B.Tech.(IV Sem) **23EE55- Induction and Synchronous Machines Lab**

L	T	P	Cr.
0	0	3	1.5

Course Objectives: This course enables the student to know the operation of various ac machines and give practical exposure on the performance of various AC machines like induction motors and synchronous machines.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Analyze the performance of single phase Induction Motor. **(Apply-L3)**
CO2: Evaluate the performance of 3-phase Induction Motor **(Apply-L3)**
CO3: Examine the performance of synchronous machines **(Apply-L3)**

List of Experiments

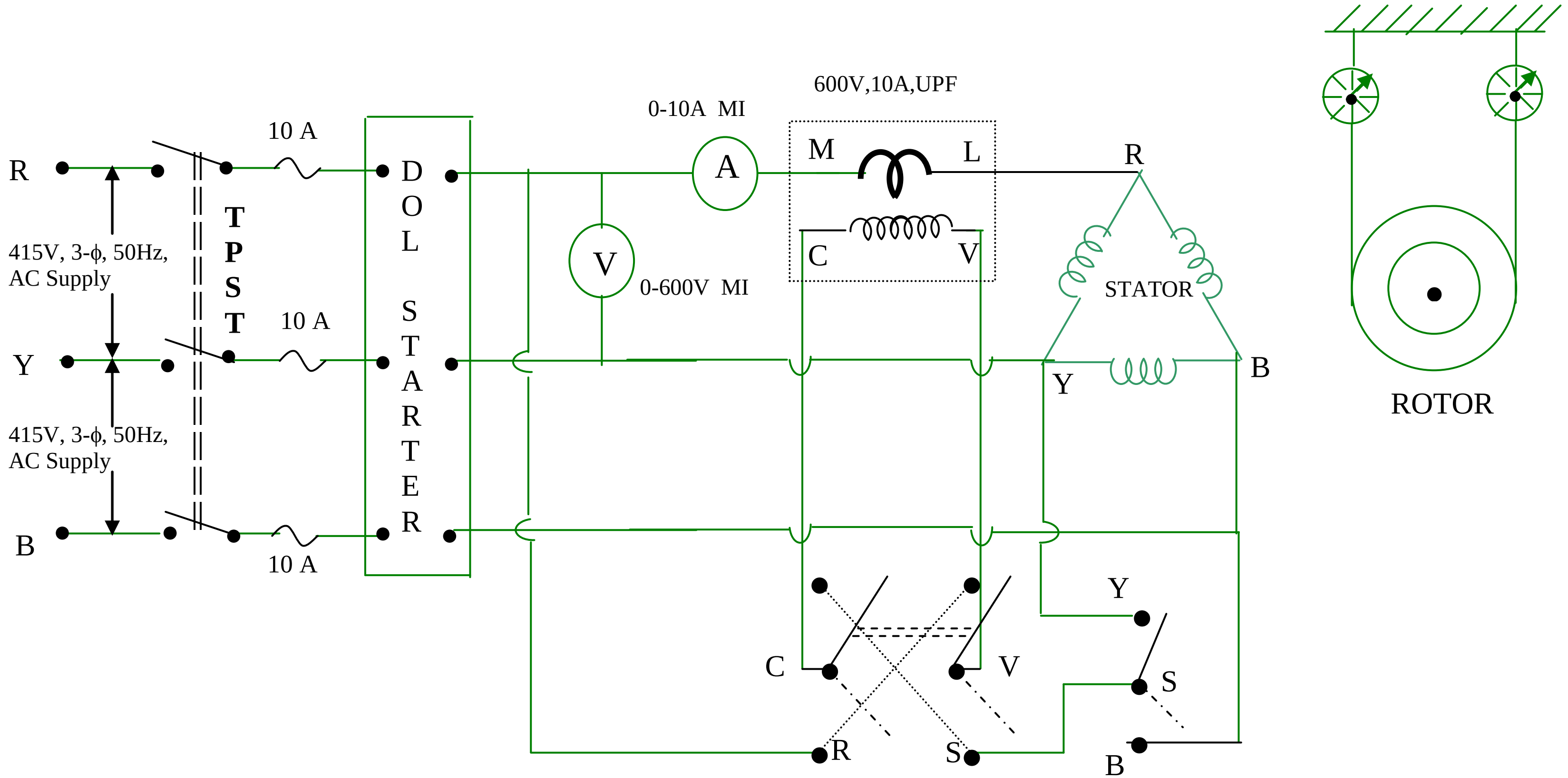
Any 10 experiments of the following are required to be conducted

1. Brake test on three phase Induction Motor.
2. Circle diagram of three phase induction motor.
3. Speed control of three phase induction motor by V/f method.
4. Equivalent circuit of single-phase induction motor.
5. Power factor improvement of single-phase induction motor by using capacitors.
6. Load test on single phase induction motor.
7. Regulation of a three -phase alternator by synchronous impedance &MMF methods.
8. Regulation of three-phase alternator by Potier triangle method.
9. V and Inverted V curves of a three-phase synchronous motor.
10. Determination of X_d, X_q& Regulation of a salient pole synchronous generator.
11. Determination of efficiency of three phase alternator by loading with three phase induction motor.
12. Parallel operation of three-phase alternator under no-load and load conditions.
13. Determination of efficiency of a single-phase AC series Motor by conducting Brake test.

Online Learning Resources:
https://em-coep.vlabs.ac.in/List%20of%20experiments.html

Brake test on three phase Induction Motor

CIRCUIT DIAGRAM: BRAKE TEST ON 3-Φ SQUIRREL CAGE INDUCTION MOTOR



1.Brake test on three phase Induction Motor

AIM: - To perform Brake test on given 3-phase Induction Motor and obtain the characteristics of the motor from the test observations.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Voltmeter	0-600V	MI	1
2	Ammeter	0-10A	MI	1
3	Wattmeter	300V, 10A	UPF	1
4	Tachometer	(0-10000)rpm	Digital	1
5	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	Rating
1	Voltage	
2	Current	
3	Output	
4	RPM	
5	Frequency	
6	Connection	

THEORY:

It is a direct method and consists of applying a brake to a water cooled pulley mounted on the motor shaft. The brake bond is fixed with the help of wooden blocks gripping the pulley. One end of the bond is fixed to earth via spring balance S and the other is connected to a suspended weight W_1, the motor is run and the load on the motor is adjusted till carries its full load current. The simple brake test described above can be used for small motors only, because in the case of large motor it is difficult to dissipate the large amount of heat generated at the brake.

Another simple method of measuring motor output is by the use of poney brake one form and which is shown. A rope is wound round the pulley and its two ends are attached to two spring balances S_1 & S_2. The tension of the rope can be adjusted with the help of squirrels. Obviously the force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances. If R is the pulley radius, the torque at the pulley is

CALCULATIONS:

Torque on the pulley (T)=9.81 * S * r N-m

Where $S = S_1 - S_2$

S_1, S_2 are load cell Readings in Kg

Where 'r' is the radius of the pulley in meters

Power Output = 2πNT/60 Watts

Power Input = (W1+W2) Watts

Where W1, W2 are the wattmeter readings.

% Efficiency (%η) = (Output/Input) *100

Synchronous speed (Ns)=120*f / p.

Where f is frequency of supply in Hz

p is no. of poles.

% Slip= (Ns-N)/Ns *100.

Where 'N' is the rotor speed in rpm.

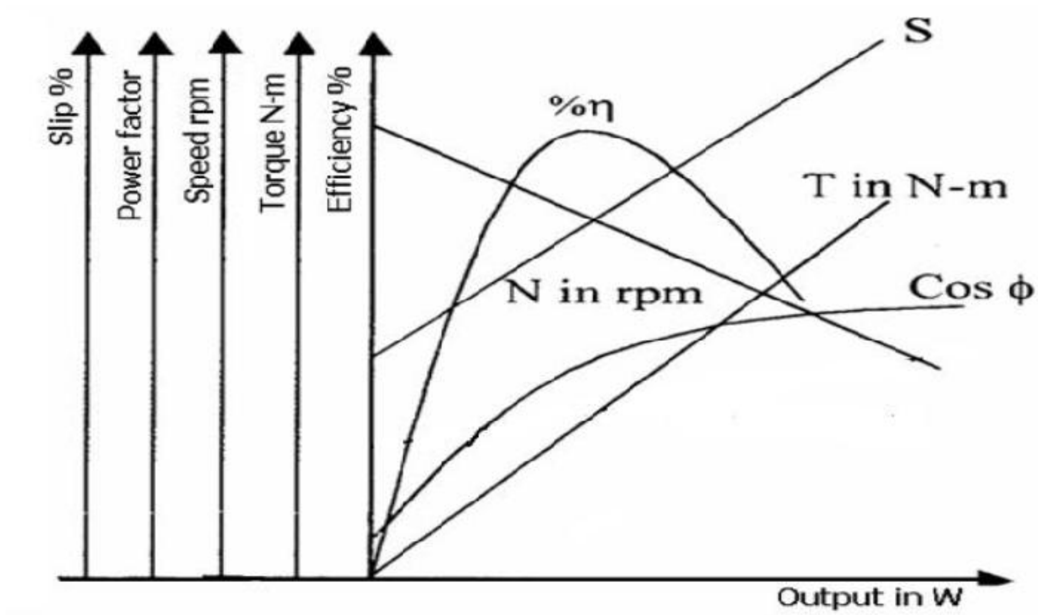
Power factor (cosΦ) = (W1+W2)/√3 VI

Where V is the Voltage across the motor & 'I' is the current drawn from the motor

PROCEDURE:

1) All connections are done as per the circuit diagram
2) Start the motor with the help of Direct Online Line (DOL) starter i.e. it is running at rated speed.
3) Note down the readings of Wattmeter, Voltmeter, speed and balance readings S_1 and S_2.
4) Apply brake to the water cooled pulley. Pulley mounted on the motor shaft and note down the corresponding balance readings S_1 and S_2.
5) For each step of the brake (load) on the motor note down the readings of voltmeter, ammeter, wattmeter and speed.
6) Take readings of all meter until motor carries its full load current.
7) From the tabulated readings required quantities are to be calculated.

MODEL GRAPH:



TABULAR FORM:

S.No	Voltage (V)	Current (A)	Speed (rpm)	Balance readings		Wattmeter Reading			Torque 9.81 x (S_1-S_2) x r (N M)	Output 2πNT/ 60 (w)	% Efficiency output / input x100	% slip	Power factor cosφ
				S_1 (kg)	S_2 (kg)	W1	W2	W_1+W_2 (Input)					

PRECAUTIONS:

1) Water is poured into the pulley when conducting the experiment.
2) Motor current should not exceed its full load current.
3) All the connections must be tight.

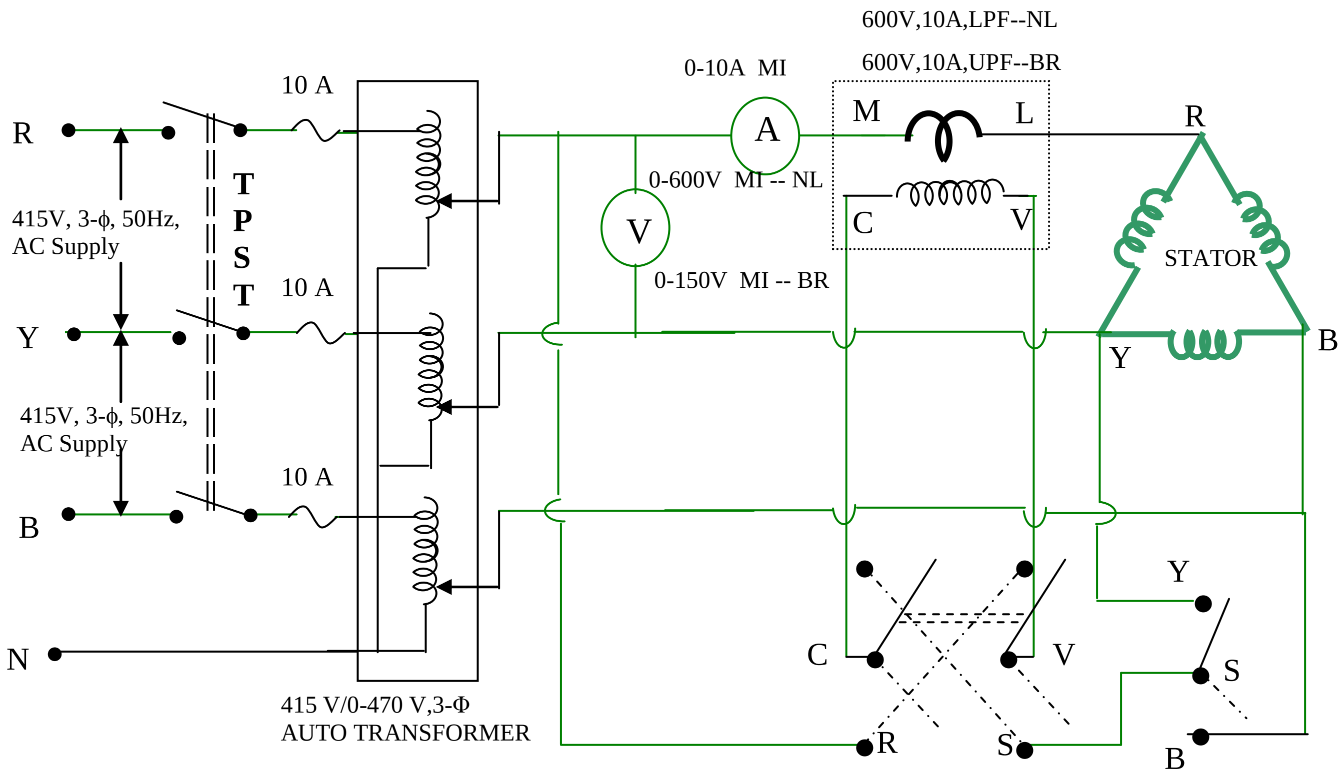
RESULT:

Viva questions:

1. What do u mean by AC three phase induction motor?
2. On what principle does induction work?
3. What are types of induction motor?
4. What is difference between squirrel cage type rotor and phase wound rotor?
5. What are different methods of speed control of three phase induction motor?
6. Explain the characteristics of squirrel cage induction motor?
7. Is three phase induction motor is self starting?
8. Explain the different methods of three phase induction motor?
9. What is effect of variation of supply frequency and supply voltage in an induction motor?

Circle diagram of Three Phase Induction Motor

CIRCUIT DIAGRAM: CIRCLE DIAGRAM OF 3-ϕ INDUCTION MOTOR



NL ---- NO LOAD TEST

BR ----BLOCKED ROTOR TEST

2.Circle diagram of Three Phase Induction Motor

AIM: To conduct no load and blocked rotor test on 3-ϕ induction motor and to draw circle diagram.

APPARATUS:

S.no	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Voltmeter	0-600V	MI	1No
3	Voltmeter	0-300V	MI	1No
4	Wattmeter	300V,10A	LPF	1N0
5	Wattmeter	300V,10A	UPF	1N0
6	Tachometer	(0-10000)rpm	Digital	1
7	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	Rating
1	Voltage	
2	Current	
3	Output	
4	RPM	
5	Frequency	
6	Connection	

THEORY:

NO LOAD TEST:

A full voltage is applied to the motor terminals and the rotor is run at no load speed. The open circuit equivalent circuit of induction motor is calculated as follows

$$\sqrt{3}\, V_0 I_0 \cos\phi_0 = W_o$$

$$\cos\phi_0 = W_o / \sqrt{3}\, V_0 I_0$$

The no load current I_O is the line current up to this level. In the equivalent circuit we require a phase value of the current.

$$I_{ph} = I_0/\sqrt{3}$$

The current I_{ph} will be divided into two components

$I_R = I_{ph} \cos\phi_0$ = Resistive current

$I_X = I_{ph} \sin\phi_0$ = Inductive current

The open circuit parameters will be given by

$R_o = V_0 / I_{ph} \cos\phi_0$ and

$X_m = V_0 / I_{ph} \sin\phi_0$

Where R_o and X_m are the resistance and magnetizing reactance of motor.

BLOCKED ROTOR TEST

In this test, block the rotor by belt or catch it by hands so that it cannot move . A reduced voltage of 20% is applied to the motor in all three phases. The adjustment of full load current is made by varying the supply voltage. Further we calculate equivalent circuit of the motor at blocked rotor condition as follows.

$$W_s = \sqrt{3}\, V_s I_s \cos\phi_s$$

$$\cos\phi_s = W_s / \sqrt{3}\, V_s I_s$$

The I_s is aline current we may change it to a phase value because equilent circuit is

found on phase values .

