DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- IV

ELECTRIC MACHINE II LAB
Subject code: LC-EE-208G

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

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Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and Managers competent to match the expanding expectations of the Corporate World has been our ever enlarging vision extending to new horizons since the inception of Dronacharya College of Engineering.

Mission:

M1: To serve the society and improve the mode of life by imparting high quality education in the field of Engineering and Management catering to the explicit and implicit needs of the students, society, humanity and industry.

M2: To create an inspiring ambience that raises the motivation level for conducting quality research

M3: To provide an environment for acquiring ethical values and positive attitude.

Vision and Mission of the Department

Vision:

"Our vision for the Electrical and Electronics Engineering (EEE) Department is to be a globally recognized centre of excellence in education, research, and innovation in the field of electrical and electronics engineering. We strive to produce competent engineers with strong technical knowledge, ethical values, and a passion for lifelong learning. And also to contribute to the sustainable development of society through cutting-edge research, industry collaborations, and community engagement"

Mission:

M1: To provide a high-quality education that equips students with a strong foundation in electrical and electronics engineering.

M2: To conduct pioneering research in diverse areas of electrical and electronics engineering

M3: To establish strong ties with industry partners to bridge the gap between academia and the professional world.

M4: To instilling ethical values, social responsibility, and environmental consciousness in our students.

M5: To regularly assess and upgrade our teaching methodologies, infrastructure, and facilities

Programme Educational Objectives (PEOs)

PEO 1. Engineers will practice the profession of engineering using a systems perspective and analyse, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2. Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3. Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4. Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5. Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: 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.

PO3: 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.

PO4: 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.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and software tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: 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.

PO7: 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.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: 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.

PO11: 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.

PO12: 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.

Programme Specific Outcomes (PSOs)

PSO1: Equip themselves to potentially rich & employable field of Engineering. Analyse and design electrical machines, circuits, controls and systems which makes the part of Power generation, transmission, distribution, utilization and conservation

PSO2: Pursue higher studies in the contemporary Technologies and multidisciplinary fields with an inclination towards continuous learning in the area of Power quality, high voltage, power electronics and Renewable energy systems

PSO3: Take up-self- employment in Indian and global software market in designing, implementing and testing analog, digital, embedded and signal processing systems

PSO4: Meet the requirements of the Indian Standards and use knowledge in different domains to identify the research gaps and to provide innovative solutions.

University Syllabus

1. To perform the open circuit test and block rotor test on 3 phase induction motor and draw the circle diagram.
2. To study the speed control of induction motor by rotor resistance control.
3. To conduct the load test to determine the performance characteristics of the I.M.
4. To compute the torque v/s speed characteristics for various stator voltages.
5. To perform the open circuit test and block rotor test on single-phase induction motor and determine equivalent circuit parameters.
6. To perform O.C. test on synchronous generator and determine the full load regulation of a three phase synchronous generator by synchronous impedance method.
7. To Study and Measure Synchronous Impedance and Short circuit ratio of Synchronous Generator.
8. Study of Power (Load) sharing between two Three Phase alternators in parallel operation Condition.
9. To plot V- Curve of synchronous motor.
10. Synchronization of two Three Phase Alternators by
    a) Synchroscope Method
    b) Three dark lamp Method
    c) Two bright one dark lamp Method
11. Determination of sequence impedances of synchronous machine for various stator voltages

Course Outcomes (COs)

Upon successful completion of the course, the student will be able to:

CO1: Able to perform different tests and demonstrate the various characteristics of three phase Induction Motor

CO2: Able to perform different tests and demonstrate the various characteristics of single Induction Motor

CO3: Able to demonstrate the working of 3-phase Synchronous machines under different operating conditions

CO4: Able to evaluate the performance and synchronization of three phase alternators

CO5: Able to determine the sequence parameters of Synchronous machines

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	1	2	2	1	1				1	2	1
CO2	3	1	2	1	1	3				3	2	2
CO3	3	2	2	2	1	2				2	2	3
CO4	2	3	2	2	2	3				2	3	2
CO5	2	2	3	3	3	2				2	2	2
Average	**2.6**	**1.8**	**2.2**	**2**	**1.6**	**2.2**				**2**	**2.2**	**2**

CO-PSO Mapping

	PSO1	PSO2	PSO3
CO1	2	2	1
CO2	2	2	3
CO3	1	2	2
CO4	2	2	3
CO5	2	3	3
Average	**1.8**	**2.2**	**2.4**

Course Overview

This is the fundamental course for the Electrical Engineering program. Also an extension to the previous semester subject, Electrical Machines –I. It introduces the basic working principle and operation of different types of Induction Motor. It also provides the basic information of its operation, speed control and characteristics.

It also gives their performance when connected in the power circuits. It also gives the invention of single phase Induction motors and their analogy with transformer construction and operation. As the induction motor is one of the important load used in all applications it is very much necessary to know about the construction, types, losses and working of different types of induction motors. It also tells us the different methods of finding the efficiency of induction motor. Also tells us different speed controlling techniques available for induction motors.

It deals about Synchronous Motor, synchronous Generator and the testing aspects of their performance. Power sharing between two three phase alternators and parallel operation condition. Methods of synchronization and its importance are also described for parallel operation.

Finally this subject gives the information of two important electrical utilities in the power transmission, distribution and utilization.

List of Experiments mapped with COs

S. No.	Name of the Experiments	Course Outcome
1	To perform the open circuit test and block rotor test on 3 phase induction motor and draw the circle diagram	CO1, CO4
2	To study the speed control of induction motor by rotor resistance control	CO2
3	To conduct the load test to determine the performance characteristics of the I.M.	CO3, CO4
4	To compute the torque v/s speed characteristics for various stator voltages.	CO3
5	To perform the open circuit test and block rotor test on single-phase induction motor and determine equivalent circuit parameters	CO2, CO3
6	To perform O.C. test on synchronous generator and determine the full load regulation of a three phase synchronous generator by synchronous impedance method	CO5
7	To Study and Measure Synchronous Impedance and Short circuit ratio of Synchronous Generator	CO4, CO3
8	Study of Power (Load) sharing between two Three Phase alternators in parallel operation Condition.	CO3
9	To plot V- Curve of synchronous motor	CO2
10	Synchronization of two Three Phase Alternators by a) Synchroscope Method b) Three dark lamp Method c) Two bright one dark lamp Method	CO5
11	Determination of sequence impedances of synchronous machine for various stator voltages	CO3

Dos and DONT's

Dos

1. Avoid contact with energized electrical circuit.
2. While handling any equipment, be sure that hands are dry and when possible wear non-conductive gloves and shoes with insulated soles.
3. If water or any chemical is spilled on to equipment, shut off power at the main switch or MCB and unplug the equipment.
4. If an individual comes in contact with a live electrical conductor, do not touch the equipment, wire or person. Shut off power at the main switch or MCB.
5. Select proper range of meters and type (AC, DC) of the supply.
6. Be sure you understand the function and wiring of an instrument before using it in the circuit.
7. Students should carry notes and records completed in all aspects and get it verified by the teacher.
8. The connections done should be checked by the teacher in charge/ technical assistant before switching ON the supply.
9. All patch cords and stools should be put back to proper position after completion of the experiment.
10. After completion of the experiment, components must be submitted properly to the lab in-charge.
11. Always wear shoes without any conducting material.
12. Be punctual, maintain discipline & silence
13. After completion of Experiment, return the bread board, trainer kits, wires, CRO probes and other components to lab in-charge.
14. Note the working range of electrical parameters of the machine and concern equipment /measuring device

DON'Ts

1. Don't exceed the permissible values of Current, Voltages and /or speed of any machines, apparatus, load etc.
2. Don't make circuit changes or perform any wiring when power is on.
3. Don't switch ON the supply without verifying by the Staff Member.
4. Don't leave the lab without the permission of the Lab In-Charge.
5. Don't use any machine if there is a smoke, spark.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.

2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.

3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.

4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.

2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth if possible isolate the burning equipment from the other surrounding equipment.

3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

4. Call security and emergency department immediately:

Emergency: Reception

Security : Main Gate

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows: -

1) All files must contain a title page followed by an index page. **The files will not be signed by the faculty without an entry in the index page.**

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.
3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Apparatus required with specification and Name plate details

(iii) Circuit diagrams, procedures, observations and calculations

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.

2. Students must ensure that their lab record is regularly evaluated.

Lab Assessment Criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes are assessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

Grading Criteria	Exemplary (4)	Competent (3)	Needs Improvement (2)	Poor (1)
AC1: **Pre-Lab written work (this may be assessed through viva)**	Complete procedure with underlined concept is properly written	Underlined concept is written but procedure is incomplete	Not able to write concept and procedure	Underlined concept is not clearly understood
AC2: **Circuit Diagram / Connection**	Circuit diagram must be neatly drawn and specification of instrument / equipment properly specified. Connection should be properly given	Circuit diagram drawn and connection given	Circuit diagram and connection to be given as per directions.	Circuit diagram is not proper. Unable to give connection as per circuit diagram.
AC3: **Identification of problems in running the equipment and note down the reading**	Able to identify the mistakes while running the machine and note down the reading accurately by varying all the related parameters	Able to identify the mistakes while running the machine and note down the reading by varying the parameters	Only few readings are taken and varying parameter is not proper	Unable to identify the mistakes
AC4: **Final Demonstration and Execution**	All variants of input /output are measured, experiment is well demonstrated and implemented concept is clearly explained	All variants of input /output are not measured, experiment is demonstrated and implemented concept is clearly explained	Only few variants are measured, experiment is demonstrated and implemented concept is not clearly explained	Not well demonstrated and not explained the concept

AC5: **Lab Record Assessment**	All the readings are properly recorded and model calculations properly executed and performance analysis- results are plotted with graph (if necessary)	70 % calculations are done results and performance analysis are plotted with graph	Less than 70 % calculations are done results are plotted with graph if necessary	Not completed

LAB EXPERIMENTS

LAB EXPERIMENT 1

To perform the open circuit test and block rotor test on 3 phase induction motor and draw the circle diagram

AIM: To determine the equivalent circuit of a 3- ϕ induction motor and calculate various parameters of induction motor with the help of circle diagram.

