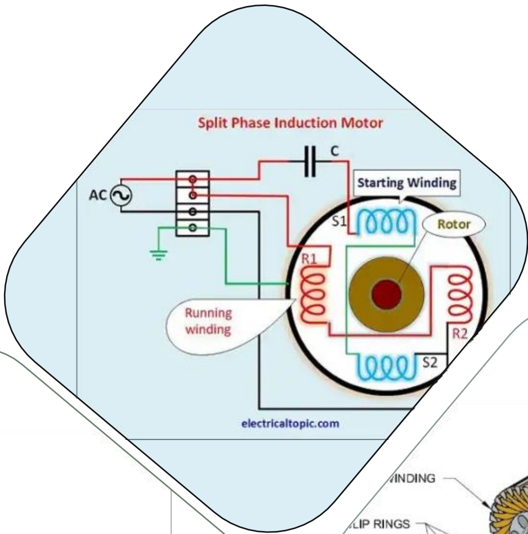
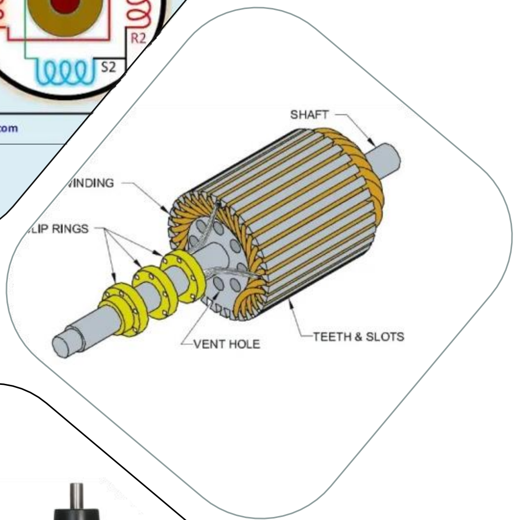
**SCHEME :K**

Name :________________________________
Roll No.:___________ Year : 20 ___20
Exam Seat No. :________________________

# LABORATORY MANUAL FOR

# A.C. MACHINES PERFORMANCE (315333)




## ELECTRICAL ENGINEERING GROUP

**MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI**
**(Autonomous)(ISO21001:2018)(ISO/IEC27001:2013)**

## VISION

To ensure that the Diploma level Technical Education constantly matches the latest requirements of Technology and industry and includes the all-round personal development of students including social concerns and to become globally competitive, technology led organization.

## MISSION

To provide high quality technical and managerial manpower, information and consultancy services to the industry and community to enable the industry and community to face the challenging technological & environmental challenges.

## QUALITY POLICY

We, at MSBTE are committed to offer the best in class academic services to the students and institutes to enhance the delight of industry and society. This will be achieved through continual improvement in management practices adopted in the process of curriculum design, development, implementation, evaluation and monitoring system along with adequate faculty development programmes.

## CORE VALUES

**MSBTE believes in the following:**

- Education industry produces live products.
- Market requirements do not wait for curriculum changes.
- Question paper is the reflector of academic standards of educational organization.
- Well-designed curriculum needs effective implementation too.
- Competency based curriculum is the backbone of need based program.
- Technical skills do need support of life skills.
- Best teachers are the national assets.
- Effective teaching learning process is impossible without learning resources.

A Laboratory Manual For

# A.C. MACHINES PERFORMANCE

## (315333)

## Semester – V

**(EE/EK/EP)**

**Maharashtra State**

**Board of Technical Education, Mumbai**

**(Autonomous) (ISO 21001:2018)(ISO/IEC 27001:2013)**

**Maharashtra State Board of Technical Education, Mumbai**

**(Autonomous) (ISO21001:2018) (ISO/IEC 27001:2013)**

**4th Floor, Government Polytechnic Building, 49, Kherwadi, Bandra (East), Mumbai- 400051**.

# MAHARASHTRA STATE
# BOARD OF TECHNICAL EDUCATION

# Certificate

This is to certify that Mr. /Ms …………………………………………………….........

Roll No. ……………………………., of Fifth Semester of Diploma in …....................................................................................................... of Institute, ……..………………………………………………………………………………

(Code : ……………………) has completed the term work satisfactorily in course **A.C. Machines Performance (315333)** for the academic year 20…….to 20…….. as prescribed in the curriculum.

**Place: ……………..** **Enrollment No: ………………..**

**Date: ……………….** **Exam Seat No: …………………**

**Course Teacher** **Head of department** **Principal**

Seal of Institution

# Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'K' Scheme curricula for engineering diploma programmes with outcome-based education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher, instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome- based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through "chalk and duster" activity in the classroom situation. Accordingly, the ‘K’scheme laboratory manual development team designed the practical to focus on the outcomes, rather than the traditional age old practice of conducting practical to 'verify the theory" (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected. from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

The electrical diploma holder has to work in industry as technical person in middle level management. He has to work as production, maintenance, testing engineer in various industries like, production industries automobile industry, power generation, transmission, distribution, traction etc. and has to deal with different electrical measurement. While performing above task he has to measure different electrical and electronic parameters with testing, therefore he/she must require the skills for these measurements and broad idea of different meters and equipment.

Although best possible care has been taken to check for errors (if any) in this laboratory manual, perfection may elude us as this is the first edition of this manual. Any errors and suggestions for improvement are solicited and highly welcome.

## Program Outcomes (POs)

- **PO 1. Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, sciences and engineering fundamentals and engineering specialization to solve the engineering problems.
- **PO 2. Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.
- **PO 3. Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of system components or processes to meet specified needs.
- **PO 4. Engineering tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.
- **PO 5. Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.
- **PO 6. Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.
- **PO 7. Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

## List of Relevant expected psychomotor domain Skills

This Lab manual intends to develop expected psychomotor domain skills of students. The skills mentioned below are expected to be developed in student by undertaking the practical of this laboratory manual.

1. Ability to make connections
2. Ability to select proper ranges of meters.
3. Ability to correctly open and close circuits.
4. Ability to use the relevant three phase induction motor (IM) for different applications.
5. Ability to use the relevant single phase induction motors in different applications.
6. Ability to use the relevant three phase alternator for different load conditions.
7. Ability to use suitable Fractional HP motors for different applications.

## Practical-Course outcome matrix

**COURSE LEVEL LEARNING OUTCOMES (COS)**

1. CO1 - Test the performance of three phase induction motor.
2. CO2 - Control the speed of three phase induction motor using appropriate technique(s).
3. CO3 - Use single phase induction motor for industrial applications.
4. CO4 - Test the performance of three phase alternator.
5. CO5 - Use special purpose electrical machines for industrial applications.

| Sr. No. | Title of the Practical | CO1 | CO2 | | CO4 | CO5 |
|---|---|---|---|---|---|---|
| 1 | * Identification of different parts of a three phase squirrel cage and slip ring induction motor, interpretation of the nameplate of three phase induction motor and reversal of the direction of rotation | ✓ | - | - | - | - |
| 2 | *Measurement of slip of a three-phase induction motor by:<br>a) using Tachometer<br>b) using galvanometer<br>c) using stroboscope | ✓ | - | - | - | - |
| 3 | *Brake test on three-phase induction motor. | ✓ | - | - | - | - |
| 4 | * Measurement of iron and copper losses through no-load and blocked rotor test on a three-phase induction motor and calculation of efficiency | ✓ | - | | - | - |
| 5 | * Starting of a three-phase induction motor using (a) auto transformer (b) DOL starter (c) star-delta starter | - | ✓ | | - | - |
| 6 | Speed control of a three-phase slip ring induction motor by varying rotor resistance. | - | ✓ | | - | - |
| 7 | Starting and controlling the speed of a three-phase induction motor using variable frequency drive (VFD) | - | ✓ | | - | - |
| 8 | * Identification of different parts of a single phase induction motor and reversing the direction of rotation of a ceiling fan/ single phase induction motor/ universal motor | - | - | ✓ | - | - |
| 9 | Operation of three phase alternator for variable frequency output by controlling speed of its prime mover | - | - | - | ✓ | - |
| 10 | Direct loading test of a three-phase alternator for determining voltage regulation with resistive, inductive, and capacitive loads | - | - | | ✓ | - |
| 11 | * Open circuit (OC) and short circuit (SC) test on three phase alternator for determining its efficiency and voltage regulation | - | - | | ✓ | - |
| 12 | *Speed control of stepper motor | - | - | | - | ✓ |

## Guidelines to Teachers

1. Teacher should provide the guideline with demonstration of practical to the students with all features.
2. Teacher shall explain prior concepts to the students before starting of each experiment
3. Involve students in performance of each experiment.
4. Teacher should ensure that the respective skills and competencies are developed in. the students after the completion of the practical exercise.
5. Teachers should give opportunity to students for hands on experience after the demonstration.
6. Teacher is expected to share the skills and competencies to be developed in the students.
7. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected the students by the industry.
8. Finally give practical assignment and assess the performance of students based on task assigned to check whether it is as per the instructions.

## Instructions for Students

1. Listen carefully the lecture given by teacher about subject, curriculum, learning structure, skills to be developed.
2. Organize the work in the group and make record all programs.
3. Students shall develop maintenance skill as expected by industries.
4. Student shall attempt to develop related hand-on skills and gain confidence.
5. Student shall develop the habits of evolving more ideas, innovations, skills etc. those included in scope of manual
6. Student shall refer technical magazines.
7. Student should develop habit to submit the report of practical on date and time.
8. Student should well prepare while submitting write-up of exercise.
9. Attach/paste separate papers wherever necessary.

## Content Page

List of Practical's and Progressive Assessment Sheet

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Operation of three phase alternator for variable frequency output by controlling speed of its prime mover | 62 | | | | | |
| 10 | Direct loading test of a three-phase alternator for determining voltage regulation with resistive, inductive, and capacitive loads | 70 | | | | | |
| 11 | * Open circuit (OC) and short circuit (SC) test on three phase alternator for determining its efficiency and voltage regulation | 80 | | | | | |
| 12 | *Speed control of stepper motor | 92 | | | | | |

**Note :**
**Out of above suggestive LLOs -**

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

**Practical No. 1: Identification of different parts of a three phase squirrel cage and slip ring induction motor, interpretation of the nameplate of three phase induction motor and reversal of the direction of rotation**

**I Practical Significance**

Three phase Induction motors are widely used in various industries as drive motors for variety of machines due to its rugged construction, smoother, efficient operation, low-priced, easy to maintain and high reliability. They run at essentially constant speed from no-load to full-load. However, the speed is frequency dependent and consequently these motors are not easily adapted to speed control. A 3 phase induction motor can be used for different applications with various load requirements. Its construction is simple consisting Stator & rotor as main parts.

Understanding how to read the nameplate of a motor can help identify faults more accurately, ensure that the right motor is being used for the job and can result in a more efficient service from a motor repair company if there is a fault.

Many industrial processes require reversing the direction of motors, such as in conveyor systems, pumps, and other machinery where the direction of movement needs to be changed. In some cases, reversing the motor's rotation can be crucial for safety, for example, to prevent machinery from running in a dangerous direction. Certain applications, like those involving materials handling or processing, may require the motor to switch direction at different stages of the process.

**II Industry/Employer Expected Outcome(s)**

Diagnose and rectify three phase squirrel cage and slip ring induction motor related problems in industry.

**III Course Level Learning Outcome(s)**

CO1 - Test the performance of three phase induction motor.

**IV Laboratory Learning Outcome(s)**

LLO 1.1 Identify the different parts of a three phase squirrel cage and slip ring induction motor.

LLO 1.2 Reverse the direction of rotation of a three phase induction motors.

LLO 1.3 Interpret the nameplate of three phase induction motor.

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background**

**LLO1: Parts of a three phase squirrel cage and slip ring induction motor.**

A typical electric motor's structure includes a stator and a rotor. The stator typically consists of a frame, core, and windings, while the rotor is the rotating part, often containing magnets or windings. Other components like bearings, brushes, and a Commutator may also be present, depending on the motor type.

In an electric motor, the stator is the stationary part that generates a magnetic field.

The stator of three phase induction motor is made up of numbers of slots to construct a 3-phase winding circuit which we connect with 3 phase AC source. The three-phase winding in is arranged in such a manner in the slots that they produce one rotating magnetic field when we switch on the three-phase AC supply source.

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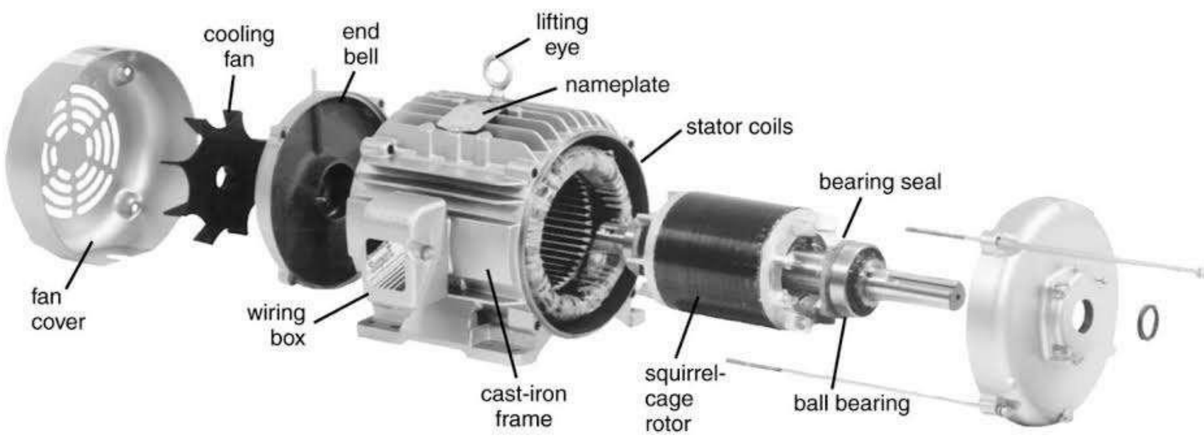


**Figure 1.1**

The rotor is the rotating part that interacts with the magnetic field to create motion. Essentially, the stator provides the force, and the rotor responds by moving. It's typically constructed as a cylindrical laminated core with slots, where conductors are placed. These conductors can be either bars (squirrel cage rotor) or insulated windings (Slip Ring/wound rotor).

**A squirrel cage rotor** consists of a laminated cylindrical core. The circular slots at the outer periphery are semi-closed. Each slot contains uninsulated bar conductor of aluminium or copper. At the end of the rotor the conductors the short-circuited by a heavy ring of copper or aluminium. The rotor slots are often skewed, which helps reduce noise and improve torque characteristics.

**The Phase wound rotor** is also called as Slip Ring Rotor. It consists of a cylindrical core which is laminated. The outer periphery of the rotor has a semi-closed slot which carries a 3 phase insulated windings. The rotor windings are connected in star. The slip rings are mounted on the shaft with brushes resting on them. The brushes are connected to the variable resistor. The function of the slip rings and the brushes is to provide a means of connecting external resistors in the rotor circuit. The resistor enables the variation of each rotor phase resistance to serve the following purposes given below.

• It increases the starting torque and decreases the starting current.

• It is used to control the speed of the motor.


Figure 1.2

**Reversal of direction of rotation of a three phase induction motors**

The direction of rotation of a 3 phase induction motor can be reversed by interchanging any two of the three motor supply lines. Such that the field rotates counter clockwise rather than clockwise. However, the number of poles and the speed at which the magnetic field rotates remain unchanged.

