Ahsanullah University of Science and Technology
Department of Electrical and Electronic Engineering

LABORATORY MANUAL

FOR

ELECTRICAL AND ELECTRONIC SESSIONAL COURSES

Student Name :

Student ID :

Course no : EEE-2188

Course Title : Electrical Machines

For the students of

Department of Mechanical and Production Engineering

2nd Year, 1st Semester

Experiment no: **1**
Experiment name: **Study of a Single-Phase Transformer.**

Introduction:

A transformer is a static device by means of which electric power in one circuit is transferred into electric power in another circuit of the same frequency. It can raise or lower voltage in the circuit with a corresponding decrease or increase in current. So the volt-ampere rating of two circuits remains same. The simple structure of a 1-ϕ transformer is shown below:

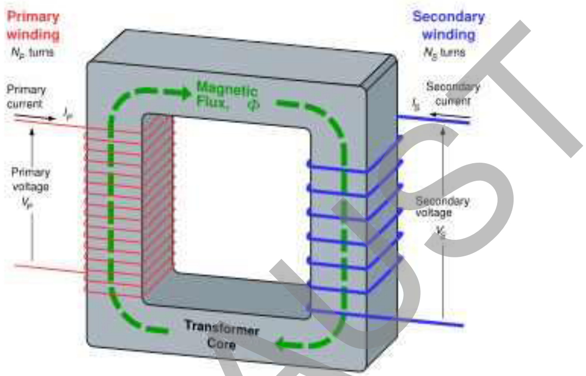


Fig: Simple structure of a 1-ϕ transformer

As the volt-ampere rating of two sides are same so

$$V_1 * I_1 = V_2 * I_2$$

i.e. $V_1/V_2 = I_2/I_1$ --(1)

Again the induced voltage in the transformer is directly proportional to the no of turns surrounding the transformer windings. So

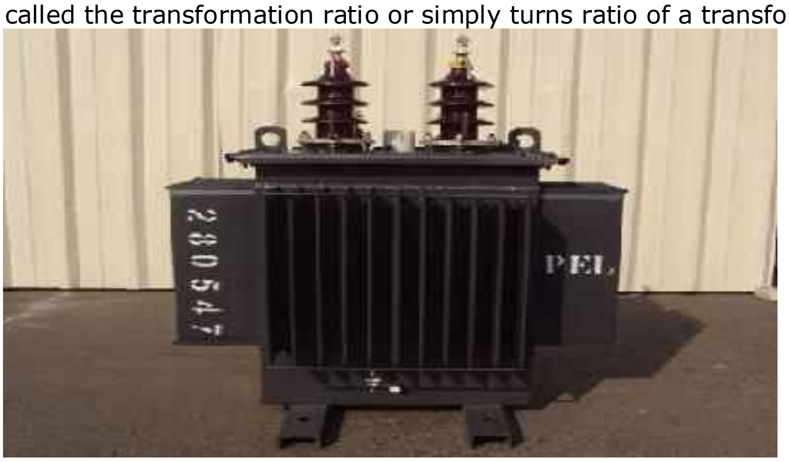
$V_1 \propto N_1$ and $V_2 \propto N_2$

i.e. $V_1/V_2 = N_1/N_2$ -------------------------- (2)

Combining these two equations, (1) and (2) we get

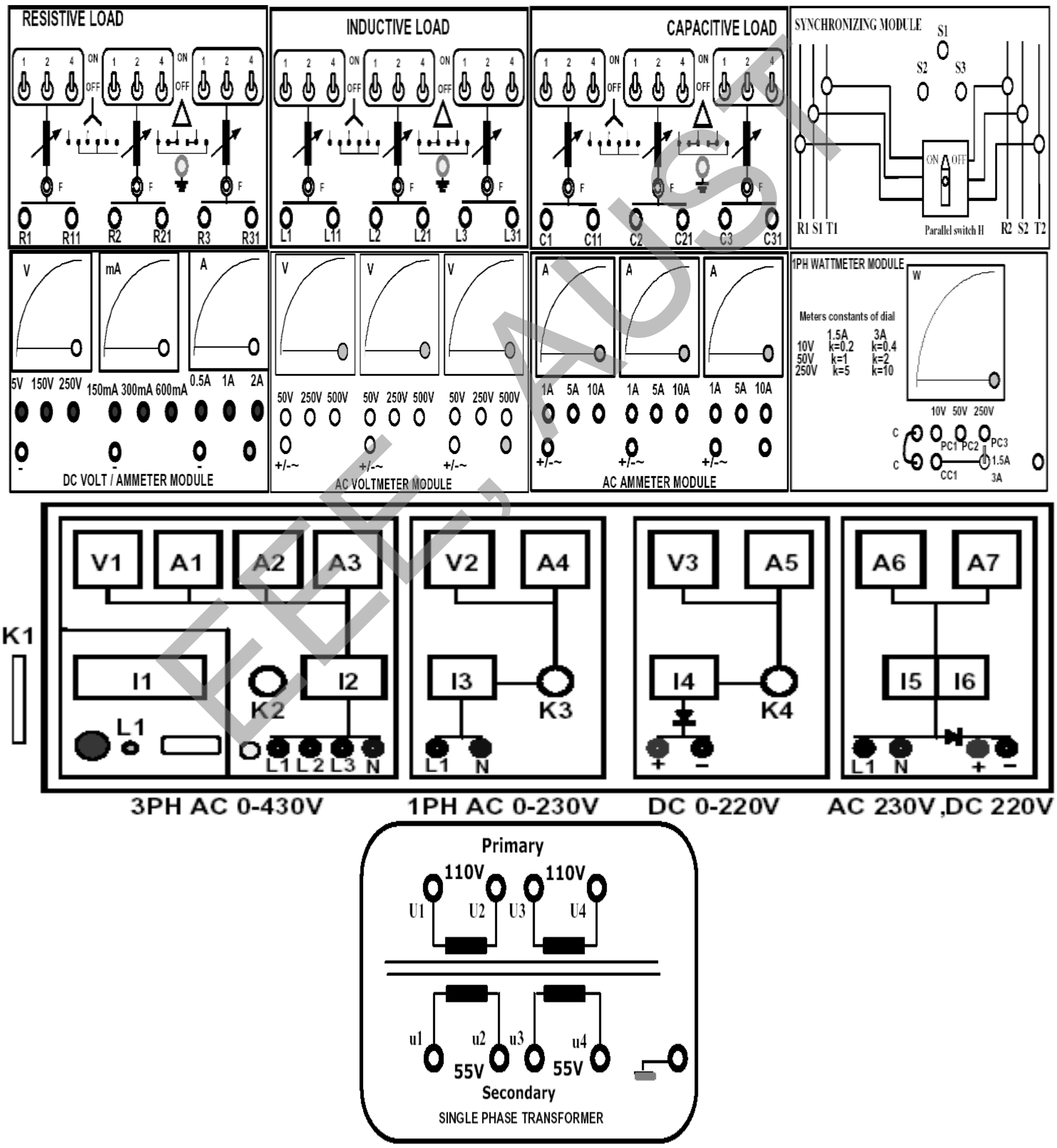
$$V_1/V_2 = I_2/I_1 = N_1/N_2$$

Where N_1/N_2 is called the transformation ratio or simply turns ratio of a transformer



Equipments:

1. Universal Power Supply Module
2. 1PH Transformer
3. AC Ammeter Module 0-1A
4. AC Voltmeter Module 0-250 V
5. Resistive Load
6. 1PH Wattmeter Module

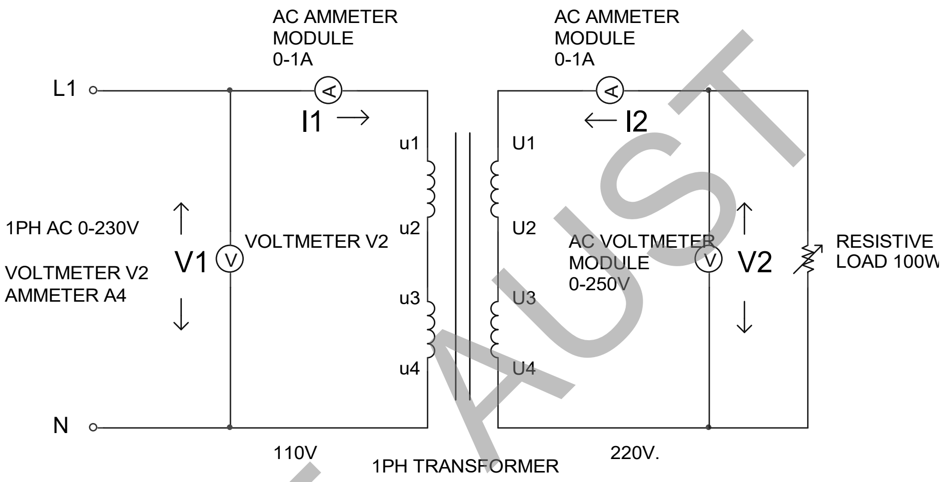


Ratio Test:

For a transformer, we know, the transformation ratio is given by

$$\frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

We shall determine the transformation ratio by measuring the voltages and currents both in the primary and secondary side.



1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make sure all the switches (1,2,4) of the Resistive Load Module are OFF (downwards)

4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher

6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.

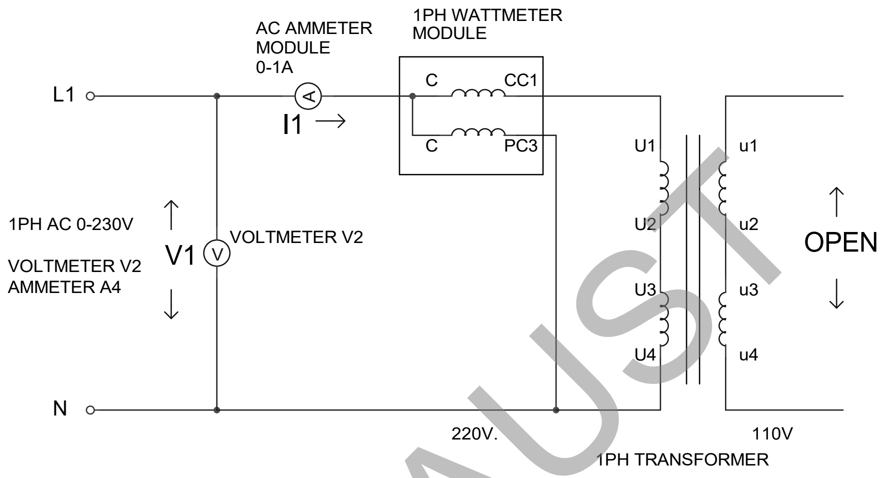
8. Make sure the 3PH supply Voltmeter V1 reading 400V.

9. Turn Knob K3 at min (CCW)
10. Turn ON switch I3 (upwards).
11. Slowly Increase 1PH AC Voltage to 110V, Turn Knob K3 CW, Voltmeter V2 reading 110V

12. Increase the Resistive Load by turning ON the switches (1,2,4) of the Resistive Load Module.
13. Increase Load until the current becomes 0.5A, so that power >= 100W

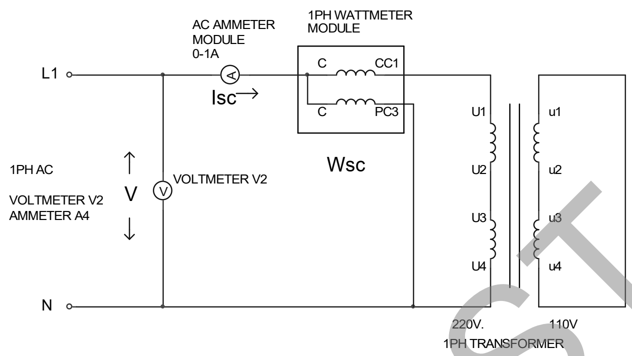
14. Note the voltages and currents both in the primary and secondary from the AC Voltmeter & Ammeter Module

Transformer on No-load/Open Circuit Test:



1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. Make sure the 3PH supply Voltmeter V1 reading 400V.
8. Turn Knob K3 at min (CCW)
9. Turn ON switch I3 (upwards).
10. Slowly Increase 1PH AC Voltage to 220V, Turn Knob K3 CW, Voltmeter V2 reading 220V
11. Note the voltages and currents in the primary from the AC Voltmeter & Ammeter Module

Short Circuit Test: This test determines copper loss in the transformer. Finding this loss the regulation of the transformer can be determined. The circuit arrangement of this test is shown below:



From the wattmeter, voltmeter, ammeter readings, we get

$$W_{CU} = W_{SC} = R_{01} * I_{SC}^2 \quad \text{i.e.} R_{01} = W_{SC}/I_{SC}^2$$

$$X_{01} = \sqrt{((V/I_{SC})^2 - R_{01}^2)}$$

Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.

3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher

5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.

7. Turn Knob K3 at min (CCW)
8. Turn ON switch I3 (upwards).
9. **Carefully increase the voltage till the rated current (300VA ÷ 220V = 1.4A) flows through the HT, Turn Knob K3 CW**

10. Note the readings on AC Voltmeter, Ammeter and Wattmeter Module

***** For each case write down the data on data sheet.**

Report:

1. What effects are produced in a transformer by change in voltage?
2. Does the transformer draw any current when its secondary is open? If yes, then why?

Group No:
Roll no:

Data Sheet

Ratio test:

V_1 = V_2 = I_1 = I_2 =

Calculate Transformation ratio:

Transformer on No-load:

I_{OC} = V_{OC} = W_{OC} =

Short Circuit Test

I_{SC} = V_{SC} = W_{SC} =

Calculation

Core loss = W_{OC} =

Φ_0 =

$I_W = I_{OC} \cos\Phi_0$ =

$I\mu = I_{OC} \sin\Phi_0$ =

Core resistance (ref. to H.T. side) = $\frac{V_{OC}}{I_W}$ =

Core reactance (ref. to H.T. side) = $\frac{V_{OC}}{I_\mu}$ =

Copper loss = $W_{Cu} = W_{SC}$ =

Equivalent Resistance (ref. to H.T. side) = $R_{01} = \frac{W_{SC}}{I_{SC}^2}$ =

Equivalent Reactance (ref. to H.T. side) = $X_{01} = \sqrt{(V_{SC}/I_{SC})^2 - R_{01}^2}$

Signature of the Lab teacher:

Experiment no: **3**

Experiment name: **Open Circuit Characteristics (OCC) Of Separately- Excited Shunt Generator**

Introduction:

In this type of generator, the field coil is energized from an independent external DC source. The circuit diagram of a separately excited shunt generator is shown below:

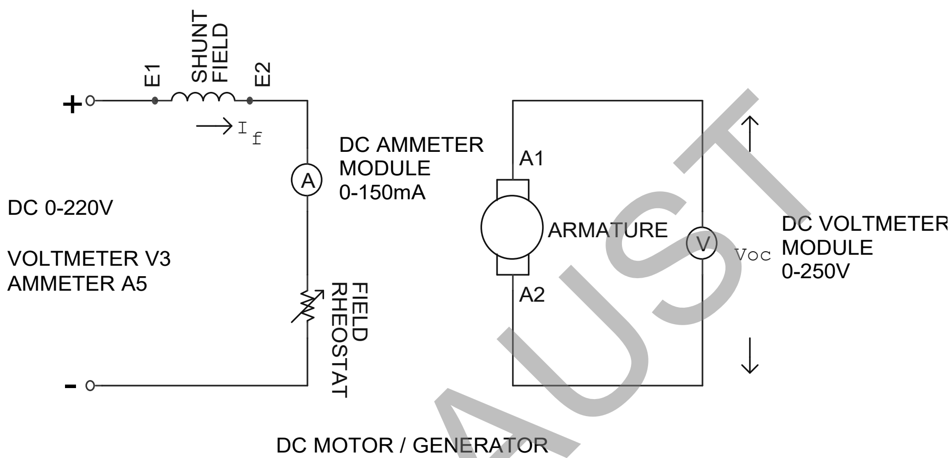


Fig: Separately Excited Shunt Generator

Voltage developed in the DC generator in general form,

$$E_G = \phi ZN/60 * (P/A) \text{ volt}$$

Where, E_G = Generated Emf.

ϕ = Flux/pole in Weber.

Z = Total no of armature conductors.

N = Armature rotation in rpm.

P = No of generator poles.

A = No of parallel paths in armature.

For a given D.C machine Z, P, A are constant. So the voltage equation becomes

$E_G = K_g \phi N$ **volt**, Where $K_g = ZP/(60*A)$

If armature rotation is constant, then $E_G = K\phi$ **volt.**

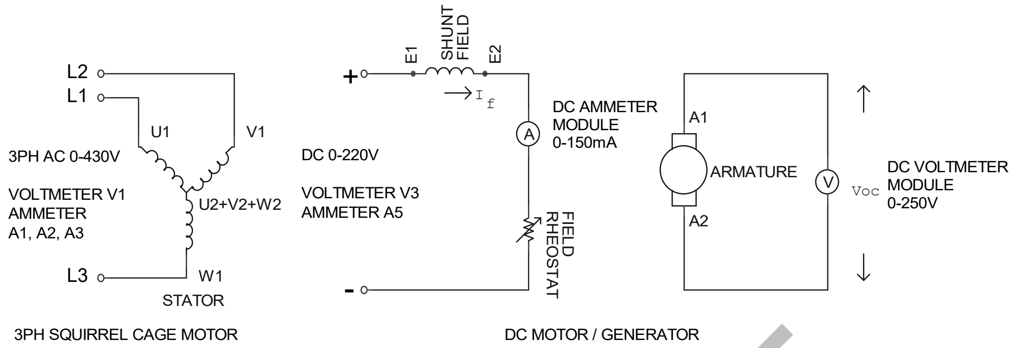
So the generated voltage is directly proportional to field flux, i.e. field current I_f.

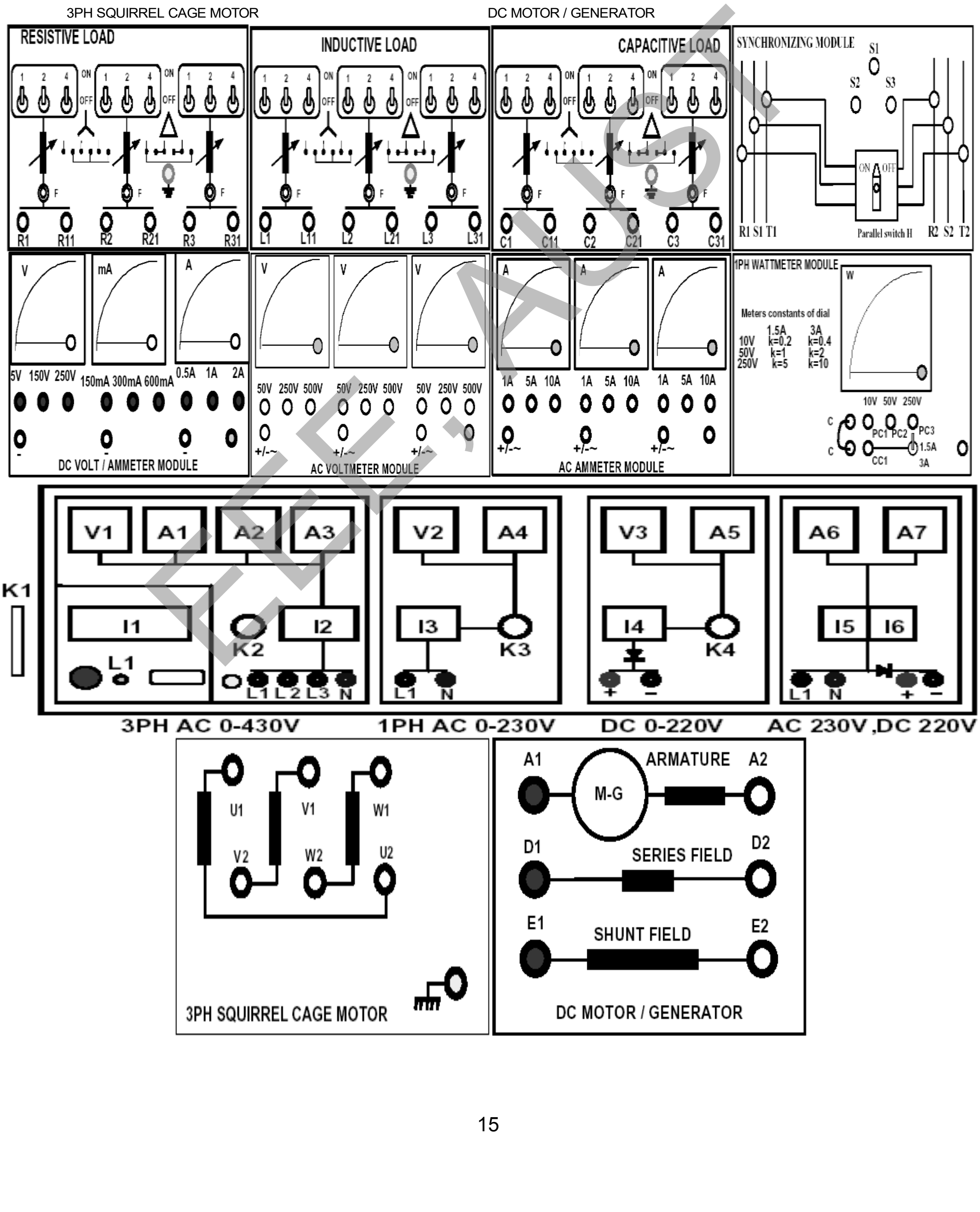
One of the generator characteristics is defined by the **O.C.C** i.e. open circuit characteristics.

The shape of the **O.C.C** is same for all kinds of generator whether separately excited or self excited. It shows the relation between the no-load generated voltage in armature, E_G and the field or exciting current I_f at a given speed.

It is just the magnetization curve for the material of the electromagnet.

Circuit Diagram:





Equipments:

1. Universal Power Supply
2. 3PH Squirrel Cage Induction Motor (Prime Mover)
3. DC Motor / Generator
4. Field Rheostat
5. DC Voltmeter / Ammeter Module
6. Coupling Sleeve
7. Connecting Cables

Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. With a sensitive Multi-meter, measure the shunt field and armature resistance; write the values on the data sheet.
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher
6. Make sure the 3PH Squirrel Cage Induction Motor is mechanically coupled with DC Motor / Generator through the coupling sleeve.
7. Turn ON Switch I1 (upwards).
8. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
9. Make the 3PH supply at 400V by turning Knob K1, the Voltmeter V1 reading 400V.
10. Turn ON Switch I2 (upwards).
11. 3PH Squirrel Cage Induction Motor should start running at this point.
12. Also DC Motor / Generator starts running since it is mechanically coupled with 3PH Squirrel Cage Induction Motor.
13. Take reading Voc on DC Voltmeter Module (0-250V), If=0.
14. Turn Knob K4 at min (CCW)
15. Turn ON switch I4 (upwards).
16. Increase Shunt Field DC Voltage to 220V, Turn Knob K4 CW, Voltmeter V3 reading 220V
17. Vary Field Rheostat from Min to Max and take readings of Voc & If. Fill up the table-1. Plot Voc vs. If.

Report:

1. Why does the curve tend to become horizontal after a certain value of field current?
2. Can you use the same machine as self-excited generator? Explain.
3. What will happen to the O.C.C curve, if the speed of the prime mover is increased?
4. What is the reason of having some voltage without any excitation?

Group No:
Roll no:

Data Sheet

Armature resistance, $\mathbf{R_a}$ **=**
Field resistance, $\mathbf{R_{sh}}$ **=**

Table-1

Field current I_f (mA)	Open circuit voltage V_{oc} (volt)

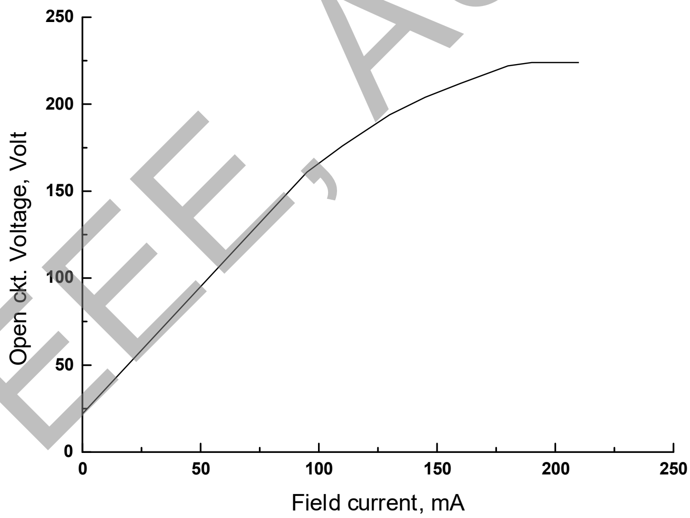
Calculation and Graph
Plot $\mathbf{V_{oc}}$ vs. $\mathbf{I_f}$ on a graph paper and determine the value of critical resistance from this plot.

Signature of the Lab teacher:

Sample Data & **Graph**

Field current I_f (mA)	Open circuit voltage V_{oc} (volt)
0	22
95	161
110	176
120	185
130	194
145	204
160	212
180	222
190	224
200	224
210	224

Plot of O.C.C:



Experiment no: **5**
Experiment name: **Speed Control of a DC Shunt Motor**

Introduction:
Voltage developed in the D.C generator in general form ---

$$\mathbf{E_g = \phi ZN/60 * (P/A)\ volt}$$

The same equation can be written for motor replacing $\mathbf{E_g}$ by $\mathbf{E_b}$ ---

$$\mathbf{E_b = \phi ZN/60 * (P/A)\ volt} \quad \text{--------------------- (1)}$$

Where, $\mathbf{E_b}$ is called the Back EMF.

The simple diagram of a DC motor is shown below:

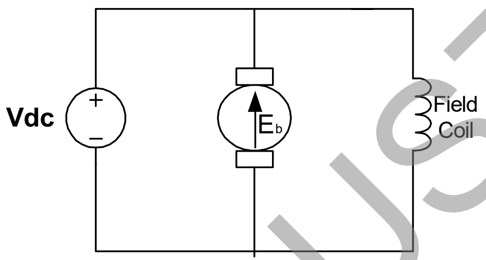


Figure 1: DC Motor

From the diagram, $E_b = V - I_a*R_a$ Where, V = Supply voltage in volt.
I_a = Armature Current in Ampere.
R_a = Armature Resistance in Ohm.

From the equation (1) we get ---- $E_b = \phi*N\,(Z*P/60*A)$
$= \phi*N*K$, where K is constant

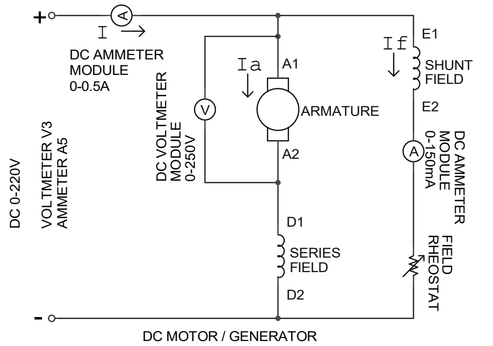
i.e. $N = (1/K)*E_b/\phi$
$= K_m * (V - I_a*R_a)/\phi$ r.p.m

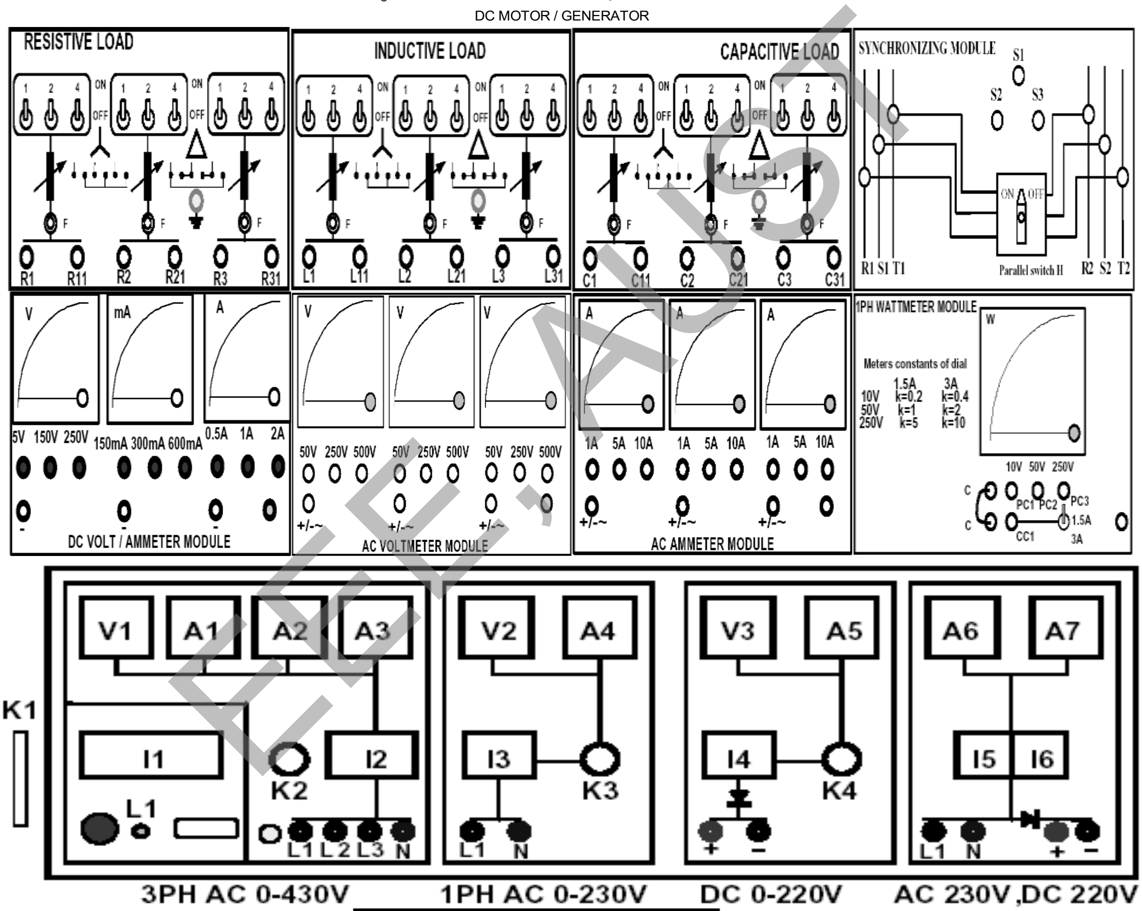
So the speed of the DC motor is directly proportional to the supplied voltage applied across the armature and Proportionally decreasing with armature current. The speed is also inversely proportional to the field flux i.e. field current.

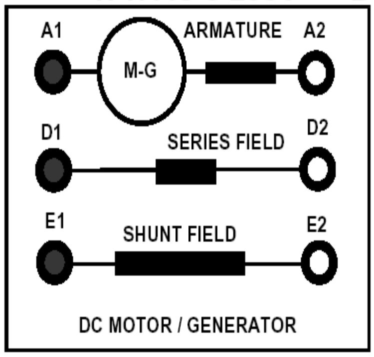
So the speed of the DC motor can be controlled by three methods. They are-
1. Flux Control
2. Armature Resistance Control
3. Voltage Control

Equipments:
1. Universal Power Supply
2. DC Motor / Generator
3. Field Rheostat
4. DC Voltmeter / Ammeter Module
5. Coupling Sleeve
6. Connecting Cables
7. Multimeter

Flux Control Method:







Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K3, K4) are at the min, counter clock wise (CCW) position.

3. With a sensitive Multi-meter, measure the Series, Shunt field and Armature resistance; write the values on the data sheet.

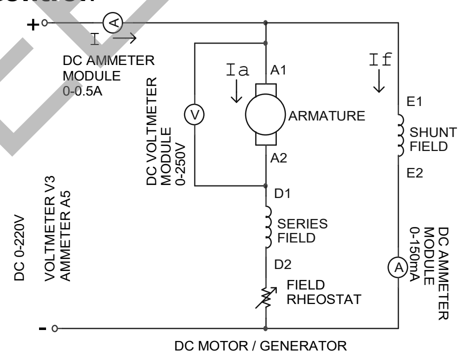
4. Make connections according to the above diagram.
5. Verify the connection by your Lab Teacher

6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.

8. Turn Knob K4 at min (CCW)
9. Turn ON switch I4 (upwards).
10. Keep the Field Rheostat to the Min
11. Make the Motor running by increasing the voltage to 200VDC

12. Make the supply voltage at **200VDC** and keep Field Rheostat at minimum position.
13. Now vary the Field Rheostat and measure the field current $\mathbf{I_f}$ and the motor speed **N** and fill up the Table-1.

b**) Armature Resistance Control**:



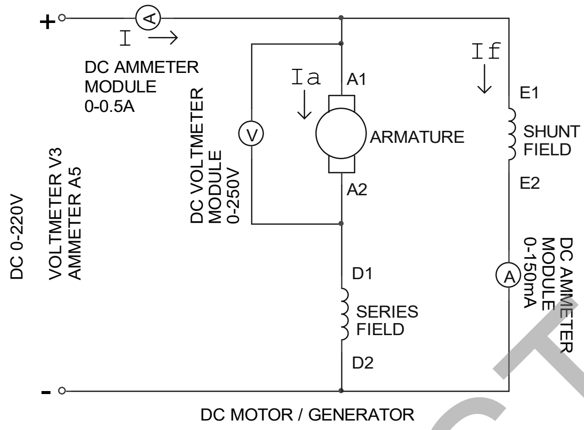
Procedure:

1. Follow the steps from 1-11 of Flux Control Method

2. Make the Motor running by increasing the voltage to **200VDC**

3. Make the supply voltage at **200VDC** and keep Field Rheostat at minimum position.
4. Now vary the Field Rheostat and measure the Armature current Ia and the motor speed N and fill up the Table-2.

c) Voltage Control:



Procedure:

1. Follow the steps from 1-11 of Flux Control Method

2. Make the Motor running by increasing the voltage to **200VDC**

3. Make the supply voltage at **120VDC**
4. Increase the supply voltage and fill up the Table-3.

Report:

1. Explain the curves plotted on the graph paper.
2. Variation of which parameter affects the speed most? Why?
3. Explain the relative merits and demerits of each method.
4. What the significance of Back EMF? Briefly explain.

Group No:
Roll no:

Data Sheet

Table-1		**Table-2**		**Table-3**	
I_f (mA)	**N (rpm)**	**I_a (mA)**	**N (rpm)**	**V_a (volt)**	**N (rpm)**

Graph

Plot $\mathbf{I_f}$ **vs. N**, $\mathbf{I_a}$ **vs. N** and $\mathbf{V_a}$ **vs. N** on the same graph paper.

Signature of the Lab Teacher

Experiment no: **8**
Experiment name: **Phasor Diagram of a Synchronous Generator.**

Introduction:

The voltage of a generator varies appreciably with the p.f. of the load. In this experiment, phasor diagram of the alternator will be drawn under different p.f. and here, the regulation of the alternator will be calculated in each case i.e. unity p.f., lagging p.f. and leading p.f.

Equipments:

1. 3-φ synchronous generator
2. 3-φ induction motor
3. DC ammeter (0-500 mA)
4. AC ammeter (0-2.5 A)
5. AC voltmeter (0-300 V)
6. Wattmeter
7. Rheostat (0- 1000 Ω)
8. Inductor bank
9. Capacitor bank
10. Tachometer

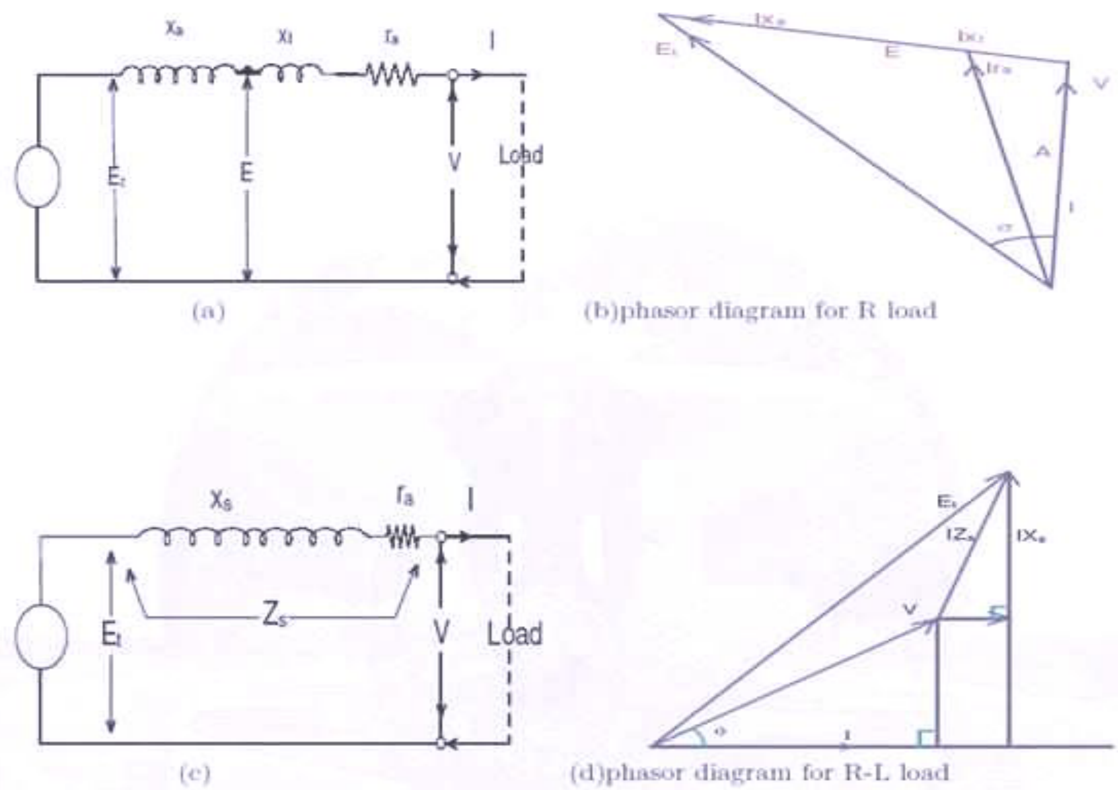
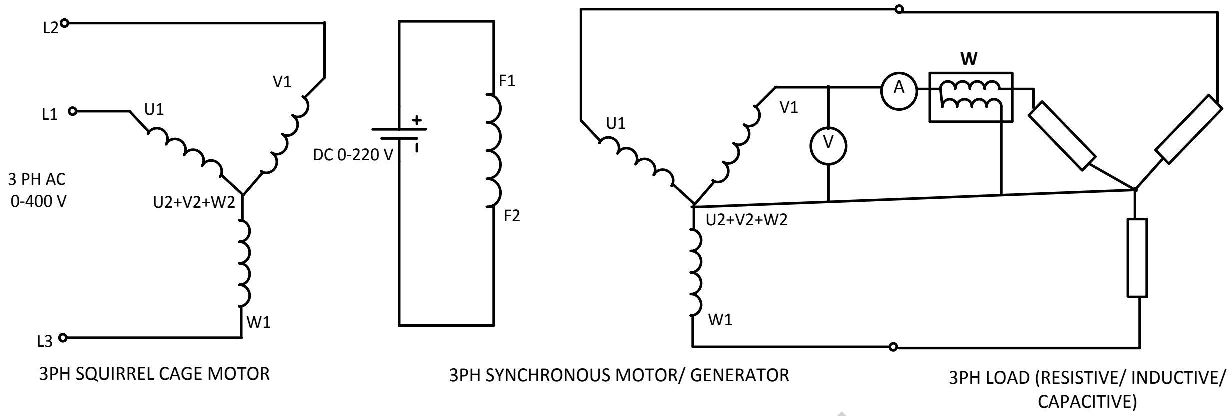
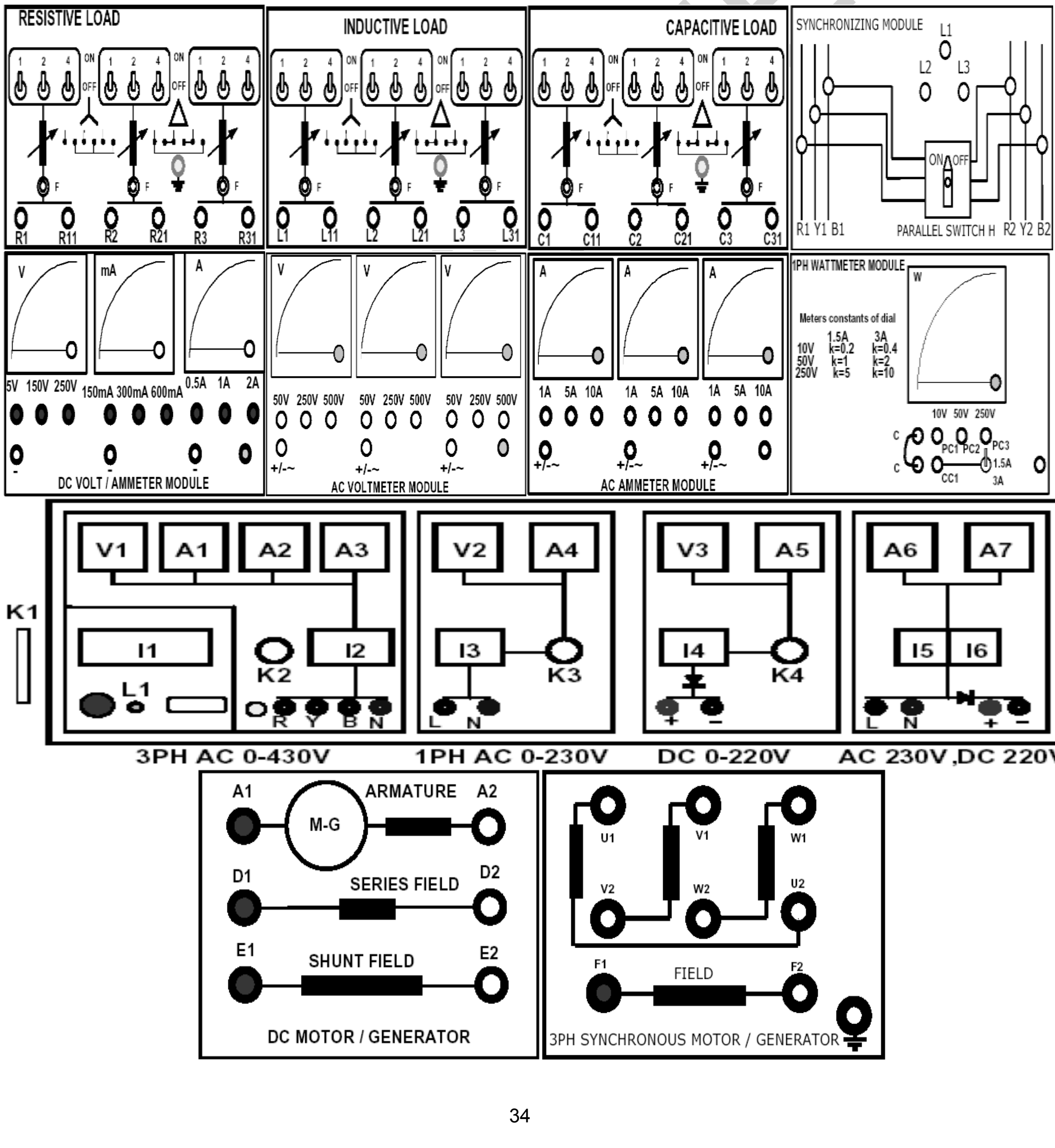


Figure 30: Equivalent circuits

Connection Diagram:





Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.
3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher
5. Make sure the 3PH synchronous Motor / Generator is mechanically coupled with DC Motor / Generator through the coupling sleeve.
6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. ****CAUTION: Turn OFF the Parallel Switch H of the Synchronizing Module**
9. ****CAUTION: Turn OFF Switch I4 (downwards).**
10. ****Starting the Prime Mover**
11. Keep the Field Rheostat of the DC Motor at **Maximum**
12. Turn ON Switch I6 (upwards).
13. Obtain speed 3000 RPM by varying the Field Rheostat, measure the speed with Tachometer
14. Make the 3PH supply at **400VAC** by turning Knob K1, Voltmeter V1.
15. Run the generator at rated speed and vary the field current till 220 volt (phase) is obtained at the generator terminals (at N.L).
16. After connecting the various type of load note down the readings on the data sheet.

Report:

1. Draw the phasor diagrams at unity, lagging and leading p.f. use the values of RA and X_S as determined from the previous experiment.
2. For each condition of p.f.; calculate the percentage regulation. Comment on the value of regulations thus obtained.
3. Calculate E_A (Generated e.m.f./phase) under each condition and compare the magnitude of E_A with that of V_{φ}. Comment on the value of EA under leading p.f.

Group No:
Roll no:

Data Sheet

1. Armature resistance, R_a =
2. Shunt Field Resistance, R_f =

At unity power factor

Load Voltage=

Load Current=

Load Power =

At lagging power factor

Load Voltage=

Load Current=

Load Power =

At leading power factor

Load Voltage=

Load Current=

Load Power =

Note: Use per phase value for all the parameters for plotting the graph.

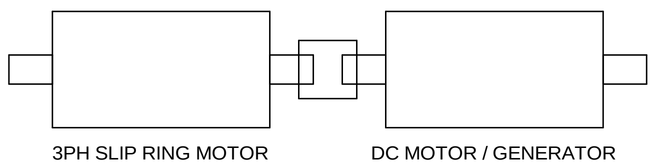
Signature of the Lab teacher:

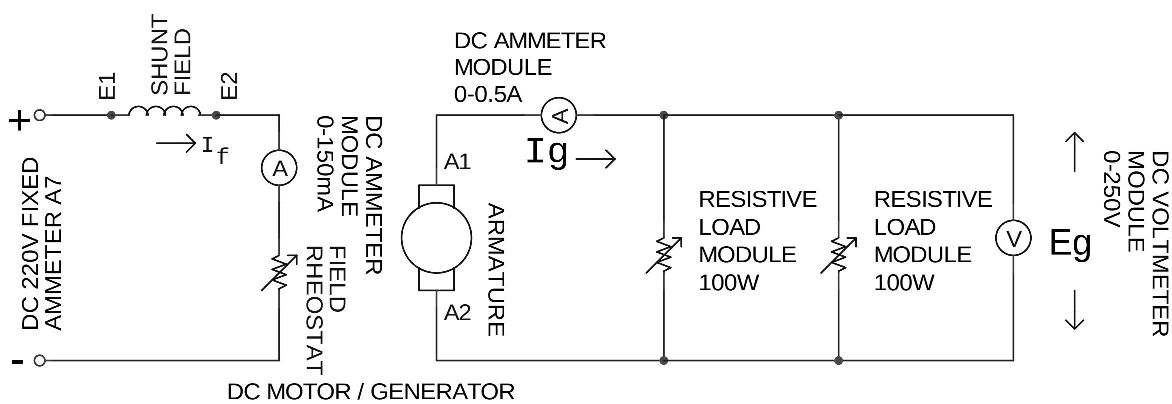
Experiment no: **10**
Experiment name: **Load Characteristics of a 3 Phase Slip Ring Induction Motor.**

Introduction:

Slip ring induction motor is an induction type motor where a three-phase resistance is externally connected to the rotor circuit. Improving its power factor by adding the external resistance increases the starting torque of such a motor. Slip ring motors maintain a slip with respect to the synchronous speed.

For a motor with P poles the synchronous speed, N_S is given by 120f/P, where f is the supply frequency. Slip, S is defined by $(N_S-N)/N_S$, where N is the speed of rotation of the motor. Measurement of Torque is done by measuring input and output power of the motor.



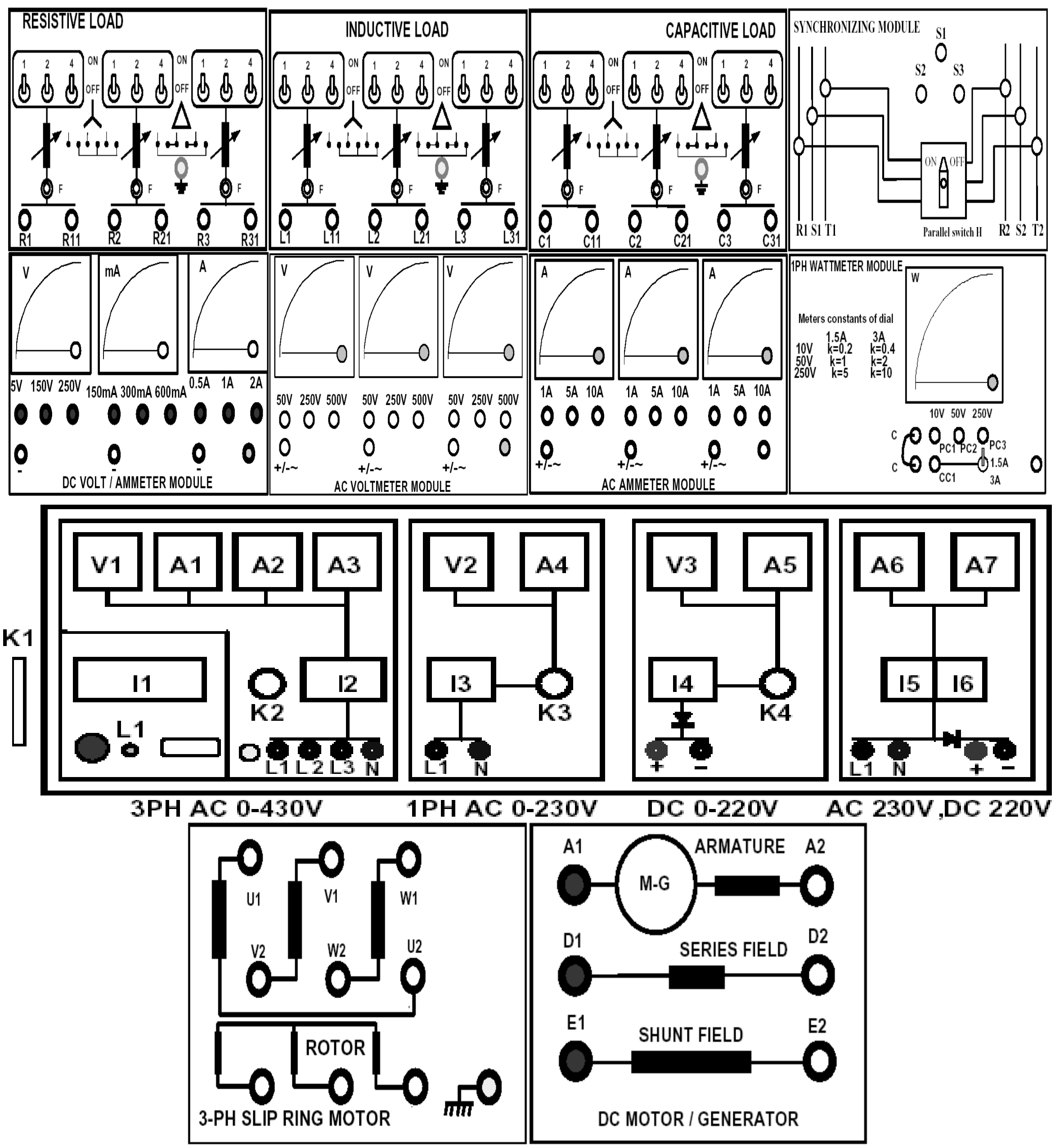


If the electrical power input to the motor is denoted as Pm, mechanical power output of the motor is shown as Po (which is assumed to be equal to the DC generator's electrical output) and the angular speed is given by Wm then Torque, T = PO/ Wm. Input and output powers can be measured as given below:

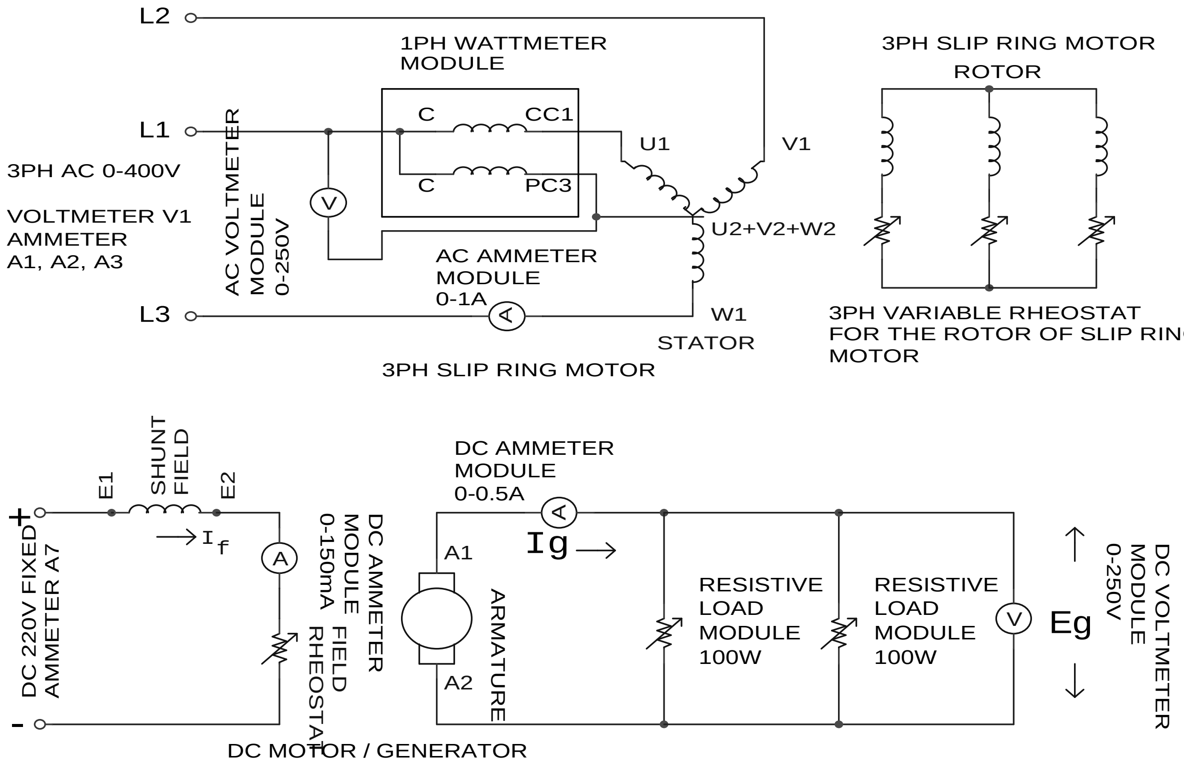
Pm = 3W where W is the readings of the wattmeter shown in the setup. Po = Ig.Eg where Ig, Eg are generator current, voltage at generator terminal.

Equipments:

1. Universal Power Supply Module
2. 3 Phase Slip Ring Induction Motor
3. DC Motor / Generator
4. Field Rheostat
5. DC Voltmeter / Ammeter Module
6. 1PH Wattmeter Module
7. Connecting Cables



Circuit Diagram:



Procedure:

1. Make sure all the switches (I1, I2, I3, I4, I5, I6) on the Power Supply are turned OFF (downwards).
2. Make sure all the variable knobs (K1, K3, K4) are at the min, counter clock wise (CCW) position.

3. Make connections according to the above diagram.
4. Verify the connection by your Lab Teacher

5. Turn ON Switch I1 (upwards).
6. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
7. ****IMPORTANT: KEEP Switch I6 OFF (downwards).**

8. Turn knob K1, Apply **400VAC** on the Stator of the Motor.
9. Turn ON Switch I2 (upwards).
10. 3 Phase Slip Ring Motor Starts Running

11. Turn ON Switch I6 (upwards).
12. Vary the field rheostat of the DC Generator, make terminal voltage **200VDC**
13. Now vary the torque, and fill the table

Report:

1. Plot power factor vs. torque for both motors.
2. Discuss various characteristics of slip ring induction motor

Group No:
Roll no:

Data Sheet

Power input, P_M =3W=

Power output =$P_O = I_g.E_g$ =
Angular speed W_m=2*pi*N=

Torque, T=P_O/W_m =
Line current, I=
Line voltage, V=
Power factor, pf=$P_M/\sqrt{3}VI$=

Power input, P_M=3W	Power output $P_O = I_g.E_g$	Angular speed $W_m=2\Pi N$	Torque, T=P_O/W_m	Line current, I	Line voltage, V	Power factor, pf=$P_M/\sqrt{3}VI$

Signature of the lab Teacher