Apparatus:

0-300 V A.C. Voltmeter 0l

0-10 A A.C. Ammeter 0l

0-3.0 KW A.C. Wattmeter 0l

0-2000 rpm A.C. Tachometer 0l

3-phase 16 Amps Auto - Transformer 0l

Motor Ratings:

Power: 3.7 KW

Voltage: 415 Volts

Current: 7.9 Amps

Speed: 1430 rpm

Connection: Star

3- ϕ Auto transformer Details:

Input Voltage: 415V

Output Voltage: 0-470V

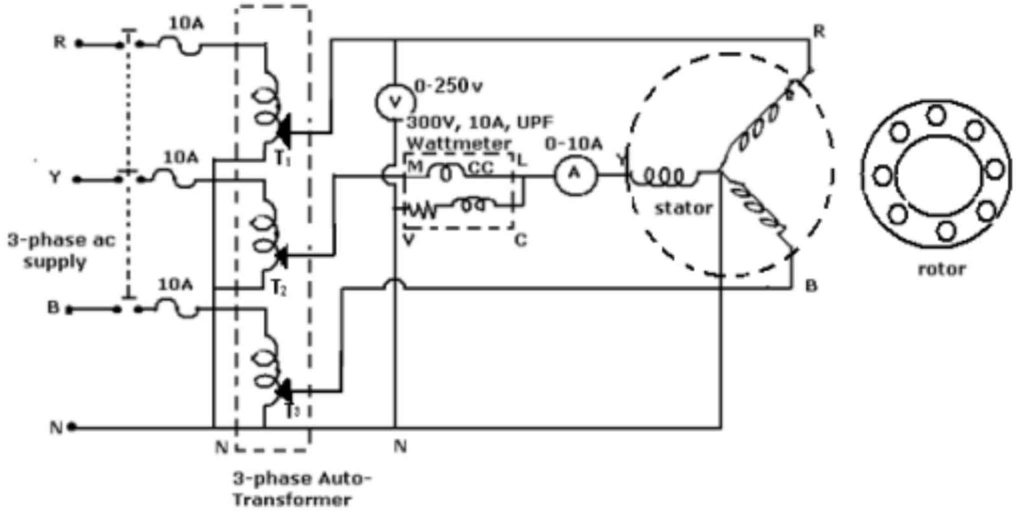
Current:______________________ (Amp.)

PRE-EXPERIMENT QUESTIONS

Q1. What is the difference between the transformer equivalent circuit and induction motor equivalent circuit?

Q2. What are the reasons in conducting no-load test with rated voltage and blocked rotor test with rated current?

CIRCUIT DIAGRAM



Theory:

This test is used to determine the no load current Io, power factor, cosϕ, wind age & friction losses, core losses, no load resistance Ro and magnetizing reactance Xo.

The motor is uncoupled from its load and rated voltage is applied to the stator. Since there is no output, the power supplied to-the stator is the sum of its copper losses, core losses and friction and wind-age losses.

The no load test is carried out with different values of applied voltage, at below and above the normal voltage. The power input is Measured by the two wattmeter, Io by an ammeter and V by a voltmeter. The total power input will be the difference of the two wattmeter reading W1 and W2. The readings of the total power input are Wo, Io and voltage V are plotted. If we subtract loss corresponding to OA from Wo, then we get the no-load electrical and magnetic losses in the machine, because the no-load input Wo to the motor consists of (i) small stator Cu loss $3Io^2 R1$ (ii) Stator core loss $Wc = 3 Go Vc^2$ (iii) Loss due to friction and windage. Hence knowing the core loss Wc, Go and Bo can be found.

$\cos\phi_0 = Wo / (\sqrt{3} Vc\ Io)$

Where Vc = Line voltage and W0 is no-load stator input.

PROCEDURE:

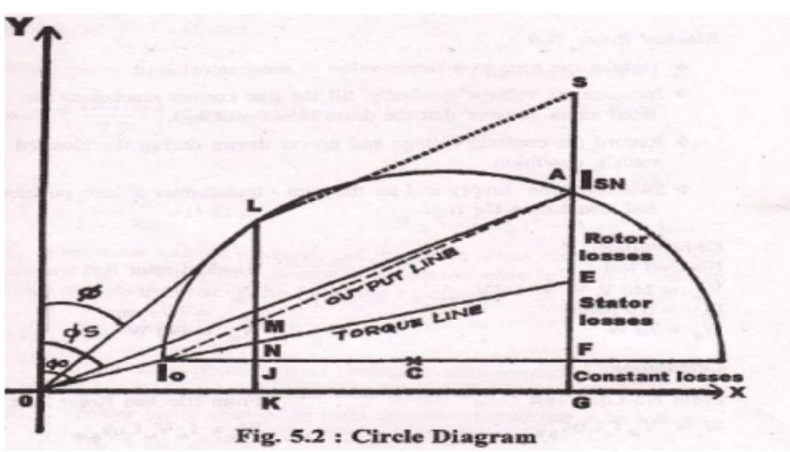
NO- LOAD TEST:

- Connections are made as per the circuit diagram.
- Loosen the rope on the brake drum.
- Push the start button and increase the voltage till the voltmeter reads the phase voltage, 230 V.
- Record the No-load current, voltage, power drawn in each phase and speed
- . • Slowly tighten the rope and record the T1 &T2 (readings of the Tension meters), line current, voltage, power drawn in each phase and rpm at different loads.
- Tight the rope (Increase the load) till the ammeter reads the rated current and record the current, voltage, power and speed.
- Switch-off the supply and set the auto-transformer at zero position.

BLOCKED ROTOR TEST:

Blocked rotor test: - This test is also known as locked-rotor or short-circuit test. It is used to find out (i) short-circuit current with normal voltage applied to the stator. (ii) Power factor at short-circuit condition. Both these values are used for the construction of the circle diagram

- Tighten the rope to a larger value of mechanical load
- Increase the voltage gradually, till the line current reaches to the rated value. (Ensure that the drum is not rotating)
- Record the current, voltage and power drawn, during the blocked rotor's condition
- Switch off the supply and set the auto - transformer at zero position and also loosen the rope



Circle Diagram

OBSERVATIONS:

No-load test :

V_{ph} =24OV, V_L= 415V

I_0 = 0.9 AmPs

W_0 =70w

Blocked Rotor Test

V_{sc} = 125V

I_{sc} =7.9A

W_{sc} = 490 W

Calculations:

From No-Load Test:

$W_0 = V_{ph} I_0 \cos\phi_0$

$\cos\phi_0 = \frac{W0}{Vph\ X\ Iph} = \frac{70}{0.9\ X\ 240} = 0.324.$

$\phi_0 = 71.10$

$I_{SN} = I_{SC}\ X\ \frac{Vph}{Vsc} = 15.168$ A

Total power Input

$=490(15.168/7.9)^2=1806.34$ W

From Blocked Rotor Test:

$W_{sc} = I_{sc}\ V_{sc}\cos\phi_{sc}$

$\cos\phi_{sc} = \frac{490}{7.9\ X\ 125} = 0.496$

$\phi_{sc} = 60.25^0$

Total losses = $W_{sc} + W_0$

= 560W

$I_{sc}^2 R_{01} = W_{sc}$

$R_{01} = 560/7.9^2 = 8.972\ \Omega.$

$Z_{01} = V_{sc} / I_{sc} = 15.82\ \Omega.$

$\therefore X_{01} = \sqrt{(Z01)^2 - (R01)^2} = 13.14\ \Omega$

X_{01} is the total leakage reactance of the motor when referred to primary (stator). R_{01} is the total resistance of the motor when referred to primary. These are obtained using the following equations: -

(a) $I_{SN} = \frac{IscXV}{Vsc}$

I_{SN} = Short-circuit current obtainable with normal V_1

I_{sc} = Short-circuit current with voltage V_{sc}

(b) Power factor calcularion from short circuit test is as follows:

$W_{sc} = I_{sc} V_{sc}\cos\phi_{sc}$

$\therefore \cos\phi_{sc} = \frac{Wsc}{Vsc\ X\ Isc}$

Where W_{sc} = total power input at short-circuit condition

V_{sc} = line voltage at the short-circuit condition

I_{sc} = line current at short-circuit condition

(c) Total cu loss = $W_{sc} - W_0$

$3I_2^2 R_{01} = W_{sc} - W_0$, $R_{01} = \frac{Wsc - W0}{3I2^2}$

$Z_{01} = V_{sc}/I_{sc}$, $X_{01} = \sqrt{(Z01)^2 - (R01)^2}$

MODEL CALCULATIONS:

$G=W_0/3V_2$, $Y_0=I_0/V$, $B_0=Y_0^2-G_0^2$

$Z_{01}=V_{sc}/I_{sc}$, $R=W_{sc}/3xI_{sc}^2$, $X_{01}=\sqrt{}Z_{01}^2-R_{01}^2$

For circle diagrm:

$\cos\Phi_0=W_0/\sqrt{3}\ V_0I_0$, $\Phi_0=\cos^{-1}(W_0/\sqrt{3}\ V_0I_0)$

$\cos\Phi_{sc}=W_{sc}/\sqrt{3}\ V_{sc}I_{sc}$, $I_{sn}=I_{sc}(V/V_{sc})$;

PRECAUTIONS:

1. Connections must be made tight
2. Before making or breaking the circuit, supply must be switched off

RESULT:

Thus, the no-load and blocked rotor tests are conducted on a 3-Phase squirrel cage induction motor and then the circle diagram is drawn.

POST-EXPERIMENT QUESTIONS:

Q1. Explain why the locus of the induction motor current is a circle.

Q2.Why do you choose LPF wattmeter in load test and HPF wattmeter in blocked rotor test?

Q3. How do you reverse the direction of rotation of induction motor?

Q4. What are the various applications of this motor?

