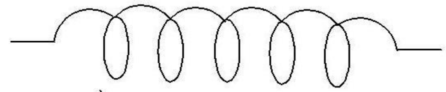
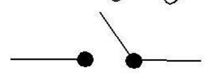
Certain standard symbols

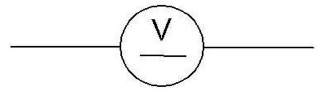
1. Winding



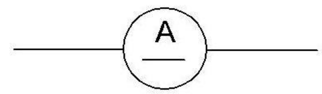
2. Knife Switch



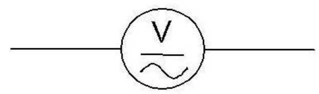
3. Moving Coil Meter



or



4. Moving Iron Meter



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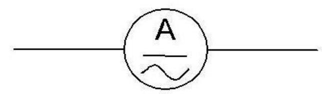
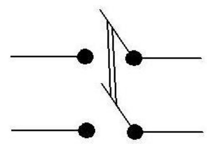
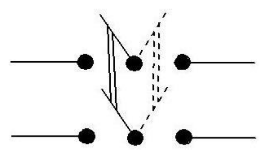
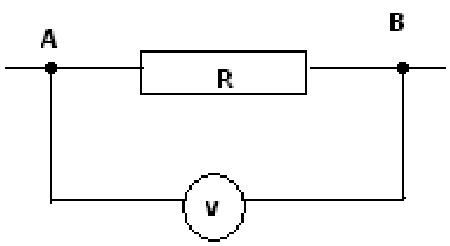


5. DPST

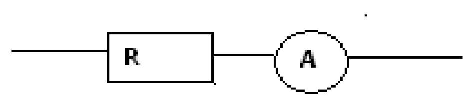


6. DPDT

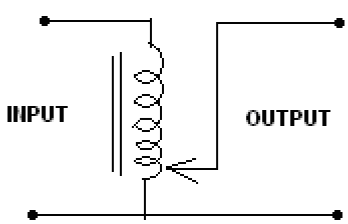




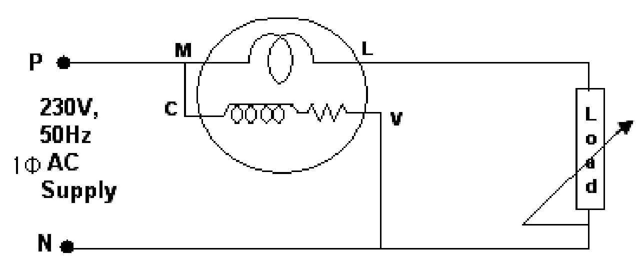
Voltmeter connections in circuit



Ammeter connections in circuit



Variac connections in circuit



Wattmeter connections in circuit

Note: - The standard symbols must be used in the circuit diagram in the report to be submitted.

Precautions and Safety Measures:

1. **All students should wear shoes with rubber sole.**
2. **Dress should be suitable for working safely near the rotating machines (**Loose clothes are NOT allowed).
3. Get your circuit connections approved by the instructors, before switching the power supply ON.
4. Do not touch any live terminals or wires. For making any changes in the connections, you must switch-off the power supply.
5. Be alert and proceed with caution at all times in the laboratory.

INSTRUCTIONS REGARDING CONDUCTION OF THE LAB

COURSE NO. EEE/INSTR F211: Electrical Machines

1. General instructions will be given in the first lab session.
2. Familiarize yourself with the laboratory with the help of instructors.
3. Note down the Name Plate Rating (NPR) of the device(s) / machine(s) for the experiment to be conducted.
4. Read the procedure carefully and be prepared to conduct the experiment.
5. Before starting the experiment:
   (a) Draw the circuit diagram on a separate sheet of paper without consulting the manual. Get it verified by the instructor.
   (b) Write down the instruments and accessories that you need to conduct the experiment (along with their ranges, rating etc.).
6. Connect the circuit components as per the circuit diagram. **Get the circuit connections verified by the instructor before you conduct the experiment.**
7. Carry out the experiment as per the steps given in the manual and record the readings.
8. All the necessary computations are to be carried out in the laboratory itself.
9. Get the readings and subsequent computations verified by the instructor.
10. If you have any suggestions/queries regarding the conduction of the experiment(s), consult the lab instructor prior to the lab session.

