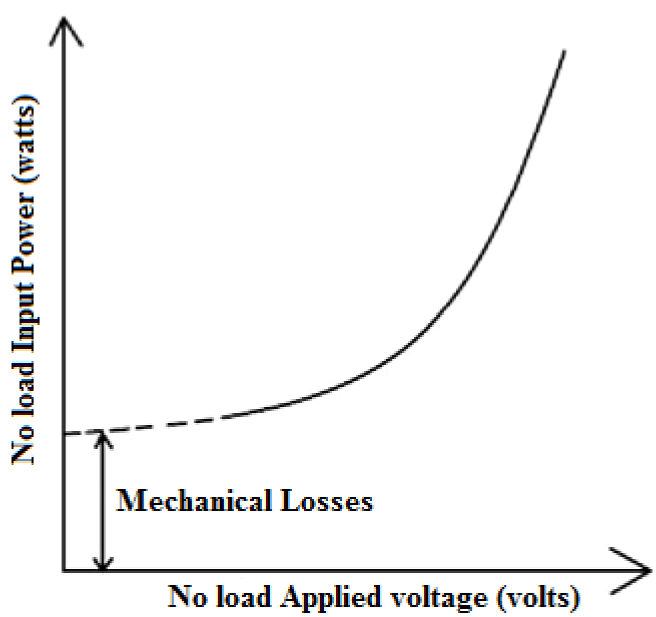
Observation Tabulation:

S.No.	No load Voltage V_0 (V)	No load Current I_0 (A)	No load Input Power P_0 (Watts)			
			W_1		W_2	
			Obs.	Act.	Obs.	Act.

Calculation Tabulation:

S.No.	Total Input power (Watts)	Stator copper loss (Watts)	Constant loss / Phase	Core loss / Phase (Watts)

MODEL GRAPHS:



PRECAUTIONS:

(1) The autotransformer should be kept in minimum voltage position.
(2) The motor should not be loaded throughout the experiment.

PROCEDURE:

(1) Connections should be made as per the circuit diagram.
(2) Apply the rated voltage to the motor by adjusting autotransformer.
(3) If any Wattmeter shows negative reading then interchange M and L connections.
(4) Note the input voltage, current and power.
(5) Repeat the same procedure for above rated voltage and below rated voltage and note the input voltage, current and power.

GRAPH:

The graph drawn between constant losses (watts) and input voltage (volts).

MODEL CALCULATIONS:

1. Input Power = $W_1 + W_2$

   = 1200 + (-800) = 400 Watts

2. Stator copper loss = $3I_{0ph}^2 R_S$ Watts   Where, $R_S = 4.5\Omega$

   = $3\times\left(\frac{5.5}{\sqrt{3}}\right)^2 \times 4.5$ = 136.13 Watts

3. Constant loss / Phase $W_C = W - 3I_{0ph}^2 R_S$

   = $400 - 136.13$ = 263.87

4. Core loss / Phase, $W_i = (W_C - W_m)$ Watts

   = $263.87 - 20 = 243.87$ Watts   Where, $W_m = 20$

VIVA QUESTION:

1. **Mention the losses that occur in induction motor.**
   a. Stator core loss
   b. Stator copper loss
   c. Rotor Copper loss
   d. Mechanical losses
2. **What are the no load losses?**
   The no load losses are the constant losses which include core loss and friction and windage loss.
3. **What is meant by plugging?**
   Plugging means stopping a motor by instantaneously reversing it till it stops.
4. **Why air gap length is minimum in an induction motor?**
   The air gap length is kept minimum in induction motor
   a) To reduce the magnetizing current which is required to set up the flux
   b) To improve the power factor
5. **How the direction of rotation of three phase induction motor can be reversed?**
   The direction of rotation of three phase induction motor can be reversed by interchanging any two terminals of the three phase windings while connecting to the three phase supply.

RESULT:

Thus the separation of losses in 3-phase squirrel-cage induction motor was performed and the respective graphs were drawn.

INFERENCE:

The separation of losses in a **3-phase squirrel-cage induction motor** allows us to pinpoint areas of inefficiency and identify how losses contribute to the overall energy consumption. Understanding the contribution of each loss type is crucial for improving motor efficiency, making design decisions, and performing maintenance effectively.

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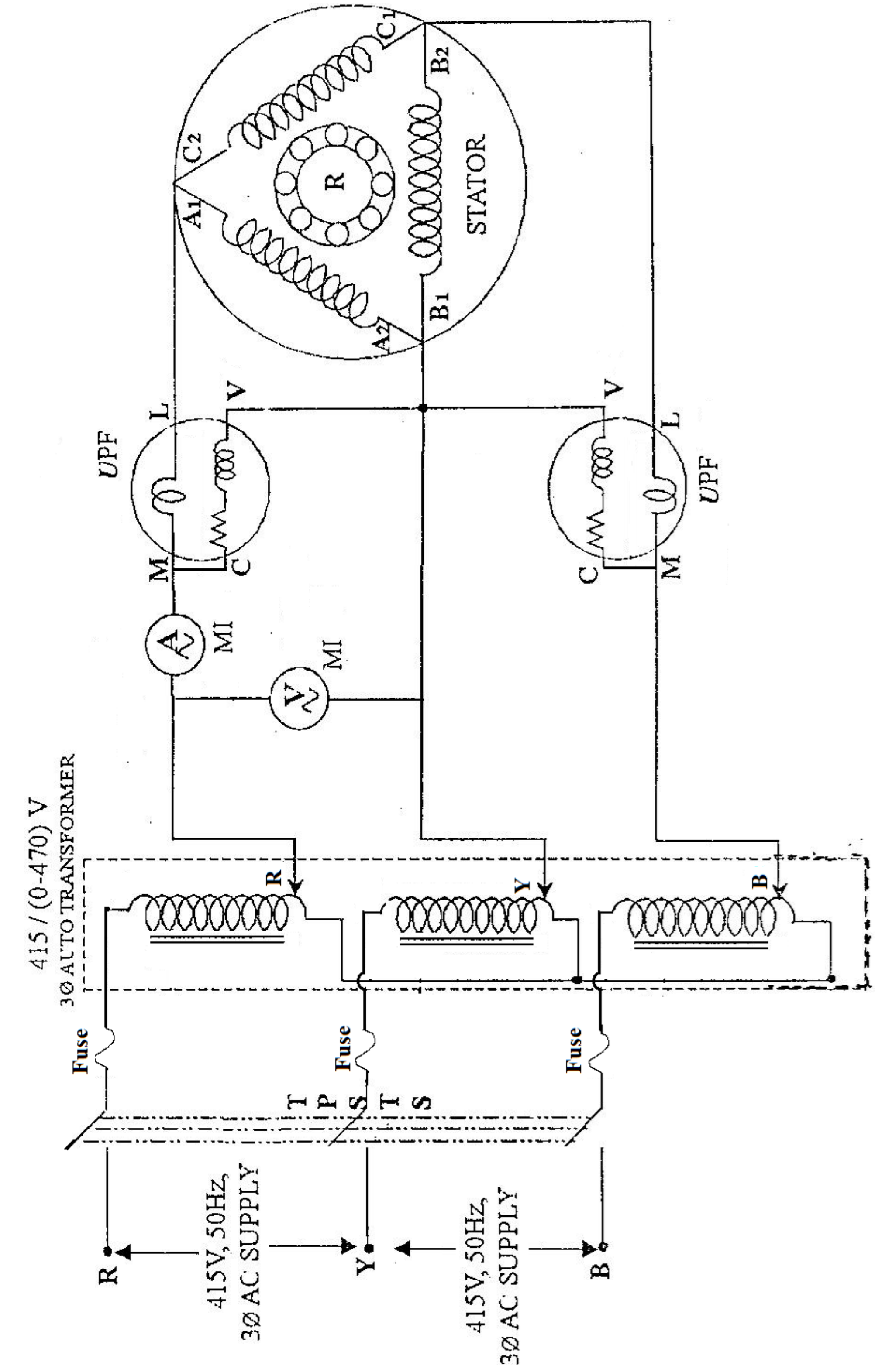
NO LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Equivalent Circuit)



EX.NO.5 **Date:**

PREDETERMINATION OF CHARACTERISTIC OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR FROM NO LOAD AND BLOCKED ROTOR TEST USING EQUIVALENT CIRCUIT

AIM:

To conduct the no load & blocked rotor test on 3- phase induction motor & to draw the equivalent circuit of 3- phase squirrel cage induction motor.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

The data required to draw the equivalent circuit is obtained by conducting two testes which are,

1. No load test or open circuit test
2. Blocked rotor test or short circuit test

NO LOAD TEST (OR) OPEN CIRCUIT TEST:

In this test, the motor is made to run without any load i.e. no load condition. The rated voltage is applied to the stator. The input line current and total input power is measured.

The total power input W_o is the algebraic sum of the two wattmeter readings.

The calculations are,

$$W_o = \sqrt{3} V_o I_o \cos\Phi_o$$

$$\cos\phi_0 = \frac{W_0}{\sqrt{3} V_0 I_0}$$

This is no load power factor.

The power input W_o consists of following losses,

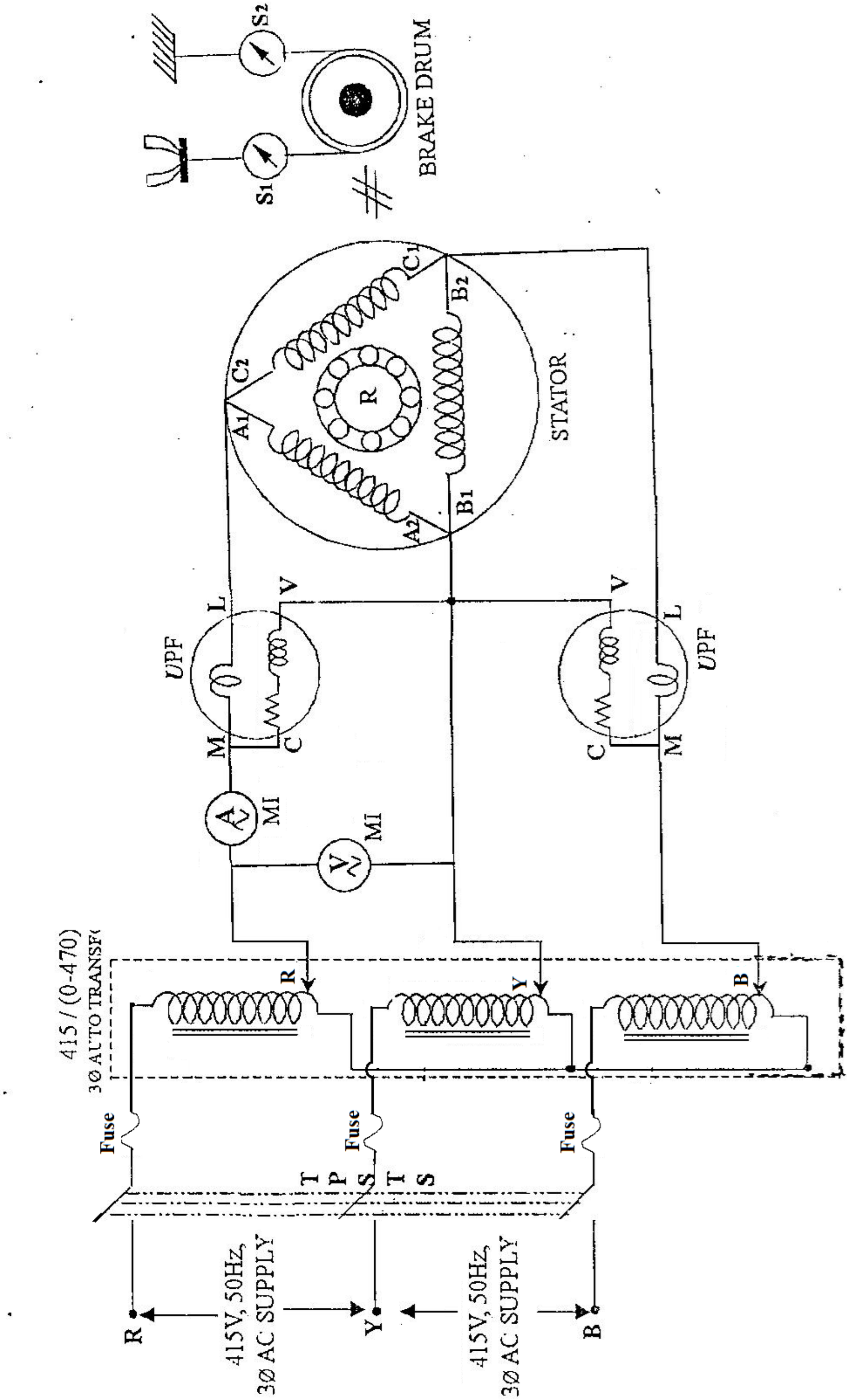
1. Stator copper loss i.e. $3\, I_o^2\, R_1^2$ where I_o is no load per phase current and R_1 is stator resistance per phase.
2. Stator core loss i.e. iron loss.
3. Friction and windage loss.

The no load rotor current is very small and hence rotor copper loss is negligibly small. The rotor frequency is s times supply frequency and on no load it is very small. Rotor iron losses are proportional to this frequency and hence are negligibly small.

$\therefore$ Fixed loss, W_o = No load power input

BLOCKED ROTOR TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Equivalent Circuit)



BLOCKED ROTOR TEST (OR) SHORT CIRCUIT TEST:

In this test, the rotor is locked and it is not allowed to rotate. Now the applied voltage V_{sc}, the input power W_{sc} and a short circuit current I_{sc} are measured. During this test, the stator carries rated current hence the stator copper loss is also dominant. Similarly the rotor also carries short circuit current to produce dominant rotor copper loss. As the voltage is reduced, the iron loss which is proportional to voltage is negligibly small. The motor is at standstill hence mechanical loss i.e. friction and windage loss is absent. Hence we can write,

W_{sc} = Stator copper loss + Rotor copper loss

FORMULA USED:

FOR NO LOAD TEST:

$$W_0 = \sqrt{3} V_0 I_0 \cos\phi_0 \quad \text{Watts}$$

$$\cos\phi_0 = \frac{W_0}{\sqrt{3} V_0 I_0}$$

$$I_W = I_{0ph} \cos\phi_0 \quad \text{A}$$

$$I_m = I_{0ph} \sin\phi_0 \quad \text{A}$$

$$X_0 = \frac{\sqrt{3} V_0}{I_m} \quad \Omega$$

$$R_0 = \frac{\sqrt{3} V_0}{I_W} \quad \Omega$$

$$I_0 = I_W + jI_m$$

FOR BLOCKED ROTOR TEST:

$$W_{SC} = 3 I_{SC}{}^2 R_{01} \quad \text{Watts}$$

$$R_{01} = \frac{W_{SC}}{3 I_{SCph}{}^2}$$

$$Z_{01} = \frac{V_{SC}}{I_{SCph}} \quad \Omega$$

$$X_{01} = \sqrt{Z_{01}{}^2 - R_{01}{}^2} \quad \Omega$$

To find R_2'

$R_{01} = R_1 + R_2'$

$R_2' = R_{01} - R_1$ Where, $R_1 = 3.5\ \Omega$

Tabulation:

Observation Tabulation:

1. NO LOAD TEST:

M.F = …………

S.No	No – load applied voltage, V_0 (or) Open circuit voltage V_{OC} (Volts)	No – load current, I_0 (or) Open circuit current, I_{OC} (Amps)	Wattmeter readings (W_1)		Wattmeter readings (W_2)		Total No – load input power, W_0 (Watts)
			Observed	Actual	Observed	Actual	

2. BLOCKED ROTOR TEST:

M.F = …………

S.No.	Blocked Rotor applied voltage, V_b (or) Short circuit voltage V_{SC} (Volts)	Blocked Rotor current, I_b (or) Short circuit current, I_{SC} (Amps)	Wattmeter readings(W1)		Wattmeter readings(W2)		Total Blocked Rotor input power, W_b (or) W_{SC} (Watts)
			Observed	Actual	Observed	Actual	

$X_1 = X_2' = X_{01}/2$

Speed, $N = N_S(1-s)$ rpm

$$I_1 = I_0 + I_2'$$

$$I_2' = \frac{V_{ph}}{R_{01} + \frac{R_2'}{s}(1-s) + jX_{01}}$$

$$PowerFactor = \cos\phi$$

$$Input = 3V_0 I_1 \cos\phi_0$$

$$Output = 3I_2'^2 \frac{R_2'}{s}(1-s) Watts$$

$$\%\eta = \frac{OutputPower}{Inputpower} \times 100$$

$$Torque = \frac{Output \times 60}{2\pi \times N_S(1-s)} N-m$$

1. NO LOAD TEST

PRECAUTIONS:

(1) The autotransformer should be kept in minimum voltage position.
(2) The motor should not be loaded throughout the experiment.

PROCEDURE:

(1) Connections should be made as per the circuit diagram.
(2) Apply the rated voltage to the motor by adjusting autotransformer.
(3) If any Wattmeter shows negative reading then interchange M and L connections.
(4) The meter readings are then tabulated.

2. BLOCKED ROTOR TEST

PRECAUTIONS:

(1) The autotransformer should be kept in minimum voltage position.
(2) There should be full load or blocked rotor position at the time of starting.

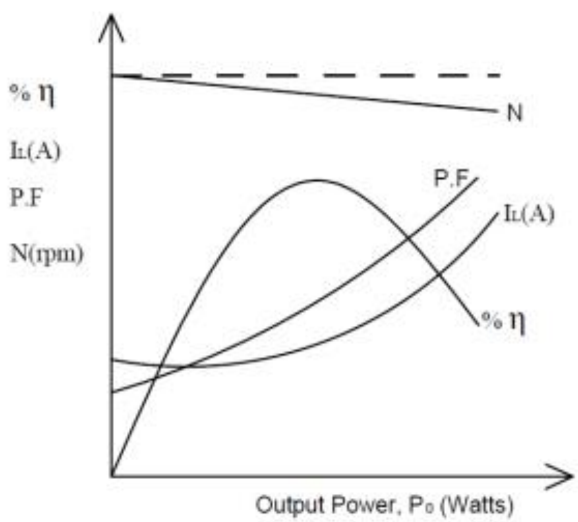
PROCEDURE:

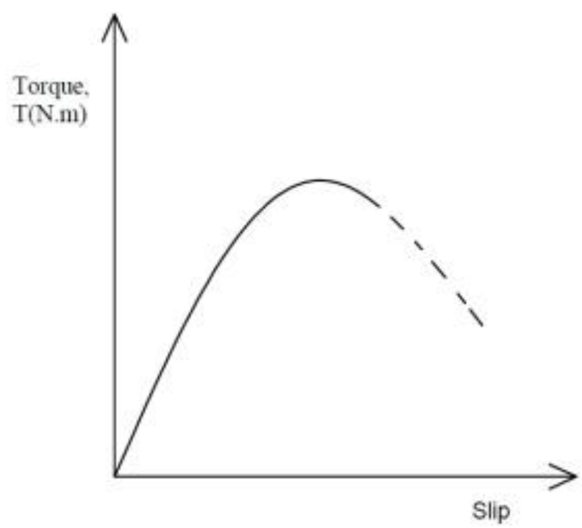
(1) Connections should be made as per the circuit diagram.
(2) Adjust the autotransformer till rated current is reached.
(3) If any Wattmeter shows negative reading then interchange M and L connections.
(4) The meter readings are then tabulated.

