MAHA BARATHI ENGINEERING COLLEGE

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Department of Electrical and Electronics Engineering

EE3411– Electrical Machines- II Laboratory

LAB MANUAL

II Year- IV Semester - Electrical and Electronics Engineering

Academic Year 2023-2024

(2021 Regulation)

EE-3411 ELECTRICAL MACHINES LABORATORY - II

OBJECTIVES:

To expose the students to the operation of synchronous machines and induction motors and give them experimental skill.

LIST OF EXPERIMENTS:

1. Regulation of three phase alternator by EMF and MMF methods.
2. Regulation of three phase alternator by ZPF methods.
3. Determination of direct axis reactance X_d and quadrature axis X_q of a salient pole alternator by Slip test.
4. Measurements of Negative sequence and Zero sequence impedance of Alternators.
5. V and Inverted V curves of Three Phase Synchronous Motor.
6. Load test on Three-phase Induction motor.
7. No load and Blocked rotor test on Three-Phase Induction motor. (Determination of equivalent Circuit parameters)
8. Pre determination of Characteristics Three phase squirrel cage Induction motor from No load and Blocked rotor test using Circle diagram.
8. Separation of No-load losses of Three-phase Induction motor.
9. Load test on Single-phase Induction motor.
10. No load and blocked rotor test on Single-phase Induction motor.
11. Study of Induction motor starters.

OUTCOMES:

- Ability to model and analyze electrical apparatus and their application to power system

CYCLE-1

1. Load test on 3-phase squirrel cage induction motor.
2. Load test on 3-phase slip ring induction motor
3. No load and blocked rotor test on three phase induction motor.
4. Separation of no load losses of three phase induction motor.
5. Load test on 1-phase induction motor.
6. No load and blocked rotor test on single phase induction motor.
7. Study of Induction motor Starters

CYCLE-2

8. V and inverted V curves of three phase synchronous motor.
9. Regulation of three phase alternator by EMF method.
10. Regulation of three phase alternator by MMF method.
11. Regulation of 3 alternator by ZPF method.
12. Regulation of three phase salient pole alternator by slip test.
13. Measurement of negative sequence and zero sequence impedance of an alternator.

INDEX

S.NO	DATE	NAME OF THE EXPERIMENT	MARKS OBTAINED OUT OF 10.	STAFF SIGNATURE
1				
2				
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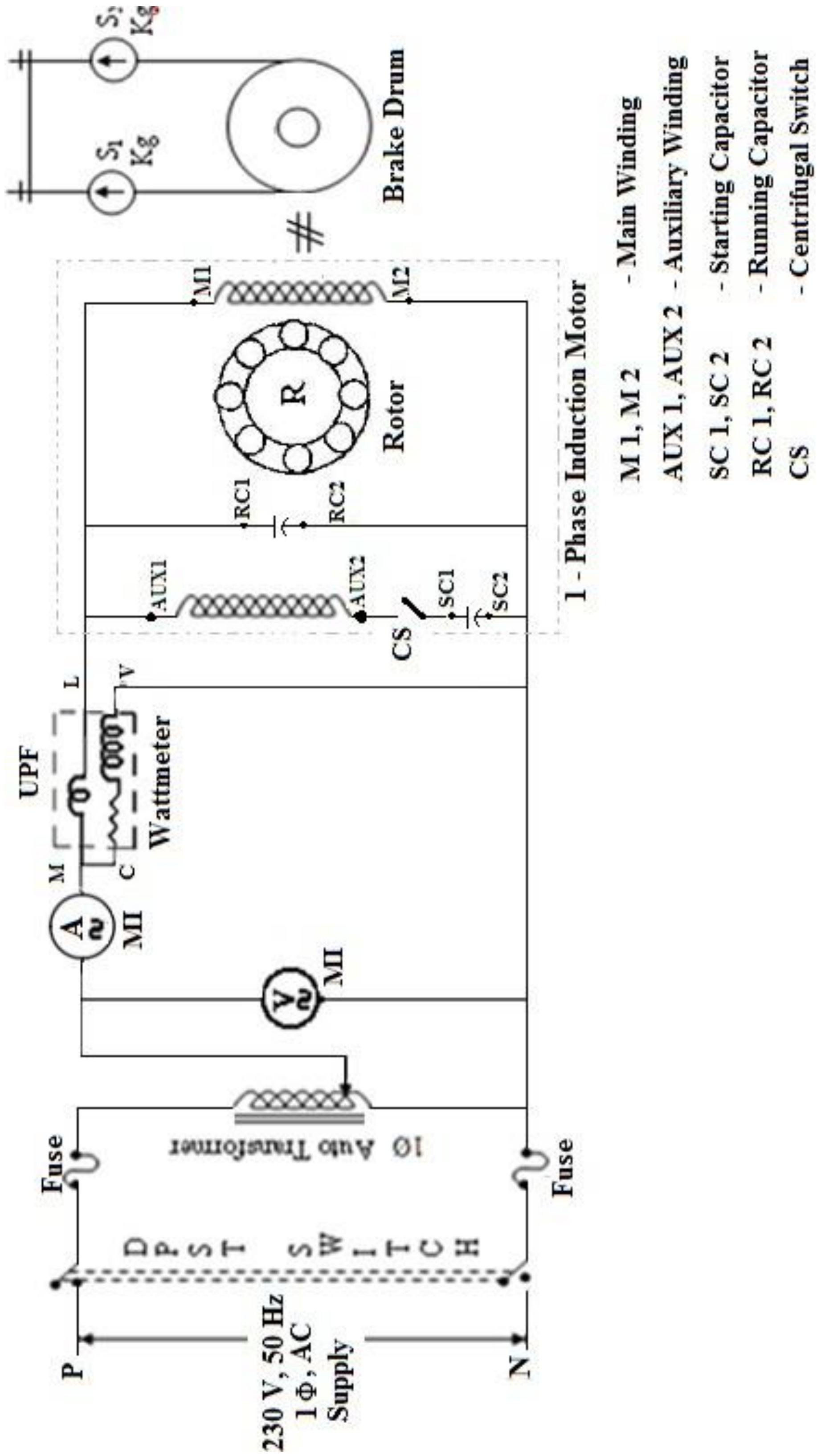
Completed Date: …………………..

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	
1.	218	7.5	480	480	1470	1	3	2

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque N-m	%Slip	Input Power P_i (W)	Output Power (W)	% η
1.	0.293	2.15	2	960	330.79	68.9

FORMULA USED:

1. Input power, P_i = W (in watts)
2. Torque = ($S_1 \sim S_2$) × R × 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, $\eta = \frac{Outputpower}{Inputpower} \times 100$
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
1.	218	7.5	480	480	1470	1	3	2

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque	Slip	Input Power P_i	Output Power	η
	No unit	N-m	%	W	W	%
1.	0.202	2.15	2	960	330.79	68.9

PRECAUTION:

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

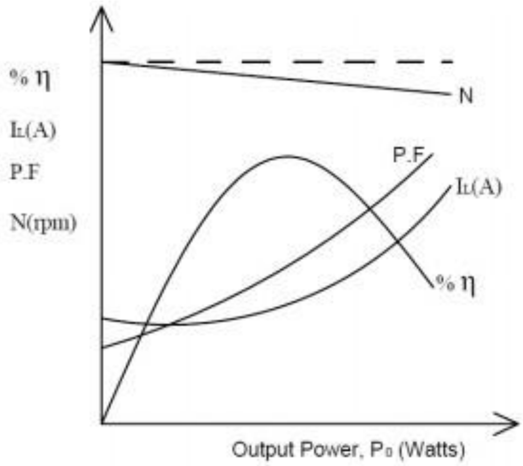
PROCEDURE:

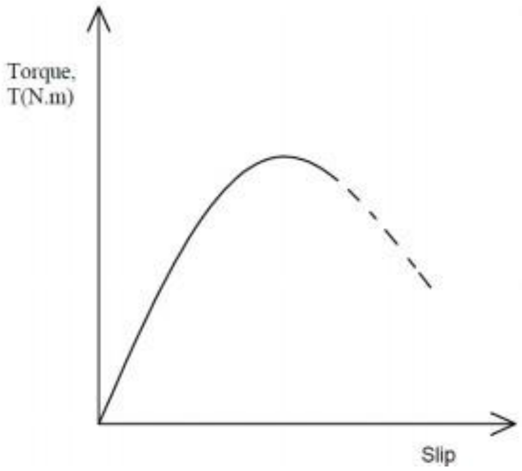
1. Connections are given as per the circuit diagram.
2. Switch on the supply at no load condition.
3. Apply the rated voltage to the motor by adjusting autotransformer.
4. The no load readings are taken.
5. Vary the load in suitable steps and note down all the readings till rated current is reached.

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 %

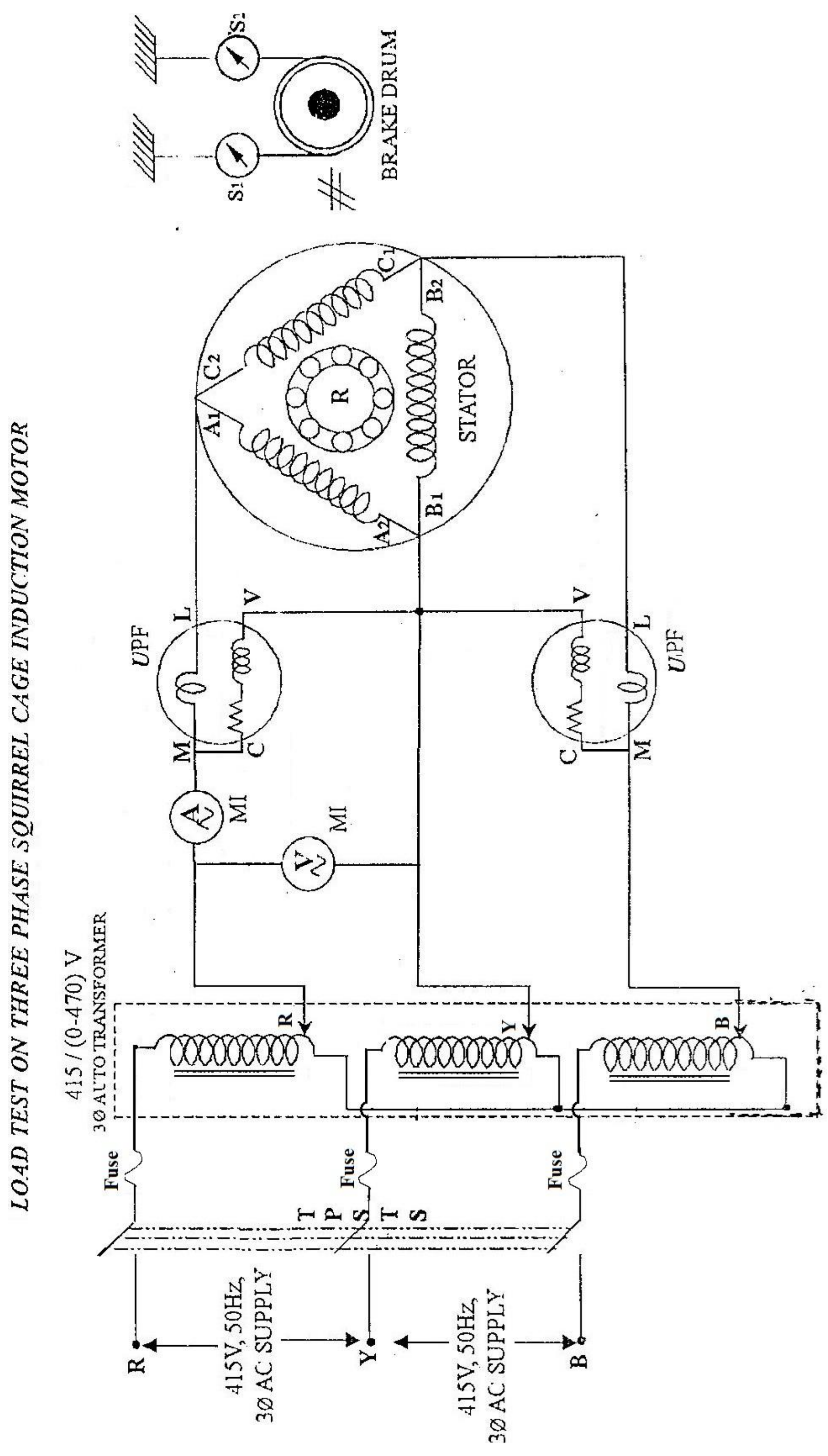
5. Slip = $\frac{N_S - N}{N_S} \times 100$
   $N_S = \frac{120 f}{P}$
   $N_S = \frac{120 \times 50}{4} = 1500$
   Slip = $\frac{1500 - 1470}{1500} \times 100$ = 2%