LAB EXPERIMENT 2

To study the speed control of induction motor by rotor resistance control

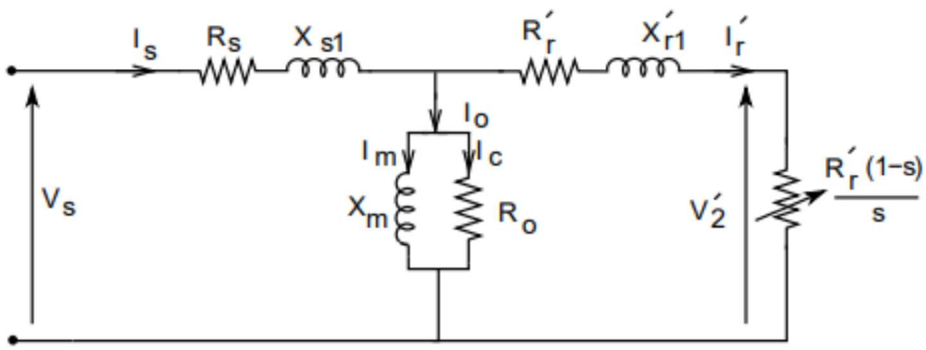
Aim

To use variable resistance in the rotor circuit to control wound rotor induction motor speed

Theory

Polyphase induction motors are mainly of two types by construction, squirrel cage and wound-rotor (with slip-rings). In the case of a squirrel cage induction motor, the rotor is inaccessible and rotor circuit resistance is fixed, whereas the wound-rotor machines are provided with slip-rings by which additional resistance can be connected in series with the machine rotor. Terminals are brought out from each phase for connecting external resistances.

The motor speed is a function of its rotor resistance. This is evident from the equivalent circuit shown in Fig.(1) and the subsequent equations (1-3).



Per phase equivalent circuit of Induction Motor

To determine expressions for torque and power, the equivalent circuit in Fig.(1) must be analyzed using its Thevenin equivalent looking into the network from the rotor side. The stator impedance $R_s + jX_{s1}$ and the magnetization branch jX_m (neglecting resistance) converted to Thevenin impedance are given by $R_e + jX_e$. The equivalent Thevenin voltage is given by V_e. With this, the rotor current I_r' is given by

$$I_r = \frac{V_e}{(R_e + \frac{R_r'}{s}) + j(X_e + X_{r1}')} \qquad (1)$$

The rotor mechanical torque developed is given by (1).

$$T_{mech} = \frac{P_{mech}}{\omega_m} = \frac{P_{air-gap}}{\omega_s} \qquad (2)$$

The mechanical torque produced is thus a function of rotor resistance and the slip. It builds up with increase in rotor speed. The total or three phase torque is given by

$$T_e = 3I_r^2\frac{R_r'}{s}$$
$$= 3\frac{V_e^2/\omega_s}{(R_e + \frac{R_r'}{s})^2 + (X_e + X_{r1}')^2}(\frac{R_r'}{s}) \qquad (3)$$

At low values of slip (s), i.e near synchronous speed, the term $\frac{R_r'}{s}$ dominates the other denominator terms, the effective torque thus reduces to

$$T_e = 3\frac{sV_e^2/\omega_s}{R_r'} \qquad (4)$$

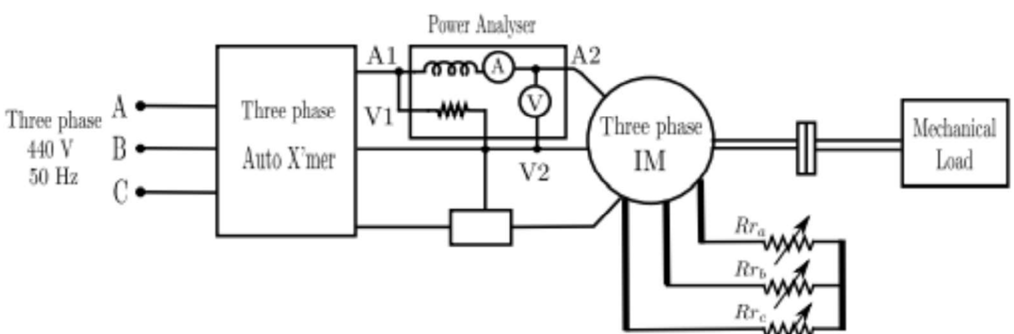
The above expression in (4), can be used to determine the effect of varying rotor resistance on the electromagnetic torque developed in the motor. As the rotor resistance is reduced, the torque increases almost linearly for near-synchronous speed operation. For slip-ring induction motors, rotor terminals are brought out and rheostats of suitable range can be connected in each phase.

PRE-EXPERIMENT QUESTIONS:

Q1. What are some of the other methods for induction machine speed control?

Q2. Name the types of Induction Machines

Procedure



Circuit Diagram for blocked-rotor test on 3 Phase Induction Motor

A. Note down the machine ratings and calculate rated current of the machine if not available

B. Connect a rheostat in each of the rotor phases brought out via the terminal box mounted on top of the machine. Keep the rheostats at the maximum positions

C. With the rheostats in maximum resistance position, slowly apply the three-phase input voltage to the stator terminals using the three-phase variac.

D. As the machine speeds up, adjust the rheostats such that each phase has equal resistances cut out (decreased) in steps.

E. Cut out the full external rotor resistance in steps and simultaneously record the machine speed.

F. Slowly decrease the applied stator voltage to zero.

Observation

SL NO	Voltage V (volt)	Rotor Current I (amp)	External Rotor Resistance R_2 (Ω)	Speed N (rpm)
1				
2				
3				
4				
5				

POST- EXPERIMENT QUESTIONS:

Q1. How the speed control of Cage motor is achieved?

Q2. How the speed control on below / above rated can be achieved

RESULT:

Draw the speed vs. rotor resistance curve of slip ring induction motor.

LAB EXPERIMENT 3

To conduct the load test to determine the performance characteristics of the I.M

AIM: To perform load test on three phase induction motor to obtain the performance characteristic

APPARATUS:

Sl No	Apparatus Name	Specification	Quantity
1)	Ammeter		
2)	Voltmeter		
3)	Wattmeter		
4)	Auto Transformer		
5)	Tachometer		

Electrical Machine Specifications:

Induction Motor: HP: __________

Voltage:_____________

Current: _______________

Speed: ________________

Theory:

The load test on induction motor helps us to compute the complete performance of induction motor means to calculate the various quantities i.e. torque, slip, efficiency, power factor etc at different loading. In this test supply voltage is applied to motor and variable mechanical load is applied to the shaft of motor. Mechanical load can be provided by brake and pulley arrangement. The input current, input voltage, input power and speed of motor are observed from the experiment and various performance quantities are calculated as explain below.

Slip: Due to the three-phase supply given to stator of an induction motor, a rotating magnetic field of constant magnitude is set up in the stator of the motor. The speed with which this rotating magnetic field rotates is known as synchronous speed and is given by

$Ns = 120 \quad / P$

Where f =supply frequency.

P = No. of poles on the stator of the rotor.

The actual speed of the rotor Nr is always less than the synchronous speed. So the slip of the motor is given by following equation. This value of slip at full load lies between 2 to 5%.

$s = (Ns - Nr) / Ns \ X \ 100$

Torque: Mechanical loading is applied on induction motor by means of brake and pulley arrangement. The belt can be tightened or loosened by means of threaded rods with handles fixed on frame. Two spring balances are provided at the end of belt. The net force exerted at the brake drum can be obtained from the readings of the two spring balance i.e. S1 and S2

Net force exerted on drum,

$W = (S1 - S2)\ Kg$f

$T = d\ 2 * W * 9.8\ Nw -$ m

Where d = effective diameter of brake drum in meter.

Output Power:

The output power of induction motor can be calculated as

$$P = \frac{2\,\pi\,N_r T}{60}$$

Where Nr is speed of motor in rpm

Input Power:

The input power can be calculated from the readings of two wattmeter connected in the circuit W1 and W2 Pi = W1 + W2 At low power i.e. under no load condition one of the wattmeter may read negative. In that case the connection of one wattmeter coil either pressure coil or current coil should be reversed however such reading should be recorded as negative reading. **Power Factor:**

The power factor can be calculated from the two wattmeter reading using following relation

$$\tan\varphi = \sqrt{3}\ \frac{W_1 - W_2}{W_1 + W_2}$$

Once the angle Φ is known, the power factor, cosΦ can be easily known.

Efficiency:

Efficiency can be calculated using

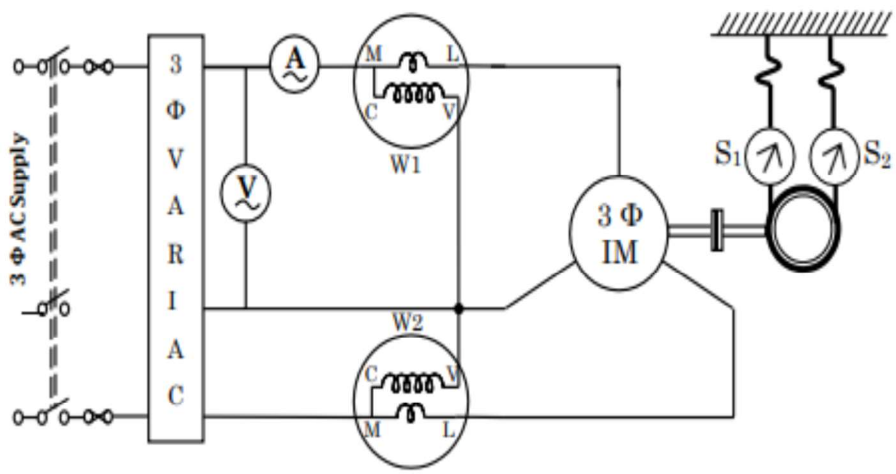
$\eta = (output\ power) / (input\ power)\ X\ 100$

PRE- EXPERIMENT QUESTIONS

Q1. What is meant by Load test on Induction Machines?

Q2. What is meant by efficiency?

CIRCUIT DIAGRAM:



PROCEDURE:

1. Connect the circuit as shown in Fig.

. Set three-phase variac for minimum voltage and brake pulley arrangement is set for no load.

3. Switch ON the power supply and start the induction motor.

4. Now gradually increase applied voltage by varying the variac very slowly up to the rated voltage.

5. Increase the mechanical load on motor step by step and note down the reading at each step.

6. Switch OFF the supply and disconnect the motor.

OBSERVATION TABLE:

SL NO	Input Voltage V (volt)	Input Current I (amp)	Input Power		Force (Kgf)			Speed
			W_1 (watt)	W_2 (watt)	S_1	S_2	$W = S_1 - S_2$	N_r (rpm)
1								
2								
3								
4								
5								

Diameter of pulley, d =____ m.