Calculation Tabulation:

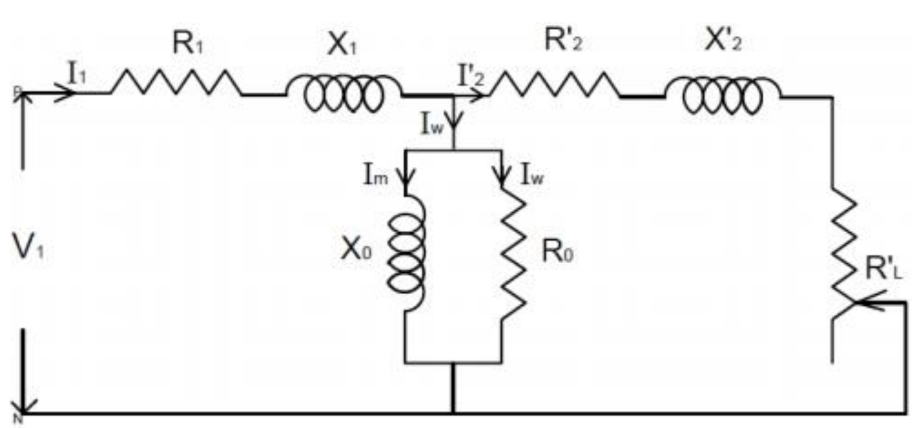
S.No.	**% Slip**	**Speed (rpm)**	**Rotor current per phase I_2' (A)**	**Resultant Current I_1 (A)**	**cosΦ**	**Output power (Watts)**	**Input power (Watts)**	**% Efficiency**	**Torque (N-m)**
1									
2									
3									
4									
5									

MODEL GRAPHS:





EQUAVALENT CIRCUIT:



MODEL CALCULATION:

$$\cos\phi_0 = \frac{W_0}{\sqrt{3}V_0 I_0} = \frac{220}{\sqrt{3}\times 415\times 4.1} = 0.074$$

$$I_W = I_{0ph}\cos\phi_0 = \left(\frac{4.1}{\sqrt{3}}\right)\times 0.074 = 0.394A$$

$$I_m = I_{0ph}\sin\phi_0 = \left(\frac{4.1}{\sqrt{3}}\right)\times \sin 85.75 = 4.08A$$

$$X_0 = \frac{\sqrt{3}V_0}{I_m} = \frac{\sqrt{3}\times 415}{4.088} = 175.83\Omega$$

$$R_0 = \frac{\sqrt{3}V_0}{I_W} = \frac{\sqrt{3}\times 415}{0.394} = 2.8K\Omega$$

$$I_0 = I_W + jI_m = 0.394 + j4.088 = 4.108\angle 84.49A$$

$$Z_{01} = \frac{V_{SC}}{I_{SCph}} = \frac{94}{\left(\frac{7.5}{\sqrt{3}}\right)} = 32.53\Omega$$

$$R_{01} = \frac{W_{SC}}{3I_{SCph}{}^2} = \frac{530}{3\times\left(\frac{7.5}{\sqrt{3}}\right)^2} = 12.85\Omega$$

$$X_{01} = \sqrt{Z_{01}{}^2 - R_{01}{}^2}$$

$$= \sqrt{(32.53)^2 - (12.85)^2} = 11.99\Omega$$

To find R_2'

$R_{01} = R_1 + R_2'$ Where, $R_1 = 3.5\ \Omega$

$R_2' = R_{01} - R_1 = 12.85 - 3.5 = 5.8\ \Omega$

$X_1 = X_2' = X_{01}/2$

$= 11.99 / 2$

$= 5.995\ \Omega$

Speed, $N = N_S(1-s)$ rpm

N = 1500 × (1 – 0.02) = 1470 rpm

$$I_2' = \frac{V_{ph}}{R_{01} + \frac{R_2'}{s}(1-s) + jX_{01}}$$

$$= \frac{415}{3.61 + \left(\frac{5.8}{0.02}\right) \times (1-0.02) + 11.99j} = 0.831\angle -2.384A$$

$$I_1 = I_0 + I_2' = 1.225 + 4.05j = 4.23\angle 73.17A$$

$$\cos\phi = \cos 73.17 = 0.289$$

$$Input = 3V_0 I_1 \cos\phi_0$$

$$= 3 \times 415 \times 4.23 \times 0.289 = 878.9W$$

$$Output = 3I_2'^2 \frac{R_2'}{s}(1-s)Watts$$

$$\%\eta = \frac{OutputPower}{Inputpower} \times 100$$

$$= \frac{587.35}{878.7} \times 100 = 66.87\%$$

$$Torque = \frac{Output \times 60}{2\pi \times N_S(1-s)} N-m$$

$$= \frac{587.35 \times 60}{2\pi \times 1500 \times (1-0.02)} = 3.815N-m$$

VIVA QUESTION:

1. **What is an Equivalent circuit of Induction motor?**
   An equivalent circuit enables the performance characteristics of the induction motor. The data obtained from the equivalent circuit can be used to calculate efficiency, torque, losses and rotor output.
2. **What is No load and Blocked rotor test?**
   No-Load test
   The no-load test of an induction motor is similar to the open-circuit test of a transformer. The motor is not connected from its load, and the rated voltage at the rated frequency is applied to the stator to run the motor without a load.
   Blocked rotor test
   The blocked rotor test of an induction motor is same as the short-circuit test of a transformer. In this test, the rotor of the motor is blocked. A reduced voltage is applied to the stator so that the rated current flows in the main winding.
3. **Why an induction motor is called asynchronous motor?**
   Since the induction motor runs always at a speed lesser than the synchronous speed, it is called asynchronous motor.
4. **Why is the efficiency of a three phase induction motor less than that of a transformer?**
   In induction motor, there are mechanical losses due to the rotation of the rotor. Hence the efficiency of an induction motor is less than that of the transformer.
5. **What is meant by crawling?**
   Induction motor particularly the squirrel cage type, sometimes exhibit a tendency to run stably at speeds as low as one seventh of their synchronous speed. This phenomenon is known as crawling.
6. **What is meant by cogging or magnetic locking?**
   The rotor of a squirrel cage induction motor sometimes refuses to start at all, particularly when the voltage is low. This happens when the number of stator teeth is equal to the number of rotor teeth and is due to the magnetic locking between the stator and rotor teeth. That is why this phenomenon is also called as teeth locking.

RESULT:

Thus the no load and blocked rotor test on 3-phase squirrel-cage induction motor was performed and the respective graphs were drawn.

INFERENCE:

The No-Load Test and Blocked Rotor Test are essential for determining the key electrical parameters and understanding the motor’s performance characteristics under different operating conditions.

- **No-Load Test** helps determine the core losses, magnetizing current, and mechanical losses.
- **Blocked Rotor Test** helps determine the starting conditions, stator resistance, leakage reactance, and impedance seen during startup.

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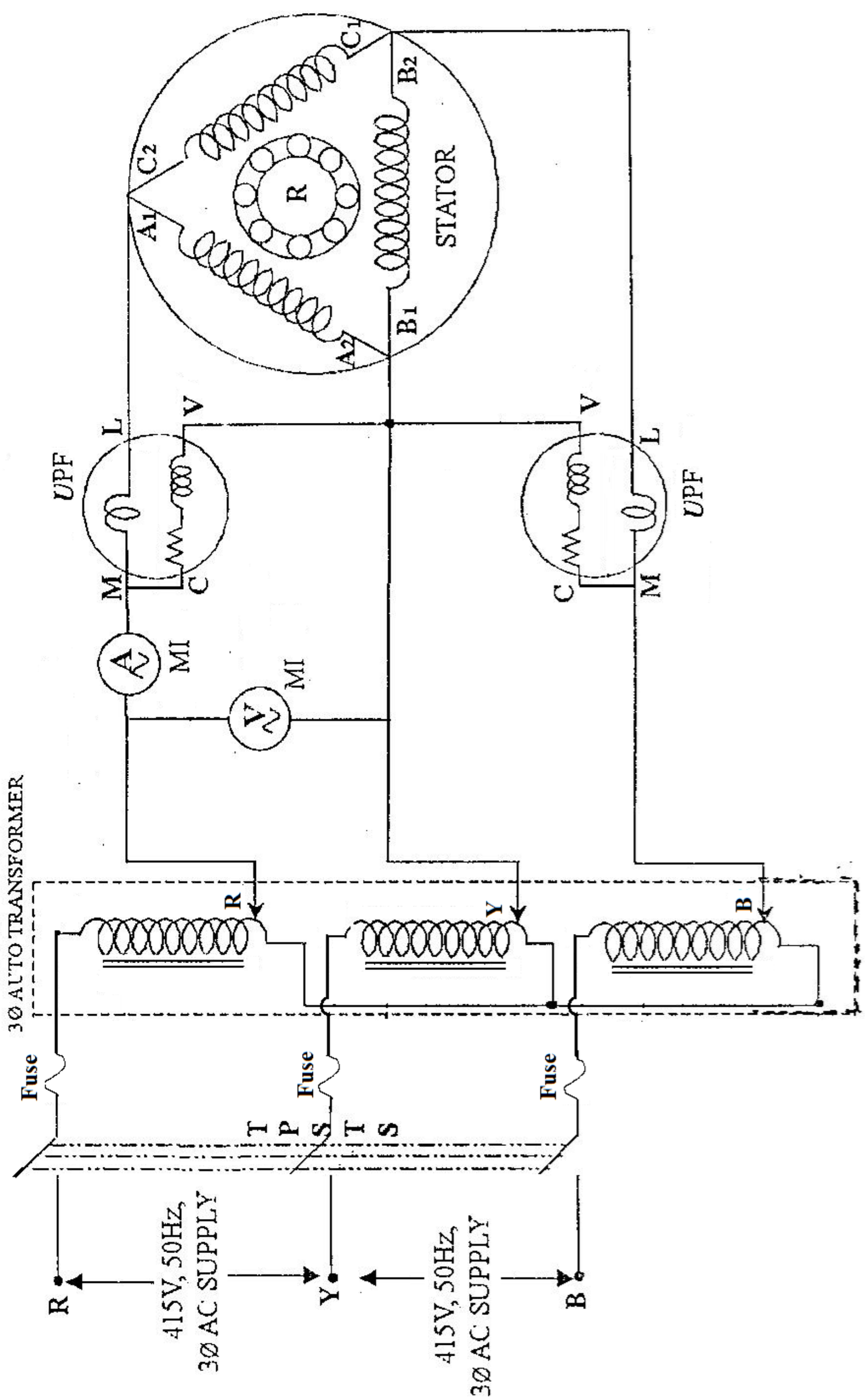
NO LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Circle Diagram)



EX.NO. 6 **Date:**

PREDETERMINATION OF CHARACTERISTIC OF THREE PHASE SQUIRREL CAGE INDUCTION MOTOR FROM NO LOAD AND BLOCKED ROTOR TEST USING CIRCLE DIAGRAM

AIM:

To conduct the no load & blocked rotor test on 3- phase induction motor & to draw the circle diagram

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

The data required to predetermine the performance characteristics is obtained by conducting two testes which are,

1. No load test or open circuit test
2. Blocked rotor test or short circuit test

NO LOAD TEST (OR) OPEN CIRCUIT TEST:

In this test, the motor is made to run without any load i.e. no load condition. The rated voltage is applied to the stator. The input line current and total input power is measured.

The total power input W_o is the algebraic sum of the two wattmeter readings.

The calculations are,

$$W_o = \sqrt{3} V_o I_o \cos\Phi_o$$

$$\cos\phi_0 = \frac{W_0}{\sqrt{3}V_0 I_0}$$

This is no load power factor.

The power input W_o consists of following losses,

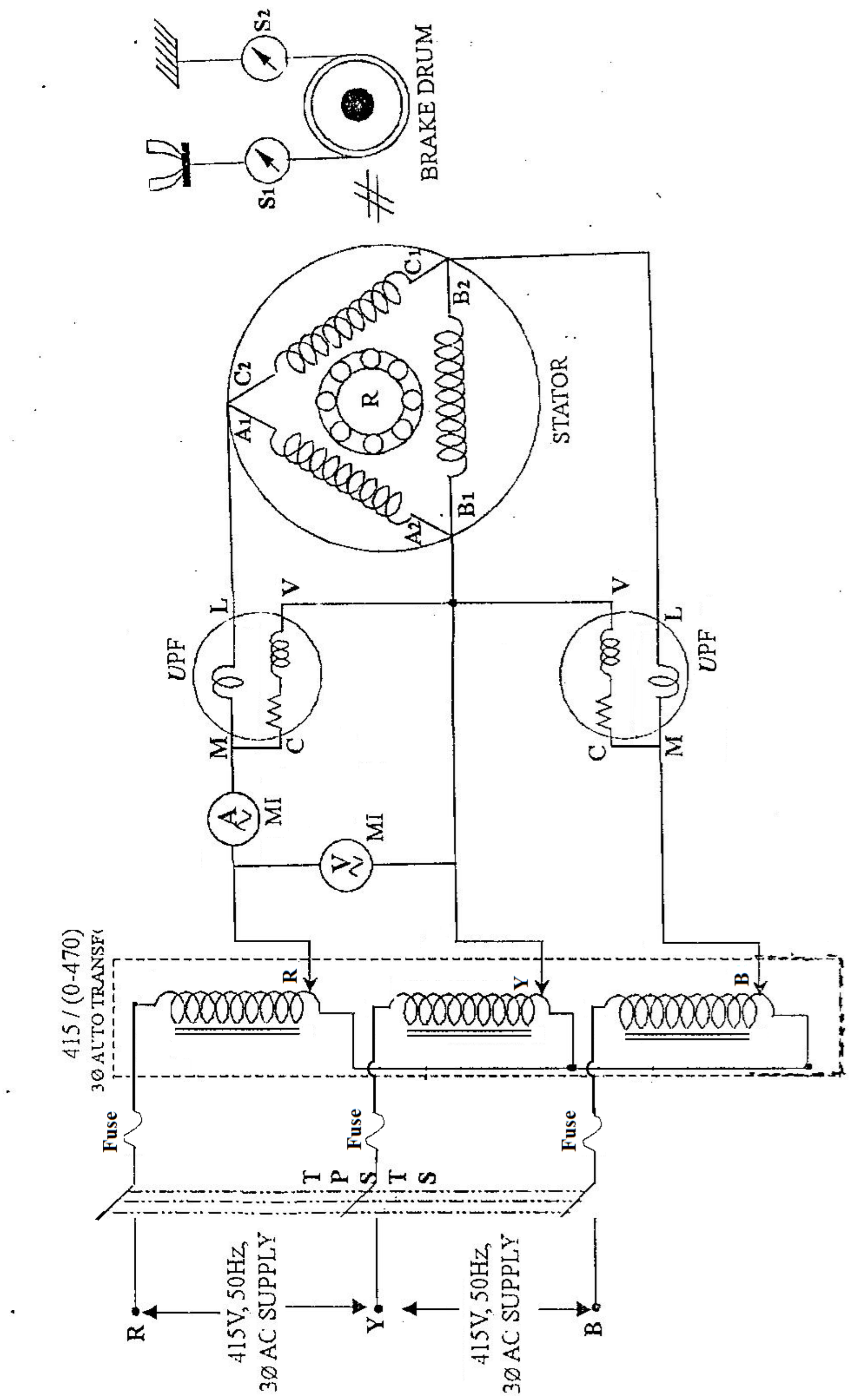
1. Stator copper loss i.e. 3 I_o^2 $R_1^2$where I_o is no load per phase current and R_1 is stator resistance per phase.
2. Stator core loss i.e. iron loss.
3. Friction and windage loss.

The no load rotor current is very small and hence rotor copper loss is negligibly small. The rotor frequency is s times supply frequency and on no load it is very small. Rotor iron losses are proportional to this frequency and hence are negligibly small.

∴ Fixed loss, W_o = No load power input

BLOCKED ROTOR TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Circle Diagram)



BLOCKED ROTOR TEST (OR) SHORT CIRCUIT TEST:

In this test, the rotor is locked and it is not allowed to rotate. Now the applied voltage V_{sc}, the input power W_{sc} and a short circuit current I_{sc} are measured. During this test, the stator carries rated current hence the stator copper loss is also dominant. Similarly the rotor also carries short circuit current to produce dominant rotor copper loss. As the voltage is reduced, the iron loss which is proportional to voltage is negligibly small. The motor is at standstill hence mechanical loss i.e. friction and windage loss is absent. Hence we can write,

W_{sc} = Stator copper loss + Rotor copper loss

FORMULA:

1. $W_0 = \sqrt{3}V_0 I_0 \cos\phi_0$
2. $W_{SC} = \sqrt{3}V_{SC} I_{SC} \cos\phi_{SC}$
3. $I_{SN} = \frac{V_0}{V_{SC}} \times I_{SC}$
4. $W_{SN} = \left(\frac{I_{SN}}{I_{SC}}\right)^2 \times W_{SC}$ Watts
5. $PowerScale = \frac{W_{SN}}{LengthofA} W/cm$
6. $\%\eta = \frac{PQ}{PT} \times 100$
7. Line current = OP
8. Input power = PT x Power scale
9. Output power = PQ x Power scale
10. Fixed loss = ST x power scale
11. Stator copper loss = SR x power scale
12. Rotor copper loss = QR x power scale
13. Total loss = QT x power scale
14. Slip s = QR/PR
15. Power factor = cosΦ
16. Motor efficiency = Output / Input = PQ/PT
17. Torque Line = PR × Power Scale

Maximum Quantities

Maximum Output = MN x Power scale

Maximum Input = LL’ x Power scale

Maximum Torque = JK x Power scale

Maximum Power Factor = $\cos\Phi_{max}$

Starting Torque = l(AE) x Power scale

TABULATION:

Observation Tabulation:

1. NO LOAD TEST:

M.F = …………

S.No	No – load applied voltage, V_0 (or) Open circuit voltage V_{OC} (Volts)	No – load current, I_0 (or) Open circuit current, I_{OC} (Amps)	Wattmeter readings (W_1)		Wattmeter readings (W_2)		Total No – load input power, W_0 (Watts)
			Observed	Actual	Observed	Actual	

2. BLOCKED ROTOR TEST:

M.F = …………

S.No.	Blocked Rotor applied voltage, V_b (or) Short circuit voltage V_{SC} (Volts)	Blocked Rotor current, I_b (or) Short circuit current, I_{SC} (Amps)	Wattmeter readings (W_1)		Wattmeter readings (W_2)		Total Blocked Rotor input power, W_b (or) W_{SC} (Watts)
			Observed	Actual	Observed	Actual	

1. NO LOAD TEST

PRECAUTIONS:

(1) The autotransformer should be kept in minimum voltage position.

