LABORATORY MANUAL

ELECTRICAL MACHINE LAB-II LAB

B.Tech. (Electrical Engineering), 4th Semester

Department of Electrical Engineering
Veer Surendra Sai University of Technology,
BURLA

Vision

To be recognized as a center of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

Mission

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1. Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.

M2. Fortifying collaboration with world class R& D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make in India' policy of the Government.

M3. Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

Program Educational Objectives

The program educational objectives of B.Tech. in Electrical Engineering program of VSSUT Burla are to prepare its graduates:

1. To have basic and advanced knowledge in Electrical Engineering with specialized knowledge in design and commissioning of electrical systems/renewable energy systems comprising of generation, transmission and distribution to become eminent, excellent and skilful engineers.
2. To succeed in getting engineering position with electrical design, manufacturing industries or in software and hardware industries, in private or government sectors, at Indian and in Multinational organizations.
3. To have a well-rounded education that includes excellent communication skills, working effectively on team-based projects, ethical and social responsibility.
4. To have the ability to pursue study in specific area of interest and be able to become successful entrepreneur.
5. To have broad knowledge serving as foundation for lifelong learning in multidisciplinary areas to enable career and professional growth in top academic, industrial and government/corporate organizations.

LIST OF EXPERIMENTS

1St Cycle

1. To perform open circuit and short circuit tests on a three phase alternator and to determine the voltage regulation by Synchronous-Impedance Method.
2. To determine the V-Curve and inverted V-Curves of a Synchronous Motor.
3. To study the various methods of speed control of a three phase induction motor.
4. To synchronise a 3-phase alternator to the infinite bus bars and to study the effect of change of excitation and input of the machine.
5. (a) To determine the variation of no load input power, p.f and current with voltage of an 3-phase Induction Motor.
   (b) To determine the parameters of the equivalent circuit of a 3-phase induction motor and to predetermine the performance of the motor.
   (c) To draw the circle diagram of the motor from the test data and to determine the maximum values of power factor output, torque and also to find the starting torque from the diagram.
6. To study Transformer Connections: Star-Star, Star-Delta, Delt-Star, Scott Connection 3-Phase to 6-Phase, Zig-Zag Connection.

COURSE OUTCOMES

Upon completion of this course, students will demonstrate the ability to:

CO1. Perform various tests on synchronous machines and to determine their characteristics.

CO2. Synchronize a given alternator to infinite bus.

CO3. Determine parameters of three phase and single phase induction motors.

CO4. Describe different losses of single phase transformer.

CO5. Determine characteristics, parameters and connections of three phase transformers.

Experiment 1

AIM OF THE EXPERIMENT:

To perform open circuit and short circuit tests on a three phase alternator and to determine the voltage regulation by Synchronous-Impedance Method.

MACHINE SPECIFICATION:

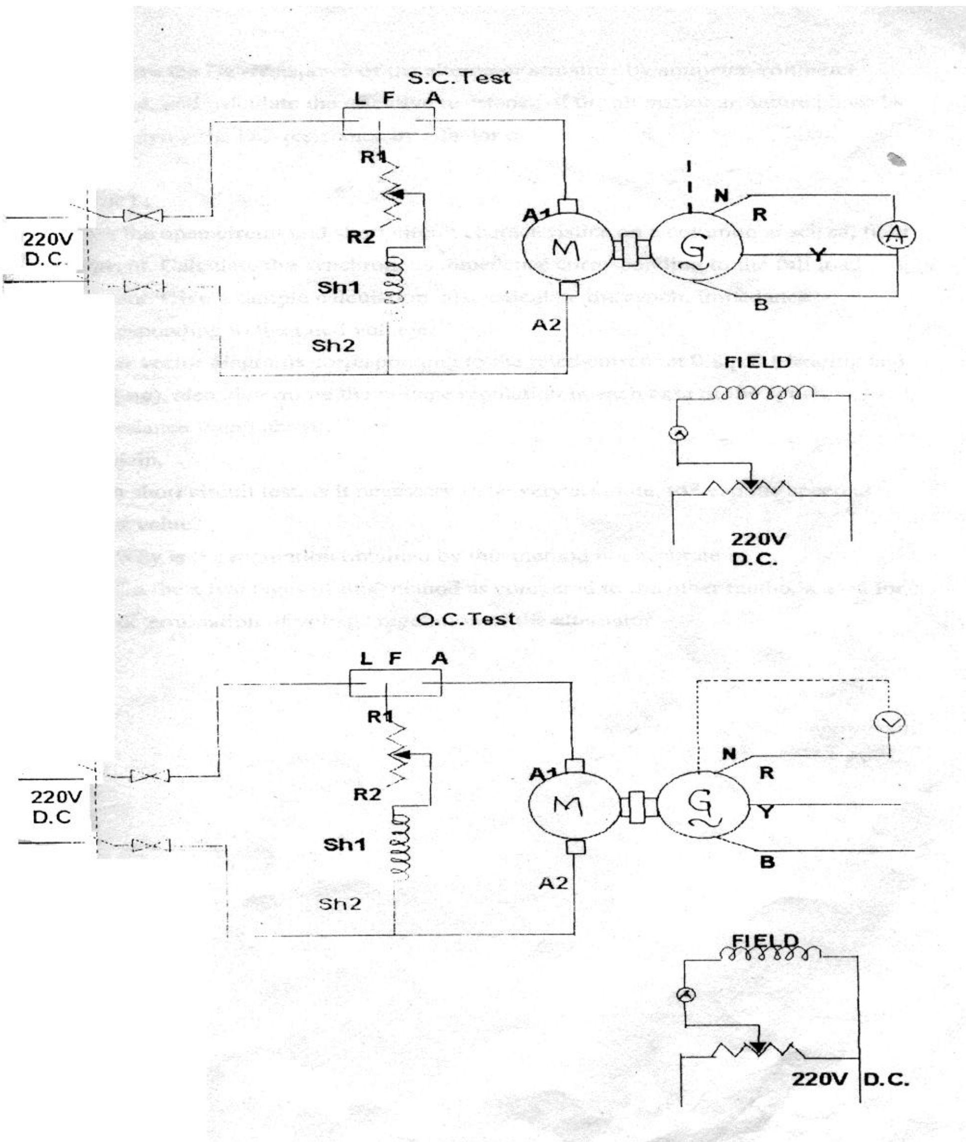
DC Shunt motor (Prime-mover): 2.5 KW, 220 V(DC), 10 A, 1450 RPM

