

**G.H.RAISONI COLLEGE OF ENGINEERING**  
**DEPARTMENT OF ELECTRICAL ENGINEERING**  
**ELECTRICAL MACHINES LAB**  
**ELECTRICAL MACHINES -II**

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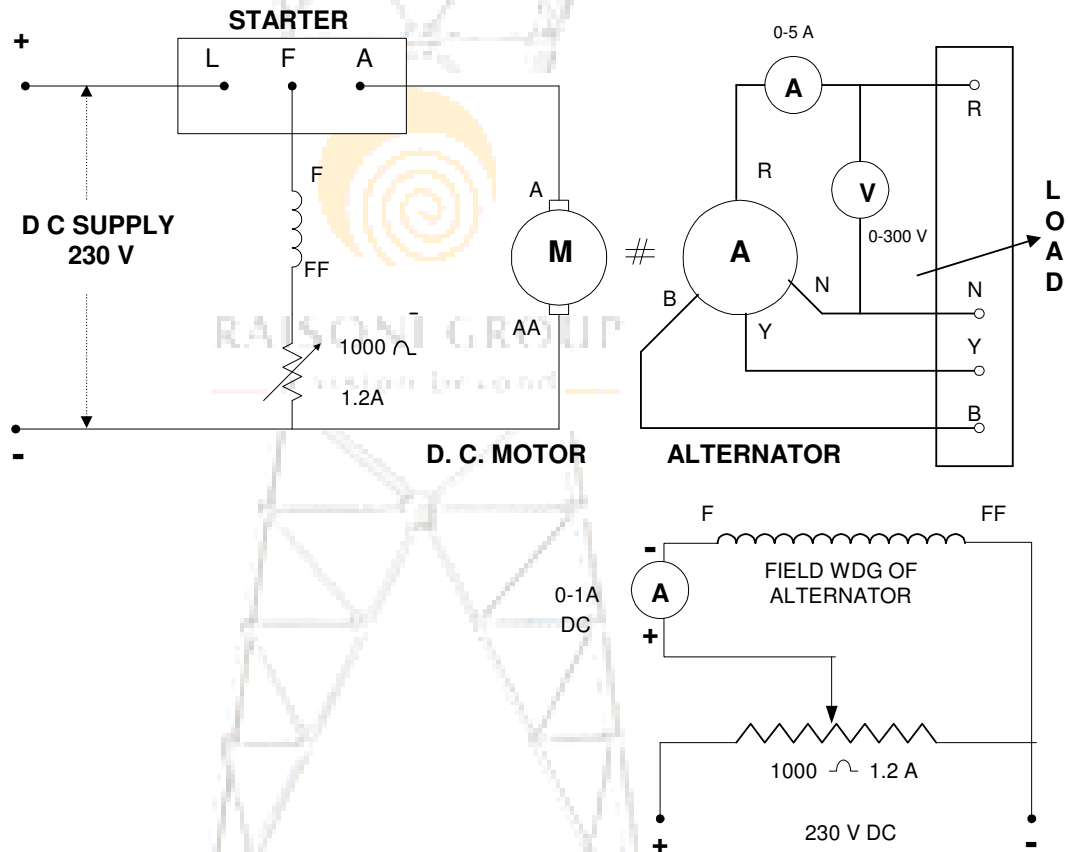


**EXPERIMENT NO.:-01**

**AIM:- TO DETERMINE VOLTAGE REGULATION OF 3 PHASE ALTERNATOR BY DIRECT LOADING.**

**APPARATUS:-**

- 1) Ammeter (0-5amp.AC) 01 No.
- 2) Ammeter (0-1amp.DC) 01 No
- 3) Voltmeter (0.300V AC) 01No
- 4) Rheostat (400 ohms.1.7 Amp) 01 No
- 5) Rheostat (1000 Ohms.1.2 Amp) 01 No
- 6) 3 Phase Resistive Load (400volts.10amp ) 01 No
- 7) Alternator (3 KVA 4.2 amp, 1500rpm) 3 Phase
- 8) D.C. Motor (Shunt Type) 3 HP, 220V, 1500rpm

**CIRCUIT DIAGRAM:**

**THEORY:** Theory should cover the following Points

1. Definition of voltage regulation and its expressions for different power factors of load.
2. Reasons for change in terminal voltage

3. Explanation about circuit diagram
4. List of other methods for finding regulation

**PROCEDURE: -**

- 1) Connect the circuit as shown in the diagram.
- 2) Keep load zero, set field potential divider to zero output voltage position.
- 3) Keep field resistance of motor to its minimum value.
- 4) Start the motor with the help of starter.
- 5) With the field rheostat of motor adjust the speed to synchronous value.
- 6) Switch on DC supply of field (Alternator) and adjust the potential divider so that the voltmeter reads rated voltage of the alternator. Note this voltage as no load voltage E.
- 7) Increase the load in steps till rated current of alternator and note the different sets of readings.
- 8) Keep speed constant during all the readings with the help of motor field rheostat..

**PRECAUTIONS:**

- 1) All connections should be perfectly tight and no loose wire should lie on the work table.
- 2) Before switching ON the dc supply, ensure that the starter's moving arm is at its maximum resistance position.
- 3) Do not switch on the supply, until and unless the connection are checked by the teacher
- 4) Avoid error due to parallax while reading the meters.
- 5) Hold the tachometer with both hands steady and in line with the motor shaft so that it reads correctly.

**OBSERVATION:** E = Terminal voltage at no load = \_\_\_\_\_ volts.

Sr. No.	Load current	Terminal voltage $V_t$	% Regulation

**CALCULATIONS:**

$$\% \text{ regulation} = \frac{E - V_t}{E} \times 100$$

**RESULT:** The regulation at full load and ---- power factor is found to be ----- %

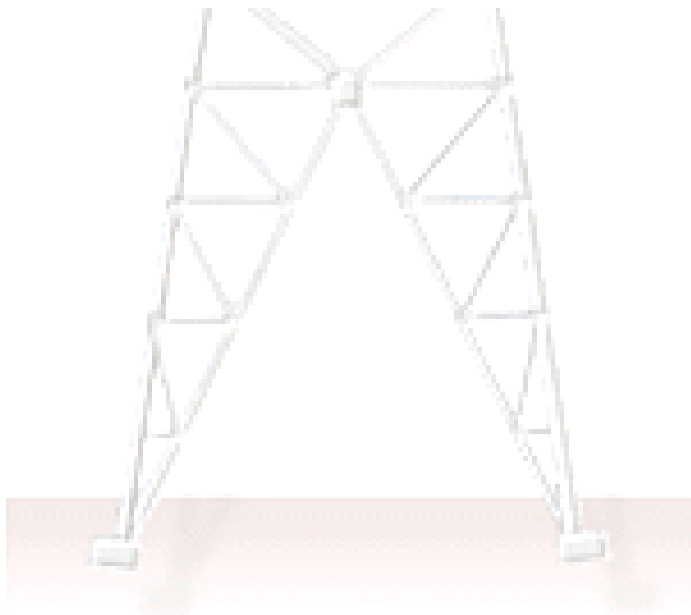
**CONCLUSION:** As the load on the alternator increases the regulation also increases

**DISCUSSION:**

- 1) Can the terminal voltage rise? Under which load?
  - 2) If the speed of the driving motor falls due to loading what will be the effects?
  - 3) Give the classification of alternator on the basis of rotor and their application?
  - 4) Why the excitation given to alternator is generally DC and not AC?
  - 5) Mention disadvantages of determining the regulation of alternator by direct loading?
  - 6) What is hunting in Alternator?
  - 7) What is the role of damper winding in Alternator?
  - 8) What is chording and write their advantages?
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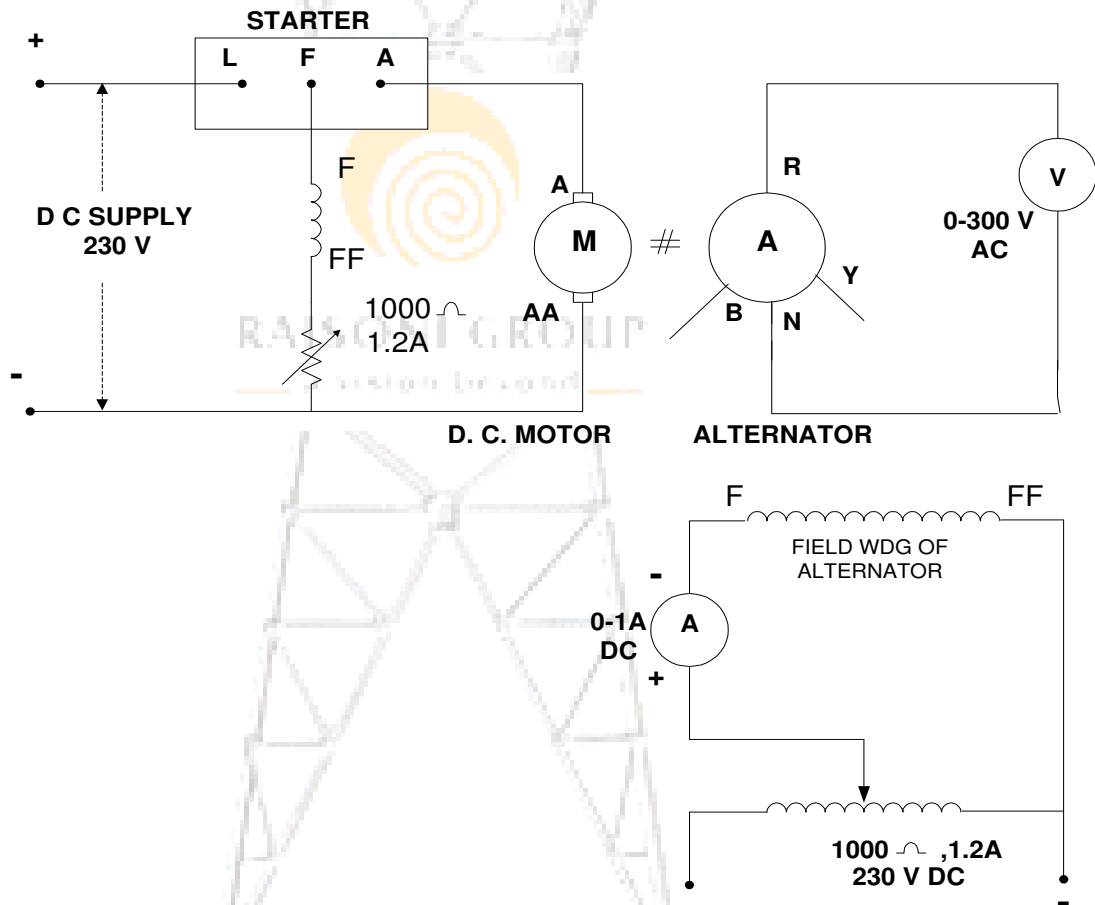


