Department of Electrical Engineering

Electrical Machine - II Manual

Year: -2nd Yr. /IV SEM

Lab Code: - 4EE4-21

INDEX

POORNIMA COLLEGE OF ENGINEERING, JAIPUR

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION

To be a model of excellence in Professional Education and Research by creating electrical engineers who are prepared for lifelong engagement in the rapidly changing fields and technologies with the ability to work in team.

MISSION

- ✓ To provide a dynamic environment of technical education wherein students learn in collaboration with others to develop knowledge of basic and engineering sciences.
- ✓ To identify and strengthen current thrust areas based upon informed perception of global societal issues in the electrical and allied branches.
- ✓ To develop human potential with intellectual capability who can become a good professional, researcher and lifelong learner.

POORNIMA COLLEGE OF ENGINEERING, JAIPUR
DEPARTMENT OF ELECTRICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEO's)

PEO 1: Graduates will have the ability to formulate, analyze and apply design process using the basic knowledge of engineering and sciences to solve complex electrical engineering problems.

PEO 2: Graduates will exhibit quality of leadership, teamwork, time management, with a commitment towards addressing societal issues of equity, public and environmental safety using modern engineering tools.

PEO 3: Graduates will possess dynamic communication and have successful transition into a broad range of multi-disciplinary career options in industry, government and research as lifelong learner.

PROGRAM OUTCOMES (PO's)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO's)

PSO1: Graduate possesses the ability to apply fundamental knowledge of basic sciences, mathematics and computation to solve the problems in the field of electrical engineering for the benefit of society.

PSO2: Graduate possesses the ability to professionally communicate and ethically solve complex electrical engineering problems using modern engineering tools.

PSO3: Graduate possesses sound fundamental knowledge to be either employable or develop entrepreneurship in the emerging areas of renewable and green energy, electric and hybrid vehicles and smart grids and shall be susceptive to life- long learning.

LAB OUTCOMES

LO1: Apply the principles of Electrical Machines through laboratory experimental work.

LO2: Prepare reports based on performed experiments with effective demonstration of diagrams and characteristics /graph

LO3: Develop the experiments on ac machines on virtual lab

LO4: Demonstrate the starting & speed control of AC motors

LO5: Perform various tests, find efficiency & voltage regulation of electrical machines

MAPPING OF LO WITH PO

LO	Lab outcome	PO											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Student will able to **Apply** the principles of Electrical Machines through laboratory experimental work.	3	-	-	-	-	-	-	-	-	-	-	3
2	Student will able to **Prepare** reports based on performed experiments with effective demonstration of diagrams and characteristics /graph	-	-	-	-	-	-	-	-	3	-	-	3
3	Student will able to **Develop** the experiments on ac machines on virtual lab	-	-	-	-	3	-	-	-	-	-	-	-
4	Student will able to **Demonstrate** the starting & speed control of AC motors	-	-	-	-	-	2	-	-	2	-	-	-
5	Student will able to **Perform** various tests, find efficiency & voltage regulation of electrical machines	-	-	-	-	-	3	-	-	-	-	-	-

MAPPING OF LO WITH PSO

LO	Lab outcome	PSO1	PSO2	PSO3
1	Student will able to **Apply** the principles of Electrical Machines through laboratory experimental work.	3	-	-
2	Student will able to **Prepare** reports based on performed experiments with effective demonstration of diagrams and characteristics /graph	-	2	-
3	Student will able to **Develop** the experiments on ac machines on virtual lab	2	-	-
4	Student will able to **Demonstrate** the starting & speed control of AC motors	2	-	-
5	Student will able to **Perform** various tests, find efficiency & voltage regulation of electrical machines	2	-	-

LAB RULES

DO'S:

- Enter the lab on time and leave at proper time.
- Wait for the previous class to leave before the next class enters.
- Keep the bag outside in the respective racks.
- Utilize lab hours in the corresponding.
- Before switching on the power supply, get it checked by the lecturer/Technical assistant.
- Switch off or silent your mobile before enter the lab.
- Maintaining discipline.
- Proper handling of equipment must be done.

DONT'S:

- Don't abuse the equipment.
- Don't bring any external material in the lab, except your lab record, copy and books.
- Don't bring the mobile phones in the lab. If necessary then keep them in silence mode.
- Please be considerate of those around you, especially in terms of noise level. While labs are a natural place for conversations of all types, kindly keep the volume turned down.
- Do not touch any the any power supply wire or main supply.
- Do not attempt experiment without permission.
- Do not overcrowd on a table.
- Do not manipulate the experiment result.
- Do not leave the lab without permission from the lecture

SAFETY MEASURES

- Specific Safety Rules like Do’s and Don’ts are displayed and instructed for all students.
- First aid box and fire extinguishers are kept in each laboratory.
- Insulation carpet is available in machine lab and Measurement and Instrumentation Lab.
- Well trained technical supporting staff monitor the labs at all times.
- Damaged equipments are identified and serviced at the earliest.
- Periodical calibration of the lab equipments are regularly done
- A clean and organized laboratories are maintained
- The use of cell phones is prohibited.
- Appropriate storage areas are available.
- In order to create more space in the laboratories, a separate section has racks to store the belongings of the students.
- Proper earthing is provided in the labs.

LIST OF EXPERIMENTS

Max. Marks=100

1) To study various types of starters used for 3 phase induction motor.
2) To connect two 3-phase induction motor in cascade and study their speed control.
3) To perform load test on 3-phase induction motor and calculate torque, output power, input power, efficiency, input power factor and slip for various load settings.
4) To perform no load and blocked rotor test on a 3-phase induction motor and determine the parameters of its equivalent circuits.
5) Draw the circle diagram and compute the following (i) Max. Torque (ii) Current (iii) slips (iv) p. f. (v) Efficiency.
6) Speed control of 3- Φ Induction Motor
7) To plot the O.C.C. & S.C.C. of an alternator.
8) To determine Zs , Xd and Xq by slip test, Zero power factor (ZPF)/ Potier reactance method.
9) To determine the voltage regulation of a 3-phase alternator by direct loading.
10) To determine the voltage regulation of a 3-phase alternator by synchronous impedance method.
11) To study effect of variation of field current upon the stator current and power factor of synchronous motor and Plot V-Curve and inverted V-Curve of synchronous motor for different values of loads.
12) To synchronize an alternator across the infinite bus and control load sharing.

EVALUATION SCHEME

Name Of Exam	Conducted By	Experiment Marks	Viva Marks	Total
I Mid Term	PCE	30	10	40
II Mid Term	PCE	30	10	40
End Term	RTU	30	10	40

Name Of Exam	Conducted By	Performance Marks	Attendance Marks	Total
Sessional	PCE	30	10	40

DISTRIBUTION OF LAB RECORD MARKS PER EXPERIMENT

Attendance	Record	Performance	Total
2	3	5	10

LAB PLAN

Total number of experiment: 14

Total number of turns required: 15

NUMBER OF TURNS REQUIRED FOR

Experiment Number	Turns	Scheduled Day
Zero Lab	1	Turn 1
Exp. 1	1	Turn 2
Exp. 2	1	Turn 3
Exp. 3	1	Turn 4
Exp. 4	1	Turn 5
Exp. 5	1	Turn 6
Exp. 6	1	Turn 7
Exp. 7	1	Turn 8
Exp. 8	1	Turn 9
Exp. 9	1	Turn 10
Exp. 10	1	Turn 11
Exp. 11	1	Turn 12
Exp. 12	1	Turn 13
Exp. 13	1	Turn 14
Exp. 14	1	Turn 15

DISTRIBUTION OF LAB HOURS

- Explanation of Experiment & Logic : 20 Minutes
- Performing the Experiment : 40 Minutes
- File Checking : 30 Minutes
- Viva/Quiz : 20 Minutes
- Solving of Queries : 10 Minutes

ROTOR PLAN

ROTOR I

1. To study various types of starters used for 3 phase induction motor.
2. To plot the O.C.C. & S.C.C. of an alternator.
3. To connect two 3-phase induction motor in cascade and study their speed control.
4. To perform load test on 3-phase induction motor and calculate torque, output power, input power, efficiency, input power factor and slip for various load settings.
5. To perform no load and blocked rotor test on a 3-phase induction motor and determine the parameters of its equivalent circuits.
6. Speed control of 3- Φ Induction Motor
7. Determination of losses and efficiency of an alternator.**[BEYOND SYLLABUS]**

ROTOR-2

8. Draw the circle diagram and compute the following (i) Max. Torque (ii) Current (iii) slips (iv) p. f. (v) Efficiency.
9. To determine Zs , Xd and Xq by slip test, Zero power factor (ZPF)/ Potier reactance method.
10. To determine the voltage regulation of a 3-phase alternator by direct loading.
11. To determine the voltage regulation of a 3-phase alternator by synchronous impedance method.
12. To study effect of variation of field current upon the stator current and power factor of synchronous motor and Plot V-Curve and inverted V-Curve of synchronous motor for different values of loads.
13. To synchronize an alternator across the infinite bus and control load sharing.
14. To determine the efficiency of two identical D.C. machine by Hopkinson's regenerative test.**[BEYOND SYLLABUS]**

ZERO LAB

Introduction to subject: -

a). Relevance to Branch:

This branch is related with our everyday of life .This is very useful in determining the electrical parameter of machine. This subject increases and sharpens the thinking power of mind. That is the reason this subject is used in various competitive exams and in job scenario..

b). Relevance to Society:

Machine is use to reduce the effort of human being .Modern Society completely depend on Industry and Industry is depend on machines. With the help of machine lot of production is obtain due to which variety of rating has great improved not only the quality of the products but also contribution to reduction of costs.

c). Relevance to Self:

This lab gives knowledge of machines. This is useful like in further studies. The slab has become interesting with the advent of Electrical machine and all the equipment becoming intelligent. As this subject brushes up the thinking power so we come up to the most optimum utilization of things and subjects. Also it is use to make new projects

d).Pre- Requisites (Connection with previous year): -

1. Electronic Devices Lab (3EE7A)
2. Analog Electronics Lab (4EE7A)
3. Electrical Machine-I Lab (4EE10A)
4. Power Electronics Lab (5EE7A)

In the previous year we had studied basic of electrical, machine equipment used in measurement etc. And next year we study power stability, power system analysis and power system engineering.

EXPERIMENT NO. 1

AIM: To study various types of starters used for 3 phase induction motor.

APPARATUS:

1. 3 phase induction motor
2. Auto transformer
3. Star delta transformer
4. Connecting leads.

BASIC CONCEPT:

"It is the device connected in series with the motor to decrease its starting current and then increase it as the motor starts rotating gradually. It consists of a connector which acts as a switch to control flow of current to the motor and a overload unit which measures the flow of current through the motor and controls the halting of motor in case of large current being drawn". In this Experiment, starting with the need for using starters in IM to reduce the starting current, first two (Star-Delta and Auto-transformer) types of starters used for Squirrel cage IM and then, the starter using additional resistance in rotor circuit, for Wound rotor (Slip-ring) IM, are presented along with the starting current drawn from the input (supply) voltage, and also the starting torque developed using the above starters.

STARTING METHODS:

1. Direct-on-Line (DOL) Starters

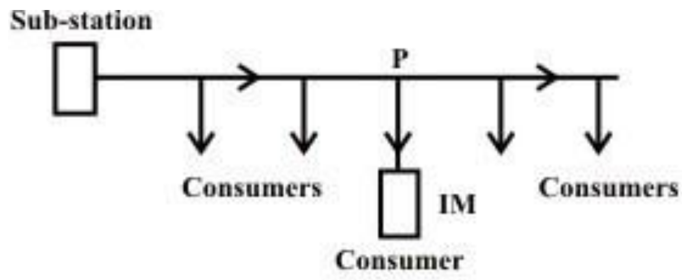
Induction motors can be started Direct-on-Line (DOL), which means that the rated voltage is supplied to the stator, with the rotor terminals short-circuited in a wound rotor (slip-ring) motor. For the cage rotor, the rotor bars are short circuited via two end rings. Neglecting stator impedance, the starting current in the stator windings is

The input voltage per phase to the stator is equal to the induced emf per phase in the stator winding, as the stator impedance is neglected.

In the formula for starting current, no load current is neglected. It may be noted that the starting current is quite high, about 4-6 times the current at full load, may be higher, depending on the rating of IM, as compared to no load current.

The starting torque is ($(T_0$

Need for Starters in IM



(Fig:-The Distribution line fed from substation for supply to various consumers)

The main problem in starting induction motors having large or medium size lies mainly in the requirement of high starting current, when started direct-on-line (DOL). Assume that the distribution line is starting from a substation Fig, where the supply voltage is constant. The line feeds a no. of consumers, of which one consumer has an induction motor with a DOL starter, drawing a high current from the line, which is higher than the current for which this line is designed. This will cause a drop (dip) in the voltage, all along the line, both for the consumers between the substation and this consumer, and those, who are in the line after this consumer. This drop in the voltage is more than the drop permitted, i.e. higher than the limit as per ISS, because the current drawn is more than the current for which the line is designed. Only for the current lower the current for which the line is designed, the drop in voltage is lower the limit. So, the supply authorities set a limit on the rating or size of IM, which can be started DOL. Any motor exceeding the specified rating, is not permitted to be started DOL, for which a starter is to be used to reduce the current drawn at starting.