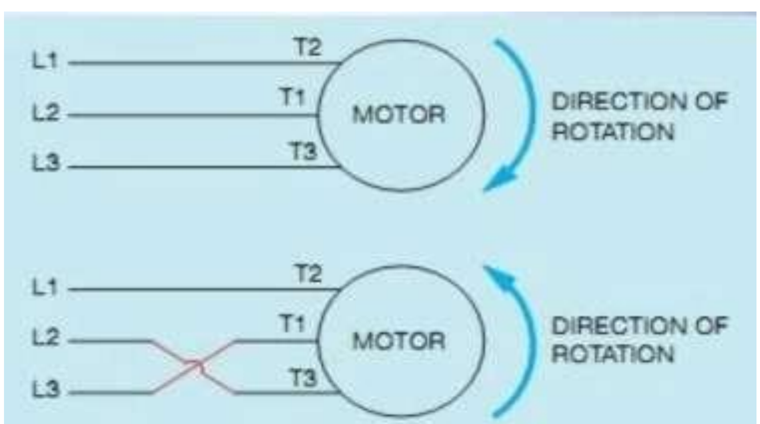


**Figure 1.3**

**Interpretation of the nameplate of three phase induction motor**

The motor nameplate provides information about the motor‟s construction and performance characteristics. Whilst motor standards are established on a country by country basis, most motors fall under the two main industry bodies: The International Electro technical Commission (IEC) and the National Electric Manufacturers Association (NEMA) and their nameplates adhere to the standards set out by the body.

1. Number of Phases
2. Rated Operating Voltage (Volts)
3. Service Duty
4. Efficiency Code
5. Frame Size
6. Degree of Protection
7. Insulation Class
8. Temperature Rise
9. Frequency (Hz)
10. Motor Rated Power
11. Full Load Speed (RPM)
12. Rated Operating Current
13. Power Factor
14. Ambient Temperature
15. Service Factor
16. Altitude
17. Motor Weight
18. Serial Number

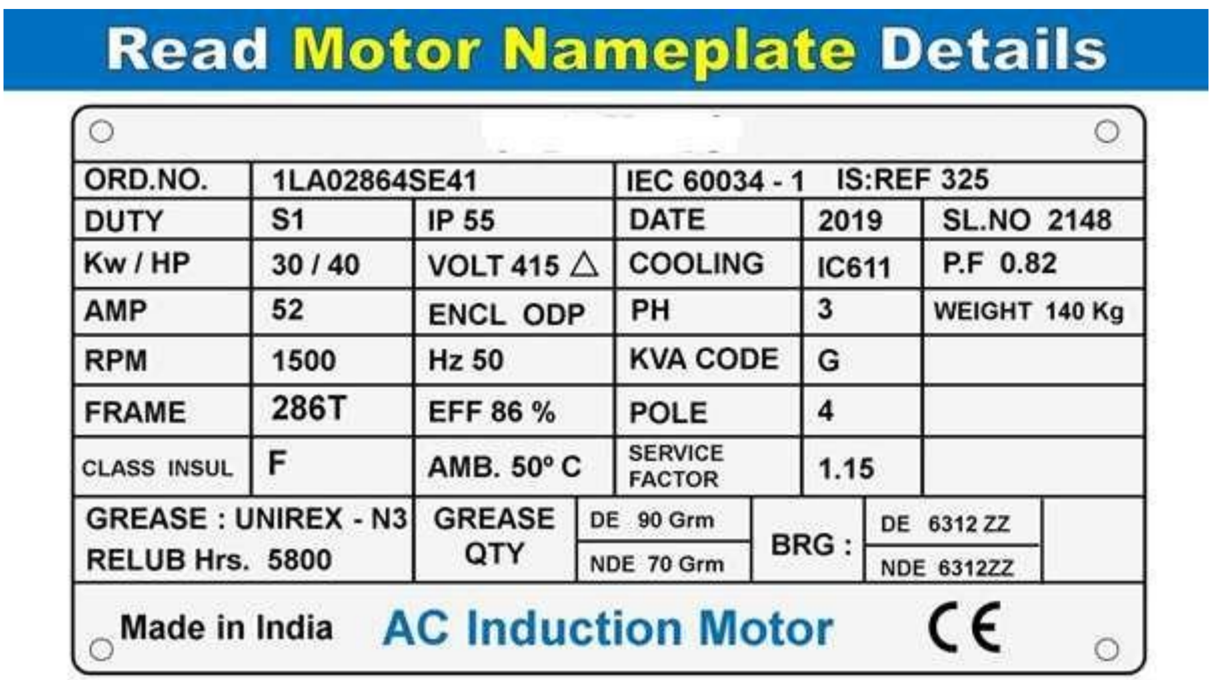


**Figure 1.4**

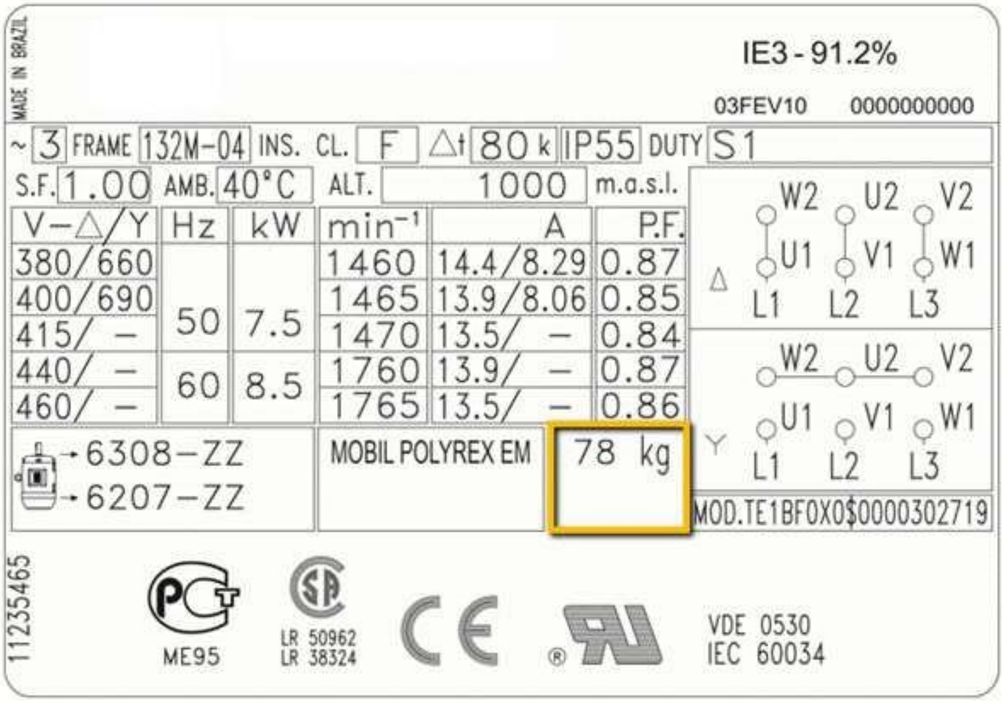


**Figure 1.5**


**Figure 1.6**

**VII Circuit Diagram/ Layout**

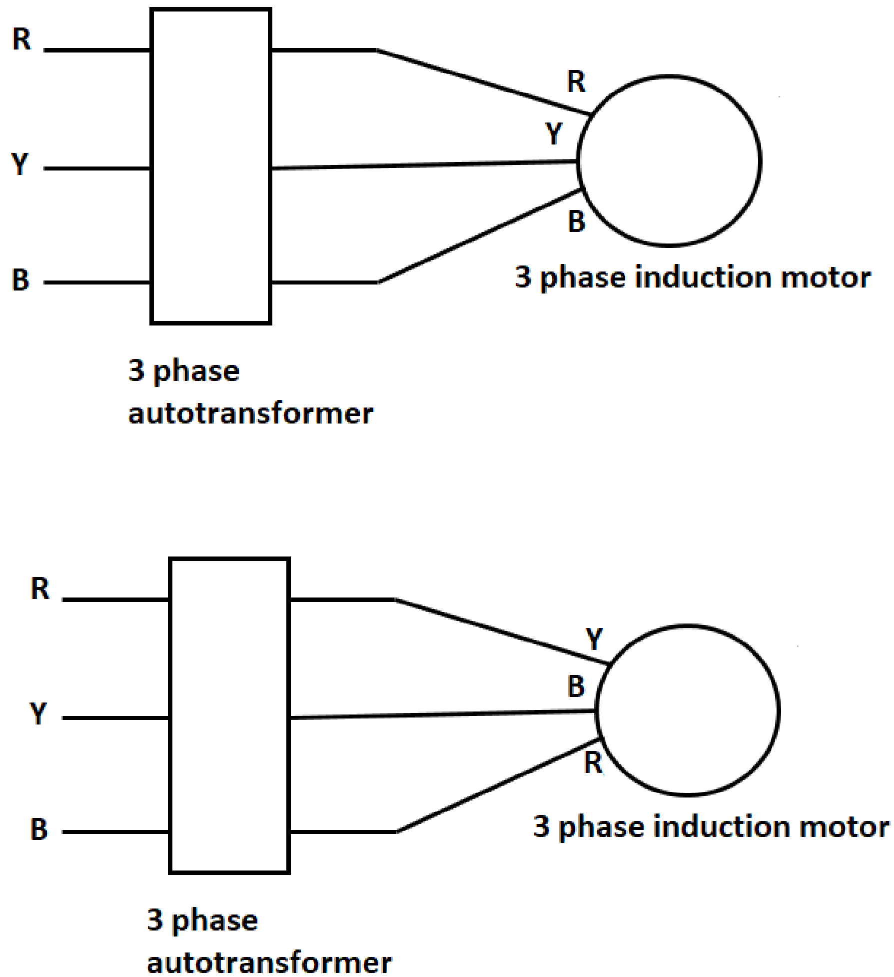


**Figure 1.7 Reversal of Three Phase Induction Motor**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Particulars | Specification | Quantity | Remark |
|---|---|---|---|---|
| 1 | Three phase variac | 5KVA OR Suitable Three phase variac | 1 | |
| 2 | Three phase Induction motor | 3-phase, 3HP,415V OR Suitable Three phase motor | 1 | |
| 3 | Multimeter | NA | 1 | |

**IX Precautions to be followed**

1. Avoid loose connections.
2. Don‟t touch live wire with wet hands.
3. Make sure that autotransformer is at zero Voltage position before switching ON the supply.

**X Procedure**

**LLO 2: Reversal of direction of rotation of a three phase induction motors.**

1. Connect the circuit as shown in circuit diagram.
2. Set the autotransformer output voltage zero.
3. Switch “On” three phase supply.
4. Gradually increase the voltage with the help of autotransformer just enough to rotate the motor.
5. Note the direction of rotation of motor.
6. Reduce the autotransformer voltage to zero and switch “OFF” the supply.
7. Exchange the connections of motor for R and Y phase “OR” Y and B phase.
8. Repeat Step No.2 to Step No.6.
9. Draw two separate waveforms showing phase sequences.

**XI Observation table**

| Sr. No. | Phase Sequence | Direction of Rotation of Motor |
|---|---|---|
| 1 | | |
| 2 | | |

**XII Result(s)**

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**XIII Interpretation of results**

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## XIV Conclusion and recommendation

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## XV Practical related questions

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. State the names of types of phase sequence indicator.
2. Describe working principle of rotating type phase sequence indicator.
3. Phase sequence indicator rotates clockwise for phase sequence of RYB. In which direction phase sequence indicator will rotate if phase sequence is i) BRY ii) YRB.

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**XVI References/Suggestions for further reading**

1. https://archive.nptel.ac.in/courses/108/106/108106072/ Operation of Induction Machine and Synchronous Machine
2. https://archive.nptel.ac.in/courses/108/105/108105131/ Construction of Three Phase Induction Motor

**XVII Suggested Assessment Scheme**

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| **Total ( 25 Marks)** | | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 2:** Measurement of slip of a three-phase induction motor by a) using Tachometer b) using galvanometer c) using stroboscope

**I Practical Significance**

Slip measurement is crucial for understanding and optimizing the performance of induction motors and for ensuring the accuracy of precision measurements.

Tachometers are typically used in motors and other machines and are widely found in the automotive and aviation industries. It measures the rate of rotation on a gasoline engine, electric motor, disk drive, or other spinning mechanism.

When connected in series with the rotor circuit, the galvanometer's needle will oscillate at the slip frequency.

The stroboscopic method is a non-contact technique used to measure the slip of a three-phase induction motor by observing the apparent motion of a mark on the rotor shaft under a flashing light source.

**II Industry/Employer Expected Outcome(s)**

Test the performance of different AC machines in industries.

**III Course Level Learning Outcome(s)**

CO 1 - Test the performance of three phase induction motor.

**IV Laboratory Learning Outcome(s)**

LLO 2.1 Measure slip of a three phase induction motor using tachometer.

LLO 2.2 Measure slip of a three phase induction motor using galvanometer.

LLO 2.3 Measure slip of a three-phase induction motor using stroboscope.

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background**

**Tachometer:**

**Contact Type Analog Tachometer**

**Contact & Non-Contact Digital Tachometer**

As in a motor or other machine, a Tachometer is an instrument that measures the rotational speed of a shaft or disk. Revolutions per minute (RPM) are typically displayed on a calibrated analogue dial, but digital displays are becoming more common.

Analog tachometers are intuitive and straightforward, perfect for users who prefer simplicity. Digital tachometers, on the other hand, are designed for convenience but might overwhelm less tech-savvy individuals.

Digital Tachometers typically use optical encoders or magnetic sensors to detect motion, converting mechanical movement into RPM readings. Measuring Range: 2.5-99999RPM with 10 Reflective Tapes.

A Tachometer works on the principle of relative motion. The device operates between the shaft of the device and the magnetic field. It works as a generator and produces the voltage as per the velocity of the stick. The device counts the number of rotations that the shaft makes per minute.

**Galvanometer**:

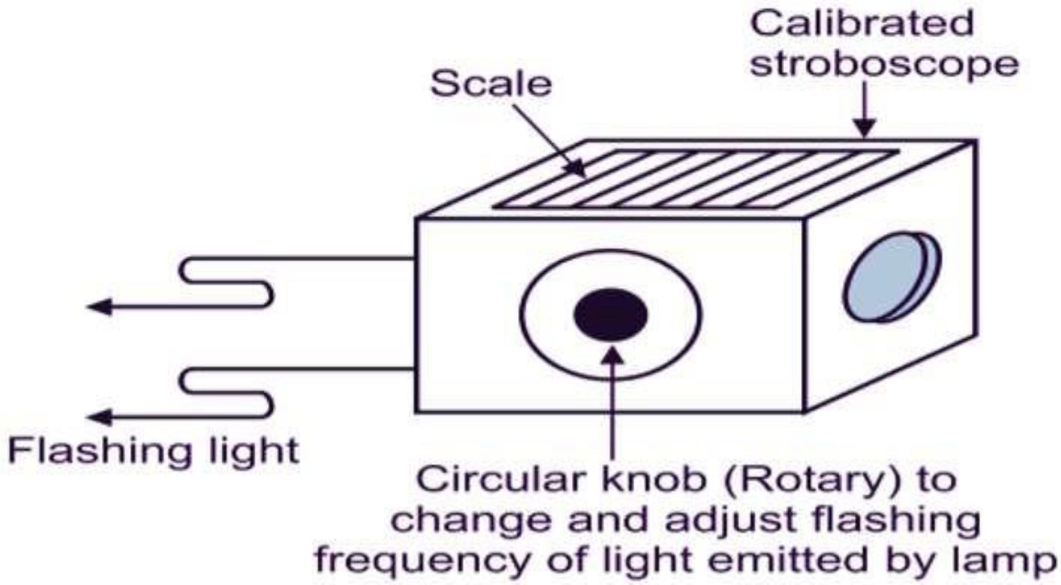
A galvanometer, particularly a centre-zero DC micro ammeter, can be used to detect the low-frequency currents induced in the rotor circuit due to slip.

When connected in series with the rotor circuit, the galvanometer's needle will oscillate at the slip frequency. This frequency is directly related to the slip speed. The slip can then be calculated using the synchronous speed and the rotor speed.

By counting the number of oscillations (cycles) of the galvanometer's needle over a specific time period, you can determine the slip frequency.