(2) The motor should not be loaded throughout the experiment.

PROCEDURE:

(1) Connections should be made as per the circuit diagram.

(2) Apply the rated voltage to the motor by adjusting autotransformer.

(3) If any Wattmeter shows negative reading then interchange M and L connections.

(4) The meter readings are then tabulated.

2. BLOCKED ROTOR TEST

PRECAUTIONS:

(1) The autotransformer should be kept in minimum voltage position.

(2) There should be full load or blocked rotor position at the time of starting.

PROCEDURE:

(1) Connections should be made as per the circuit diagram.

(2) Adjust the autotransformer till rated current is reached.

(3) If any Wattmeter shows negative reading then interchange M and L connections.

(4) The meter readings are then tabulated.

3. PROCEDURE FOR CONSTRUCTING THE CIRCLE:

By using the data obtained from the no load test and the blocked rotor test, the circle diagram can be drawn using the following steps:

Step 1 : Take reference phasor V as vertical (Y-axis).

Step 2 : Select suitable current scale such that diameter of circle is about 20 to 30 cm.

Step3 : From no load test, I_o and are Φ_o obtained. Draw vector I_o, lagging V by angle Φ_o. This is the line OO'.

Step 4 : Draw horizontal line through extremity of I_o i.e. O', parallel to horizontal axis.

Step 5 : Draw the current I_{SN} calculated from I_{sc} with the same scale, lagging V by angle Φ_{sc}, from the origin O. This is phasor OA.

Step 6 : Join O'A is called output line.

Step 7 : Draw a perpendicular bisector of O'A. Extend it to meet line O'B at point C. This is the centre of the circle.

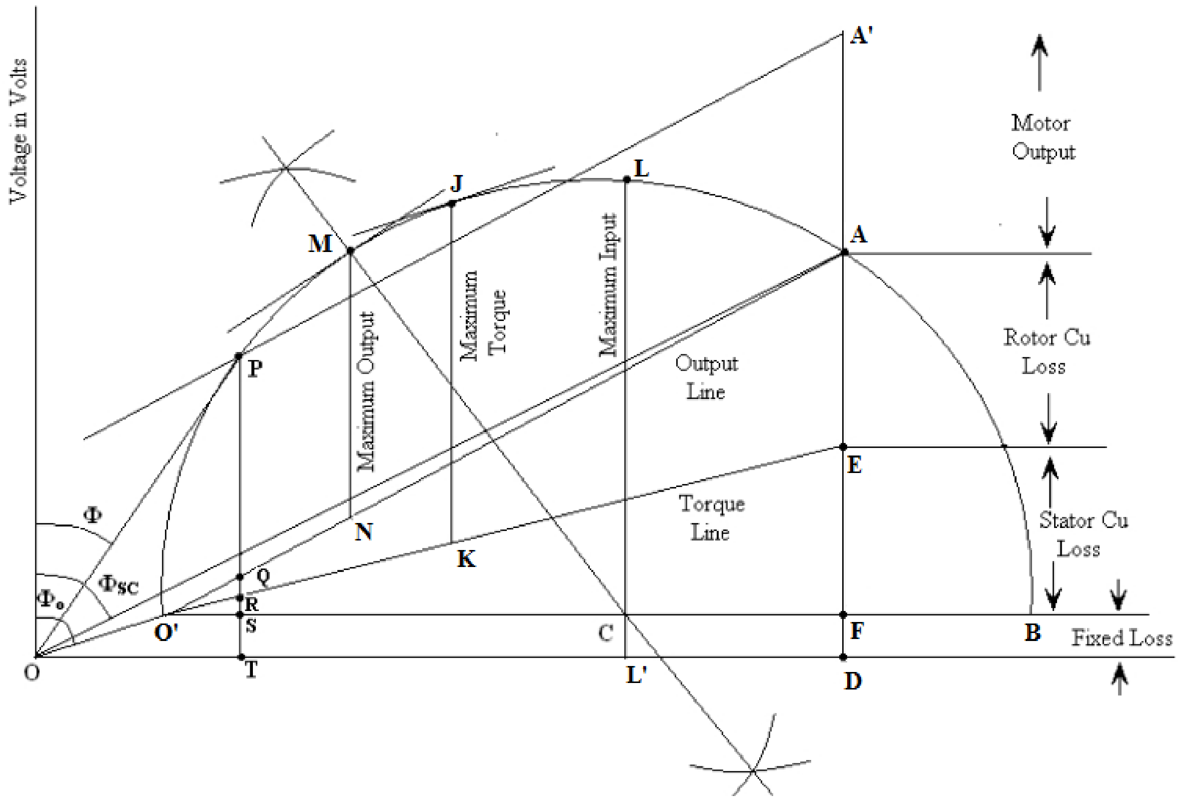
Step 8 : Draw the circle, with C as a center and radius equal to O'C. This meets the horizontal line drawn from O' at B.

Step 9 : Draw the perpendicular from point A on the horizontal axis, to meet O'B line at F and meet horizontal axis at D.

Step 10 : Torque line.

The torque line separates stator and rotor copper losses. Stator copper loss = $3I_{SN}^2 R_S$ where $R_S = 7.05\Omega$

MODEL GRAPHS:
CIRCLE DIAGRAM:



Step 11 : The full load motor output is given on the name plates in watts or h.p. Calculates the distance corresponding to the full load output using the power scale.

Then extend AD upwards from A onwards, equal to the distance corresponding to full load output, say A'.

Step 12 : Draw parallel to the output line O'A from A' to meet the circle at point P. This is the point corresponding to the full load condition.

Once point P is known, the other performance parameters can be obtained easily as discussed above.

Step 13 : Draw perpendicular from point P to meet output line at Q, torque line at R, the base line at S and horizontal axis at T.

<u>Predicting Performance From Circle Diagram</u>

Line current = OP
Input power = PT x Power scale
Output power = PQ x Power scale
Fixed loss = ST x power scale
Stator copper loss = SR x power scale
Rotor copper loss = QR x power scale
Total loss = QT x power scale
Slip s = Rotor Cu loss = QR/PR
Power factor cosΦ = PT/OP
Motor efficiency = Output / Input = PQ/PT
Torque Line = PR × Power Scale

<u>Maximum Quantities</u>

1. Maximum Output : Draw a line parallel to O'A and is also tangent to the circle at point M. The point M can also be obtained by extending the perpendicular drawn from C on O'A to meet the circle at M. Then the maximum output is given by l(MN) at the power scale.

2. Maximum Input : It occurs at the highest point on the circle i.e. at point L. At this point, tangent to the circle is horizontal. The maximum input given l(LL') at the power scale.

3. Maximum Torque : Draw a line parallel to the torque line and is also tangent to the circle at point J. The point J can also be obtained by drawing perpendicular from C on torque line and extending it to meet circle at point J. The l(JK) represents maximum torque in synchronous watts at the power scale. This torque is also called stalling torque or pull out torque.

4. Maximum Power Factor : Draw a line tangent to the circle from the origin O and that angle is Φ_{max}.

Maximum Power factor = $\cos\Phi_{max}$

5. Starting Torque : The torque is proportional to the rotor input. At s = 1, rotor input is equal to rotor copper loss i.e. l (AE).

∴ T_{start} = l(AE) x Power scale synchronous watts

MODEL CALCULATIONS:

$$W_0 = \sqrt{3} V_0 I_0 \cos\phi_0$$

$$220 = \sqrt{3} \times 415 \times 4.1 \cos\phi_0$$

$$\cos\phi_0 = 0.07$$

$$\phi_0 = 85.98$$

$$W_{SC} = \sqrt{3} V_{SC} I_{SC} \cos\phi_{SC}$$

$$610 = \sqrt{3} \times 94 \times 7.5 \cos\phi_{SC}$$

$$\cos\phi_{SC} = 0.49$$

$$\phi_{SC} = 60.65$$

$$I_{SN} = \frac{V_0}{V_{SC}} \times I_{SC}$$

$$= \frac{415}{94} \times 7.5 = 33.11A$$

$$W_{SN} = \left(\frac{I_{SN}}{I_{SC}} \right)^2 \times W_{SC}$$

$$= \left(\frac{33.11}{7.5} \right)^2 \times 610 = 11888.46 \text{ Watts}$$

$$PowerScale = \frac{W_{SN}}{LengthofA} W / cm$$

$$= \frac{11888.46}{8.2} = 1449.8W / cm$$

Stator copper loss = $3I_{SN}^2 R_S$ where $R_S = 7.05\Omega$

Stator copper loss = 3× $(33.11)^2$ ×7.05 = 8426.19 W

Stator copper loss in cm = 8426.19 / 1499.8 = 3.2 cm

Full load power in cm, $A' = \frac{3.7 \times 10^3}{1449.8} = 2.8cm$

Line current = OP x current scale = 30 A

Input power = PT x Power scale = 4.3 x 1449.8 = 6132.73 W

Output power = PQ x Power scale = 3.5 x 1449.8 = 5421.35 W

Fixed loss = ST x power scale = 0.7 x 1449.8 = 975.42 W

Stator copper loss = SR x power scale = 3.1 x 1449.8 = 5182.45 W

Rotor copper loss = QR x power scale = 3.4 x 1449.8 = 5328.31 W

Total loss = QT x power scale = 7.2 x 1449.8 = 11391 W

$$Slip = \frac{QR}{PR} = 0.266$$

$$PowerFactor = \cos\phi$$

$$= \cos 36 = 0.809$$

Motor efficiency, $\%\eta = \frac{PQ}{PT} \times 100$

$$= \frac{3.5}{4.3} \times 100 = 81.3\%$$

Torque Line = PR × Power Scale

$= 3.8 \times 1449.8 = 5509.24$ W

Maximum Quantities

Maximum Output = MN x Power scale = 4.2 × 1499.8 = 6054.82 W

Maximum Input = LL’ x Power scale = 7.5 × 1499.8 = 12042.45 W

Maximum Torque = JK x Power scale = 3.6 × 1499.8 = 5712.35 W

Maximum Power Factor = $\cos\Phi_{max}$ = cos28 = 0.882

Starting Torque = l(AE) x Power scale = 3.4 x 1449.8 = 5237. 52 W

VIVA QUESTION:

1. **What is the circle diagram of an induction motor?**
   The circle diagram is a graphical representation of the performances of an induction motor. It is very useful to study the performance of an induction motor under all operating conditions.
2. **What is the necessity of starter?**
   The starter is a device which is basically used to limit high starting current by supplying reduced voltage to the motor at the time of starting. Such a reduced voltage is applied only for short period and once rotor gets accelerated, full normal rated voltage is applied.
3. **What are the starters used in three phase induction motor?**
   a. Primary resistance starter
   b. Auto transformer starter
   c. Direct on line starter
   d. Star Delta starter
   e. Rotor resistance starter
4. **Define operating torque, starting torque and breakdown torque. Which of these is the largest?**
   Operating Torque : Torque from light load to full load
   Starting Torque : Torque at start ie, speed =0 or slip =1
   Breakdown Torque : Maximum torque that motor can develop.
   If loaded beyond this torque the motor will decelerate and come to standstill. Breakdown torque is the largest among these for normal induction motor.
5. **What is induction generator?**
   When run faster than its synchronous speed, an induction motor runs as a generator called as induction generator. Slip is negative.

RESULT:

Thus the no load and blocked rotor test on 3-phase squirrel-cage induction motor was performed and using circle diagram, the performance parameters were obtained.

INFERENCE:

The No-Load Test and Blocked Rotor Test are essential for determining the key electrical parameters and understanding the motor’s performance characteristics under different operating conditions.

- **No-Load Test** helps determine the core losses, magnetizing current, and mechanical losses.
- **Blocked Rotor Test** helps determine the starting conditions, stator resistance, leakage reactance, and impedance seen during startup.

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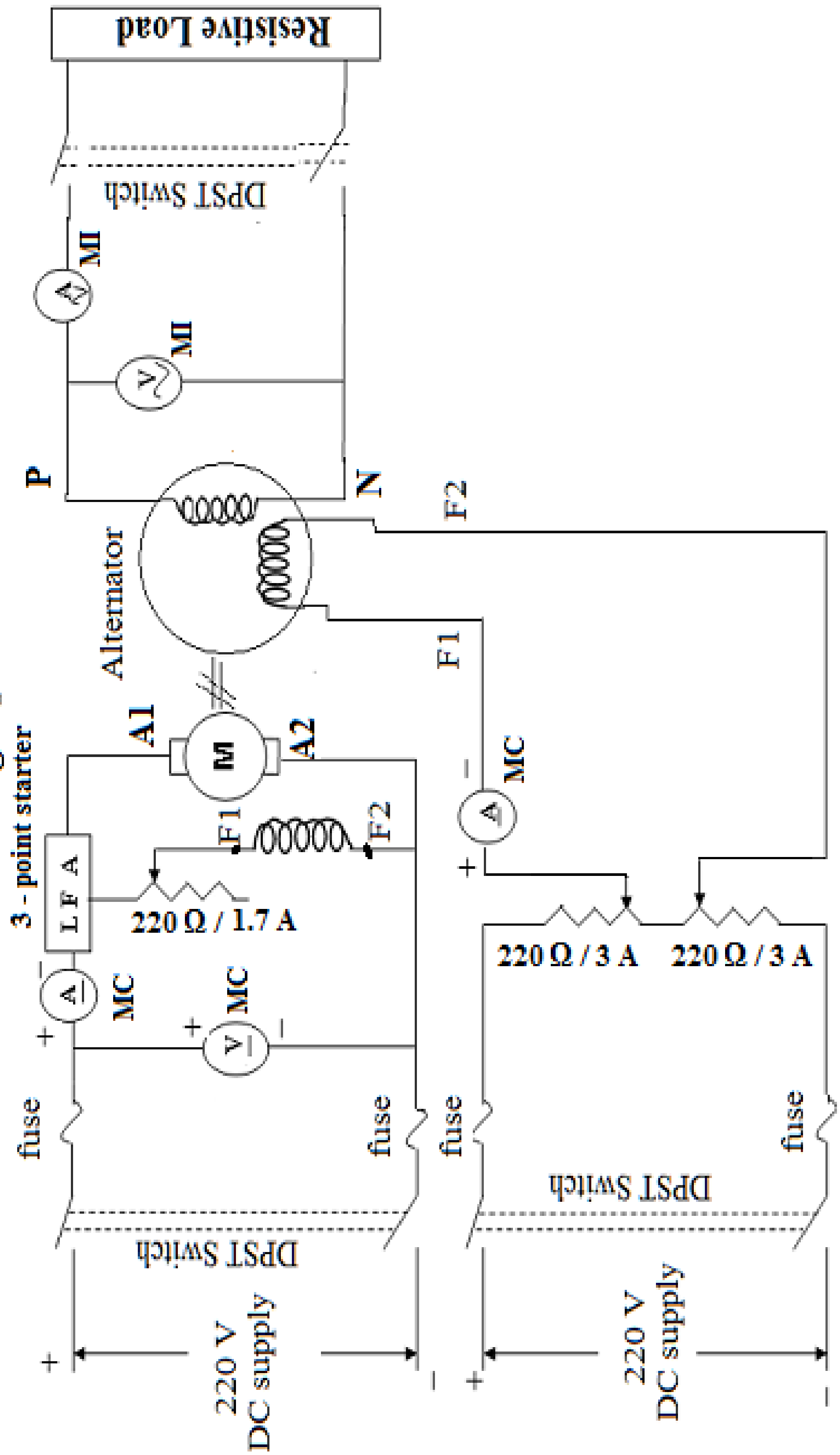
Load test on single phase Alternator



EX.NO.7 **Date:**

LOAD TEST ON SINGLE PHASE ALTERNATOR

AIM:

To conduct load test on single phase alternator and to obtain the performance characteristics

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

The machines generating a.c. e.m.f. are called alternators or synchronous generators. While the machine accepting input from a.c. supply to produce mechanical output are called synchronous motors. Both these machines work at a specific constant speed called synchronous speed and hence in general called synchronous machines.

The alternators work on the principle of electromagnetic induction. When there is a relative motion between the conductors and the flux, e.m.f. gets induced in the conductors. The d.c. generators also work on the same principle. The only difference in practical alternator and a d.c. generator is that in an alternator the conductors are stationary and field is rotating.