2. Star-Delta Starter

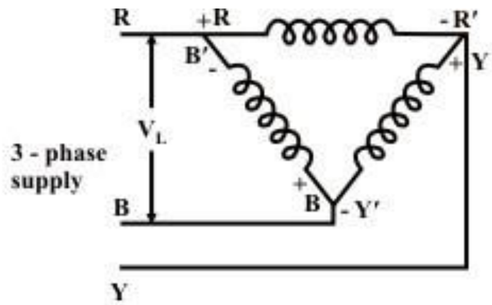


Fig. : Delta-connected stator winding of IM at run

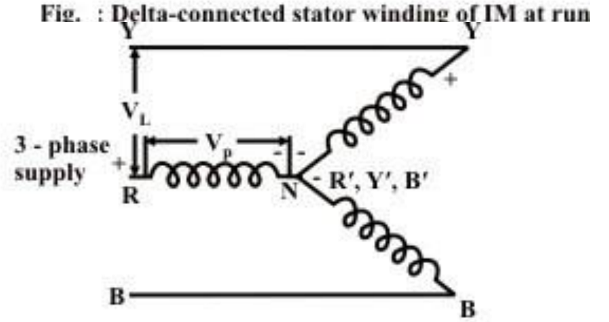


Fig. : same winding of IM, reconnected as star at start.

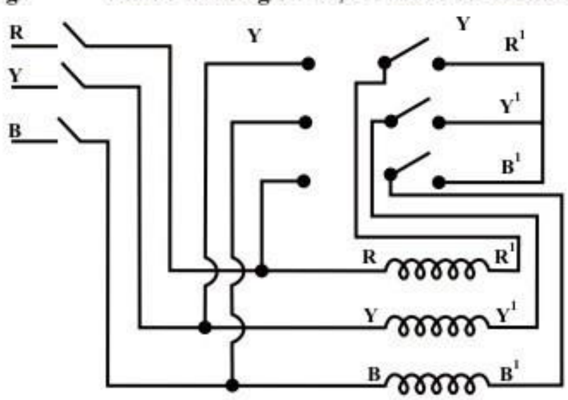


Fig. T.P.D.T. switch used to first start the motor with the windings connected in star and then switch for delta connection in run position(star-delta starter).

Voltages applied to each winding as shown earlier. So, the starting torque is reduced by 33.3%, which is a disadvantage of the use of this starter. The load torque and the loss torque, must be lower than the starting torque, if the motor is to be started using this starter. The advantage is that, no extra component, except that shown in Fig. 33.2c, need be used, thus making it simple. As shown later, this is an auto-transformer starter with the voltage ratio as 57.7%. Alternatively, the starting current in the second case with the stator winding reconnected as star, can be found by using star-delta conversion as given in lesson #18, with the impedance per phase after converting to delta, found as (3 □ Zs), and the starting current now being reduced to (1/ 3) of the starting current obtained using DOL starter, with the stator winding connected in delta.

3. Auto-transformer Starter

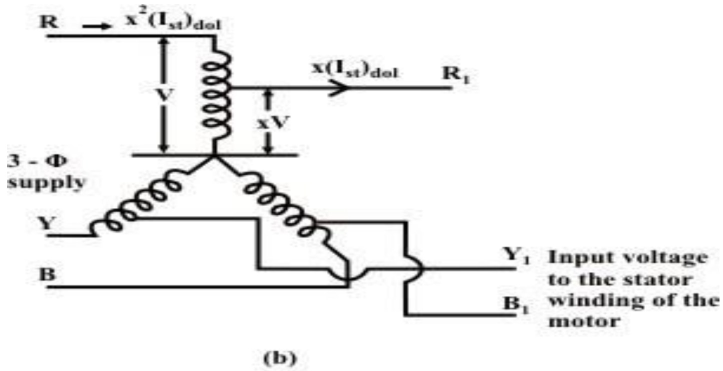
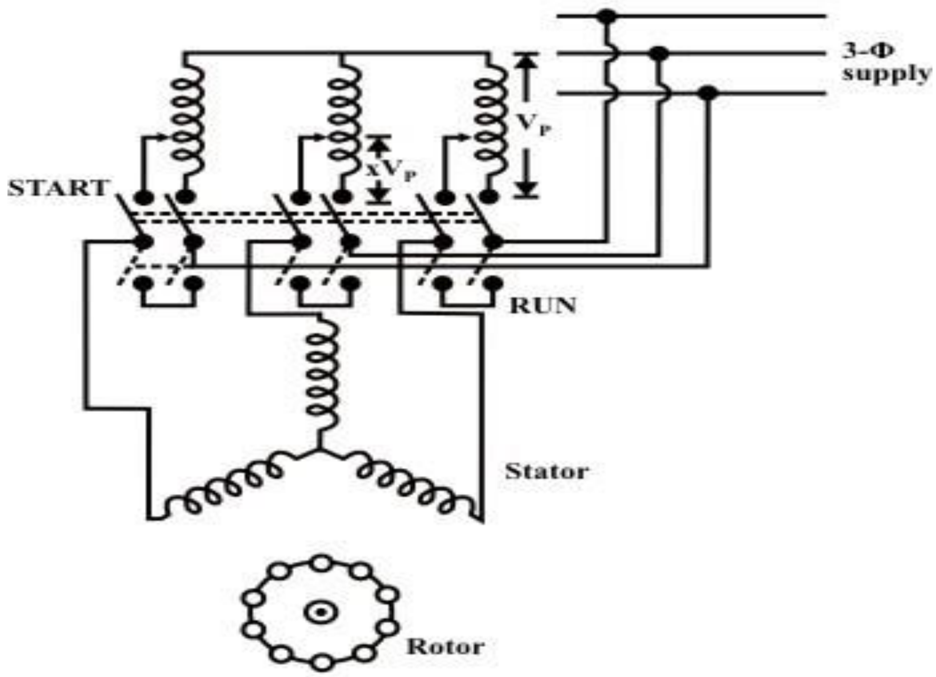


Fig. Auto-transformer starter for IM

Auto-Transformer Starter



(a)

4. Rotor Resistance Starters for Slip-ring (wound rotor) IM

In a slip-ring (wound rotor) induction motor, resistance can be inserted in the rotor circuit via slip rings

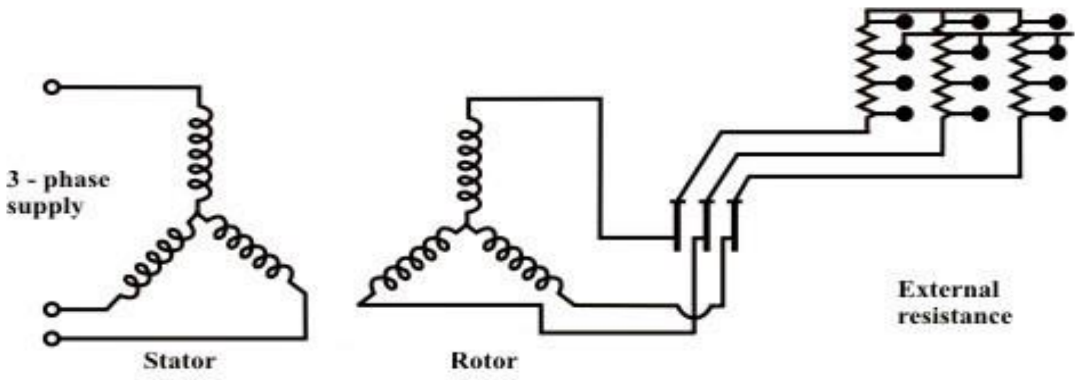


Fig. : Rotor resistance starter for IM

Starting torque, increases, as the total resistance in the rotor circuit is increased. Though the starting current decreases, the total resistance increases, thus resulting in increase of starting torque as shown in Fig., and also obtained by using the expression given earlier, for increasing values of the resistance in the rotor circuit. If the additional resistance is used only for starting, being rated for intermittent duty, the resistance is to be decreased in steps, as the motor speed increases. Finally, the external resistance is to be completely cut out, i.e. to be made equal to zero (0.0), thus leaving the slip-rings short-circuited. Here, also the additional cost of the external resistance with intermittent rating is to be incurred, which results in decrease of starting current, along with increase of starting torque, both being advantageous. Also it may be noted that the cost of a slip-ring induction is higher than that of IM with cage rotor, having same power rating. So, in both cases, additional cost is to be incurred to obtain the above advantages. This is only used in case higher starting torque is needed to start IM with high load torque.

It may be observed from Fig. 32.2b that the starting torque increases till it reaches maximum value, i.e. ($(T_0)_{st} < (T_0)_m$), as the external resistance in the rotor circuit is increased, the range of total resistance being [$r_2 < (r_2 + R_{ext}) < x_2$]. The range of external resistance is between zero (0.0) and ($x_2 - r_2$). The starting torque is equal to the maximum value, i.e. ($(T_0)_{st} = (T_0)_m$), if the external resistance inserted is equal to ($x_2 - r_2$). But, if the external resistance in the rotor circuit is increased further, i.e. [$R_{ext} > (x_2 - r_2)$], the starting torque decreases ($(T_0)_{st} < (T_0)_m$). This is, because the starting current decreases at a faster rate, even if the total resistance in the rotor circuit is increased.

In this lesson − the fifth one of this module, the direct-on-line (DOL) starter used for IM, along with the need for other types of starters, has been described first. Then, two types of starters − star-delta and auto-transformer, for cage type IM, are presented. Lastly, the rotor resistance starter for slip-ring (wound rotor) IM is briefly described. In the next (sixth and last) lesson of this module, the various types of single phase induction motors, along with the starting methods, will be presented.

RESULT : Hence, we study and test the firing circuit of three phase half controlled bridge converter.

VIVA QUESTION

1. Can you explain the purpose of using starters in 3-phase induction motors?
2. What are the different types of starters commonly used for 3-phase induction motors?
3. How does a direct online (DOL) starter function, and what are its advantages and disadvantages?
4. Describe the working principle of a star-delta starter and its application in 3-phase induction motors.
5. What is the role of a autotransformer starter in the operation of a 3-phase induction motor?
6. How does a resistance starter work, and under what conditions is it most suitable for use?
7. Explain the concept of a soft starter and its benefits in comparison to traditional starters.
8. What safety considerations should be taken into account when using starters for 3-phase induction motors?
9. How do electronic starters differ from traditional electromechanical starters in terms of functionality?
10. Discuss the importance of selecting the appropriate starter type based on the characteristics of the connected load.
11. What challenges may arise when starting a 3-phase induction motor, and how do starters address these challenges?
12. Can you compare the energy efficiency of different starter types for 3-phase induction motors?
13. How does the choice of a starter impact the overall performance and lifespan of a 3-phase induction motor?
14. In what scenarios would you recommend using a soft starter over other types of starters for induction motors?
15. Are there any advancements or emerging technologies in the field of starters for 3-phase induction motors that you find noteworthy

EXPERIMENT NO:2

AIM: To plot the O.C.C. & S.C.C. of an alternator.

APPARATUS:

S.No	Name of Apparatus	Type	Range	Quantity
1	Ammeter	MC	0-1 A	1
2	Ammeter	MI	0-5 A	1
3	Voltmeter	MI	0-500 V	1
4	Rheostats	Variable	230Ω,1.7 A	1
5	Rheostats	Variable	500Ω,1.2 A	2
6	Tachometer	Digital	0-2000rpm	1
7	Alternator		2HP	1

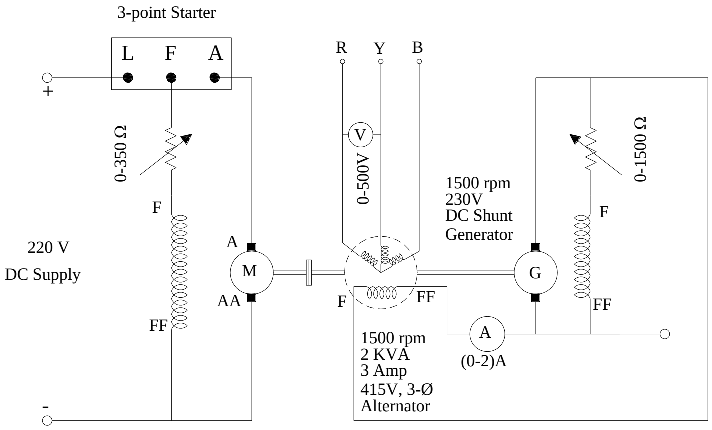
BASIC CONCEPT:

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

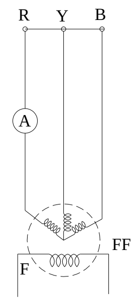
As the field current is gradually increased from zero. It is a graph between field current If and generated emf. The final value of Ef should be 125% of the rated voltage. The O.C.C. will not be a straight-line b'coz of the saturation in the iron part of the magnetic circuit.