EXPERIMENT No. 1

TESTS ON A SINGLE-PHASE TRANSFORMER

Name ____ ID No.____________________________

Sec.No ______________________ Batch No.____________ Marks obtained________________

Date___________________________ Instructor's signature______________________________

---

1. Introduction

Equivalent Circuit

Taking into account each winding resistance and leakage reactance, magnetizing current and no-load losses, a transformer can be represented by the equivalent circuit shown in Fig.1.1. The equivalent circuit, though approximate, is quite accurate for practical purposes.

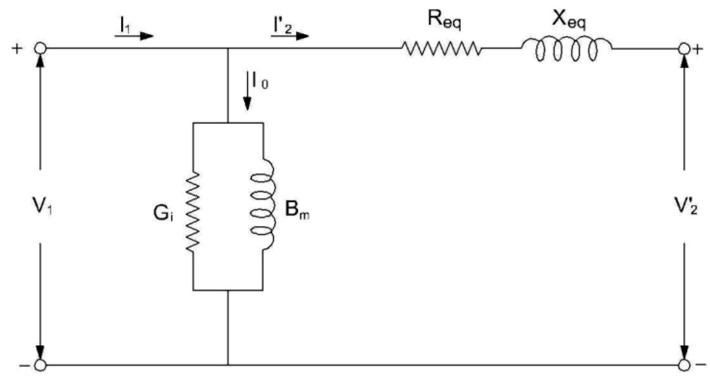


Fig.1.1 Equivalent circuit of transformer

$$R_{eq} = R_1 + R_2^{'} \qquad X_{eq} = X_1 + X_2^{'}$$

Here, R_1 and X_1 are resistance and inductance of primary winding. R_2' and X_2' are the resistance and inductance of secondary winding referred to the primary side.

2. Objective

To determine the parameters of the equivalent circuit of a single-phase transformer and estimate the performance characteristics.

3. Name plate ratings of the transformer to be tested:

……………………………………………………………………………………………..

……………………………………………………………………………………………..

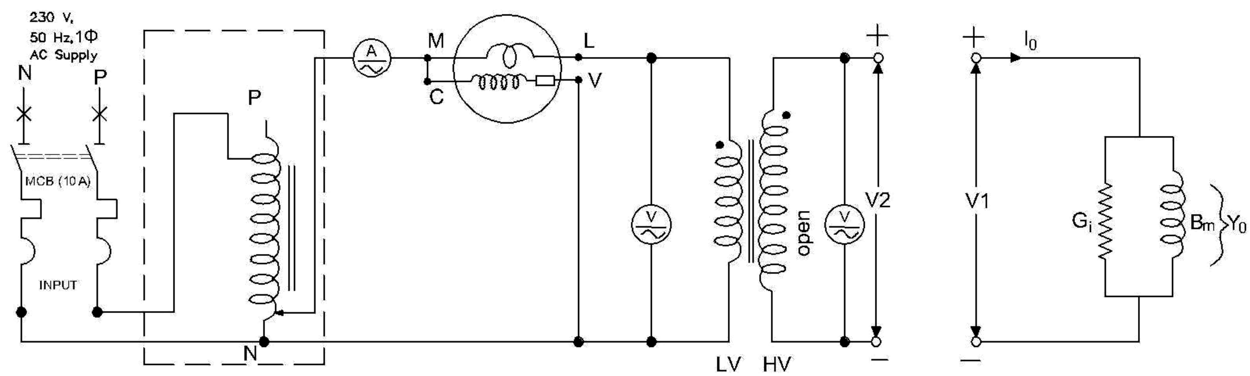
4. Range of instruments and accessories (standard format)

S. No.	DESCRIPTION	TYPE	RANGE	MFR. NAME	MFR. NO.

Note: In O.C. test, voltage applied is rated while current drawn is 5-8% of full-load current.