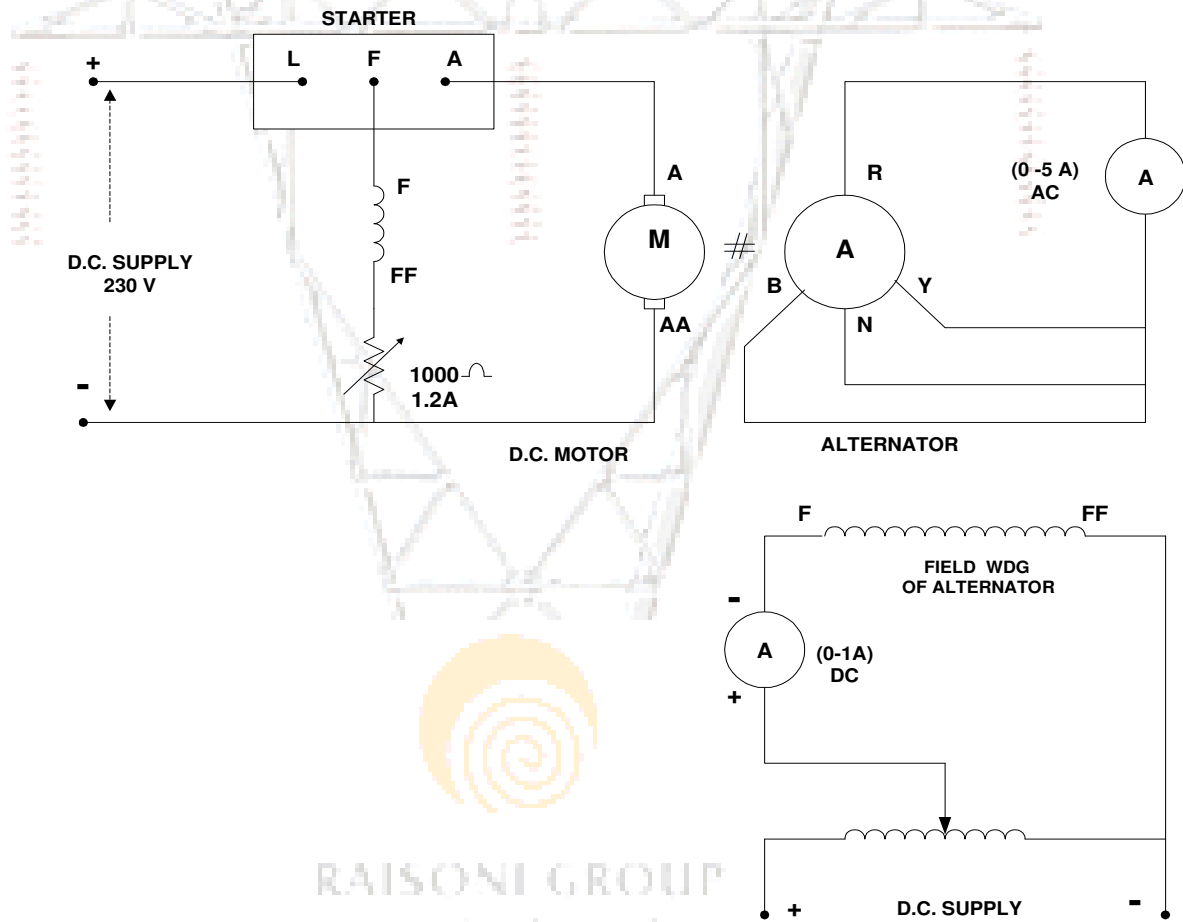
**EXPERIMENT NO:02**

**AIM:- TO FIND REGULATION OF A THREE-PHASE ALTERNATOR BY OPEN CIRCUIT AND SHORT CIRCUIT TESTS**

**APPARATUS:-**

1. Ammeter (0-5A) AC-1No; (0-1A) DC-1 No.
2. Voltmeter (0-300V) AC-1 No.
3. Tachometer – 1 No.
4. Rheostats (400 $\Omega$ . 1.7A) 1No; 1000 $\Omega$ . 1.2A 1No.
5. Alternator 3 kVA, 4.2A, 1500 RPM, 3 $\phi$
6. D.C. Motor 3 HP, 220V, 1500RPM
7. Connecting wires etc.

**CIRCUIT DIAGRAM:-****[A] OPEN CIRCUIT TEST**

**[B] SHORT CIRCUIT TEST**

**THEORY:** The theory should cover following points

1. Meanings of regulation and synchronous impedance
2. Details about synchronous impedance method for finding regulation
3. Explanation about above circuit diagrams
4. List of other possible methods for finding regulation

**PROCEDURE:****[A] OPEN CIRCUIT TEST**

- 1) Connect the circuit as shown.
- 2) Set potential divider to zero output position and motor field rheostat to minimum value.
- 3) Switch on dc supply and start the motor.
- 4) Adjust motor speed to synchronous value by motor field rheostat and note the meter readings.
- 5) Increase the field excitation of alternator and note the corresponding readings.
- 6) Repeat step 5 till 10% above rated terminal voltage of alternator.
- 7) Maintain constant rotor speed for all readings.

**[B] SHORT CIRCUIT TEST**

- 1) Connect the circuit as shown.
- 2) Star the motor with its field rheostat at minimum resistance position and the potential divider set to zero output.
- 3) Adjust the motor speed to synchronous value.
- 4) Increase the alternator field excitation and note ammeter readings.
- 5) Repeat step 4 for different values of excitations (field current). Take readings up to rated armature current. Maintain constant speed for all readings
- 6) Measure the value of armature resistance per phase  $R_a$  by multimeter or by ammeter-voltmeter method.
- 7) Plot the characteristics and find the synchronous impedance.

**PRECAUTIONS:**

- 1) All connections should be perfectly tight and no loose wire should lie on the work table.
- 2) Before switching ON the dc supply, ensure that the starter's moving arm is at its maximum resistance position.
- 3) Do not switch on the supply, until and unless the connections are checked by the teacher
- 4) Avoid error due to parallax while reading the meters.
- 5) Hold the tachometer with both hands steady and in line with the motor shaft so that it reads correctly.
- 6) Ensure that the winding currents do not exceed their rated values.

**OBSERVATIONS:**

Alternator armature resistance per phase  $R_a$  = -----  $\Omega$

Rotor speed = ----- RPM (constant).

**O.C TEST.**

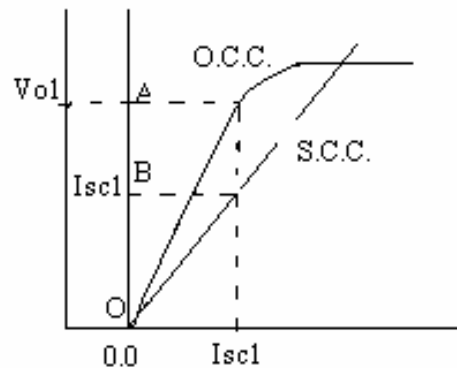
Sr. No	Field current $I_f$ (Amp)	Terminal voltage Per phase $V_o$

**S.C.TEST.**

Sr. No.	Field current $I_f$	Short circuit current $I_{sc}$

**GRAPH:** Plot the readings to draw following graphs. Use same graph paper for both curves.

1.  $I_f$  versus  $V_o$  (from OC test)
2.  $I_f$  versus  $I_{sc}$  (from SC test)



### CALCULATIONS:

Synchronous impedance  $Z_s = \frac{OA}{OB} = \frac{V_{o1}}{I_{sc1}}$  for field current  $I_{sc1}$

$I_{sc1}$  is selected over the linear part of OCC, generally it corresponds to rated armature current.

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

Where  $R_a$  = Armature resistance of alternator (per phase)

S.N.	$Z_s$	$Z_s$ (av).	$X_s$	$X_s$ (av).

Calculate the excitation emf  $E_o$  and voltage regulation for full-load and

1. 0.8 lagging p.f.
2. UPF
3. 0.8 leading p.f.

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

+ sign is for lagging pf load.

- sign is for leading pf load.

$V$  = rated terminal voltage per phase of alternator

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



**PHASOR DIAGRAMS:**

Draw phasor diagrams for above three loads and verify the calculated results.

**RESULT:**

Regulation of alternator at full load is found to be,

At unity pf = -----

At 0.8 lagging = -----

At 0.8 leading = -----

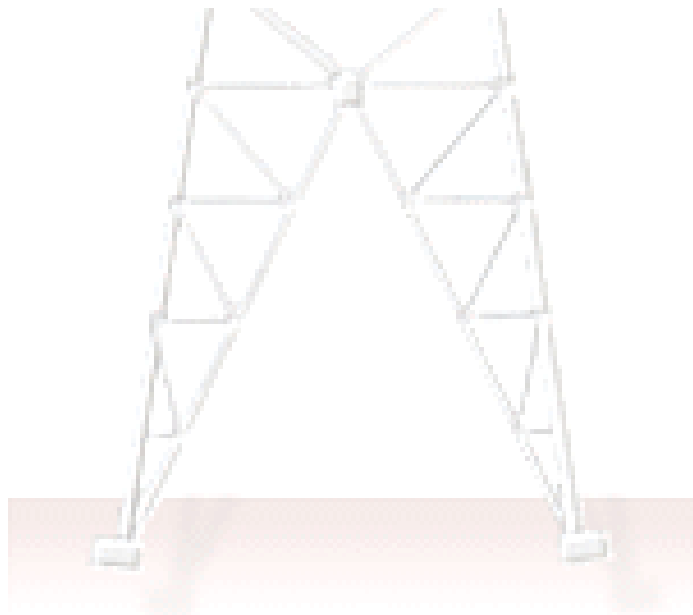
Synchronous Impedance varies for different values of excitation.

**DISCUSSION:**

1. Why OCC looks like B-H curve?
2. Why SCC is a straight line?
3. What is armature reaction effect?
4. What are the causes of voltage drop?
5. When is the regulation negative and why?
6. Can we find regulation of a salient pole machine by this test? Justify your answer.