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

CIRCUIT DIAGRAM:



Circuit Diagram for OCC



Circuit Diagram for SCC

PROCEDURE:

Open circuit test

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

Short Circuit test

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

OBSERVATION TABLE:

At rated Speed

S.No.	Field current (I_f)	Open Circuit voltage (V_{oc})	Short circuit current (I_{sc})
1			
2.			
3.			

CALCULATIONS:

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

Then impedance Zs =Voc/Isc

Reactance $Xs=\sqrt{(Zs^2-Ra^2)}$

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

RESULT: As doing this experiment we plot the O.C.C. & S.C.C. characteristics of an alternator is shown in the graph.

PRECAUTIONS:

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

VIVA QUESTION

1. What is advantage of this method over direct loading test of an alternator?
2. State why the OC characteristics is non linear?
3. How the synchronous impedance is affected by the frequency?
4. State the values of field current at which synchronous impedance should be calculated?
5. Why this method is called as pessimistic method?
6. Whether the value of synchronous impedance (Zs) is constant? State the conditions on which it depends?
7. Why the saturation under short circuit conditions is low?

8. Draw the labeled vector diagram for lagging power factor load.
9. Why the regulation is negative in case of leading power factor load?
10. What are the causes of changes in voltage in Alternators when loaded?
11. What is meant by armature reaction in Alternators?
12. What do you mean by synchronous reactance?
13. What is meant by synchronous impedance of an Alternator?
14. What is meant by load angle of an Alternator?

EXPERIMENT NO. -3

AIM: To connect two 3-phase induction motor in cascade and study their speed control

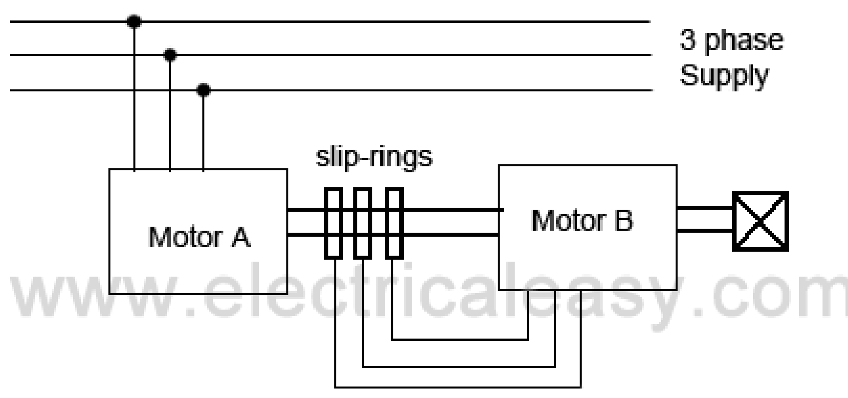
APPARATUS:

1. 3 phase induction motor
2. Auto transformer
3. Tachometer
4. Connecting leads.

BASIC CONCEPT:

An induction motor is practically a constant speed motor that means, for the entire loading range, change in speed of the motor is quite small. Speed of a DC shunt motor can be varied very easily with good efficiency, but in case of Induction motors, speed reduction is accompanied by a corresponding loss of efficiency and poor power factor.

CIRCUIT DIAGRAM:



WORKING PRINCIPLE:

Speed control method of induction motor control by cascade operation

In this method of speed control, two motors are used. Both are mounted on a same shaft so that both run at same speed. One motor is fed from a 3phase supply and the other motor is fed from the induced emf in first motor via slip-rings. The arrangement is as shown in following figure.

Motor A is called the main motor and motor B is called the auxiliary motor.
Let, Ns1 = frequency of motor A

Ns2 = frequency of motor B

P1 = number of poles stator of motor A

P2 = number of stator poles of motor B

N = speed of the set and same for both motors

f = frequency of the supply

Now, slip of motor A, S1 = (Ns1 - N) / Ns1.

frequency of the rotor induced emf in motor A, f1 = S1f

Now, auxiliary motor B is supplied with the rotor induce emf

therefore, Ns2 =(120f1)/P2 = (120S1f)/P2.

Now putting the value of S1 = (Ns1 - N) / Ns1

$$N_{s2} = \frac{120f(N_{s1} - N)}{P_2 N_{S1}}$$

At no load, speed of the auxiliary rotor is almost same as its synchronous speed.

i.e. N = Ns2.

from the above equations, it can be obtained that

$$N = \frac{120f}{P_1 + P_2}$$

With this method, four different speeds can be obtained

1. when only motor A works, corresponding speed = .Ns1 = 120f / P1
2. when only motor B works, corresponding speed = Ns2 = 120f / P2
3. if commulative cascading is done, speed of the set = N = 120f / (P1 + P2)
4. if differential cascading is done, speed of the set = N = 120f (P1 - P2)

PROCEDURE:

1. Connect three phase supply to the unit in proper R-Y-B-N Sequence.
2. Keep the alpha/Speed pot at minimum position.
3. Connect two Induction motor in parallel condition.
4. Switch on the 3 phase supply to find out the voltage and current value.
5. Connect 4-pin plug Induction motor to the unit lightly.
6. Wait the motor response increase speed clockwise & observe the motor speed.
7. Find the Value of Output Voltage current V_1 $I_1$and V_2 I_2 and Motor rpm speed N_1 andN_2

RESULT: Hence, we study and calculate the value of two 3-phase Induction motor in casecade connection mode.

PRECAUTIONS:

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

VIVA QUESTION

1. What is the purpose of connecting two 3-phase induction motors in cascade, and how does it contribute to speed control?
2. Can you explain the concept of cascade connection in the context of 3-phase induction motors?
3. What are the advantages of using cascade connection for speed control compared to other methods?
4. How do you physically connect two 3-phase induction motors in cascade for the experiment?
5. What are the potential challenges or limitations associated with cascade connection in 3-phase induction motors?
6. Describe the control strategy employed in the experiment to regulate the speed of the cascade-connected motors.
7. What types of speed control mechanisms are commonly used in 3-phase induction motors, and how does cascade connection compare to them?
8. How does the load torque affect the speed control performance in cascade-connected motors, and how can it be managed?
9. Can you discuss the impact of voltage variations on the speed control characteristics of cascade-connected induction motors?
10. Explain the role of feedback systems in optimizing the speed control of cascade-connected motors.

11. What instrumentation and measurement techniques are utilized to monitor and analyze the speed control parameters in the experiment?
12. How does the speed-torque characteristic vary for cascade-connected motors compared to a single motor configuration?
13. Discuss the energy efficiency implications of cascade connection for speed control in 3-phase induction motors.
14. Are there any specific applications or industries where cascade connection for speed control is particularly advantageous?

EXPERIMENT NO. -4

AIM: To perform load test on 3-phase induction motor and calculate torque, output power, input power, efficiency, input power factor and slip for various load settings.

APPARATUS:

Name	Range	Type	Qty
Ammeter	0-10A	MI	1
Voltmeter	0-500V	MI	1
Wattmeter(u.p.f)	600V/5A	Dynamo	2
Auto-transformer	3KVA	-	1
Tachometer	1500rpm	-	1
Induction Motor	2HP	-	1

BASIC CONCEPT:

This test is performed to compute the complete performance of induction motor. This means calculations of different quantity at different loading of induction motor.

Typical performance characteristics of induction motor is-

Speed

An induction motor is a shunt characteristics machine i.e. the speed drops only slightly as the load is increased, the fall in speed from no load to full load being of the order of 5% of the rated speed.

In the normal working region the characteristics is almost straight line.

Power factor

The induction motor stator current is made up of following components-

a. Magnetizing current to develop a rotating magnetic field.
b. A component to supply the stator iron losses and stator copper losses.
c. A component to balance the rotor current.

Under no load conditions the motor is required to develop power only to supply the friction and windage losses and therefore the rotor current, which depends upon the rotor power developed, is very small.

Out of three components at no load, component 1 is comparatively very large and therefore the input current power factor at no load is very low.

The best power factor of about .85 to .9 is obtained between 60% to 80% of full load.

Efficiency

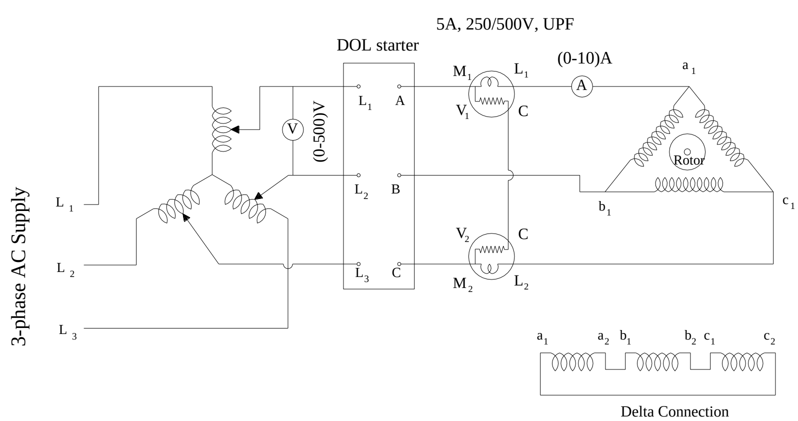
The losses of induction motor are a) fixed losses- composed of stator core losses, friction and windage losses b) Variable losses-composed of rotor and stator Cu losses, rotor iron losses and stray load losses.

Under running conditions the rotor iron losses are negligible and stray load losses are very small. At no load efficiency is zero. As the load increases the efficiency also rises. The maximum efficiency lies in range 80% to 95%.

Input current

The no load current is approx. 0.2 to 0.3 times full load current. As load is increased the current rises rapidly. After 755 of the load the variation of input current with power output is linear.

CIRCUIT DIAGRAM:



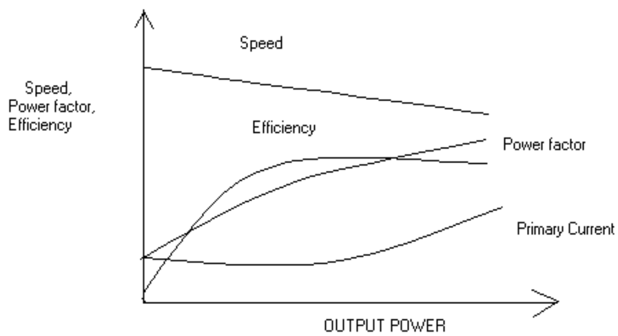
PROCEDURE:

1. Connect the circuit as shown in the fig.
2. Start the motor without load. When the rotor has attained the steady speed, record the applied voltage, line current and the reading of two wattmeter.And the speed.
   Also record the readings of the loading arrangement.
3. Gradually increase the load on the motor and for suitably spaced values of load record data in steps.Take observations up to about 120% of rated load.
4. Reduce the load and stop the motor.

OBSERVATION TABLE:

S.no	Supply voltage(v_s)volt	Load current I_L(amp.)	m.f.*input power	Speed in rpm	Load W_1(kg)	Load W_2(kg)	Diameter Of the brake drum in meter
1.							
2.							
3.							
4.							
5.							

CALCULATIONS & GRAPH:



RESULT: We perform load test on 3-phase induction motor and determine its performance characteristics as shown in graph.

PRECAUTIONS:

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

VIVA QUESTION

1. Why does the direction of rotation reverse when any two stator terminals are interchanged?
2. What is the reason for decreasing the speed of the motor to a very low value and then interchanging any two stator terminals in order to reverse the direction of rotation?
3. Which type of motor is used in (i) ceiling fan (ii) mixer (iii) vacuum cleaner ?
4. What are the advantages of induction motor over separately excited dc motor?
5. Why induction motor is also known as asynchronous motor?
6. You might have observed the intensity of the lamp reducing momentarily when an induction motor of 3-4 HP is switched ON. What could be the reason?
7. Can the starting torque of of a slip ring induction motor being increased?
8. Induction motor can run at synchronous speed ? True or false? Explain .
9. What are the inherent characteristics of plain 1-phase Induction motor ?
10. How does increase in excitation of the Alternator connected to infinite bus-bars affect this operation?

EXPERIMENT NO. -5

AIM: To perform no load and blocked rotor test on a 3-phase induction motor and determine the parameters of its equivalent circuits.

APPARATUS:

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

BASIC CONCEPT:

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

No load test

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

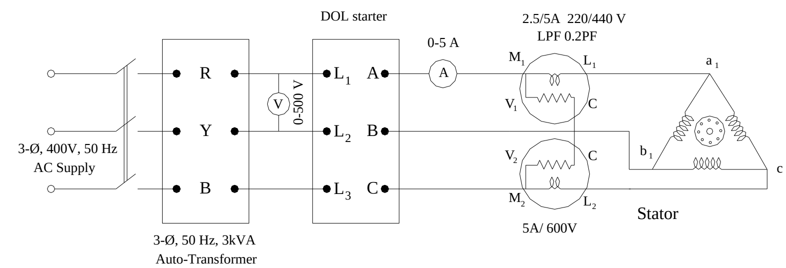
Blocked rotor test

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

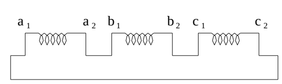
The power input during blocked rotor test is wholly consumed in the stator and the rotor copper losses. From the short circuit current and power input therefore total equivalent resistance of the stator and rotor can be obtained.