3-Ph Alternator/ Synchronous Generator: 3 KVA, 400 V, 4.5 A, 1500 RPM

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

CIRCUIT DIAGRAM:



APARATUS REQUIRED:

Sl. No.	Item	Range/Rating	Maker's Name	Maker's No.

THEORY:

The voltage regulation of alternator = $\frac{No\ load\ voltage - full\ load\ voltage}{full\ load\ voltage\ .}$

O.C. Test

PROCEDURE:

1. The connections are made as per circuit diagram.
2. The alternator is run at rated speed with three terminal open.
3. The excitation of the alternator is increased in steps and a set of the terminal voltage readings are taken. (The speed of the alternator should remain constant throughout the experiment).
4. The excitation of the alternator is reduced to zero, driving it to its rated speed.
5. The voltmeter and the frequency meter are removed.

S.C. Test

6. The three terminals of the alternator is short circuited through suitable range of ammeter.
7. The excitation is increased in steps as previous one and short circuit currents are noted down.

Note: The short circuit current should not exceed more than 125% of the rated value.

8. The DC resistance (R_{dc}) of the armature of the alternator is measured by voltmeter-ammeter method and the effective resistance is taken as (1.3) x R_{dc}

REPORT:

1. Plot the open circuit and short circuit characteristics on a common abscissa, field current. Calculate the synchronous impedance corresponding to the full load current. Give a sample calculation, also calculate the synch. Impedance corresponding to the rated voltage.
2. Draw vector diagrams corresponding to the rated current at 0.8 p.f. (leading and lagging), also, determine the voltage regulation in each case of the synch. Impedance found above.
3. Explain,
   a. In short circuit test, is it necessary to be very accurate, to keep the speed at rated value?
   b. Why is the regulation obtained by this method not accurate
4. Discuss the advantages of this method as compared to the other methods used for the determination of voltage regulation of the alternator.

Experiment 2

AIM OF THE EXPERIMENT:

To determine the V-Curve and inverted V-Curve of a Synchronous Motor.

MACHINE SPECIFICATION:

Synchronous Motor (AC): 7.5 KW, 400 V, 13.5 A, 1500 RPM; Rotor – 55 V, 4 A

DC Compound Generator: 5 KW, 230 V (DC), 21.7 A, 1500 RPM

APARATUS REQUIRED:

Sl. No.	Item	Range/Rating	Maker's Name	Maker's No.

THEORY:

At constant power input the input current and power factor of a synchronous motor, connected to the infinite bus bars changes if the excitation of the motor is varied.

Explanation

The applied voltage V to the motor is balanced by the excitation voltage E and synchronous impedance drop IZ_S. That is

$$V = E + IZ_S$$

Since V is constant and if Z_S is treated as constant (Neglecting Saturation), then the input current will change if excitation is changed.