Calculation :

SL NO	Input Power Pin (watt)	Total Force W (Kgf)	Output Torque T (Nw-m)	Output Power P_o (watt)	Slip (%)	Power Factor cosΦ	Efficiency (%)
1							
2							
3							
4							
5							

PRECAUTIONS:

1. All connections should be neat and tight.
2. Special care should be taken about the sign of the readings of watt meter.
3. Special attention should be given for cooling of the break pulley, otherwise the wearing out of belt may be very rapid.
4. The current ratings should be-given special care while selecting wattmeter.

POST-EXPERIMENT QUESTIONS:

Q1. How the performance is being analysed in this experiment

Q2. What is the maximum load that can be added to conduct load test?

Result:

Draw the following curve of three-phase slip ring induction motor

a) Efficiency vs. output power

b) Torque vs. output power

c) Line current vs. output power

d) Power factor vs. output power

e) Slip vs. output power

f) Torque vs. slip.

LAB EXPERIMENT 4

To compute the torque v/s speed characteristics for various stator voltages

AIM: To compute the torque v/s speed characteristics for various stator voltages.

THEORY:

An induction motor compared to a dc motor has some major advantages such as - Absence of brushes, commutator segments, rugged construction, being cheap, lesser maintenance requirements and smaller size for the same power output. Due to these advantages induction machines have become more popular in industrial applications. For any motor load application, it is imperative to know the torque speed characteristic of the motor. Consider a three phase squirrel cage induction motor whose stator has three windings displaced in space by 120◦. When they are excited with currents that are displaced in time by 120◦, a rotating magnetic field rotating at a speed called synchronous speed Ns is set up. The synchronous speed, Ns is given by (1).

$$N_s = \frac{120f}{P} \tag{1}$$

where, f is the frequency of the currents and P is the number of poles. If the rotor of the induction motor rotates at a speed, N_r, then the slip, s is defined by (2).

$$s = \frac{N_s - N_r}{N_s} \tag{2}$$

The torque developed by the induction motor is given by (3).

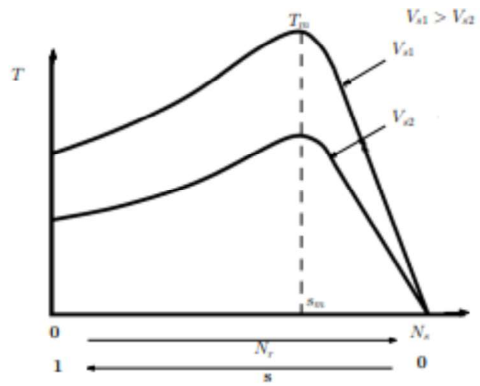
$$T = \frac{3}{\omega_s}\frac{I_2{}^2R_2}{s} = \frac{3}{\omega_s}\frac{V_s{}^2R_2/s}{(R_1 + R_2/s)^2 + (X_1 + X_2)^2} \tag{3}$$

where ω_s is the synchronous speed in rps, V_s is the voltage applied to the stator, I_2, R_2, X_2 are the rotor current, resistance and reactance referred to stator respectively. R_1, X_1 are the stator resistance and reactance respectively. If (3) is plotted, we get the T-N_r characteristics as shown in Fig. 1. The maximum torque developed, T_m and the slip,s_m at which T_m occurs is given by (4).

$$T_m = \frac{3}{2\omega_s}\frac{V_s^2}{R_1 \pm \sqrt{R_1{}^2 \pm (X_1 + X_2)^2}}$$
$$s_m = \frac{R_2}{\sqrt{R_1{}^2 + (X_1 + X_2)^2}} \tag{4}$$

T-Nr characteristics with variable stator voltage

If voltage applied to the stator of the induction motor is varied, developed torque will vary with a relation $T \propto V_s^2$. The maximum torque developed, Tm is also proportional to square of the applied voltage as in (4), but sm is independent of applied voltage. So, if the T-Nr characteristics is plotted for different voltages, we get the characteristics as shown in Fig.



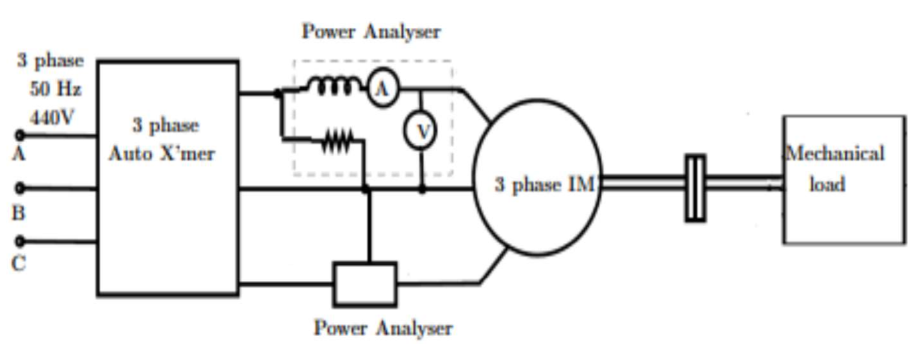
T-N_r characteristics of a three phase induction motor with variable voltage control

PRE-EXPERIMENT QUESTIONS:

Q1. Why speed control is necessary?

Q2. State the relation between Torque and Speed

CIRCUIT DIAGRAM:



Circuit diagram for variable voltage control

PROCEDURE:

A. Connect the circuit as shown in figure . In this experiment the motor is loaded with a mechanical system.
B. Initially no load is applied to the motor. Set the output of the autotransformer to zero and switch on the three phase supply.
C. Vary the voltage applied to the stator using autotransformer. Increase the voltage to half the rated value. Increase the load slowly to get different torque and speed points to get the T-Nr characteristics at half the rated voltage. Make sure that the motor is not loaded above its rated current.
D. Now reduce the load to zero and repeat the same steps [A-C] with rated voltage applied to the stator.
E. Bring the load to zero. Then bring the autotransformer to zero position and switch off the supply.

POST-EXPERIMENT QUESTIONS

Q1. What is the advantage and disadvantage of stator voltage control?

Q2. What is the function of Auto- Transformer here?

RESULT:

Thus we have computed the torque v/s speed characteristics for various stator voltages.

LAB EXPERIMENT 5

To perform the open circuit test and block rotor test on single-phase induction motor and determine equivalent circuit parameters

AIM: To perform the open circuit test and block rotor test on single-phase induction motor and determine equivalent circuit parameters

Name Plate details:

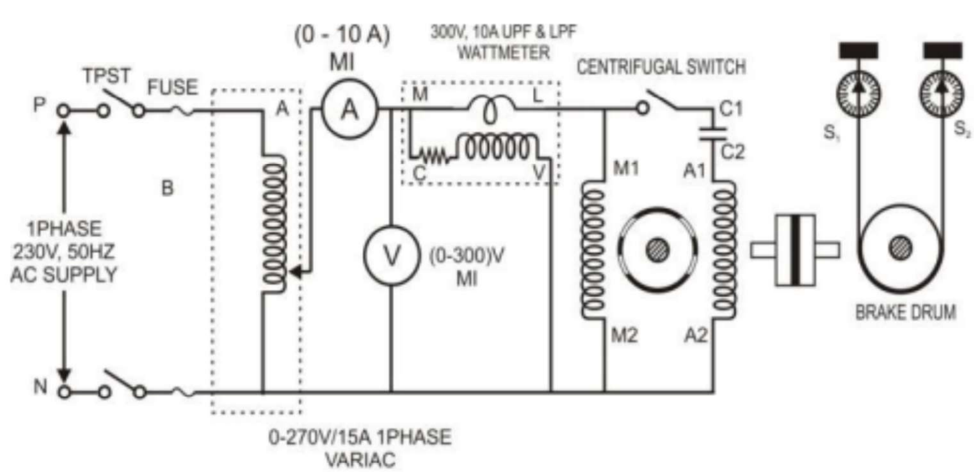
Motor

HP	
Voltage	
Current	
Output	
Speed	

Apparatus:

NAME	RANGE	TYPE	QUANTITY
Ammeter			
Ammeter			
Voltmeter			
Voltmeter			

CIRCUIT DIAGRAM:



PRE-EXPERIMENT QUESTIONS

Q1. Why star point of the motor is not connected to neutral point of the supply?

Q2.Does the motor start when supply lines are connected?

Q3.What are the two different types of rotors?

PROCEDURE:

OPEN CIRCUIT OR NO-LOAD TEST

1. Connections are made as per the circuit diagram.
2. Apply the rated voltage to the induction motor by varying auto transformer, so that the machine runs at rated speed.
3. Note down the corresponding Ammeter, Voltmeter and Wattmeter readings
4. Restore the autotransformer to its initial position, and switch off the supply.

BLOCKED ROTOR TEST

1. Connections are made as per the circuit diagram
2. Block the rotor with the help of brake drum arrangement.
3. Vary the supply voltage with the help of autotransformer so that the ammeter reads rated current and note down the corresponding Ammeter, Voltmeter and Wattmeter readings.
4. Reduce voltage to zero with auto transformer and switch off the supply.

OBSERVATION TABLE:

BLOCKED ROTOR TEST

S.No	V_{sc} (Volts)	I_{sc} (amps)	W_{sc} (W)

NO LOAD TEST

S.No	V_o(Volts)	I_o(Amps)	W_o (W)

CALCULATIONS:

No-Load test

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

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

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

$$X_o = Z_o \sin\phi_o \qquad =$$

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

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

Blocked Rotor Test

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

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

r_1 is the DC resistance of stator of motor

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

$$x_1 + x_2 = X_{sc} \qquad = \Omega$$

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

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

PRECAUTIONS:

1. While conducting the Block rotor test, never apply the full voltage. Gradually increase the voltage from zero till full load current Flows in the circuit.

2. While conducting the no load test, make sure that brake drum is Released fully.

3. Under blocked rotor test, auxiliary winding should be opened before the start of the blocked rotor test.

RESULTS:

Thus we have performed the open circuit test and block rotor test on single-phase induction motor and determine d equivalent circuit parameters

POST-EXPERIMENT QUESTIONS

Q1. How do you change the direction of rotation?

