

**SRM VALLIAMMAI ENGINEERING COLLEGE**  
*(An Autonomous Institution)*

**SRM NAGAR, KATTANKULATHUR**

**DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING**  
II YEAR / IV SEMESTER



**EE3464 ELECTRICAL MACHINES LABORATORY-II**

(Regulation - 2023)

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**Prepared by**

**Ms.R.Elavarasi / AP-O.G/EEE**

**Mr.V.Sudhagar / AP-Sr.G/EEE**

## COURSE OBJECTIVES

To impart knowledge on the following topics

- To expose the students to the operation of synchronous machines.
- To impart knowledge on voltage regulation of alternators.
- To expose the students to the operation of induction motors.
- To impart knowledge on equivalent circuit of the induction motors.
- To impart knowledge on necessity of starters.

## LIST OF EXPERIMENTS

1. Load test on three-phase induction motor.
2. No load and blocked rotor tests on three-phase induction motor. (Determination of equivalent circuit parameters).
3. Load test on single-phase induction motor.
4. No load and blocked rotor test on single-phase induction motor.
5. Separation of No-load losses of three-phase induction motor.
6. Regulation of three phase alternator by EMF and MMF methods.
7. Regulation of three phase alternator by ZPF and ASA
8. Regulation of three phase salient pole alternator by slip test.
9. Measurements of negative sequence and zero sequence impedance of alternators.
10. V and Inverted V curves of Three Phase Synchronous Motor.
11. Study of Induction motor Starters.
12. Synchronization of Alternator.
13. Determination of Circle Diagram of three phase induction motor.

## COURSE OUTCOMES

1. Ability to understand and analyze EMF and MMF methods
2. Ability to analyze the characteristics of V and Inverted V curves.
3. Acquire hands on experience of conducting various tests on alternators and obtaining their performance indices using standard analytical as well as graphical methods to understand the importance of Synchronous machines
4. Acquire hands on experience of conducting various tests on single and three phase Induction motors and obtaining their performance indices using standard analytical as well as graphical methods to understand the importance of single and three phase Induction motors
5. Ability to acquire knowledge on separation of losses.

### CYCLE – 1

1. Load test on three-phase induction motor.
2. No load and blocked rotor tests on three-phase induction motor. (Determination of equivalent circuit parameters).
3. Load test on single-phase induction motor.
4. No load and blocked rotor test on single-phase induction motor.
5. Separation of No-load losses of three-phase induction motor.
6. Regulation of three phase alternator by EMF and MMF methods.
7. Regulation of three phase alternator by ZPF and ASA

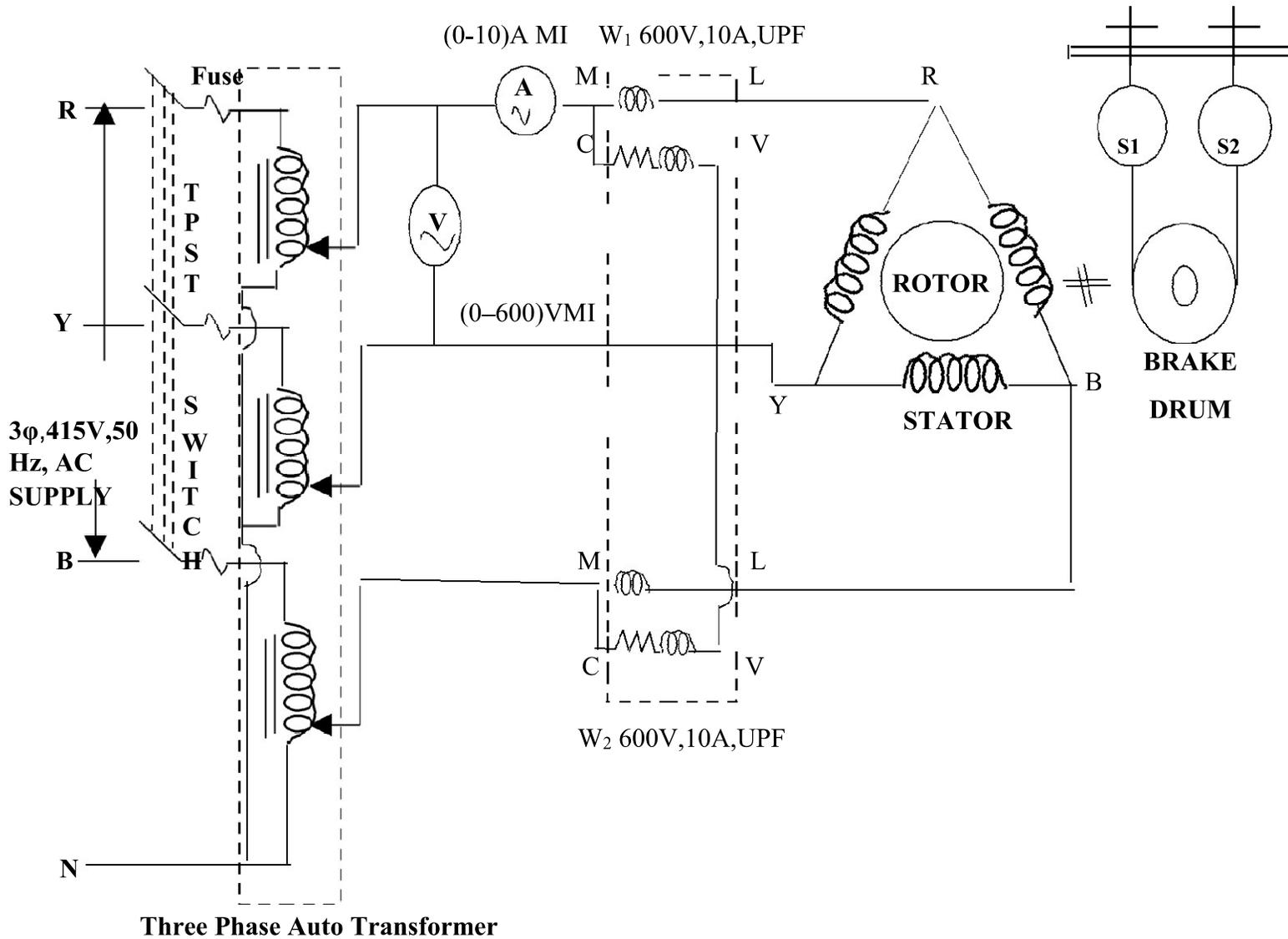
## **CYCLE – 2**

1. Regulation of three phase salient pole alternator by slip test.
2. Measurements of negative sequence and zero sequence impedance of alternators.
3. V and Inverted V curves of Three Phase Synchronous Motor.
4. Study of Induction motor Starters.
5. Synchronization of Alternator.
6. Determination of Circle Diagram of three phase induction motor.



CIRCUIT DIAGRAM:

LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR



Fuse Rating Calculation:

Name Plate Details:

**Expt. No:**

**Date:**

**LOAD TEST ON 3-PHASE SCOURREL CAGE INDUCTION MOTOR**

AIM:

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

APPARATUS REQUIRED:

SL. NO	APPARATUS REQUIRED	TYPE	RANGE	QUANTITY
1	Voltmeter	MI	0-600V	1
2	Ammeter	MI	0-10A	1
3	Watt Meter	UPF	600V,10A	2
4	Auto Transformer	3 Phase	0-600 V	1
5	Connecting Wires			Required

THEORY:

The load test on 3-phase induction motor is performed to obtain its various characteristics including efficiency. A belt and brake drum arrangement as shown in the circuit diagram can load the motor. If  $S_1$  and  $S_2$  are the tensions provided at the two sides of the belt, then the load torque is given by

$$T = (S_1 - S_2) * 9.81 * R \text{ N-m.}$$

Where R is the radius of the brake drum in metre.

The mechanical output of the motor is given by

$$P_m = 2\pi NT/60 \text{ Watt.}$$

Where N is the speed of the motor in RPM.

The power input to the motor is given by

$$P_i = V_L I_L \text{ Watt.}$$

The efficiency of the motor is given by

$$\text{Efficiency} = P_m / P_i$$

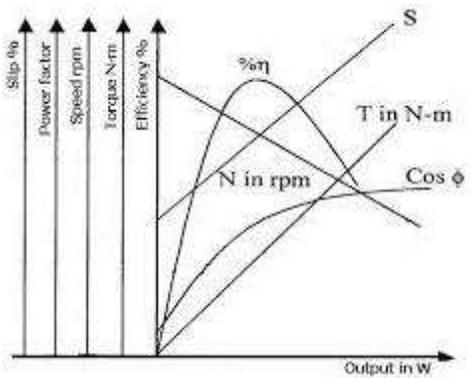
OBSERVATION TABLE:

M.F=

Radius of the brake drum=

Sl. No.	Voltage (Volts)	Current (Ampere)	Speed (Rpm)	Spring Balance		Torque (Nm)	W <sub>1</sub>		W <sub>2</sub>		I/P Power (Watts)	O/P Power (Watts)	Efficiency (%)	% Slip
				S <sub>1</sub> (Kg)	S <sub>2</sub> (Kg)									

MODEL GRAPH:



MODEL CALCULATION:

#### FORMULA USED:

Torque,

$$T = (S1 - S2) * 9.81 * R \text{ (Nm)}$$

Input power

$$P_i = V_L I_L \text{ (Watt)}$$

Output power

$$P_o = 2\pi I N T / 60 \text{ (Watt)}$$

Efficiency

$$= (P_o / P_i) * 100 \text{ (\%)}$$

Power Factor,  $\cos\phi = W / (\sqrt{3} V_L I_L)$

$$\text{Where } W = (W_1 + W_2)$$

$$\text{Slip} = [(N_s - N) / N_s] * 100$$

#### PRECAUTION:

1. TPST switch should be at open position.
2. 3-phase autotransformer should be at minimum voltage position.
3. There should be no-load at the time of starting (Loosen the belt on the brake drum).
4. Brake drum should be cooled with water during loading.

#### PROCEDURE:

1. The connections are made as per the circuit diagram.
2. Power supply is obtained from the control panel.
3. The TPST switch is closed.
4. Rated voltage of 3-phase induction motor, is applied by adjusting autotransformer.
5. The initial readings of ammeter, voltmeter and wattmeter are noted.
6. By increasing the load step by step, the readings of ammeter, voltmeter and wattmeter are noted.
7. Step 1 to 6 is repeated till the ammeter shows the rated current of 3-phase induction motor.
8. Decrease the load, bring auto-transformer to its minimum voltage position.
9. Switch off the supply.

RESULT:

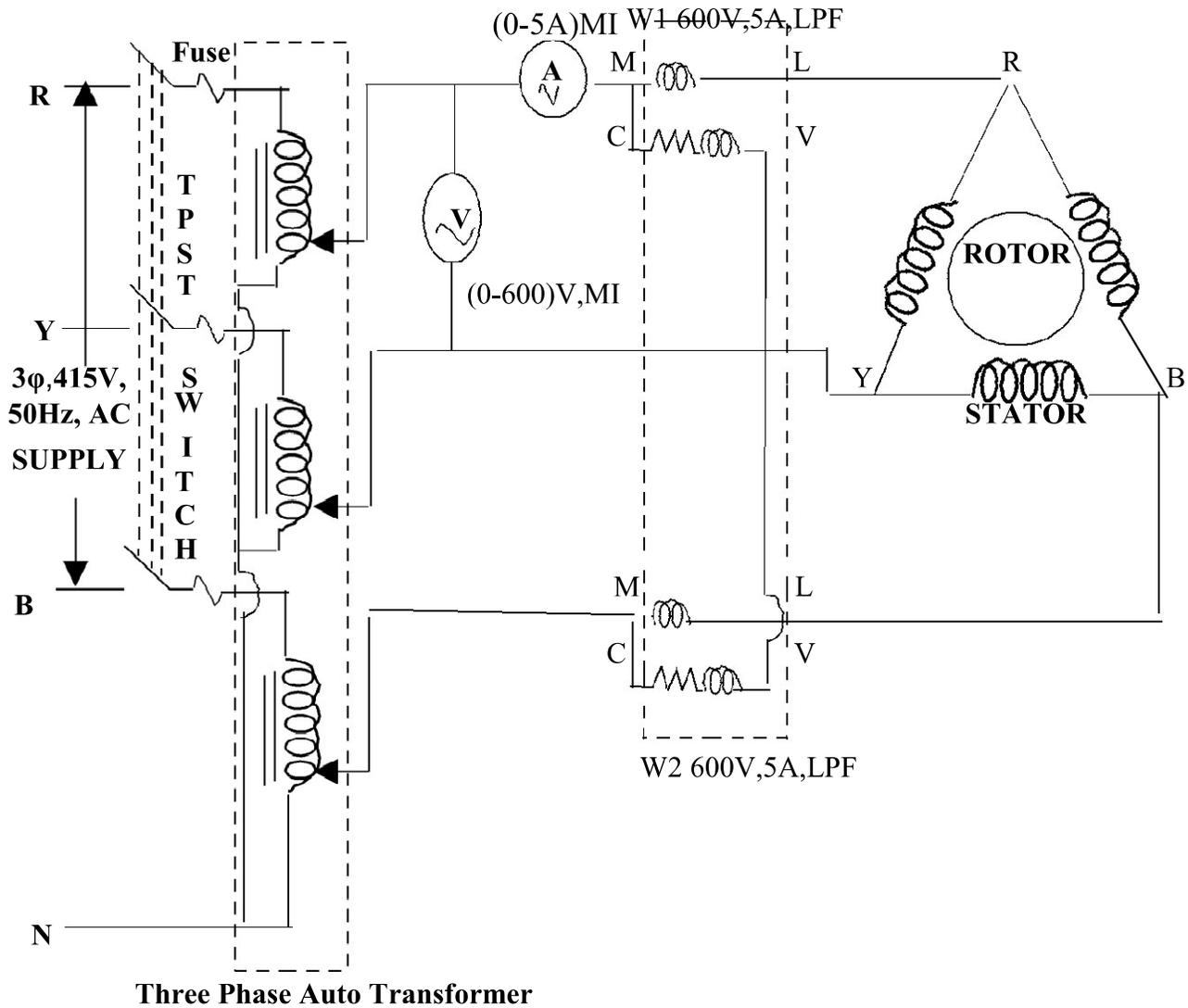
### VIVA QUESTIONS:

1. Explain what is meant by a 3-phase induction motor?
2. Write the classification of 3-phase induction motor?
3. State the steps to draw the equivalent circuit of 3-phase induction motor?
4. State the condition for maximum torque of 3-phase induction motor?
5. Give the different methods of speed control of I.M?
6. How do you calculate slip speed?
7. State the condition when induction motor acts as induction generator?
8. Give the other name for induction generator?

CIRCUIT DIAGRAM:

NO LOAD AND BLOCKED ROTOR TEST ON THREE PHASE SQUIRREL CAGE  
INDUCTION MOTOR

NOLOAD TEST:



Fuse Rating Calculation:

Name Plate Details:

**Expt. No:**

**Date:**

**NO LOAD AND BLOCKED ROTOR TEST ON 3-PHASE SQUIRREL  
CAGE INDUCTION MOTOR**

**AIM:**

To conduct no load test and blocked rotor test on given 3Ph squirrel cage induction motor and to draw the circle diagram.

**APPARATUS REQUIRED:**

SL.NO.	APPARATUS	RANGE	TYPE	QUANTITY
1.	Voltmeter	(0-600) V	MI	1
2.	Ammeter	(0-5)A, (0-10)A	MI	1 Each
3.	Wattmeter	600V,5A 600V,10A	LPF, UPF	2 Each
4.	Three Phase Auto Transformer	(0-600) V		1
5.	Connecting Wires			As Required

**FORMULAE:**

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

$$\cos\Phi_r = W_{br} / \sqrt{3} V_{br} I_{br}$$

$$I_{bm} = I_{br} (V_o / V_{br})$$

$$W_{bm} = W_{br} (V_o / V_{br})^2$$

$$\text{Stator copper loss} = 3 I_{br}^2 R_s$$

**PRECAUTION:**

1. The 3Ph autotransformer should be kept at initial position.
2. Initially the machine should be under no load condition.

**PROCEDURE:**

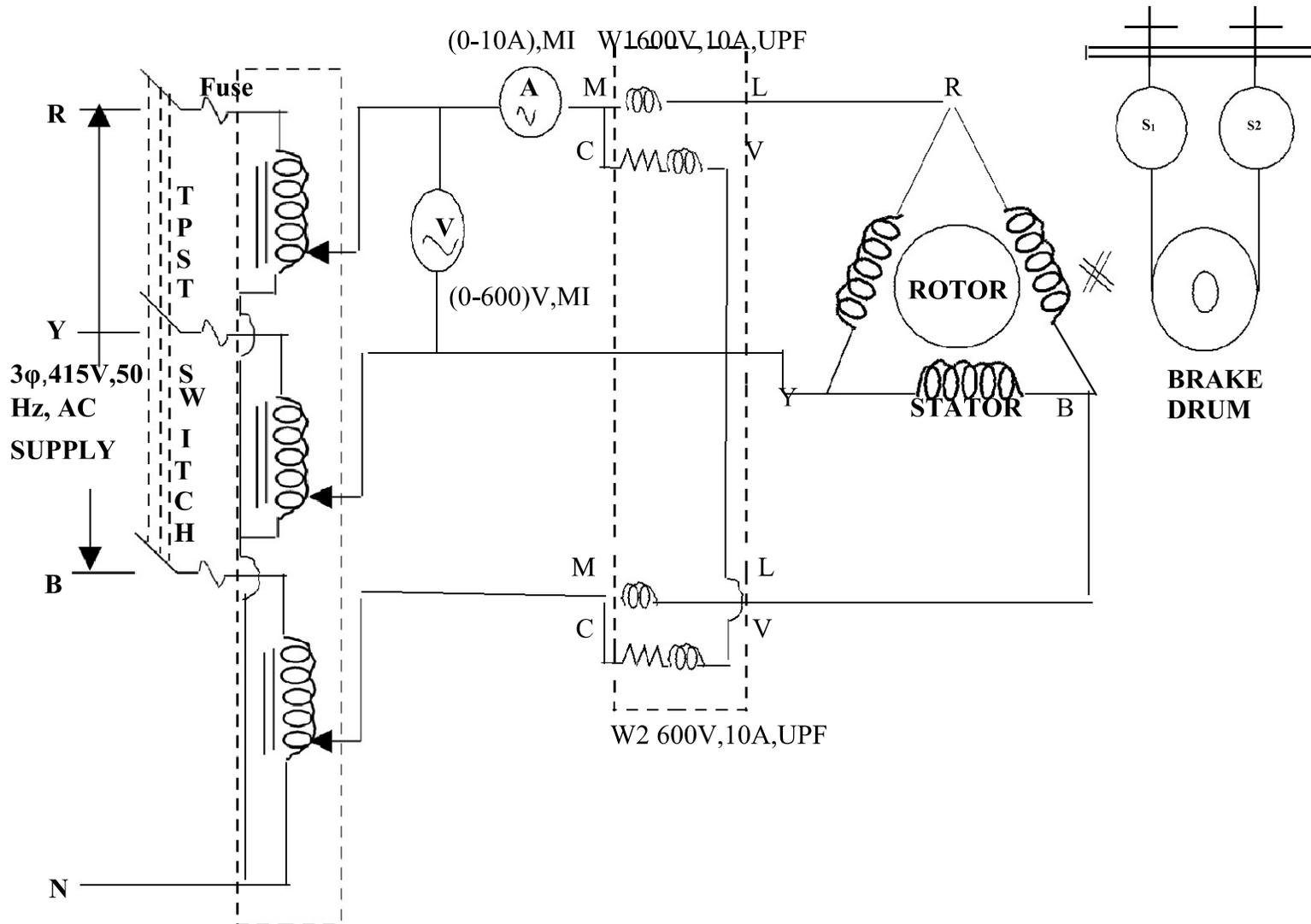
**NO LOAD TEST**

1. Connections are made as per the circuit diagram.
2. 3Ph AC supply is increased gradually using 3Ph autotransformer till rated voltage is applied.
3. Readings of voltmeter and wattmeter are noted.