FORMULA USED:

1. DC Motor Input power = $V_m \times I_m$ Watts
2. DC Motor Output power = $\frac{\eta \times MotorInputpower}{100}$ Watts
3. Assume efficiency of motor =80%
4. Output Power of Alternator = $V_L I_L \cos\phi$

   cos Ø =1 (for resistive load)
5. Input Power of alternator= Output Power of DC motor
6. % Alternator efficiency η = $\frac{Output}{Input} \times 100$
7. % Regulation = $\frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$

   V_{NL}- No load voltage
   V_{FL}- Full load voltage

TABULAR COLUMN:

Observation Tabulation:

S.No.	Motor input voltage V_m (V)	Motor input Current I_m (A)	Alternator output voltage V_L (V)	Alternator output current I_L (A)	Alternator Field Current

Calculation Tabulation:

S.No.	Motor Input power (W)	Motor output power (W)	Alternator output power (W)	Alternator % η	% Regulation

PRECAUTION:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum resistance position at the time of starting
3. There should be no load at the time of starting

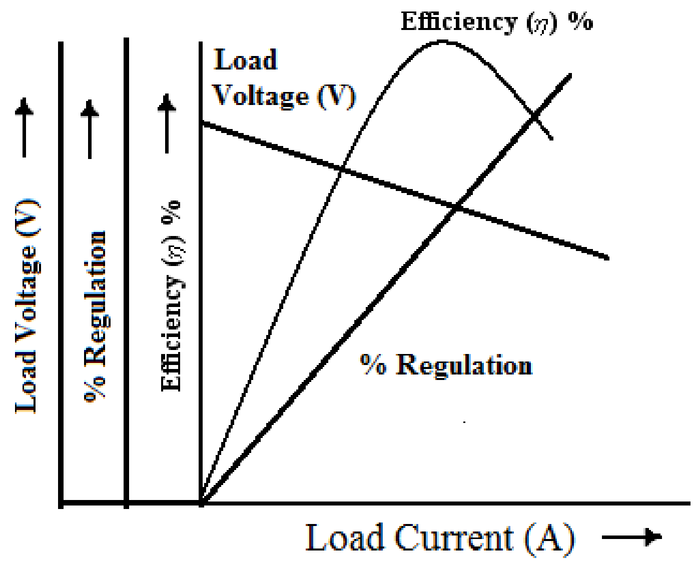
PROCEDURE:

1. Connection are given as per the circuit diagram
2. The supply is given and the DC motor is started using a 3 point starter
3. The field rheostat in the motor side is adjusted till synchronous speed is reached
4. The DPST switch is closed and the potential divider is varied for rated voltage of alternator
5. The no load readings are taken.
6. Vary the load in suitable steps and note down all the readings till rated current is reached. Maintain the speed of the motor as constant throughout the experiment.

GRAPHS:

1. Load current Vs Efficiency
2. Load current Vs % Regulation
3. Load current Vs Load voltage

MODEL GRAPHS:



MODEL CALCULATION:

1. DC Motor Input power = $V_m \times I_m$ Watts

   = 218 × 8

   = 1744 W

2. DC Motor Output power = $\dfrac{\eta \times MotorInputpower}{100}$

   = $\dfrac{80 \times 1744}{100}$

   = 1395.2 Watts

3. Output Power of Alternator = $V_L I_L \cos\phi$

   = 208 × 4 × 1

   = 832 Watts

4. % η = $\dfrac{Output}{Input} \times 100$

   = $\dfrac{832}{1395.2} \times 100$ = 59.63 %

5. % Regulation = $\dfrac{V_{NL} - V_{FL}}{V_{NL}} \times 100$

   % Regulation = $\dfrac{220 - 208}{220} \times 100 = 5.45\%$

VIVA QUESTION:

1. **What are synchronous machines?**
   The machines generating ac emf are called alternating or synchronous generators. While the machine accepting input from ac supply to produce mechanical output are called synchronous motors. Both these machines work at a specific constant speed called synchronous speed and hence in general called synchronous machines.
2. **State the principle of alternator.**
   When the rotor is rotated by the prime mover, the stator windings or conductors are cut by the magnetic flux hence an emf is induced in the stator conductors. (Faraday's law of electromagnetic induction)
3. **Why is the field system of an alternator made as a rotor?**
   The field system of an alternator is made rotating to avoid interaction of mechanical and electrical stress. So with rotating field system, it is easier to collect currents at very high voltages from stationary member. The insulation required is less; the problem of sparking is avoided.
4. **What are the two types of alternators?**
   (a). Non salient pole alternator
   (b). Salient pole alternator.
5. **What is known as Armature reaction?**
   The effect of armature flux on main flux is called as armature reaction.

APPLICATIONS:

Single-phase generators are found in applications that are most often used when the loads being driven are relatively light, and not connected to a three-phase distribution, for instance, portable engine-generators.

RESULT:

Thus the load test on single phase alternator was performed and the respective graphs were drawn.

INFERENCE:

The load test on a single-phase alternator is essential to evaluate the performance of the alternator under different load conditions. This test helps in determining key parameters such as the alternator's voltage regulation, efficiency, power factor, and the behaviour of the alternator under varying loads.

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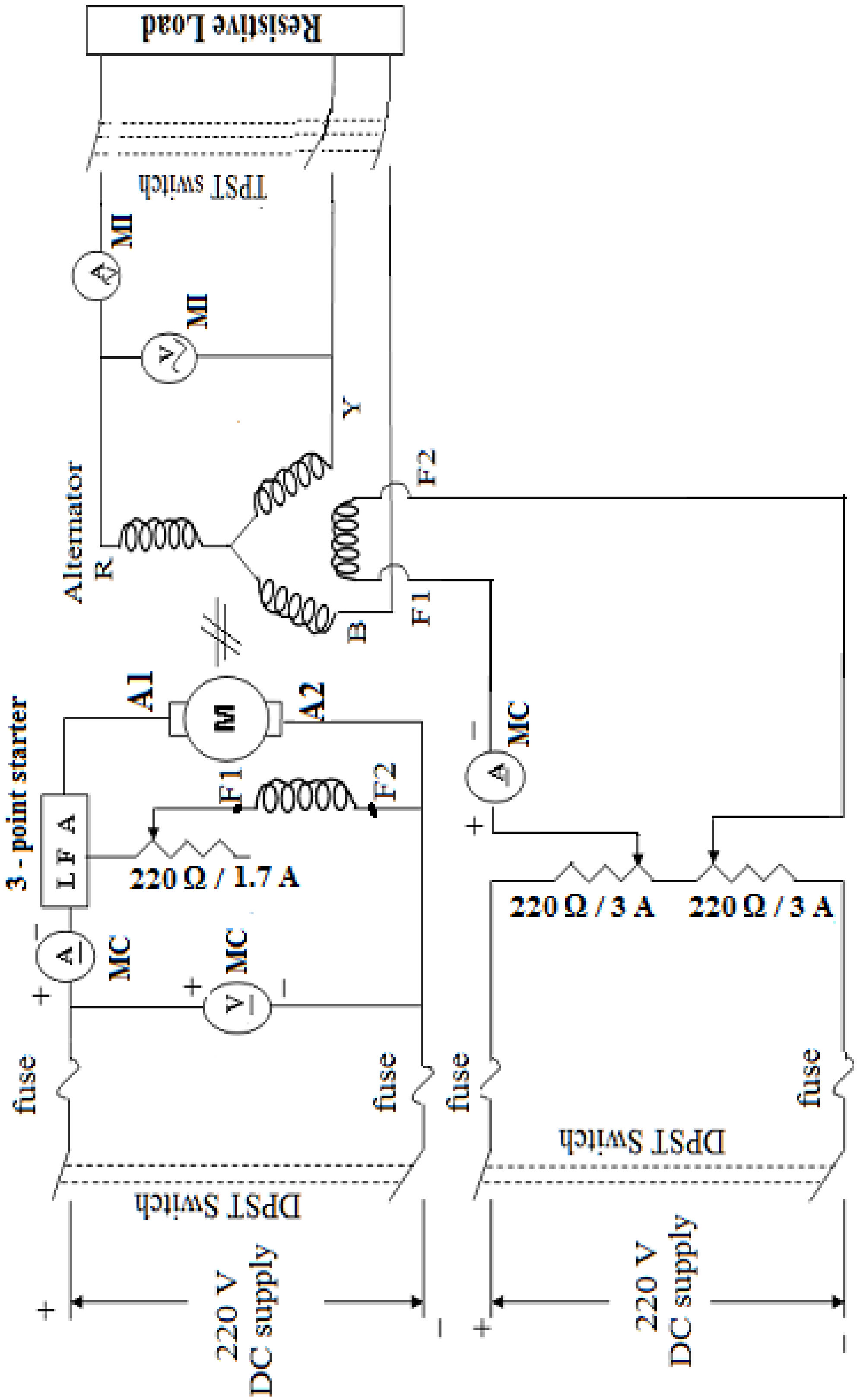
Load test on three phases Alternator



EX.NO.8 **Date:**

LOAD TEST ON THREE PHASE ALTERNATOR

AIM:

To conduct load test on three phase alternator and to obtain the performance characteristics

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

A.C. generators or Alternators (as they are usually called) operate on the same fundamental principles of electromagnetic induction as D.C. generators. They also consist of an armature winding and a magnetic field. But there is one important difference between the two.

Whereas in D.C. generators, the armature rotates and the field system is stationary, the arrangement in alternators is just the reverse of it. In their case, standard construction consists of armature winding mounted on a stationary element called stator and field windings on a rotating element called rotor.

It is clear that with change in load, there is a change in terminal voltage of an alternator. The magnitude of this change depends not only on the load but also on the load power factor. The voltage regulation of an alternator is defined as “the rise in voltage when full load is removed (field excitation and speed remaining the same) divided by the rated terminal voltage.”

TABULAR COLUMN:

Observation Tabulation:

S.No.	Motor input voltage V_m (V)	Motor input Current I_m (A)	Alternator output voltage V_L (V)	Alternator output current I_L (A)	Alternator Field Current

Calculation Tabulation:

S.No.	Motor Input power (W)	Motor output power (W)	Alternator output power (W)	Alternator % η	% Regulation

FORMULA USED:

1. DC Motor Input power = $V_m \times I_m$ Watts
2. DC Motor Output power = $\frac{\eta \times MotorInputpower}{100}$ Watts
3. Assume efficiency of motor =80%
4. Output Power of Alternator = $\sqrt{3} V_L I_L \cos\phi$

   cos Ø =1 (for resistive load)
5. Input Power of alternator= Output Power of DC motor
6. % Alternator efficiency $\eta = \frac{Output}{Input} \times 100$
7. % Regulation = $\frac{V_{NL} - V_{FL}}{V_{NL}} \times 100$

   V_{NL}- No load voltage
   V_{FL}- Full load voltage

PRECAUTION:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum resistance position at the time of starting
3. There should be no load at the time of starting

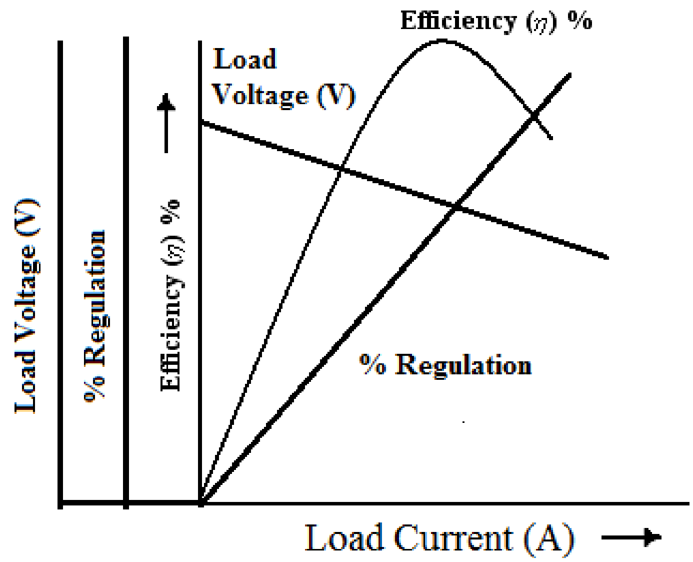
PROCEDURE:

1. Connection are given as per the circuit diagram
2. The supply is given and the DC motor is started using a 3 point starter
3. The field rheostat in the motor side is adjusted till synchronous speed is reached
4. The DPST switch is closed and the potential divider is varied for rated voltage of alternator
5. The no load readings are taken.
6. Vary the load in suitable steps and note down all the readings till rated current is reached. Maintain the speed of the motor as constant throughout the experiment.

GRAPHS:

1. Load current Vs Efficiency
2. Load current Vs % Regulation
3. Load current Vs Load voltage

MODEL GRAPHS:



MODEL CALCULATION:

1. DC Motor Input power = $V_m \times I_m$

   $= 190 \times 18.8$

   $= 3575$ W

2. DC Motor Output power = $\dfrac{\eta \times MotorInputpower}{100}$

   $= \dfrac{84 \times 3572}{100}$

   = 3032.63 Watts

3. Output Power of Alternator = $\sqrt{3} V_L I_L \cos\phi$

   $= \sqrt{3} \times 350 \times 4.2 \times 1$

   = 2546.11 Watts

4. % η = $\dfrac{Output}{Input} \times 100$

   $= \dfrac{2546.11}{3032.63} \times 100$ = 83.9 %

5. % Regulation = $\dfrac{V_{NL} - V_{FL}}{V_{NL}} \times 100$

   % Regulation = $\dfrac{415 - 350}{415} \times 100 = 15.66\%$

VIVA QUESTION:

1. **Why are Alternators rated in kVA and not in kW?**

   Apart from the constant loss incurred in Alternators is the copper loss, occurring in the 3 – phase winding which depends on I^2R, the square of the current delivered by the generator. As the current is directly related to apparent – power delivered by the generator , the Alternators have only their apparent power in VA/kVA/MVA as their power rating.

2. **Define voltage regulation of an alternator?**

   The voltage regulation of an alternator is defined as the increase in terminal voltage when full load is thrown off, assuming field current and speed remaining the same.

$$\%\ Regulation\ = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

   E_{ph} = No load terminal voltage V_{ph} = Full load rated terminal voltage.

3. **Can a DC generator be converted into an alternator? How?**

   Yes, by providing two collector rings on end of the armature and connecting these two rings to two points in the armature windings 180 degree apart.

4. **Compare salient pole rotor & smooth cylindrical rotor.**

Salient Pole Rotor	Cylindrical Rotor
1.Has projecting poles	1. No projecting poles
2 Large diameter and short axial	2 . Small diameter and long axial length, length
3. Used for low speed alternators	3. Used for high - speed turboalternators
4. Needs damper windings	4. Does not need damper windings.
5.Windage loss is more	5. Windage loss is less

5. **What is the necessity of damper winding?**

   Most of the alternators have the pole shoes slotted for receiving copper bars of a grid or damper winding. They are useful in preventing the hunting in generators and are needed in synchronous motors to provide the starting torque.

APPLICATIONS:

- Power generation
- Traction power for railway electrification systems.

RESULT:

Thus the load test on three phase alternator was performed and the respective graphs were drawn.

INFERENCE:

The load test on a three-phase alternator provides valuable information about the alternator's operational performance such as voltage regulation, efficiency and power factor**.**

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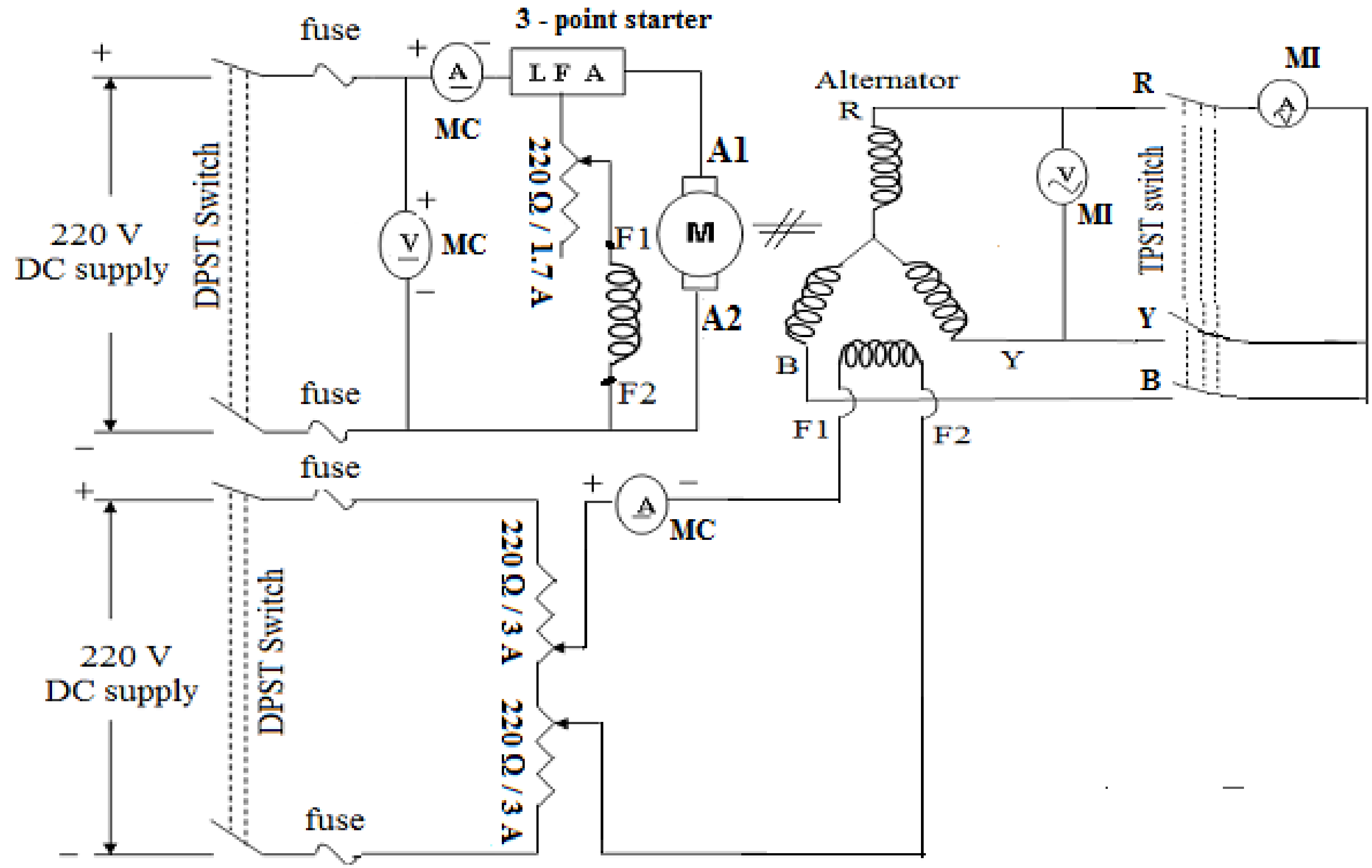
REGULATION OF THREE PHASE ALTERNATOR BY EMF AND MMF METHOD
(Open Circuit and Short Circuit tests)



EXP.NO. 9 **DATE:**

REGULATION OF 3–PHASE ALTERNATOR BY EMF AND MMF METHODS

AIM:

To predetermine the regulation of 3-phase alternator by EMF and MMF methods and also draw the vector diagrams.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

SYNCHRONOUS IMPEDANCE METHOD (OR) E.M.F. METHOD

The method is also called E.M.F. method of determining the regulation. The method requires following data to calculate the regulation.
1. The armature resistance per phase (R_a).
2. Open circuit characteristics which are the graph of open circuit voltage against the field current. This is possible by conducting open circuit test on the alternator.
3. Short circuit characteristics which is the graph of short circuit current against field current. This is possible by conducting short circuit test on the alternator.