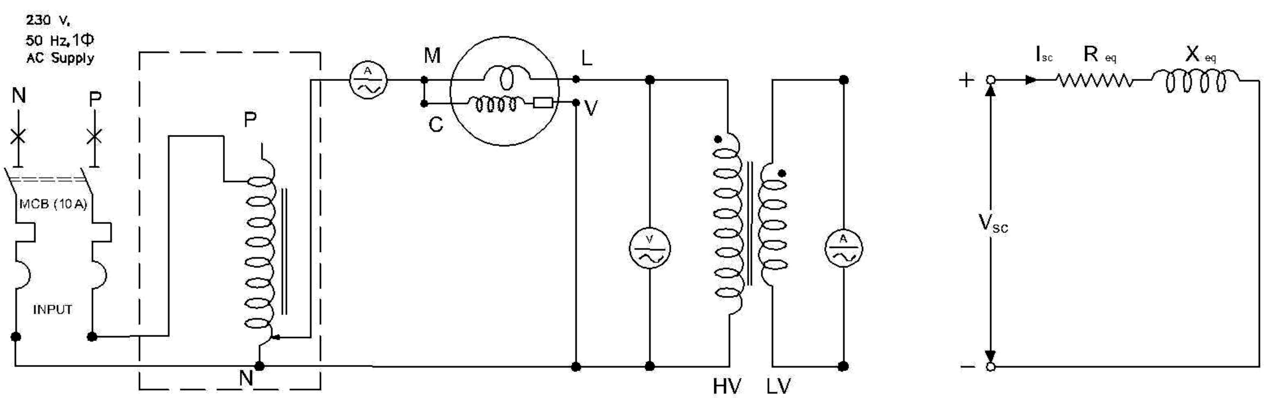
In S.C. test, full-load current is drawn while the voltage applied is 5-8% of rated-voltage.

5. Circuit Diagrams



(a) Circuit diagram *(b) Equivalent circuit*

Fig.1.2 O.C. Test; conducted from LV side



(a) Circuit diagram *(b) Equivalent circuit*

Fig.1.3 S.C. Test; conducted from HV side

6. Methodology

The parameters of the equivalent circuit of Fig.1.1 can be determined by the non–loading tests.

Open Circuit Test – for determining shunt parameters **(G_i and B_m)**

Short Circuit Test – for determining series parameters **(R_{eq} and X_{eq})**

a) Voltage ratio (≈ turns ratio) Test

Now, temporarily connect a voltmeter (of appropriate rating) on HV side (open) and record V_2.

Then, voltage ratio (≈ turns ratio) = $\frac{V_2}{V_1}$ = (1.4)

b) Open Circuit (O.C.) Test

Connect the transformer as in Fig.1.2 (a), keeping the HV side open and LV side to be excited from mains. Switch on the mains and take the following readings.

Readings

Applied voltage (rated), V_1 =

No load current, I_0 =

No load power (= core loss), P_i =

c) Short-Circuit

Conduct the test from HV side with LV short-circuited as in the diagram of Fig.1.3 (a). To circulate full–load current through the transformer, reduced voltage of about 5 -8% of the rated voltage is needed. This supply is obtained from a variac.

Turn the variac wheel to zero voltage output position and then switch on the supply for the transformer under test. Raise the variac voltage gradually till input current to transformer reaches it’s full –load value. Record meter readings.

Readings

Applied Voltage, V_{SC} =

Input current, I_{SC} =

Input power (=copper loss at rated current), P_{SC} =

7. Calculations

$$Y_0 = \frac{I_0}{V_1} = \tag{1.5}$$

$$G_i = \frac{P_i}{V_1^2} = \tag{1.6}$$

$$B_m = \sqrt{\left(Y_0^2 - G_i^2\right)} = \tag{1.7}$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}} = \tag{1.8}$$