6. Power factor = $\cos\phi = \frac{P_{in}}{V_L I_L}$
   $= \frac{480}{218 \times 7.5} = 0.202(no unit)$

RESULT:

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

CIRCUIT DIAGRAM



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	
1.	410	5.6	100	400	400	1600	1465	18	5	13

Calculation Tabulation:

S.No.	Power Factor = $\cos\phi$	Torque N-m	%Slip	Input Power P_i (W)	Output Power (W)	% η
1.	0.48	12.49	2.3	2000	1916.14	95.8

FORMULA:

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

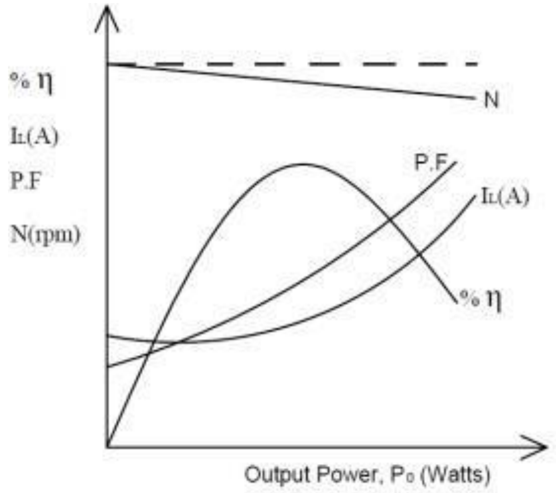
   N_r=speed of the rotor in rpm

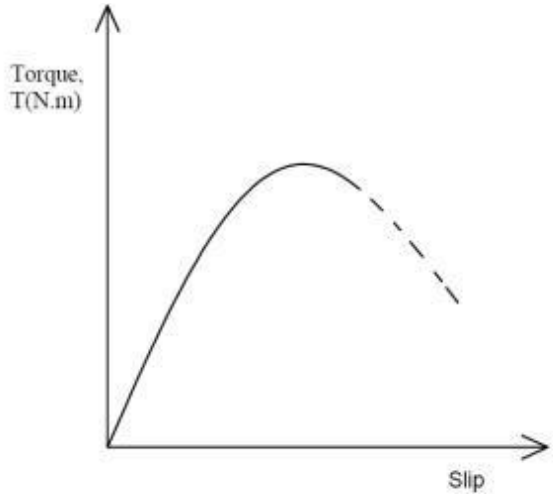
   Where, R = Radius of brake drum of motor in meter

   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.

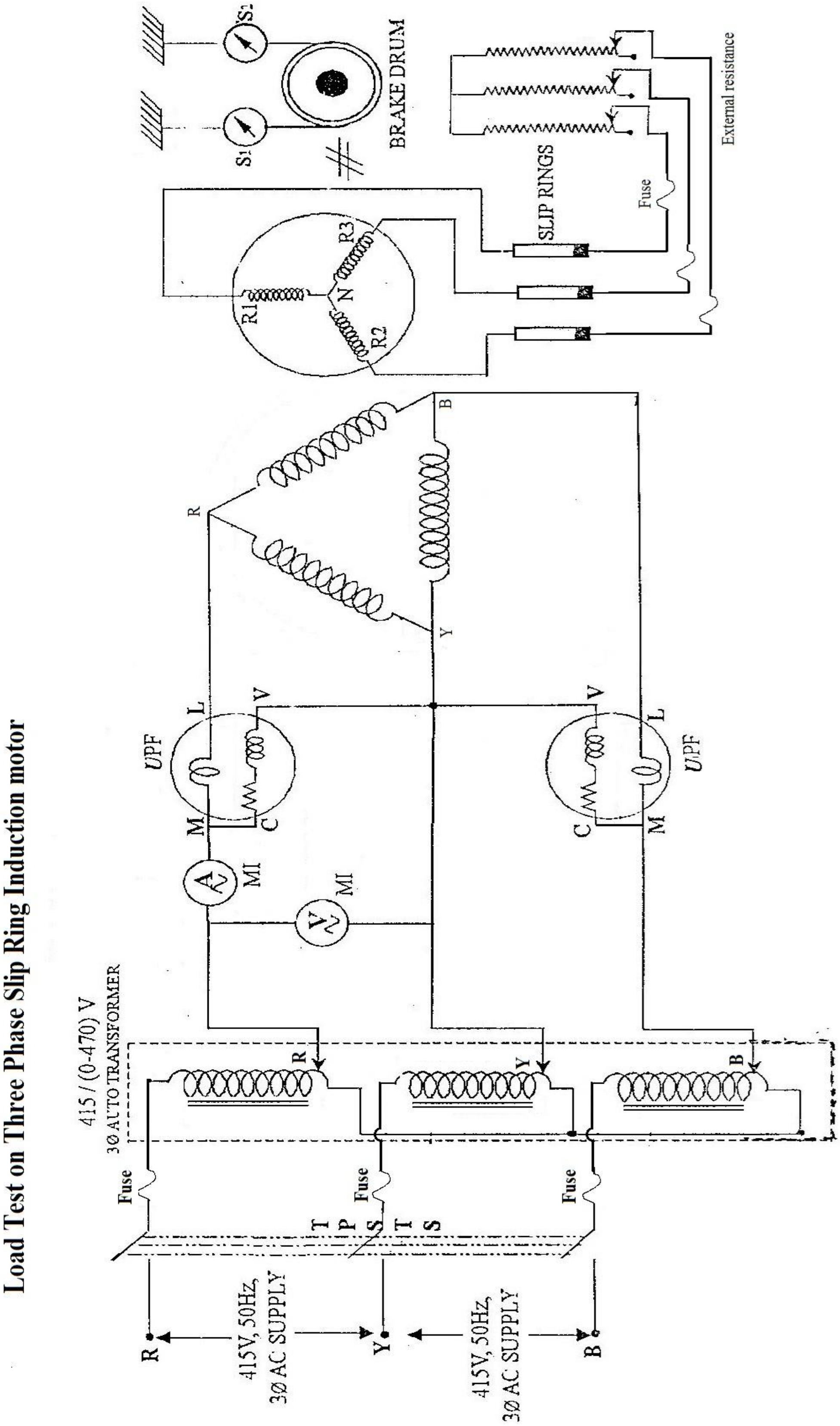
GRAPHS:

1. Output Power Vs Efficiency
2. Output Power Vs Torque
3. Output Power Vs Speed
4. Output Power Vs %s

RESULT:

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

Load Test on Three Phase Slip Ring Induction motor



EX.NO.3 **Date:**

LOAD TEST ON THREE PHASE SLIP RING INDUCTION MOTOR

AIM :

To conduct a direct load test on a 3-phase slip ring induction motor and to draw 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:

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

Slip Ring Rotor or Wound Rotor

In this type of construction, rotor winding is exactly similar to the stator. The rotor carries a three phase star or delta connected, distributed winding, wound for same number of poles as that of stator. The rotor construction is laminated and slotted. The slots contain the rotor winding. The three ends of three phase winding, available after connecting the winding in star or delta, are permanently connected to the slip rings. The slip rings are mounted on the same shaft. So in this type of rotor, the external resistances can be added with the help of brushes and slip ring arrangement, in series with each phase of the rotor winding.

When a three phase supply is given to the three phase stator winding, a rotating magnetic field of constant magnitude is produced. So its obvious that there exists a relative motion between the R.M.F. and rotor conductors. Whenever conductors cuts the flux, e.m.f. gets induced in it. So e.m.f. gets induced in the rotor conductors called rotor induced e.m.f. As rotor forms closed circuit, induced e.m.f. circulates current through rotor called rotor current. This rotor current produces another flux called rotor flux required for the motoring action. When rotor starts rotating, it tries to catch the speed of rotating magnetic field. But due to inertia of rotor, this does not happen in practice and motor continues to rotate with a speed slightly less than the synchronous speed of the rotating magnetic field in the steady state.

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 ~ S_2) Kg
			W_1		W_2					
			Obs.	Act.	Obs.	Act.		S_1 Kg	S_2 Kg	
1.	413	8	580	2320	- 40	-160	973	18	5	13

Calculation Tabulation:

S.No.	Power Factor = cosϕ	Torque N-m	%Slip	Input Power P_i (W)	Output Power (W)	% η
1.	0.273	15.38	2.7	2160	1567.3	72.56

FORMULAE USED:

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 = $\cos\phi = \frac{P_{in}}{\sqrt{3} V_L I_L}$

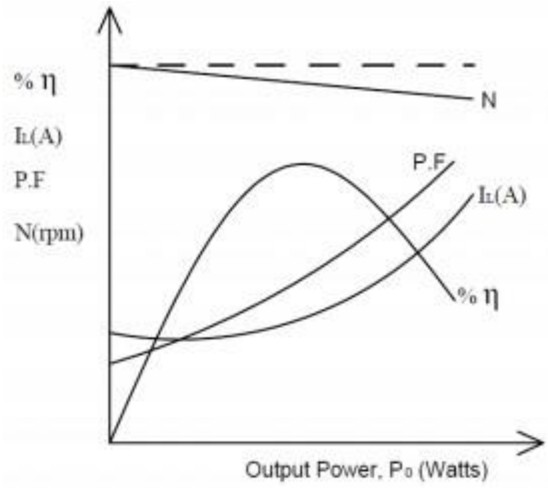
PRECAUTIONS:

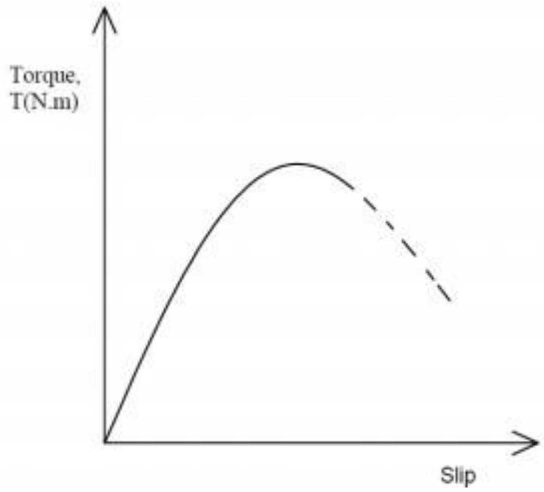
1. 3-phase autotransformer should be at minimum voltage position.
2. There should be no-load at the time of starting.
3. The external resistance in the rotor circuit should be kept at maximum value.