From O.C.C. and S.C.C., Z_s can be determined for any load condition.

The armature resistance per phase (R_a) can be measured by different methods. One of the methods is applying d.c. known voltage across the two terminals and measuring current. So value of R_a per phase is known.

Now,

Synchronous Impedance, $Z_S = \dfrac{V_0}{I_{SC}}$

Synchronous Reactance, $X_S = \sqrt{{Z_S}^2 - {R_a}^2}$

No load induced e.m.f. per phase, E_{ph} can be determined by the mathematical expression derived earlier.

Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_a R_a\right)^2 + \left(V_{ph}\sin\phi \pm I_a X_s\right)^2}$

TABULAR COLUMNS:

OBSERVATION TABULATION:

Open Circuit Test:

S.No.	Field Current (I_f) Amps	Open Circuit Line Voltage (V_{OL}) Volts	Open circuit Phase Voltage (V_{oph}) Volts

Short Circuit Test:

S.No	Field Current (I_f) Amps	Short Circuit Current (120% to 150% of rated current) (I_{SC}) Amps

M.M.F. METHOD (OR) AMPERE – TURNS METHOD

This method of determining the regulation of an alternator is also called Ampere-turn method or Rothert's M.M.F. method. The method is based on the results of open circuit test and short circuit test on an alternator.

For any synchronous generator i.e. alternator, it requires m.m.f. which is product of field current and turns of field winding for two separate purposes.
1. It must have an m.m.f. necessary to induce the rated terminal voltage on open circuit.
2. It must have an m.m.f. equal and opposite to that of armature reaction m.m.f.

The field m.m.f. required to induce the rated terminal voltage on open circuit can be obtained from open circuit test results and open circuit characteristics. This is denoted as F_O.

We know that the synchronous impedance has two components, armature resistance and synchronous reactance. Now synchronous reactance also has two components, armature leakage reactance and armature reaction reactance. In short circuit test, field m.m.f. is necessary to overcome drop across armature resistance and leakage reactance and also to overcome effect of armature reaction. But drop across armature resistance and also to overcome effect of armature reaction. But drop across armature resistance and leakage reactance is very small and can be neglected. Thus in short circuit test, field m.m.f. circulates the full load current balancing the armature reaction effect. The value of ampere-turns required to circulate full load current can be obtained from short circuit characteristics. This is denoted as F_{AR}, then total field m.m.f. is the vector sum of its two components F_O and F_{AR}. This depends on the power factor of the load which alternator is supplying. The resultant field m.m.f. is denoted as F_R.

FORMULAE:

EMF METHOD:

1. Armature Resistance R_a = 1.8 Ω
2. From graph, measure V_0
3. Synchronous Impedance, $Z_S = \dfrac{V_0}{I_{SC}}$
4. Synchronous Reactance, $X_S = \sqrt{{Z_S}^2 - {R_a}^2}$

   For Lagging Power Factor 0.8,
5. Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_a R_a\right)^2 + \left(V_{ph}\sin\phi + I_a X_s\right)^2}$

   For Leading Power Factor 0.8,

   Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_a R_a\right)^2 + \left(V_{ph}\sin\phi - I_a X_s\right)^2}$
6. For Unity Power Factor,

   Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph} + I_a R_a\right)^2 + \left(I_a X_s\right)^2}$
7.
8. Percentage regulation, $\%VR = \dfrac{E_{ph} - V_{ph}}{V_{ph}} \times 100$

CALCULATION TABULATION:

1. **EMF Method:**

S.No.	Power factor	E_{ph} (V)		% Regulation	
		Lag	Lead	Lag	Lead

2. **MMF Method:**

S.No.	Power factor	V_{ph} (V)	F_0 (A)	F_{AR} (A)	F_R (A)		E_{ph} (V)		% Regulation	
					Lag	Lead	Lag	Lead	Lag	Lead

MMF METHOD:

From Graph,

Measure F_0 for corresponding V_{ph}

Measure F_{AR} for corresponding I_{SC}

For Lagging,

1. $F_R{}^2 = \left(F_0 + F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$

For Leading,

2. $F_R{}^2 = \left(F_0 - F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$

From graph, measure E_{ph} for corresponding F_R

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

OPEN CIRCUIT TEST:

PRECAUTIONS:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. TPST switch is kept open.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. Supply is given to alternator field winding by closing the DPST switch.
5. By varying alternator potential divider, the field (I_f) current is varied in steps, and E_o (internal emf) is noted.
6. Above procedure is noted till 125% of rated voltage.

SHORT CIRCUIT TEST:

PRECAUTIONS:

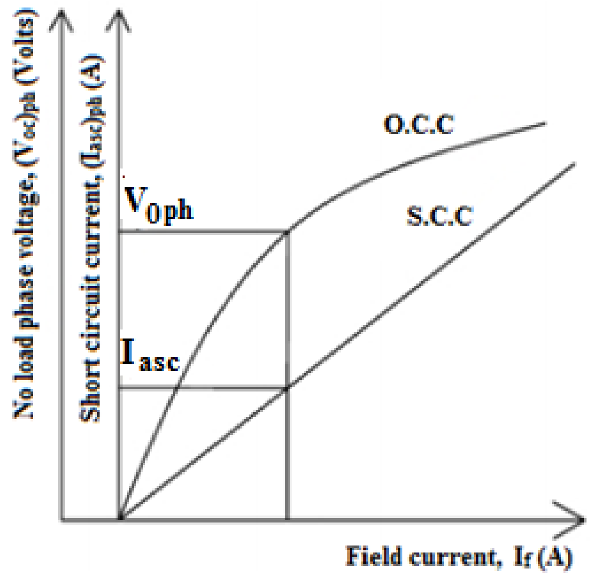
1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. TPST switch is kept closed.

PROCEDURE:

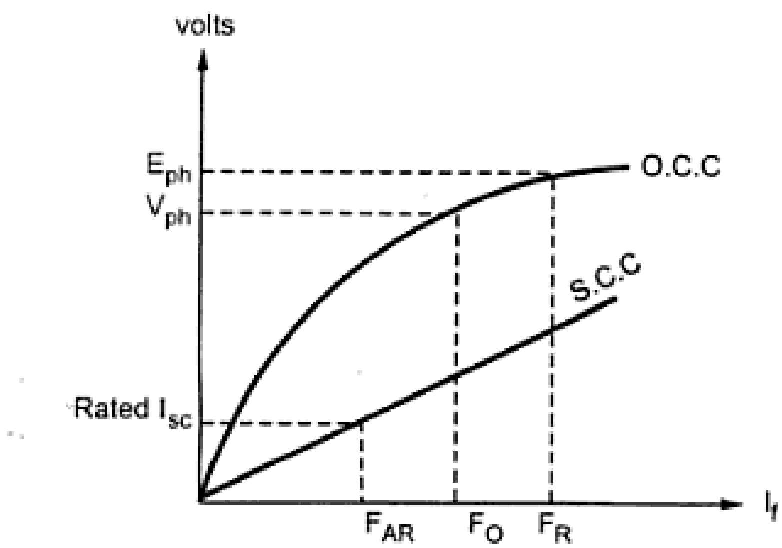
1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. Supply is given to alternator field winding by closing the DPST switch.
5. By varying alternator potential divider, the field current (I_f) is varied till rated current (I_{sc}) is reached.

MODEL GRAPHS:

1. **EMF METHOD:**



2. **MMF METHOD:**



PROCEDURE TO DRAW GRAPH FOR EMF METHOD:

1. Draw the Open Circuit Characteristic curve (Generated Voltage per phase vs Field current).
2. Draw the Short Circuit Characteristics curve (Short circuit current vs Field current)
3. From the graph find the open circuit voltage per phase (V_0) for the rated short circuit current (I_{sc}).
4. By using respective formulae find the Z_s, X_s, E_{ph} and percentage regulation.

PROCEDURE TO DRAW GRAPH FOR MMF METHOD:

1. Draw the Open Circuit Characteristic curve (Generated Voltage per phase VS Field current).
2. Draw the Short Circuit Characteristics curve (Short circuit current VS Field current)
3. From the graph, find the F_0 for the rated phase voltage V_{ph}.
4. From the graph, find the F_{AR} for the rated short circuit current (I_{sc}).
5. Using F_0 and F_{AR}, find $F_{R.}$
6. Find E_{ph} corresponding F_R from OCC.
7. The regulation is calculated as,

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

MODEL CALCULATION:

EMF METHOD:

From Graph,

Measure V_{0ph} = 146 V

$$Z_S = \frac{V_{0ph}}{I_{SC}} = \frac{146}{6.5} = 22.46\Omega$$

$$X_S = \sqrt{Z_S{}^2 - R_a{}^2} = \sqrt{22.46^2 - 1.8^2}$$ (R_a=1.8Ω)

$$X_S = 22.387\Omega$$

For Lagging Power Factor 0.8,

$$E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_a R_a\right)^2 + \left(V_{ph}\sin\phi + I_a X_s\right)^2}$$

$$= \sqrt{\left(239.6\times0.8 + 6.5\times1.8\right)^2 + \left(239.6\times0.6 + 6.5\times22.3\right)^2}$$

$$= \sqrt{\left(41363.42 + 83653.9\right)}$$

$$E_{ph} = 353.57 \text{ V}$$

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}}\times100 = \frac{353.57 - 239.6}{239.6}\times100$$

$$\%VR = 24.68\%$$

For Leading Power Factor 0.8,

$$E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_a R_a\right)^2 + \left(V_{ph}\sin\phi - I_a X_s\right)^2}$$

$$= \sqrt{\left(239.6\times0.8 + 6.5\times1.8\right)^2 + \left(239.6\times0.6 - 6.5\times22.3\right)^2}$$

$$= \sqrt{\left(41363.42 + 2.9241\right)}$$

$$E_{ph} = 203.38 \text{ V}$$

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 = \frac{203.38 - 239.6}{239.6} \times 100$$

$$\%VR = -20.68\%$$

MMF METHOD:

From Graph,

Measure F_0 for corresponding V_{ph}, $F_0 = 1.0$ A

Measure F_{AR} for corresponding I_{SC}, $F_{AR} = 0.46$ A

For Lagging,

$$F_R^{\,2} = \left(F_0 + F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

$$= \left(1 + 0.46 \times 0.6\right)^2 + \left(0.46 \times 0.8\right)^2$$

$$F_R = 1.337A$$

From Graph, measure E_{ph} for corresponding F_R

$E_{ph} = 270$ V

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 = \frac{270 - 239.6}{239.6} \times 100$$

$$\%VR = 4.72\%$$

For Leading,

$$F_R^{\,2} = \left(F_0 - F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

$$= \left(1 - 0.46 \times 0.6\right)^2 + \left(0.46 \times 0.8\right)^2$$

$$F_R = 0.81A$$

From Graph, measure E_{ph} for corresponding F_R

$E_{ph} = 214$ V

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 = \frac{214 - 239.6}{239.6} \times 100$$

$$\%VR = -3.52\%$$

VIVA QUESTIONS:

1. **What are the different methods available to determine the voltage regulation of an alternator?**
   i. Direct loading method
   ii. Synchronous Impedance method or EMF method
   iii. Ampere Turn method or MMF method
   iv. Zero Power Factor method or Potier method
   v. ASA method
   vi. Two reaction theory
2. **Why is EMF method called Pessimistic method?**
   The value of voltage regulation obtained by EMF method is always more than the actual value, therefore it is called Pessimistic method.
3. **Why is MMF method called Optimistic method?**
   The value of voltage regulation obtained by MMF method is less than the actual value, therefore it is called Optimistic method.
4. **What do you mean by synchronous reactance and synchronous impedance of an Alternator?**
   Synchronous reactance
   The complex addition of leakage reactance X_l and armature reaction effect, Xa can be represented together is called Synchronous reactance X_s.
   Synchronous reactance $X_s = (X_l + X_a)$
   Synchronous impedance
   The complex addition of resistance, R and synchronous reactance , jXs can be represented together by a single complex impedance Z_s called synchronous impedance.
   In complex form $Z_s = (R + jX_s)$

RESULT:

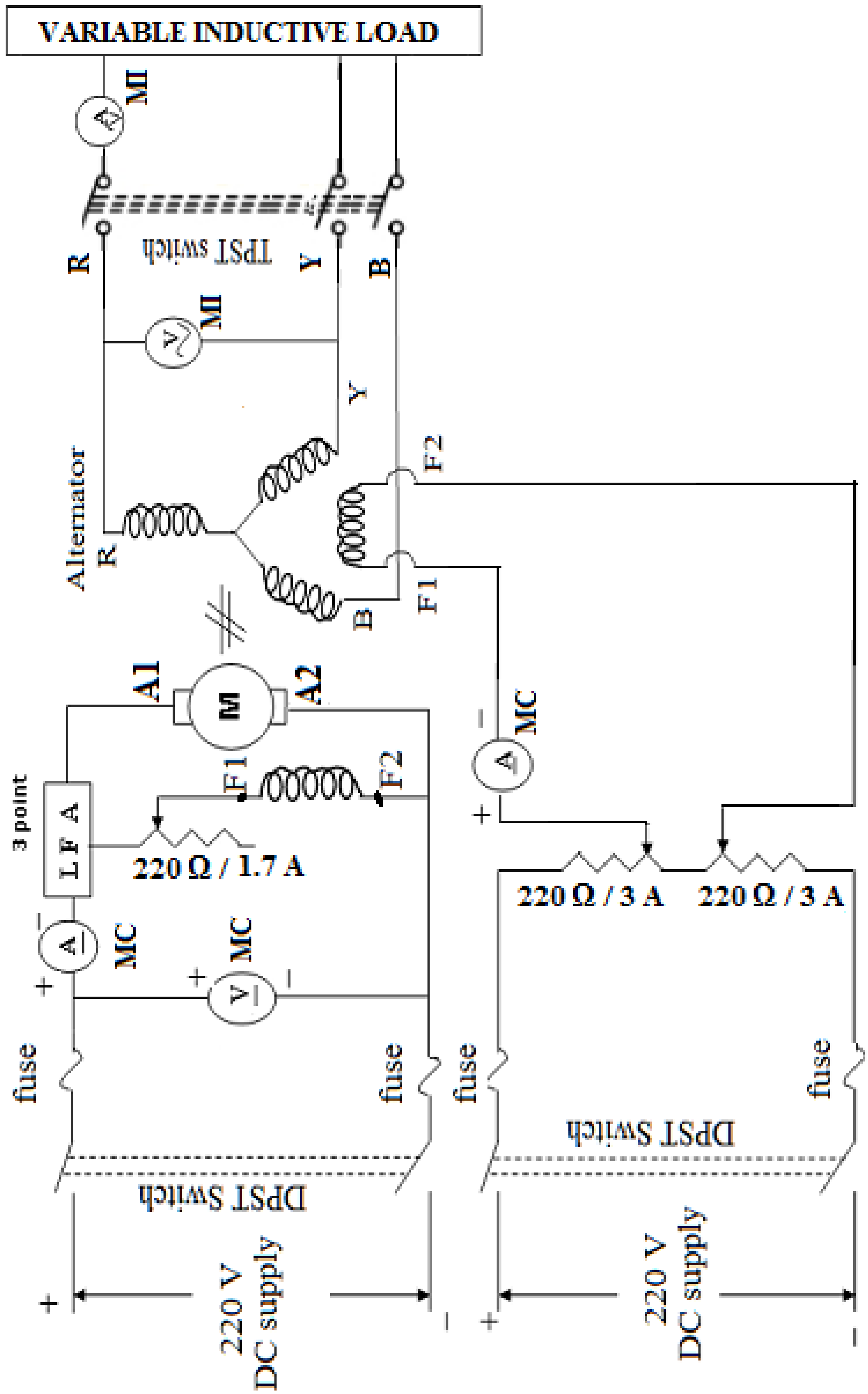
Thus the regulation of 3-phase alternator has been predetermined by the EMF and MMF methods.

INFERENCE:

These methods offer theoretical predictions of the alternator's behaviour, specifically the voltage regulation, which is essential for ensuring stable operation of the alternator in power generation systems.

Mark Allocation	
Experiment Conduction	
Viva Voce	
Total	

REGULATION OF THREE PHASE ALTERNATOR BY ZPF METHOD



EXP.NO. 10 **DATE:**

PREDETERMINATION OF VOLTAGE REGULATION OF THREE PHASE ALTERNATOR BY ZPF METHOD

AIM:

To predetermine the regulation of a given 3Φ alternator at full load condition and different power by ZPF method.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

To conduct zero power factor test, the switch S is kept closed. Due to this, a purely inductive load gets connected to an alternator through an ammeter. A purely inductive load has power factor of cosΦ i.e. zero lagging hence the test is called zero power factor test.ZPF method is based on the separation of armature leakage reactance and armature reaction effects. To determine armature leakage reactance and armature reaction mmf separately, two tests are performed on the alternator.

The two tests are

1. Open circuit test
2. Short circuit test
3. Zero power factor tests

This method takes into consideration the armature resistance and leakage reactance voltage drops as e.m.f. quantities and the effect of armature reaction as m.m.f. quantity. This is reality hence the results obtained by this method are nearer to the reality than those obtained by synchronous impedance method and ampere-turns method.

FORMULA:

1. From graph, measure Length (RS)

   $X_L = L(RS) / I_a$

For Lagging,

2. $E_{ph1} = \sqrt{\left(V_{ph}\cos\phi\right)^2 + \left(V_{ph}\sin\phi + I_a X_{Lph}\right)^2}$

3. From Graph, measure F_{f1} for corresponding E_{ph1}

TABULAR COLUMN:

OBSERVATION TABULATION:

Open Circuit Test:

S.No.	Field Current (I_f) Amps	Open Circuit Line Voltage (V_{OL}) Volts	Open circuit Phase Voltage (V_{oph}) Volts

Short Circuit Test:

S.No	Field Current (I_f) Amps	Short Circuit Current (120% to 150% of rated current) (I_{SC}) Amps

OBSERVATION TABULATION:

ZPF Method:

S.No	Field Current (I_f) Amps	Rated Armature current (I_a) Amps	Rated Armature voltage (V_a) Volts

4. From graph, measure Length (PS)

$$L(PS) = F_{AR}$$

$$F_R^{\,2} = \left(F_{f1} + F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

5. For Leading, consider same X_L and F_{AR}

6. $E_{ph1} = \sqrt{\left(V_{ph}\cos\phi\right)^2 + \left(V_{ph}\sin\phi - I_a X_{Lph}\right)^2}$

7. From Graph, measure F_{f1} for corresponding E_{ph1}

8. $F_R^{\,2} = \left(F_{f1} - F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$

9. From Graph, measure E_{ph} for corresponding F_R

10. % Voltage Regulation,

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

OPEN CIRCUIT TEST:

PRECAUTIONS:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. TPST switch is kept open.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. Supply is given to alternator field winding by closing the DPST switch.
5. By varying alternator potential divider, the field (I_f) current is varied in steps, and Internal emf (E_o) is noted.
6. Above procedure is noted till 125% of rated voltage.