$$R_{eq} = \frac{P_{sc}}{I_{sc}^2} = \tag{1.9}$$

$$X_{eq} = \sqrt{\left(Z_{eq}^2 - R_{eq}^2\right)} = \tag{1.10}$$

Table 1.1

Serial No.	1	2	3	4	5	6	7	8
Different transformer Loading (K)	0.15	0.30	0.45	0.6	0.75	0.90	1.05	1.20
Copper loss ($K^2.P_{SC}$) in kW								
Iron loss (P_i) in kW								
Total loss(P_L) = ($P_i + K^2.P_{SC}$) in kW								
Output Power (P_{out}) in kW = K.(Rated kVA).cos θ								
Input Power (P_{in}) in kW = $P_0 + P_L$								
Estimated Efficiency $\eta = \frac{Pout}{Pin}$								

a) Efficiency vs. Load characteristic at 0.8 power factor lag

Output power, P_{out} = K.(Rated kVA).cos θ = K.(Rated kVA).(0.80) =

Iron loss (constant loss) = P_i =

Copper loss = $K^2.P_{SC}$ =

Total loss, $P_L = (P_i + K^2.P_{SC})$ =

Input Power, $P_{in} = P_{out} + P_L$ =

Efficiency, $\eta = \dfrac{\text{Pout}}{\text{Pin}}$ =

b) Maximum Efficiency

Loading at which maximum efficiency occurs, $K_{max} = \sqrt{\dfrac{P_i}{P_{SC}}} =$

Maximum efficiency, $\eta_{max} = \left(\dfrac{K_{max}\,(\text{Rated kVA})\cos\theta}{K_{max}\,(\text{Rated kVA})\cos\theta + 2P_i} \right) =$

η_{max} at 0.8 power factor (lagging/leading) =

η_{max} at unity power factor =

c) Regulation vs. Power factor

Determine the following either on LV or HV side

Rated voltage V = , Rated current I =

R = , X =

Table 1.2

Power factor, cos θ	1.0	0.8	0.6	0.4	0.2
R cos θ					
X sin θ					
Regulation (for lagging power factor) = I(R cos θ + X sin θ) / V					
Regulation (for leading power factor) = I(R cos θ - X sin θ) / V					

Mark the power factor corresponding to zero voltage regulation.

8. GRAPHS:

Draw: (a) Estimated Efficiency vs. output, at 0.8 power factor lag and unity power factor.

(b) Estimated Regulation vs. power factor.

9. RESULTS:

a. Load — Efficiency

Load	Efficiency
$\frac{1}{4}FL$	________
$\frac{1}{2}FL$	________
$\frac{3}{4}FL$	________
FL	________

b. Maximum efficiency =

Load at which maximum efficiency occurs =

c. Power factor at which regulation is zero =

EXPERIMENT No. 2

LOAD TEST ON A DC SHUNT GENERATOR

Name____ ID No.________________________

Sec.No ________________________ Batch No.______________ Marks obtained______________

Date___________________________ Instructor's signature_______________________________

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1. Introduction

Use the circuit diagram as given in Fig. 2.1. With the field resistance adjusted to a certin value by means of the regulating resistnce, the desired no load voltage can be obtained. The external charactersistics (effect of the load on the generated voltage) can then be obtained by a load test with total field resistance remaining fixed in the process. Speed is to be kept constant.

2. Objective

To obtain external characteristic of a DC shunt generator.

3. Name plate ratings:

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

……………………………………………………………………………………………..

4. Range of instruments and accessories (standard format)

S.No.	DESCRIPTION	TYPE	RANGE	MFR. NAME	MFR. NO.

1. Connection Diagram

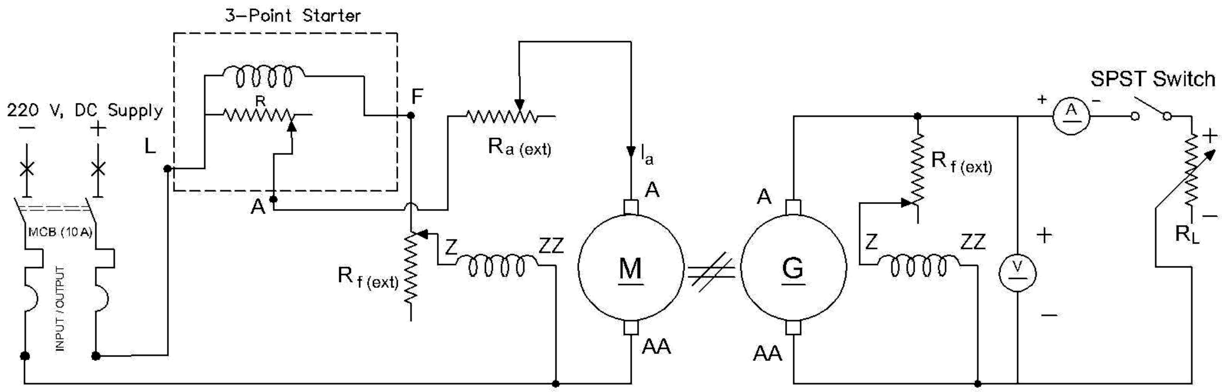

Fig.2.1

6. Methodology:

1. Connect as shown in Fig.2.1.
2. Switch on the supply and run the set at rated speed.
3. Adjust the no-load voltage to the rated value with the help of field regulating resistance R_f in the generator field circuit and note the speed.
4. Connect the load. Increase the load. For each load, note down the load current and voltage across load. Maintain the speed of the set at its no-load value and field resistance of generator is kept constant.

Readings

Generator field resistance =

No-load speed, n_0 = (to be kept constant)

No-load voltage, V_0 =

Table 2.1

V_L										
I_L										

7. Calculations: NIL

8. Graph to be drawn

(1) V_L vs. I_L

9. Results

The external characteristic of the given DC shunt generator is shown in graph.

EXPERIMENT No. 3

OC AND SC TESTS ON A SYNCHRONOUS MACHINE

Name______________________________ ID No.__________________

Sec.No ________________ Batch No.__________ Marks obtained__________

Date__________________ Instructor's signature____________________

1. Introduction

A synchronous machine can be represented by its equivalent circuit (per phase) as in Fig.3.1. The machine is run at rated (synchronous) speed.

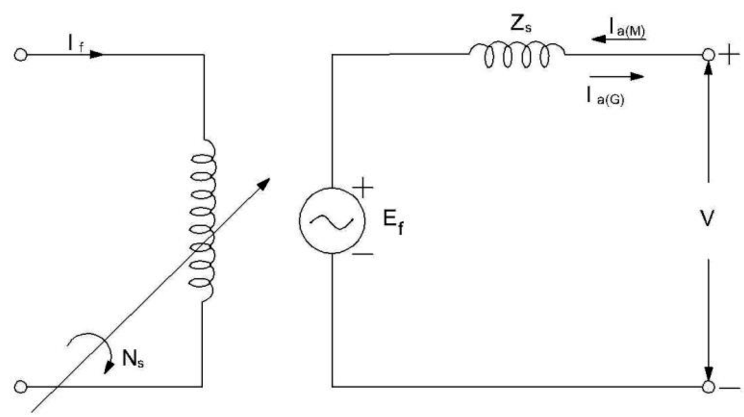

Fig.3.1

The synchronous impedance (Z_s) can be determined by means of O.C. and S.C. tests.

OC Test

The machine is run (as a generator) at synchronous speed with armature terminals open. The graph of V_{OCL} vs. I_f is the O.C.C. (open-circuit-characteristic) which indeed is the magnetization characteristic of the machine. It exhibits the saturation effects.

SC Test

The armature terminals are shorted. The machine is run at synchronous speed and I_f is gradually increased, starting from zero value. The field current needed for $I_{SCL} = I_{FL}$ (rated) is very small. The graph of I_{SCL} vs. I_f is S.C.C. (short-circuit-characteristic). The field current being very small, this operates in linear region. So S.C.C. is a straight line, only one point on S.C.C. corresponding to $I_{SCL} = I_{FL}$ need to be determined experimentally.

2. Objective:

To determine the equivalent circuit parameters of a synchronous machine and hence to estimate the percentage regulation at different power factors.

3. Name plate ratings:

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

4. Range of instruments and accessories (standard format)

S.No.	DESCRIPTION	TYPE	RANGE	MFR. NAME	MFR. NO.

5. Connection Diagram

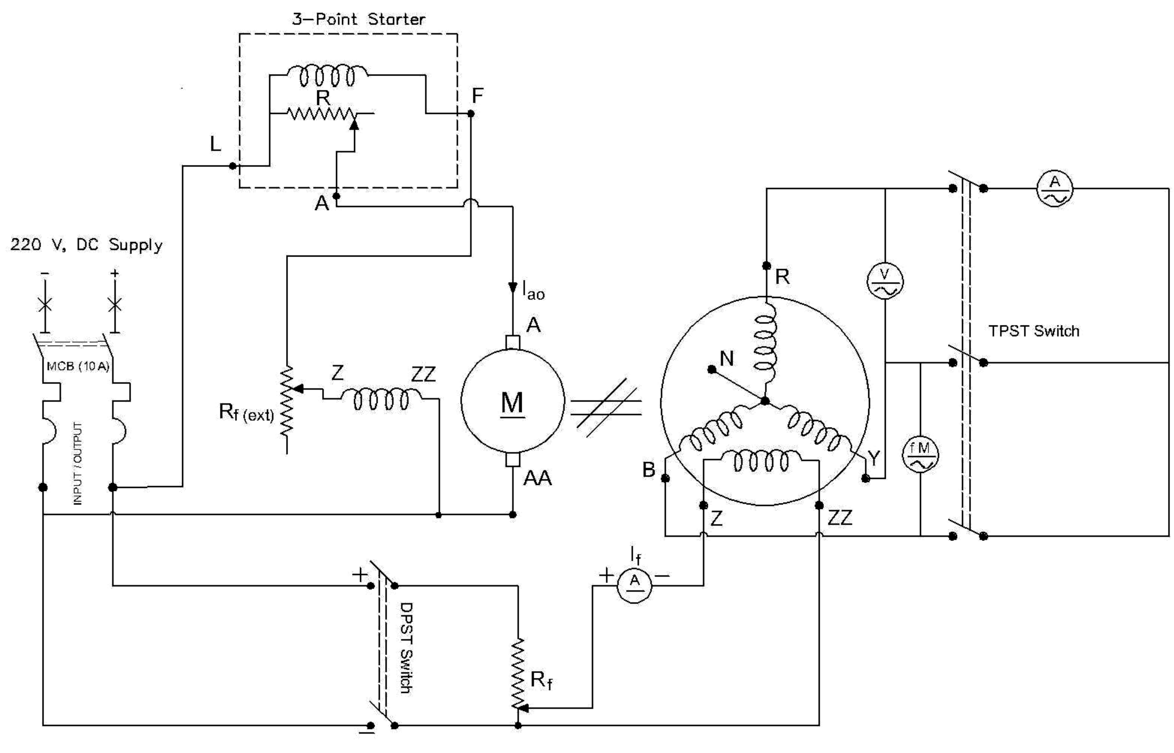

Fig.3.2 Connection diagram for conducting O.C. and S.C. test.

6. Methodology and Readings

The synchronous machine you are required to test is mechanically coupled to a DC shunt motor. Connect the synchronous machine with DC shunt motor as shown in Fig.3.2

O.C. Test

- Keep the TPST switch of the synchronous machine circuit in open state. Start the DC shunt motor of motor- generator (M-G) set. Adjust its speed to the synchronous speed.
- Adjust the potentiometer of synchronous machine field circuit so as to have minimum voltage across the field winding. Then, switch ON the DC mains of the field circuit.
- The synchronous machine is now running as a generator.
- Gradually increase I_f and read the line voltage V. Record the observations in Table 3.1 and plot open circuit characteristic (O.C.C).

Table 3.1 (O.C.C.)

I_f (A)								
V_{OCL} (line) (V)								
V_{OC} (phase) (V)								

SC Test

- With the set running at n_s, switch off the DC excitation of the synchronous machine.
- Close the TPST switch to short circuit the generator terminals.
- Adjust the potentiometer of synchronous machine field circuit so as to have minimum voltage across the field winding. Then, switch ON the DC mains of the field circuit.
- Gradually raise the I_f. Go on till the ammeter reads 15% above the rated value of AC current of the armature.
- Record I_f, I_{SCL} at this value and plot the short circuit characteristic (S.C.C).