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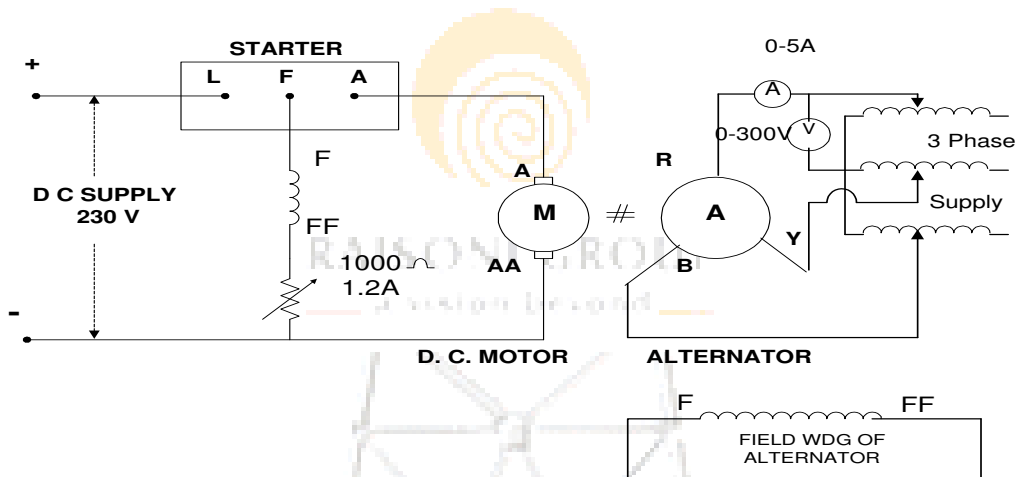


**EXPERIMENT NO: -03**

**AIM: - TO FIND  $X_d$  AND  $X_q$  OF A SALIENT POLE ROTOR TYPE SYNCHRONOUS MACHINE BY SLIP TEST**

1. Alternator ( 3 phase, 1 kw, 4.2A, 1500 rpm)
2. DC motor (8A, 220 V, 1500 rpm, shunt)
3. Voltmeter (0-150V) AC.
4. Ammeter (0-5A) A.C
5. Dimmer stat (3 phase, 440 V, 50Hz)
6. Tachometer

**CIRCUIT DIAGRAM:-**

**THEORY:-**

The armature reactance varies from  $X_q$  to  $X_d$  periodically.  
 $X_d$  - is the synchronous reactance of armature coil offered to the flow of direct axis current.  
 $X_q$  - is the synchronous reactance of armature coil offered to the flow of quadrature axis current.

When voltage induced in the field winding is zero, armature current is minimum and the terminal voltage is maximum. At this instant direct axis coincides with armature mmf and corresponding reactance is  $X_d$  is given by

$$X_d = \frac{\text{Maximum value of armature voltage / phase}}{\text{Minimum value of armature current / phase}}$$

Similarly when the voltage induced in the field winding is maximum ( positive or negative) armature current is maximum and terminal voltage is minimum. At this instant quadrature axis coincides with armature mmf and corresponding reactance is  $X_q$  is given by

$$X_q = \frac{\text{Minimum value of armature voltage / phase}}{\text{Maximum value of armature current / phase}}$$

If the readings of maximum and minimum armature current and voltage are taken  $X_d$  and  $X_q$  can be determined. The readings can not be taken at higher armature current to avoid synchronization. The ratio of  $X_q / X_d$  for the cylindrical rotor machine is around 0.95 this generally taken as one and for salient pole m/c this ratio is 0.66 to 0.7.

### PROCEDURE :

- (1) Connect the circuit as shown. Set the variac output zero.
- (2) Put on the DC supply and run the DC motor of a speed close to the synchronous speed of alternator but less than synchronous speed.
- (3) Put on the ac supply and increase the variac output to suitable value , observe the variations in the voltmeter and ammeter readings.
- (4) Adjust the speed of complete dc motor further to get maximum swings in ammeter and voltmeter printers.
- (5) Note maximum and minimum readings of voltage and current.
- (6) Take additional sets of reading by adjusting different variation outputs.
- (7) Now adjust the dc motor speed to a value little higher than synchronous speed and take similar readings as above.

### OBSERVATION:

S.N.	Speed	Armature voltage		Armature current		$X_d$	$X_q$	$X_q/X_d$	Avg. $X_q/X_d$
		Max. V	Min. V	Max. A	Min. A				





**EXPERIMENT NO: -04**

**AIM:- TO DETERMINE SUB TRANSIENT DIRECT AXIS ( $X_d''$ ) AND QUADRATURE AXIS ( $X_q''$ ) SYNCHRONOUS REACTANCE OF AN ALTERNATOR**

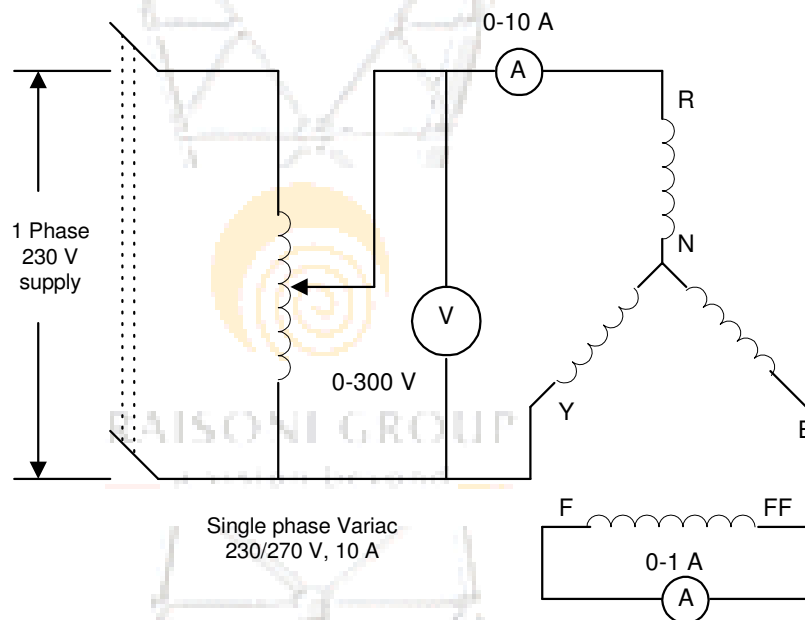
**APPARATUS ::**

Alternator: - 3 phase, 1KW, 4.2 A, 1500 RPM

Dimmer stat: 230 V/ 270 V, 10 Amp

Ammeter: - 0-10 AC, 0-1 A AC

Voltmeter:-0-300 V AC , connecting wires etc.

**CIRCUIT DIAGRAM:****THEORY**

This theory is related to behavior of an alternator under transient conditions. In purely inductive closed circuit the total flux linkages cannot change suddenly at the time of any disturbance. Now if all the three phases of an unloaded alternator with normal excitation are suddenly short circuited, there will be short circuit current flowing in the armature. As the resistance is assumed to be zero this current lag behind the excitation voltage by 90 degree and the mmf produced by this current will be in d- axis and the first conclusion is that, this current will be affected by d axis parameters  $x_d$ ,  $x_d'$  and  $x_d''$  only.

Further there will be demagnetizing effect of this current but as the flux linkages with field can not change the effect of demagnetizing armature mmf must be counter balanced by a

proportional increase in the field current, This additional induced component of field current gives rise to greater excitation, under transient state and results in more short circuit current at this time than the steady state short circuit.

If field poles are provided with damper bars. Then at the instant three phase short circuit the demagnetizing armature mmf induces current in damper bars which in turn produces field in the same direction as main field and hence and at this instant the excitation.

Further increases in short circuit armature current. This is for a very short duration. Normally 5 to 4 cycles and this period is known as sub-transient period. Since the field voltages are constant, there is no additional voltage to sustain these increased excitation during sub transient period or transient period. Consequently the effect of increased field current decreases with a time constant determined by the field and armature circuit parameter and accordingly the short circuit armature current also decays with the same time constant.

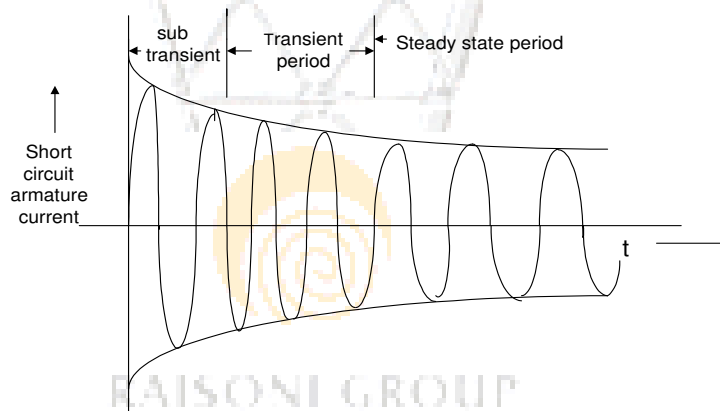


Fig. shows a symmetrical waveform for a armature short circuit for one phase of three phase alternator. The DC component is taken to be zero for this phase.

The reactance's offered by the machine during sub transient periods are known as sub transient reactances. In direct axis it is  $x_d''$  and in quadrature axis it is  $x_q''$

### PROCEDURE:

- 1) Make the connections as shown in the circuit diagram
- 2) Set the dimmerstat output to zero and put on the supply.
- 3) Gradually rotate the armature and see the field current and the armature current. Note the values of applied voltage and armature currents. When field current is maximum, and when minimum.
- 4) Repeat the step three for other applied voltage Take care that armature current does not go beyond its rated value during the experiment.

**OBSERVATION TABLE:**

Sr.No	Armature voltage	Armature voltage phase	Armature current		Direct axis sub transient reactance's $x_d''$	$X_q''$	Avg $x_d''$	Avg. $x_q''$
			If Max	If Min .				
1								
2								
3								

**CALCULATIONS:**

$$X_d'' = \frac{\text{Voltage / Phase}}{\text{Current / phase}} \quad (\text{If max})$$

$$X_q'' = \frac{\text{Voltage / Phase}}{\text{Current / phase}} \quad (\text{If min})$$

$$X_d'' (\text{pu}) = \frac{X_d''}{\text{Base impedance}}$$

$$X_q'' (\text{pu}) = \frac{X_q''}{\text{Base impedance}}$$

$$\text{Basic impedance} = \frac{(\text{base voltage})^2}{\text{Base VA}}$$

**RESULT:**

The average values and per unit are found as follows.