SHORT CIRCUIT TEST:

PRECAUTIONS:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. Alternator armature winding should be short circuit.

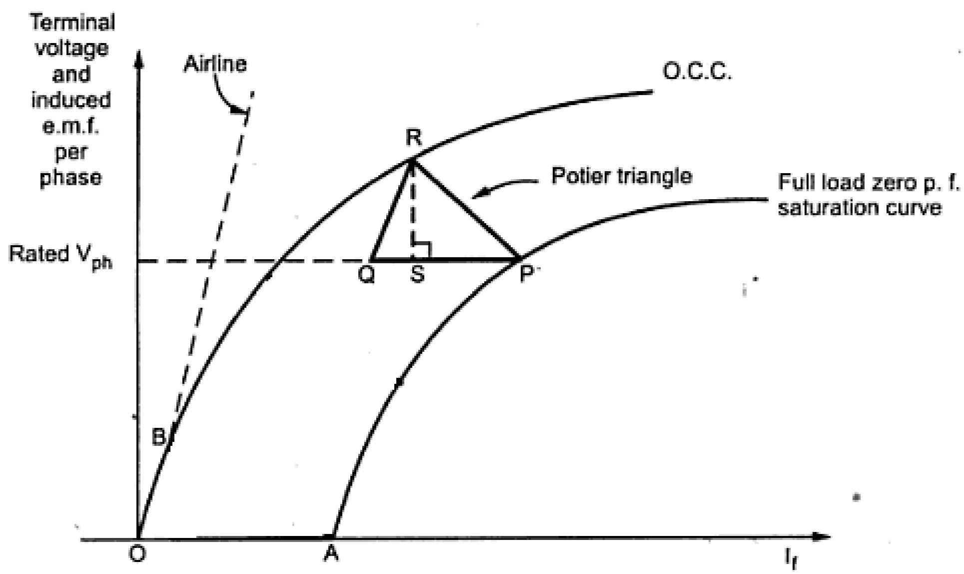
PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. Supply is given to alternator field winding by closing the DPST switch.
5. By varying alternator potential divider, the field current (I_f) is varied till rated current (I_{sc}) is reached.

CALCULATION TABULATION:

S.No.	Power factor	E_{ph1}		F_{f1}		F_{AR}	F_R		E_{ph} (V)		% Voltage Regulation	
		Lag	Lead	Lag	Lead		Lag	Lead	Lag	Lead	Lag	Lead

MODEL GRAPHS:



ZPF TEST:

PRECAUTIONS:

1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. There should be no-load at the time of starting.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. 3Φ ZPF load is connected to alternator by closing TPST switch.
5. Supply is given to alternator field winding by closing the DPST switch.
6. By alternatively varying field rheostat, ZPF load, alternator is made to deliver rated voltage and rated current.

MODEL CALCULATION:

From Graph, measure Length (RS)

$X_L = L(RS) / I_a$

$= 56 / 7 = 8\ \Omega$

For Lagging,

$$E_{ph1} = \sqrt{\left(V_{ph}\cos\phi + I_a R_{aph}\right)^2 + \left(V_{ph}\sin\phi + I_a X_{Lph}\right)^2}$$

$$= \sqrt{36741.22 + 29904.05}$$

$$E_{ph1} = 276.84V$$

From Graph, measure F_{f1} for corresponding E_{ph1}

$$F_{f1} = 1.32$$

From Graph, measure Length (PS)

$L(PS) = F_{AR} = 1.5 \times 0.2 = 0.3$ A

$$F_R{}^2 = \left(F_{f1} + F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

$$= (1.32 + 0.3\sin 36.86)^2 + (0.3\cos 36.86)^2$$

$$= 1.3324 + 0.475$$

$$F_R{}^2 = 2.307$$

$$F_R = 1.51$$

From Graph, measure E_{ph} for corresponding F_R

$E_{ph} = 276.8$ V

DRAWING ZPF CURVE:

1. Plot open circuit characteristics on graph as shown in the Figure.
2. Plot the excitation corresponding to zero terminal voltage i.e. short circuit full load zero p.f. armature current. This point is shown as A in the Figure which is on the x-axis. Another point is the rated voltage when alternator is delivering full load current at zero p.f. lagging. This point is P as shown in the Figure.
3. Draw the tangent to O.C.C. through origin which is line OB as shown dotted in the Figure. This is called air line.
4. Draw the horizontal line PQ parallel and equal to OA.
5. From point Q draw the line parallel to the air line which intersects O.C.C. at point R. Join RQ and join PR. The triangle PQR is called potier triangle.
6. From point R, drop a perpendicular on PQ to meet at point S.
7. The perpendicular RS gives the voltage drop due to the armature leakage reactance i.e. IX_L.
8. The length PS gives field current necessary to overcome demagnetising effect of armature reaction at full load.

   So armature leakage reactance can be obtained as,

$$l\,(RS) = l\,(BC) = (I_{aph})_{F.L.} \times X_{L\,ph}$$

$$\therefore \quad \boxed{X_{L\,ph} = \frac{l\,(RS) \text{ or } l(BC)}{(I_{aph})\text{ F.L.}} \quad \Omega}$$

9. Internal emf, E_{ph1} is calculated as,

   For lagging,

$$E_{ph1} = \sqrt{\left(V_{ph}\cos\phi\right)^2 + \left(V_{ph}\sin\phi + I_a X_{Lph}\right)^2}$$

   For leading,

$$E_{ph1} = \sqrt{\left(V_{ph}\cos\phi\right)^2 + \left(V_{ph}\sin\phi - I_a X_{Lph}\right)^2}$$

10. Find F_{f1} corresponding E_{ph1} from OCC.
11. F_{AR} is field current, required to overcome armature reaction L(PS)
12. Find F_R using the formula,

    For lagging,

$$F_R^{\,2} = \left(F_{f1} + F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

    For leading,

$$F_R^{\,2} = \left(F_{f1} - F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

13. Find E_{ph} corresponding F_R from OCC.
14. The regulation is calculated as,

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

% Voltage Regulation,

For Lagging,

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 = \frac{276.8 - 239.6}{239.6} \times 100$$

$$\%VR = 8.52\%$$

For Leading, consider same X_L and F_{AR}

$$E_{ph1} = \sqrt{\left(V_{ph}\cos\phi + I_a R_{aph}\right)^2 + \left(V_{ph}\sin\phi - I_a X_{Lph}\right)^2}$$

$$E_{ph1} = 210.81V$$

From Graph, measure F_{f1} for corresponding E_{ph1}

$$F_{f1} = 0.76$$

$$F_{AR} = 0.3A$$

$$F_R{}^2 = \left(F_{f1} - F_{AR}\sin\phi\right)^2 + \left(F_{AR}\cos\phi\right)^2$$

$$= (1.32 - 0.3\sin 36.86)^2 + (0.3\cos 36.86)^2$$

$$F_R = 0.58$$

From Graph, measure E_{ph} for corresponding F_R

E_{ph} = 210.84 V

% Voltage Regulation,

For Leading,

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100 = \frac{210.84 - 239.6}{239.6} \times 100$$

$$\%VR = -7.42\%$$

VIVA QUESTIONS:

1. **What is the necessity for predetermination of voltage regulation?**
   Most of the Alternators are manufactured with large power rating , hundreds of kW or MW, and also with large voltage rating upto 33kV. For Alternators of such power and voltage ratings conducting load test is not possible. Hence other indirect methods of testing are used and the performance like voltage regulation then can be predetermined at any desired load currents and power factors.
2. **Potier method is also called Potier reactance method. Why?**
   It is based on the separation of armature leakage reactance and armature reaction effects. The armature leakage reactance XL is called Potier reactance in this method, hence this method is also called as Potier reactance method.
3. **What are the tests data required for predetermining the voltage regulation of an Alternator?**
   Data required for MMF method are:
   (i). Effective Resistance per phase of the 3-phase winding R
   (ii).Open Circuit Characteristic (OCC) at rated speed/frequency
   (iii). Short Circuit Characteristic (SCC) at rated speed/frequency
   (iv). Zero Power Factor (ZPF) test
4. **State the merits of the ZPF method.**
   The results obtained by this method are nearer to the reality than those obtained by synchronous impedance method and ampere-turns method.

RESULT:

Thus the regulation of 3-phase alternator has been predetermined by the ZPF method.

INFERENCE:

The Zero Power Factor (ZPF) method provides a useful way to predict the voltage regulation of a 3-phase alternator under extreme reactive load conditions. This method focuses on the effect of the synchronous reactance on the alternator's output voltage.

Mark Allocation	
Experiment Conduction	
Viva Voce	
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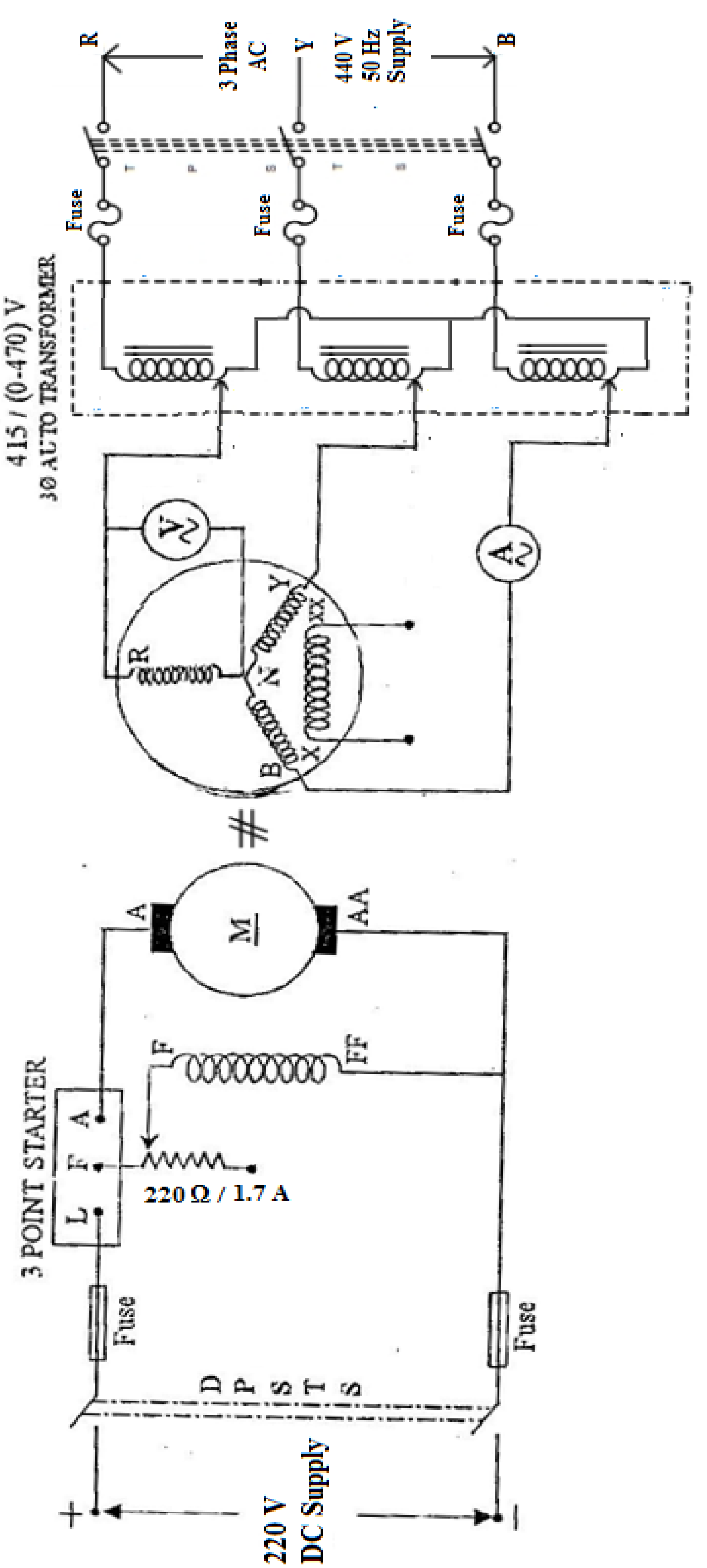
R
3 Phase AC
Y
440 V 50 Hz Supply
B
Fuse
Fuse
Fuse
415 / (0-470) V
3Ø AUTO TRANSFORMER
V
A
R
Y
N
B
X
XX
A
M
AA
F
FF
3 POINT STARTER
L F A
220 Ω / 1.7 A
Fuse
Fuse
D P S T S
+
−
220 V DC Supply

EXP.NO. 11 **DATE:**

DETERMINATION OF DIRECT AXIS REACTANCE X_D AND QUADRATURE AXIS REACTANCE X_Q OF A SALIENT POLE ALTERNATOR BY SLIP TEST

AIM:

To determine of direct axis reactance X_d and quadrature axis reactance Xq of a salient pole alternator by slip test.

APPARATUS REQUIRED:

S.no	Name of Apparatus	Range	Type	Quantity
1	Ammeter			
2	Voltmeter			
3	Rheostat			
4	Tachometer			
5	TPST Switch			
6	Connecting Wires			

THEORY:

The method used to determine X_q and X_d, the direct and quadrature axis reactance is called slip test. In an alternator we apply excitation to the field winding and voltage gets induced in the armature. But in the slip test, a three phase supply is applied to the armature, having voltage must less than the rated voltage while the field winding circuit is kept open.

The three phase currents drawn by the armature from a three phase supply produce a rotating flux. Note that the armature is stationary, but the flux and hence m.m.f. wave produced by three phase armature currents is rotating. This is similar to the rotating magnetic field existing in an induction motor.

The rotor is made to rotate at a speed little less than the synchronous speed. Thus armature m.m.f. having synchronous speed, moves slowly past the filed poles at a slip speed (n_s -n) where n is actual speed of rotor. This causes an e.m.f. to be induced in the field circuit.

When the stator m.m.f. is aligned with the d-axis of field poles then flux Φ_d per poles is set up and the effective reactance offered by the alternator is X_d.

When the stator m.m.f. is aligned with the q-axis of field poles then flux Φ_q per pole is set up and the effective reactance offered by the alternator is X_q.

As the air gap is nonuniform, the reactance offered also varies and hence current drawn the armature also varies cyclically at twice the slip frequency.

The r.m.s. current is minimum when machine reactance is X_d and it is maximum when machine reactance is X_q. As the reactance offered varies due to nonuniform air gap, the voltage drops also varies cyclically. Hence the impedance of the alternator also varies cyclically. The terminal voltage also varies cyclically. The voltage at terminals is maximum when current and various drops are minimum while voltage at terminals is minimum when current and various drops are maximum.

TABULAR COLUMNS:

S.No.	V_{max}	V_{min}	I_{max}	I_{min}	X_d	X_q

MODEL CALCULATION:

1. $X_d = \dfrac{V_{max}}{\sqrt{3} I_{\min}} = \dfrac{45}{\sqrt{3} \times 5.4}$

$$X_d = 4.812\Omega$$

2. $Xq = \dfrac{V_{\min}}{\sqrt{3} I_{\max}} = \dfrac{37}{\sqrt{3} \times 7.1}$

$$Xq = 3.008\Omega$$

FORMULAE USED:

1. $X_d = \dfrac{V_{max}}{\sqrt{3} I_{\min}}$

2. $Xq = \dfrac{V_{\min}}{\sqrt{3} I_{\max}}$

Where,

X_d = direct axis reactance in Ω

X_q = quadrate axis reactance in Ω

PRECAUTIONS:

1. The motor field rheostat should be kept in minimum position.
2. 3-phase autotransformer should be at minimum voltage position.
3. Field winding of alternator is kept open.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. The supply is given and the DC motor is started using a 3 point starter
3. The field rheostat in the motor side is adjusted till synchronous speed is reached
4. Apply 20% to 30% of the rated voltage to the alternator by adjusting the autotransformer.
5. To obtain the slip and the maximum oscillation of pointers, the speed is reduced slightly lesser than the synchronous speed.
6. Maximum current, minimum current, maximum voltage and minimum voltage are noted.

VIVA QUESTIONS:

1. **What is meant by salient pole type rotor?**

   The rotor poles projecting out from the rotor core of large diameter but small length. This is used in low and medium speed (engine driven alternator)

2. **What is meant by Two Reaction theory?**

   The method of analysis of the distributing effects caused by salient pole construction is called Two Reaction theory.

   The armature mmf can be divided into two components as

   i). Component acting along the pole axis called direct axis (d)

   ii). Component acting along at right angles to the pole axis called quadrature axis (q).

3. **What is d axis and q axis?**

   The reluctance offered to the mmf wave is lowest when it is aligned with the field pole axis. This axis is called direct axis of pole.

   The reluctance offered is highest when the mmf wave is oriented at 90 to the field pole axis which is called quadrature axis.

4. **What is meant by magnetizing and cross magnetizing component?**

   The component along direct axis can be magnetizing and the component acting along the quadrature axis is called cross magnetizing component.

5. **What is called slip test?**

   The method used to determine X_d and X_q, the direct and quadrature axis reactance's is called slip test.

RESULT:

Thus the slip test on salient pole alternator was performed and the direct axis reactance X_d and quadrature axis reactance X_q were obtained.

INFERENCE:

This test helps in optimizing the alternator's design, ensuring stable voltage regulation, and understanding how the alternator will behave under different loading conditions in real-world applications.