Q2. Draw a two-phase supply waveform & leading current, lagging current with respect to the voltage.

Q3. Draw the 3-phase supply waveform & leading current, lagging current, with respect to the voltage.

Q4. What is the advantage of star-delta starter when compared to D.O.L Starter?

Q5. For a 6-pole machine what is the value of synchronous speed?

Q6. Why slip cannot be zero in induction motor.

LAB EXPERIMENT 6

To perform O.C. test on synchronous generator and determine the full load regulation of a three phase synchronous generator by synchronous impedance method

AIM: To perform O.C. test on synchronous generator and determine the full load regulation of a three phase synchronous generator by synchronous impedance method.

APPARATUS:

Sl. No.	Equipment	Type	Range	Quantity
1	Voltmeter	MI	(0-300/600)V	1 no
2	Ammeter	MI	(0-5/10)A	1 no
3	Ammeter	MI	(0-2.5/5)A	1 no
3	Rheostat	Wire-wound	400 Ω /1.7A 145Ω /2A	1 no 2 no
4	Tachometer	Digital	*****	1 no
5	Connecting Wires	*****	*****	Required

Name Plate Details

DC Motor(prime mover)	3- ϕ Alternator
KW : 3	Power Rating: 3
Voltage : 220V	PF :LAG
Current : 15A	Line voltage: 440V
Speed : 1500RPM	Speed 1500RP
Exctn : Shunt	Exctn Voltage:230V
Voltage :220V	Rated Current :15A

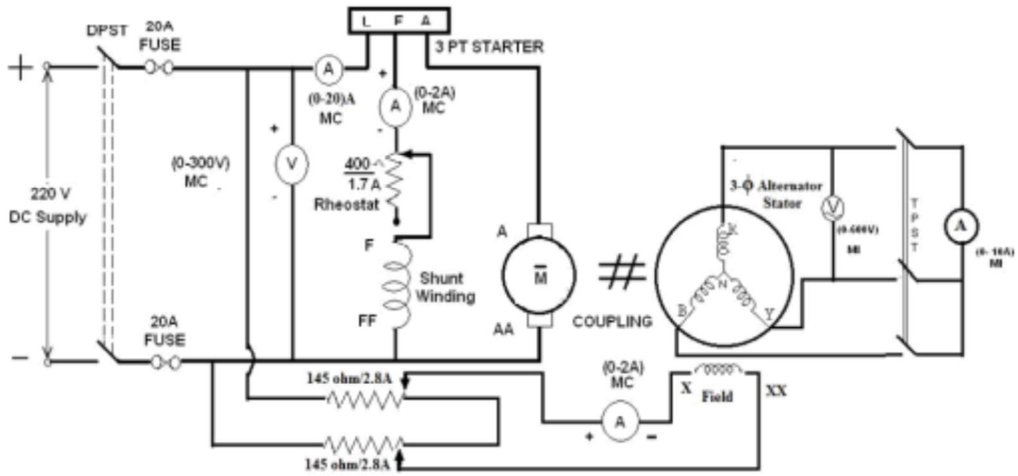
PRE-EXPERIMENT QUESTIONS

Q1. What is Synchronous Generator/ Alternator?

Q2. What is the principle of alternator?

Q3. Define regulation of an Alternator?

CIRCUIT DIAGRAM



PROCEDURE:

Open Circuit Test:

1. Make the connections as per the circuit diagram.

2. Before starting the experiment, the potential divider network in the alternator field circuit and field regulator rheostat of motor circuit is set minimum resistance position.

3. Switch ON the supply and close the DPST switch. The DC motor is started by moving starter handle.

4. Adjust the field rheostat of DC motor to attain rated speed (equal to synchronous speed of alternator) 5. By decreasing the field resistance of Alternator, the excitation current of alternator is increased gradually in steps.

6. Note the readings of field current, and its corresponding armature voltage in a tabular column.

7. The voltage readings are taken up to and 10% beyond the rated voltage of the machine.

Short Circuit Test:

1. For Short circuit test, before starting the experiment the potential divider is brought back to zero output position, i.e., resistance should be zero in value.

2. Now close the TPST switch.

3. The excitation of alternator is gradually increased in steps until rated current flows in the machine and note down the readings of excitation current and load current (short circuit current)

4. Switch OFF the supply.

OBSERVATION TABLE:

Open Circuit Test

S.NO	I_f (amps)	V_{oc} (volts)
1		
2		
3		
4		
5		
6		

Short Circuit Test

S.NO	I_f (amps)	I_{sc} (amps)
1		

Voltage Regulation Characteristics

S.No	Cos Φ	Sin Φ	Lagging P.F full load Eo	Leading P.F full load Eo
1	0.2	0.97	436.4	72.03
2	0.4	0.91	430.08	113.57
3	0.6	0.8	420.36	189.98
4	0.8	0.6	401.07	215.09
5	1	0	324.18	324.18

CALCULATONS

$V_{Ph} = \frac{V_L}{\sqrt{3}} =$

$Z = \frac{V_{OC}}{I_{SC}} = 198/4.2 =$

$R_{AC} = 1.5 \times R_{DC} =$

$X_S = \sqrt{Z^2 - R_{AC}^2} =$

For lagging P.F:

Let : 0.8 PF ,sinφ = 0.6.

By substituting all the values in E_o, We will get

$$E_0 = \sqrt{((V_{Ph}Cos\,\emptyset + I_{Sc}R_a)^2) + ((V_{Ph}Sin\,\emptyset + I_{Sc}x)^2)}$$

For leading P.F:

Let: 0.8 PF, sinφ = 0.6.

By substituting all the values in E_o, We will get

$$E_0 = \sqrt{((V_{Ph}Cos\,\emptyset + I_{Sc}R_a)^2) + ((V_{Ph}Sin\,\emptyset - I_{Sc}x)^2)}$$

=

Percentage Regulation: At 08 PF lag

$$\% R = \frac{E_0 - V_{Ph}}{V_{Ph}} \times 100$$

=

Procedure to find synchronous impedance from OC and SC tests:

1. Plot open circuit voltage, short circuit current verses field current on a graph sheet.

2. From the graph, the synchronous impedance for the rated value of excitation is calculated. 3. The excitation emf is calculated at full load current which is equal to the terminal voltage at No load.

4. The voltage regulation is calculated at rated terminal voltage.

MODEL CALCULATIONS:

$Z_s = \frac{V_{oc}}{I_{sc}}$ for the same I_f and speed: $X_s = \sqrt{Z_s^2 - R_a^2}$ [R_a R_{dc}]

Generated emf of alternator on no load is

$$E_0 = \sqrt{(v\cos\phi + I_a R_a)^2 + (v\sin\phi \pm I_a X_s)^2}$$

+ for lagging

p.f. - for

leading p.f

The percentage regulation of alternator for a given p.f. is

$$\%\,Reg = \frac{E_0 - V}{V} x\,100$$

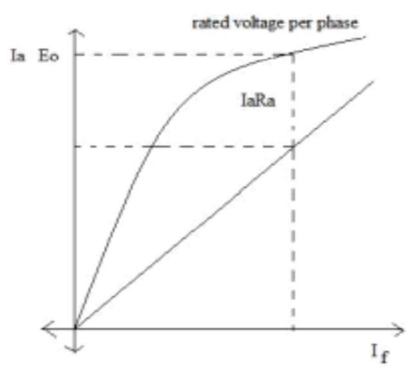
Where

E_0 – generated emf of alternator (or excitation voltage per phase)

V – Full load, rated terminal voltage per phase

MODEL GRAPH

Draw the graph between I_f V_S E_0 per phase
And I_f V_S I_{SC}



PRECAUTIONS:

1. Avoid loose connections.

2. Switch OFF the Supply before making connections.

3. Do not touch the bare conductors.

4. Avoid parallax error while making observations.

RESULT:

Thus we performed O.C. test on synchronous generator and determined the full load regulation of a three phase synchronous generator by synchronous impedance method.

.

POST-EXPERIMENT QUESTIONS

Q1. What are the different methods for finding regulation of an alternator?

Q2. What are the applications of an alternator?

LAB EXPERIMENT 7

To Study and Measure Synchronous Impedance and Short circuit ratio of Synchronous Generator

AIM: To Study and Measure Synchronous Impedance and Short circuit ratio of Synchronous Generator

THEORY:

The *synchronous impedance method* or *EMF method* is used to determine the voltage regulation of the larger alternators. The synchronous impedance method is based on the concept of replacing the effect of armature reaction by an imaginary reactance.

For an alternator,

$V = E_a - I_a Z_s = E_a - I_a(R_a + jX_s)$…(1)

At first, the synchronous impedance (Z_s) is measured and then, the value of actual generated EMF (E_a) is calculated. Thus, from the values of (E_a) and V, the voltage regulation of the alternator can be calculated.

Measurement of Synchronous Impedance

In order to determine the value of synchronous impedance, following tests are performed on an alternator −

- Open-Circuit Test
- Short-Circuit Test

Open-Circuit Test

To perform the open-circuit test, the load terminals are kept open and the alternator is run at rated synchronous speed.

PRE- EXPERIMENT QUESTIONS:

Q1. What is armature reaction effect?

Q2. What are the causes of voltage drop?

CIRCUIT DIAGRAM –Open-Circuit Test

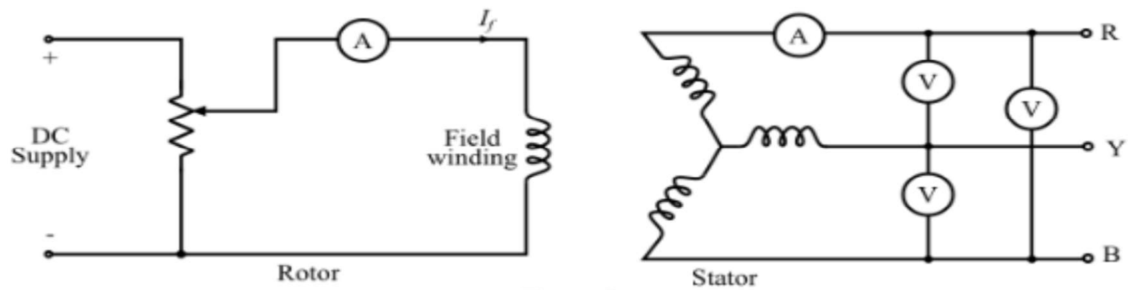


Figure-2

Initially, the field current is set to zero. Then, the field current is gradually increased in steps and the open-circuit terminal voltage E_t is measured in each step. The field current may be increased to obtain 25 % more than rated voltage of the alternator.

