

**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-2206  
Course Title : Energy Conversion II

For the students of  
Department of Electrical and Electronic Engineering  
2<sup>nd</sup> Year, 2<sup>nd</sup> Semester

<b>Experiment No.</b>	<b>Name of the Experiments</b>
01	Open Circuit Characteristics (OCC) of Separately- Excited Shunt Generator
02	To find the Efficiency of a Shunt Generator
03	Determination of losses of a DC machine.
04	Speed Control of a DC Shunt Motor
05	Plotting of V-curves for Synchronous motor.
06	Phasor Diagram of a Synchronous motor.
07	Measuring Synchronous Generator Model Parameters.
08	Phasor Diagram of a Synchronous Generator.
09	Prediction of regulation of three-phase alternator by Synchronous impedance method.
10	Parallel Operation of Alternators.

Experiment no: **1**  
 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:

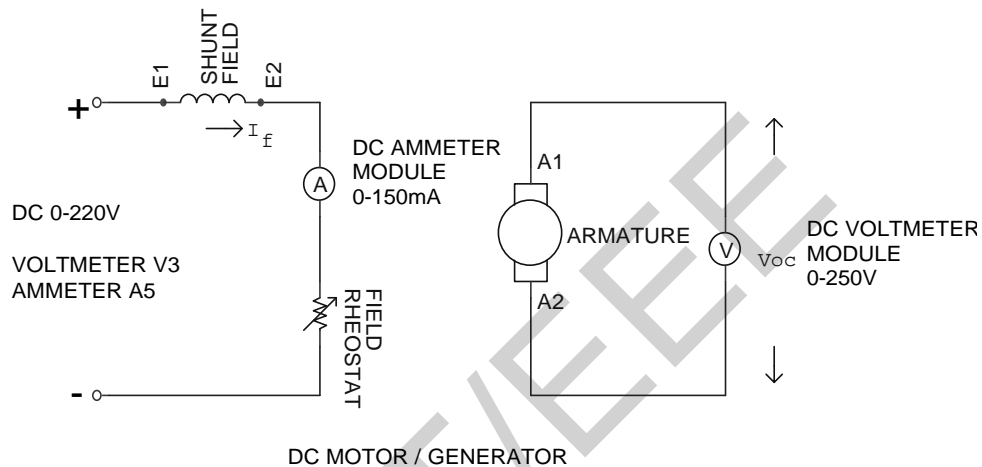


Fig: Separately Excited Shunt Generator

Voltage developed in the DC generator in general form,

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

Where,  $E_G$  = Generated Emf.

$\phi$  = 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

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

If armature rotation is constant, then  $E_G = K\phi \text{ volt}$ .

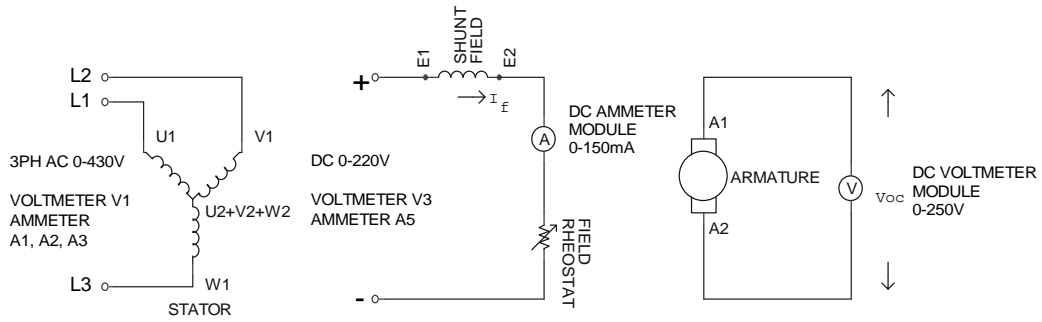
So the generated voltage is directly proportional to field flux, i.e. field current  $I_f$ .

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.

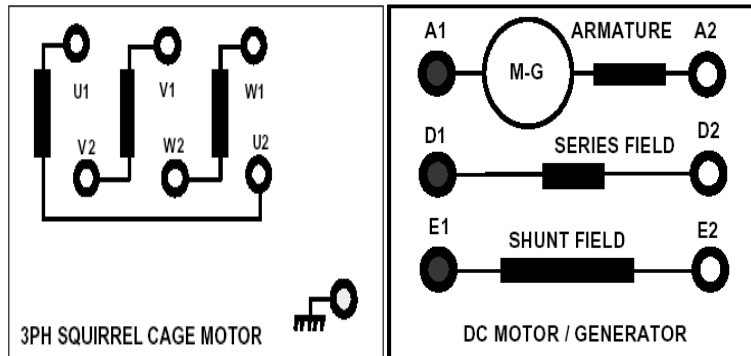
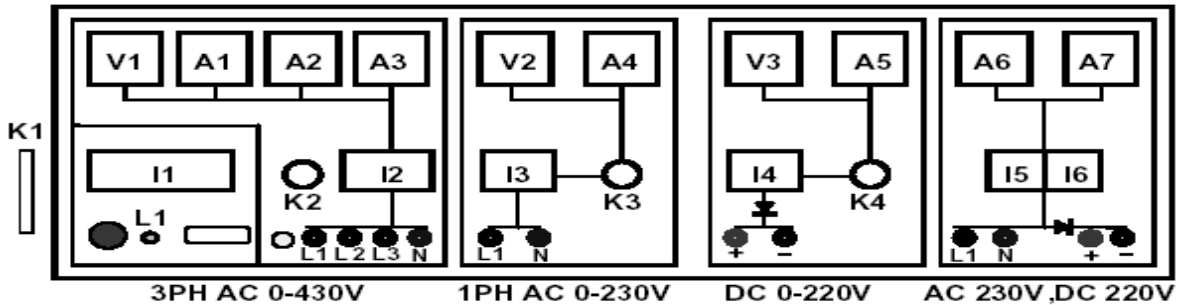
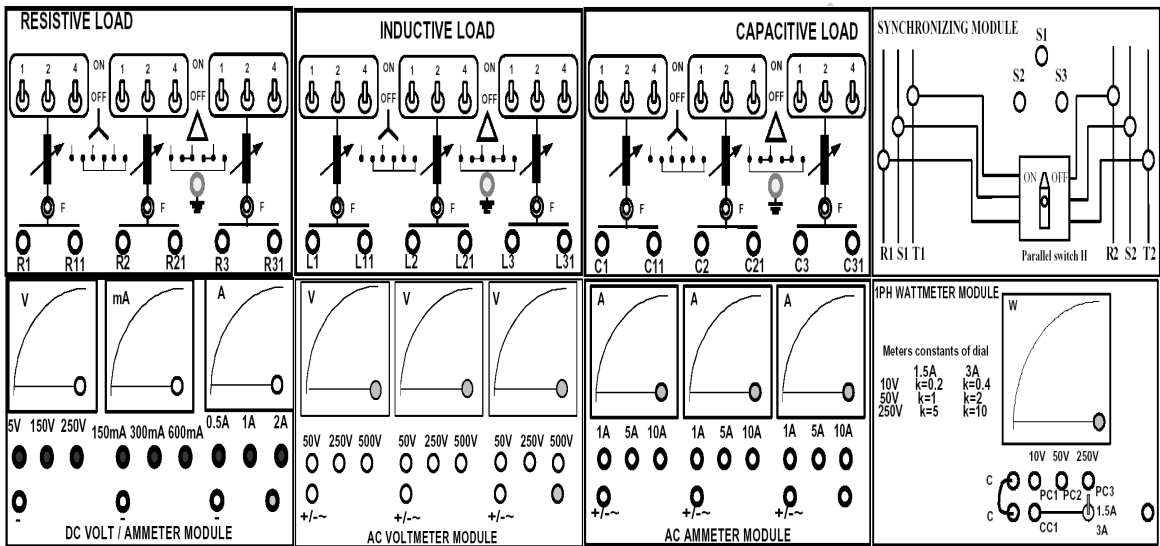
It is just the magnetization curve for the material of the electromagnet.

**Circuit Diagram:**



3PH SQUIRREL CAGE MOTOR

DC MOTOR / GENERATOR



3PH SQUIRREL CAGE MOTOR

DC MOTOR / GENERATOR

**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  $V_{oc}$  on DC Voltmeter Module (0-250V),  $I_f=0$ .
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  $V_{oc}$  &  $I_f$ . Fill up the table-1. Plot  $V_{oc}$  vs.  $I_f$ .

**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?
5. What do you understand by critical resistance?
6. How does the commutator converts ac into dc?

Group No:  
Roll no:

**Data Sheet**

Armature resistance,  $R_a =$

Field resistance,  $R_{sh} =$

**Table-1**

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

***Calculation and Graph***

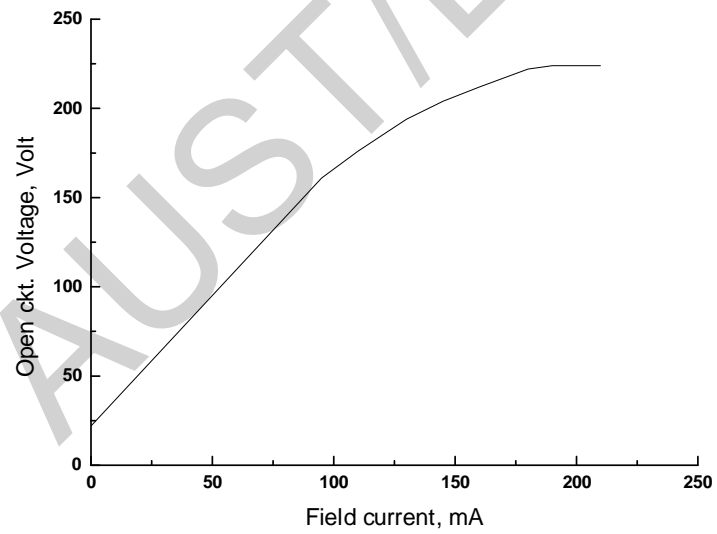
Plot  $V_{oc}$  vs.  $I_f$  on a graph paper and determine the value of critical resistance from this plot.

***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: 2  
Experiment name: To Find The Efficiency of a Shunt Generator

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### Introduction:

The efficiency of a generator is defined by,

$$\eta = \frac{\text{Output}}{\text{input.}} \\ = \frac{\text{Watts available in load}}{\text{Total watts generated.}}$$

If the load voltage is  $V$  and load current is  $I$  then generator output is  $VI$  watts.

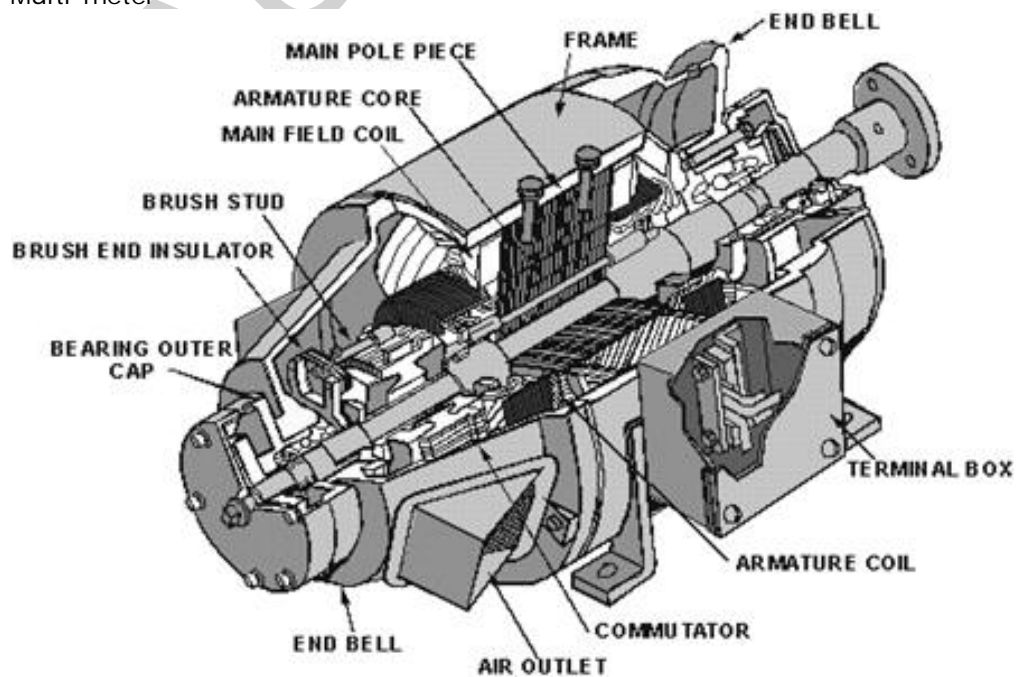
So generator input = Output + losses.

$$\begin{aligned} &= V \cdot I + I_a^2 \cdot R_a + W_c \\ &= V \cdot I + (I + I_{sh})^2 \cdot R_a + W_c \\ &= V \cdot I + I^2 \cdot R_a + W_c \quad \text{as } I_a \text{ is approximately equals to } I \end{aligned}$$

Where,  $I_a$  = Armature current.  
 $I_{sh}$  = Shunt field current.  
 $R_a$  = Armature resistance.  
 $W_c$  = Constant losses = Magnetic losses + Mechanical losses.

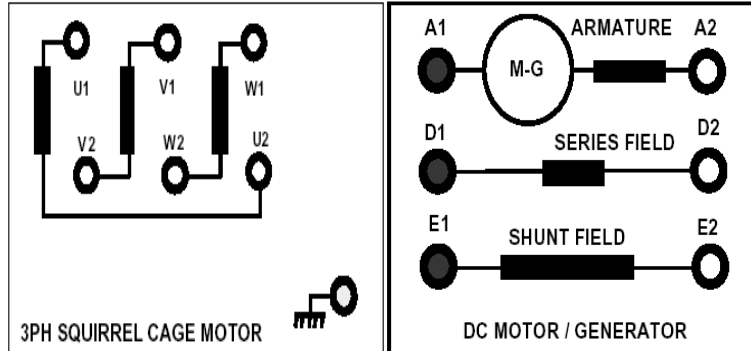
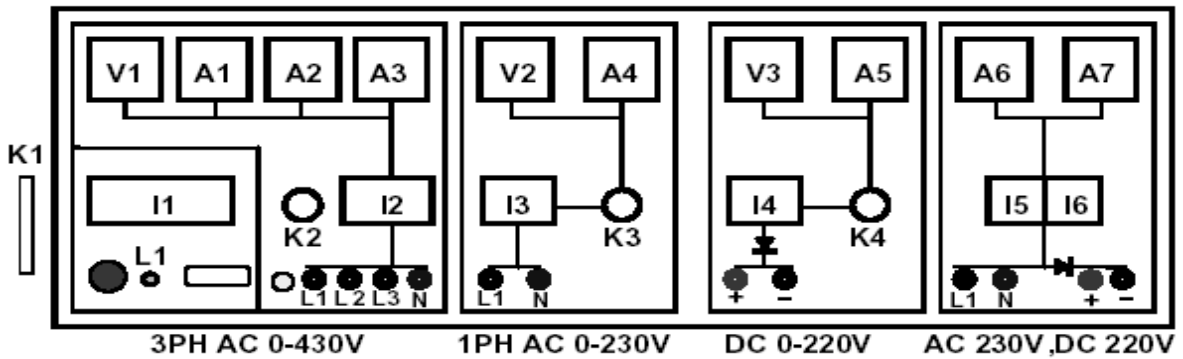
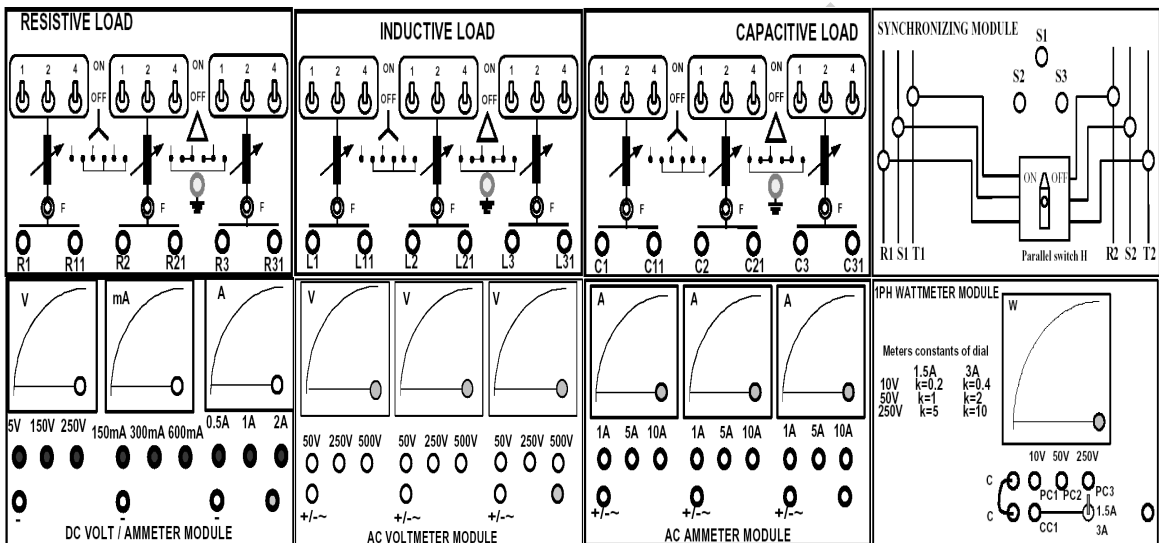
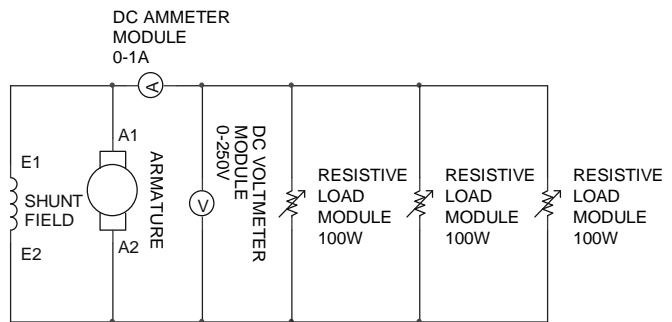
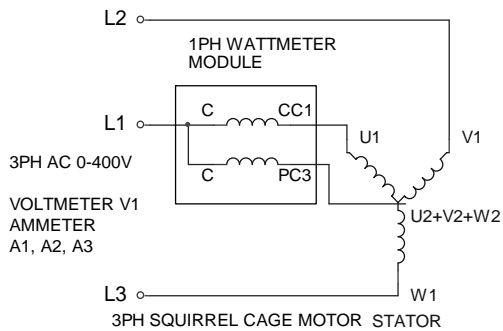
### Equipments:

1. Universal Power Supply
2. 3PH Squirrel Cage Induction Motor (Prime Mover)
3. DC Motor / Generator
4. DC Voltmeter / Ammeter Module
5. 1PH Wattmeter Module
6. Resistive Load Module
7. Coupling Sleeve
8. Connecting Cables
9. Multi-meter





**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. 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. Turn OFF (downwards) all the loads connected to DC Generator
14. Make sure that **200VDC** is developed at the generator terminals at no-load. Note down the wattmeter reading on the data sheet and treat this power as no-load loss for the generator.
15. Note down the rated current of the generator. Run the generator at half of the full load rated current.
16. Now load the generator at full load current and fill up the data sheet.

### Report:

1. Comment on the efficiencies in steps Half-Load and Full-Load
2. Determine the condition for which maximum efficiency will occur for this generator. Calculate the numerical value of this efficiency.

Group No:  
Roll no:

Data Sheet

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

**At no load**

- 1- $\phi$  input power into motor,  $W =$   
3- $\phi$  input power into motor,  $W_c = 3 \times W =$

**At 1/3rd of total resistive load**

Terminal voltage of generator,  $V =$  Load current,  $I_L =$

**Calculate**

1. Armature Cu-loss =
2. Output power =
3. Efficiency =

**At 2/3rd of total resistive load**

Terminal voltage of generator,  $V =$  Load current,  $I_L =$

**Calculate**

1. Armature Cu-loss =
2. Output power =
3. Efficiency =

**At 3/3rd of total resistive load**

Terminal voltage of generator,  $V =$  Load current,  $I_L =$

**Calculate**

1. Armature Cu-loss =
2. Output power =
3. Efficiency =

**Note: Express your used resistive load in terms of machine rated capacity.**

Experiment no: 3  
Experiment name: **Determination of losses of a DC machine.**

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### **Introduction:**

When a DC machine runs either as a motor or generator, losses take place.

These losses are:

Copper losses: Armature copper loss + field copper loss.

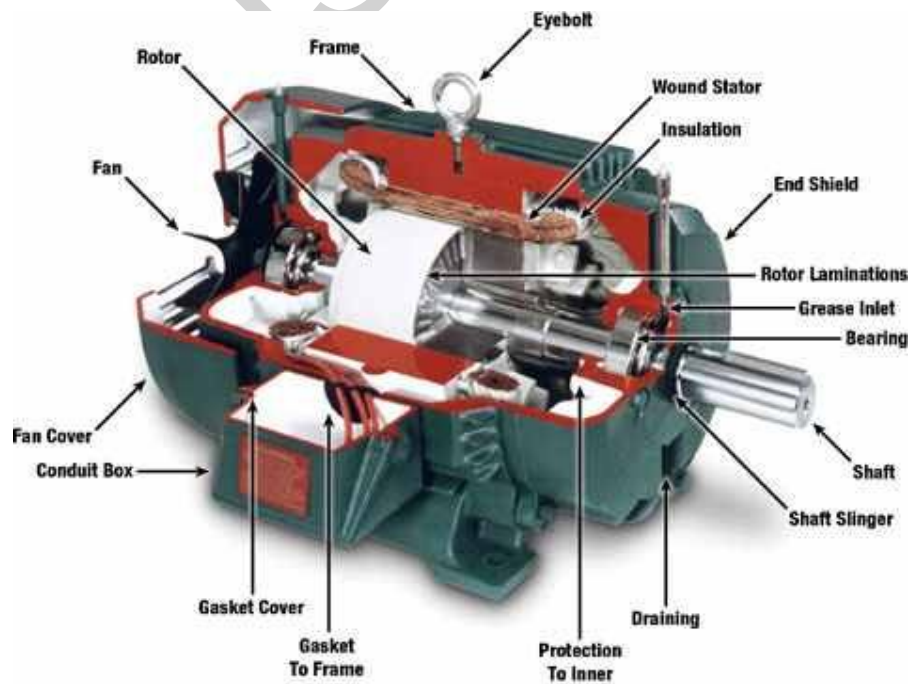
Magnetic losses: Eddy current loss + Hysteresis loss

Mechanical losses: Friction loss + bearing loss

Magnetic losses and mechanical losses are collectively known as stray losses. They are also known as rotational losses.

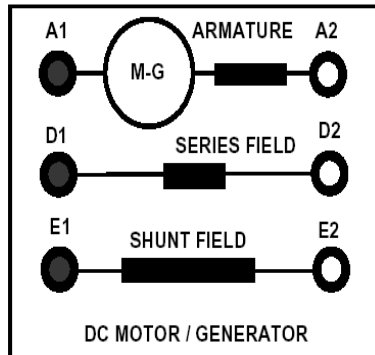
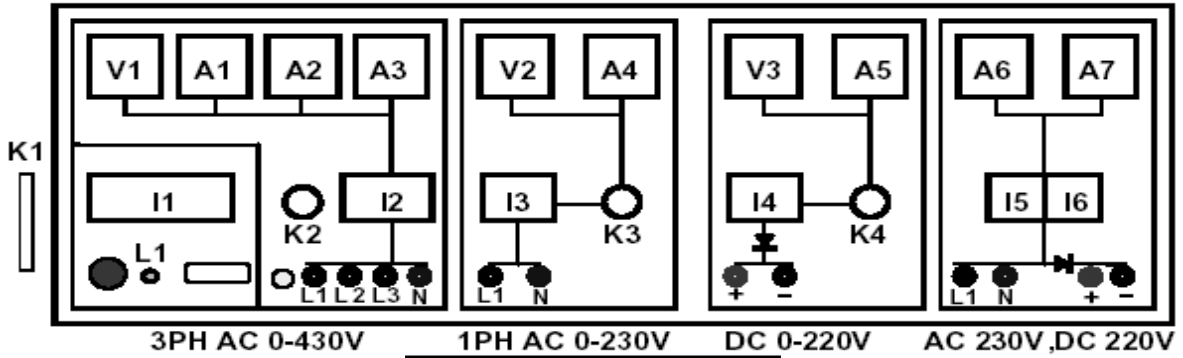
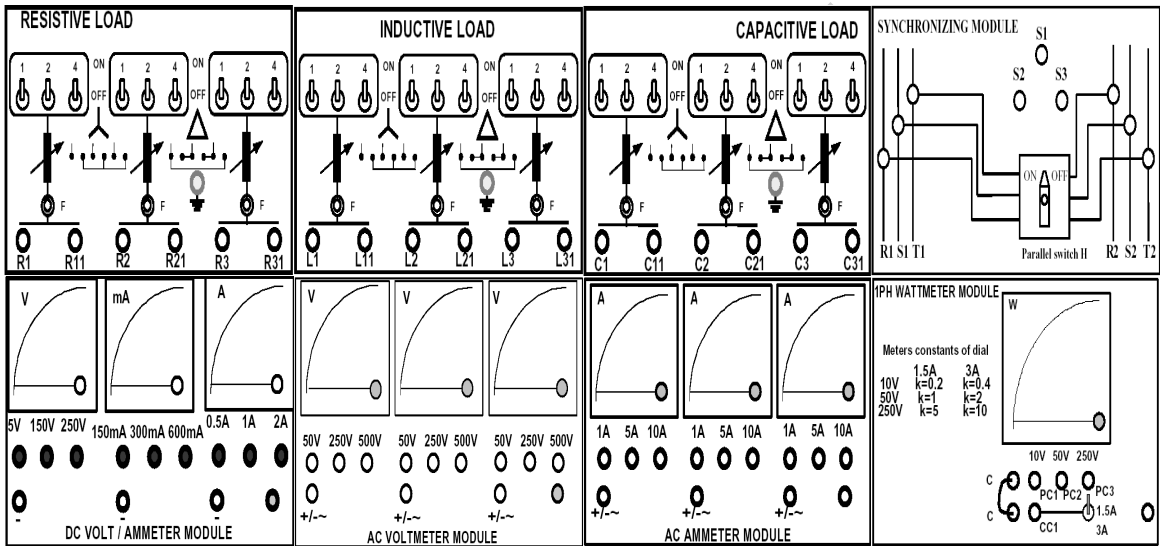
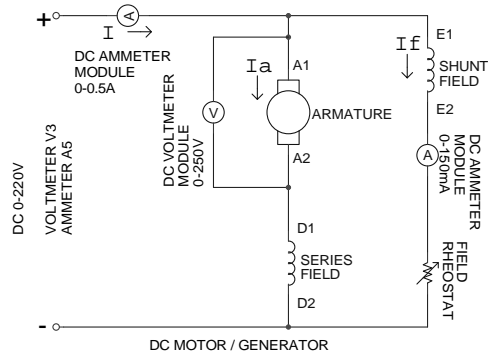
### **Equipments:**

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



**Figure 8 - Motor Construction**

**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 (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. 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 K4 at min (CCW)
10. Turn ON switch I4 (upwards).
11. **SLOWLY** Increase Armature DC Voltage to 120V, Turn Knob K4 CW, Voltmeter V3 Adjust field rheostat to obtain the rated speed 3000RPM
12. Now increase the armature voltage by 20 V in each step and adjust the speed to rated speed 3000 RPM by varying field rheostat.
13. Take readings up to rated armature voltage 220V. Fill-up the table-1.
14. Now repeat step 11-13, adjust field rheostat to obtain 75% of rated speed 3000 RPM fill-up table-2.

### Calculation + Graph:

1. Calculate copper losses, total power input and armature power output,  $P_o$
2.  $P_o$  vs. armature voltage,  $V_a$  using the data of table-1 and extend the trend of the curve to the axis. This interception at the Y-axis is the mechanical loss of a machine at rated speed.
3. Repeat step-2 using the data of table-2.
4. At first from plot-1 find  $P_o$  for a voltage say 180 V. Then subtract mechanical loss (from step-2) from that  $P_o$ . This will represent the Eddy current and Hysteresis loss. Term this loss as  $W_1$ .
5. Repeat step-4 using plot-2 and term this loss as  $W_2$ .
6. Now use this equation to isolate Eddy current and Hysteresis loss.
7.  $W_1 = AN_1 + BN_1^2$ , where  $N_1$  is rated speed (3000 rpm)
8.  $W_2 = AN_2 + BN_2^2$ , where  $N_2$  is 2500 rpm.
9. A and B are Hysteresis loss and Eddy current loss coefficients respectively. Solve two equations to find A and B.

### Report:

1. Discuss about the nature of  $P_o$  vs. armature voltage curve at two different speeds.
2. Comment on the results.
3. Hysteresis loss and eddy current losses are frequency dependent loss. How these losses occurred in DC machine having zero frequency?

Data Sheet

Armature resistance,  $R_a =$   
 Field resistance,  $R_{sh} =$   
 Rated Speed,  $N =$   
 Rated Voltage =

<b>Group No:</b> <b>Roll no:</b>
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At rated Speed,  $N = 3000$  rpm

(A)	(B)	(C)	(D)	(E)	(F)	(G)
$V_a$ (Volt)	$I_a$ (D)-(C) (Amp)	$I_f$ (Amp)	Total Current, $I$ (Amp)	Copper loss (Watt) $V_a I_f + I_a^2 R_a$	Power Input (watt) $V_a \times I$ (A) $\times$ (D)	Armature Power Output (watt) $P_o = (F) - (E)$

Table-1

At  $N = 2500$  rpm

(A)	(B)	(C)	(D)	(E)	(F)	(G)
$V_a$ (Volt)	$I_a$ (Amp)	$I_f$ (Amp)	Total Current, $I$ (B)+(C)	Copper loss (Watt) $V_a I_f + I_a^2 R_a$	Power Input (watt) (A) $\times$ (D)	Armature Power Output (watt) $P_o = (F) - (E)$

Table-2

Signature of the Lab Teacher

Experiment no: **4**  
 Experiment name: **Speed Control of a DC Shunt Motor**

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**Introduction:**

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

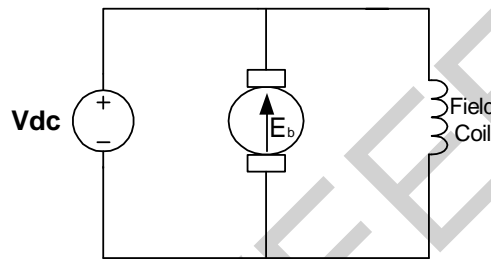
$$E_g = \phi ZN/60 * (P/A) \text{ volt}$$

The same equation can be written for motor replacing  $E_g$  by  $E_b$  ---

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

Where,  $E_b$  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

$$\text{i.e. } N = (1/K) * E_b / \phi$$

$$= K_m * (V - I_a * R_a) / \phi \text{ r.p.m}$$

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-

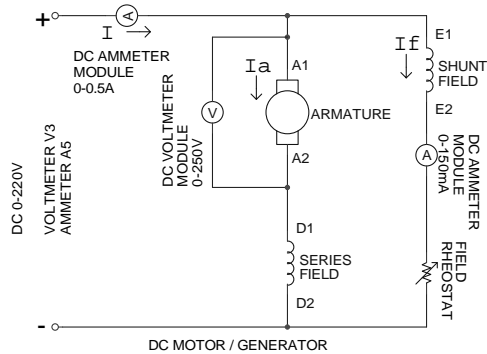
1. Flux Control
2. Armature Resistance Control
3. Voltage Control

**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

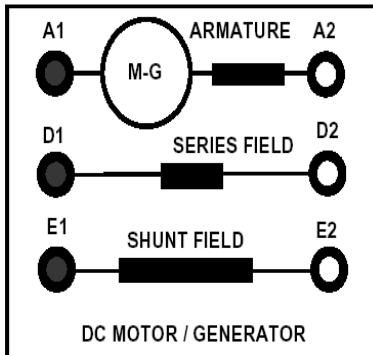


**Flux Control Method:**



<p><b>RESISTIVE LOAD</b></p>	<p><b>INDUCTIVE LOAD</b></p>	<p><b>CAPACITIVE LOAD</b></p>	<p><b>SYNCHRONIZING MODULE</b></p>
<p><b>DC VOLT / AMMETER MODULE</b></p>	<p><b>AC VOLT METER MODULE</b></p>	<p><b>AC AMMETER MODULE</b></p>	<p><b>1PH WATTMETER MODULE</b></p> <p>Meters constants of dial          1.5A k=0.2, 3A k=0.4          10V k=1, 50V k=2, 250V k=10</p>

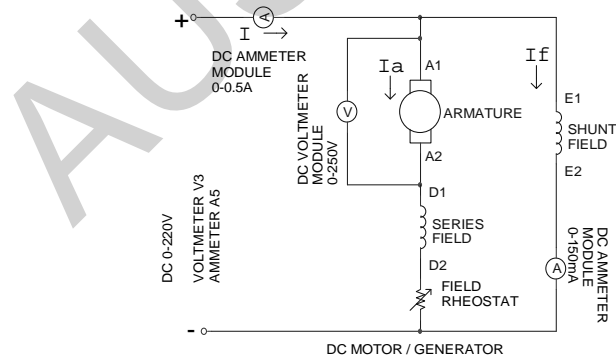
<p><b>3PH AC 0-430V</b></p>	<p><b>1PH AC 0-230V</b></p>	<p><b>DC 0-220V</b></p>	<p><b>AC 230V, DC 220V</b></p>
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### Procedure:

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  $I_f$  and the motor speed  $N$  and fill up the Table-1.

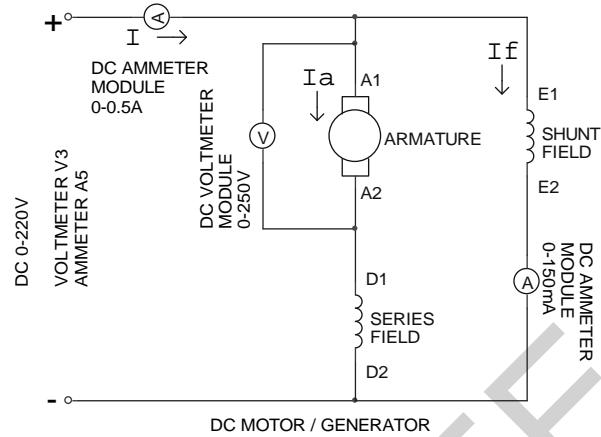
### b) Armature Resistance Control:



### 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  $I_a$  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.

Data Sheet

Group No:
Roll no:

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

**Graph**

Plot  $I_f$  vs. N,  $I_a$  vs. N and  $V_a$  vs. N on the same graph paper.

*Signature of the Lab Teacher*

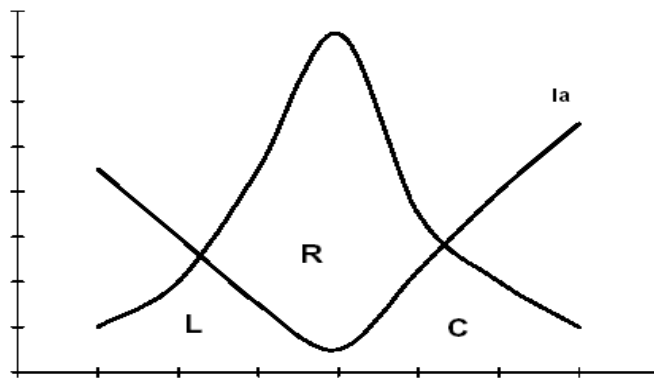
Experiment no: 5  
Experiment name: Plotting of V-curves for Synchronous motor.

### Introduction:

When the rotor of the synchronous motor is locked with the rotating magnetic field; then the variation of field current does not change the speed of the motor.

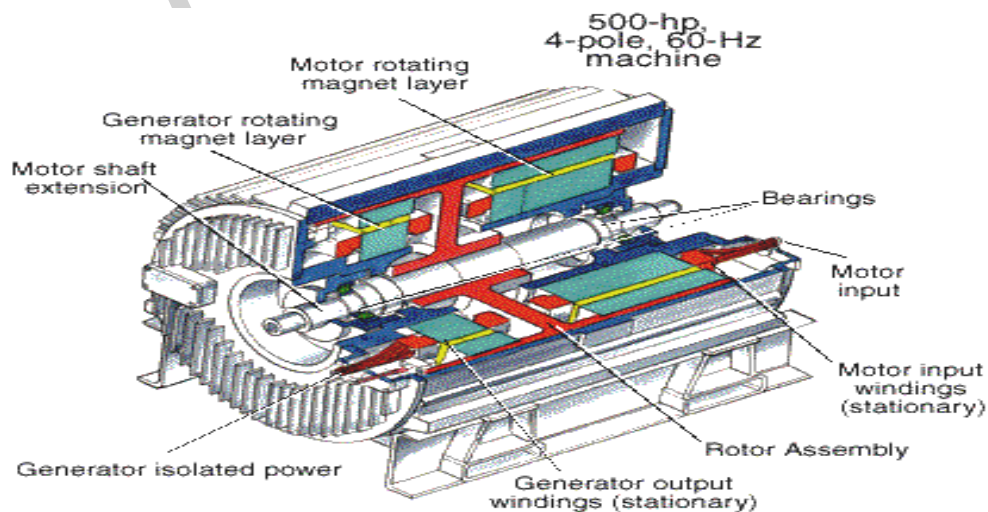
However, interesting changes take place in the stator side. When the motor is over-excited the system Pf leads and reactive power is supplied to the system. Under excited machine consumes reactive power and Pf lags.

If Pf Vs If is plotted it gives a V-shaped curve.

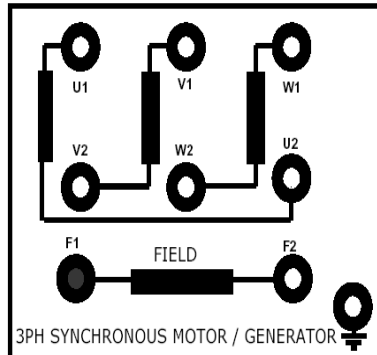
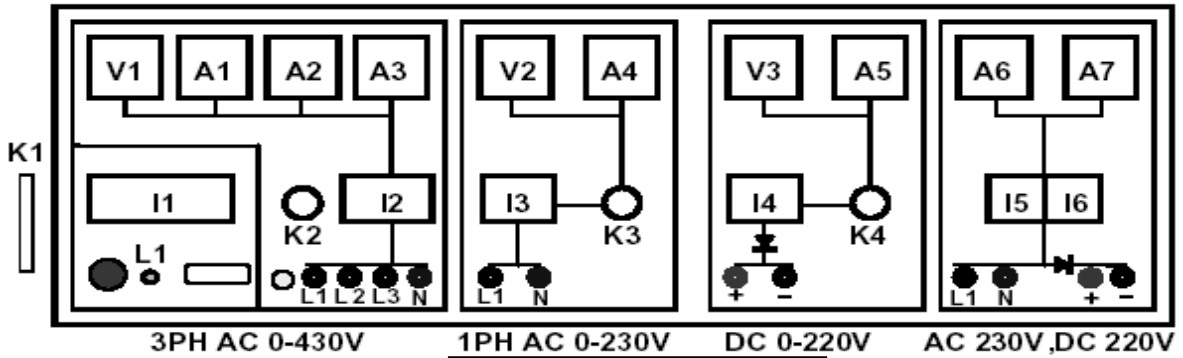
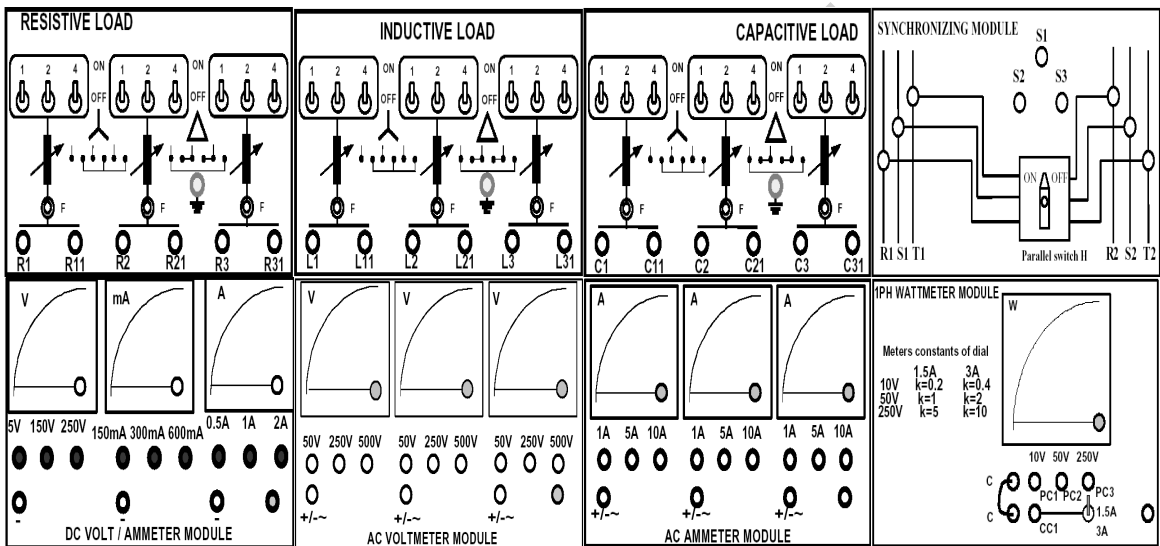
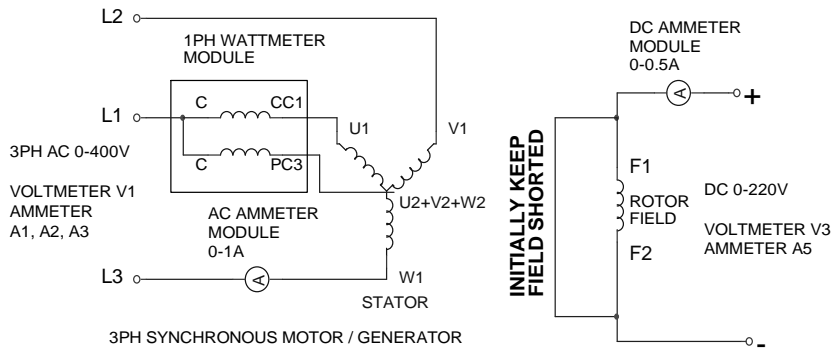


### Equipments:

1. Universal Power Supply
2. 3PH Synchronous Motor / Generator
3. 1PH Wattmeter Module
4. AC Ammeter Module 0-1A
5. DC Voltmeter / Ammeter Module
6. Tachometer
7. Connecting Cables



### 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. **\*\*CAUTION: Initially SHORT Field F1 & F2 of the 3PH Synchronous Motor**
6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. Make the 3PH supply at **400V** by turning Knob K1, Voltmeter V1.
9. **\*\*CAUTION: Make sure Field F1 & F2 of the 3PH Synchronous Motor are SHORTED**
10. Turn ON Switch I2 (upwards).
11. 3PH Synchronous Motor should start running at this point.
12. Turn Knob K4 at min (CCW)
13. **\*\*CAUTION: Open the SHORTED Field F1 & F2 of 3PH Synchronous Motor and Turn ON switch I4 (upwards).**
14. Turn Knob K4 apply 200VDC to the Rotor Field
15. Now make the machine run at Synchronous speed by varying the Field EXCITATION. When the machine becomes synchronized with the Supply frequency then the speed becomes constant. The speed will not change if the field excitation is further varied.
16. Now vary the Field Excitation from **200VDC - 220VDC** and measure the field current  $I_f$  and fill up the Table-1.

### Report:

1. Explain with vector diagram how the reactive power can be supplied or consumed with the help of field current of synchronous motor.
2. For a total load of 5 kw at 0.95 lagging how much reactive power should be supplied by the motor to make the power factor =1. What should be the value of field current under this condition?
3. Suppose the rotor is running at synchronous speed. Suddenly D.C supply is disconnected, will the motor continue to run? Give reasons for your answer.

Data Sheet

Group No:  
Roll no:

**Table1:**

$V_L$ (L-L)	Field Current $I_f$	Armature Current $I_a$	Wattmeter Reading W	$P_t = 3W$	$PF = \frac{P_t}{\sqrt{3}V_L I_a}$	$Q_T = \sqrt{3}V_L I_a \sin\theta$

**Graph:**

1. Draw  $I_a$  Vs  $I_f$  and P.f Vs  $I_f$  on the same graph paper. Clearly mark the zones of lagging, leading & unity power factor.
2. Draw  $P_T$  Vs  $I_f$  and  $Q_T$  and  $I_f$  on the same graph paper.

**Signature of the Lab Teacher**



Experiment no: **6**  
 Experiment name: **Phasor diagram of a Synchronous motor.**

**Introduction:**

A synchronous machine (motor) needs two sets of supply for its operation. A D.C voltage is applied across the rotor terminals and a 3-phase voltage is impressed across the stator. The equivalent circuit can be drawn as follows:

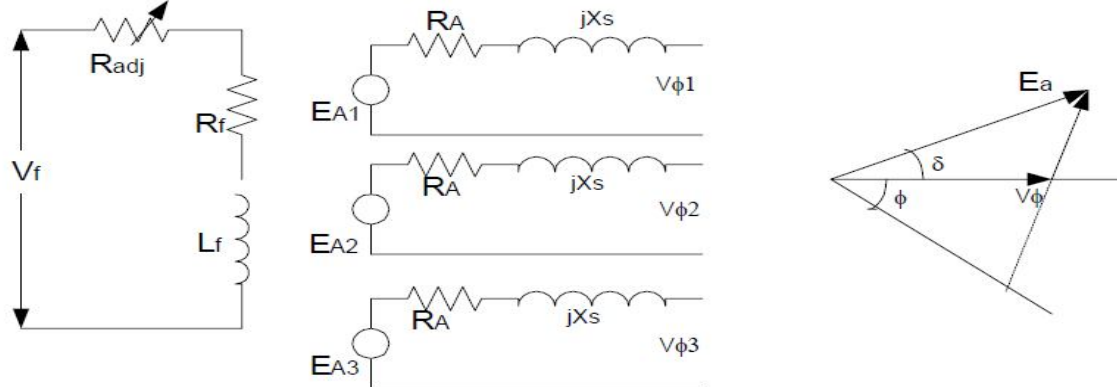
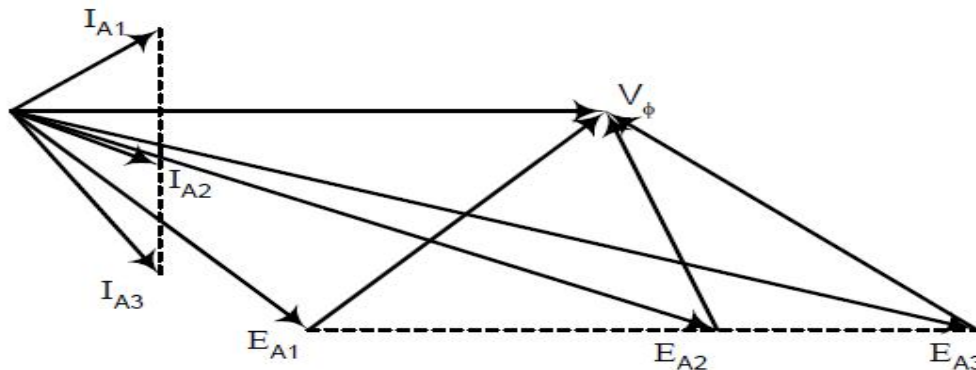


Figure no: 1

$P_{in} = 3 \cdot V_{\phi} \cdot I_a \cos\theta = 3 \cdot V_{\phi} \cdot E_A \sin\delta$  where,  $E_A \sin\delta = I_a \cdot X_s \cdot \sin(90-\phi)$   
 If excitation is increased (i.e; IF is increased),  $E_A$  tends to increase. However as no extraload is added to the motor shaft,  $E_A \sin\delta$  &  $I_a \cos\theta$  remains constant. So, tip of  $E_A$  and  $I_a$  moves along the dashed line as shown below.

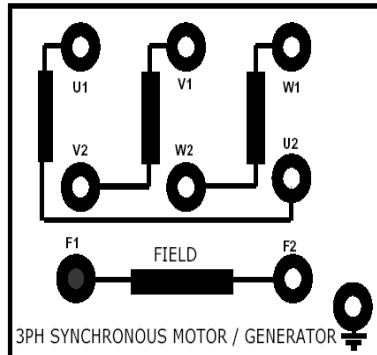
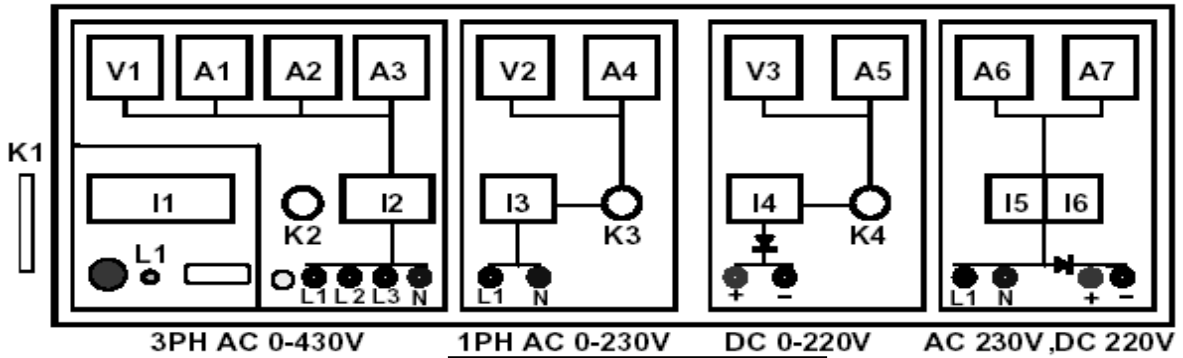
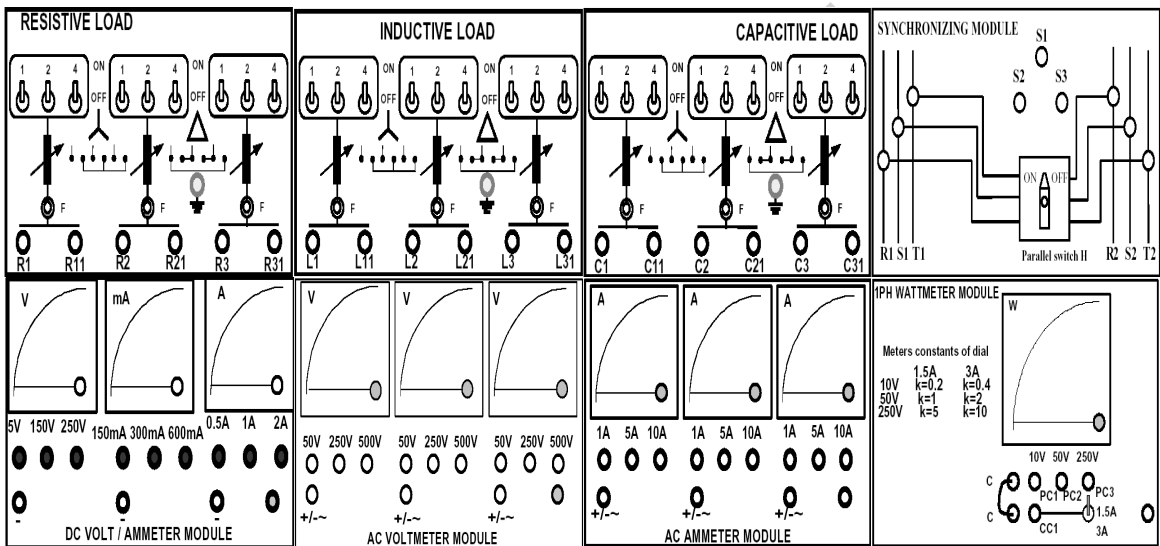
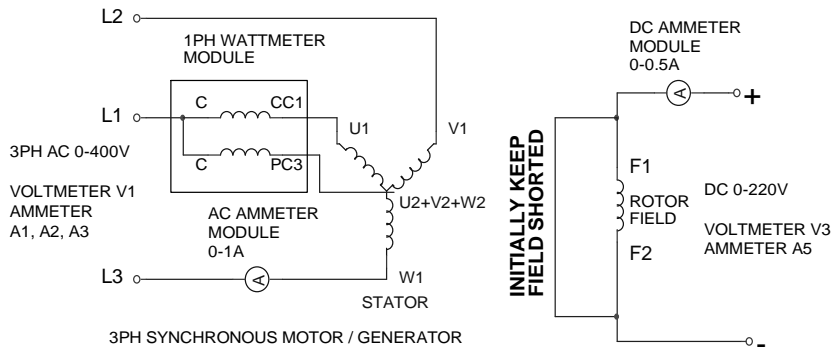


The purpose of the experiment is to draw the phasor diagram under different excitation conditions.

**Equipments:**

1. Universal Power Supply
2. 3PH Synchronous Motor / Generator
3. 1PH Wattmeter Module
4. AC Ammeter Module 0-1A
5. DC Voltmeter / Ammeter Module
6. Tachometer
7. Connecting Cables

**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. **\*\*CAUTION: Initially SHORT Field F1 & F2 of the 3PH Synchronous Motor**
6. Turn ON Switch I1 (upwards).
7. Turn Key K2 Clock Wise Once, the Indicator Lamp L1 becomes Green.
8. Make the 3PH supply at **400V** by turning Knob K1, Voltmeter V1.
9. **\*\*CAUTION: Make sure Field F1 & F2 of the 3PH Synchronous Motor are SHORTED**
10. Turn ON Switch I2 (upwards).
11. 3PH Synchronous Motor should start running at this point.
12. Turn Knob K4 at min (CCW)
13. **\*\*CAUTION: Open the SHORTED Field F1 & F2 of 3PH Synchronous Motor and Turn ON switch I4 (upwards).**
14. Turn Knob K4 apply 200VDC to the Rotor Field
15. Now make the machine run at Synchronous speed by varying the Field EXCITATION. When the machine becomes synchronized with the Supply frequency then the speed becomes constant. The speed will not change if the field excitation is further varied.
16. Now vary the Field Excitation from **200VDC - 220VDC** and measure the field current  $I_f$  and fill up the Table-1.

### Graph:

1. Draw  $I_a$  Vs  $I_f$  and P.f Vs  $I_f$  on the same graph paper. Clearly mark the zones of lagging, leading & unity power factor.
2. Draw PT Vs  $I_f$  and QT and  $I_f$  on the same graph paper.

**Group No:**  
**Roll no:**

Data Sheet

1. Rotor resistance  $R_F =$
2. Rotor Inductance  $L_F =$
3. Stator resistance/Phase  $R_A =$
4. Stator Induction/Phase  $L_A =$
5.  $X_S = 2\pi fLS =$
- 6. Fill up the table**

$P_{in} = 3 \times W$	$V_\phi$	$I_A$	$\cos\theta = \frac{P_{in}}{3V_\phi I_A}$	$E_A = V_\phi - jI_A X_S$	$\sin\delta = \frac{P_{in} \times X_S}{3 V_\phi E_A}$

**Signature of the Lab Teacher**

Experiment no: 7

Experiment name: **Measuring Synchronous Generator Model Parameters.**

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### **Introduction:**

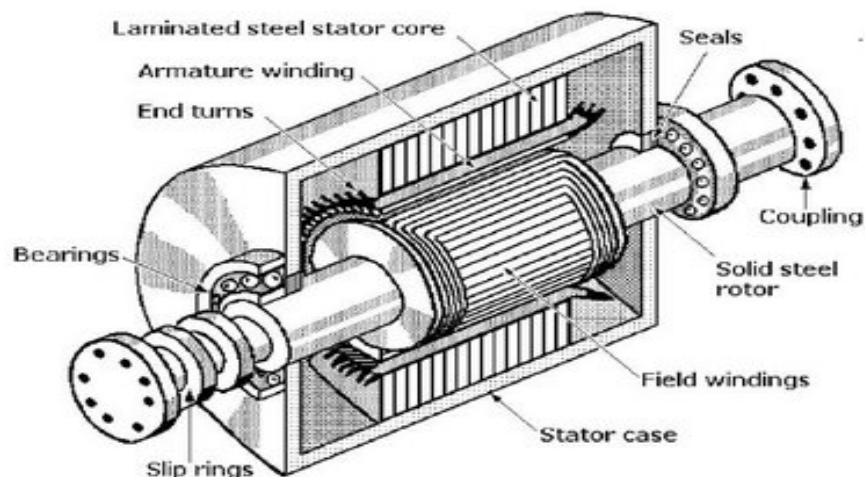
Three quantities are required to describe the behavior of a synchronous generator. These are:

1. The relationship between field current and flux, i.e. EA Vs If.
2. Synchronous reactance.
3. Armature resistance.

The first step is to perform the open circuit test. To perform this test, the generator is turned at the rated speed. The terminals are disconnected from load and the field current is set to zero. Then the field current is gradually increased in step and the corresponding terminal voltage is measured. Plotting of VT Vs If gives the open circuit characteristic of the generator (O.C.C).

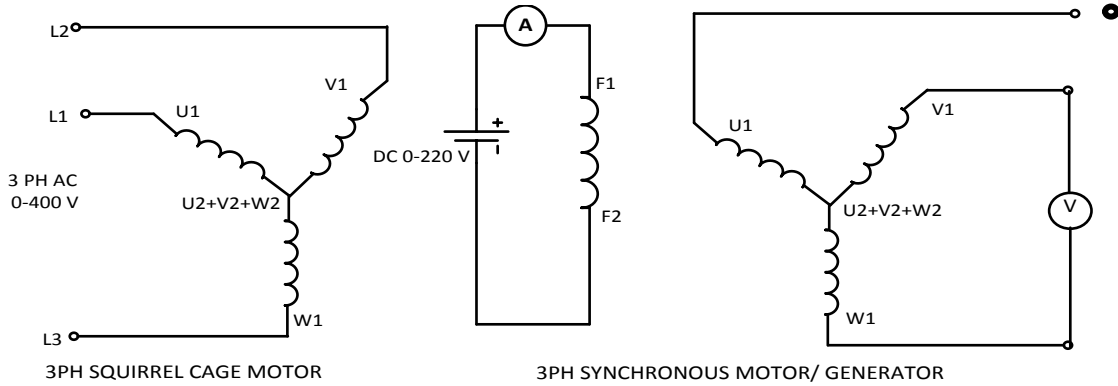
### **Equipments:**

1. 3- $\phi$  synchronous generator
2. 3- $\phi$  induction motor
3. DC ammeter (0-500 mA)
4. AC ammeter (0-2.5 A)
5. AC voltmeter (0-300 V)
6. Rheostat (0- 1000  $\Omega$ )
7. Tachometer
8. Wire for connection.

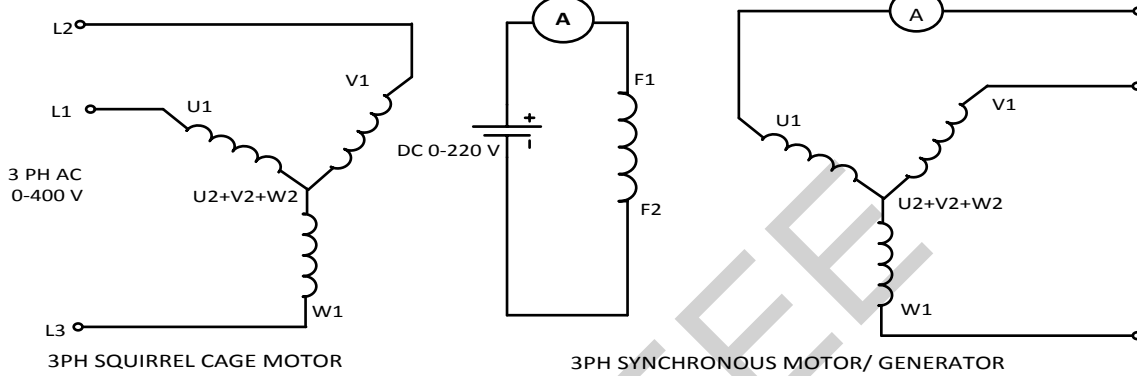


**Cutaway view of a synchronous AC generator with a solid cylindrical rotor capable of high-speed rotation.**

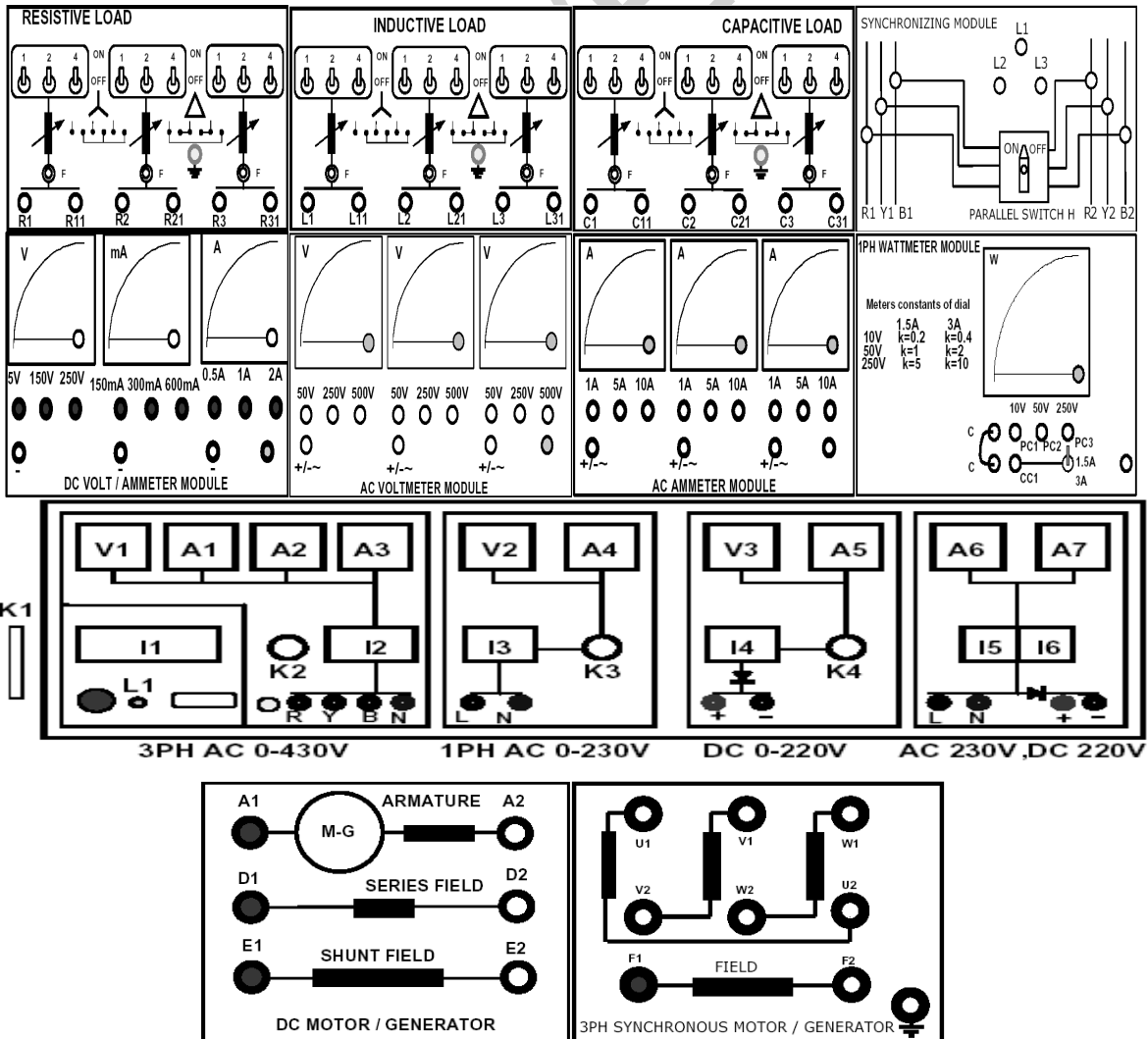
**Connection Diagram:**



**Fig 01: Open Circuit Test**



**Fig 02: Short Circuit Test**



### 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. Make the 3PH supply at **400VAC** by turning Knob K1, Voltmeter V1
9. **\*\*Starting the Prime Mover**
10. Keep the Field Rheostat of the DC Motor at **Maximum**
11. Turn ON Switch I6 (upwards).  
Obtain speed 3000 RPM by varying the Field Rheostat, measure the speed with Tachometer

### For Open circuit test:

12. Put highest resistance in the rotor of the alternator.
13. Open the stator terminals. Apply voltage on the rotor while the prime mover is rotating at the rated speed.
14. Slowly increase the field current and fill up the table for O.C test.

### For Short circuit test:

15. Put highest resistance in the rotor of the alternator.
16. Short the stator terminals. Apply voltage on the rotor while the prime mover is rotating at the rated speed.
17. Slowly increase the field current and fill up the table for S.C. test.
18. For each step, at constant  $I_f$ , divide  $V_T$  by  $I_{SC}$  to determine  $X_S$ .

### Report:

1. On the same graph paper draw  $V_T$  Vs  $I_f$ ,  $I_{SC}$  Vs  $I_f$  and  $X_S$  Vs  $I_f$ .
2. Why the value of  $X_S$  does not remain constant?
3. Why do you get a linear relationship between  $I_A$  Vs  $I_f$  during short circuit test?

Group No:  
Roll no:

Data Sheet

**O.C.C. Test**

$I_f$	$V_T$

**Short Circuit Test**

$I_f$	$I_{SC}$

**By Calculation**

$I_f$	$X_S$

*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- $\phi$  synchronous generator
2. 3- $\phi$  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  $\Omega$ )
8. Inductor bank
9. Capacitor bank
10. Tachometer

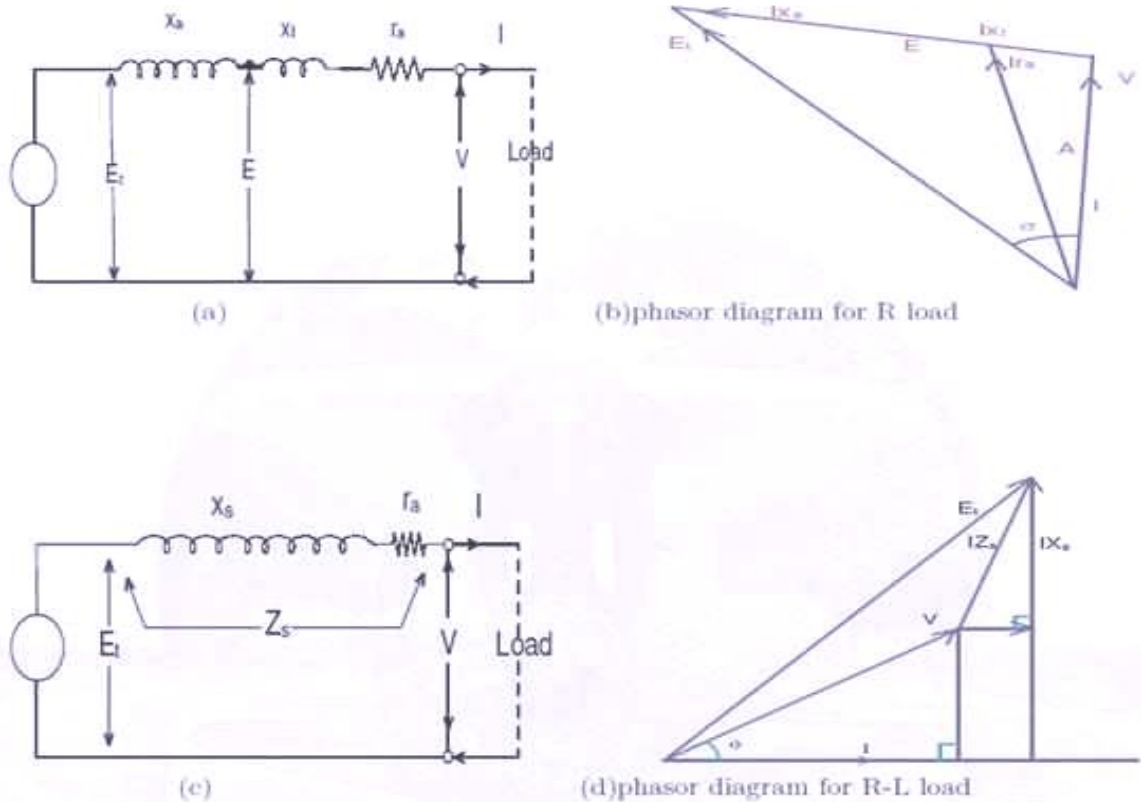
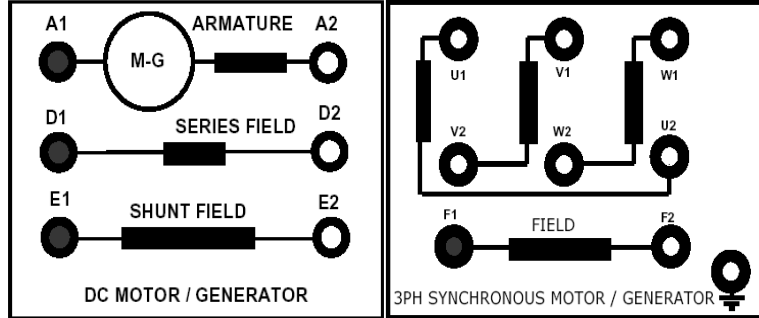
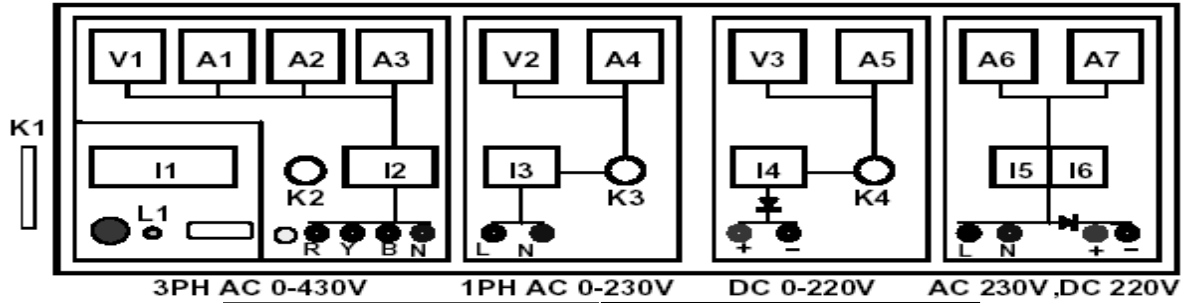
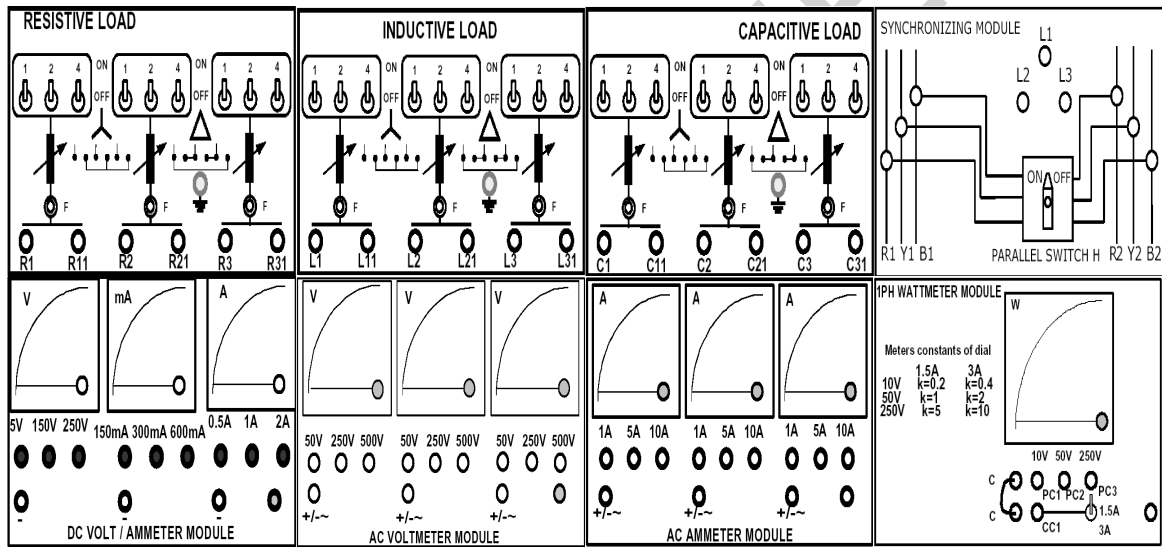
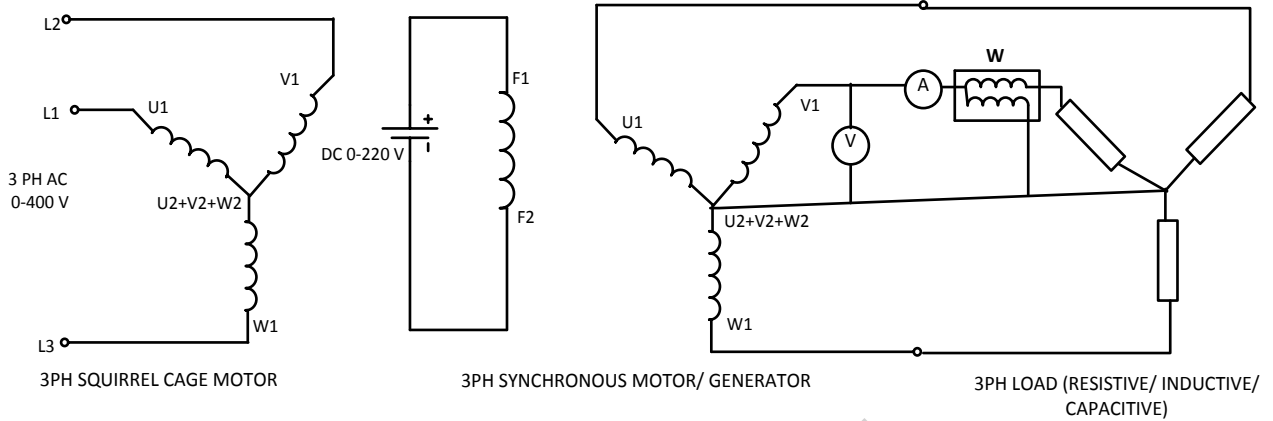


Figure 30: Equivalent circuits

### 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  $R_A$  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  $V_\phi$ . Comment on the value of  $E_A$  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: 9

Experiment name: **Prediction of regulation of three-phase alternator by Synchronous impedance method.**

---

**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.

The experiment involves the determination of the following characteristics and parameters:

1. The open -circuit characteristic(the O.C.C)
2. The short-circuit characteristic(the S.C.C)
3. The effective resistance of he armature winding.

The O.C.C is a plot of the armature terminal voltage as a function of field current with a symmetrical three phase short-circuit applied across the armature terminals with the machine running at rated speed.

At any value of field current, if E is the open circuit voltage and I<sub>sc</sub> is the short circuit current then for this value of excitation

$$Z_s = E/I_{sc}$$

At higher values of field current, saturation increases and the synchronous impedance decreases. The value of Z<sub>s</sub> calculated for the unsaturated region of the O.C.C is called the unsaturated value of the synchronous impedance.

If R<sub>a</sub> is the effective resistance of the armature per phase, the synchronous reactance X<sub>s</sub> is given by

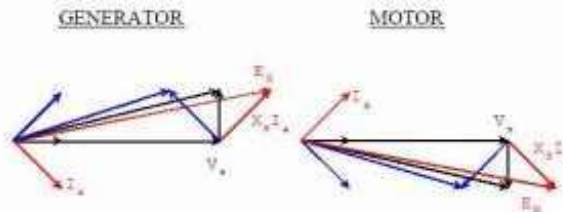
$$X_s = \sqrt{(Z_s^2 - R_a^2)}$$

If V is the magnitude of the rated voltage of he machine and the regulation is to be calculated for a load current I at a power factor angle f, then the corresponding magnitude of the open circuit voltage E is

$$E = V + IZ_s$$

Here bold letters indicate complex numbers.

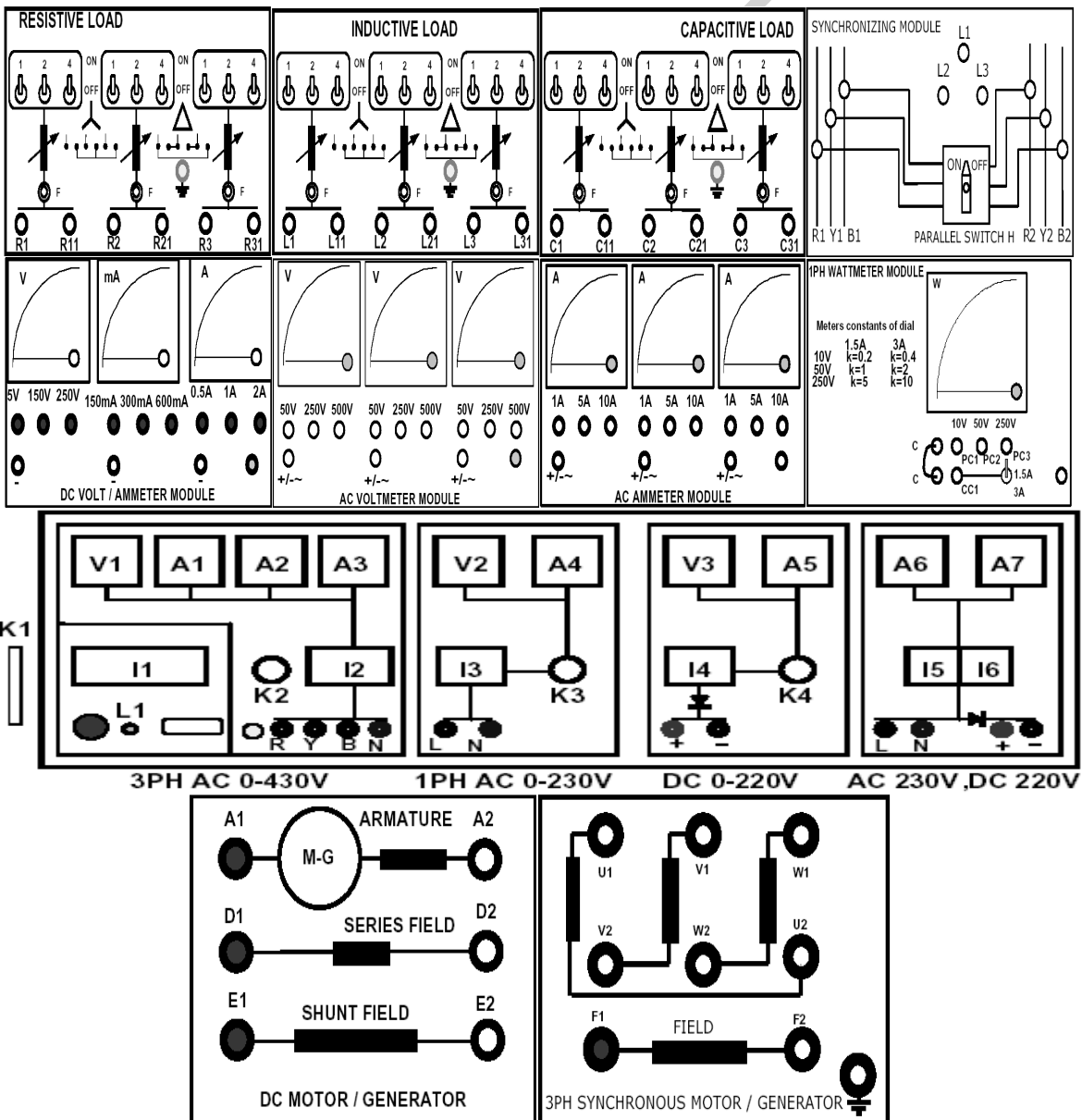
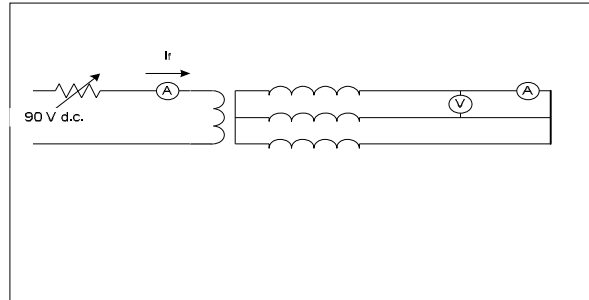
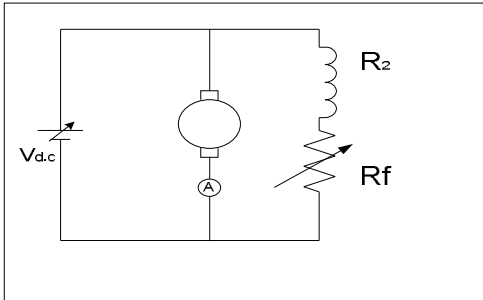
Regulation = (E-V)/V



**Equipments:**

1. 3-φ synchronous generator
2. D.C. 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)

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. \*\*Starting the Prime Mover

9. Keep the Field Rheostat of the DC Motor at **Maximum**
10. Turn ON Switch I6 (upwards).
11. Obtain speed 3000 RPM by varying the Field Rheostat, measure the speed with Tachometer.

### 12. \*\*Adjusting Terminal Voltage of the 3PH Generator

13. Turn Knob K4 at min (CCW)
14. Turn ON switch I4 (upwards). Adjust field rheostat to obtain field current between 130 mA to 320 mA. Take readings of field current and no load terminal voltage for each setting of field rheostat and complete the 2<sup>nd</sup> column of data sheet.
15. Remove the voltmeter from machine. Connect an ammeter according to the diagram. Adjust the field rheostat until the excitation current is 0.15 A.
16. Again set the speed of the motor at 3000 rpm. Now progressively increase field rheostat, taking readings of line current for the same values of excitation current between 130 mA to 320 mA. Complete the rest of the column of data sheet.
17. Plot graph of open circuit voltage and short circuit current to a base of excitation current.

**\*\*\*CAUTION: KEEP SPEED OF THE DRIVING MOTOR CONSTANT AT 3000 RPM THROUGH OUT THE EXPERIMENT.**

### Report:

1. Draw the phasor diagrams at unity, lagging and leading p.f. use the values of  $R_A$  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  $V_\phi$ . Comment on the value of  $E_A$  under leading p.f.
4. Explain the shape of open circuit and short circuit characteristics curve.

**Group No:**  
**Roll no:**

Data Sheet

Stator resistance:  $R_a =$                        $R_b =$                        $R_c =$

Average stator resistance =  $(R_a + R_b + R_c) / 3 =$

$I_f$ (mA)	V (volt)	$I_{sc}$ (mA)
120		
140		
160		
180		
200		
220		
240		
260		
280		
300		

**Calculation:**

Alternators specification at 1400 RPM:

Rated Current = 300 mA per line

Rated Voltage = 240 V per phase

Excitation current required to circulate full load line current

= ..... mA (at  $I_{rated}$  from graph)

Open circuit voltage at excitation current determined above

= ..... Volt (from graph)

Synchronous impedance per phase,  $Z_s$

= Open circuit phase voltage / Rated phase current =

$$X_s = \sqrt{Z_s^2 - R_a^2}$$

$$E_o = \sqrt{[V^2 + 2.V.I_a(R_a \cos\theta + X_s \sin\theta) + I_a^2 Z_s^2]}$$

Where,  $I_a$  is load current and  $\theta$  is power factor angle

$$\% \text{ Regulation} = \frac{(E_o - V)}{V} \times 100\%$$

**Signature of the Lab Teacher**



Experiment no: **10**  
 Experiment name: **Parallel Operation of Alternators.**

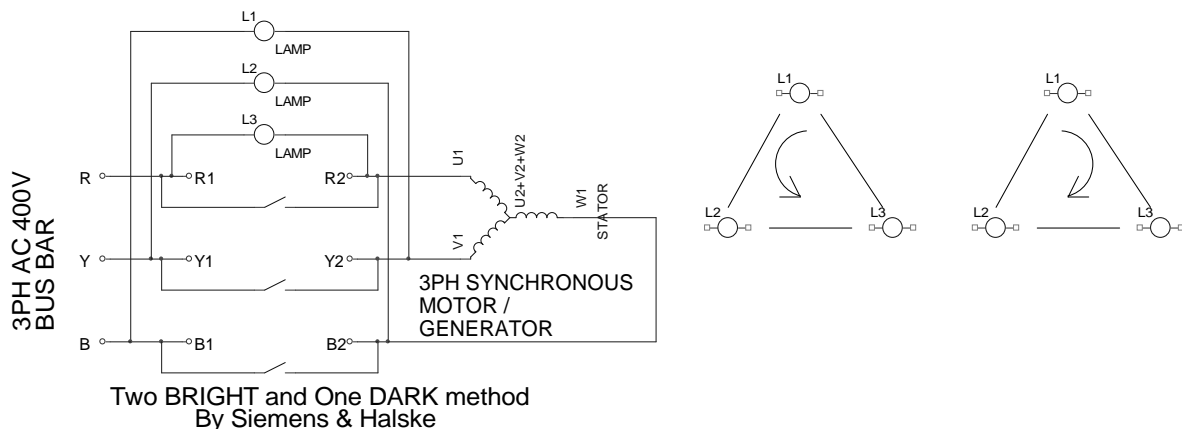
**Introduction:**

Due to increase in loads in the power system, a single generator cannot operate alone. To share the loads properly more than one generator operates in parallel. To achieve this, the following paralleling condition must be met:

1. The terminal voltage of the incoming generator must be equal to the bus bar voltage
2. The frequency of the incoming generator must be equal to the frequency of the bus bar.
3. The phase sequence of the incoming generators voltage must be same as the bus bar voltage phase sequence.
4. The phase angles of two corresponding phases must be equal.



Condition 1 can be verified easily by a Voltmeter. For condition 2, 3, 4 Synchronizing Lamp is used for paralleling Generators with the bus bar. Below is the circuit diagram with synchronizing lamp L1, L2, L3. **This is called Two BRIGHT and One DARK method suggested by Siemens and Halske.**



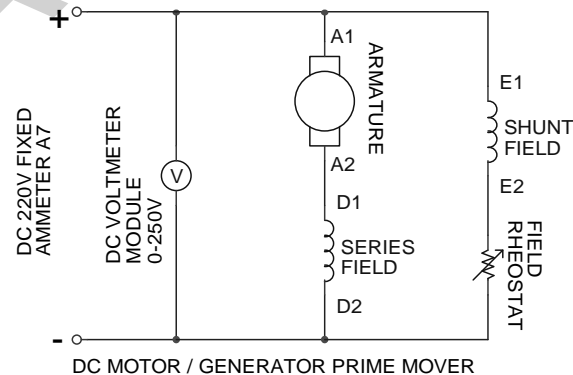
Below are the steps for synchronizing generator with the bus bar:

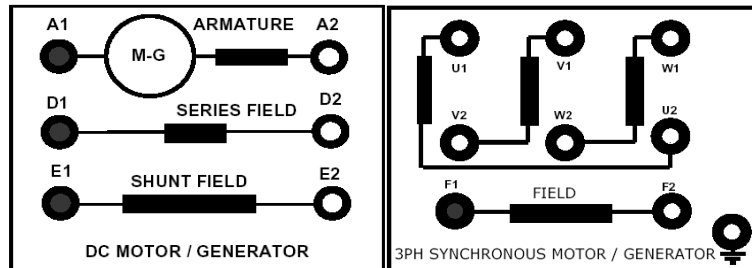
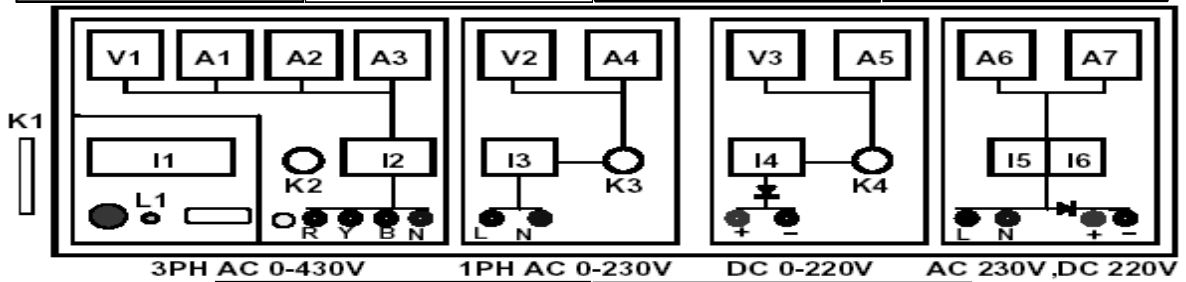
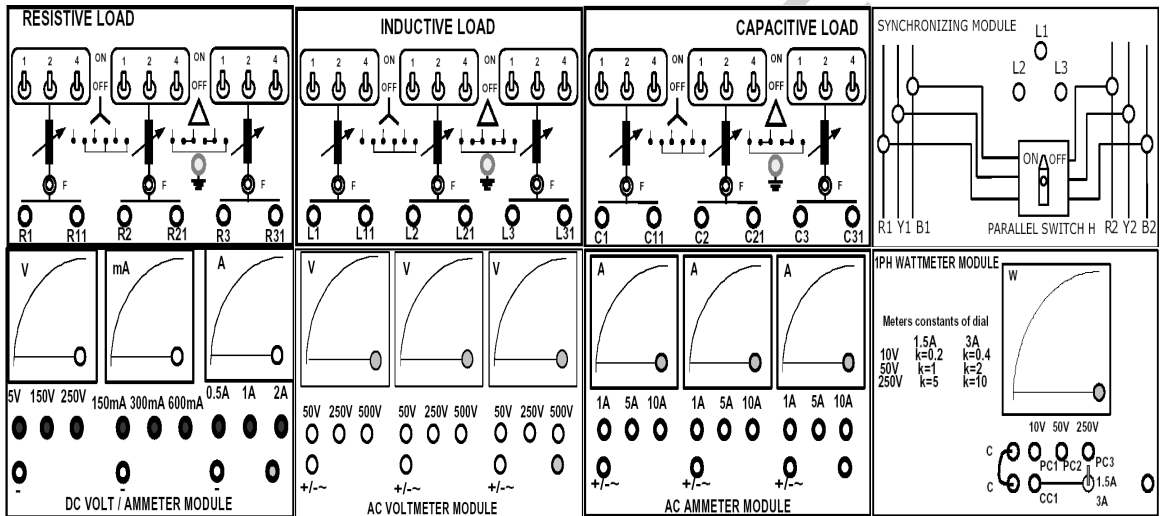
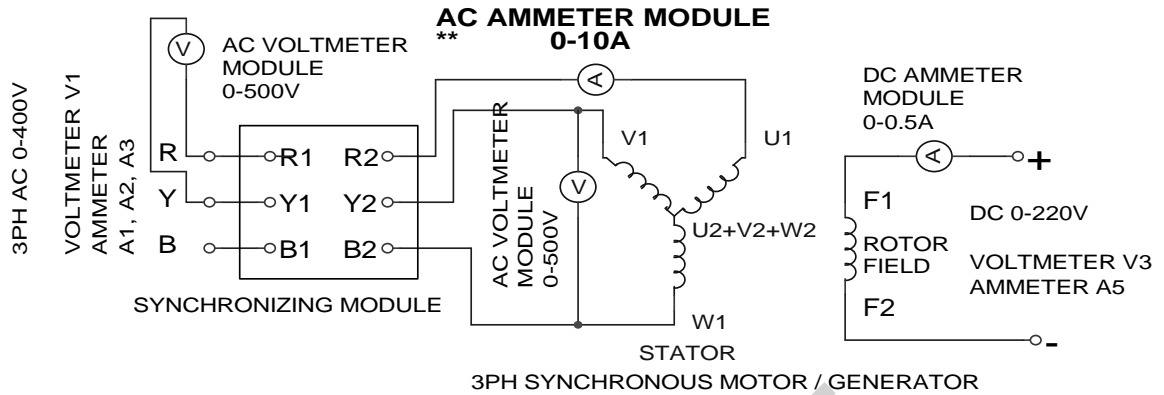
1. By varying the field excitation make the stator voltage of the 3 phase synchronous generator equal to the bus bar 400VAC
2. Observe the lamps L1, L2 and L3; when the lamps becomes dark and bright sequentially which give the impression of a "rotation" of the lights. That is the lamps will light up one after another in the order Clock Wise 1,2,3 or Anti Clock Wise 1,3,2.
3. The speed of this rotation of light is proportional on the difference of the frequency of the generator voltage and the bus bar.
4. \*\*If all the Three Lamps L1, L2, L3 becomes DARK and BRIGHT at the same time then interchange Y2, B2
5. Now slightly readjust (increase or decrease) the speed of the prime mover so that the rotation becomes slow. When L3 becomes DARK and L1, L2 becomes dim but equally bright, now the generator is ready to be paralleled with the bus bar.

#### Equipments:

1. Universal Power Supply
2. DC Motor / Generator
3. 3 Phase Synchronous Motor Generator
4. Synchronizing Module
5. DC Voltmeter / Ammeter Module
6. AC Ammeter Module 0-1A
7. AC Voltmeter Module 0-250 V
8. Tachometer
9. Coupling Sleeve
10. Connecting Cables

#### 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. **\*\*Connecting the Bus Bar**
15. Make the 3PH supply at **400VAC** by turning Knob K1, Voltmeter V1.
16. **\*\*CAUTION: The Parallel Switch H of the Synchronizing Module must be turned OFF**
17. Turn ON Switch I2 (upwards).
18. **\*\*Adjusting Terminal Voltage of the 3PH Generator**
19. Turn Knob K4 at min (CCW)
20. Turn ON switch I4 (upwards).
21. Increase the Rotor Field Voltage so that the 3PH AC Output of the Generator becomes equal to the Bus Bar **400VAC**.
22. **\*\*Synchronizing the Generator with the Bus Bar**
23. Now Observe the lamps L1, L2 and L3 on the synchronizing module; when the lamps becomes **DARK** and **BRIGHT** sequentially which give the impression of a "rotation" of the lights. That is the triangle of three lamps will light up one after another in the order of **Clock Wise 1,2,3** or **Anti Clock Wise 1,3,2**
24. The speed of this rotation of light is proportional to the difference between the frequency of the generator voltage and the bus bar.
25. **\*\*If all the Three Lamps L1, L2, L3 becomes DARK and BRIGHT at the same time then interchange Y2, B2 and Verify again the step 23.**
26. Now slightly readjust (increase or decrease) the speed of the prime mover so that the rotation speed of the lamps becomes slow. When L3 becomes DARK and L1, L2 becomes **Dim But Equally Bright**, now the generator is ready to be paralleled with the bus bar.
27. **\*\*CAUTION: Carefully Turn ON the Parallel Switch H of the Synchronizing Module, if a high current shows on AC Ammeter Module 0-10A then Turn OFF the Switch H.**

### Report:

1. What will happen if the prime mover on the field excitation of the on-coming generator fails? Explain.
2. Why is paralleling necessary in a power system?