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

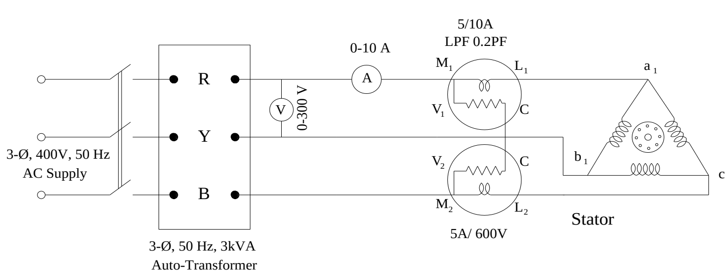
CIRCUIT DIAGRAM:



For no Load Test



Delta Connection



For Block Rotor Test

PROCEDURE:

1. Connect the circuit shown in the fig.
2. Increase the voltage gradually till the motor starts. Record the current, voltage and power input.

3. Increase the applied voltage in suitable steps, record the input current & power for various values of applied voltage up to 125% of rated voltage.
4. Now block the rotor and apply a reduced voltage and record the voltage applied, current and power input.
5. Gradually increase the applied voltage with rotor kept blocked and record 3 or 4 sets as in step 4 till the stator current is about 1.2 times the rated current.
6. Measure the resistance per phase of the stator

Rph=3/2Rt if motor in delta

Rph=1/2Rt if motor in star

Here Rt is the resistance between two terminals.

OBSERVATION TABLE:

Open Circuit test			**Blocked rotor test**		
Vo	**Io**	**Wo=W1+W2**	**Vbr**	**Ibr**	**Wbr=W1+W2**

CALCULATIONS:

For open circuit test

$W_o=\sqrt{3}\, V_o I_o \cos\phi$

$\cos\phi= W_o/\sqrt{3}\, V_o I_o$

$\phi=\cos^{-1}[W_o/\sqrt{3}\, V_o I_o]$

$I_w=I_o \cos\phi$

$I_m=I_o \sin\phi$

$R_o=V/\sqrt{3}\, I_w$

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

For blocked rotor test-

$R_{br}=W_{br}/3*I_{br}^2$

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

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

RESULT: We perform no load and blocked rotor test on 3-phase squirrel cage induction motor and determine the parameters of its equivalent circuit.

PRECAUTIONS:

7. No loose connection is allowed.
8. Switch on the Supply after checking the connections by faculty/Lab assistant.
9. Take the observation carefully.
10. Wear shoes, while working in machine lab.
11. Don’t touch any live part or wire, it may be dangerous.
12. Vary Rheostat & Autotransformer smoothly.

VIVA QUESTION

1. What is the analogy between O.C. & S.C. test of transformer & no load test & Block rotor test of an Induction motor?
2. For an IM, Pf = 40W/ph , net stator input = 70W/ph, calculate iron loss.
3. What are the various losses in an Induction motor?
4. What is the effect of temperature rise on winding resistance?
5. What are the advantages and disadvantages of direct load test for 3 –phase I M?
6. What are the informations obtained from blocked rotor test in a 3-phase I M?
7. What are the informations obtained from no-load test in a 3-phase
8. I M?
9. Name the tests to be conducted for predetermining the performance of 3-phase induction machine.
10. How does the shaft torque differ from the torque developed in 3-phase Induction motor?

EXPERIMENT NO. – 6

AIM: To study speed control of 3- Φ Induction Motor

APPARATUS:

1. Three phase Full controlled bridge rectifier
2. Induction motor
3. CRO
4. Connecting leads
5. Multimeter

BASIC CONCEPT:

An induction motor is practically a constant speed motor, which means, for the entire loading range, change in speed of the motor is quite small. Speed of a DC shunt motor can be varied very easily with good efficiency, but in case of Induction motors, speed reduction is accompanied by a corresponding loss of efficiency and poor power factor. As induction motors are widely being used, their speed control may be required in many applications.

INDUCTION MOTOR SPEED CONTROL FROM STATOR SIDE:

1. By Changing the Applied Voltage:

From the torque equation of induction motor,

$$T = \frac{k_1 s E_2^2 R_2}{\sqrt{(R_2^2 + (s X_2)^2)}} = \frac{3}{2\pi N_s} \frac{s E_2^2 R_2}{\sqrt{(R_2^2 + (s X_2)^2)}}$$

Rotor resistance R_2 is constant and if slip s is small then $(sX_2)^2$ is so small that it can be neglected. Therefore, $T \propto sE_2^2$ where E_2 is rotor induced emf and $E_2 \propto V$

Thus, $T \propto sV^2$, which means, if supplied voltage is decreased, the developed torque decreases. Hence, for providing the same load torque, the slip increases with decrease in voltage, and consequently, the speed decreases. This method is the easiest and cheapest, still rarely used, because

a) Large change in supply voltage is required for relatively small change in speed.

b) Large change in supply voltage will result in a large change in flux density; hence, this will disturb the magnetic conditions of the motor.

2. By Changing the Applied Frequency

Synchronous speed of the rotating magnetic field of an induction motor is given by,

$$Ns = \frac{120\ f}{P} \quad (RPM)$$

where, f = frequency of the supply and P = number of stator poles. Hence, the synchronous speed changes with change in supply frequency. Actual speed of an induction motor is given as N = Ns (1 - s). However, this method is not widely used. It may be used where, the induction motor is supplied by a dedicated generator (so that frequency can be easily varied by changing the speed of prime mover). Also, at lower frequency, the motor current may become too high due to decreased reactance. And if the frequency is increased beyond the rated value, the maximum torque developed falls while the speed rises.

3. Constant V/F Control Of Induction Motor

This is the most popular method for controlling the speed of an induction motor. As in above method, if the supply frequency is reduced keeping the rated supply voltage, the air gap flux will tend to saturate. This will cause excessive stator current and distortion of the stator flux wave. Therefore, the stator voltage should also be reduced in proportional to the frequency so as to maintain the air-gap flux constant. The magnitude of the stator flux is proportional to the ratio of the stator voltage and the frequency. Hence, if the ratio of voltage to frequency is kept constant, the flux remains constant. Also, by keeping V/F constant, the developed torque remains approximately constant. This method gives higher run-time efficiency. Therefore, majority of AC speed drives employ constant V/F method (or variable voltage, variable frequency method) for the speed control. Along with wide range of speed control, this method also offers 'soft start' capability.

4. Changing the Number Of Stator Poles

From the above equation of synchronous speed, it can be seen that synchronous speed (and hence, running speed) can be changed by changing the number of stator poles. This method is generally used for squirrel cage induction motors, as squirrel cage rotor adapts itself for any number of stator poles. Change in stator poles is achieved by two or more independent stator windings wound for different number of poles in same slots.

For example, a stator is wound with two 3phase windings, one for 4 poles and other for 6 poles. For supply frequency of 50 Hz

i) Synchronous speed when 4 pole winding is connected, Ns = 120*50/4 = 1500 RPM
ii) synchronous speed when 6 pole winding is connected, Ns = 120*50/6 = 1000 RPM

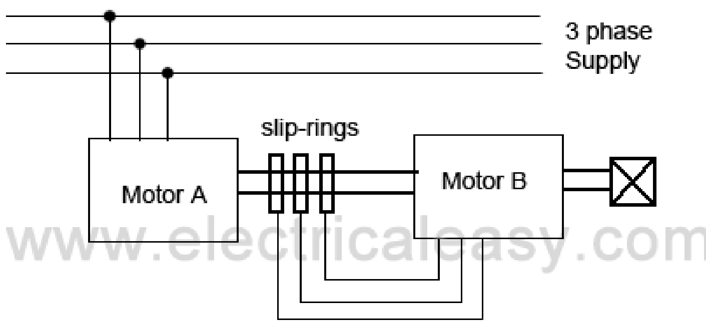
SPEED CONTROL FROM ROTOR SIDE:

1. Rotor Rheostat Control

This method is similar to that of armature rheostat control of DC shunt motor. But this method is only applicable to slip ring motors, as addition of external resistance in the rotor of squirrel cage motors is not possible.

2. Cascade Operation

In this method of speed control, two motors are used. Both are mounted on a same shaft so that both run at same speed. One motor is fed from a 3phase supply and the other motor is fed from the induced emf in first motor via slip-rings. The arrangement is as shown in following figure.



Motor A is called the main motor and motor B is called the auxiliary motor.
Let, Ns1 = frequency of motor A   Ns2 = frequency of motor B

P1 = number of poles stator of motor A P2 = number of stator poles of motor B

N = speed of the set and same for both motors, f = frequency of the supply

Now, slip of motor A, S1 = (Ns1 - N) / Ns1.

frequency of the rotor induced emf in motor A,   f1 = S1f

Now, auxiliary motor B is supplied with the rotor induce emf

therefore, Ns2 =(120f1)/P2 = (120S1f)/P2.

Now putting the value of S1 = (Ns1 - N) / Ns1

$$N_{s2} = \frac{120f(N_{s1} - N)}{P_2 N_{S1}}$$

At no load, speed of the auxiliary rotor is almost same as its synchronous speed.
i.e. N = Ns2.

from the above equations, it can be obtained that

$$N = \frac{120f}{P_1 + P_2}$$

With this method, four different speeds can be obtained

1. when only motor A works, corresponding speed = .Ns1 = 120f / P1

2. when only motor B works, corresponding speed = Ns2 = 120f / P2

3. if commulative cascading is done, speed of the set = N = 120f / (P1 + P2)

4. if differential cascading is done, speed of the set = N = 120f (P1 - P2)

3. Injecting EMF In Rotor Circuit

In this method, speed of an induction motor is controlled by injecting a voltage in rotor circuit. It is necessary that voltage (emf) being injected must have same frequency as of the slip frequency. However, there is no restriction to the phase of injected emf. If we inject emf which is in opposite phase with the rotor induced emf, rotor resistance will be increased. If we inject emf which is in phase with the rotor induced emf, rotor resistance will decrease. Thus, by changing the phase of injected emf, speed can be controlled. The main advantage of this method is a wide range of speed control (above normal as well as below normal) can be achieved. The emf can be injected by various methods such as Kramer system, Scherbius system etc.

RESULT: We have successfully studied the speed control of 3- Φ Induction Motor

VIVA QUESTION

1. What is the significance of studying speed control in 3-phase induction motors?
2. Can you explain the basic principles of speed control in 3-phase induction motors?
3. What are the different methods available for speed control in 3-phase induction motors?
4. How does voltage control contribute to speed regulation in induction motors, and what are its limitations?
5. Discuss the concept of stator voltage control and its impact on the speed of a 3-phase induction motor.
6. What role does frequency control play in the context of speed regulation in induction motors?

7. Explain the principle of pole-changing as a method for speed control in 3-phase induction motors.
8. How does rotor resistance control affect the speed characteristics of an induction motor, and under what conditions is it suitable?
9. What is the role of slip in determining the speed of a 3-phase induction motor, and how can it be controlled for speed regulation?
10. Describe the working principle of a variable frequency drive (VFD) and its application in speed control for induction motors.
11. Can you compare the advantages and disadvantages of open-loop and closed-loop speed control systems for 3-phase induction motors?
12. How does the load torque influence the effectiveness of speed control methods in induction motors, and how can it be managed?
13. Discuss the impact of temperature variations on the speed control characteristics of 3-phase induction motors.

EXPERIMENT NO. -7

AIM: Determination of losses and efficiency of an alternator.

APPARATUS:

Name	Type	Range	Quantities
3 PHASE ALTERNATOR		1500 RPM,2 KVA,3A	1
D.C GENERATOR		1500 RPM,75 KVA, 220 V	1
D.C MOTOR		5 H.P,1500 RPM , 20A,220V	1
VOLTMETER	DIGITAL	0-300V	2
VOLTMETER	DIGITAL	0-500V	1
AMMETER	DIGITAL	0-20A	1
AMMETER	DIGITAL	0-2A	1
AMMETER	DIGITAL	0-5 A	1
RHEOSTATE	VARIABLE	3A,350 OHM	1
RHEOSTATE	VARIABLE	0.5A,1500 OHM	1

BASIC CONCEPT:

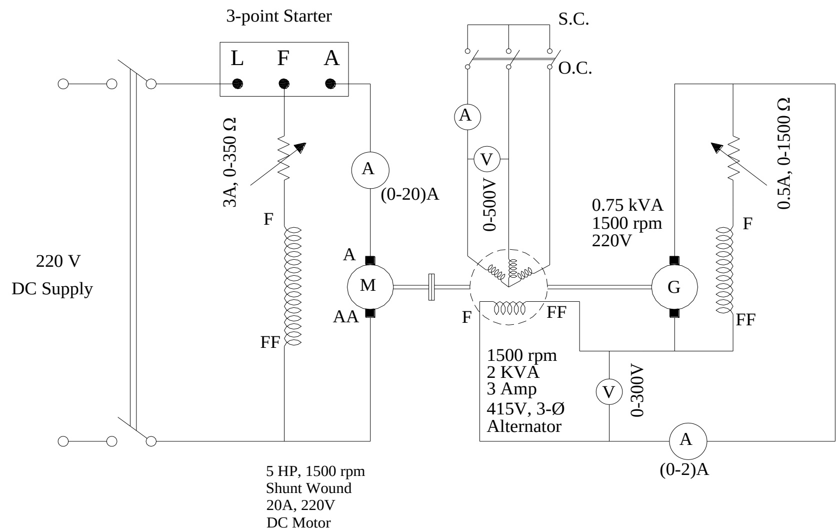
A rotating machine has following type of losses

1. Magnetic Losses These losses are mainly Hysteresis Losses and Eddy current losses.

2. Mechanical Losses These losses are mainly windage Loses and friction losses.

3. Electrical Losses The losses which occur due to flow of current

CIRCUIT DIAGRAM:



Circuit Diagram for Losses & efficiency of an alternator

PROCEDURE:

1. Connect the circuit as shown in figure.
2. Start the DC motor with the help of starter and speed the motor.
3. Change the Excitation of synchronous machine so that rated voltage obtain at load terminal.
4. Put some load on the alternator and record all the apparatus readings.