CIRCUIT DIAGRAM:

NO LOAD AND BLOCKED ROTOR TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

BLOCKED ROTOR TEST:



**Three Phase Auto Transformer**

Fuse Rating Calculation:

Name Plate Details:

### BLOCKED ROTOR TEST

1. Connections are made as per the circuit diagram and rotor is blocked from rotating.
2. Applied voltage is increased until rated load current flows.
3. Readings of all meters are noted.

### MEASUREMENT OF STATOR RESISTANCE:

1. Connections are made as per the circuit diagram.
2. Supply is given by closing the DPST switch.
3. Readings of voltmeter and ammeter are noted.
4. Stator resistance in ohms is calculated as

$$R_{a/\text{phase}} = (V \times 1.5) / 2I$$

### PROCEDURE FOR CONSTRUCTING THE CIRCLE:

1. Vector  $OO'$  is drawn at an angle of phase with respect to  $OY$  represents the output line.
2.  $O'X'$  is drawn parallel to  $OX$ .
3. Vector  $OA$  is  $I_{br}$  plotted at an angle of phasor with respect to  $OY$ .  $O'A$  is joined which represents the output line.
4. A perpendicular bisector from output line which cuts  $O'Y$  at  $C$ . With  $C$  as centre and  $O'C$  as radius draw a semi-circle passing through  $A$ .
5. From  $A$ , a perpendicular is drawn meeting  $O'X'$  at  $E$  and  $OD$  at  $D$ .
6.  $AD$  represents  $W_{br}$  in CM.  
 $EF$  represents stator copper loss in CM.  
 $AD$  represents rotor copper loss in CM.
7. Join  $OF'$  which represents the torque line.
8. Line  $AD$  is extended and points  $S$  is marked, where  $AS$  is equal to rated output power.
9. Line  $PS$  is drawn parallel to output line.
10. From  $P$ , perpendicular line is drawn meeting  $OX$  at  $y$ .
11. Join  $OP$ .

### MEASUREMENT OF PARAMETER AT FULL LOAD

$$\begin{aligned}\text{Stator current} &= OP \times X \\ \% \eta &= (PQ/PV) \times 100 \\ \% \text{Slip} &= (QR/PR) \times 100 \\ \text{Torque} &= (PR \times V / (2\pi n T / 60)) \\ \text{Pf} &= PV/OP\end{aligned}$$

### MAXIMUM OUTPUT

The perpendicular at  $O'A'$  line cuts the circle at  $P$  and  $O'A'$  at  $PQ'$ .  
Maximum output =  $P_1Q_1 \times$  power scale (W)

### MAXIMUM TORQUE

The perpendicular bisector of line cuts the circle at  $PR$  and  $OF'$  at  $Q_2$ .  
Maximum torque =  $(PF \times \text{power scale}) / T$  Nm

NO LOAD TEST:

S.No	V <sub>o</sub> (V)	I <sub>o</sub> (A)	W <sub>o</sub> (W)		W <sub>o</sub> =(W <sub>1</sub> +W <sub>2</sub> ) W
			W <sub>1</sub>	W <sub>2</sub>	

BLOCKED ROTOR TEST:

S.No	V <sub>sc</sub> (V)	I <sub>sc</sub> (A)	W <sub>sc</sub> (W)		W <sub>sc</sub> =(W <sub>1</sub> +W <sub>2</sub> ) W
			W <sub>1</sub>	W <sub>2</sub>	

MEASUREMENT OF STATOR RESISTANCE:

S.No	Voltage (V)	Current (A)	$R_s = (V \times 1.5) / 2I$ ohms

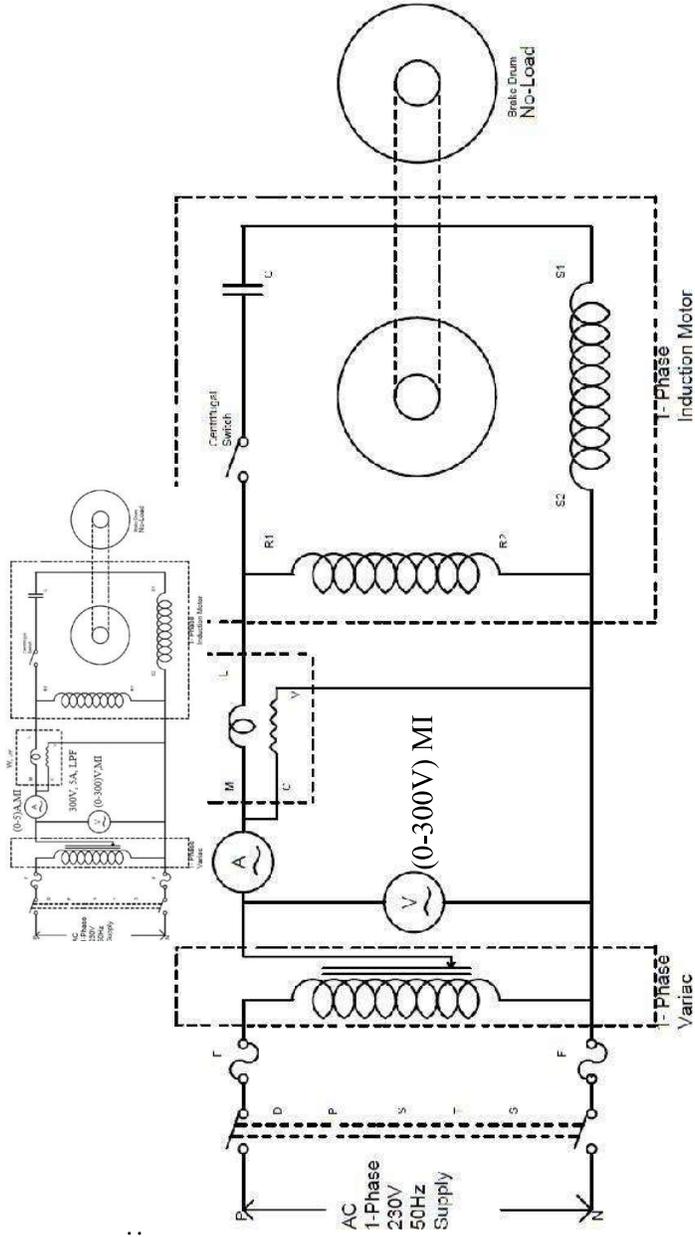
MODEL CALCULATION:

RESULT:

VIVA QUESTIONS:

1. What is the objective of Conducting this experiment?
2. What are the equivalent circuit parameters?
3. Write the classification of 3-phase induction motor?
3. State the steps to draw the equivalent circuit of 3-phase induction motor?
4. State the condition for maximum torque of 3-phase induction motor?
5. Give the different methods of speed control of I.M.
6. How do you calculate slip speed?
7. State the condition when induction, motor acts as induction generator?

**CIRCUIT DIAGRAM:  
NO LOAD TEST:**



**NAME PLATE DETAILS**

Capacity :  
 Voltage :  
 Current :  
 Speed:

**OBSERVATION TABULATION:**

M.F.= .....

Sl.No.	No-Load Voltage $V_0$ (Volts)	No-Load Current $I_0$ (Amps)	No-Load Power, $P_0$ (Watts)	
			Observed	Actual
1.				

**Expt. No:**

**Date:**

**NO LOAD AND BLOCKED ROTOR TEST ON 1-PHASE  
INDUCTION MOTOR**

AIM :

To obtain the equivalent circuit of the given 1-phase induction motor by no-load test and blocked rotor test.

APPARATUS REQUIRED:

SL.NO.	APPARATUS	RANGE	TYPE	QUANTITY
1.	Voltmeter	(0-300) V	MI	1
2.	Ammeter	(0-5)A, (0-10)A	MI	1 Each
3.	Wattmeter	300V,5A 300V,10A	LPF, UPF	1 Each
4.	Single Phase Auto Transformer	(0-300) V		1
5.	Connecting Wires			As Required

FUSE RATING CALCULATION:

Blocked rotor test: 125% of rated current

No-load test: 25% of rated current

FORMULA:

**NO-LOAD TEST**

$$W_o = V_o I_o \cos \theta_o$$

$$\text{Where, } \cos \theta_o = W_o / V_o I_o$$

$$I_w = I_o * \cos \theta_o$$

$$I_m = I_o * \sin \theta_o$$

**BLOCKED ROTOR TEST**

$$Z_{01} = V_{sc} / I_{sc}$$

$$R_{01} = W_{sc} / I_{sc}^2$$

$$X_{01} = [Z_{01}^2 - R_{01}^2]^{1/2}$$

$$X_m = [Z_m^2 - R_m^2]^{1/2}$$

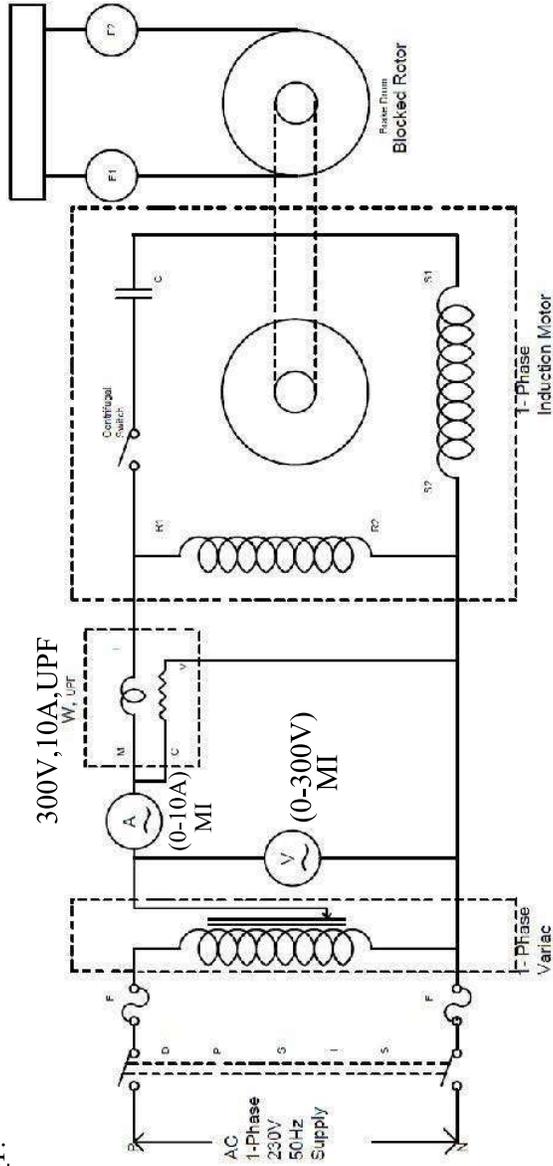
$$X_s = [Z_s^2 - R_s^2]^{1/2}$$

$$R_2 = R_{01} - R_m \parallel R_s$$

$$X_2 = X_{01} - [X_m \parallel (X_s - X_c)]$$

CIRCUIT DIAGRAM:

BLOCKED ROTOR TEST:



OBSERVATION TABULATION:

M.F= .....

Sl.No.	Blocked Rotor Voltage $V_b$ (Volts)	Blocked Rotor Current $I_b$ (Amps)	Blocked Rotor Power $P_b$ (Watts)	
			Observed	Actual
1.				

NO-LOAD TEST:

PRECAUTION:

1. DPST switch should be at open position.
2. Auto transformer should be at minimum position.

PROCEDURE:

1. The connections are made as per the circuit diagram.
2. Get the power supply from the control panel.
3. Close the DPST switch.
4. Adjust the auto-transformer to the rated voltage of 1-phase induction motor.
5. Note the readings of ammeter, voltmeter and wattmeter.
6. Bring auto-transformer to minimum voltage position. Switch of the supply.

BLOCKED ROTOR TEST:

PRECAUTION:

1. Keep the DPST switch in open position.
2. Auto- transformer should be at minimum position.
3. Before switching on the supply, some load is applied in the brake drum, so that rotor does not rotate.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Get the power supply from the control panel.
3. Close the DPST switch.
4. Auto transformer is adjusted to rated current of 1-phase induction motor.
5. Readings of ammeter, voltmeter and wattmeter are noted down.
6. Bring auto-transformer to its minimum voltage position and switch off the supply, after removing the load.

MODEL CALCULATION:

RESULT:

VIVA QUESTIONS:

1. What is a 1-phase induction motor?
2. Write the classification of 1-phase induction motor?
3. Why do we draw the equivalent circuit of 1-phase induction motor? What is double-field revolving theory?
4. Why 1-phase induction, motor is not self starting?

TABULAR COLUMN:

V (Volts)	I (Amps)	Speed N (RPM)	Wattmeter reading (Watts)	Spring balance readings (Kg)			Torque (T) N-m	Output Power (watts)	Power factor (Cos $\Phi$ )	% Efficiency ( $\eta$ )	% Slip (s)
				S <sub>1</sub>	S <sub>2</sub>	S <sub>1</sub> ~S <sub>2</sub>					

**Expt. No:**

**Date:**

**LOAD TEST ON SINGLE PHASE INDUCTION MOTOR**

AIM:

To conduct load test on the given single phase induction motor and to plot its performance characteristics.

APPARATUS REQUIRED:

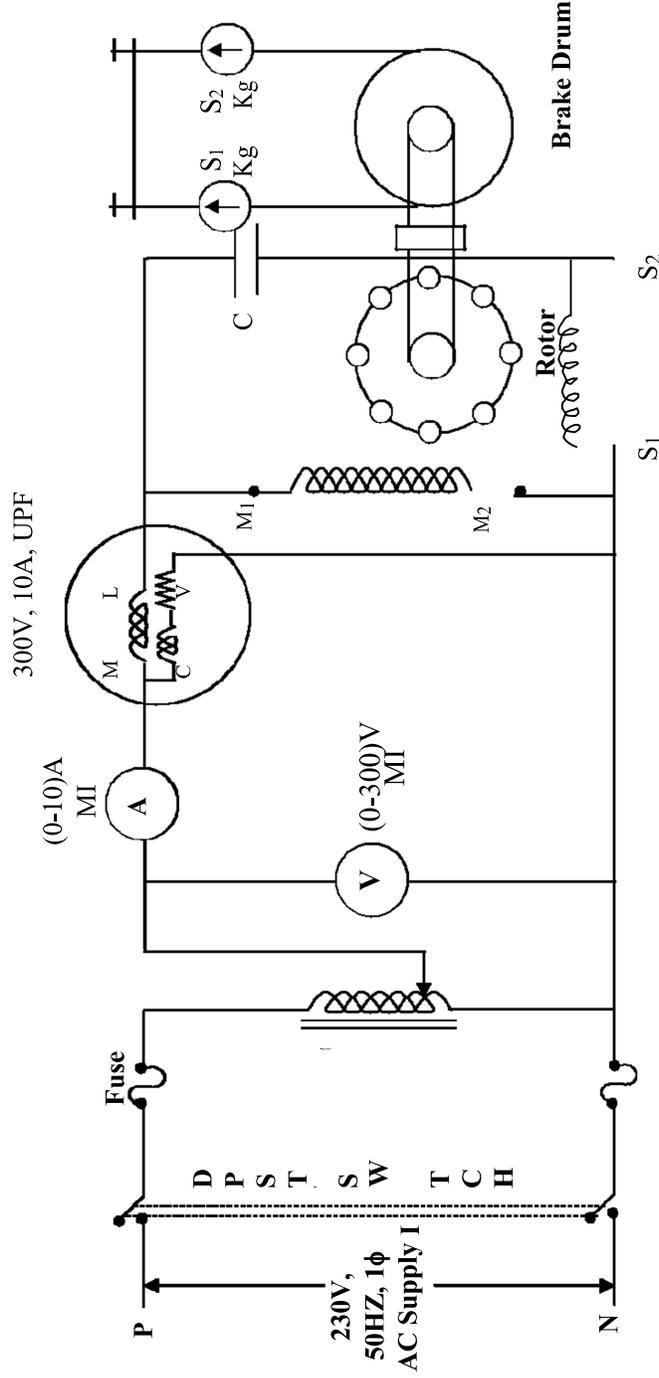
S.NO	APPARATUS	RANGE	TYPE	QUANTITY
1.	Voltmeter	(0-300V)	MI	1
2.	Ammeter	(0-10A)	MI	1
3.	Wattmeter	(300V,10A)	UPF	1
4.	Tachometer	(0-10000 RPM)	-	1