Table 3.2

I_f (A)					
I_{SC} (A)					

Measurement of Armature Resistance

Using a DC source, voltmeter and ammeter, take a few readings across two terminals of Synchronous Machine. Record in Table 3.3

Table 3.3

V							
I							

7. Calculations & Results (all calculations are done on per phase basis)

1. Plot the O.C.C. (V_{OCL} vs. I_f)
2. Plot on the same graph S.C.C. (I_{SCL} vs. I_f)

   Using the above graph, calculate the following parameters.

1. $Z_s(unsaturated) = \left(\frac{V_{OC}}{I_{SC}}\right)\Bigg|_{I_f = \text{constant}} =$

2) Calculate Z_s for all values of I_f. Plot Z_s against I_f. Comment on the variation of Z_s and explain reasons for the same.

I_f										
Z_s										

1) Calculate

$$Z_s(adjusted) = \left(\frac{V_{OC}(rated)}{I_{SC}}\right)\Bigg|_{I_f \text{ corresponding to } V_{OC} \text{ (rated value)}} =$$

$$X_s(adjusted) = \sqrt{\left(Z_s(adj)^2 - R_e^2\right)} =$$

Observe that in your calculation of X_s (adj), effect of R_e (phase) can be ignored so that

$X_s(adj) = Z_s(adj)$

2) Calculate the percentage regulation at full load 0.8 power factor lag/ lead and unity power factor for synchronous generator.

8. Graphs

O.C.C., S.C.C. and Z_S vs. I_f.

9. Results

Percentage regulation at upf =

at 0.8 pf lag =

at 0.8 pf lead =

EXPERIMENT NO.4

MEASUREMENT OF POWER IN THREE-PHASE CIRCUIT

Name____ ID No.______________________

Sec.No _______________________ Batch No.____________ Marks obtained____________

Date__________________________ Instructor's signature____________________________

1. Introduction

Use the circuit diagram shown in Fig. 4.1. A three phase induction machine coupled with a DC generator is used as the load. The load is gradually increased. Two- wattmeter method is used for the power measurement - active power, reactive power and power factor.

2. Objective

To measure the active power, reactive power, apparent power & power factor in the three phase circuit by two-wattmeter method.

3. Name plate ratings:

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

4. Range of instruments and accessories (standard format)

S.No.	DESCRIPTION	TYPE	RANGE	MFR. NAME	MFR. NO.