OBSERVATION TABLE:

TABLE 1

Uncouple dc motor & alternator & rotate dc motor at rated speed

S.no.	V_A	I_A	R_A
1.			

TABLE 2

Couple dc motor & alternator & rotate dc motor at rated speed

S.NO.	V_A	I_A	R_A
1.			

CALCULATIONS:

Total power Input P_{mi}=VI

Power input to alternator $P_{gi}=\eta_m VI$

Power output from Alternator P_{go}=W1+W2

Total losses = P_{gi}-P_{go}

Efficiency $ŋ_a$=P_{go}/P_{gi}

RESULTS: We determine the losses and efficiency of a synchronous machine.

PRECAUTIONS:

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

VIVA QUESTION

1. What do you mean by losses in the alternator?
2. What do you mean by efficiency of the alternator?
3. At what load angle is power developed in a synchronous motor becomes its maximum value ?
4. Write down the equation for frequency of emf induced in an Altenator.
5. Name the types of Alternator based on their rotor construction?
6. Why do cylindrical Alternators operate with steam turbines?
7. Why is the stator core of Alternator laminated?
8. How does electrical degree differ from mechanical degree?
9. What is distributed winding?
10. Why are Alternators rated in kVA and not in kW?

EXPERIMENT NO. -8

AIM: Draw the circle diagram and compute the following (i) Max. Torque (ii) Current (iii) slips (iv) p. f. (v) Efficiency.

APPARATUS:

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

BASIC CONCEPT:

A **circle diagram** is a graphical representation of the performance of an electrical machine. It is commonly used to illustrate the performance of transformers, alternators, synchronous motors, and induction motors. It is very useful to study the performance of an electric machine under a large variety of operating conditions. The diagrammatic representation of a circle diagram makes it much easier to understand and remember compared to theoretical and mathematical descriptions

The diagram provides information which is not provided by an ordinary phasor diagram. A phasor diagram gives relation between current and voltage only at a single circuit condition. If the condition changes, we need to draw the phasor diagram again. But a circle diagram may be referred to as a phasor diagram drawn in one plane for more than one circuit conditions. On the context of induction motor, which is our main interest, we can get information about its power output, power factor, torque, slip, speed, copper loss, efficiency etc. in a graphical or in a diagrammatic representation.

Test Performed to Compute Data Required for Drawing Circle Diagram

In perform of no load and blocked rotor test in an induction motor. In no load test, the induction motor is run at no load and by two watt meter method, its total power consumed is calculated which is composed of no load losses only. Slip is assumed to be zero. From here no load current and the angle between voltage and current required for drawing circle diagram is calculated. The angle will be large as in the no load condition induction motor has high inductive reactance.

In block rotor test, rotor is blocked which is analogous to short circuiting secondary of a transformer. From this test, we need to calculate short circuit current and the lag angle between voltage and current for drawing circle diagram. Also, we need rotor and stator copper loss.

CIRCLE DIAGRAM:

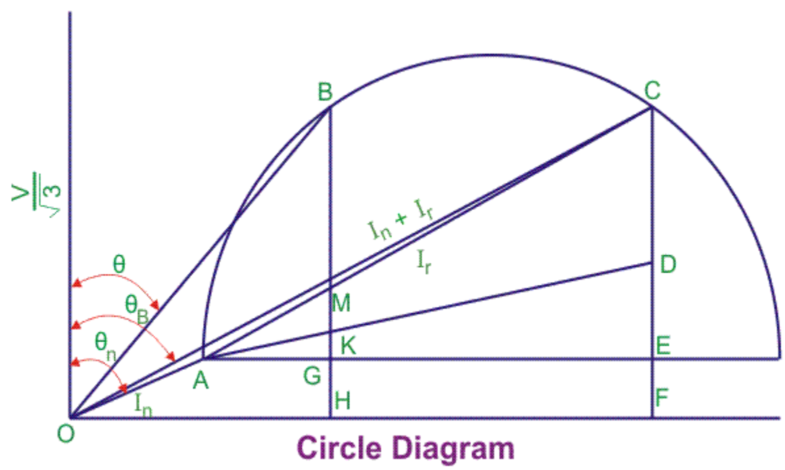


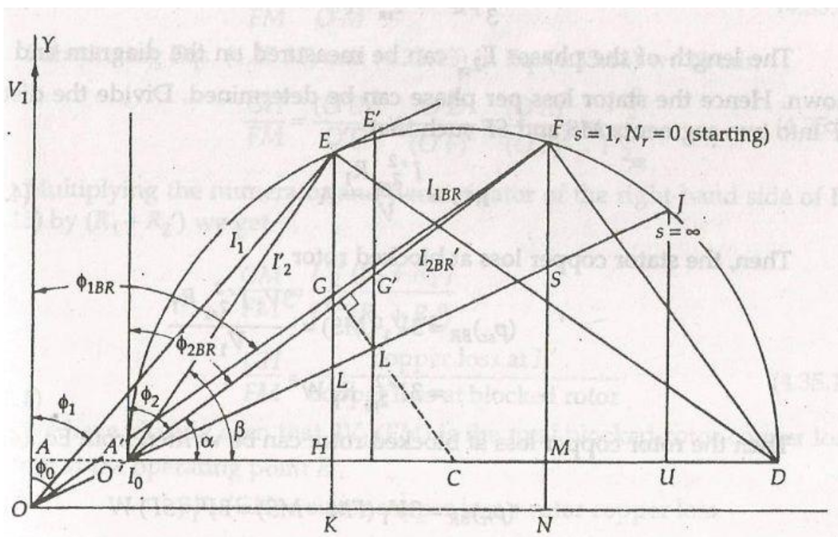
Fig.1 Three-phase, three-wire ac regulator.

PROCEDURE:

1. The no-load current and the no load angle calculated from no load test is plotted. This is shown by the line OA, where Θ_0 is the no load power factor angle.
2. The short circuit current and the angle obtained from block rotor test is plotted. This is shown by the line OC and the angle is shown by Θ_B.
3. The right bisector of the line AC is drawn which bisects the line and it is extended to cut in the line AE which gives us the centre.

4. The stator current is calculated from the equivalent circuit of the induction motor which we get from the two tests. That current is plotted in the circle diagram according to the scale with touching origin and a point in the circle diagram which is shown by B.
5. The line AC is called the power line. By using the scale for power conversion that we have taken in the circle diagram, we can get the output power if we move vertically above the line AC to the periphery of the circle. The output power is given by the line MB.
6. The total copper loss is given by the line GM.
7. For drawing the torque line, the total copper loss should be separated to both the rotor copper loss and stator copper loss. The line DE gives the stator copper loss and the line CD gives the rotor copper loss. In this way, the point E is selected.
8. The line AD is known as torque line which gives the torque developed by induction motor.

CALCULATION OF THE CIRCLE DIAGRAM:



Assume that the line current I1 is known. With the centre at O, draw an arc with the radius I1. This arc intersects the circle at the operating point E. Draw the line EK and locates the point H, L, G.

The following results are obtained from the circle diagram shown above.

a) Input power = $3V_1$ KE
b) Rotational losses = $3V_1$ KH
c) Stator copper loss = $3V_1$ HL
d) Rotor copper loss = $3V_1$ LG

e) Output power = $3V_1$ GE

f) Output torque = $3V_1$ LE/ω_s

g) Starting torque = $3V_1$ SF/ω_s

h) Slip = LG/LE

i) Speed = GE/LE X n_s

j) Efficiency = GE/KE

k) Power factor = KE/OE

SIGNIFICANCE OF LINES ON THE CIRCLE DIAGRAM:

Input line ON

The vertical distance between any point on the circle and the line **ON** represent the input power. Therefore, line ON is called the **input line**.

Output Line O'F

The vertical distance between any point on the circle and the line **O'G** represents the **output power**. Hence, line **O'F** is called the **output line**.

RESULT: We have successfully completed the study of Induction motor circle diagram.

VIVA QUESTION

1. What is the purpose of the circle diagram in the context of 3-phase induction motors?
2. Can you describe the components and layout of the circle diagram used in your experiment?
3. How is the circle diagram helpful in analyzing the performance characteristics of an induction motor?
4. Walk me through the steps involved in drawing the circle diagram for a 3-phase induction motor.
5. Explain the significance of the maximum torque point on the circle diagram and its relevance to motor operation.

6. How is the maximum torque computed from the circle diagram, and what factors influence this value?
7. What information does the circle diagram provide about the current in the induction motor, and how is it calculated?
8. Discuss the concept of slip in the context of the circle diagram and how it is determined.
9. Explain the relationship between power factor and the circle diagram, and how is power factor computed from the diagram?
10. Can you elaborate on the efficiency of the induction motor and how it is derived from the circle diagram data?
11. What role do the various regions on the circle diagram play in understanding the motor's performance characteristics?
12. How does the shape of the circle change with varying loads, and what insights can be gained from these changes?
13. Describe any assumptions or simplifications made in the process of drawing and interpreting the circle diagram.
14. Are there any practical considerations or challenges in applying the circle diagram method to real-world induction motors?

EXPERIMENT NO. – 9

AIM: To determine Zs , Xd and Xq by slip test, Zero power factor (ZPF)/ Potier reactance method.

APPARATUS:

Name	Range	Type	Quantities
Ammeter	0-20A	MI	1
Ammeter	0-5A	MI	1
Voltmeter	0-500V	MI	1
Voltmeter	0-500V	MI	1
Rheostate	350Ohms,3A		1
Rheostate	1500Ohms ,0.5A		1
Auto transformer	415/0-470V,12KVA		

BASIC CONCEPT:

Direct Axis synchronous reactance and Quardature axis synchronous reactance are the steady state Synchronous reactance of Synchronous Machine .These reactance can be measured by performing the Open circuit and Short circuit test on Synchronous machine.

(a) Direct axis synchronous reactance (X_d):- The direct axis synchronous reactance of synchronous machine in per unit is equal to the ratio of Maximum voltage on the air gap and minimum armature current.

(b) Quadrature axis synchronous reactance (X_q):- The Quadrature axis synchronous reactance of synchronous machine in per unit is equal to the ratio of Maximum voltage on the air gap and minimum armature current.

For the slip test the alternator is driven at speed ,slightly less than the synchronous speed with its field supply open circuited . 3-phase balanced supply (reduced) with ratde voltage and rated frequency is given to the stator of the alternator .Applied voltage is to be adjusted so that the current drawn by the stator winding is full load rated current.Under this condition we find vibration in ammeter and voltmetr reading.

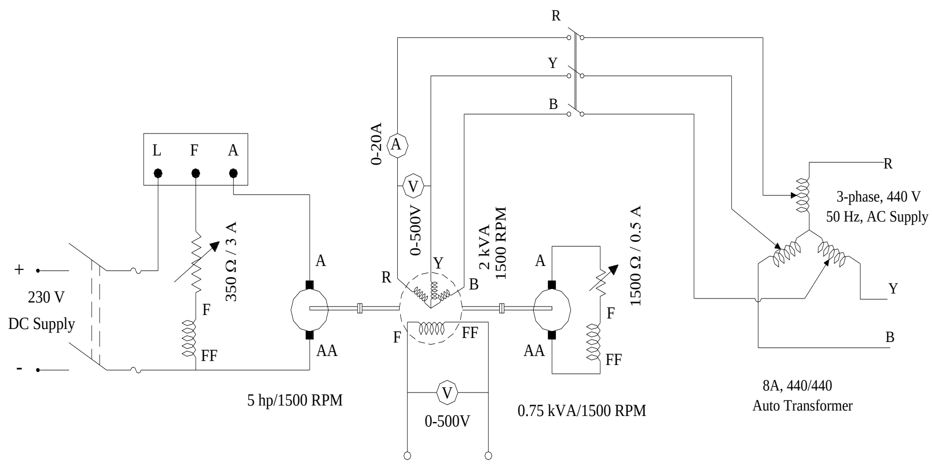
The approximate value of Direct axis synchronous reactance is given by

$$X_{ds}=E_{max}./I_{min}$$

The approximate value of quadrature axis synchronous reactance is given by

$$X_{qs}=E_{min}./I_{max.}$$

CIRCUIT DIAGRAM:



PROCEDURE:

1. Make the circuit according the figure.
2. Start the DC motor with the help of starter to rated speed.
3. A coupled D.C motor very near to synchronous speed runs the salient- pole synchronous machine. If the synchronous speed is 1500 rpm, the set is run at 1750 rpm.
4. The stator of the salient pole alternator is supplied from a low voltage (10-20 Volts), 3 -phase supply. The supply frequency is more than 50 Hz as the supplying alternator is run at 1750 rpm.
5. The field is kept open and the maximum and minimum deflections in the ammeter (to read the supply voltage) are read.
6. Feed reduced voltage to alternator with the use of autotransformer.
7. Note the reading in field voltmeter of alternator. if it is zero than change the any two terminals of Alternator.
8. Record the reading of all apparatus.