$$As\left(I = \frac{V - E}{Z_S}\right)$$

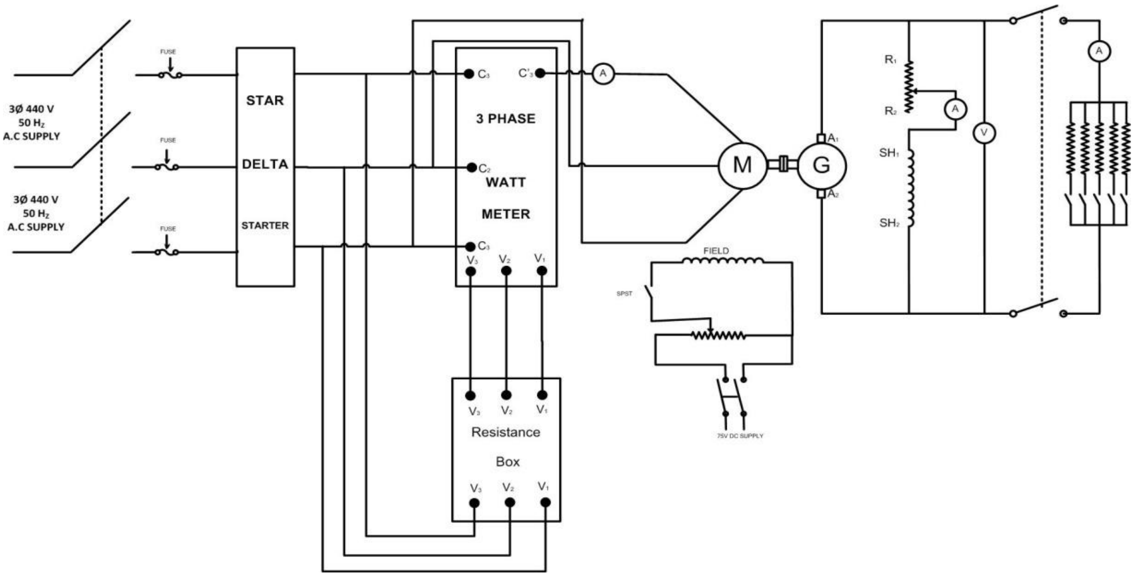
Further, the input power is given by

P = VI Cosϕ, where Cosϕ is the power factor

At constant power, I Cosϕ is constant and hence, if excitation is varied then current (I) as well as power factor (Cosϕ) must vary.

The V-curves give relation between excitation and motor current and inverted V-curves give relation between excitation and power factor at constant power.

CIRCUIT DIAGRAM



PROCEDURE:

1. The connections are done as per the Circuit Diagram.
2. Keeping the load switch on D.C. side open, the motor is started as an induction motor. After the motor attains its maximum speed as an induction motor, the field circuit is closed.
3. After the motor is pulled on synchronous speed, the excitation of the motor is reduced until the input current is equal to or somewhat higher than the rated value.
4. The instrument reading are noted down.
5. The excitation is increased at suitable steps, until the field current is equal to or a little higher than its rated value.
6. The instrument readings are taken at each step.
7. It is to be noted the value of the excitation at minimum input current. (i.e. unity power factor)
8. The load switch is closed and the motor is loaded to about 25% of its rated value.
9. The excitation is varied in the suitable steps both in lagging and leading power factor regions.
10. The instrument readings are taken at each steps.
11. The same procedure is repeated for 50% and 75% of the rated load.
12. The machine is brought to rest after uploading the machine.

CALCULATION AND GRAPHS:

1. Calculate the power factors.
2. Plot the relation between the line current and field current taking power as the parameter. Join the unity power factor points and the leading and lagging power factor regions.
3. Find out the excitation current for each load at unity, 0.8 leading and 0.8 lagging power factors.

DISCUSSION:

1. Explain how to confirm whether the motor has pulled to synchronism or not.
2. Explain how to test whether the motor is running at leading or lagging power factor region.
3. Explain why the excitation for leading power factor is higher than the excitation at lagging power factor and the slope of the characteristics in the leading power factor range is less than that in the lagging power factor range of operation.

Experiment 3

AIM OF THE EXPERIMENT:

To study the various methods of speed control of a three phase induction motor.

MACHINE SPECIFICATION:

Slip Ring Induction Motor (M/C-1): 7 KW, 400/231 V, 14.7/ 25.4 A, 50 Hz, 1450 RPM

Squirrel Cage Induction Motor (M/C-2): 7 KW, 400/231 V, 14.5/25 A, 50Hz, 960 RPM

APARATUS REQUIRED:

Sl. No.	Item	Range/Rating	Maker's Name	Maker's No.

SOME OF THE METHODS:

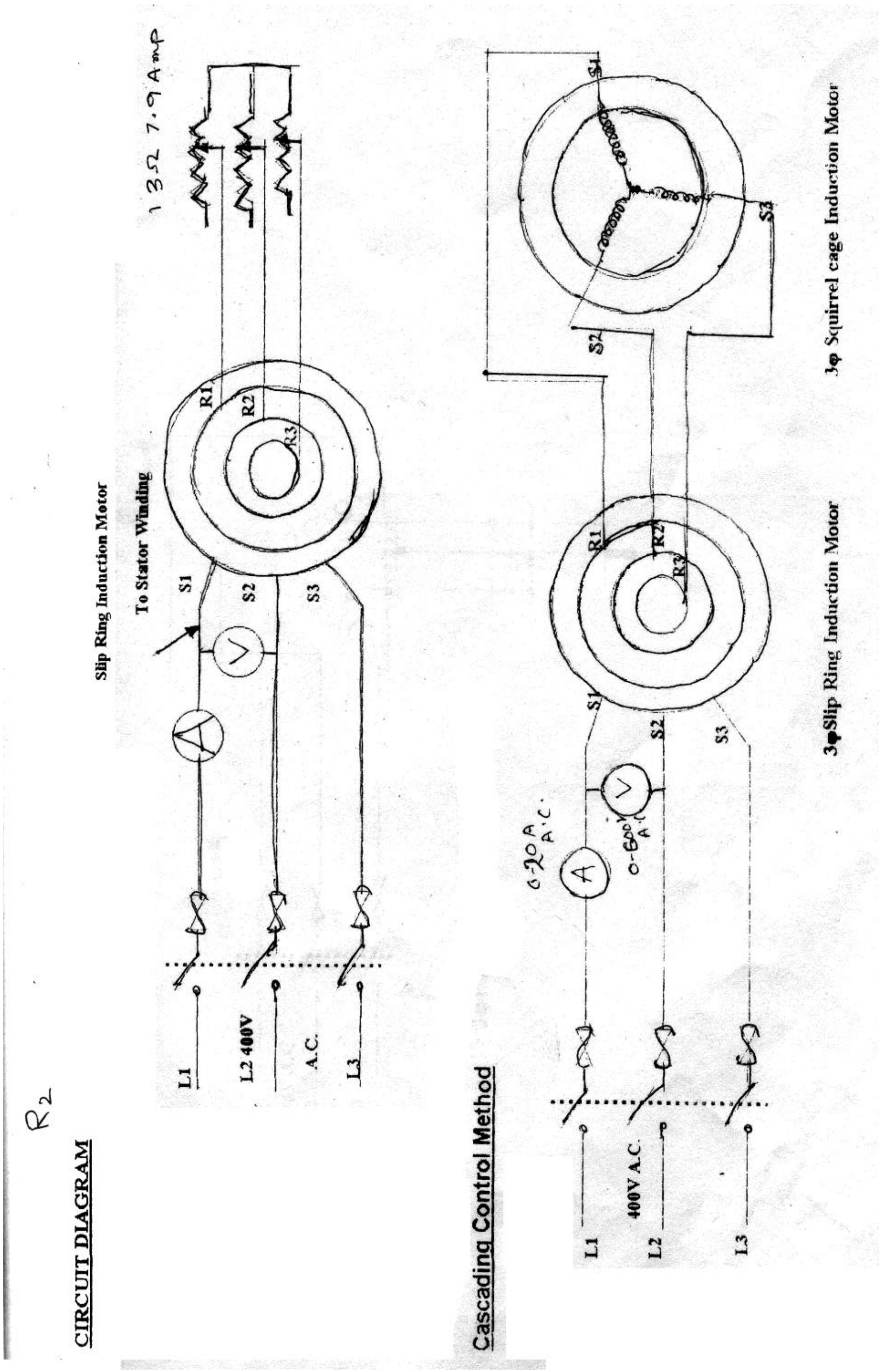
Some of the methods of speed control are:

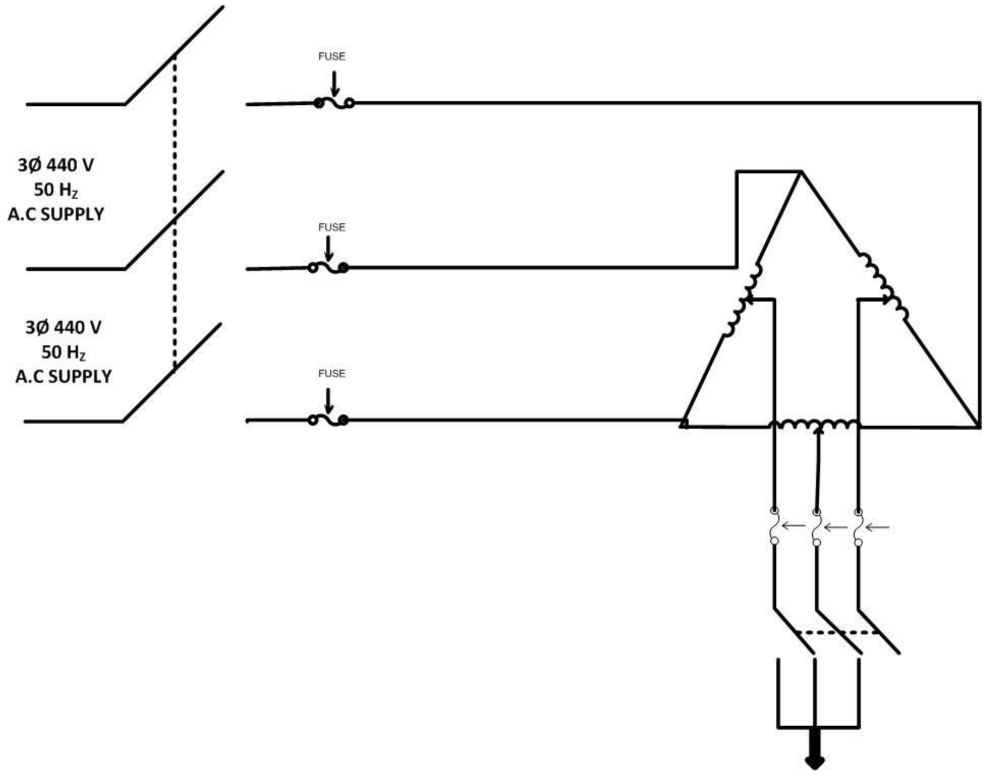
A. **Rheostatic Control:**
   1. The Connection are done as per the circuit diagram.
   2. Three phase supply is given and the speed of the wound rotor motor is taken at 100%, 75%, 50%, 25% rotor resistance position.
   3. Line voltage and line current are taken at the above condition.

B. **By changing the number of poles:**
   1. This method is suitable for a squirrel cage motor.
   2. The Squirrel cage winding is capable of adjusting to any number of poles. By suitably connecting the tapings brought out from the stator winding.
   3. Speed control of the above two methods is possible because of the synchronous speed of the motor depends upon the frequency and number of poles ($N_S = 2f/p$) rps.

C. **Cascade Control:** This method requires two induction motors; one of the motors must be of slip ring type. If P_1 and P_2 are the number of poles of the two motors, three synchronous speeds are possible in practice. They are $2f/P_1$, $2f/P_2$, $2f/(P_1+P_2)$. Thus the set can run at the three different speeds.

CIRCUIT DIAGRAM





PROCEDURE:

1. a. Explain briefly the principles involved in each method
   b. Illustrate your explanation with necessary diagram and characteristics of the machine.
   c. State the advantages and disadvantages of each method.

CONCLUSION:

Experiment 4

AIM OF THE EXPERIMENT:

To synchronise a 3-phase alternator to the infinite bus bars and to study the effect of change of excitation and input of the machine.