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. As speed increases, the external resistance is gradually cut out.
5. If any Wattmeter shows negative reading then interchange M and L connections.
6. The no load readings are taken.
7. Vary the load in suitable steps and note down all the readings till rated current is reached.

MODEL GRAPHS:





MODEL CALCULATION:

1. Torque = ($S_1 \sim S_2$) × 9.81 × R
   = 16 × 9.81× 0.098
   = 15.38 Nm
2. Output Power = $\frac{2\pi NT}{60}$
   $= \frac{2\pi \times 973 \times 15.38}{60}$
   = 1567.3 Watts
3. % η = $\frac{Output}{Input} \times 100$
   $= \frac{1567.3}{2160} \times 100$ = 72.56 %
4. Slip = $\frac{N_S - N}{N_S} \times 100$
   $= \frac{1000-973}{1000} \times 100 = 1.4\%$
5. Power factor = $\cos\phi = \frac{P_{in}}{\sqrt{3} V_L I_L}$
   $= \frac{1567.3}{\sqrt{3} \times 413 \times 8} = 0.273$

GRAPHS:

1. O/P power vs Speed
2. O/P power vs Torque
3. O/P Power vs η
4. O/P Power vs slip
5. Torque vs Speed
6. Torque vs Slip

RESULT:

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

VIVA QUESTIONS:

1. **What is the function of slip rings and brush assembly in three phase induction motor?**
   Slip rings are used to connect external stationary circuit to the internal rotating circuit. Hence in induction motor, the external resistances can be added with the help of brushes and slip ring arrangement in series with each phase of rotor winding.
2. **List the difference between squirrel cage rotor and slip ring rotor**

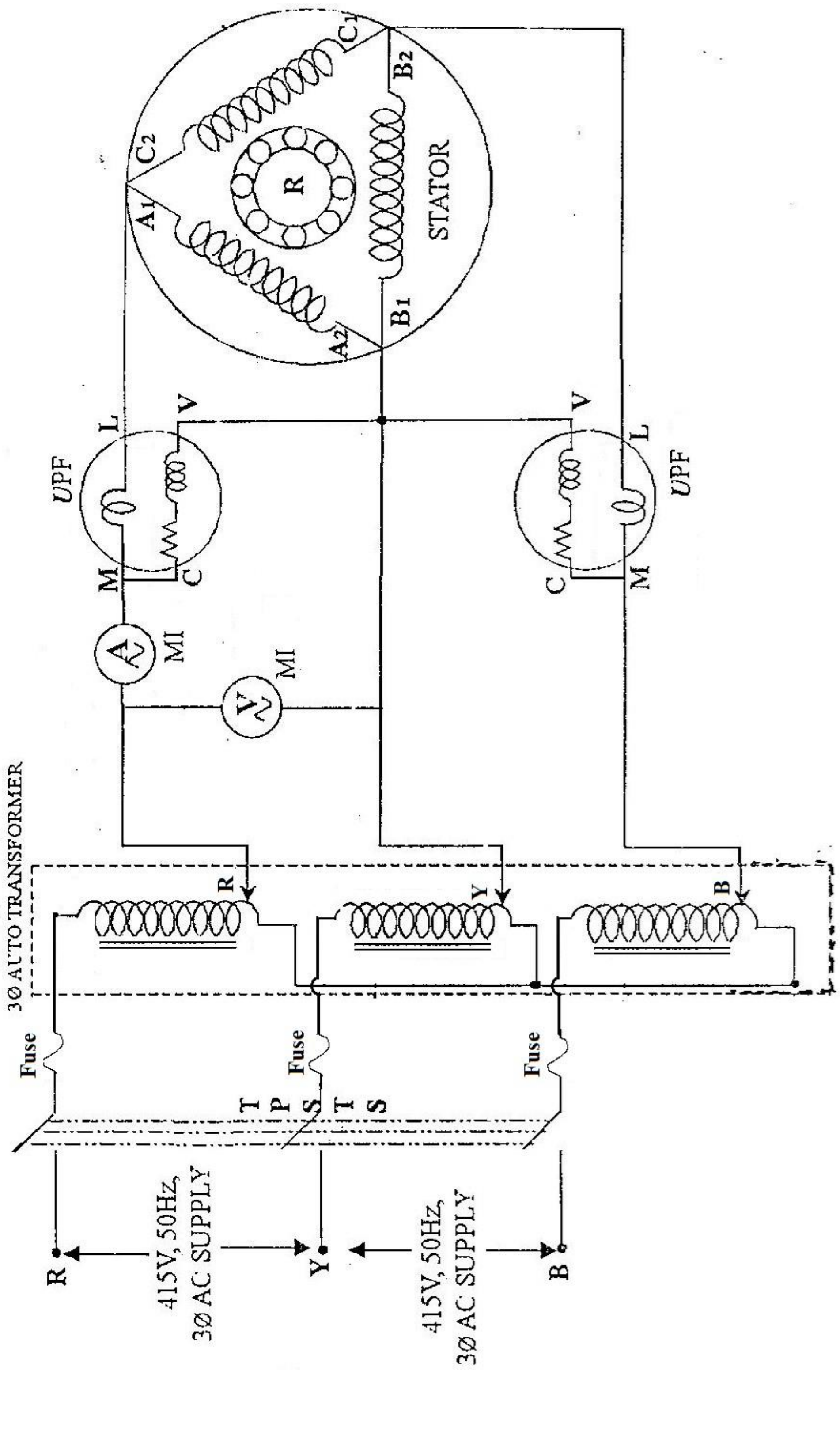
S.no	SLIP RING ROTOR	SQUIRREL CAGE ROTOR
1.	Rotor consists of winding similar to the stator winding.	Rotor consists of bars which are short circuited at the ends with the help of end rings.
2.	Resistances can be added externally.	External resistances cannot be added.

3. **Define the term slip**
   Slip of the induction motor is defined as the difference between the synchronous speed and actual speed of rotor expressed as a fraction of the synchronous speed.
4. **In which type of induction motor can resistance be introduced in the rotor circuit?**
   In slip ring induction motor the resistance can be introduced in the rotor circuit.
5. **Under what condition, the slip in an induction motor is zero, one, negative and greater than one.**
   Zero: when N =Ns, S=0 which is not possible for an induction motor.
   One: when N = 0, S=1. At start motor is at rest and hence its speed Nis zero.
   Negative: When the rotor is running at a speed above synchronous speed, slip is negative.
   Greater than one: When the motor is rotated in opposite direction to that of rotating field, Slip is greater than 1. When slip is greater than one, the machine works in breaking mode.

APPLICATIONS:

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

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.
1.	415	4.4	600	1200	-400	-800

Calculation Tabulation:

S.No.	Total Input power (Watts)	Stator copper loss (Watts)	Constant loss / Phase	Core loss / Phase (Watts)
1.	400	598.95	66.8	46.8

PRECAUTIONS:

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

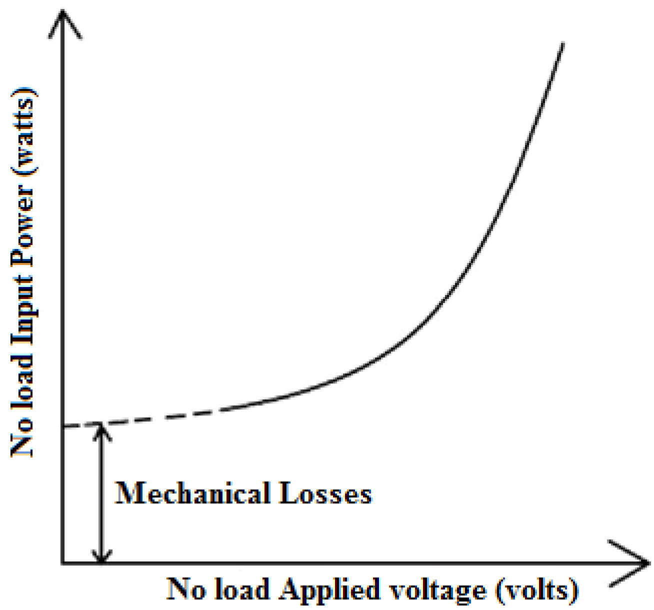
PROCEDURE:

(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 GRAPHS:



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

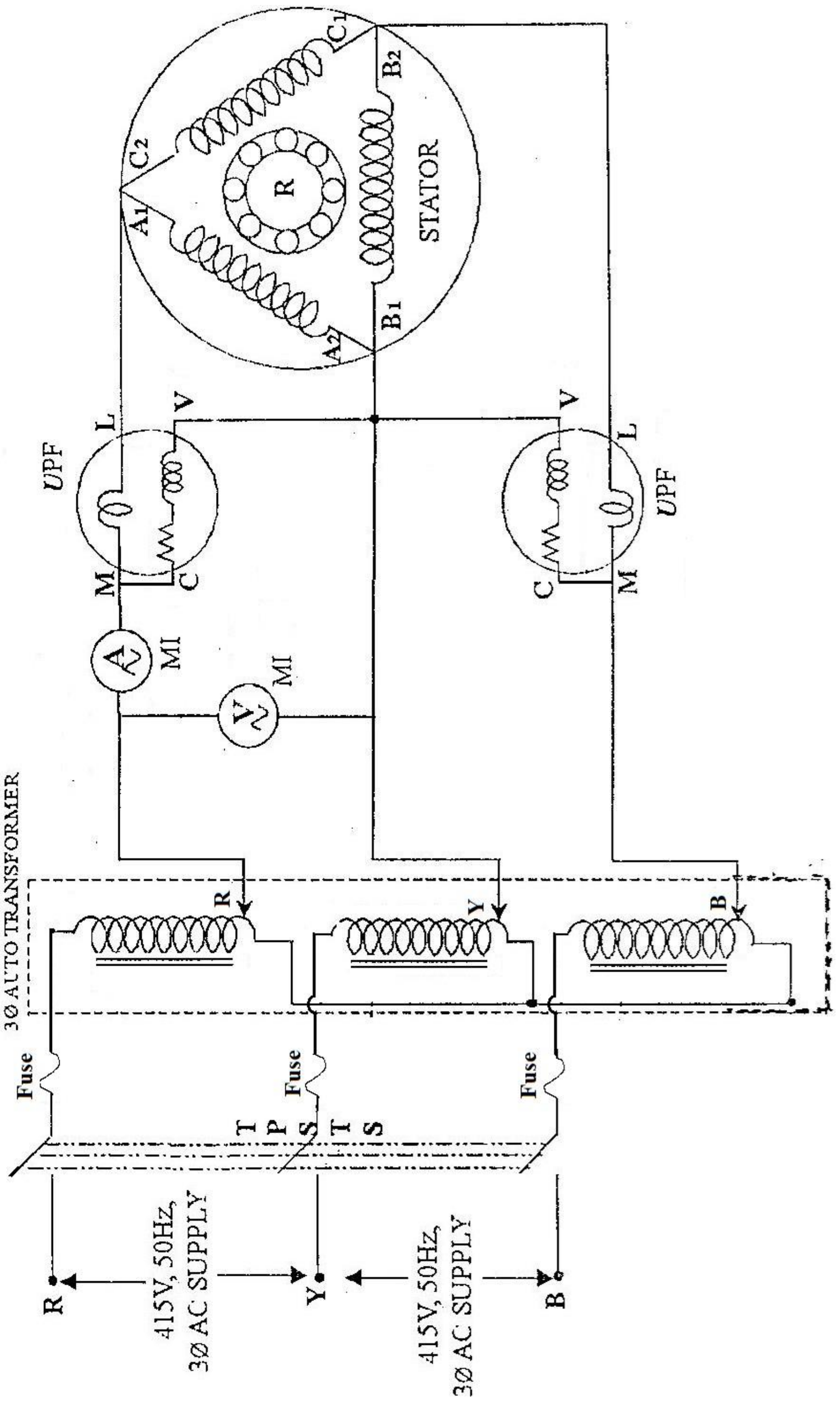
   Where, $W_m = 20$

RESULT:

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

NO LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Equivalent Circuit)



EX.NO.4 **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.

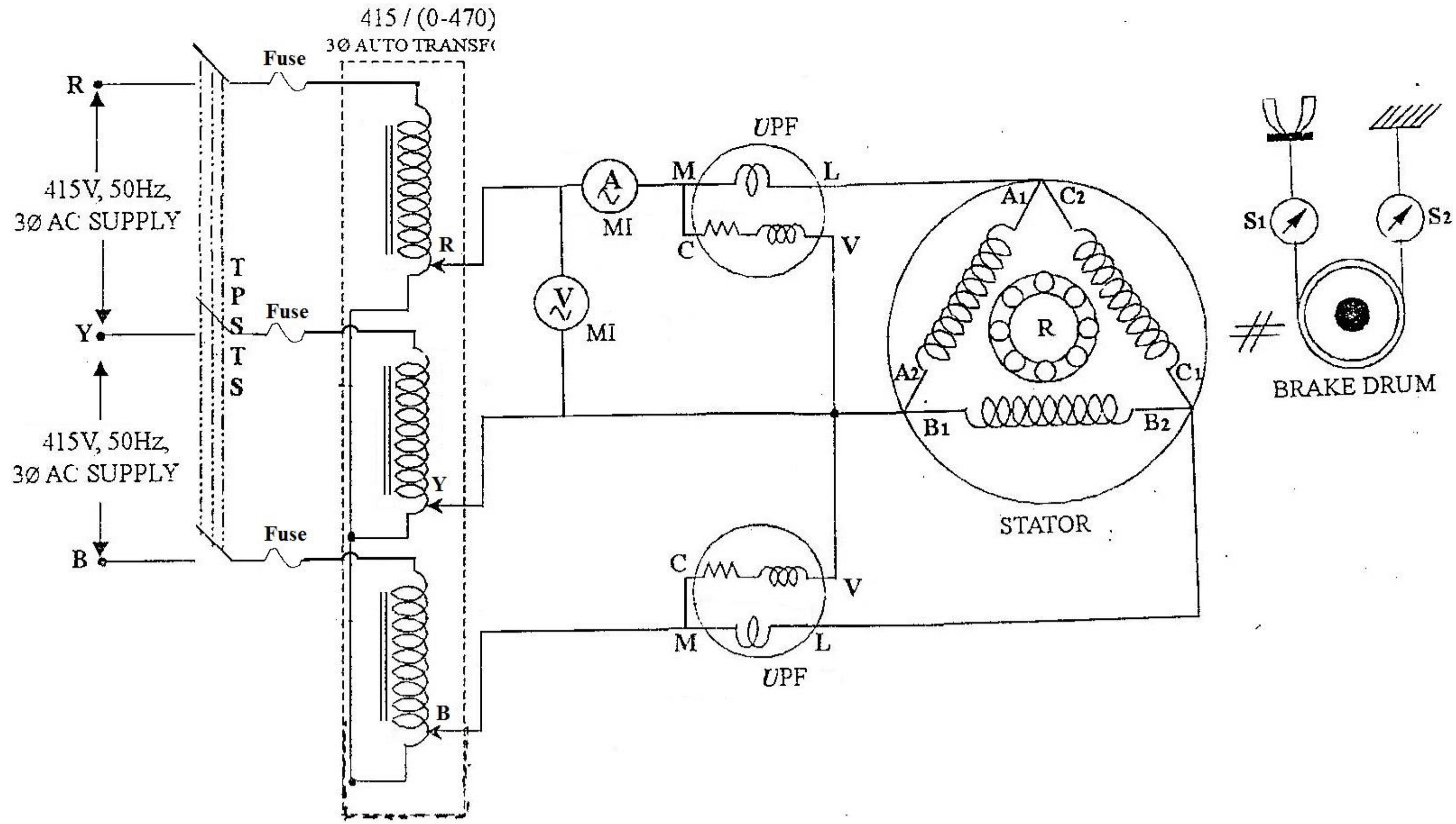
The power input W_o consists of following losses,

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.

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

<u>FORMULA USED:</u>

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	
1	415	4.1	-120	-240	260	520	280

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	
1.	94	7.5	10	10	520	520	530

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

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.

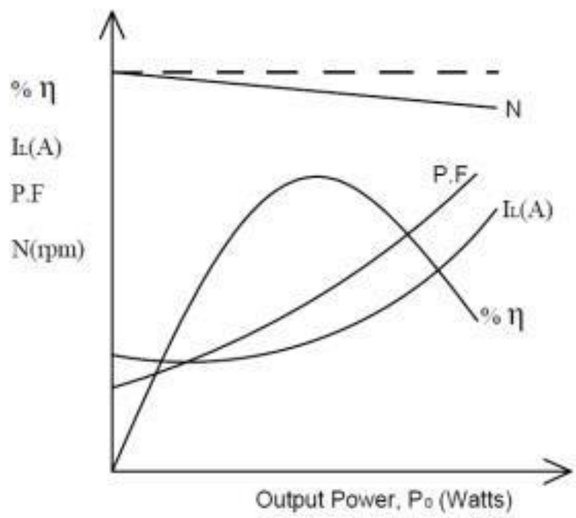
PROCEDURE:

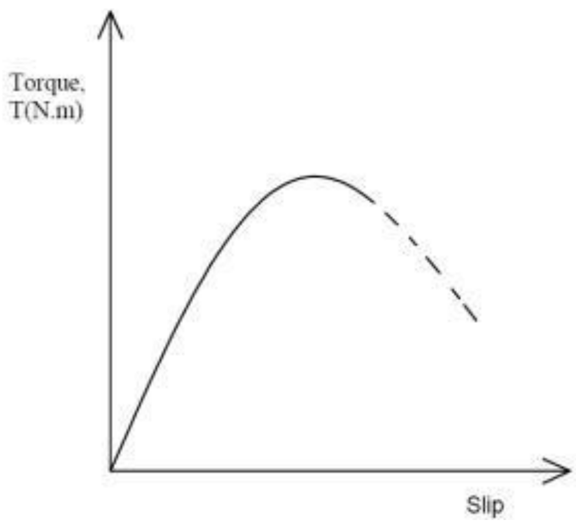
(1) Connections should be made as per the circuit diagram.
(2) Adjust the autotransformer till rated current is reached.
(3) If any Wattmeter shows negative reading then interchange M and L connections.
(4) The meter readings are then tabulated.

Calculation Tabulation:

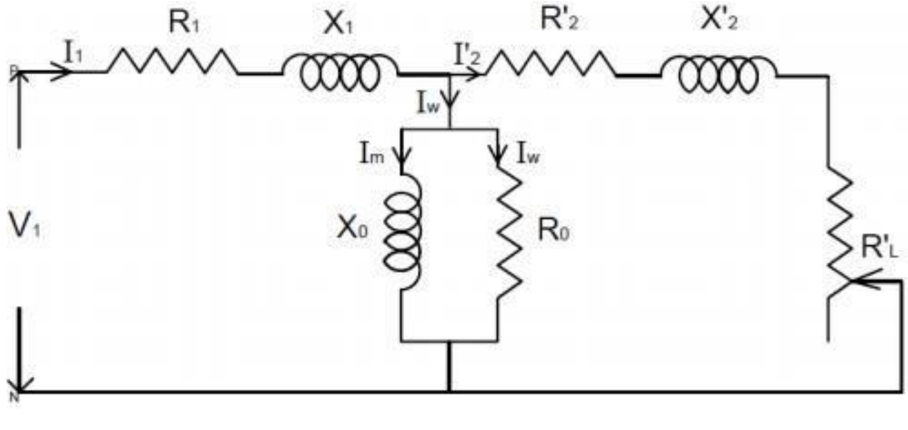
S.No.	% Slip	Speed (rpm)	Rotor current per phase I_2' (A)	Resultant Current I_1 (A)	cosΦ	Output power (Watts)	Input power (Watts)	% Efficiency	Torque (N-m)
1	0.02	1470	0.83	4.23	0.289	587.3	878.7	66.8	3.81
2	0.04								
3	0.06								
4	0.08								
5	0.1								