9. Now, reduced the supply by autotransformer & than switch off the DC motor taking all precautions.

10. Xd, Xq are calculated.

OBSERVARION TABLE:

N_S(RPM)	N_R(RPM)	SLIP(S)	VOLTAGE ACROSS ARMATURE TERMINAL(V)		ARMATURE(A)AMP	
			MAX.	MIN.	MAX.	MIN.

RESULT: We have successfully completed the Xd and Xq by slip test of a 3-phase alternator.

Xd = Maximum V/Minimum I
Xq = Minimum V/ Maximum I

PRECAUTIONS:

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

VIVA QUESTION

1. Why it is necessary to keep the field open while taking the reading during slip test?
2. Justify that the reactance obtained by O.C. & S.C test is Xd and not Xq?
3. Justify that the reactance obtained by O.C. & S.C test is Xd and not Xq?
4. What are the normal values of Xq/Xd for the two types of syn. Machines?
5. How will you recognize whether a given syn. machine is cylindrical rotor type or salient pole type?

6. Why this test is called slip test?
7. Why it is necessary to maintain the slip?
8. What are the main assumptions during this test?
9. What is the purpose of damper winding in synchronous machines?
10. Generally whether Xd’’ > Xq’’ or Xd’’< Xq’’ and why ?
11. What is hunting of synchronous machine ?
12. What happen if there is sudden short circuit on the alternator

EXPERIMENT NO. -10

AIM: To determine the voltage regulation of a 3-phase alternator by direct loading.

APPARATUS:

S.No	Name of Apparatus	Type	Range	Quantity
1	Ammeter	MC	0-1 A	1
2	Ammeter	MI	0-5 A	1
3	Voltmeter	MI	0-500 V	1
4	Rheostats	Variable	230Ω,1.7 A	1
5	Rheostats	Variable	500Ω,1.2 A	2
6	Tachometer	Digital	0-2000rpm	1
7	Alternator	-	2HP	1
8	DC Motor	-	2HP	1

BASIC CONCEPT:

The voltage regulation of a synchronous generator [Alternator] can be determined by various methods. In case of small capacity alternators, direct loading test used to determine regulation, while in case of large capacity Alternators Synchronous Impedance method is used.

The below figure shown is three phase alternator on which Direct Loading test is conducted.

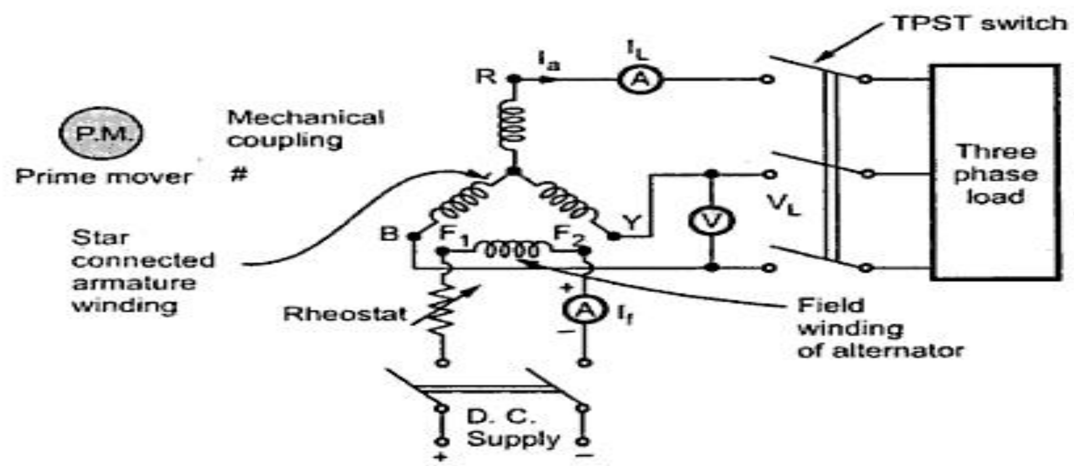
shows the circuit diagram for conducting the direct loading test on the three phase alternator. The star connected armature is to be connected to a three phase load with the help of triple pole single throw (TPST) switch. The field winding is excited by separate d.c. supply. To control the flux i.e. the current through field winding, a rheostat is inserted in series with the field winding. The prime mover is shown which is driving the alternator at its synchronous speed.

The alternator is first driven at its synchronous speed Ns by means of a prime mover. By giving d.c. supply to the field winding, the field current is adjusted to adjust the flux so that rated voltage is available across the terminals. This can be observed on the voltmeter connected across the lines. The load is then connected by means of a TPST switch. The load is then increased so that ammeter reads rated value of current. This is full load condition of the alternator. Again adjust the voltage to its rated value by means of field excitation using a rheostat connected. The throw off the entire load by opening the TPST switch, without changing the speed and the field excitation. Observe the voltmeter reading. As load is thrown off, there is no armature current and associated drops. So the voltmeter reading in this situation indicates the value of internally induced e.m.f. called no load terminal voltage. Convert both the reading to phase values. The rated voltage on full load is Vph while reading when load is thrown off is Eph. So by using the formula,

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

the full load regulation of the alternator can be determined. The value of the regulation obtained by this method is accurate as a particular load at required p.f. is actually connected to the alternator to note down the readings.

CIRCUIT DIAGRAM:



PROCEDURE:

1.Firstly connections are to be made as given in the circuit diagram:

2. Armature which is star connected is connected to the three phase load with the help of TPST. TPST is a switch and it means triple pole single through.

3. A rheostat is connected in series with the field winding.

4. Field winding is excited by using D.C supply and flux is adjusted by adjusting the rheostat. Flux adjustment is nothing but adjust the current flow through field winding.

CALCULATION OF VOLTAGE REGULATION:

1. Adjust the prime mover such that the alternator rotates at synchronous speed Ns.

we know Eph α **ϕ** from emf equation

2. Now DC supply is given to the field winding and the current flow through field is adjusted so that the flux is adjusted such that the rated voltage is obtained at its terminals which can be seen on the voltmeter connected across the lines.

3. Now load is connected to alternator with the help of TPST switch.

4. The load is then increased such that the ammeter reads rated current. This is full load condition of alternator. Now as load is connected due to armature reaction there is loss in voltage so let the induced voltage be V.

5. Now again adjust the rheostat of the field winding to get rated voltage at alternator terminals.

6. Now remove the load by opening TPST switch and the excitation , speed should not be changed it should be same as before removing the load.

7. As there is no load there is no armature reaction the induced emf is equal to terminal voltage which is E.

Now we can calculate **voltage regulation of synchronous machine** by

Voltage regulation% =(E - V / V) × 100 at a specific power factor.

CALCULATION:-

Example : While supplying a full load, running at synchronous speed, the terminal voltage of an alternator is observed to be 1100 V. When the load is thrown off, keeping field excitation and speed constant, the terminal voltage is observed to be 1266 V. Assuming star connected alternator, calculate its regulation on full load.

Solution : On full load, terminal voltage is 1100 V.

So $V_L = 1100$ V

∴ $V_{ph} = V_L/\sqrt{3} = 635.0853$ V

When load is thrown off, $V_L = 1266$ V. But on no load,

$V_L = E_{line}$

∴ $E_{line} = 1266$ V

∴ $E_{ph} = 1266/\sqrt{3}$

$= 730.925$ V

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

$$= \frac{730.925 - 635.0853}{635.0853} \times 100 = \mathbf{15.09\ \%}$$

RESULT: We have successfully determine the voltage regulation of a 3-phase alternator by direct loading

PRECAUTIONS:

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

VIVA QUESTION

1. What is the significance of determining the voltage regulation in a 3-phase alternator?
2. Can you explain the concept of voltage regulation in the context of alternators?
3. What are the different factors that contribute to voltage regulation in a 3-phase alternator?
4. How does direct loading contribute to the determination of voltage regulation in the alternator?
5. Walk me through the experimental setup for determining the voltage regulation of a 3-phase alternator under direct loading.
6. What instrumentation and measurement devices are used in the experiment to measure voltage and other relevant parameters?
7. Explain the procedure for loading the alternator directly and the corresponding adjustments made during the experiment.
8. How is the percentage voltage regulation calculated, and what does a positive or negative value indicate?

9. Discuss the impact of load changes on the voltage regulation characteristics of the alternator.
10. Can you explain the significance of the synchronous impedance method in the context of voltage regulation determination?
11. What are the limitations or challenges associated with the direct loading method for voltage regulation determination?
12. How does the power factor of the load affect the voltage regulation in a 3-phase alternator?
13. Describe any precautions or safety measures taken during the experiment to ensure accurate results.

EXPERIMENT NO. -11

AIM: To determine the voltage regulation of a 3-phase alternator by synchronous impedance method.

APPARATUS:

S.No.	Name	Type	Range	Quantity
1.	Ammeter	Mc	0-1/2 A	1
2.	Ammeter	MI	0-10/20 A	1
3.	Voltmeter	MI	0-300/600V	1
4.	Rheostat	Single tube	272ohm,1.7A	2
5.	Tachometer	Digital	0-2000 rpm	1

BASIC CONCEPT:

To find out the regulation of alternator by synchronous impedance method, following characteristics and data has to be obtained experimentally.

(i) Open circuit characteristic at synchronous speed.

(ii) Short ckt characteristic at synchronous speed.

(iii) A.C. resistance. of the stator winding, per phase i.e.Ra.

Fig.(1)shows the open ckt and short ckt characteristics of a 3 phase alternator, plotted on the phase basis. To find out the synchronous impedance from these characteristics, open ckt voltage E1 and short ckt current,I1(preferably full load current),corresponding to a particular value of field current is obtained. Then, synchronous impedance per phase is given by,

Synchronous impedance, $Zs=E_1/I_1$

Then, Synchronous reactance, $Xs=\sqrt{}\ (Zs_2-Ra_2)$.

Fig (2)Shows the phasor diagram of the alternator, supplying full load current of Ia ampere, lagging the terminal voltage V by an angle ø. Then open ckt voltage E of the alternator is given by,

$E= V+ I_aR_a + I_aX_s$ (Phasor sum)

The diagram has been draw with the current as the reference phasor and self-explanatory. The open ckt voltage as finally obtained from the phasor diagram, corresponding to this loading condition is given by,

Regulation = {(E-V)/V}*100 %

An approximant expression for the open ckt voltage can be established referring to phasor diagram.

Open ckt voltage=$\sqrt{}OD^2+DC^2=\sqrt{}(OF+FD)^2+(DB+BC)^2$

$E=\sqrt{[(V\cos\phi+I_aR_a)^2+(V\sin\phi+I_aX_s)^2]}$ (for lagging p.f. load)

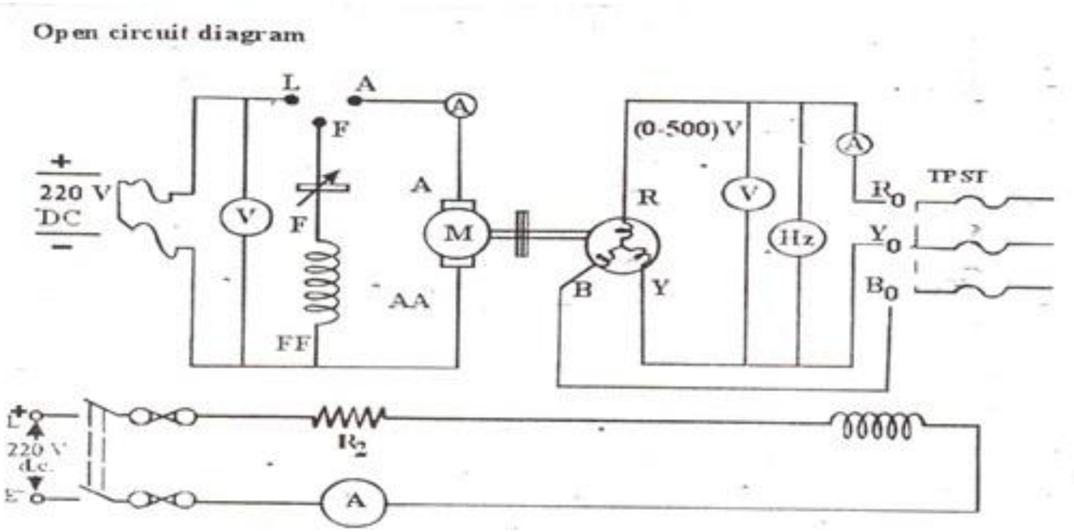
The above expression is for lagging power factor load. In case, alternator at leading power factor.