**Stroboscope:**

The Stroboscopic Method is a way to measure the slip of a rotating machine like an induction motor. This method involves illuminating the rotating shaft with a flickering light (stroboscope) and observing the apparent motion of a mark on the shaft.




The stroboscope does not require physical contact with the rotating shaft, making it a convenient method. The method relies on visual perception of the apparent motion of the mark, which can be subjective and influenced by lighting conditions. The accuracy of the measurement depends on the precision of the stroboscope's flash frequency adjustment.

## VII. Actual Circuit Diagram used in laboratory with related equipment rating

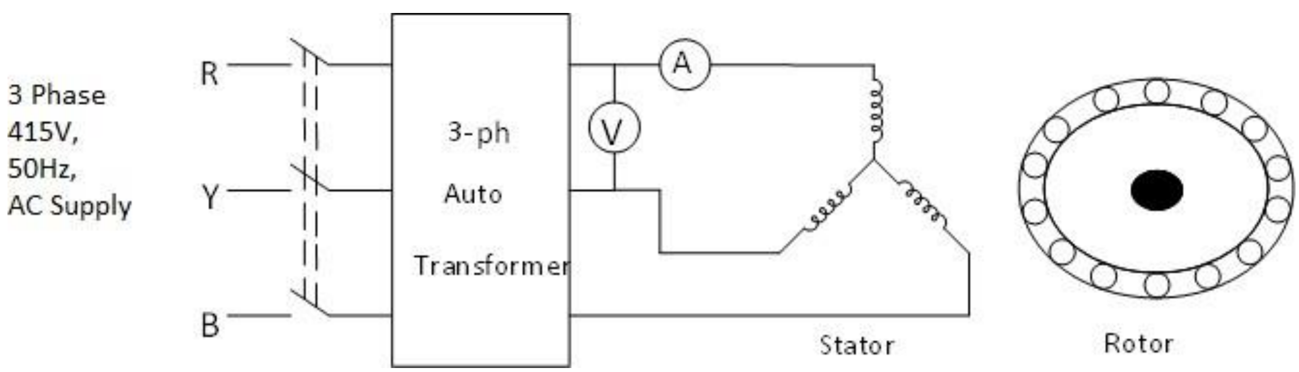
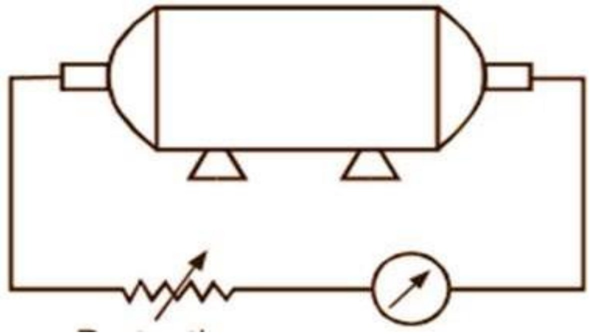



**Figure 2.1: Using Tachometer**



Rheostat Galvanometer

**Figure 2.2: Using Galvanometer**

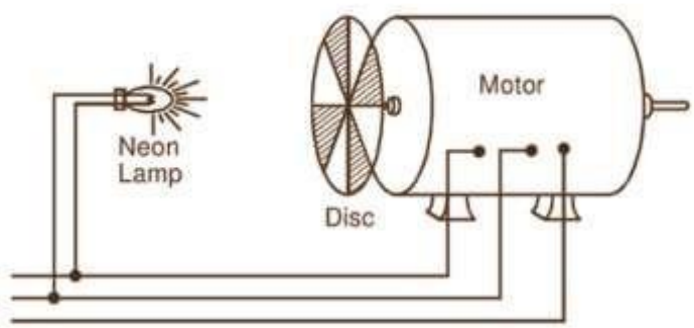



**Figure 2.3: Using Stroboscope**

## VIII Required Resources/apparatus/equipment with specification

| Sr. No. | Instrument/ Object | Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1(A) | Induction motor | 3-phase,3 HP/ 5 HP, 415 V,4.5A, 50 Hz, 1440 RPM, Squirrel cage | 01 | |
| 2. | Suitable Three phase Variac as a Starter | 3-Phase, 5KVA ,415V, 50 Hz Auto transformer | 01 | |
| 5 | Ammeter | MI type :AC/DC,0-5-10Amp OR Suitable Ammeters | 1 | |

| | | | | |
|---|---|---|---|---|
| 6 | Voltmeter | MI Type: AC/DC, ,0-500V OR Suitable Voltmeter | 1 | |
| 7 | Tachometer | Analog/Digital/Non-contact Type | 1 | |
| 8 | Galvanometer | -35mA to +35mA or ±50-0-50μA | 1 | |
| 9 | Stroboscope | 60 to 20,000 rpm. | 1 | |
| 10. | Screw driver | Suitable set | 01 | |
| 11 | Plier | Suitable | 01 | |
| 12. | Multimeter | Digital | 01 | |

## IX Precautions to be followed

1. Avoid loose connections.
2. Don"t touch wire with wet hands.
3. Make sure that autotransformer is at zero Voltage position before switching ON the supply.
4. When using a stroboscope, it's crucial to follow safety guidelines, especially when dealing with high-speed rotating machinery.

## X Procedure

**1) Using Tachometer:**

a) Align the shaft of the tachometer to the shaft of the motor.
b) Insert the shaft of the motor in the small groove of the shaft for the reading in RPM

**2) Using Galvanometer:**

a) Connect the galvanometer in series with the rotor circuit, ensuring it's correctly wired according to the motor's specifications.
b) Observe the oscillations: Start the motor and observe the oscillations of the galvanometer's needle.
c) Count the cycles: Count the number of complete oscillations (cycles) of the needle over a known time interval (e.g., 10 seconds).
d) Calculate slip frequency: Divide the number of cycles by the time interval to get the slip frequency (fs).
e) Calculate slip: Use the formula s = fs / f to calculate the slip, where 'f' is the supply frequency.
f) Calculate percentage slip: Multiply the slip by 100 to express it as a percentage.

**3) Using Stroboscope:**

a) Mark the Rotor: A contrasting mark (like a piece of chalk or a sticker) to be placed on the rotor shaft. A stroboscope, which emits brief, controlled flashes of light, is positioned to illuminate the rotating shaft.
b) The frequency of the stroboscope's flashes is adjusted until the marked spot on the rotor appears stationary.
c) When the spot appears stationary, the stroboscope's flash frequency is equal to the rotor's speed.
d) The slip speed is the difference between the synchronous speed (calculated based on the motor's poles and supply frequency) and the rotor speed (as measured by the stroboscope).
e) The slip percentage is then calculated by dividing the slip speed by the synchronous speed and multiplying by 100%.

## XI Observation table

| Type of Measurement | Speed of Motor in RPM | Slip at the measured speed | % Slip |
|---|---|---|---|
| Using Tachometer | | | |
| Using Galvanometer | | | |
| Using Stroboscope | | | |

## XII Result(s)

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## XIII Interpretation of results

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## XIV Conclusion and recommendation

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## XV Practical related questions

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. Define Slip. On which factors the slip of Induction motor depends?
2. Describe how slip is related to speed of Induction Motor
3. Slip increases as speed decreases. True or False?
4. Which is simplest non-contact type method of Slip of Induction motor?

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## XVI References/Suggestions for further reading

1. https://ems-iitr.vlabs.ac.in/exp/speed-control-slip-ring/

Speed Control of Slip Ring Induction Motor (VLAB)

2. https://archive.nptel.ac.in/courses/108/106/108106072/
Operation of Induction Machine and Synchronous Machine
3. https://archive.nptel.ac.in/courses/108/105/108105131/
Construction of Three Phase Induction Motor

## XVII Suggested Assessment Scheme

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| **Total ( 25 Marks)** | | **100 %** |

| Marks Obtained | | | Dated signature of teacher |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

## Practical No. 3: Brake test on three-phase induction motor.

### I Practical Significance

A brake test is a direct method used to evaluate the performance parameters of a three-phase induction motor like speed, input stator current, power factor and efficiency under varying load conditions.

### II Industry/Employer Expected Outcome(s)

Test the performance of different AC machines in industries.

### III Course Level Learning Outcome(s)

CO-1 Test the performance of three phase induction motor.

### IV Laboratory Learning Outcome(s)

LLO 3.1 Perform brake test on a three-phase induction motor.

### V Relevant Affective Domain related outcome(s)

Select, test, operate, and maintain various types of AC machines.

### VI Relevant Theoretical Background

Brake test is suitable for small and medium capacity motors due to non- availability of large loading facility. The performance of the motor is founded by conducting brake test on the motor at different loads. Motor can be tested gradually increasing the load by tightening the tension on the belt. The spring balance readings in kg on slack (S1) and tight (S2) side of the belt are noted and respective readings on input side of the motor such as current, voltage, power are noted. Speed is measured. From the observations the performance characteristics can be plotted. This test is also carried out for measurement of temperature rise of a motor.

**VII Actual Circuit Diagram used in laboratory with related equipment rating**

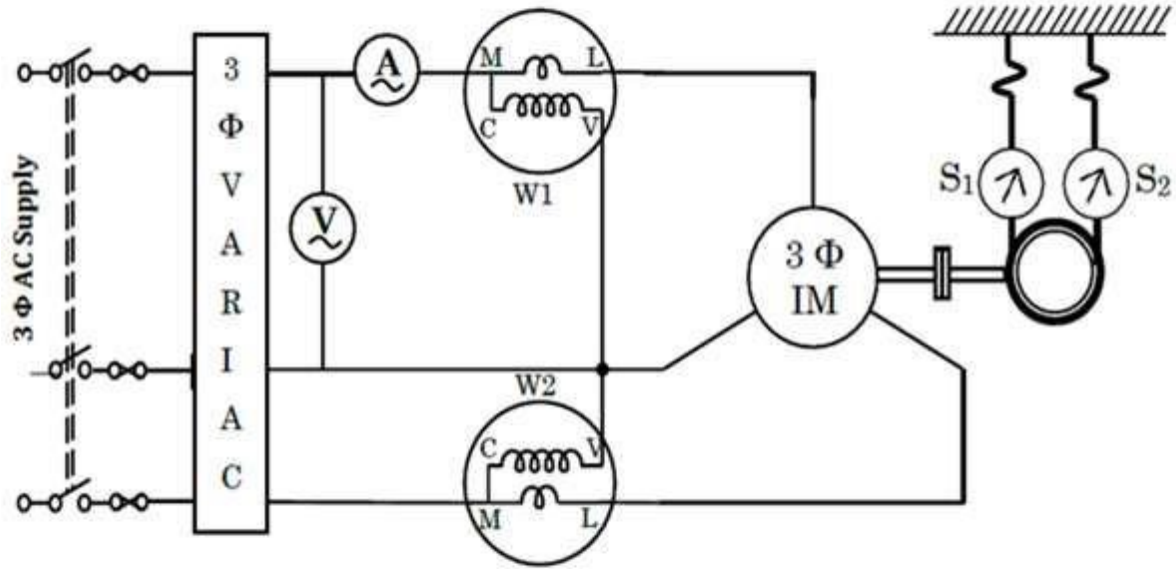


**Figure: 3.1 Brake test on three phase induction motor**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remark |
|---|---|---|---|---|
| 1 | Three Phase Induction Motor 3HP 415 V, 50 Hz, 1440 RPM Squirrel Cage type with Brake and Pulley arrangement | 3HP, 415V, 50Hz, 1440 RPM | 1 No. | |
| 2 | AC Ammeter | 0-10A | | |
| 3 | AC Voltmeter | 0-500V | | |
| 4 | Autotransformer | 3-Phase, 5kVA,<br>0 to 470V | 1 No. | |
| 5 | Multimeter | Suitable rating | 1 No. | |
| 6 | Tachometer | Suitable rating | 1 No. | |

## IX Precautions to be followed

1. Make sure that the main switch on the panel board is in „OFF" position and three phase induction motor is disconnected from the supply.
2. All electrical connections should be neat and tight.
3. There must be no load when starting the motor.

## X Procedure

1. Connections are made as per circuit diagram.
2. Ensure that the 3- ϕ variac is kept at minimum output voltage position and belt is freely suspended.
3. Pour some water inside the brake drum so as to cool the rotor belt.
4. Switch ON the supply. Increase the variac output voltage gradually until rated voltage is observed in voltmeter. Note that the induction motor takes large current initially, so, keep an eye on the ammeter for starting current
5. By the time speed gains rated value, note down the readings of voltmeter, ammeter, and wattmeter at no-load.
6. Now the increase the mechanical load by tightening the belt around the brake drum gradually in steps.
7. Note down the various meters readings at different values of load till the ammeter shows the rated current.
8. Decrease the load step by step and note corresponding speed, load, current, and voltage and wattmeter readings.

## XI Observations and Calculations

| Sr. No. | VL (V) | IL (A) | Input (W) | Load of brake drum in kg | | Speed (N) rpm | Torque (N-m) | Output (W) | % slip | %η | PF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | S1 | S2 | | | | | | |
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**Calculations:**

**Radius of Brake drum R= ________________m**

**Ns = Synchronous speed in rpm______________**

**N= Rotor Speed in rpm______________**

**S1 & S2 = Load of brake drum in kg_____________**

**VL = Line voltage in Volts____________**

**IL = Line current in Amps_____________**

**% slip = [(Ns-N)/Ns]*100=____________%**

**Input Power (W) = (W1+W2) = ___________watts**

**Torque (T) = 9.81*(S1-S2)*R = ______________N-m**

**Output power =** $\frac{2\pi NT}{60}$ **= ____________ watts**

**% efficiency = (output power/input power)*100 = _____________%**

**Power Factor =** $\frac{input\ powwer}{\sqrt{3}*VL*IL}$ **= ______________**

**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. State the relation between torque and supply voltage in three phase induction motor.
2. Efficiency of induction motor increases with increase in load. Justify.
3. Power factor of induction motor is low at no load. Give reasons.
4. Why the starting torque is zero for a Single Phase induction motor and non-zero of 3phase induction motor?
5. What are the disadvantages of this method?

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**XVI References/Suggestions for further reading**

1. Principals of Electrical Machines Rohit Mehta and V. K. Mehta S Chand Publications
2. A Textbook of Electrical Technology Vol II Theraja B. L., Theraja A. K. S. Chand and Co. New Delhi ISBN10:8121924375

**XVII Suggested Assessment Scheme**

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| **Total ( 25 Marks)** | | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 4:** Measurement of iron and copper losses through no-load and blocked rotor test on a three-phase induction motor and calculation of efficiency

## I Practical Significance

The Open Circuit (OC) and Short Circuit (SC) tests on a three-phase induction motor are crucial for determining its equivalent circuit parameters, which are essential for understanding and predicting the motor's performance under various load conditions.

## II Industry/Employer Expected Outcome(s)

Test the performance of different AC machines in industries.

## III Course Level Learning Outcome(s)

CO 1 - Test the performance of three phase induction motor.

## IV Laboratory Learning Outcome(s)

LLO 4.1 Measure iron and copper losses in a three-phase induction motor.

LLO 4.2 Calculate the efficiency of a three-phase induction motor.

## V Relevant Affective Domain related outcome(s)

Follow safety electrical rules for safe practices.

## VI Relevant Theoretical Background

In No load test, motor is allowed to run with no-load at the rated voltage of rated frequency across its terminals. Machine will rotate at almost synchronous speed, which makes slip nearly equal to zero. This causes the equivalent load resistance $R2'\{(1/s)-1\}$ tends to infinity. Hence rotor current is negligible &the rotor equivalent impedance is an open circuit. So the data obtained from this test will give information on no load branch parameters.

In blocked rotor test rotor is blocked to prevent rotation which makes slip equal to unity. This causes the equivalent resistance $R2'\{(1/s)-1\}$ tends to very low value. So the rotor current is much larger than current in the excitation branch of the circuit such that the excitation branch can be neglected. Hence, the data obtained from this test will give information on winding parameters.