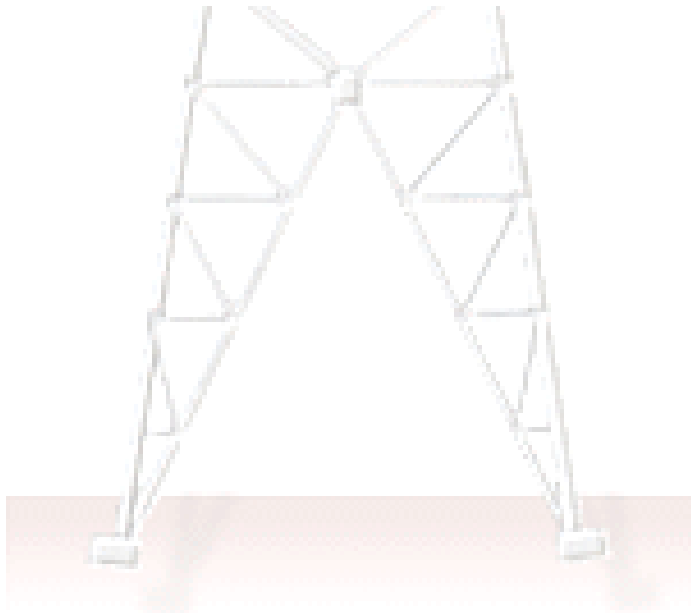
Direct axis sub transient reactance's  $X_d'' = \dots\dots\dots$

Quadrature axis sub transient reactance  $X_q'' = \dots\dots\dots$

**DISCUSSION AND QUESTIONS**

- 1) In this experiment why 1 phase supply is used and not three phase?
- 2) What is the purpose of damper winding in synchronous machines?
- 3) Generally whether  $X_d'' > X_q''$  or  $X_d'' < X_q''$  and why.
- 4) What is the frequency of rotor induced emf in this test and why?
- 5) What is meant by  $X_d''$  and  $X_q''$ ?
- 6) Out of  $X_q$ ,  $X_q'$ ,  $X_q''$  which one is minimum? Why?
- 7) Out of  $X_d$ ,  $X_d'$ ,  $X_d''$  which one is minimum? Why?
- 8) What is hunting of synchronous machine?
- 9) What happen if there is sudden short circuit on the alternator?
- 10) What do meant by transient stability?

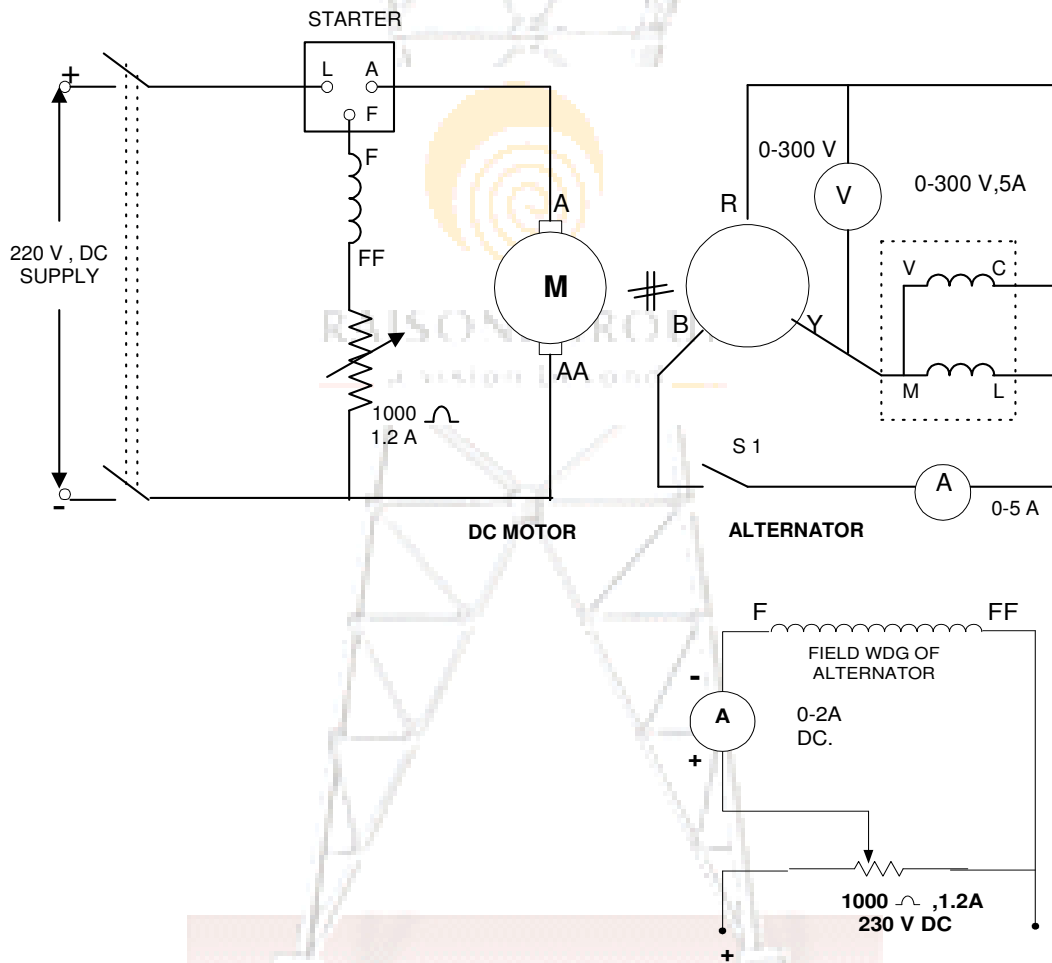
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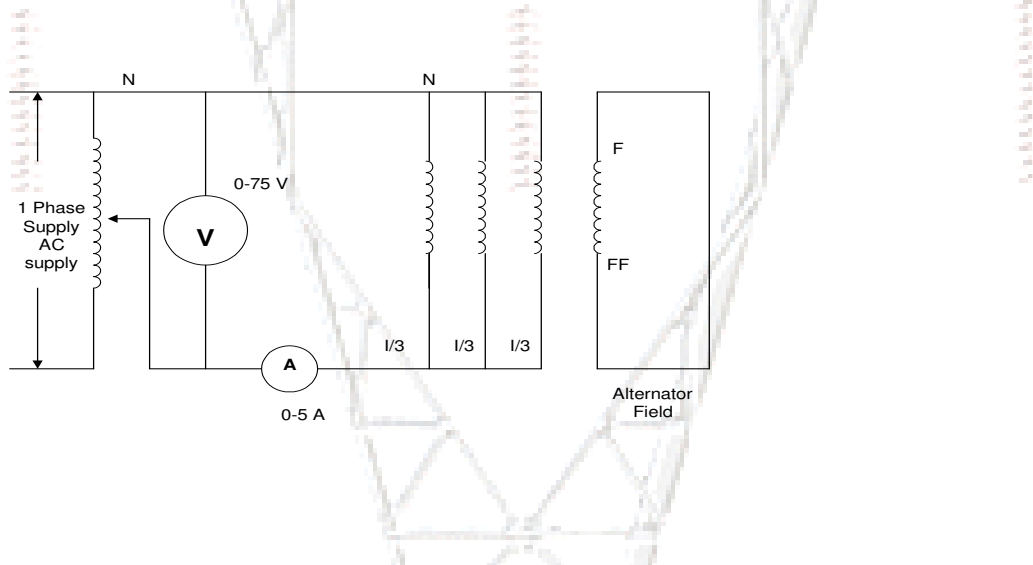




**EXPERIMENT NO: -05****AIM: - DETERMINATION OF NEGATIVE SEQUENCE AND ZERO SEQUENCE REACTANCE OF A SYNCHRONOUS GENERATOR.**

1. Alternator ( 3 phase, 415 V, 4.2A, 1500 rpm)
2. DC motor (8A, 215 V, 1500 rpm, shunt)
3. Voltmeter (0-300V, 0-75 V) AC.
4. Ammeter (0-5A) A.C., (0-2 A) DC
5. Dimmer stat (1 phase, 230 V, 50Hz)
6. Wattmeter (150 V, 5A)

**CIRCUIT DIAGRAM:-****Negative Sequence Reactance:-**

**Zero Sequence Reactance:-****THEORY:-**

When a synchronous generator is carrying an unbalanced load its operation may be analyzed by symmetrical components. In a synchronous machine the sequence current produce an armature reaction which is stationary with respect to reactance and is stationary with respect to field poles. The component currents therefore encounter exactly same as that by a balanced load as discussed. The negative sequence is produced and armature reaction which rotates around armature at synchronous speed in direction to that of field poles and therefore rotates part the field poles at synchronous speed. Inducing current in the field damper winding and rotor iron. The impedance encountered by the negative sequence is called the – ve sequence impedance of the generator. The zero sequence current produce flux in each phase but their combined armature reaction at the air gap is zero. The impedance encountered by their currents is therefore different from that encountered by + ve and –ve sequence components and is called zero sequence impedance of generator.

### Negative Sequence Impedence:-

The –ve sequence impedance may be found by applying balanced –ve sequence voltage to the armature terminals. While the machine is driven by the prime mover at its rated synchronous speed with the field winding short circuited. The ratio of  $v/ph$  and  $I_a/ph$  gives –ve sequence  $Z/ph$ . The reading of the wattmeter gives  $I^2 R$  losses. This loss  $/ph$  divided by  $I_{ph}$  required gives the –ve sequence  $R/ph$  from the impedance and reactance  $/ph$ . –ve sequence can be calculated.

Another method of measuring –ve sequence reactance is found to be connect the arm terminals. The machine is driven at synchronous speed and field current adjusted until rated current flows in the phases shorted through armature and current coil of wattmeter respectively

$$Z_2 = \frac{V_{RY}}{\sqrt{3} I_{sc}} = \frac{W}{V_{RY} I_{sc}} \quad X_2 = Z_2$$

$$X_2 = \frac{W}{\sqrt{3} I_{sc}} \text{ and } R_2 = \sqrt{Z_2^2 - X_2^2}$$

### Zero sequence impedance

The sequence impedance may be determined by the connecting the armature windings of the three phase in series and then connecting them to the single phase source of power. If the machine is driven at synchronous speed with field winding shorted, then  $Z_0 = V/3I$  practically the same results will be obtained with rotor stationary.

If windings are connected in parallel, then

$$Z_0 = \frac{\text{Voltage applied to phase}}{\text{Current through each phase}} = \frac{V}{I/3} = \frac{3V}{I}$$

**PROCEDURE****(A) For Negative Sequence Reactance:**

- (1) Make connection as shown in circuit diagram.
- (2) Run DC motor with synchronous speed.
- (3) Keeping the speed constant, vary the excitation and measure the voltmeter, ammeter and wattmeter reading.
- (4) Take 3-4 readings for different excitation.
- (5) The excitation should not be increased beyond the rated capacity of synchronous machine i.e. 4.2 A.

**(B) For Zero Sequence Reactance:**

- (1) Make connection as shown in circuit diagram.
- (2) Set the dimmer stat output to zero volts and switch on the supply.
- (3) Gradually increase dimmer stat output and note the ammeter reading for suitable voltage applied.
- (4) Repeat reading for suitable voltage applied.
- (5) It should be kept in mind that the ammeter reading should not exceed the rated current capacity of the machine i.e. 4.2 A.

**OBSERVATION:-****A) For Negative Sequence Reactance:**

S.N.	$V_{RY}$ (V)	$I_{sc}$ (A)	W (Watt)	$V_{RY}$ $Z_2 = \frac{\text{-----}}{\sqrt{3} I_{sc}}$	$X_2 = Z_2(W/V_{RY} I_{sc})$	Avg. $X_2(\Omega)$
1						
2						
3						
4						

**B) For Zero Sequence Reactance:**

S.N.	$V_{RY}$ (V)	$I_{sc}$ (A)	$X_0 = \frac{3V}{I}$	Avg. $X_0(\Omega)$
1				
2				
3				
4				

**RESULT:-** The negative sequence reactance and zero sequence reactance of an alternator are found to be

$X_2 =$

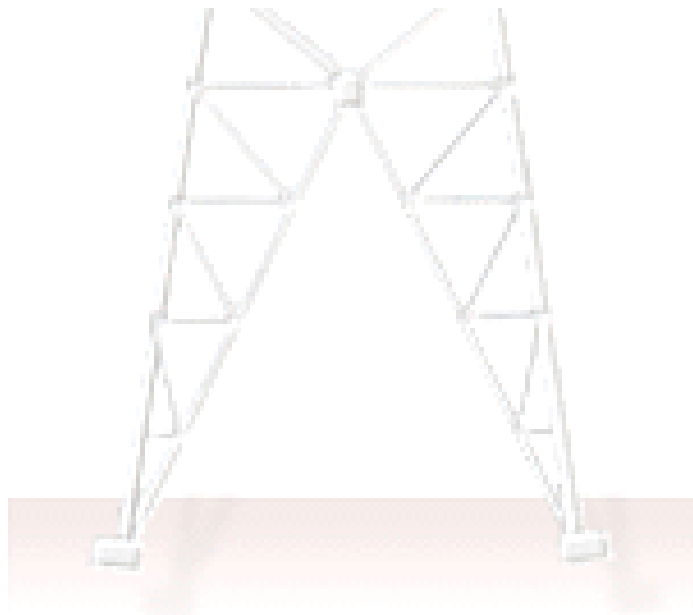
$X_0 =$

### DISCUSSION QUESTIONS :-

1. Define  $X_2$  and  $X_0$ .
2. What are sequence currents?
3. What are the effects of Negative currents on the rotor (field)winding ?
4. What are the effects of zero sequence currents on the rotor (field)winding ?
5. Give the equivalent circuits of synchronous machine under the influence of the three sequence currents.



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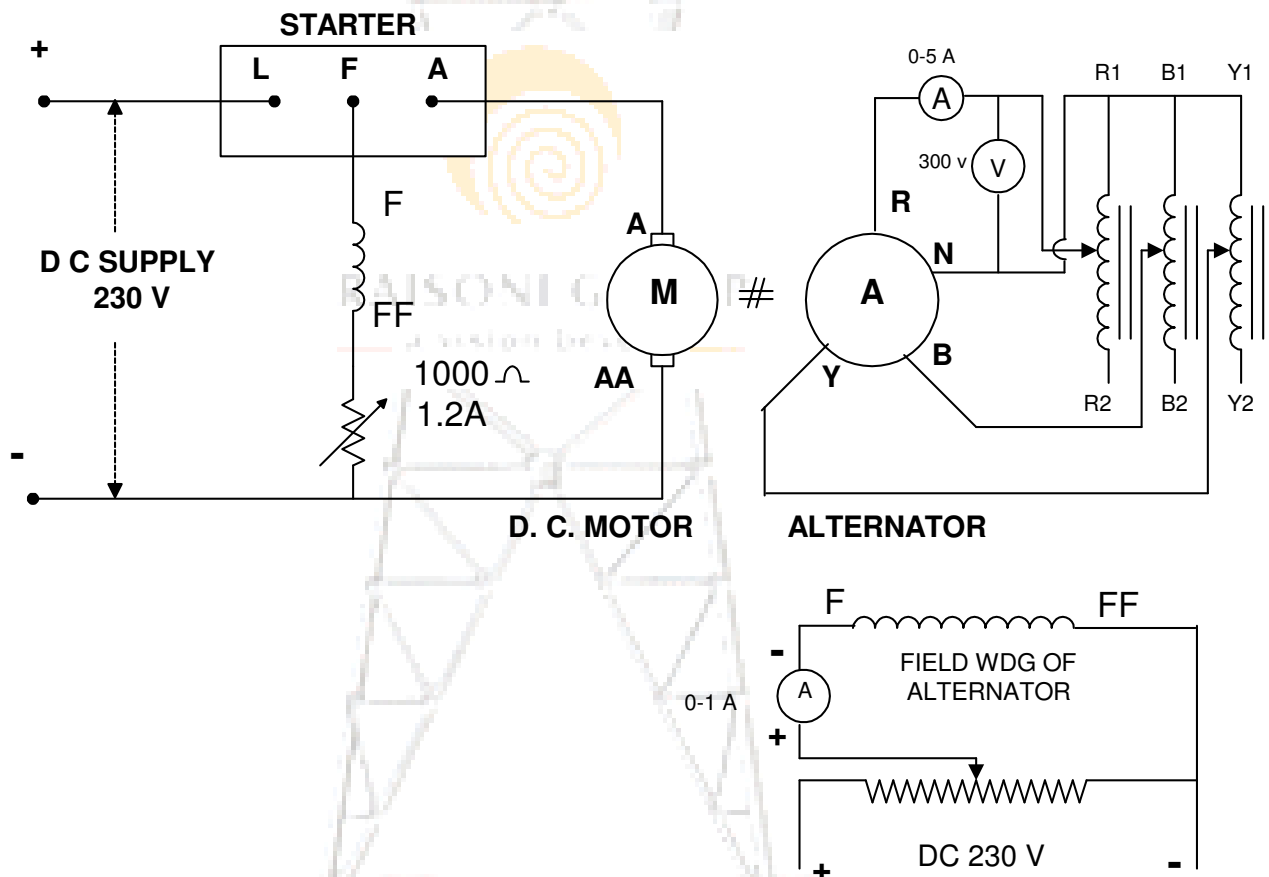


**EXPERIMENT NO: -06**

**AIM:- TO DETERMINE THE POTIER REACTANCE AND VOLTAGE REGULATION OF 3 PHASE ALTERNATOR BY ZERO POWER FACTOR METHOD .**

**APPARATUS :-**

Alternator – 03 phase 415V, 4.2 A, 1500 rpm .  
 DC shunt motor – 5 HP , 220 V , 19 A, 1500 rpm  
 Voltmeter -0-300V AC  
 Ammeter -0-5- A . AC, 0-1 A DC  
 Rheostat :- 400 ohms , 1.7 A., 1000 ohms , 1.2 A  
 Tachometer, connecting wires

**CIRCUIT DIAGRAM:-**

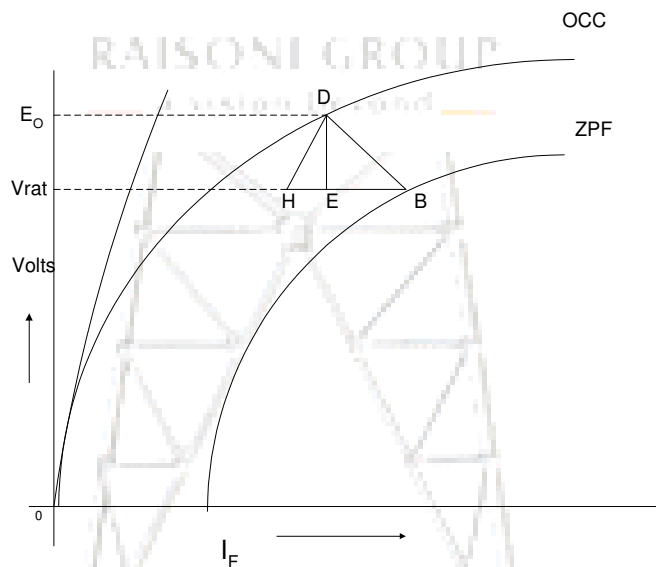
**THEORY: -**

This method is based on the separation of armature leakage drop and the armature reaction effects. Hence it gives more accurate results. It makes use of (i) Open circuit characteristics and (ii) zero power factor were also called wattless load characteristic. It is the curve of terminal volts against excitation which the armature is delivering full load at zero power factors.

By using the two characteristics the potier triangle can be found out. From the potier triangle the armature reaction mmf and armature leakage reactance or the Potier reactance can be determined by combining these two values the total Voltage induced  $E_0$  can be calculated.

The synchronous machine is run at rated synchronous speed by a prime mover. A purely inductive load is connected across the armature terminals and the field current is increased till full load armature current is flowing. The load is then carried in steps and field current is adjusted to maintain full load armature current.

The armature terminal voltage and field current are recorded at each step to get point "A" short circuit the output terminal of alternator. Vary the excitation to get rated current flowing through armature.

**METHODS TO DRAW POTIER TRIANGLE:**

Plot OCC and ZPF locate terminal voltage on OCC mark at B on ZPF corresponding to some value from point B mark distance HB equal to OA. Draw tangent to OCC. Point 'H'

draw line parallel to the tangent to intersect OCC at 'D'.  $\Delta DHB$  is the potier triangle draw altitude from point D. The height of the altitude represents the armature leakage reactance drop. Whereas that of ED represents mmf required to overcome the armature reaction drop.

### PROCEDURE:-

#### (a) TO PLOT OCC

- Connect the circuit diagram as shown in figure.
- Start the motor and run it at synchronous speed.
- Vary the excitation applied to alternator in steps and note down the corresponding voltages.
- Plot the characteristics between open circuit and field current.

#### (b) TO PLOT ZPF

- Connect the circuit diagram as shown in figure.
- Start the motor and run it at synchronous speed.
- Vary the inductive load in steps and adjust the field current to a value till full load armature current is flowing.
- Every time note down the field current and the terminal voltage of alternator.

#### (c) TO GET STARTING POINT OF ZPF

- Connect the circuit diagram as shown in figure.
- Start the motor and run it at synchronous speed.
- Vary the field excitation to get rated current flowing through armature.
- Note down this value of field current.

#### a) OCC

Sr.No	Voltage	Field Current $I_F$

#### b) ZPF

Sr.No	Voltage	Field Current

#### c) Short Circuit Test

$I_A$	$I_F$



**RESULTS:**

The potier reactance's of 3 phase alternator is found to be .....

The regulation of the 3 phase alternator is

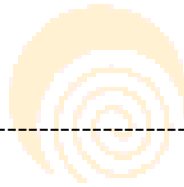
At Unity Power Factor:.....

At 0.8 lagging: .....

