SRM VALLIAMMAI ENGINEERING COLLEGE

(An Autonomous Institution)

SRM NAGAR, KATTANKULATHUR

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

II YEAR / IV SEMESTER

1905406 - ELECTRICAL MACHINES LABORATORY-II

(Regulation - 2019)

Academic Year 2022-2023 Even Semester

Prepared by

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1905406 **ELECTRICAL MACHINES LABORATORY - II**

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OBJECTIVES:

- 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 methods.
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.

OUTCOMES:

At the end of the course, the student should have the:

- Ability to understand the importance of Induction machines.
- Ability to acquire knowledge on separation of losses.
- Ability to understand and analyze EMF and MMF methods.
- Ability to understand the importance of Synchronous machines.
- Ability to analyze the characteristics of V and Inverted V curves

CYCLE-1

1. Load test on 3-phase squirrel cage induction motor.
2. No load and blocked rotor test on 3phase squirrel cage induction motor.
3. Load test on 1-phase squirrel cage induction motor.
4. No load and blocked rotor test on single phase induction motor.
5. Separation of no load losses in three phase induction motor.
6. Regulation of three phase alternator by EMF and MMF methods.

CYCLE-2

1. Regulation of three phase alternator by ZPF and ASA methods.
2. V and inverted V curves of three phase synchronous motor.
3. Regulation of three phase salient pole alternator by slip test.
4. Measurement of negative sequence and zero sequence impedance of an alternator.
5. Study of Induction motor Starters.
6. Synchronization of alternator to Infinite Busbar.

1905406-Electrical Machines Laboratory – II

(Electrical and Electronics Engineering)

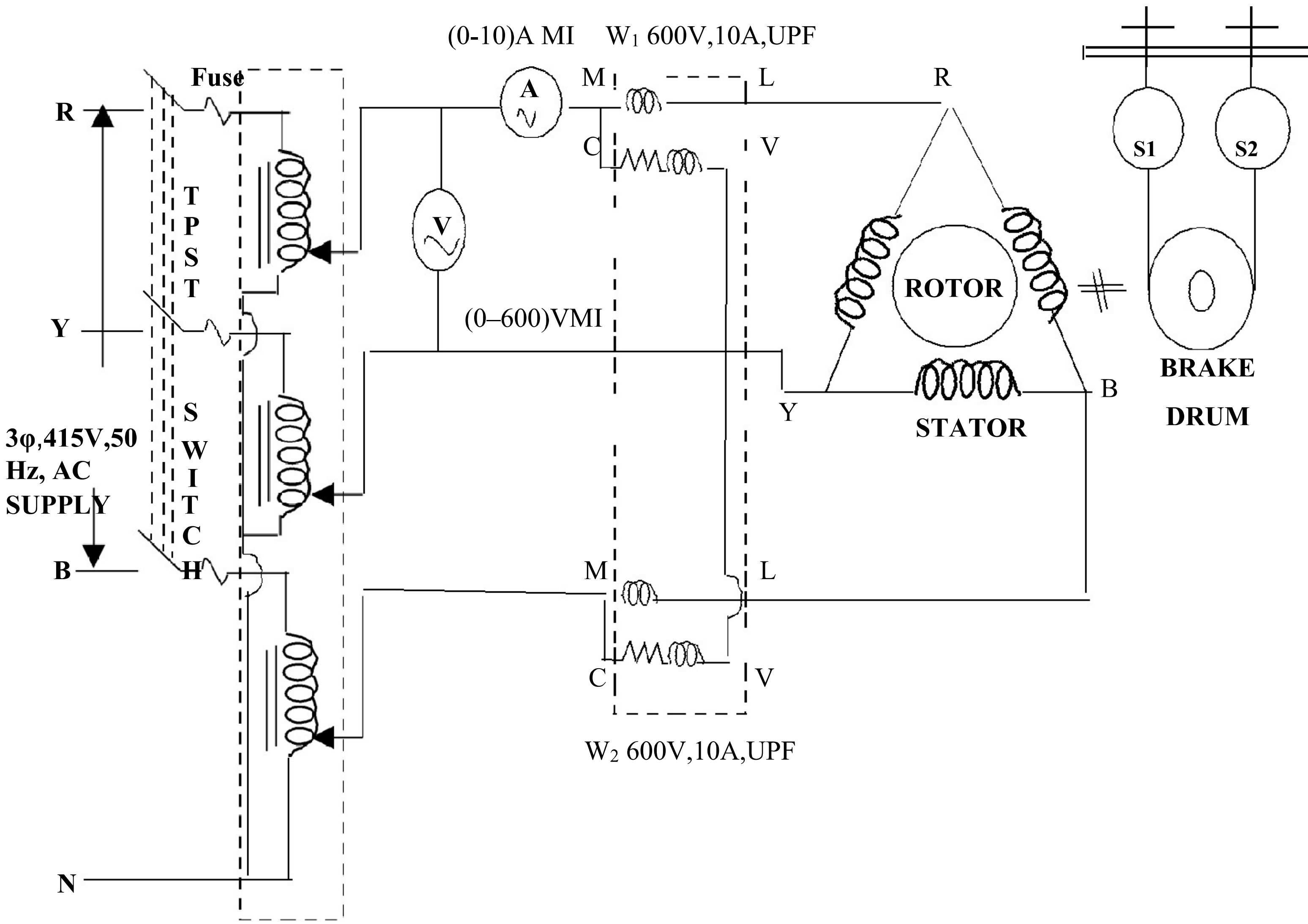
Name of the student :

Reg. Number :

Sl.No.	Date of Expt.	Name of the Experiment	Marks	Signature

CIRCUIT DIAGRAM:

LOAD TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR



Three Phase Auto Transformer

Fuse Rating Calculation:

Name Plate Details:

Expt. No:
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:

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

$$T = (S1 - S_2) * 9.81 * R \text{ N-m.}$$

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

The mechanical output of the motor is given by

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

Where N is the speed of the motor in RPM.

The power input to the motor is given by

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

The efficiency of the motor is given by

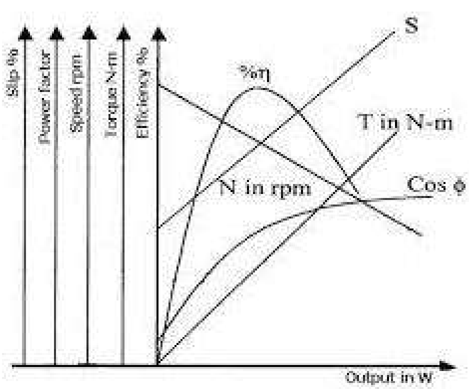
$$\text{Efficiency} = P_m / P_i$$

OBSERVATION TABLE:

M.F= Radius of the brake drum=

Sl. No.	Voltage (Volts)	Current (Ampere)	Speed (Rpm)	Spring Balance		Torque (Nm)	W_1		W_2		I/P Power (Watts)	O/P Power (Watts)	Efficiency (%)	% Slip
				S_1 (Kg)	S_2 (Kg)									

MODEL GRAPH:



MODEL CALCULATION:

FORMULA USED:

Torque,

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

Input power

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

Output power

$$Po = 2\Pi NT / 60 \text{ (Watt)}$$

Efficiency

$$= (Po / Pi) * 100 \text{ (\%)}$$

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

Where $W=(W1 + W2)$

Slip = $[(Ns - N) / Ns] *100$

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. Step1 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:

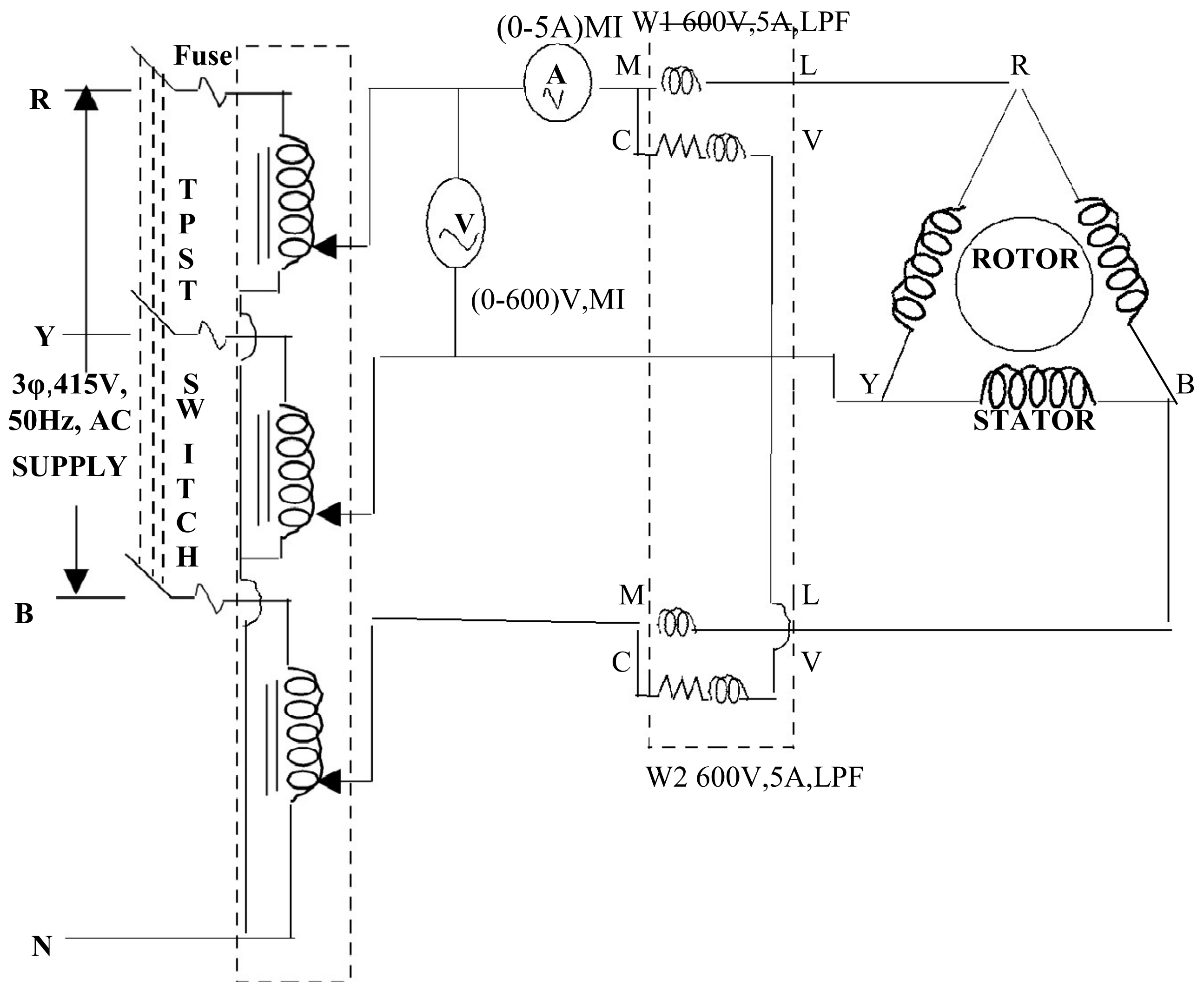
VIVA QUESTIONS:

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:



Three Phase Auto Transformer

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:

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

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

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

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

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:

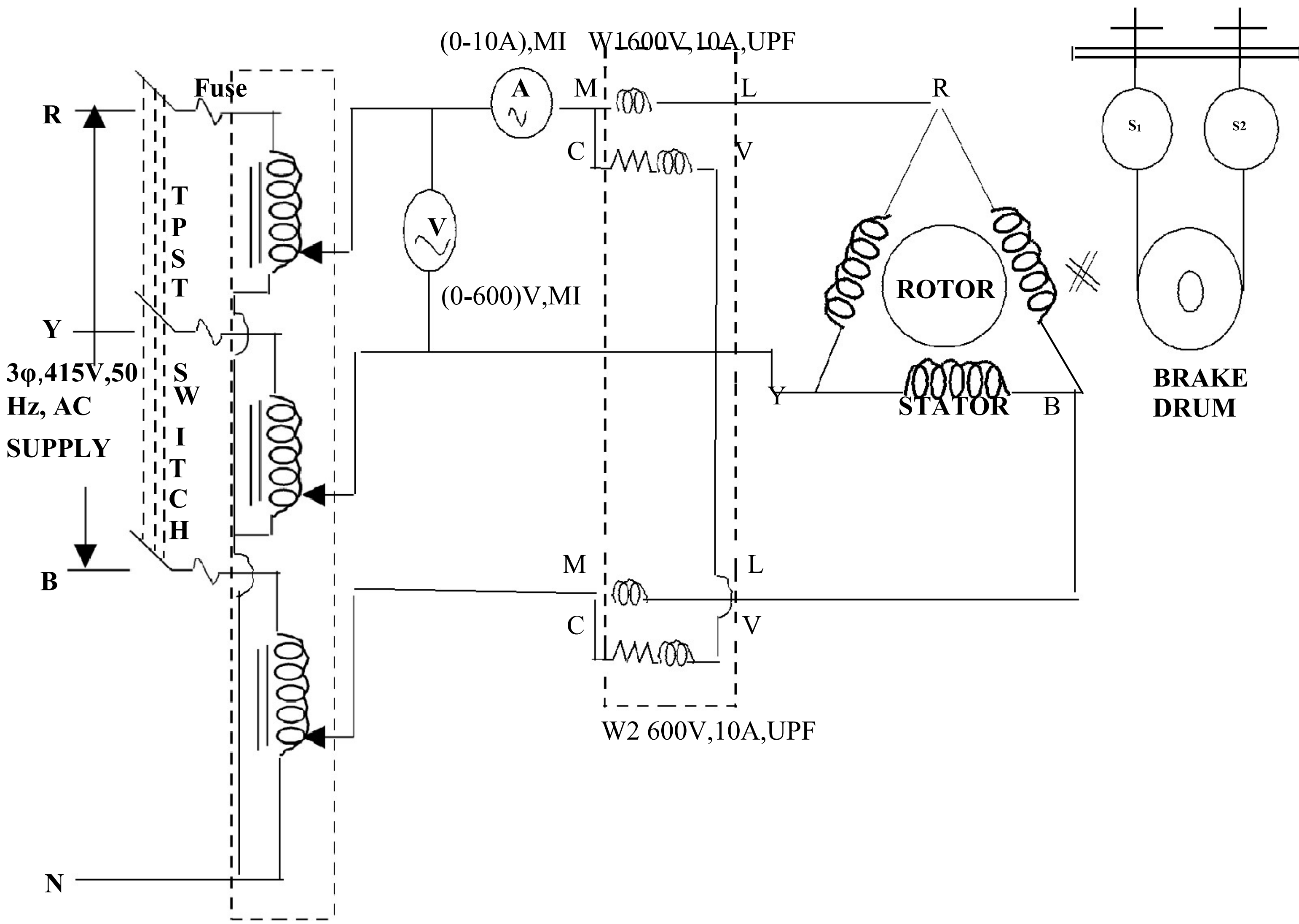
NO LOAD TEST

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

   $R_{a/phase} = (Vx1.5) /2I$

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

Stator current = OP x X
%η = (PQ/PV)x 100
%Slip = (QR/PR)x 100
Torque = (PRxV/(2ΠNT/60))
Pf = PV/OP

MAXIMUM OUTPUT

The perpendicular at O'A' line cuts the circle at P and O'A' at PQ'.
Maximum output = P_1Q_1x power scale (W)

MAXIMUM TORQUE

The perpendicular bisector of line cuts the circle at PR and OF' at Q_2.
Maximum torque = (PFx power scale)/T Nm

NO LOAD TEST:

S.No	Vo (V)	Io (A)	Wo (W)		Wo=(W1+W2) W
			W1	W2	

BLOCKED ROTOR TEST:

S.No	Vsc (V)	Isc (A)	Wsc (W)		Wsc=(W1+W2) W
			W1	W2	

MEASUREMENT OF STATOR RESISTANCE:

S.No	Voltage (V)	Current (A)	R_s = (Vx1.5) /2I ohms

MODEL CALCULATION:

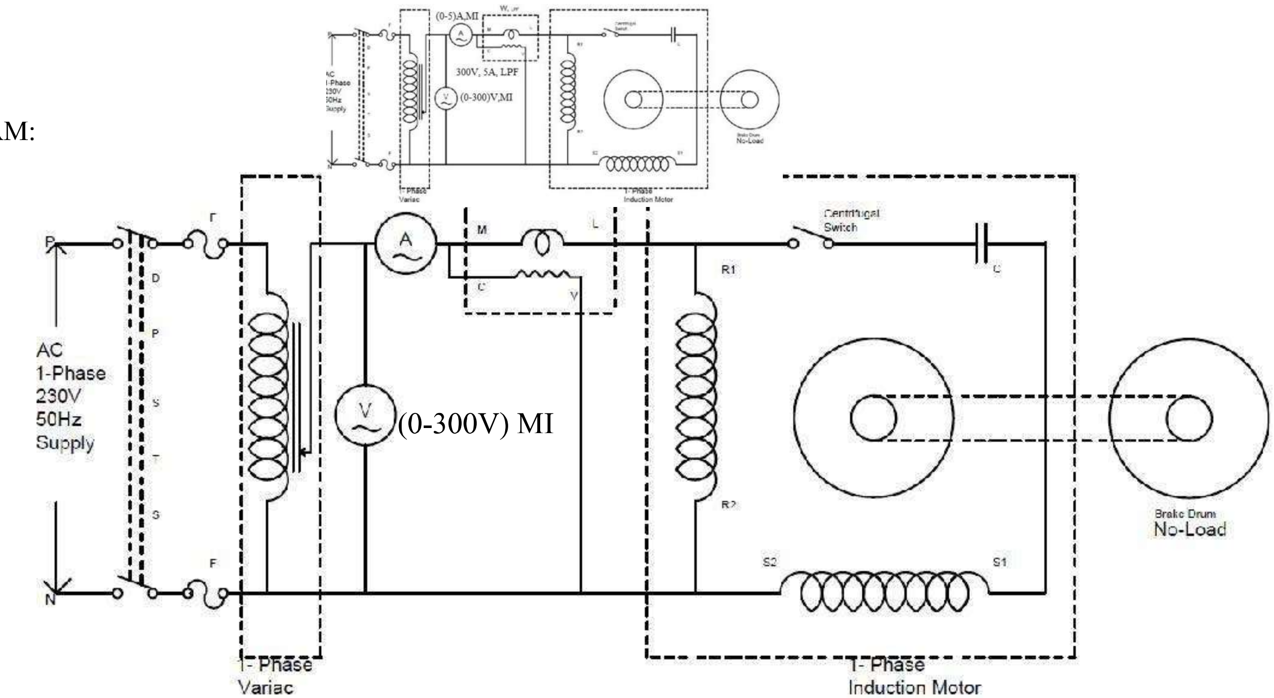
RESULT:

VIVA QUESTIONS:

1. What is the objective of Conducting this experiment?
2. What are the equivalent circuit parameters?
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?

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 rater current

FORMULA:

NO-LOAD TEST

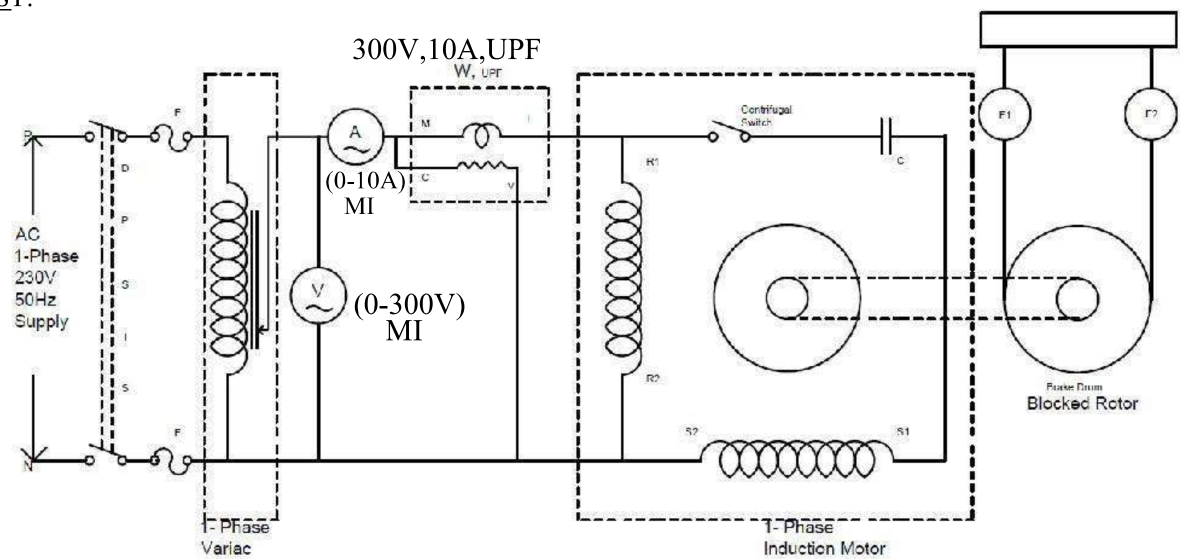
$Wo = VoIo\ Cos\O_0$
Where, $Cos\ \O_0 = Wo / VoIo$
$Iw = Io * Cos\O_0$
$Im = Io * Sin\O_0$

BLOCKED ROTOR TEST

$Z_{01} = Vsc / Isc$
$R_{01} = Wsc / Isc^2$
$X_{01} = [Z_{02}^2 - R_{02}^2]^{1/2}$
$Xm = [Zm^2 - Rm^2]^{1/2}$ $\quad$ $R_2 = R_{01} - Rm \| Rs$
$Xs = [Zs^2 - Rs^2]^{1/2}$ $\quad$ $X_2 = X_{01} - [Xm \| (Xs-Xc)]$

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 Φ)	% Efficiency (η)	%Slip (s)
					S_1	S_2	S1~S2					

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 = 2ΠR (m)
   R = Radius of the brake drum

2. Input power = W (watts)
   W = Wattmeter readings

3. Torque (T) = 9.81* R * (S_1 ~ 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

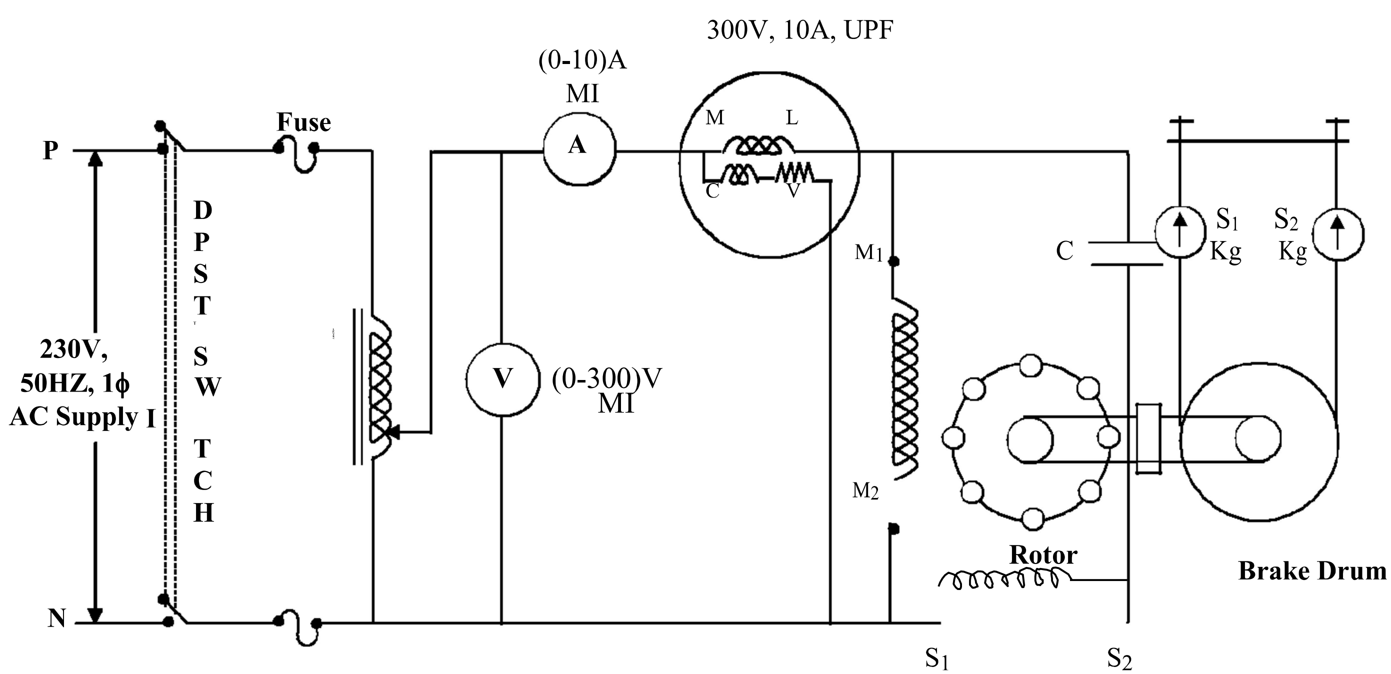
5. % Efficiency (η) = (Output Power/Input Power) * 100