**VII Actual Circuit Diagram used in laboratory with related equipment rating**

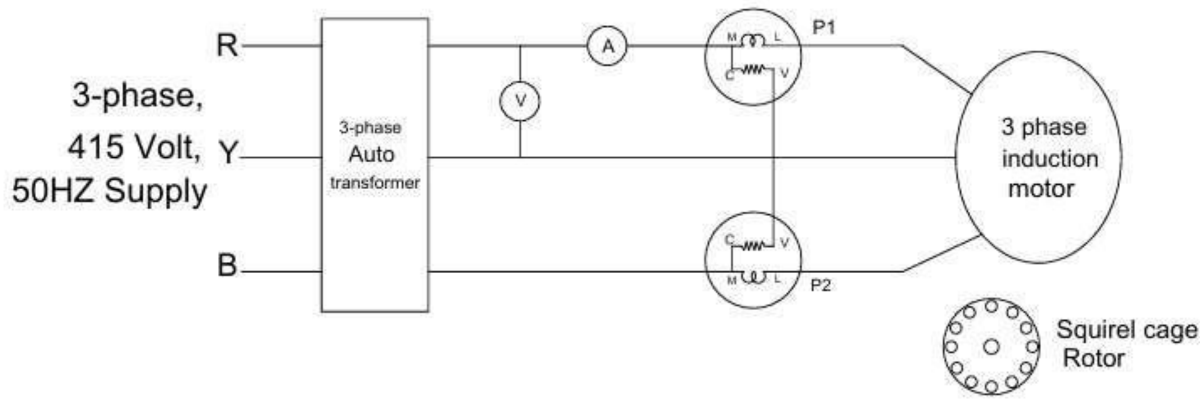


**Figure 4.1 No Load and Blocked Rotor Test on 3 phase Induction Motor**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Instrument/ Object | Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1 | Induction motor | 3-phase,3 HP/ 5 HP, 415 V,4.5A, 50 Hz, 1440 RPM, Squirrel cage | 01 | |
| 2. | Suitable Three phase Variac as a Starter | 3-Phase, 5KVA ,415V, 50 Hz Auto transformer | 01 | |
| 5 | Ammeter | MI type :AC/DC,0-5-10Amp OR Suitable Ammeters | 1 | |
| 6 | Voltmeter | MI Type: AC/DC, ,0-500V OR Suitable Voltmeter | 1 | |
| 7 | Tachometer | Analog/Digital/Non-contact Type | 1 | |
| 8 | Wattmeter | Single Phase, Single Element, 2.5/5A, 200/400V | 2 | |
| 9 | Screw driver | Suitable set | 01 | |
| 10 | Plier | Suitable | 01 | |
| 11 | Multimeter | Digital | 01 | |

## IX Precautions to be followed

1. Avoid loose connections.
2. Don"t touch wire with wet hands.
3. Make sure that autotransformer is at zero Voltage position before switching ON the supply.

## X Procedure

**No load test on 3 phase Induction motor**

1. Select the instruments and meter ranges as per the resources required table.
2. Make the connections as per the circuit diagram shown in Fig.
3. Switch ON the 3 phase supply, start the motor at reduced voltage& then run at rated voltage with the help of Autotransformer.
4. Note down all meter readings.
5. Switch OFF the power supply.

**Blocked Rotor test 3 phase Induction motor**

1) Select meter ranges required for blocked rotor test.
2) Hold rotor by hand/ Brake system
3) Switch ON the 3 phase supply & apply voltage slowly with the help of autotransformer so that rated current flows to motor.
4) Note down all meter readings.
5) Reduce Voltage & Switch OFF the power supply.
6) Using appropriate method measure Stator resistance across the motor terminals determine per phase AC value

## XI Observation table

**No load test:**

| Motor voltage $V_{rated}$ Volts | Motor current $I_o$ Amps | Wattmeter Readings | | Motor no load power $W_o$ watts $W=W_1+W_2$ |
|---|---|---|---|---|
| | | $W_1$ | $W_2$ | |
| | | | | |
| | | | | |
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**Blocked rotor test :**

| Motor current $I_{rated}$ Amps | Motor voltage $V_{sc}$ Volts | Wattmeter Readings | | Motor blocked rotor power Wsc watts $W=W_1+W_2$ |
|---|---|---|---|---|
| | | $W_1$ | $W_2$ | |
| | | | | |

**Calculations**

- **Fixed losses =$W_O$= _____W**

- **Full load stator+ rotor cu losses = WSC = ___W**

- **% Full load efficiency =** $\frac{Output*100}{Input}$

$= \frac{Output*100}{Output+Losses}$

$= \frac{Output*100}{Output+Copper\ Losses+Iron\ Losses+Mechanical\ Losses}$

**XII Results:**

**Motor Full Load Efficiency = ______________%**

**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. State the criteria used to select Voltmeter, Ammeter and Wattmeter?
2. State the reason for selecting wires/conductors of different sizes for making connections?
3. Why No Load current of an Induction Motor is 25 to 30% of rated current which is much more compared to transformer?
4. What is the slip of induction motor when rotor is blocked?

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## XVI References/Suggestions for further reading

1. https://ems-iitr.vlabs.ac.in/exp/speed-control-slip-ring/ Speed Control of Slip Ring Induction Motor (VLAB)
2. https://archive.nptel.ac.in/courses/108/106/108106072/ Operation of Induction Machine and Synchronous Machine
3. https://archive.nptel.ac.in/courses/108/105/108105131/ Construction of Three Phase Induction Motor

## XVII Suggested Assessment Scheme

| | Performance Indicators | Weightage |
|---|---|---|
| | **Process Related : 15 Marks** | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| | **Product Related: 10 Marks** | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| | **Total ( 25 Marks)** | **100 %** |

| Marks Obtained | | | Dated signature of teacher |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 5: Starting of three phase induction motor using a) DOL b) Star-Delta, c) Auto-transformer starter**

**I Practical Significance**

Most of the small induction motors are started directly on line, but when very large motors are started that way, the high starting current will produce a severe voltage drop and will affect the operation of other equipment connected to the same line. To limit this starting current surge, large induction motors are started at reduced voltage and then have full supply voltage when they start to accelerate.

**II Industry/Employer Expected Outcome(s)**

Diagnose and rectify three phase squirrel cage and slip ring induction motor related problems in industry.

**III Course Level Learning Outcome(s)**

CO2 - Control the speed of three phase induction motor using appropriate technique(s).

**IV Laboratory Learning Outcome(s)**

LLO 5.1 Start a three phase induction motor using a given starter.

LLO 5.2 Set the current rating of DOL/ star-delta starter.

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background**

The high starting current will produce a severe voltage drop and will affect the operation of other equipment. So it is not desirable to start large motors direct on line (giving full voltage to the stator). Normally with motors beyond 5 HP, starters are provided. For reduction in the starting current, a lower voltage is applied to the stator, especially for the squirrel cage induction motor & full voltage is only applied when the motor picks up speed. Starting methods of Induction motor by reducing voltages are

1. Direct –On– line (DOL) starters are used for less than 10 Kw motors. Motor is started directly at rated voltage. This starter gives overload & no volt protection.

2. Star–Delta starters for large motors. The stator winding is initially connected in a star configuration and later on changed over to a Delta connection, when the motor reaches rated speed.

3. Auto transformer--In starting position supply is connected to stator windings through an auto-transformer which reduces applied voltage to 50, 60, and 70% of normal value depending on tapping used.

## VII Actual Circuit Diagram used in laboratory with related equipment rating

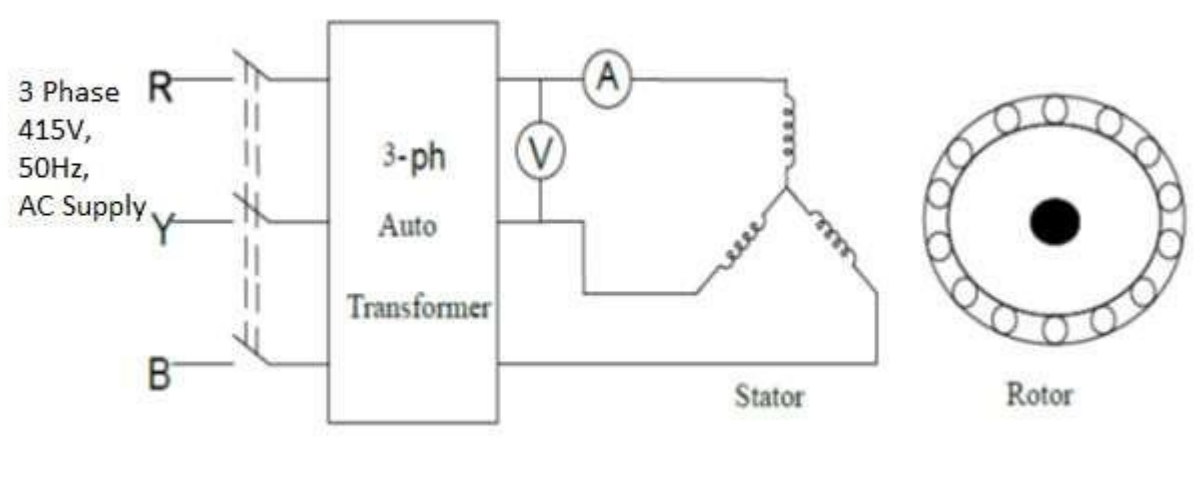


**Figure 5.1: Using Autotransformer Starter**

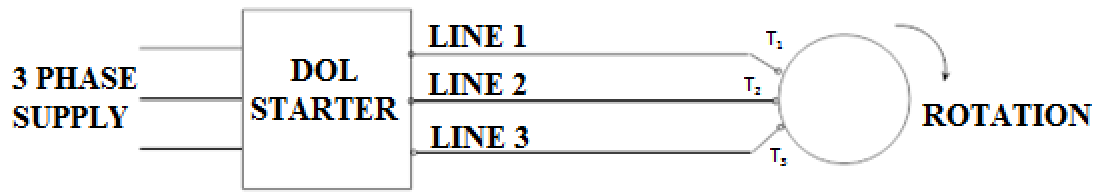


**Figure 5.2: Using DOL Starter**

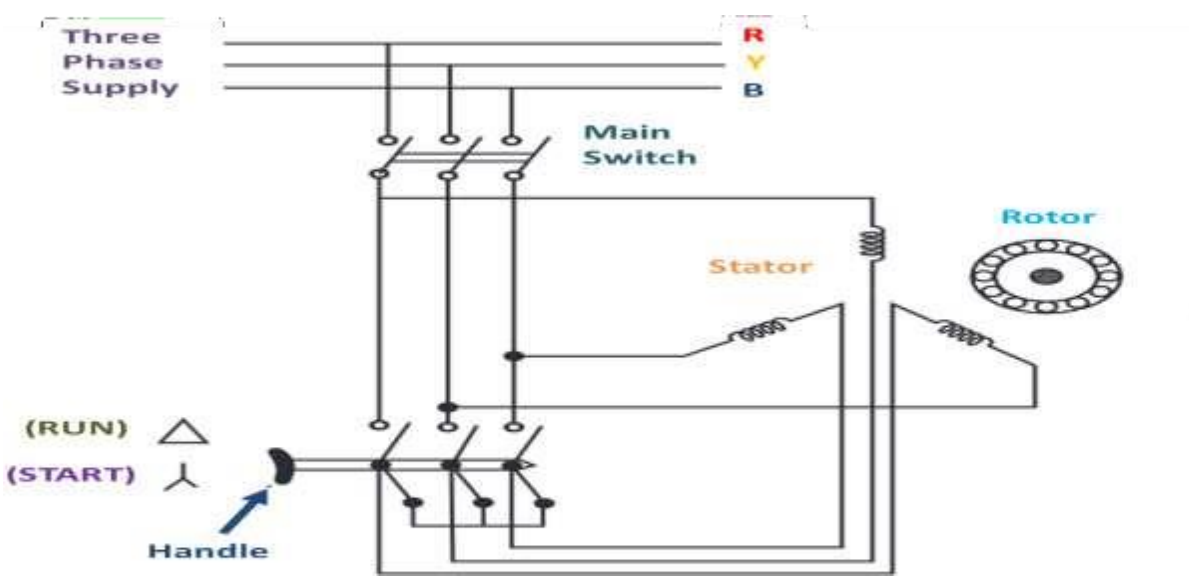


**Figure 5.3: Using Star Delta Starter**

## VIII Required Resources/apparatus/equipment with specification

| Sr. No. | Instrument/ Object | Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1(A) | Induction motor | 3-phase,3 HP/ 5 HP, 415 V,4.5A, 50 Hz, 1440 RPM, Squirrel cage | 01 | |
| 1(B) | Induction motor | 3-phase,3 HP/ 5 HP, 415 V,4.5A, 50 Hz, 1440 RPM, Delta Connected Squirrel cage | 01 | |
| 2 | Starter | DOL | 01 | |
| 3 | Starter | Star –Delta | 01 | |
| 4 | Suitable Three phase Variac as a Starter | 3-Phase, 5KVA ,415V, 50 Hz Auto transformer | 01 | |
| 5 | Ammeter | MI type :AC/DC,0-5-10Amp OR Suitable Ammeters | 1 | |
| 6 | Voltmeter | MI Type: AC/DC, ,0-500V OR Suitable Voltmeter | 1 | |
| 7 | Screw driver | Suitable set | 01 | |
| 8 | Plier | Suitable | 01 | |
| 9 | Multimeter | Digital | 01 | |

## IX Precautions to be followed

1. Avoid loose connections.
2. Don"t touch wire with wet hands.
3. Make sure that autotransformer is at zero Voltage position before switching ON the supply.

## X Procedure

Using Autotransformer:

1. Connect the circuit as shown in circuit diagram.
2. Set the autotransformer output voltage zero.
3. Switch "ON" three phase supply.
4. Set the supply voltage and record the readings of ammeter, voltmeter.

Using DOL Starter:

1. Connect the circuit as shown in circuit diagram.
2. Switch "ON" three phase supply.
3. Record the readings of ammeter, voltmeter.

Using Star Delta Starter:

1. Connect the circuit as shown in circuit diagram.
2. Switch "ON" three phase supply.
3. Record the readings of ammeter, voltmeter instantly.
4. Change the mode of star-delta starter from Star to Delta.
5. Decide the current rating of the starter by observing the readings.

**XI Observation table**

| **Type of Starter** | **Supply Voltage to the stator of induction motor in Volts** | **(Momentary)Maximum Current shoot in Ammeter** | **Value of settled current (At No Load) in Ampere** |
|---|---|---|---|
| Autotransformer Starter | | | |
| DOL Starter | | | |
| Star-Delta Starter | | | |

**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. Draw neat diagram and describe working of DOL starter.
2. Draw neat diagram of Star/Delta starter. State advantage & drawback of it.
3. Draw neat diagram of an Auto transformer starter.
4. Select suitable starter for following motor. Give justification of selection. 2 HP Squirrel Cage Induction motor10 HP delta connected Squirrel cage induction motor 15 HP Squirrel Cage Induction motor 3 HP slip ring Induction motor.
5. State the concept of Soft starter.

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## XVI References/Suggestions for further reading


1. https://ems-iitr.vlabs.ac.in/exp/speed-control-slip-ring/ Speed Control of Slip Ring Induction Motor (VLAB)
2. https://archive.nptel.ac.in/courses/108/106/108106072/ Operation of Induction Machine and Synchronous Machine
3. https://archive.nptel.ac.in/courses/108/105/108105131/ Construction of Three Phase Induction Motor


## XVII Suggested Assessment Scheme

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | **10%** |
| 2 | Identification of components | **20%** |
| 3 | Measuring value using suitable instrument | **20%** |
| 4 | Working in teams | **10%** |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | **10%** |
| 6 | Interpretation of result | **05%** |
| 7 | Conclusions | **05%** |
| 8 | Practical related questions | **15%** |
| 9 | Submitting the journal in time | **05%** |
| **Total ( 25 Marks)** | | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 6: Speed control of a three-phase slip ring induction motor by varying rotor resistance.**

**I Practical Significance**

Slip ring induction motor is widely used in industries since it is easier to obtain its speed control by varying the resistance of rotor resistance starter. Further the rotor resistance starter is used to reduce the starting current, improve the power factor at start and produces higher starting torque.

