SAMRAT ASHOK TECHNOLOGY INSTITUTE (S.A.T.I.) Vidisha

ELECTRO MECHENICAL ENERGY CONVERSION-I LABORATORY (EE1842)

LAB MANUAL

Department of Electrical Engineering

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Experiment 1

OBJECT: -

(a) To study the effect of variation of field current upon the stator current and power factor with synchronous motor running at no load, hence to draw V and inverted V curves of the motor.
(b) To repeat the above, with synchronous motor loaded to half the full load and 3/4the full load.
(c) To draw the unity power factor curve on the above characteristics.
(d) To compare the above characteristics critically and discuss the effect of loading the motor on the nature of these characteristics.

APPARATUS REQUIRED: -

S. No.	NAME OF INSTRUMENT	RANGE	TYPE	QTY.
1.	Voltmeter	0-500V	M.I.	1
2.	Ammeter	10-20Amp	M.I.	1
3.	Ammeter	0-2Amp	M.C.	1
4.	Rheostat	350 ohms, 1.4A	Wire wound	1
5.	Wattmeter Three phase	10/20 Amp, 300/600V	Dynamo	1
6.	Auto Transformer	3- phase, 440V-12.5 Hp	Start / Run	1
7.	Knife switch	5 Amp	DPDT	1
8.	TPIC Switch	16 Amp	Single Through	1

SPECIFICATION OF MACHINE: -

Power	10 HP
R.P.M	1500
Volts	440V

THEORY: -

With constant mechanical load on the synchronous motor, the variation of field current changes the armature current drawn by the motor and also its operating power factor, as such, the behaviour of the synchronous motor is described below under three different modes of field excitation.

1. Normal excitation:

The armature current is minimum at a particular value of field current, which is called the p field excitation. The operating power factor of the motor is unity at this excitation and thus the mot equivalent to a resistive type of load.

2. Under excitation:

When the field current is decreased gradually below the normal excitation, the armature current increases and the operating power factor of the motor decreases. The power factor under this condition is lagging. Thus, the synchronous motor draws a lagging current, when it is under excited and is equivalent to an inductive load.

3. Over Excitation:

When the field current is increased gradually beyond the normal excitation, the armature current again increases and the operating power factor decreases. However, the power factor is leading under this condition. Hence, the synchronous motor draws a leading current, when it is over excited and is equivalent to a capacitive load.

If the above variation of field current and the corresponding armature current are plotted for a constant mechanical load, a curve of the shape of 'V is obtained as shown in fig. Such a characteristic of synchronous motor is commonly called as 'V' curve of the motor. The characteristic curve plotted between input power factor and the ficld current for a constant mechanical load on the motor are of the shape of inverted 'V' and are known as inserted 'V' curves.

For increased constant mechanical load on the motor, V curves bodily shift upwards as shown in fig. The curve joining the minimum current points of various 'V' curves plotted for different mechanical loads, is normally called a unity power factor compounding curve.

PROCEDURE: -

1. Connect the circuit as per fig.

2. Switch-on the ac supply feeding to 3-phase synchronous motor and start the motor, using the starter

3. Observe the direction of rotation of the motor, in case, it is rotating in opposite direction, stop the motor and reverse the phase sequence. Start the motor again, using the starter. Ensure that the motor is running on no load. 4. In this case, field winding is excited automatically with the help of exciter, provided on the shaft of the main motor.

5. Set the rheostat in the field circuit of the motor to the position of normal excitation. Under this condition, armature will draw minimum current from the mains. Note down the readings of all the meters connected in the circuit.

6. Reduce the excitation in steps and note down the corresponding armature current and reading of both the watt meters. Excitation may be reduced, till the current in the armature winding is of rated value. Under this condition, armature current should increase on reducing the excitation.

7. Again, adjust the rheostat in the field circuit to normal excitation. Now increase the excitation in steps and note-down the readings of all the meters at each setting of increased excitations. Excitation may be increased, till the behaviour of the motor is normal. At large excitation, the motor will try to fall out of step.

8. Adjust the voltage of the dc generator coupled to synchronous motor to rated value by varying the field current of the generator.

9. Load the dc generator to half the full load and maintain it constant throughout the next part of the experiment.

10. Repeat step 5,6, and 7 sequentially under this condition of loading

11. Increase the load on the generator to 3/4th of full load, keeping its voltage constant. Maintain this load constant throughout the next part of the experiment.

12. Repeat step 5, 6 and 7 sequentially for this increased load on the motor. 13. Remove the load on the dc generator gradually.

14. Switch-off the supply to the motor to stop it.

CIRCUIT DIAGRAM: -

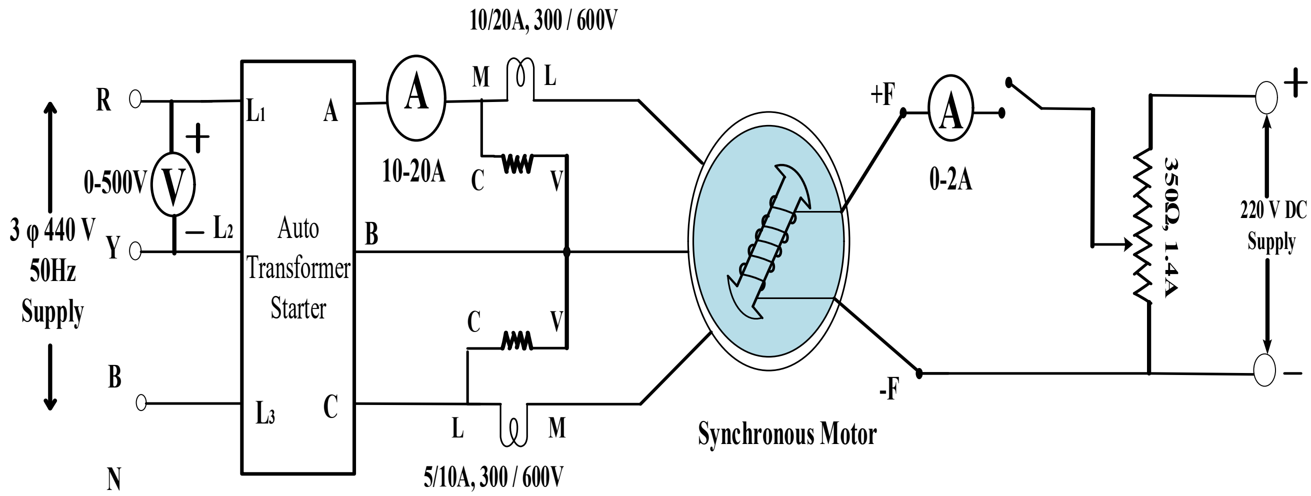


Fig. 1

OBSERVATION TABLE: -

S. No.	I_L	V_L	I_f	W_1	W_2	$W_1 + W_2$	N(rpm)

QUESTIONS: -

1. What are the basic differences between a 3-phase synchronous motor and 3-phase induction motor?

2. What is the magnitude of starting torque in 3-phase synchronous motor?

3. What are various methods of starting a 3-phase synchronous motor? What is the power factor of the motor at normal excitation?

5. What is the nature of power factor, when a synchronous motor is operated () under excited (i) over excited?

6. Draw on the same graph, approximate V curves, corresponding to 25% and 100 percent load. 7. Is it possible to operate a synchronous motor on any other speed than the synchronous speed?

Experiment 2

OBJECT: -

a) Perform no load and short circuit tests on a 3-phase alternator.
b) Measure the resistance of the stator winding of alternator.
c) Find out regulation of alternator at full load and at
   (i) unity p.f. (ii) 0.85 p.f. lagging (iii) 0.85 p.f. leading, using synchronous impedance method.

APPARATUS REQUIRED: -

S. No.	NAME OF INSTRUMENT	RANGE	TYPE	QTY.	remark
1.	Voltmeter	0-500V	M.I.	1	For output
2.	Voltmeter	0-30/60 V	M.C.	1	For Ra
3.	Ammeter	0-20A	M.I.	1	For output current
4.	Ammeter	0-10A	M.C.	1	For Ra
5.	Ammeter	0-2A	M.C.	1	For Ip circuit
6.	Rheostat	350Ω /1.4 A	Wire wound	2	For field circuit
7.	Rheostat	35Ω 1.4 A	Wire wound	1	For armature circuit Of D.C. motor
8.	Tachometer	0-2000 rpm	Pointer Type	1	
9.	Lamp load	230V/200W	Switch able	1	For Ra

SPECIFICATION OF MACHINE: -

(1). D.C. Shunt motor: - 10HP,230V,1440

(2). Alternator: -7.5 KVA, 400/440V, 10.8 A ,1500 rpm

CIRCUIT DIAGRAM: -

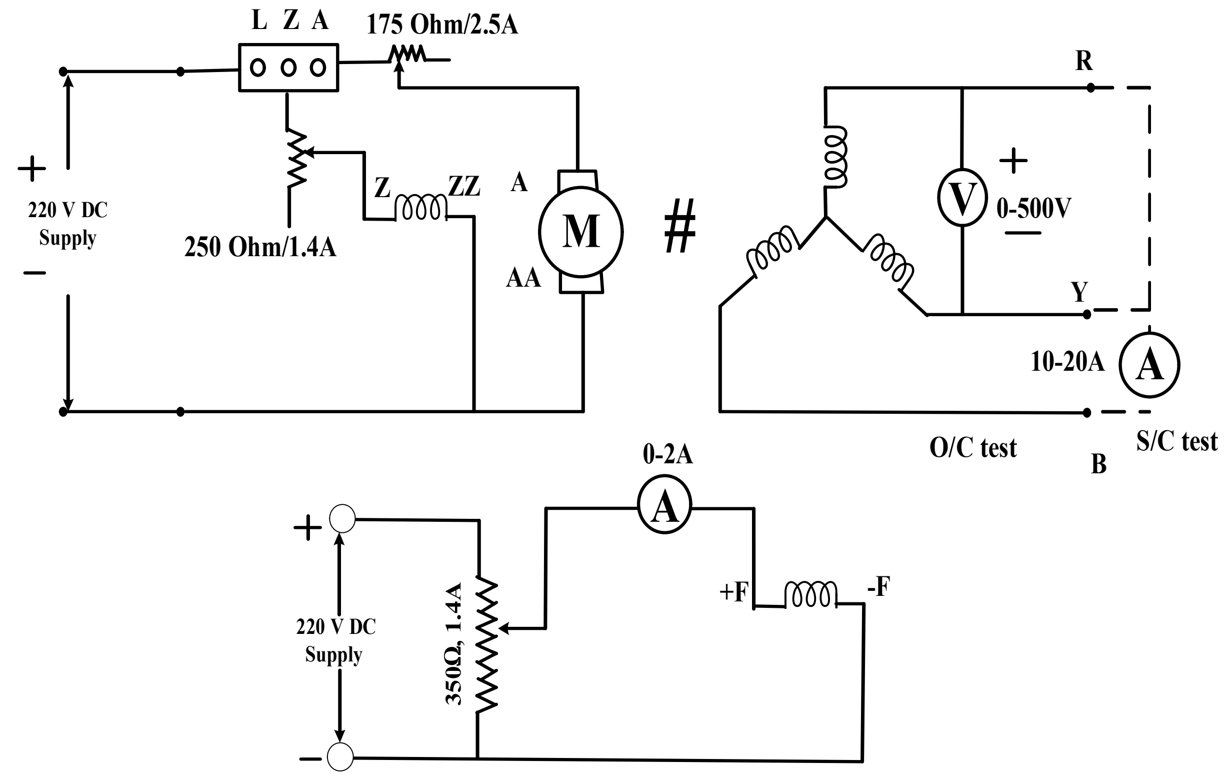


Fig. 2

THEORY AND FORMULA: -

To find out the regulation of alternator by synchronous impedance method, following characteristics and data has to be obtained experimentally,

(i) open circuit characteristic at synchronous speed.

(ii)short circuit characteristic at synchronous speed. (ii) ac resistance of the stator winding, per phase i.e., R_a

Fig. shows the open circuit and short circuit characteristics of a 3-phase alternator, plotted on the phase basis. To find out the synchronous impedance from these characteristics, open circuit voltage, E and short circuit current, I (preferably full load current), corresponding to a particular value of field current is obtained. Then, synchronous impedance per phase is given by,

Synchronous impedance, $Z_a = E_1/I_1$

Then, Synchronous reactance, $X_s = \sqrt{(Z_a^2 - R_a^2)}$

Fig. shows the phasor diagram of the alternator, supplying full load current of I, ampere, lagging the terminal voltage V by an angle p. The open circuit voltage E of the alternator is given by,

$E = V + I_a R_a + I_a X_s$ (Phasor sum)

The diagram has been drawn with the current as the reference phasor and is self-explanatory. The open circuit voltage as finally obtained from the phasor diagram, corresponding to this loading condition is E volts. Then the regulation of the alternator under the above loading condition is given by,

Regulation=(E-V)/V x 100 percent

An approximate expression for the open circuit voltage can be established referring to the phasor diagram.

Open circuit voltage,

$E = \sqrt{(OD^2+DC^2)}$

$=\sqrt{((OF+FD)^2+(DB+BC)^2)}$

(for lagging p.f. load)

The above expression is for lagging power factor load. In case, alternator is operating at leading power factor, open circuit voltage, E can be found out in a similar way and is given by, $E = (V \cos\varphi + I_l R_l^2) - (V \sin\varphi + I_l X_l^2)$ (for leading p.f. load)

The value of regulation obtained by this method is higher than obtained from as actual load test, as such it is called the pessimistic method.

PROCEDURE: -

1. Connect the circuit as per fig

2. Adjust the position of rheostat, Ri for maximum possible current in the field circuit of dc motor, to ensure (i) low starting speed (i) high starting torque. 3. Set the position of rheostat, R for minimum current in the field circuit of alternator, to ensure low value of generated emf at starting.

4. Switch on the dc mains, feeding the dc motor and the field circuit of alternator.

5. Start the dc motor, using the starter properly. Various resistance steps of the starter should be cut out slowly, so that the motor does not draw high current during starting.

6. Set the speed of the motor and hence the alternator at its rated value by varying rheostat, Ri, provided in the field circuit of the motor.

7. Note-down the open circuit voltage of the alternator and the field current. 8. Repeat step 7 for various values of field current (can be obtained by varying the

rheostat, R provided in the field circuit of alternator). Observations should be continued, till the open circuit voltage is 25 to 30 percent higher than its rated value.