A graph is plotted between the open-circuit phase voltage ((Eph=Et/3–√))((Eph=Et/3)) and the field current (I_f). The obtained characteristic curve is known as **open-circuit characteristic (O.C.C)** of the alternator

Short-Circuit Test

For performing the short-circuit test, the armature terminals are short-circuited through three ammeters

CIRCUIT DIAGRAM –Short Circuit Test

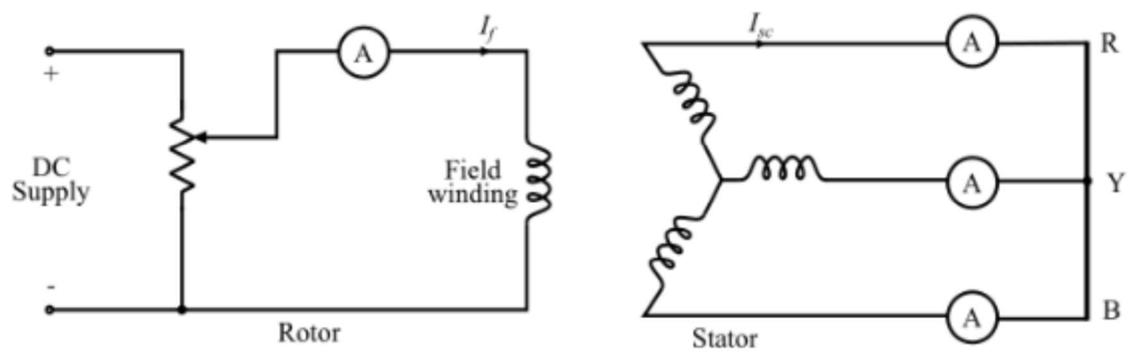


Figure-4

Before starting the alternator, the field current should be decreased to zero. Each ammeter should have a range more than the rated full-load value. Now, the alternator is run at synchronous speed. Then, the field current is gradually increased in steps and the armature current is measured at each step. The field current may be increased to obtain the armature currents up to 150 % of the rated value.

The field current (I_f) and the average of the three ammeter readings is taken at each step. A graph is plotted between the armature current (I_a) and the field current (I_f). The obtained characteristic is known as **short-circuit characteristic (S.C.C.)** of the alternator and this characteristic is a *straight line*

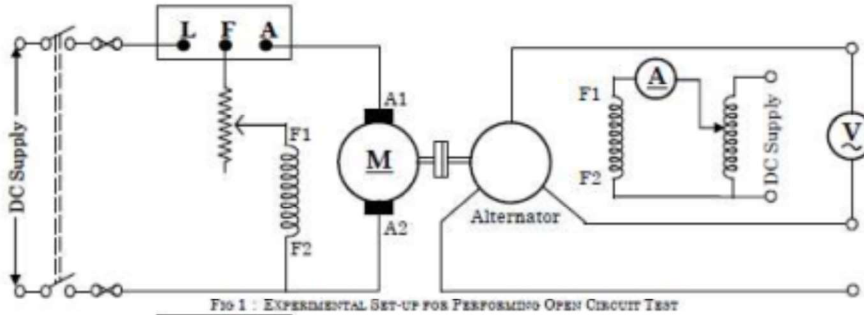


Fig 1 : Experimental Set-up for Performing Open Circuit Test

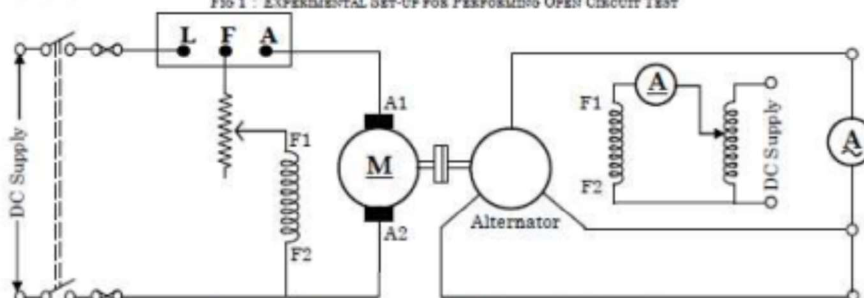


Fig 2 : Experimental Set-up for Performing Short Circuit Test

PROCEDURE:

[A] Open Circuit Test:

1) Connect the circuit as shown.

2) Set potential divider to zero output position and motor field rheostat to minimum value.

3) Switch on dc supply and start the motor.

4) Adjust motor speed to synchronous value by motor field rheostat and note the meter readings.

5) Increase the field excitation of alternator and note the corresponding readings.

6) Repeat step 5 till 10% above rated terminal voltage of alternator.

7) Maintain constant rotor speed for all readings.

[B] Short Circuit Test:

1) Connect the circuit as shown.

2) Star the motor with its field rheostat at minimum resistance position and the potential divider set to zero output.

3) Adjust the motor speed to synchronous value.

4) Increase the alternator field excitation and note ammeter readings.

5) Repeat step 4 for different values of excitations (field current). Take readings up to rated armature current. Maintain constant speed for all readings

6) Measure the value of armature resistance per phase Ra by multimeter or by ammeter- voltmeter method.

7) Plot the characteristics and find the synchronous impedance.

OBSERVATIONS:

SL NO	Open-circuit Test		Short-circuit Test	
	Field Current I_f (amp)	Terminal Voltage V_t (volt)	Field Current I_f (amp)	Short-circuit Current I_{sc} (amp)
1				
2				
3				
4				
5				

Armature resistance per phase = Ω

Effective value of armature resistance = Ω

CALCULATIONS:

In order to calculate the synchronous impedance of the alternator, the O.C.C. and the S.C.C. are drawn on the same curve sheet.

Then, determine the value of short-circuit current (**I_{SC}**) at the field current that gives the rated voltage per phase of the alternator. The synchronous impedance (Z_S) will then be equal to the ratio of the open-circuit voltage to the short-circuit current at the field current which gives the rated voltage per phase, i.e.,

$$Z_s = \frac{\text{open circuit voltage per phase}}{\text{short circuit armature current}} \ldots (2)$$

From the figure; the synchronous impedance can be written as

$$\Rightarrow Z_s = \frac{AB\,(\text{volts})}{AC\,(\text{amperes})} \ldots (3)$$

Also, the synchronous reactance of the alternator is

$$X_s = \sqrt{Z_s^2 - R_a^2} \ldots (4)$$

Therefore, the percentage voltage regulation of the alternator will be,

$$\text{Percentage voltage regulation} = \frac{E_a - V}{V} \times 100 \ldots (5)$$

GRAPH:

OCC & SCC

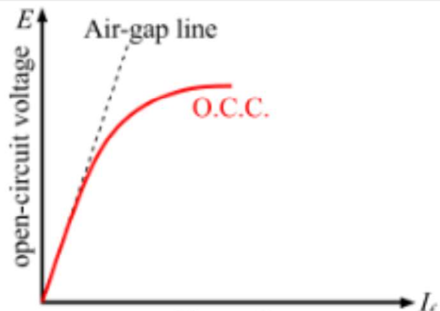


Figure-3

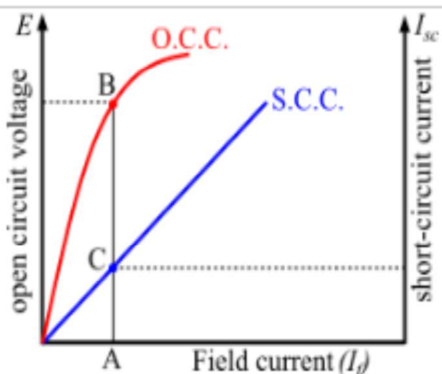
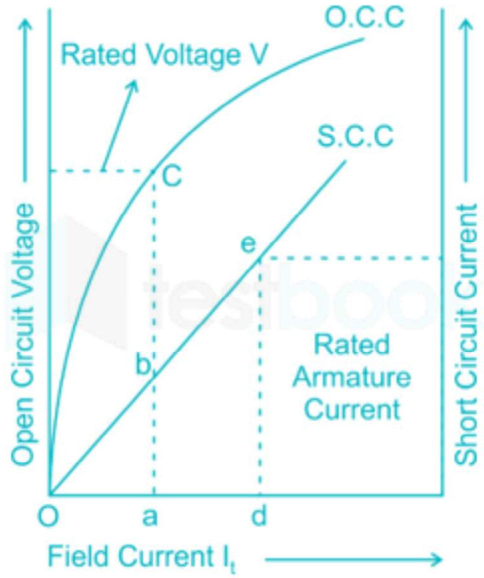


Figure-6

Short circuit Ratio

The short circuit ratio (SCR) of a synchronous machine is defined as the ratio of the field current required to generate rated voltage on an open circuit to the field current required to circulate rated armature current on a short circuit.



$$SCR = \frac{I_f \text{ for rated O.C. voltage}}{I_f \text{ for rated S.C. current}} = \frac{Oa}{Od} = \frac{1}{X_s(\text{saturated p.u.})}$$

For the small value of the short circuit ratio (SCR), the synchronizing power is small. As the synchronizing power keeps the machine in synchronism, a lower value of the SCR has a low stability limit. Thus, a machine with a low SCR is less stable when operating in parallel with the other generators.

A synchronous machine with the high value of SCR had a better voltage regulation and improved steady-state stability limit, but the short circuit fault current in the armature is high.

PRECAUTIONS:

1. All connections should be perfectly tight and no loose wire should lie on the work table.

2. Before switching ON the dc supply , ensure that the starter's moving arm is at it's maximum

3. resistance position.

4. Do not switch on the supply, until and unless the connections are checked by the teacher

5. Avoid error due to parallax while reading the meters

6. Hold the tachometer with both hands steady and in line with the motor shaft so that it reads correctly.

7. Ensure that the winding currents do not exceed their rated values.

RESULTS:

Thus we have studied and Measured Synchronous Impedance and Short circuit ratio of Synchronous Generator

POST- EXPERIMENT QUESTIONS:

Q1. Why OCC looks like B-H curve?