**II Industry/Employer Expected Outcome(s)**

Diagnose and rectify three phase squirrel cage and slip ring induction motor related problems in industry.

**III Course Level Learning Outcome(s)**

CO2 - Control the speed of three phase induction motor using appropriate technique(s).

**IV Laboratory Learning Outcome(s)**

LLO 6.1 Control the speed of a three phase slip ring induction motor by varying rotor resistance.

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background**

The speed of an induction motor depends upon slip (s), frequency of the stator supply (f) and the number of poles (P) for which the windings are wound. The ability of varying any one of the above three quantities will provide methods of speed control from stator side. The speed of induction motor is changed from rotor side by varying the resistance of the rotor circuit, injecting emf in phase with rotor induced emf.

**VII Actual Circuit Diagram used in laboratory with related equipment rating:**

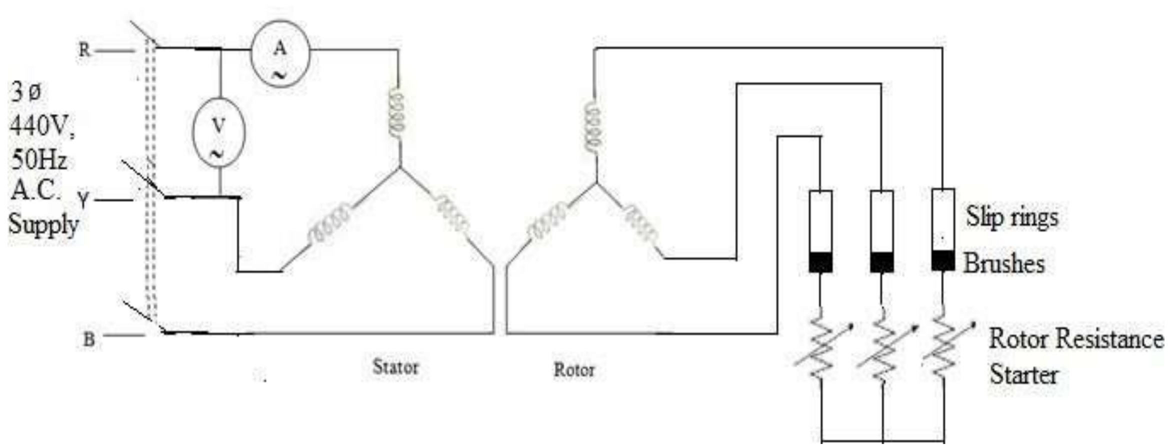


**Figure 6.1**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Instrument/ Object | Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1 | Induction motor | 3-Phase-Slip Ring Induction Motor with rotor Resistance Starter:3 HP/ 5 HP, 415 V, 4.5A, 50 Hz, 1440 RPM, | 01 | |
| 2. | Suitable Three Phase Variac as a Starter | 3-Phase, 5KVA ,415V, 50 Hz Auto transformer | 01 | |
| 3 | Tachometer | 0-3000 Rpm, Digital type | 1 | |
| 5 | Ammeter | MI type :AC/DC,0-5-10Amp OR Suitable Ammeters | 1 | |
| 6 | Voltmeter | MI Type: AC/DC, ,0-500V OR Suitable Voltmeter | 1 | |
| 7 | Screw driver | Suitable set | 01 | |
| 8 | Plier | Suitable | 01 | |
| 9 | Multimeter | Digital multimeter with standard make | 01 | |

**IX Precautions to be followed**

1. Avoid loose connections.
2. Don"t touch wire with wet hands.
3. Make sure that autotransformer is at zero Voltage position before switching ON the supply.

**X Procedure**

1. Connect the circuit as shown in circuit diagram 1.
2. Switch ON the supply and increase the input voltage to stator winding up to its rated value.
3. Measure the speed using tachometer.
4. Now decrease the rotor resistance in steps and note the corresponding values of speed.
5. Draw a graph of rotor resistance versus speed.

**XI Observation table**

Stator supply voltage = Volts

| Sr. No. | External rotor resistance in Ohms Approximate % of external resistance in rotor circuit | Speed (rpm) | Stator current (Amp) |
|---|---|---|---|
| 1 | 100% (full) | | |
| 2 | 75% | | |
| 3 | 50% | | |
| 4 | 25% | | |
| 5 | 0% | | |

**Graph:** Draw a graph taking rotor resistance in % on X – axis and speed in rpm on Y-axis

Scale

X-axis -

Y-axis -

**XII Result(s)**

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**XII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. "The rotor circuit of a slip ring induction motor is kept open and electric supply is given to stator winding" Mention what will happen at rotor side of the motor.
2. List out the different methods of speed control of three phase induction motor based on the principle of changing synchronous speed.
3. Draw and explain the Torque-speed characteristic of a slip ring I.M. for different values of rotor resistance.
4. State the effect of changing the rotor resistance on the slip at max torque SMT?
5. List two methods of speed control of three phase induction motor which can be applied from rotor side.

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**XVI References/Suggestions for further reading**


1. https://archive.nptel.ac.in/courses/108/106/108106072/(Operation of Induction Machine and Synchronous Machine)
2. https://archive.nptel.ac.in/courses/108/102/108102146/(Electromechanical Energy Conversion and Synchronizations of Alternators)
3. https://ems-iitr.vlabs.ac.in/exp/lab-equipment-familiarization


**XVII Suggested Assessment Scheme**

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| **Total ( 25 Marks)** | | **100 %** |

| Marks Obtained | | | Dated signature of teacher |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No.7: Starting and controlling the speed of a three-phase induction motor using variable frequency drive (VFD)**

## I Practical Significance

Three phase induction motor is widely used in many industries. Different methods are used to control the speed of three phase induction motor. VFD provides more benefits as compared to other methods of speed control.

## II Industry/Employer Expected Outcome(s)

Test the performance of different AC machines in industries.

## III Course Level Learning Outcome(s)

CO-2 Control the speed of three phase induction motor using appropriate technique(s).

## IV Laboratory Learning Outcome(s)

LLO 7.1 Control the speed of a three phase slip ring induction motor by varying rotor resistance.

LLO 7.2 Start the three phase induction motor using VFD.

LLO 7.3 Control the speed of three phase induction motor using VFD.

## V Relevant Affective Domain related outcome(s)

Select, test, operate, and maintain various types of AC machines.

## VI Relevant Theoretical Background

A Variable Frequency Drive (VFD) provides precise control of a three-phase induction motor's speed by adjusting the frequency and voltage of the power supply. This is achieved by converting the incoming fixed-frequency AC power to DC, then inverting it back to AC at a variable frequency, and finally applying it to the motor. VFDs provide smooth starts, reduce inrush current, and allow for efficient speed control.

VFD provides smooth starting, smooth speed control and less maintenance cost due to optimum working.

**Speed control of slip ring induction motor:**

The speed of an induction motor depends upon slip (s), frequency of the stator supply (f) and the number of poles (p) for which the windings are wound. The ability of varying any one of the above three quantities will provide methods of speed control from stator side. The speed of induction motor is changed from rotor side by varying the resistance of the rotor circuit, injecting emf in phase with rotor induced emf.

**VII Actual Circuit Diagram used in laboratory with related equipment rating**

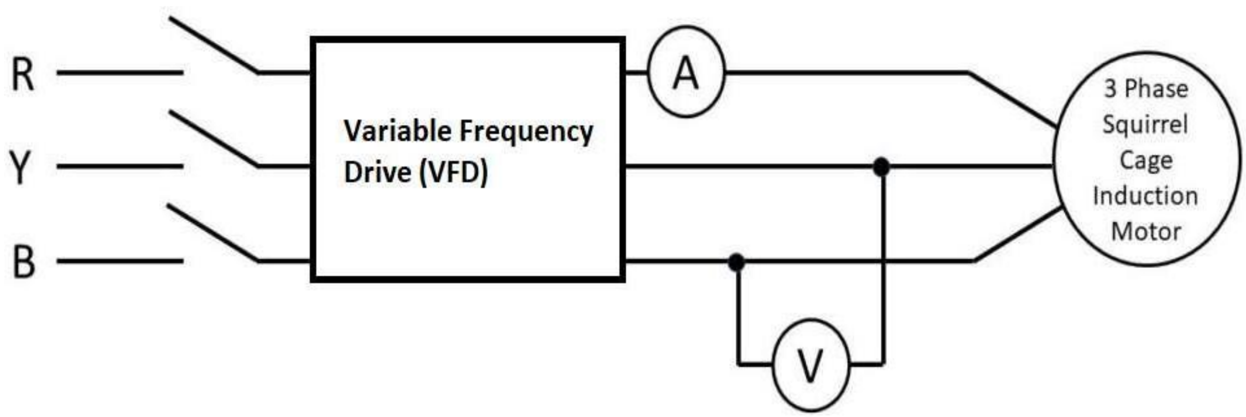


**Figure:7.1 speed control of three phase induction motor by using VFD**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1 | Three Phase Induction Motor 3HP 415 V, 50 Hz, 1440 RPM Slip Ring type | 3HP, 415V, 50Hz, 1440 RPM | 1 No. | |
| 2 | Three Phase Induction Motor 3HP 415 V, 50 Hz, 1440 RPM | 3HP, 415V, 50Hz, 1440 RPM | 1 No. | |
| 3 | AC Ammeter | 0-10A | 1 No. | |
| 4 | AC Voltmeter | 0-500V | 1 No. | |
| 5 | Autotransformer | 3-Phase, 5kVA, 0 to 470V | 1 No. | |
| 6 | Multimeter | Suitable rating | 1 No. | |
| 7 | Tachometer | Suitable rating | 1 No. | |

## IX Precautions to be followed

1. Make sure that the main switch on the panel board is in „OFF" position and Three phase induction motor is disconnected from the supply.
2. Wires used for circuit connection have proper size & insulation cover.
3. All electrical connections should be neat and tight.

## X Procedure

1. Connect the circuit as per the circuit diagram.
2. By using VFD start the motor.
3. Note down the speed of motor for different voltages

## XI Observations

| Sr. No. | Applied Voltage (Volt) | Variable Frequency (Hz) | Speed in RPM |
|---|---|---|---|
| | | | |
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## XII Result(s)

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## XIII Interpretation of results

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**XIV Conclusion and recommendation**

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**XV Practical related questions (Provide space for answers)**

(Teacher should provide various questions related to practical- sample given)

1 List the methods of speed control of 3 phase induction motor.

2 State the advantages of VFD method of speed control.

3 With neat sketch explain the working of VFD.

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**XVI References/Suggestions for further reading**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. Principals of Electrical Machines Rohit Mehta and V. K. Mehta S Chand Publications
2. A Textbook of Electrical Technology Vol II Theraja B. L., Theraja A. K. S. Chand and Co. New Delhi ISBN10:8121924375

**XVII Suggested Assessment Scheme**

| | Performance Indicators | Weightage |
|---|---|---|
| | **Process Related : 15 Marks** | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| | **Product Related: 10 Marks** | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| | **Total ( 25 Marks)** | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 8: Identification of different parts of a single phase induction motor and reversing the direction of rotation of a ceiling fan/ single phase induction motor/ universal motor.**

## I Practical Significance

Single phase induction motors are widely used in various home appliances and industries as drive motors for variety of machines due to its rugged construction, smoother and efficient operation. Reversal of rotation of single phase induction motor and Universal motor plays an important role in electrical and electronic engineering for different medical instrumentation applications.

## II Industry/Employer Expected Outcome(s)

Test the performance of different AC machines in industries.

## III Course Level Learning Outcome(s)

CO-3 Use single phase induction motor for industrial applications.

## IV Laboratory Learning Outcome(s)

LLO 8.1 Identify different parts of a single phase induction motor.

LLO 8.2 Reverse the direction of rotation of a single phase induction motor.

## V Relevant Affective Domain related outcome(s)

Select, test, operate, and maintain various types of AC machines.

## VI Relevant Theoretical Background

Stator of Single phase Induction motor consist of Main winding & starting winding placed at 90° electrically apart to produce rotating magnetic field. For this capacitor is connected in series with starting winding along with centrifugal switch. Starting winding can be disconnected with the help of centrifugal switch. In single phase induction motor main winding is designed for low resistance & starting winding for high resistance. Direction of rotation of single phase induction motor depends upon the instantaneous polarities of main winding flux & starting winding flux. So direction of rotation can be changed by reversing the polarity of either main or starting winding as shown in figure.

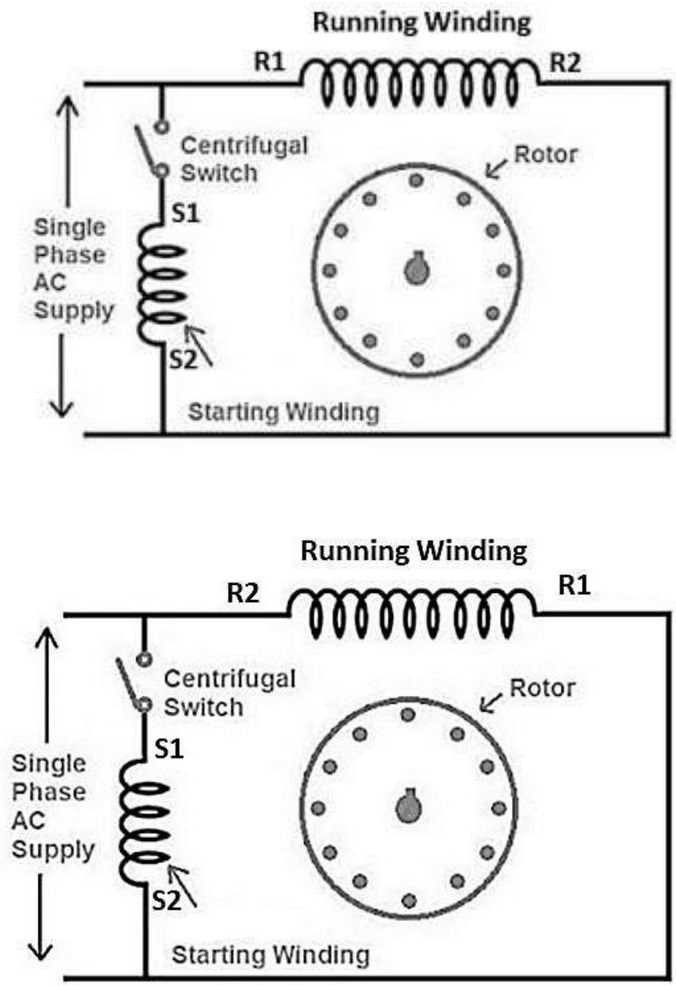
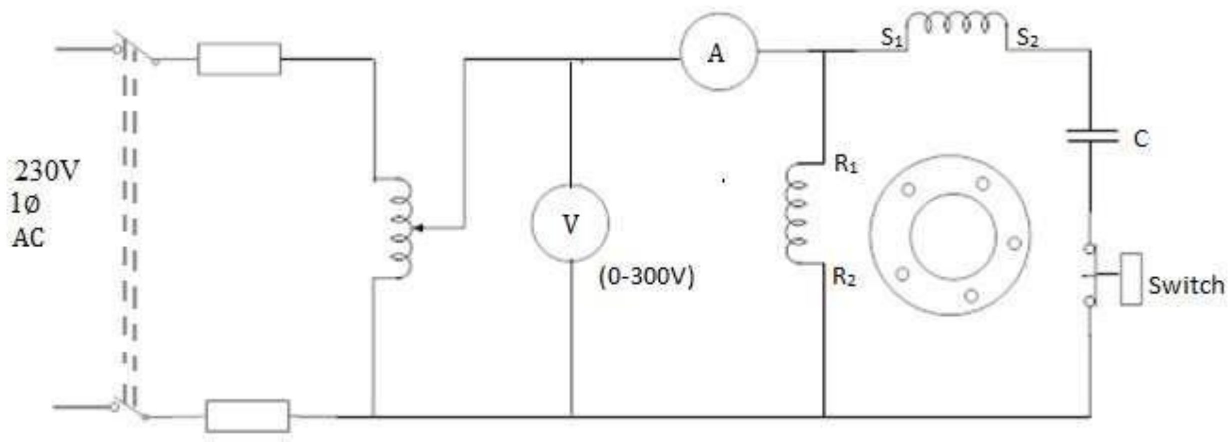

Running Winding
R1
R2
Centrifugal Switch
Rotor
S1
Single Phase AC Supply
S2
Starting Winding
Running Winding
R2
R1
Centrifugal Switch
Rotor
S1
Single Phase AC Supply
S2
Starting Winding

**Figure 8.1**

## VII Actual Circuit Diagram used in laboratory with related equipment rating




## VIII Required Resources/apparatus/equipment with specification

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1 | Single phase induction motor | Suitable rating | 1 No. | |
| 2 | Universal motor | Suitable rating | 1 No. | |
| 3 | Multimeter | Suitable rating | 1 No. | |
| 4 | Single phase autotransformer | Single phase 230V, 5A | 1 No. | |
| 5 | Tachometer | 100 to 10000 RPM | 1 No. | |
| 6 | Ammeter | AC (0-5 Amp) | 1 No. | |
| 7 | Voltmeter | AC (0-230 Volt) | 1 No. | |
| 8 | Screw driver | Suitable set | 1 No. | |
| 9 | Plier | Suitable set | 1 No. | |
| 10 | Spanner | Suitable set | 1 No. | |
| 11 | Wooden mallet | Suitable set | 1 No. | |
| 12 | Hammer | Suitable set | 1 No. | |

## IX Precautions to be followed

1. Make sure that main switch is in OFF position while making connection
2. Wires used for circuit connection have proper size & insulation cover.
3. All electrical connections should be neat and tight.

## X Procedure

**Part-I**

**Identify different parts of a single phase induction motor**

1. Dismantle and identify different parts of single phase Induction motor.
2. Observe the parts and fill the following information.

**Part-II**

**For reversal of single phase induction motor**

1. Select the instruments and meter ranges as per the resources required table.
2. Disconnect the 1 phase capacitor start Induction run motor from supply if it is connected.
3. Open terminal box & discharge capacitor.
4. Separate winding & capacitor terminals.
5. Identify winding terminals by continuity test.
6. Measure resistance of each winding.
7. Note down resistance & identify type of winding.
8. Make the connections as per the circuit diagram shown in Fig.
9. Switch ON the supply & observe the direction of rotation.
10. Switch OFF the supply & interchange connection of starting winding or main winding.
11. Switch ON the supply & observe the direction of rotation.
12. Switch OFF the supply & interchange supply terminals –phase & neutral.
13. Switch ON the supply & observe the direction of rotation.
14. Switch OFF the supply.

## XI Observations and calculations

**Part-I**

**Identify different parts of a single phase induction motor**

| Sr.No. | Parts | Material | Function |
|---|---|---|---|
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**Part-II**

**For reversal of single phase induction motor**

| **Condition** | **Voltmeter reading** | **Ammeter reading** | **Direction of rotation** |
|---|---|---|---|
| Initial condition | | | |
| Reversing main winding | | | |
| Reversing supply terminals | | | |

**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. Differentiate between main winding & starting winding
2. Give classification of 1 phase induction motor.
3. State the type of capacitors used in 1 phase induction motor.
4. State the function of centrifugal switch.
5. Compare resistance split phase & capacitor split phase induction motor.
6. „Main winding resistance is low & starting winding resistance is high. „Give reason.
7. Give applications of of various types of 1 phase induction motor and universal motor.

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## XVI References/Suggestions for further reading


1. Principals of Electrical Machines Rohit Mehta and V. K. Mehta S Chand Publications
2. A Textbook of Electrical Technology Vol II Theraja B. L., Theraja A. K. S. Chand and Co. New Delhi ISBN10:8121924375
3. https://archive.nptel.ac.in/courses/108/105/108105131/
4. https://jimhedges.weebly.com/parts-of-an-induction-motor.html
5. https://www.electrical4u.com/types-of-single-phase-induction-motor/


## XVII Suggested Assessment Scheme

| | Performance Indicators | Weightage |
|---|---|---|
| | **Process Related : 15 Marks** | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| | **Product Related: 10 Marks** | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| | **Total ( 25 Marks)** | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 9: Operation of three phase alternator for variable frequency output by controlling speed of its prime mover**

**I Practical Significance**

The reliability of power system depends on constant frequency of power supply. The frequency of supply can change with changes in the speed of prime mover.

**II Industry/Employer Expected Outcome(s)**

Diagnose, rectify and test the performance of three phase alternator, related problems in power stations or industry.

**III Course Level Learning Outcome(s)**

CO-4 Test the performance of three phase alternator.

**IV Laboratory Learning Outcome(s)**

LLO 9.1 Operate three phase alternator for variable frequency output

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background:**

The output frequency of an alternator is primarily determined by the rotational speed of the rotor and the number of poles in the alternator. To change the frequency, you can adjust either the rotational speed of the rotor (prime mover) or the number of poles. However, varying the frequency significantly can be challenging, especially when connected to a power grid, as it needs to synchronize with other generators.

**VII Actual Circuit Diagram used in laboratory:**

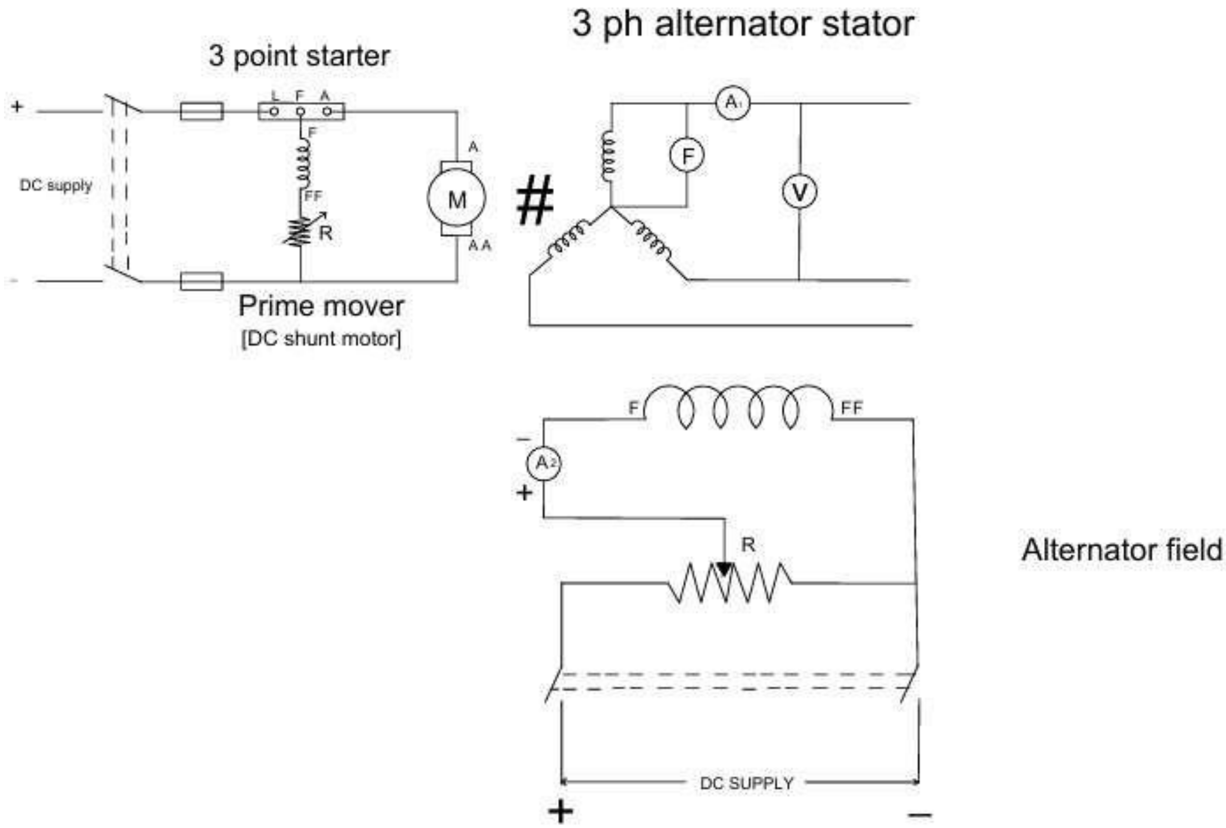


Figure 9.1 Variable frequency output by controlling speed of its prime mover

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remark |
|---|---|---|---|---|
| 1 | Three phase alternator | 7.2 Amp,3KVA, 1500 Rpm with exciter voltage 220 V | 1 | |
| 2. | D.C. Shunt motor | 220 V, 19 Amp, 5 HP, 1500 Rpm | 1 | |
| 3. | Exciter | 220 V, 2.3 Amp, 0.5KW, 1500 Rpm | 1 | |
| 4. | Ammeter | MI type 0-10 Amp | 1 | |

| | | | | |
|---|---|---|---|---|
| 5. | Ammeter | PMMC type,<br>0-20 Amp ,0-2 Amp | 1<br>1 | |
| 6. | Voltmeter | MI type 0-300 V | 1 | |
| 7. | Voltmeter | PMMC type 0-300 V | 1 | |
| 8. | Rheostat | 400 Ohm, 1.7 Amp<br>1000 Ohm, 1.2 Amp | 1<br>2 | |
| 9. | Starter for D.C. motor or any prime mover | 3 point starter | 1 | |
| 10. | Frequency Meter(Analog/Digit) | 40Hz to 60HZ | 1 | |

## IX Precautions to be followed

1. Do not switch on the supply without the connections checked thoroughly by the competent staff.
2. Ensure that the field rheostat in the D.C. motor side is kept at minimum resistance position and the field rheostat in the shut exciter side at maximum resistance position when the supply is switched on.
3. Do not touch/make/alter any connection when the circuit is live.
4. All the load connected to the alternator stator winding should be in off position initially when the circuit is given supply.

## X Procedure

1. Connect the circuit as shown in the circuit diagram with proper wires, meters, and equipment as per the rating of D.C. motor and alternator.
2. Ensure that all the load switches on alternator are in off position.
3. Set the rheostat on the alternator exciter winding at maximum resistance position.
4. Set the rheostat on the D.C. motor field winding at minimum resistance position.
5. Switch ON the supply of D.C. motor and move the starter to zero resistance position smoothly and gradually.
6. Adjust the speed of prime mover to the synchronous speed of alternator using field rheostat of D.C.Motor.
7. Close the switch so that rotor winding of alternator is connected to D.C. shunt exciter.

8. Decrease the resistance of the field rheostat of shunt exciter so that current will start to flow in the field winding of alternator. Adjust the field current so that alternator will build up voltage up to rated terminal voltage.
9. Do not switch on the load of the alternator
10. Keeping the generated voltage of the set constant ,Change the speed of the DC motor( Prime mover) and take the readings .

## XI Observation table

**I. Field current of alternator = _____Amp (constant)**

| Sr. No. | Speed of Prime mover RPM | Terminal Voltage (V) Volts | Frequency HZ |
|---|---|---|---|
| | | | |
| | | | |
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**Graph : Draw a graph showing Speed of the Prime Mover on X – axis and Frequency of generated voltage on Y-axis.**

Scale

X-axis -

Y-axis -

**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions (Provide space for answers)**

1. On which factors the frequency of generated voltage depends in 3-phase generator?
2. List the types of prime movers used in alternator.
3. What are the effects of change in frequency of alternator on power system?
4. Is 60 Hz more powerful than 50Hz?

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## XVI References/Suggestions for further reading


1. https://archive.nptel.ac.in/courses/108/106/108106072/
(Operation of Induction Machine and Synchronous Machine)
2. https://archive.nptel.ac.in/courses/108/102/108102146/
(Electromechanical Energy Conversion and Synchronisation of Alternators)
3. https://ems-iitr.vlabs.ac.in/exp/lab-equipment-familiarizati(on/index.html
Familiarization of the electrical machine laboratory apparatus (VLAB)


## XVII Suggested Assessment Scheme

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | **10%** |
| 2 | Identification of components | **20%** |
| 3 | Measuring value using suitable instrument | **20%** |
| 4 | Working in teams | **10%** |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | **10%** |
| 6 | Interpretation of result | **05%** |
| 7 | Conclusions | **05%** |
| 8 | Practical related questions | **15%** |
| 9 | Submitting the journal in time | **05%** |
| **Total ( 25 Marks)** | | **100 %** |

| Marks Obtained | | | Dated signature of teacher |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No. 10: Direct loading test of a three-phase alternator for determining voltage regulation with resistive, inductive, and capacitive loads**

**I Practical Significance**

Determination of voltage regulation of 3 phase alternator is one of the prime requirements to understand the performance and efficient working of alternators which are widely used in generating stations. Direct loading test gives accurate results of regulation of alternator.

**II Industry/Employer Expected Outcome(s)**

Diagnose, rectify and test the performance of three phase alternator, related problems in power stations or industry.

**III Course Level Learning Outcome(s)**

CO-4 Test the performance of three phase alternator.

**IV Laboratory Learning Outcome(s)**

LLO 10.1 Perform a direct loading test on a three phase alternator to determine voltage regulation under various loads.

LLO 10.2 Calculate up and down regulation of three phase alternator.

**V Relevant Affective Domain related outcome(s)**

Follow safety electrical rules for safe practices.

**VI Relevant Theoretical Background**

1. Voltage regulation of an alternator is defined as “The rise in voltage when full load is removed (with field excitation and speed remaining the same) divided by the rated terminal voltage”.
2. % voltage regulation „UP‟ = $\frac{E_o - V}{V} \times 100$
3. % regulation „Down‟ = $\frac{E_o - V}{E_o} \times 100$

- Eo is no load induced emf of alternator
- V is rated terminal voltage of alternator

"Regulation UP" (positive regulation) means the voltage increases when the load decreases (like removing a load), while "Regulation DOWN" (negative regulation) means the voltage decreases when the load increases (like adding a load).

**VII Actual Circuit Diagram used in laboratory with related equipment rating:**

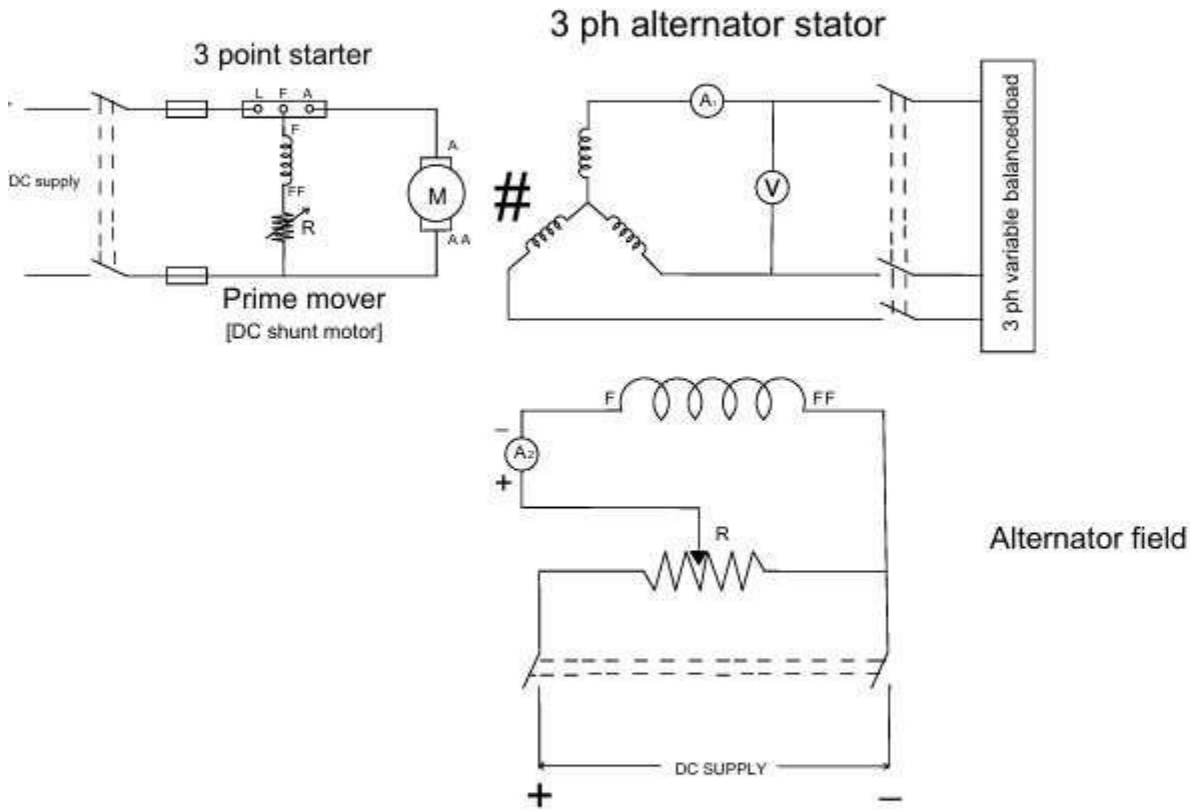



Figure 10.1 Direct Loading Test of a 3-ph Alternator

## VIII Required Resources/apparatus/equipment with specification

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1. | Three phase alternator with shunt exciter | 240 V, 7.2 Amp, 3 KVA, 1500 Rpm with exciter voltage 220 V | 1 | |
| 2. | D.C. Shunt motor coupled with Alternator | 220 V, 19 Amp, 5 HP,<br>1500 Rpm | 1 | |
| 3 | Ammeter | MI type 0-10 Amp | 1 | |
| 4 | Ammeter | PMMC type, 0-20 Amp<br>0-2 Amp | 1<br>1 | |
| 5 | Voltmeter | MI type 0-300 V | 1 | |
| 6 | Voltmeter | PMMC type 0-300 V | 1 | |
| 7 | Rheostat | 400 Ohm, 1.7 Amp<br>1000 Ohm, 1.2 Amp | 1<br>2 | |
| 8 | Starter for D.C. motor or any prime mover | 3 point starter | 1 | |
| 9 | 3 phase balanced resistive load | 230 V | 1 | |
| 10 | 3 phase balanced inductive load | 230 V | 1 | |
| 11 | 3 phase balanced capacitive load | 230 V | 1 | |

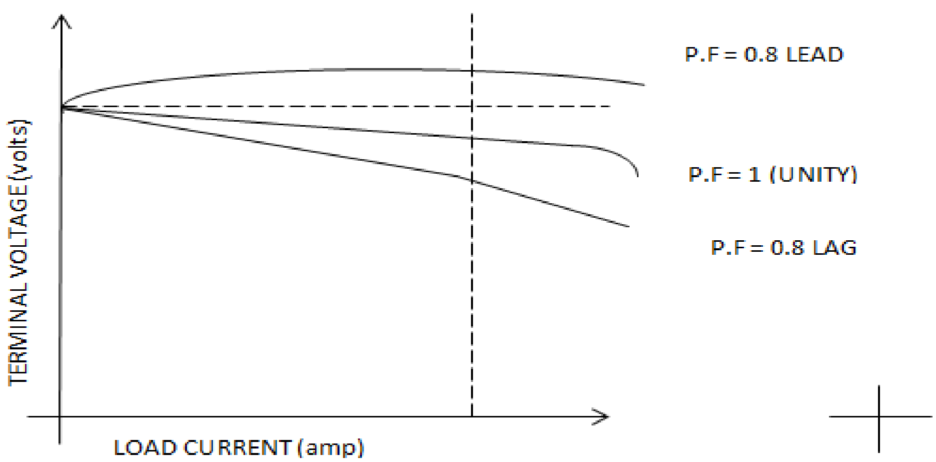
## IX Precautions to be followed

1. Do not switch on the supply without the connections checked thoroughly by the competent staff.
2. Ensure that the field rheostat in the D.C. motor side is kept at minimum resistance position and the field rheostat in the shut exciter side at maximum resistance position when the supply is switched on.
3. Do not touch/make/alter any connection when the circuit is live.
4. All the load connected to the alternator stator winding should be in off position initially when the circuit is given supply.

**X Procedure**

1. Connect the circuit as shown in the circuit diagram with proper wires, meters, and equipment as per the rating of D.C. motor and alternator.
2. Ensure that all the load switches on alternator are in off position.
3. Set the rheostat on the alternator exciter winding at maximum resistance position.
4. Set the rheostat on the D.C. motor field winding at minimum resistance position.
5. Switch ON the supply of D.C. motor and move the starter to zero resistance position smoothly and gradually.
6. Adjust the speed of prime mover to the synchronous speed of alternator using field rheostat of D.CMotor.
7. Close the switch so that rotor winding of alternator is connected to D.C. shunt exciter.
8. Decrease the resistance of the field rheostat of shunt exciter so that current will start to flow in the field winding of alternator. Adjust the field current so that alternator will build up voltage up to rated terminal voltage.
9. Start to switch on the load of the alternator in steps so that the load current increases up to rated load current keeping the speed of the set constant for each loading and note down load current and terminal voltage readings at each load conditions in the observation table.
10. Switch "OFF" complete load keeping the speed and field current constant. Note down alternator terminal voltage at no load.
11. Repeat the steps 3-10 for inductive load and capacitive load.
12. Switch off supply and remove connections.

Plot the graph between terminal voltage V and load current $I_L$ for resistive, inductive and capacitive load on same graph paper.The nature of graph will be as shown in figure.



**XI Observation table**

Synchronous speed of alternator = ________ rpm (constant)

Field current of alternator = ________________Amp (constant)

Rated terminal voltage of alternator = ______Volts

**For Resistive load:**

| Sr. No. | Load Current ($I_L$) | Terminal Voltage (V) | Regulation |
|---|---|---|---|
| | Amperes | Volts | % |
| | | | |
| | | | |
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**For Inductive load:**

| Sr. No. | Load Current ($I_L$) | Terminal Voltage (V) | Regulation |
|---|---|---|---|
| | Amperes | Volts | % |
| | | | |
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**For capacitive load:**

| Sr. No. | Load Current ($I_L$) Amperes | Terminal Voltage (V) Volts | Regulation % |
|---|---|---|---|
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**Calculations** (Sample calculation)

1. For Resistive load (unity PF)
   % voltage regulation „UP" = $\frac{Eo - V}{V}$ x 100 =______%

   %Voltage regulation „Down" = $\frac{Eo - V}{Eo}$ x 100 =______%

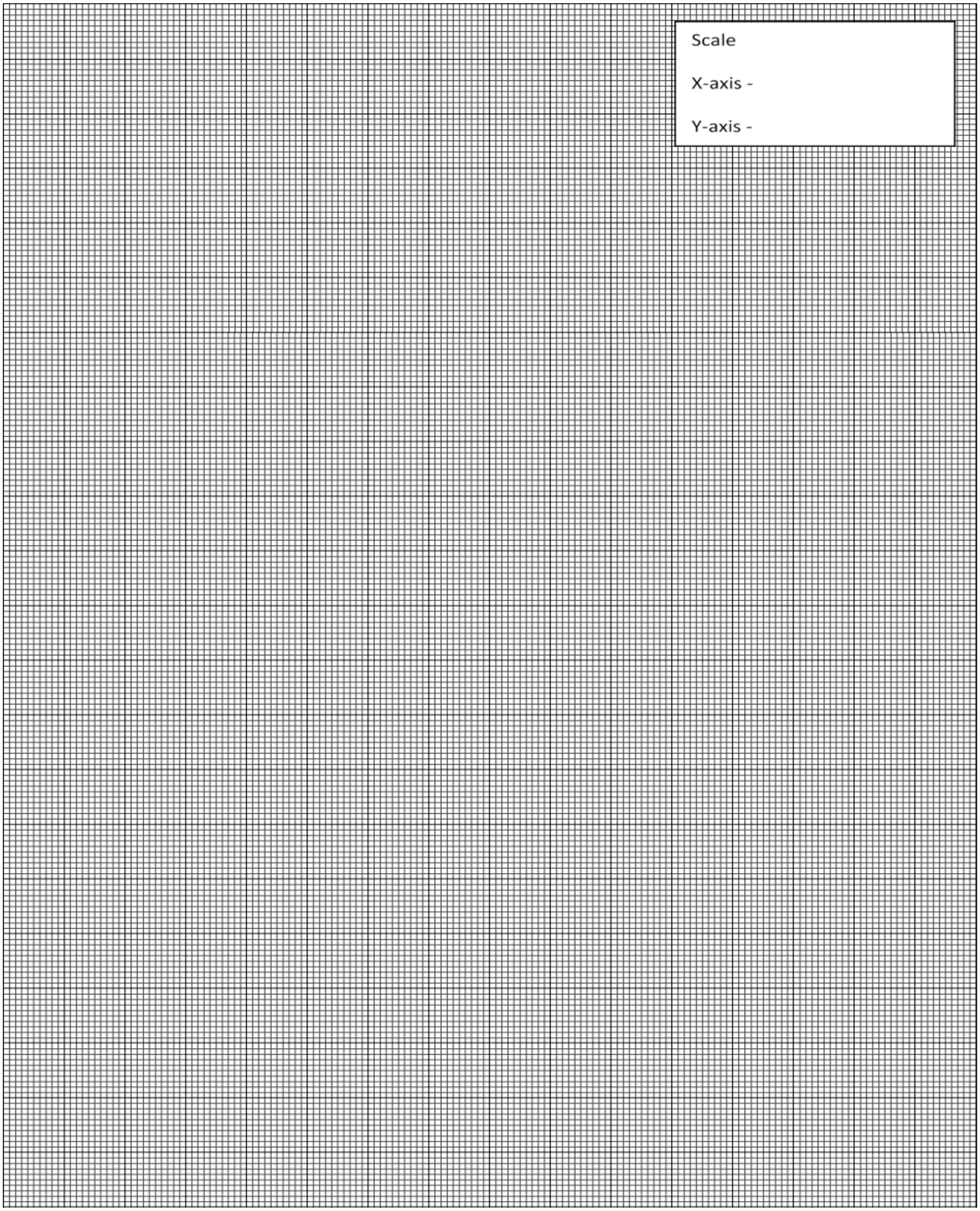
2. For inductive load (lagging Pf) =__________________ 100

   =_________________%

3. For capacitive load (Leading PF) = _________________ 100

   = ____________%

**Graph :** Draw a graph showing load current on X – axis and terminal Voltage on Y-axis at constant speed.



**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. Define voltage regulation.
2. List out the different voltage drops in an alternator.
3. Define the term "armature reaction" in case of an alternator.
4. Describe the effect of armature reaction at unity lagging and leading PF.
5. Draw phasor diagram of a loaded alternator for Resistive, Inductive & capacitive load.
6. „Alternators are designed with high regulation compared with transformer‟.- Justify

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## XVI References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/108/106/108106072/
(Operation of Induction Machine and Synchronous Machine)
2. https://archive.nptel.ac.in/courses/108/102/108102146/
(Electromechanical Energy Conversion and Synchronisation of Alternators)
3. https://ems-iitr.vlabs.ac.in/exp/lab-equipment-familiarizati(on/index.html
Familiarization of the electrical machine laboratory apparatus (VLAB))

## XVII Suggested Assessment Scheme

| | Performance Indicators | Weightage |
|---|---|---|
| | **Process Related : 15 Marks** | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| | **Product Related: 10 Marks** | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| | **Total ( 25 Marks)** | **100 %** |

| Marks Obtained | | | Dated signature of teacher |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

**Practical No.11: Open circuit (OC) and short circuit (SC) test on three phase alternator for determining its efficiency and voltage regulation**.

## I Practical Significance

Determination of voltage regulation of 3 phase alternator is one of the prime requirements to understand the performance and efficient working of alternators which are widely used in generating stations. This is indirect method for calculation of efficiency and regulation. It gives approximate results.

## II Industry/Employer Expected Outcome(s)

Diagnose, rectify and test the performance of three phase alternator, related problems in power stations or industry.

## III Course Level Learning Outcome(s)

CO-4 Test the performance of three phase alternator**.**

## IV Laboratory Learning Outcome(s)

LLO 11.1 Perform open circuit (OC) and short circuit (SC) test on three-phase alternator.

LLO 11.2 Calculate the efficiency of a three-phase alternator.

LLO 11.3 Calculate the up and down regulation of three phase alternator**.**

## V Relevant Affective Domain related outcome(s)

Follow safety electrical rules for safe practices.

## VI Relevant Theoretical Background

Synchronous impedance is predetermination method of calculating regulation of an alternator which gives higher value of regulation than obtained from actual loading. This method is indirect method of finding out regulation. In this method O.C. and SC. Characteristics are plotted by conducting the OC and SC test and synchronous impedance is calculated from it. Measure the value of stator resistance Ra by voltmeter ammeter method. Then Xs can be calculated using the values of Zs and Ra. Then induced EMF of alternator $E_O$ can be calculated for any load current and at any power factor using the values of Xs and Ra. The percentage regulation of alternator can be obtained knowing the value of $E_0$ and rated terminal voltage V. All the above values should be per phase values.

Synchronous Impedance (ZS):

The synchronous impedance is calculated from the OCC and SCC data, considering the alternator's resistance (Ra) and reactance (Xs).

Voltage Regulation Calculation:

The voltage regulation is calculated using a vector diagram, considering the generated EMF, armature current, and synchronous impedance.