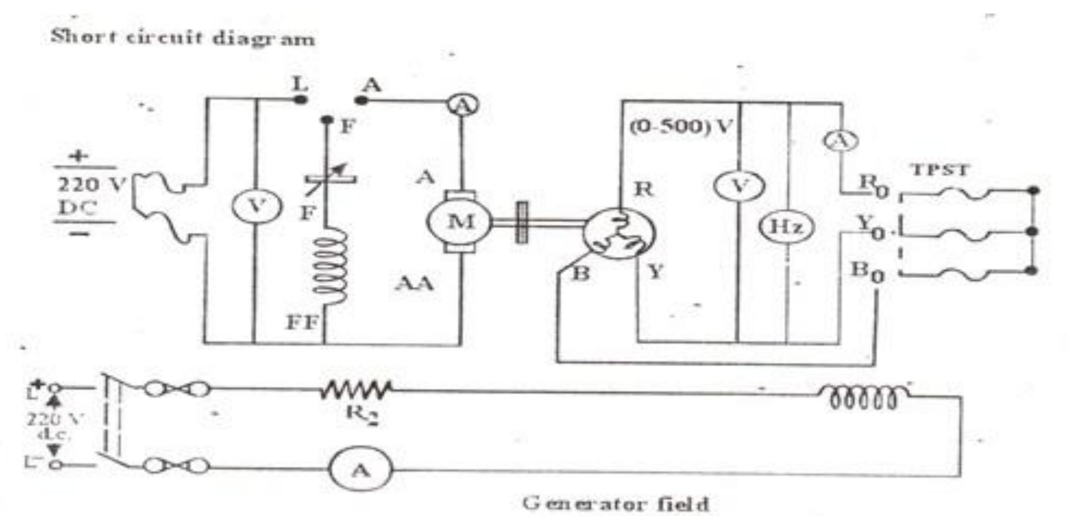
Open ckt voltage can be found out in a similar way and is given by,

$E=\sqrt{[(V\cos\phi+I_aR_a)^2-(V\sin\phi+I_aX_s)^2]}$ (for leading p.f. load)

The value of regulation obtained by this method is higher than obtained from as actual load test; as such it is called pessimistic method.

CIRCUIT DIAGRAM:





PROCEDURE:

1. Connect the circuit as per fig.

2. Adjust the position of rheostat R1 for maximum possible current in the field circuit of DC motor, to ensure (1) low starting speed (2) high starting torque.

3. Set the position of rheostat, R2 for minimum current in the field circuit of alternator, to ensure low value of generated emf at starting.

4. Switch on the dc mains, feeding the dc motor and then field circuit of alternator.

5. Start the dc motor, using the starter properly. Various resistance steps of the starter should be cut out slowly, so that the motor does not draw high current during starting.

6. Set the speed of the motor and hence the alternator its rated value by varying rheostat, R provided in the field circuit of the motor.

7. Note down the open circuit voltage of the alternator and the field current.

8. Repeat step 7 for various values of the field current (can be obtained by varying the rheostat, R2 provided in the field circuit of alternator). Observation should be continued, till the open circuit voltage is 25 to 30 percent higher then the rated value.

9. Set the position of rheostat, R2 again for minimum possible current in the field circuit of alternator.

10. Short – circuit the stator winding of the alternator, by closing the switch, provided for this purposing the circuit diagram.

11. Note down the short circuit current and the field current.

12. Repeat step 11, for various values of the field current, till the short circuit current becomes equal to the full load current of the alternator.

13. Read just the setting of the rheostat R1 and r2 to their initial position and then switch off the DC supply to stop the DC motor.

14. Measure the dc resistance of the stator winding by usual voltmeter –ammeter method .To obtain AC resistance ,skin effect must be taken into account .A such ,AC resistance may be taken approximately 1.3 times the DC resistance measured.

OBSERVATION TABLE:

D.C. MOTOR			A.C. GENERATOR			D.C. EXCITOR	
V_S	I_S	R.P.M	E	I	HZ	V	I

RESULT: We have successfully completed the study of alternator and also determined its regulation by synchronous impedance method.

VIVA QUESTION

1. What is the importance of determining the voltage regulation of a 3-phase alternator using the synchronous impedance method?
2. Explain the concept of voltage regulation in the context of alternators and its significance in power systems.
3. How does the synchronous impedance method differ from other methods in determining voltage regulation?
4. What are the key components of the experimental setup for measuring voltage regulation using the synchronous impedance method?
5. Can you describe the role of synchronous impedance in the context of voltage regulation and how it is determined?
6. Walk me through the step-by-step procedure of conducting the experiment to determine

voltage regulation by the synchronous impedance method.

7. What are the advantages of using the synchronous impedance method for voltage regulation compared to other techniques?
8. How does the excitation voltage of the alternator affect the synchronous impedance method's accuracy in determining voltage regulation?
9. Explain the calculations involved in determining percentage voltage regulation using the synchronous impedance method.
10. Discuss the factors that may introduce errors or uncertainties in the measurements during the synchronous impedance experiment.
11. How does the synchronous impedance method account for changes in load conditions on the alternator?
12. Can you compare the synchronous impedance method with the direct loading method for determining voltage regulation, highlighting their respective strengths and weaknesses?
13. Describe any safety precautions taken during the experiment to ensure accurate and secure measurements.
14. What implications does voltage regulation have on the overall performance and stability of a power system?
15. Can you propose any modifications or improvements to the experimental setup for a more precise determination of voltage regulation using the synchronous impedance method?

EXPERIMENT NO. -12

AIM: To study effect of variation of field current upon the stator current and power factor of synchronous motor and Plot V-Curve and inverted V-Curve of synchronous motor for different values of loads.

APPARATUS:

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

BASIC CONCEPT:

The armature current drawn by a synchronous motor for a definite power output is a function of its field current. For a given load on the motor, as the field current is varied, both the input current and the input power factor change. the plot of armature current as the function of field current for a constant power output is called a V curve because of its characterstics shape. It given load the armature current is minimum at a particular value of field current. If field current is gradually decreased below this value, the armature current will gradually increase till a point is reached where the motor starts hunting.

A similar phenomenon is observed if the field current is increased above this value. The points on the V curve where the armature current is minimum corresponding to unity power factor of the input current. The curve joining the minimum current points of a set of V-curves is often called a unity power factor-compounding curve. Synchronous motor is not self-starting if it is coupled with a d.c. Machine, the latter may be used as an auxiliary motor for starting. The synchronous machine is run up to its synchronous speed using d.c.motor drive and then synchronized with three phase main supply. If the D.C. motor is now switched off the synchronous machine will start running as a synchronous motor off the a.c. supply. Now the field current is increased in steps and corresponding armature current are noted.

THEORY:

With constant mechanical load on the synchronous motor, the variation of field current change the armature current drown by the motor and its operating power factor. As such, the behavior of synchronous motor is described below under three different modes of field excitation.

1. **Normal Excitation**: - The armature current is minimum at a particular value of field current, which is called the normal excitation. The operating power factor is unity at this excitation.
2. **Under Excitation**:-when the field current is decreased gradually below the normal excitation, the armature current is increases and operating power factor of the motor decreases. The power factor under this condition is lagging.
3. **Over excitation:**-when the field current increases gradually beyond the normal excitation, the armature current again increases and operating power factor decreases. However, the power factor is leading under this condition. Hence, the synchronous motor draws a leading power current, when it is over excited and is equivalent to a capacitive load. If the above variation of field current and the corresponding armature current are plotted for a constant mechanical Ioad, a curve of the safe of ‘V ’is obtained and commonly called a ‘V ‘curve of the motor. For increases constant mechanical load on the motor, V curves bodily shift upwards as shown in

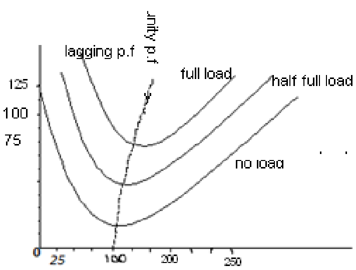
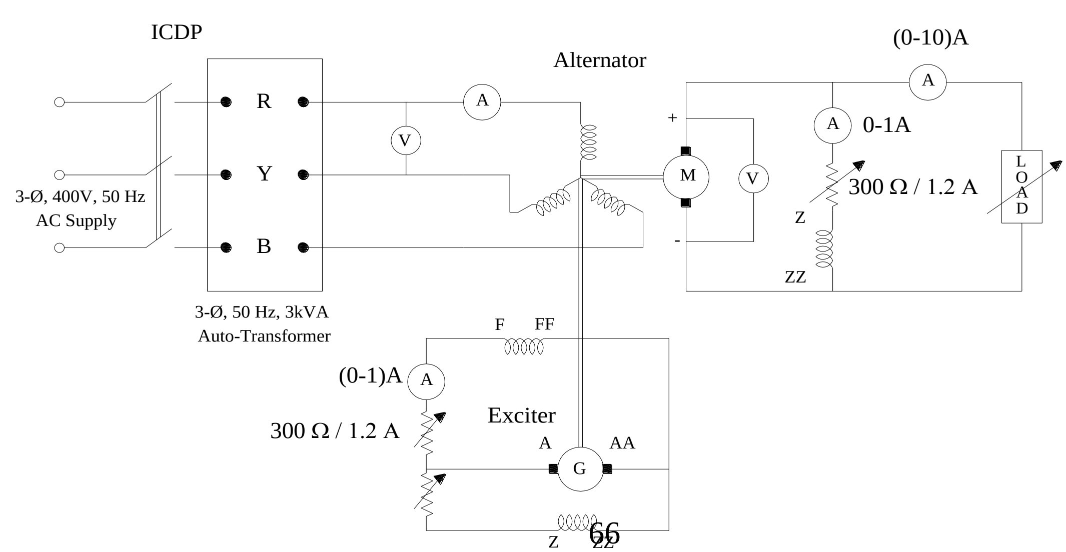


Fig. 1:- The curve joins the minimum current point of ‘V’

CIRCUIT DIAGRAM:



V-Curve for a Synchronous motor

P
R
O
C
E
D
U

PROCEDURE:

1. Connect the circuit as per fig.1
2. Switch on the AC supply feeding to 3-phase synchronous motor and starts motor, using the starter.
3. Observe the direction of motor rotation, if its rotating opposite then stop it and reverse the phase sequence.
4. In thus case, field winding is excited automatically with the help of exciter, provid on the shift of the main motor.
5. Set the rheostat in the circuit of the motor to the position of normal excitation.
6. Reduce the excitation in steps and note down the corresponding armature current and reading of both the wattmeter.
7. Again, adjust the rheostat in the field circuit to normal excitation. Now increase the excitation in step and note the reading of all meter at each setting of increased excitation.
8. Load the DC generator coupled synchronous motor to rated value by varying the field current of the generator.
9. Repeat step 5, 6 and7 sequentially under this condition of loading.
10. Increase the load on the generator to $3/4^{th}$ of full load, keeping its voltage constant.
11. Repeat step 5,6 and 7 sequentially for this increase load on the motor.
12. Remove the DC generator gradually.
13. Switch of the supply for stop the motor.

OBSERVATION TABLE:

S.NO.	V	I_f	I_A	W_1	W_2	V_{DC}	I_{DC}	COSØ

RESULT: We have plotted the V curve for a synchronous motor for different values of load**.**

PRECAUTIONS:

1. No loose connection is allowed.
2. Switch on the Supply after checking the connections by faculty/Lab assistant.

3. Take the observation carefully.
4. Wear shoes, while working in machine lab.
5. Don’t touch any live part or wire, it may be dangerous.
6. Vary Rheostat & Autotransformer smoothly.

VIVA QUESTION

1. What do you mean by V-curve in synchronous motor?
2. Why almost all large size Synchronous machines are constructed with rotating field system type?
3. Which type of Synchronous generators are used in Hydro-electric plants and why?
4. What are the applications of synchronous motors?
5. Create the V-curve plots for this motor by plotting the armature current magnitude versus field current. This should be one plot with both power levels?
6. Give the formula of synchronous speed?
7. What do you mean by synchronous speed?
8. Draw the phasor diagram of synchronous motor?

EXPERIMENT NO. -13

AIM: To synchronize an alternator across the infinite bus and control load sharing.