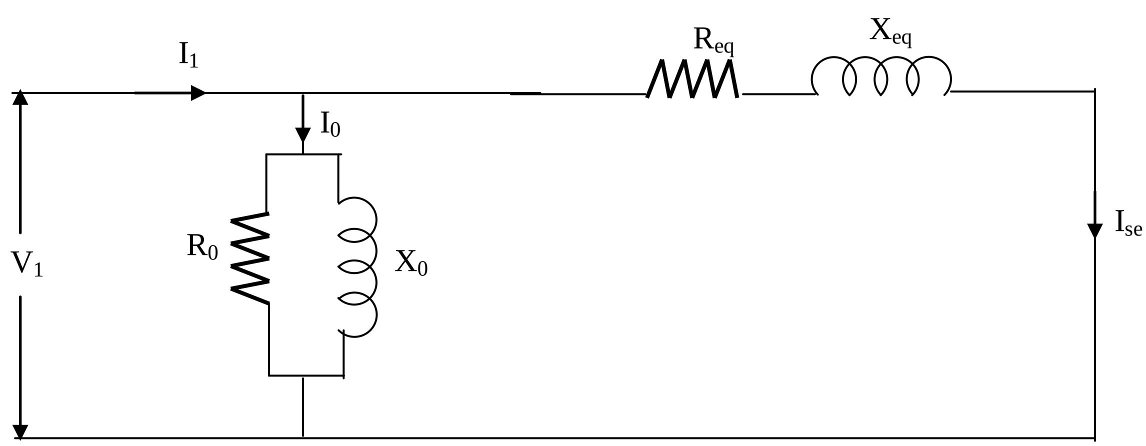
$$I_{sp} = I_s / \sqrt{3}$$

The impedance of motor will be

$$Z_s = V_s / I_{sp}$$

$R_{eq} = Z_s \cos\phi_s$ and $X_{eq} = Z_s \sin\phi_s$

The above two tests will give us a complete equilent circuit.



PROCEDURE:

NO-LOAD TEST :

(1) Connections are done as per the circuit diagram.
(2) By using the 3-φ auto transformer apply rated voltage to the stator winding of motor.
(3) Voltmeter, ammeter and wattmeter readings are tabulated at this rated voltage.

BLOCKED ROTOR TEST :

(1) Connections are done as per the circuit diagram by replacing the necessary meters.
(2) Block the rotor by brake.
(3) By using the 3-φ auto transformer rated current is made to flow in the line.
(4) At this rated current all the meter readings are tabulated.

TABULAR FORM:

NO-LOAD TEST			BLOCKED ROTOR TEST		
Vo	I_o	W_o	V_{sc}	I_{sc}	W_{sc}

PRECAUTIONS:

(1) While conducting the rotor blocked test the rotor must be blocked.
(2) Care must be taken while applying rated voltage and rated current in no-load and blocked rotor tests respectively.
(3) All the connections must be tight.

RESULT:

Viva questions

1. What do u mean by AC three phase induction motor?
2. On what principle does induction work?
3. What are types of induction motor?
4. What are different types of squirrel cage induction motor?
5. What is difference between squirrel cage type rotor and phase wound rotor?
6. What is the purpose of conducting no-load and blocked rotor test ?
7. Explain the torque equations in different conditions?
8. Explain circle diagram for a three phase induction motor?
9. Is three phase induction motor is self starting?
10. Explain the different starting methods of three phase induction motor?
11. What is effect of variation of supply frequency and supply voltage in an induction motor?

CONSTRUCTION OF CIRCLE DIAGRAM

By using the data obtained from the no load test and the blocked rotor test, the circle diagram can be drawn using the following steps:

1. Take reference phasor V as vertical (Y-axis)
2. Select suitable current scale such that diameter of circle is 20-30cm.
3. From No laod test, I_0 and ϕ_0 are obtained. Draw vector I_0, lagging V by angle ϕ_0. This is line OA
4. Draw horizontal line through extremity of I_0 i.e., A parallel to horizontal axis.
5. Draw the current I_{SN} calculated from I_{SC} with the same scale, lagging V by angle ϕ_{SC}, from origion O. This is phasor OB.
6. Join AB. The line AB is called output line.
7. Draw a perpendicular bisector to AB Extend it to meet line AD at point C. This is the centre of the circle.
8. Draw the circle with C as a centre and radius equal to AC. This meets the horizontal line drawn from A at B.
9. Draw the perpendicular from point B on the horizontal axis to meet AF line at D and meet horizontal axis at E.
10. Torque line:

    The torque line separates stator and rotor copper losses.

    The vertical distance BD represents power input at short circuit i.e., W_{SN} which consist of core loss, stator and rotor copper losses.

    F_D = DE = fixed loss

    A_F α sum of stator & rotor copper losses.

    Pt 'G' is located as

    $$\frac{BG}{GD} = \frac{Rotor\ copper\ loss}{Stator\ copper\ loss}$$

    The line AG in called torque line

Power Scale: As AD represents W_{SN} i.e., power input on short circuit at normal voltage, the power scale can be obtained as

$$\text{Power scale} = \frac{W_{SN}}{\ell\,(BE)} = W/cm$$

ℓ (BE) = Distance BE in cm

Location of point E (slip ring induction motor):

$$K = \frac{I_1}{I_2} = \text{transformation ratio}$$

$$\frac{AE}{EF} = \frac{Rotor\ copper\ loss}{stator\ copper\ loss} = \frac{I_2^2 R_2}{I_1^2 R_1} = \frac{R_2}{R_1}\left(\frac{I_2}{I_1}\right)^2$$

$$R_2^1 = \frac{R_2}{K_2} = \text{Rotor resistance referred to stator.}$$

$$\frac{BG}{GD} = \frac{R_2^1}{R_1}$$

Thus pt G can be obtained by dividing the line BD in the ratio $R_2^{'}\ R_1$

Location of point D (squirrel cage induction motor):

In a squirrel cage motor, the stator resistance can be measured by conducting resistance test.

i.e., Stator copper loss = $3I_{SN}^2\ R_1$ where I_{SN} is phase value.
Neglecting core loss, W_{SN} = stator Cu loss + Rotor Cu loss
i.e., Rotor copper loss = $W_{SN} - 3I_{SN}^2 R_1$

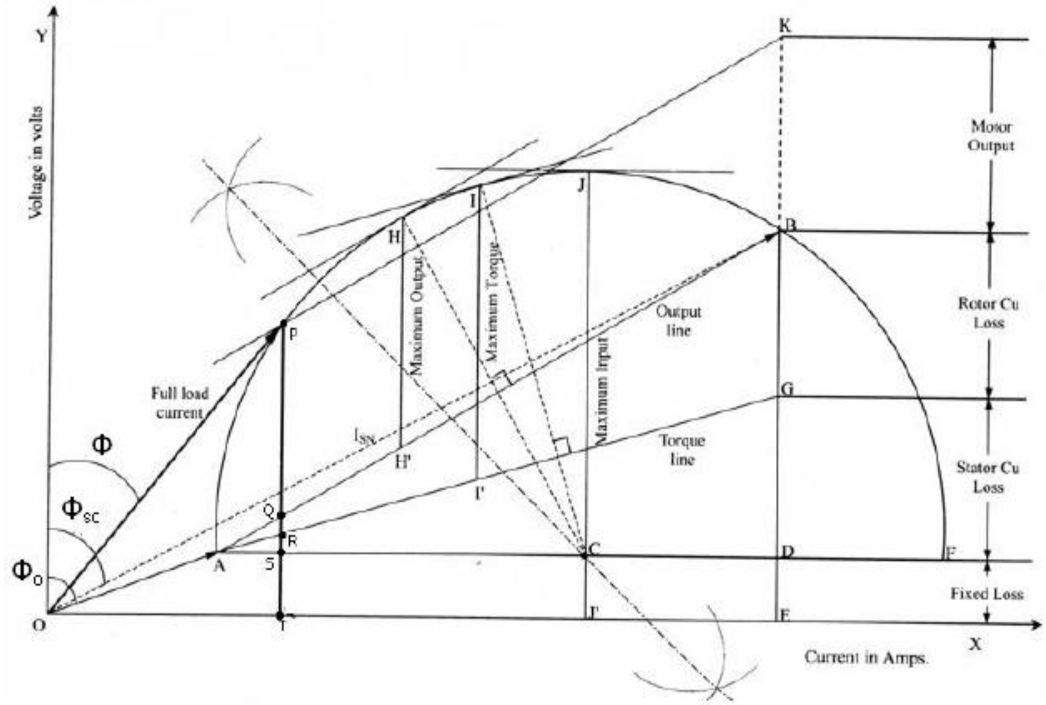
$$\frac{BG}{GD} = \frac{WSN - 3_{SN}^2 R_1}{3I_{SN}^2 R_1}$$

Dividing line BD in this ratio, the point G can be obtained and hence AG represents torque line.

To get the torque line, join the points A and G.

11. To find the full load quantities, draw line BK (=Full load output/power scale). Now, draw line PK parallel to output line meeting the circle at point P.
12. Draw line PT parallel to Y-axis meeting output line at Q, torque line at R, constant loss line at S and X-axis at T.

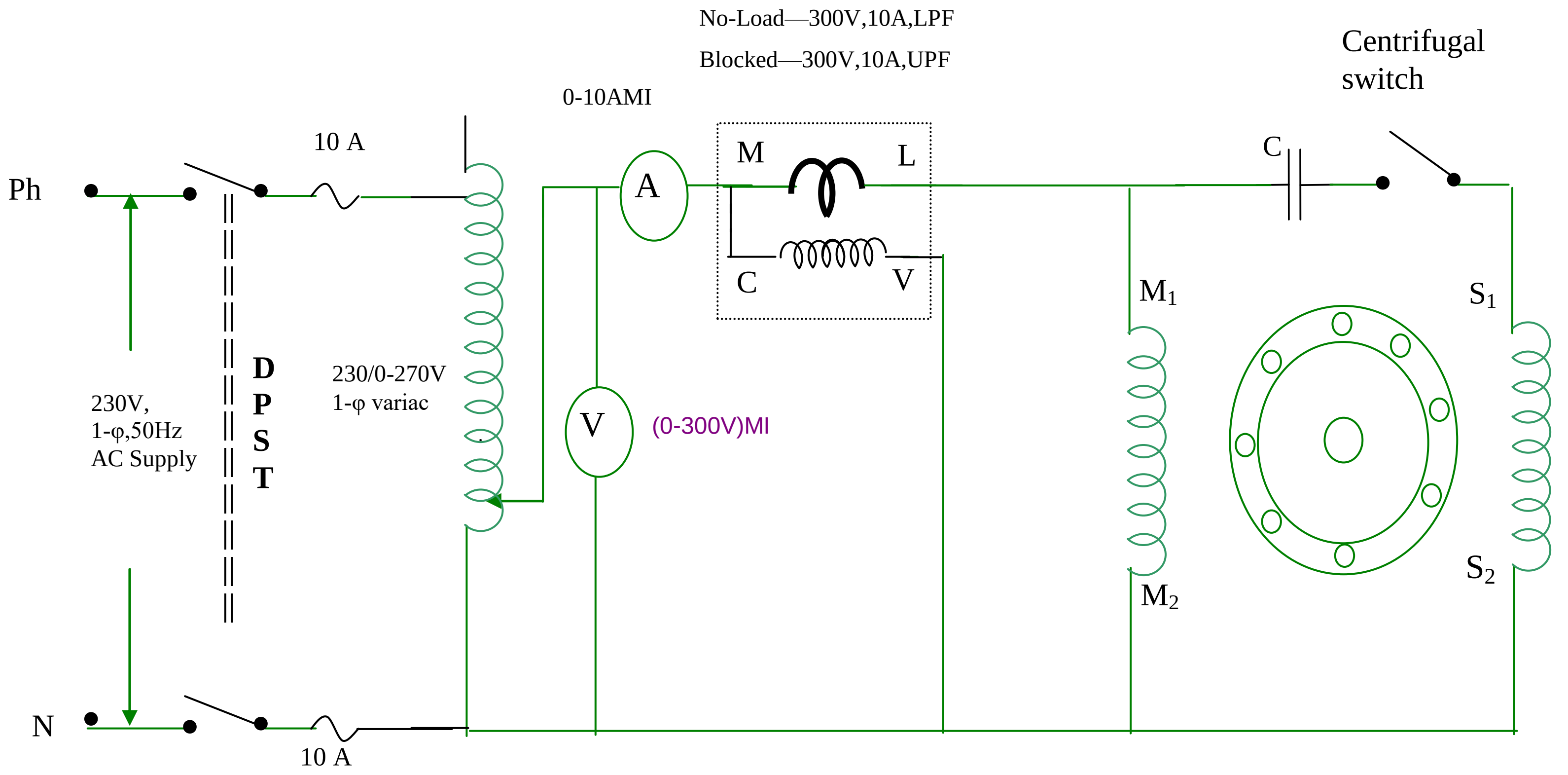
MODEL GRAPH:



Y
X
O
Voltage in volts
Current in Amps.
K
J
I
H
B
P
G
Q
R
S
A
C
D
F
T
I'
E
H'
I'
Φ
Φ_sc
Φ_0
Full load current
Output line
Torque line
Maximum Output
Maximum Torque
Maximum Input
I_SN
Motor Output
Rotor Cu Loss
Stator Cu Loss
Fixed Loss

Equivalent Circuit of Single-phase Induction Motor

CIRCUIT DIAGRAM: EQUIVALENT CIRCUIT OF A SINGLE PHASE INDUCTION MOTOR



3.Equivalent Circuit of Single-phase Induction Motor

AIM: To determine the equivalent circuit parameters of a 1- Ø induction motor by conducting No-Load and Blocked Rotor Tests.

APPARATUS:

S.no	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Voltmeter	0-300V	MI	1No
3	Wattmeter	300V,10A	LPF	1N0
4	Wattmeter	300V,10A	UPF	1N0
5	Tachometer	(0-10000)rpm	Digital	1
6	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

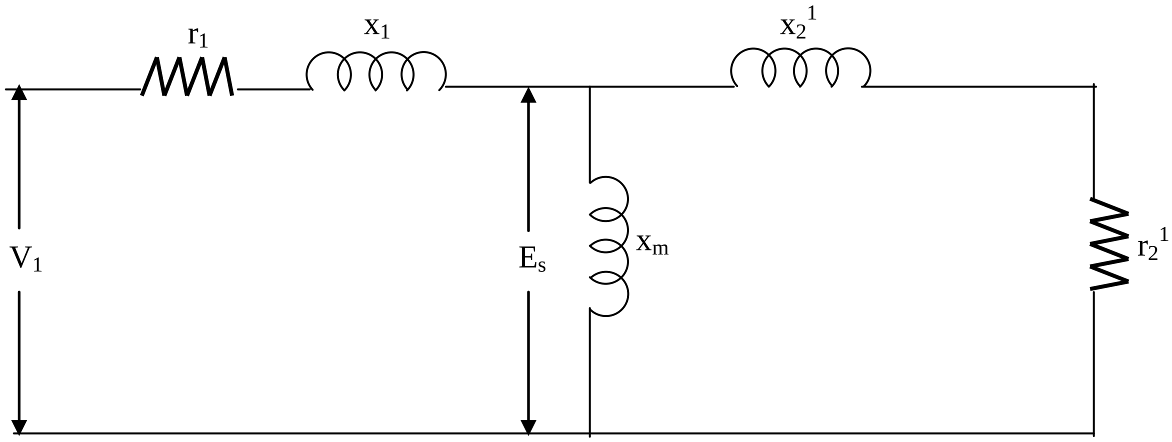
S.No	Specifications	Rating
1	Rated Voltage	
2	Rated Current	
3	Rated Power	
4	Rated speed	
5	Frequency	

THEORY:

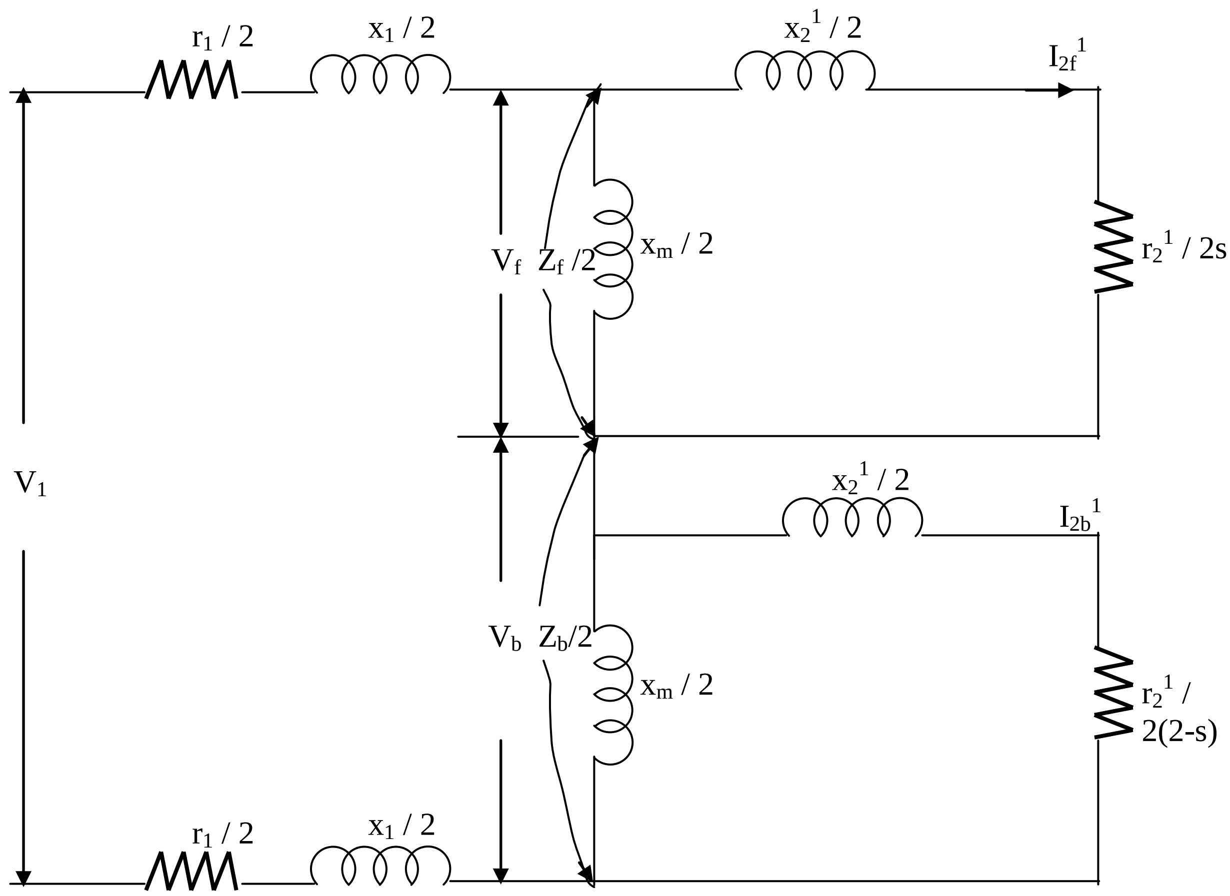
When the rotor is stationary, the pulsating stator field induces voltages in the rotor by the transformer action. The e.m.f induced in the stator winding by the alternating field is referred to as (E_s)in the equivalent circuit of the motor shown in the fig(1) r_1 and x_1 are the resistance and reactance of the stator winding.r_2 and x_2 are the resistance and reactance of rotor referred to the stator side. Using the concept of the rotating field, the e.m.f induced,(E_s) can be shown as composed of equal components induced by the two oppositely rotating fields of the same strength, namely (E_f)and (E_b).

Then the $Es = E_f + E_b$

The magnetizing and rotor impedances are divided into two equal halves connected in series. The motor behaves like a two series connected motors, one corresponding to each rotating field. The circuit elements of the two component motors are identical with the condition of stationary rotor since the rotor has same slip with respect to each rotating field.However, when the rotor is running at a speed N in the direction of the forward field with a slip s, the corresponding slip with backward running field will be (2-s)and the equivalent circuit components of the two rotors are then modified shown in fig(2).It can be seen from these parameters that the impedance ($z_f/2$)of the rotor to forward field is much higher than the impedance ($z_b/2$)offered to the backward field, and therefore E_f will be much greater than E_b. This implies that the resultant torque is generally by the forward field which is dominant one.



Fig(1): Equivalent circuit when the rotor is stationary
(Transformer action)



Fig(2): Equivalent circuit of single phase induction motor based on the rotating field when the rotor is stationary.

CALCULATIONS:

NO LOAD TEST:

$$V_o I_o \cos\phi_o = W_o$$

$$\cos\phi_o = \frac{W_o}{V_o I_o}$$

$$Z_o = \frac{V_o}{I_o}$$

$$X_o = Z_o \sin\phi_o$$

$$X_o = X_1 + \frac{1}{2}(X_2 + X_m)$$

$$X_m = 2(X_o - X_1) - X_2$$

BLOCKEDROTOR TEST:

$$Z_{sc} = \frac{V_{sc}}{I_{sc}}$$

$$R_{sc} = \frac{W_{sc}}{I_{sc}^2}$$

r_1 is the DC resistance of stator of motor

$$r_2 = R_{sc} - r_1$$

$$x_1 + x_2 = X_{sc}$$

since leakage reactance can't be seperated out , it is common practice to to assume $x_1 = x_2$

$$x_1 = x_2 = \frac{X_{sc}}{2} = X_{sc} = \frac{1}{2}\sqrt{Z_{sc}^2 - R_{sc}^2}$$

PROCEDURE :

NO-LOAD TEST :-

(1) Connections are done as per the circuit diagram.
(2) By using 1-ϕ auto transformer apply rated voltage to the motor.
(3) After getting rated speed of motor tabulate all the meter readings and speed.

BLOCKED ROTOR TEST :-

(1) Replace the meters as per the blocked rotor test.
(2) Block the rotor of the 1-ϕ induction motor by brake.
(3) By using the 1-ϕ auto transformer apply reduced voltage to the motor till the motor draws the rated current of the motor
(4) After getting rated current tabulate all the meter readings From the above two tests we can find the parameters of 1-ϕ induction motor

OBSERVATIONS:

NO-LOAD TEST

S.NO	V_0 in volts	I_0 in amps	W_0 in watts	Speed in r.p.m

BLOCKED ROTOR TEST

S.NO	V_s in volts	I_s in amps	W_s in watts

PRECAUTIONS:

1) Don't switch on power supply without concerning teacher.
2) Single phase autotransformer must be kept at minimum potential point before switch on the experiment

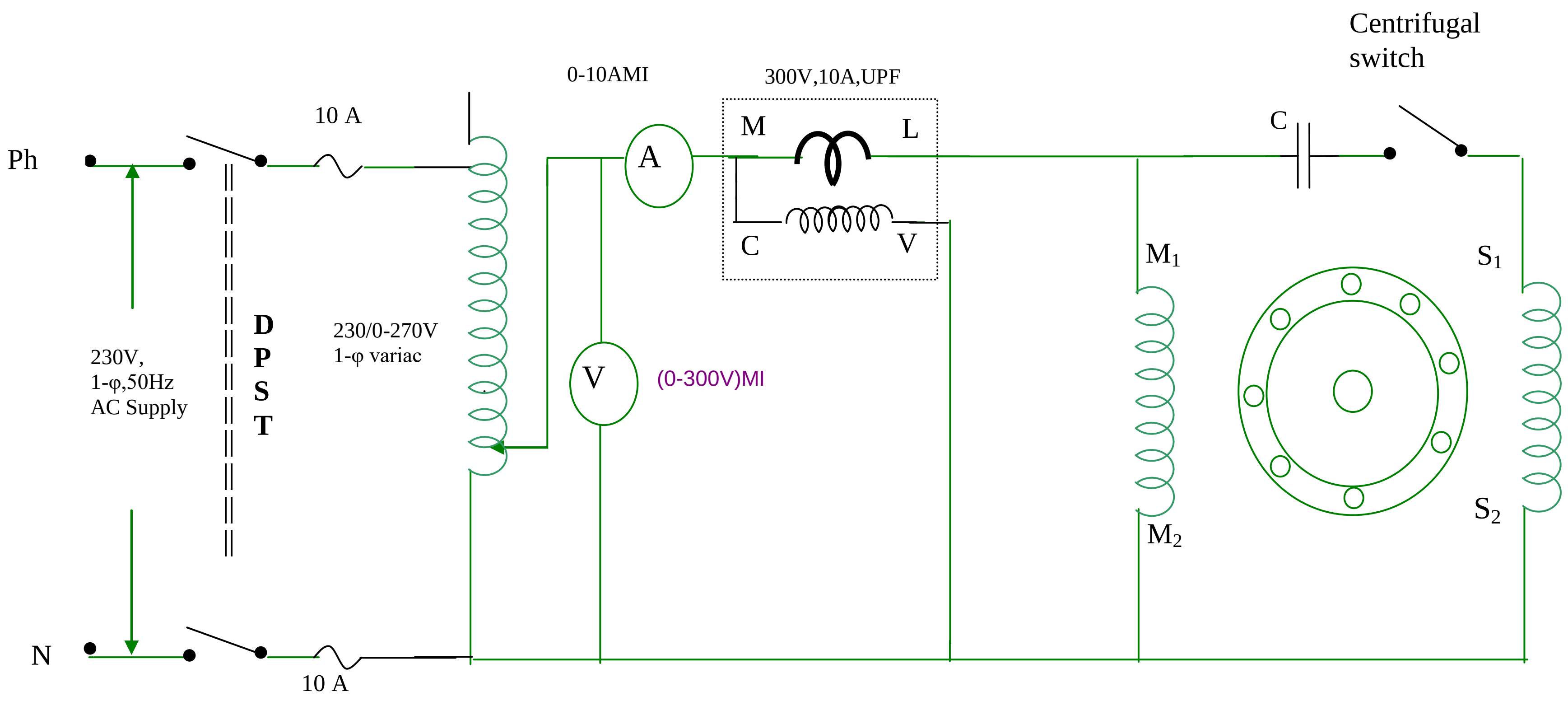
RESULT:

Viva Questions:

1. What is the principle of single phase induction motor?
2. What is difference between single phase induction motor and three phase induction motor?
3. Is single phase induction motor is self starting?
4. What are the different starting methods of single phase induction motor?
5. Explain Double field revolving field theory
6. Explain shaded pole induction motor
7. Explain the difference between capacitor start and capacitor run motor?
8. What is the difference between Induction motor and conduction motor?
9. What is the purpose of centrifugal switch in induction motor?
10. Difference between induction motor and synchronous motor?

Power Factor improvement of Single-phase Induction Motor by using Capacitors

CIRCUIT DIAGRAM: POWER FACTOR IMPROVEMENT OF SINGLE-PHASE INDUCTION MOTOR BY USING CAPACITORS



4.Power Factor improvement of Single-phase Induction Motor by using Capacitors

AIM: To measure the power factor in a single phase induction motor with and without capacitor in series with auxiliary winding and study of improvement of power factor using capacitor.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Voltmeter	0-300V	MI	1No
3	Wattmeter	300V,10A	LPF	1N0
4	Tachometer	(0-10000)rpm	Digital	1
5	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	Rating
1	Rated Voltage	
2	Rated Current	
3	Rated Power	
4	Rated speed	
5	Frequency	

THEORY:

When single-phase supply is applied across one single phase winding on the stator of a single phase Induction Motor, the nature of the field produced is alternating and as such the rotor will not develop any starting torque. It has however been observed that once the motor is given an initial rotation it continues to rotate. In a single-phase motor, to provide starting torque, an additional winding is provided, which is called the auxiliary winding. The main and the auxiliary windings are connected in parallel across a single-phase supply. The impedance of the two windings are made different so that currents flowing through these windings will have a time phase difference as shown in Fig '1'.

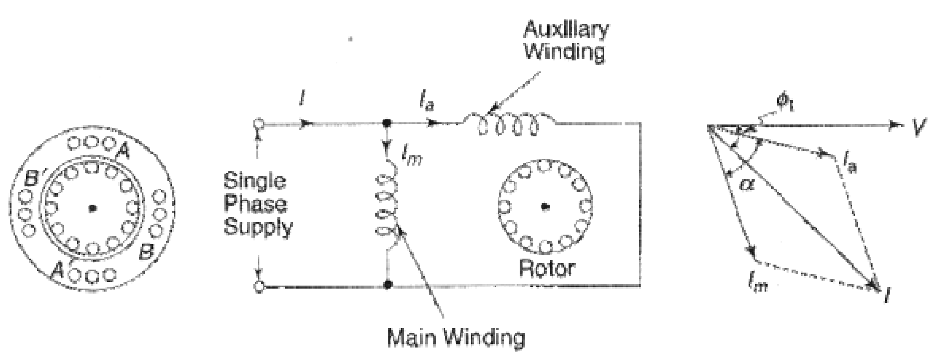
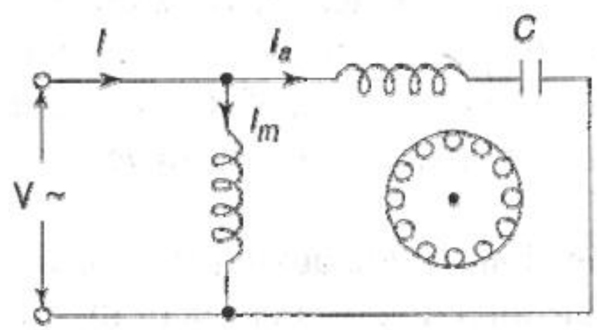


Fig-'1' : Single Phase Induction Motor winding carrying currents which have a time phase difference of α degree.

Need of a Capacitor in the Auxiliary Winding Circuit

A single phase motor having a main winding and an auxiliary winding fed from a single phase supply can be considered as equivalent to a two phase motor having a single phase supply. Since the two windings are not identical, the two currents Im and Ia will have a time phase displacement. Now if by any means the time phase displacement between the two currents I_m and I_a flowing through the two windings can be made 90^0, a single phase motor will behave exactly like a two phase motor. The time phase displacement between Im and Ia can be increased by using a capacitor in the auxiliary winding as shown in Fig -'2'. The capacitor will also improve the overall power factor of the motor. From the phasor diagrams of Fig –'1' & Fig –'2' it will be observed that the power factor of the motor is improved when a capacitor is introduced in the auxiliary winding circuit. If a capacitor is to be used only for achieving high starting torque, then the auxiliary winding can be switched off when the motor picks up speed.



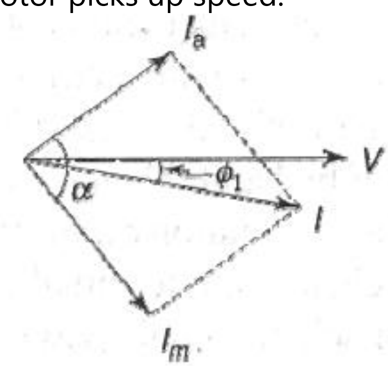


Fig-'2': Time phase difference of nearly 90^0 between the main and auxiliary winding current is achieved by using a capacitor in the auxiliary winding circuit.

PROCEDURE:

1) All the connections are done as per the circuit diagram.
2) Switch on the supply through variac. Note the direction of rotation of the rotor.
3) Remove the auxiliary winding connections after switching off the supply. Switch on supply and note that the rotor does not rotate. Give a slight rotation to the rotor in a particular direction and note that the rotor picks up speed in that direction.
4) Reconnect the auxiliary winding across the supply but without the capacitor in the circuit (short the two terminals across which the capacitor was connected).
5) Switch on the supply and observe if the rotor starts rotating. In case the rotor rotates, feel the magnitude of starting torque by holding the shaft by hand. Allow the rotor to rotate and then record voltmeter, ammeter and wattmeter readings.
6) Run the rotor with auxiliary winding connected across the supply with the capacitor in the circuit. At starting feel the magnitude of starting torque by holding the rotor by hand. Then release the rotor and record the meter readings. Not the direction of rotation of the rotor.

TABULAR FORM:

(a) Without capacitor in series with auxiliary winding

S.NO	Input Power (W)	Input Voltage (V)	Input Current (I)	Power Factor cosϕ = W/VI

(b) With capacitor in in series with auxiliary winding

S.NO	Input Power (W)	Input Voltage (V)	Input Current (I)	Power Factor cosϕ = W/VI

PRECAUTIONS:

1. Make sure that all connections are tight.
2. The connections should be according to circuit diagram.
3. Don't touch the naked connection, it may give shock

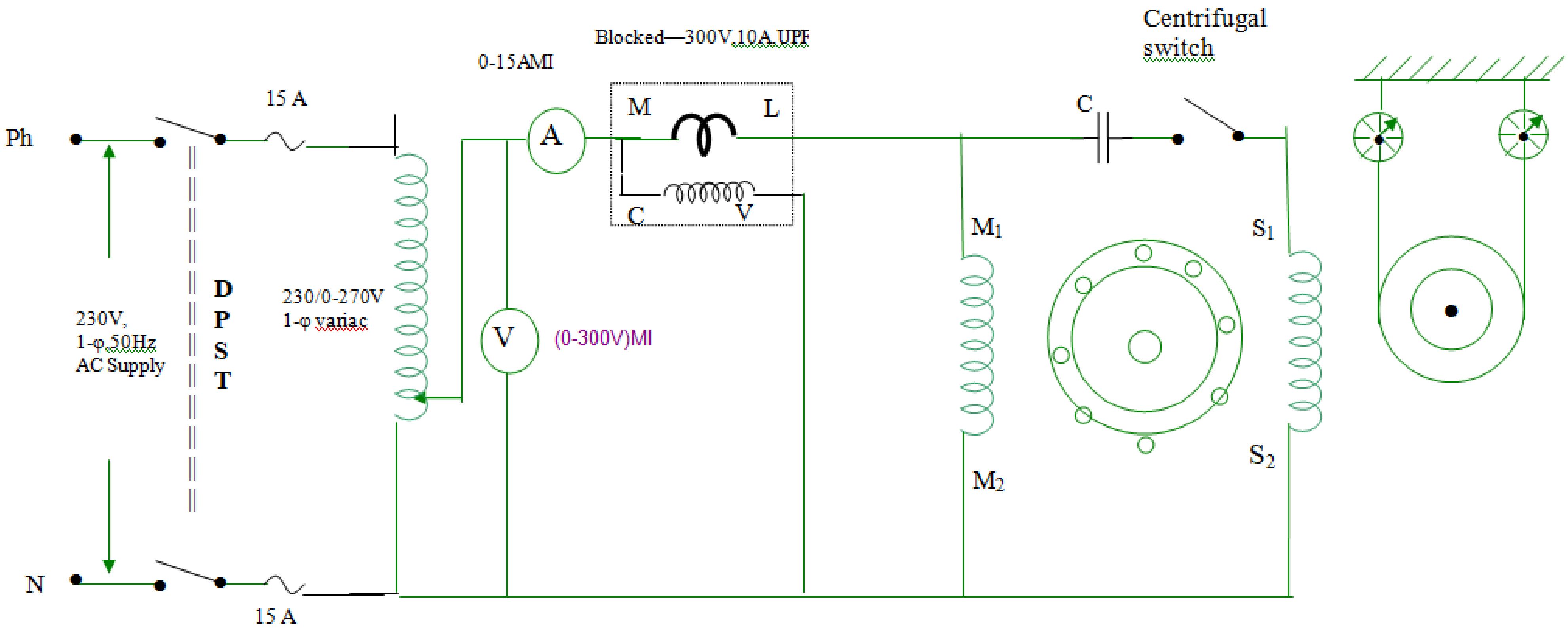
RESULT:

Viva Questions:

1. What is the principle of single phase induction motor?
2. What is difference between single phase induction motor and three phase induction motor?
3. Is single phase induction motor is self starting?
4. What are the different starting methods of single phase induction motor?
5. Explain Double field revolving field theory
6. What is the purpose of centrifugal switch in induction motor?
7. Difference between induction motor and synchronous motor?

Load Test on Single-phase Induction Motor

CIRCUIT DIAGRAM: LOAD TEST ON SINGLE PHASE INDUCTION MOTOR



5.Load Test on Single-phase Induction Motor

AIM: To conduct load test on the given single phase induction motor and to plot its performance characteristics.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Voltmeter	0-300V	MI	1
2	Ammeter	0-15A	MI	1
3	Wattmeter	300V, 15A	UPF	1
4	Tachometer	(0-10000)rpm	Digital	1
5	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	Rating
1	Rated Voltage	
2	Rated Current	
3	Rated Power	
4	Rated speed	
5	Frequency	

THEORY:

It is a direct method and consists of applying a brake to a water cooled pulley mounted on the motor shaft. The simple brake test described above can be used for small motors only, because in the case of large motor it is difficult to dissipate the large amount of heat generated at the brake. The simple method of measuring motor output by the use of poney brake. A rope is wound round the pulley and its two ends are attached to two spring balances S_1 & S_2. The tension of the rope can be adjusted with the help of squirrels. Obliviously the force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances.

FORMULAE:

1. Circumference of the brake drum = 2Π r (m)

   Where r = Radius of the brake drum

2. Input power = W (watts)

   Where W = Wattmeter readings

3. Torque (T) = 9.81* r * (S1 ~ S2) (N-m)

   Where S1, S2 = Spring balance readings (Kg)

4. Output power = $2\pi NT / 60$ (watts)

Where N- Speed in rpm

5. % Efficiency (η) = (Output Power/Input Power) * 100

6. Power factor, Cos Φ= W/VI

7. % Slip, s = [(Ns-N)/Ns]*100

Where Ns = Synchronous speed = 120 f / P (rpm)

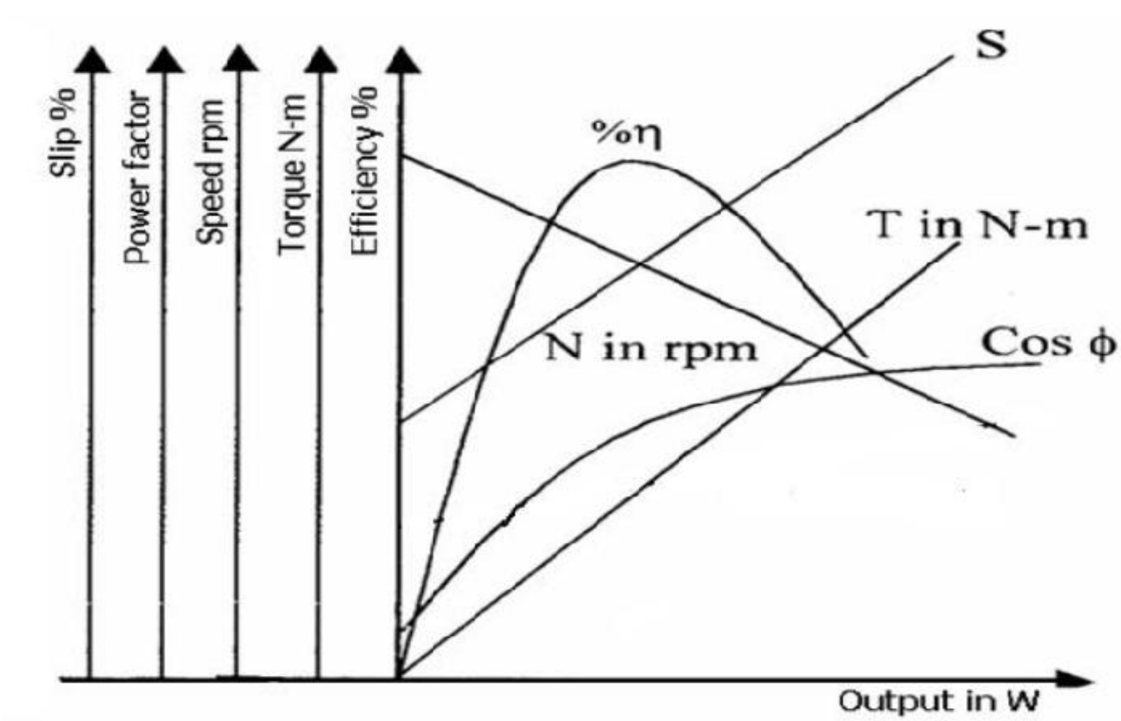
P = No. of poles

f = Frequency of supply (Hz

PROCEDURE:

1) All the connections are done as per the circuit diagram.
2) Motor is started with the help of **1-ϕ** Auto transformer starter i.e it is running at rated speed.
3) Note down the readings of wattmeter, voltmeter, ammeter, speed and balance readings S_1 and S_2.
4) Brake is applied to the water cooled pulley. Pulley is mounted on the motor shaft and note down the corresponding balance readings S_1 and S_2 .
5) For each step of the brake (load) on the motor note down the readings of voltmeter, ammeter, wattmeter and speed and balance readings S_1 and S_2.
6) Take readings of all meter until motor carries its full load current.
7) From the tabulated readings required quantities are to be calculated.

MODEL GRAPH:



TABULAR FORM:

S.No	Voltage (V)	Current (A)	Speed (rpm)	Balance readings		Wattmeter reading (w)	Torque 9.81 x (S1 ~ S2) x r (N- M)	Output $2\pi NT/60$ (w)	% Efficiency output / input x100	% slip	Power factor $\cos\varphi$
				S_1 (kg)	S_2 (kg)						

PRECAUTIONS:

1) Water is poured into the pulley when conducting the experiment.
2) Motor current should not exceed its full load current.
3) All the connections must be tight.

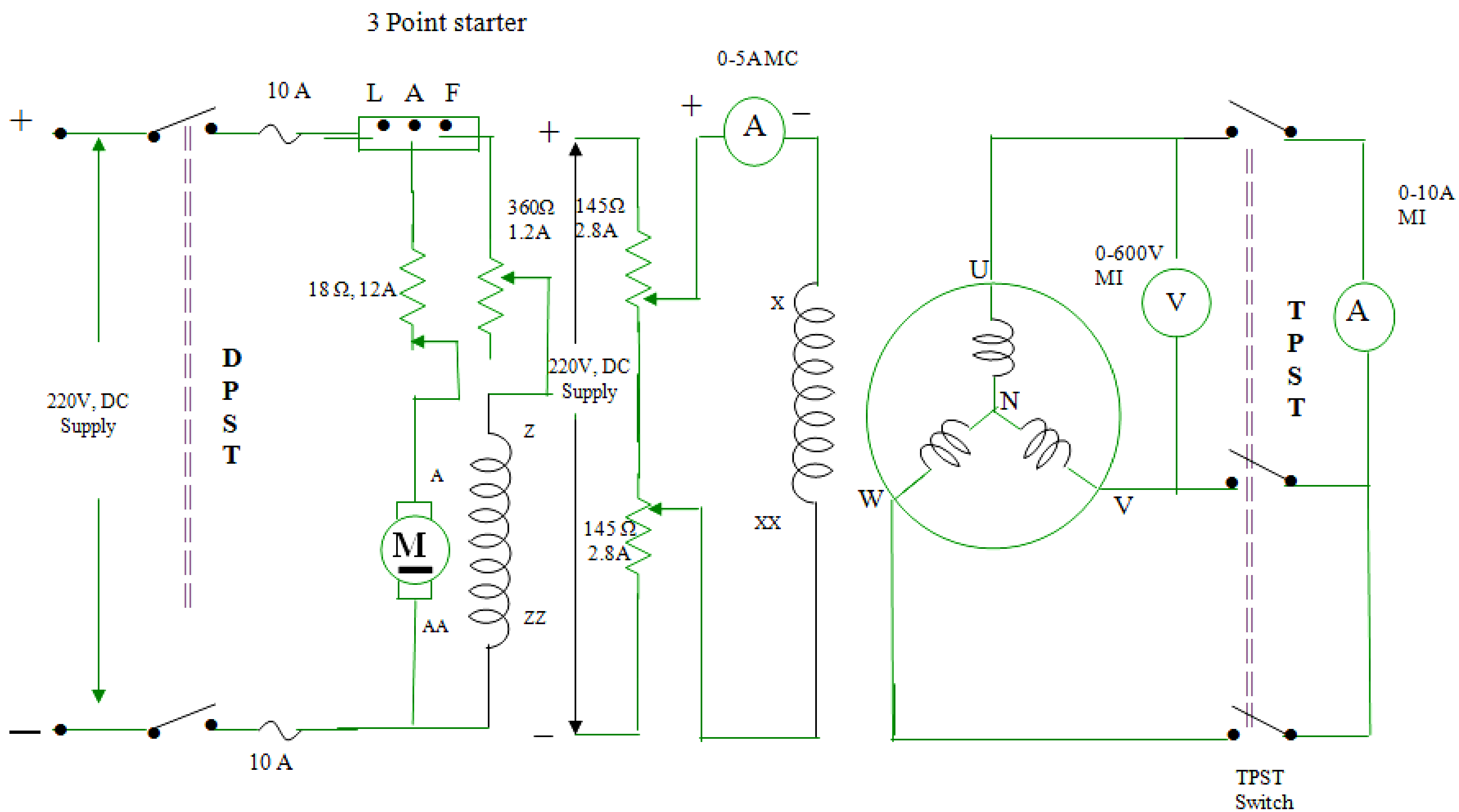
RESULT:

Viva Questions:

1. What is the principle of single phase induction motor?
2. What is difference between single phase induction motor and three phase induction motor?
3. Is single phase induction motor is self starting?
4. What are the different starting methods of single phase induction motor?
5. Explain Double field revolving field theory
6. Explain shaded pole induction motor
7. Explain the difference between capacitor start and capacitor run motor?
8. What is the difference between Induction motor and conduction motor?
9. What is the purpose of centrifugal switch in induction motor?

Regulation of 3-phase Alternator by Synchronous impedance & MMF methods

CIRCUIT DIAGRAM: REGULATION OF 3-ϕ ALTERNATOR BY EMF & MMF



6.Regulation of 3-phase Alternator by synchronous impedance & MMF methods

AIM: To obtain the regulation of a 3-ϕ alternator by synchronous impedance and MMF methods.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Ammeter	0-5A	MC	1No
3	Voltmeter	0-600V	MI	1No
4	Rheostat	18 Ω,12A	Wire wound	1N0
5	Rheostat	360Ω,1.2A	Wire wound	1No
6	Rheostat	145Ω,2.8A	Wire wound	2No
7	Tachometer	(0-10000)rpm	Digital	1
8	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	DC Motor	Alternator
1	Rated Voltage		
2	Rated Current		
3	Rated Power		
4	Rated Speed		

THEORY:

Open-circuit Characteristic (OCC)

In this test the machine is run mechanically at synchronous speed N_s to generate voltage at the rated frequency, while the armature terminals are open-circuited. The readings of the open- circuited line-to-line armature voltage, V_{oc} are taken for various values of I_f , the rotor field current. The OCC exhibits the saturation phenomenon of the iron in machine. At the values of I_f when iron is in the unsaturated state, the OCC is almost linear and the mmf applied is mainly consumed in establishing flux in the air-gap, the reluctance of the iron path being almost negligible. The straight-line part of the OCC, if extended is called the air-gap line and would indeed be the OCC if iron did not get saturated.

Short-circuit Characteristic (SCC)

The short-circuit characteristic of the machine is obtained by means of the short circuit test. While the rotor is run at synchronous speed N_s, the rotor is kept unexcited to begin with. The field excitation is then gradually increased till the armature current equals about 150% of its rated value.

From the graphs of OC and SC test results.

CALCULATIONS:

Synchronous Impedance (EMF) Method:

Synchronous Impedance Zs = V_{oc} / I_{sc} at same I_f

Synchronous reactance $X_S = \sqrt{Z_S^2 - R_a^2}$

=

1. No-load induced emf E_O at 0.8 lag

$$E_O = \sqrt{(V cos\emptyset + IR_a)^2 + (V sin\emptyset + IX_S)^2}$$

=

% Regulation at 0.8 p.f lag

$$\frac{Eo - V_{ph}}{V_{ph}} * 100 =$$

2. No load induced emf at unity power factor

$$E_o = \sqrt{(V cos\emptyset + IR_a)^2 + (IX_S)^2}$$
$$= \sqrt{(V + IR_a)^2 + (IX_S)^2} =$$

%Regulation at U.P.F

$$\frac{E_O - V}{V} * 100 =$$

3. No-load induced emf at 0.6 lead pf

$$E_O = \sqrt{(V cos\emptyset + IR_a)^2 + (V sin\emptyset + IX_S)^2}$$

=

%Regulation at 0.6 lead pf

$$\frac{E_O - V}{V} * 100 =$$

Ampere Turn Method (MMF Method):

The effect of armature leakage reactance is replaced by an equivalent additional armature reaction MMF so that this MMF can be combined with the armature reaction MMF.

$$E_{ph} = V_{ph} + I_a R_a + j I_a X_l + j I_a X_a$$

$$E_{ph} = V_{ph} + I_a R_a + j I_a X_a$$

$$E = V_{ph} + I_a R_a \cos\phi$$

I_{fm} = Main Field current required to generate rated voltage under O.C condition.

I_{fa} = Main Field current required to produce rated armature current under S.C Condition.

$$I_{fr} \nearrow I_{f_0} = \sqrt{I_{f_1}^2 + I_{f_2}^2 + 2 I_{f_1} I_{f_2} \cos\left[180 - (90 \pm \phi)\right]}$$

$+$ for lagging P.F

$-$ for leading P.F

$$\left(\begin{array}{l} I_{fm} = I_{f_1} \\ I_{fa} = I_{f_2} \end{array} \right)$$

%Regulation at 0.8 PF

$$\frac{E_0 - V}{V} * 100 =$$

PROCEDURE:

OC Test

(1) Connections are done as per the circuit diagram.
(2) Initially rheostat in the armature circuit of motor is kept at maximum position, the rheostat in the field circuit of motor is kept at minimum position and the rheostats in the field circuit (potential divider)of the alternator are kept so that minimum voltage is given to the field circuit of the alternator.
(3) Start the motor with the help of 3-point starter
(4) Bring the speed of the motor to rated speed by using the rheostats of the motor.
(5) Vary the field current in the field circuit of alternator by using the rheostats in the alternator field .
(6) For every step of variation of rheostat tabulate the voltmeter and ammeter readings until the voltmeter reads just above the rated voltage.

SC-Test

(1) Reduce the excitation to the alternator field for conducting SC test.
(2) Before closing the TPST switch ensure that the voltmeter reads zero volts.
(3) Now close the TPST test
(4) By varying excitation, tabulate I_f and I_{se} readings until I_{se} equal to full load current of alternator.

TABULAR FORMS:

OC TEST:

S.No	V_L(volts)	I_f(amps)	V_{ph}(Volts)

S.C TEST:

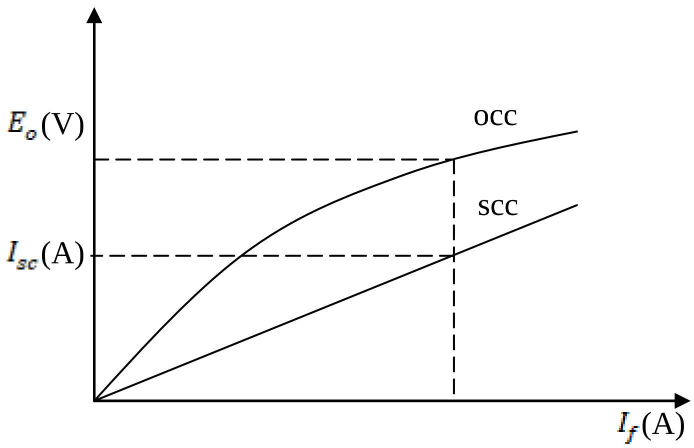
S.No	V_{SC}(volts)	I_f(amps)	I_{sc}(amps)

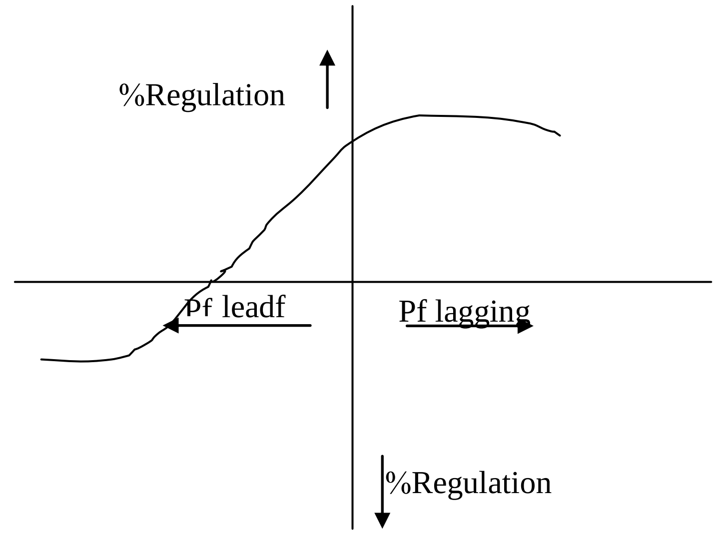
S.No	Power Factor	% Regulation	
		P.F Lag	P.F Lead

PRECAUTIONS:

(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) While conducting SC test the voltmeter across armature should read zero.
(4) The readings should not exceed meter readings.

MODEL GRAPHS:





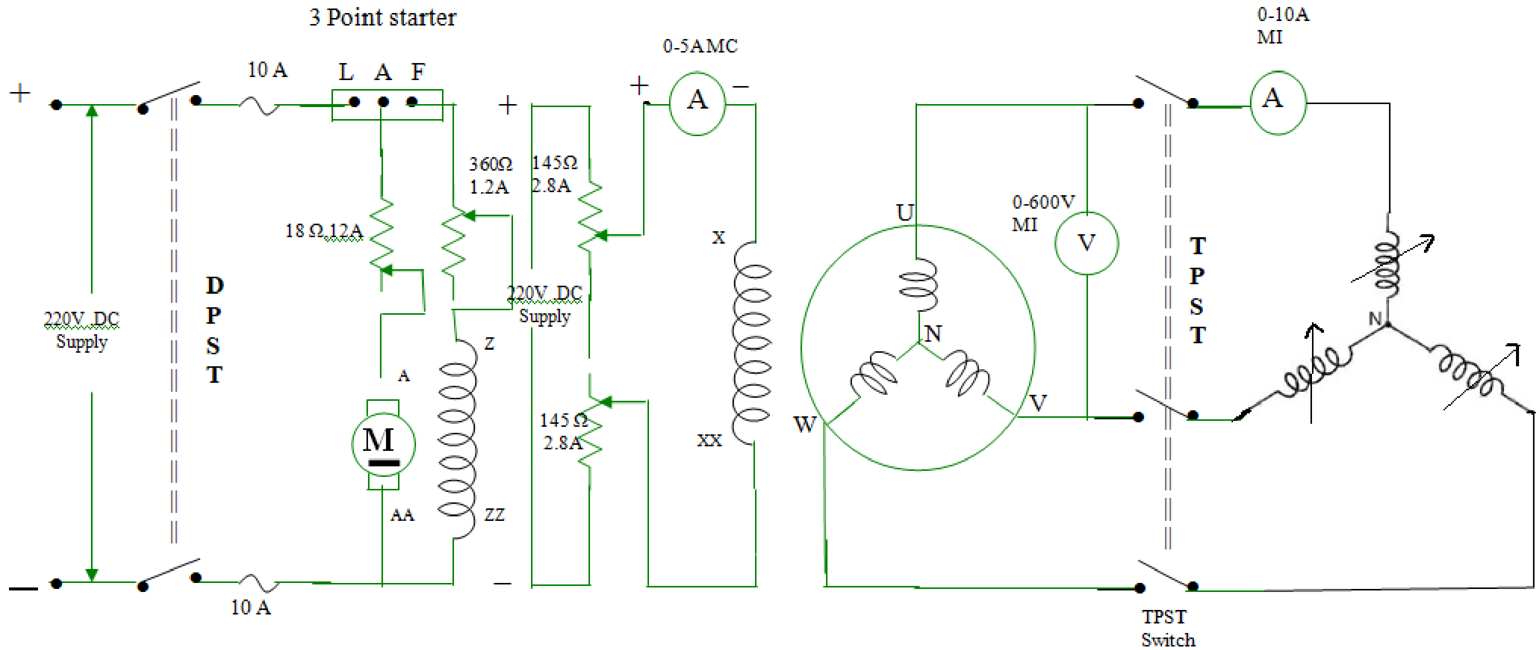
RESULT:

Viva Questions

1. Explain principle and operation of alternator?
2. What is the different between alternator and dc generator?
3. What is the emf equation of induced emf in an alternator?
4. Does changing the number of conductor have any effect on the frequency?
5. What is called the armature reaction of an alternator?
6. What is the formula for calculating the generated emf on load condition?
7. What are different methods used for determination of voltage regulation?
8. What is the effect of hunting? How can we reduce the Hunting?
9. What is the effect of change of excitation in alternator?
10. On which factors the frequency value depends?

Regulation of 3-phase Alternator by Potier triangle method

CIRCUIT DIAGRAM: REGULATION OF 3-ϕ ALTERNATOR BY ZPF METHOD



NAME PLATE DETAILS:

7.Regulation of 3-phase Alternator by Potier triangle method

AIM: To obtain the regulation of a 3-ϕ alternator by using Potier triangle (ZPF) method.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Ammeter	0-5A	MC	1No
3	Voltmeter	0-600V	MI	1No
4	Rheostat	18 Ω,12A	Wire Wound	1N0
5	Rheostat	360Ω,1.2A	Wire Wound	1No
6	Rheostat	145Ω,2.8A	Wire Wound	2No
7	3- Ø inductive Load			1
8	Tachometer	(0-10000)rpm	Digital	1
9	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	DC Motor	Alternator
1	Rated Voltage		
2	Rated Current		
3	Rated Power		
4	Rated Speed		

THEORY:

The **Potier triangle** determines the voltage regulation of the machines. This method depends on the separation of the leakage reactance of armature and their effects. In the e.m.f. method. the phasor diagram involving voltages is used, For the z.p.f method, the e.m.fs. are handled as voltages and the m.m.fs. as field ampere-turns or field amperes. Zero-power-factor characteristic (z.p.f.c.), in conjunction with O.C.C., is useful in obtaining the armature leakage reactance X_l and armature reaction m.m.f. This method gives the voltage regulation near to actual value. Therefore this is accurate method.

The ZPF method requires the following data's to determine the voltage regulation of alternator.

- Armature resistance/phase
- Open circuit characteristics (I_f vs V_{OC})
- Short circuit characteristics (I_f vs I_{SC})
- ZPF Characteristics (I_f vs V_{ph}) where Ia=Rated current

Open-circuit Characteristic (OCC)

In this test the machine is run mechanically at synchronous speed N_s to generate voltage at the rated frequency, while the armature terminals are open-circuited. The readings of the open- circuited line-to-line armature voltage, V_{oc} are taken for various values of I_f , the rotor field current. The OCC exhibits the saturation phenomenon of the iron in machine. At the values of I_f when iron is in the unsaturated state, the OCC is almost linear and the mmf applied is mainly consumed in establishing flux in the air-gap, the reluctance of the iron path being almost negligible. The straight-line part of the OCC, if extended is called the air-gap line and would indeed be the OCC if iron did not get saturated.

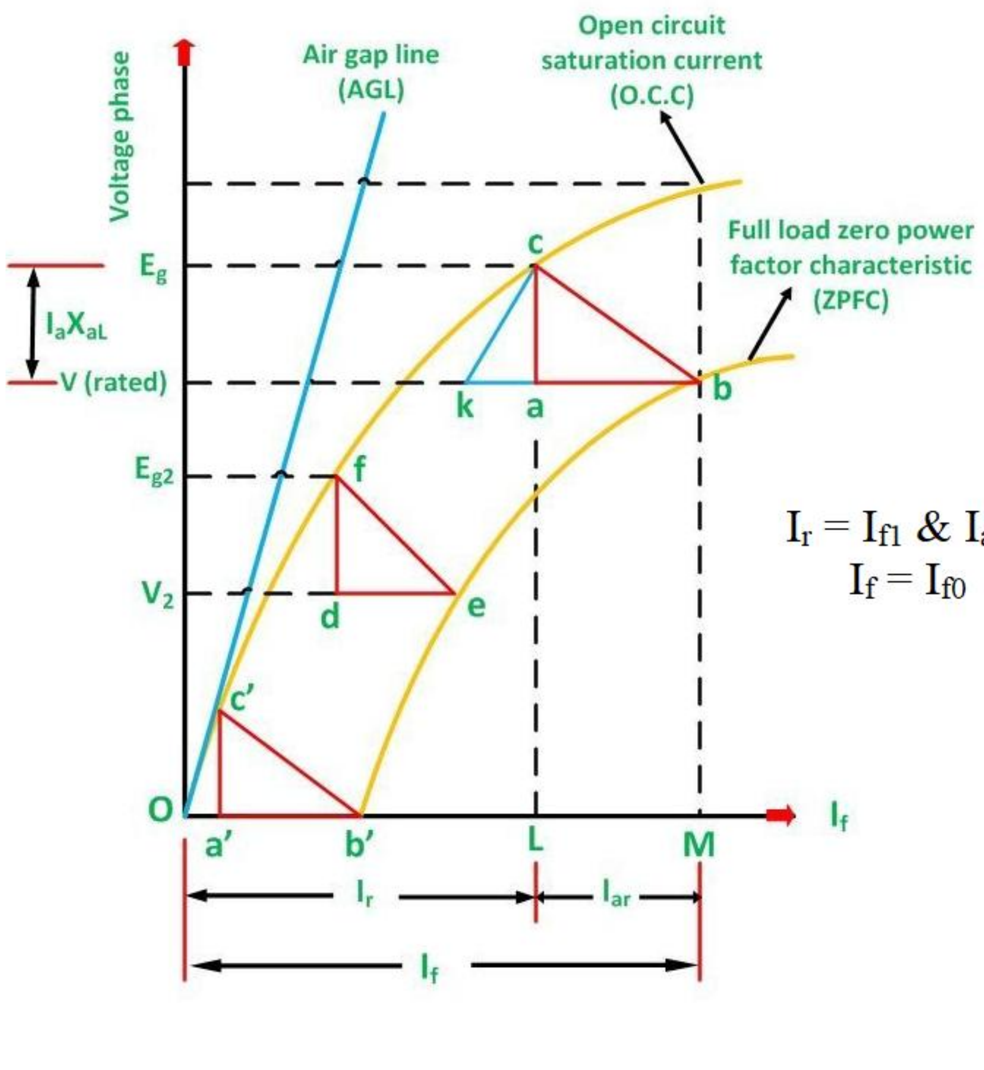
Short-circuit Characteristic (SCC)

The short-circuit characteristic of the machine is obtained by means of the short circuit test. While the rotor is run at synchronous speed N_s, the rotor is kept unexcited to begin with. The field excitation is then gradually increased till the armature current equals about 150% of its rated value.

ZPF Characteristics (ZPFC)

The ZPF characteristics are drawn between I_f vs. V_{ph} where Ia=Rated current

MODEL GRAPH:



$I_r = I_{f1}$ & $I_{ar} = I_{f2}$

$I_f = I_{f0}$

CALCULATIONS:

$ca = I_a X_\lambda$

$ab = I_{f2}$

$$E_1 = \sqrt{(V_{ph}\cos\phi + I_a R_a)^2 + (V_{ph}\sin\phi \pm I_a X_\lambda)^2}$$

+ for Lagging P.F
- for Leading P.F

$\rightarrow$ Y-axis $\rightarrow E_1 \rightarrow$ OCC $\rightarrow$ X-axis $\rightarrow I_{f1}$

$$I_{f_0} = \sqrt{I_{f_1}^2 + I_{f_2}^2 + 2 I_{f_1} I_{f_2} \cos[180 - (90 + \phi)]}$$

$\rightarrow$ X-axis $\rightarrow I_{f0} \rightarrow$ OCC $\rightarrow$ Y-axis $\rightarrow E_{ph}$

$$\% \text{Reg} = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

PROCEDURE:

(1.Note down the complete nameplate details of motor and alternator.
2. Connections are made as per the circuit diagram.
3. Switch on the supply by closing the DPST main switch.
4. Using the Three point starter, start the motor to run at the synchronous speed by varying the motor field rheostat.
5. Conduct an Open Circuit Test by varying the Potential Divider for various values of Field current and tabulate the corresponding Open circuit voltage readings.
6. Conduct a Short Circuit Test by closing the TPST knife switch and adjust thepotential divider the set the rated Armature current, tabulate the corresponding Field current.
7. Conduct a ZPF test by adjusting the potential divider for full load current passing through either an inductive or capacitive load with zero power and tabulate the readings.
8. Conduct a Stator Resistance Test by giving connection as per the circuit diagram and tabulate the voltage and Current readings for various resistive loads.

PROCEDURE TO DRAW THE POTIER TRIANGLE:

(All the quantities are in per phase value)

1. Draw the Open Circuit Characteristics (Generated Voltage per phase VS Field Current)
2. Mark the point $\mathbf{b^1}$ at X-axis, which is obtained from short circuit test with full load armature current.
3. From the ZPF test, mark the point **b** for the field current to the corresponding rated armature current and the rated voltage.

4. Draw the ZPF curve which passing through the point **b^1** and **b** in such a way parallel to the open circuit characteristics curve.
5. Draw the tangent for the OCC curve from the origin (i.e.) air gap line.
6. Draw the line **bk** from B towards Y-axis, which is parallel and equal to **a^1 b^1**.
7. Draw the parallel line for the tangent from **k** to the OCC curve.
8. Join the points **b** and **c** also drop the perpendicular line **ca** to **bk** , where the line **ca** represents armature leakage reactance drop (IX_L), **ba** represents armature reaction excitation (I_{fa}).
9. Extend the line **bk** towards the Y-axis up to the point O'. The same line intersects the airgap line.
10. Mark the point I in Y-axis with the magnitude of Eair and draw the line from I towards OCC curve which should be parallel to X-axis. Let this line cut the air gap line and the OCC curve.

TABULAR FORMS:

OC TEST:

S.No	V_L(volts)	I_f(amps)	V_{ph}(Volts)

S.C TEST:

S.No	V_{SC}(volts)	I_f(amps)	I_{sc}(amps)

Z.P.F TEST :

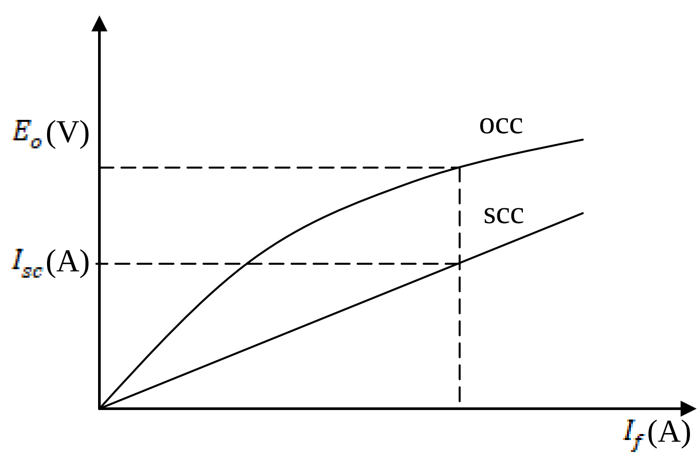
S.No	E_f(V)	I_f(A)	Rated Ia

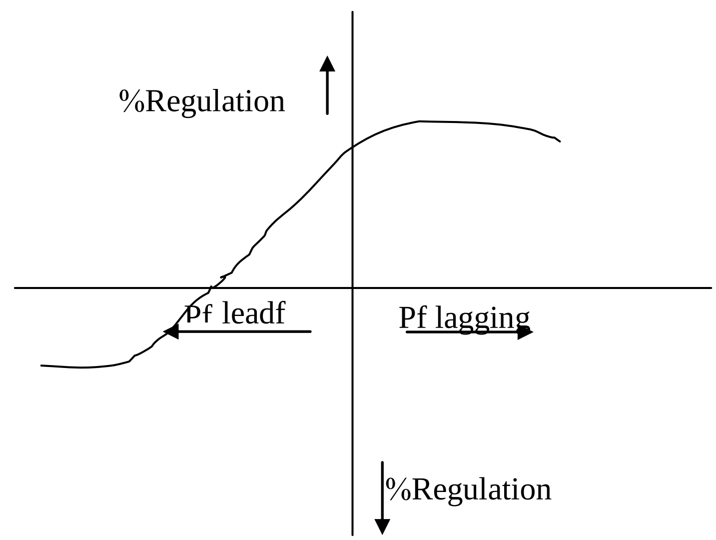
S.No	Power Factor	% Regulation	
		P.F Lag	P.F Lead

PRECAUTIONS:

(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) While conducting SC test the voltmeter across armature should read zero.
(4) The readings should not exceed meter readings.

MODEL GRAPHS:





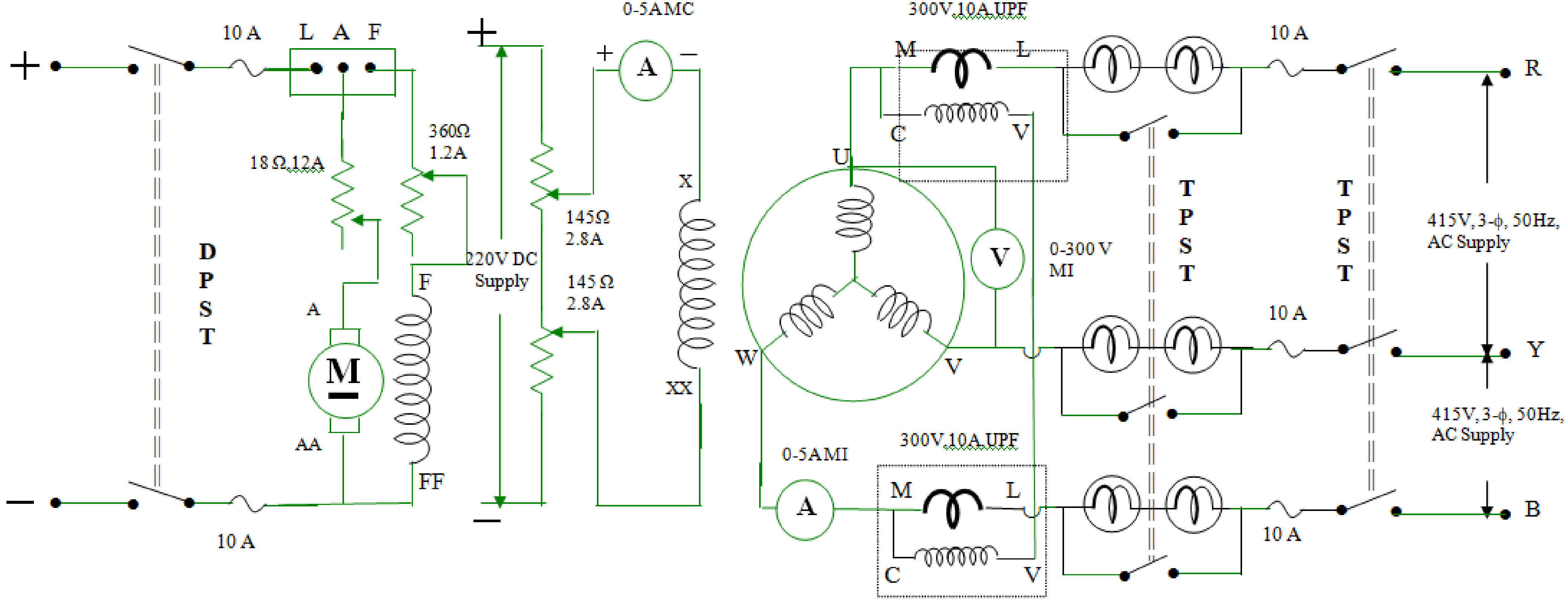
RESULT:

Viva Questions

1. Explain principle and operation of alternator?
2. What is the different between alternator and dc generator?
3. What is the emf equation of induced emf in an alternator?
4. Does changing the number of conductor have any effect on the frequency?
5. What is called the armature reaction of an alternator?
6. What is the formula for calculating the generated emf on load condition?
7. What are different methods used for determination of voltage regulation?
8. What is the effect of hunting? How can we reduce the Hunting?
9. What is the effect of change of excitation in alternator?

V & Inverted V curves of a three –phase Synchronous Motor

CIRCUIT DIAGRAM: V AND INVERTED V CURVES OF A SYNCHRONOUS MOTOR



NAME PLATE DETAILS:

8.V & Inverted V curves of a three –phase Synchronous Motor

AIM: To draw the V and inverted V curves of a synchronous motor at different loads.

APPARATUS:

S.no	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Ammeter	0-5A	MC	1No
3	Voltmeter	0-600V	MI	1No
4	Wattmeter	300V,10A	UPF	2N0
5	Rheostat	18Ω,12A	Wire wound	1N0
6	Rheostat	360Ω,1.2A	Wire wound	1N0
7	Rheostat	145Ω,2.8A	Wire wound	2N0
8	Tachometer	(0-10000)rpm	Digital	1
8	Connecting Wires	1.5Sqmm	Copper	As per required

THEORY

Synchronous motor is constant speed motor which are not self starting in nature, so that we have to start this motor by any one of the following starting methods

1. Pony motor method starting
2. Auto induction starting
3. DC exciter starting
4. Damper winding method of starting

By construction there is no difference between synchronous generator and synchronous motor. It is capable of being operated under wide range of power factor, hence it can be used for power factor correction. The value of excitation for which back EMF is equal to applied voltage is known as 100% excitation. The other two possible excitations are over excitations and under excitation if the back emf is more or less to the applied voltage respectively.

The variations of armature current with field current are in the form of V curves and the variation of power factor with field current are in the form of Inverted V curves.

PROCEDURE:

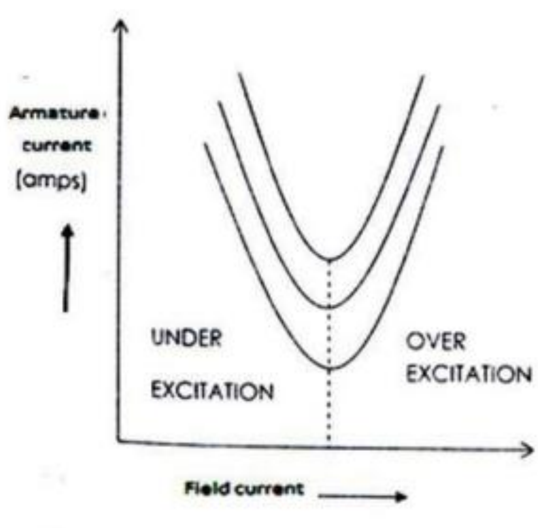
1) Connections are done as per the circuit diagram.
2) In the DC motor initially the armature rheostat and field rheostat is kept at maximum and minimum respectively.
3) The rheostats in the rotor circuit of alternator initially kept in a position so that less current will be flow through rotor circuit.

4) Supply is given to the motor and start the DC motor by 3-point starter, adjust the speed of the motor to its rated speed by using rheostats of the motor.
5) Now by varying rotor field rheostats adjust the voltage of alternator to its rated voltage.
6) Keeping synchronous switch off, close the supply switch and observe the lamps across the supply lines and machine terminals.
7) If any difference of glowing of lamps (i.e. one set after another is observed it indicates that the phase sequence is not correct .Then reduce rotor field current to zero. So that no voltage is induced from synchronous machine and inter change any two terminals of machine.
8) Try to get the dark period which will be sufficient to close synchronous switch by adjusting the motor rheostats.
9) Close the synchronous switch at the middle of the dark period of lamps and immediately open the supply switch of D.C motor.
10) Now the field excitation of rotor is varied and note the corresponding readings of field current, armature current and wattmeter.

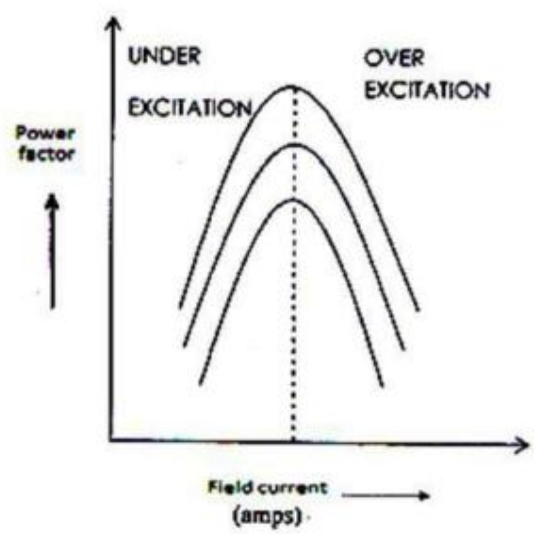
Model Graph:

The graph is drawn for
1. Armature current Vs Excitation current
2. Power Factor Vs Excitation current.

V Curves



Inverted V Curves



TABULAR FORM:

S.No	V(volts)	I_F (A)	Ia(A)	W_1	W_2	$W = W_1 + W_2$	cosΦ

FORMULAE USED:

$\cos \Phi = W / \sqrt{3} V_L I_L$

Where Φ – Phase angle between voltage and current

W – Input Power

V_L - Line voltage

I_L – Line current

PRECAUTIONS:

(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) The readings should not exceed meter readings.

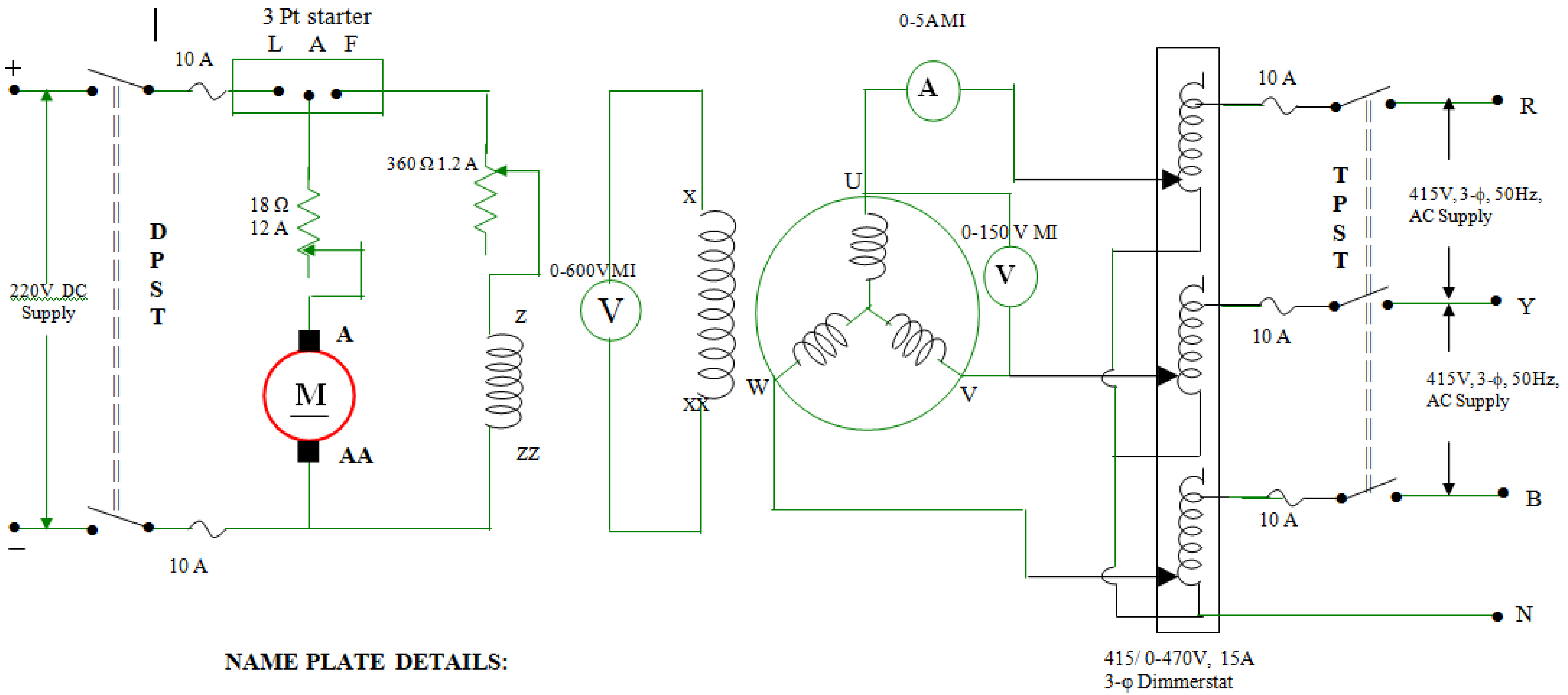
RESULT:

Viva Questions

1. What are called V Curves?
2. What are called Inverted V- Curves?
3. What do you mean by exciter?
4. How does synchronous motor improve power Factor?
5. What will happen if a synchronous motor is under excited?
6. Why is it necessary to employ special starting equipment for starting a synchronous motor?
7. Explain the principle of synchronous motor?
8. Is the synchronous motor is Self- Started?
9. How can the speed of a synchronous motor can be changed?
10. What is synchronous speed?

Determination of $X_{d,}$ X_q & Regulation of a Salient pole synchronous generator

CIRCUIT DIAGRAM: Determination of X_d, X_q & Regulation of a Salient pole synchronous generator



NAME PLATE DETAILS:

9.Determination of X_d, X_q & Regulation of a Salient pole synchronous generator

AIM:

(a) to determine the X_d and X_q of a Salient pole synchronous generator using Slip test.
(b) To determine regulation of a Salient pole synchronous generator using Two Reaction theory (Blondel's theory)

APPARATUS:

S.no	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	1No
2	Voltmeter	0-600V	MI	1No
3	Wattmeter	300V,10A	UPF	1N0
4	Rheostat	18Ω,12A	Wire wound	1N0
5	Rheostat	360Ω,1.2A	Wire wound	1N0
6	Tachometer	(0-10000)rpm	Digital	1
7	Connecting Wires	1.5Sqmm	Copper	As per required

Name Plate details:

S.No	Specifications	DC Motor	Alternator
1	Rated Voltage		
2	Rated Current		
3	Rated Power		
4	Rated Speed		

THEORY:

SLIP TEST:

The method used to determine X_q and X_d , the direct and quadrature axis reactance is called slip test. In an alternator we apply excitation to the field winding and voltage gets induced in the armature. But in the slip test, a three phase supply is applied to the armature, having voltage must less than the rated voltage while the field winding circuit is kept open.The alternator is run at a speed close to synchronous but little less than synchronous value. The three phase currents drawn by the armature from a three phase supply produce a rotating flux. Note that the armature is stationary, but the flux and hence m.m.f. wave produced by three phase armature currents is rotating. This is similar to the rotating magnetic field existing in an induction motor.