FORMULAE:

1. Circumference of the brake drum =  $2\pi R$  (m)  
R = Radius of the brake drum
2. Input power = W (watts)  
W = Wattmeter readings
3. Torque (T) =  $9.81 \cdot R \cdot (S_1 \sim S_2)$  (N-m)  
 $S_1, S_2$  = Spring balance readings (Kg)
4. Output power =  $\frac{2\pi NT}{60}$  (watts)  
N- Speed in rpm
5. % Efficiency ( $\eta$ ) = (Output Power/Input Power) \* 100
6. Power factor,  $\cos \Phi = W/VI$
7. % Slip,  $s = [(N_s - N)/N_s] \cdot 100$   
 $N_s = \text{Synchronous speed} = \frac{120f}{P}$  (rpm)  
P = No. of poles  
f = Frequency of supply (Hz)

CIRCUIT DIAGRAM:

LOAD TEST ON SINGLE PHASE INDUCTION MOTOR



FFuse Rating Calculation:

NAME PLATE DETAILS:

S<sub>1</sub>, S<sub>2</sub>- AUXILIARY WINDING  
M<sub>1</sub>, M<sub>2</sub>- MAIN WINDING

Rated Voltage :  
Rated Current :  
Rated Power :  
Rated Speed :

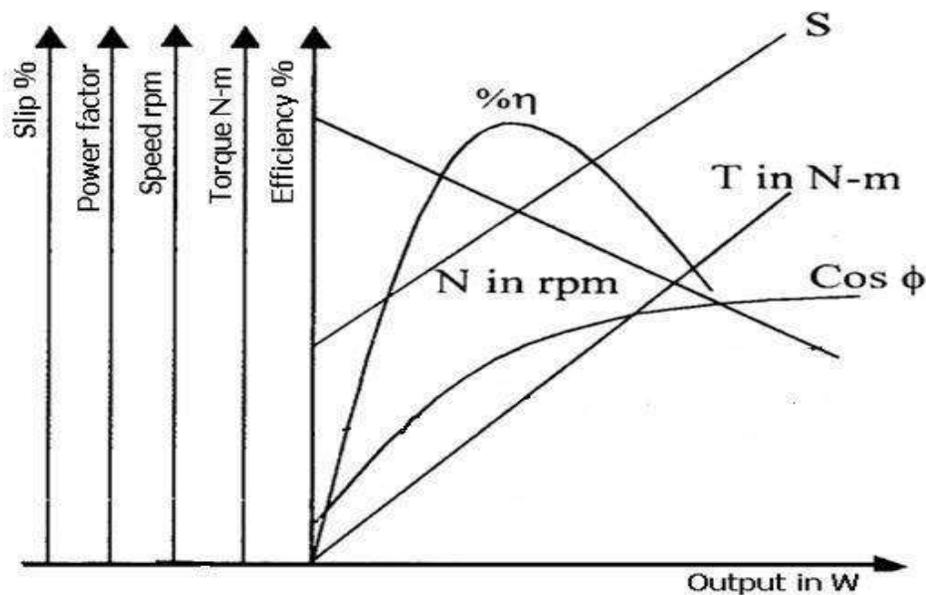
## PRECAUTIONS:

1. The auto transformer is kept at minimum voltage position.
2. The motor is started at no load condition.

## PROCEDURE:

1. Connections are given as per the circuit diagram.
2. The DPST switch is closed and the single phase supply is given.
3. By adjusting the variac the rated voltage is applied and the corresponding no load values of speed, spring balance and meter readings are noted down. If the wattmeter readings show negative deflection on no load, switch of the supply & interchange the terminals of current coils (M & L) of the wattmeter. Now, again starting the motor (follow above procedure for starting), take readings.
4. The procedure is repeated till rated current of the motor.
5. The motor is unloaded, the auto transformer is brought to the minimum voltage position, and the DPST switch is opened.

## MODEL GRAPH:



## RESULT:



**Expt. No:**

**Date :**

**REGULATION OF ALTERNATOR BY EMF AND MMF METHOD**

AIM :

To predetermine the percentage regulation of the given alternator by EMF (Synchronous Impedance Method) and MMF (Ampere Turns Method) by conducting OC and Short circuit test.

APPARATUS REQUIRED:

SL NO	APPARATUS REQUIRED	TYPE	RANGE	QUANTITY
1.	Voltmeter	MI	(0-600V)	1
2.	Ammeter	MC, MI	(0-2A), (0-5A)	1
3.	Rheostat	Wound	400ohm,1.1A 250ohm,2.5A	1 each
4.	Connecting Wires			As Required

FUSE RATING CALCULATION:

DC shunt motor : 125 % of rated current

Alternator : 125 % of rated current

FORMULA USED:

EMF Method:

$$R_e = 1.6 * R_s$$

Where,

$R_s$  - DC resistance and

$R_e$  - Equivalent AC resistance

$$Z_s = E_1 (\text{open circuit voltage}) / I_1 (\text{short circuit current})$$

$$X_s = (Z_s^2 - R_e^2)^{1/2}$$

$$E_o = [(V \cos \theta + I R_e)^2 + (V \sin \theta (+ \text{ or } -) I X_s)^2]^{1/2}$$

Where,

'+' sign for lagging Power Factor

'-' sign for leading Power Factor

$$\% \text{ Regulation (up)} = [(E_o - V)/V] * 100$$

OBSERVATION TABLE:

OPEN CIRCUIT TEST:

$I_f$ (A)	V (Volt)	$V_{ph}$ (Volt)

SHORT CIRCUIT TEST:

$I_f$ (A)	$I_a$ (A)

TO FIND ARMATURE RESISTANCE ( $R_a$ ):

Sl.No:	Voltage (V)	Current (A)	Resistance $R=V/I \Omega$

Mean:

$$R_{ac} = R_{dc} \times 1.6$$

### MMF Method:

$$I_f = [I_{f1}^2 + I_{f2}^2 - 2 I_{f1} I_{f2} \cos (90 (+ \text{ or } -) \phi)]^{0.5}$$

- ‘+’ for lagging power factor,
- ‘-’ for leading power factor.

Where,

$I_{f1}$  - Field current corresponding to  $V_1$

$I_{f2}$  - Field current corresponding to  $I_{sc}$

$$V_1 = V + I_a R_a \cos \phi$$

$$\% \text{ Regulation (up)} = [(E_o - V)/V] * 100$$

$E_o$  - Voltage corresponding to  $I_f$ .

### PRECAUTION:

1. DC shunt motor field rheostat should be in minimum resistance position to get minimum speed at the time of starting.
2. Alternator field rheostat should be in minimum position.
3. DPST and TPST switches should be in open position.

### PROCEDURE:

#### Open Circuit Test:

1. Connections are made as per the circuit diagram is obtained.
2. The supply is obtained from control panel.
3. Observing the precautions, DPST switch on motor side is closed.
4. Using 3-point starter, the DC motor is started.
5. Varying the field rheostat of DC shunt motor, it is set to run at rated speed as per name plate detail.
6. DPST switch in alternator field circuit is closed.
7. Keeping the TPST switch of alternator side open, the field current is varied using the alternator potential divider. For various values of alternator field current ( $I_f$ ), the generated AC line voltage ( $E_{OL}$ ) is noted down and the readings are tabulated. (This should be done upto 125% of rated voltage).

TABULATION:  
For Full Load

Sl.No	Cos $\phi$	Sin $\phi$	E <sub>o</sub> (V)		Terminal Voltage(V)	%Regulation	
			Lag	Lead		Lag	Lead

For Half Load

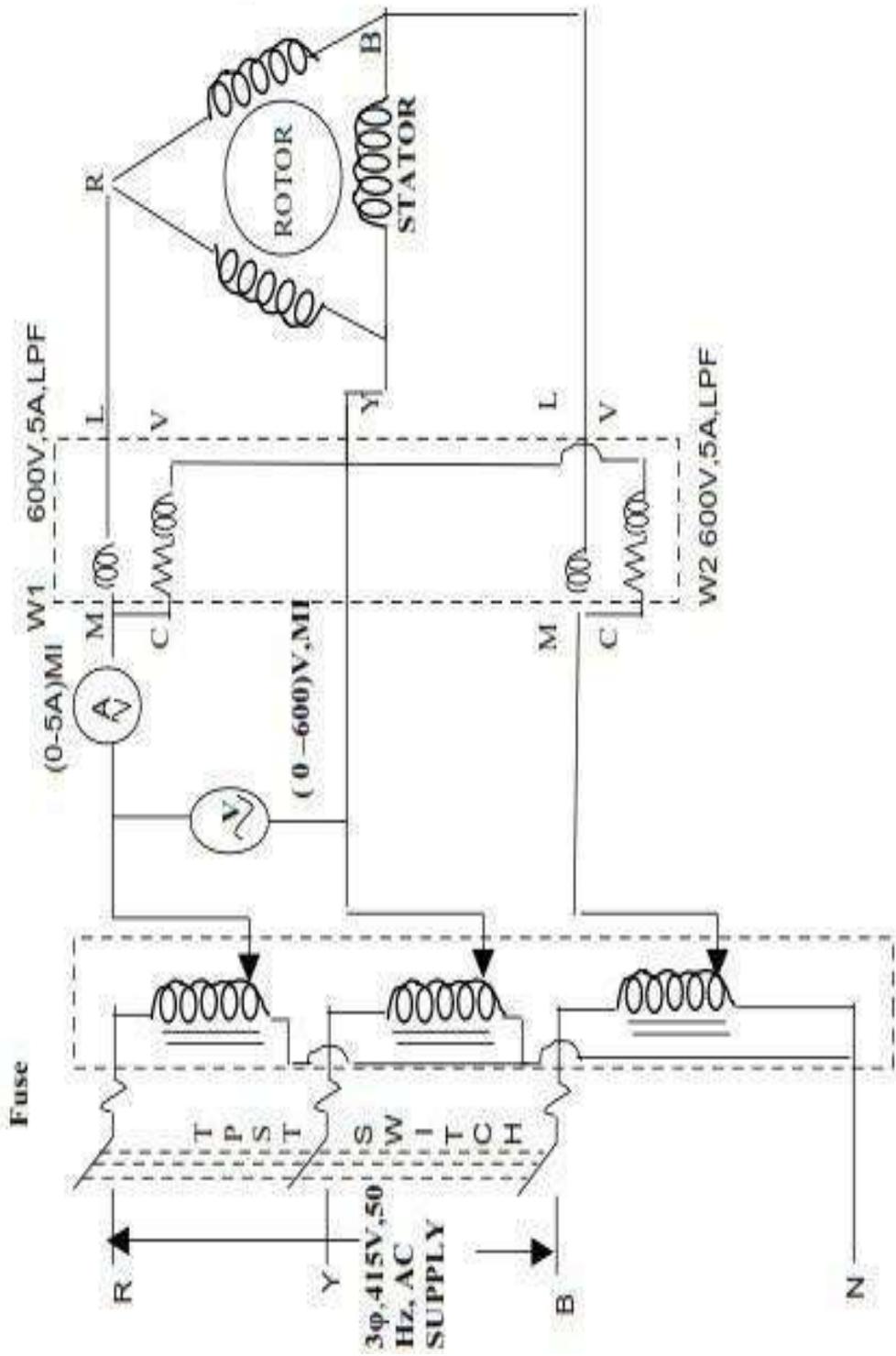
Sl.No	Cos $\phi$	Sin $\phi$	E <sub>o</sub> (V)		Terminal Voltage(V)	%Regulation	
			Lag	Lead		Lag	Lead

MODEL CALCULATION:

### Short Circuit Test:

1. TPST switch on alternator side is closed.
2. By slowly increasing potential divider from minimum potential position, the values of  $I_r$  and corresponding  $I_{sc}$  values are noted till rated current flows through the alternator.
3. The readings are tabulated.
4. Potential divider is adjusted to original position (minimum potential position) and field rheostat on motor side is adjusted to minimum resistance position.
5. DPST and TPST switches are opened.
6. The supply is switched off.

RESULT:



**FUSE RATING CALCULATION:**

25% of full load current rating

**NAME PLATE DETAILS:**

**Expt.No:**

**Date:**

**SEPERATION OF LOSSES IN A THREE PHASE INDUCTION MOTOR**

**AIM:**

To separate the no load losses in a given three phase induction motor.

**APPARATUS REQUIRED:**

SL.NO	APPARATUS	RANGE	TYPE	QUANTITY
1	Ammeter	0-5A	MI	1
2	Voltmeter	0-600V	MI	1
3	Wattmeter	600V,5A	LPF	2
4	Auto Transformer	0-600 V	Three Phase	1
5	Connecting Wires			As Required

**FORMULA USED:**

Magnetic Loss =  $[W_o - \text{mechanical losses} - 3I_o^2R_s]$

Where  $W_o$  = wattmeter reading

$I_o$  = current at rated voltage

$R_s$  = stator resistance

Mechanical losses are obtained from the graph

**PRECAUTIONS:**

1. The motor should be at the no load condition while starting.
2. The 3 $\Phi$  auto-transformer (variac) should be kept at initial zero position.

**PROCEDURE:**

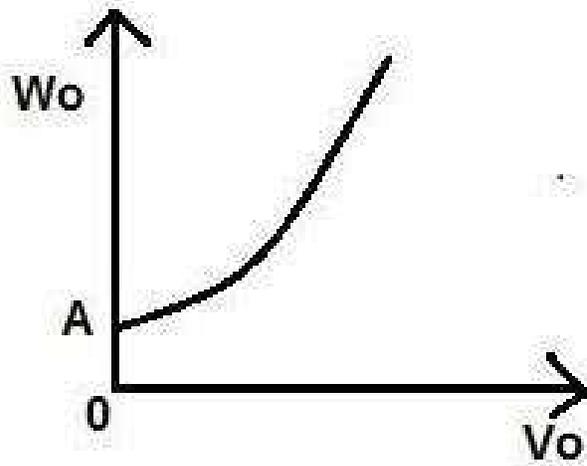
**SEPERATION OF LOSSES:**

1. Connections are given as per the circuit diagram.
2. The 3 $\Phi$  A.C supply is given by closing the TPST switch.
3. The induction motor is started gradually by applying voltage through the 3 $\Phi$  auto-transformer.
4. At rated voltage, power input  $W_o$  is measured by using wattmeter and no load current  $I_o$  and voltage  $V_o$  are noted.
5. Voltage is gradually reduced till the motor continues to run.
6. For each voltage, readings of ammeter, voltmeter and wattmeter are noted.

**MEASUREMENT OF STATOR RESISTANCE ( $R_s$ ):**

1. Connections are given as per the circuit diagram.
2. The D.C supply is given through a DPST switch.
3. The loading rheostat is varied, the readings of ammeter and voltmeter are noted.
4. Armature resistance in ohms is calculated as  $R_s/\text{ph} = (V*1.5)/2I$

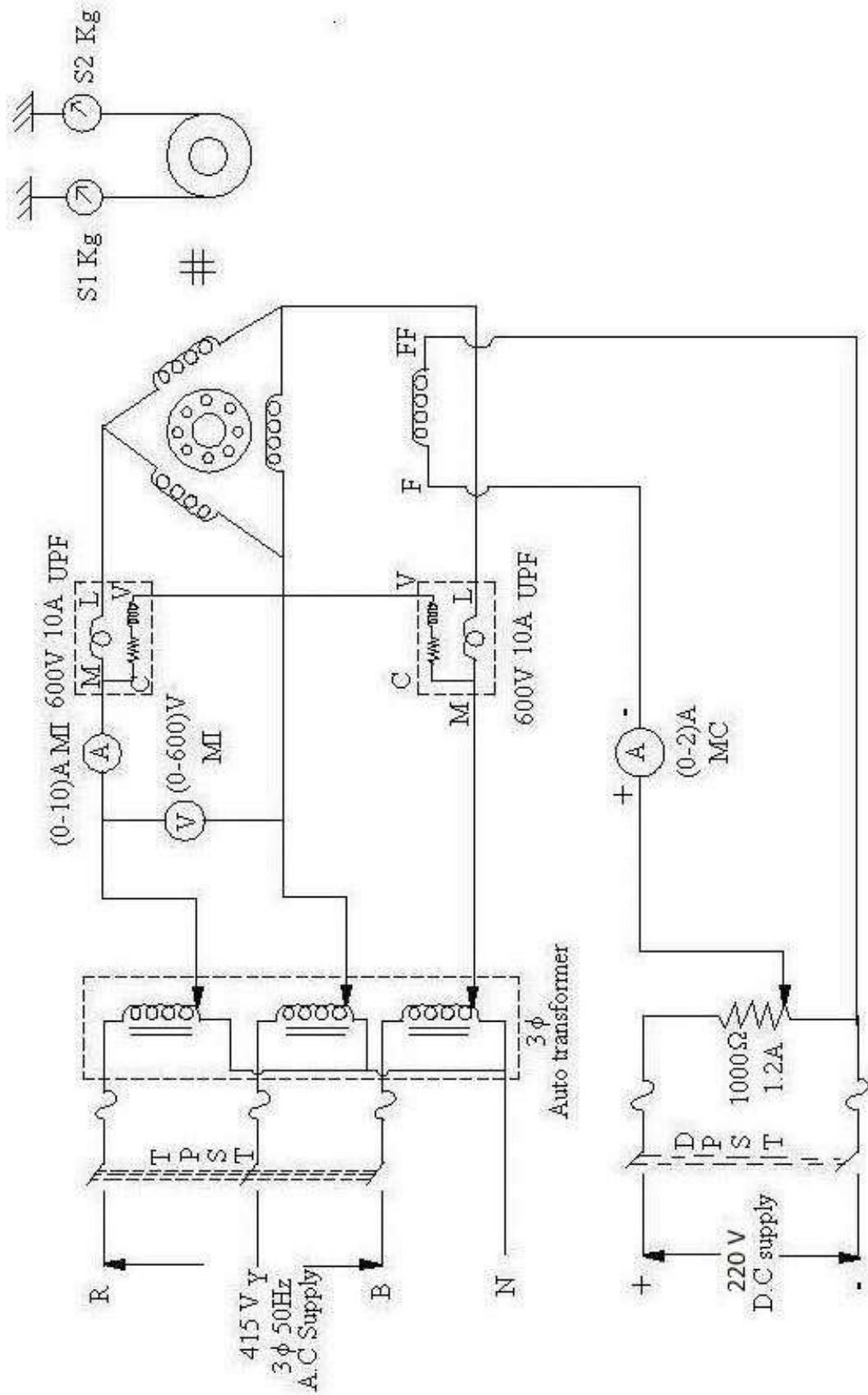
MODEL GRAPH:



MODEL CALCULATION:

RESULT:

CIRCUIT DIAGRAM:



**Expt.No:**

**Date:**

**V CURVE AND INVERTED V CURVE OF THREE  
PHASE SYNCHRONOUS MOTOR**

AIM:

The aim of the experiment is to draw the V and inverted V curves of three phase synchronous motor.