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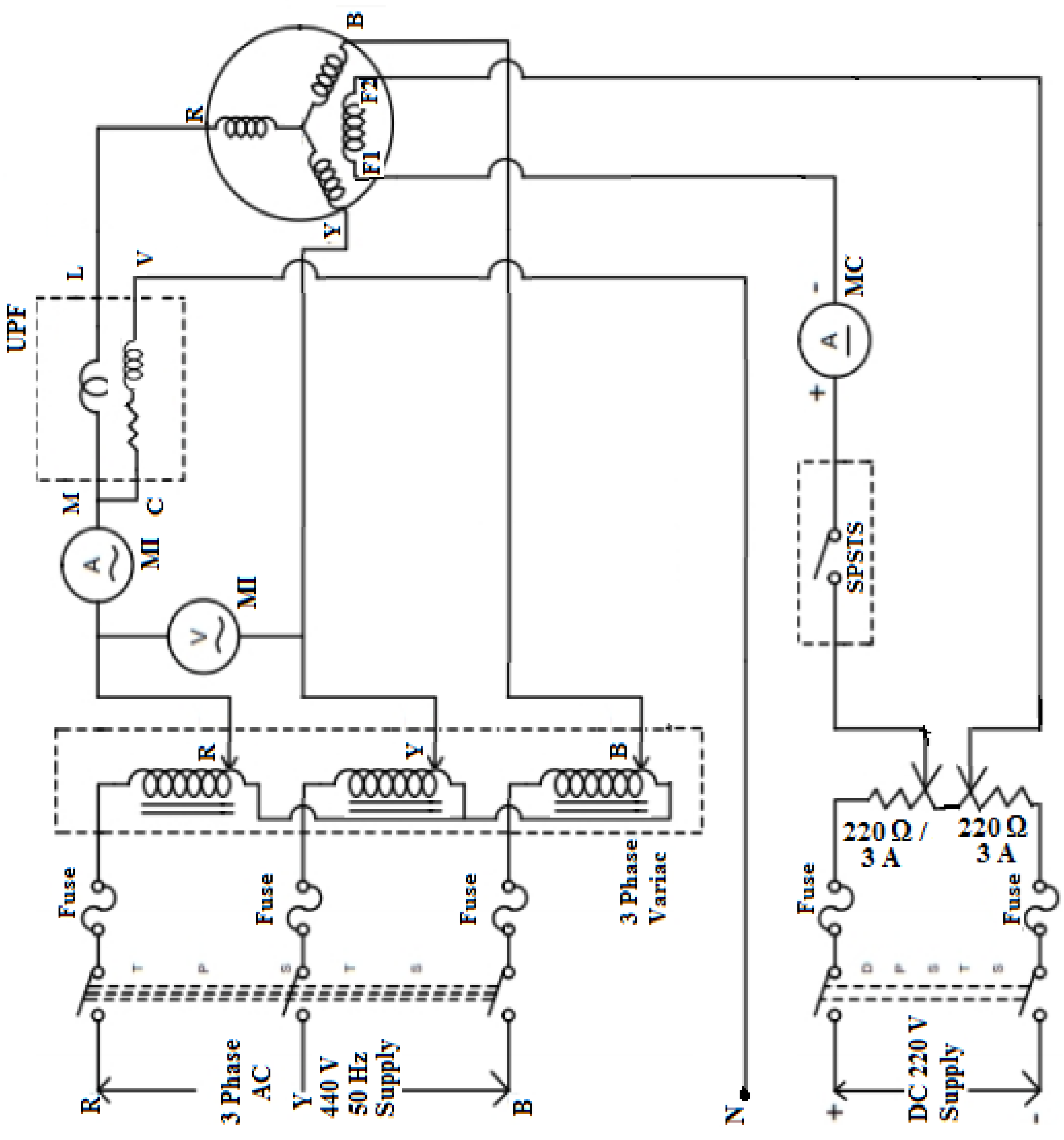
CIRCUIT DIAGRAM:



EXP.NO. 12 **DATE:**

V AND INVERTED V CURVE OF SYNCHRONOUS MOTOR

AIM:

To draw the V and inverted V curves of a 3 phase Synchronous Motor.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

Synchronous motor works on the principle of the magnetic locking. When two unlike poles are brought near each other, if the magnets are strong, there exists a tremendous force of attraction between those two poles. In such condition the two magnets are said to be magnetically locked.

If now one of the two magnets is rotated, the other also rotates in the same direction, with the same speed due to the force of attraction i.e. due to magnetic locking condition.

It is capable of being operated under wide range of power factor; hence it can be used for power factor correction. The value of excitation for which back emf is equal to applied voltage is known as 100% excitation. The other two possible excitations are over excitations and under excitation if the back emf is more or less to the applied voltage respectively.

The excitation is varied from very low (under excitation) to very high (over excitation) value, then current I_a decreases, becomes minimum at unity p.f. and then again increases.

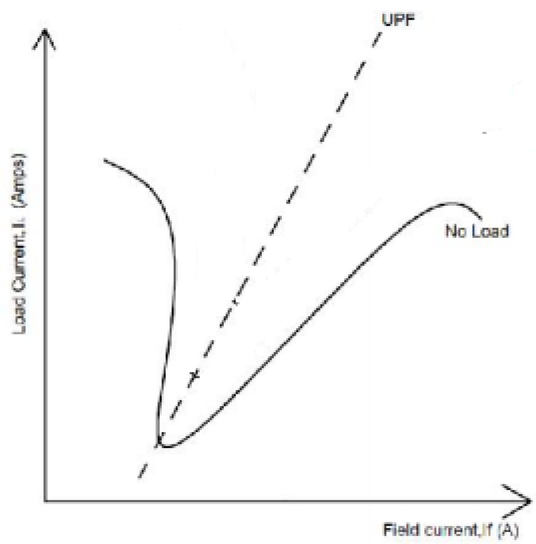
Excitation can be increased by increasing the field current passing through the field winding of synchronous motor. If graph of armature current drawn by the motor (I_a) against field current (I_f) is plotted, then its shape looks like an english alphabet V. If such graphs are obtained at various load conditions we get family of curves, all looking like V. Such curves are called V-curves of synchronous motor.

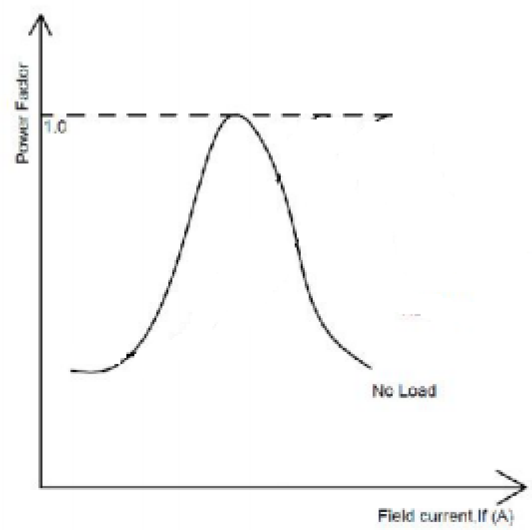
As against this, if the power factor (cos Φ) is plotted against field current (I_f), then the shape of the graph looks like an inverted V. Such curves obtained by plotting p.f. against I_f, at various load conditions are called Inverted V-curves of synchronous motor.

TABULATION:

S.No.	Line Voltage V_L (V)	Line Current I_L (A)	Field Current	Input Power P_{in} (Watts)		Power Factor
				Obs.	Act.	

MODEL GRAPHS:





MODEL CALCULATION:

1. Input Power, P_{in} = 160 Watts

2. $$\cos\phi = \frac{P_{in}}{V_{ph} I_{ph}}$$

$$\cos\phi = \frac{160}{\left(\frac{240}{\sqrt{3}}\right) \times 6.4}$$

= 0.18

FORMULA:

1. Input Power, $W_{in} = W_1 + W_2$ Watts

2. $$\cos\phi = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}\left(W_1 - W_2\right)}{\left(W_1 + W_2\right)}\right]\right\}$$

PRECAUTION:

(1) 3-phase autotransformer should be at minimum voltage position.
(2) The potential divider should be kept at maximum resistance position at the time of starting
(3) The motor should not be loaded throughout the experiment.
(4) SPST switch is kept open.

PROCEDURE:

(1) Connections are made as per the circuit diagram.
(2) Close the TPST switch and apply the rated voltage to the motor by adjusting autotransformer.
(3) In order to give the excitation to the field, close the DPST switch.
(4) By varying the field rheostat within the rated armature current, note down the line voltage, armature current, excitation current and the wattmeter for various values of excitation.

GRAPHS:

The graph is drawn for,

(1) Armature current Vs Excitation current.
(2) Power factor Vs Excitation current.

VIVA QUESTION:

1. **Define V and Inverted V curves.**

   The magnitude of armature current varies with excitation. If graph of armature current drawn by the motor against field current is plotted then we get V curves.

   If the power factor is plotted against field current then the shape of the graph looks like an inverted V and are called as Inverted v curves.

2. **When Synchronous motor is said to receive 100% excitation?**

   The value of excitation for which back emf is equal to the applied voltage is known as 100% excitation or when the power factor of the synchronous motor is unity.

   $E_b = V$ (or) $\cos\Phi = 1$

3. **Define critical excitation.**

   When the excitation is changed, the power factor changes. The excitation for which the power factor of the motor is unity is called critical excitation.

4. **What do you mean by under excitation and over excitation?**

   When the excitation is adjusted in such a way that the magnitude of induced emf is less than the applied voltage the excitation is called under excitation (lagging power factor)

   When the excitation is adjusted in such a way that the magnitude of induced emf is greater than the applied voltage the excitation is called over excitation (leading power factor).

5. **What do you mean by synchronous condenser?**

   A single machine which is available to convert ac to dc is known as synchronous converter or rotary converter. A synchronous converter combines the function of a synchronous motor and a dc generator.

6. **What is hunting?**

   The oscillations of the rotor about its new equilibrium position, due to sudden variation or removal of load is called hunting.

7. **What are the various methods of starting synchronous motor?**

   (a). Pony motor method starting

   (b). Auto induction starting

   (c). DC exciter starting

   (d). Damper winding method of starting

8. **What significant characteristic of a synchronous motor is revealed by its V-curves?**

   The V curves of synchronous motor reveals the fact that its power factor is controllable by means of its excitation.

APPLICATIONS:

Improving the power factor as Synchronous condensers.

Constant speed load service

Reciprocating compressor drives

Voltage regulation of transmission lines

RESULT:

Thus the V and Inverted V curve of three phase synchronous motor were obtained.

INFERENCE:

These curves are essential for understanding the performance of synchronous motors, particularly in applications requiring power factor correction and in systems where efficient motor operation is critical.

Mark Allocation	
Experiment Conduction	
Viva Voce	
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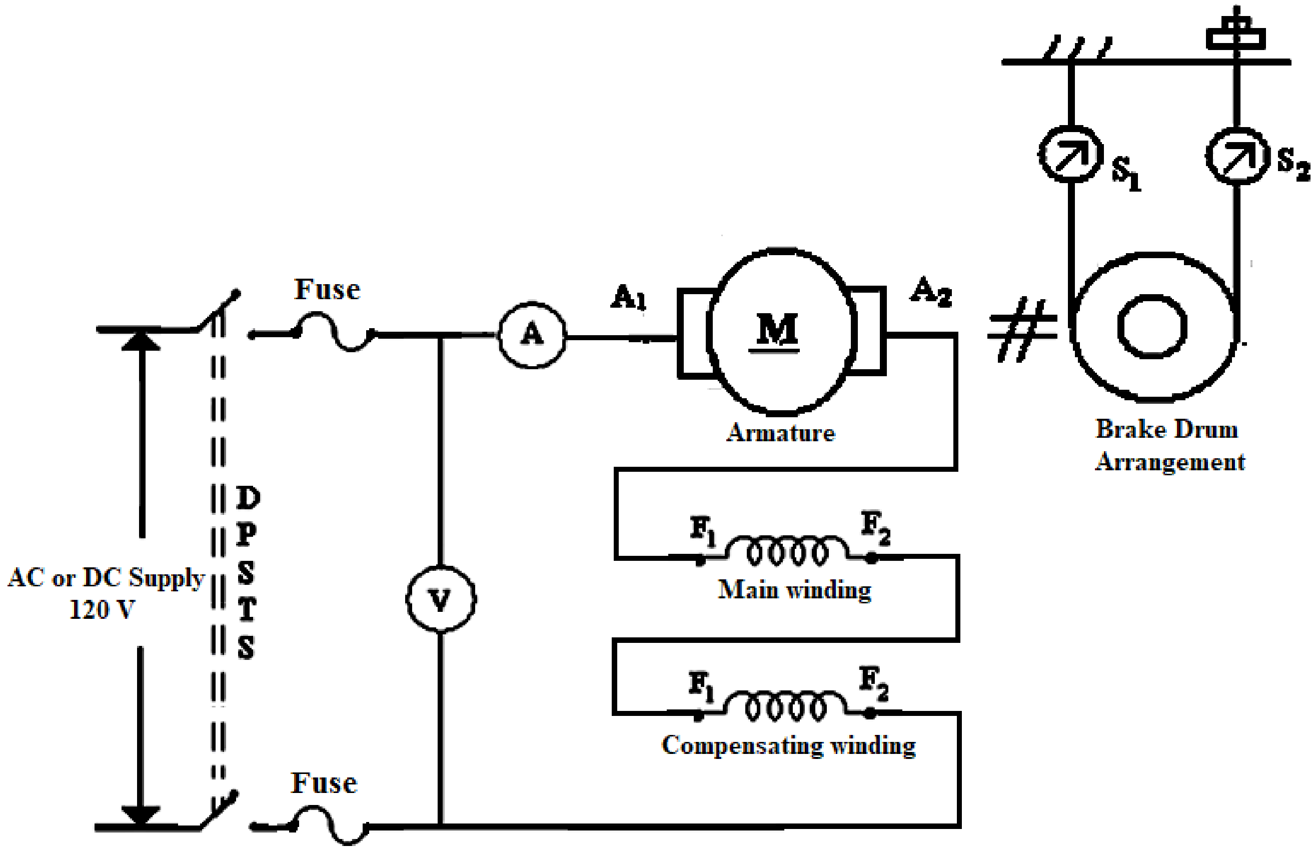
CIRCUIT DIAGRAM:



EXP.NO. 13 **DATE:**

LOAD TEST ON UNIVERSAL MOTOR

AIM:

To determine the performance characteristic of a given universal motor by conducting load test.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Tachometer			
5.	Connecting wires			

THEORY:

The universal motor is basically as series DC motor which is specially designed to operate on AC as well as on DC. A standard DC series motor has very poor characteristics when operated on AC, mainly due to two reasons:

a) The high reactance of both the armature and field windings limit AC current to a much lower value than DC current (for the same line voltage).
b) If solid steel is used for the stator frame, AC flux will produce large eddy currents in the frame with consequent heating.

The reactance of the armature winding can be lowered by placing a compensating winding on the stator so that the fluxes oppose or cancel each other. This same compensating winding can be connected in series with the armature winding. In this case, the motor is said to be conductively compensated. Under these conditions, the universal motor will have similar operating characteristics whether on AC or DC power.

The compensating winding may be simply shorted upon itself, so that it behaves like a short-circuited secondary of a transformer (the armature winding acting as the primary). The induced AC current in the compensating winding again opposes or 'bucks' the armature current and the motor is said to be inductively compensated. The reactance of the field winding can be kept low by limiting the number of turns.

TABULATION:

S. No.	Line Voltage V_L (V)	Line Current I_L (A)	Input Power W_i (Watts)	Speed (N) rpm	Spring Balance Reading		$(S_1 \sim S_2)$ Kg	Torque N-m	Output Power W_o (Watts)	% η
					S_1 Kg	S_2 Kg				

FORMULA:

1. Input power, W_i = W (in watts) For AC supply

   $\text{Input Power } W_i = V_L\ I_L \text{ Watts}$ For DC supply

2. Torque = $9.81 \times R \times (S_1 \sim S_2)$ Nm

   Where, R = Radius of brake drum of motor in meter

   S_1, S_2 = spring balance reading in kg

3. Output Power, $W_o = \frac{2\pi NT}{60}$ Watts

4. % Efficiency, $\eta = \frac{Outputpower}{Inputpower} \times 100$

PRECAUTION:

1. Ensure that some load is applied to the brake drum initially (S_1=S_2=5kg).
2. Ensure that there are no loose connections.
3. Under no circumstances, the motor should be unloaded fully during operation.
4. The motor should be cooled by circulating water in the brake drum throughout the experiment.

PROCEDURE:

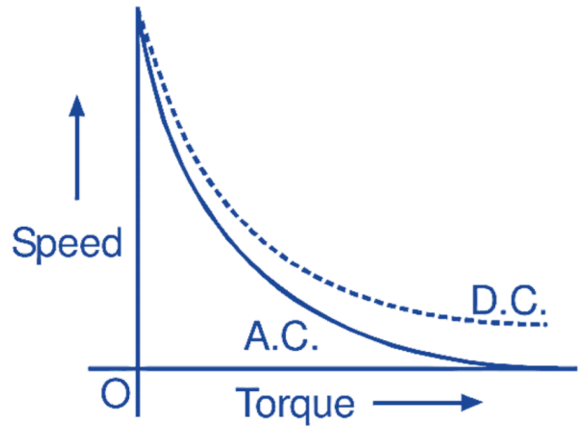
1. The connections are given as per the circuit diagram.
2. Ensure that some load is applied to the brake drum initially (S_1=S_2=5Kg).
3. Apply 120 V supply across the Universal motor by closing the DPST Switch.
4. Motor is started and the readings of ammeter, voltmeter, tachometer and spring balance are noted.
5. The load is then gradually increased in steps and the readings are noted up to rated load.
6. Decrease the load on the brake drum (until S_1=S_2=5Kg).
7. The motor is switched off using the DPST switch.

GRAPHS:

The graph is drawn for,

(1) Speed Vs Torque

MODEL GRAPH:



VIVA QUESTION:

1. **What is a universal motor?**
   There are small capacity series motors which can be operated on dc supply or single phase ac supply of same voltage with similar characteristics called universal motors.

2. **What are the types of compensated AC series motor?**
   Conductively compensated type of motors
   Inductively compensated type of motors

3. **What is non-compensated type AC series motor?**
   Non compensated type pole has 2 poles, having entire magnetic path as laminated. Armature is wound type similar to the normal DC motor and produces severe armature reaction which affects motor performance characteristics.

4. **What is compensated type AC series motor?**
   In compensated type, the motor has distributed field winding consisting of main field and compensating winding. It is used to compensate the armature flux which produce severe armature reaction and improve the performance characteristics.

RESULT:

Thus the load test on universal motor was performed and the respective graphs were drawn.

INFERENCE:

The load test on a universal motor refers the motor's speed, current drawn, torque, and efficiency under different load conditions.