MACHINE SPECIFICATION:

DC Compound/shunt Motor: 16 HP, 220 V, 58 A, 1500 RPM

3-Ph Alternator: 8 KVA, 400/231 V, 11.5 A, 1500 RPM

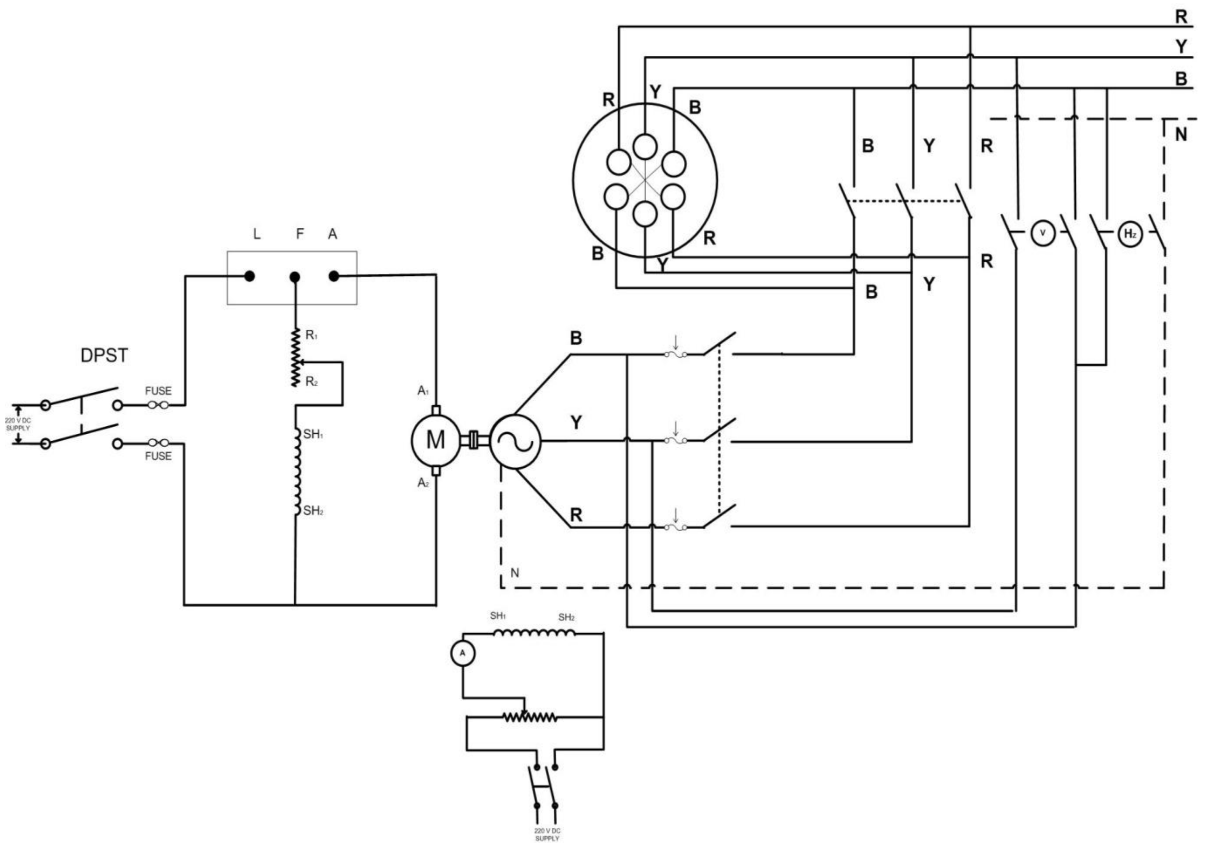
APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

THEORY:

For proper synchronization, the voltage magnitude, frequency and the phase sequence of the incoming machine must be equal to those of the bus bars. Also the incoming machine and bus bar voltages must be in phase.

CIRCUIT DIAGRAM:-



PROCEDURE:

1. The Synchronous machine is run at rated speed.
2. The field circuit is closed and adjust the field current is adjusted so that, the generator voltage is equal to the bus bar voltage.
3. The frequency is adjusted if necessary and the phase sequence checked.
4. The alternator are synchronized using 2 dark 1 bright lamp method or with the help of a synchroscope.
5. The effect of change in excitation and speed of the machine is studied.
6. The synchronous machine is brought to rest by opening the synchronizing switch and opening the field excitation.

DISCUSSION:

1. Discuss the effect of wrong synchronization.
2. Why only the power factor changes when the excitation is changed, and how does the power transfer takes place.
3. Under what condition an additional machine is synchronized with the bus bar.

CONCLUSION:

Experiment 5

AIM OF THE EXPERIMENT:

A. To determine the variation of no load input power, p.f and current with voltage of an 3-phase Induction Motor
B. To determine the parameters of the equivalent circuit of a 3-phase induction motor and to predetermine the performance of the motor.
C. To draw the circle diagram of the motor from the test data and to determine the maximum values of power factor output, torque and also to find the starting torque from the diagram.