APPARATUS REQUIRED:

SL. NO.	NAME OF THE APPARATUS	RANGE	TYPE	QUANTITY
1.	Ammeter	(0-10) A	MI	1
2.	Ammeter	(0-2) A	MC	1
3.	Voltmeter	(0-600) V	MI	1
4.	Wattmeter	600V,10A,UPF		1
5.	Rheostat	250 $\Omega$ ,1.5 A	Wire wound	2
6.	Tachometer		Digital	1
7.	3 $\Phi$ Auto transformer	415/(0-470)V		1
8.	Connecting wires			As required

FUSE RATING:

125% of rated current (full load current)

For DC excitation:

For Synchronous motor:

**TABULAR COLUMN:**

Armature voltage:

Without load:

Sl. No.	Excitation current (I <sub>f</sub> ) Ampere	Armature current (I <sub>a</sub> ) Ampere	Wattmeter - I		Wattmeter - II		Power factor (CosΦ)
			Observed watts	Actual watts	Observed watts	Actual watts	

With load:

Sl. No.	Excitation current (I <sub>f</sub> ) Ampere	Armature current (I <sub>a</sub> ) Ampere	Wattmeter - I		Wattmeter - II		Power factor (CosΦ)
			Observed watts	Actual watts	Observed watts	Actual watts	

#### FORMULAE USED:

$$\cos \Phi = P_i / \sqrt{3} V_L I_L$$

Where  $\Phi$  – Phase angle between voltage and current

$P_i$  – Input Power

$V_L$  - Line voltage

$I_L$  – Line current

#### THEORY:

Synchronous motor is constant speed motor which are not self starting in nature, so that we have to start this motor by any one of the following starting methods,

1. Pony motor method starting
2. Auto induction starting
3. DC exciter starting
4. Damper winding method of starting

By construction there is no difference between synchronous generator and synchronous motor. 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.

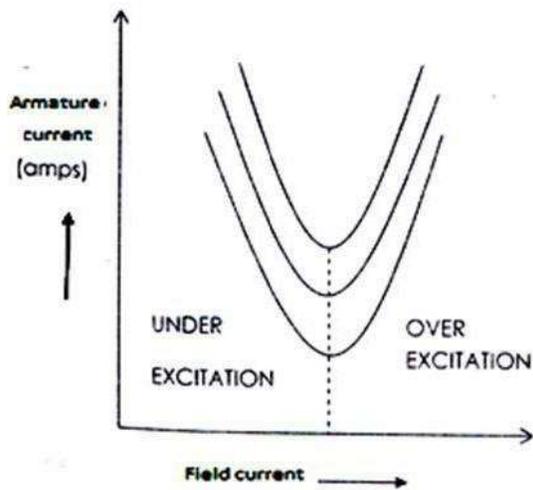
The variations of armature current with field current are in the form of V curves and the variation of power factor with field current are in the form of Inverted V curves.

## MODEL GRAPH:

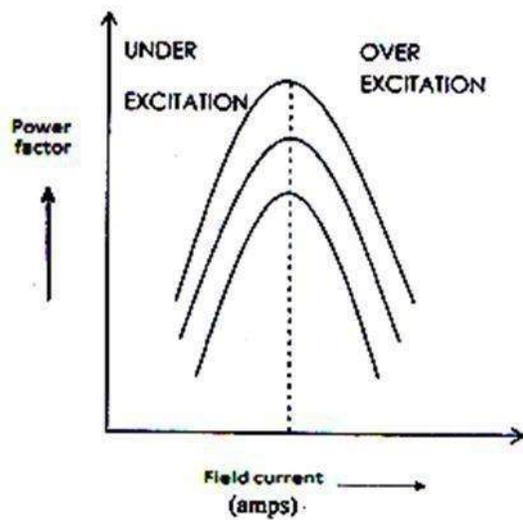
The graph is drawn for

1. Armature current Vs Excitation current
2. Power Factor Vs Excitation.

### V Curves



### Inverted V Curves



#### PRECAUTIONS:

1. The potential divider should be in the maximum position.
2. The motor should be started without any load.
3. Initially TPST switch is in open position.

#### PROCEDURE:

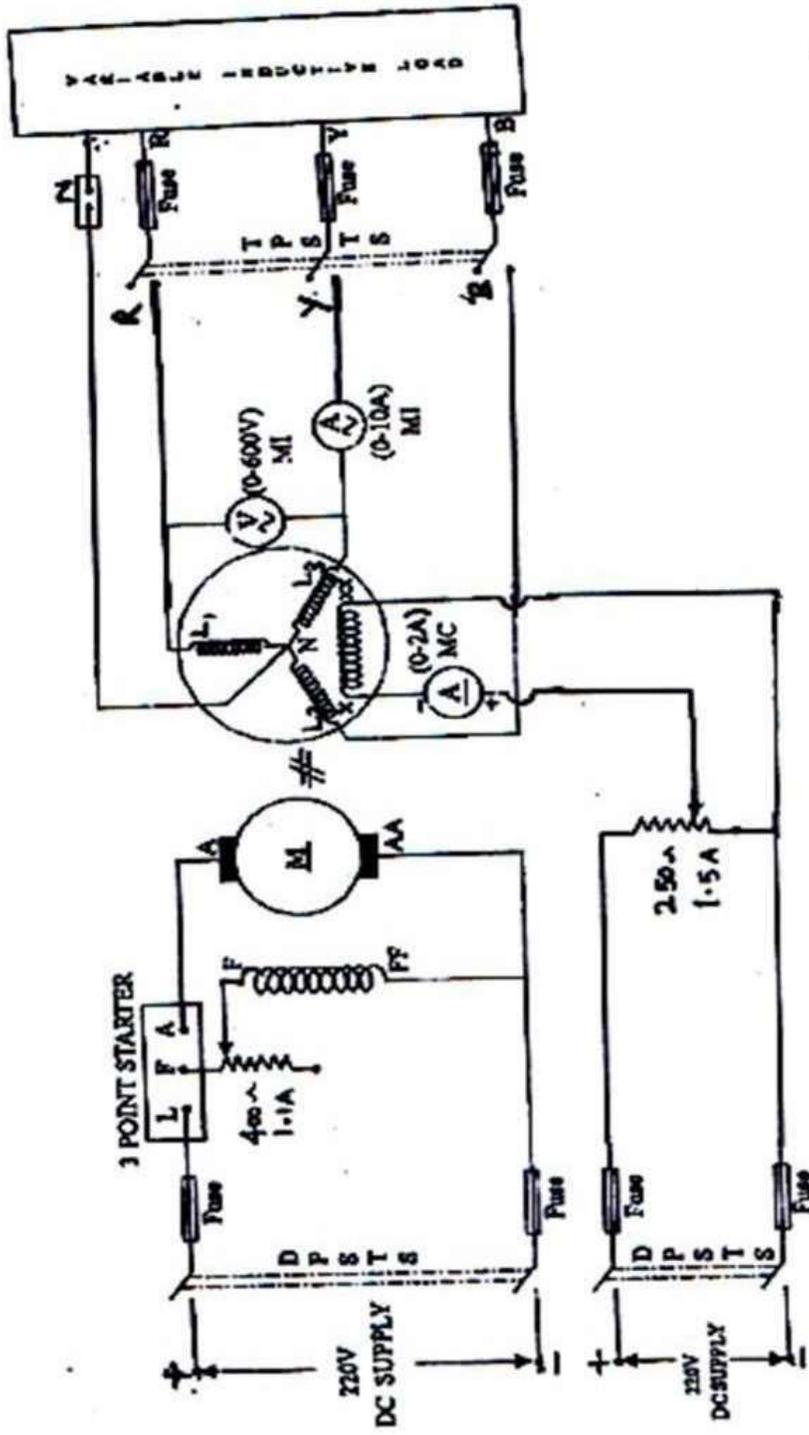
1. Note down the name plate details of motor.
2. Connections are given as per the circuit diagram.
3. Close the TPST switch.
4. By adjusting the auto transformer from minimum position to maximum position the rated supply is given to the motor. The motor starts as an induction motor.
5. In order to give the excitation to the field winding, close the DPST switch.
6. By varying the field current with the help of field rheostat from under excitation to over excitation, note down the armature current and the input power at no load, half load and full load conditions .
7. Later reduce the load and the motor is switched off after observing the precautions.

#### VIVA QUESTIONS:

1. Define V and inverted V curves?
2. Define critical excitation?
3. What is advantage of plotting the V &  $\Lambda$  Curves?
4. What is Load Angle?
5. What do you mean by under excitation and over excitation?
6. What happens to the Power factor if the field current is gradually increased?

#### RESULT:

CIRCUIT DIAGRAM:



**Expt. No:**

**Date:**

**PREDETERMINATION OF REGULATION OF 3PH ALTERNATOR BY  
A.S.A. METHOD**

AIM:

To predetermine the regulation of a given 3 phase alternator by ASA(American Standards Association) method and to draw the vector diagrams.

APPARATUS REQUIRED:

Sl.No.	Name of the Apparatus	Type	Range	Quantity
1.	Ammeter	MC	0–2 A	1
2.	Ammeter	MI	0–10 A	1
3.	Voltmeter	MI	0–600 V	1
4.	Rheostat	Wire wound	250 $\Omega$ , 1.5 A	1
5.	Rheostat	Wire wound	1200 $\Omega$ , 0.8 A	1
6.	Tachometer	Digital	--	1
7.	TPST knife switch	--	--	1

FUSE RATING:

For motor: 125% of rated current

For Alternator: 125% of rated current

FORMULAE USED:

$$\text{Percentage regulation} = \frac{E_o - V_{\text{rated}}}{V_{\text{rated}}} \times 100$$

PRECAUTIONS:

1. Motor field rheostat should be kept at minimum resistance position.
2. Alternator field rheostat should be kept at maximum resistance position.

OBSERVATION:

OPEN CIRCUIT TEST:

<b>Sl.No</b>	<b>Field current (If) Ampere</b>	<b>Open circuit Voltage(Line) Volts</b>	<b>Open circuit Voltage(Phase) Volts</b>

SHORT CIRCUIT TEST:

<b>Sl.No</b>	<b>SHORT CIRCUIT TEST</b>		<b>ZERO POWER FACTOR TEST</b>		
	<b>Field Current (If) Ampere</b>	<b>Rated Armature current (Ia) Ampere</b>	<b>Field Current (If) Ampere</b>	<b>Rated Armature current (Ia) Ampere</b>	<b>Rated Armature Voltage (Va) Volts</b>

**PROCEDURE:**

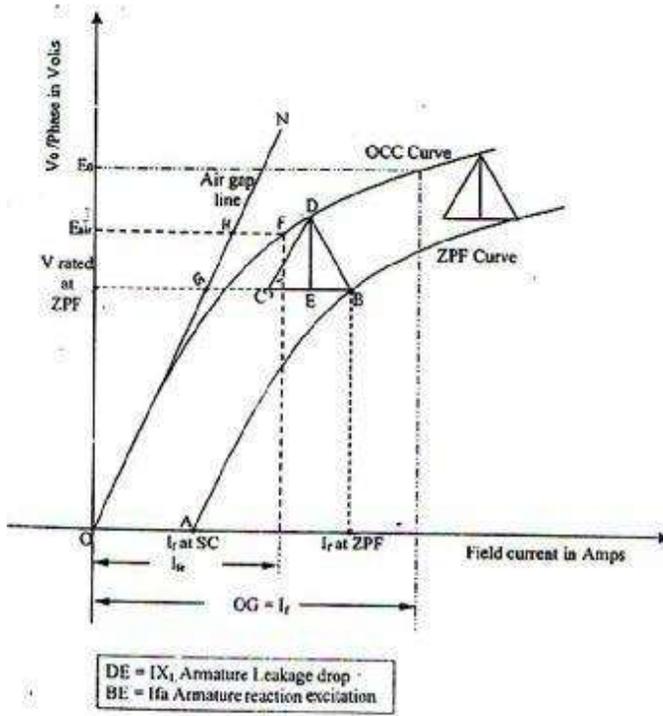
1. Note down the complete nameplate details of motor and alternator.
2. Connections are made as per the circuit diagram.
3. Switch on the supply by closing the DPST main switch.
4. Using the Three point starter, start the motor to run at the synchronous speed by varying the motor field rheostat.
5. Conduct an Open Circuit Test by varying the Potential Divider for various values of Field current and tabulate the corresponding Open circuit voltage readings.
6. Conduct a Short Circuit Test by closing the TPST knife switch and adjust the potential divider the set the rated Armature current, tabulate the corresponding Field current.
7. Conduct a ZPF test by adjusting the potential divider for full load current passing through either an inductive or capacitive load with zero power and tabulate the readings.
8. Conduct a Stator Resistance Test by giving connection as per the circuit diagram and tabulate the voltage and Current readings for various resistive loads.

**PROCEDURE TO DRAW THE POTIER TRIANGLE (ASA METHOD):**

(All the quantities are in per phase value)

1. Draw the Open Circuit Characteristics (Generated Voltage per phase VS Field Current)
2. Mark the point A at X-axis, which is obtained from short circuit test with full load armature current.
3. From the ZPF test, mark the point B for the field current to the corresponding rated armature current and the rated voltage.
4. Draw the ZPF curve which passing through the point A and B in such a way parallel to the open circuit characteristics curve.
5. Draw the tangent for the OCC curve from the origin (i.e.) air gap line.
6. Draw the line BC from B towards Y-axis, which is parallel and equal to OA.
7. Draw the parallel line for the tangent from C to the OCC curve.
8. Join the points B and D also drop the perpendicular line DE to BC, where the line DE represents armature leakage reactance drop ( $IX_L$ ) BE represents armature reaction excitation ( $I_f a$ ).
9. Extend the line BC towards the Y-axis up to the point O'. The same line intersects the airgap line at point G.
10. Mark the point I in Y-axis with the magnitude of  $E_{air}$  and draw the line from I towards OCC curve which should be parallel to X-axis. Let this line cut the air gap line at point H and the OCC curve at point F.
11. Mention the length O'G, HF and OA.

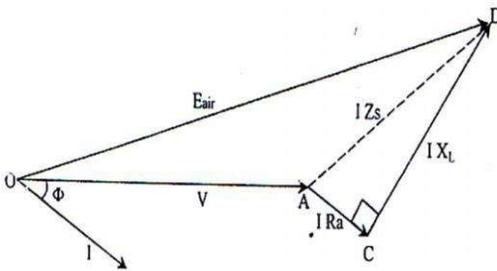
MODEL GRAPH FOR ZPF METHOD:



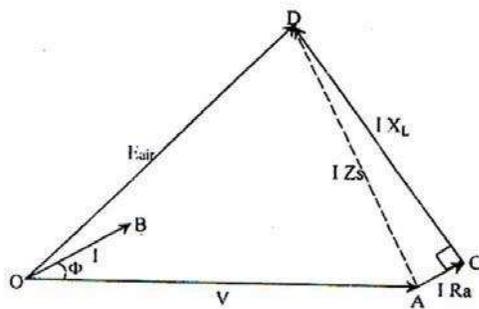
VECTOR DIAGRAMS (ASA METHOD):

To find the airgap voltage ( $E_{air}$ ):

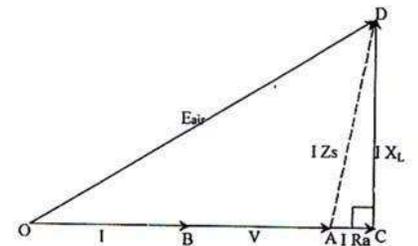
Lagging power factor



Leading power factor



Unity power factor



PROCEDURE TO DRAW THE VECTOR DIAGRAM (ASA METHOD):

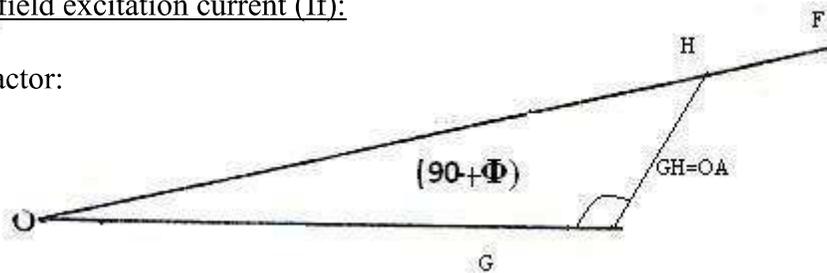
(To find the field Excitation current  $I_f$ )

1. Draw the vector with the magnitude  $O'G$ .
2. From G draw a vector with the magnitude of GH (OA) in such a way to make an angle of  $(90 \pm \Phi)$  from the line  $O'G$  [  $(90 + \Phi)$  for lagging power factor and  $(90 - \Phi)$  for leading power factor]
3. Join the points O' and, H also extend the vector  $O'F$  with the magnitude HF. Where O'F is the field excitation current ( $I_f$ ).
4. Find out the open circuit voltage ( $E_o$ ) for the corresponding field excitation current ( $I_f$ ) from the OCC curve.
5. Find out the regulation from the suitable formula.

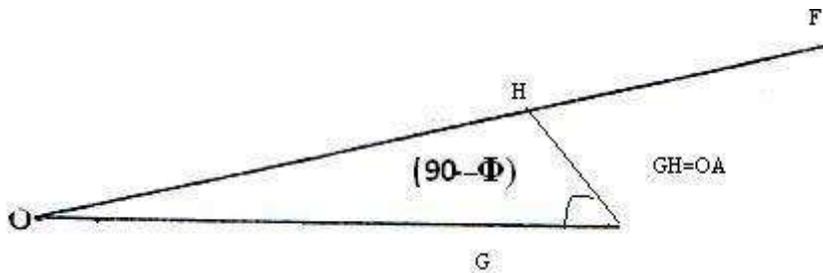
VECTOR DIAGRAMS (ASA METHOD):

To find the field excitation current ( $I_f$ ):

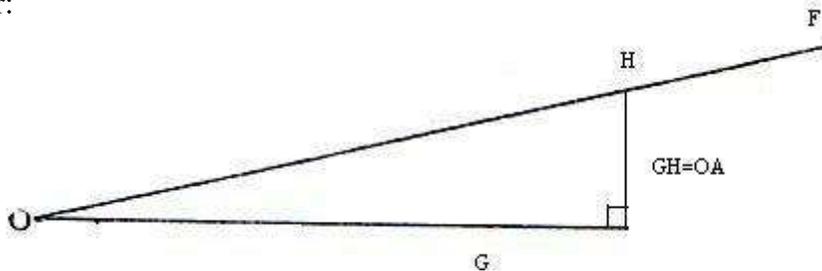
Lagging power factor:



Leading power factor:



Unity power factor:



TABULATION:

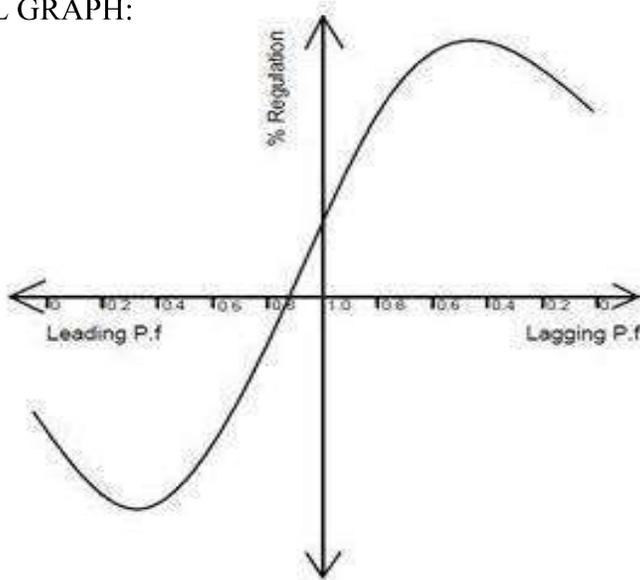
To find Armature Resistance ( $R_a$ ):

Sl. No:	Voltage (Volts)	Current (Amps)	Resistance = $V/I$ ( $\Omega$ )

Mean=

$$R_{ac} = R_{dc} \times 1.6$$

MODEL GRAPH:



Tabulation for calculating % Regulation:

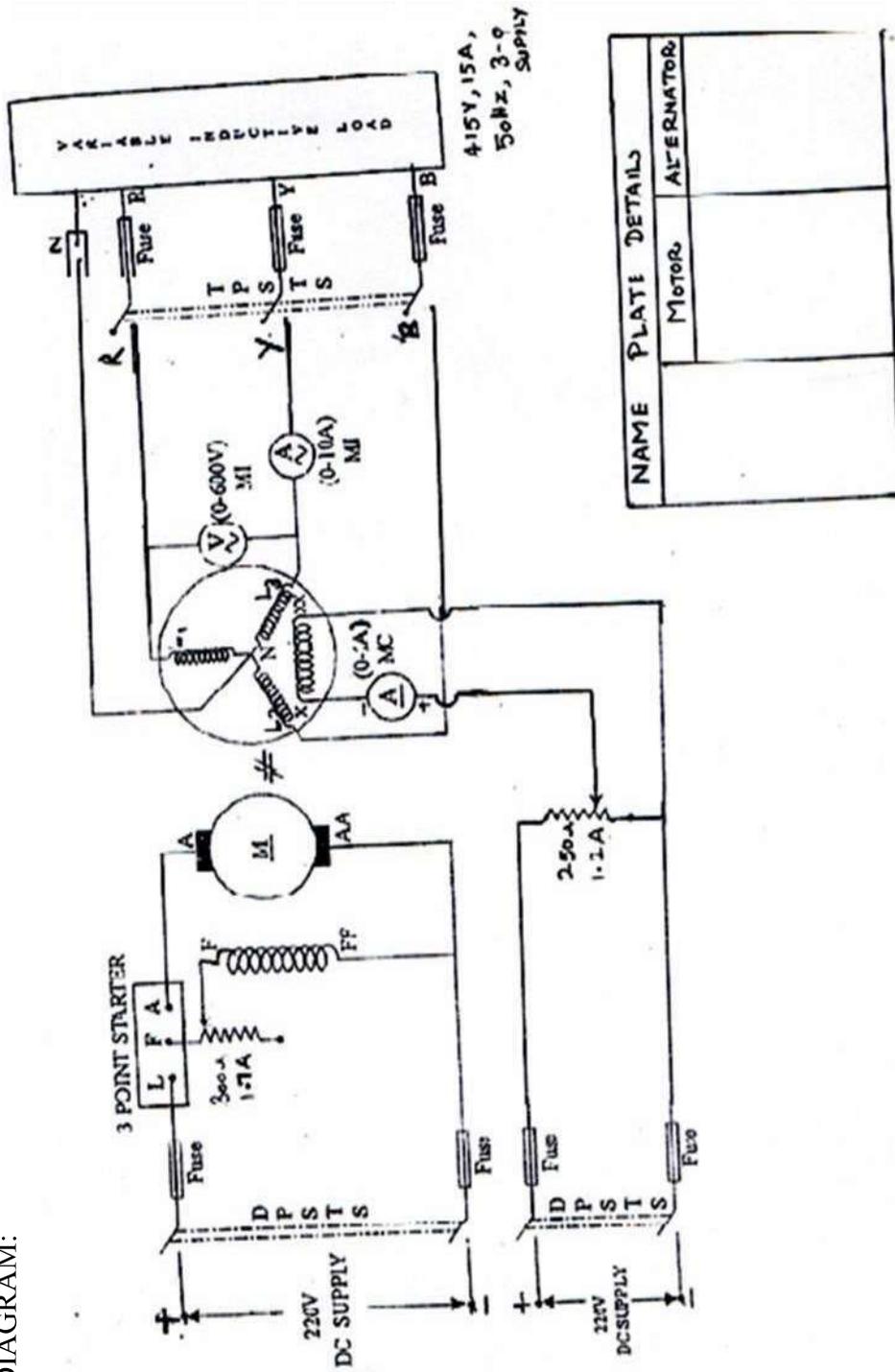
Sl. No:	$\cos\Phi$	$\sin\Phi$	$E_a$ (Volts)		$I_{f1}$ (Amps)		$I_f$ (Amps)		$E_o$ (Volts)		%Regulation	
			Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead

VIVA QUESTIONS:

1. What is ASA method?
2. What are the experimental data required for ASA method?
3. What is potier triangle?
4. Define percentage regulation?
5. Define voltage regulation?
6. What are the different methods available to determine the voltage regulation of an alternator?

RESULT:

CIRCUIT DIAGRAM:



**Expt.No:**

**Date:**

**PREDETERMINATION OF REGULATION OF 3 ALTERNATOR BY ZPF METHOD**

**AIM:**

To predetermine the regulation of a given 3 phase alternator by ZPF method and to draw the vector diagrams.

**APPARATUS REQUIRED:**

<b>Sl.No.</b>	<b>Name of the Apparatus</b>	<b>Type</b>	<b>Range</b>	<b>Quantity</b>
1	Ammeter	MC	(0 – 2) A	1
2	Ammeter	MI	(0 – 10) A	1
3	Voltmeter	MI	(0 – 600) V	1
4	Rheostat	Wire wound	250 Ω, 1.2 A	1
5	Rheostat	Wire wound	300Ω, 1.7 A	1
6	Tachometer	Digital	---	1
7	TPST knife switch	--	--	1

**FUSE RATING CALCULATION:**

For motor: 125% of rated current

For Alternator: 125% of rated current

**FORMULAE USED:**

$$\text{Percentage regulation} = \frac{E_o - V_{\text{rated}}}{V_{\text{rated}}} \times 100$$

**PRECAUTIONS:**

1. Motor field rheostat should be kept at minimum resistance position.
2. Alternator field rheostat should be kept at maximum resistance position.

OBSERVATION:

OPEN CIRCUIT TEST:

<b>S.No</b>	<b>Field current (<math>I_f</math>)</b>	<b>Open circuit Voltage(Line)</b>	<b>Open circuit Voltage(Phase)</b>
<b>Unit</b>	<b>Ampere</b>	<b>Volts</b>	<b>Volts</b>

SHORT CIRCUIT TEST:

<b>S.No</b>	<b>SHORT CIRCUIT TEST</b>		<b>ZERO POWER FACTOR TEST</b>		
	<b>Field current (<math>I_f</math>) Ampere</b>	<b>Rated Armature current (<math>I_a</math>) Ampere</b>	<b>Field current (<math>I_f</math>) Ampere</b>	<b>Rated Armature current (<math>I_a</math>) Ampere</b>	<b>Rated Armature Voltage (<math>V_a</math>) Volts</b>

#### PROCEDURE:

1. Note down the complete nameplate details of motor and alternator.
2. Connections are made as per the circuit diagram.
3. Switch on the supply by closing the DPST main switch.
4. Using the Three point starter, start the motor to run at the synchronous speed by varying the motor field rheostat.
5. Conduct an Open Circuit Test by varying the Potential Divider for various values of Field current and tabulate the corresponding Open circuit voltage readings.
6. Conduct a Short Circuit Test by closing the TPST knife switch and adjust the potential divider to set the rated Armature current, tabulate the corresponding Field current.
7. Conduct a ZPF test by adjusting the potential divider for full load current passing through either an inductive or capacitive load with zero power and tabulate the readings.
8. Conduct a Stator Resistance Test by giving connection as per the circuit diagram and tabulate the voltage and Current readings for various resistive loads.

#### PROCEDURE TO DRAW THE POTIER TRIANGLE (ZPF METHOD):

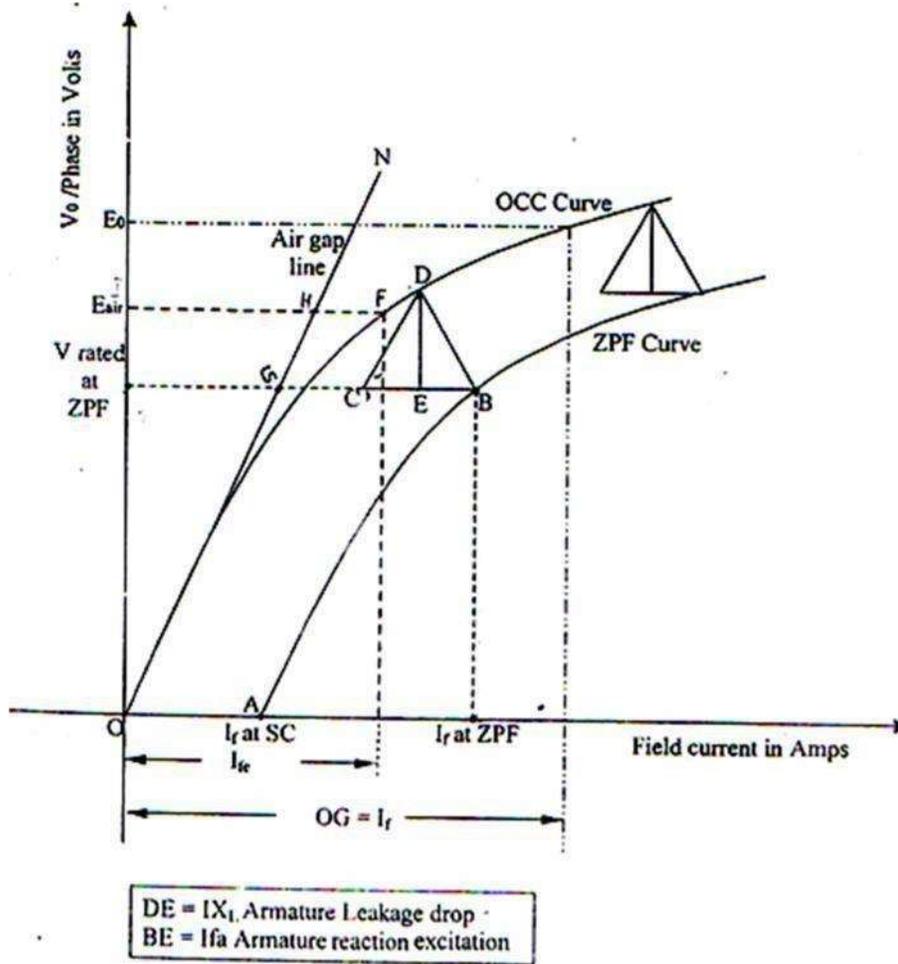
(All the quantities are in per phase value)

1. Draw the Open Circuit Characteristics (Generated Voltage per phase VS Field Current)
2. Mark the point A at X-axis, which is obtained from short circuit test with full load armature current.
3. From the ZPF test, mark the point B for the field current to the corresponding rated armature current and the rated voltage.
4. Draw the ZPF curve which passing through the point A and B in such a way parallel to the open circuit characteristics curve.
5. Draw the tangent for the OCC curve from the origin (i.e.) air gap line.
6. Draw the line BC from B towards Y-axis, which is parallel and equal to OA.
7. Draw the parallel line for the tangent from C to the OCC curve.
8. Join the points B and D also drop the perpendicular line DE to BC, where the line DE represents armature leakage reactance drop ( $IX_L$ ) and BE represents armature reaction excitation ( $I_{fa}$ ).

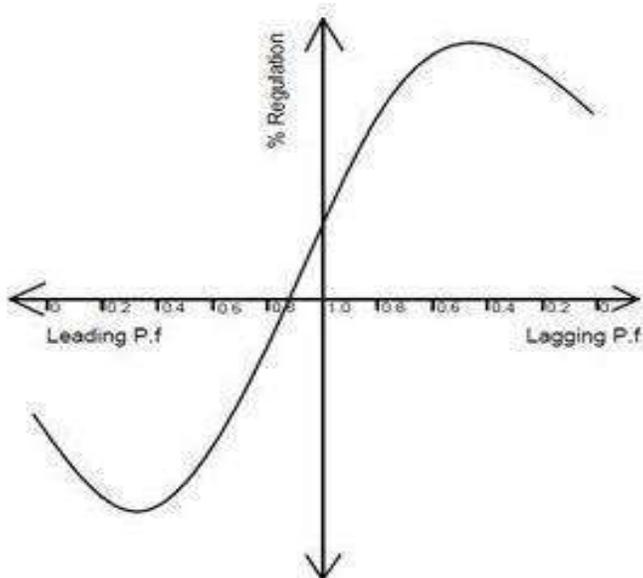
#### PROCEDURE TO DRAW THE VECTOR DIAGRAM (ZPF METHOD):

1. Select the suitable voltage and current scale.
2. For the corresponding power angle (Lag, Lead, Unity) draw the voltage vector and current vector OB.
3. Draw the vector AC with the magnitude of  $IR_a$  drop, which should be parallel to the vector OB.
4. Draw the perpendicular CD to AC from the point C with the magnitude of  $IX_L$  drop.

MODEL GRAPH FOR ZPF METHOD:



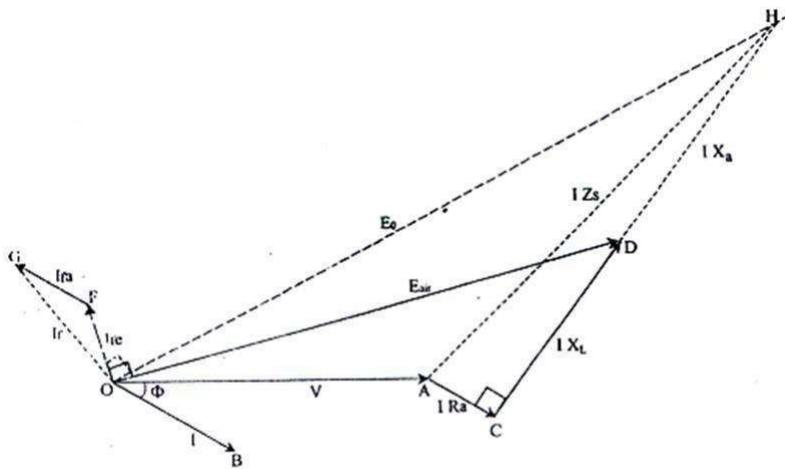
MODEL GRAPH:



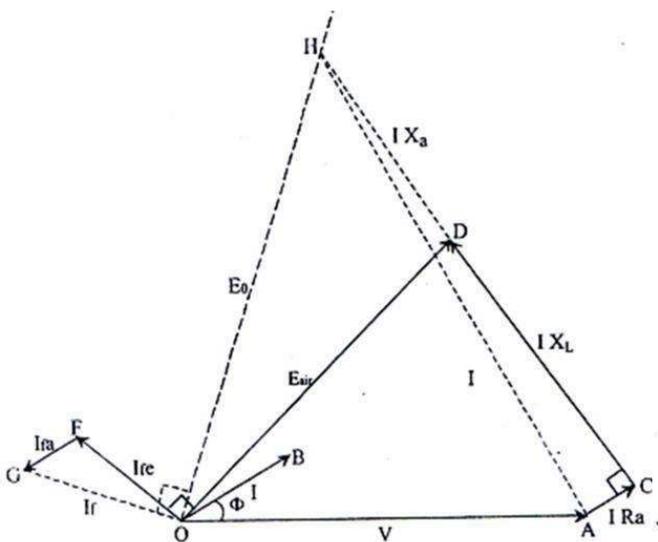
5. Join the points O and D, which will be equal to the air gap voltage ( $E_{air}$ ).
6. Find out the field current ( $I_{fc}$ ) for the corresponding air gap voltage ( $E_{air}$ ) from the OCC curve.
7. Draw the vector OF with the magnitude of  $I_{fc}$  which should be perpendicular to the vector OD.
8. Draw the vector FG from F with the magnitude  $I_{fa}$  in such a way it is parallel to the current vector OB.
9. Join the points O and G, which will be equal to the field excitation current ( $I_f$ ).
10. Draw the perpendicular line to the vector OG from the point O and extend CD in such a manner to intersect the perpendicular line at the point H.
11. Find out the open circuit voltage ( $E_o$ ) for the corresponding field excitation current ( $I_f$ ) from the OCC curve.
12. Find out the regulation from the suitable formula.

### VECTOR DIAGRAMS FOR POTIER TRIANGLE:

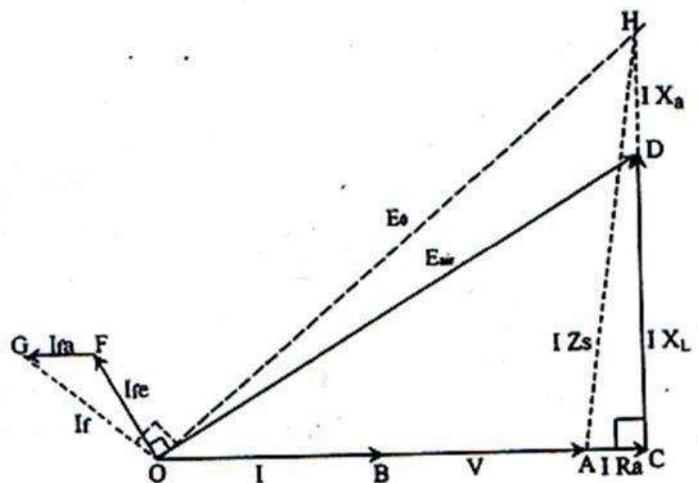
Lagging power factor:



Leading power factor:



Unity power factor:



TABULATION:

To find Armature Resistance ( $R_a$ ):

S.No	Voltage(V)	Current(A)	Resistance $R=V/I(\Omega)$

Mean=

$$R_{ac} = R_{dc} \times 1.6$$

Tabulation for calculating % Regulation:

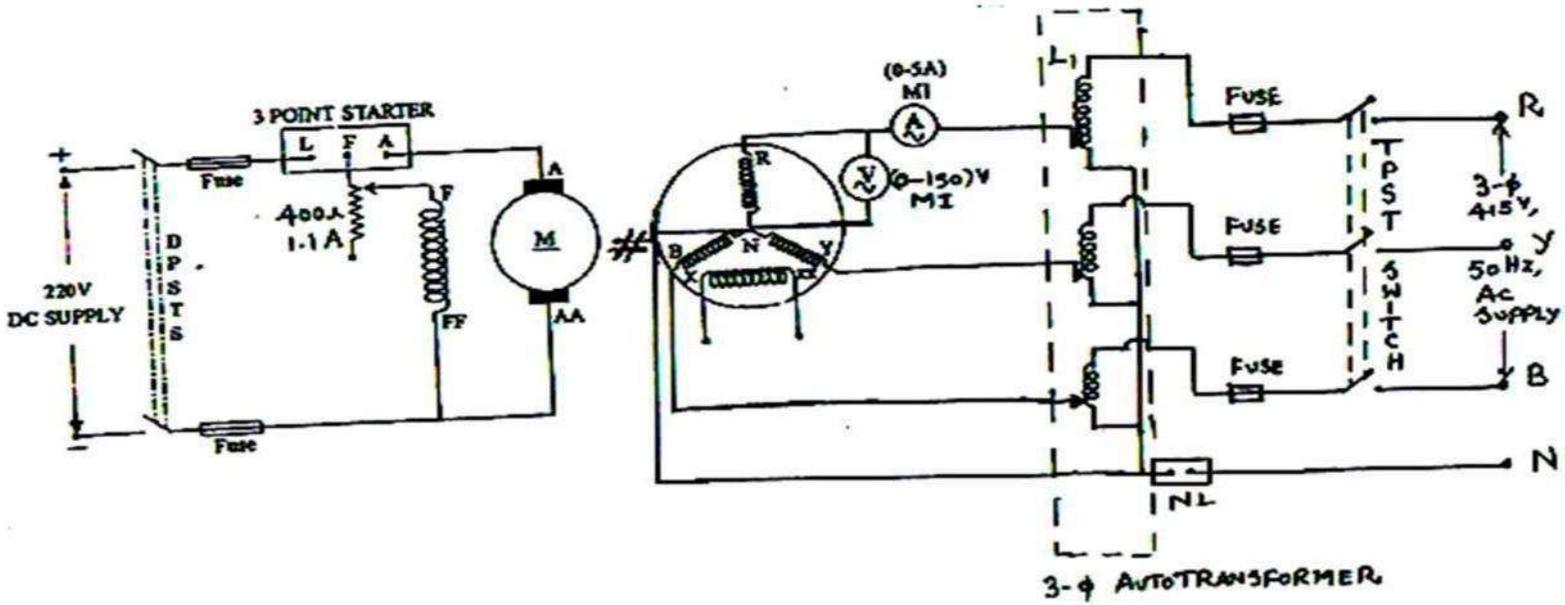
Sl. No:	Cos $\Phi$	Sin $\Phi$	Ea(Volts)		If1(Amps)		If(Amps)		Eo(Volts)		%Regulation	
			Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead

VIVA QUESTIONS:

1. Define regulation of an alternator?
2. What is ZPF?
3. What is disadvantage of Emf and Mmf method?
4. What is potier triangle?
5. Does the regulation by ZPF method gives the exact value?
6. What is the advantage and disadvantage of ZPF?

RESULT:

CIRCUIT DIAGRAM:



NAME PLATE DETAILS		
	MOTOR	ALTERNATOR
VOLTAGE		
SPEED		
CURRENT		
POWER		

**Expt.No:**

**Date:**

**REGULATION OF THREE PHASE SALIENT POLE ALTERNATOR BY SLIP TEST**

AIM:

The aim of the experiment is to predetermine the regulation of three phase salient pole alternator by conducting the slip test.

APPARATUS REQUIRED:

S.NO	NAME OF THE APPARATUS	RANGE	TYPE	QUANTITY
1.	Ammeter	(0-5) A	MI	1
2.	Ammeter	(0-1) A	MC	1
3.	Voltmeter	(0-150) V	MI	1
4.	Voltmeter	(0-5)V	MC	1
5.	Voltmeter	(0-300)V	MI	1
6.	Rheostat	400Ω,1.1A	Wire wound	1
7.	Tachometer		Digital	1
8.	TPST Switch			1
9.	Connecting wires			As required

FUSE RATING CALCULATION:

125% of rated current (full load current)

For DC shunt motor:

For Alternator:

TABULAR COLUMN:

TO FIND OUT THE DIRECT AXIS IMPEDANCE ( $Z_d$ ):

Speed of the alternator:

Minimum Voltage applied to the stator:

(Nearly 20% to 30% of rated voltage)

Sl.No	Speed (RPM)	Minimum current per phase ( $I_{min}$ ) (Ampere)	Maximum Voltage per phase ( $V_{max}$ ) (Volts)	Direct axis impedance per phase ( $Z_d$ ) ( $\Omega$ )	Direct axis Reactance per phase ( $X_d$ ) ( $\Omega$ )

TO FIND OUT THE DIRECT AXIS IMPEDANCE ( $Z_q$ ):

Sl.No	Speed (RPM)	Maximum current per phase ( $I_{max}$ ) (Ampere)	Minimum Voltage per phase ( $V_{min}$ ) (Volts)	Quadrature axis impedance per phase ( $Z_q$ ) ( $\Omega$ )	Quadrature axis Reactance per phase ( $X_q$ ) ( $\Omega$ )

## FORMULA USED:

1. Armature Resistance  $R_a = 1.6 * R_{dc}$
2. Direct impedance per phase  $(Z_d) = V_{min} / I_{max}$  in  $\Omega$
3. Quadrature axis impedance per phase  $(Z_q) = V_{max} / I_{min}$  in  $\Omega$
4. Direct axis reactance per phase  $(X_d) = \sqrt{(Z_d^2 - R_a^2)}$  in  $\Omega$
5. Quadrature axis reactance per phase  $(X_q) = \sqrt{(Z_q^2 - R_a^2)}$  in  $\Omega$
6. Percentage Regulation =  $(E_o - V_{rated}) / V_{rated} * 100$
7.  $E_o = V_t \cos \delta - I_q R_a - I_d X_d$  (Motoring)
8.  $E_o = V_t \cos \delta + I_q R_a + I_d X_d$  (Generating)
9.  $\delta = \Psi - \Phi$  (Generator)
10.  $\delta = \Phi - \Psi$  (Motor)
11.  $\Psi = \tan^{-1} (V_t \sin \Phi \pm I_a X_q) / (V_t \cos \Phi \pm I_a R_a)$ 
  - + For generating mode
  - For Motoring mode

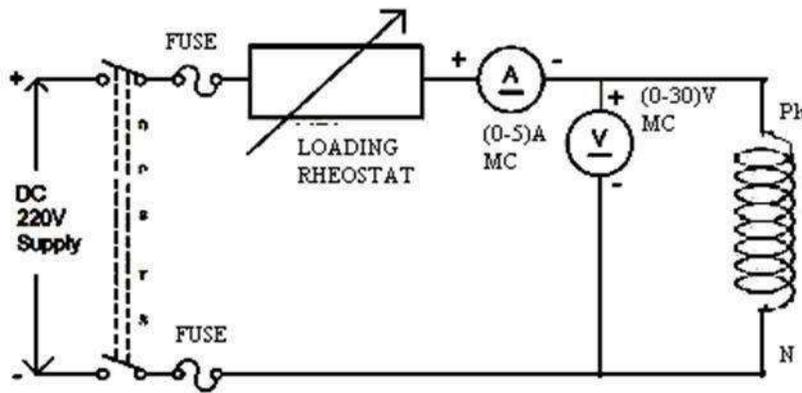
## THEORY:

In non salient pole alternators air gap length is constant and reactance is also constant. Due to this the mmfs of armature and field act upon the same magnetic circuit all the time hence can be added vector ally. But in salient pole alternators the length of the air gap varies and reluctance also varies. Hence the armature flux and field flux cannot vary sinusoidally in the air gap. So the reluctance of the magnetic circuit on which mmf act is different in case of salient pole alternators. This can be explained by two reaction theory.

## PRECAUTIONS:

1. The motor field rheostat should be kept in minimum resistance position.
2. The alternator field should be kept open throughout the experiment.
3. The direction of rotation due to prime mover and due to the alternator run as the motor should be same.
4. Initially all the switches are kept open.

Determination Stator armature resistance,  $R_a$ :



TABULATION:

Sl.No	Armature Voltage, $V_a$ (Volts)	Armature Current, $I_a$ (Amps)	Armature Resistance, $R_a(\Omega)$

RESULTANT TABULATION FOR SLIP TEST IN SALIENT POLE SYNCHRONOUS GENERATOR:

S.No	Power Factor	Percentage of Regulation	
		Lagging	Leading

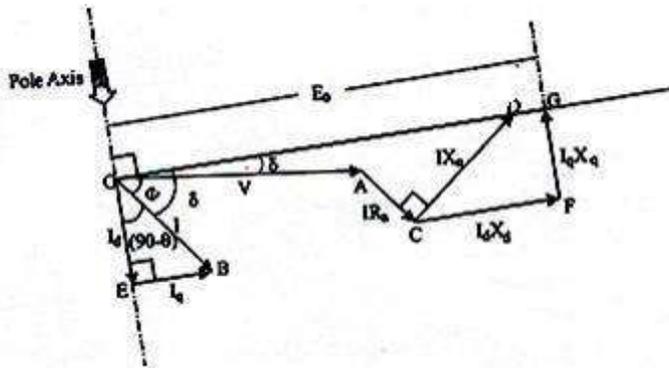
#### PROCEDURE:

1. Note down the name plate details of motor and alternator.
2. Connections are given as per the circuit diagram.
3. Give the supply by closing the DPST switch.
4. Using the three point starter start the motor to run at the synchronous speed by varying the motor field rheostat at the same time check whether the alternator field has opened or not.
5. Apply 20% to 30% of the rated voltage to the armature of the alternator by adjusting the autotransformer.
6. To obtain the slip and maximum oscillations of pointers, the speed is reduced slightly lesser than the synchronous speed.
7. Maximum current, minimum current, maximum voltage and Minimum voltage are noted.
8. Find out the direct and quadrature axis impedance ( $Z_d$  &  $Z_q$ ).

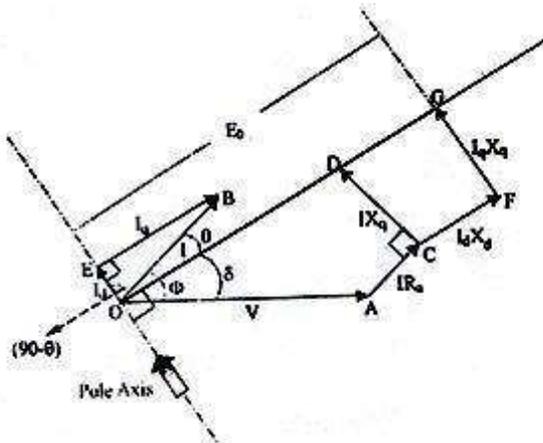
#### PROCEDURE TO DRAW THE VECTOR DIAGRAM (ZPF METHOD)

1. Draw the line OA vector that represents the rated voltage V.
2. Draw the line OB vector to represent the rated current I, which makes an angle  $\Phi$  ( it may be Lag, Lead, Unity) with the voltage.
3. Draw the vector AC with the magnitude of  $IR_a$  drop, which should be parallel to the vector OB.
4. Draw the perpendicular line CD vector to the line AC from that represents magnitude of  $IX_q$  drop.
5. Draw the line from the origin through the point D, which will be equal to no load voltage ( $E_o$ ).
6. Draw the pole axis through origin, which should be perpendicular to vector OD.
7. Draw the perpendicular line to the pole axis from the same(point E),which should be passed through the point B.[Where vector OE represent direct axis current( $I_d$ ) and vector EB represents quadrature axis current ( $I_q$ )]
8. Find out the reactive voltage drops  $I_d X_d$  and  $I_q X_q$ .

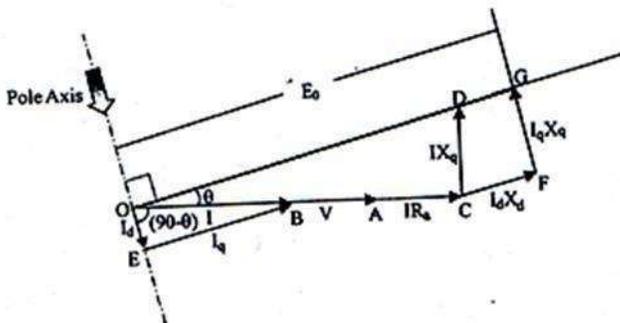
Lagging power factor:



Leading power factor:

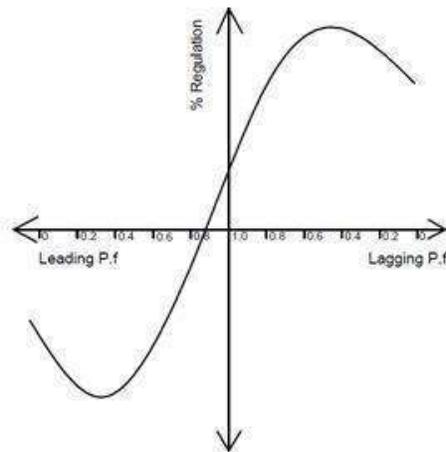


Unity power factor:



9. Draw the parallel line(i.e. Perpendicular to  $I_d$ ) to the vector OD from the point C,with the magnitude of the drop  $I_d X_d$  (Line CF).
10. Draw the parallel line(i.e. Perpendicular to  $I_q$ ) to the vector OE from the point F,with the magnitude of the drop  $I_q X_q$  (Line FG).
11. Let the point at where the drop  $I_q X_q$  meets the OD line be G, here the vector OG is representing the noload voltage( $E_o$ ).
12. Find out the regulation from the suitable formula.