6. Power factor, Cos Φ= W/VI

7. % Slip, s = [(Ns-N)/Ns]*100
   Ns = 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:

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

S_1, S_2- AUXILLARY WINDING
M_1, M_2- MAIN WINDING

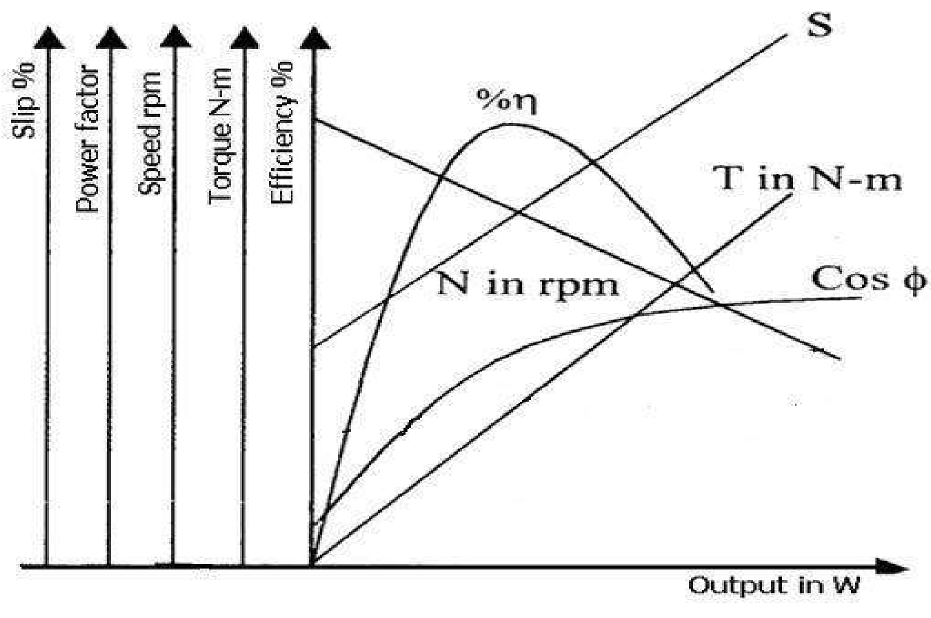
PRECAUTIONS:

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.

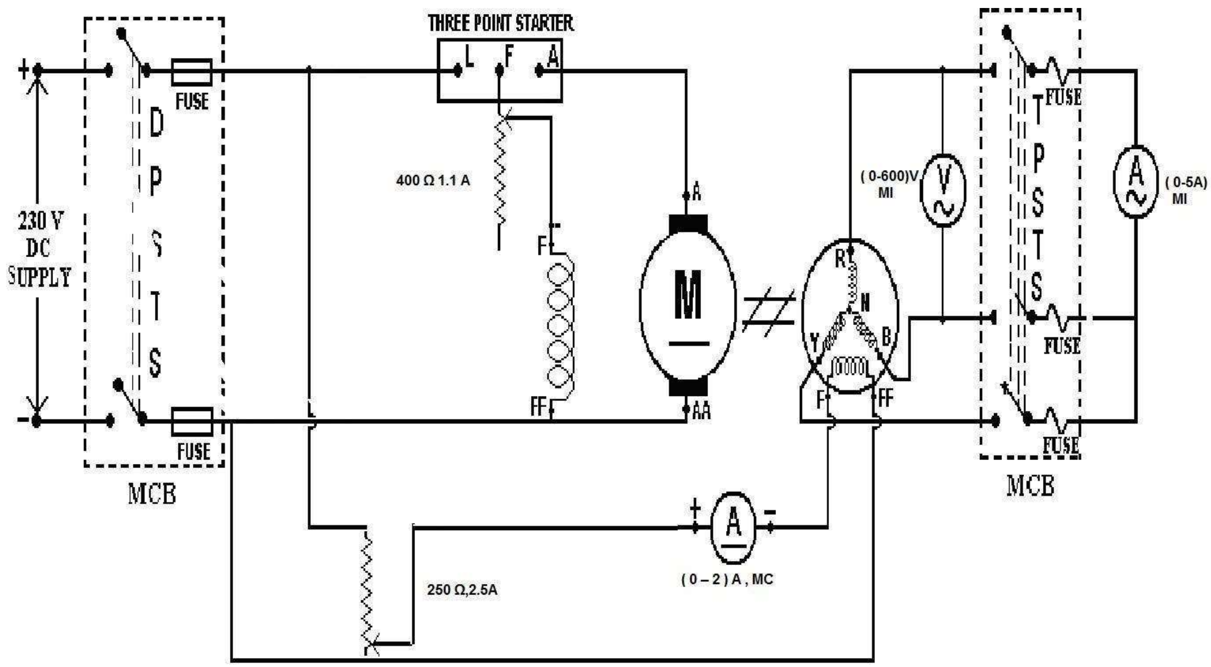
MODEL GRAPH:



RESULT:

CIRCUIT DIAGRAM:

<u>REGULATION OF ALTERNATOR BY EMF AND MMF METHOD</u>



Fuse Rating Calculation:

Name plate Details:

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:

Re = 1.6 * Rs
Where,
Rs - DC resistance and
Re - Equivalent AC resistance

$Zs = E_1$ (open circuit voltage) / I_1 (short circuit current)
$Xs = (Zs^2 – Re^2)^{1/2}$
$Eo = [(V\cos Ø + IRe)^2 + (V\sin Ø(+ \text{ or } -) IX_s)^2]^{1/2}$
Where,
'+' sign for lagging Power Factor
'-' sign for leading Power Factor
% Regulation (up) = [(Eo – V)/V] * 100

OBSERVATION TABLE:

OPEN CIRCUIT TEST:

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

SHORT CIRCUIT TEST:

I_f (A)	Ia(A)

TO FIND ARMATURE RESISTANCE (Ra):

Sl.No:	Voltage (V)	Current (A)	Resistance R=V/I Ω

Mean:

$R_{ac}=R_{dc}$ x1.6

MMF Method:

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

'+' for lagging power factor,
'-' for leading power factor.

Where,

I_{f1} - Field current corresponding to V_1
I_{f2} - Field current corresponding to Isc
$V_1 = V+I*Re*CosØ$

% Regulation (up) = [(Eo – V)/V] * 100

Eo - 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 upto125% of rated voltage).

TABULATION:

For Full Load

Sl.No	CosØ	SinØ	E_o (V)		Terminal Voltage(V)	%Regulation	
			Lag	Lead		Lag	Lead

For Half Load

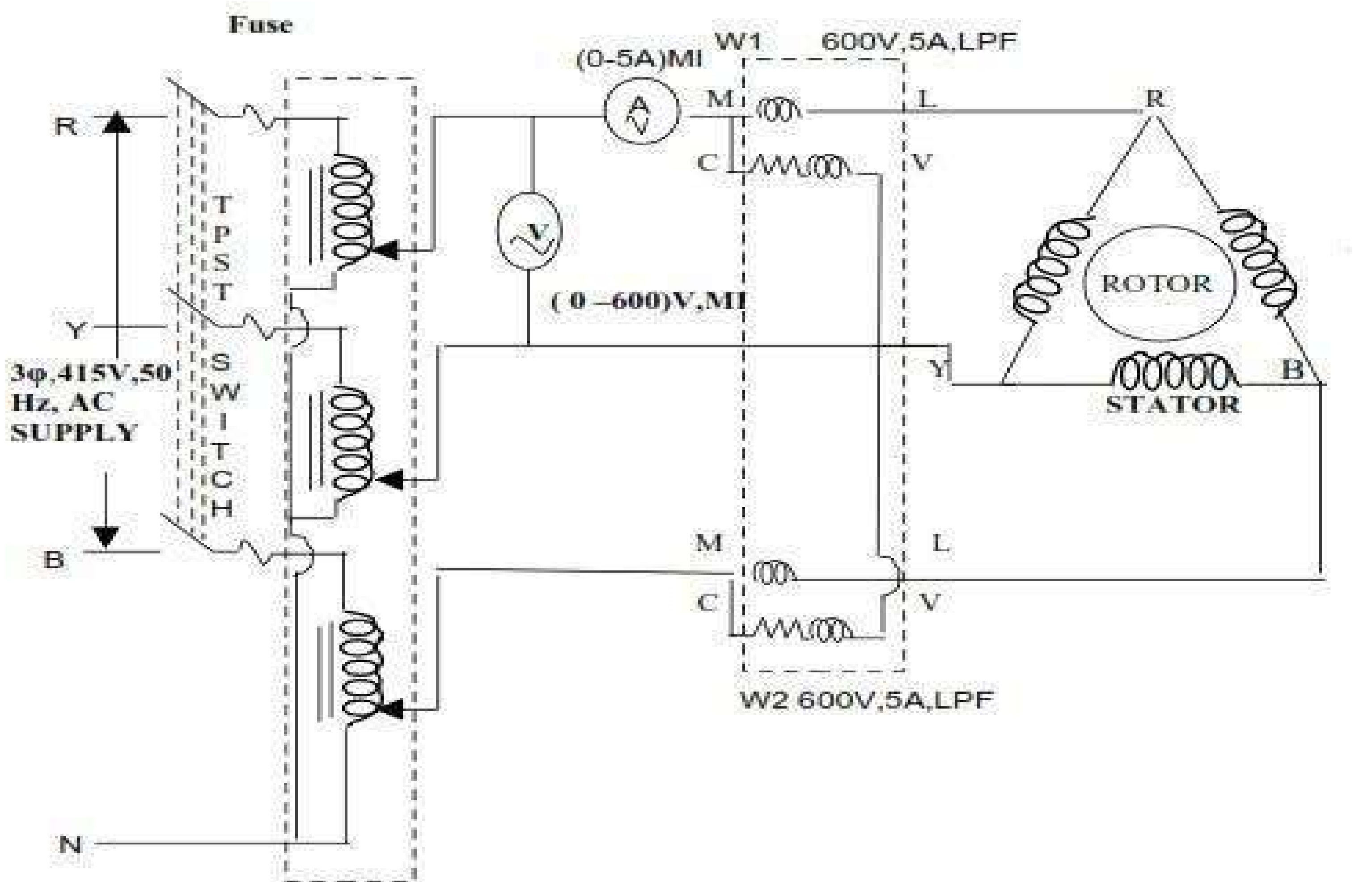
Sl.No	CosØ	SinØ	E_o (V)		Terminal Voltage(V)	%Regulation	
			Lag	Lead		Lag	Lead

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_f 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.-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 3Φ auto-transformer (variac) should be kept at initial zero position.

PROCEDURE:

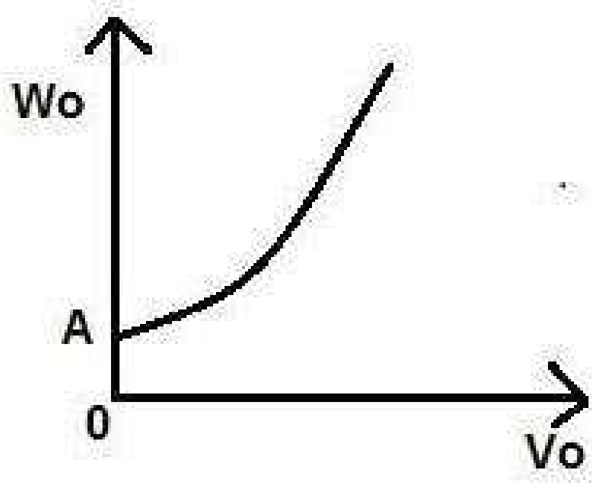
SEPERATION OF LOSSES:

1. Connections are given as per the circuit diagram.
2. The 3Φ A.C supply is given by closing the TPST switch.
3. The induction motor is started gradually by applying voltage through the 3Φ 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/ph = (V*1.5)/2I

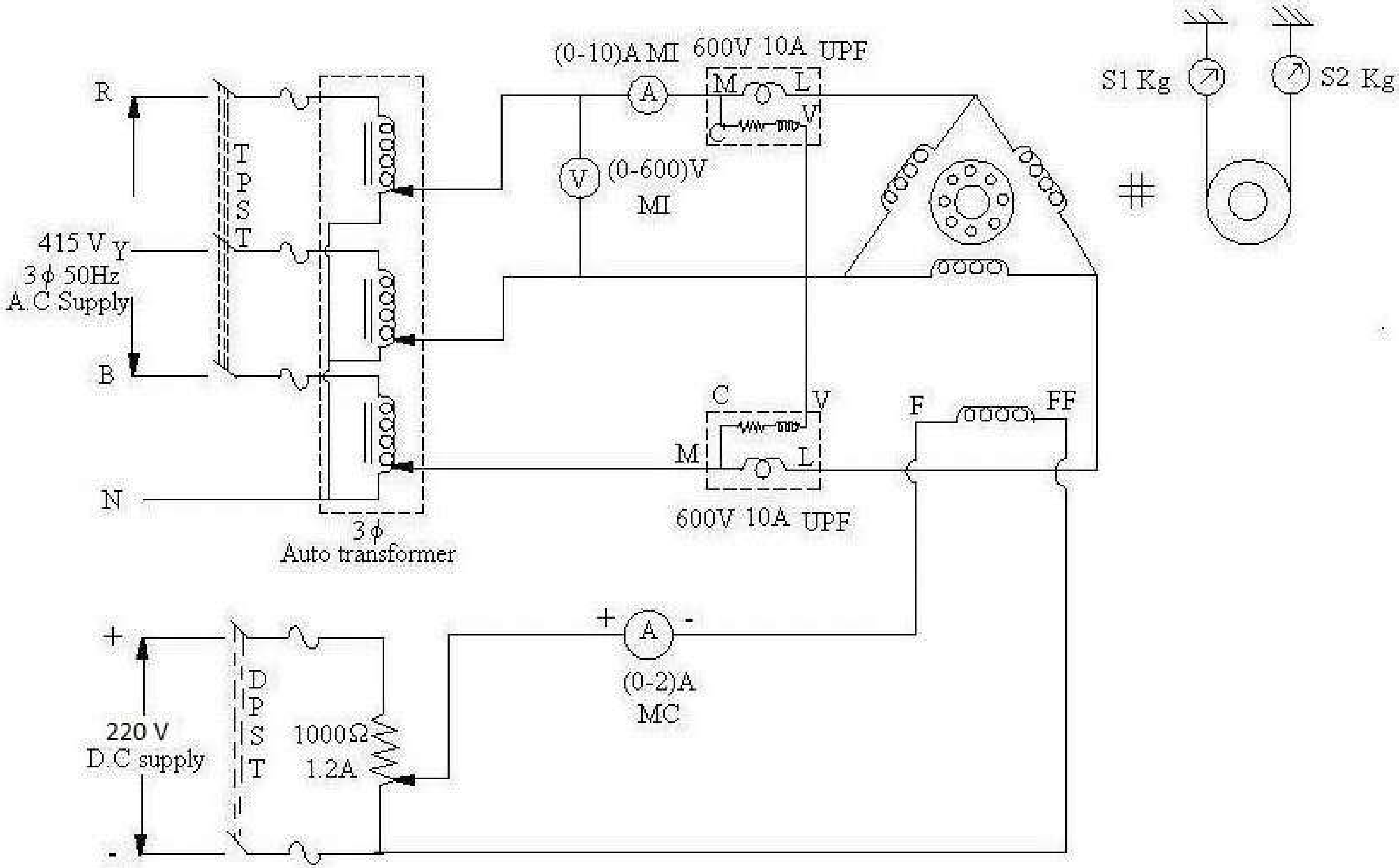
MODEL GRAPH:



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	250Ω,1.5 A	Wire wound	2
6.	Tachometer		Digital	1
7.	3 Φ 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_f) Ampere	Armature current (I_a) Ampere	Wattmeter - I		Wattmeter - II		Power factor (CosΦ)
			Observed watts	Actual watts	Observed watts	Actual watts	

With load:

Sl. No.	Excitation current (I_f) Ampere	Armature current (I_a) 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 Φ – 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.

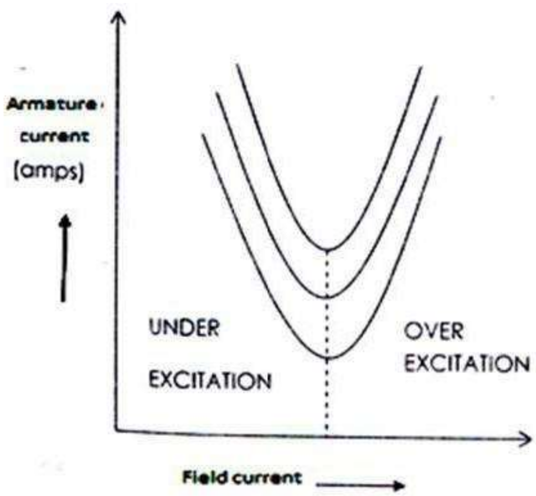
The variations of armature current with field current are in the form of V curves and the variation of power factor with field current are in the form of Inverted V curves.

MODEL GRAPH:

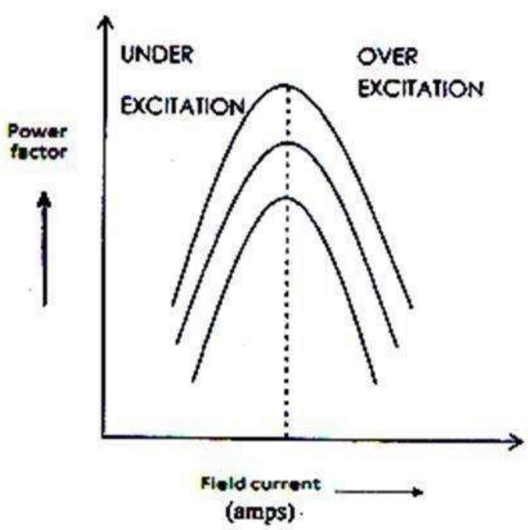
The graph is drawn for

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:

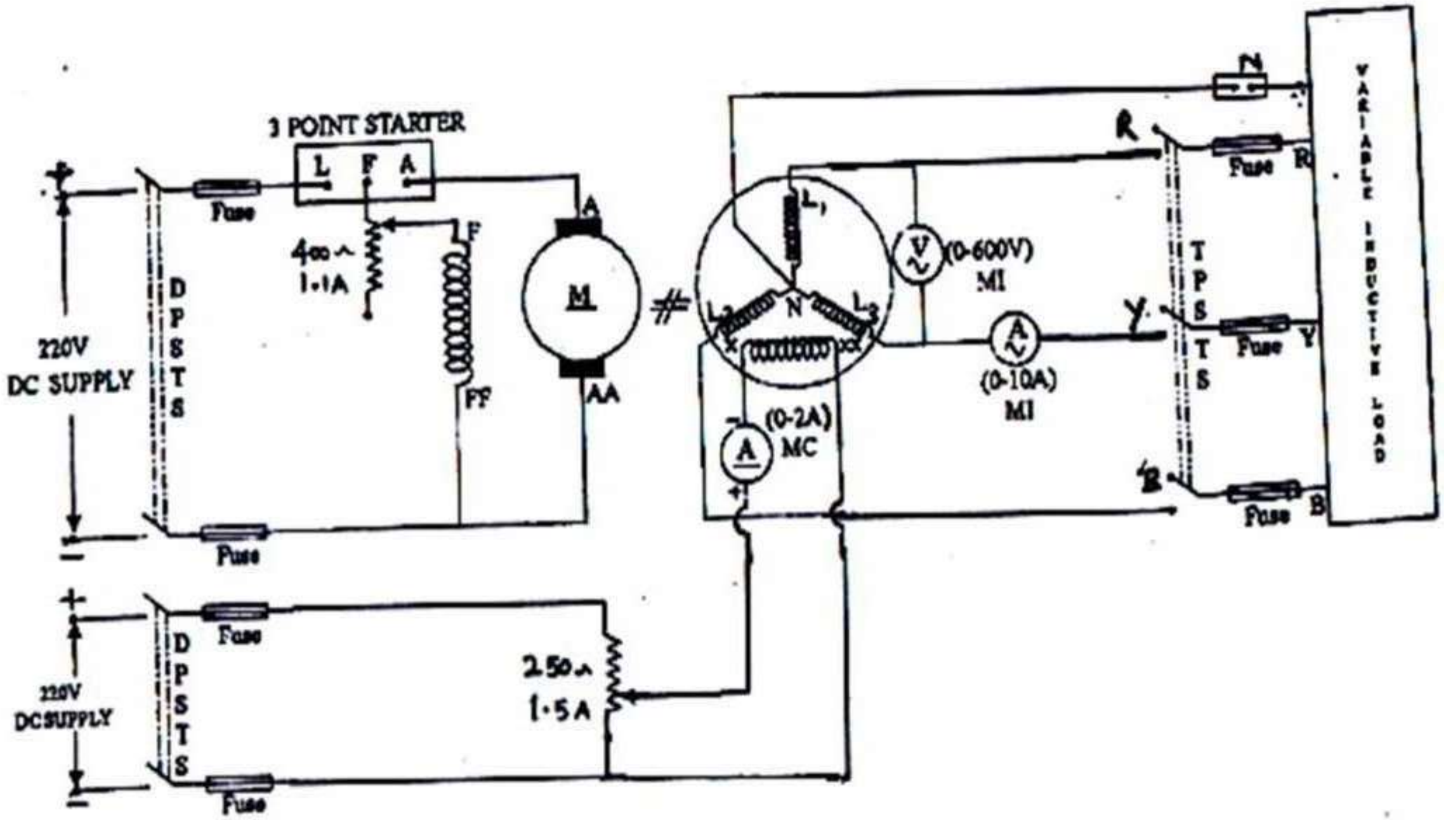
1. Note down the name plate details of motor.
2. Connections are given as per the circuit diagram.
3. Close the TPST switch.
4. By adjusting the auto transformer from minimum position to maximum position the rated supply is given to the motor. The motor starts as an induction motor.
5. In order to give 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 & Λ 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 Ω, 1.5 A	1
5.	Rheostat	Wire wound	1200Ω, 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:

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

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:

Sl.No	Field current (If) Ampere	Open circuit Voltage(Line) Volts	Open circuit Voltage(Phase) Volts

SHORT CIRCUIT TEST:

Sl.No	SHORT CIRCUIT TEST		ZERO POWER FACTOR TEST		
	Field Current (I_f) Ampere	Rated Armature current (Ia) Ampere	Field Current (I_f) Ampere	Rated Armature current (Ia) Ampere	Rated Armature Voltage (Va) Volts

PROCEDURE:

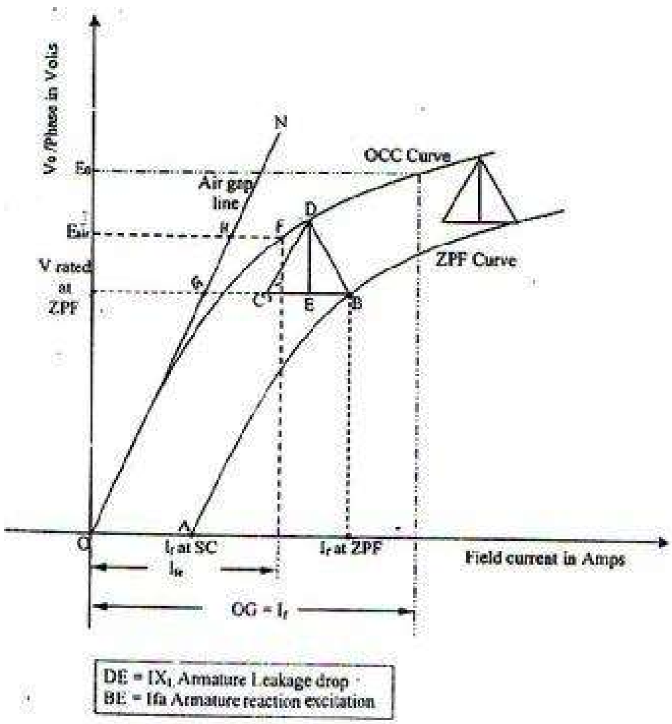
1. Note down the complete nameplate details of motor and alternator.
2. Connections are made as per the circuit diagram.
3. Switch on the supply by closing the DPST main switch.
4. Using the Three point starter, start the motor to run at the synchronous speed by varying the motor field rheostat.
5. Conduct 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 (Ifa).
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 Eair 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.

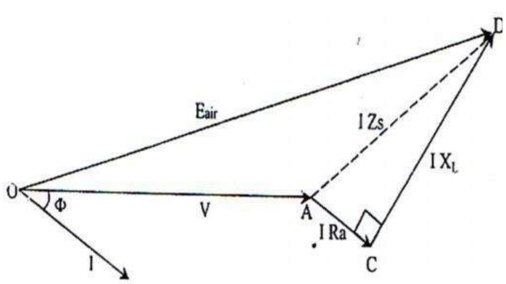
MODEL GRAPH FOR ZPF METHOD:



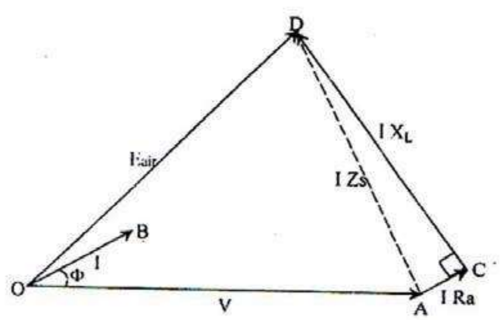
VECTOR DIAGRAMS (ASA METHOD):

<u>To find the airgap voltage (Eair):</u>

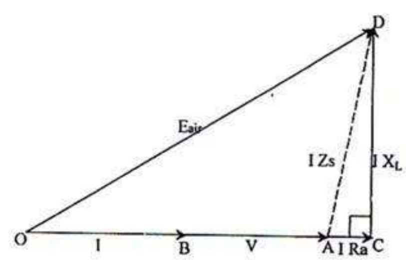
Lagging power factor



Leading power factor



Unity power factor



PROCEDURE TO DRAW THE VECTOR DIAGRAM (ASA METHOD):

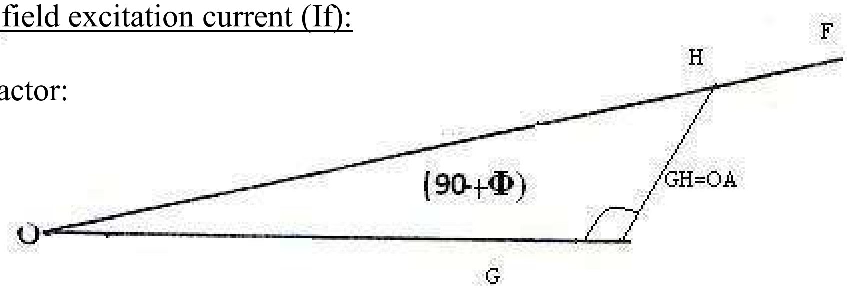
(To find the field Excitation current I_f)

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 ± Φ) from the line O'G [(90 + Φ) for lagging power factor and (90 – Φ) 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 (If).
4. Find out the open circuit voltage (Eo) for the corresponding field excitation current (If) from the OCC curve.
5. Find out the regulation from the suitable formula.

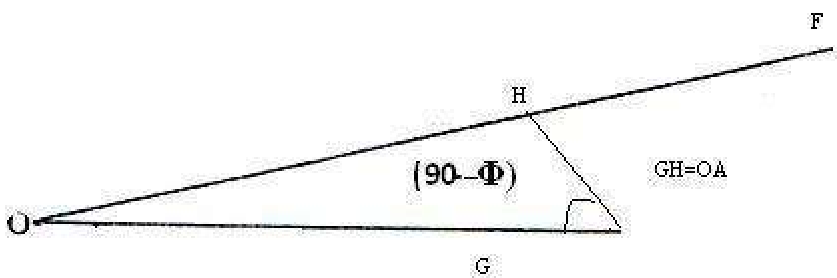
VECTOR DIAGRAMS (ASA METHOD):

To find the field excitation current (If):

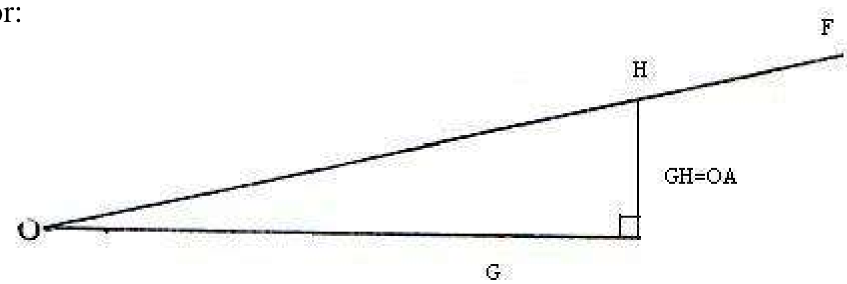
Lagging power factor:



Leading power factor:



Unity power factor:



TABULATION:

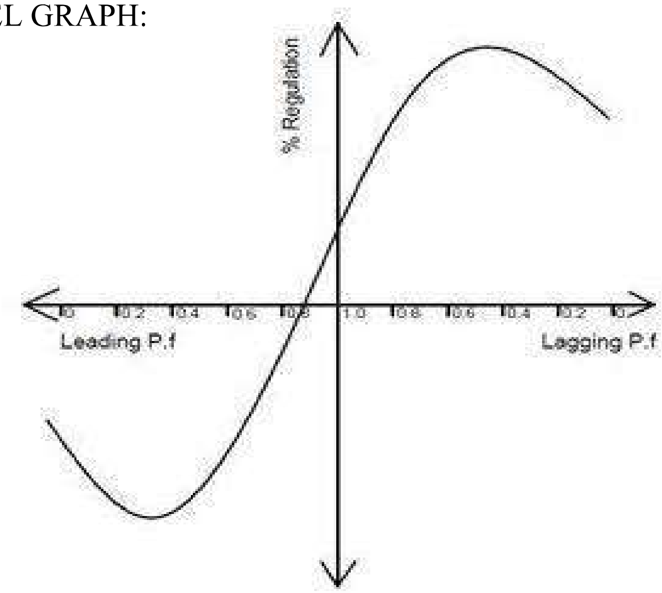
To find Armature Resistance (R_a):

Sl. No:	Voltage (Volts)	Current (Amps)	Resistance = V/I (Ω)

Mean=

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

MODEL GRAPH:



Tabulation for calculating % Regulation:

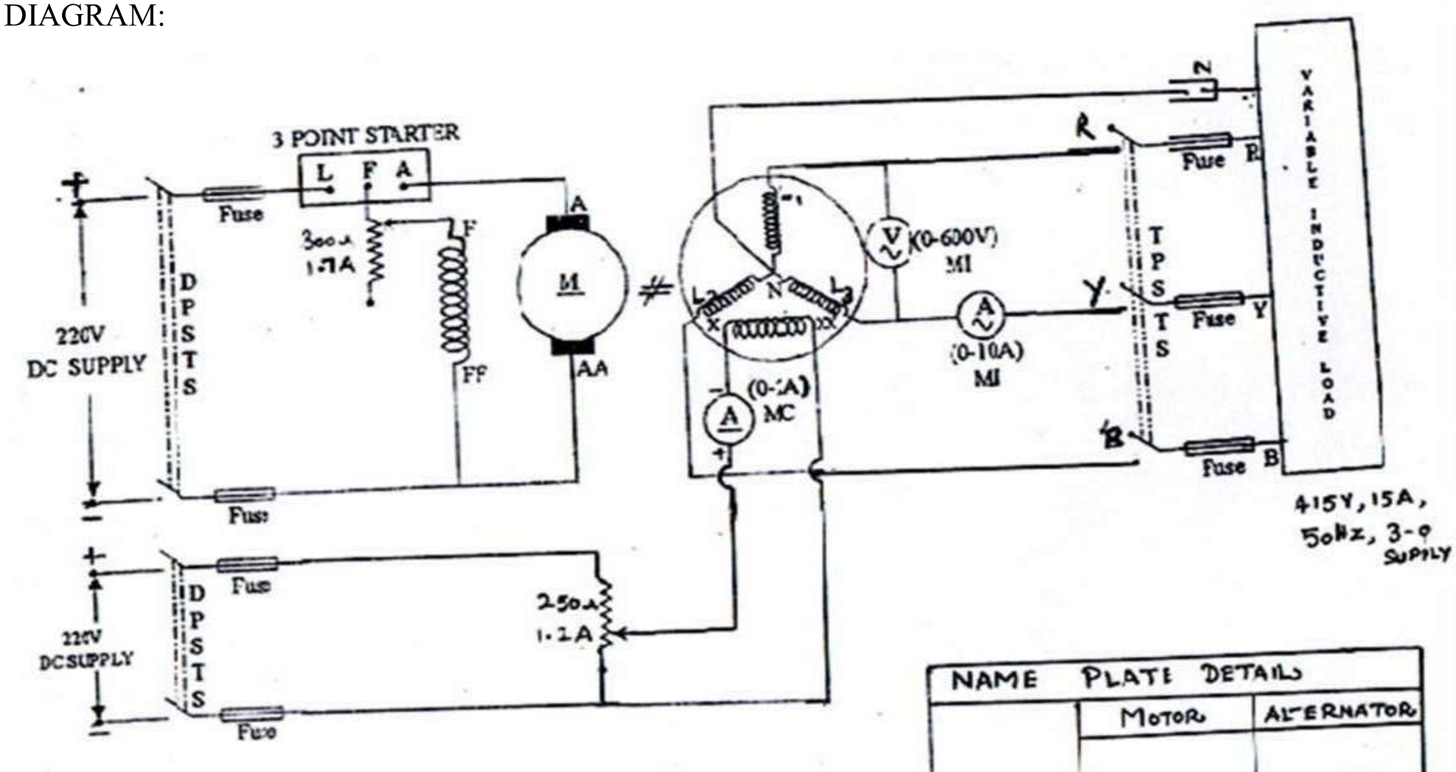
Sl. No:	CosΦ	SinΦ	Ea(Volts)		I_{f1}(Amps)		I_f(Amps)		Eo(Volts)		%Regulation	
			Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead

VIVA QUESTIONS:

1. What is ASA method?
2. What are the experimental data required for ASAmethod?
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:



NAME PLATE DETAILS		
	MOTOR	ALTERNATOR

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:

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 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:

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

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:

S.No	Field current (I_f)	Open circuit Voltage(Line)	Open circuit Voltage(Phase)
Unit	Ampere	Volts	Volts

SHORT CIRCUIT TEST:

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

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.

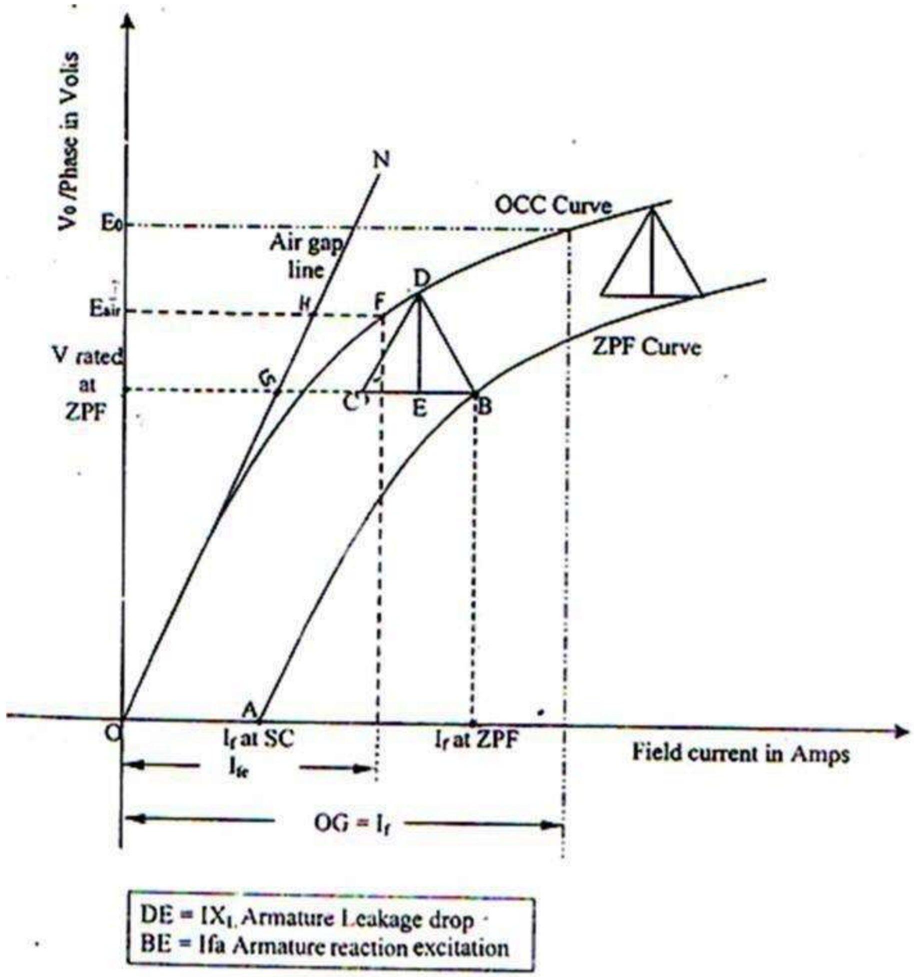
PROCEDURE TO DRAW THE POTIER TRIANGLE (ZPF METHOD):
(All the quantities are in per phase value)

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}).

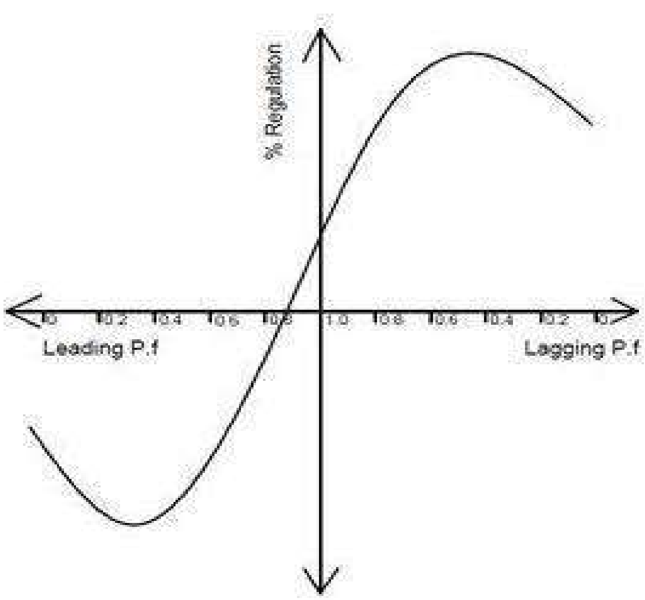
PROCEDURE TO DRAW THE VECTOR DIAGRAM (ZPF METHOD):

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 IRa 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:



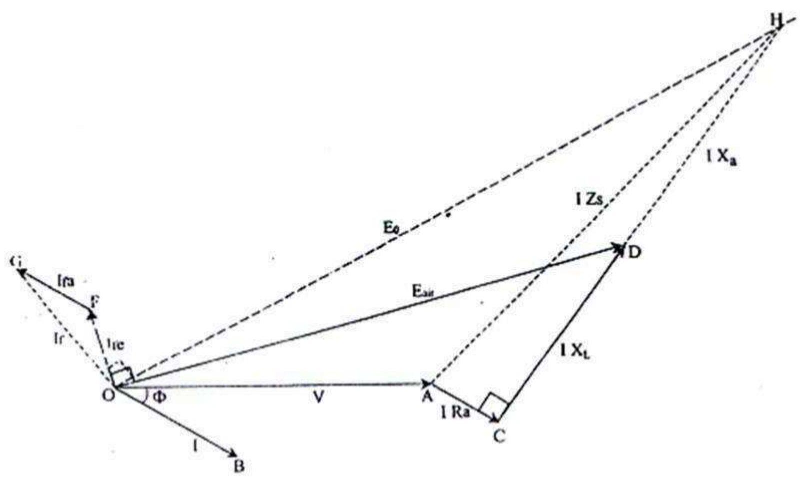
MODEL GRAPH:



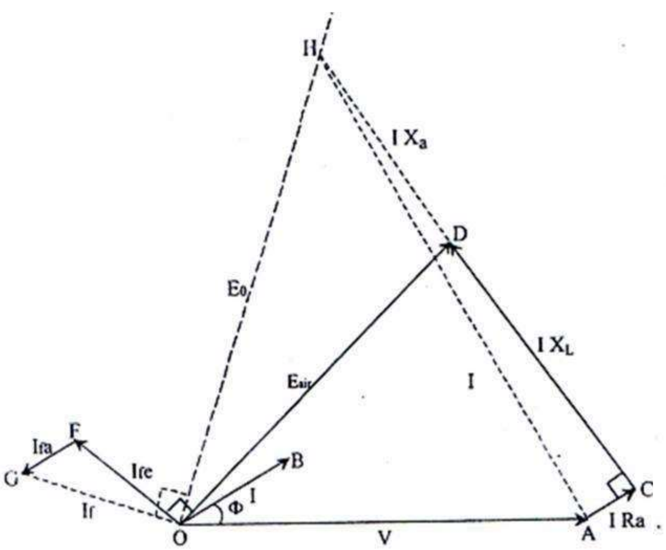
5. Join the points O and D, which will be equal to the air gap voltage (Eair).
6. Find out the field current (Ifc) for the corresponding air gap voltage (Eair) from the OCC curve.
7. Draw the vector OF with the magnitude of Ifc which should be perpendicular to the vector OD.
8. Draw the vector FG from F with the magnitude Ifa 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 (If).
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 (Eo) for the corresponding field excitation current (If) from the OCC curve.
12. Find out the regulation from the suitable formula.

VECTOR DIAGRAMS FOR POTIER TRIANGLE:

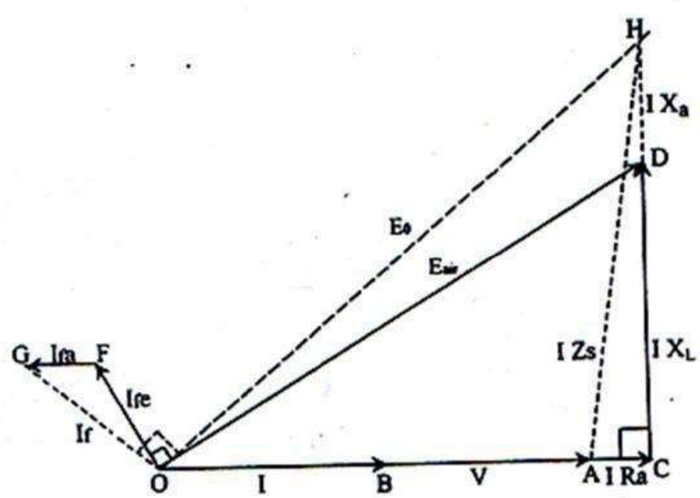
Lagging power factor:



Leading power factor:



Unity power factor:



TABULATION:

To find Armature Resistance (R_a):

S.No	Voltage(V)	Current(A)	Resistance R=V/I(Ω)

Mean=

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

Tabulation for calculating % Regulation:

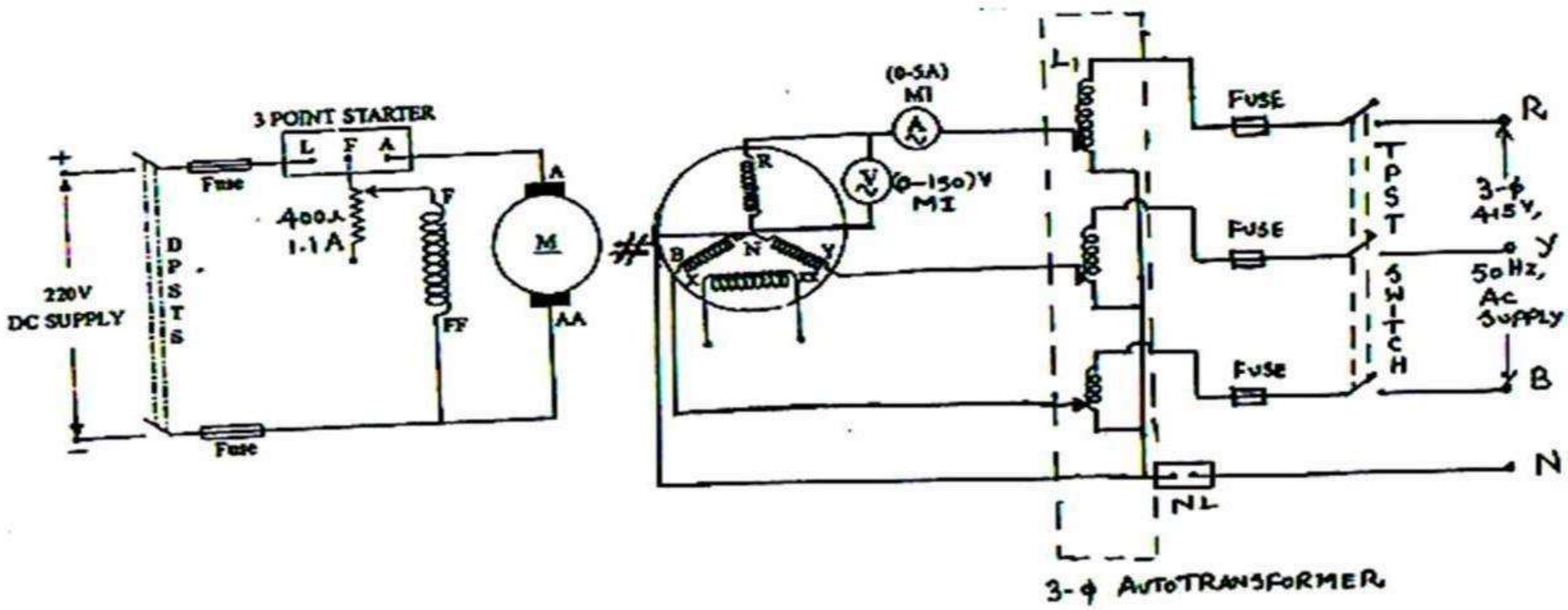
Sl. No:	CosΦ	SinΦ	Ea(Volts)		I_{f1}(Amps)		I_f(Amps)		Eo(Volts)		%Regulation	
			Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead

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) (Ω)	Direct axis Reactance per phase (X_d) (Ω)

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) (Ω)	Quadrature axis Reactance per phase (X_q) (Ω)

FORMULA USED:

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

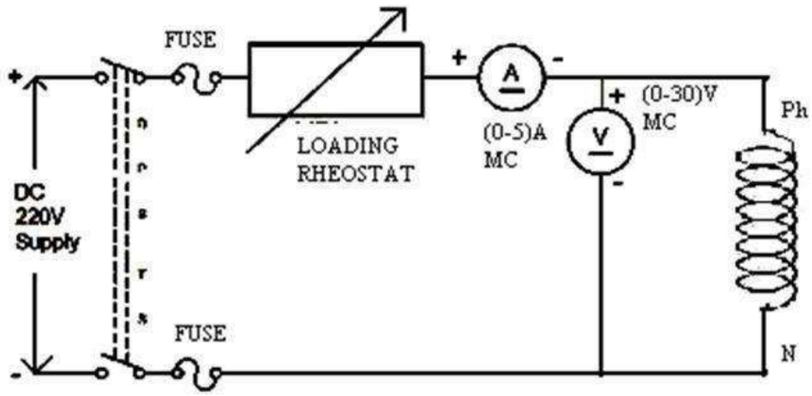
THEORY:

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 SYNCHROUNOUS GENERATOR:

S.No	Power Factor	Percentage of Regulation	
		Lagging	Leading

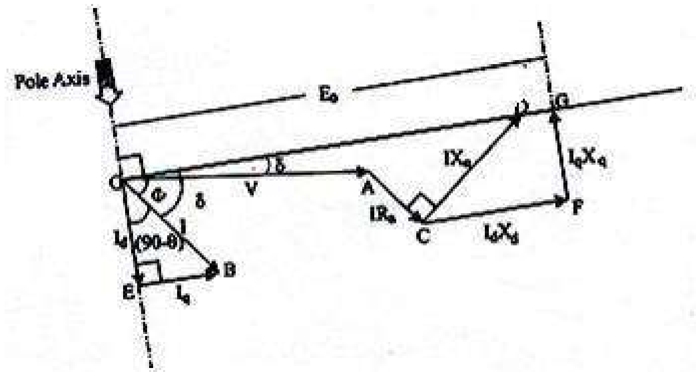
PROCEDURE:

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).

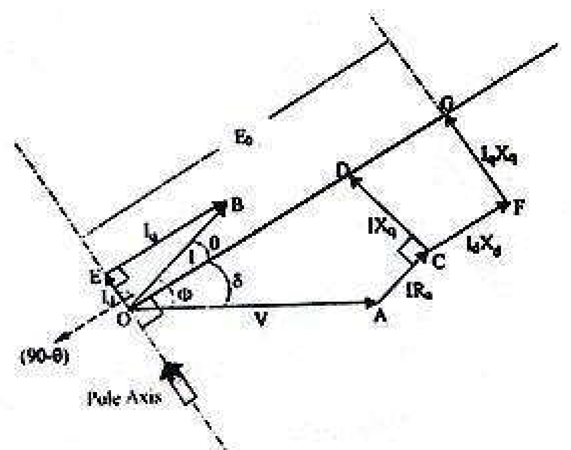
PROCEDURE TO DRAW THE VECTOR DIAGRAM (ZPF METHOD)

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 Φ (it may be Lag, Lead, Unity) with the voltage.
3. Draw the vector AC with the magnitude of IRa 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_dX_d and I_qX_q.

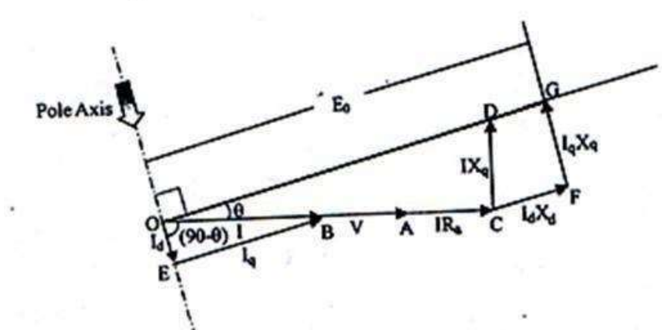
Lagging power factor:



Leading power factor:



Unity power factor:



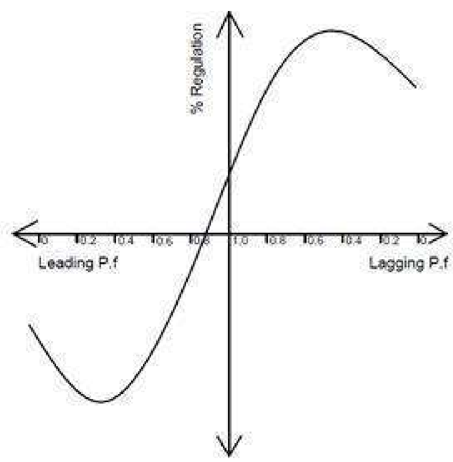
9. Draw the parallel line(i.e. Perpendicular to I_d) to the vector OD from the point C,with the magnitude of the drop I_dX_d (Line CF).

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_qX_q (Line FG).

11. Let the point at where the drop I_qX_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:

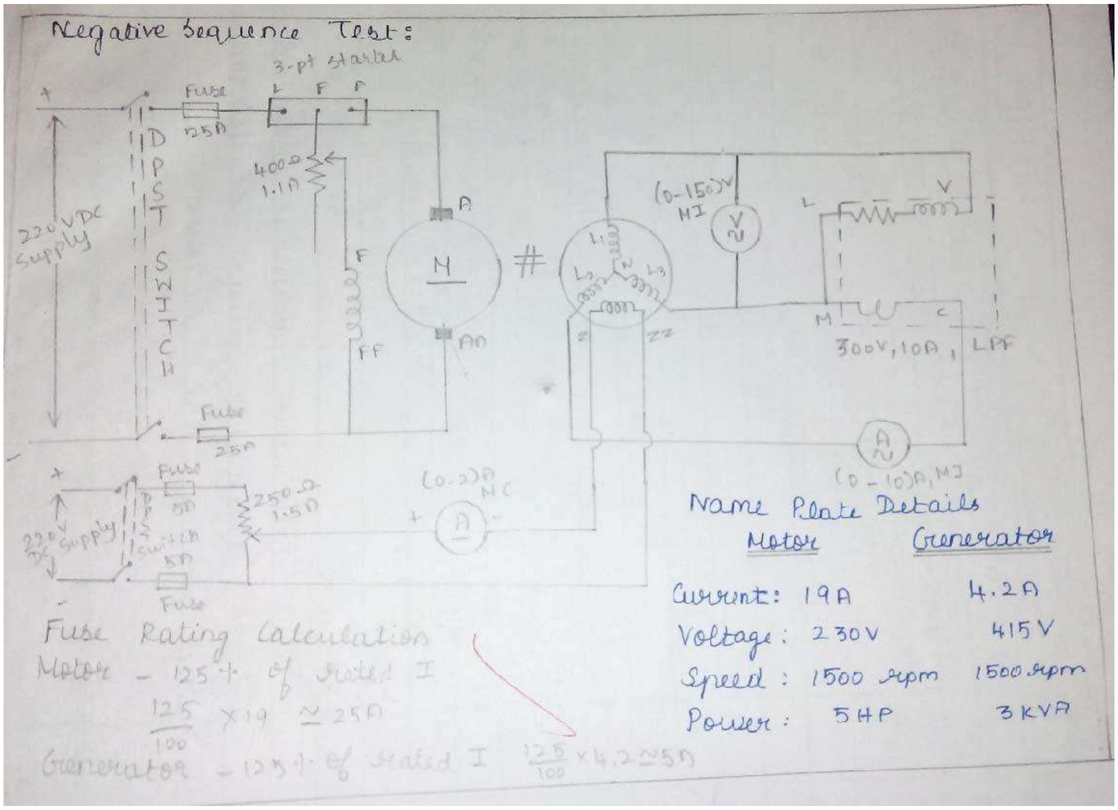


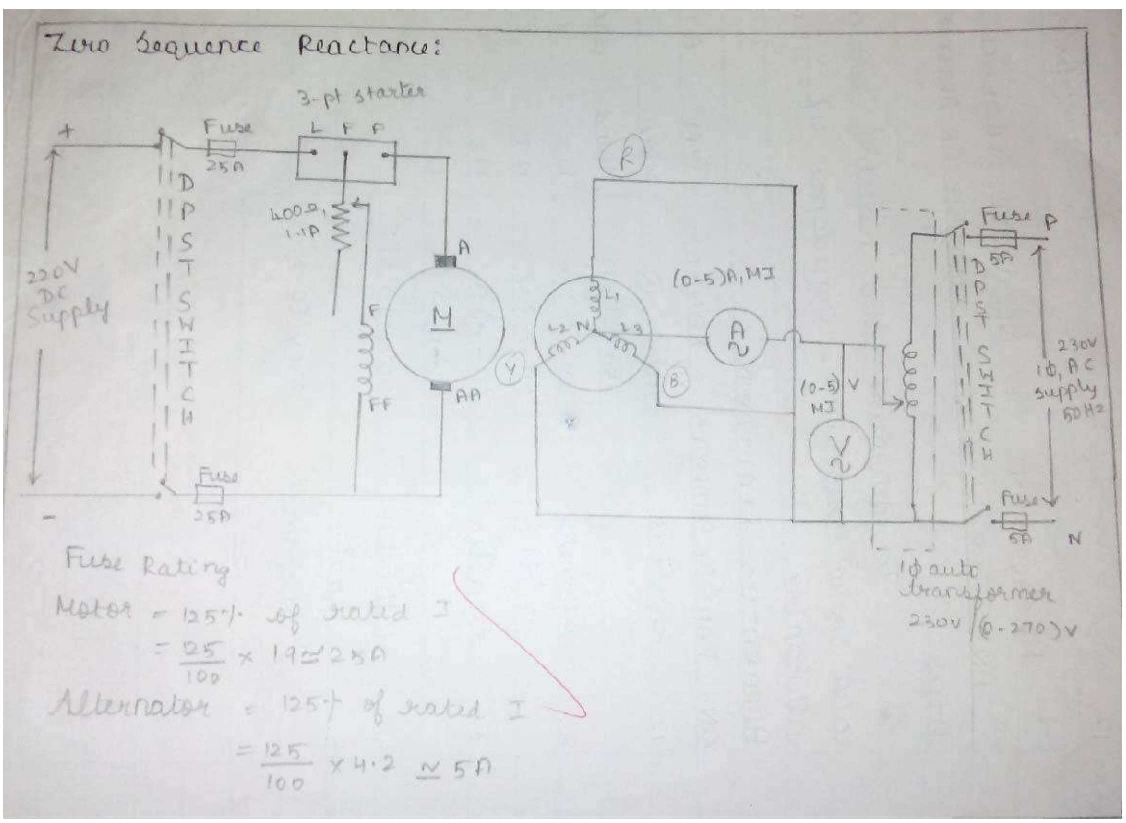
VIVA QUESTIONS:

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 SEQUANCE 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	400Ω, 1.1A 250 Ω, 1.5A	Wire Wound	1 each
5.	Auto Transformer	230V / (0-270)V	1 ϕ	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)	I_{SC} (A)	W (Watt)	$Z_2 = \frac{V_{RY}}{\sqrt{3}\, I_{SC}}$	$X_2 = Z_2 * (W/(V_{RY} * I_{SC}))$	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 impendence encountered by the negative sequence is called the – ve sequence impedance of the generator. The zero sequence current produce flux in each phase but their combined armature reaction at the air gap is zero. The impedance encountered by their currents is therefore different from that encountered by + ve and –ve sequence components and is called zero sequence impedance of generator.

<u>Negative Sequence Impendence:</u>

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

$$Z_2 = V/\sqrt{3}\, I_{SC} = \frac{V_{RY}}{\sqrt{3}\, I_{SC}} \qquad X_2 = Z_2 \left(\frac{W}{V_{RY}\, I_{SC}}\right)$$

$$X_2 = W/\sqrt{3}\, I_{sc}^2 \qquad R_2 = \sqrt{(Z_2^2 - X_2^2)}$$

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 ZO=V/3I practically the same results will be obtained with rotor stationary. If windings are connected in parallel, then

$$Z0 = \frac{\text{Voltage applied to phase}}{\text{Current through each phase}} = \frac{V}{I/3} = \frac{3V}{I}$$

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.

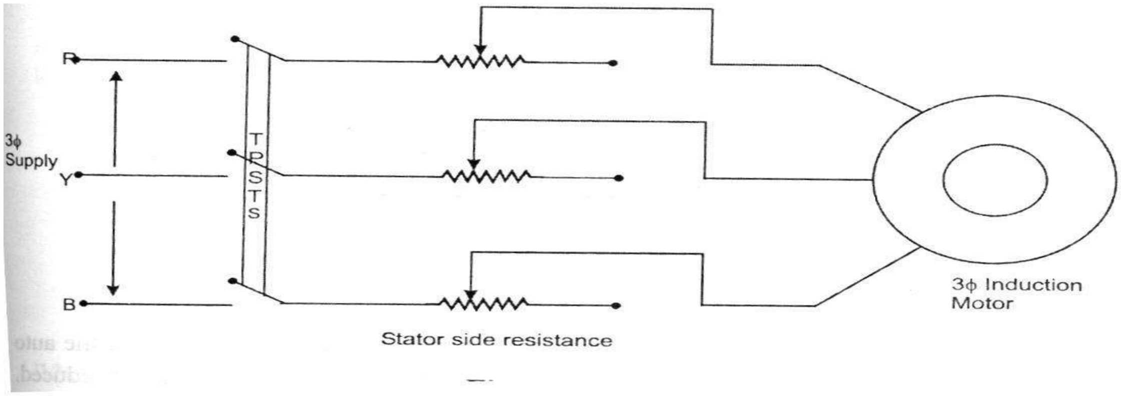
3) Gradually increase the autotransformer output by varying the VARIAC and note the ammeter reading for suitable voltage applied.

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.

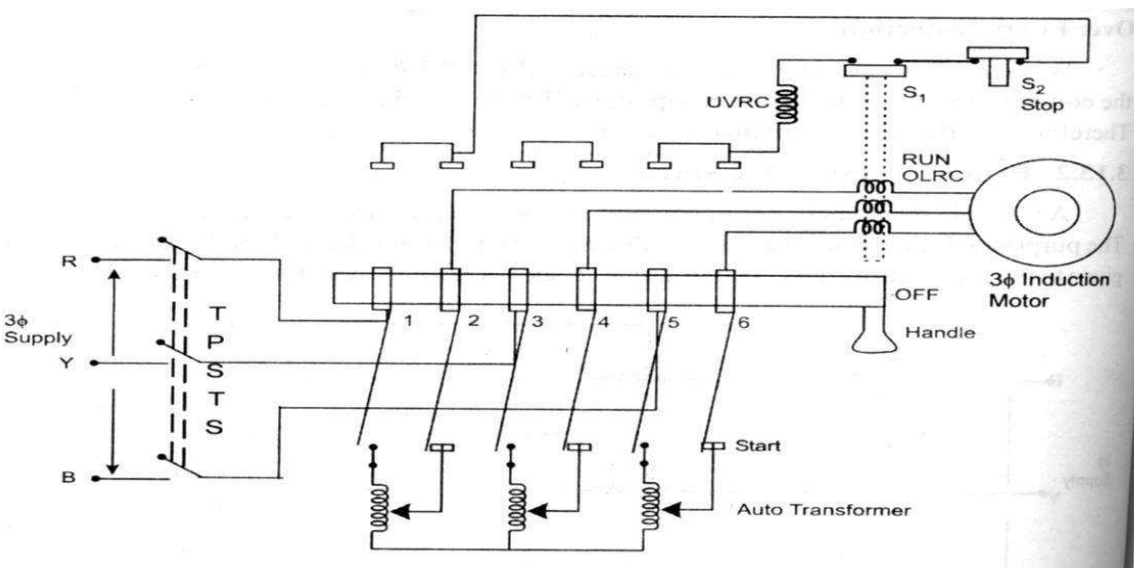
RESULT:

CIRCUIT DIAGRAM:

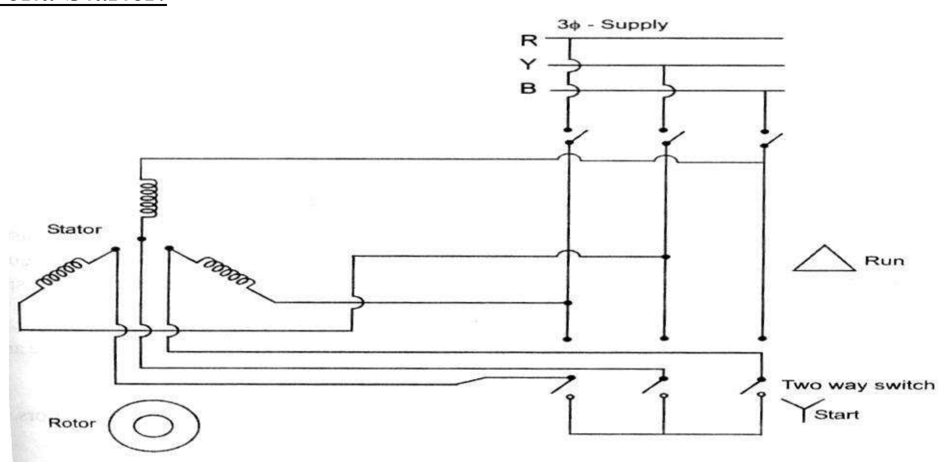
Stator Resistance Starter:



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 if 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.

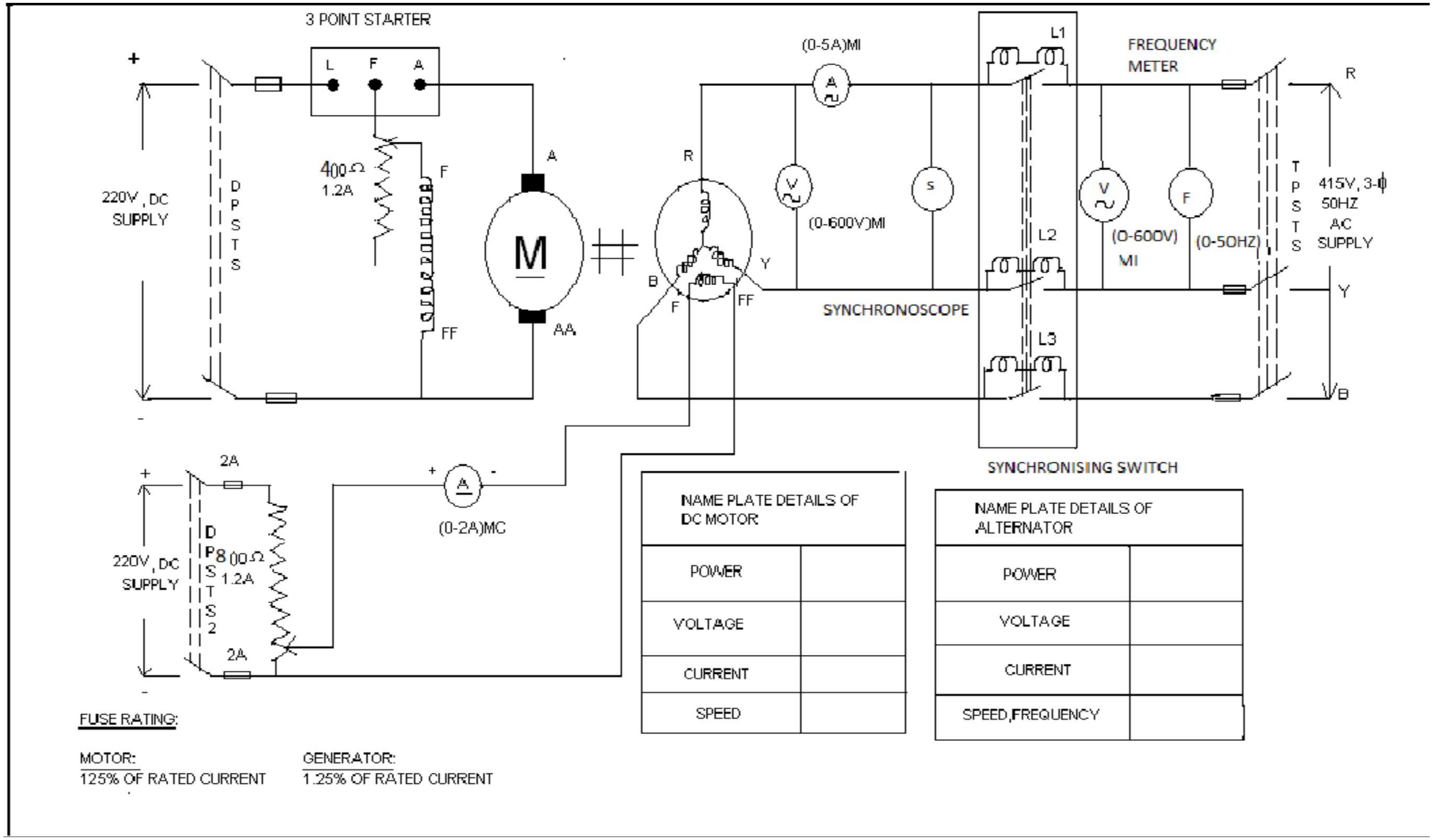
Star – Delta Starter:

This is the cheapest starter of all and hence used very commonly for the induction motors. It uses triple pole double throw (TPDT) 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 is limitations are, it is suitable for normal delta connected motors and the factor by while voltage change is $1 \sqrt{3}$ which cannot be changed.

RESULT:

CIRCUIT DIAGRAM:

SYNCHRONISATION OF ALTERNATOR TO INFINITE BUSBAR



NAME PLATE DETAILS OF DC MOTOR	
POWER	
VOLTAGE	
CURRENT	
SPEED	

NAME PLATE DETAILS OF ALTERNATOR	
POWER	
VOLTAGE	
CURRENT	
SPEED,FREQUENCY	

FUSE RATING:

MOTOR:
125% OF RATED CURRENT

GENERATOR:
1.25% OF RATED CURRENT

Expt. No:
Date :

SYNCHRONISATION OF ALTERNATOR TO INFINITE BUSBAR

AIM:

To synchronize the 3Φ alternator to the infinite bus bar.

APPARATUS REQUIRED:

SI.NO	APPARATUS	SPECIFICATIONS	QUANTITY
1	Voltmeter	(0-600V) MI	2
2	Ammeter	(0-2A) MC	1
3	Rheostat	300Ω,1.2A	1
		350Ω,2A	1
4	Synchronising Lamps	230V,15A	6

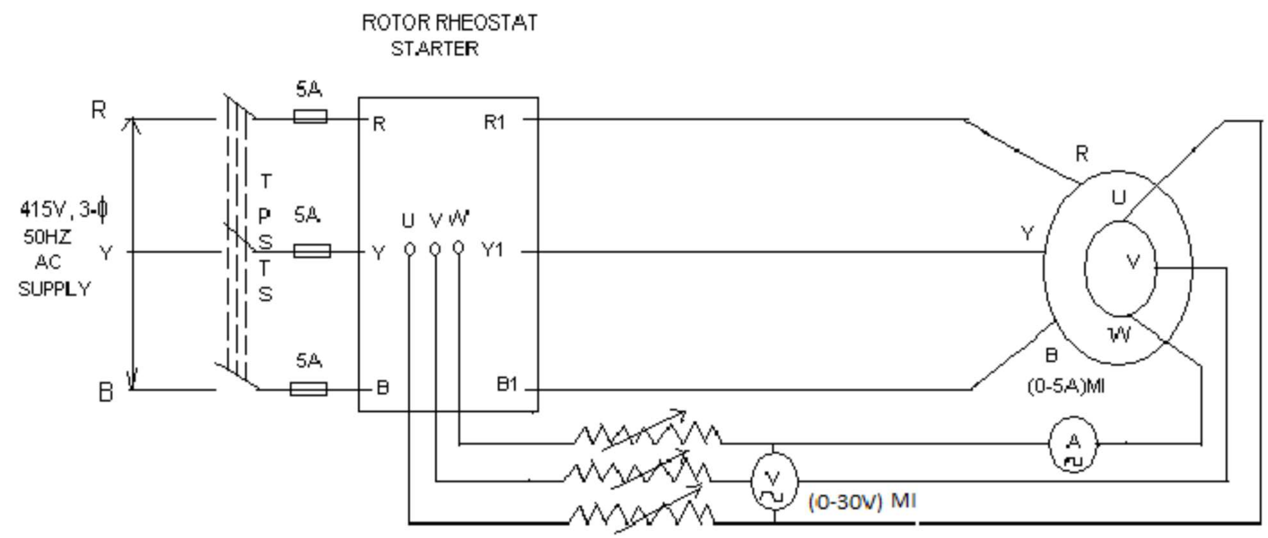
PROCEDURE:

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



NAME PLATE DETAILS OF 3ϕ SLIP RING INDUCTION MOTOR

	STATOR	ROTOR
RATED VOLTAGE		
RATED CURRENT		
POWER		
SPEED		

FUSE RATING

0.25% OF RATED CURRENT

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

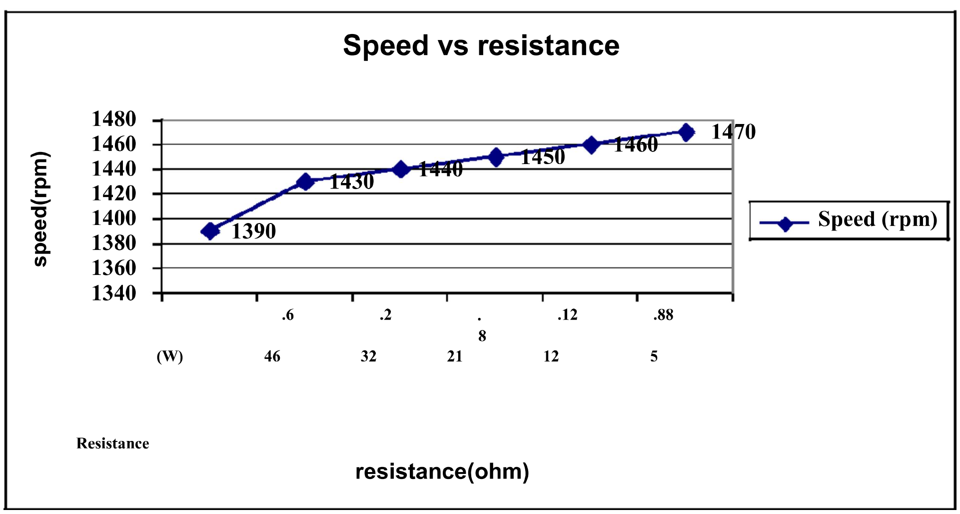
PROCEDURE:

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 (^)	Speed (rpm)

MODEL GRAPH:



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RESULT: