Bhartiya Institute of Engineering & Technology, Sikar

ELECTRICAL MACHINE MANNUAL

LAB MANUAL
OF
ELECTRICAL MACHINE

DO'S

- Maintain strict discipline.
- Proper handling of apparatus must be done.
- Before switching on the power supply get it checked by the lecturer.
- Switch off your mobile.
- Be a keen observer while performing the experiment

DONT'S

- Do not touch or attempt to touch the mains power directly with bare hands.
- Do not manipulate the experiment results.
- Do not overcrowd the tables.
- Do not tamper with equipments.
- Do not leave the lab without prior permission from the teacher.

INSTRUCTIONS TO THE STUDENTS

GENERAL INSTRUCTIONS

- Maintain separate observation copy for each laboratory.
- Observations or readings should be taken only in the observation copy.
- Get the readings counter signed by the faculty after the completion of the experiment.
- Maintain Index column in the observation copy and get the signature of the faculty before leaving the lab.

BEFORE ENTERING THE LAB

- The previous experiment should have been written in the practical file, without which the students will not be allowed to enter the lab.
- The students should have written the experiment in the observation copy that they are supposed to perform in the lab.
- The experiment written in the observation copy should have aim, apparatus required, circuit diagram/algorithm, blank observation table (if any), formula (if any), programme (if any), model graph (if any) and space for result.

WHEN WORKING IN THE LAB

- Necessary equipments/apparatus should be taken only from the lab assistant by making an issuing slip, which would contain name of the experiment, names of batch members and apparatus or components required.
- Never switch on the power supply before getting the permission from the faculty.

BEFORE LEAVING THE LAB

- The equipments/components should be returned back to the lab assistant in good condition after the completion of the experiment.
- The students should get the signature from the faculty in the observation copy.

They should also check whether their file is checked and counter signed in the index

4EE10A ELECTRICAL MACHINE LAB

1. Speed control of D.C. shunt motor by (a) Field current control method & plot the curve for speed verses field current. (b) Armature voltage control method & plot the curve for speed verses armature voltage.
2. To perform O.C. and S.C. test on a 1-phase transformer and to determine the parameters of its equivalent circuit its voltage regulation and efficiency.
3. To perform back-to-back test on two identical 1-phase transformers and find their efficiency & parameters of the equivalent circuit.
4. To determine the efficiency and voltage regulation of a single-phase transformer by direct loading.
5. To plot the O.C.C. & S.C.C. of an alternator and to determine its Zs, Xd and regulation by synchronous impedance method.
6. To plot the V-curve for a synchronous motor for different values of loads.
7. To perform the heat run test on a delta/delta connected 3-phase transformer and determine the parameters for its equivalent circuit.
8. To perform no load and blocked rotor test on a 3 phase induction motor and to determine the parameters of its equivalent circuits. Draw the circle diagram and compute the following (i) Max. Torque (ii) Current (iii) slips (iv) p.f. (v) Efficiency.
9. To Plot V-Curve and inverted V-Curve of synchronous motor.
10. To synchronize an alternator across the infinite bus (RSEB) and control load sharing.

EXPERIMENT # 1

OBJECT: To control the speed of D.C. Shunt Motor by –

a) Armature Control method and plot the curve for speed v/s armature voltage.
b) Field Control method and plot the curve for speed v/s field current.

APPARATUS REQUIRED:

S.No.	Name of Apparatus	Type	Range	Quantity
1	Ammeter	Digital	0-2A	1
2	Ammeter	Digital	0-10A	1
3	Voltmeter	Digital	0-300V	2
4	Motor	DC Shunt Motor	[1500rpm/220V/14A/3hp]	1
5	Rheostat		150 Ω / 1 A	1
6	Rheostat		150 Ω / 1.6 A	1
7	Connecting Leads		-	As per requirement
8	Digital Techometer	Digital	0-3000 RPM	

THEORY:

The back emf for a D.C. motor is given by -Back EMF $E_B = P\,\Phi\,N\,Z / 60\,A$

The number of poles P, the armature conductor Z & number of parallel paths, A are constant for a particular Macine: so speed-

$$N = K\,E_b / \Phi = K\,(V - I_a R_a) / \Phi\ ;$$

it gives-

a) Speed of the DC motor can be controlled below the base speed by varying resistance in armature circuit. (Armature Voltage Control Method).

b) Speed of DC motor can be controlled above base speed by decreasing the flux i.e. decreasing field current I_f by including extra resistance. (Field Control Method)

Armature Voltage Control Method:-

Let the external resistance in the armature circuit be R ohms, as shown in fig1.1, then speed equation modifies to

$$N = K \{V - I_a (R_a + R)\} / \Phi$$

Hence the motor speed decreases with an increase in the value of external resistance R.

Field Control Method:-

The speed of motor can be increased beyond the no load speed by inserting an external resistance in the shunt field circuit. The current in external resistance is very low hence the losses occurring in the additional resistance is quite small.

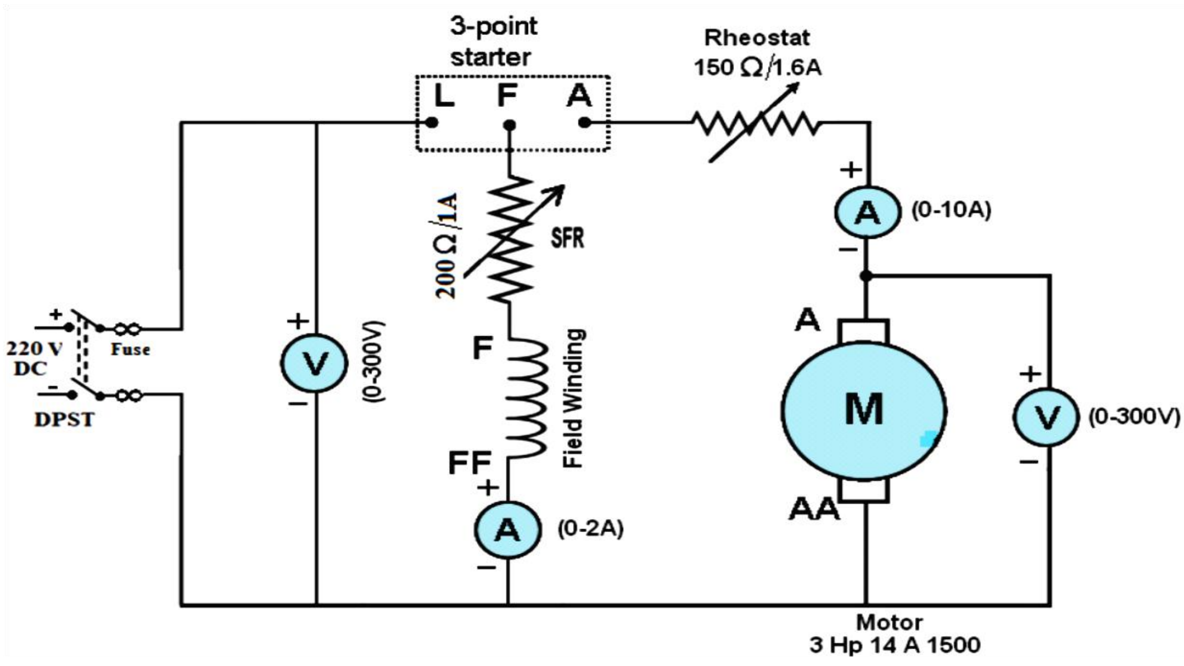


Fig1.1 : Speed Control of DC Machine

PROCEDURE:

1. Connect the circuit as per diagram.
2. Ensure that the external resistance in the armature circuit is at maximum position.
3. Ensure that the external resistance in the field circuit is at minimum position.

4. After ensuring step 2 & 3, switch ON the DC supply, as a result motor will start running at a low speed.
5. Cut out the external resistance in the armature circuit and adjust the field current, so that speed of motor become rated speed.
6. The field current is kept constant to the above value. Vary the voltage applied to the armature by varying the external resistance in the Armature circuit Record the applied Voltage and the corresponding speed.
7. Repeat step 6 for various value of applied voltage to the armature, till the rated voltage of the motor.

a) Keep the applied voltage to the armature constant at the rated value .Vary the speed of the motor by inserting external resistance in the field circuit record the field current & the corresponding speed of the motor.
b) Repeat step (a) for various values of field current till, the speed of the motor is about 1.4 times the rated speed, otherwise mechanical stress will be high which may damage the motor. Hence the field current should not be decreased to a very low value.

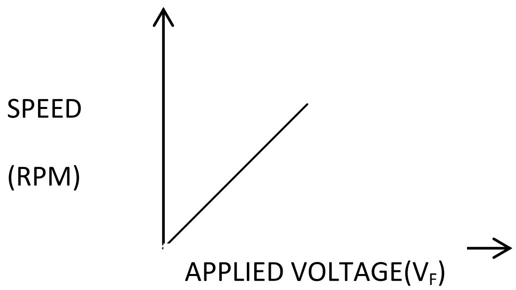
OBSERVATION TABLE:

Armature Voltage Control			**Field Control**		
Sr.No.	**Applied Voltage V_a(Volt)**	**Speed N(rpm)**	**Sr.No.**	**Field Current I_f(Amp)**	**Speed N(rpm)**
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		

CHARACTERISTICS:

The speed control characteristic of DC shunt motor by-

a) Armature Control method
b) Field Control method are shown in fig 1.2(a) and fig1.2(b) in ideal case.



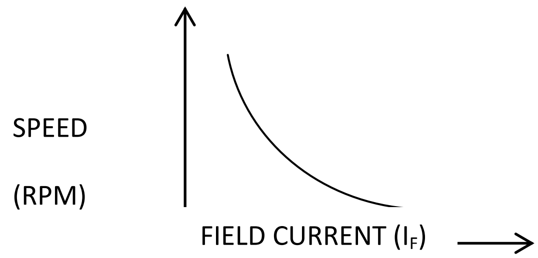


Fig1.2(a) **fig1.2(b)**

RESULTS:

The speed control characteristics of the DC shunt motor in case of-

a) Armature Control method
b) Field Control methodare shown in graph.

PRECAUTIONS:

1. No loose connection is allowed.
2. Switch on the Supply after checking the connections by faculty/Lab assistant.
3. Take the observation carefully.
4. Wear shoes, while working in machine lab.
5. Don't touch any live part or wire, it may be dangerous.
6. Vary Rheostat & Autotransformer smoothly.

VIVA QUIZ:

(1) Can we get speeds below the rated speed by field control method?
(2) Is it possible to obtain speeds above rated speed by the armature voltage control method?
(3) Is it possible to obtain a reversal in speed by either the armature resistance or field control method?
(4) In D.C. shunt motors for speed control the resistance is inserted in armature circuit. Why?
(5) Why is it necessary to give excitation to field before giving supply to armature in a separately excited motor?

EXPERIMENT # 2

OBJECT:To perform Open Circuit & Short Circuit test on the single phase transformer. Calculate the complete parameters of the equivalent circuit of this transformer.

APPARATUS REQUIRED:

S.No	Name of Apparatus	Type	Range	Quantity
1.	Ammeter	MI	0-2 A	1
2.	Ammeter	MI	0-15 A	1
3.	Voltmeter	MI	0-300 V	1
4.	Voltmeter	MI	0-30 V	1
5.	Wattmeter	Dynamometer	1 / 2 A, 250 V	1
6.	Wattmeter	Dynamometer	5 / 10 A, 75 V	1
7.	Single Phase Variac	Type	230/0-270 V,8 A	1
	Connecting Leads	MI	As per requirement	

THEORY:

Open circuit test-

In this test low voltage winding (primary) is connected to a supply of normal voltage and frequency (as per rating of transformer) and the high voltage winding (secondary) is left open as shown in figure, the primary winding draws very low current hardly 3 to 5 percent of full load current (may be up to 10% for very small rating transformers used for laboratory purposes) under this condition. As such copper losses in the primary winding will be negligible thus mainly iron losses occur in the transformer under no load or open circuit condition, which are indicated by the wattmeter connected in the circuit.

Hence, total iron losses = W_0 (Reading of wattmeter)

From the observations of this test, the parameters R_0 and X_m of the parallel branch of the equivalent circuit can also be calculated, following the steps given below:

Power drawn, $W_0 = V_0 \ I_0 \cos \varphi_0$

Thus, no load power factor, $\cos \varphi_0 = W_0 / V_0 I_0$

Core loss component of no load current, $I_W = I_0 \cos \varphi_0$

And, magnetizing component of no load current, $I_M = I_0 \sin \varphi_0$
Equivalent resistance representing the working current, $R_0 = V / I_W$
Equivalent resistance representing the magnetizing current, $X_M = V / I_M$

Short circuit test-

- In this test low voltage winding is short circuited and a low voltage hardly 5 to 8 percentage of the rated voltage of the high voltage winding is applied to this winding.
- This test is performed at rated current flowing in both the windings. Iron losses occurring in the transformer under this condition is negligible, because of very low applied voltage. Hence the total losses occurring under short circuit are mainly the copper losses of both the winding, which are indicated by the wattmeter connected in the circuit.
- Thus total full load copper losses = W_{SC} (reading of wattmeter)
- The equivalent resistance R_{eq}, and reactance X_{eq} referred to a particular winding can also be calculated from the observations of this test, following the steps given below.

Equivalent resistance referred to H.V. winding, $R_{eq} = W_{SC} / I^2_{SC}$
Also, equivalent impedance referred to H.V. winding, $Z_{eq} = V_{sc} / I_{SC}$
Thus equivalent reactance referred to H.V. winding, $X_{eq} = \sqrt{(Z^2_{eq} - R^2_{eq})}$

PROCEDURE:

(a) **Open Circuit Test:**
1) Connect the circuit as per figure.
2) Ensure that the setting of the variac is at low output voltage.
3) Switch on the supply and adjust rated voltage across the transformer circuit.
4) Record no load current, voltage applied and no load power, corresponding to the rated voltage of the transformer winding.
5) Decrease the supply voltage by variac.
6) Switch- off the ac supply.

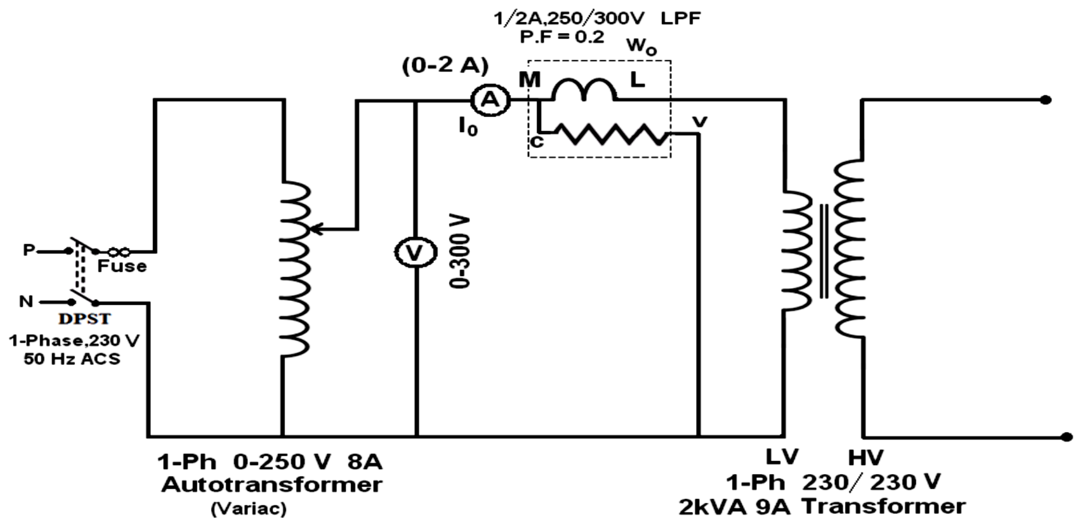


Fig 5.1 Open Circuit Test for Single Phase Transformer

(b)Short Circuit Test:

1) Connect the circuit as per figure.
2) Adjust the setting of the variac, so that output voltage is zero.
3) Switch on the supply to the circuit.
4) Increase the voltage applied slowly, till the current in the winding of the transformer is full load rated value.
5) Record short circuit current, corresponding voltage and power with full load current

flowing under short circuit conditions.

6) Decrease the supply voltage by variac.
7) Switch- off the ac supply.

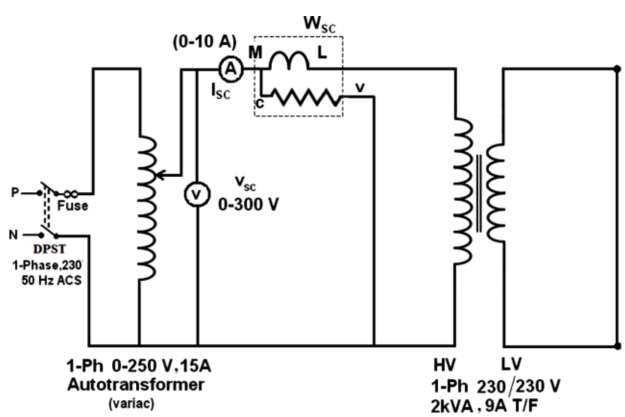


Fig 5.2 Short Circuit Test for Single Phase Transformer

OBSERVATION TABLE:

S.No.	**Open Circuit test**			**Short circuit test**		
	Open circuit voltage V_0 **(Volts)**	**Open circuit current** I_0 **(Amp)**	**No load power** W_0 **(Watts)**	**Short circuit voltage** V_{SC} **(Volts)**	**Short circuit current** I_{SC} **(Amp)**	**Short circuit power** W_{SC} **(Watts)**
1						
2						

PERFORMANCE CALCULATION:

Complete performance of the transformer can be calculate based on the above observation of open circuit and short circuit test, following the step given by:

1. Efficiency at different loads:

(a) Efficiency at full load:

Total losses at full load = W_0+W_{SC}

Let the full load out put power of the transformer in KVA be P_0

Then,

$P_0 \times 1000 \times \cos \varphi$

Percentage efficiency at full load, $\eta_f = \frac{P0 \times 1000 \times \cos \varphi}{P0 \times 1000 \times \cos \varphi + W0 + WSC}$ ***100**

$P_0 \times 1000 \times \cos \varphi + W_0+W_{SC}$

(b) Efficiency at half the full load:

Iron losses at half the full load = W_0 (constant)

Total copper losses at half the full load = $(1/2)^2 W_{SC}$ = ¼ W_{SC}

Output power at half full load = ½ P_0 KVA

Thus,

½ $P_0 \times 1000 \times \cos \varphi$

Percentage efficiency at half the full load, $\boldsymbol{\eta_f}$= ________________ × 100

½ P_0×1000 ×cos φ + W_0+ ¼ W_{SC}

Equivalent circuit parameters:

(1) core losses of each transformer $P_c = W_1/2$
(2) copper losses of each transformer $P_{cu} = W_2/2$

From open circuit test data

$V_0 I_0 \cos\varphi_0 = P_c$

$\cos\varphi_0 = P_c/V_0 I_0$

$I_m = I_0 \sin\varphi_0$

$I_c = I_0 \cos\varphi_0$

$R_0 = V_0/I_c = V_0/ I_0 \cos\varphi_0$

$X_m = V_0/I_m = V_0/I_0 \sin\varphi_0$

$Z_0 = (R_0^2 + X_0^2)^{1/2}$

From short circuit test data

$P_{cu} = I^2_{sc} R_t$

$R_t = P_{cu}/I_{sc}$

$Z_t = V_{sc}/I_{sc}$

$X_t = (Z_t^2 - R_t^2)$

R_t = Total Resistance

Z_t= Equivalent Impedance

X_t = Leakage Reactance

$R_t = R_{01} = R_1 + R_2'$

$X_t = X_{01} = X_1 + X_2'$

RESULTS: The efficiency as obtained by the O.C. & S.C. test is ……………%.

DISCUSSIONS: To be written by students.

PRECAUTIONS:

1. No loose connection is allowed.
2. Switch on the Supply after checking the connections by faculty/Lab assistant.
3. Take the observation carefully.
4. Wear shoes, while working in machine lab.
5. Don’t touch any live part or wire, it may be dangerous.
6. Vary Rheostat & Autotransformer smoothly.

VIVA QUIZ

(1) Explain the role of power transformer in ‘power system’?
(2) Why is it that the primary and secondary windings are interlaced?
(3) What are the losses in a transformer?

(4) Derive the condition for which the efficiency of a transformer is maximum?
(5) What is meant by voltage regulation?
(6) Derive the condition for which the voltage regulation is maximum?
(7) What are the assumptions made in drawing the approximate equivalent circuit?

(8) For power transformers, open circuit test is usually performed on the low voltage side, keeping the high voltage side open and short circuit test is carried out on high voltage side, keeping the low voltage side shorted. Explain, Why?
(9) How will you justify in taking the open circuit input as iron loss only?
(10) How will you justify in taking the short circuit input as copper loss only?
(11) Can the voltage regulation of a transformer be negative? If so, When?
(12) Draw the equivalent circuit of transformer with showing all the calculated parameters.
(13) Write down the formula of finding out the efficiency of a transformer in terms if its rating, power factor, percentage of load and losses?

EXPERIMENT # 3

OBJECT:

To perform sumpner's back-to-back test on 3 phase transformers, find its efficiency &

parameters for its equivalent circuits.

EQUIPMENT:

S No.	Name	Type	Range	Quantity
1.	Ammeter	MI	0-5A	2
2.	Voltmeter	MI	0- 150/300V/600 V	2
3.	3-Phase Varic	Fully Variable	400/0-470 V,15A	2
4.	Wattmeter	Dyanometer	2.5A,600V/5A,75V	2
5.	Voltmeter	MI	(0-60)V	1
6.	Wattmeter	Dyanometer	2.5A,600V/5A,75V	2
7.	3-PhTransformer		400/400V	2

THEORY:

If Wi is the total iron loss as recorded by Wattmeter W1 and Wc is the total full-load copper loss as recorded by Wattmeter W2 , then

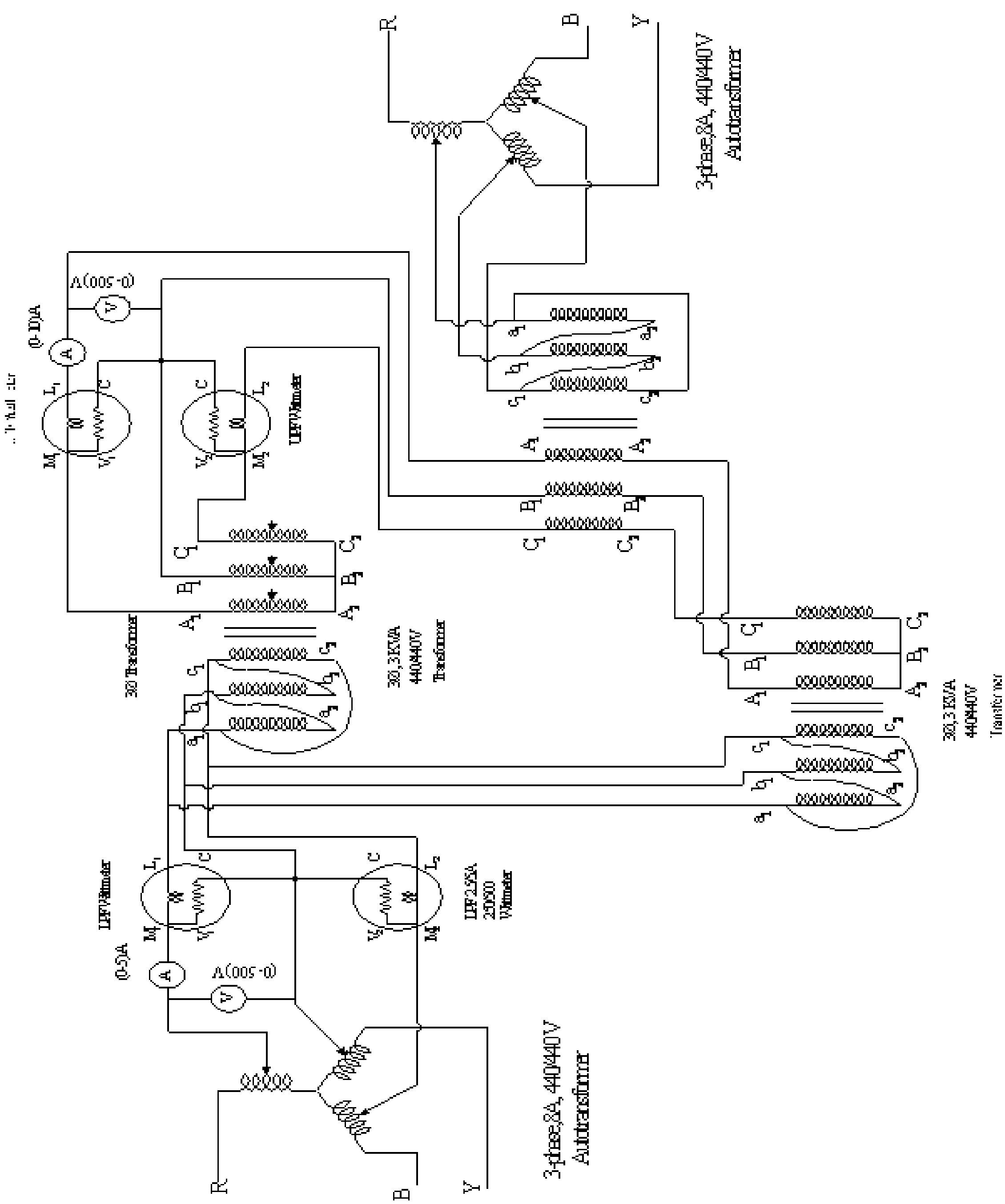
iron loss of each transformer = ½(Wc) = ½(Wi) , and ,

full load copper-loss of each transformer = W_c.

If ‘Q’ is the KVA rating of each transfomer, then for a load KVA equal to xQ and load power factor cosϕ, the efficiency ‘η’is given as

$$\eta = xQ\cos\phi/(xQ\cos\phi + 1/2W_i + x^2\, 1/2W_c)$$

CIRCUIT DIAGRAM:



PROCEDURE:

1. Do the connections as shown in diagram.ensure that the switches are open to start with.

2. Energize the primaries by closing the switch ‘S’.Check the voltage recorded by ‘V1’.If the voltage is zero, the secondary’s are connected in opposition correctly.If ‘V1’ Reads twice the secondary rated voltage, the windings are not properly connected, in which case denergize the circuit and enter change the connections of any two phase at the secondary terminals of one of the transformer.close ‘S1’ and verify the ‘V1’ now reads zero.

3. Ensure that the setting of the induction regulator (or autotransformer) is such as to give nearly zero output voltage.Close switch ‘S4, recorded by ‘V2’ to be zero.

4. Close switches ‘S2’and ‘S3’, keeping a watch on the ammeter.If the current through the ammeter shows a tendency to shoot up, ‘S3’ should be immediately opened. If however, steps 2 and 3 have been satisfactorily carried out,this contingency will not arise.

5. Increase the voltage injected in the secondary circuit such that rated current is flowing in the secondary circuit.

6. Record the readings of the two wattmeters and the ammeter in primary side as well as secondary side..

OBSERVATIO:

No.	Vo	Io	Wo		Vsc	Isc	Wsc	
			W1	W2			W1	W2
1.								
2.								
3.								

RESULT:

I have successfully completed the experiment for determining the efficiency of the 3 phase transformer.

The efficiency of the transformer is:

PRECAUTIONS:

1. Do the connections correctly, after checking the circuit diagram.
2. Use correct instrument rating for each test.
3. Connections should be right and tight.
4. Do check the connection by class teacher and than perform the experiment.
5. Note the reading precisely.
6. Do not touch any equipment when performing experiment.

ASSIGNMENT:

1.Why two transformers, and that two identical, are needed in this test.

2.Discuss various losses occurring in a transformer.

3.If the iron losses and copper losses at full load in a single phase,30 KVA,1100/250V,50 hz,transformer are 300 watts and 400watts resp. find out these losses ¾ of the full load.

EXPERIMENT # 4

OBJECT: To determine the efficiency and voltage regulation of a single phase transformer by direct loading.

APPARATUS REQUIRED:

S.No.	Name of apparatus	Type	Range	Quantity
1	Voltmeter	MI	(0-300)V	02
2	Ammeter	MI	(0-10)A	02
3	Single phase Transformer		2 KVA,230/230 V	01
4	Single phase Auto Transformer		8A,0-250 V	01

THEORY:

Although two chief difficulties which do not warrant the testing of large transformers by direct load test are:

Large amount of energy has to be wasted in such a test.

(1) It is stupendous (impossible for large transformers) task to arrange a load large enough for direct loading.

Yet this test can be performed to find out the efficiency & voltage regulation of small rating transformers.

Efficiency η = Output / Input

$$\%\eta = (V_2 \times I_2 / V_1 \times I_1) \times 100$$

Voltage Regulation = (No load voltage – Full load voltage)
Full load voltage

$$\%\ \text{Voltage Regulation} = (E_2 - V_2) / V_2 \times 100$$

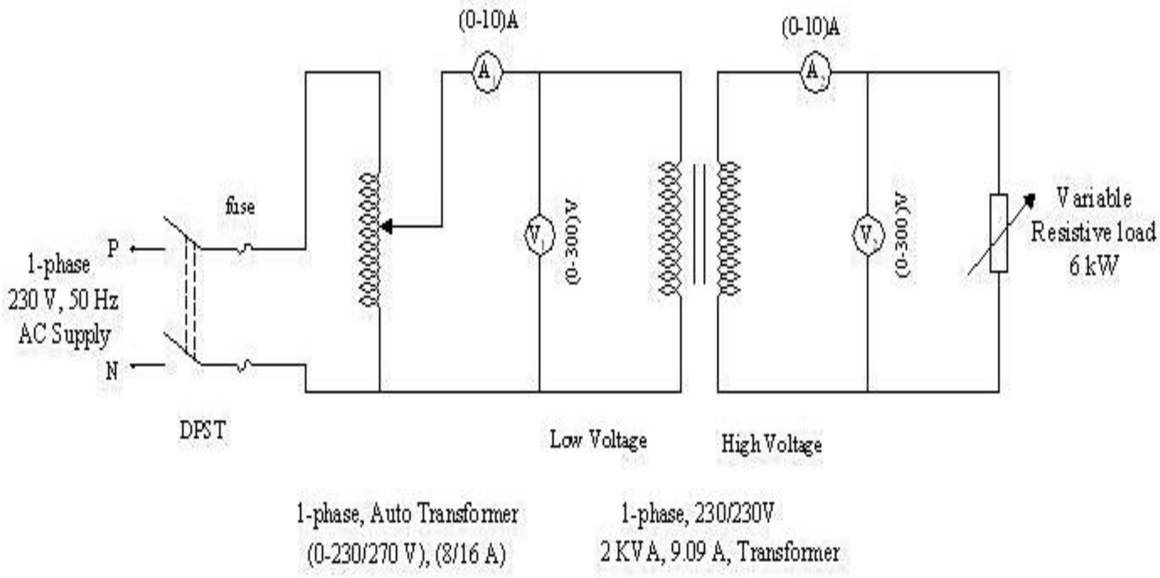


Fig. 8.1: Direct Loading Test of a Single Phase Transformer

PROCEDURE:

(a) Connect the circuit as shown in fig. 8.1.
(b) Ensure that variac is at its minimum position.
(c) Switch ON the supply by closing switch $S_1$and apply the rated voltage slowly by increasing the position of variac.
(d) Now adjust the load in such a way that rated current starts to flow in primary side, by closing the switch S_2.
(e) Note down the reading of Ammeters & Voltmeters.
(f) Now open the switch S_2 and take the reading of voltmeter connected in the secondary side, this voltage will be the no load secondary voltage E_2.
(g) Now decrease the applied voltage up to zero by decreasing the position of variac.
(h) Switch OFF the supply.

OBSERVATION TABLE:

S.No.	**Primary voltage V_1 (volts)**	**Primary current I_1 (Amp)**	**Secondary voltage V_2 (Volts)**	**Secondary current I_2 (Amp)**
2				

3				
4				
5				

CALCULATIONS:

RESULTS:

DISCUSSIONS: To be written by students.

PRECAUTIONS:

1. No loose connection is allowed.
2. Switch on the Supply after checking the connections by faculty/Lab assistant.
3. Take the observation carefully.
4. Wear shoes, while working in machine lab.
5. Don’t touch any live part or wire, it may be dangerous.
6. Vary Rheostat & Autotransformer smoothly.

VIVA QUIZ:

(1) Why is it that the determination of performance characteristics of large power transformers by direct load test is not advisable?
(2) How do the magnitude and quality (ratio of equivalent resistance to reactance) of the leakage impedance of transformers effect their load sharing?
(3) Is there any difference in the efficiencies of the transformer calculating by this method and open circuit & short circuit test?
(4) What is all day efficiency?

EXPERIMENT # 5

OBJECT:

To plot the O.C.C. & S.C.C. characteristics of an alternator and to determine its regulation by synchronous impedance method.

APPARATUS REQUIRED:

Name	Range	Type	**Quantity**
Ammeter	0-1A	MC	1
Ammeter	0-5A	MI	1
Voltmeter	0-500V	MI	1
Rheostat	230Ω/1.7A	Variable	1
Rheostat	500Ω/5A	Variable	1
Rheostat	500Ω/1.2 A	Variable	1
Tachometer	Digital	0-20002rpm	1

THEORY:

The open circuit characteristic is a plot of the terminal voltage as a function of the field excitation with machine running at rated speed without any load.

As the field current is gradually increased from zero. It is a graph between field current If and generated emf. The final value of Ef should be 125% of the rated voltage. The O.C.C. will not be a straight-line b'coz of the saturation in the iron part of the magnetic circuit.

The short circuit characteristic is a plot of armature current as a function of field excitation with a symmetrical three-phase terminal. Under this condition current in the armature winding is wholly depends upon on the internal impedance and armature reaction. Therefore when the rated full load current is flowing under short circuit conditions the resultant excitation acting on the magnetic circuit is low and the magnetic circuit is unsaturated. The short circuit characteristics are straight line.

Synchronous Impedance method

For any value of excitation if the Voc is the open circuit voltage and Isc is the short circuit current then for this value of excitation the synchronous impedance is given by,

Zs=Vo/Isc

At high value of field currents saturation increases and the synchronous impedance decreases. The value of Zs calculated for unsaturated region of the saturation curve.

If V is the rated voltage of the machine and regulation is to be compute for the load current I at a power factor angle then the corresponding open circuit voltage is

Voc=V+IZs

And regulation =(Voc-V)/V

<u>PROCEDURE:</u>

pen circuit test

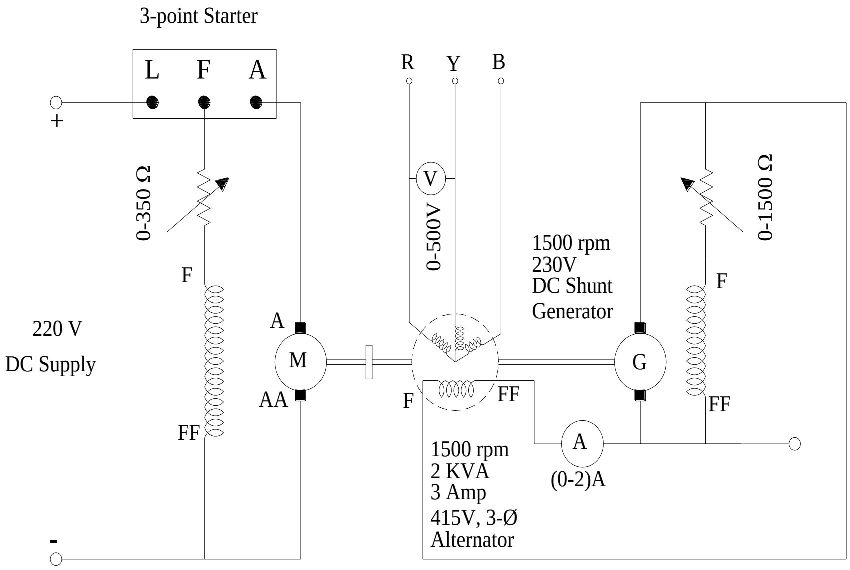
1. Connect the circuit shown in fig.
2. Start the prime mover motor and bring the set to the rated speed.
3. Measure the line voltage across the armature terminals.
4. Switch on the excitation & adjust it so that about the 10% of rated voltage is
5. Obtained across armature terminals.
6. Increase If & record terminal voltage.
7. Record several value till 125% rated voltage is obtained.

Short Circuit test

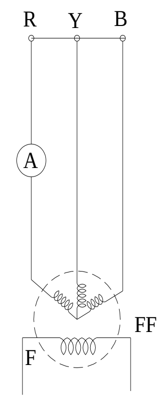
1. Connect the circuit shown in fig.
2. Start the prime mover motor and bring the set to the rated speed.
3. Switch on the field current after ensuring that there is sufficient external resistance So as to keep the field current within 10% of normal field.
4. Increase If in steps and record corresponding values of Ia. Repeat till short circuit
5. Current is 25% more than rated current. Later reading must be taken quickly to avoid
6. Overheating.

7. Stop the set.

CIRCUIT DIAGRAM:



Circuit Diagram for OCC



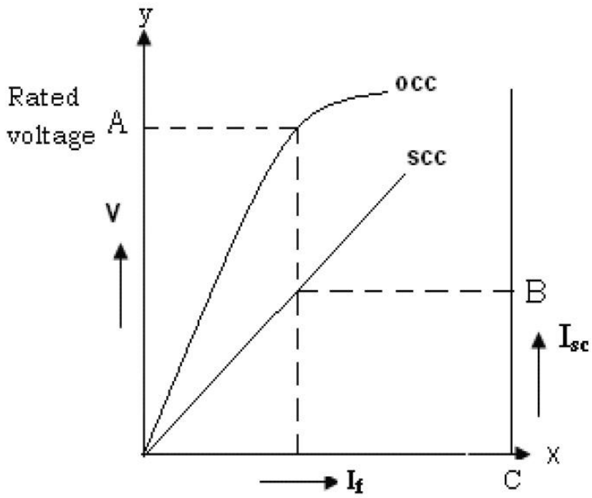
Circuit Diagram for SCC

OBSERVATIONS:

At rated speed

Field current (I_f)	Open Circuit voltage Voc	Short circuit current Isc

MODEL GRAPH:



CALCULATIONS:

By the observations we obtained Voc And Isc& Ra &cosϕ is given

Then impedance **Zs =Voc/Isc**

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

Voltage at no load **$E_o=\sqrt{(V\cos\phi+IR)^2+(V\sin\phi-IX)^2}$**

% Voltage regulation=**(Eo-V)/V**

RESULT:

PRECAUTIONS:

1.All the connections should be tight.

2.Note reading carefully.

3.Handle all the apparatus with care.

4.Later reading must be taken quickly during the short circuit test to avoid overheating of the alternator

DISCUSSION:

ASSIGNMENT:

1. What is the significance of air gap line in relation to the magnetization characterstic of an alternator?
2. Why is the synchronous impedance method of estimating regulation also called emf method?
3. If the synchronous machine is not running at rated speed what will be effect on

   a) Regulation

   b) Short circuit current

   c) Open circuit characteristics

EXPERIMENT # 6

OBJECT:

To plot the V-curves for a synchronous motor for different values of load.

APPARATUS REQUIRED:

Name	Range	Type	Quantity
Ammeter	0-1A	MC	1
Ammeter	0-1A	MC	1
Ammeter	0-10A	MI	1
Ammeter	0-10A	MI	1
Voltmeter	0-600V	MI	1
Wattmeter	600V/10A	Dynamo	2
Rheostat	-	-	1

THEORY:

- The armature current drawn by a synchronous motor for a definite power output is a function of its field current. For a given load on the motor, as the field current is varied, both the input current and the input power factor change. the plot of armature current as the function of field current for a constant power output is called a V curve because of its characterstics shape.
- It given load the armature current is minimum at a particular value of field current. If field current is gradually decreased below this value, the armature current will gradually increase till a point is reached where the motor starts hunting.
- A similar phenomenon is observed if the field current is increased above this value. The points on the V curve where the armature current is minimum corresponding to unity power factor of the input current. The curve joining the minimum current points of a set of V-curves is often called a unity power factor-compounding curve.
- Synchronous motor is not self-starting if it is coupled with a d.c. Machine, the latter may be used as an auxiliary motor for starting. The synchronous machine is run up to its synchronous speed using d.c.motor drive and then

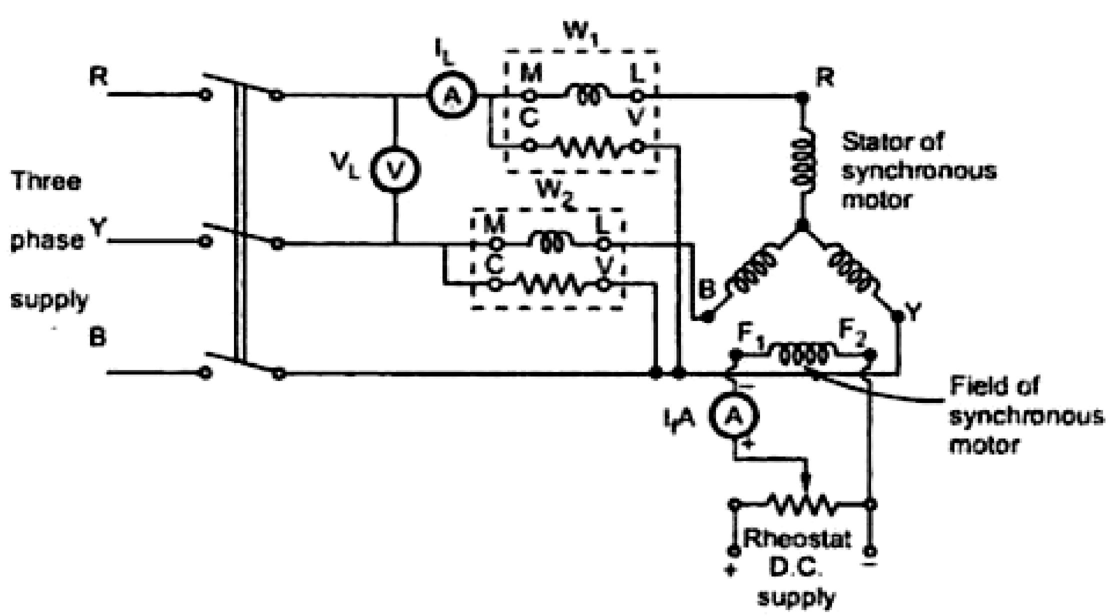
synchronized with three phase main supply. If the D.C. motor is now switched off the synchronous machine will start running as a synchronous motor off the a.c. supply.

- Now the field current is increased in steps and corresponding armature current are noted.

PROCEDURE:

1. Connect the circuit shown in the fig.
2. Increased the supply voltage slowly till the needle in armature vibrates.
3. Now switch on the synchronizing switch at given rated voltage.
4. Run the motor at rated speed.
5. Now for no load vary the field current in small steps and note down the corresponding armature current
6. Repeat the above step for full load and half load.
7. Plot the above values of Ia and If on graph to obtain V curves for no load,half load and full load

CIRCUIT DIAGRAM:



PRECAUTIONS:

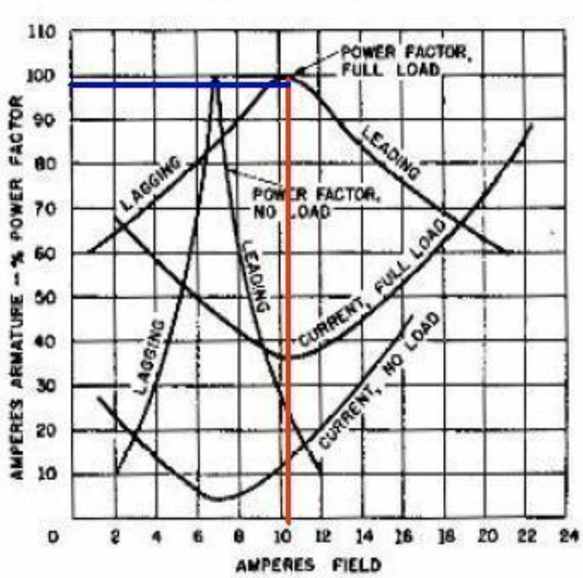
1. Connection should be tight.
2. Phase sequence should be checked carefully.
3. Supply voltage should be increased gradually.

OBSERVATIONS:

S.No	Load	Field Current If	Armature current Ia

CALCULATIONS & GRAPH:

Typical "V" Curves



RESULT:

DISSCUSSION:

ASSIGNMENT:

1. Why the synchronous motor is not self-starting?
2. What is the function of damper winding in a synchronous motor?
3. What are the advantages of synchronous motor over induction motor?
4. What are the advantages of running a synchronous motor at a excitation higher than that which give minimum current?

EXPERIMENT # 7

OBJECT:

To perform the heat run test on a Delta –Delta connected 3-phase transformer and determine the parameter for its equivalent circuit.

APPARATUS REQUIRED:

Name	**Range**	**Type**	**Quantities**
Voltmeter	0-100V	MI	1
Ammeter	0-5A	MI	2
Wattmeter	75V,5A	Dynamometer	1
Voltmeter	0-500V	MI	1
Wattmeter	600V,5A	Dynamometer	2
3-phaseAuto transformer	415/0-470V,12KVA		1
1-phaseAuto transformer	230/0-280V,3KVA		1
Transformer	3-Phase 400/400V		1

THEORY:

In this test the three phase supply is feeded to primary side of transformer while single phase supply is feeded to secondary side of transformer.In primary side we supply rated voltage at rated frequency and secondary side we supply rated current.The primary side wattmetr give core losses while secondary side wattmeter give copper losses.

CALCULATION:

The equivalent circuit parameters can be calculated as follows

Open Circuit Parameter

$$P_o=\sqrt{3}V_oI_o\cos\acute{\varnothing}$$

$$\cos\acute{\varnothing}= P_o/\sqrt{3}V_oI_o$$

$I_w=I_o\cos\acute{Ø}$

$I_m=I_o\sin\acute{Ø}$

$R_o=V_o/I_w/\sqrt{3}$

$X_o=V_o/I_m/\sqrt{3}$

Short Circuit Parameter

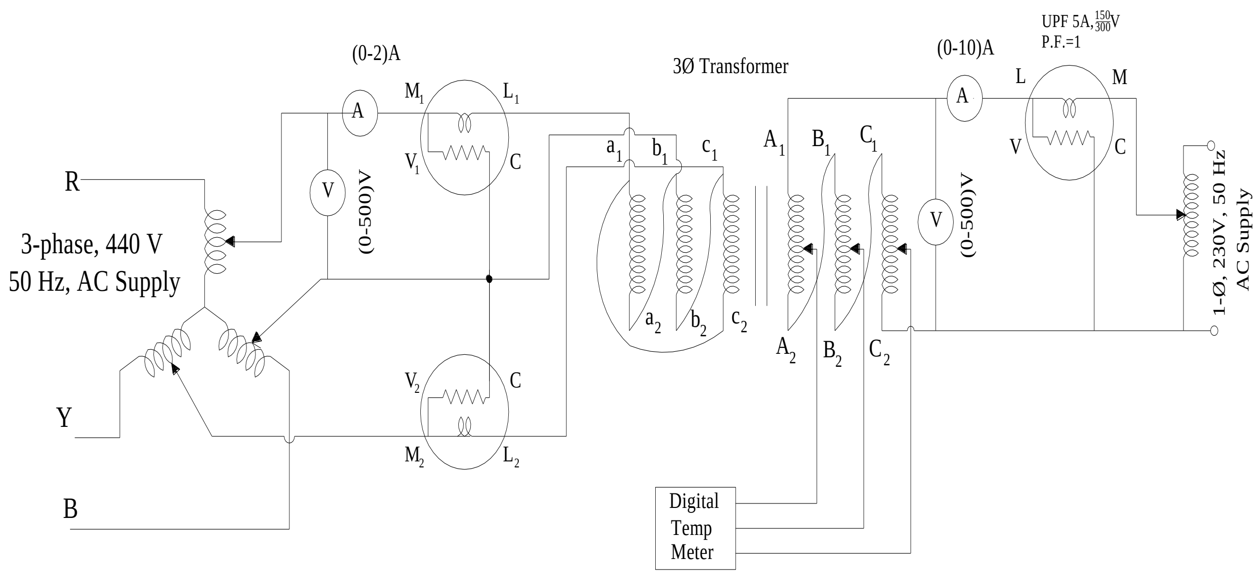
$P_{sc}=3I_{sc}^2R_{sc}$

$R_{cs}=P_{sc}/3I_{sc}^2$

$Z_{sc}=V_{sc}/I_{sc}/\sqrt{3}$

$X_{sc}=\sqrt{Z_{sc}^2-R_{sc}^2}$

<u>CIRCUIT DIAGRAM:</u>



<u>PROCEDURE:</u>

1. Connect the circuit according to the figure.

2. Give Rated voltage at rated frequency to the primary of the arrangement.

3. After checking the polarity at secondary side of transformer gives rated current to the secondary,

4. Record all the readings of apparatus.

OBSERVATION TABLE:

S.No	Vo	Io	Wo		Vsc	Isc	Wsc
			W1	W2			
1.							
2.							

RESULTS:

PRECAUTIONS:

1. Do the connections correctly, after checking the circuit diagram.
2. Use correct instrument rating for each test.
3. Connections should be right and tight.
4. Do check the connection by class teacher and than perform the experiment.
5. Note the reading precisely.
6. Do not touch any equipment when performing experiment.

EXPERIMENT # 8

OBJECT:

To perform no load and blocked rotor test on 3-phase squirrel cage induction motor and to determine the parameters of its equivalent circuit. Draw the circle diagram and compute the following-

1. Maximum torque
2. Current
3. Slip
4. Power factor
5. Efficiency

APPARATUS REQUIRED:

Name	Range	Type	**Quantity**
Ammeter	0-5A	MI	1
Ammeter	0-20A	MI	1
Voltmeter	0-75V	MI	1
Voltmeter	0-600V	MI	1
Wattmeter	600/5A,75/10A	Dynamo	2
Auto-Transformer	3KVA	3phase core type	1

THEORY:

The locus of the stator current of an induction motor is a circle under certain valid assumptions. This locus may be drawn using the test data obtained from the no load and blocked rotor test.

No load test

If the motor is run at the rated voltage and the frequency without any mechanical load, it will draw power corresponding to its no load losses. The current drawn will have two components, the active component and the magnetizing component. The former component is very small as the no load losses are small. The power factor at no load is thus very small. No load test gives one point o the current locus.

Blocked rotor test

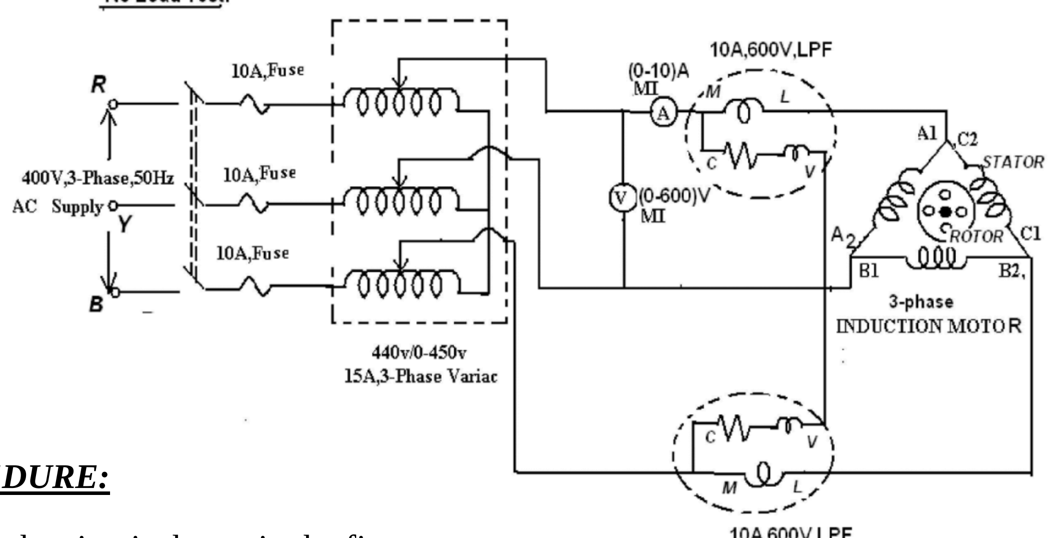
This test affords a second point on the current locus and is analogues to the short circuit test in the 3-phase transformer. The stator is supplied with the low voltage of rated frequency and with the rotor blocked. The power input, current and voltage are recorded. The data when converted to rated voltage gives the short circuit current and the power factor.

The power input during blocked rotor test is wholly consumed in the stator and the rotor copper losses. From the short circuit current and power input therefore total equivalent resistance of the stator and rotor can be obtained.

From the values of no load & blocked rotor current at rated voltage corresponding power factors and equivalent stator and rotor resistance’s the complete circle diagram may be drawn.

Circuit Diagram:

No Load Test:



PROCEDURE:

1. Connect the circuit shown in the fig.

2. Increase the voltage gradually till the motor starts. Record the current, voltage and power input.

3. Increase the applied voltage in suitable steps, record the input current & power for various values of applied voltage up to 125% of rated voltage.

4. Now block the rotor and apply a reduced voltage and record the voltage applied, current and power input.

5. Gradually increase the applied voltage with rotor kept blocked and record 3 or 4 sets as in step 4 till the stator current is about 1.2 times the rated current.

6. Measure the resistance per phase of the stator

   R_{ph}=3/2Rt if motor in delta

   R_{ph}=1/2Rt if motor in star

   Here Rt is the resistance between two terminals.

PRECUATIONS:

- Connection should be tight.
- During the blocked rotor test readings should be taken quickly to avoid the overheating.

OBSERVATIONS:

Open Circuit test			**Blocked rotor test**		
$\mathbf{V_o}$	$\mathbf{I_0}$	**Wo=W1+W2**	$\mathbf{V_{Br}}$	$\mathbf{I_{Br}}$	$\mathbf{W_{Br}}$**=W1+W2**

CALCULATIONS:

For open circuit test

Wo= √(3 Vo Io cosϕ)

cosϕ = Wo / (√3 Vo Io)

$\phi = \cos^{-1}[Wo / \sqrt{3}\ Vo\ Io]$

$Iw = Io\cos\phi$

$Im = Io\ \sin\phi$

$Ro = V / \sqrt{3}\ I_W$

$Xo = V / \sqrt{3} I_m$

For blocked rotor test-

$R_{Br} = W_{Br} / 3*(I_{Br})^2$

$Z_{Br} = V_{Br} / \sqrt{3} I_{Br}$

$X_{Br} = \sqrt{((Z_{Br})^2 - (R_{Br})^2)}$

<u>RESULT:</u> We have successfully performed the no- load and blocked rotor test of the induction motor

EXPERIMENT # 9

OBJECT: To Plot V-Curve and inverted V-Curve of synchronous motor.

APPARATUS REQUIRED

Equipments	Type	Rating	Qty
1. wattmeter	Analog wattmeter	10A, 600V	2
2. Ammeter	MI, MC	10A, 01A	2
3. voltmeter	MI	0-500V	1
4. Motor	Synchronous		1
5. DC excitation			
6. 3Φ auto transformer			

THEORY

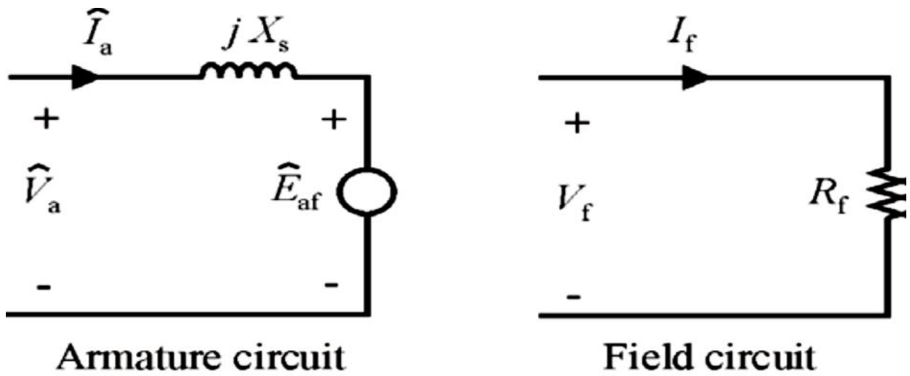
- After the machine starts, it will not completely reach synchronous speed. This is because if therotor is moving in synchronism with the stator poles, the flux linking the rotor damper windings will be constant.
- Thus the induced voltage will be zero and the torque will go to zero. In practice, the rotor accelerates to near synchronous speed since a small amount of torque is required to overcome friction losses.
- At this point, a DC current can be switched into the rotor field winding to establish rotor poles and the machine will lock into synchronism with the rotor operating at a synchronous speed of

$$\omega_s = 2\pi f \left(\frac{2}{pole}\right) \quad \ldots\ldots\ldots..(1)$$

wheree *f* is the frequency of the stator currents. In RPM, the synchronous speed may be calculated as

$$N_s = \frac{120f}{pole} \ldots\ldots\ldots..(2)$$

- The motor will now remain at synchronous speed unless it is overloaded.After the motor is started and is operating under normal conditions, the machine performance can be observed.
- For this analysis, the traditional per-phase model is shown in Figure 3. One phase of the armature circuit is seen to contain reactance and an induced voltage (back-emf) which is proportional to rotor field current.
- Typically the motor is driven by a constant voltage source and is supplying a mechanical load. The motor synchronous mechanical speed is determined by the voltage source frequency *f*.



Synchronous motor equivalent circuit

The input power can be defined from the per-phase model as

$P = 3V_a I_a \cos(\theta)$………..(3)

where $\theta = \angle V_a\hat{} - \angle I_a\hat{}$. It can be shown from the machine equations and power relationships that
$X_s I_a \; Cos(\theta) = E_{af} Sin\;(\delta)$………..(4)
Therefore, for constant power operation
$I_a\; Cos(\theta) = C_1$ ………..(5)
$E_{af} Sin\;(\delta) = C_2$ ………..(6)
where $C1$ and $C2$ are constants.

From a KVL equation, the phase voltage is

$E_{af} = V_a - j\, X_s I_a$ ………..(7)

- Using the information from (3-7), the circuit phasor can be plotted for constant power as the field current is varied. This is shown for three values of field current in Figure below. Note that the synchronous motor can operate with a lagging power factor, unity power factor, or leading power factor.
- Another important aspect of this is that the reactive power goes from positive to negative as field current is increased. This means that the synchronous motor can absorb or supply reactive power.
- Since the magnitude of E_{af} is proportional to field current excitation, the lagging power factor condition is sometimes referred to as under-excited operation and leading power factor condition is referred to as over-excited operation for the synchronous motor.
- These terms refer to the magnitude of the field current. Note that the current I_a and the voltage E_{af} follow the lines of constant power given by (5-6)

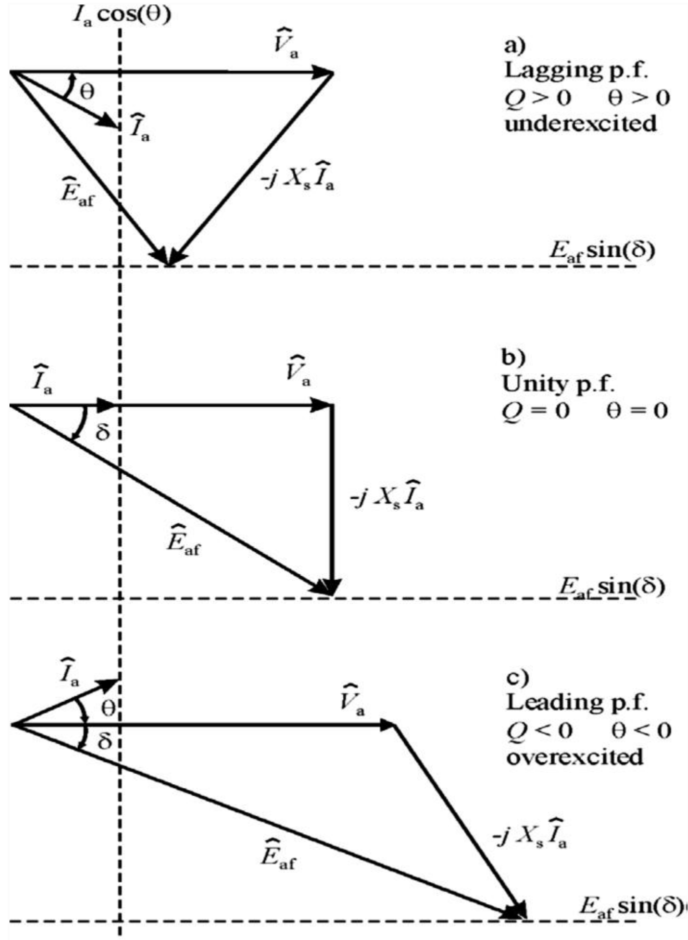


Figure 4. Synchronous motor phasor diagrams.

Synchronous Motor phasor Diagram

- If the armature current is plotted versus field current for several power levels, the regulating plotsare the motor V-curves shown in below Figure
- The points marked *a*, *b*, and *c* on the upper curve correspond to the operating conditions in above Figure . Note that for *P*=0, the lagging power factor operation is electrically equivalent to an inductor and the leading power factor operation is electrically equivalent to a capacitor.
- Leading power factor operation with *P*=0 is sometimes referred to as synchronous condenser or synchronous capacitor operation. Typically, the synchronous machine V-curves are provided by the manufacturer so that the user can determine the resulting operation under a given set of conditions.

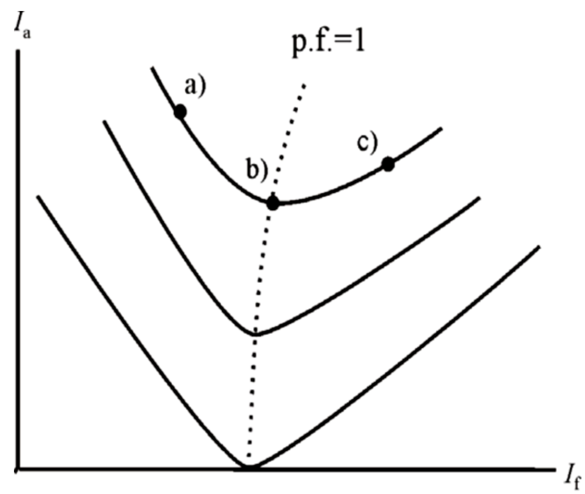
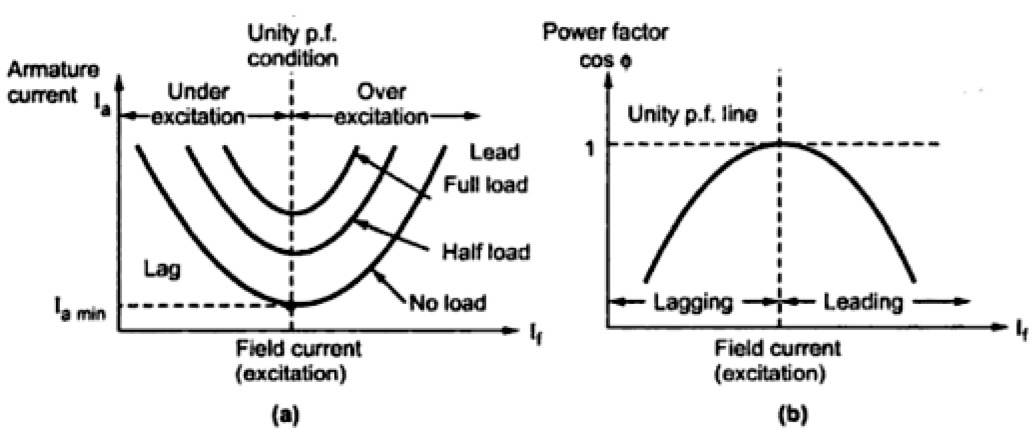


Figure 5. Synchronous motor V-curves.

Synchronous motor V-curve

Excitation can be increased by increasing the field current passing through the field winding of synchronous motor. If graph of armature current drawn by the motor (I_a) against field current (I_f) is plotted, then its shape looks like an english alphabet V. If such graphs are obtained at various load conditions we get family of curves, all looking like V. Such curves are called V-curves of synchronous motor.

As against this, if the power factor (cos Φ) is plotted against field current (I_f), then the shape of the graph looks like an inverted V. Such curves obtained by plotting p.f. against I_f, at various load conditions are called Inverted V-curves of synchronous motor.

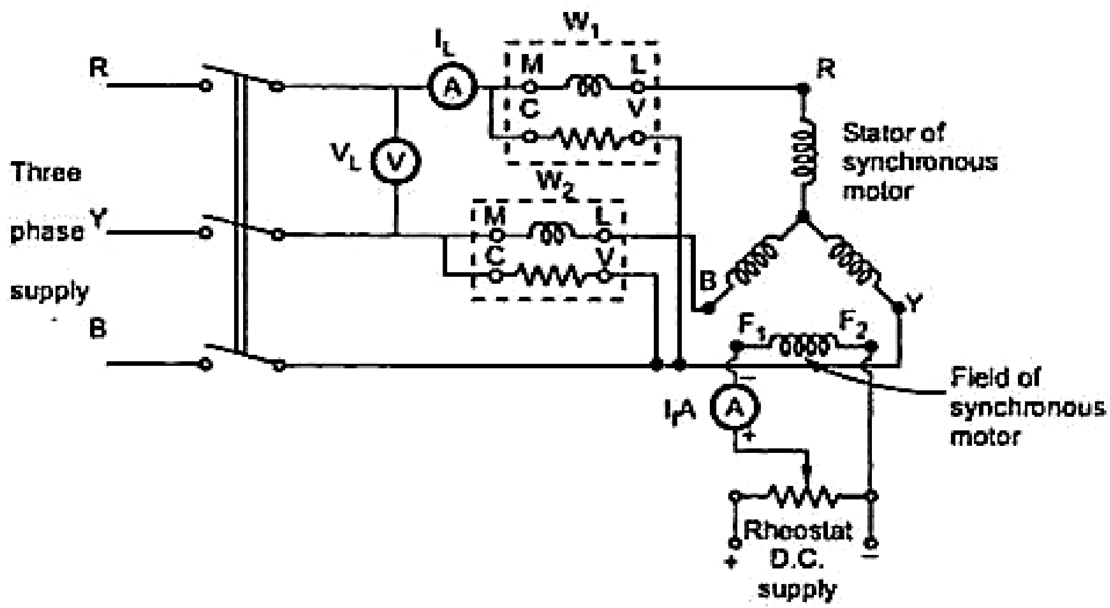


PROCEDURE

- Stator is connected top three phase supply through wattmeters and ammeter.
- The two wattmeter method is used to measure input power of motor.
- The ammeter is reading line current which is same as armature (stator) current.

- Voltmeter is reading line voltage.
- A rheostat in a potential divider arrangement is used in the field circuit.
- By controlling the voltage by rheostat, the field current can be changed.
- Hence motor can be subjected to variable excitation condition to note down the readings.

CIRCUITDIAGRAM



OBSERVATIONAL TABLE:

Sr. No.	V_L (V)	I_L (A)	W_1 (W)	W_2 (W)	I_f excitation (A)
1					
2					
:					

Now $I_L = I_a$, per phase value can be determined, from the stator winding connections.

$I_L = I_{aph}$ for stator connection

$I_L/\sqrt{3} = I_{aph}$ for delta connection

The power factor can be obtained as

$$\cos\phi = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}\right]\right\}$$

S.no.	I_f (Amp.)	I_a (Amp.)	Cos Φ

RESULTThe graph can be plotted from this result table.

a. I_a Vs I_f → V-curve
b. cosΦ Vs I_f → Inverted V-curve
c. The entire procedure can be repeated for various load conditions to obtain family of V-curves and Inverted V-curves.

EXPERIMENT # 10

OBJECT:

To synchronize an alternator to the infinite bus and summarizes the effects of variation of excitation on load sharing.

APPARATUS REQUIRED:

Name	Range	Type	**Quantity**
Ammeter	0-1A	MC	1
Ammeter	0-10A	MI	1
Voltmeter	0-500V	MI	2
Lamps	-		3
Tachometer	1500rpm		1
Rheostat	300Ω/2A	Variable	1
Rheostat	500Ω/1.2A	Variable	1
Auto-Transformer	3KVA, 50HZ	3phase core type	1

THEORY:

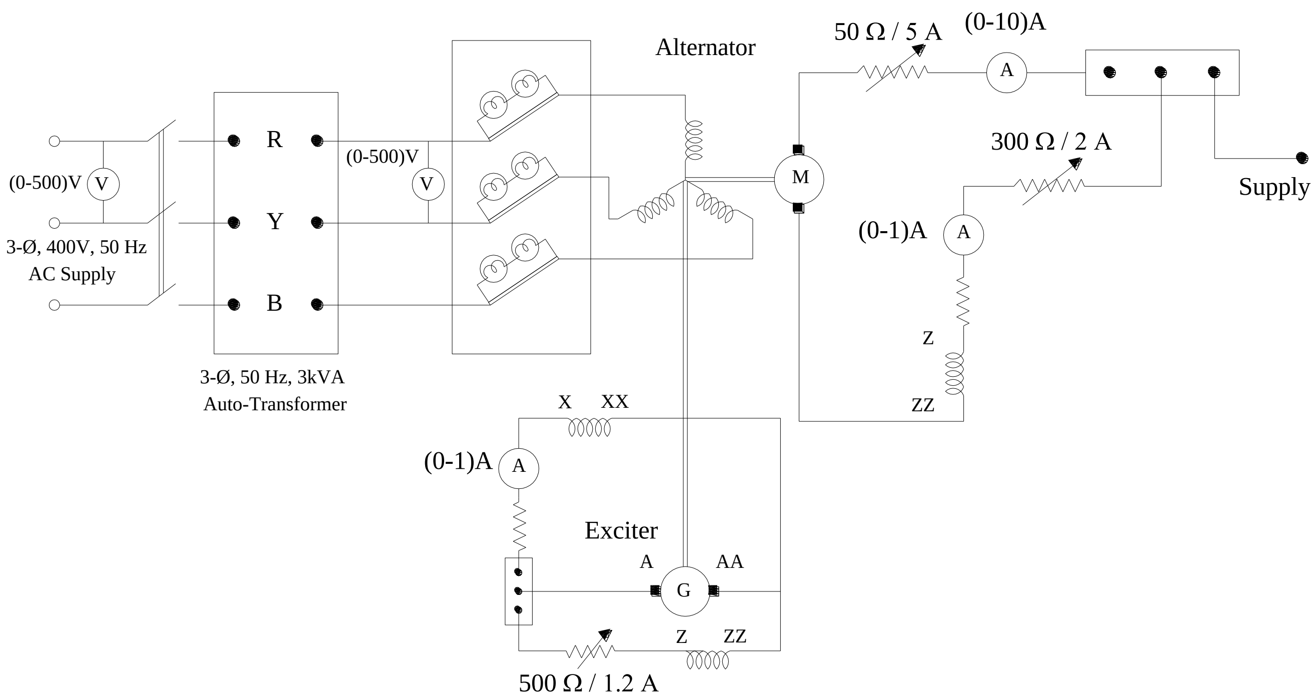
The operation of connecting an alternator in parallel with another alternator or with common bus bar is known as synchronization.

For proper synchronization of alternator-

1. The effective terminal voltage of the incoming alternator must be same as bus bar voltage.
2. The speed of the incoming machine must be such that its frequency equals to the bus bar frequency.
3. The phase of the alternator voltage must be identical with the phase of bus bar voltage.

In 3-phase alternator only one phase out of three have to be synchronized. First of all the phase sequence of the alternator is judged with the help of three lamps. If the lamps are connected symmetrically i.e. if the phase rotation is same as the bus bar, they would dark out or glow up simultaneously.

CIRCUIT DIAGRAM:



Syncronization of Alterantor with RSEB supply(Infinite Bus)

PROCEDURE:

1. Run the alternator at rated speed.
2. The terminal voltage of the alternator is made equal to bus bar voltage by varying the field current.
3. The-phase sequence of the alternator and bus bar is checked and corrected if required.
4. The-darking period of the lamps is increased gradually by adjusting field current.
5. The synchronizing switch is closed when all three lamps become dark.

6. The alternator has now synchronized with infinite bus bar. In order to check this switch off the supply the incoming supply of alternator. In correct synchronization the motoring mode without any variation in frequency or shock.

<u>OBSERVATIONS:</u>

Observe the lamps.

<u>RESULT:</u>

<u>PRECAUTIONS:</u>

- The connections must be tight.
- The incoming supply voltage should be increased gradually to its rated value.

The phase sequence should be checked carefully

<u>ASSIGNMENT:</u>

1. While synchronizing it is desirable that the frequency of incoming machine be kept slightly higher than that of the bus bar and not lower, why?

2. Define the infinite bus bar.