9. Set the position of rheostat, R; again, for minimum possible current in the field circuit of alternator.

10. Short-circuit the stator winding of the alternator, by closing the switch, provided for this purpose in the circuit diagram.

11. Note-down the short circuit current and the field current.

12. Repeat step 11, for various values of field current, till the short circuit current becomes equal to the full load current of alternator.

13. Readjust the setting of rheostats R1 and Ra to their initial positions and then switch-off the dc supply to stop the dc motor. 14. Measure the dc resistance of the stator winding by usual voltmeter-ammeter method. To obtain ac resistance, skin effect must be taken into account. As such, ac resistance may be taken approximately 1.3 times the dc resistance measured.

OBSERVATION TABLE: -

S.No.	I_f (O.C. Test)	E_o (O.C. Test)	$E_{ph}=E_o/\sqrt{3}$	I_f (S.C. Test)	I_f (S.C. Test)

S. No.	V	I	$V/I=R_a$	$R_a=[R_{a(av)}/2] * 1.3$	Remark
					$R_{a(av)}/2$ is due to two phases in series

QUESTIONS: -

1. Write down and discuss the approximate expression for the regulation of alternator (i) for lagging load (ii) for resistive load (ii) for leading load.
2. Is the value of synchronous impedance constant at various values of field excitation? If not explain why?
3. Find out the value of synchronous impedance, for various values of field current and plot a curve on the same graph, where o.c & s.c. characteristics have been drawn.
4. Using the same o.c and s.c. characteristics, find out the regulation of alternator at full load and at 0.85 p.f. lagging, using the mmf method. Draw the corresponding phasor diagram and explain the method involved.
5. Discuss in details, why the value of regulation obtained in synchronous impedance method is higher than that obtained from an actual load test.

Experiment 3

OBJECT: -

(a) To measure direct-axis synchronous reactance of synchronous machine.
(b) To measure quadrature-axis synchronous reactance by slip test.

APPARATUS REQUIRED: -

S.No.	Name of instrument	Range	Qty.	Supply
1.	Ammeter	0-10A	1	MI
2.	Ammeter	0-20A	1	MI
3.	Voltmeter	0-75A	1	MI
4.	Wattmeter	5/10Amp,150/300V	1	Dynamo
5.	Single phase variac	0-270V, 7.5A	1	Single phase

SPECIFICATION OF MACHINE: -

Rated KVA	**7.5KVA**
Voltage	400/440V
Rated current	10.8A
Speed	1500 rpm

CIRCUIT DIAGRAM: -

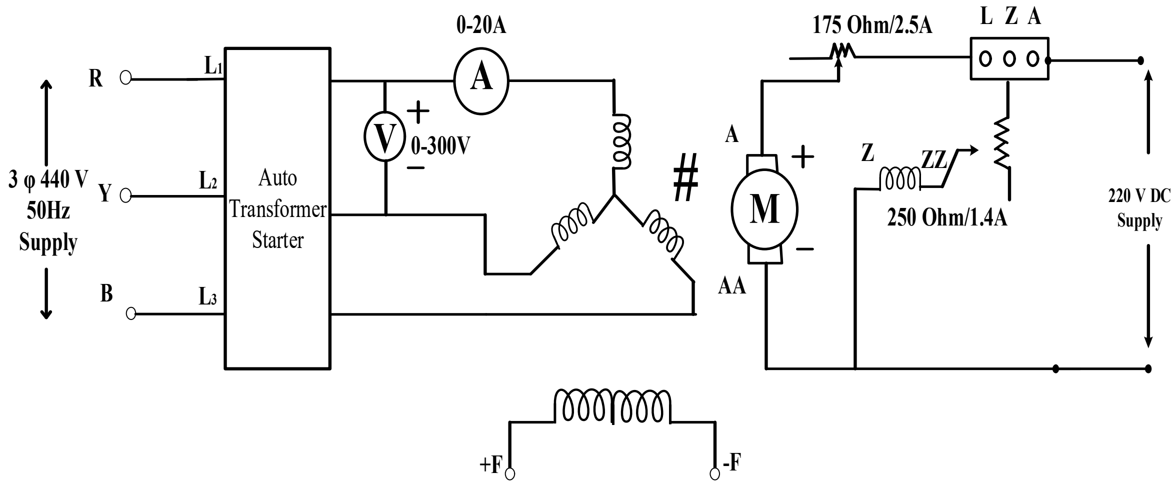


Fig. 3

THEORY: -

Direct-axis synchronous reactance and quadrature-axis synchronous reactance are the steady state reactance of the synchronous machine. This reactance can be measured by performing, open circuit, short-circuit tests and the slip test on a synchronous machine.

(i) Direct-axis synchronous reactance, X_d

The direct-axis synchronous reactance of synchronous machine in per unit is equal to the ratio of field current, I at rated armature current from the short circuit test, to the field current, Is at rated voltage on the air gap line (fig).

Direct-axis synchronous reactance,

$$X_d = I_{fsc} / I_{fo}$$

Thus direct-axis synchronous reactance can be found out by performing open circuit and short circuit test on an alternator.

(ii)Quadrature-axis synchronous reactance, X_q by slip test:

For the slip test, the alternator should be driven at a speed, slightly less than the synchronous speed, with its field circuit open. 3 phase balanced reduced voltage of rated frequency is applied to armature (stator) terminals of the synchronous machine. Applied voltage is to be adjusted, so that the current drawn by the stator winding is full load rated current. Under these conditions of operation, the variation of the current drawn by the stator winding, voltage across the stator winding and the voltage across the field winding will be as shown in Fig. The wave shapes of stator current and stator voltage clearly indicate that these are changing between minimum and maximum values. When the crest of the stator mmf wave coincides with the direct axis of the rotating field, the induced emf in the open field is zero, the voltage across the stator terminals will be maximum and the current drawn by the stator winding is minimum as shown clearly in Fig.

$$X_{ds} = E_{max} / I_{min}$$

$$X_{qs} = E_{min} / I_{max}$$

$$X_q = (X_{qs} / X_{ds})\, X_d$$

PROCEDURE: -

(a) Open circuit test

1. Connect the circuit as per fig.

2. Ensure that the external resistance in the field circuit of dc motor acting as a prim-over for alternator is minimum and the external resistance in the field circuit of alternator is maximum.

3. Switch on dc supply to dc motor and the field of alternator.

4. Start the de motor with the help of starter. The starter arm should be moved slowly, till the speed of the motor builds up and finally all the resistance steps are cut out and the starter arm is held in on position by the magnet of no volt release.

5. Adjust the speed of the dc motor to rated speed of the alternator by varying the external resistance in the field circuit of the motor.

6. Record the field current of the alternator and its open circuit voltage per phase.

7. Increase the field current of alternator in steps by decreasing the resistance and record the field current and open circuit voltage of alternator for various values of field current.

8 Field current of alternator is increased, till the open circuit voltage of the alternator is 25 to 30 percent higher than the rated voltage of the alternator.

9. Decrease the field current of alternator to minimum by inserting the rheostat fully in the field circuit

(b) Short circuit test

10. With the dc motor running at rated speed and with minimum field current of alternator, close the switch s, thus short-circuiting the stator winding of alternator.
11. Record the field current of alternator and the short circuit current.

12. Increase the field current of alternator in steps, till the rated full load short-circuit current. Record the readings of ammeters in both the circuits at every step. 4 to 5 observations are sufficient, as short circuit characteristic is a straight line.

13. Decrease the field current of alternator to minimum and also decrease the speed of dc motor by field rheostat of the motor. 14. Switch off the de supply to de motor as well as to alternator field.

(c) Slip Test

1. Connect the circuit of alternator as shown in fig (10.13), keeping the connections of the de motor same.

2. Ensure that the resistance in the field circuit of de motor is minimum.

3. Switch on the dc supply to the motor.

4. Repeat steps 4 described in (a).

5. Adjust the speed of the dc motor slightly less than the synchronous speed of the alternator by varying the resistance in the field circuit of the motor. Slip should be extremely low, preferably less that 4 percent. 6 Ensure that the setting of 3 phase variac is at zero position.

7. Switch on 3-phase ac supply to the stator winding of alternator.

8. Ensure that the direction of rotation of alternator, when run by the dc motor and when run as a 3-phase induction motor at reduced voltage (alternator provided with damper winding can be run as 3- phase induction motor) is the same.

9. Adjust the voltage applied to the stator winding, till the current in the stator winding is approximately full load rated value.

10. Under these conditions, the current in the stator winding, the applied voltage to the stator winding and the induced voltage in the open field circuit will fluctuate from minimum values to maximum values, which may be recorded by the meters included in the circuit. For better results, oscillogram may be take of stator current, applied voltage and induced voltage in the field circuit.

11. Reduce the applied voltage to the stator winding of alternator and switch off 3 phase ac supply.

12. Decrease the speed of dc motor and switch off dc supply.

OBSERVATION TABLE: -

	O.C. Test		S.C. Test		Slip Test			
S.No	I_f	V_0	I_f	I_{SC}	I_{min}	I_{max}	V_{min}	V_{max}
1								
2								
3								

CALCULATION: -

RESULT: -

QUESTIONS: -

1. Define and discuss with suitable diagrams, the direct-axis and quadrature-axis synchronous reactance, of synchronous machine.

2. Express direct-axis and quadrature-axis synchronous reactance in terms of leakage reactance of stator winding per phase and the armature reaction reactance along the direct-axis and quadrature-axis.

3. What is normally the range of steady state reactance of large rating synchronous machine?

4. Why X_q is less than X_d in salient pole alternators, where as they are approximately equal in non-salient pole alternators?

5. Why synchronous machines are built with high values of steady state reactance?

Experiment 4

OBJECT: -

To Perform the Parallel operation of two 3- phase alternator or incoming alternator with the existing Bus bar by bright lamp method.

APPARATUS REQUIRED: -

S. No.	NAME OF APPARATUS	TYPE	RANGE	QTY.
1.	Voltmeter	M.I.	0-300-600V	2
2.	Rheostat	Wire wound	350ohm.1.4Amp	2
3.	Synchronizing switch Board	Consisting of 3-Set		1
4.	3 phase variac.	Switch manual	0-470V,15 Amp	1

SPECIFICATION OF MACHINE: -

(1). D.C. Shunt motor- 10HP,230V,1440 rpm (2- Set)

(2). Alternators- 400/440V, 7.5 KVA, 1500 rpm, 10.8 A

CIRCUIT DIAGRAM: -

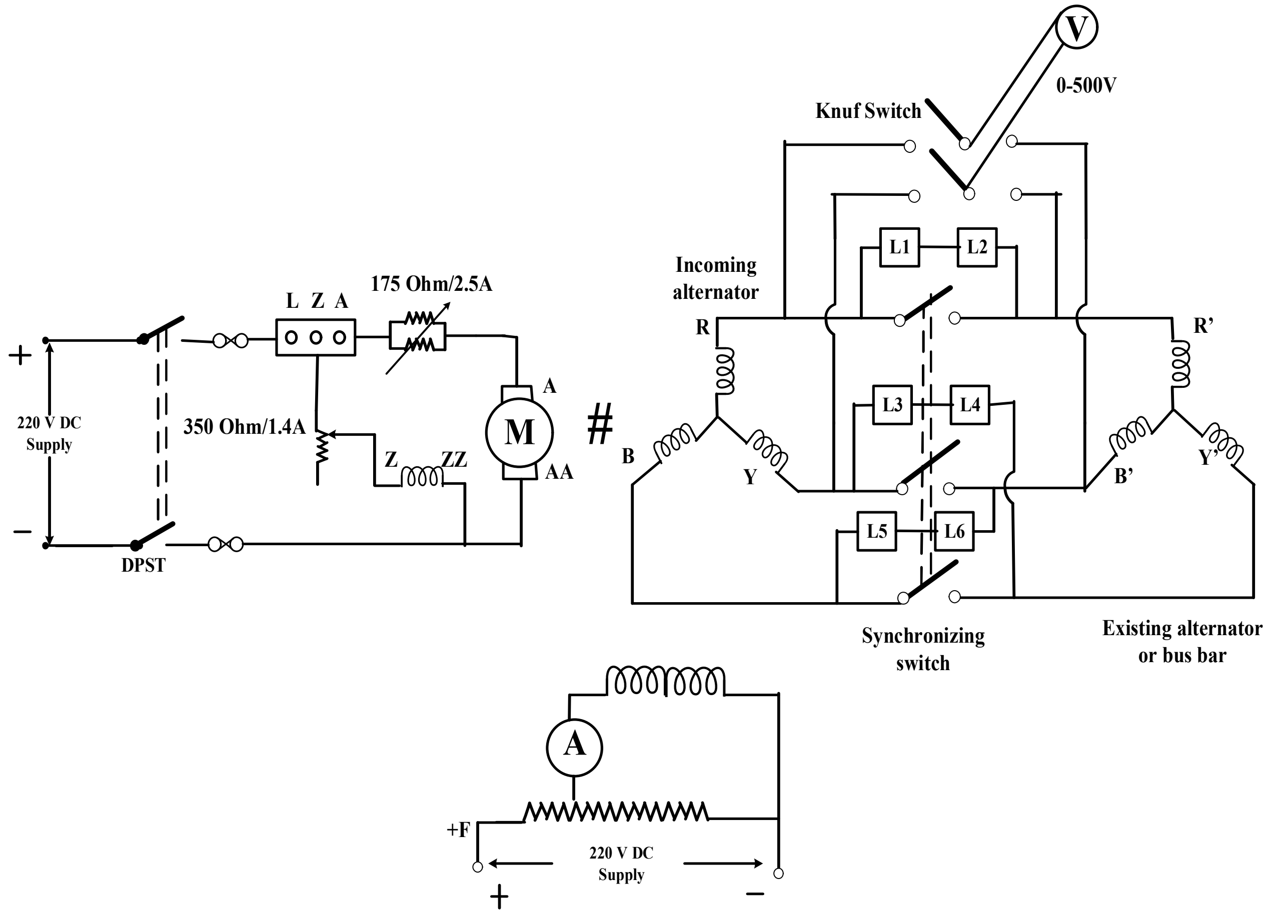


Fig. 4

THEORY: -

A large generating station normally consist of several ac generators to supply the total load on the station. During light load on the generating station, only a few generators are operated to supply the demand. When the load on the station increases heavily other than ac generators are also operated in parallel with the existing generator, in order to cope up with the increased load on the generating station is switching of an incoming alternator to the bs bar is done so that it can operate in parallel with other alternator already connected to the bus bar to share the load on the generating station.

Before an incoming alternator can be synchronized to the bus bar, the following conditions must be fulfilled.

The voltage generated by the incoming alternator is equal to the bus bar voltage. It is advisable to check this condition using the same voltmeter for measuring both voltages.

The phase sequence of he generated voltage of incoming alternator is the same as that of bus bar voltage.

The frequency of the generated voltage of incoming alternator is the same as the bus bar frequency.

Conditions:

- Can be satisfied by equalizing the two voltages which are indicated by a voltmeter other condition of synchronization are indicated by a synchronoscope and by lamp method, before using any one of the above methods to ascertain condition b and c the speed of the incoming alternator is adjusted to its rated value by varying the field current of the dc motor, which is the prime mover for this alternator. Synchronoscope is a device by means of which we can correctly deduct the frequency or the speed of the incoming alternator with respect to the busbar, the device is fed by he generated to the phase voltage of the incoming alternator on one side and by the bus-bar phase voltage on the other side.
- It clearly indicates by a printer whether the incoming alternator is running fast or slow, as per the indication obtained by this device, the speed of the alternator can be increased or decreased as in case may be equalized the frequency of the alternator with that of bus bar.
- To indicate the correct equalization of the frequency and the same phase sequence of the incoming alternator and bus bar, dark lamp synchronization or bright lamp synchronization are generally used in the laboratory. In dark lamp method of synchronization all the three sets of bulbs become dark at the same time at different instant become bright at the same time. The three sets of lamps are connected directly across the phases R-R', Y-Y', B-B' of the incoming alternator and that of bus bar so that synchronizing of incoming alternator is carried out while all the three sets of lamps are dark. This method of synchronizing is not preferred because it is easier to judge the instant of the bright period then the instant of the dark period at the time of the synchronizing. Hence the bright lamp method is commonly used for synchronizing the incoming alternator with the bus-bar.

PROCEDURE: -

(1) Make the connections as per the ckt diagram.

(2) Ensure that the synchronizing switch is open external resistance in the fields ckt. of the motor is Zero and external resistance in the field ckt. of alternator is maximum.

(3) Switch on the D.C. supply to the D.C. motor& start it swing the stator

(4) Adjust the speed of the D.C. motor to rated speed of alternator varying the rheostat in its field ckt.

(5) Switch on the D.C. supply to the field of alternator & adjust the field current, so that the generated voltage of the alternator is equal to the bus bar voltage.

(6) Switch on the bus bar voltage the three set of lamps will flicker in case flickering is fast adjust slowly the speed of the incoming alternator so that its frequency become equal to the bus bar frequency. check the equality of two voltage that of the alternator bus bar again under such a condition the set of lamps will go in & out very slowly.

(7) Observe that the phase sequence of the alternator is the same as that of bus bar, which can be checked by the order of the set becoming dark and bright as per the connection of the set of lamps, one set is directly connected between the same phases, should be dark & at the same instant the other two set of lamps which are cross connected should be bright.

(8) Watch for the correct instance of synchronizing with the synchronizing switch in hand and close this switch when the directly connected set of lamps is dark & the other two set of lamps are equally bright thus synchronizing the incoming alternator with bus bar.

(9) Switch off the synchronizing switch bus bar switch & than the d.c. means to step the d.c. motor & the alternator

RESULT: -

An alternator can be synchronized with the bus. At the time of synchronization, voltage and frequency of the incoming alternator should be equal to the bus voltage and frequency and hence equal to the voltage with respected to the external load.

QUESTIONS: -

1. Discuss the dark lamp method of synchronisation, giving a suitable diagram for the connection of set of lamps.

2. Discuss in details, how synchrono-scope is helpful in synchronising an alternator with the bus.

3. What will happen, if the schronisation switch is closed at wrong instant?

4. What is the condition of the incoming alternator, when it has been synchronised ?

Experiment 5

OBJECT: -

To measure negative sequence reactance X_2 of of the 3- ϕ Synchronous machine.

APPARATUS REQUIRED: -

S. No.	NAME OF INSTRUMENT	RANGE	TYPE	QTY.	SUPPLY
1.	Ammeter	0-10Amp	M.I.	1	A.C.
2.	Rheostat	350Ω 1.4 A	Wire wound	2	-
3.	Rheostat	35Ω 4.5 A	Wire wound	1	-
4.	Voltmeter	0-150 V	M.I.	1	A.C.
5.	Wattmeter	150/300V,10A	M.I.	1	A.C.
6.	Variac	230V,1-ph.	A.C.	1	A.C.
7.	Lamp load	230V,1-ph.	Resistive load	1	-

SPECIFICATIONS OF MACHINES: -

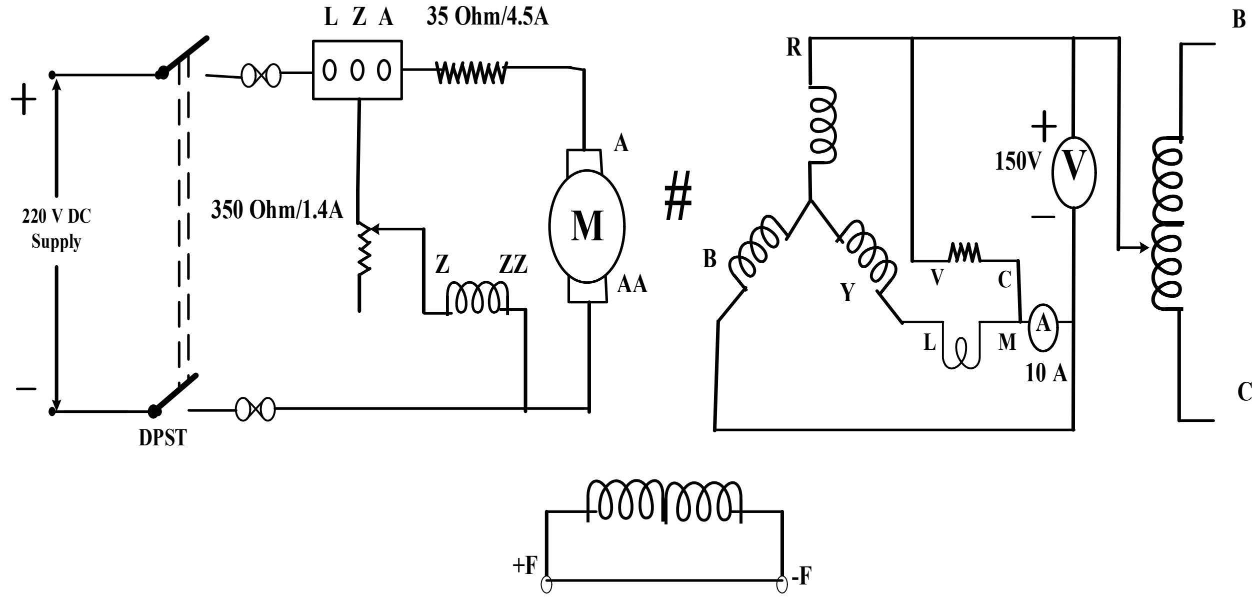
D.C. shunt motor

Power	10 HP
R.P.M	1440
Volts	220V

Salient pole type alternator

Power Rating	7.5 KVA
Rated voltage	440 V
Speed	1500 rpm
Rated current	10.8 Amp

CIRCUIT DIAGRAM: -



THEORY: -

- Negative sequence reactance of the synchronous machine can be measured I the number of ways. One possible method follows directly from its basic definition, where the machine is run at rated speed with its field winding closed and balance voltage of the negative sequence applied on the armature terminals. Then the ratio of impressed voltage per phase to current gives the value of negative sequence impedance. Negative sequence reactance can be found out by a watt meter also in the circuit. However, the method suggested below is the most convenient to measure the X_2. To measure the negative sequence reactance X_2 of synchronous machine, the concept of single-phase line to line sustained short circuit at the terminal of stator winding may be adopted.
- The synchronous machine is to be driven at rated speed as an alternator.
- Single phase line to line short circuited is created between the two terminals of the stator winding of alternator.
- Alternator is excited at reduced field current, so that the current is short circuited phases does not exceed the rated value.
- Let the voltage across the open terminal and one of the terminals of short circuited phases be V volt and the current and power in the short circuited phase be I amp. and P watts respectively.

$Z_2 = V/\sqrt{3}\,I$ $\qquad$ $\cos\phi = W/\sqrt{3}VI$

$X_2 = Z_2 \cos\phi$ $\qquad$ $X_2 = X_d'' + X_q''/2$

Negative sequence reactance X_2 is approx. equal to the average of the direct and quadrature axis sub transient reactance.

PROCEDURE:

- Connect as per the circuit diagram
- Ensure that the external resistance in the field circuit of the motor is practically zero.
- Ensure that the external resistance in the field circuit of the alternator is maximum.
- Switch on the DC supply to the DC motor and start it by the starter observing that the starter arm is moved slowly till the motor build up its speed and finally all the starting resistance steps are cut out.
- Adjust the speed of the DC motor to rated speed of the alternator by the rheostat provided in the field circuit of the motor.
- Switch on the DC supply to the field circuit of the alternator.
- Adjust the field current of the alternator by the rheostat provided in the field circuit so that the current in the short-circuited phases as read by the ammeter is rated full load current.
- Record the reading of all the meters connected in the circuit.
- Switch off the DC supply both of the field circuit of alternator and of DC motor.

OBSERVATION: -

S.No.	Voltage	Current	Watts	$Z_2=V/\sqrt{3}\,I$	$\cos\phi=W/\sqrt{3}V\,I$	$X_2= Z_2 \cos \phi$

CALCULATION & RESULTS: -

QUESTIONS: -

1. Define negative sequence reactance of synchronous machine.

2 Discuss along with circuit diagram an alternative method for the determination of negative sequence reactance.

3. What is normally its value as compared to direct-axis synchronous reactance?
4. Express negative sequence reactance in terms of sub transient reactance of synchronous machine and give an explanation for this relationship.

5. What is the typical value of negative sequence reactance in per unit for larger rating alternators?

Experiment 6

OBJECT: -

(a) To measure the direct-axis sub transient reactance of synchronous machine.

(b) To measure the quadrature-axis sub transient reactance.

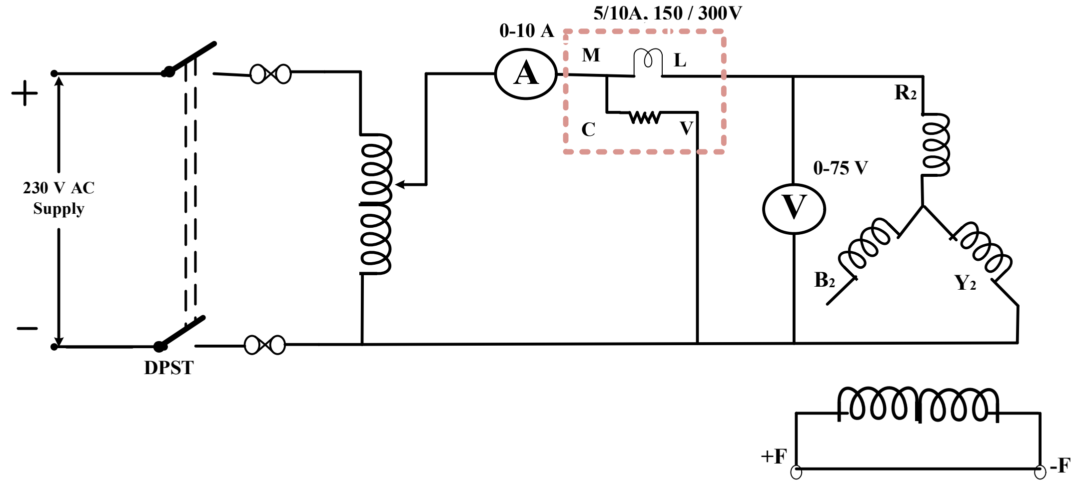
APPARATUS REQUIRED: -

S.No.	*Name of instrument*	*Range*	*Qty.*	*Type of instruments Supply*
1.	Ammeter	0-10A	1	MI
2.	Ammeter	0-20A	1	MI
3.	Voltmeter	0-75A	1	MI
4.	Wattmeter	5/10Amp,150/300V	1	Dynamometer
5.	Single phase variac	0-270V, 7.5A	1	Fully variable

SPECIFICATION OF MACHINE: -

Rating of the machine	**7.5 KVA**
Voltage	400/440 V
Rated current	10.8 A
Speed	1500 rpm

CIRCUIT DIAGRAM: -



THEORY: -

The direct-axis and quadrature-axis sub transient reactance's of 3- phase synchronous machine be measured by applying a reduced single-phase voltage to the two stator phases connected in series, with the field winding short circuited and the machine being stationary. The rotor is moved by hand, so that the current in the short-circuited field winding is maximum. Under this condition. The reactance offered by the armature is direct axis sub transient reactance i.e.

$$X_d'' = V/2I''$$

Next the rotor is turned through half a pole pitch, so that q-axis coincides with the crest of the armature mmf and the current in the field winding is minimum. The reactance offered by the armature under this condition will be quadrature-axis sub transient reactance. This method necessitates an exact alignment of the rotor with the armature mmf wave, which is not possible. As such a more convenient method discussed below can be adopted for the measurement of sub transient reactance's.

Direct-axis sub-transient reactance X_d''

Direct-axis sub transient reactance can be determined by applied voltage method (most convenient method), in which single phase voltage of reduced magnitude and of rated frequency is applied across the two terminals of the stator winding, the third being left isolated.

$\cos\phi = W/Vmax*1min$	$\cos\phi = W/Vmin*1max$
$Z_d'' = Vmax/2/1min$	$Zq'' = Vmin/2/1max$
$X_d'' = Zd''*\cos\phi$	$Xq'' = Zq''*\cos\phi$

PROCEDURE: -

- Connect the circuit as per diagram
- Ensure that the moving knob of single phase variac is at zero position
- Switch on the ac supply.
- Apply reduce voltage to the circuit consisting of stator terminal A & B in series, so that the current flowing in the stator winding is of full load value. Record the voltage applied and the current flowing in the circuit.
- Repeat the step 4 with stator terminal B and C connected in series.
- Repeat the step 4 with stator terminal C and A connected in series.