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 Ω

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

N = 1500 × (1 – 0.02) = 1470 rpm

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

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

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

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

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

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

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

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

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

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

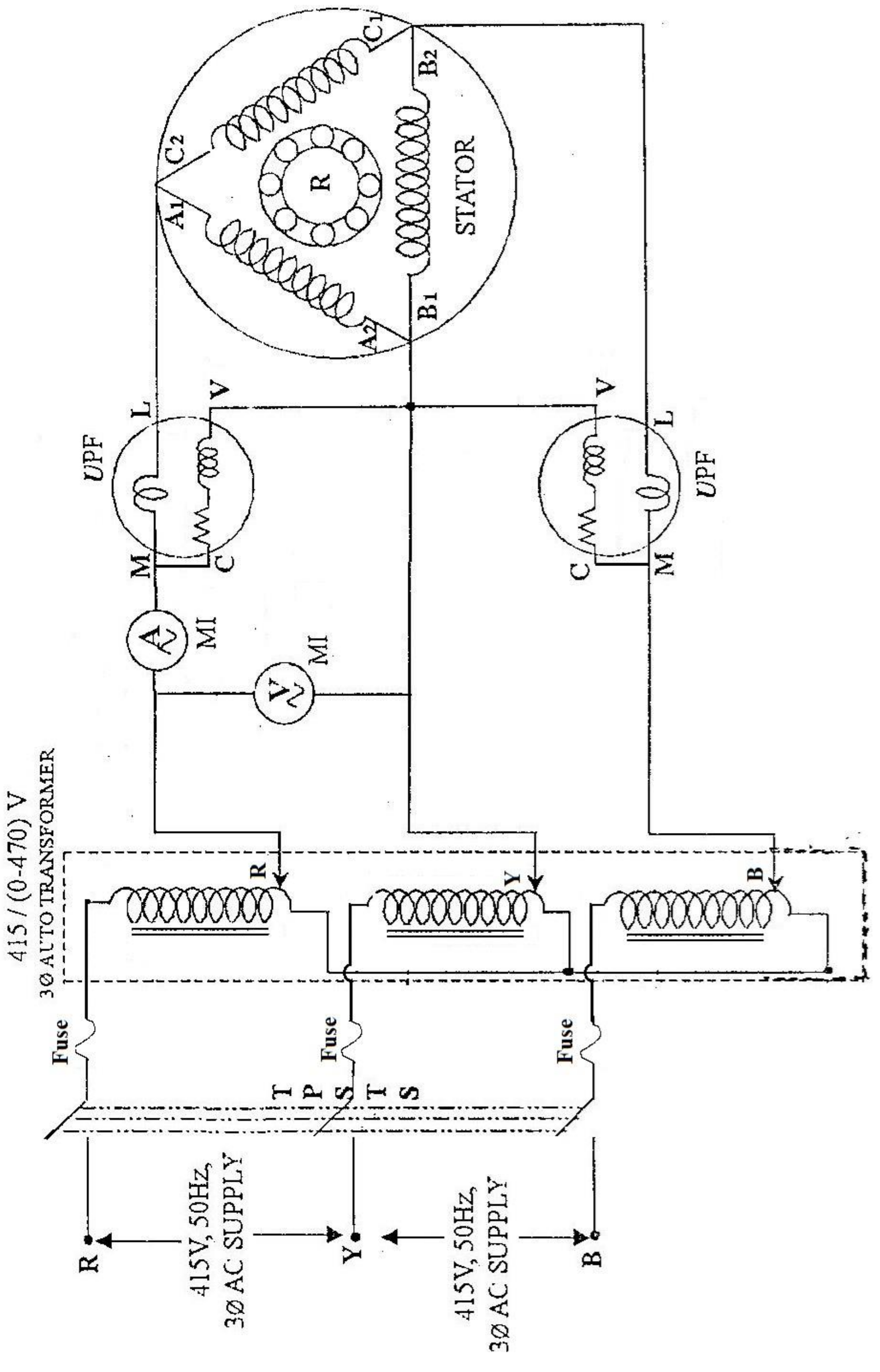
$$= \frac{587.35 \times 60}{2\pi \times 1500 \times (1-0.02)} = 3.815N-m$$

RESULT:

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

NO LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

(Circle Diagram)



EX.NO. 5 **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,

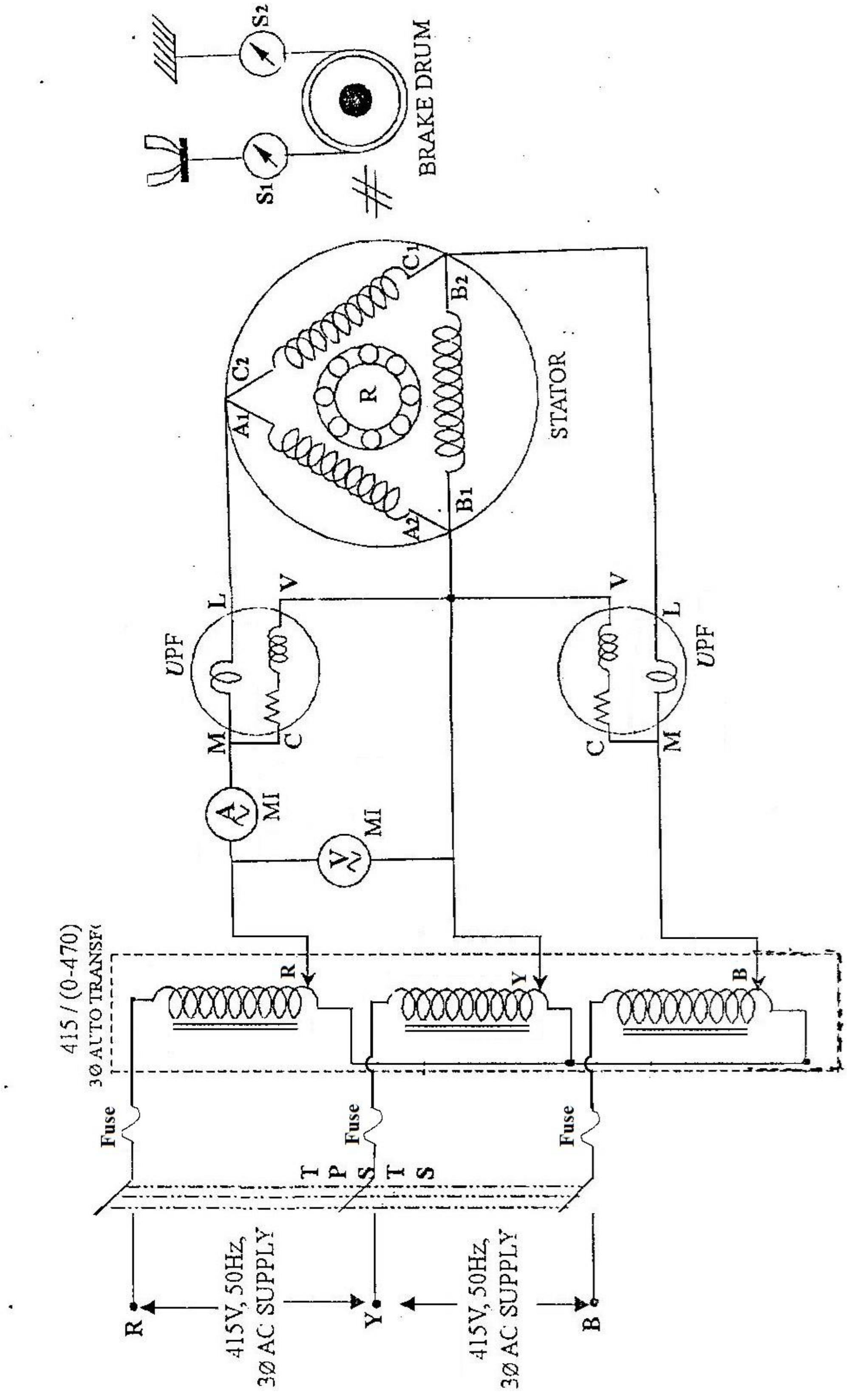
1. Stator copper loss i.e. $3 I_o^2 R_1^2$ where I_o is no load per phase current and R_1 is stator resistance per phase.
2. Stator core loss i.e. iron loss.
3. Friction and windage loss.

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.

$\therefore$ 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 = ……2……

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	
1	415	4.4	-120	-240	260	520	280

2. BLOCKED ROTOR TEST:

M.F = ……1……

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	
1.	94	7.5	10	10	520	520	530

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.

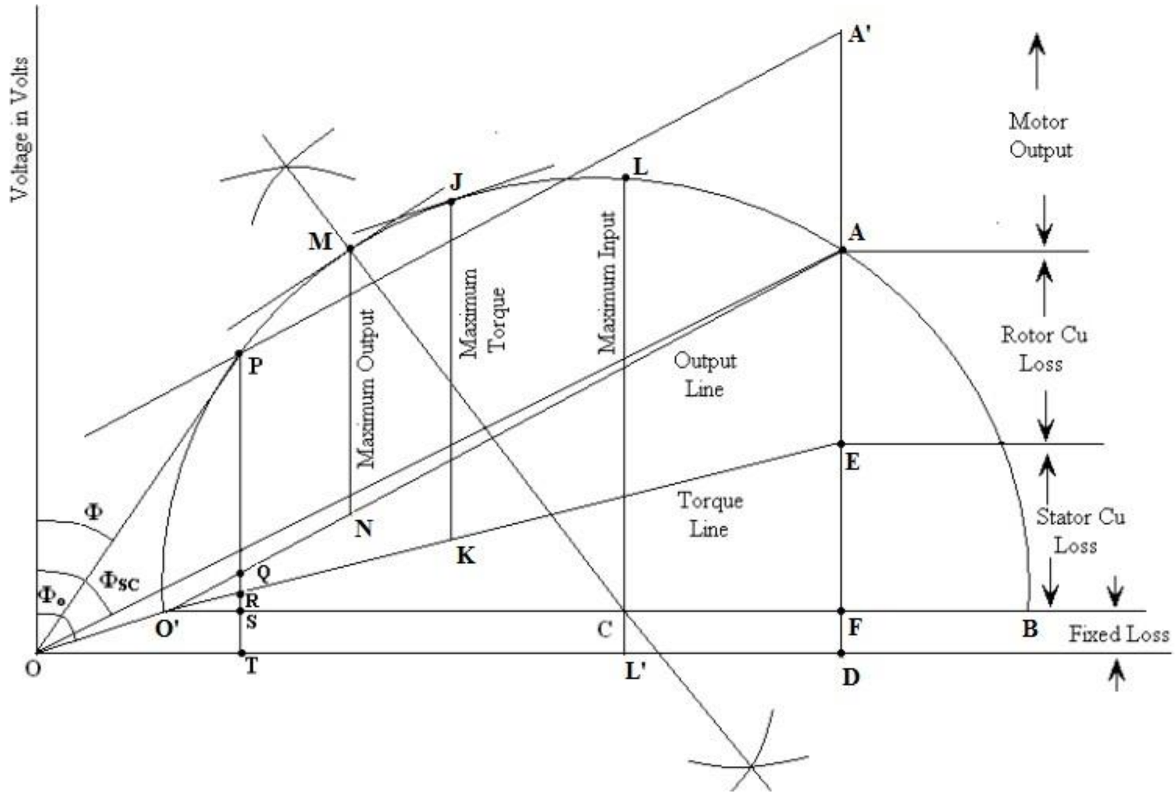
Step 10 : Torque line.