5. Connection diagram

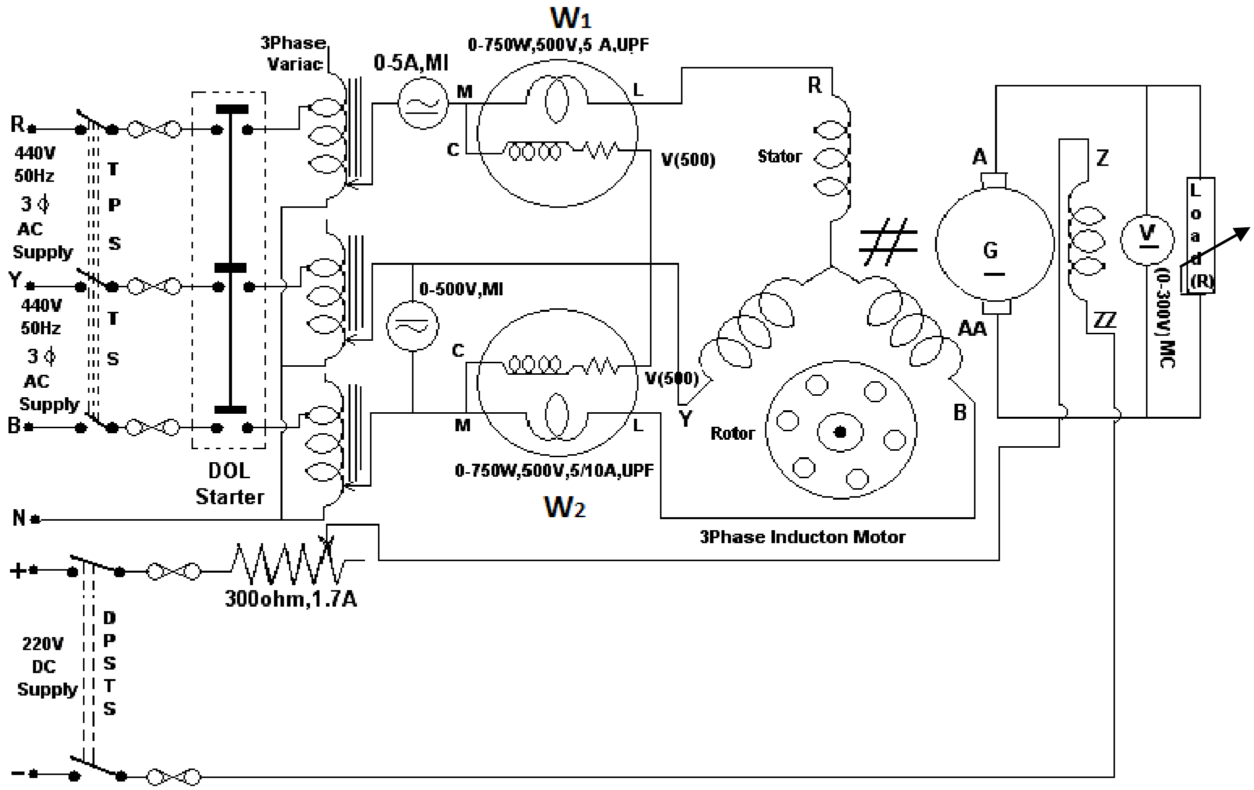

Fig 4.1: Power measurement by using two-wattmeter method

6. Methodology and Readings

1. Make the connections as per circuit diagram given in Fig.4.1.
2. Consider two watt meters as W1 and W2.
3. Calculate multiplication factor of each watt meter by observing ranges which you have selected.
4. Check the circuit connections. Switch on the main supply.
5. Note that you connected COM terminal of watt meters to one of its pressure coil terminals i.e. M and voltage range terminal (V--) to third phase line(Y) .
6. You observe that the pointer of one of the wattmeter gives some reading. (If you do not observe it, then immediately switch off the supply and check the connections once again).
7. Now in the watt meter which kicks back, interchange the connections of the two terminals of its pressure coil (i.e. connect COM terminal to third phase line (Y) and voltage range terminal to 'M').Assume the reading of this wattmeter is negative,
8. Note readings of the wattmeter's, ammeter& voltmeter.

$$\text{Multiplication Factor (MF) of Wattmeter (WM)} = \frac{\text{(P.C. range} \times \text{C. C. range} \times \text{pf)}}{\text{(Total no. of divisions on the scale)}}$$

1. Multiplication factor (M.F.) of W1 =________________

2. Multiplication factor(M.F.) of W2 =_________________

7. Observations:

Table 4.1

S.NO	Wattmeter1 ×MF (W_1) Watts	Wattmeter2 ×MF (W_2) Watts	Ammeter (I_L) Amps	Voltmeter (V_L) Volts	Active Power (KW)	Reactive Power (KVAR)	Apparent Power (KVA)	Power Factor CosΦ
Load 0								
Load I								
Load II								
Load III								
Load IV								
Load V								

8. Calculations

1. Reading of wattmeter 1
   W_1 = No. of Div.× M.F. = ____________________

2. Reading of wattmeter '2'
   W_2 =No. of Div.× M.F. = _____________________

3. Active power in three phase load;
   $P = W_1 + W_2$ = ______________

4. Reactive power in three phase load;
   $Q=\sqrt{3}\,(W_2 - W_1)$ Vars = _____________________
5. Apparent power in three phase load
   $S= \sqrt{P^2 + Q^2}$

6. Power factor of the load
   p.f. $=\cos(\tan^{-1}(Q/P))$ =_____________________

9. Graphs :NIL

10. Results