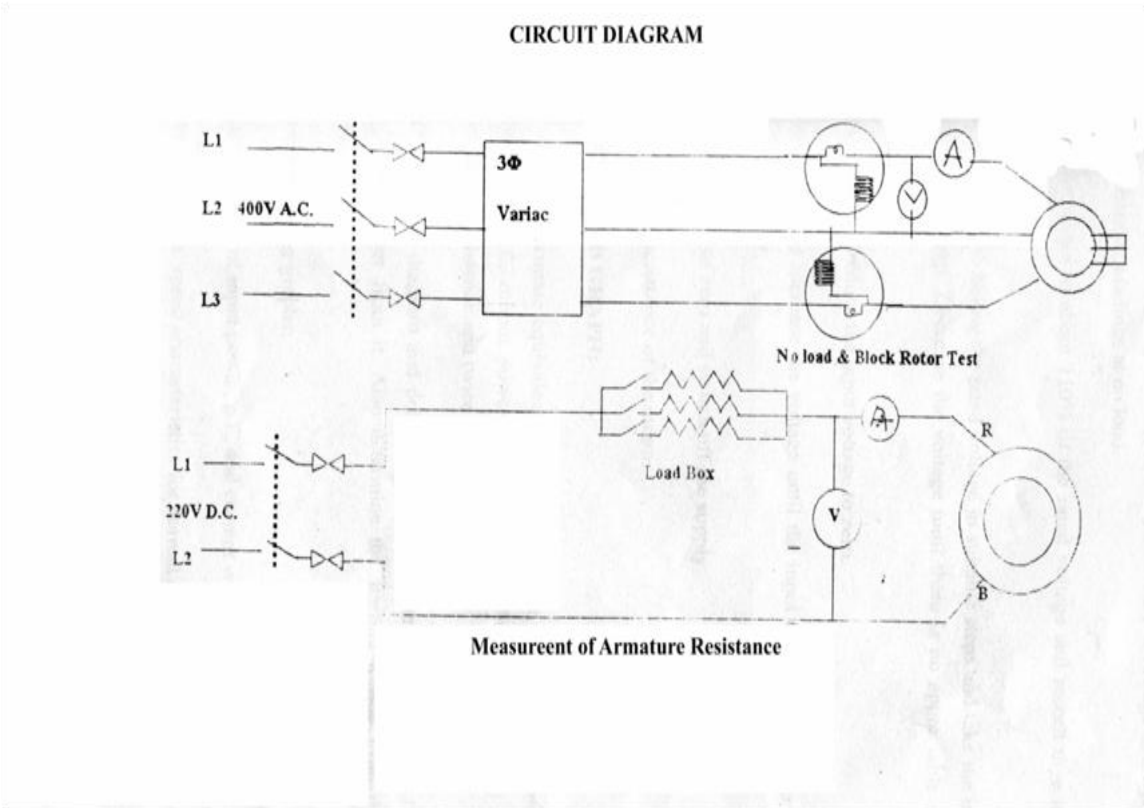
MACHINE SPECIFICATION:

3-Ph Induction Motor: 3.7 KW, 5HP, 400/440 V, 7.5 A, 1400 RPM

APPARATUS REQUIRED:

Sl. No.	Item	No. of Items	Rating

CIRCUIT DIAGRAM:-



THEORY:

A. The approximate equivalent circuits under no load and blocked rotor conditions are given in the figure.
B. If the voltage per phase is drawn along the vertical direction the blocked rotor current, which is a chord of the circle, is inclined at an angle ϕ_{SC} to the vertical, where ϕ_{SC} is the blocked rotor p.f. angle. The meeting point of the perpendicular bisector of the chord and the horizontal line is the center of the circle.

PROCEDURE:

1. The motor is started under no load condition and the input voltage is adjusted to the rated value and the instrument readings are taken at no load.
2. The voltage is increased to about 110% of the rated voltage.
3. The voltage is decreased below the rated voltage in suitable steps and the instrument readings are taken at each step. The voltage is decreased until there is no appreciable change in speed.
4. The motor is stopped and the input voltage is reduced to zero.
5. The rotor is blocked and the voltage is increased until the input current is equal to the rated current of the motor.
6. The voltage is reduced to zero and the supply is switched off.
7. The stator resistance of the motor is measured.

CALCULATION AND GRAPH:

1. From the approximate equivalent circuit of the motor, calculate the current, input power, input p.f., output power, output torque, efficiency of various slips, at normal rotor resistance and twice the rotor resistance.
2. Draw the circle diagram and determine the maximum values of the p.f., torque and output power from it. Also determine the starting torque from the circle diagram
3. Plot the following graphs:
   a. Variation of input power, p.f., and current with voltage at no load.
   b. Torque Vs. Speed characteristics for normal and twice the rotor resistance.

Experiment 6

AIM OF THE EXPERIMENT:

To study Transformer Connections: Star-Star, Star-Delta, Delt-Star, Scott Connection 3 Phase to 6 phase, Zig-Zag Connection.