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:

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

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

$\cos\phi_0 = 0.07$

$\phi_0 = 85.98$

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

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

$\cos\phi_{SC} = 0.49$

$\phi_{SC} = 60.65$

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

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

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

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

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

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

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

<u>Maximum Quantities</u>

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

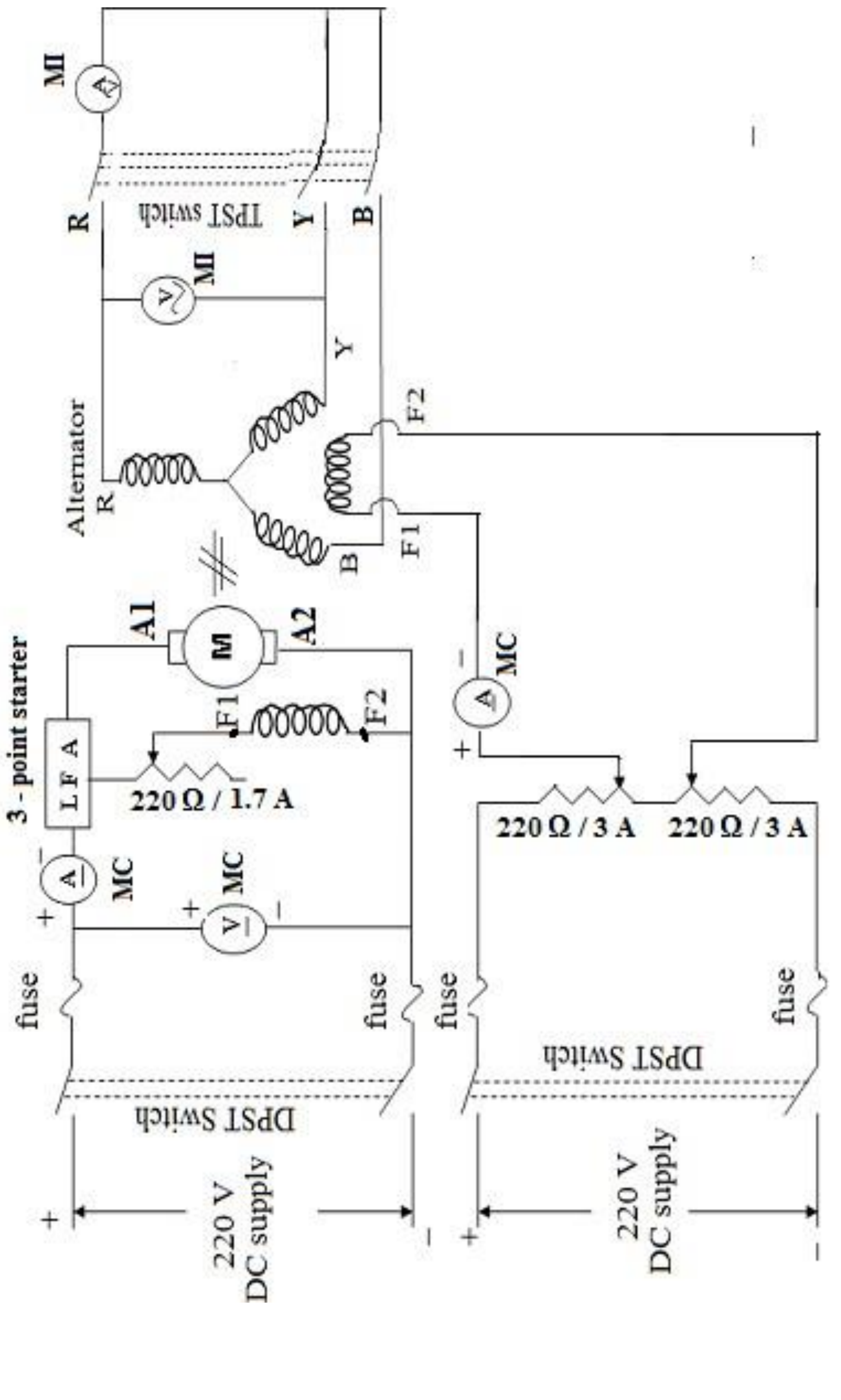
Maximum Power Factor = $\cos\Phi_{max}$ = cos28 = 0.882

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

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.

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



EXP.NO. 6 &7 **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, $Z_S = \frac{V_0}{I_{SC}}$

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
1.	0.1	50	28.867

Short Circuit Test:

S.No	Field Current (I_f) Amps	Short Circuit Current (120% to 150% of rated current) (I_{SC}) Amps
1.	0.44	6.5

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 $R_a = 1.8\ \Omega$
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, $E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_aR_a\right)^2 + \left(V_{ph}\sin\phi + I_aX_s\right)^2}$

   For Leading Power Factor 0.8,
6. Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph}\cos\phi + I_aR_a\right)^2 + \left(V_{ph}\sin\phi - I_aX_s\right)^2}$

   For Unity Power Factor,
7. Open circuit voltage, $E_{ph} = \sqrt{\left(V_{ph} + I_aR_a\right)^2 + \left(I_aX_s\right)^2}$
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
1.	0.8	353.57	203.38	24.68	– 20.68

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
1.	0.8	239.96	1.0	0.46	1.3	0.81	270	214	4.72	– 3.52

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:

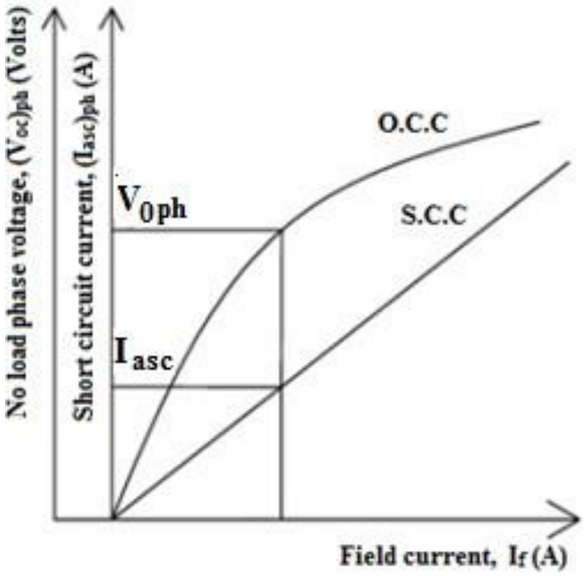
1. Motor filed rheostat should be kept in minimum resistance position at the time of starting.
2. The potential divider should be kept at maximum position at the time of starting
3. TPST switch is kept closed.

PROCEDURE:

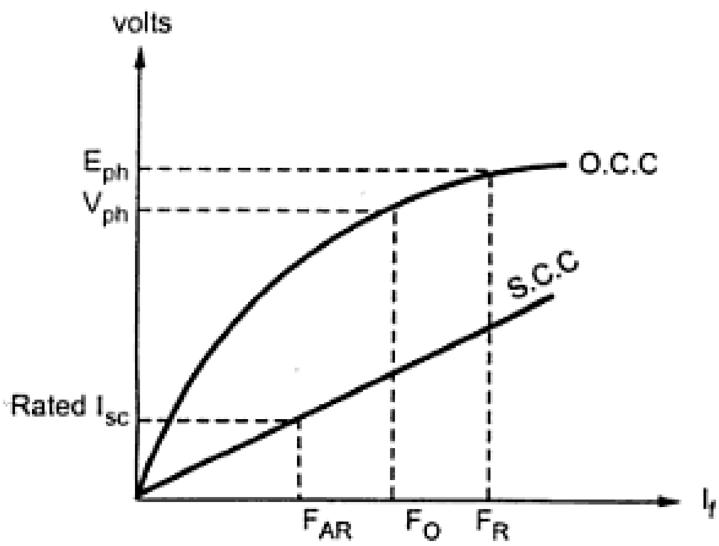
1. Connections are made as per the circuit diagram.
2. Supply is given to DC motor by closing the DPST switch.
3. Using the Three point starter, start the motor to run at the synchronous speed by adjusting the motor field rheostat.
4. Supply is given to alternator field winding by closing the DPST switch.
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,

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

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

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

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

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}}\times100 = \frac{203.38-239.6}{239.6}\times100$$

$\%VR = -20.68\%$

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,

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

$$= \left(1 + 0.46\times0.6\right)^2 + \left(0.46\times0.8\right)^2$$

$$F_R = 1.337A$$

From Graph, measure E_{ph} for corresponding F_R

E_{ph} = 270 V

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}}\times100 = \frac{270-239.6}{239.6}\times100$$

$$\%VR = 4.72\%$$

For Leading,

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

$$= \left(1 - 0.46\times0.6\right)^2 + \left(0.46\times0.8\right)^2$$

$$F_R = 0.81A$$

From Graph, measure E_{ph} for corresponding F_R

E_{ph} = 214 V

$$\%VR = \frac{E_{ph} - V_{ph}}{V_{ph}}\times100 = \frac{214-239.6}{239.6}\times100$$

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

RESULT:

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

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. **Define voltage regulation. Name two methods used to determine voltage regulation of alternators.**

   $\%Reg=(E-V_{rated} /V_{rated}) *100$

   Where, E= No load voltage

   V_{rated} =Rated voltage
3. **Two methods to determine voltage regulation:**
   a) EMF method
   b) MMF method
4. **Is EMF method an accurate method?**

   No, it is not an accurate method because the value of synchronous impedance found is always more than the original value.
5. **What is meant by synchronous reactance?**