The rotor is made to rotate at a speed little less than the synchronous speed. Thus armature m.m.f. having synchronous speed, moves slowly past the filled poles at a slip speed (N_s -N) where n is actual speed of rotor. This causes an e.m.f. to be induced in the field circuit. When the stator m.m.f. is aligned with the d-axis of field poles then flux Φ_d per poles is set up and the effective reactance offered by the alternator is X_d. When the stator m.m.f. is aligned with the q-axis of field poles then flux Φ_q per pole is set up and the effective reactance offered by the alternator is X_q.

As the air gap is non-uniform, the reactance offered also varies and hence current drawn the armature also varies cyclically at twice the slip frequency. The r.m.s. current is minimum when machine reactance is X_d and it is maximum when machine reactance is X_q. As the reactance offered varies due to non-uniform air gap, the voltage drops also varies cyclically. Hence the impedance of the alternator also varies cyclically. The terminal voltage also varies cyclically.

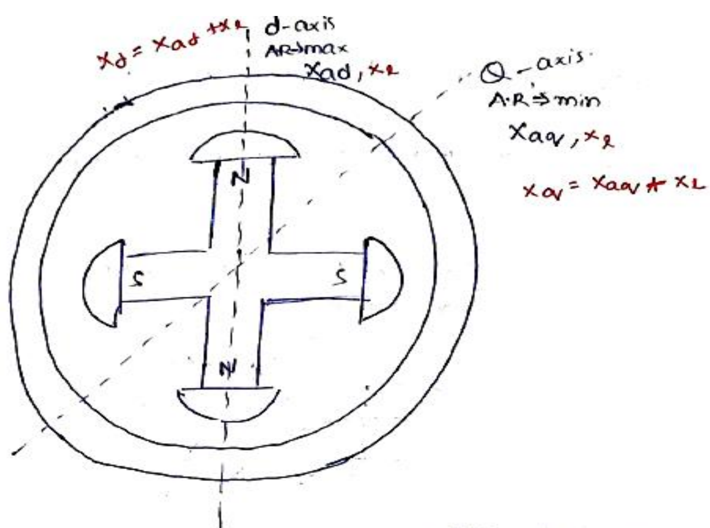
The voltage at terminals is maximum when current and various drops are minimum while voltage at terminals is minimum when current and various drops are maximum.

$$X_d = V_{max} / \sqrt{3} I_{min}$$

$$X_q = V_{min} / \sqrt{3}\, I_{max}.$$

BLONDEL'S TWO REACTION THEORY:

Andre Blondel proposed the Two Reaction Theory of synchronous machines. The two reaction theory was proposed to resolve the given armature MMF (Fa) into two mutually perpendicular components, with one located along the d-axis of the salient-pole rotor. This component is known as the **direct axis or d-axis component** and is denoted by (Fd).The other component is located perpendicular to the d-axis of the salient pole rotor. It is known as the **quadrature axis or q-axis component** and denoted by (Fq). The d-axis component (Fd) is either magnetising or de-magnetising while the q-axis component (Fq) results in a cross-magnetising effect.



Two Components (X_{ad}, X_{aq}) are required for modelling A.R.

$X_{ad} > X_{aq}$ (∵ A.R is more in d-axis)

$X_{ad} = (1.5 - 2)\, X_{aq}$

Along d-axis, A.G is less,Reluctance is less,X_{ad} is more

Along q-axis, A.G is more,Reluctance is more,X_{aq} is less

so $X_{ad} > X_{aq}$

Blondel's two reaction theory proposed these points:

1) I_a → $I_d \perp E_{ph}$; I_q along E_{ph}

2) X_a → X_{ad} ; X_{aq}

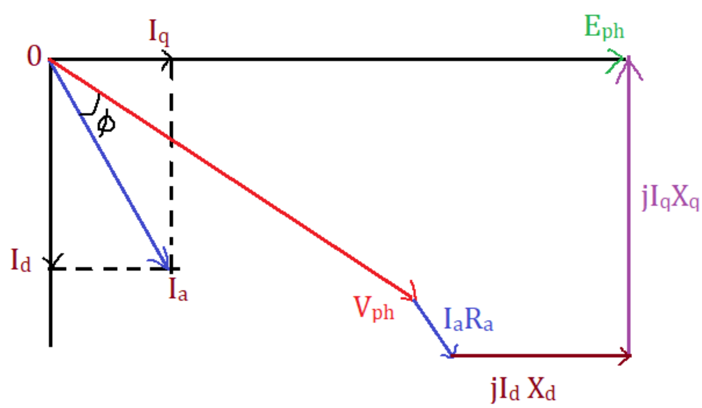
3) $X_d = X_{ad} + X_{\lambda}$

$Xq = X_{aq} + X_{\lambda}$

4) $E_{ph} = V_{ph} + I_a R_a + j\, I_d X_d + j\, I_q X_q$

Phasor diagram:

$I_a = I_d + I_q$



$$E_{ph} = V_{ph} + I_a R_a + j\, I_d X_d + j\, I_q X_q$$

$$\% \text{ Reg} = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

PROCEDURE:

1. Connections are done as per the circuit diagram.
2. In the DC motor initially the armature rheostat and field rheostat is kept at maximum and minimum respectively.
3. Supply is given to the motor and start the DC motor by 3-point starter, adjust the speed of the motor to just below the rated speed by using rheostats of the motor.

4. Close the TPST switch and apply the reduced 3-ϕ A.C voltage through the 3-ϕ dimmerstat.
5. The reading of the voltmeter connected across the field circuit of alternator must be zero if not reduce the applied 3-ϕ A.C voltage to zero and change the phase sequence and apply the reduced 3-ϕ A.C voltage.
6. Then note down the minimum and maximum readings of voltmeter and ammeter.

TABULAR FORM:

S. No	Voltage (V)		Current (A)		X_d (Ω)	X_q (Ω)	$\frac{Xd}{Xq}$
	V_{min}	V_{max}	I_{min}	I_{max}			

CALCULATIONS:

Slip Test:

$$Xd = \frac{Vmax}{\sqrt{3}\ Imin} = \quad \Omega$$

$$Xq = \frac{Vmin}{\sqrt{3}\ Imax} = \quad \Omega$$

$$\frac{Xd}{Xq} =$$

Blondel's two reaction Theory:

$$E_{ph} = V_{ph} + I_a R_a + j\, I_d X_d + j\, I_q X_q$$

$$\% \text{ Reg} = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

PRECAUTIONS:

(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) The readings should not exceed meter readings.

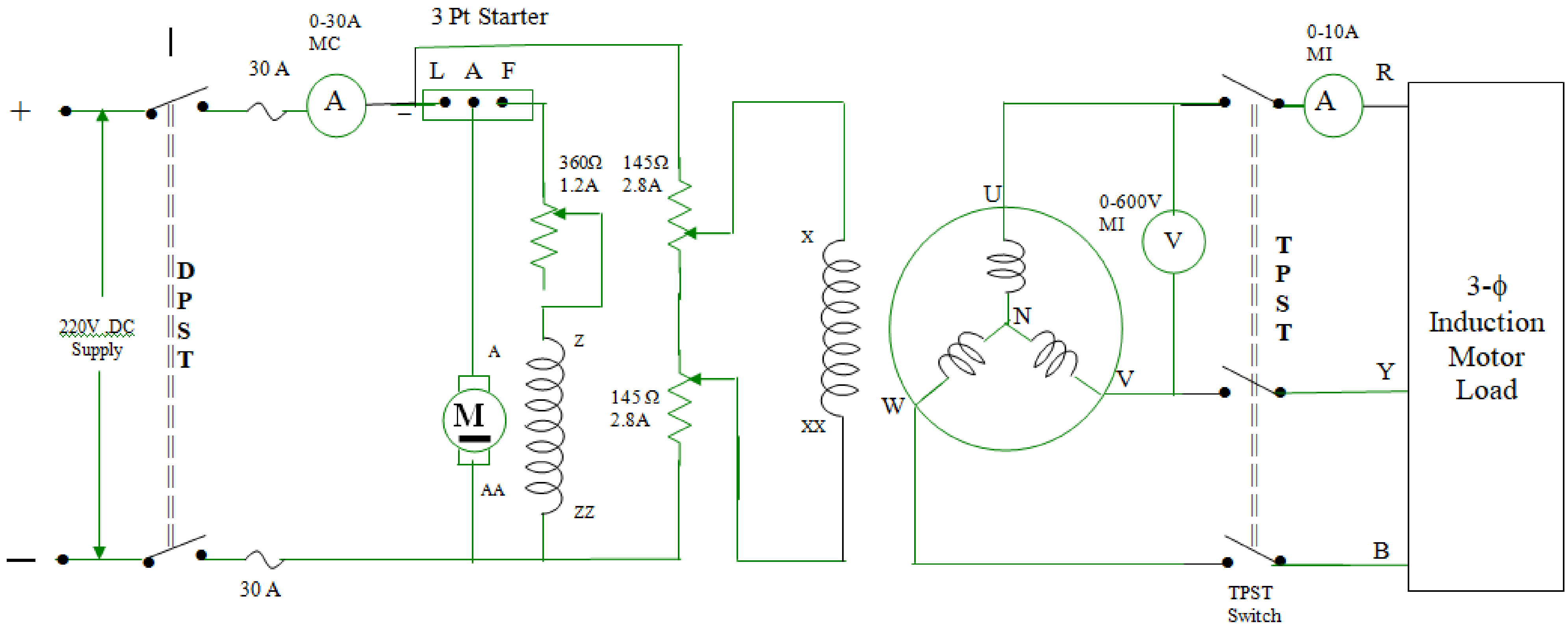
RESULT :

Viva Questions:

1. Explain the term X_d
2. Explain the term X_q
3. What do you mean by exciter?
4. How does synchronous motor improve power Factor?
5. What will happen if a synchronous motor is under excited?
6. Why is it necessary to employ special starting equipment for starting a synchronous motor?
7. Explain the principle of synchronous motor?
8. Is the synchronous motor is Self- Started?
9. How can the speed of a synchronous motor can be changed?
10. What is synchronous speed?

Determination of efficiency of three phase alternator by loading with three phase induction motor

CIRCUIT DIAGRAM: Three phase alternator by loading with three phase induction motor



NAME PLATE DETAILS:

10.Determination of efficiency of three phase alternator by loading with three phase induction motor

AIM: To determine the efficiency of 3-ϕ alternator by loading with 3-ϕ induction motor.

APPARATUS:

S.No	Name of the Equipment	Range	Type	Quantity
1	Ammeter	0-30A	MC	1No
2	Ammeter	0-10A	MI	1No
3	Voltmeter	0-600V	MI	1No
4	Rheostat	360Ω,1.2A	Wire Wound	1No
5	Rheostat	145Ω,2.8A	Wire Wound	2Nos
6	3-ϕ induction motor		Wire Wound	1
7	Tachometer	(0-10000)rpm	Digital	1
8	Connecting Wires	1.5Sqmm	Copper	As per required

THEORY:

Whenever we convert one form of energy into another there are bound to be losses. No machine is perfect. Power is supplied to an alternator both in the form of electrical energy and in the form of mechanical energy. The electrical energy is supplied to the field coil. This energy is used to set up the main magnetic field. This field is constant. There is no energy taken from it in the generation of electricity. Therefore, since none of the power out comes from this energy, the power by the field must be counted as a loss. Most of the power comes from the prime mover. Some of this mechanical power is lost to the windings and friction of the alternator. The mechanical losses do not depend on the alternator's load. To find these losses it is necessary to determine the overall mechanical losses then subtract the losses of the prime mover.

Another class of losses that does not vary with load is the core losses. We are speaking here about the armature's core. Since there is an alternating voltage generated, the core is continually becoming magnetized with one polarity, de-magnetized, then magnetized with the other polarity each cycle. All of this magnetic activity in the core causes eddy current and hysteresis losses. These core losses depend on the alternator's voltage, not on load. As load current flows through the armature coils the resistance of the wire causes a power loss. This copper loss is proportional to the square of the current, $P=I^2R$ Copper losses, therefore, increase rapidly with load.

Percent efficiency is the ratio between the power out and the power in.

$$\% \text{ Eff.} = P_{out}/P_{in} \times 100.$$

PROCEDURE:

A. ROTATIONAL LOSSES:

1. Connect the DC machine as a shunt motor.
2. Clamp the motor but do not couple the alternator.
3. Give the 220VDC supply to the DC shunt motor.
4. Run the DC shunt motor to the above synchronous speed (1600RPM).
5. Read the motor's voltage and current and record these readings in TABLE 1.
6. Turn off the DC supply to the motor.
7. Multiply voltage and current values of motor. This value is rotational losses in motor (P_{ML}).
8. Couple the alternator to the motor.
9. With no connections made to the alternator.
10. Run the DC shunt motor to the above synchronous speed (1600RPM)
11. Read the motor's voltage and current and record these readings.
12. Turn off the DC supply to the motor.
13. Multiply voltage and current values of motor to find total rotational losses in the motor and alternator (P_{MAL}). Record this value in TABLE 1.
14. Compute the alternator's rotational losses, P_{AL}, by subtracting P_{ML} from P_{MAL}, Record in TABLES 1 and 5.

B. FIELD LOSS:

1. Run the DC shunt motor to the synchronous speed (1500 RPM).
2. Slowly increase the excitation voltage until the terminal voltage of the alternator is 400 (L to L volts).
3. Read the field voltage and amps of alternator and record in TABLE 3.
4. Multiply field volts and amps of alternator to find field loss PFL.
   Record in TABLE 3 and 5.

C. CORE LOSSES:

1. Read the motor's voltage and current readings at alternator rated voltage condition and record these readings in TABLE 4.
2. Multiply the voltage and current readings of motor to find total no-load losses of motor P_{NLL}. Record in TABLE 4.
3. Compute the alternator's core losses, P_{CL}, by subtracting the total rotational losses P_{MAL} from the total no-load losses, P_{NLL}.
   Record in TABLE 4 and TABLE 5.

D. OUTPUT POWER:

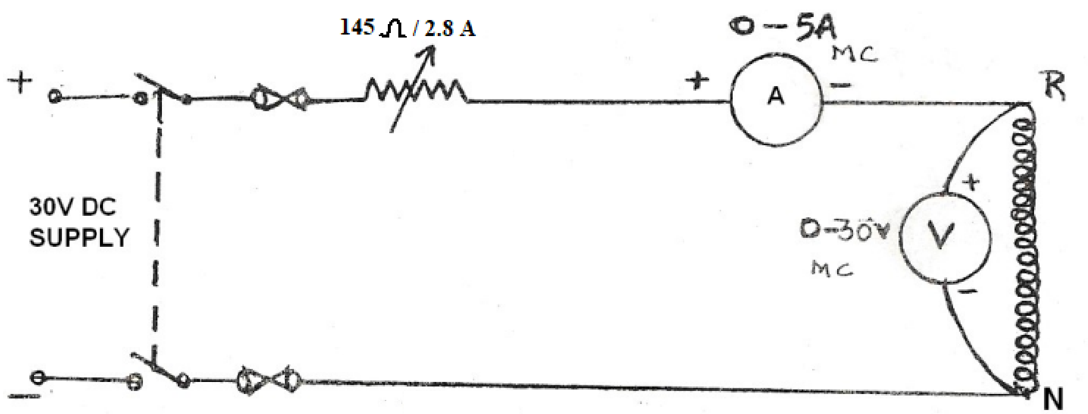
1. Load the alternator by using 3 phase induction motor load.
2. Break the induction motor drum to load the alternator.
3. Read the terminal voltage and the load current of the alternator at load condition.
   Record these values in TABLE 6.
4. Calculate the output power of the alternator using following formula
   ($\sqrt{3} \times V_L I_L \times \cos\emptyset$)
5. Find out the full load armature copper losses (I^2R) by using full load alternator armature current and total alternator armature resistance Ra.

6. Add the rotational, field, core, and armature losses and record the value in TABLE 5
7. Determine the power input =power out put +total losses

Note:

P_{ML} =Motor Rotational Losses
P_{AL} =Alternator Rotational Losses
P_{MAL} = Motor Alternator Rotational Losses
P_{FL} = Alternator Field Copper Losses
P_{NLL} = Motor No Load Losses
P_{CL} = Alternator Core Losses
I^2R = Alternator Armature Copper losses
R_a = Total Armature Resistance

TO FINDOUT THE ARMATURE RESISTANCE:



ARMATURE RESISTANCE DETERMINATION:

S.No	V	I	R_{dc}= V/I

Ra = 1.25 x R_{dc} (For one winding)

Total armature resistance=3 x Ra (For three windings).

CALCULATIONS:

Total losses in alternator:

- Iron or core losses (W1)
- Copper Losses (W2&W3)
    1. Field Copper Losses (W2)
    2. Armature copper losses (W3)
- Rotational Losses (W4)

W_1 = Core Losses (P_{CL})

W_2 = Field Losses (P_{FL})

W_3 = Armature Copper Losses (I^2R)

W_4 = Rotational Losses (P_{AL})

Power Output = ($\sqrt{3} \times V_L I_L \times \cos\emptyset$)

Power Input = Power Output +Total Losses

Total Losses =W1+W2+W3+W4

The percentage efficiency of alternator is calculated by

$$\% \text{ Efficiency} = \frac{\text{Power output}}{\text{Power output+Total losses}} \times 100$$

OBSERVATION TABLES :

	E	I	E x I
UNCOUPLED MOTOR			P_{ML} = ______
COUPLED MOTOR			P_{MAL} = ______
$P_{AL} = P_{MAL} - P_{ML}$ = ______			

TABLE 1 - ROTATIONAL LOSSES

I	E	R_{DC} = E/I	R_{DC} x 1.5	ARM. RES.
0.3A				

TABLE 2 - ARMATURE RESISTANCE

CURRENT	VOLTAGE	P_{FL} = E x I

TABLE 3 - FIELD LOSSES

CURRENT	VOLTAGE	P_{NLL}	$P_{CL} = (P_{NLL} - P_{MAL})$

TABLE 4 - CORE LOSSES

ROT. (P_{AL})	
FIELD (PFL)	
CORE (P_{CL})	
$(I_{ALT})^2R(P_{LOAD})$	
TOTAL	

TABLE 5 - TOTAL LOSSES

V	I	POUT	P_{IN} = POUT + LOSS

& EFFICIENCY = ____________

TABLE 6 - EFFICIENCY

PRECAUTIONS:

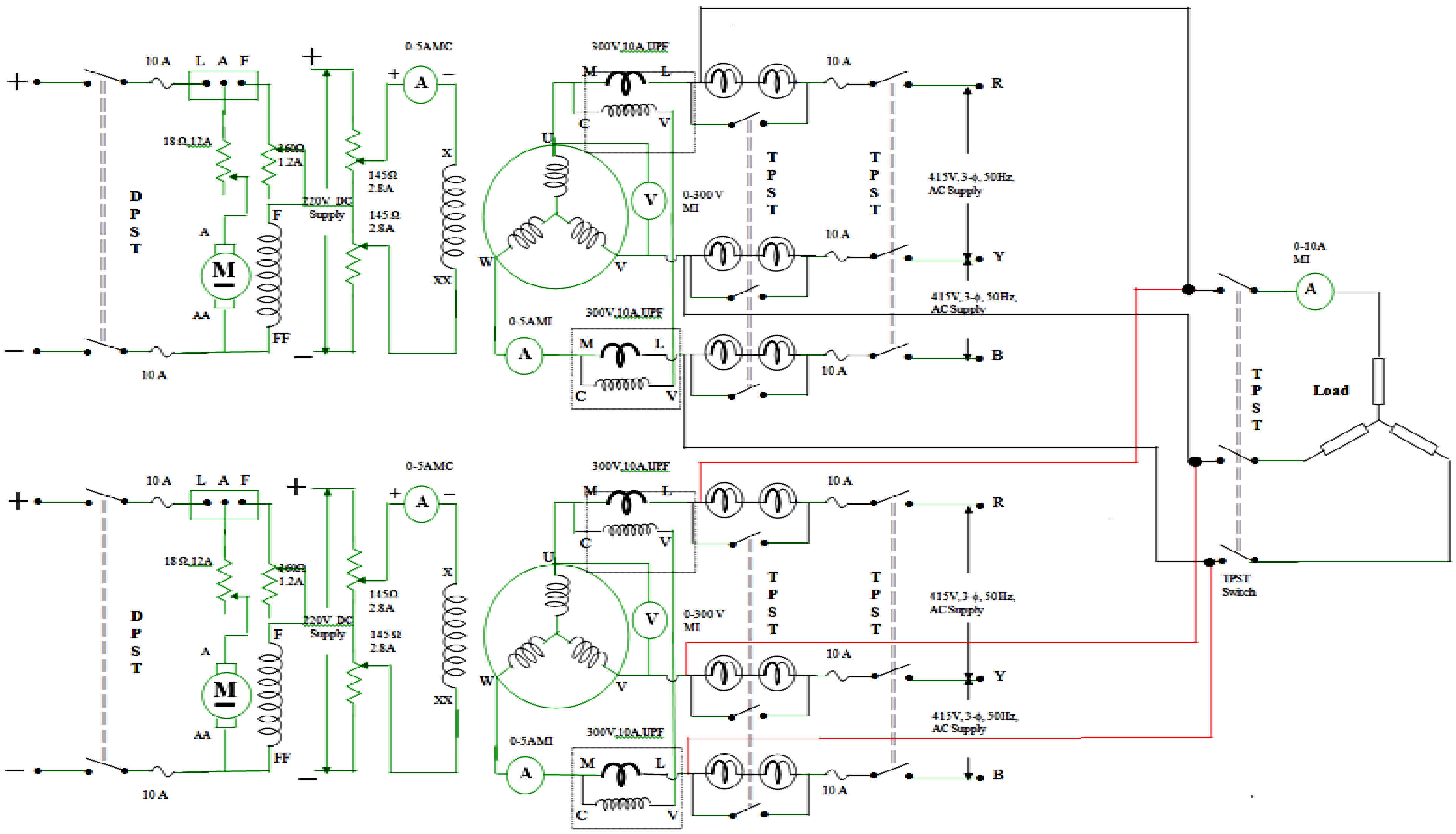
(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) The readings should not exceed meter readings.

RESULT:

VIVA-QUESTIONS:

1. What are the types of three-phase induction motors?
2. why the three phase induction motor draws heavy current at starting?
3. What are the effects of increasing rotor resistance on starting current and starting torque?
4. How to keep the synchronous speed of rotor in alternator?
5. How to determination of efficiency of alternator

Parallel Operation of Three-phase Alternator under No-Load and Load conditions



NAME PLATE DETAILS:

11.Parallel Operation of three-phase alternator under no-Load and Load conditions

AIM: Study the parallel operation of three phase alternator under load and no-load conditions.

APPARATUS:

S.No	Name of the equipment	Range	Type	Quantity
1	Ammeter	0-10A	MI	3No
2	Ammeter	0-5A	MC	2No
3	Voltmeter	0-600V	MI	2No
4	Wattmeter	300V,10A	UPF	4No
5	Rheostat	18Ω,12A	Wire Wound	2No
6	Rheostat	360Ω,1.2A	Wire Wound	2No
7	Rheostat	145Ω,2.8A	Wire Wound	4No
8	3-ph resistive Load			1No
9	Tachometer	(0-10000)rpm	Digital	1
10	Connecting Wires	1.5Sqmm	Copper	As per required

THEORY:

Alternator is really an AC generator. In alternator, an EMF is induced in the stator (stationary wire) with the influence of rotating magnetic field (rotor) due to Faraday‟s law of induction. Due to the synchronous speed of rotation of field poles, it is also known as synchronous generator. Here, we can discuss about parallel operation of alternator. When the AC power systems are interconnected for efficiency, the alternators should also have to be connected in parallel. There will be more than two alternators connected in parallel in generating stations.

Necessity of Parallel Operation of Alternators

i) For a given capacity of a generating station, either a single large unit or many small units may be installed. If there are many small units operating in parallel instead of single large unit then number of alternators operating at a time can be changed depending upon electricity requirements or load demands. This will help in operating the alternator near its full load capacity so that efficiency will also be better.

ii) The operating cost will be significantly reduced compared to single large unit.

iii) A particular unit may be shut down for certain period during the maintenance and inspection at the power stations. For that period the load can be transferred to other units if numbers of units are operating in parallel.

iv)Several power stations are interconnected by a grid which is economical and advantageous. This will make sure the optimum utility of the alternators.

v) The continuity and reliability of the supply can be maintained at better level due to interconnections.

vi) The future load demand can be satisfied by adding more alternators in parallel without disturbing the original setup.

The interconnection of alternators i.e. the process of synchronization is already discussed in previous section. Now we will consider how the two alternators will operate in parallel. What will happen if the driving torque or the excitation for any of the alternator is changed. In practice it is rare to have two alternators operating in parallel. But the concept of parallel operation of alternators can be well understood by considering two alternators in parallel.

Before synchronization, following conditions must be satisfied:

(1) EQUALITY OF VOLTAGE The terminal voltage of both the systems i.e. the incoming alternator and the bus bar voltage or other alternator must be same.
(2) PHASE SEQUENCE The phase sequence of both the systems must be same.
(3) EQUALITY OF FREQUENCY The frequency of both the systems must be same.

The condition (1) can be checked with the help of voltmeter and the condition (2) and (3) by any synchronizing method.

There are two synchronizing methods –

a. Using incandescent lamp
b. Using synchroscope

Now we discuss in detail about these methods.

(a)Using Incandescent lamp

Let machine G2 be synchronized with machine G1 which is already connected with the bus bar, using three lamps (L1, L2 and L3) method. These lamps are known as synchronizing lamps connected as shown in Fig.1 If the speed of machine 2 is not brought upto that of machine 1 then its frequency will also be different, hence there will be a phase difference between their voltages as shown in Fig.2. Due to difference in frequencies the resultant voltage will under go changes similar to the frequency changes of beats produced when two sound sources of nearly equal frequencies are sounded together.

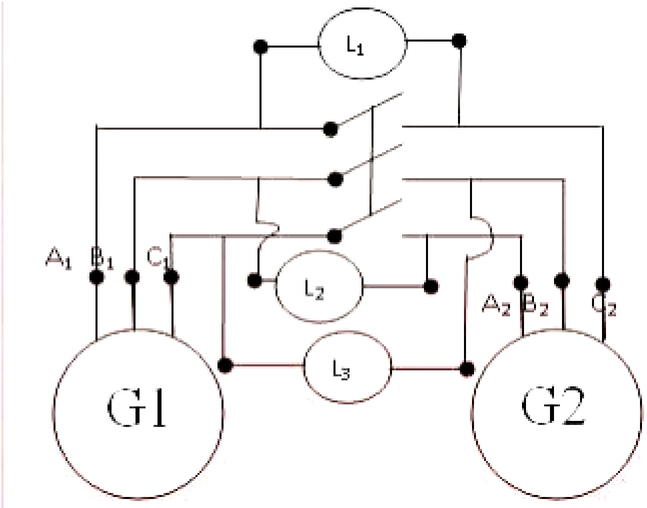


Fig. 1 Synchronization using three lamp method

The resultant voltage is sometimes maximum and sometimes minimum. Hence, the lamps will flicker, sometimes dark and sometimes bright. Synchronization is done at the middle of the dark period. This method of synchronizing is known as dark lamp method.Lamp L1 is connected between A1 and A2, L2 between B1 and C2 and L3 between C1 and B2. These three lamps slowly brighten and darken in cyclic successor in a direction depending upon whether incoming machine 2 is fast or slow. The synchronizing switch will be closed at the moment when lamp L1 will be completely dark. This transposition of two lamps suggested by Siemens and Aalske helps to indicate whether the incoming machine 2 is running too slow or too fast. If lamps were connected symmetrically, they would dark out or glow up simultaneously (if phase rotation is same.).

(b) SYNCHRONIZING BY SYNCHROSCOPE:

Synchroscope is a device that shows the correct instant of closing the synchronizing switch with the help of a pointer which will rotate on the dial. The rotation of pointer also indicates whether the incoming machine is running too slow or too fast. If incoming machine is slow then pointer rotates in anticlockwise direction and if machine is fast then pointer rotates in clockwise direction.

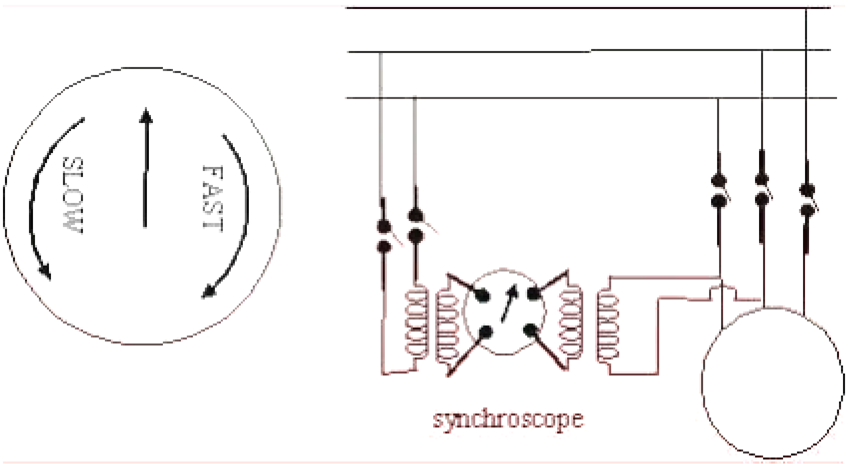


Fig. ˉ Synchronizing by Synchroscope

PROCEDURE:

1) Connections are done as per the circuit diagram.
2) In the DC motor initially the armature rheostat and field rheostat is kept at maximum and minimum respectively.
3) The rheostats in the rotor circuit of alternator initially kept in a position so that less current will be flow through rotor circuit.
4) Supply is given to the motor and starts the DC motor by 3-point starter, adjust the speed of the motor to its rated speed by using rheostats of the motor.
5) Now by varying rotor field rheostats adjust the voltage of alternator-1 to its rated voltage.
6) Keeping synchronous switch off, close the supply switch and observe the lamps across the supply lines and machine terminals.
7) If any difference of glowing of lamps (i.e. one set after another is observed it indicates that the phase sequence is not correct .Then reduce rotor field current to zero. So that no voltage is induced from synchronous machine and inter change any two terminals of machine.
8) Try to get the dark period which will be sufficient to close synchronous switch by adjusting the motor rheostats.
9) Close the synchronous switch at the middle of the dark period of lamps and immediately open the supply switch of D.C motor.
10) Now the field excitation of rotor is varied and note the corresponding readings of field current, armature current and wattmeter.
11) Repeat the same procedure to alternator-2
12) Take the readings of all meters without and with three phase resistive load on alternators.

TABULAR FORM:

S.No	Load Voltage In Volts	Load Current In Amps

MODEL GRAPH:

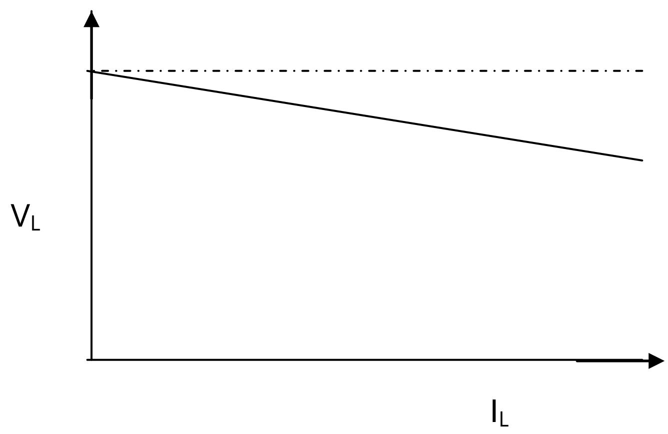


Fig: Load Characteristics of Alternator

PRECAUTIONS:

(1) Initially the rheostat in field circuit of motor must be kept at minimum position.
(2) The rheostat in the alternator field circuit must be kept at maximum position initially.
(3) The readings should not exceed meter readings.

RESULT:

VIVA 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 then the synchronous speed during synchronization.
7) In parallel operation of generator, for which condition circulating current develop even no load on the machine.