Q2. Why SCC is a straight line?

Q3. When is the regulation negative and why?

Q4. Can we find regulation of a salient pole machine by this test? Justify your answer.

LAB EXPERIMENT 8

Study of Power (Load) sharing between two Three Phase alternators in parallel operation Condition

AIM: To Study of Power (Load) sharing between two Three Phase alternators in parallel operation Condition.

APPARATUS:

Sl. No	Name of the Equipment	Specification	Quantity
1	DC Motor Coupled to Alternator	Motor- 220V DC, 3KW, 1500RPM Alternator- 440V, 3 KVA,50 Hz	2nos
2	Line Tester	1100v, 6''	1no
3	Wire Stripper	150mm	1 no
4	Voltmeter	500v AC	2nos
5	Ammeter	5A AC	2 nos
6	Rheostat	750ohm, 1.5A	2 nos
7	Multimeter	-	1 no
7	Frequency Meter	Digital Type	2 nos
8	Syncchonoscope	-	1 no
9	Lamps	100W	3nos
10	Wires	2.5 sq mm	As per required

PRE- EXPERIMENT QUESTIONS

Q1. State the necessary condition for parallel operation of three phase alternators

Q2. Why Parallel operation is necessary?

THEORY:

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

Condition for Parallel Operation of Alternator:

There are some conditions to be satisfied for parallel operation of the alternator. Before entering into that, we should understand some terms which are as follows.

- The process of connecting two alternators or an alternator and an infinite bus bar system in parallel is known as synchronizing.
- Running machine is the machine which carries the load.
- Incoming machine is the alternator or machine which has to be connected in parallel with the system.

The conditions to be satisfied are:-

1. The phase sequence of the incoming machine voltage and the bus bar voltage should be identical.

2. The RMS line voltage (terminal voltage) of the bus bar or already running machine and the incoming machine should be the same.

3. The phase angle of the two systems should be equal.

4. The frequency of the two terminal voltages (incoming machine and the bus bar) should be nearly the same. Large power transients will occur when frequencies are not nearly equal.

Departure from the above conditions will result in the formation of power surges and current. It also results in unwanted electro-mechanical oscillation of rotor which leads to the damage of equipment

POST- EXPERIMENT QUESTIONS

Q1. How the load sharing occurs in alternators?

Q2. State the benefits of load sharing in Power stations

RESULTS:

Thus we studied the Power (Load) sharing between two Three Phase alternators in parallel operation Condition

LAB EXPERIMENT 9

To plot V- Curve of synchronous motor

AIM: To plot V- Curve of synchronous motor.

APPARATUS:

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Wattmeters		
	3-phase Auto transformer		
	Rheostats		

Specification:

Synchronous Motor: Power: __________ Voltage:_____________ Current: _______________ Speed: ________________

THEORY:

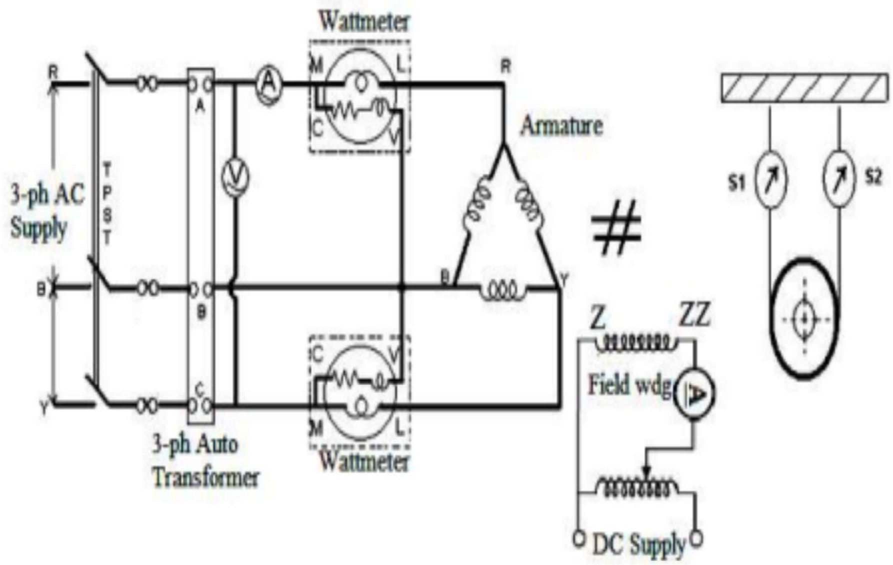
V-curve of a synchronous machine shows its performance in terms of variation of armature current with field current when the load and input voltage to the machine is constant. When a synchronous machine is connected to an infinite bus, the current input to the stator depends upon the shaft-load and excitation (field current). At a constant load, if excitation is changed the power factor of the machine changes, i.e. when the field current is small (machine is under-excited) the P.F. is low and as the excitation is increased the P.F. improves so that for a certain field current the P.F. will be unity and machine draws minimum armature current. This is known as normal excitation. If the excitation is further increased the machine will become overexcited and it will draw more line current and P.F. becomes leading and decreases. Therefore, if the field current is changed keeping load and input voltage constant, the armature current changes to make VIcosφ constant. Because of their shape as English letter 'V', graphs of variation of armature current with excitation are called 'V' curves. If the 'V' curves at different load conditions are plotted and points on different curves having same P.F. are connected the resulting curve is known as "compounding curves"

PRE- EXPERIMENT QUESTIONS

Q1. With what condition synchronous motor can be used as a synchronous condenser?

Q2. What are the special applications of an over excited synchronous motor?

CIRCUIT DIAGRAM:



PROCEDURE:

1) Make the connections as shown in circuit diagram.

2) Adjust the field rheostat of DC generator at maximum position, the potential divider at zero output position and the load at off condition.

3) Switch on the 3-ph. supply, start the synchronous motor and let it run at its rated speed.

4) Switch on the DC supply and adjust the generator field current to a suitable value so that it generates rated voltage.

5) Increase the alternator field current and note down corresponding power factor and armature current covering a range from low lagging to low leading power factor through a unity power factor. Note that armature current is minimum when the p.f. in unity.

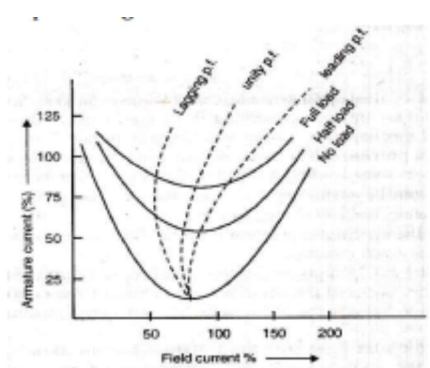
6) Increase load on synchronous motor and repeat step no.5

OBSERVATION TABLE:

S. No.	Supply Voltage V	Exciter Current If	Power input			Power Factor cosφ
			W1	W2	P=W1+W2	

GRAPH

Plot the curves between armature current (Ia) vs field current (If) and power factor (cosΦ) vs field current (If)



V-curves for Synchronous motor

POST- EXPERIMENT QUESTIONS

Q1. Explain the effect of change of excitation of a synchronous motor on its armature current.

Q2. Explain the effect of change of excitation of a synchronous motor on its power factor.

Q3. With the given excitation a synchronous motor draws a unity power factor current. If the mechanical load is increased what will be the power factor and current for the same excitation.

Q4. Explain the effect of change of excitation of a synchronous generator on its armature current.

Q5. Explain the effect of change of excitation of a synchronous generator on its power factor

RESULTS:

Thus we have plotted V- Curve of synchronous motor.

LAB EXPERIMENT 10

Synchronization of two Three Phase Alternators by a) Synchroscope Method b) Three dark lamp Method c) Two bright one dark lamp Method

AIM: To Synchronize two Three Phase Alternators by a) Synchroscope Method b) Three dark lamp Method c) Two bright one dark lamp Method

APPARATUS:

1. DC Motor - Alternator Set

2. Voltmeter-1

3. Rheostats-2

4. Tachometer- 1

PRE- EXPERIMENT QUESTIONS

Q1. What do you meant by Synchronization?

Q2. What is the purpose of synchronization of alternator?

THEORY:

Before synchronization, following conditions must be satisfied:

(1) EQUALITY OF VOLTAGE The terminal voltage of both the systems i.e. the incoming alternator and the bus bar voltage or other alternator must be same.

(2) PHASE SEQUENCE The phase sequence of both the systems must be same.

(3) EQUALITY OF FREQUENCY The frequency of both the systems must be same

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

There are two synchronizing methods - a. using incandescent lamp

b. Using Synchroscope.

Now we discuss in detail about these methods.

(a) Using Incandescent lamp

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

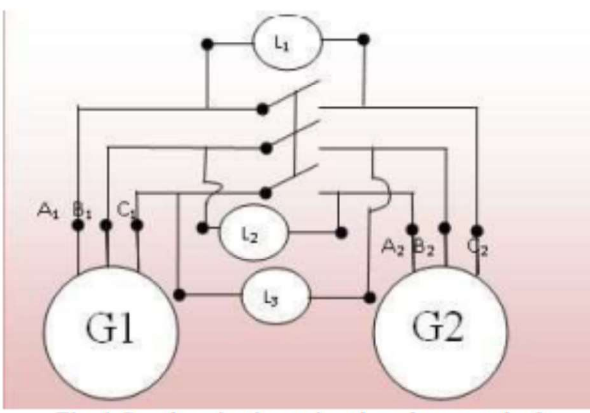


Fig. 1 Synchronization using three lamp method

The resultant voltage is sometimes maximum and sometimes minimum. Hence, the lamps will flicker, sometimes dark and sometimes bright. Synchronization is done at the middle of the dark period. This method of synchronizing is known as dark lamp method.

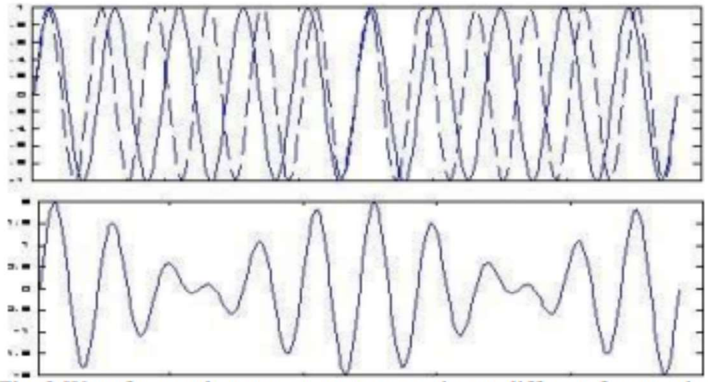


Fig. 2 Waveforms when two systems operating at different frequencies

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

This method has following drawbacks:

1. The lamps become dark at about one third of the rated voltage. Hence, faulty synchronizing may be done in dark period.

2. Using this method it is not possible to find out that how much the machine is slow or fast.

3. This method is not applicable for high voltage alternators, because lamp ratings are normally low. For such situations we need an extra transformer to step down the voltage.

(b) Synchronizing by Synchroscope:

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

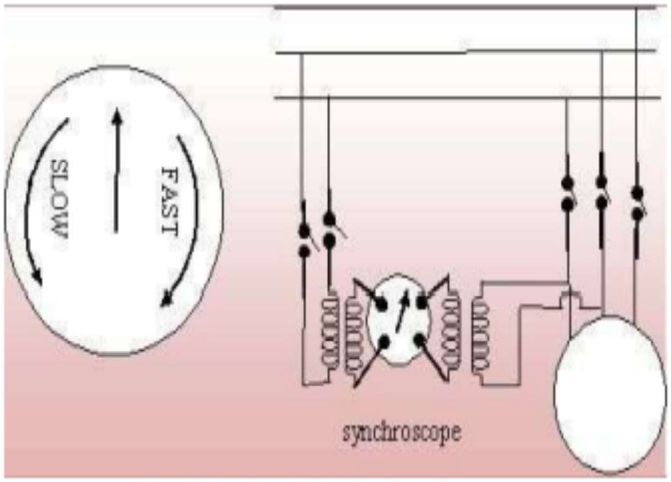


Fig. 3 Synchronizing by Synchroscope

CIRCUIT DIAGRAM

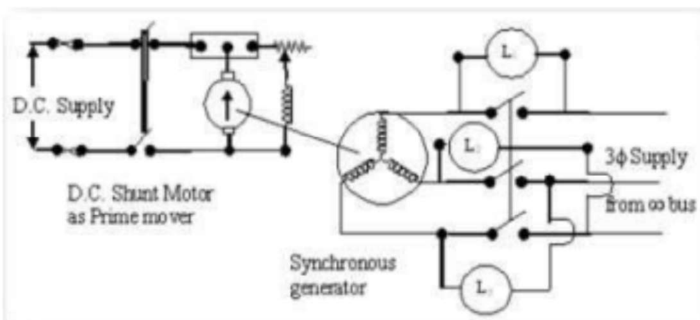


Fig 1.1:Connection diagram for synchronizing the alternator with 3-lamp method

PROCEDURE:

1. Make the connection diagram as shown in figure 1.1

2. Run one of the alternators and adjust its voltage at rated value and close switch to bus bar.

3. Start the second set (alternator 2), bring it up to proper speed equal to that of the running alternator (or bus bar voltage).

4. Synchronize the incoming alternator by any one method described in theory.

Observations:

1. Measure and adjust voltage of incoming machine (Vg) and bus bar (Vs) till Vg=Vs.

2. Measure and adjust the speed of incoming machine, till synchroscope needle creeps.

3. Close synchronizing switch

PRE- EXPERIMENT QUESTIONS

Q1. Which method is best for synchronization?

Q2. What does the pointer synchroscope indicates when it is rotating in anticlockwise direction and when it is rotating in clockwise direction?

RESULTS:

Thus we Synchronized the two Three Phase Alternators by a) Synchroscope Method b) Three dark lamp Method c) Two bright one dark lamp Method

LAB EXPERIMENT 11

Determination of sequence impedances of synchronous machine for various stator voltages

AIM: To determine the sequence impedances of synchronous machine for various stator voltages

APPARATUS:

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Connecting leads		
	Auto transformer		

SPECIFICATION:

Synchronous Machine: Power: __________ Voltage:_____________ Current: _______________

Speed: ________________

DC Shunt Motor Power: __________ Voltage:_____________ Current: _______________

Speed: ________________

PRE-EXPERIMENT QUESTIONS

Q1. What is the use of sequence impedance?

Q2. What are the types of sequence impedance?

THEORY:

Various sequence impedances are defined for equipment or a component of power system. The sequence impedance of equipment is defined as the impedance offered by the equipment to the flow of corresponding sequence current. This means the positive sequence impedance of equipment is the impedance offered by the equipment to the flow of positive sequence currents. Similarly, the negative sequence impedance of an equipment is the impedance offered by the equipment to the flow of negative sequence currents. Further, the zero sequence impedance of equipment is the impedance offered by the equipment to the flow of zero sequence currents.

The positive, negative and zero sequence impedances are represented by Z1, Z2 and Z0 respectively. It is important to mention here that for the symmetrical systems there is no mutual coupling between the sequence networks. Therefore, the three-sequence systems can be considered separately. The resultant phase currents and voltages can be determined by superposing their symmetrical components of currents and voltages respectively.

Positive Sequence Impedance: The value of positive sequence impedance depends upon the working of the machine 1.e., whether it is working under sub-transient, transient or steady state condition. The impedance under steady state condition is termed as synchronous impedance.

Negative Sequence Impedance: Negative sequence impedance of a machine is the impedance offered to the flow of negative sequence current. In this test the synchronous machine under test is driven at the rated speed by a prime mover. The field circuit is short circuited. A reduced voltage is applied to circulate approximately the rated current. Only negative sequence current is flow under this condition. There is a possibility of hunting due to which the pointer of the ammeter may oscillate. In such a case mean reading of the ammeter should be recorded. Then negative sequence impedance can be calculated using the following equation

$$Z_2 = \frac{V}{\sqrt{3} * I}$$

Zero Sequence impedance: Zero sequence impedance is the impedance offered by the machine to the flow of the zero sequence current. Zero sequence impedance is much smaller than positive and negative sequence impedances. The zero sequence has a meaning for a star connected system only, because otherwise no zero sequence current flows. To perform this test the machine remains at stands still. A reduced A.C. voltage is impressed across the three windings (connected in series). The zero-sequence impedance is calculated using the following relation

$$Z_0 = \frac{V}{3I}$$

CIRCUIT DIAGRAM

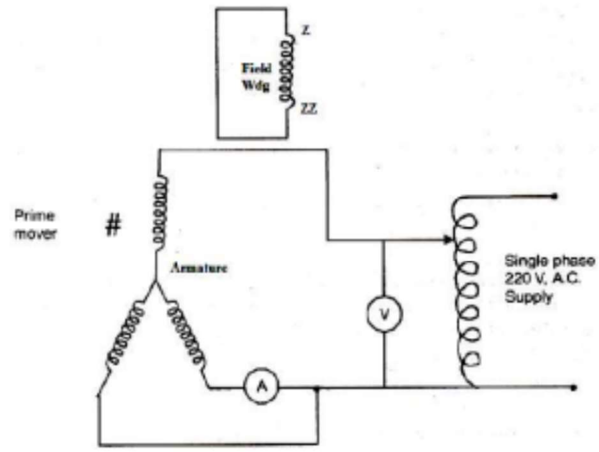


Fig-1 Experimental set up for determination of negative sequence impedance.

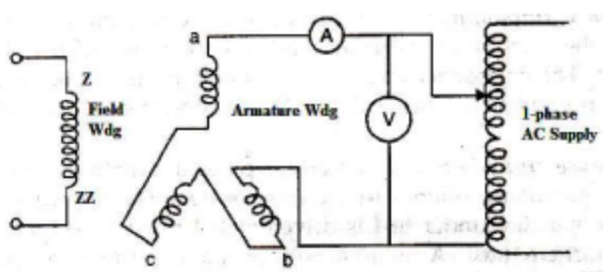


Fig-2 Experimental set up for determination of zero sequence impedance.

PROCEDURE

Negative Sequence Impedance

1. Connect the circuit as Per Fig.1.

2. Here we use a D.C. shunt motor as prime mover to synchronous Generator. Ensure that the external resistance in the field circuit of D.C. shunt motor is zero.

3. Switch-on the D.C. supply to the D.C. shunt motor. Start the motor using a starter.

4. Adjust the field resistance of the D.C. shunt motor so that it runs at the rated speed of the synchronous machine.

5. Adjust the variac so that the rated current flows through the stator windings of the alternator

6. Record the readings of voltmeter and ammeter. 7. Switch-off A.C. supply. Switch-off D.C. supply.

Zero Sequence Impedance

1. Connect the circuit as given in Fig. 3.

2. Ensure that the variac is at zero position. Switch-on A.C. supply

3. Increase the variac position so that the ammeter reads the rated of the synchronous machine.

4. Record the readings of voltmeter and ammeter.

5. Switch-off A.C. supply.

OBSERVATIONS:

Negative Sequence Impedance:

Voltmeter reading (V) = ______________volts Ammeter readings

(I) =______________ amps

Negative-sequence Impedance, $\boldsymbol{Z2} = \boldsymbol{V} / \sqrt{\boldsymbol{3}} * \boldsymbol{I}$

Zero-sequence Impedance:

Voltmeter reading (V) = ______________volts Ammeter reading (I) = _______________ amps

Zero-sequence Impedance, $\boldsymbol{Z0} = \boldsymbol{V} / \boldsymbol{3}\mathrm{I}$

PRECAUTIONS

Following precautions should be taken care of while performing this :

1. All connections should be neat and tight.

2. Zero settings of the meters should be checked before connecting them in the circuit

POST-EXPERIMENT QUESTIONS

Q1. Define symmetrical components.

Q2. What is the importance of sequence impedances?

Q3. The impedances of rotating machines to currents of the three sequences will generally be a) Same for each sequence b) Different for each sequence

Q4. What is the utility of three-phase three-winding transformer?

Q5. Why is tertiary winding connected in delta?

RESULTS:

Thus we determined the sequence impedances of synchronous machine for various stator voltages

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