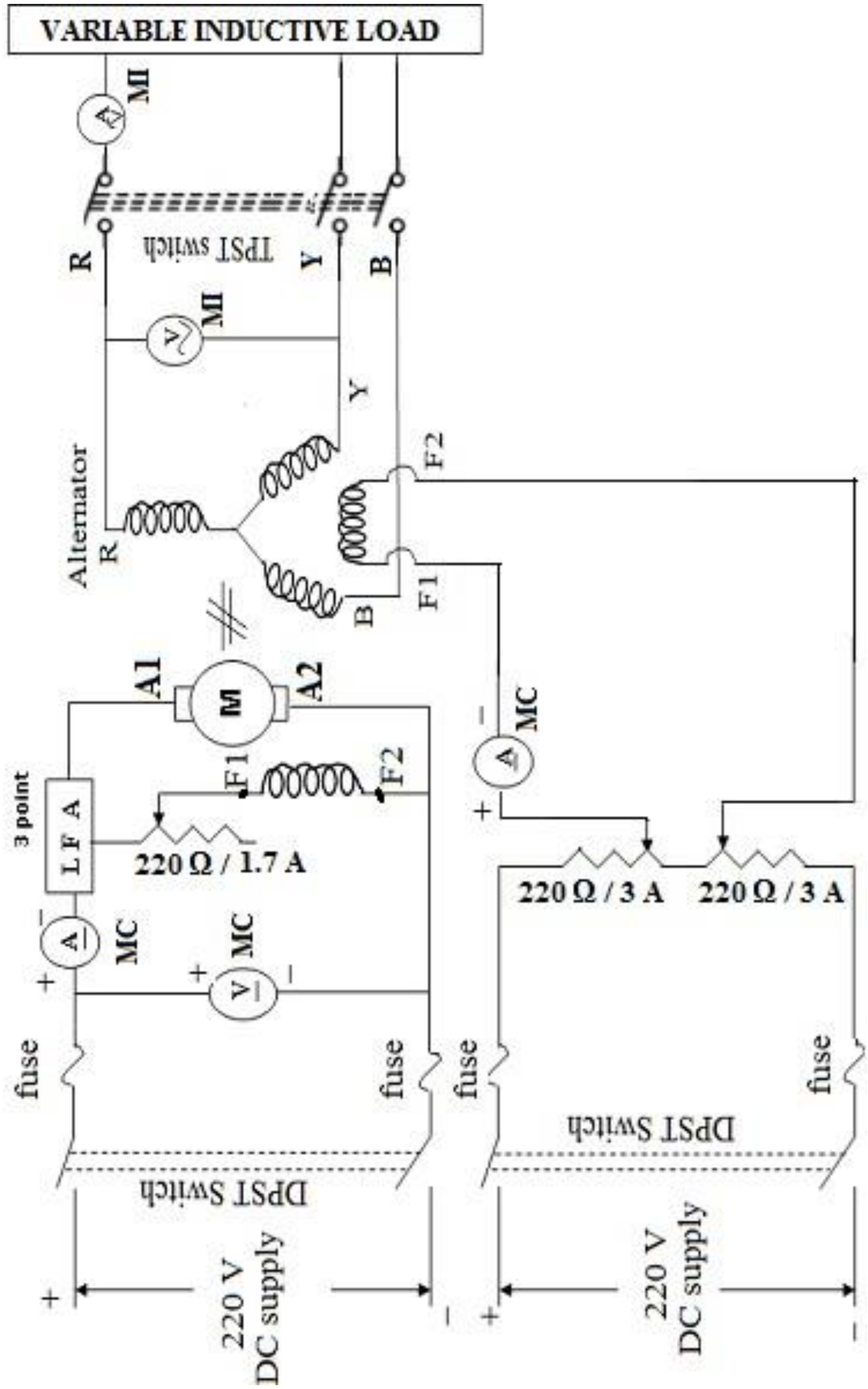
   Synchronous reactance $X_s = X_L + X_a$

   Where,

   X_L =leakage reactance X_a =

   Armature reactance

REGULATION OF THREE PHASE ALTERNATOR BY ZPF METHOD



EXP.NO. 08 **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. $E_{ph1} = \sqrt{(V_{ph}\cos\phi)^2 + (V_{ph}\sin\phi + I_a X_{Lph})^2}$

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
1.	0.1	50	28.867

Short Circuit Test:

S.No	Field Current (I_f) Amps	Short Circuit Current (120% to 150% of rated current) (I_{SC}) Amps
1.	0.44	6.5

OBSERVATION TABULATION:

ZPF Method:

S.No	Field Current (I_f) Amps	Rated Armature current (I_a) Amps	Rated Armature voltage (V_a) Volts
1.	1.84	7	415

3. From Graph, measure F_{f1} for corresponding E_{ph1}
4. From graph, measure Length (PS)

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

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

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.

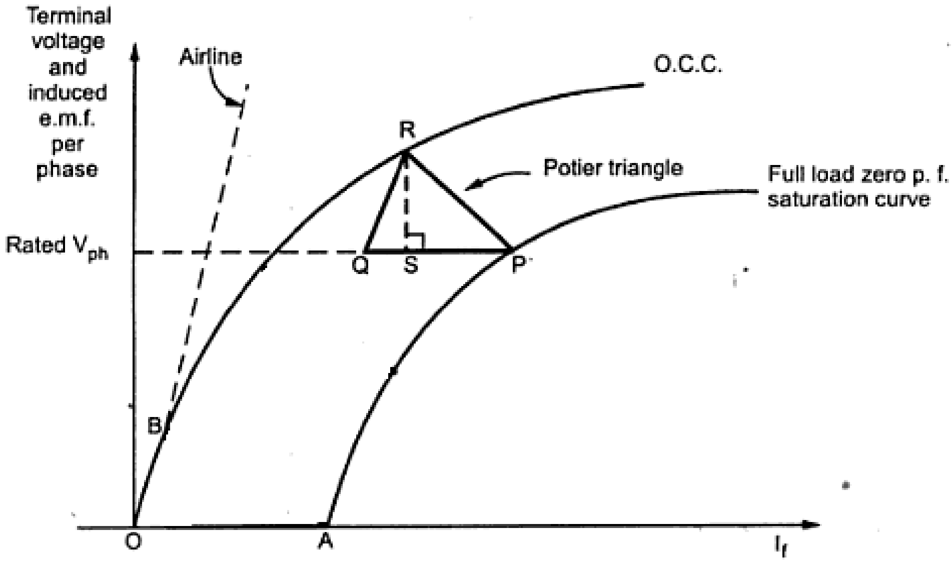
PROCEDURE:

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
1.	0.8	276.84	210.81	1.32	0.76	0.3	1.51	0.58	276.8	210.84	8.52	–7.42

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,

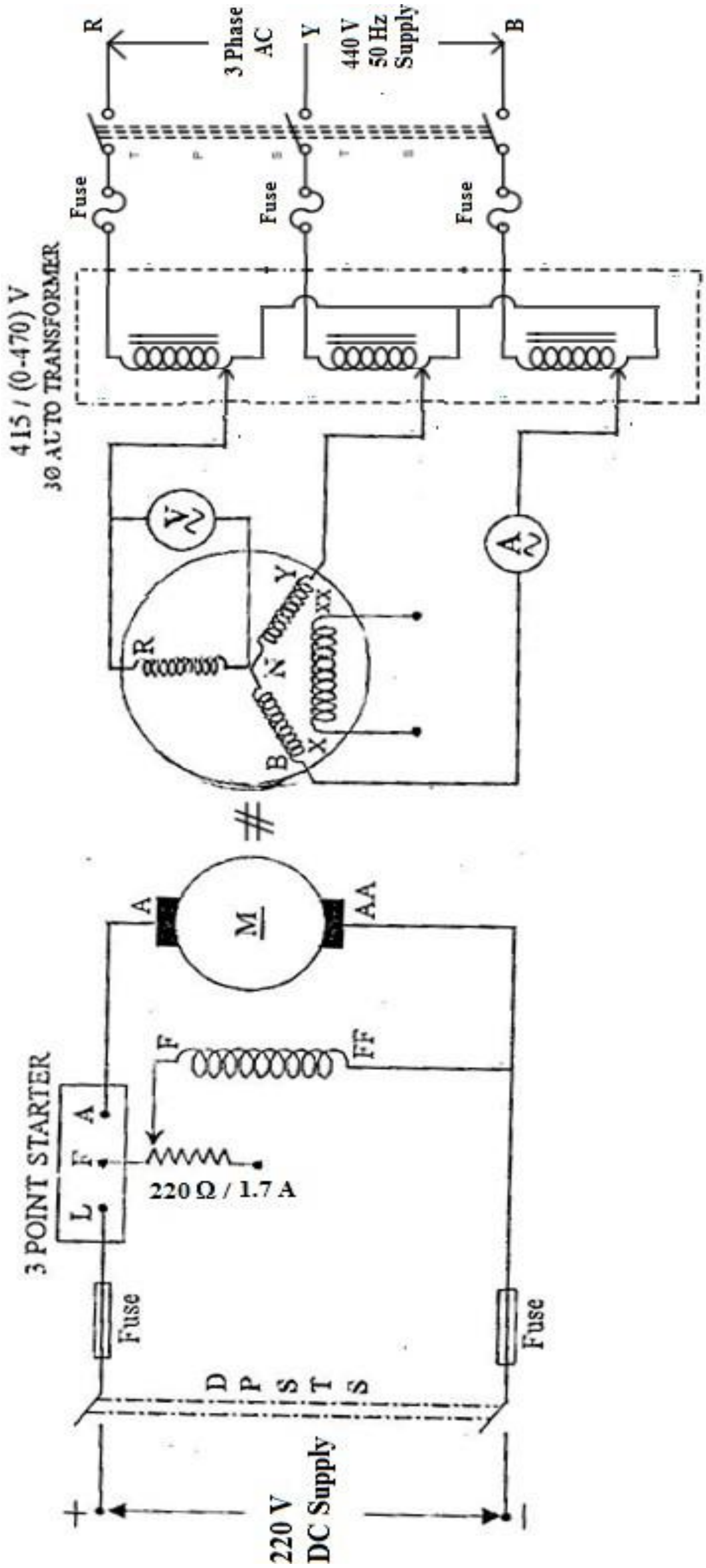
For Leading,

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

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

RESULT:

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


R
Y
B
3 Phase AC
440 V
50 Hz
Supply
Fuse
Fuse
Fuse
415 / (0-470) V
3Ø AUTO TRANSFORMER
V
A
R
Y
B
N
X
XX
M
A
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. 09 **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
1.	45	37	7.1	5.4	4.812	3.008

MODEL CALCULATION:

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

$$X_d = 4.812\Omega$$

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

$$Xq = 3.008\Omega$$

FORMULAE USED:

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

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

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.

