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

2nd Year, 2nd Semester

Experiment No.	Name of the Experiments
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:
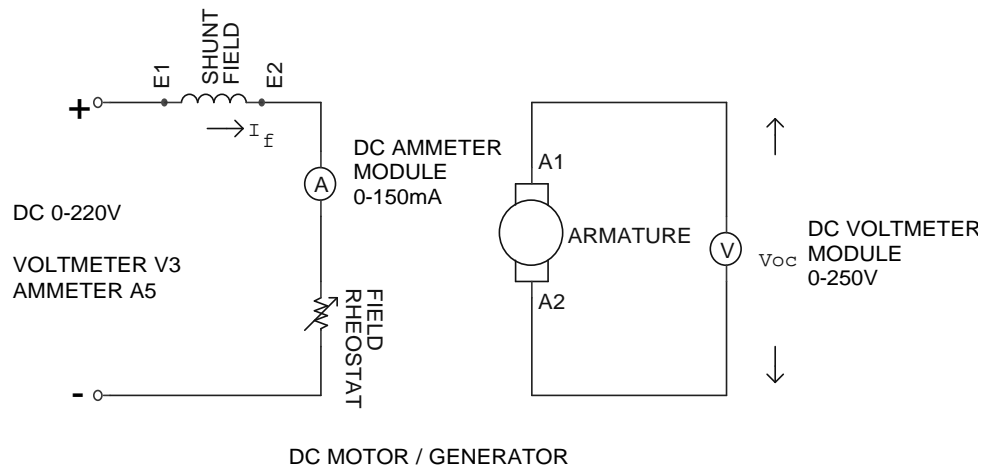

Fig: Separately Excited Shunt Generator

Voltage developed in the DC generator in general form,
$$E_G = \phi ZN/60 *(P/A) \text{ volt}$$
Where, E_G = Generated Emf.
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
$$E_G = K_g \phi N \text{ volt}, \text{ Where } K_g = ZP/(60*A)$$

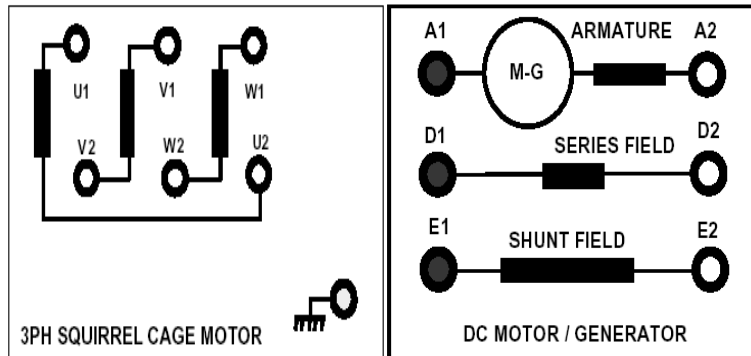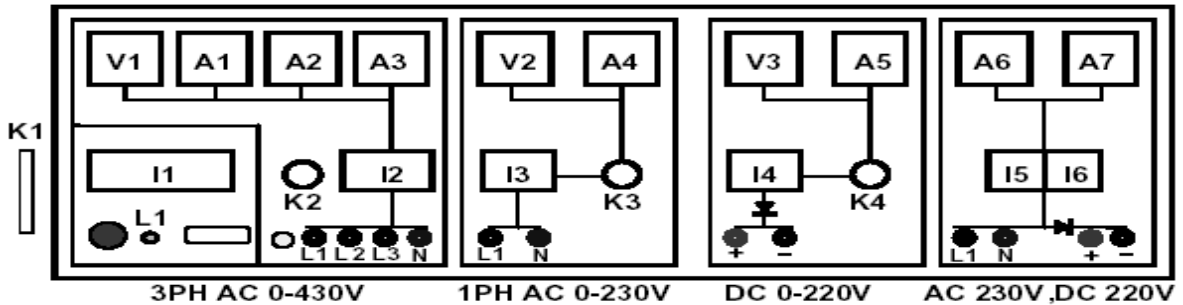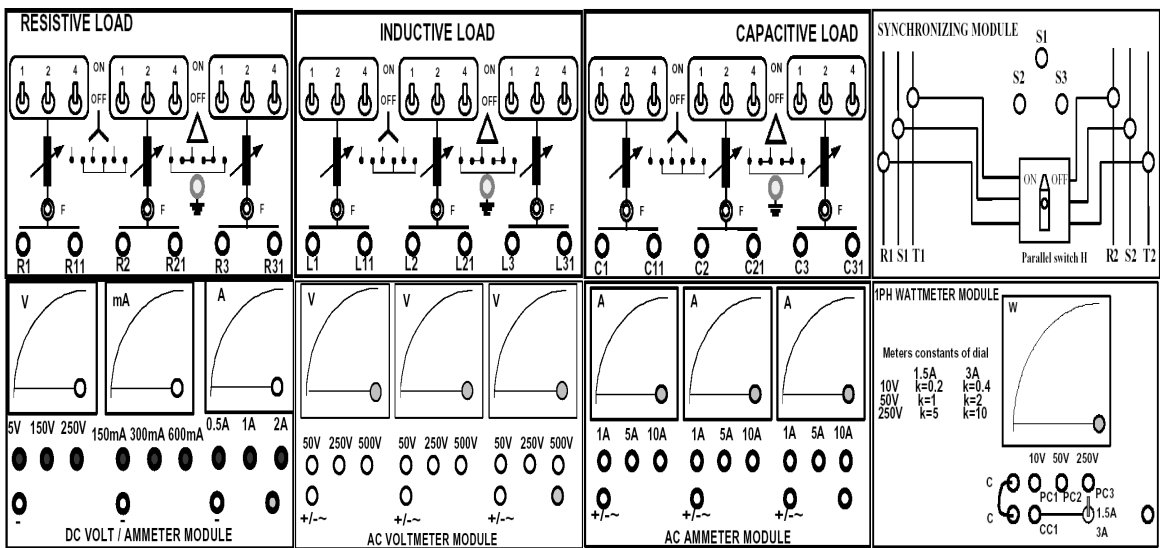If armature rotation is constant, then $E_G = K\phi$ **volt.**

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:

3PH SQUIRREL CAGE MOTOR

DC MOTOR / GENERATOR

L2
L1
U1   V1
3PH AC 0-430V
VOLTMETER V1
AMMETER
A1, A2, A3
U2+V2+W2
L3
W1
STATOR

+ E1 SHUNT FIELD E2
I_f
DC 0-220V
VOLTMETER V3
AMMETER A5
A DC AMMETER MODULE 0-150mA
FIELD RHEOSTAT
−

A1
ARMATURE
A2
V V_{OC}
DC VOLTMETER MODULE 0-250V

RESISTIVE LOAD
ON OFF
R1 R11 R2 R21 R3 R31

INDUCTIVE LOAD
ON OFF
L1 L11 L2 L21 L3 L31

CAPACITIVE LOAD
ON OFF
C1 C11 C2 C21 C3 C31

SYNCHRONIZING MODULE
S1
S2 S3
ON OFF
R1 S1 T1 Parallel switch H R2 S2 T2

V mA A
5V 150V 250V 150mA 300mA 600mA 0.5A 1A 2A
−
DC VOLT / AMMETER MODULE

V V V
50V 250V 500V 50V 250V 500V 50V 250V 500V
+/-~ +/-~ +/-~
AC VOLTMETER MODULE

A A A
1A 5A 10A 1A 5A 10A 1A 5A 10A
+/-~ +/-~ +/-~
AC AMMETER MODULE

1PH WATTMETER MODULE
W
Meters constants of dial
	1.5A	3A
10V	k=0.2	k=0.4
50V	k=1	k=2
250V	k=5	k=10
10V 50V 250V
C PC1 PC2 PC3
C CC1 1.5A 3A

K1

V1 A1 A2 A3
I1
L1 K2 I2
L1 L2 L3 N

V2 A4
I3 K3
L1 N

V3 A5
I4 K4
+ −

A6 A7
I5 I6
L1 N + −

3PH AC 0-430V   1PH AC 0-230V   DC 0-220V   AC 230V ,DC 220V

U1 V1 W1
V2 W2 U2
3PH SQUIRREL CAGE MOTOR

A1 ARMATURE A2
M-G
D1 SERIES FIELD D2
E1 SHUNT FIELD E2
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 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?

Data Sheet

Armature resistance, R_a =
Field resistance, R_{sh} =

Table-1

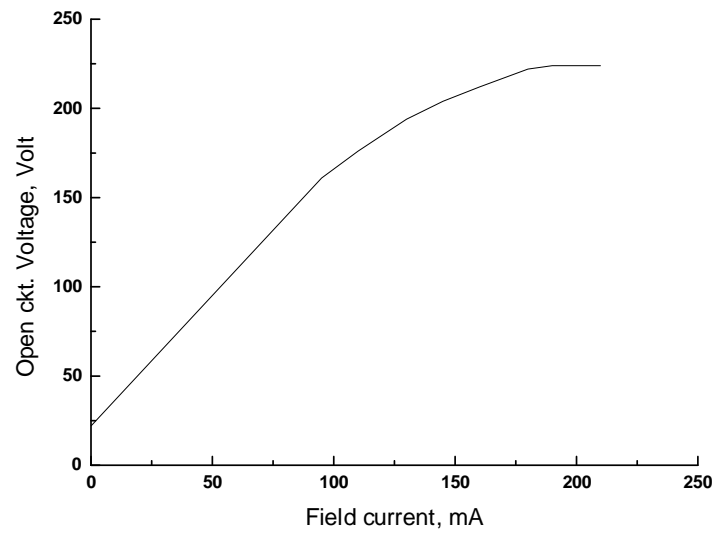| Field current I_f (mA)	Open circuit voltage V_{oc} (volt)

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**

Introduction:

The efficiency of a generator is defined by,

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

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

So generator input = Output + losses.

$$= V*I + I_a^2 *R_a + W_C$$
$$= V*I + (I+I_{sh})^2 *R_a + W_C$$
$$= V*I + I^2 *R_a + W_C \quad \text{as } I_a \text{ is approximately equals to I}$$

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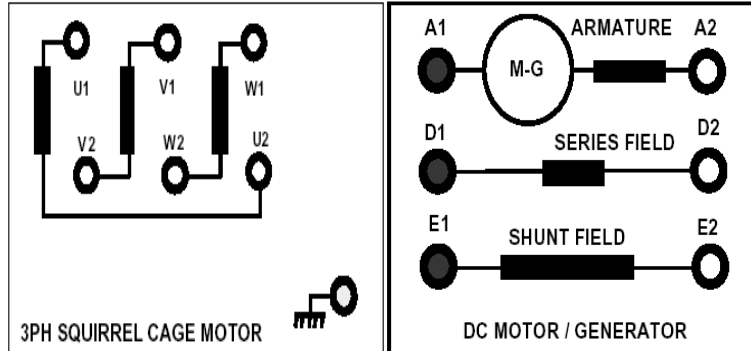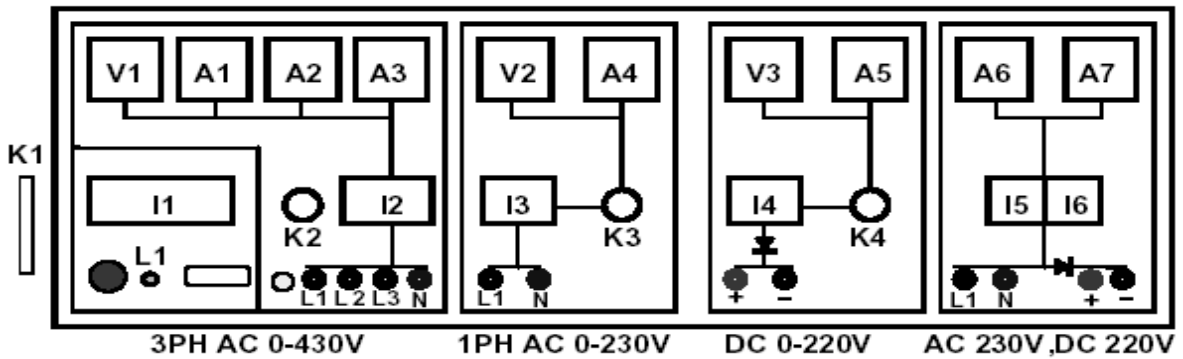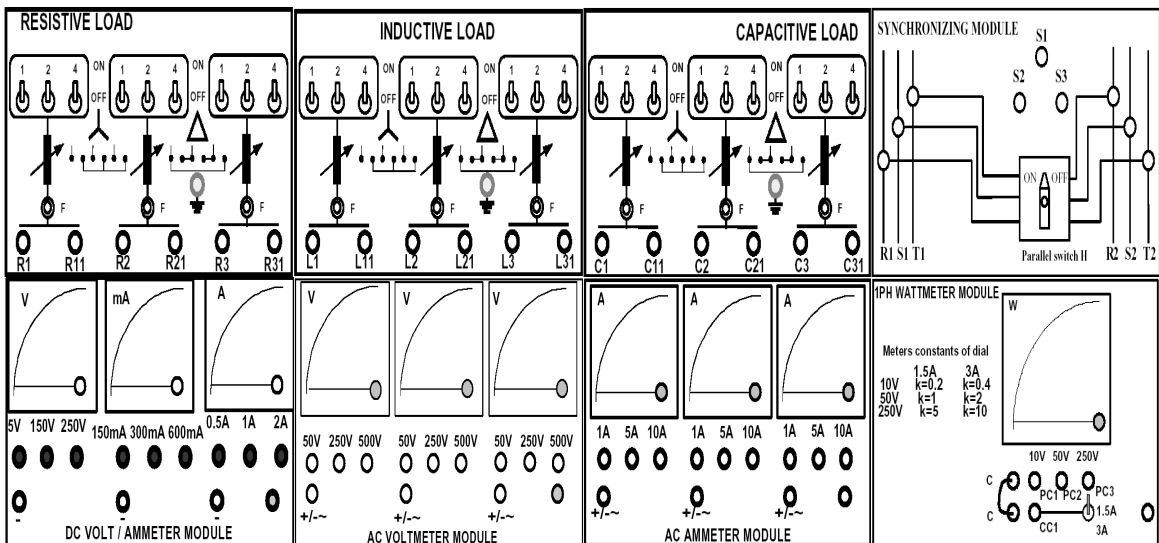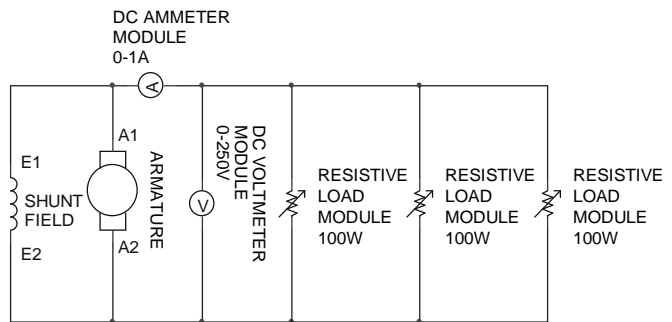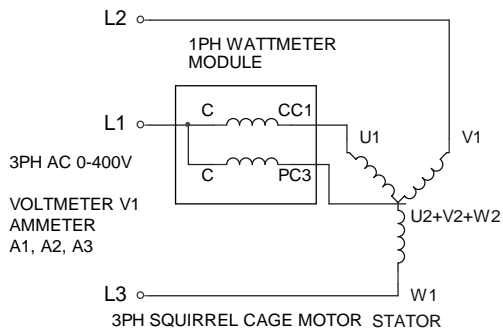
Equipments:

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
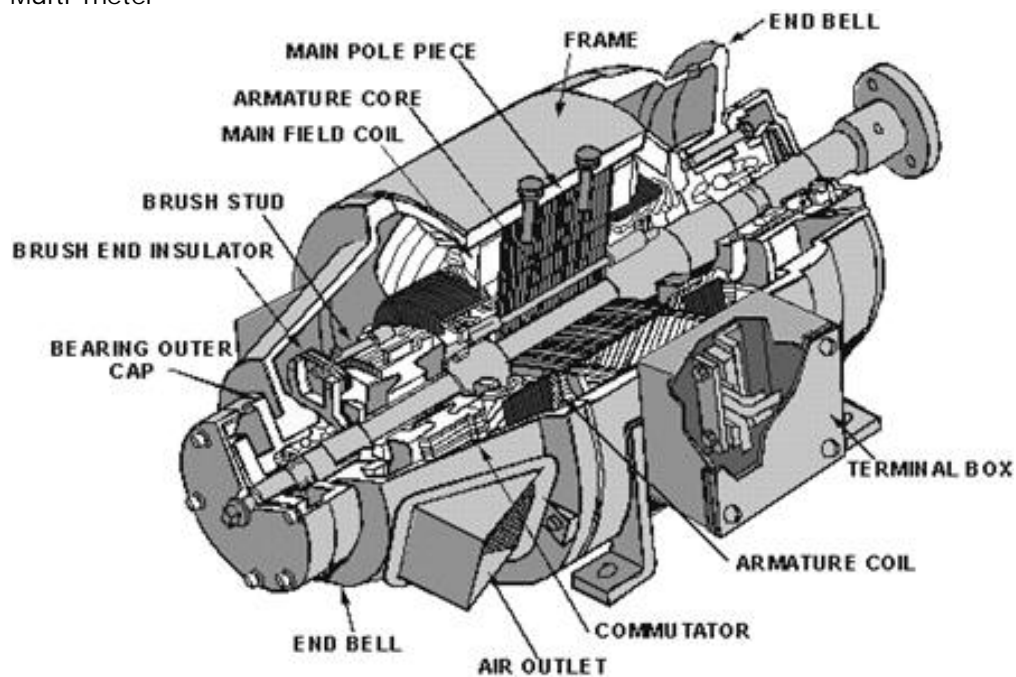
Circuit Diagram:

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.

<u>Data Sheet</u>

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

At no load

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

At half full load

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

Calculate

1. Armature Cu-loss =

2. Output power =

3. Efficiency =

At full load

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

Calculate

1. Armature Cu-loss =

2. Output power =

3. Efficiency =

Signature of the Lab teacher:

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

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

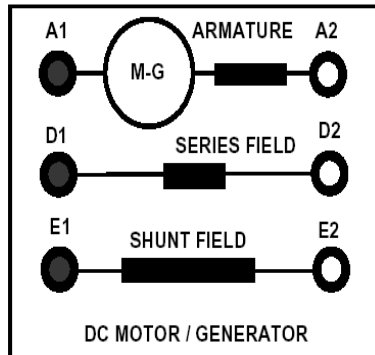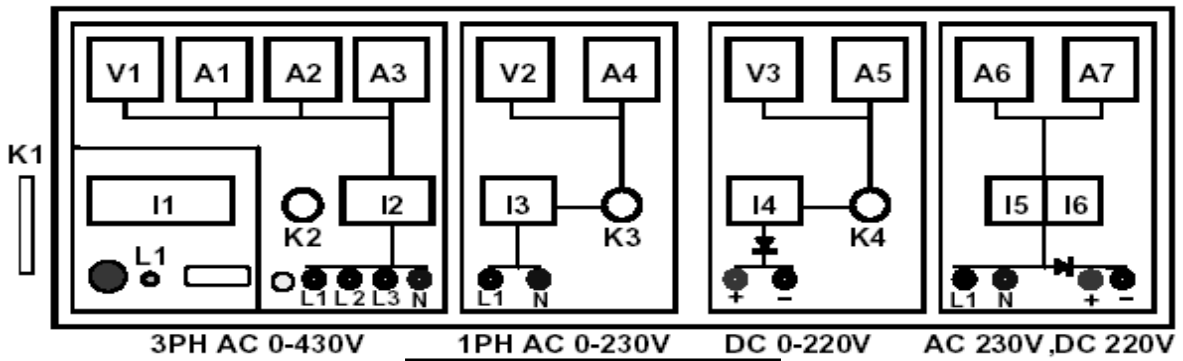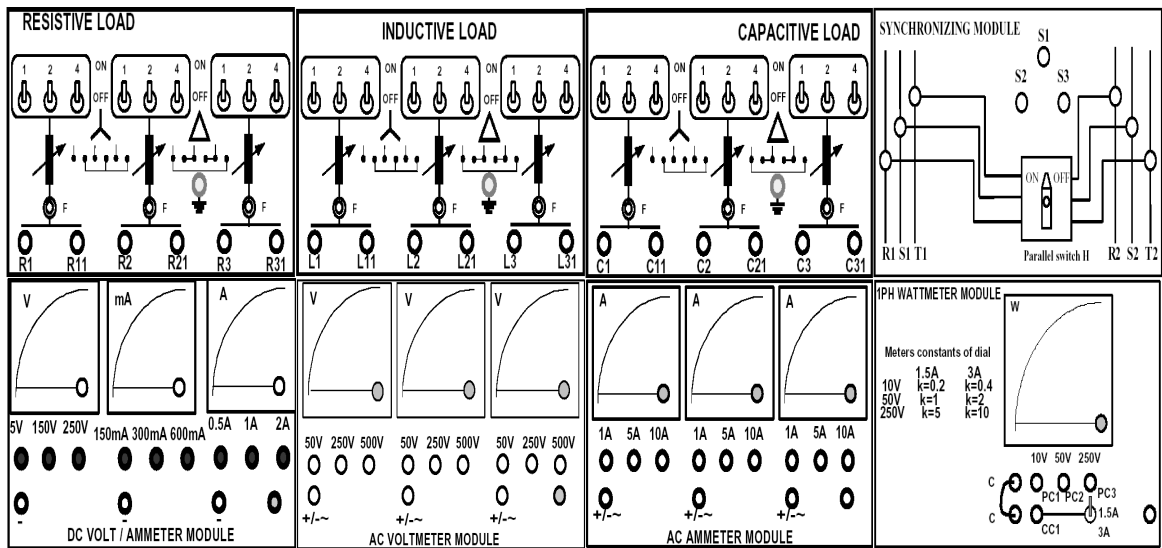Magnetic losses and mechanical losses are collectively known as stray losses. They are also known as rotational losses.
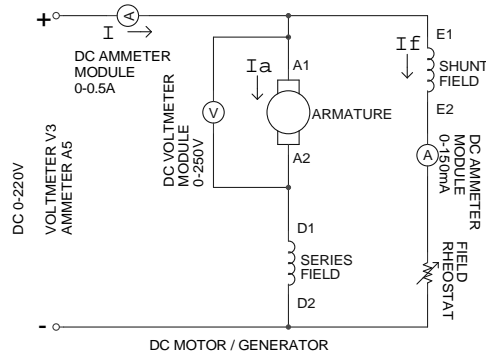
Equipments:

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
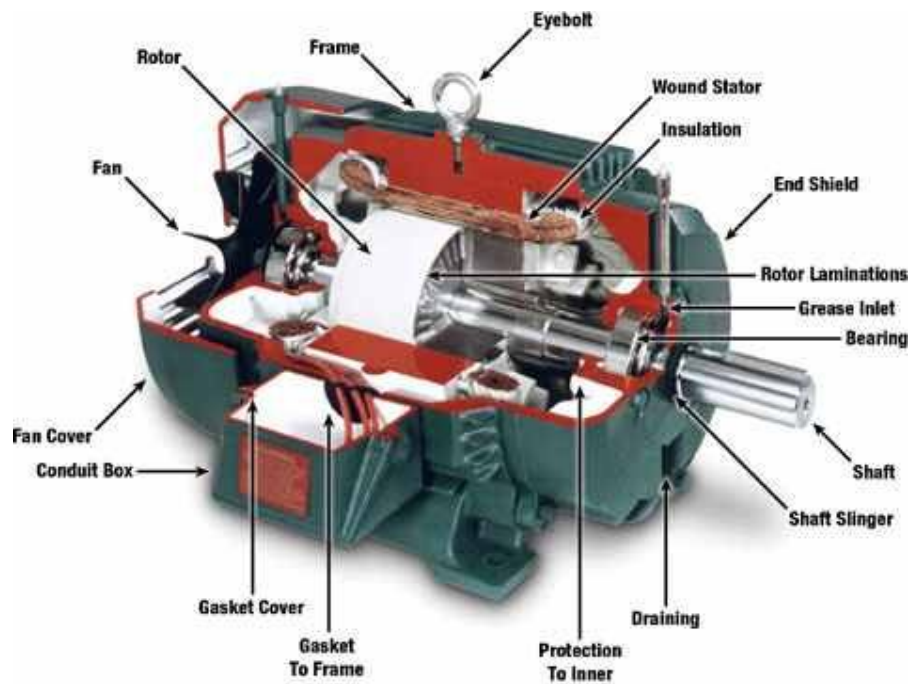
Figure 8 – **Motor Construction**

Connection Diagram:

DC MOTOR / GENERATOR

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, Po

2. Po vs. armature voltage, Va using the data of table-1 and draw a tangent and extend the tangent to Y-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 Po for a voltage say 180 V. Then subtract mechanical loss (from step-2) from that Po. 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
8. $W_2 = AN_2 + BN_2^2$, where N_2 is 75% of rated speed.

9. A and B are Eddy current and Hysteresis loss respectively. Solve two equations to find A and B.

Report:

1. Discuss about the nature of Po vs. armature voltage curve at two different speeds.
2. Comment on the results.

<u>Data Sheet</u>

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

Group No:
Roll no:

At rated Speed, N =

(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) Va x I (A)×(D)	Armature Power Output (watt) Po=(F)-(E)

Table-1

At 75% of rated Speed, N =

(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)×(D)	Armature Power Output (watt) Po=(F)-(E)

Table-2

Signature of the Lab Teacher

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

Introduction:
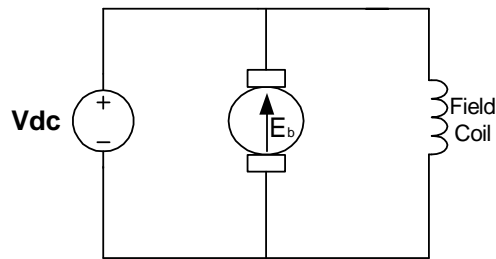Voltage developed in the D.C generator in general form ---
$$E_g = \phi ZN/60 * (P/A) \text{ volt}$$
The same equation can be written for motor replacing E_g by E_b ---
$$E_b = \phi ZN/60 * (P/A) \text{ volt} \quad \text{-------------------- (1)}$$
Where, E_b is called the Back EMF.
The simple diagram 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

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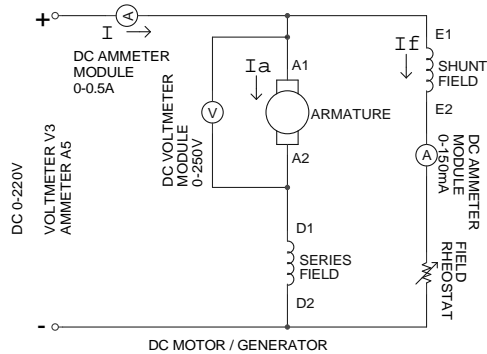1. Flux Control
2. Armature Resistance Control
3. Voltage Control

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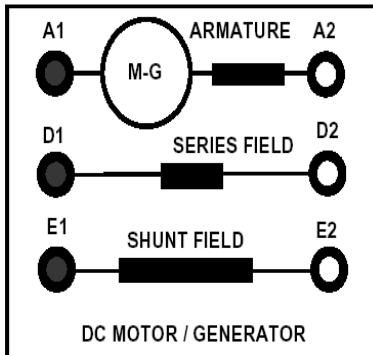6. Connecting Cables
7. Multimeter

Flux Control Method:

DC MOTOR / GENERATOR

RESISTIVE LOAD

INDUCTIVE LOAD

CAPACITIVE LOAD

SYNCHRONIZING MODULE

DC VOLT / AMMETER MODULE

AC VOLTMETER MODULE

AC AMMETER MODULE

1PH WATTMETER MODULE

3PH AC 0-430V   1PH AC 0-230V   DC 0-220V   AC 230V ,DC 220V

DC MOTOR / GENERATOR

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**:
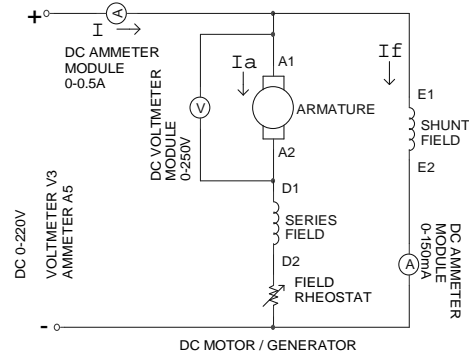
DC MOTOR / GENERATOR

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.
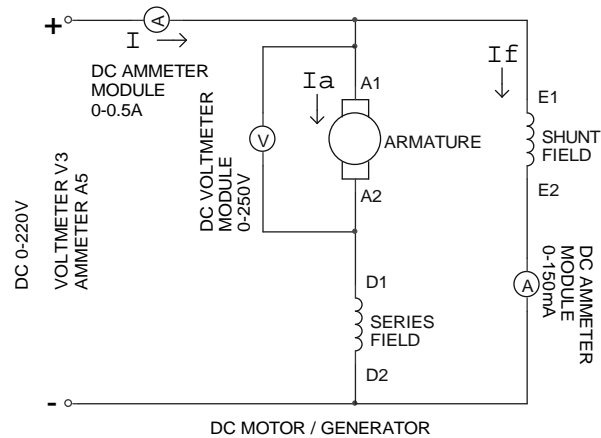4. Now vary the Field Rheostat and measure the Armature current Ia and the motor speed N and fill up the Table-2.

c) Voltage Control:

DC MOTOR / GENERATOR

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

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.
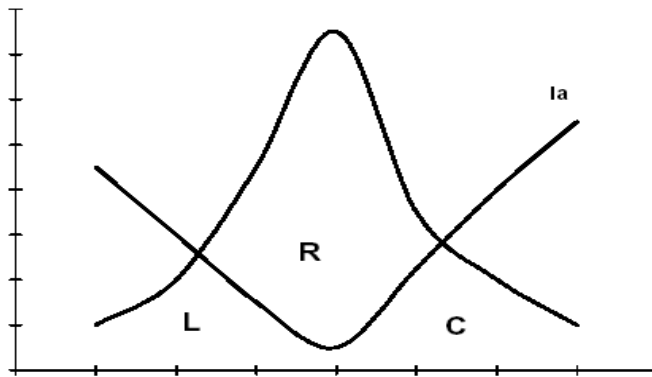
Signature of the Lab Teacher

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:
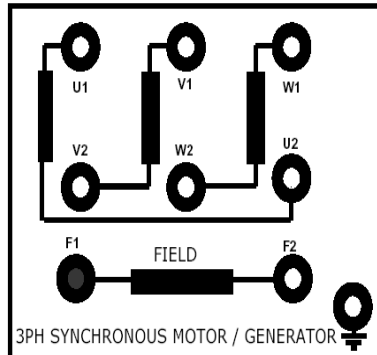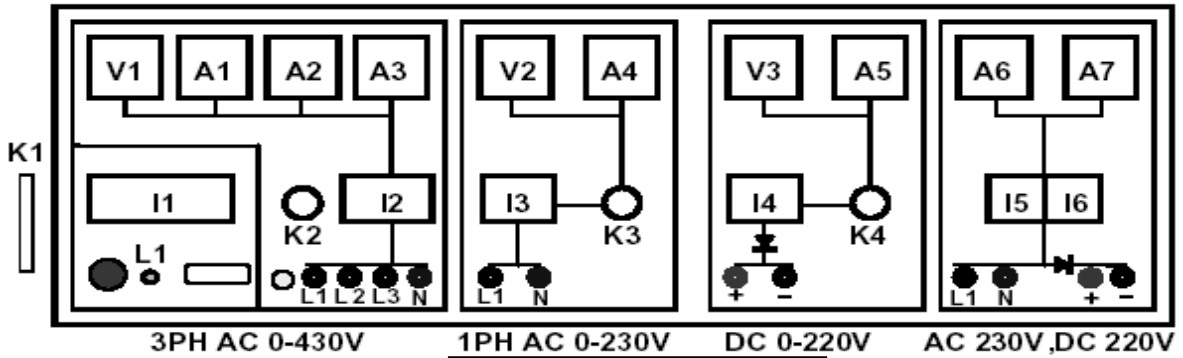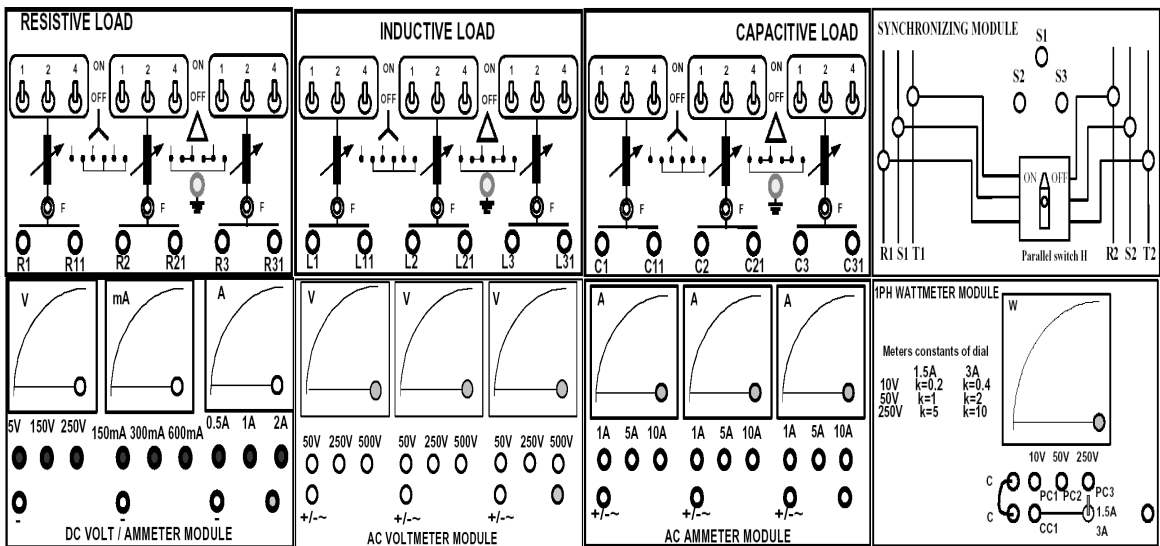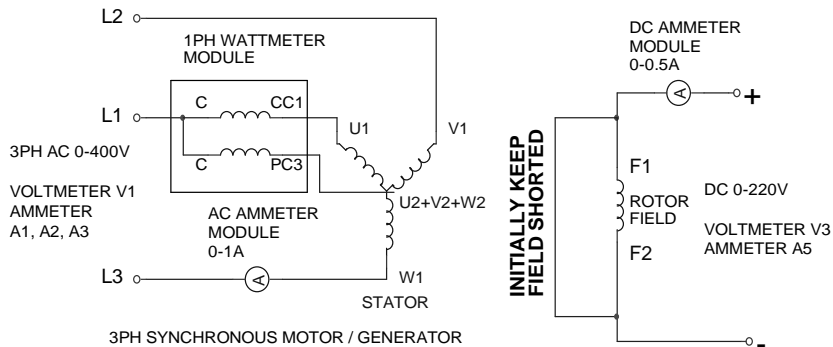

3PH SYNCHRONOUS MOTOR / GENERATOR

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

Table1:

V_L (L-L)	Field Current If	Armature Current Ia	Wattmeter Reading W	Pt = 3W	PF = Pt/$\sqrt{3}V_L$Ia	QT = $\sqrt{3}V_L$IaSinθ

Graph:

1. Draw Ia Vs If and P.f Vs If on the same graph paper. Clearly mark the zones of lagging, leading & unity power factor.

2. Draw PT Vs If and QT and If 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:
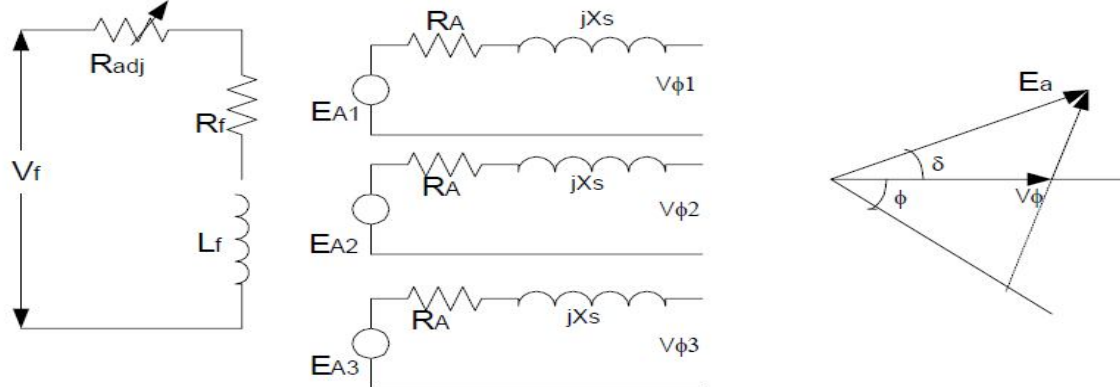
Figure no: 1

$Pin = 3*V\varphi*Ia\ COS\theta = 3*V\varphi*EA\ SIN\delta$ where, $EA\ SIN\delta = Ia*XS*SIN\ (90-\varphi)$

If excitation is increased (i,e; IF is increased), EA tends to increase. However as no extraload is added to the motor shaft, EAsinδ & IAcosθ remains constant. So, tip of EA and IA **moves along the dashed line as shown below.**
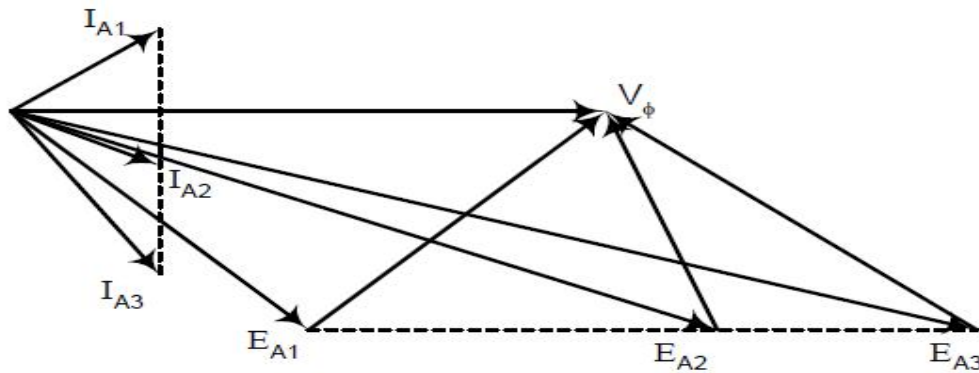
The purpose of the experiment is to draw the phasor diagram under different excitation **conditions.**

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

25

Connection Diagram:

3PH AC 0-400V

VOLTMETER V1
AMMETER
A1, A2, A3

1PH WATTMETER MODULE

AC AMMETER MODULE
0-1A

3PH SYNCHRONOUS MOTOR / GENERATOR

STATOR

DC AMMETER MODULE
0-0.5A

INITIALLY KEEP FIELD SHORTED

ROTOR FIELD

DC 0-220V

VOLTMETER V3
AMMETER A5

RESISTIVE LOAD

INDUCTIVE LOAD

CAPACITIVE LOAD

SYNCHRONIZING MODULE

DC VOLT / AMMETER MODULE

AC VOLTMETER MODULE

AC AMMETER MODULE

1PH WATTMETER MODULE

Meters constants of dial

	1.5A	3A
10V	k=0.2	k=0.4
50V	k=1	k=2
250V	k=5	k=10

3PH AC 0-430V

1PH AC 0-230V

DC 0-220V

AC 230V ,DC 220V

3PH SYNCHRONOUS MOTOR / GENERATOR

26

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.

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. $X_S = 2\pi f LS$ =

6. **Fill up the table**

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

Signature of the Lab Teacher

Experiment no: **7**
Experiment name: **Measuring Synchronous Generator Model Parameters.**

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 a gradually increased in step and the corresponding terminals voltage is measured. Plotting of VT Vs If gives the open circuit characteristic of the generator (O.C.C).

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. Rheostat (0- 1000 Ω)
7. Tachometer
8. Wire for connection.
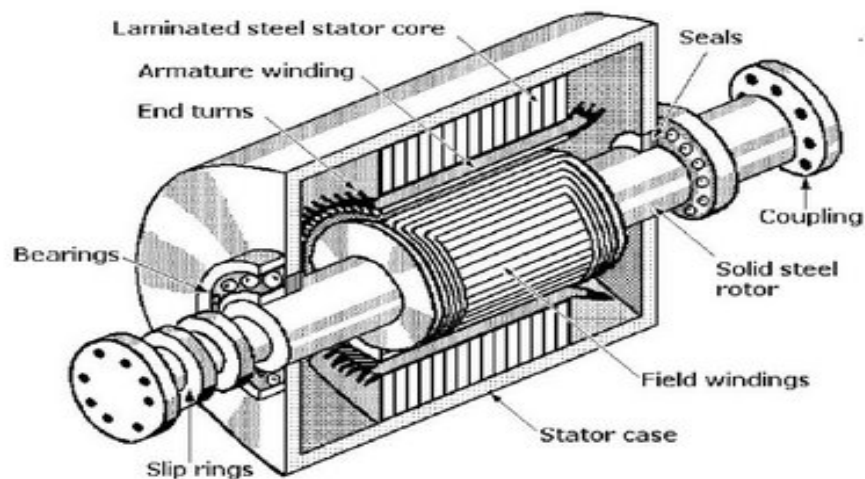
Cutaway view of a synchronous AC generator with a solid cylindrical rotor capable of high-speed rotation.

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 If, 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?

<u>Data Sheet</u>

O.C.C. Test			Short Circuit Test			By Calculation	
I_f	V_T		I_f	I_{SC}		I_f	X_S

Signature of the Lab teacher:

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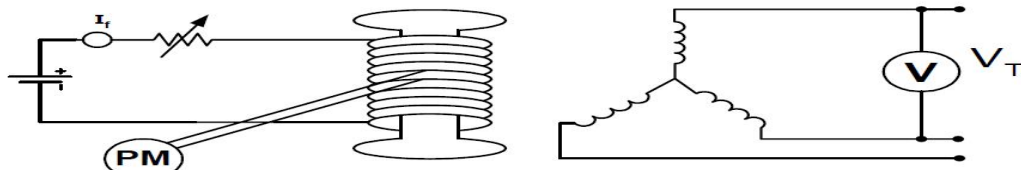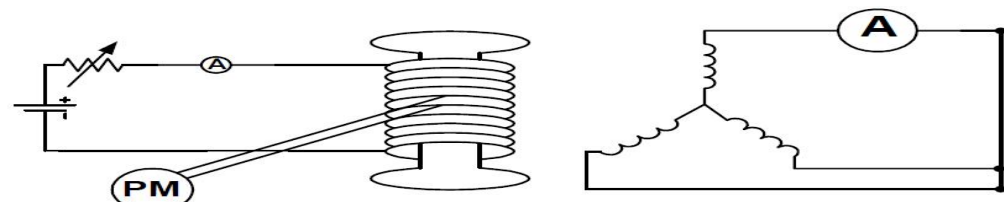Experiment name: **Phasor Diagram of a Synchronous Generator.**

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-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

(a)

(b)phasor diagram for R load

(c)

(d)phasor diagram for R-L load
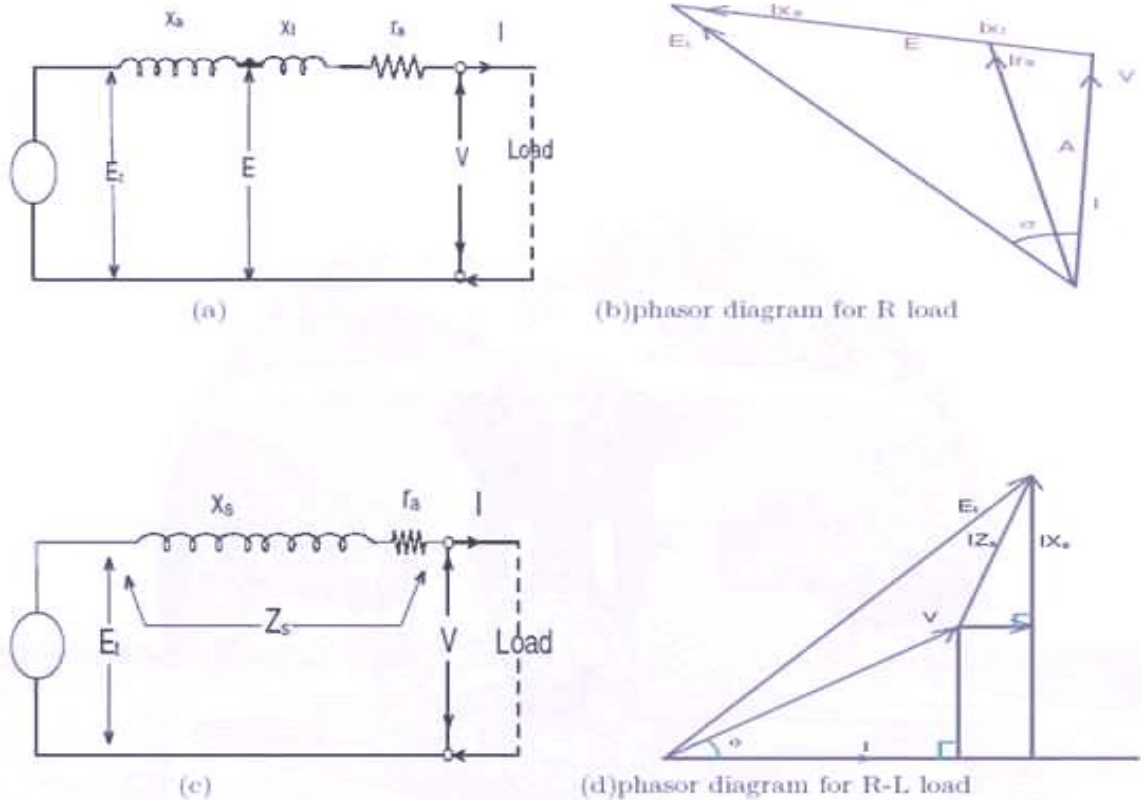
Figure 30: Equivalent circuits

Connection Diagram:

RESISTIVE LOAD

1 2 4	ON OFF	1 2 4	ON OFF	1 2 4

R1 R11 R2 R21 R3 R31

INDUCTIVE LOAD

1 2 4	ON OFF	1 2 4	ON OFF	1 2 4

L1 L11 L2 L21 L3 L31

CAPACITIVE LOAD

1 2 4	ON OFF	1 2 4	ON OFF	1 2 4

C1 C11 C2 C21 C3 C31

SYNCHRONIZING MODULE

L1 L2 L3

ON OFF

R1 Y1 B1   PARALLEL SWITCH H   R2 Y2 B2

DC VOLT / AMMETER MODULE

V   mA   A

5V 150V 250V   150mA 300mA 600mA   0.5A 1A 2A

+/-~

AC VOLTMETER MODULE

V   V   V

50V 250V 500V   50V 250V 500V   50V 250V 500V

+/-~   +/-~   +/-~

AC AMMETER MODULE

A   A   A

1A 5A 10A   1A 5A 10A   1A 5A 10A

+/-~   +/-~   +/-~

1PH WATTMETER MODULE

W

Meters constants of dial

	1.5A	3A
10V	k=0.2	k=0.4
50V	k=1	k=2
250V	k=5	k=10

10V 50V 250V

C   PC1 PC2 PC3
C   CC1   1.5A   3A

K1

V1	A1	A2	A3

I1
L1
K2   I2
R Y B N

3PH AC 0-430V

V2	A4

I3   K3
L N

1PH AC 0-230V

V3	A5

I4   K4
+ -

DC 0-220V

A6	A7

I5 I6
L N   + -

AC 230V ,DC 220V

A1   ARMATURE   A2
M-G

D1   SERIES FIELD   D2

E1   SHUNT FIELD   E2

DC MOTOR / GENERATOR

U1   V1   W1

V2   W2   U2

F1   FIELD   F2

3PH SYNCHRONOUS MOTOR / GENERATOR

34

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.

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 =

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 Isc is the short circuit current then for this value of excitation

$$Z_s = E/Sic$$

At higher values of field current, saturation increases and the synchronous impedance decreases. The value of Zs calculated for the unsaturated region of the O.C.C is called the unsaturated value of the synchronous impedance.

If Ra is the effective resistance of the armature per phase, the synchronous reactance X_s is given by

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

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

$$E = V + IZs$$

Here bold letters indicate complex numbers.

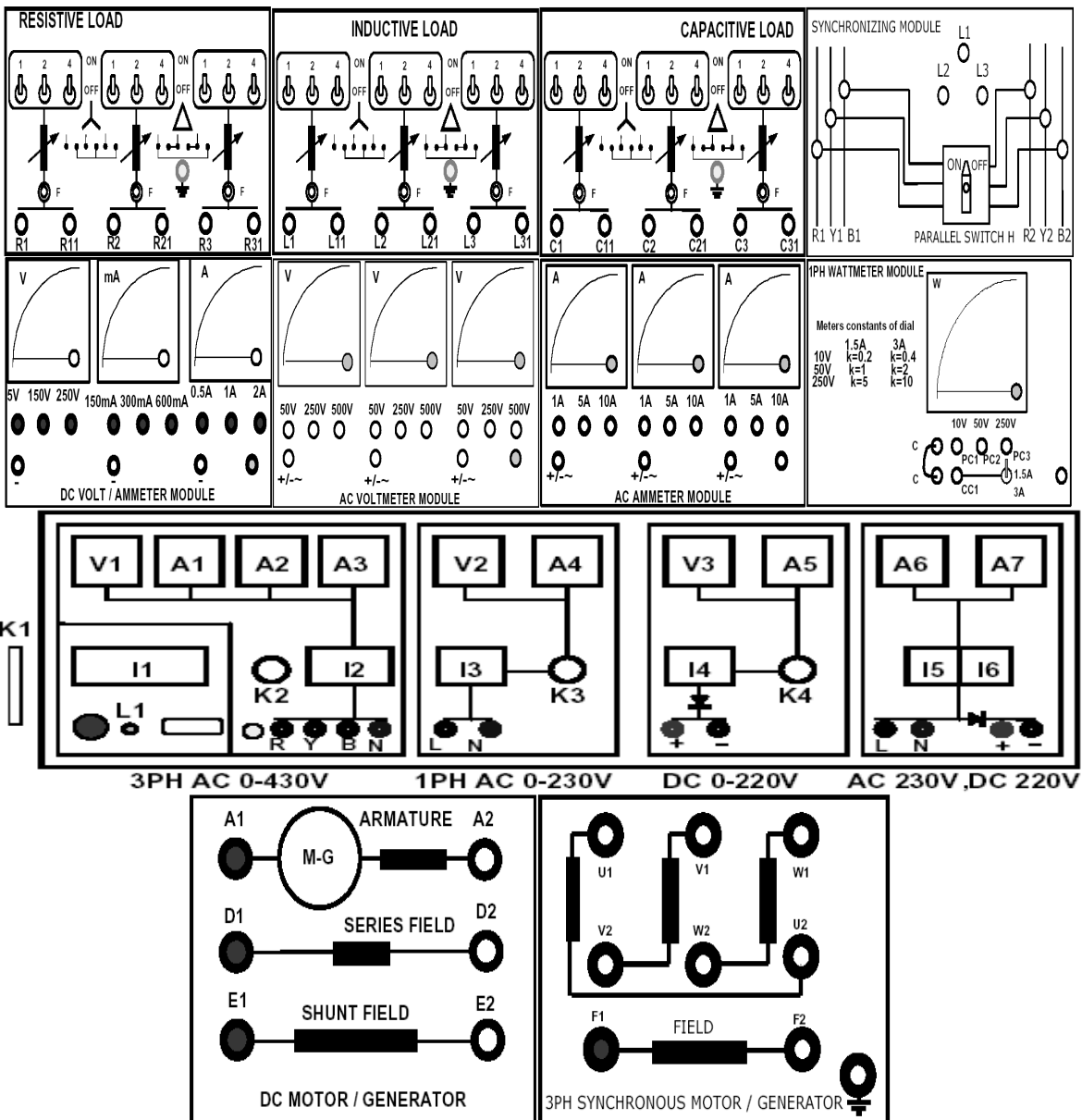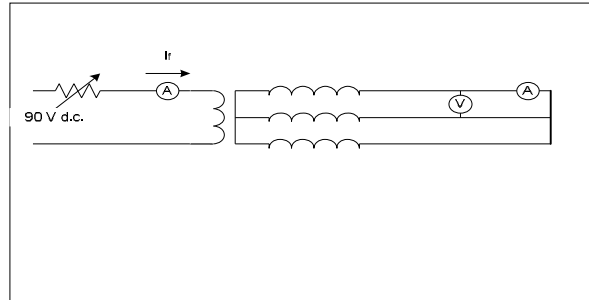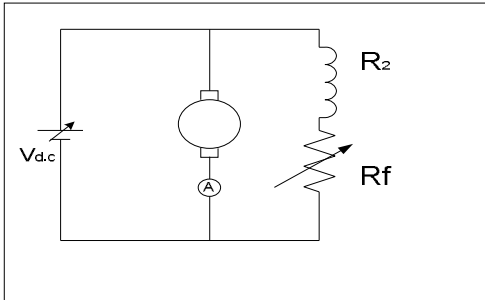Regulation =(E-V)/V
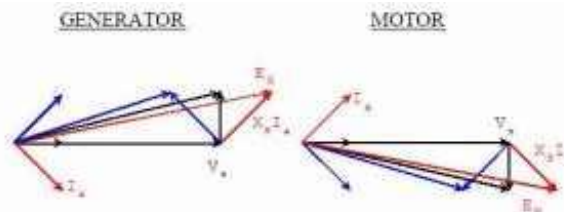
Equipments:

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 2nd 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_ϕ. Comment on the value of EA under leading p.f.
4. Explain the shape of open circuit and short circuit characteristics curve.

<u>Data Sheet</u>

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 =

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

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

Where, I_a is load current and θ is power factor angle

% Regulation = $\dfrac{(Eo - V)}{V} \times 100\%$

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.**
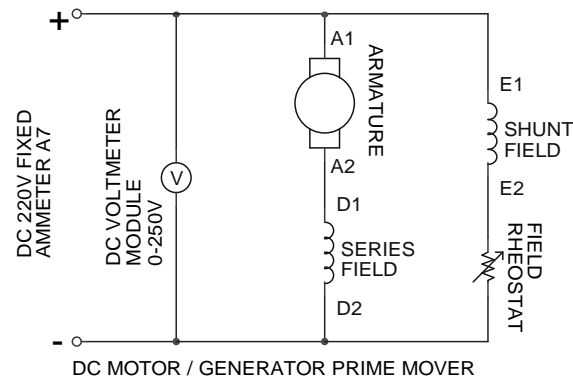

Two BRIGHT and One DARK method
By Siemens & Halske
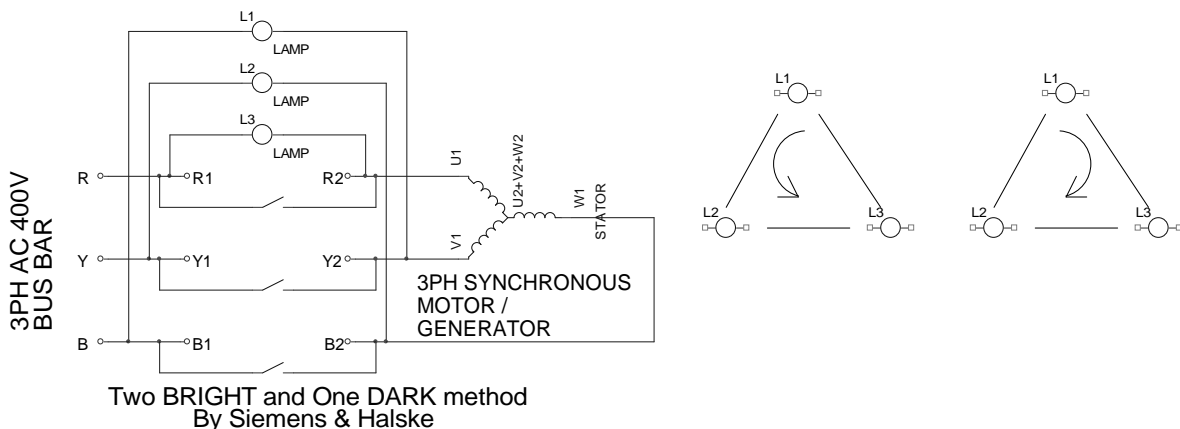
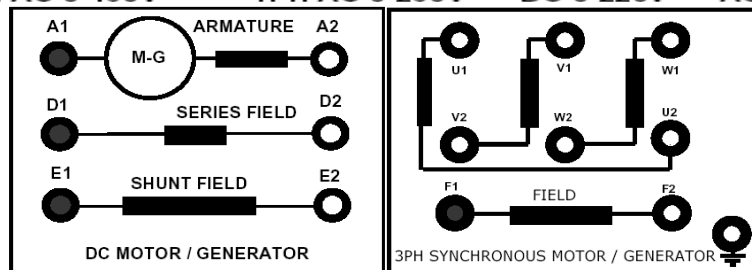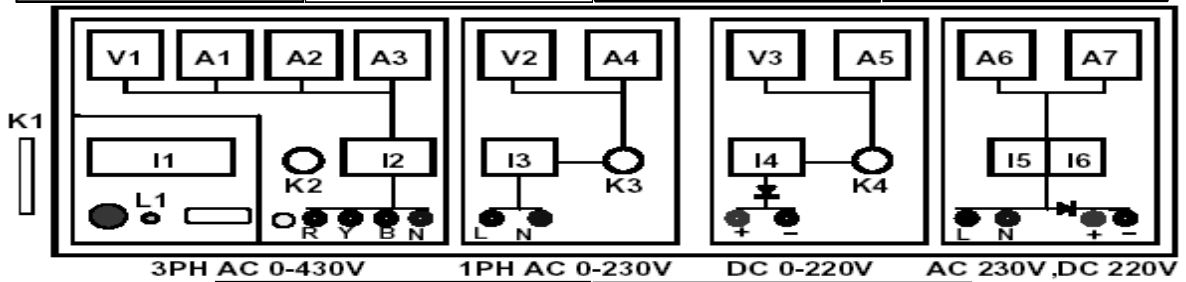Below are the steps for synchronizing generator with the bus bar:

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:

DC MOTOR / GENERATOR PRIME MOVER

AC AMMETER MODULE **
0-10A

AC VOLTMETER MODULE 0-500V

DC AMMETER MODULE 0-0.5A

3PH AC 0-400V

VOLTMETER V1
AMMETER A1, A2, A3

R   R1   R2
Y   Y1   Y2
B   B1   B2

SYNCHRONIZING MODULE

AC VOLTMETER MODULE 0-500V

V1   U1

U2+V2+W2

W1

STATOR

3PH SYNCHRONOUS MOTOR / GENERATOR

DC 0-220V

F1
ROTOR FIELD
F2

VOLTMETER V3
AMMETER A5

RESISTIVE LOAD

INDUCTIVE LOAD

CAPACITIVE LOAD

SYNCHRONIZING MODULE

L1
L2   L3

ON OFF

R1 Y1 B1   PARALLEL SWITCH H   R2 Y2 B2

R1 R11 R2 R21 R3 R31

L1 L11 L2 L21 L3 L31

C1 C11 C2 C21 C3 C31

V   mA   A

5V 150V 250V   150mA 300mA 600mA   0.5A 1A 2A

DC VOLT / AMMETER MODULE

V   V   V

50V 250V 500V   50V 250V 500V   50V 250V 500V

AC VOLTMETER MODULE

A   A   A

1A 5A 10A   1A 5A 10A   1A 5A 10A

AC AMMETER MODULE

1PH WATTMETER MODULE

Meters constants of dial

	1.5A	3A
10V	k=0.2	k=0.4
50V	k=1	k=2
250V	k=5	k=10

W

10V 50V 250V

C   PC1 PC2 PC3
C   CC1   1.5A 3A

K1

V1 A1 A2 A3

I1
L1

K2   I2

R Y B N

V2 A4

I3   K3

L N

3PH AC 0-430V

1PH AC 0-230V

V3 A5

I4   K4

+   −

DC 0-220V

A6 A7

I5 I6

L N   + −

AC 230V ,DC 220V

A1   M-G   ARMATURE   A2

D1   SERIES FIELD   D2

E1   SHUNT FIELD   E2

DC MOTOR / GENERATOR

U1   V1   W1
V2   W2   U2

F1   FIELD   F2

3PH SYNCHRONOUS MOTOR / GENERATOR

43

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?