#### MODEL GRAPHS:

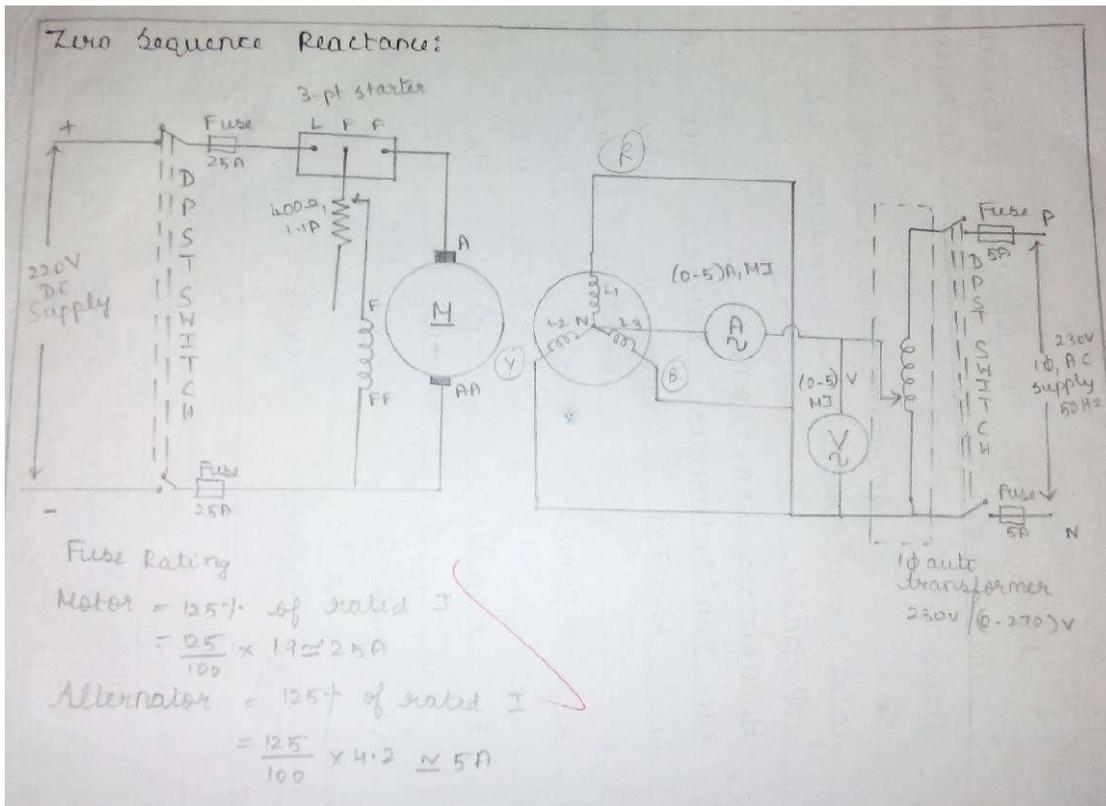
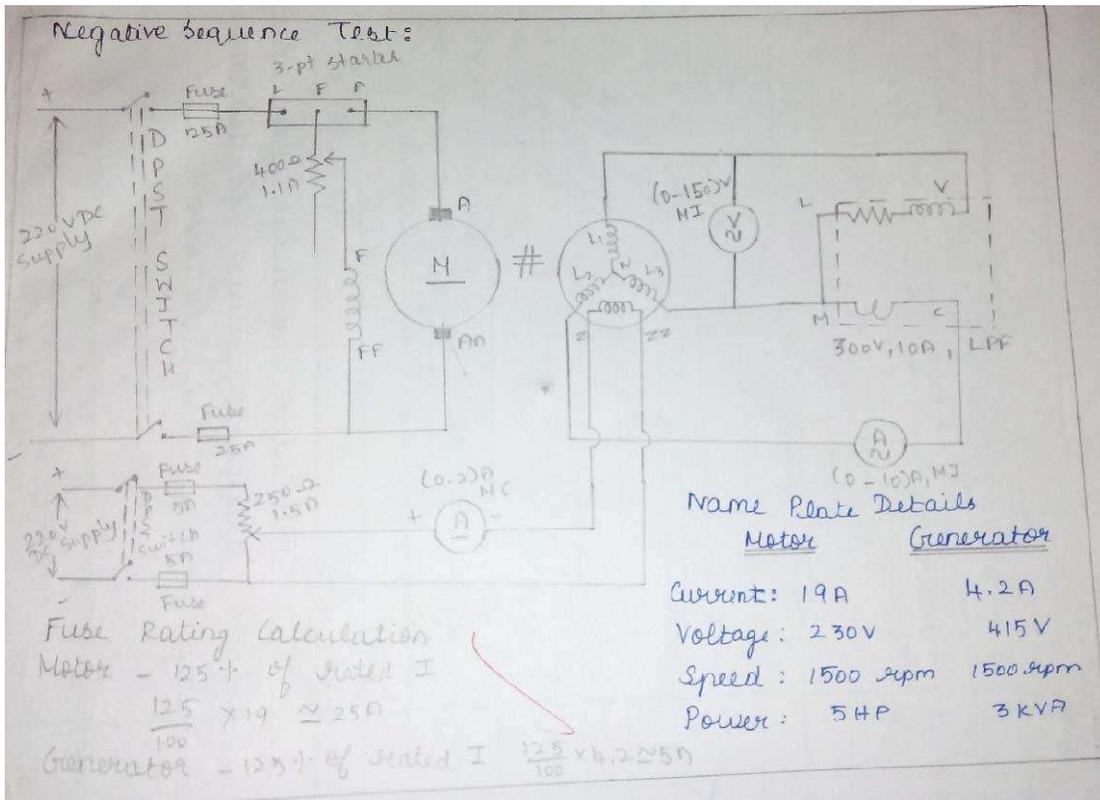


#### VIVA QUESTIONS:

1. What is the necessity of damper winding?
2. What is d axis?
3. What is q-axis?
4. What is called slip test?
5. What is meant by power angle?

#### RESULT:

CIRCUIT DIAGRAM:



**Expt.No:**

**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:

Sl.No.	Name of the Apparatus	Range	Type	Quantity
1.	Ammeter	(0-5)A, (0-10)A (0-2)A	MI MC	1 each
2.	Voltmeter	(0-5)V, (0-150)V	MI	1 each
3.	Wattmeter	300V,10A	LPF	1
4.	Rheostat	400 $\Omega$ , 1.1A 250 $\Omega$ , 1.5A	Wire Wound	1 each
5.	Auto Transformer	230V / (0-270)V	1 $\phi$	1
6.	Tachometer	-	Digital	1
7.	Connecting Wires	-	-	As Required

FUSE RATING CALCULATION:

125% of rated current (full load current)

For DC shunt motor:

For Alternator:

OBSERVATION:

A) For Negative Sequence Reactance:

S.No.	$V_{RY}$ (V)	Isc (A)	W (Watt)	$Z_2 = \frac{V_{RY}}{\sqrt{3} \text{Isc}}$	$X_2 = Z_2 * (W / (V_{RY} * \text{Isc}))$	Avg. $X_2(\Omega)$

B) For Zero Sequence Reactance:

S.No.	$V_{RY}$ (V)	Isc (A)	$X_0 = \frac{3V}{I}$	Avg. $X_0(\Omega)$

**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 impedance 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 Impedence:

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<sup>2</sup>R losses. This loss /ph divided by I<sub>ph</sub> 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.

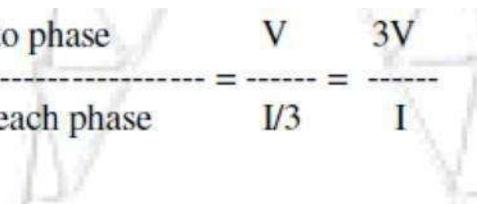
$$Z_2 = \frac{V_{RY}}{\sqrt{3} I_{sc}} \qquad X_2 = Z_2 \left( \frac{W}{V_{RY} I_{sc}} \right)$$

$$X_2 = \sqrt{Z_2^2 - R_2^2} \qquad R_2 = \frac{W}{\sqrt{3} I_{sc}^2}$$

MODEL CALCULATION:

### 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

$$Z_0 = \frac{\text{Voltage applied to phase}}{\text{Current through each phase}} = \frac{V}{I/3} = \frac{3V}{I}$$


### PROCEDURE:

#### (A) For Negative Sequence Reactance:

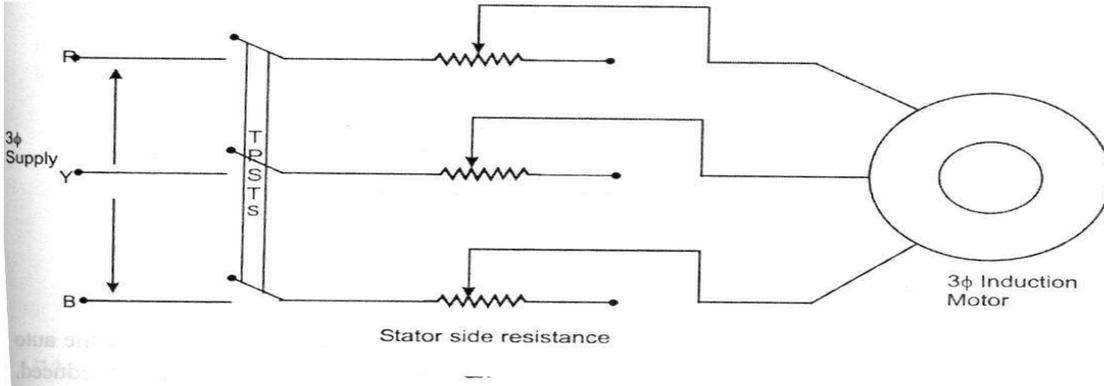
- (1) Make connection as shown in circuit diagram.
- (2) Run DC motor with synchronous speed.
- (3) Keeping the speed constant, vary the excitation and measure the voltmeter, ammeter and wattmeter reading.
- (4) Take 3 - 4 readings for different excitation.
- (5) The excitation should not be increased beyond the rated capacity of synchronous machine i.e. 4.2 A.

#### (B) For Zero Sequence Reactance:

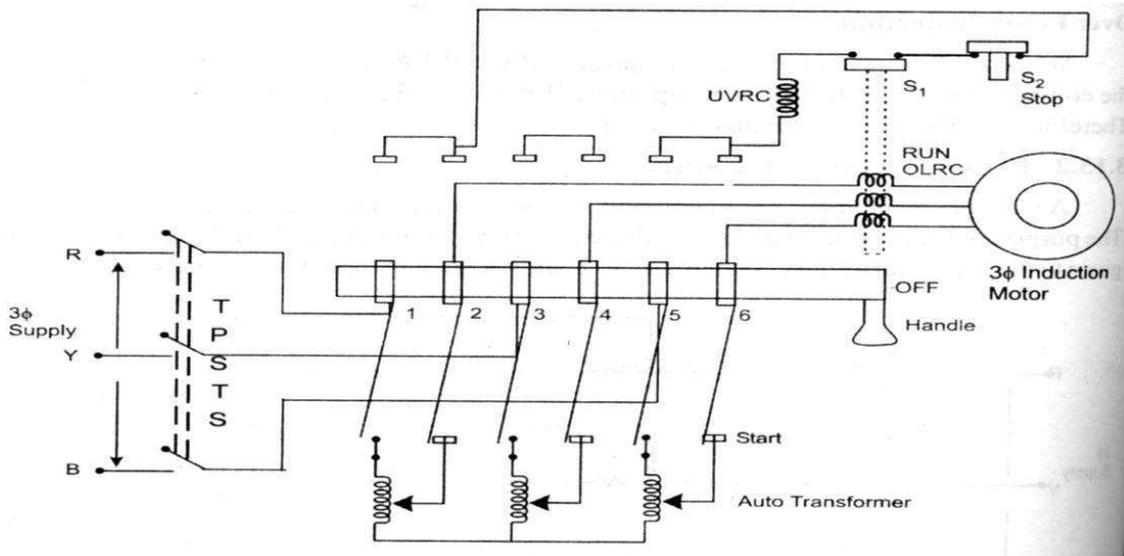
- (1) Make connection as shown in circuit diagram.
- (2) Switch on the AC supply by keeping autotransformer in zero volt position.
- (3) Gradually increase the autotransformer output by varying the VARIAC and note the ammeter reading for suitable voltage applied.
- (4) It should be kept in mind that the ammeter reading should not exceed the rated current capacity of the machine i.e. 4.2 A.

### RESULT:

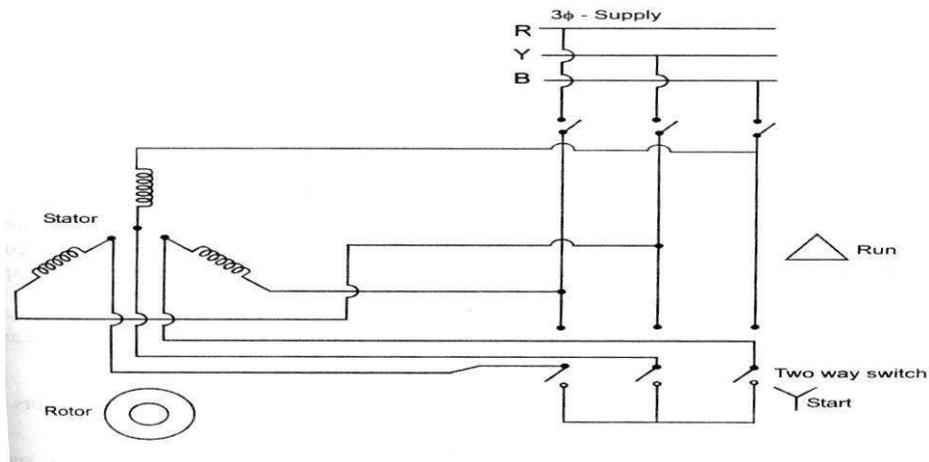
**CIRCUIT DIAGRAM:**  
Stator Resistance Starter:



Autotransformer Starter:



Star-Delta Starter:



**Expt. No:**

**Date:**

## **STUDY OF INDUCTION MOTOR STARTERS**

AIM:

To Study the AC motor starters.

NECESSITY OF STARTER:

In a three phase induction motor, the magnitude of an induced e.m.f. in the rotor circuit depends on the slip of the induction motor. This induced e.m.f. effectively decides the magnitude of the rotor current. The rotor current in the running condition is given by,

$$I_{2r} = \frac{sE_2}{\sqrt{R_2^2 + (s\chi_2)^2}}$$

But at start, the speed of the motor is zero and slip is at its maximum i.e. unity. So magnitude of rotor induced e.m.f. is very large at start. As rotor conductors are short circuited, the large induced e.m.f. circulates very high current through rotor at start.

The condition is exactly similar to a transformer with short circuited secondary. Such a transformer when excited by a rated voltage, circulates very high current through short circuited secondary. As secondary current is large, the primary also draws very high current from the supply.

Similarly in a three phase induction motor, when rotor current is high, consequently the stator draws a very high current from the supply. This current can be of the order of 5 to 8 times the full load current, at start.

Due to such heavy inrush of current at start there is possibility of damage of the motor winding. Similarly such sudden inrush of current causes large line voltage drop. Thus other appliances connected to the same line may be subjected to voltage spikes which may affect their working. To avoid such effects, it is necessary to limit the current drawn by the motor at start. 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.

Not only the starter limits the starting current but also provides the protection to the induction motor against overt loading and low voltage situations. The protection against single phasing is also provided by the starter. The induction motors having rating below 5 h.p. can withstand starting currents hence such motors can be started directly on line. But such motors also need overload, single phasing and low voltage protection which is provided by a starter.

### Stator Resistance Starter:

In order to apply the reduced voltage to the stator of the induction motor, three resistances are added in series with each phase of the stator winding. Initially the resistances are kept maximum in the circuit. Due to this large voltage gets dropped across the resistances. Hence a reduced voltage gets applied to the stator, which reduces the high starting current. The schematic diagram showing stator resistances is shown in the Fig.3.1. When the motor starts running, the resistances are gradually cut off from the stator circuit. When the resistances are entirely removed from the stator circuit i.e. rheostats in RUN position then rated voltage gets applied to the stator. Motor runs with normal speed. The starter is simple in construction and cheap. It can be used for both star and delta connected stator. But there are large power losses due to resistances. Also the starting torque of the motor reduces due to reduced voltage applied to the stator.

### Autotransformer Starter:

A three phase star connected autotransformer can be used to reduce the voltage applied to the stator. Such a starter is called an autotransformer starter. The schematic diagram of autotransformer starter is shown in the Fig. It consists of a suitable change over switch. When the switch is in the start position, the stator winding is supplied with reduced voltage. This can be controlled by tapping provide with autotransformer. When motor gathers 80% of the normal speed, the change over switch is thrown into run position. Due to this, rated voltage gets applied to stator winding. The motor starts rotating with normal speed. Changing of switch is done automatically by using relays. The power loss is much less in this type of starting. It can be used for both star and delta connected motors. But it is expensive than stator resistance starter.

### Star – Delta Starter:

This is the cheapest starter of all and hence used very commonly for the induction motors. It uses triple pole double throw (TPDPT) switch. The switch connects the stator winding in star at start. Hence per phase voltage gets reduced by the factor  $1 / \sqrt{3}$ . Due to this reduced voltage, the starting current is limited. When the switch is thrown on other side, the winding gets connected in delta, across the supply. So it gets normal rated voltage. The windings are connected in delta when motor gathers sufficient speed. The agreement of star – delta starter is shown in the Fig. The operation of the switch can be automatic by using relays which ensures that motor will not start with the switch in Run position. The cheapest of all and maintenance free operation are the two important advantages of this starter. While its limitations are, it is suitable for normal delta connected motors and the factor by which voltage change is  $1 / \sqrt{3}$  which cannot be changed.

RESULT:



**Expt. No:**

**Date :**

## **SYNCHRONISATION OF ALTERNATOR TO INFINITE BUSBAR**

**AIM:**

To synchronize the 3 $\Phi$  alternator to the infinite bus bar.