APPARATUS:

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

BASIC CONCEPT:

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

For proper synchronization of alternator-

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

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

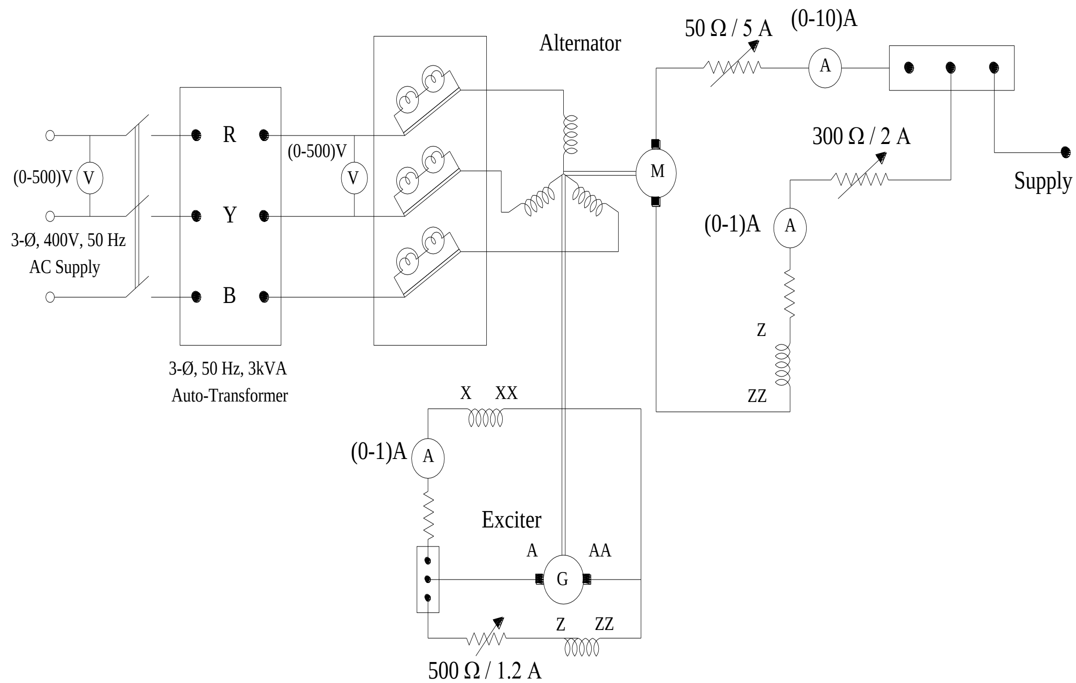
Synchronization by three dark lamp methods:

Connect the D.C. motor -synchronous generator as shown in FIG.2. Start the D.C. motor by switching on S1 and bring its speed to the synchronous speed of the generator (1500-rpm). Adjust the field excitation of the generator using Rf2 and Rf3 so that about rated voltage (400V, L-L) is obtained. Switch on the a.c mains switch S2 and adjust the VARIAC so that Vb is 400 V. Let the phase sequence of the generator terminals RYB be the same as that of the respective terminals of the mains, RYB. The voltage phasors for this condition are shown in FIG.3.If the generator frequency is slightly more than that of the bus, then the phasors R1, Y1 and B1 move anti-clockwise relative to R2, Y2, and B2. The voltages across the lamps L1, L2, L3 (which are indicated by the phasors R1R2, Y1Y2, and B1B2) will increase & decrease simultaneously and therefore, the three lamps will brighten up and darken at the same time. If the phase sequences are R1Y1B1 and R2 B2Y2, the phase diagram of voltages will be as shown in FIG.4. For this condition the voltages across lamps given by phasors R1R2, Y1Y2 and B1B2 are not equal to each other at the instant shown. Therefore the lamps go through their zero voltage one after the other. The phase sequences are thus different and can be corrected by interchanging any two terminals either on the generator side or on the bus side. When such a change is *made both the three-phase main switch S2 and he D.C. main switch S1 should be switched off. With the phase* sequence corrected, if there is a large difference between the frequency of the generator and that of the bus, the lamps will brighten & darken in quick succession. By adjusting the speed of the generator, this rapidity can be reduced, which indicates that the frequencies are coming closer and the lamps will brighten up & darken slowly. The correct moment of synchronization in this method is when all the lamps are completely dark, at which time all the voltages of her bus are exactly in phase with the corresponding voltages of the generator. At this moment the synchronizing switch S3 is closed and the generator is synchronized with the mains. After synchronization do not allow the synchronous machine to run as a motor, i.e. do not allow the wattmeter to read negative. If it reads negative it means that the machine receives power from the a.c mains. In such a case, reduce the excitation of the D.C. motor so that the wattmeter reads a few positive watts.

Study of the influence of the change in input power of the synchronous Generator

After synchronization If is kept constant and the prime -mover excitation Ifpm is slowly decreased taking care that the positive power is shown by the wattmeter which indicates that the machine is only generating. For each value of If pm, Ia, W, V, and the power angle are noted. The power angle may be noted using a stroboscope. The generator may become unstable for higher values of current; care should be taken to switch off the a.c mains then. Load of suitable values is connected to the D.C. bus bar to absorb the D.C. power in the event the synchronous machine operates as a motor. This load is switched on before synchronization.

CIRCUIT DIAGRAM:



Syncronization of Alterantor with RSEB supply(Infinite Bus)

PROCEDURE:

1) Connect the D.C. motor as shown in the circuit diagram.
2) With maximum resistance in the armature circuit start the motor gradually, cutting out the armature resistance and run the motor at speed "ON NO LOAD" at rated terminal voltage.
3) Measure the terminal voltage, current through the armature, current through the shunt field and speed. Note them in observation table.
4) Repeat the same at different speeds**.**

CALCULATION:

Power output, P=

1. Calculate the power factor in each case, Cos f = P/(1.73 Via)
2. Plot power P against d (on X-axis) for different excitations.
3. Plot p.f against P (on X-axis) for different excitations.
4. Plot Ia against P (on X-axis) for different excitations.

5. Suppose lamps 2 & 3 were cross-connected as shown in FIG.5, how will the

Observe the lamps glow for

· Correct phase sequence

· Incorrect phase sequence?

Draw phasor diagrams to justify your results.

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

VIVA QUESTION

1. How does the change in prime mover input affect the load sharing?
2. How does change in excitation affects the load sharing?
3. List the factors that affect the load sharing in parallel operating generators?
4. Why synchronous generators are to be constructed with more synchronous reactance and negligible resistance?
5. What steps are to be taken before disconnecting one Alternator from parallel operation?
6. What is meant by infinite bus-bars?
7. How does increase in excitation of the Alternator connected to infinite bus-bars affect this operation?
8. In what respect does a 1-phase Induction motor differ from a 3-phase Induction motor?
9. State double revolving field theory.
10. State the principle of 3 phase IM?
11. An induction motor is generally analogous to ?
12. Can the starting torque of of a slip ring induction motor being increased?
13. What do you mean by synchronization?
14. What is the effects of variation of excitation on load sharing?
15. What would happen if a 3 phase induction motor is switched on with one phase

disconnected?

EXPERIMENT NO. -14

AIM: To determine the efficiency of two identical D.C. Machine by Hopkinson's regenerative test.

APPARATUS:

Sr.No.	Name of Apparatus	Type	Range	Quantity
1.	Ammeter	MI	0-2 A	2
2.	Ammeter	MI	0-10 A	3
3.	Voltmeter	MI	0-300 V	3
4.	Rheostats		200 Ω,1 A	2
5.	Motor generator set			1

BASIC CONCEPT:

By this method full load test can be carried out on two shunt machines, preferably identical ones, without wasting their output. The two machines are mechanically coupled and are also so adjust that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator and the electrical output of generator is used in supplying the greater part of input to the motor. If there were no losses, generator output is not sufficient to drives the motor and vice-versa. The losses are supplied by electrically from the supply mains.

To calculate the efficiency-

Generator current- I_1

Current taken from supply- I_2

Supply voltage-V

Armature resistance of each machine-R_a

Exciting current of generator-I_3

Exciting current of motor-I_4

Armature Cu loss in generator = $(I_1 + I_3)^2 R_a$

Armature Cu loss in motor = $(I_1 + I_2 - I_4)^2 R_a$

Shunt Cu loss in generator = VI_3

Shunt Cu loss in generator = VI_4

But total motor –generator losses are equal to the power supplied by the mains.

Power drawn from supply = VI_2

If we subtract the armature and shunt Cu losses from this, we get the stray losses of both machines.

Total stray losses for the set = $VI_2 - [(I_1 + I_3)^2 R_a + (I_1 + I_2 - I_4)^2 R_a + VI_3 + VI_4]$= **W** (say)

Stray loss per machine= W/2

For generator -

Total losses = $(I_1 + I_3)^2 R_a + VI_3 + W/2 = W_G$ (say)

Output = VI_1

$\eta_g = VI_1 / (VI_1 + W_G)$ ……..(1)

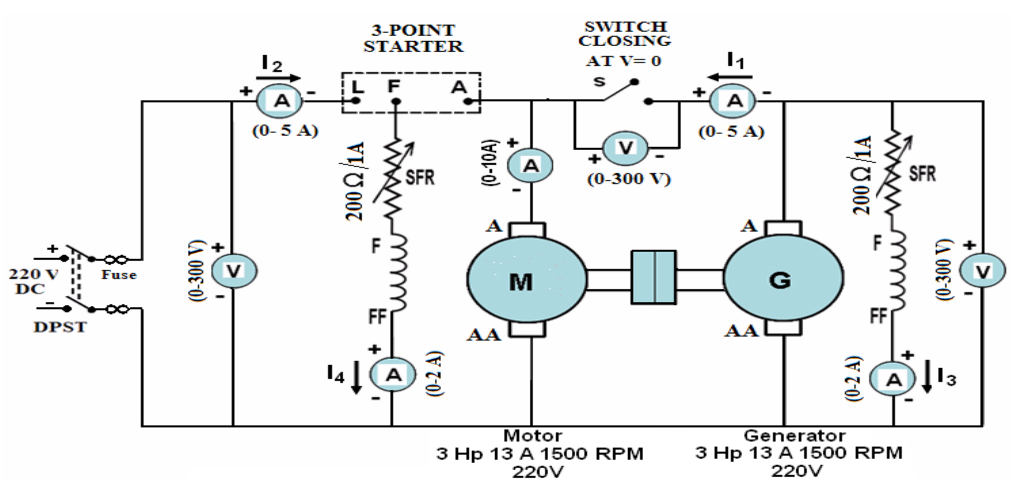
For motor-

Total losses = $(I_1 + I_2 - I_4)^2 R_a + VI_4 + W/2 = W_M$ (say)

Input = $V (I_1 + I_2)$

$\eta_m = V(I_1 + I_2) - W_M / V(I_1 + I_2)$ ……..(2)

CIRCUIT DIAGRAM:



PROCEDURE:

1) Connect the circuit as per the circuit shown in figure.
2) Initially, the switch S interconnecting the two machines should be open.

3) Adjust the field rheostat of the motor, so that motor field current , I_4 is maximum.
4) Adjust the field rheostat of the generator, so that the generator field current, I_3 is minimum.
5) Switch –ON D.C. supply.
6) Start the motor through starter.
7) By using the rheostat of the field circuit of the motor, adjust the speed of the motor to its rated value.
8) Adjust the generated voltage of the generator equal to supply voltage by adjusting its field rheostat.
9) Check the reading of the voltmeter V_1, it should be zero. In case the generator voltage and the supply voltage are of opposite polarities , this voltmeter will read double the supply voltage. In such a case the D.C. supply should be switched-off and the armature terminal of the generator should be reversed. Repeat step 5 to 8. Now the voltmeter should read zero. Once it is ensured close the switch S. The machine operating as generator floats on the D.C. supply. This means the generator neither gives any current to the supply nor takes any current from the supply.
10) Adjust the field current of both the machines so as to achieve a load condition of generator as 10% of the full load value. Repeat this step for values of load current.
11) Reduce the load on the supply to minimum, by adjusting the field rheostat of both the machines. Then Switch-OFF the D.C. supply.
12) Measure the armature resistances of both the machines. This is being measured in the end, so that we can get the value of hot resistance.

OBSERVATION TABLE:

Sr.No	Terminal Voltage V (Volts)	Generator Current I_1 (Amp)	Current taken from supply I_2 (Amp)	Field current of generator I_3 (Amp)	Field current of motor I_4 (Amp)	Total constant losses of M-G set W (Watt)	η_γ	η_μ

1								
2								
3								
4								

CALCULATIONS:

$\eta_g = VI_1 / (VI_1 + W_G)$ …….. (1)

$\eta_m = V(I_1 + I_2) - W_M / V(I_1 + I_2)$ ……..(2)

Where $W = VI_2 - [(I_1 + I_3)^2 R_a + (I_1 + I_2 - I_4)^2 R_a + VI_3 + VI_4]$

RESULTS: The efficiency of the DC machine as obtained by the Hopkinsion's Test is …

PRECAUTIONS:

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

VIVA QUESTION

1) How you will define the efficiency of a machine and how you will calculate the efficiency of D.C. generator and D.C. motor?
2) Why two identical machines are used to perform the HOPKINSON'S test?
3) Why this test is called regenerative?
4) Why it is also called BACK to BACK test?
5) Can a D.C. shunt motor work as a D.C. shunt generator? How?
6) What is the condition of maximum efficiency of D.C. machine?
7) What is the difference in efficiencies of two identical machines? Justify your answer?
8) What are the advantages and disadvantages of this test?

9) If efficiencies of both machines are equal say $\eta_g = \eta_m = \eta$ and armature current in generator is I_{ag} and armature current in motor is I_{am} then what will be the relation of these currents with efficiency?