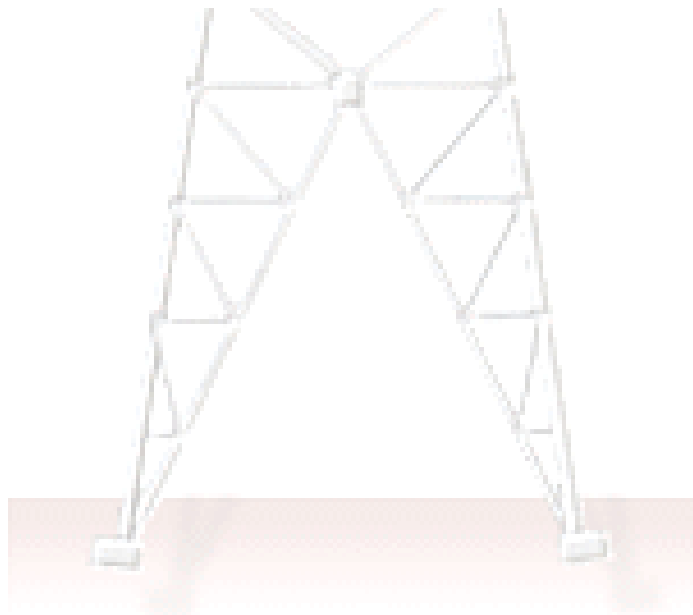
At 0.8 Lead :.....

**DISCUSSION QUESTIONS:-**

- i) Why OCC & ZPF have similar shapes.
- ii) What is additional effect taken in to account using potier reactance?
- iii) What are the advantages of this method
- iv) How regulation is found out from this test .



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**EXPERIMENT NO: -07**

**AIM: - TO STUDY THE SYNCHRONIZATION OF ALTERNATOR WITH INFINITE BUS BY BRIGHT LAMP METHOD.**

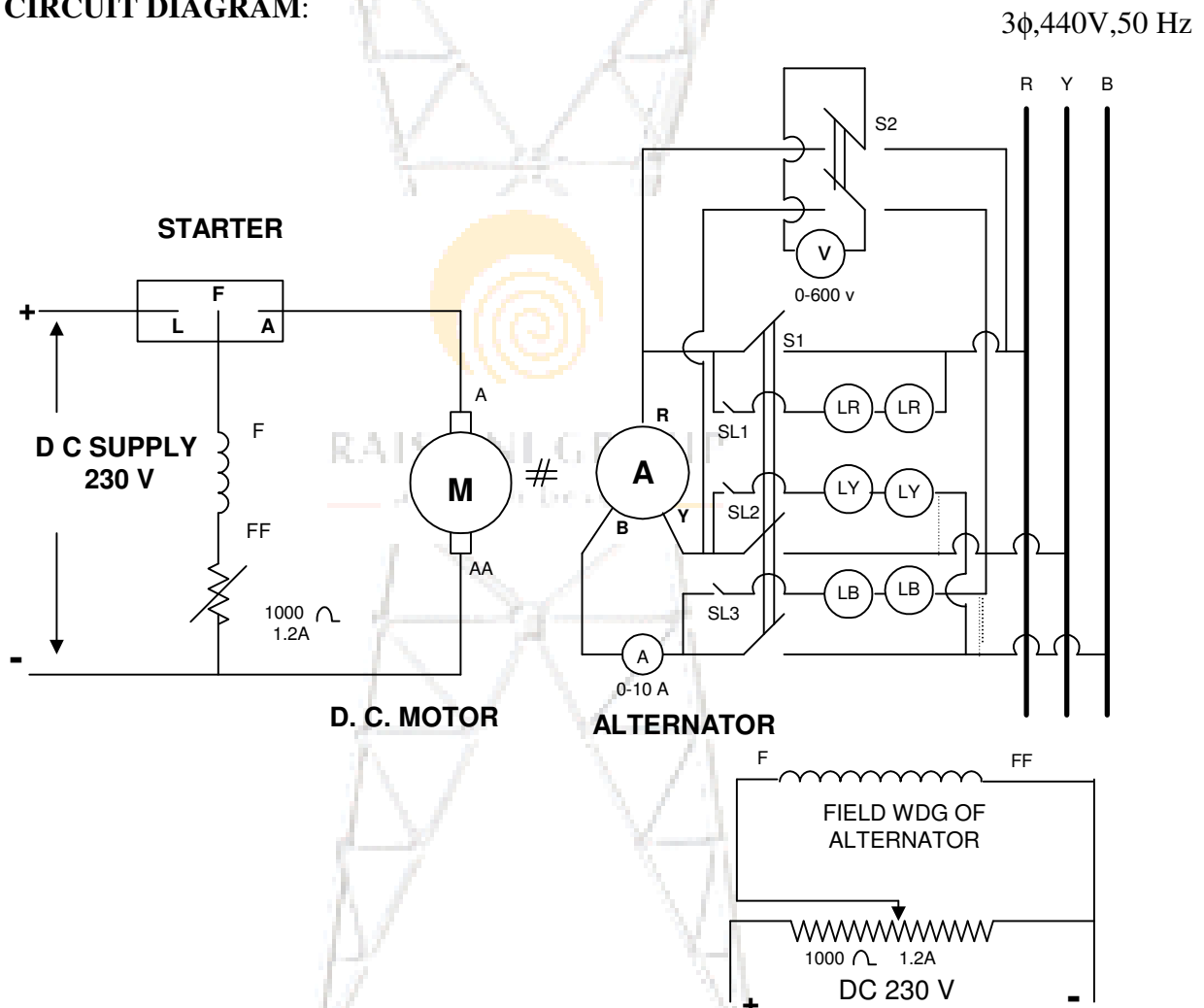
**APPARATUS:-**

3 phase alternator: - 1 KW , 4.2A, 1500 rpm , 3 phase , 440 V

DC shunt motor - 1.5 Kw , shunt , 8 A , 220V , 1500 rpm , self excited .

Voltmeter 0-600 V AC

Lamp bank, rheostats, 400 ohms – 1.7 A, A knife switches, connecting wires

**CIRCUIT DIAGRAM:**

(i) Dark lamp method, Lamps connected as shown by dotted Lines

(ii) Bright lamp method, Lamps connected as shown by dark Lines

**THEORY:**

Following conditions must be satisfied for the synchronization of alternator with infinite bus.

- 1) The terminal voltage of the incoming alternator must be equal to the bus voltage.
- 2) The frequency of incoming alternator must be equal to the bus frequency.
- 3) The voltage of incoming alternator and bus must be in the same phase with respect to the external load.

A voltmeter can be used to check the voltage of bus and incoming alternator for frequency and phase lamps are used.

Following are the advantages of parallel operation of alternators.

- 2) Repairs and maintenance of individual generating unit can be done by keeping the continuity of supply.
- 3) Economy
- 4) Additional sets can be connected in parallel to meet the increasing demand.

**PROCEDURE:**

- 1) Connect the circuit as shown in the diagram.
- 2) Keep all the switches S1, S2, SL1, SL2, and SL3 in open position and put on the DC supply.
- 3) Start the DC motor and bring the speed very near to synchronous speed of the alternator.
- 4) Put on AC supply and measure its voltage by keeping the position of switch S2 on line side.
- 5) Now keep the switch S2 on alternator side and adjust its field current such that it gives voltage equal to the line voltage.
- 6) Now put on the switches SL1, SL2, SL3 watch the changes in the glow of three sets of lamps. At one instant two will be equally bright while the third set will be fully dark. Then the set which is fully dark slowly starts becoming bright and one set from the to which were bright starts dimming. A position will come when this set will become fully dark while other two will be equally bright.
- 7) Make small adjustment in speed and excitation of alternator to get long dark and bright periods.
- 8) At an instant when pair IR –IR is dark and IB-IB are equally bright, close switch S-1 to synchronize the alternator to bus. Observe the reading of ammeter which should be minimum.



**RESULT & CONCLUSION:**

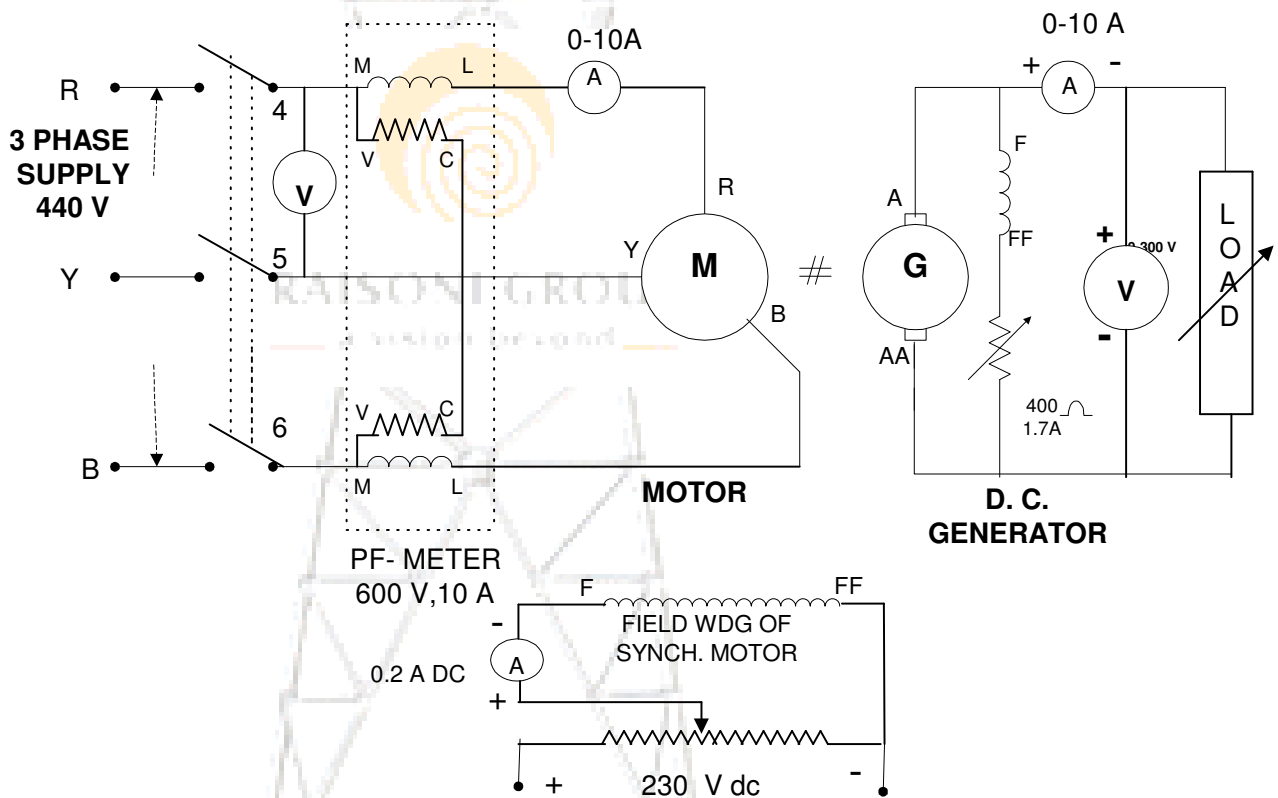
An alternator can be synchronized with the bus. At the time of synchronization voltage and frequency of the incoming alternator should be equal to the bus voltage and frequency and also the voltage of incoming alternator should be in phase with the bus with respect to external load .

**DISCUSSION QUESTIONS:-**

- 1) What are the conditions of synchronization of two alternators?
- 2) What are the possible effects of wrong synchronization?
- 3) What are the different methods for synchronization?
- 4) Why a lamp pair is required in this experiment?
- 5) After synchronizing what is the effect of changing the excitation of the alternators.
- 6) Why the incoming m/c in parallel operation is operated at slightly higher speed than the synchronous speed during synchronization.
- 7) In parallel operation of generator, for which condition circulating current develop even no load on the machine.
- 8) What will happen, if synchronization takes place without proper phase sequence?

**EXPERIMENT NO: 08****AIM: - TO PLOT V & INVERTED V CURVES OF A SYNCHRONOUS MOTOR.****APPARATUS:-**

- 1) Synchronous motor 3 Phase, 3 HP, 440V, 8.2A ,1500 rpm,
- 2) DC shunt Generator 220V, 9A, 1500 rpm
- 3) Power factor meter-600V, 10A
- 4) Voltmeter AC- (0-600V), DC- (0-300V)
- 5) Ammeter AC- (0-10A)
- 6) Ammeter DC (0-2A), DC (0-10A)
- 7) Rheostat-470 ohm, 1.2A,
- 8) Resistive load bank, tachometer, connecting wires, etc.

**CIRCUIT DIAGRAM:-****THEORY:-**

Theory should cover the following points

1. Significance of V & inverted V curves of synchronous motor.
2. Phasor diagram of a synchronous motor showing effect of change in excitation
3. Necessary condition for obtaining V & inverted V curves
4. Explanation about circuit diagram

**PROCEDURE:-**

- 1) Make the connections as shown in circuit diagram.
- 2) Adjust the field rheostat of DC generator at maximum position, the potential divider at zero output position and the load at off condition.
- 3) Switch on the 3-ph. supply, start the synchronous motor and let it run at its rated speed.
- 4) Switch on the DC supply and adjust the generator field current to a suitable value so that it generates rated voltage.
- 5) Increase the alternator field current and note down corresponding power factor and armature current covering a range from low lagging to low leading power factor through a unity power factor. Note that armature current is minimum when the p.f. in unity.
- 6) Repeat step No.5 for some constant load on the Generator.

**OBSERVATIONS:-****[A] AT NO LOAD**

Sr. No.	$I_f$	Power Factor ( $\cos\phi$ )	$I_a$

**[B] AT LOAD**

Sr. No.	$I_f$	Power Factor ( $\cos\phi$ )	$I_a$

**GRAPH:** Plot the curves between armature current ( $I_a$ ) vs field current ( $I_f$ ) and power factor ( $\cos\phi$ ) vs field current ( $I_f$ )

**CONCLUSION:**

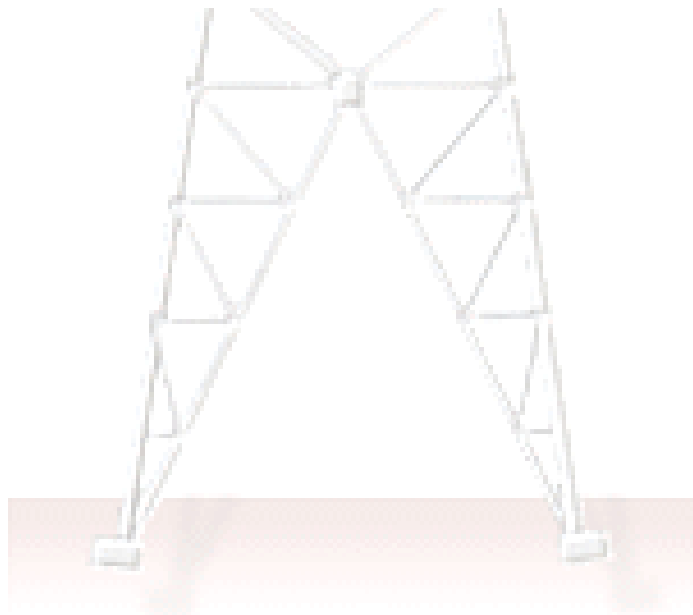
1. The variation of armature current (line current) and its power factor due to field current variation at load and at no load are shown. The armature current is minimum when the PF is unity.
2. As load increases the V curve shifts upward and the inverted V curve shift towards right.

**DISCUSSION :-**

1. With what condition synchronous motor can be used as a synchronous condenser.
2. What are the special applications of an over excited synchronous motor.
3. Explain the effect of change of excitation of a synchronous motor on its armature current.
4. Explain the effect of change of excitation of a synchronous motor on its power factor.
5. With the given excitation a synchronous motor draws a unity PF current . if the mechanical load is increased what will be the power factor and current for the same excitation.
6. Why V curve shift upwards and inverted V curve shift right as the load increases.
7. Explain the effect of change of excitation of a synchronous generator on its armature current.
8. Explain the effect of change of excitation of a synchronous generator on its power factor.

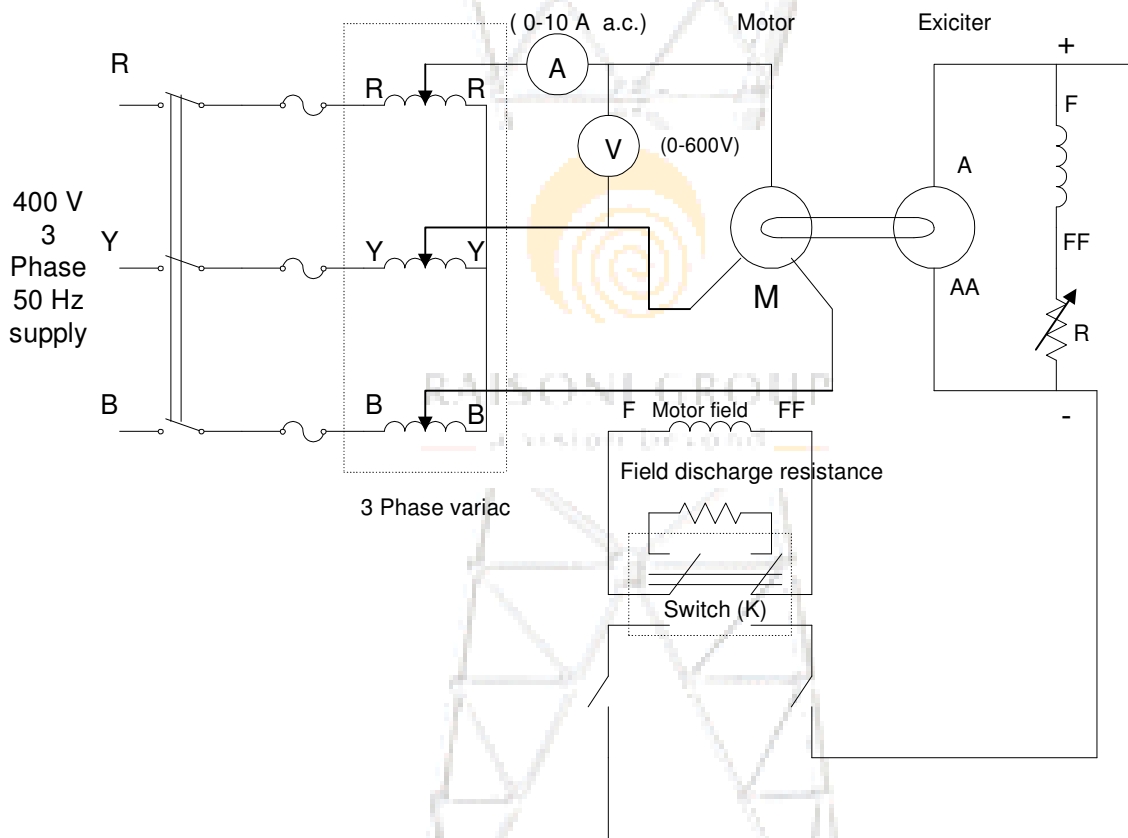
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**EXPERIMENT NO. :-09****AIM: TO STUDY THE STARTING & REVERSAL OF SYNCHRONOUS MOTOR.****APPARATUS:**

1. Three Phase Variac 400v , 50Hz
2. Ammeter (0-10 A Ac)
3. Voltmeter (0-600 V Ac)
4. Motor 3hp, 200v 1500rpm
5. Exciter.

**CIRCUIT DIAGRAM:-**



**THEORY :-** If synchronous motor is connected to a 3- ph. Ac supply with its field winding excited the torque acting on rotor will be of pulsating nature & will change its direction every half revolution of field rotation . Hence the average torque is zero & motor does not start – while if the speed of the motor is brought very near the synchronous speed & then the field winding is excited , the torque acts in one direction for quite a long time & in this time , the motor is pulled into synchronism. To start the motor, thus , it is required to bring it near the synchronous speed & then excite the field . This can be achieved by two methods.

1) Run the motor by an auxiliary motor in a proper direction at the synchronous speed, then switch on the supply to its armature & excite the field . synchronous motor is pulled into synchronous . the supply the auxiliary motor is then switched off the excitation can be adjusted to given required power factor.

2) A synchronous motor which is provided with damper winding can be started as an Induction motor .the field winding is kept open . A reduced voltage supply is given to the Armature'. This induces a voltage in damper bars & the motor starts running as an Induction motor . The supply voltage is now increased to its normal value. The Speed increases and is allowed to reach synchronous speed .At this speed, the field is excited which pulls the motor into synchronism at synchronous speed , there is no current in damper bars & hence no induction torque acts .

In a synchronous motor ,the rotor follows rotating magnetic field . If the direction of rotation is to be reversed. This can be achieved by changing the phase sequence of the voltage to the armature winding.

### **PROCEDURE:-**

#### **Starting and normal running.**

- 1) Connect as shown in figure.
- 2) Keep the switch (k) connected to the field circuit in position no.1
- 3) Set the variac to minimum o/p & switch on the supply.
- 4) Increase the o/p of variac gradually to a suitable value. The motor starts due to the torque produced by the damper windings. the motor gains speed & the current tends to decrease.
- 5) Increase the voltage applied further (watching the current which should not exceed safe limits )& note that the speed rises.
- 6) when the motor speed is close to the synchronous speed change – over the switch (k) to position '2' connecting the field winding to the exciter output, the machine runs at synchronous speed .
- 7) apply rated voltage to the motor by adjusting the variac.
- 8) Adjust the shunt field regulator so that the a.c. line current is reduced to lower value.
- 9) Note down its speed (if run at its synchronous speed .)



**Reversal.**

For reversal of the motor, interchange two motor terminals. other connections remain the same as in fig for build up of voltage of the exciter run in the opposite direction, interchange its field winding terminal to do this, if in the previous case the terminal 'f' was connected to 'a' & the other end of the field rheostat was connection to 'a', now connect 'F' to 'A' & 'R' to 'A', (see the exciter terminals marked in fig.) then repeat (2) to (7) above. The motor runs in the opposite direction.

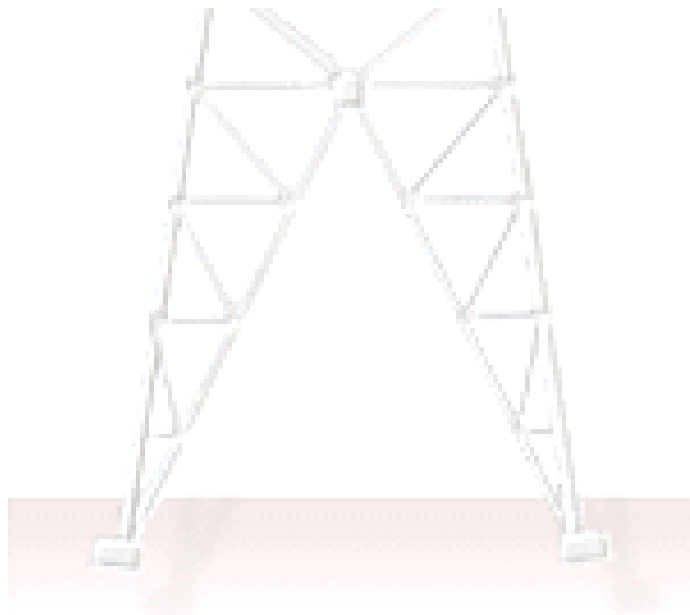
**RESULT & CONCLUSION:-**

Starting & running up of a synchronous motor have been studied the motor runs at its synchronous speed. the motor can be reversed by interchanging any two of its ac connection.

**DISCUSSION QUESTIONS:-**

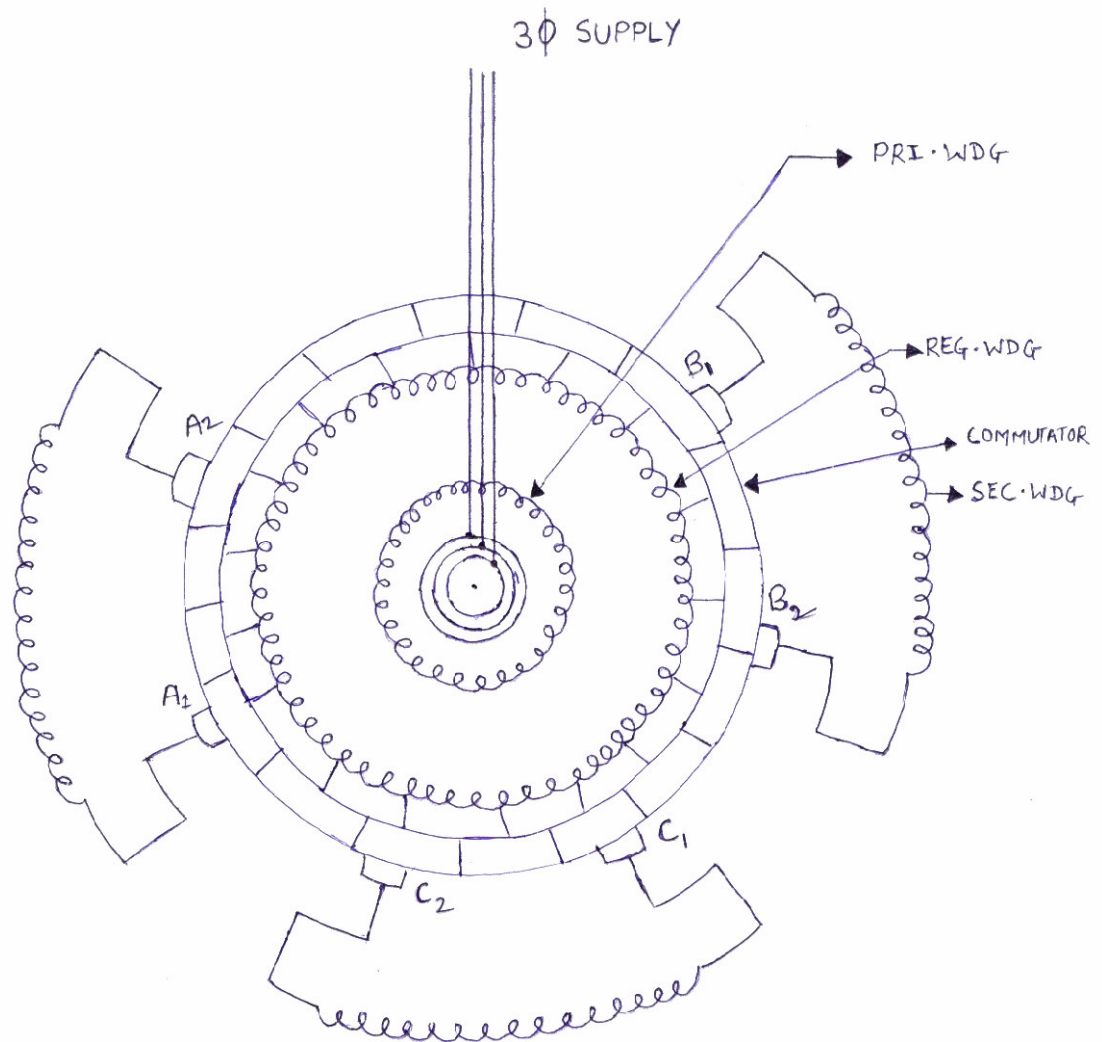
- Q.1) At starting, what is the nature of induced emf in the field winding ?
- Q.2) What is the damper winding ?
- Q.3) What is the purpose of putting the field discharge resistances in the field circuit at starting ?
- Q.4) What is the effect of reversing the field polarity on the direction of the rotation of the motor ?
- Q.5) Briefly describe a static arrangement to obtain the DC supply of the field winding?

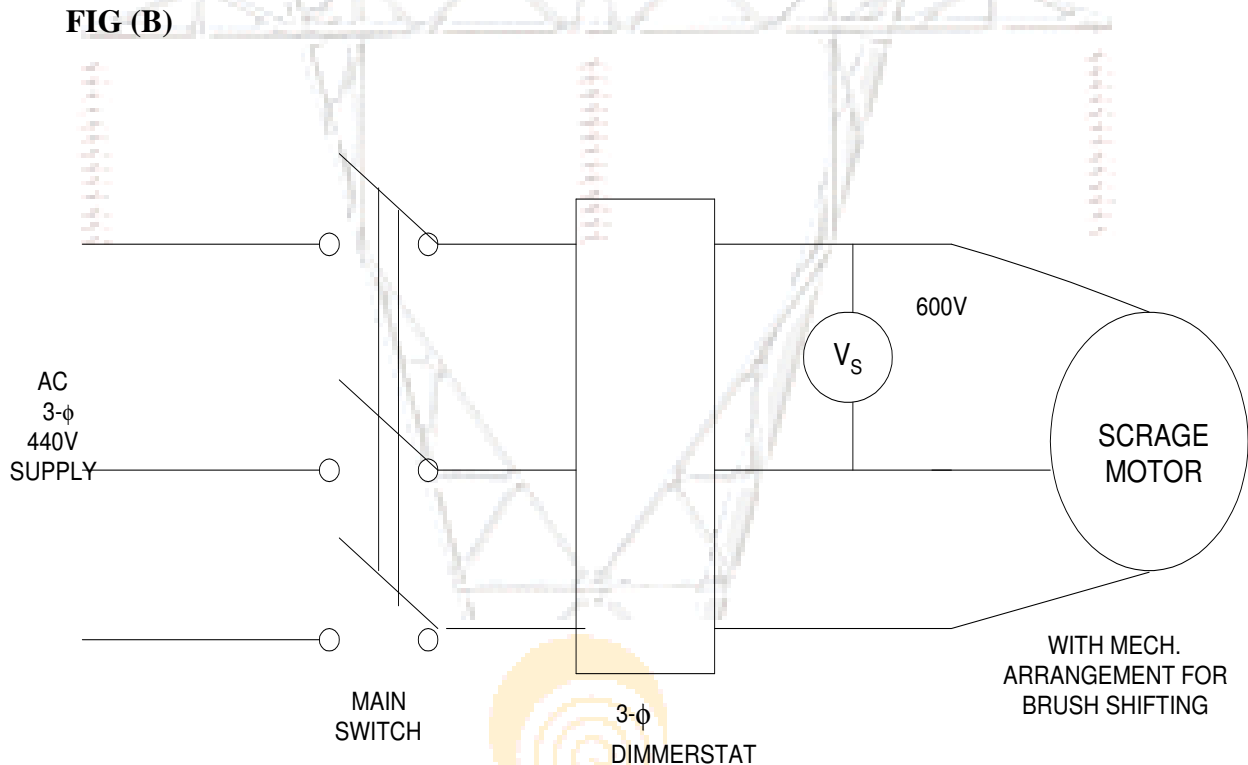
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**EXPERIMENT NO:10****AIM:- TO PERFORM SPEED CONTROL OF SCHRAGE MOTOR .****APPARATUS: -**

Schrage Motor 5HP ,415V 50HZ,  
600 TO 2000 RPM.  
Voltmeter (0-600v,Ac.), Tachometer,  
Connecting Wires. Etc

**CIRCUIT DIAGRAM:-****FIG. (A)**



**THEORY:-** Theory should cover the following points

- 1) Working principle of schrage motor.
- 2) Construction of schrage motor
- 3) Speed control of schrage motor.
- 4) Power factor improvement in schrage motor.
- 5) Advantages, disadvantages & applications.

**PROCEDURE:-**

- 1) Connect the circuit as shown.
- 2) Keep the brush angle to zero ( $\theta = \text{zero degree}$ ) i.e. brushes are shorted.
- 3) Switch on AC supply apply the rated voltage by means of dimmerstat.
- 4) Increase brush angle from zero degree to 360 degree gradually at regular interval and for each note down the speed.
- 5) Plot the graph angle ( $\theta$ ) vs speed (N).

**OBSERVATION TABLE:-**

S.N.	BRUSH ANGLE ( $\theta$ )	SPEED (N) RPM

**GRAPH:-** Plot the graph brush angle ( $\theta$ ) vs. speed in RPM

**PRECAUTION:-**

While change the angle between the brush , operate the Mechanical gear system very smoothly and carefully.

**RESULT:-** Speed variation on Schrage motor was preformed. The graph drawn and studied. It is observed that with the increase in brush angle the speed goes an increases.

**DISCUSSION QUESTIONS:-**

- 1.Explain how power factor can be made leading using Schrage Motor?
- 2.Why three windings are needed ?
- 3.Explain the relationship between brush angle and speed?
- 4.Draw the phasor diagram for Schrage Motor