**APPARATUS REQUIRED:**

<b>Sl.NO</b>	<b>APPARATUS</b>	<b>SPECIFICATIONS</b>	<b>QUANTITY</b>
1	Voltmeter	(0-600V) MI	2
2	Ammeter	(0-2A) MC	1
3	Rheostat	300 $\Omega$ ,1.2A	1
		350 $\Omega$ ,2A	1
4	Synchronising Lamps	230V,15A	6

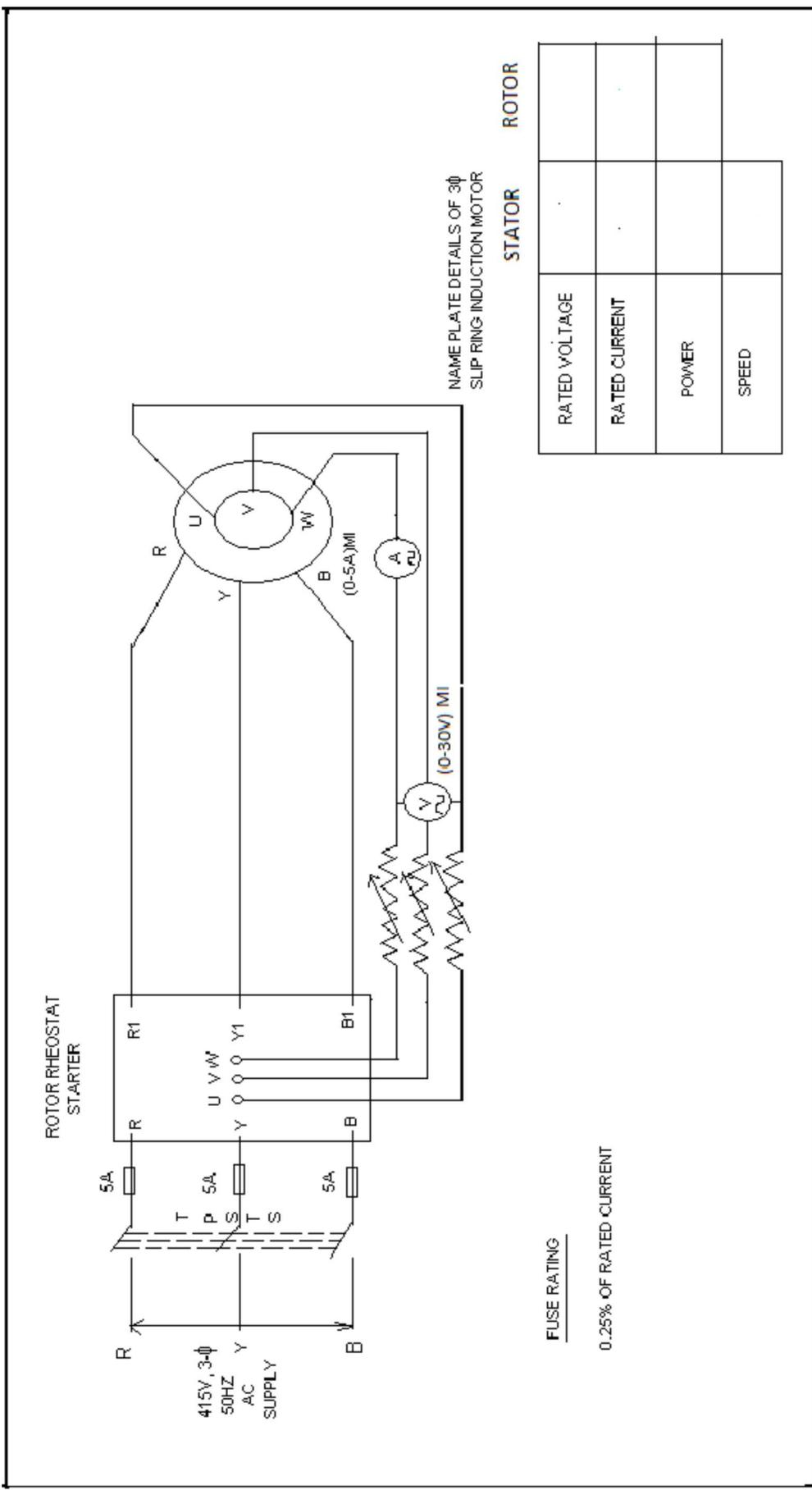
**PROCEDURE:**

- 1) The DPST-1 is closed and the motor field rheostat is adjusted to make the alternator run at rated speed.
- 2) The DPST-2 is closed and by keeping the TPST open, adjusts the alternator field rheostat to supply the voltage equal to infinite bus bar.
- 3) The phase sequence of the alternator is made as same as that of the infinite bus bar by observing the sequence of glowing of synchronizing lamps. If the phase sequence is not same, any of the two phases are interchanged.
- 4) The field rheostat is adjusted to bring the frequency of the alternator to same frequency of infinite bus bar. When the phase sequence of the two sides are same all the lamps will begin to glow bright and dark simultaneously. In this condition, when the frequencies are equal, the variation of lamps bright to dark is lowest.
- 5) At the dimmest point the TPST switch is closed thereby synchronizing the alternator to the bus bar.

**RESULT:**

CIRCUIT DIAGRAM:

ROTOR RHEOSTAT SPEED CONTROL OF INDUCTION MOTOR



**Expt. No:**

**Date:**

**ROTOR RHEOSTAT SPEED CONTROL OF SLIP RING  
INDUCTION MOTOR**

**AIM:**

To vary the speed of the slip ring induction motor using rotor rheostat control.

**APPARATUS REQUIRED:**

Sl.NO	APPARATUS	SPECIFICATIONS	QUANTITY
1	Voltmeter	(0-600V) MI	1
2	Ammeter	(0-10A) MI	1
3	Tachometer	0-10000 (Rpm)	1

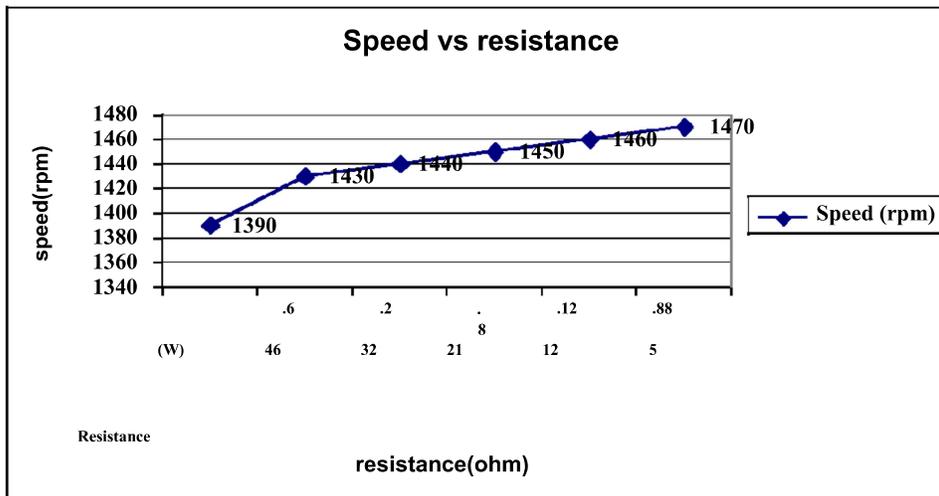
**PROCEDURE:**

1. The Connection are made as per circuit diagram
2. The TPST switch is closed and three phase supply is given.
3. The motor is started with rotor rheostat starter.
4. The rotor resistance is varied and corresponding values of speed, voltage and current are noted down.

**TABULAR COLUMN:**

Voltage (V)	Current (A)	Resistance ( $\wedge$ )	Speed (rpm)

**MODEL GRAPH:**



RESULT:

**Expt. No:**

**Date:**

**DETERMINATION OF CIRCLE DIAGRAM OF THREE PHASE INDUCTION MOTOR**

**Aim:**

To conduct No Load, Blocked rotor test on a Three Phase Induction motor and to find various parameters from circle diagram.

**Apparatus:**

S.NO	Equipment	Specification	Quantity
1	Watt Meter	(600V, 10A Dynamo)	2
2	Voltmeter	(0-600V, MI)	1
3	Ammeter	(0-10A, MI)	1
4	3 – Ø Variac	(0-440 V, 15A)	1

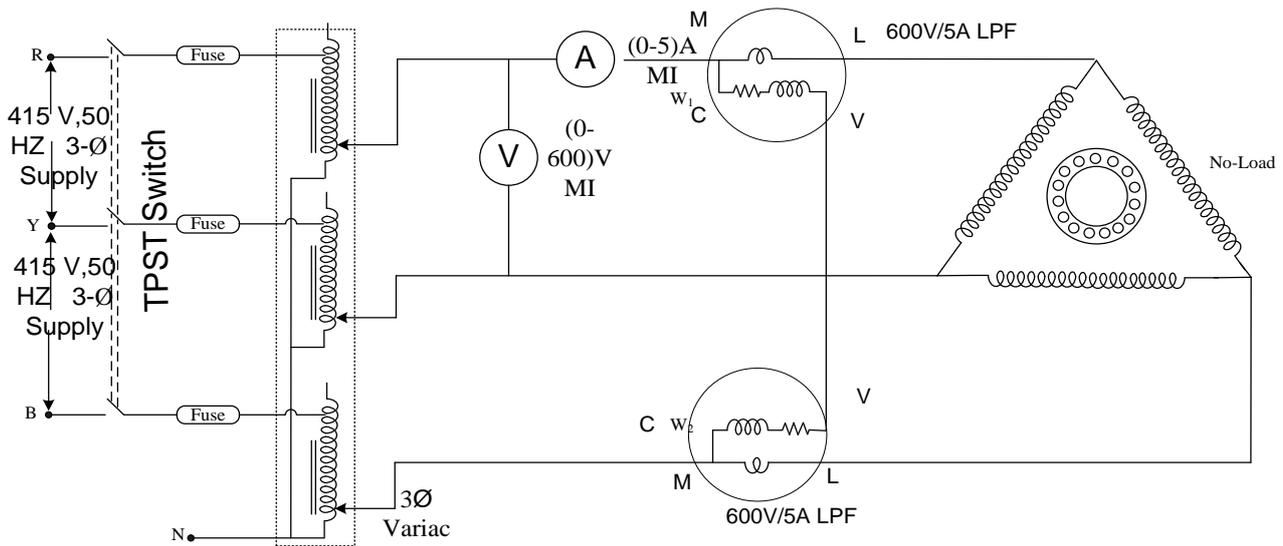
**Theory:**

The induction motor is called as rotating transformer and the parameters of the equivalent circuit are determined through the tests called No load test and blocked rotor tests. These tests are similar to OC and SC tests of transformer. From the OC test on the transformer, the core resistance and reactance are determined, core losses are known and from the SC test, the winding resistance and reactance are determined, full load copper losses are known.

In the No load test, the induction motor is started on no load and rated voltage is applied and in blocked rotor test, the rotor of the induction motor is mechanically locked or manually blocked from rotation and the motor is applied rated current through a variac so that the stator current does not exceed the rated current. From these two tests the equivalent circuit of the induction motor is determined and performance parameters are predetermined through a circle diagram.

The circle diagram of an induction motor is helpful in finding the performance details i.e. full load current, full load power factor, full load slip, efficiency, maximum power output and maximum torque through the no load and blocked rotor tests which are performed.

**Circuit Diagram:**



**Procedure:**

**No – load test**

1. Make the connections as per the Circuit Diagram.
2. Before starting of motor remove the load (by slackening the brake band).
3. Gradually apply the rated voltage i.e. 415 V to the motor with 3 Phase variac.
4. Tabulate the readings of different meters.

**NOTE:** At the no load, the power factor of induction motor is less than 0.5 and when one of the wattmeter shows negative readings either current coil or pressure coil of that meter should be reversed.

**Readings and tabular form:**

Sl.No	V(volts)	I <sub>0</sub> (Amps)	W <sub>1</sub> (watts)	W <sub>2</sub> (watts)	W <sub>0</sub> = W <sub>1</sub> +W <sub>2</sub>

**Blocked – rotor test**

1. Block or hold the rotor by hand or tightening the brake belt.
2. Apply the low voltage and increase it till full load current flows.
3. Tabulate the readings of all meters.

**Readings and tabular form:**

Sl. No	V <sub>s</sub> (volts)	I <sub>s</sub> (Amps)	W <sub>1</sub> (watts)	W <sub>2</sub> (watts)	W <sub>s</sub> = W <sub>1</sub> +W <sub>2</sub>

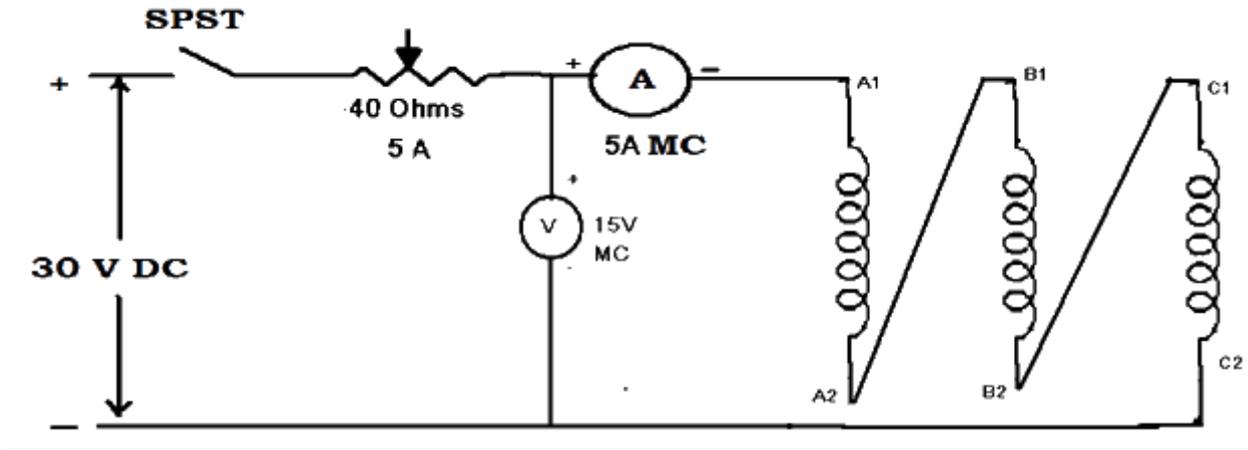
**Calculations:**

Short circuit current at Normal voltage is  $I_{sc} = I_s (V_{rated} / V_{sc})$

No load power factor  $\cos \phi_0 = W_0 / (\sqrt{3} V I_0)$  find  $\phi_0$

Short circuit P.F  $\cos \phi_{sc} = W_s / (\sqrt{3} V_s I_s)$  find  $\phi_s$

**Measurement of stator resistance**



1. Connect as per the Circuit Diagram given above.
2. Keep the 40 ohms resistance in maximum position.
3. Switch on the 30V DC supply and change the applied voltage by adjusting the rheostat. Note down the voltage and current readings.

**Readings and tabular form:**

S. No	V	I	$R_{dc} = V/3I$
AC			

Stator

resistance per phase  $R_s = 1.5 R_{dc}$

### Performance computation and circle diagram:

Draw the circle diagram and find Efficiency, full load current and power factor of the given induction motor.

#### Construction of Circle Diagram:

➤ The data of No load test and blocked rotor test on the induction motor are used.

1. Draw horizontal axis OX and vertical axis OY. Here the vertical axis represents the voltage reference.
2. With suitable scale, draw phasor OA with length corresponding to  $I_0$  at an angle  $\Phi_0$  from the vertical axis. Draw a horizontal line AB.  $\Phi_0 = \cos^{-1} (W_{oc} / \sqrt{3} V_0 I_0)$ .  
 $\Phi_{sc} = \cos^{-1} (W_{sc} / \sqrt{3} V_{sc} I_{sc})$ .
3. Draw OS equal to  $I_{SN}$  at an angle  $\Phi_{SC}$  and join AS.
4. Draw the perpendicular bisector to AS to meet the horizontal line AB at C.
5. With C as centre, draw a semi-circle passing through A and S. This forms the circle diagram which is the locus of the input current.
6. From point S, draw a vertical line SL to meet the line AB.
7. Fix the point K as below.

For wound rotor machines where equivalent rotor resistance  $R_2'$  can be found out:  
Divide SL at point K so that SK: KL = equivalent rotor resistance: stator resistance.

For squirrel cage rotor machines:

Find Stator copper loss using  $I_{SN}$  and stator winding resistance  $R_1$ .

Rotor copper loss = total copper loss – stator copper loss.

Divide SL at point K so that SK: KL = rotor copper loss: stator copper loss.

*Note:* If data for separating stator copper loss and rotor copper loss is not available then assume that stator copper loss is equal to rotor copper loss. So divide SL at point K so that SK=KL

8. For a given operating point P, draw a vertical line PE FG D as shown.

Then,

PD = input power,

PE = output power,

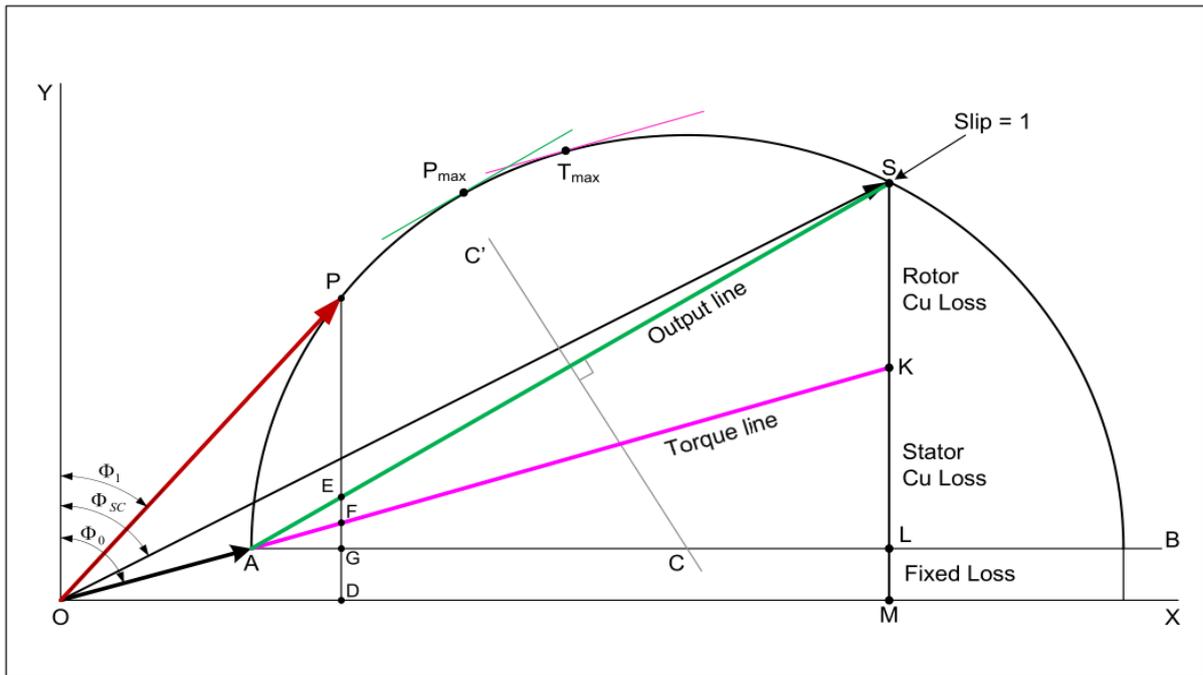
EF = rotor copper loss,

FG = stator copper loss,

GD = constant loss (iron loss + mechanical loss)

9. Efficiency of the machine at the operating point P,  $\eta = \frac{PE}{PD}$
10. Power factor of the machine at operating point P =  $\cos \Phi_1$
11. Slip of the machine at the operating point P,  $S = \frac{EF}{PF}$
12. Starting to rated voltage (in syn. watts) = SK

13. To find the operating points corresponding to maximum power and maximum torque, draw tangents to the circle diagram parallel to the output line and torque line respectively. The points at which the set an



gents touch the circle are respectively the maximum power point( $T_{max}$ ) and maximum torque point( $P_{max}$ )

**Result:**

**Discussion:**

- How can the maximum torque and maximum power be determined from the circle diagram?
- Show the motoring, generating and braking regions for an induction machine on its circle diagram.
- How can the equivalent circuit of an induction motor be found from the no load and blocked rotor tests.