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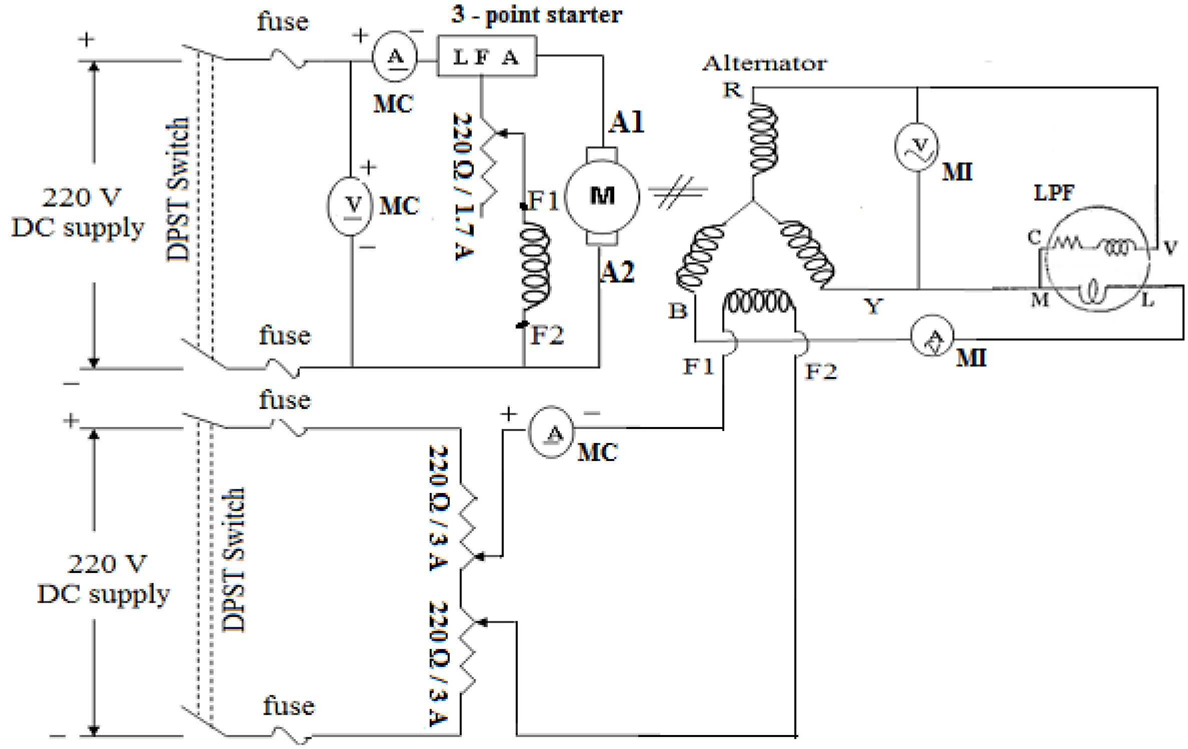
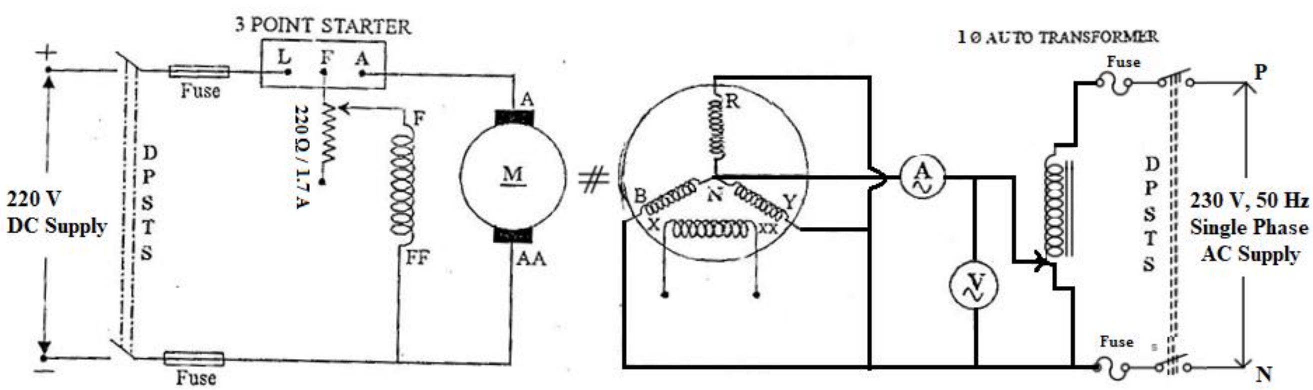
CIRCUIT DIAGRAM TO DETERMINE NEGATIVE SEQUENCE IMPEDANCE:



CIRCUIT DIAGRAM TO DETERMINE ZERO SEQUENCE IMPEDANCE:



EXP.NO. 14 **DATE:**

MEASUREMENTS OF NEGATIVE SEQUENCE AND ZERO SEQUENCE IMPEDANCE OF AN ALTERNATOR

AIM:

To determine the negative sequence and zero sequence impedance of an alternator.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Ammeter			
2.	Voltmeter			
3.	Wattmeter			
4.	Rheostat			
5.	Autotransformer			
6.	Tachometer			
7.	Connecting wires			

THEORY:

When a synchronous generator is carrying an unbalanced load its operation may be analyzed by symmetrical components. In a synchronous machine the sequence current produce an armature reaction which is stationary with respect to reactance and is stationary with respect to field poles. The component currents therefore encounter exactly same as that by a balanced load as discussed. The negative sequence is produced and armature reaction which rotates around armature at synchronous speed in direction to that of field poles and therefore rotates part the field poles at synchronous speed. Inducing current in the field damper winding and rotor iron. The impendence encountered by the negative sequence is called the – ve sequence impedance of the generator. The zero sequence current produce flux in each phase but their combined armature reaction at the air gap is zero. The impedance encountered by their currents is therefore different from that encountered by + ve and –ve sequence components and is called zero sequence impedance of generator.

Negative Sequence Impendence:

The –ve sequence impedance may be found by applying balanced –ve sequence voltage to the armature terminals. While the machine is drive by the prime mover at its rated synchronous speed with the field winding short circuited. The ratio of V/ph and Ia/ph gives –ve sequence Z/ph.The reading of the wattmeter gives I^2R losses. This loss/ph divided by Iph required gives the –ve sequence R/ph from the impedance and reactance/ph. –ve sequence can be calculated. Another method of measuring –ve sequence reactance is found to be connect the arm terminals. The machine is driven at synchronous speed and field current adjusted until rated current flows in the phases shorted through armature and current coil of wattmeter respectively.

Negative Sequence Impedance, $Z_2 = \dfrac{V_{RY}}{\sqrt{3}I_{SC}}$ in Ω

Negative Sequence Reactance, $X_2 = Z_2 \times \left(\dfrac{W}{V_{RY} \times I_{SC}}\right) = \dfrac{W}{\sqrt{3}I_{SC}{}^2}$ in Ω

TABULATION FOR NEGATIVE SEQUENCE REACTANCE:

S. No.	Voltage V_{RY} (V)	Current I_{SC} (A)	Power W (Watts)	Negative Sequence Impedance $Z_2 = \frac{V_{RY}}{\sqrt{3}I_{SC}}$	Negative Sequence Reactance $X_2 = Z_2 \times \left(\frac{W}{V_{RY} \times I_{SC}} \right)$	Average X_2 (Ω)

TABULATION FOR ZERO SEQUENCE REACTANCE:

S. No.	Voltage V (V)	Current I (A)	Zero Sequence Impedance Z_0 (Ω)	Zero Sequence Reactance $X_0 = \frac{3V}{I}$ (Ω)	Average X_0 (Ω)

Zero Sequence Impedance:

The sequence impedance may be determined by the connecting the armature windings of the three phase in series and then connecting them to the single phase source of power. If the machine is driven at synchronous speed with field winding shorted, then Z_0=V/3I practically the same results will be obtained with rotor stationary. If windings are connected in parallel, then

Zero Sequence Impedance, $Z_0 = \frac{3V}{I}$ in Ω

Zero Sequence Impedance, $X_0 = Z_0$ in Ω

FORMULA:

1. Negative Sequence Impedance, $Z_2 = \frac{V_{RY}}{\sqrt{3}I_{SC}}$ in Ω
2. Negative Sequence Reactance, $X_2 = Z_2 \times \left(\frac{W}{V_{RY} \times I_{SC}} \right)$ = $\frac{W}{\sqrt{3}I_{SC}{}^2}$ in Ω
3. Zero Sequence Impedance, $Z_0 = \frac{3V}{I}$ in Ω
4. Zero Sequence Impedance, $X_0 = Z_0$ in Ω

PRECAUTION:

1. All the switches should be kept open at the time of starting the experiment.
2. The DC motor field rheostat should be kept at minimum resistance position at the time of starting the experiment.
3. The generator field potential divider should be kept at minimum potential position.
4. The auto transformer should be kept at minimum potential position.

PROCEDURE:

(A) For Negative Sequence Reactance:

1. Make connection as shown in circuit diagram.
2. Run DC motor with synchronous speed.
3. Keeping the speed constant, vary the excitation and measure the voltmeter, ammeter and wattmeter reading.
4. Take 3 - 4 readings for different excitation.
5. The excitation should not be increased beyond the rated capacity of synchronous machine.

(B) For Zero Sequence Reactance:

1. Make connection as shown in circuit diagram.
2. Switch on the AC supply by keeping autotransformer in zero volt position.
3. Gradually increase the autotransformer output by varying the variac and note the ammeter reading for suitable voltage applied.
4. It should be kept in mind that the ammeter reading should not exceed the rated current capacity of the machine.

VIVA QUESTION:

1. **What are sequence impedance and sequence networks?**
   The sequence impedances are the impedances offered by the devices or components for the like sequence components of the current.
   The single phase equivalent circuit of a power system consisting of impedances to current of any sequence only is called sequence network.
2. **What are negative sequence components?**
   It consists of three vectors of equal magnitude, displaced from each other by 120 degree in phase and having the phase sequence opposite to that of the original vectors.
3. **What are zero sequence components?**
   It consists of three vectors of equal magnitude, and with zero phase displacement from each other.
4. **Define negative sequence impedance?**
   It is the impedance offered by the equipment to the flow of negative sequence current.
5. **Define zero sequence impedance?**
   It is the impedance offered by the equipment to the flow of zero sequence current.

RESULT:

Thus the negative sequence and zero sequence impedance of an alternator were determined.

INFERENCE:

These impedance tests are used to ensure that the alternator operates safely and efficiently, even under unbalanced load conditions, and to improve the robustness of the machine under fault conditions.

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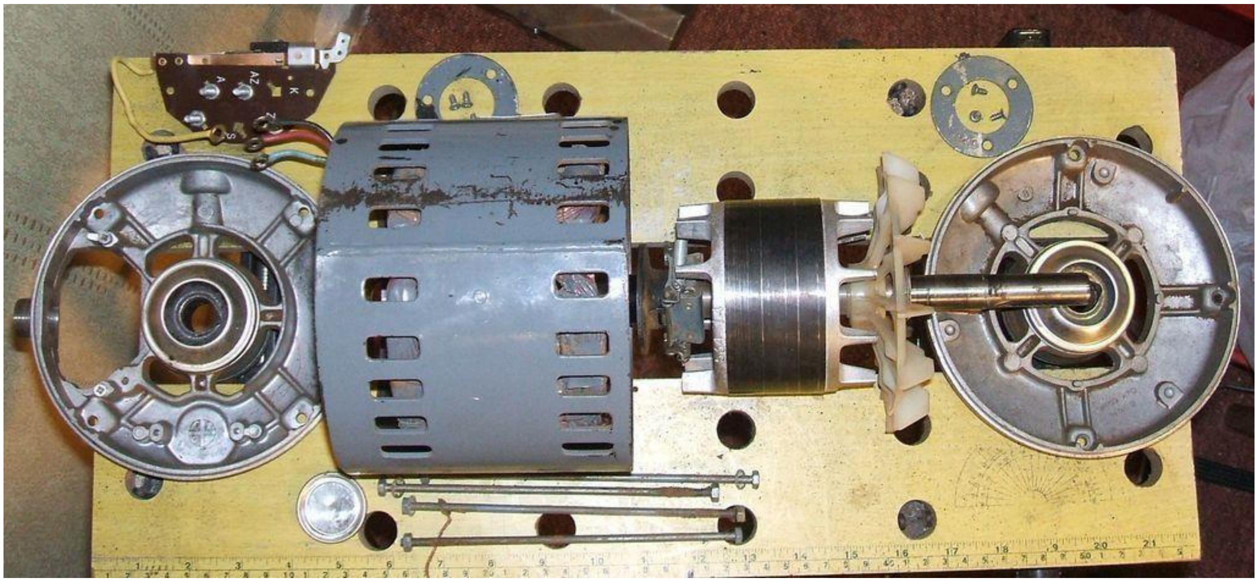

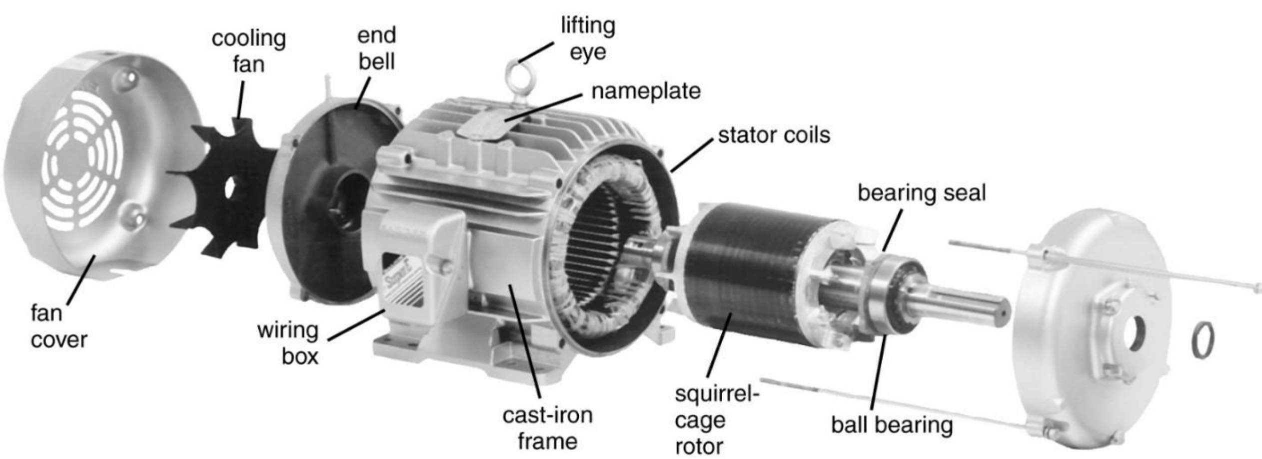
cooling fan
end bell
lifting eye
nameplate
stator coils
bearing seal
fan cover
wiring box
cast-iron frame
squirrel-cage rotor
ball bearing

EXP.NO.15 **DATE:**

ASSEMBLING AND TESTING OF AC MACHINES

AIM:

To dismantle and assemble an AC machine and do the different performance tests.

APPARATUS REQUIRED:

S.No	Name of apparatus	Range	Type	Qty.
1.	Multimeter			
2.	Insulation tape			
3.	Knife			
4.	Spanner			
5.	Screw driver			
6.	Tester			
7.	Connecting wires			

THEORY:

AC machines are motors that convert ac electric energy to mechanical energy and generators that convert mechanical energy to ac electric energy. The two major classes of ac machines are synchronous and induction machines. The field current of synchronous machines (motors and generators) is supplied by a separate dc power source while the field current of induction machines is supplied by magnetic induction (transformer action) into the field windings.

AC machines differ from dc machines by having their armature windings almost always located on the stator while their field windings are located on the rotor. A set of three-phase ac voltages is induced into the stator armature windings of an ac machine by the rotating magnetic field from the rotor field windings (generator action). Conversely, a set of three-phase currents flowing in the stator armature windings produces a rotating magnetic field within the stator. This magnetic field interacts with the rotor magnetic field to produce the torque in the machine (motor action).

Basic Parameters to be checked

Current

As line current in all the phases are not equal so the arithmetic mean of the phase currents should be used for evaluating machine performance.

Voltage

Voltage is measured at the motor terminals and at the time of test, it should be approximately balanced. Machine performance can be calculated by using average of the phase voltages.

Power

Power input to three phase motor can be calculated by two single wattmeters as they are connected in two wattmeter method.

Resistance

It is necessary to check the ground resistance between the motor body and terminals of the machine.

Tests for Induction Motor

Number of test is done on AC machine to check its different parameters. All the tests are divided into two parts:

Preliminary Tests

These tests are performed to check the electrical or mechanical defects of the AC machine.

1. Firstly check the components of AC machine like
   - Broken rotor bars
   - High resistance joints
   - Cracked end rings
2. No-load running current test
3. High potential test
4. Air-gap measurement
5. Balancing of current
6. Temperature rise in bearing
7. Voltages in shaft
8. Direction of rotation
9. Level of noise
10. Strength of vibration
11. Air gap eccentricity

Performance Tests

The purpose of these tests is to estimate the performance characteristics of the AC machine. Along with preliminary tests, these tests are also done on AC machine.

1. No load test
2. Locked rotor test
3. Breakdown torque load performance test
4. Temperature test
5. Stray load loss test
6. Determination of efficiency test

STEPS TO DISMANTLE AN AC MACHINE

1. First of all, remove the pulley of motor on the shaft, also remove the fan cover and then open the fan which is screwed on the shaft of motor for cooling purpose.
2. The shaft or pulley of the motor is always in front of your eyes and then you mark a line on the cover and yoke. The advantage of this line is that, when you closing the motor you easily meet these mark points and close the motor cover.
3. Open the nut-bolts or screws of the end cover of the motor by using spanner or screw driver.
4. Two screw drivers are inserted in motor cover and apply a little pressure internally as a result;the cover of the motor is easily opened.
5. After that, the rotor of the motor easily comes out.
6. The bearings of the motor are dip into kerosene oil and then apply the grease into the bearing.
7. Clean the stator of the motor carefully.

STEPS TO ASSEMBLE AN AC MACHINE

1. First of all, the end cover of the motor is screwed with the yoke.
2. Enter the rotor of the motor in stator.
3. Fit the rotor in exact position in stator and then screwed the front cover of the motor.
4. The cooling fan of the motor is screwed on the shaft.
5. In last, tight the cover of the cooling fan with the yoke of the motor.

RESULT: -

Thus the dismantling and assembling of an AC machine was done and different performance tests were performed.

INFERENCE:

This hands-on experiment not only helps in diagnosing and maintaining the machine but also enhances the understanding of AC machines operation and the importance of their regular maintenance.

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