- Repeat the step 4,5,6 for a new position of the rotor, to confirm that the value of K & M is same for both the position of rotor.
- Switch off the supply.

OBSERVATION TABLE: -

For RY phase							
S.No.	**I (amp)**		**V (volt)**		**WATTS**	**Xd”**	**Xq”**
	MIN	**MAX**	**MIN**	**MAX**		**(ohm)**	**(ohm)**
For YB phase							
For BR phase							

CALCULATION: -

RESULT: -

Mean X_d” (p.u.) =

Mean X_d” (p.u.) =

Base Impedance $Z_{base} = V_L / \sqrt{3}\, I_{base}$

QUESTIONS: -

1. Will the sub-transient phenomenon occur in synchronous machines without damper winding?
2. Define and discuss sub-transient reactance with suitable diagrams.

3. Out of the sub-transient reactance, why X''_q is higher than X''_d for salient pole synchronous machines?
4. What is approximately the range of these reactance as compared to steady state reactance?
5. What is the relationship of X_q'' with X_q' and X_q for a salient pole synchronous machine?

Experiment 7

OBJECT: -

(a) Perform open circuit and short circuit test on a 3-phase alternator.
(b) Perform load test on 3-phase alternator with highly lagging load, (Approximately zero power factor) and at rated voltage with rated current flowing in the stator winding.
(c) Draw open circuit and zero power factor saturation characteristics of the alternator on the same graph.
(d) Calculate the regulation of alternator by drawing the proper phasor diagrams, connected with the above characteristics.

APPARATUS REQUIRED: -

S.No.	*Name of instrument*	*Range*	*Qty.*	*Type of instruments Supply*
1.	Ammeter	0-10A	1	MI
2.	Ammeter	0-2A	1	MC
3.	Voltmeter	0-500V	1	MI
4.	Rheostat	350 Ohm/1.4 A	2	Single tube
5.	3- Phase highly inductive load	-	1	Lagging

SPECIFICATION OF MACHINE: -

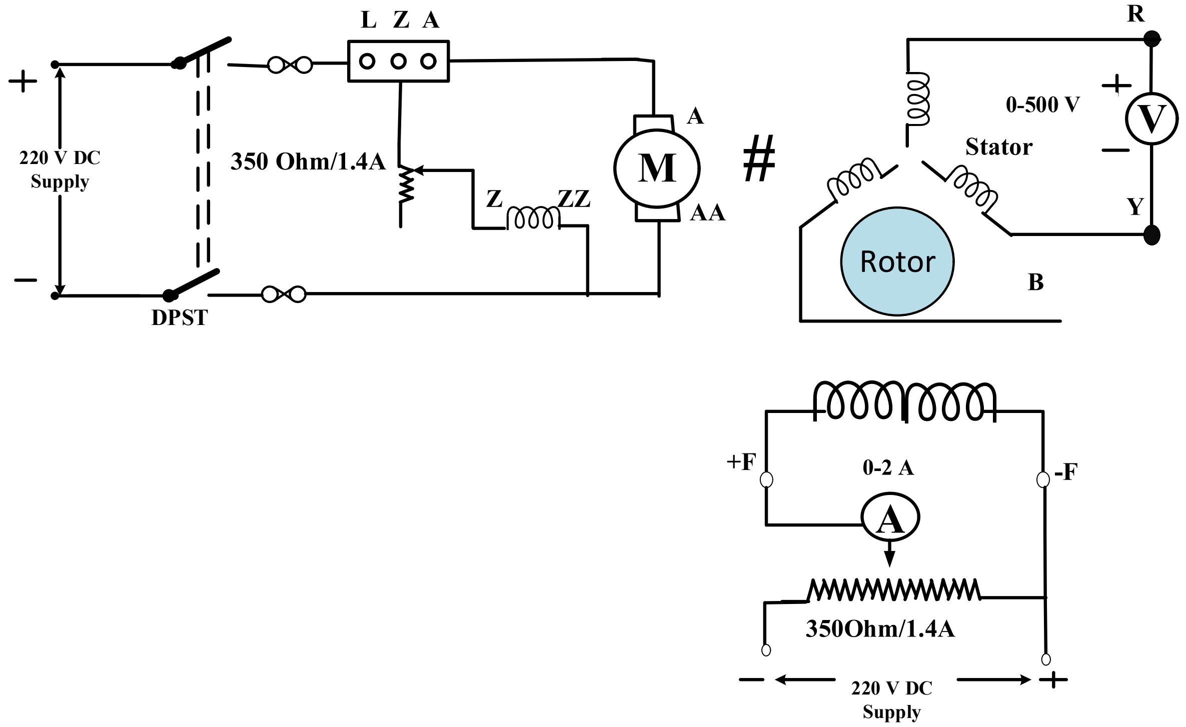
D.C. shunt motor

Power	**10 HP**
R.P.M	1440
Volts	220V

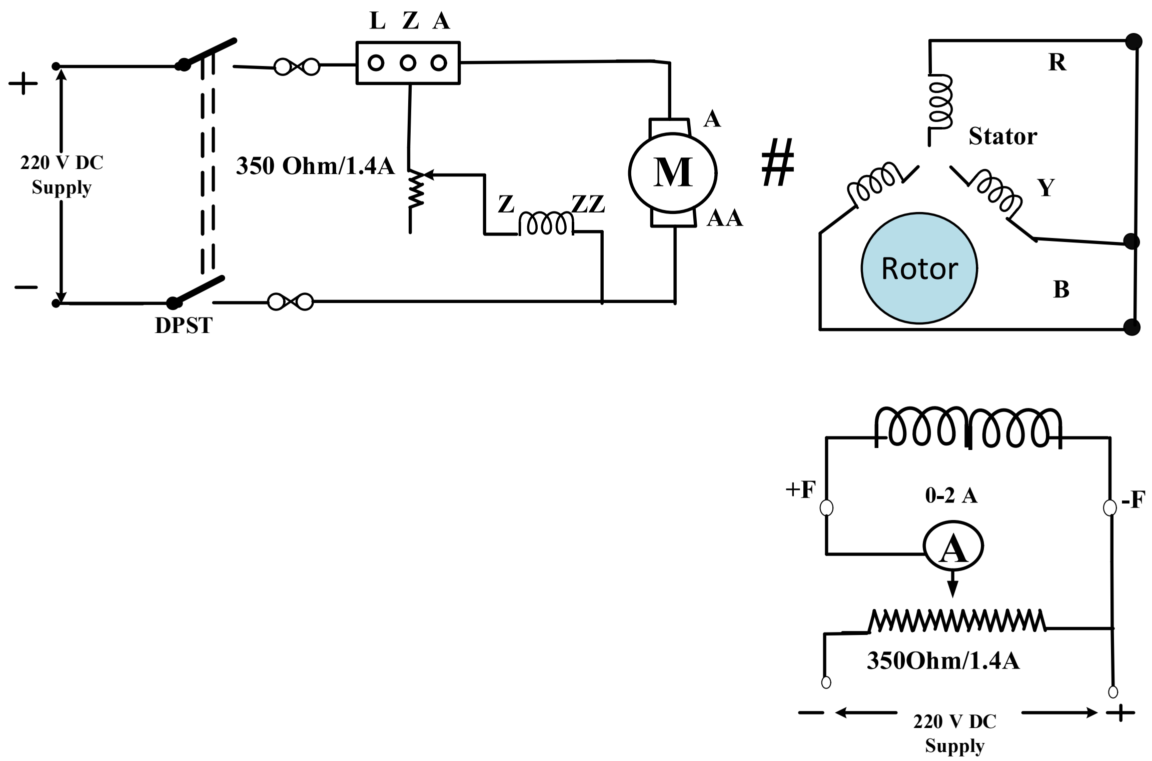
3-Phase Alternator

Rating of the machine	**7.5 KVA**
Voltage	400/440 V
Rated current	10.8 A
Speed	1500 rpm

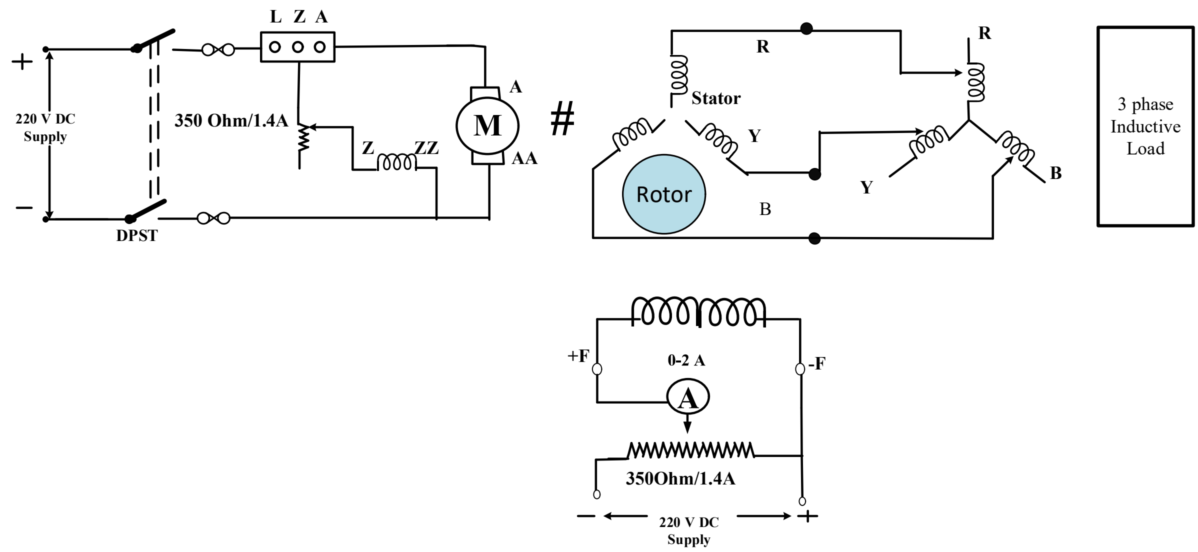
CIRCUIT DIAGRAM: -



Open Circuit Test



Short Circuit Test



THEORY: -

Zero power factor saturation curve method is most reliable for determining the regulation of alternators, because it properly takes into account, the effect of armature leakage reactance drop and the saturation. The following experimental data is needed to determine the regulation by this method.

(i) Open circuit characteristic at the rated speed of the alternator.

(ii) Field current corresponding to full load short circuit current i.e. only one reading short-circuit test.

(iii) Field current corresponding to full load, rated voltage, zero power factor i.e. again only one reading of zero power factor full load characteristic.

(iv) AC resistance of the stator winding per phase of the alternator.

Plotting of zero power factor, full load characteristic:

To plot zero power factor, full load characteristic from the experimental data, proceed as follows.

1. Draw the open circuit characteristic to proper scale and also draw the air gap line. 2. Draw the field current, Ie corresponding to full load short circuit current. This has been represented by the line OB in fig

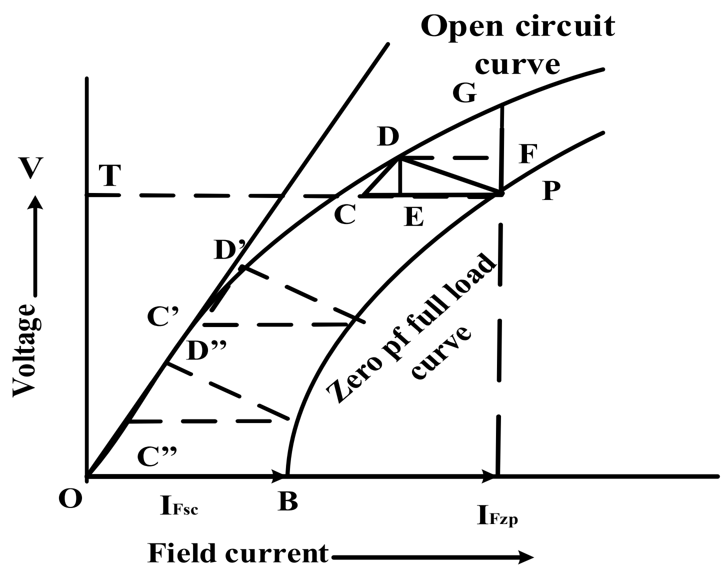
3. Draw the field current, I at rated voltage (line TP) which corresponds to full load zero power factor, thus obtaining a point, P on the zero power factor, full load characteristic.

4. From the point, P, draw a horizontal line PC representing the field current corresponding to full load short circuit current i.e., PC OB

5. From the point C, draw a line CD parallel to air gap line.

6. Join D to P. Now PCD is a triangle, which is normally called as potier triangle.

7. Points P' and P" on the zero-power factor full load curve can be obtained by tracing the potier triangle as shown in fig .



Zero power factor characteristics of alternator

Determination of leakage reactance

Drop a perpendicular from the point D, meeting the line PC at the point E. Then line ED represents the leakage reactance drop, which is also called as potier reactance drop (E).

Determination of Regulation: -

Regulation= $(E_0 - V)$ *100%

PROCEDURE: -

Open circuit test:

- Connections are given as per the circuit diagram.
- The motor field rheostat should be kept in minimum resistance position
- The D.C Motor is started and its speed is adjusted to the synchronous speed of the alternator.
- The field rheostat (Alternator) is varied and for various values of field current, the corresponding values of open circuit voltage are noted down.

- The open circuit characteristic is drawn. (If Vs Eo)

Short circuit test:

- The alternator is made to run at synchronous speed.
- The Armature terminals of the alternator are shorted by an Ammeter.
- The field rheostat (Alternator) is varied up to rated current (short circuit current) is circulating in short circuited stator winding corresponding meters reading is noted down.
- The Short circuit characteristic is drawn. (I_f Vs I_{SC}).

OBSERVATION: -

(a) For ZPF Test

S.No.	Stator current	Term Voltage	Watts	Field Current

(a) For Open circuit Test and Short circuit Test

Open circuit Test			Short circuit Test		
S.No.	E.M.F.	Field Current	S.No.	E.M.F.	Field Current

QUESTIONS: -

1. Why the ZPF method gives more accurate results for regulation compared to other methods?

2. Utilizing the experimental data obtained, find out the regulation by old A.I.E.E. method.

3. What is the major drawback of old A.I.E.E. method for finding the regulation?

4. Why the regulation of alternator is generally very high?

5. How the terminal voltage is maintained at constant value under varying load conditions in large rating alternators, used in power system? 6. Differentiate clearly between the leakage reactance and potier reactance of alternator.