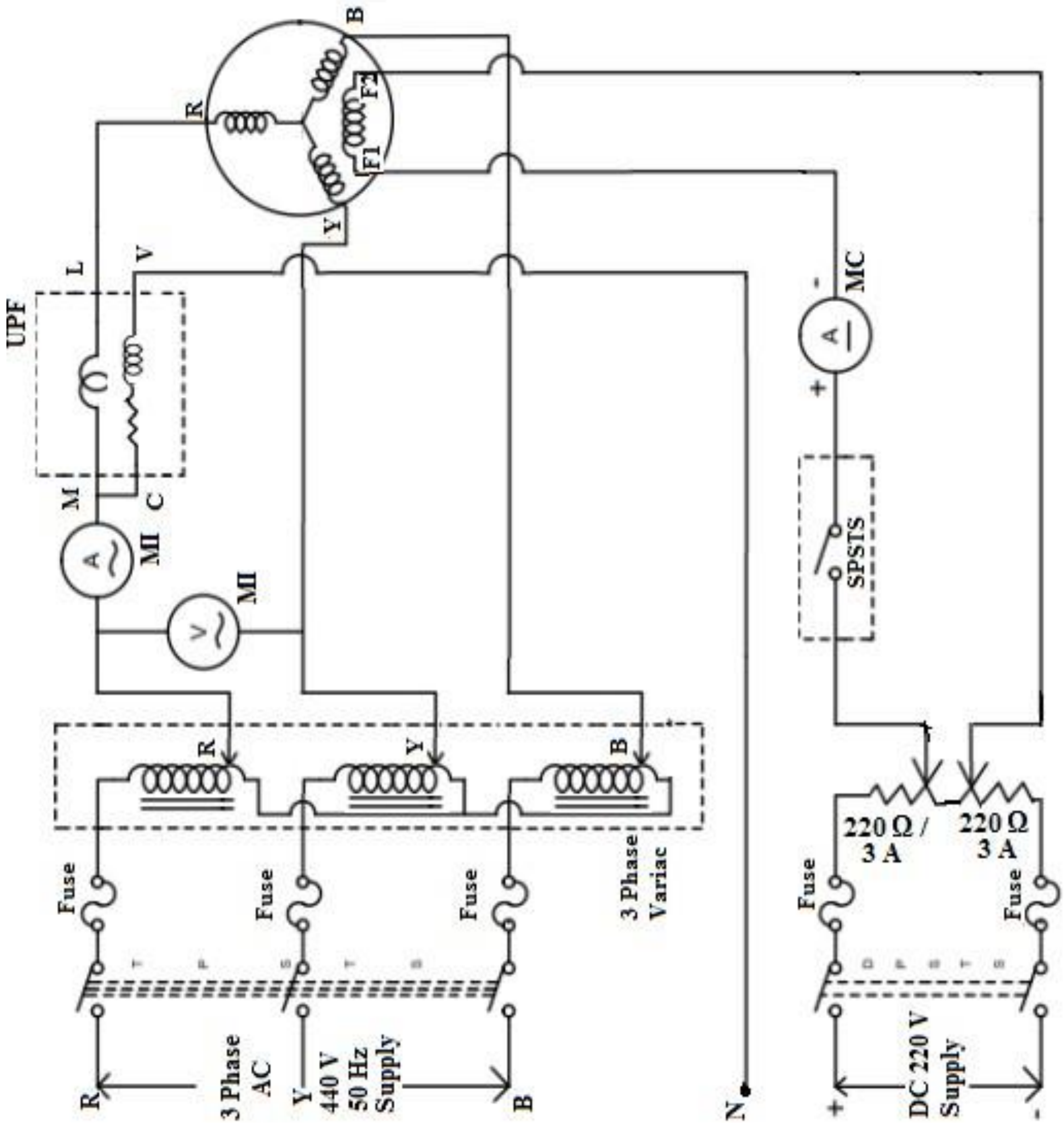
PROCEDURE:

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.

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.

CIRCUIT DIAGRAM:



EXP.NO. 10 **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.

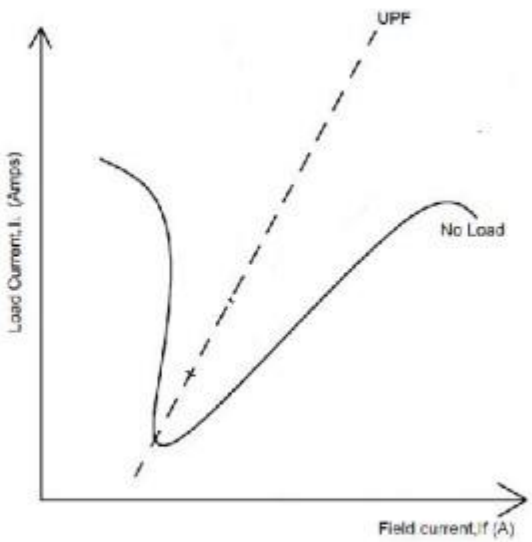
Excitation can be increased by increasing the field current passing through the field winding of synchronous motor. If graph of armature current drawn by the motor (I_a) against field current (I_f) is plotted, then its shape looks like an english alphabet V. If such graphs are obtained at various load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

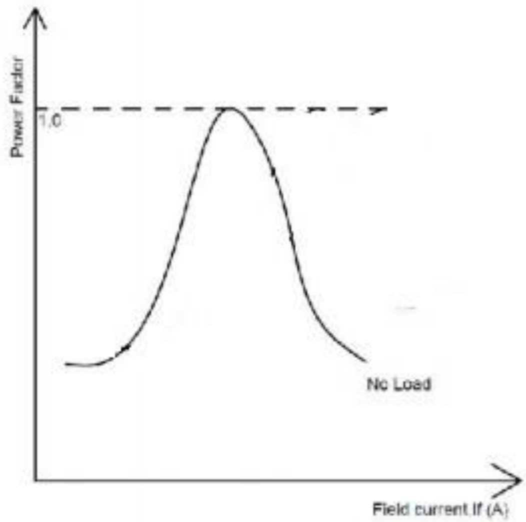
As against this, if the power factor (cos Φ) is plotted against field current (I_f), then the shape of the graph looks like an inverted V. Such curves obtained by plotting p.f. against I_f, at various load conditions are called Inverted V-curves of synchronous motor.

TABULATION:

S.No.	Line Voltage V_L (V)	Line Current I_L (A)	Field Current	Input Power P_{in} (Watts)		Power Factor
				Obs.	Act.	
1.	240	6.4	0.1	80	160	0.18

MODEL GRAPHS:





MODEL CALCULATION:

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

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

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

= 0.18

FORMULA:

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

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:

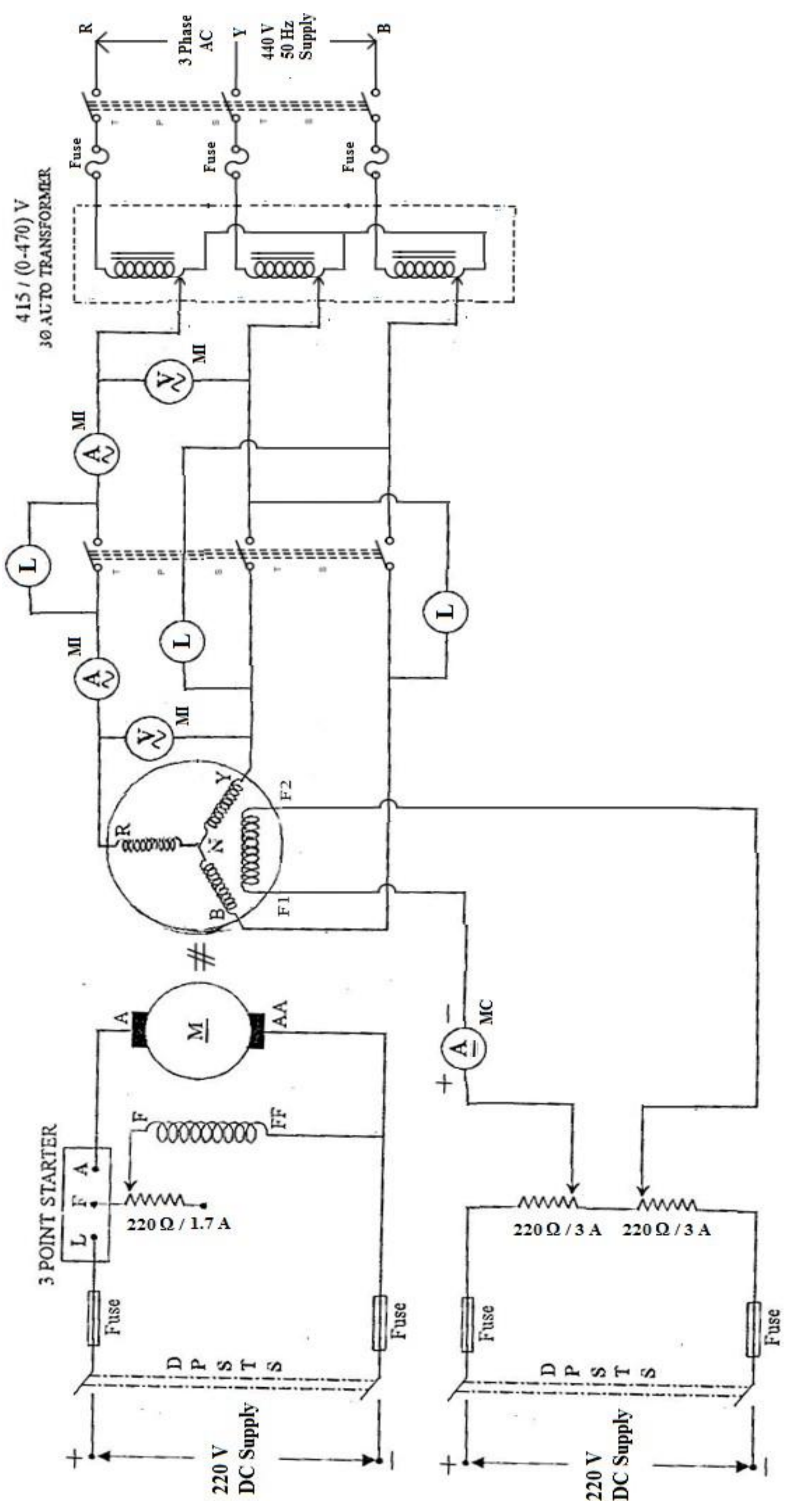
The graph is drawn for,

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

RESULT:

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

CIRCUIT DIAGRAM:



EX.NO.11 **DATE:**

MEASUREMENT 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	Quantity
1	Voltmeter	(0-300)V	MI	1
2	Ammeter	(0-10)A	MI	1
3	Ammeter	(0-2)A	MC	1
4	Wattmeter	300V,10A	LPF	1
5	Rheostat	100Ω,1.2A	Wire wound	1
6	Variac	270A,5A	Single phase	1
7	Connecting Wires	-	-	Required

NAME PLATE DETAILS:

PARAMETERS	DC MOTOR	ALTERNATOR
Rated Voltage	220V	415V
Rated Amps	19A	4.2A
Rated Power	5 HP	3.0 KVA
Rated Speed	1500 RPM	1500 RPM

FUSE RATING CALCULATION:

125% of rated current.

FORMULAE USED:

1. Negative Sequence impedance, $Z2 = VRY / (\sqrt{3} * ISC)$ in Ω

   VRY – Line voltage in volts

   ISC – line current in A

2. Negative Sequence Reactance, $X2 = Z2 * W / (VRY * ISC) = W / (\sqrt{3}\ ISC^2)$ in Ω

   W – Wattmeter Reading in W

3. Zero Sequence Impedance, Z0 = = = in Ω

4. Zero Sequence Reactance, X0 = Z0 in Ω

PRECAUTION:

1. All the switches should be kept open at the time of starting the experiment.

2. The D. C. 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

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

1. Make connection as shown in circuit diagram.

2. Set the Variac output to zero volts and switch on the supply.

3. Gradually increase Variac output and note the ammeter reading for suitable voltage applied.

4. Repeat reading for suitable voltage applied.

5. It should be kept in mind that the ammeter reading should not exceed the rated current Capacity of the machine.

TABULATION:

FOR NEGATIVE SEQUENCE

S.No.	Voltage V_{RV} (V)	Current Isc (A)	Power W (Watts)	Negative Sequence Impedance Z_2(Ω)	Negative Sequence Reactance X_2(Ω)	Average X_2 (Ω)
.						

FOR ZERO SEQUENCE

S.No.	Voltage V (V)	Current I (A)	Negative Sequence Impedance Z_0(Ω)	Negative Sequence Reactance X_0(Ω)	Average X_0 (Ω)
.					

MODEL CALCULATION:

RESULT:

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

Negative Sequence Reactance X_2 = Ω

Zero Sequence Reactance X_0 = Ω