**VII Actual Circuit Diagram used in laboratory with related equipment rating:**

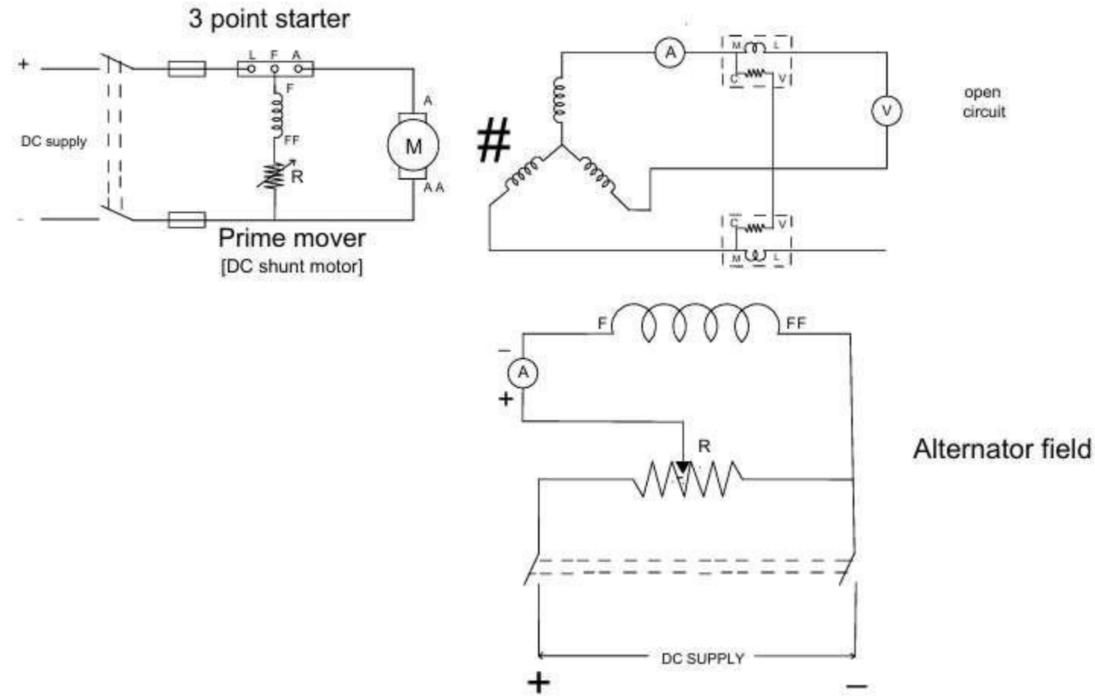


Figure 11.1[A] O.C Test on 3-ph Alternator

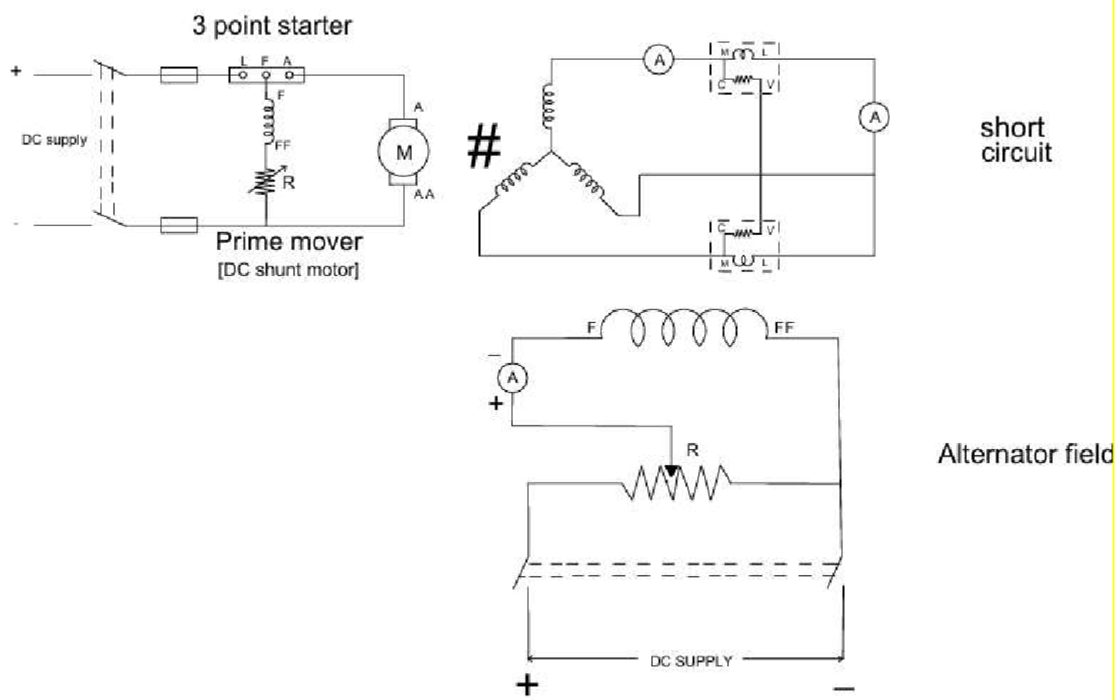


Figure 11.1[B] S.C.Test on 3-ph Alternator

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1. | Three phase alternator with shunt exciter | 240 V , 7.2 Amp, 3 KVA, 1500 Rpm with exciter voltage 220 V | 1 | |
| 2. | D.C. Shunt motor as a Prime mover | 220 V, 19 Amp, 5 HP, 1500 Rpm | 1 | |
| 3. | Exciter | 220 V, 2.3 Amp, 0.5 KW, 1500 Rpm | 1 | |
| 4. | Ammeter | MI type 0-10 Amp | 1 | |
| 5. | Ammeter | PMMC type, 0-20 Amp<br>0-2 Amp | 1<br>1 | |
| 6. | Voltmeter | MI type 0-300 V | 1 | |
| 7. | Voltmeter | PMMC type 0-300 V | 1 | |
| 8. | Rheostat | 400 Ohm, 1.7 Amp<br>1000 Ohm, 1.2 Amp | 1<br>2 | |
| 9. | Starter for D.C. motor | 3 point starter | 1 | |

**IX Precautions to be followed**

1. Do not switch on the supply without the connections checked thoroughly by the competent staff.
2. Ensure that the field rheostat in the D.C. motor side is kept at minimum resistance position and the field rheostat in the shut exciter side at maximum resistance position when the supply is switched on.
3. Do not touch/make/alter any connection when the circuit is live.
4. All the load connected to the alternator stator winding should be in off position initially when the circuit is given supply.

**X Procedure**

**Part-I**

**Open circuit test**

1. Connect the circuit as shown in the circuit diagram (1) with proper wires, meters, and equipment as per the rating of D.C. motor and alternator.
2. Set the rheostat on the alternator exciter winding at maximum resistance position.
3. Set the rheostat on the D.C. motor field winding at minimum resistance position.
4. Switch ON the supply of D.C. motor and move the starter to zero resistance position smoothly and gradually.
5. Adjust the speed of prime mover to the synchronous speed of alternator using field rheostat of D.C.motor.
6. Close the switch so that rotor winding of alternator is connected to D.C. shunt exciter.
7. Decrease the resistance of the field rheostat of shunt exciter so that current will start to flow in the field winding of alternator.
8. Increase the field current of alternator in steps.
9. Adjust the field current so that alternator will build up voltage up to rated terminal voltage and even 10% more than the rated voltage.
10. Take the corresponding meter readings of field current of alternator and induced emf of alternator.
11. Switch off supply and remove connections.

**Part-II**

**Short Circuit Test**

1. Connect the circuit as shown in the circuit diagram (2) with proper cables (wires), meters, equipment as per the rating of D.C. motor and alternator.
2. Ensure that all the load switches on alternator are in off position.
3. Set the rheostat on the alternator exciter winding at maximum resistance position.
4. Set the rheostat on the D.C. motor field winding at minimum resistance position.
5. Switch ON the supply of D.C. motor and move the starter to zero resistance position smoothly and gradually.
6. Adjust the speed of prime mover to the synchronous speed of alternator using field rheostat of D.C.motor.
7. Close the switch so that rotor winding of alternator is connected to D.C. shunt exciter.
8. Decrease the resistance of the field rheostat of shunt exciter so that current will start to flow in the field winding of alternator.
9. Increased the field current of alternator
10. Adjust the field current so that full load current as given in the rating flows in the short circuited stator winding of alternator.

11. Take the corresponding meter readings of field current of alternator and short circuit winding current of alternator.
12. Switch off supply and remove connections.

**Part-III**

**Measurement of alternator stator winding resistance**

1. Connect the circuit as per circuit diagram (3)
2. Switch on the D.C.supply
3. By varying the loading rheostat note down the ammeter reading and volt meter reading.
4. The current can be increased till the rated current of alternator.

## XI Observation table

Synchronous speed of alternator = ____________ rpm (constant)

**Part-I**

**Open circuit test**

| Sr. No. | Field current ($I_f$) | Induced voltage ($V_1$) | Constant Losses= $W_{O=} W_1+W_2$ |
|---|---|---|---|
| | Amperes | Volts | |
| | | | |
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**Part-II**
**Short Circuit Test**

| Sr. No. | Field current ($I_f$ ) | Armature short circuit current ($I_1$) | Copper Losses= $W_{O=}$ $W_1$+$W_2$ |
|---|---|---|---|
| | Amperes | Amperes | |
| | | | |

**Part-III**
**Measurement of alternator stator winding resistance**

| Sr. No. | Voltage | Current | $R_a$ = V/I | $R_a$ (avg) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

**Calculation:**
**Regulation:**

- Synchronous impedance Zs is calculated from OC and SC characteristics at a given field current by the formula
  $Z_s$ (per phase)= $\frac{\text{open circuit voltage per phase (from OCC)}}{\text{Short circuit current per phase (from SCC)}}$
- Alternator stator winding resistance $R_a$ = 1.2 x $R_a$ (dc)
  = ___________ ohms per phase
- Synchronous reactance $X_s$ (per phase) = $\sqrt{Z_s^2 - R_a^2}$ =______________

  Where $R_a$ is the resistance of the stator winding per phase
  $X_s$ (per phase) = _______ ohms per phase
- Full load current $I_a$ of alternator is calculated from the KVA and KV rating of alternator.
  $I_a$ (Rated) = $\frac{\text{Rated KVA x 1000}}{\sqrt{3} \text{ x VL (Rated)}}$ = __________ amp (Line)

$I_a$ (Rated) (phase) = $\frac{I_a \text{ (Rated) (Line)}}{\sqrt{3}}$ = (for delta connected stator winding)

= ________________

- Then % regulation is calculated as given below:

**1. At Unity power factor**

$E_o = \sqrt{(V + I_a R_a)^2 + (I_a X_s)^2}$ = _______________

Where E0 is no load induced EMF per phase of alternator and V is the rated voltage of alternator per phase.

$E_0$ = __________Volts per phase

- Then voltage regulation can be calculated using the following formulae :

% voltage regulation „UP‟ = $\frac{Eo - V}{V} \times 100$

- % regulation „Down‟ = $\frac{Eo - V}{Eo} \times 100$

**2. At 0.8 lagging power factor**

$E_0 = \sqrt{(V \cos Ø + I_a R_a)^2 + (V \sin Ø \ I_a + I_a X_s)^2}$

$E_0$ = __________Volts per phase

- Then voltage regulation can be calculated using the following formulae : % voltage regulation „UP‟ = $\frac{Eo - V}{V} \times 100$

- % regulation „Down‟ = $\frac{Eo - V}{Eo} \times 100$

3. **At 0.8 leading power factor**

$E_0 = \sqrt{(V \cos Ø + I_a R_a)^2 + (V \sin Ø - I_a X_s)^2}$

$E_0$ =___________Volts per phase

- Then voltage regulation can be calculated using the following formulae :
  % voltage regulation „UP‟ = $\frac{Eo - V}{V} \times 100$

- % regulation „Down‟ = $\frac{Eo - V}{Eo} \times 100$

**Efficiency:**

- **% Full load efficiency =** $\frac{Output*100}{Input}$

$= \frac{Output*100}{Output+Losses}$

$= \frac{Output*100}{Output+Copper\ Losses+Iron\ Losses+Mechanical\ Losses}$

**Graph :** Draw a graph showing SC and OC characteristics to calculate $Z_s$.

Scale

X-axis -

Y-axis -

**XII Result(s)**

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**XIII Interpretation of results**

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**XIV Conclusion and recommendation**

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**XV Practical related questions**

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. "Open circuit characteristics of Synchronous motor are nonlinear". Justify.
2. "Synchronous impedance method is called as pessimistic method". Justify.
3. "Regulation is negative in case of leading power factor". Justify.
4. State and explain the accurate method of determining voltage regulation in case of synchronous alternator.
5. Define voltage regulation.

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## XVI References/Suggestions for further reading

1. https://archive.nptel.ac.in/courses/108/106/108106072/
   (Operation of Induction Machine and Synchronous Machine)
2. https://archive.nptel.ac.in/courses/108/102/108102146/
   (Electromechanical Energy Conversion and Synchronizations of Alternators)
3. https://ems-iitr.vlabs.ac.in/exp/lab-equipment-familiarizati(on/index.html
   Familiarization of the electrical machine laboratory apparatus (VLAB))

## XVII Suggested Assessment Scheme

| Performance Indicators | | Weightage |
|---|---|---|
| **Process Related : 15 Marks** | | **60 %** |
| 1 | Handling of the components | 10% |
| 2 | Identification of components | 20% |
| 3 | Measuring value using suitable instrument | 20% |
| 4 | Working in teams | 10% |
| **Product Related: 10 Marks** | | **40%** |
| 5 | Calculated theoretical values of given component | 10% |
| 6 | Interpretation of result | 05% |
| 7 | Conclusions | 05% |
| 8 | Practical related questions | 15% |
| 9 | Submitting the journal in time | 05% |
| **Total ( 25 Marks)** | | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |

## Practical No. 12: Speed control of stepper motor

### I Practical Significance

Stepper motors are DC motors that moves in discrete steps. Stepper motors are widely used in industrial, medical, consumer electronics applications ie. Especially anywhere Precision rotation or Positioning of an object is needed, stepper motors are used along with a microcontroller. Stepper motors are used in control systems for precision motion control applications such as 3D printers, CNC, Robotics etc

### II Industry/Employer Expected Outcome(s)

Test the performance of different AC machines in industries.

### III Course Level Learning Outcome(s)

CO-5 Use special purpose electrical machines for industrial applications

### IV Laboratory Learning Outcome(s)

LLO 12.1 Control the speed of a stepper motor.

### V Relevant Affective Domain related outcome(s)

Select, test, operate, and maintain various types of AC machines.

### VI Relevant Theoretical Background

Stepper motors convert electrical energy into precise mechanical motion. These motors rotate a specific incremental distance per each step. As the name indicates it rotates insteps according to the input Pulses. A stepper motor usually have a number of field coils (Phases) and a toothed rotor. The number of steps executed controls the degree of rotation of the motor‟s. It moves in discrete steps, known as the step angle. Step angle usually ranges from 90 degrees (360°/90° per step = 4 steps per revolution) to 0.75 degrees (360°/0.75° per step = 500 steps per revolution). Their basic construction consists of an outer stator and an inner rotor. Stator has uniform teeth around its perimeter and containing a specified number of poles. Poles are simply magnetic sections of the stator and each pole has a winding that is connected to the pole opposite it on the stator. Thus the opposing poles are magnetized with the opposite polarity when current is applied to the winding

**VII Actual Circuit Diagram used in laboratory with related equipment rating**


**Figure 12.1 Speed control of stepper motor**

**VIII Required Resources/apparatus/equipment with specification**

| Sr. No. | Name of Resource | Suggested Broad Specification | Quantity | Remarks |
|---|---|---|---|---|
| 1 | Experimentation kit of speed control of stepper motor for 1.8 degree step angle | 3HP, 415V, 50Hz, 1440 RPM | 1 No. | |

**IX Precautions to be followed**

1. Make sure that the main switch on the panel board is in „OFF" position.
2. All electrical connections should be neat and tight.

**X Procedure**

Follow the guidelines given with the Experimentation kit of speed control of stepper motor to perform this experiment

## XI Observations

| Sr. No. | Step angle | Steps per revolution |
|---|---|---|
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## XII Result(s)

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## XIII Interpretation of results

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## XIV Conclusion and recommendation

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## XV Practical related questions

*(Note:- Teacher should provide various questions related to practical- sample given)*

1. State different types of stepper motors.
2. State applications of stepper motors
3. Write specifications of 4 different stepper motors available in the market

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**XVI References/Suggestions for further reading**


1. Principals of Electrical Machines Rohit Mehta and V. K. Mehta S Chand Publications
2. A Textbook of Electrical Technology Vol II Theraja B. L., Theraja A. K. S. Chand and Co. New Delhi ISBN10:8121924375


**XVII Suggested Assessment Scheme**

| | Performance Indicators | Weightage |
|---|---|---|
| | **Process Related : 15 Marks** | **60 %** |
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| 9 | Submitting the journal in time | 05% |
| | **Total ( 25 Marks)** | **100 %** |

| **Marks Obtained** | | | **Dated signature of teacher** |
|---|---|---|---|
| **Process Related (15)** | **Product Related (10)** | **Total (25)** | |
| | | | |