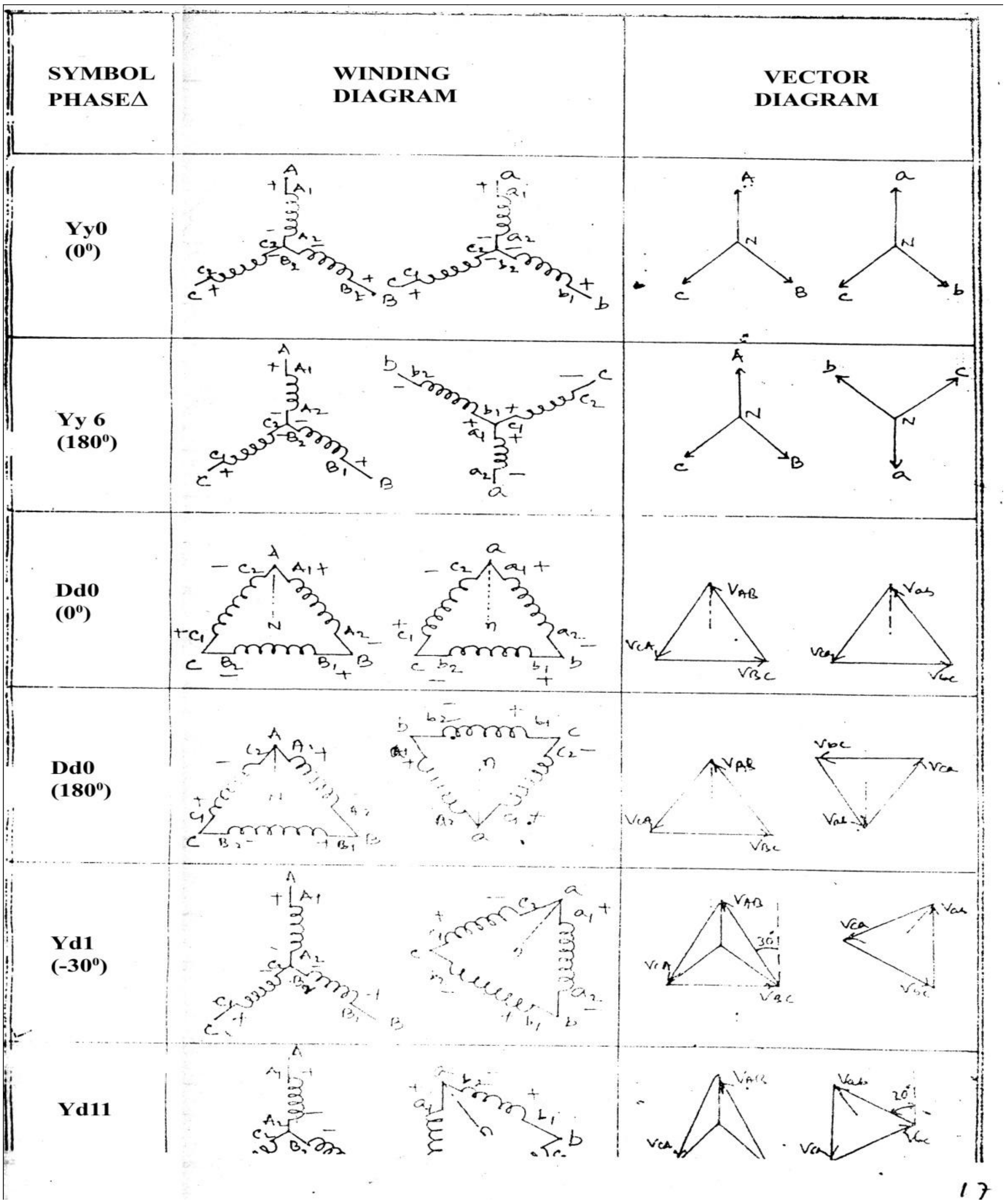
MACHINE SPECIFICATION:

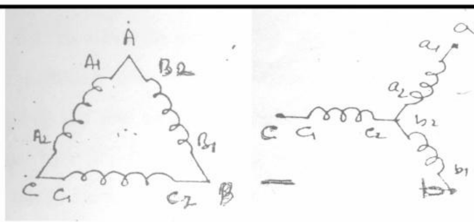
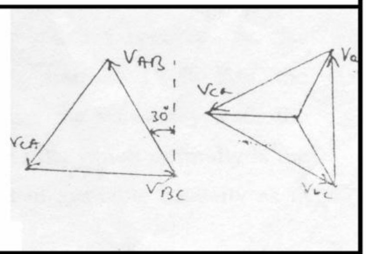
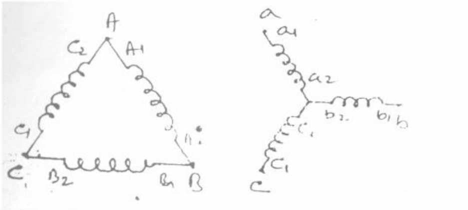
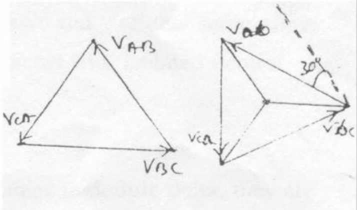
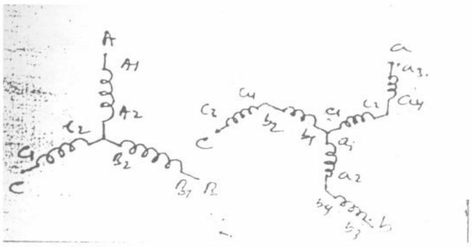
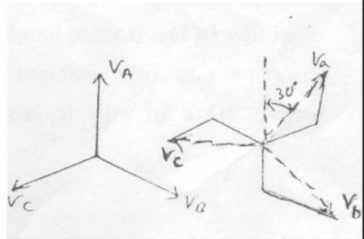
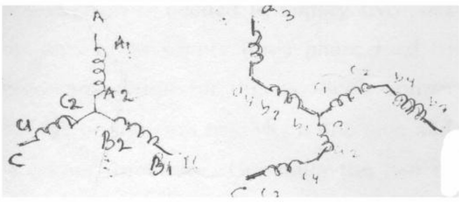
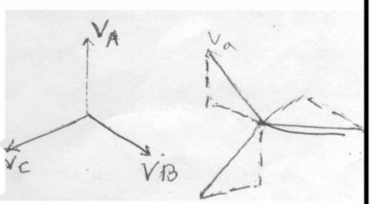
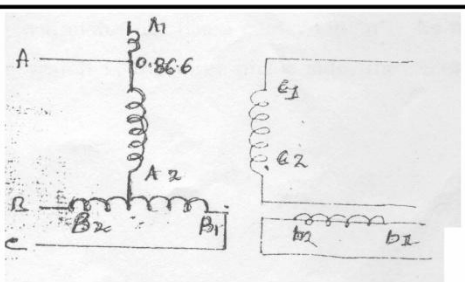
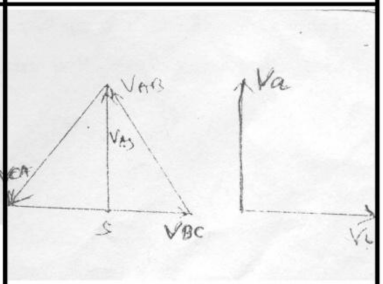
Transformer: 3KVA, 230/230 V (1:1), 13 A, 50Hz.

APPARATUS REQUIRED:

Sl. No.	Item	Rating	Nos.

CIRCUIT DIAGRAM:-



SYMBOL PHASE Δ	WINDING DIAGRAM	VECTOR DIAGRAM
Dy 1 (-30⁰)		
Dy 11 (+30⁰)		
Yz 1 (-30⁰)		
Yz 11 (+30⁰)		
3/2 Ph SCOTT CONNECTION		

THEORY:

(STAR-STAR Connection)

Star-Star: The connection for Y-Y connections are shown in fig. The line voltage is $\sqrt{3}$ times the phase voltage and the two are displaced by 30^0. The secondary voltage system is in phase with the primary in and the secondary voltage system is 180^0 out of phase from the primary and is designated as Y_{Y6} if it is a 3-ϕ transformer.

Star-Star poly phase transformer or bank of 1-ϕ connection in star-star operated with grounded neutral i.e. the neutral of the primary is connected with the neutral of the power source.

(STAR-DELTA Connection)

This is the most popular connection used in high voltage circuit and is shown in fig. 30^0 shift appears in line voltage as well as in system phase voltage between primary and secondary side. The 3^{rd} harmonic current found within the mesh to provide a sinusoidal flux, the ratio between primary and secondary system voltage is $\sqrt{3}$ times, the phase turn ratio. When operated in star-delta, the primary neutral is sometimes grounded to connect it to Y wire system. Y_{d11} specifies that, the voltage side is Y connected and secondary leads by primary by 30^0 and Y_{d1} means secondary lags primary by 30^0.

(STAR-ZIG-ZAG Connection)

In the fig. Two configuration Y_{Z1} and Y_{Z11} are available and Y specifies the star connection of primary side and secondary side is in zigzag connection. In Y_{Z1}, the secondary Zigzag lag the primary voltage by 30^0 and in Y_{Z11}, the secondary leads the primary voltage by 30^0. If the Zigzag is on the load voltage side, which normally is the case and the transformer is poly phase. There is reduction in available capacity as in Delta-Zigzag connection

The Zigzag connection reduces 3^{rd} harmonic voltage and at the same time permits unbalanced loading, even though the primary is connected with isolated neutral.

(THREE PHASE TO SIX PHASES):

Instead of connecting the two sets of secondary windings in double delta, they are connected in double star as shown in Fig. Here the primary side connected in delta & the two sets of secondary are connected in double star. The neutral point n and n^1 will have the same potential when the secondary leads are connected together. This common wire terminal now connected together. This common wire terminal are of a DC 3-wire system.

SCOTT CONNECTION:

Scott connection is needed to supply two-phase furnace or to out link two and three phase systems or to supply three phase load from two-phase system. The most extensively used connection for this is "Scott connection" involving two single-phase transformers. This connection has 3ϕ on one side and 2-phase system on the other with power flow in either direction. Generally the two transformers are identical, which is usually the case, the three phase side of the teaser transformer should have GO 866 tap while the main transformer has a center-tap 'n'. As the voltage per turn is same in the primary side, which is the three-phase side, the secondary will develop the voltage of equal magnitude, but these voltage are in quadrature with respect to each other as the voltage applied to primary winding are in phase quadrature.

Let balanced current each of equal magnitude and at a p.f. "Cosϕ" leg be taken from the two secondary. Neglecting the magnetizing current, the primary ampere – turn in each transformer must balance the secondary ampere turn. The current in teaser primary will be $2I_aT_2/\sqrt{3}T_1 = 1.15KI_a$ where T_1 and T_2 are total primary and secondary turns in each transformer and $K = T_2/T_1$. In the main transformer, the primary balancing current will be $I_bT_2 = KI_b$. Here when the load on one side is balanced, the input currents in the other side are balanced. However while the p.f. of the teaser of Cosϕ while that of one half of the winding on the main transformer. On 3ϕ side is Cos (30+ϕ) and that of half is Cos(30+ϕ).

PROCEDURE:

The circuit connections were done as per the circuit diagram one by one. Before the connections were made, the polarity test of the transformer was done to find out the same polarity. Then for every connection, the line voltages for primary and secondary were noted down.

DISCUSSION:

CONCLUSION: