Electrical Machines Laboratory-II

MANUAL

Electrical Engineering Dept. | EEN 3rd Year | 6th Semester | EE 391

Name of the Program: **B. Tech (EE), 3rd Year, 6th Semester**

Course/Subject: **Electrical Machines Lab-II**

Course code: **EE 391**

Electrical Machines Laboratory-II is very important laboratory of Electrical Engineering Department. In this lab students perform experiments on three phase transformer, single-phase induction motor, three-phase induction motor and alternator. The experiments in this lab are designed to provide students with practical skills on electrical machines that will empower them to work in an industrial environment. This laboratory is used for the undergraduate 3rd year 1st semester students for course EE 391.

The course outcomes:

At the end of the course the student will be able to

1. Conduct different tests on single-phase induction motor.
2. Conduct different tests on three-phase induction motor.
3. Control the speed of 3-phase Slip-ring Induction Motor.
4. Connect the three-phase transformer in different fashions.
5. Calculate voltage regulation of alternator by different test.

Assessment Criteria:

1. Regular attendance to classes.
2. Experimental result and lab report.
3. End semester final examinations.

ELECTRICAL MACHINES LAB-II

List of the Experiments

1. Study of the different connections of three-phase transformers
2. To study SCOTT. connections of transformer (Study of three phase to two phase conversion)
3. To perform no load and blocked rotor test on a three phase induction motor
4. To perform Load Test on three phase Induction Motor
5. Speed Control of 3 Phase Slip-ring Induction Motor by Rotor Resistance Control
6. To draw the performance characteristics of a single phase induction motor by conducting the no-load and blocked rotor test
7. Open Circuit and Short Circuit Tests on a Three-Phase Alternator
8. To Determine Voltage Regulation of 3 Phase Alternator By Zero Power Factor Method.

<u>EXPERIMENT NO.:1</u>

Study of the different connections of three-phase transformers

OBJECT:

To connect three single-phase transformers in (a) delta/star, (b) delta/delta, (c) star/delta, and (d) star/star and obtain their no-load line voltage ratios and their phase relationships.

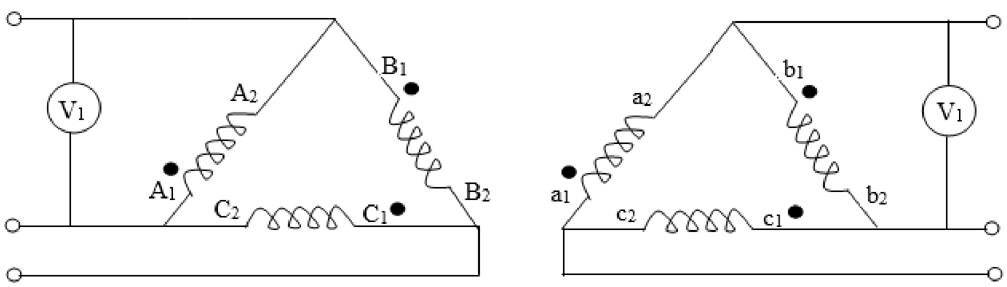
APPARATUS REQUIRED:

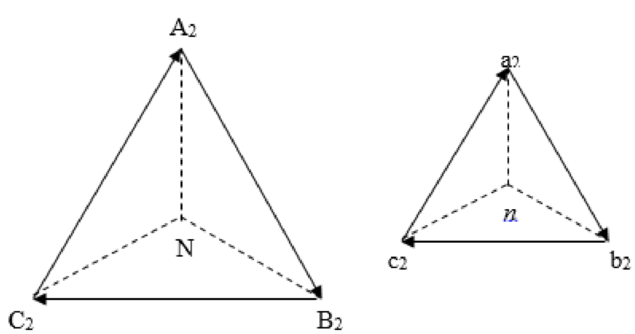
Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:

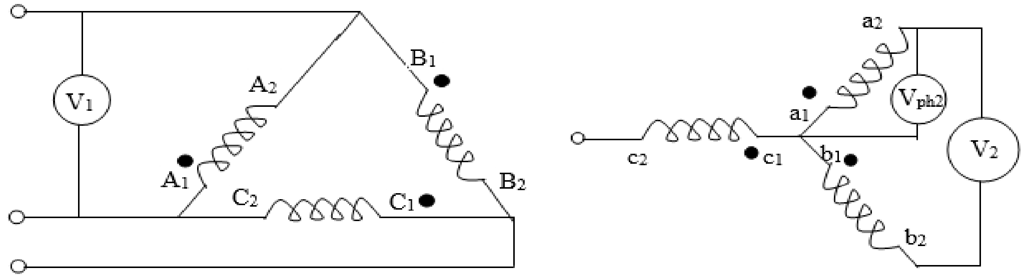
Delta-delta:

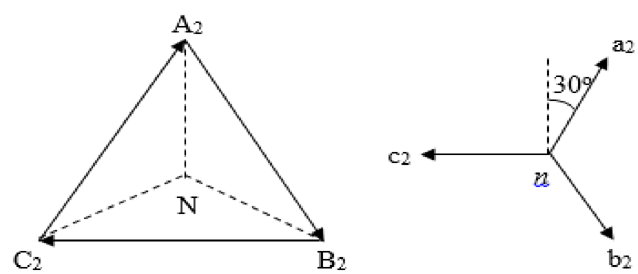




Phasor diagram of a delta-delta connection

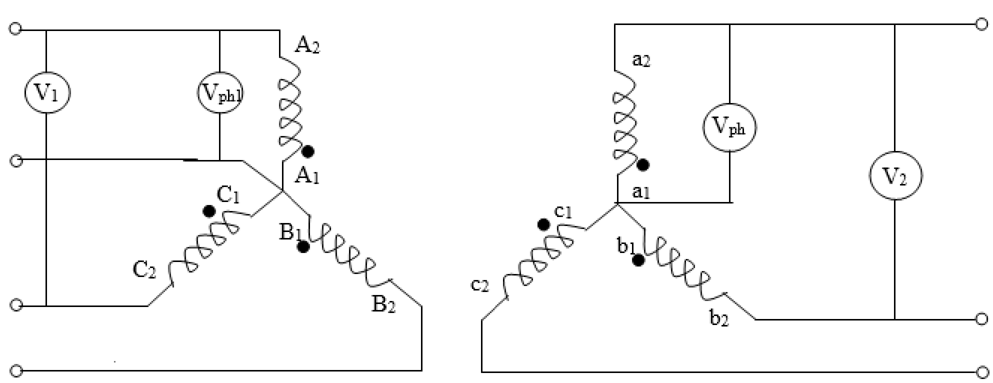
Delta-star:

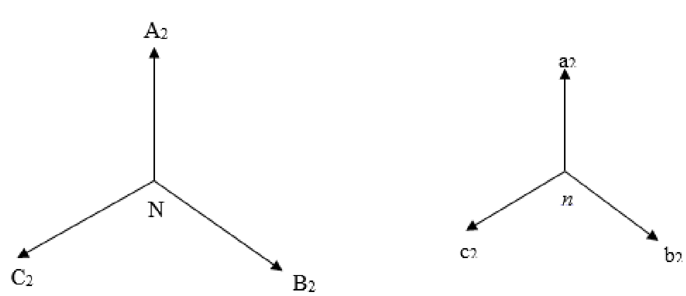




Phasor diagram of delta-star connection

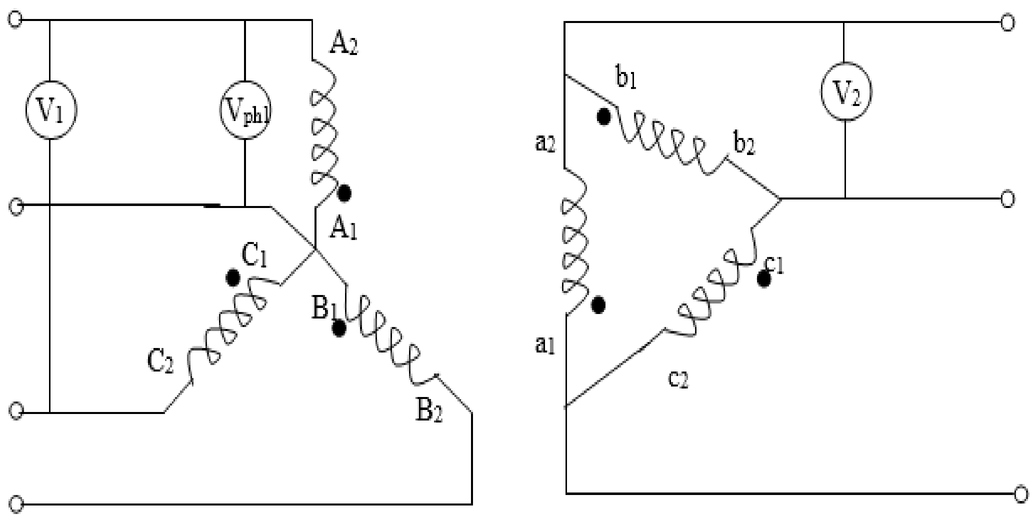
Star-star:

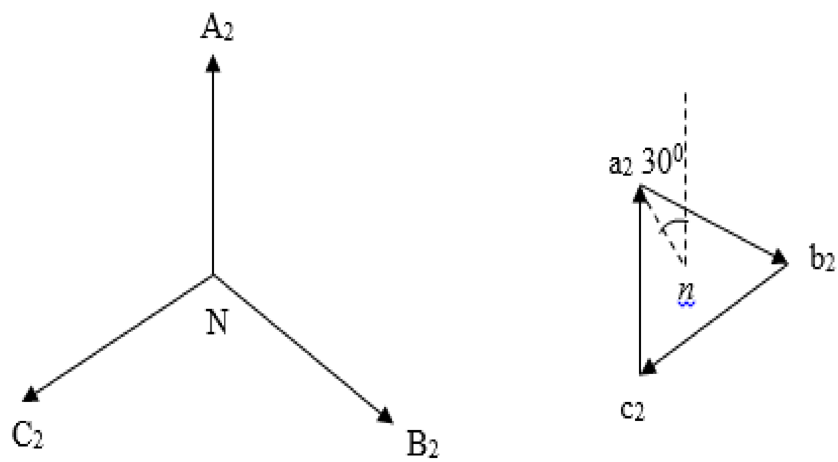




Phasor diagram of star-star connection

Star-delta:





Phasor diagram of star-delta connection

PROCEDURE:

1. With due regard to the polarities of the windings connect the primaries and the secondaries of the transformers in the manner indicated in Figs. 1-4.
2. For balanced applied voltage note down the readings of ammeters and voltmeters.

OBSERVATION TABLE:

Connection	Primary voltages (V)		Secondary voltages (V)		$\frac{V_1}{V_{ph1}}$	$\frac{V_2}{V_{ph2}}$	$\frac{V_1}{V_2}$
	Line to line (V_1)	Phase (V_{ph1})	Line to line (V_2)	Phase (V_{ph2})			
Delta/delta							
Delta/star							
Star/star							
Star/delta							

Questions:

What are the relative merits and demerits of different three phase transformer connections?

EXPERIMENT NO.:2

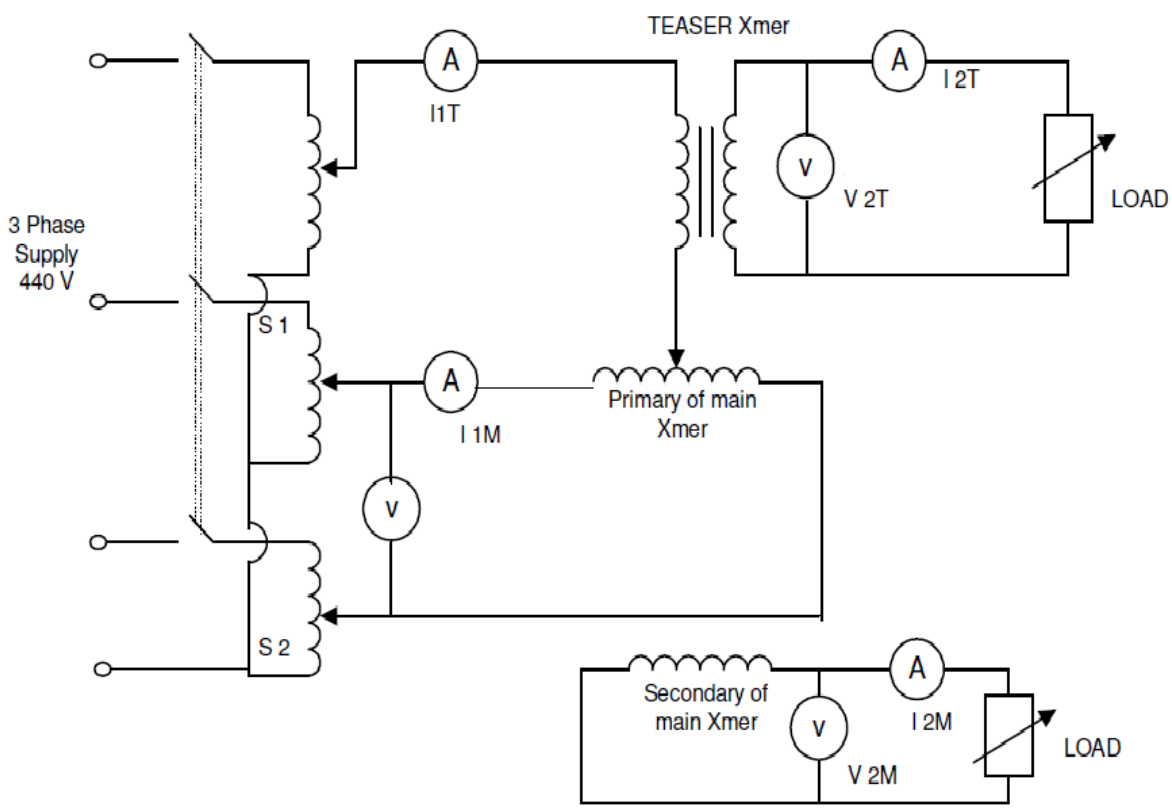
OBJECT: To Study Scott. Connections of Transformer (Study of three phase to two phase conversion).

APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:



Procedure:

1. Connect the circuit as shown.
2. Use 86.6% tapping for teaser transformer and 50% tapping for main transformer.
3. Keep both loads zero
4. Switch on the 3-ph. supply and take the readings.
5. Vary the loads as per given in observation table and take the readings.

Observation Table:

For Balanced Load:

Sl. No.	Load Condition	Teaser Transformer			Main Transformer			
		I_{1T}	I_{2T}	V_{1T}	I_{1M}	I_{2M}	V_{1M}	V_{2M}
1.	No Load							
2.								

Calculations:

Verify the following calculated values from the measured values

1. $I_{1T} = 1.15 \times K \times I_{2T}$
2. $I_{1M} = \sqrt{[(K \times \boldsymbol{I_{2M}})^2 + (0.5 \times K \times I_{2T})^2]}$
3. If $|V_{2T}| = |V_{2M}|$ then $\sqrt{[{V_{2T}}^2 + {V_{2M}}^2]} = \sqrt{2}V_{2T} = \sqrt{2}V_{2M}$

   Where $K = \frac{N_2}{N_1}$ = transformation ratio.

EXPERIMENT NO.:3

To perform no load and blocked rotor test on a three phase induction motor

OBJECT:

To determine equivalent circuit parameters of a three Phase induction motor by performing no load and blocked rotor test

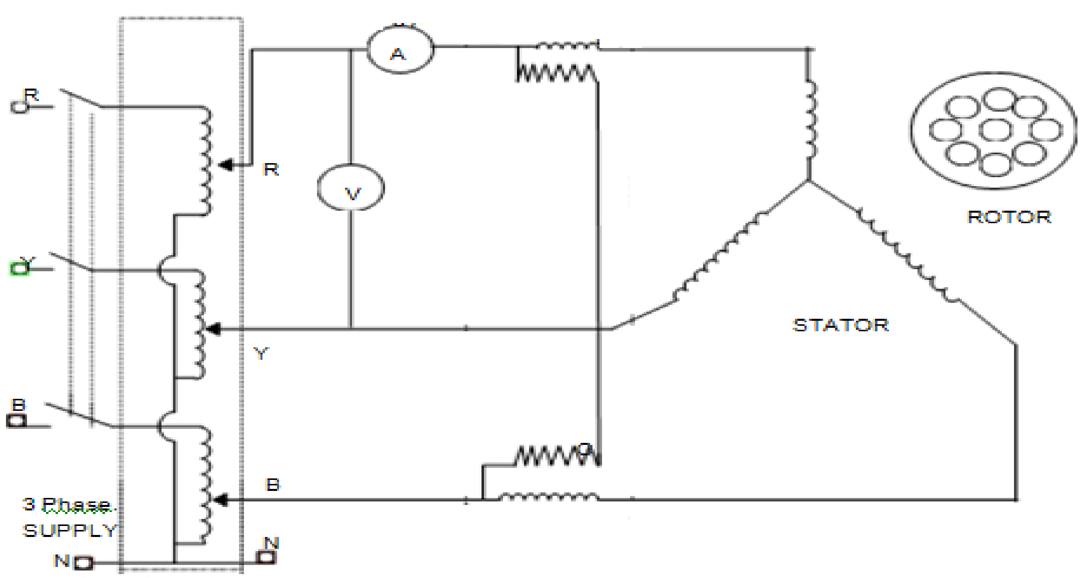
APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

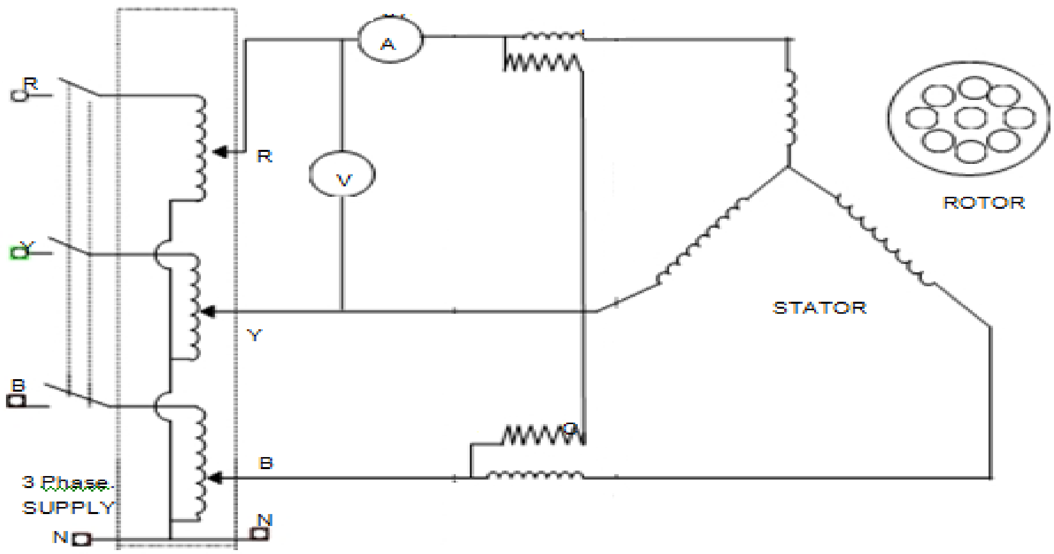
NAME PLATE DETAILS:

CIRCUIT DIAGRAM:

NO LOAD TEST:



BLOCKED ROTOR TEST:



PROCEDURE:

NO LOAD TEST:

1) Connections are made as per the circuit diagram.
2) Keep the dimmerstat position at zero output voltage and the motor at no-load.
3) Switch on the A.C. supply and gradually increase the motor input voltage to a value slightly greater than its rated value.
4) Note all the meter readings and also the speed.
5) Now reduce the motor input voltage to its rated value and take all the readings.
6) Reduce motor input voltage subsequently in 9 to 10 steps and note the corresponding readings.
7) After finishing both tests, measure the stator winding resistance per phase (R) by using a multimeter or by ammeter-voltmeter method. This will give the D.C. resistance of stator winding.

BLOCKED ROTOR TEST:

1) Connections are made as per diagram.
2) Keep the dimmerstat position at zero output voltage and hold the rotor shaft so as to disallow its rotation.
3) Switch on the A.C. supply and gradually increase the motor input voltage till the ammeter indicates rated current of the motor.
4) Note all the meter readings.

OBSERVATIONS:

For No-load test

Motor Voltage $V_{0(L-L)}$	No load current I0	Power P0(3-ph)	$(P_o - I_o^2 R_1)$

For Blocked-rotor test

Motor Voltage $V_{sc(L-L)}$	Motor Rated current Isc	Input power Psc(3-ph)

Calculations:

AC resistance of stator winding due to skin effect approximately is- **R1= 1.5 x D.C. value of resistance**

For no load test:

Per phase voltage $V_o = V_{o\,(L-L)} / \sqrt{3}$

Per phase power $P_o = P_{o\,(3\,ph)} / 3$

The no-load power drawn from the supply comprises of no-load Cu loss, iron loss (Pc) and friction/ windage loss (Pf)

$$P_o = I_o^2 R_1 + P_c + P_f$$

The net power input to the stator is- $(P_o - I_o^2 R_1) = (P_c + P_f)$

For blocked rotor test:

Per phase voltage $V_{sc} = V_{sc(L\text{-}L)} / \sqrt{3}$

Per phase power $P_{sc} = P_{sc(3\,ph)} / 3$

Per phase equivalent impedance of motor $Z_{sc/ph} = V_{sc} / I_{sc} = (R_1 + R_2') + j(X_1 + X_2')$

Per phase equivalent resistance of motor $R_{sc/ph} = P_{sc} / I_{sc}^2$

$$R_2' = R_{sc/ph} - R_1$$

Per phase equivalent reactance of **motor** $X_{sc/ph} = \sqrt{(Z_{sc/ph}^2 - R_{sc/ph}^2)}$

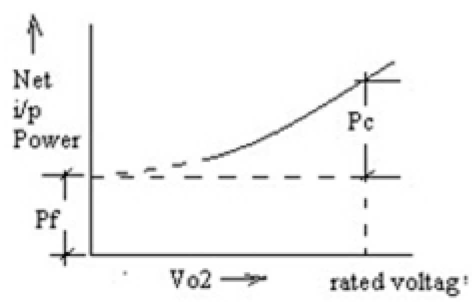
$$X_1 = X_2' = X_{sc/ph} / 2$$

Shunt resistance $R_o = V_o^2(\text{rated}) / P_c$

No-load power-factor $\cos\theta = P_c / (V_{o(rated)} . I_{o(\text{at rated } V_o)})$

Shunt reactance $X_o = V_{o(rated)} / I_{o(\text{at rated } V_o)} . \sin\theta$

Plot net power input versus square of input voltage V_o^2, the intercept of the curve with power axis will give P_f and P_c.



Equivalent Circuit:

Draw equivalent circuits of 3-phase I. M. at no-load and blocked rotor conditions.

EXPERIMENT NO.:4

To perform Load Test on three phase Induction Motor

OBJECT: To perform load test on 3-phase squirrel cage induction motor.

APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:

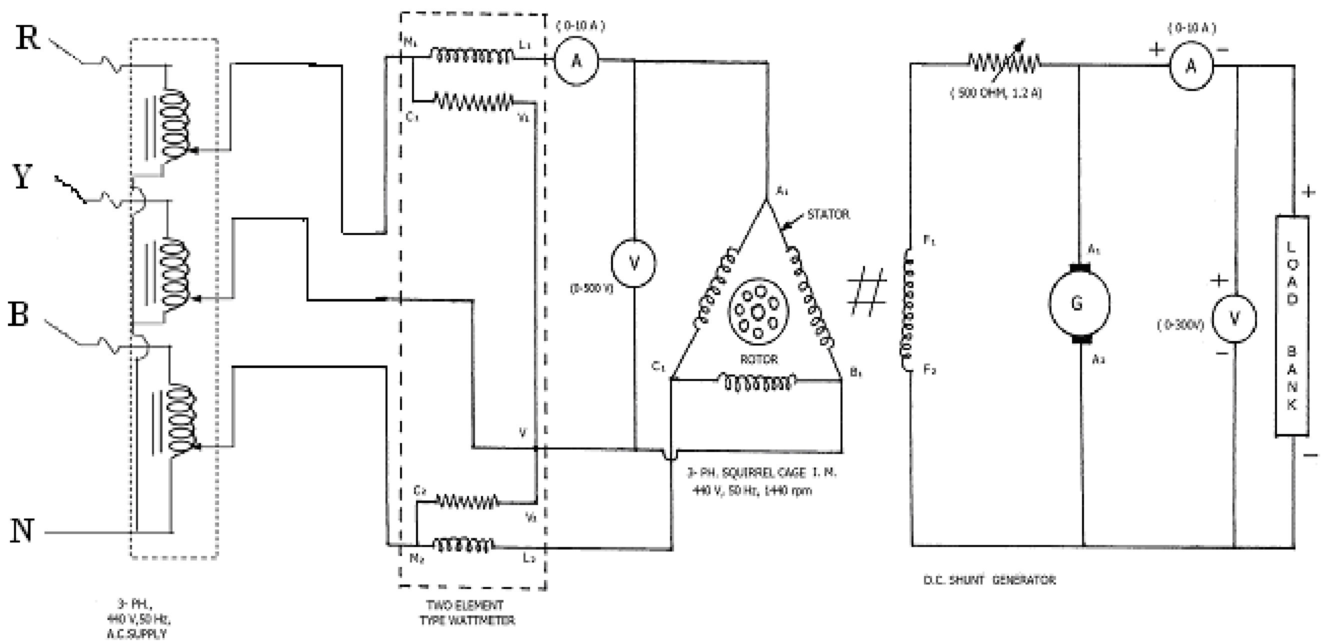


Figure-1

PROCEDURE:

1) Connect the circuit as shown in Figure-1.

2) Put all the load switches off. Set the generator field rheostat to its maximum.

3) Apply the 3-phase supply to the induction motor with the help of 3-phase auto-transformer and

run it to its normal speed.

4) Reduce the field resistance of D.C. shunt generator so that it generates rated voltage.

5) Note the meter readings and the speed with the load at zero.

6) Increase the load in steps keeping the D.C. generator voltage constant .Note the D.C. generator voltage, generator current, motor current, motor voltage, Power and speed.

7) Take more readings increasing the load gradually till the full load is reached.

8) Calculate performance parameters & plot the different graphs.

OBSERVATIONS:

Sl. no.	**Motor side**			**Generator side**		**Speed in r.p.m.**	**% Efficiency**	**Slip**	**Power factor**
	V_m (Volts)	**I_m (Apms)**	**W_m (Watts)**	**V_{dc} (Volts)**	**I_{dc} (Apms)**				

Armature resistance of generator Ra= ………Ω

Calculations: (For each reading):

Power factor of motor = $\frac{W_m}{3\times V_m\times I_m}$

Output power of generator = V_{dc} x I_{dc}
Total losses of generator = $I^2_{dc} R_a$ + constant losses
Constant loss = ½ x wattmeter reading at no load condition.
Output Power of motor = Input power of generator = Output power of generator + total losses of generator

Motor efficiency $\%\eta = \frac{Output\ power\ of\ motor}{Input\ power\ of\ motor} \times 100$

$$Slip\ (s) = \frac{(N_0 - N)}{N_0} \times 100$$

N_0=No load speed
N= Speed at load

Graph: Draw graphs (on same graph paper) of motor output power versus

i) Motor efficiency

ii) Motor input current

iii) Motor power factor

iv) Motor speed

Answer the following questions:

1. Why power factor is poor at no-load?

2. At what load, the efficiency will be maximum?

EXPERIMENT NO.:5

OBJECT: Speed Control of 3 Phase Slip-ring Induction Motor by Rotor Resistance Control.

APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:

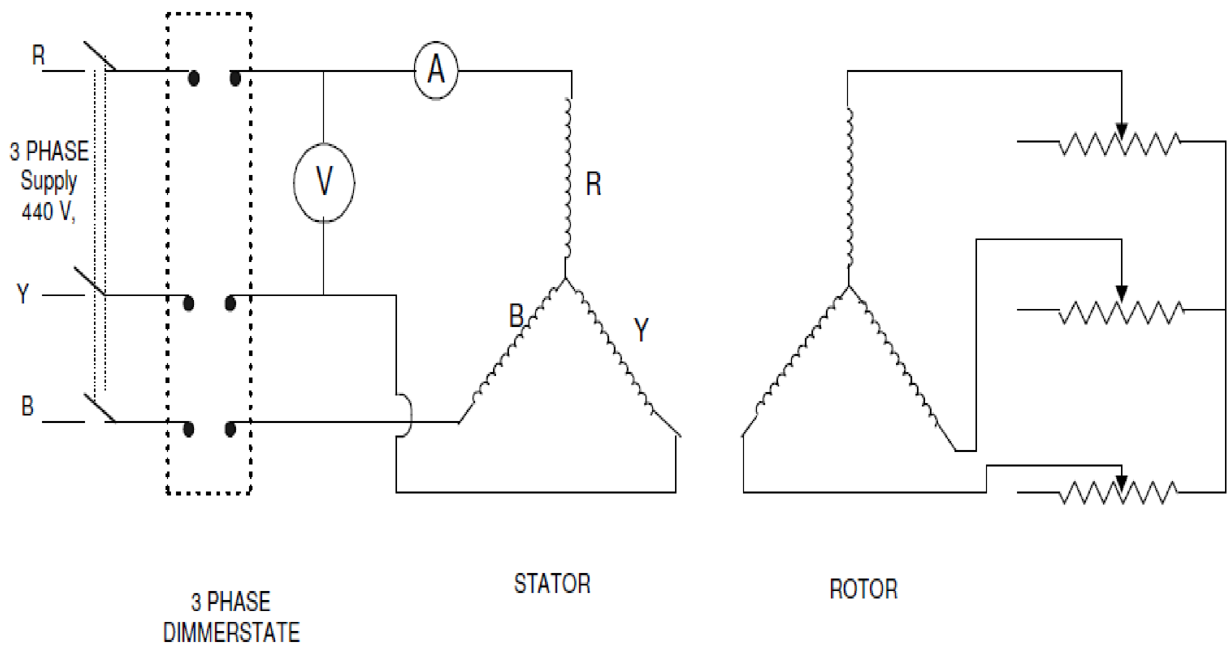


Figure-1

Procedure:

1. Connect the ckt. as shown in Figure-1.
2. Keep the dimmerstat as zero output voltage & the external rotor resistance at minimum resistance position.

3. Switch ON the supply & increase the input voltage to stator winding upto its rated value.
4. Measure the speed.
5. Now increase the rotor resistance in steps & note the corresponding values of speed.
6. Draw a graph of rotor resistance versus speed.

Observation Table:

Sr. no.	Rotor current	External rotor resistance	Speed (r.p.m)

Graph: Draw a graph of rotor external resistance versus speed**.**

EXPERIMENT NO.:6

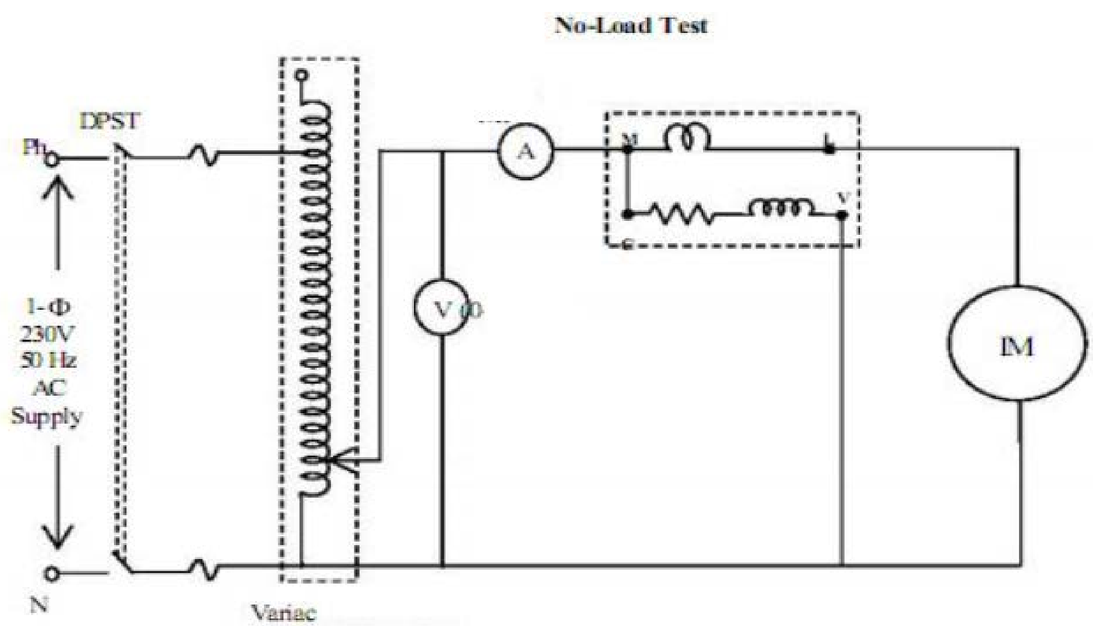
OBJECT: To draw the performance characteristics of a single phase induction motor by conducting the no-load and blocked rotor test.

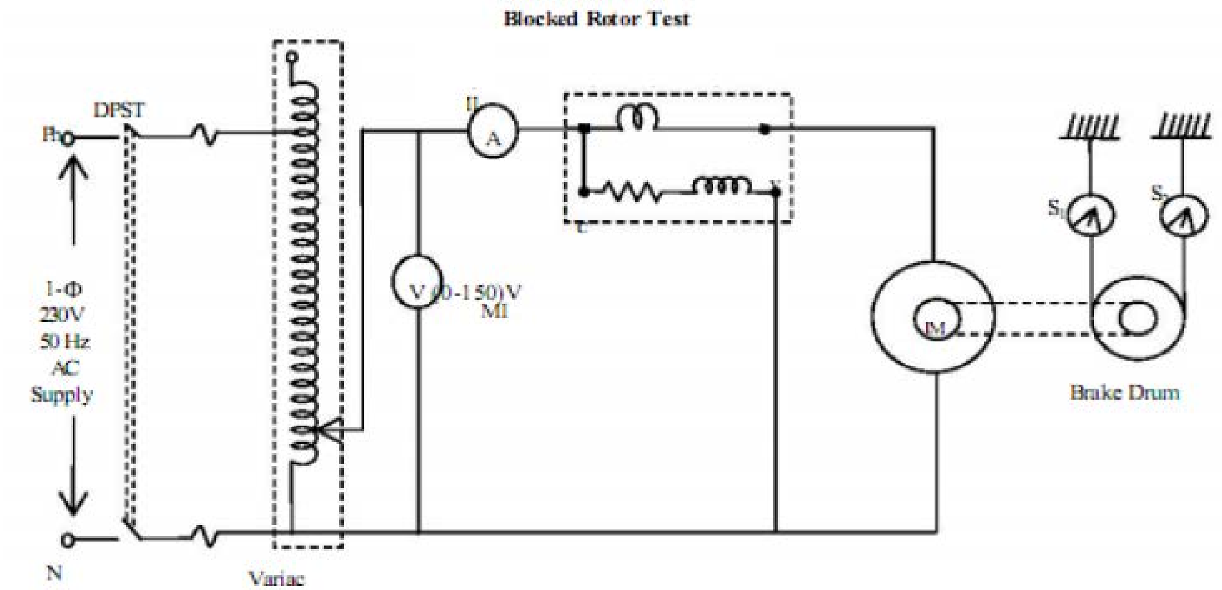
APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:





PROCEDURE:

NO LOAD TEST:

1. Connections are given as per the circuit diagram.
2. Precautions are observed and the motor is started at no load.
3. Autotransformer is varied to have a rated voltage applied.

BLOCKED ROTOR TEST:

1. Connections are given as per the circuit diagram.
2. Precautions are observed and motor is started on full load or blocked rotor position.
3. Autotransformer is varied to have rated current flowing in motor.
4. Meter readings are the noted.

Observation Table:

No Load Test:

Sl. No.	Vo (Volts)	Io (Amps)	Wo (Watts)

Blocked Rotor Test:

Sl. No.	Vsc (Volts)	Isc (Amps)	Wsc (Watts)

Calculations:

Effective resistance $\boldsymbol{R_{eff} = 1.5 \times R_{dc}}$

No load test:

$$\boldsymbol{\cos\emptyset = \frac{W_0}{V_0 I_0};\quad I_w = I_0 \cos\emptyset;\quad I_m = I_0 \sin\emptyset;\quad R_0 = \frac{V_0}{I_w}\ \Omega;\ X_0 = \frac{V_0}{I_m}\Omega}$$

Blocked Rotor test:

$$\boldsymbol{Z_{sc} = \frac{W_{sc}}{I_{sc}}\ \Omega;\quad R_{sc} = \frac{W_{sc}}{I_{sc}^2}\ \Omega;\qquad X_{sc} = \sqrt{Z_{sc}^2 - R_{sc}^2}\ \Omega}$$

EXPERIMENT NO.:7

Open Circuit and Short Circuit Tests on a Three-Phase Alternator

OBJECT:

i) **To find regulation of a three-phase alternator by open circuit and short circuit tests**

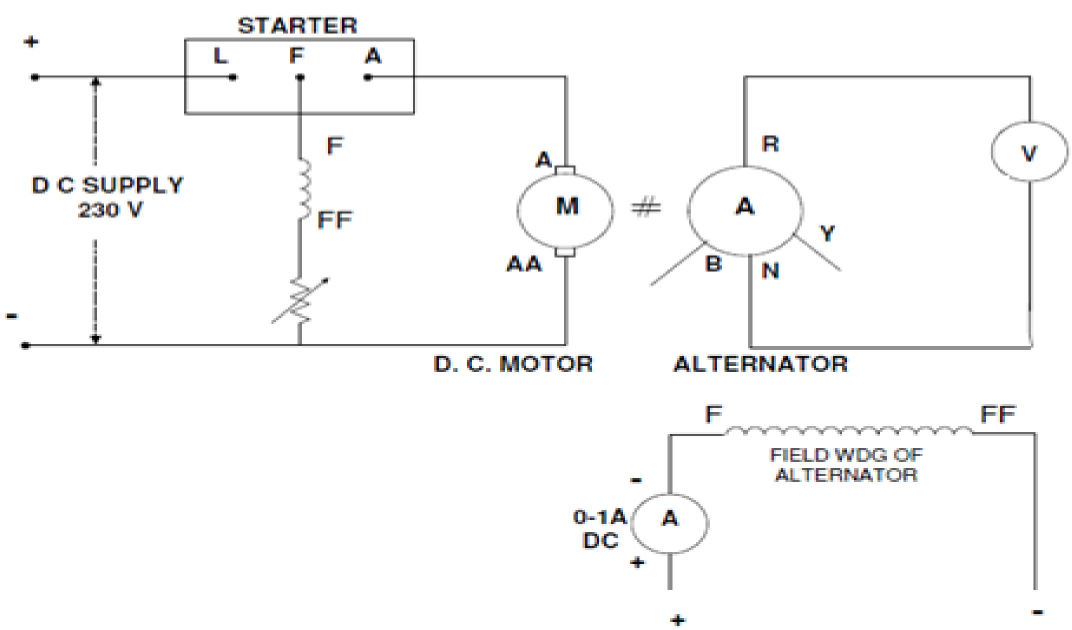
APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

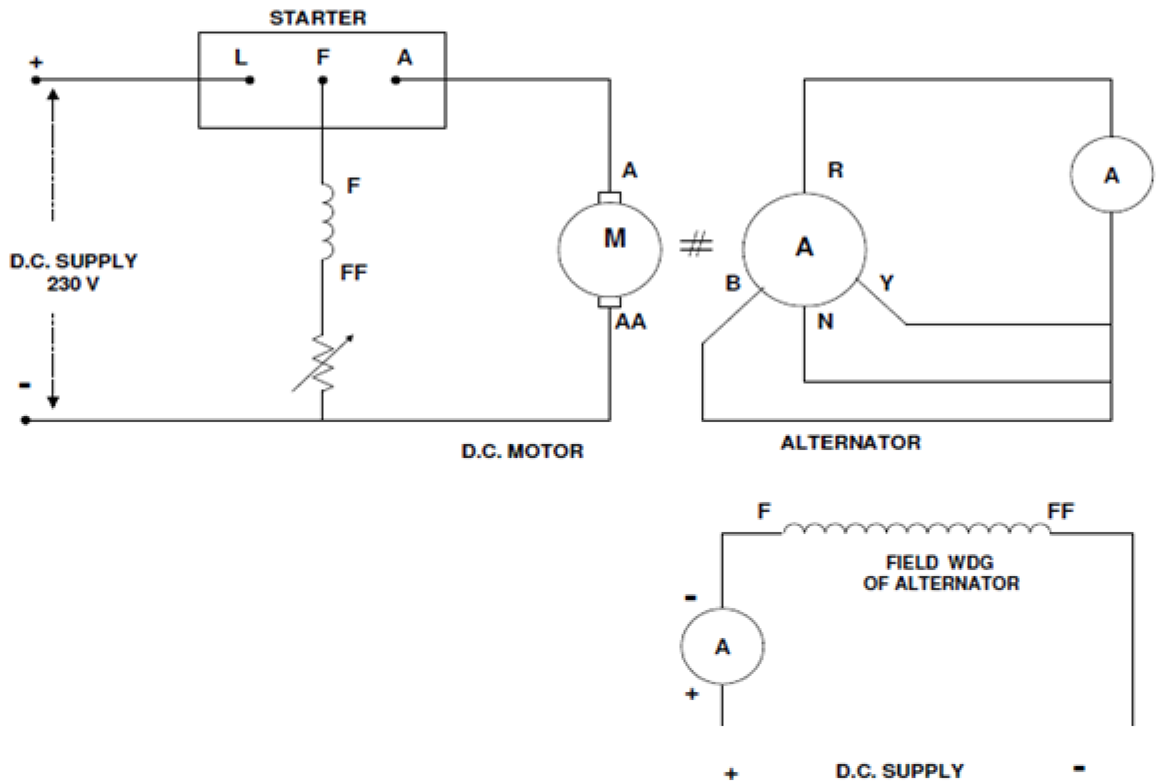
NAME PLATE DETAILS:

CIRCUIT DIAGRAM:

Open Circuit Test:



Short Circuit Test:



Procedure:

OPEN CIRCUIT TEST:

1) Connect the circuit as shown.

2) Set potential divider to zero output position and motor field rheostat to minimum value.

3) Switch on dc supply and start the motor.

4) Adjust motor speed to synchronous value by motor field rheostat and note the meter readings.

5) Increase the field excitation of alternator and note the corresponding readings.

6) Repeat step 5 till 10% above rated terminal voltage of alternator.

7) Maintain constant rotor speed for all readings.

SHORT CIRCUIT TEST:

1) Connect the circuit as shown.

2) Star the motor with its field rheostat at minimum resistance position and the potential divider set to zero output.

3) Adjust the motor speed to synchronous value.

4) Increase the alternator field excitation and note ammeter readings.

5) Repeat step 4 for different values of excitations (field current). Take readings up to rated armature
current. Maintain constant speed for all readings

6) Measure the value of armature resistance per phase Ra by multimeter or by ammeter-voltmeter method.

7) Plot the characteristics and find the synchronous impedance.

OBSERVATIONS:

Alternator armature resistance per phase Ra=…………ohm.
Rotor speed = ……………RPM (const)

Open Circuit Test:

Sl. No.	Field current(I_f)	Terminal voltage per phase Vo

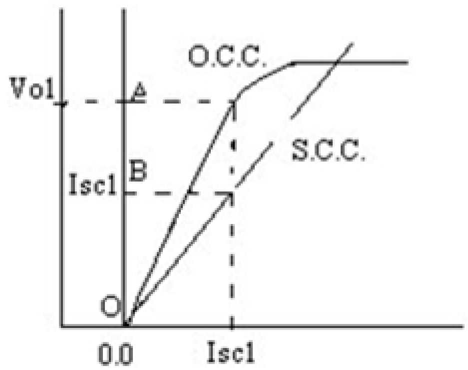
Short Circuit Test:

Sl. No.	Field current(I_f)	Short circuit current I_{sc}

Graph:

Plot the readings to draw following graphs. Use same graph paper for both curves.

1. I_f versus Vo (for O.C. test) 2. I_f versus Isc (from S.C. test)



Calculations:

Synchronous impedance $Z_S = \frac{OA}{OB} = \frac{V_{O1}}{I_{SC1}}$ for field current I_{SC1}

I_{SC1} is selected over the linear part of OCC, generally it corresponds to rated armature current. Synchronous impedance $X_S = \sqrt{Z_S^2 - R_a^2}$ where Ra=armature resistance of alternator per phase.

Calculate the voltage regulation for full load current and

i) Unity power factor
ii) 0.8 pf lagging
iii) 0.8 pf leading

EXPERIMENT NO.:8

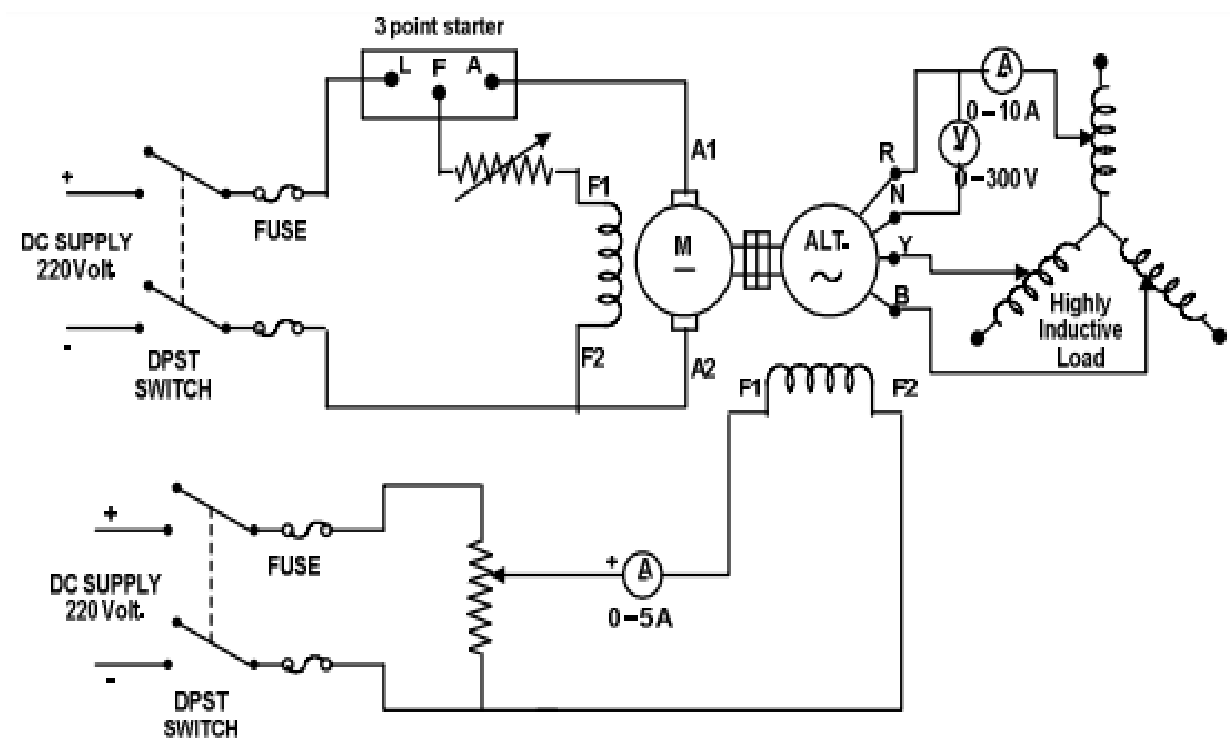
OBJECT: To Determine Voltage Regulation of 3 Phase Alternator By Zero Power Factor Method.

APPARATUS REQUIRED:

Sl. No.	Apparatus Required	Type	Range	Quantity

NAME PLATE DETAILS:

CIRCUIT DIAGRAM:



PROCEDURE:-

(a) TO PLOT OCC

i) Connect the circuit diagram as shown in figure.

ii) Start the motor and run it at synchronous speed.

iii) Vary the excitation applied to alternator in steps and note down the corresponding voltages.

iv) Plot the open circuit characteristics.

(b) TO PLOT ZPF

(i) Connect the circuit diagram as shown in figure.

(ii) Start the motor and run it at synchronous speed.

(iii) Vary the inductive load in steps and adjust the field current to a value till full load armature current is flowing.

(iv) Every time note down the field current and the terminal voltage of alternator.

(c) TO GET STARTING POINT OF ZPF

(i) Connect the circuit diagram as shown in figure.

(ii) Start the motor and run it at synchronous speed.

(iii) Vary the field excitation to get rated current flowing through armature.

(iv)Note down this value of field current.

Observation Tables:

OCC:

Sl. No.	Open circuit voltage	Field current

ZPF:

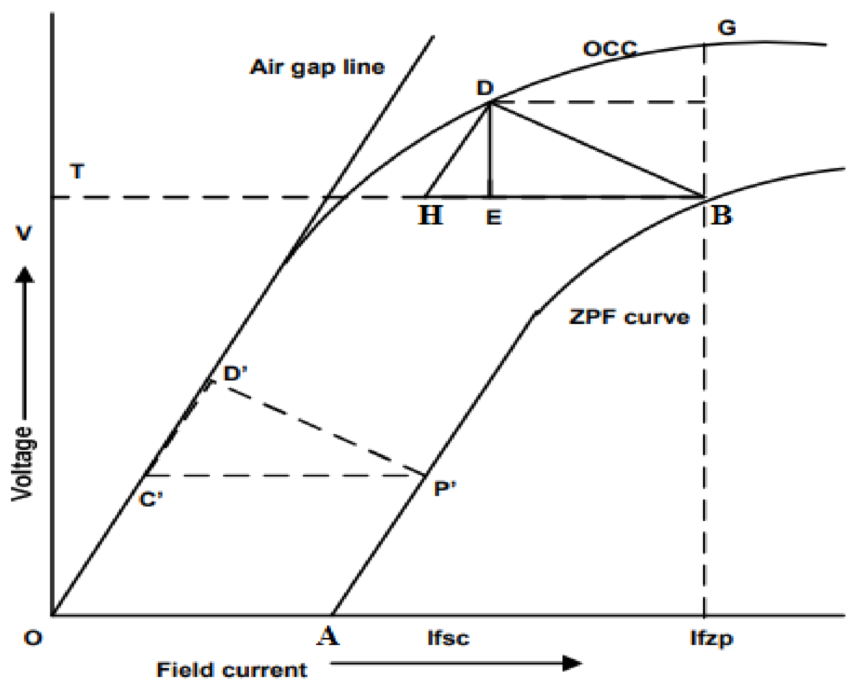
Sl. No.	Terminal voltage	Field current

SCC:

Sl. No.	Short circuit current	Field current

METHODS TO DRAW POTIER TRIANGLE:

Plot OCC and ZPF locate terminal voltage on OCC mark at B on ZPF corresponding to some value from point B mark distance HB equal to OA . Draw tangent to OCC. Point 'H' draw line parallel to the tangent to intersect OCC at 'D'. The ΔDHB is the potier triangle draw attitude from point D. The height of the altitude represents the armature leakage reactance drop where as that of ED represents m.m.f requires to overcome the armature reaction drop .



Questions:

1. Draw the OCC and ZPF .
2. Calculate the voltage regulation for full load current and
   iv) Unity power factor
   v) 0.8 pf lagging
   vi) 0.8 pf leading