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BAPATLA

Department of Electrical &Electronics Engineering

Induction Motor's and Synchronous Machine's Lab

(20EEL503) LAB MANUAL

R20 REGULATIONS

Bapatla Engineering College:: Bapatla

(Autonomous under Acharya Nagarjuna University)

(Sponsored by Bapatla Education Society)

BAPATLA-522102, Guntur District, A.P.

www.becbapatla.ac.in

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Vision of the Institute

To build centers of excellence, impart high quality education and instill high standards of ethics and professionalism through strategic efforts of our dedicated staff, which allows the college to effectively adapt to the ever-changing aspects of education.

To empower the faculty and students with the knowledge, skills and innovative thinking to facilitate discovery in numerous existing and yet to be discovered the fields of engineering, technology and inter-disciplinary endeavors.

Mission of the Institute

To impart the quality education at par with global standards to the students from all over India and in particular those from the local and rural areas.

To maintain high standards so as to make them technologically competent and ethically strong individuals who shall be able to improve the quality of life and economy of our country.

Vision of the Department

The Department of Electrical & Electronics Engineering will provide programs of the highest quality to produce globally competent technocrats who can address challenges of the millennium to achieve sustainable socio - economic development.

Mission of the Department

M1. To provide quality teaching blended with practical skills.

M2. To prepare the students ethically strong and technologically competent in the field of Electrical and Electronics Engineering.

M3. To motivate the faculty and students in the direction of research and focus to fulfill social needs.

Program Educational Objectives (PEOs)

PEO1. To have a strong foundation in the principles of Basic Sciences, Mathematics and Engineering to solve real world problems encountered in modern electrical engineering and pursue higher studies/placement/research.

PEO2. To have an integration of knowledge of various courses to design an innovative and cost effective product in the broader interests of the organization & society.

PEO3. To have an ability to lead and work in their profession with multidisciplinary approach, cooperative attitude, effective communication and interpersonal skills by participating in team oriented and open ended activities.

Program Outcomes:

Engineering graduates will be able to:

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

PO2. Problem analysis: Identify, formulate, 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 problems in the field of Electronics and Instrumentation Engineering and design system components or processes that meet the specified needs with appropriate consideration for 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 IT 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 Electronics and Instrumentation Engineering solutions in societal and environmental contexts, and demonstrate the 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 Electronics and Instrumentation Engineering activities with the engineering community and with the society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations 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 in a multidisciplinary environment.

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.

Program Specific Outcomes (PSO's)

PSO1: The Electrical and Electronics Engineering graduates are capable of applying the Knowledge of mathematics and sciences in modern power industry.

PSO2: Analyse and design efficient systems to generate, transmit, distribute and utilize electrical energy to meet social needs using power electronic systems.

PSO3: Electrical Engineers are capable to apply principles of management and economics for providing better services to the society with the technical advancements in renewable and sustainable energy integration.

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ELECTRICAL MACHINES LABORATORY

SAFETY RULES

1. Do not touch any terminals (or) Switch without ensuring that it is dead.
2. Wearing shoes with rubber sole is desirable.
3. Use a fuse wire of proper rating.
4. Use sufficient long connecting leads rather than joining two or there small ones, because in case any joint is open it could be dangerous.
5. Make sure that all the electrical connections are correct before switchingon any circuit. Wrong connections may cause large amount of current which results damage of equipment.
6. The circuit should be de-energized while changing any connection.
7. In case of emergency or fire switch-off the master switch on the mainpanel board.
8. Keep away from all the moving parts as for as possible.
9. Do not renew a blown fuse until you are satisfied to the cause and rectified problem.
10. Do not touch an electric circuit when your hands are wet or bleeding from acut.
11. Do not disconnect plug by pulling a flexing cable when the switch is on.
12. Do not throw water on live electrical equipment in case of fire.
13. Do not test the circuit with bear fingers.
14. Do not use loose garments while working in Laboratory.
15. Do not open (or) close a switch (or) fuse slowly or hesitatingly. Do it quicklyand positively.

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Induction Motors and Synchronous Machines Lab

III B.Tech – V Semester (Code: 20EEL~~503~~)

Lectures	0	Tutorial	0	Problem Solving	0	Practical	3	Credits	1.5
Continuous Internal Assessment				30	Semester End Examination (3 Hours)				70

Course Objective: To make the students.

- Develop experimental setups for studying the performance and operation of squirrelcage and slip ring induction motors.
- Perform Direct and Indirect tests of various induction motors.
- Acquire hands on experience for conducting various tests on alternators and obtainingtheir performance indices using standard analytical as well as graphical methods.
- Develop experimental setups for studying the performance and operation of synchronous Motors.

COURSE OUTCOMES: After completion of this lab course, the student is able to

CO1. Compare the performance characteristics of Induction motors.

CO2. Distinguish the performance of the given Induction motors.

CO3. Test the performance of synchronous generators.

CO4. Evaluate the performance of synchronous motors.

CO's	PO's												PSO's		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
CO1	3	3	1	3	0	0	0	0	3	3	0	0	3	0	0
CO2	3	3	1	3	0	0	0	0	3	3	0	0	3	0	0
CO3	3	3	1	3	0	0	0	0	3	3	0	0	3	0	0
CO4	3	3	1	3	0	0	0	0	3	3	0	0	3	0	0

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Induction Motors & Synchronous Machines Lab
III B.Tech – V Semester (Code: 20EEL~~50~~3)

List of Experiments:

1. Load test on Squirrel-Cage Induction motor.
2. Load test on Slip-Ring Induction motor.
3. No-load and Blocked rotor test on 3-phase induction motor.
4. Separation of losses of 3-phase Induction motor.
5. Brake test on single - phase induction motor.
6. Determination of Equivalent circuit of single - phase induction motor.
7. Real Power flow Control of 3-Phase Induction Generator.
8. Regulation of alternator by EMF &MMF method.
9. Regulation of alternator by ZPF method.
10. Synchronization of alternator with infinite bus with P & Q control.
11. Load test on Alternator.
12. Measurement of Xd and Xq of a three phase alternator.
13. V and inverted V curves of synchronous motor.
14. Synchronous Motor performance with constant excitation.
15. Load test on Universal Motor.

Note: Minimum 10 experiments should be conducted.

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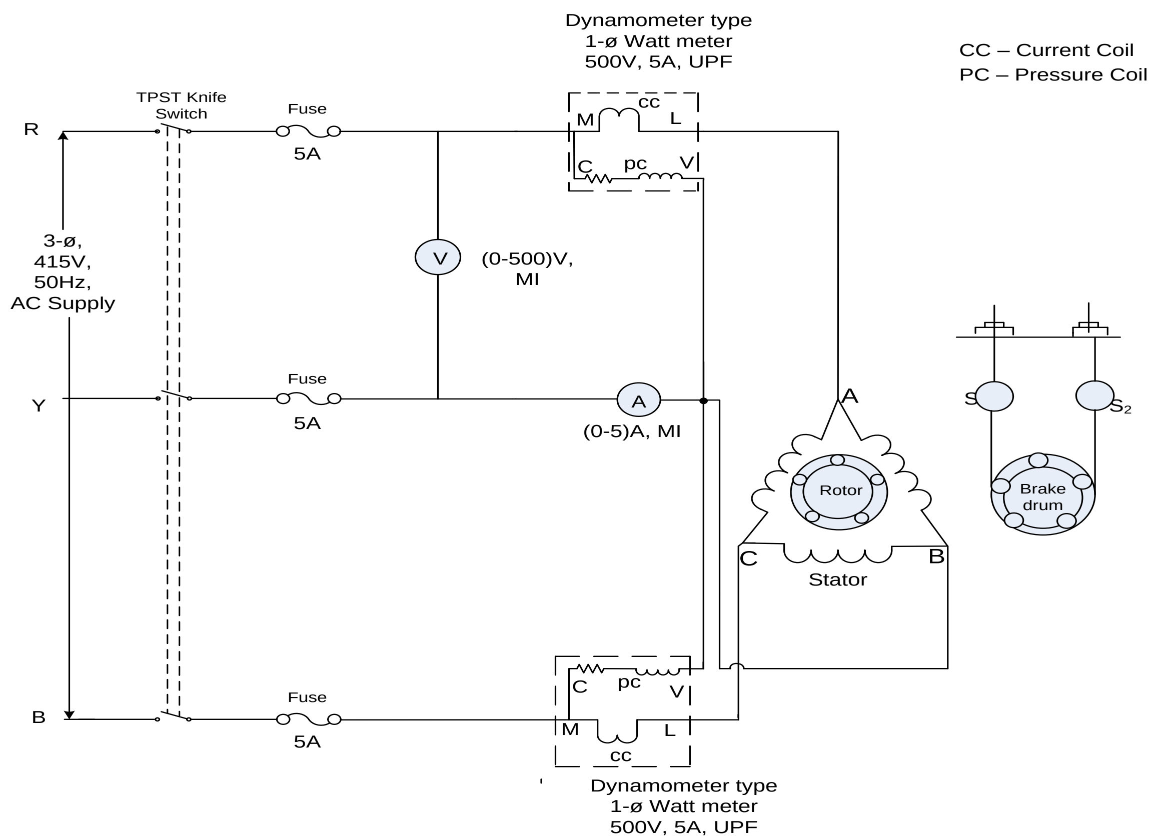
LOAD TEST ON 3 PHASE SQUIRREL CAGE INDUCTION MOTOR

AIM:
To draw performance curves of 3-phase squirrel cage induction motor by conducting direct load test.

APPARATUS:

SNO	APPARATUS	TYPE	RANGE	QUANTITY
1.	VOLTMETER	MI	0-500V	1NO
2.	AMMETER	MI	0-10A	1NO
3.	WATTMETER	DYNAMOMETER	500V, 10A, UPF	2NOs
4.	TACHOMETER	ANALOG	0-10000RPM	1NO
5.	FUSE WIRE	TCC	5A	15CM

CIRCUIT DIAGRAM:



Name plate details:

Voltage: 440 V
Current: 5.2 A
Power: 3 H.P
Frequency: 50Hz
Speed:1440 rpm

THEORY:

A squirrel cage induction motor essentially consists of a stator and a rotor. The stator is a hollow cylindrical structure with slots on the inner periphery and carries a three phase winding. The winding can be connected in star or delta and is connected across a 3-phase supply. The rotor is also a cylindrical structure with slots

on the outer periphery. The slots carry thick Al or Cu bars. These bars are short circuited at both ends by means of end rings. When a 3-phase supply is given to a 3-phase winding displaced by 120^0 in space, a magnetic field of constant magnitude but rotating at synchronous speed is produced. This flux links with the stationary rotor, thus inducing an emf in it. As the rotor circuit is closed, a current flows through it. The direction of the induced current is such as to oppose the cause producing it. The cause is the relative motion between the stator magnetic field and the rotor. So the rotor starts rotating in the same direction as the stator magnetic field and tries to catch up with it. But practically it is never able to do so. Because if it does so, there would be no relative motion, no emf and hence no torque.
Thus an induction motor always runs at a speed slightly less than the synchronous speed.
The term slip is of importance in an induction motor and is defined as
%slip =(Ns – N)/Ns × 100
Where,Ns - Synchronous speed =120 × f/P
N - rotor speed
f - frequency
P - No. of poles of the machine
An induction motor can never operate at s=0. It always operates between s=0 and s=1(starting).
The performance characteristics are plots of efficiency, torque, speed, slip, pf and line cur-rent versus output. Current and torque increases with increase in output. The induction motor is essentially a constant speed motor. However speed reduces gradually with increase in output and slip increases gradually with increase in output. The pf is low at low loads and increases with increase in output. The efficiency increases with increase in output, reaches a peak value and then gradually drops with further increase in output.

PROCEDURE:
1. Connect the circuit as per the circuit diagram.
2. Set the brake drum free before supply is given.
3. Switch ON the supply and note down no-load readings.
4. Then increase the load in steps up to rated load and note down readings in each step.
5. Pour water into motor brake drum gently for cooling.
6. Remove the load and switch-OFF the supply.
7. Measure the radius of brake drum.

OBSERVATIONS AND CALCULATIONS:

S.No	V	I	W_1 with MF	W_2 with MF	S_1 Kg	S_2 Kg	N RPM	Input= (W_1+W_2)	T	Output	Slip	% Efficiency	P.F=cosΦ

Note:
MF→‘Multiplication factor’

$T=9.81*(S_1 \sim S_2)*R$, N-m

Output=(2*Π*N*T)/60, Watts

Slip=(N_s-N)*100/N_s

Efficiency = output* 100/Input,

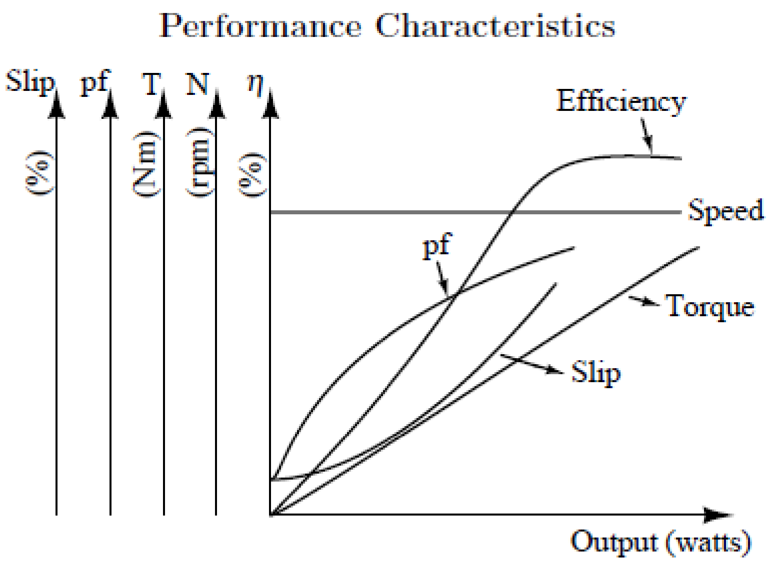
$\Phi = \tan^{-1}(\sqrt{3}(W_1-W_2))/(W_1+W_2)$

Where R is Radius of Brake drum in meters

N_S=120f/P f→Supply frequency, P→ Number of poles stator

PRECAUTIONS:

1. Loose connections are to be avoided.
2. Readings must be taken without any parallax error.



RESULT:

VIVA;

1. Why the power factor of a squirrel cage induction motor is low at light loads?
2. Why do we require starters for starting of 3phase induction motor?
3. Is the maximum torque of a 3phase induction motor dependent on the rotor resistance?
4. What is the relationship of developed torque of a 3phase induction motor with the supply voltage?
5 Why is that the V/f ratio is kept constant while controlling the speed of a 3phase induction motor by

varying the supply frequency?

6. What are the main advantages of squirrel cage induction motor?
7. What are the disadvantages of cage motors?
8. How will you improve starting torque of a 3phase induction motor?
9. At what slip the torque developed in an induction motor will be maximum?

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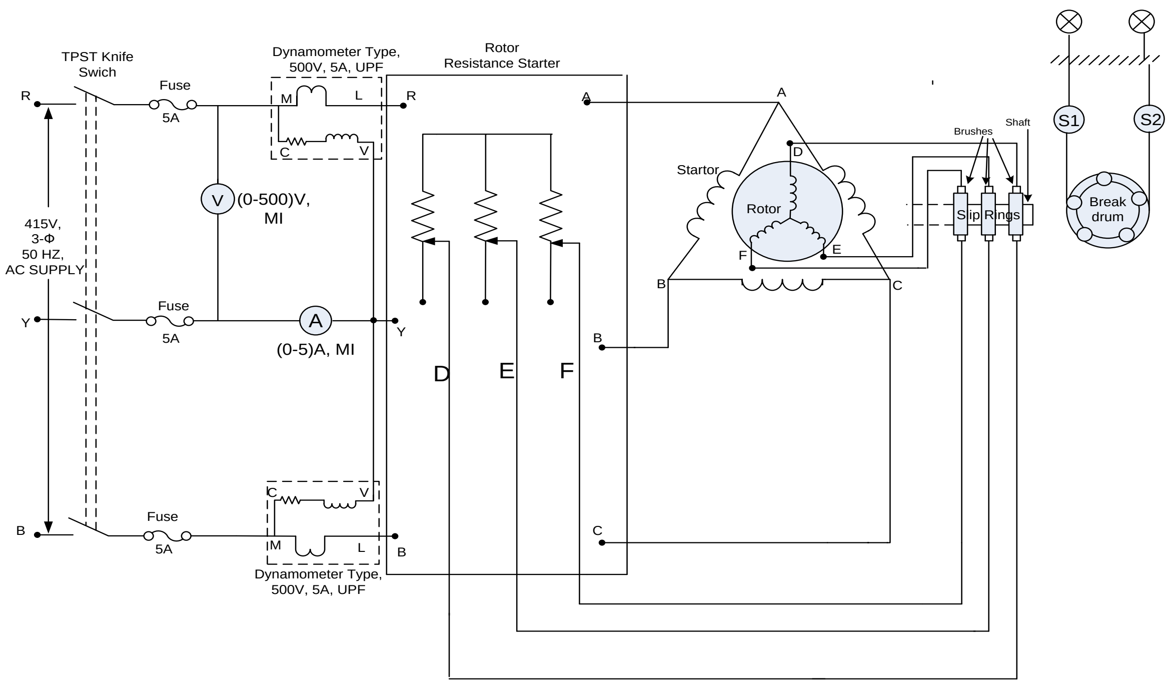
LOAD TEST ON 3 PHASE SLIPRING INDUCTION MOTOR

AIM:
To draw performance curves of 3-phase slip-ring induction motor by conducting direct load test.

APPARATUS:

S.N0	APPARATUS	TYPE	RANGE	QUANTITY
1.	Ammeter	MI	(0-5)A	1no.
2.	Voltmeter	MI	(0-500)V	1no.
3.	Wattmeter	Dynamometer	500V,5A,UPF	2no
4.	Tachometer	Analog	(0-10,000)RPM	1no.
5.	Fuse wire	TCC	5A	15cm

CIRCUIT DIAGRAM:



<u>Name plate details:</u>

Voltage: 415 V
Current: 4 A
Power: 3 H.P
Frequency: 50Hz
Speed: 1440 rpm

THEORY:

When the stator of a 3-phase motor is connected to a 3-phase power source, currents flow in the three stator windings and a revolving magnetic field is established. These three exciting currents supply the reactive power to establish the rotating magnetic field. They also supply the power consumed by the copper and iron losses in the motor.

The speed of the rotating magnetic field is entirely determined by the frequency of the three phase power source, and is known as the synchronous speed. The frequency of electric power systems is accurately maintained by the electric power companies. Therefore, the synchronous speed of the stator field [rpm] remains constant.

The wound rotor consists of a rotor core with three windings in place of the conducting bars of the squirrel cage rotor. In this case, currents are induced in the windings just as they would be in shorted turns. However, the advantage of using windings is that the wires can be brought out through slip rings so that resistance, and, therefore, the current through the windings, can be controlled.

The rotating stator field induces an alternating voltage in each winding of the rotor. When the rotor is at standstill the frequency of the induced rotor voltage is equal to that of the power source. If the rotor is now rotated by some external means – in the same direction as the rotating stator field – the rate at which the magnetic flux cuts the rotor windings will diminish. The induced voltage and its frequency will drop. When the rotor revolves at the same speed and in the same direction as the rotating stator field, the induced voltage, as well as its frequency, will drop to zero. *(The rotor is now at synchronous speed).* Conversely, if the rotor is driven at synchronous speed, but in the opposite direction to the rotating stator field, the induced voltage, as well as its frequency, will be twice the value as when the rotor was at standstill. A considerable voltage appears across the rotor windings on open circuit, and this voltage varies linearly with rotor slip in rpm, becoming zero at synchronous speed.

If the rotor windings are short-circuited, the induced voltage will cause large circulating currents in the windings.

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Set the brake drum free before supply is given.
3. Switch ON the supply and note down no-load readings.
4. Then increase the load in steps up to rated load and note down readings in each step.
5. Pour water into motor brake drum gently for cooling.
6. Remove the load and switch-OFF the supply.
7. Measure the radius of brake drum.

OBSERVATIONS AND CALCULATIONS:

S.No	V	I	W_1 with MF	W_2 with MF	S_1 Kg	S_2 Kg	N RPM	Input= (W_1+W_2)	T	Output	Slip	% Efficiency	P.F=cosΦ

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Note:

MF→'Multiplication factor'

$T=9.81*(S_1 \sim S_2)*R$, N-m

Output=(2*Π*N*T)/60, Watts

$Slip=(N_s-N)*100/N_s$

Efficiency = ouput* 100/Input,

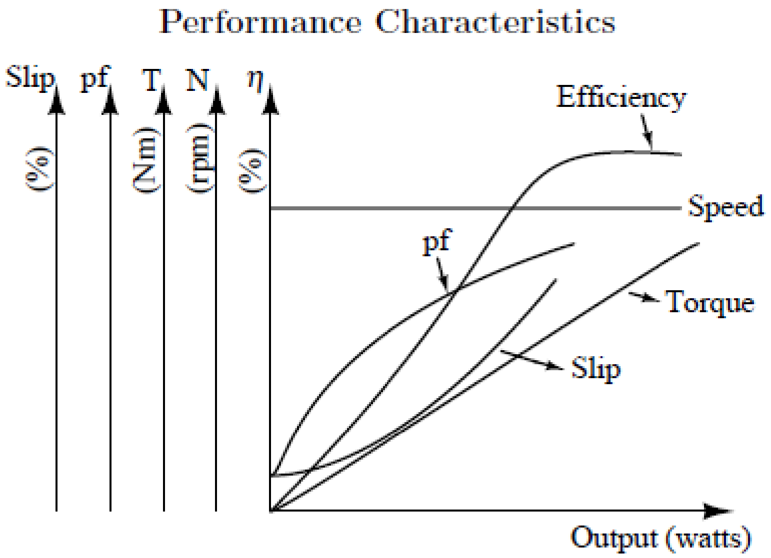
$\Phi= Tan^{-1}(\sqrt{3}(W_1-W_2))/(W_1+W_2)$

Where R is Radius of Brake drum in meters

$N_S=120f/P$ f→Supply frequency, P→ Number of poles stator

PRECAUTIONS:

1. Loose connections are to be avoided.
2. Readings must be taken without any parallax error.



RESULT:

VIVA

1. Why the rotor of slip-ring induction motor should be wound for the same no. of poles as its stator?
2. Which type of induction motor develops higher starting torque?
3. What is the condition for maximum torque at starting in a 3 phase induction motor?
4. At what slip the torque developed in an induction motor will be maximum?
5. What is the parameter other than the ratio of rotor current limits which decides the number of resistance sections of a slip-ring induction motor starter?
6. On what factors does the speed of an induction motor depend?
7. What is meant by plugging?

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NO-LOAD AND BLOCKED ROTOR TESTS ON 3PHASE SQIRRELL CAGE INDUCTION MOTOR

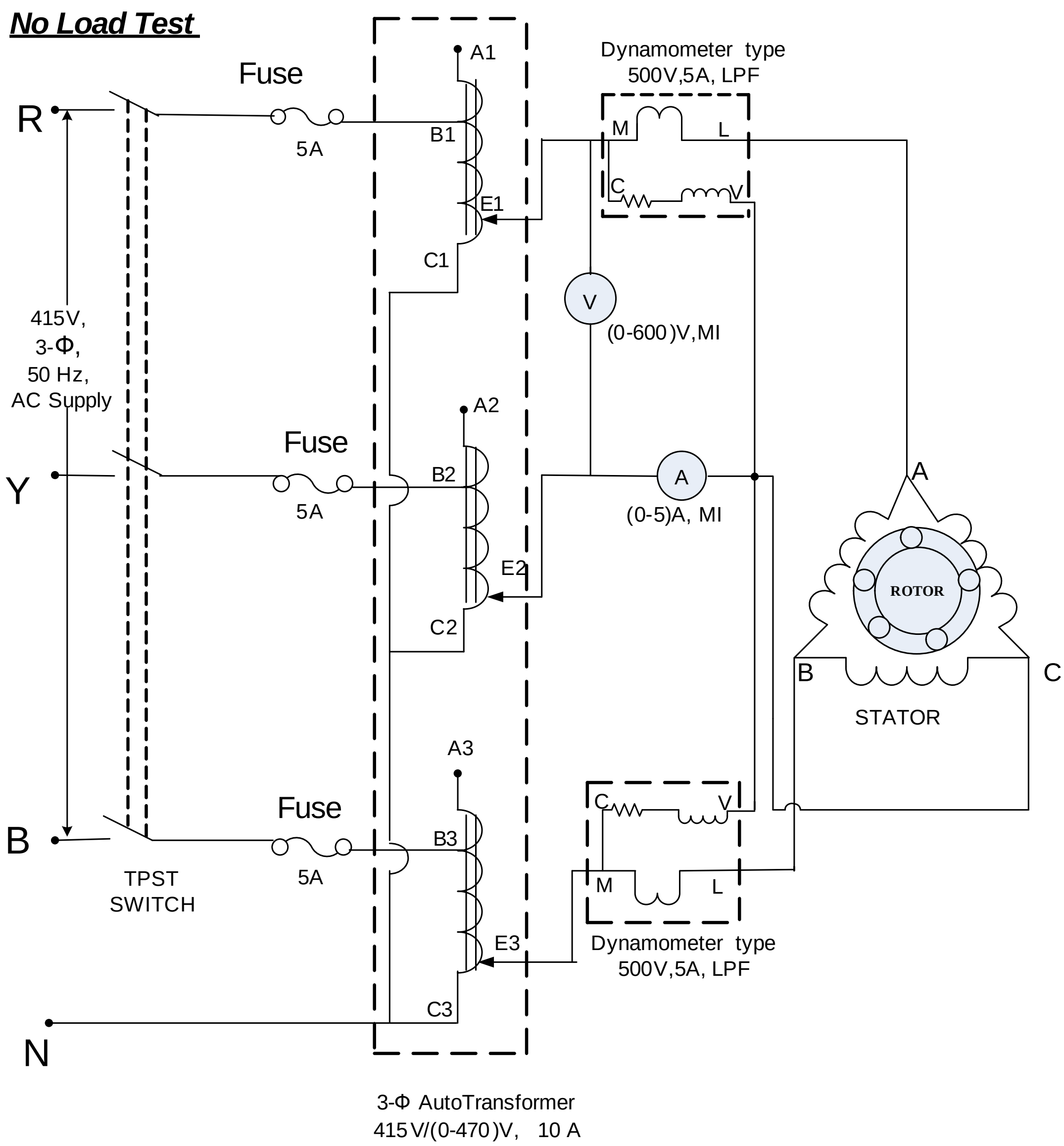
AIM:

To conduct no-load test and blocked rotor test on 3 phase squirrel cage induction motor and construct circle diagram to observe the performance of a motor.

APPARATUS:

S.NO	APPARATUS	RANGE	TYPE	QUANTITY
1.	VOLTMETER	0-500V 0-150V	MI	1.NO EACH
2.	AMMMETER	0-5/10A	MI	1.NO
3.	WATTMETER	500V,5A,LPF 150V,10A,UPF	DYNAMOMETER TYPE	2.NO 2.NO
4.	TACHOMETER	0-10,000	ANALOG	1.NO
5.	FUSEWIRE	5A,10A	TINNED COPPER	15CM

CIRCUIT DIAGRAM:



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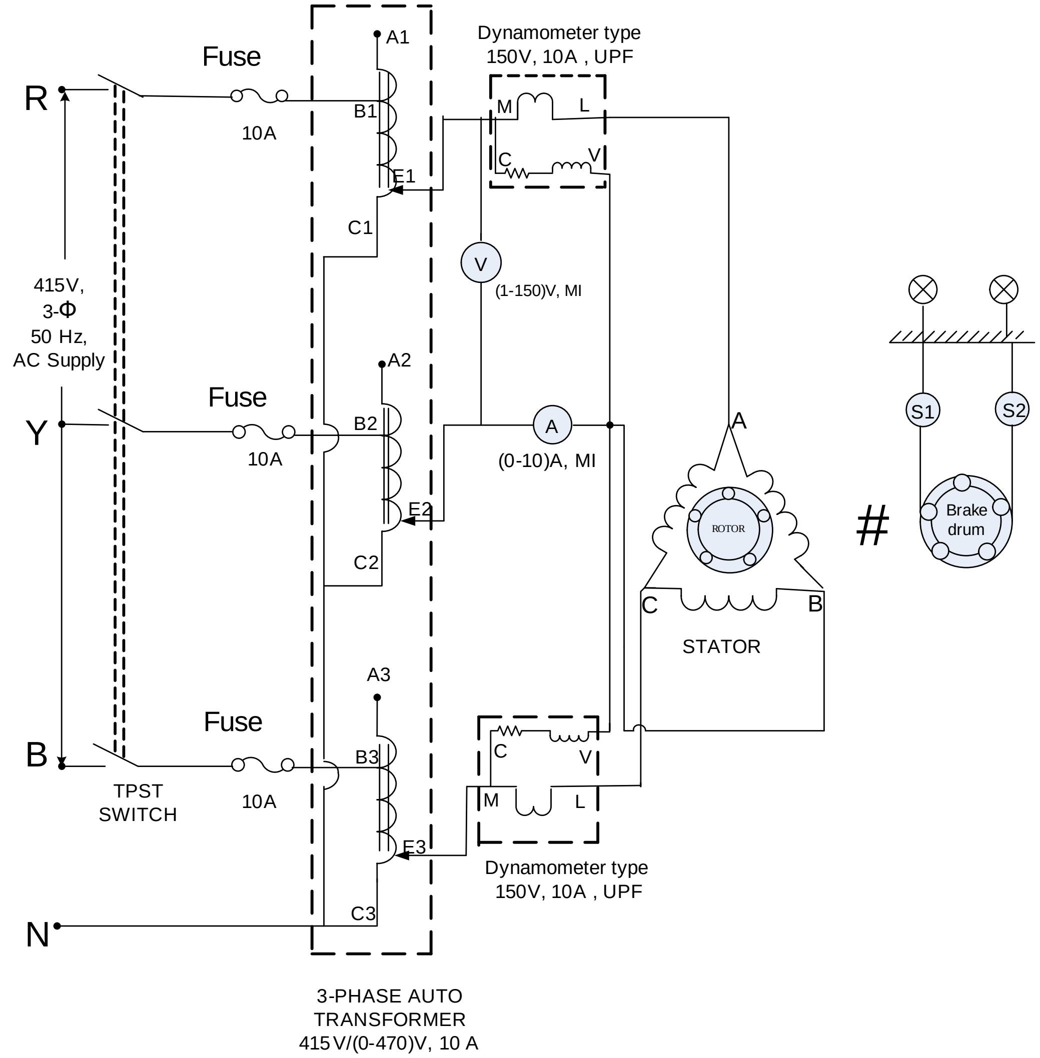
Blocked Rotor Test



Name plate details:

Voltage: 415 V
Current: 7.5 A
Power: 5 H.P
Frequency: 50Hz
Speed: 1430 rpm

THEORY:

The efficiency of small motors can be determined by directly loading them and by measuring their input and output powers. For larger motors, it may be difficult to arrange loads for them. Moreover, the power loss will be large with direct loading tests. Therefore, indirect methods are used to determine the efficiency of three phase induction motors. The following tests are performed on the motor:

(a) No – load test (b) Blocked – rotor test

These tests also enable us to determine the circuit parameters of the equivalent circuit of a 3 – phase induction motor.

No Load Test or Open Circuit Test:

This test is similar to the open – circuit test on a transformer. The motor is uncoupled from its load and the rated voltage at the rated frequency is applied to the stator to run the motor without load. The input power is measured by the two – wattmeter method. The ammeter measures the no-load current and the voltmeter gives the normal rated supply voltage. Since the no-load current is 20 - 30% of the full load current, the I^2R losses in the primary may be neglected as they vary with the square of the current. Since the motor is running at no load, total input power is equal to constant iron loss, friction and windage losses of the motor.

Blocked Rotor Or Short Circuit Test:

This test is analogous to the short circuit test of a transformer. In this test, the shaft of the motor is clamped so that it cannot move and rotor winding is short circuited. In a slip ring motor, the rotor winding is short-circuited through slip rings and in cage motors, the rotor bars are permanently short-circuited. This test is also called as locked – rotor test.

A reduced voltage at normal frequency is applied to the stator through a 3 – phase auto transformer so that full –load rated current flows in the stator. The following three readings are obtained:

(i) Total power input on short – circuit W_{sc} = algebraic sum of the two wattmeter readings

The power input in this test is equal to the sum of copper losses of stator and rotor for all the three phases. This is due to the fact that a reduced voltage is applied to the stator, and rotation is not allowed and therefore, core and mechanical losses are negligible.

(ii) Reading of ammeter I_{sc} = line current on short circuit

(iii) Reading of voltmeter V_{sc} = line voltage on short circuit

PROCEDURE:

No-Load Test:

1. Connect the circuit as per the circuit diagram.
2. Set the brake drum free before supply is given.
3. Kept the dimmerstat in zero voltage position.
4. Switch ON the supply and apply the rated voltage by variac.
5. Note down no-load readings.
6. Decrease the supply voltage to zero and switch-OFF the supply.

Blocked rotor test:

1. Connect the circuit as per the circuit diagram.
2. Block the rotor by brake arrangement.
3. Kept the dimmerstat in zero voltage position.
4. Switch ON the supply and vary the variac slowly till full load current is obtained.
5. Note down the readings.
6. Decrease the supply voltage to zero and switch-OFF the supply.
7. Release the load on brake drum.

OBSERVATIONS:

No-Load Test:

S.No	Voltage(V_0)	No load current(I_0)	Speed,N RPM	W_1 with MF	W_2 with MF	W_O= W_1 +W_2	COSΦ_0

Blocked rotor test:

S.No	Voltage(V_{SC})	Full load current (I_{SC})	W_1 with MF	W_2 with MF	W_{SC} =W_1+ W_2	COSΦ_{SC}

Note:
MF→'Multiplication factor'

$$\cos\Phi_0 = \frac{W_0}{\sqrt{3} * V_0 * I_0} \qquad COS\Phi_{sc} = \frac{W_{SC}}{\sqrt{3} * V_{SC} * I_{SC}}$$

<u>Procedure to draw the circle diagram</u>:

Circle diagram of an induction motor can be drawn by using the data obtained from **(1) no-load (2) short-circuit test** and **(3) stator resistance test**, as shown below.

Step No. 1

From no-load test, I_0 and Φ_0 can be calculated. Hence, as shown in Fig. 1, vector for I_0 can be laid off lagging Φ_0 behind the applied voltage *V*.

Step No. 2

Next, from blocked rotor test or short-circuit test, short-circuit current I_{SN} ***corresponding to normal voltage*** and φ_S are found. The vector ***OA*** represents *ISN* = (*Isc***V*/*Vsc*) in magnitude and phase. Vector O^IA represents rotor current I^I as referred to stator. Clearly, the two points O^I and *A* lie on the required circle. For finding the centre *C* of this circle, chord O^IA is bisected at right angles–its bisector giving point *C*. The diameter O^ID is drawn perpendicular to the voltage vector. As a matter of practical contingency, it is recommended that the scale of current vectors should be so chosen that the diameter is more than 25 cm, in order that the performance data of the motor may be read with reasonable accuracy from the circle diagram. With centre *C* and radius = CO^I, the circle can be drawn. The line O^IA is known as **out-put line.** It should be noted that as the voltage vector is drawn vertically, all vertical distances represent the active or power or energy components of the currents. For example, the vertical component O^IP of no-load current OO^I represents the no-load input, which supplies core loss, friction and windage loss and a negligibly small amount of stator I^2R loss. Similarly, the vertical component *AG* of short-circuit current *OA* is proportional to the motor input on short-circuit or if measured to a proper scale, may be said to equal power input.

Step No. 3

Torque line. *This is the line which separates the stator and the rotor copper losses*.

When the rotor is locked, then all the power supplied to the motor goes to meet core losses and Cu losses in the stator and rotor windings. The power input is proportional to *AG*. Out of this, *FG* (= O^IP) represents fixed losses *i.e*. stator core loss and friction and windage losses. *AF* is proportional to the sum of the stator and rotor Cu losses.

The point *E* is such that *AE/ EF*= rotor Cu loss/stator Cu loss

As said earlier, line O^IE is known as torque line.

How to locate point E ?

With the assumption of rotor and stator cu losses as equal, bisect the line AF.

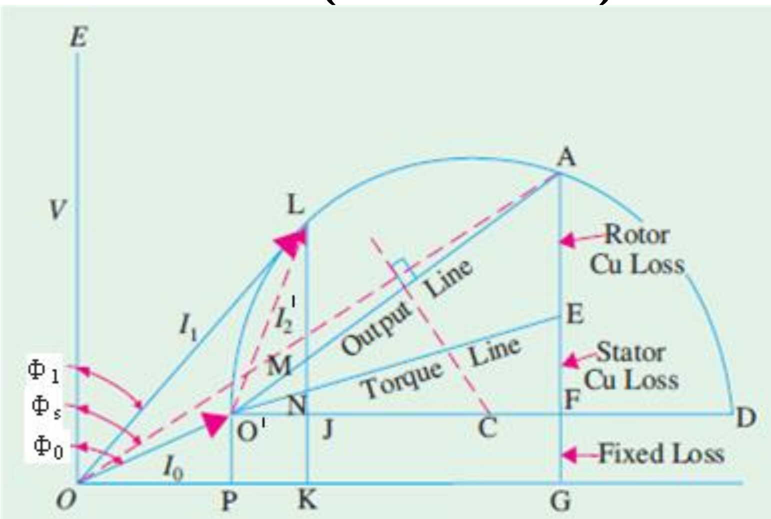


Fig. 1

Let us assume that the motor is running and taking a current *OL* (Fig. 1). Then, the perpendicular *JK* represents fixed losses, *JN* is stator Cu loss, *NL* is the rotor input, *NM* is rotor Cu loss, *ML* is rotor output and *LK* is the total motor input.

From our knowledge of the relations between the above-given various quantities, we can write:

$\sqrt{3}$. *VL* . *LK* = motor input $\sqrt{3}$. *VL* . *JK* = fixed losses

$\sqrt{3}$. *VL* . *JN* = stator copper loss $\sqrt{3}$. *VL* . *MN* = rotor copper loss

$\sqrt{3}$. *VL* . *MK* = total loss $\sqrt{3}$. *VL* . *ML* = mechanical output

$\sqrt{3}$. *VL*. *NL* = rotor input $\propto$ torque

1. *ML* / *LK* = output/input = efficiency

2. *MN* / *NL* = (rotor Cu loss)/(rotor input) = slip, *s*.

3. *ML/NL*== rotor output/rotor input= 1 - *s* =*N/Ns*=actual speed/synchronous speed

4. *LK/OL*= power factor

Hence, it is seen that, at least, theoretically, it is possible to obtain all the characteristics of an induction motor from its circle diagram. As said earlier, for drawing the circle diagram, we need **(*a*)** stator-resistance test for separating stator and rotor Cu losses and **(*b*)** the data obtained from **(*i*)** no-load test and **(*ii*)** short-circuit test.

Maximum Quantities:

It will now be shown from the circle diagram-2 that the maximum values occur at the positions stated below:

(*i*) Maximum Output

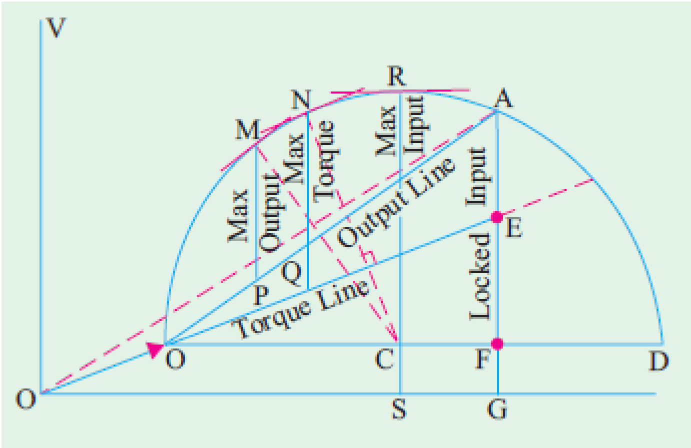
It occurs at point M where the tangent is parallel to output line $O^I A$. Point *M* may be located by drawing a line *CM* from point *C* such that it is perpendicular to the output line $O^I A$. Maximum output is represented by the vertical MP.

(*ii*) Maximum Torque or Rotor Input

It occurs at point *N* where the tangent is parallel to torque line $O^I E$. Again, point *N* may be found by drawing *CN* perpendicular to the torque line. Its value is represented by *NQ* . Maximum torque is also known as stalling or pull-out torque.

(*iii*) Maximum Input Power

It occurs at the highest point of the circle *i.e*. at point R where the tangent to the circle is horizontal. It is proportional to RS. As the point R is beyond the point of maximum torque, the induction motor will be unstable here. However, the maximum input is a measure of the size of the circle and is an indication of the ability of the motor to carry short-time over-loads. Generally, RS is twice or thrice the motor input at rated load.



The circle diagram-2

PRECAUTIONS:
1. Loose connections are to be avoided.
2. Readings must be taken without any parallax error.

RESULT:

VIVA:

1. What is the difference between the no load on an induction motor and the O.C test on transformer, as far the secondary (rotor) circuit is concerned?
2. If the blocked rotor test is performed on a wound rotor motor and if the rotor winding is kept open, will you able to perform the test?
3. The induction motor always draws a lagging current. Explain it with the help of the circle diagram.
4. Draw the equivalent circuit of an induction motor.
5. If the rotor circuit is open, will the motor work?
6. What is the synchronous speed for 50Hz supply and a 4-pole motor?
7. What are similarities and dissimilarities of an induction motor and transformer?

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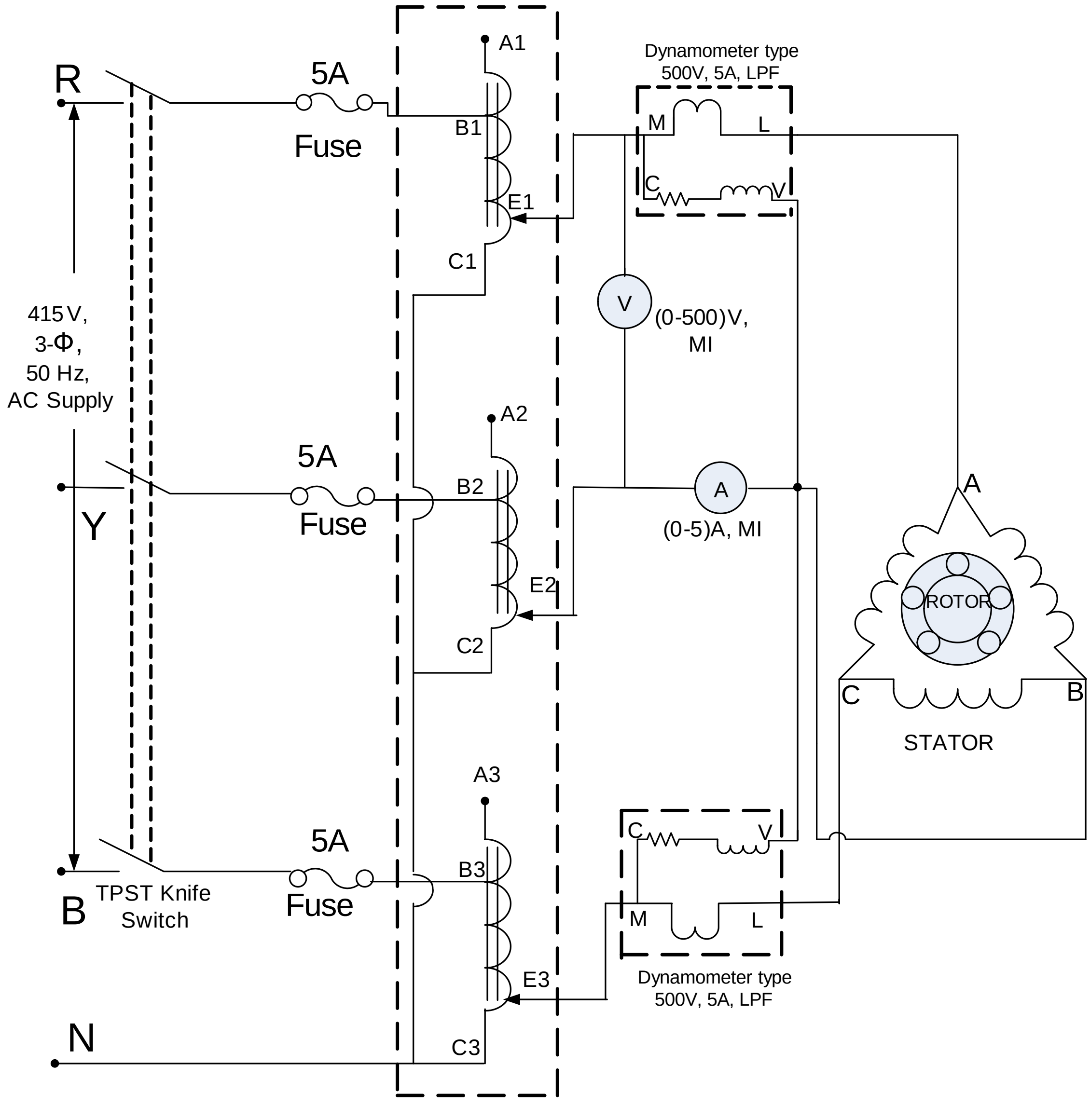
SEPARATION OF NO-LOAD LOSSES OF A 3- PHASE INDUCTION MOTOR

AIM:
To conduct an experiment to separate no-load losses of a 3 phase induction motor.

APPARATUS:

S.NO	APPARATUS	TYPE	RANGE	QUANITY
1.	AMMETER	MI	0-5A	1.NO
2.	VOLTMETER	MI	0-500V	1.NO
3.	WATTMETER	DYNAMOMETER	500V,5A,LPF	2.NO
4.	VARIAC	IRONCORED	400/0-470V	1.NO
5.	FUSE WIRE	TINNED COPPER	5A	1.NO

CIRCUIT DIAGRAM:



3- Phase Variac

Name plate details:

Voltage: 415 V   Current: 4 A   Power: 3 H.P
Frequency: 50Hz   Speed: 1440 rpm

THEORY:

The no load losses are the constant losses which includes core loss and friction and windage loss. The separation between the two can be carried out by the **no load** test conducted from variable voltage, rated frequency supply.

When the voltage is decreased below the rated value, the core loss reduces as nearly square of voltage. The slip does not increase significantly the friction and windage loss almost remains constant.

The voltage is continuously decreased till the machine slip suddenly begins to increase and the motor tends to stall. At no load, this takes place at a sufficiently reduced voltage. The graph showing no load losses ***VS*** Voltage as shown in figure is extrapolated to V = 0 which gives friction and windage loss as iron or core loss is zero at zero voltage.

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Set the brake drum free before supply is given.
3. Kept the dimmerstat in zero voltage position.
4. Switch ON the supply and apply the rated voltage by variac.
5. Note down readings at rated voltage.
5. Decrease the voltage until the motor gets stopped in various steps and note down readings in each step.
6. Bring the variac to the minimum position and switch off the supply.
7. Measure stator resistance per phase, R_a.

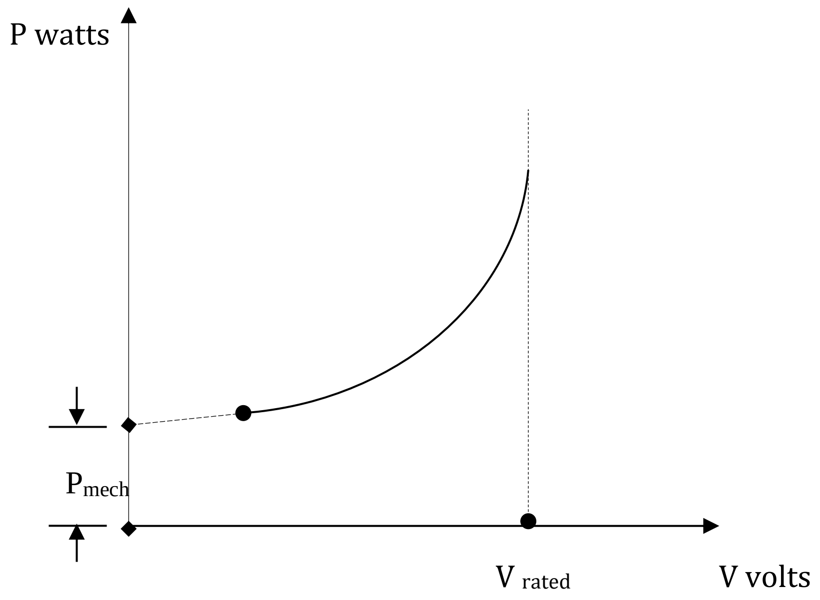
TABULAR FORMS:

Voltage(V)	Current(I)	W_1 with MF	W_2 with MF	Input power, $P=W_1+W_2$	Mechanical losses, P_{mech} (from graph)	No-load cu loss, $P_{cu}=3\left(\frac{I}{\sqrt{3}}\right)^2 R_a$	Iron losses = $P- P_{mech}-P_{cu}$

Note: MF→'Multiplication factor'

CALCULATIONS:

Plot input power 'P' *Vs* applied voltage 'V' and extrapolate to V = 0, this will give friction and windage (Mechanical loss) loss.



PRECAUTIONS:

1. Loose connections are to be avoided.
2. Readings must be taken without any parallax error.

RESULT:

VIVA:

1. What are the total losses of an induction motor?
2. Draw the power flow diagram of an induction motor?
3. Express the input power to the rotor in terms of slip?
4. Write the relation between P_2 **:** P_m **:** I^2r losses.
5. What are the iron losses of an induction motor?

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EQUIVALENT CIRCUIT OF A SINGLE PHASE INDUCTION MOTOR

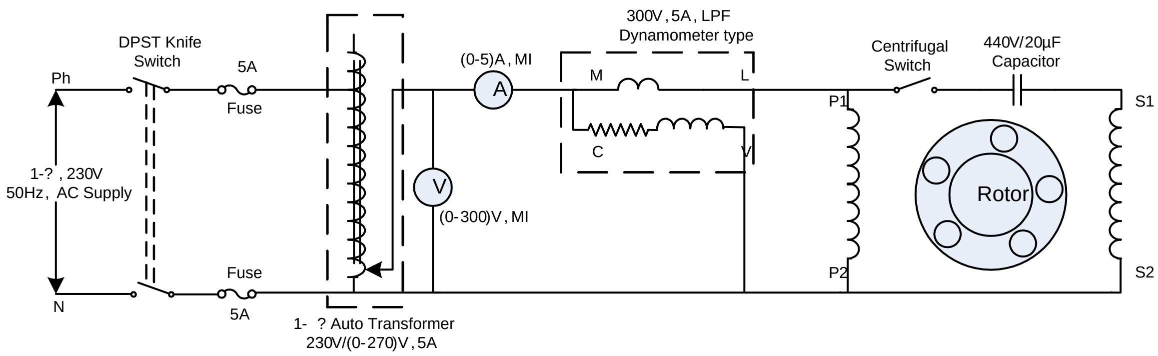
AIM:
To draw the equivalent circuit of a single phase induction motor.

APPARATUS:

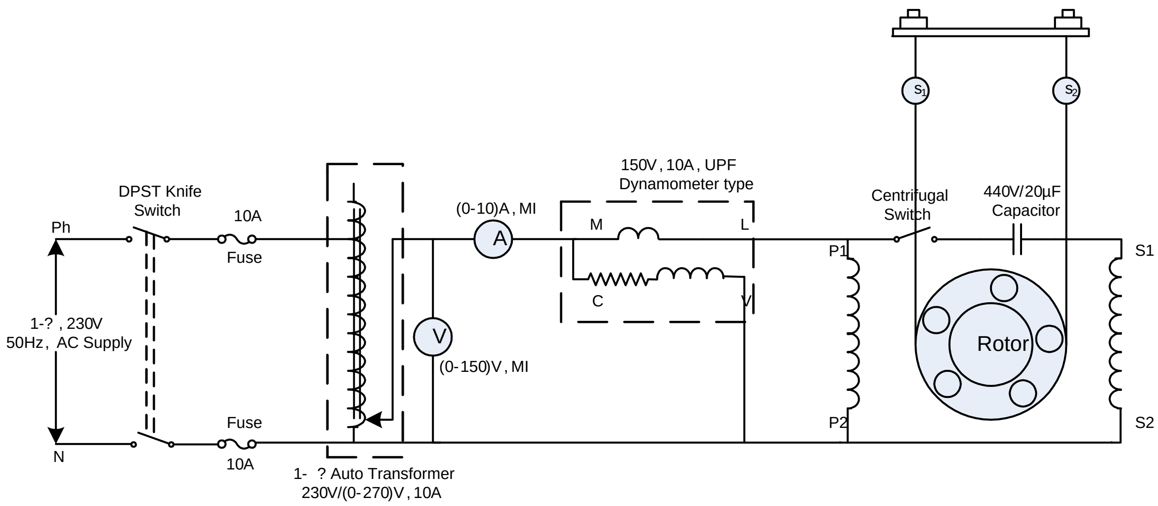
SNO	APPARATUS	RANGE	TYPE	QUANTITY
1.	VOLTMETER	(0-150)V (0-300)V	MI	1NO each
2.	AMMETER	0-5A,0-10A	MI	1NO each
3.	WATTMETER	300V,5A,LPF 150V,10A,UPF	DYNAMOMETER	1NO each
4.	VARIAC	230/(0-270V),10A		1NO

CIRCUIT DIAGRAM:

NO LOAD TEST:



BLOCKED ROTOR TEST:



Name plate details:

Voltage: 220 V   Current: 5 A
Power: 1 H.P   Frequency: 50Hz
Speed: 1420 rpm

THEORY:
Single phase induction motor suffers from several drawbacks such as low over-load capacity, low

efficiency, and low power factor. The peculiar behavior can be explained from following two theories.

1. Double revolving field theory
2. Cross field theory.

Double revolving field theory:-

This theory is based on the idea that pulsating field produced in a single phase motor can be represented by two revolving fluxes each equal to half of the value of the alternating flux and each rotating at synchronous speed in opposite direction.

Cross field theory:-

The field created by the rotor currents becomes maximum nearly at ¼ cycle after the generated EMF has reached its maximum value. Since the field created by rotor currents is at right angles to the field by the stator currents, it is known as cross-field theory.

No load and blocked rotor tests are performed on single phase induction motor to determine its parameters of the equivalent circuit. the motor consists of a stator winding, represented by its resistance R_1 and leakage reactance X_1 and two imaginary rotors, generally called as forward and backward rotors and each rotor has been assigned half the total magnetizing reactance. Forward rotor has a slip of s then the backward rotor has a slip of (2-s). The complete parameters of this equivalent circuit can be calculated from blocked rotor and no load test.

PROCEDURE:

No-Load Test:

1. Connect the circuit as per the circuit diagram.
2. Set the brake drum free before supply is given.
3. Kept the dimmerstat in zero voltage position.
4. Switch ON the supply and apply the rated voltage by variac.
5. Note down no-load readings.
6. Decrease the supply voltage to zero and switch-OFF the supply.
7. Measure stator resistance, R_{dc}

Blocked rotor test:

1. Connect the circuit as per the circuit diagram.
2. Block the rotor by brake arrangement.
3. Kept the dimmerstat in zero voltage position.
4. Switch ON the supply and vary the variac slowly till full load current is obtained.
5. Note down the readings.
6. Decrease the supply voltage to zero and switch-OFF the supply.
7. Release the load on brake drum.

OBSERVATIONS:

No Load Test:

S.NO	V_0(v)	I_0 (A)	W_0 (w)	Speed,N

Blocked rotor test:

S.NO	V_{SC} (v)	Isc (A)	W_{SC} (w)

Formulae used:

OC Test:

1. No load power factor ($Cos\Phi_0$) = W_o / V_oI_o

V_o – No-load voltage in volts.

I_o – No-load current in amps.

W_o – No-load power in watts.

2. Working component current (I_w) = $I_0 \times Cos\Phi_0$
3. Magnetizing current (I_m) = $I_0 \times sin\Phi_0$
4. No-load resistance (R_0) = V_0 / $I_0cos\Phi_0$ in Ω
5. No-load reactance (X_0) = V_0 / $I_0Sin\Phi_0$ in Ω

SC Test:

6. Equivalent Impedance of motor referred to stator (Z_{SC})

$$=V_{SC} / I_{SC} \text{ in } \Omega$$

7. Equivalent Resistance of motor referred to stator (R_{SC})

$$=V_{SC} / I_{SC}^2 \text{ in } \Omega$$

8. Equivalent Reactance of motor referred to stator (X_{SC})

$$= \sqrt{\left(Z_{sc}^{\ 2} - R_{sc}^{\ 2}\right)} \text{ in } \Omega$$

9. Rotor Resistance referred to stator (R_2^I) = $R_{SC} - R_1$ in Ω
10. Rotor Reactance referred to stator (X_2^I) = $X_{SC}/ 2 = X_1$ in Ω

    Where, R_1 is stator resistance, $R_1=R_{(AC)} = 1.6 \times R_{(DC)}$

    X_1 is stator reactance
11. Magnetizing Reactance (X_m) = $2(X_0 – X_1 – X_2^I/2)$
12. The resistance of each rotor (r_2) = $R_2^I/2$

    The reactance of each rotor (x_2) = $X_2^I/2$
13. Slip (S) = $(N_S – N) / N_S$

    Where, N_S – Synchronous speed in rpm,

    N – Speed of motor in rpm.

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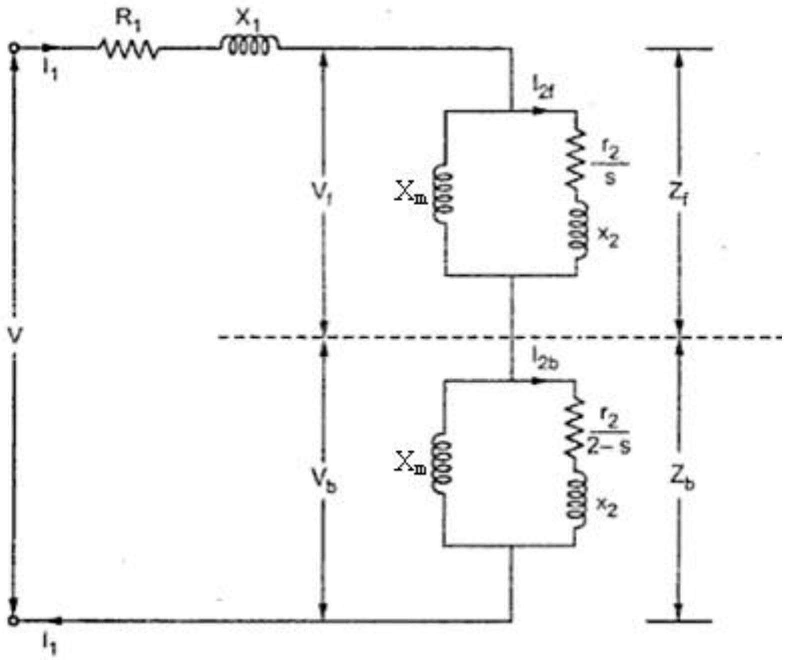

The equivalent circuit of a single phase induction motor without core-loss

PRECAUTIONS:
1. Loose connections are to be avoided.
2. Readings must be taken without any parallax error.

RESULT:

VIVA:

1 .What is the cause of lagging power factor of induction motor?
1 .What is the fractional slip of an induction motor?
3. On what factors the torque developed by a three phase induction motor depends?
4. What are the types of single phase induction motors?
5. What is the purpose of switch in single phase induction motors?
6. What is the purpose of capacitor in single phase induction motors?
7. Which theories explain the peculiar behavior of single Phase Induction Motors?

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LOAD TEST ON A SINGLE PHASE INDUCTION MOTOR

Aim: To perform load test on single phase induction motor to obtain the performance characteristics.

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 single-phase ac 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

$$N_s = \frac{120\,f}{P}$$

Where f =supply requency.

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

The actual speed of the rotor N_r 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%.

$$s = \frac{N_s - N_r}{N_s} X\ 100$$

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,

$$W = (S_1 - S_2)K_gf$$

$$T = (\frac{d}{2}) * W * 9.8\ Nw - m$$

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 N_r is speed of motor in rpm.

Input Power :

The input power can be determined from the readings of wattmeter connected in the circuit.

$$P_i = W$$

Power Factor :

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

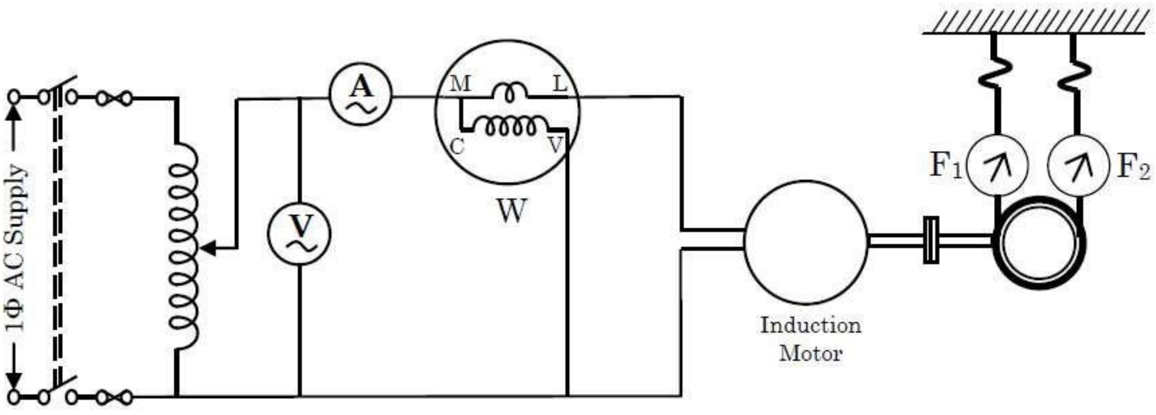
$$\cos \varphi = \frac{P_{in}}{VI}$$

Efficiency :

Efficiency can be calculated using

$$\square = \frac{output\ power}{input\ power}\ X\ 100$$

Circuit Diagram :



Procedure :

1. Connect the circuit as shown in Fig.
2. Set 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.
7. Calculate the various quantities and draw the various curves as stated above.

Observation Table :

SL NO	Input Voltage V (volt)	Input Current I (amp)	Input Power	Force (Kgf)			Speed N_r (rpm)
			W (watt)	S1	S2	F = S1 – S2	
1							
2							
3							
4							
5							

Diameter of pulley, d =___ m.

Calculation :

SL NO	Input Power P_{in} (watt)	Total Force F (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 attention should be given for cooling of the break pully, otherwise the wearing out of belt may be very rapid.
3. The current ratings should be-given special care while selecting wattmeters.

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.

RESULT:

Thus load test on the single phase induction motor has been conducted and itsperformance characteristics determined.

VIVAQUESTIONS

1. What is the purpose of this experiment?
2. Whether single phase induction motor self starting motor?
3. What are the starting methods of single phase induction motor?

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Load Test on a 3-Phase Alternator by direct Loading.

AIM:- To determine voltage regulation of three phase alternator by direct loading.

Apparatus :

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Frequency meter		
	Tachometer		
	Connecting leads		
	3-phase load		

Electrical Machine Specifications:

Synchronous Machine: Power: _______ Voltage:_________ Current: ___________

Speed: ________________________________

DC Motor: Power: _______ Voltage:_________ Current: ___________

Speed: ________________________________

Theory :

This decrease in the terminal voltage of an alternator is due to the following three reasons.

1. Armature resistance.
2. Armature leakage reactance.
3. Decrease in flux/pole due to armature reaction.

The effect of armature reaction on the terminal voltage of the alternator can be accounted for by assuming a fictitious reactance X_a in the armature-windings. The voltage drop due to armature reaction is represented by I X_a, where I represents the load current and X_a, represents the equivalent (fictitious) reactance due to the armature reaction.

At this stage, we can define a new term, known as synchronous reactance, X_s as the sum of leakage reactance X_L and the fictitious reactance representing the armature reaction X_a. Thus

$X_s = X_L + X_a$

Further, we define another term as synchronous impedance (Z_s) as

$Z_s = R_a + jX_s$

The voltage regulation of an alternator is defined as the increase in the terminal voltage when full load is thrown off, provided field current and speed remain the same.

Mathematically,

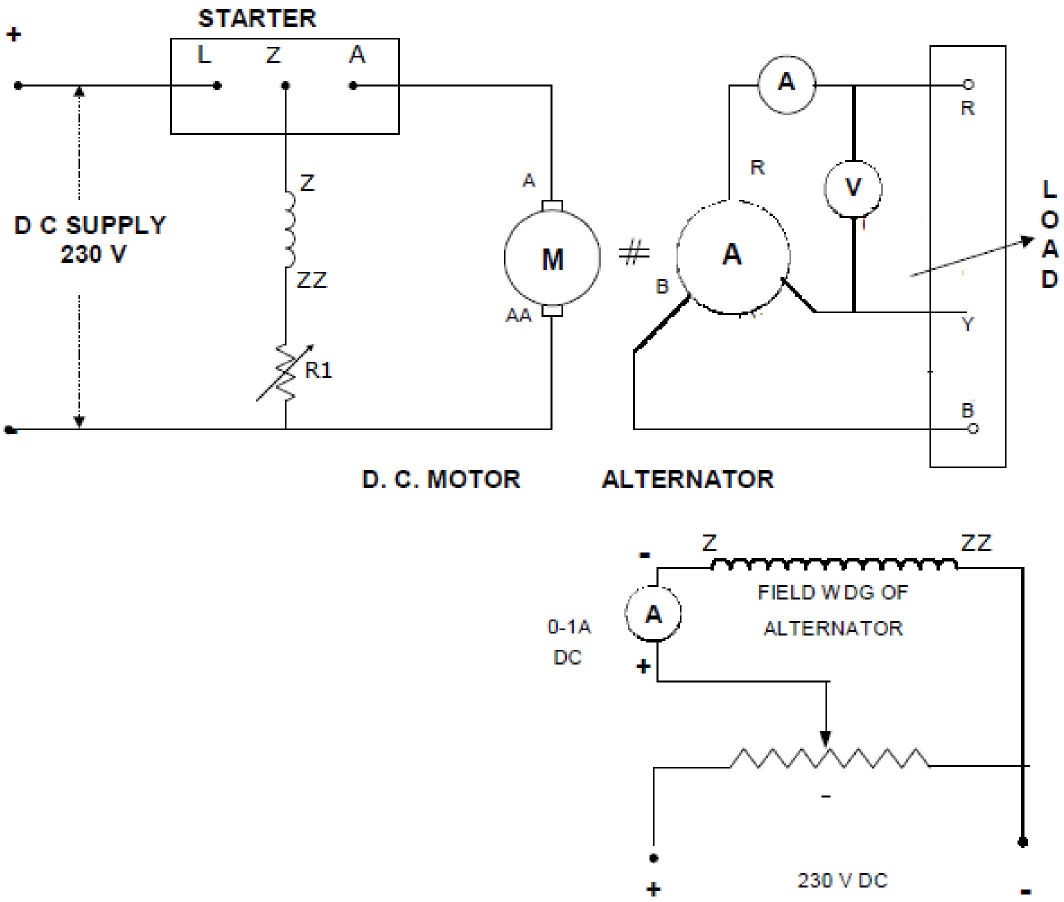
Percentage regulation = $(E_o – V)*100/V$ Where, E_o

= No load terminal voltage

V = Full load terminal voltage

In case of a lagging power factor E_o is more than V and voltage regulation is positive whereas in case of a leading power factor E_o is less than V and voltage regulation is negative.

Circuit Diagram:-



Procedure: -

1) Connect the circuit as shown in the diagram.
2) Keep load zero, set field potential divider to zero output voltage position.
3) Keep field resistance of motor to its minimum value.
4) Start the motor with the help of starter.
5) With the field rheostat of motor adjust the speed to synchronous value.
6) Switch on DC supply of field (Alternator) and adjust the potential divider so that the voltmeter reads rated voltage of the alternator.
7) Increase the load in steps till rated current of alternator and set the voltage and speed rated.
8) Now sudden thrown off the load and set the speed rated. Keep the field current same as at full load.
9) Note down the no load voltage at same field current.

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 resistance position.
3) Do not switch on the supply, until and unless the connection are checked by the teacher
4) Avoid error due to parallax while reading the meters.

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

Observation:

Sr. No.	Voltage at Full load V_t (V)	Voltage at no load E_o (V)	% Regulation

Calculations:

$$\% \text{ regulation} = \frac{E_o - V_t}{V_t} \times 100$$

Result: The regulation at full load ____________________

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Regulation of a three-phase alternator by synchronous impedance method (EMF method)

AIM:- To find regulation of a three-phase alternator by synchronous impedance method (EMF method)

Apparatus :

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Frequency meter		
	Tachometer		
	Connecting leads		
	3-phase load		

Electrical Machine Specifications:

Synchronous Machine: Power: ________ Voltage:_________ Current: ___________
Speed: _____________

DC Motor: Power: _______ Voltage:_________ Current: ___________
Speed: ______________________________

Theory:

The synchronous impedance of a given three phase alternator can be determined from the following two experiments.

1. **Open Circuit Test:**

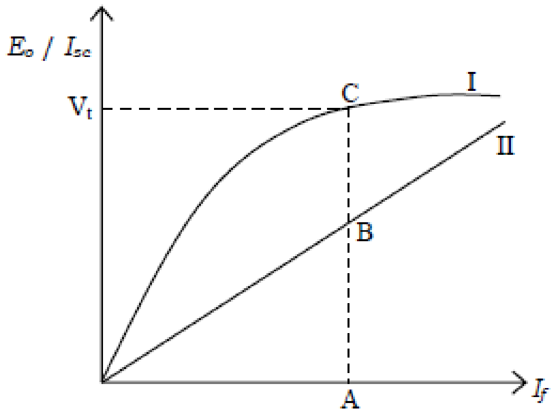
In this test, the alternator is run with the prime mover i.e. dc motor. The output terminals of the alternator are kept open i.e. alternator run on no-load. The induce emf per phase corresponding to various values of field current is measured. The curve is drawn between the induced emf per phase and the field current as shown in Fig. This curve is known as open circuit characteristics (O.C.C.).

2. **Short Circuit Test:**

In this test, the output terminals of the alternator are short circuited through low resistance ammeter. The short circuit current is measured corresponding to various values of field current while speed is kept constant with the help of field rheostat. The curve is drawn between short circuit current and field current as shown in Fig. (Curve II). This curve is known as short circuit current (S.C.C.).

From the Fig. let OA represent the field current corresponding to rated terminal voltage. Then AB represents the rated short circuited current and AC represents the induced emf per phase. Under the short circuit condition whole of the emf AC is used to create the short circuit current AB. Now, we can write

Synchronous impedance, Z_s = AC (in volts)/ AB (in amp)



The value of armature resistance per phase R_a can be determined by an accurate ohmmeter. The effective value of armature resistance can be determined by increasing the measured value by 20% to account for the skin effect and effect of temperature rise. Then, synchronous reactance X_S can be calculated using the following relation

$X_S = \sqrt{Z_S^2 - R_a^2}$

No load induced emf per phase

$$E_o = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi + IX_s)^2}$$

Percentage Regulation

$$= \frac{E_o - V}{V} \times 100\%$$

Circuit Diagram:

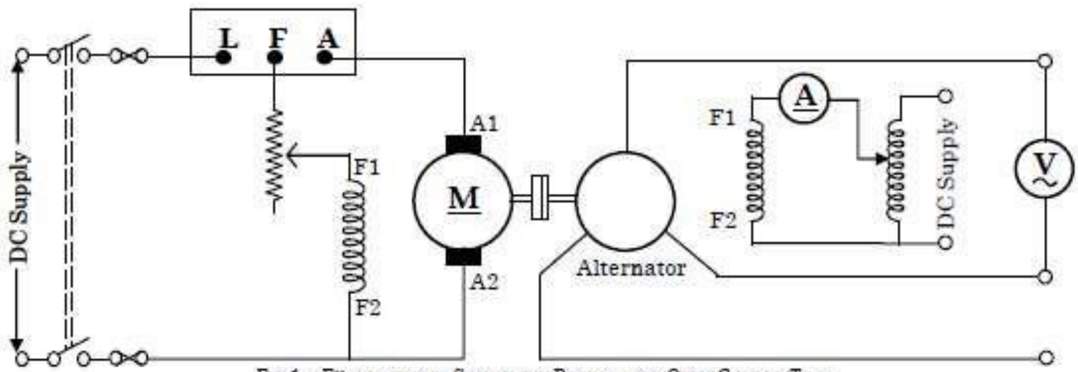


FIG 1 : EXPERIMENTAL SET-UP FOR PERFORMING OPEN CIRCUIT TEST

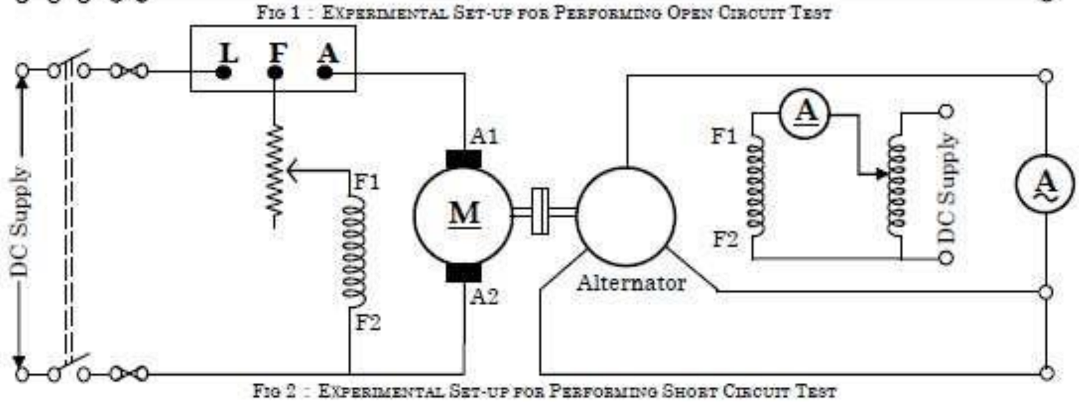


FIG 2 : EXPERIMENTAL SET-UP FOR PERFORMING SHORT CIRCUIT TEST

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

Calculate the excitation emf Eo and voltage regulation for full-load and

1. 0.8 lagging p.f.
2. UPF
3. 0.8 leading p.f.

$$Eo = [(V \cos\emptyset + Ia\ Ra)^2 + (V \sin \emptyset \pm Ia\ Xs)^2]$$

+ sign is for lagging pf load.
- sign is for leading pf load.

V = rated terminal voltage per phase of alternator

%Regulation $= \frac{E_o - V}{V} \times 100\%$

Result:

Regulation of alternator at full load is found to be,

At unity pf = --------------

At 0.8 lagging = ---------------

At 0.8 leading = --------------

Synchronous Impedance varies for different values of excitation.

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 Øresistance position.
3. Do not switch on the supply, until and unless the connections are checked by the teacher
4. Avoid error due to parallax while reading the meters.
5. Hold the tachometer with both hands steady and in line with the motor shaft so that it reads correctly.
6. Ensure that the winding currents do not exceed their rated values.

Discussion:

1. Why OCC looks like B-H curve?
2. Why SCC is a straight line?
3. What is armature reaction effect?
4. What are the causes of voltage drop?
5. When is the regulation negative and why?
6. Can we find regulation of a salient pole machine by this test? Justify your answer.

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Regulation of a three-phase alternator by ZPF method

AIM:- To determine voltage regulation of three phase alternator by ZPF method.

Apparatus :

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Frequency meter		
	Tachometer		
	Connecting leads		
	3-phase load		

Electrical Machine Specifications:

Synchronous Machine: Power: _______ Voltage:_________ Current: ___________

Speed: ________________________________

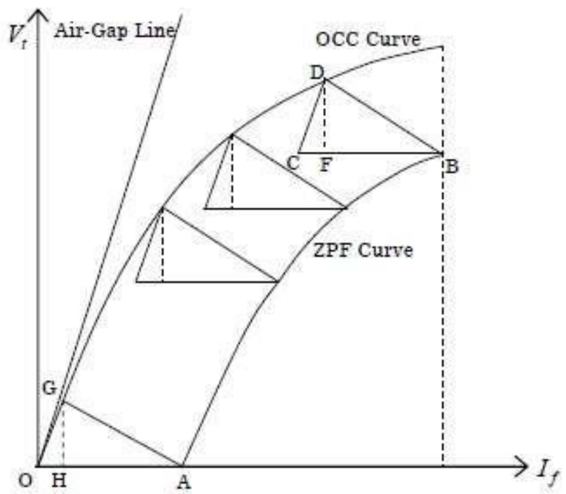
DC Motor: Power: _______ Voltage:_________ Current: ___________

Speed: ________________________________

Theory :

The regulation obtained by synchronous impedance method is based on total synchronous reactance i.e. sum of armature leakage flux reactance and reactance due to armature reaction. But in Zero Power Factor (ZPF) or Potier reactance method regulation calculation is based on separation of reactance due to leakage flux and that due to armature reaction flux.

To determine the voltage regulation by this method, a curve between terminal voltage and field excitation while machine is being run on synchronous speed and delivering full load at zero power factor (lagging) have to be drawn along with no load characteristic as show in figure. The ZPF characteristic curve is of exactly same shape, as the OCC but it is shifted vertically downward by leakage reactance drop $IX_L$and horizontally by armature reaction mmf.



The point A is obtained from a short circuit test with full load armature current. Hence OA represents excitation (field current) required to overcome demagnetizing effect of armature reaction and to balance leakage reactance drop at full load. Point B is obtained when full load current flows through the armature. From B, line BC is drawn and parallel to OA. Then a line is drawn through c parallel to initial straight part of OCC (parallel to OG), intersecting the OCC at D. BD is joined and a perpendicular DF is dropped on BC. The triangle BFD is imposed at various points OCC to obtain corresponding points on the ZPF curve. The length BF in □BFD represents armature reactance and the length DF represents leakage reactance drop IX_L . This known as Potier reactance voltage drop and the triangle is known as Potier Triangle. The potier reactance is given as

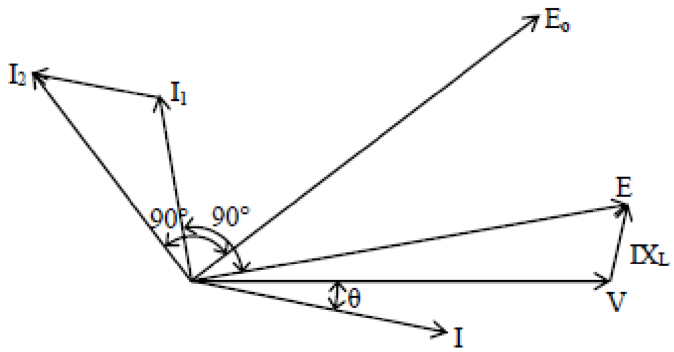
$$X_p = \frac{\text{voltage drop per phase (DF)}}{\text{zero power factor current per phase}}$$

In case of cylindrical rotor machines, potier reactance is nearly equal to armature leakage reactance. In case of salient pole machine, the magnetizing circuit is more saturated and the armature leakage reactance is smaller than the potier reactance.

Potier Regulation Diagram:

OV is drawn horizontally to represent full load terminal voltage, V and OI is drawn to represent full load current at a given power factor. VE is drawn perpendicular to phasor OI and equal to reactance drop (IX_L), neglecting resistance drop. Now phasor OE represents generated emf E. From OCC field excitation I_1 corresponding to generated emf E is determined, OI_1 is drawn perpendicular to phasor OE to represent excitation required to induce emf OE on open circuit. I_1I_2 is drawn parallel to load current phasor OI to represent excitation equivalent to full load armature reaction. OI_2 gives total excitation required. If the load is thrown off, then terminal voltage will be equal to generated emf corresponding to field excitation OI_2. Hence OE_o will lag behind phasor OI_2 by 90°. EE_o represents voltage drop to armature reaction. So, regulation can be obtained from the relation below

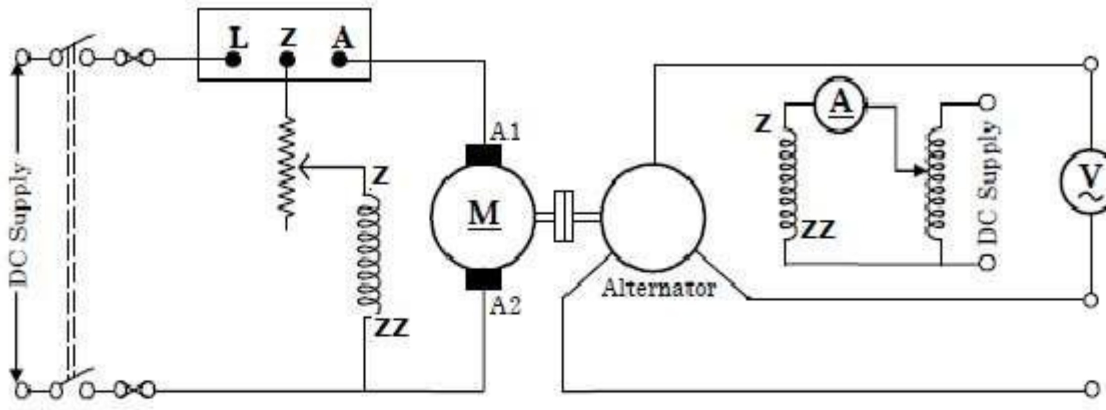
$$\text{Percentage regulation} = \frac{E_o - V}{V} \times 100\%$$



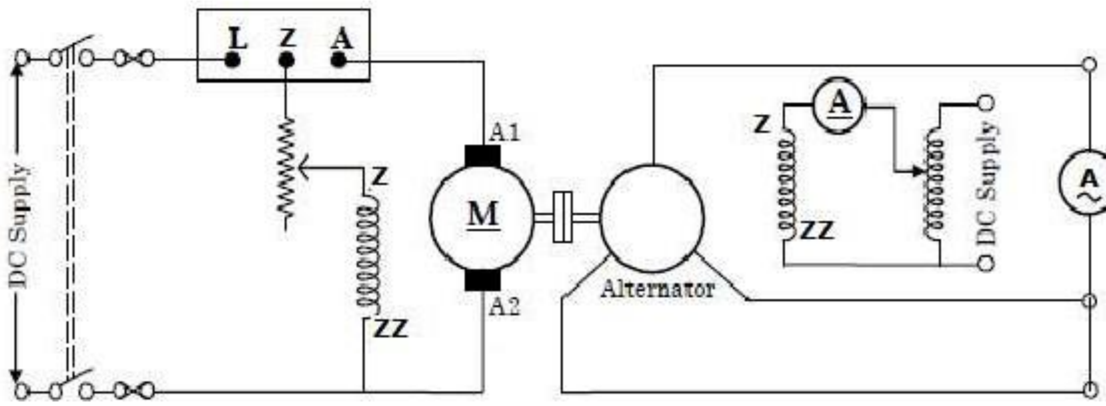
Potier regulation diagram

Circuit Diagram:-

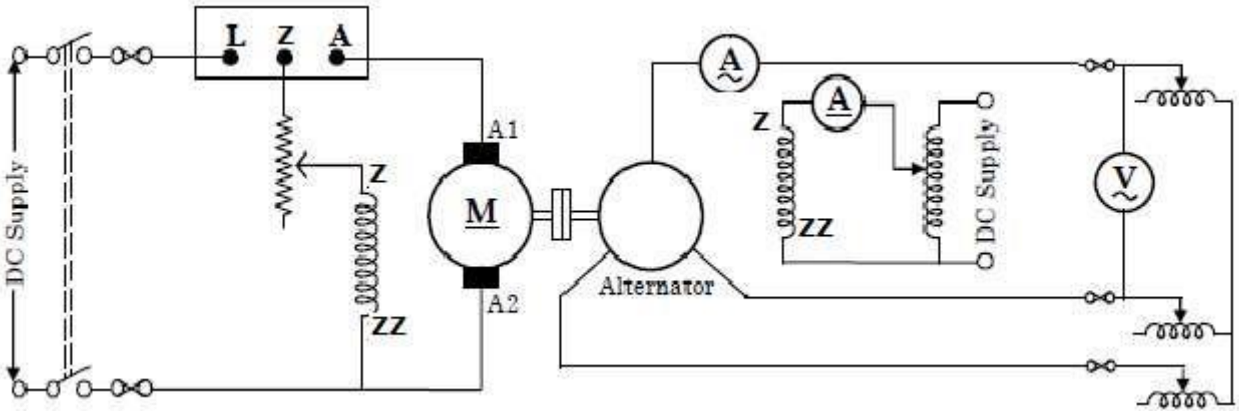
i) **Open Circuit Test (Fig-1)**



ii) **Short circuit Test (Fig-2)**



iii) **Set up for ZPF Curve (Fig-3)**



Procedure: -

To plot Open Circuit Characteristics:

1) Connect the circuit as shown in Fig. 1.
2) Switch ON the dc power supply and start the motor with the help of three point starter keeping the field rheostat at its minimum value.
3) Now adjust the speed of motor equal to the synchronous speed of alternator with the

help of field rheostat. Maintain this synchronous speed throughout the experiment.

4) Increase alternator field current by varying the field voltage gradually. Note down the voltmeter reading connected across the alternator terminals for various values of alternator field current. Go up to 10 % above the rated voltage of alternator.
5) Switch OFF the dc supply.
6) Short the alternator output through ammeter as shown in Fig. 2 and repeat steps 2 and 3 above.
7) Increase alternator field current by varying the field voltage gradually. Note the ammeter readings connected across the alternator terminals for various values of alternator field current.
8) Switch OFF the dc supply.
9) Measure per phase armature resistance and field resistance.
10) Plot the O.C.C. and S.C.C. curves.

To Plot ZPF Curve

1) Connect the circuit as shown in figure.
2) Start the motor and run it at synchronous speed.
3) Vary the inductive load in steps and adjust the field current to a value till full load armature current is flowing.
4) Every time note down the field current and the terminal voltage of alternator.
5) Plot the ZPF curves and draw potier triangle.

Observation:

SL NO	Open-circuit Test		Short-circuit Test		Zero Power Factor Test	
	Field Current I_f (amp)	Terminal Voltage V_t (volt)	Field Current I_f (amp)	Short-circuit Current V_t (volt)	Field Current I_f (amp)	Terminal Voltage V_t (volt)
1						
2						
3						
4						
5						

Armature resistance per phase = Ω
Effective value of armature resistance = Ω
Field resistance = Ω

Calculation:

Potier reactance = No
load voltage E_O =
%age regulation = (Eo-V)*100/V

Result: The regulation at full load ___________________

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Measurement of sub transient direct axis (X_d'') and quadrature axis (X_q'') synchronous reactance of an alternator.

AIM:- To determine sub transient direct axis (X_d'') and quadrature axis (X_q'') synchronous reactance of an alternator.

Apparatus :

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

Electrical Machine Specifications:

Synchronous Machine: Power: _______ Voltage:_________ Current: ___________

Speed: ______________________________

Theory:

To understand the behavior of an alternator under transient conditions, the armature and field resistance is assumed to be negligibly small. In purely inductive closed circuit the total flux linkages cannot change suddenly at the time of any disturbance. Now if all the three phases of an unloaded alternator with normal excitation are suddenly short circuited there will be short circuit current flowing in the armature. As the resistance is assumed to be zero this current lag behind the excitation voltage by 90 degree and the mmf produced by this current will be in d- axis and the first conclusion is that , this current will be affected by d axis parameters *Xd, Xd'* and X*d''* only.

Further there will be demagnetizing effect of this current but as the flux linkages with field cannot change the effect of demagnetizing armature mmf must be counter balance by a proportional increase in the field current ,This additional induced component of field current gives rise to greater excitation , under transient state and results in more short circuit current at this time than the steady state short circuit.

If field poles are provided with damper bars, then at the instant three phase short circuit the demagnetizing armature mmf induces current in damper bars which in turn produces field in the same direction as main field and hence at this instant, the excitation further increases and gives rise to further increase in short circuit armature current.

This is for a very short duration, normally 3 to 4 cycles and this period is known as sub- transient period. Since the field voltages are constant, there is no additional voltage to sustain this increased excitation during sub transient period or transient period. Consequently the effect of increased field current decrease with a time constant determined by the field and armature circuit parameter and accordingly the short circuit armature current also decays with the same time constant.

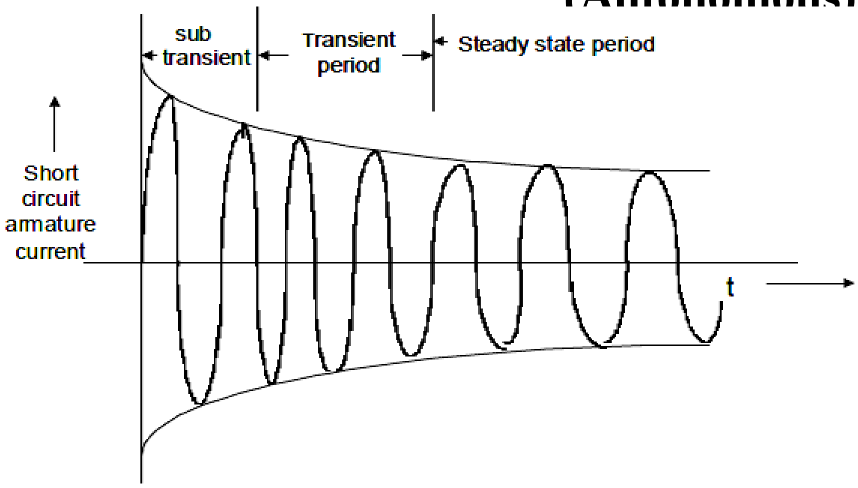
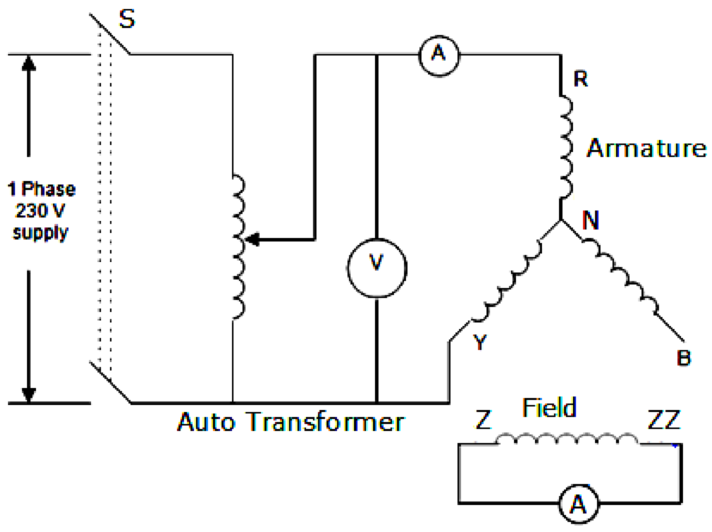


Fig. shows a symmetrical waveform for an armature short circuit for one phase of three phase alternator. The DC component is taken to be zero in this phase.
The reactances offered by the machine during sub transient period are known as sub transient reactances. Along the direct axis, it is direct axis sub transient reactance, *Xd″* and along the quadrature axis, it is quadrature axis sub-transient reactance, Xd″.

Circuit Diagram:



Procedure:

1) Make the connections as shown in the circuit diagram
2) Set the dimmerstat output to zero and put on the supply.
3) Adjust the stator current to 50% of the rated value rotate the rotor slowly with hands and note down the current through field winding and respective readings. When
    - The current flowing through field winding is Maximum.
    - The current flowing through field winding is Minimum.
4) Repeat the step three for other applied voltage Take care that armature current does not go beyond its rated value during the experiment.

Observations:

S.No.	Armature Voltage (V)	Armature Current		Calculations	
		at I_f max.	at I_f min.	$X_d'' = \frac{(2)}{2.(3)}$	$X_q'' = \frac{(2)}{2.(4)}$
1	2	3	4	5	6

Average Value of X_d'' = ... Ω.
Average value of X_q'' = ... Ω.

Result:
The average values and per unit are found as follows. Direct axis sub transient reactance's Xd" =………………
Quadrature axis sub transient reactance Xq"=…………………..

Discussion:

1. In this experiment why 1 phase supply is used and not three phase?
2. What is the purpose of damper winding in synchronous machines?
3. Generally whether Xd" > Xq" or Xd"< Xq" and why.
4. What is the frequency of rotor induced emf in this test and why?
5. What is meant by Xd" and Xq"?
6. Out of Xq, Xq', Xq" which one is minimum? Why?
7. Out of Xd,Xd',Xd" which one is minimum ? Why?
8. What is hunting of synchronous machine?
9. What happen if there is sudden short circuit on the alternator?
10. What do meant by transient stability?

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Measurement of t r a n s i e n t direct axis (X_d) and quadrature axis (X_q) Synchronous reactance of an alternator.

AIM:- To determine direct axis (Xd) and quadrature axis (Xq) synchronous reactance of a three phase synchronous machine by slip test.

Apparatus :

Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Auto transformer		
	Tachometer		

Electrical Machine Specifications:

Synchronous Machine: Power: _______ Voltage:_________ Current: ___________

Speed: ______________________________

DC Motor Power: _______ Voltage:_________ Current: ___________

Speed: ______________________________

Theory:

When a three phase synchronous alternator operates under normal condition, the resultant armature mmf is stationary with respect to the field mmf. As such the effect of armature mmf cannot be studied unless it is resolved into two components, one is along the axis of pole known as direct axis and another is along the axis quadrature to this known as quadrature axis. The component of armature mmf acting along direct axis has overcome lesser reluctance as compared the component of armature mmf acting along quadrature axis, and can therefore, establish more flux. On the other hand, quadrature axis path has higher reluctance and therefore, quadrature axis mmf will establish lesser flux. So, under the steady stat operation condition of the synchronous machine we define two reactance as follows

Direct axis reactance = Xd

Quadrature axis reactance = Xq

The value of $d\ X$ and $q\ X$ are determined by applying a balanced reduced external voltage to an unexcited synchronous machine at a speed of little less than the synchronous speed. Due to applied voltage to the stator terminals a current will flow causing a stator mmf. This stator mmf moves slowly relative to the poles and induced an emf in the field circuit in a similar fashion to that of rotor in an induction motor at slip frequency. The effect will be that the stator mmf. will move slowly relative to the poles. The physical poles and the armature-reaction mmf are alternately in phase and out, the change occurring at slip frequency.

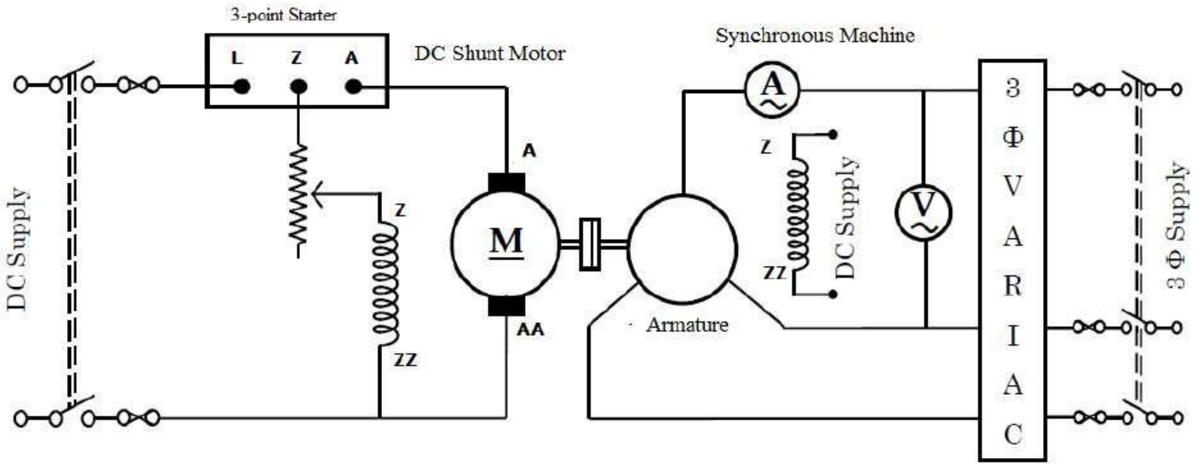
When axis of the pole and axis of armature reaction mmf wave coincide, the armature mmf acts through the field circuit. Therefore, the corresponding reactance is direct axis reactance and is given by

$$X_d = \frac{maximum\ value\ of\ armature\ voltage\ (phase\ value)}{minimum\ value\ of\ armature\ current\ (phase\ value)}$$

When armature reaction mmf is in quadrature with the field poles, the applied voltage is equal to the leakage reactance drop plus the equivalent voltage drop of the cross-magnetizing field component. Therefore, the corresponding reactance is quadrature axis reactance and is given by

$$X_q = \frac{minimum\ value\ of\ armature\ voltage\ (phase\ value)}{maximum\ value\ of\ armature\ current\ (phase\ value)}$$

Circuit Diagram:



Procedure:

1. Connect the circuit as shown in Fig.
2. Bring the field circuit rheostat of D.C. motor to its minimum value and switch ON the supply.
3. Start the D.C. motor with the help of three point stater.
4. Check the direction of rotation of the synchronous machine. The direction of rotation of synchronous machine when run by D.C. motor should be the direction of rotation when run as induction motor. If it is not same, change either the direction of rotation of D.C. motor or the phase sequence of synchronous machine.
5. Increase the speed of D.C. motor by increasing the field rheostat so that the speed reaches a little less than the synchronous speed of machine. Maintain the slip to be less than 5 %.
6. Check that the three phase variac is set to zero position. Switch ON the ac supplies with opening field circuit and apply it to the stator of synchronous machine.
7. Increase the supply voltage using three phase variac so that the machine draw the rated current.
8. It will be observe that induced voltage, applied voltage to the stator winding and current in stator winding will fluctuate from their minimum values to maximum values.
9. Note down the reading.
10. Repeat the step 5, 7 and 8 for some other suitable speeds.
11. Reduce the applied voltage to stator winding of synchronous machine by means of three phase variac to zero and switch OFF the ac supply.
12. Reduce the speed of dc motor by decreasing its field resistance and switch OFF the dc supply.

Observations:

SL NO	Speed N (rpm)	Slip S (%)	Armatures Voltage		Armature current		X_d (Ω)	X_q (Ω)	$\frac{X_q}{X_d}$
			Maximum (V)	Minimum (V)	Maximum (A)	Minimum (A)			
1									
2									
3									
4									
5									

Result:
The average direct axis reactance X_d = _____________Ω
The average quadrature axis reactance X_q = ___________Ω

Discussion:
1. What should be the value of Xq/Xd?
2. What should be the permissible value of slip for this experiment?
3. Why the reading of Voltmeter and Ammeter are fluctuating?

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V and Inverted V Curves of a 3-phase Synchronous Motor

AIM:- To study the effect of variation of field current upon the stator current and power factor of a synchronous motor at various load and draw V-curves and invert V-curves.

Apparatus :

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

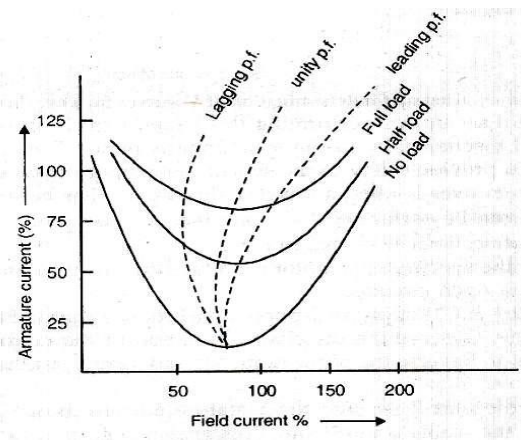
Electrical Machine Specifications:

Synchronous Motor: Power: _______ Voltage:_________ Current: ___________

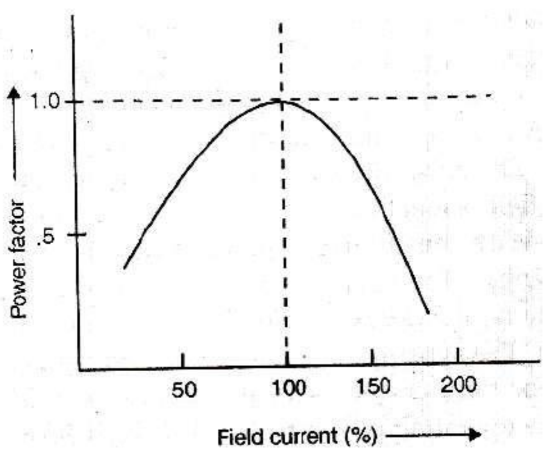
Speed: ______________________________

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 $VI\cos\varphi$ 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".

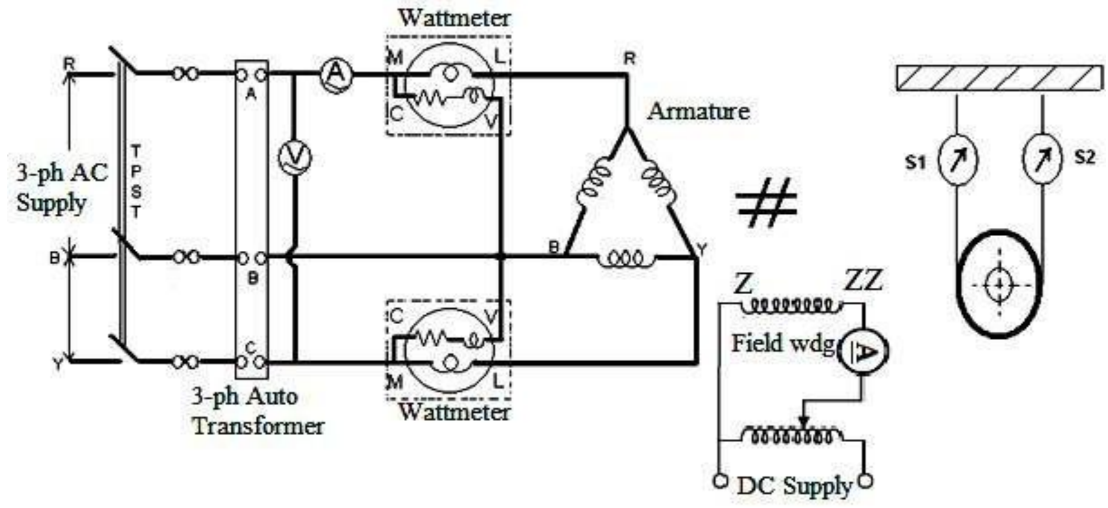


V-curves for Synchronous motor



Invert V-curves for 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.

Observations:

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

Graph: Plot the curves between armature current (I_a) vs field current (If) and power factor (cosΦ) vs field current (If)

Discussion:

1. With what condition synchronous motor can be used as a synchronous condenser**.**
2. What are the special applications of an over excited synchronous motor.
3. Explain the effect of change of excitation of a synchronous motor on its armature current.
4. Explain the effect of change of excitation of a synchronous motor on its power factor.

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SYNCHRONIZATION OF ALTERNATOR WITH INFINITE BUS BAR

AIM: - To Study the synchronization of alternator with infinite busby bright lamp method.

Apparatus :

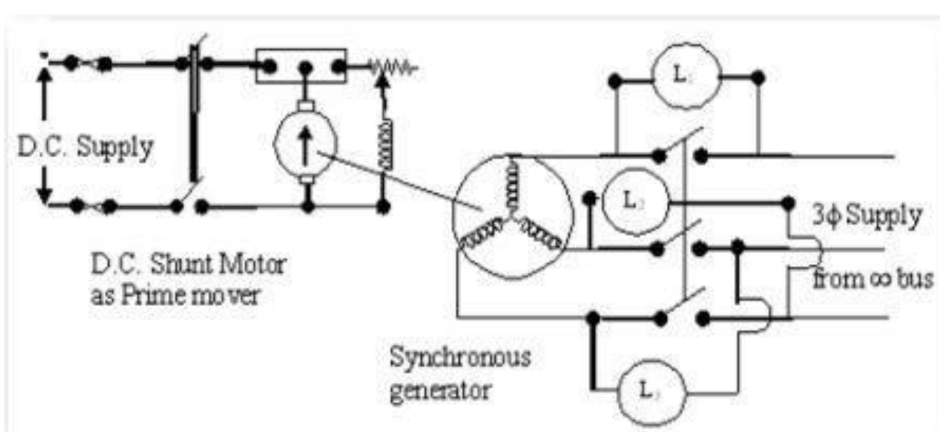
Sl No	Apparatus Name	Specification	Quantity
	Ammeter		
	Voltmeter		
	Wattmeters		
	3-phase Auto transformer		
	Rheostats		

Electrical Machine Specifications:

Synchronous Generator: Power: ________ Voltage:____________

Current: _____ Speed: _________________________________

CIRCUIT DIAGRAM:-



THEORY:

Following conditions must be satisfied for the synchronization of alternator with infinitebus.

1) The terminal voltage of the incoming alternator must be equal to the bus voltage.
2) The frequency of incoming alternator must be equal to the bus frequency.
3) The voltage of incoming alternator and bus must be in the same phase with respect to the external load.

A voltmeter can be used to check the voltage of bus and incoming alternator for frequency and phaselamps are used.

Following are the advantages of parallel operation of alternators.

2) Repairs and maintenance of individual generating unit can be done by keeping thecontinuity of supply.
3) Economy
4) Additional sets can be connected in parallel to meet the increasing demand.

PROCEDURE:

1) Connect the circuit as shown in the diagram.
2) Keep all the switches S1, S2, SL1, SL2, and SL3 in open position and put on the DC supply.
3) Start the DC motor and bring the speed very near to synchronous speed of the alternator.
4) Put on AC supply and measure its voltage by keeping the position of switch S2 online side.
5) Now keep the switch S2 on alternator side and adjust its field current such that itgives voltage equal to the line voltage.
6) Now put on the switches SL1, SL2, SL3 watch the changes in the glow of three sets of lamps. At one instant two will be equally bright while the third set will befully dark. . Then the set which is fully dark slowly starts becoming bright and oneset from the to which were bright starts dimming. A position will come when this set will become fully dark while other two will be equally bright.
7) Make small adjustment in speed and excitation of alternator to get long dark and bright periods.
8) At an instant when pair IR -IR is dark and IB-IB are equally bright, close switch S-1 to synchronizethe alternator to bus. Observe the reading of ammeter

which should be minimum.

RESULT & CONCLUSION

An alternator can be synchronized with the bus. At the time of synchronization voltage and frequency of the incoming alternator should be equal to the bus voltage and frequency and also the voltage of incoming alternator should be in phase with the bus with respect to external load .

DISCUSSION QUESTIONS:-

1) What are the conditions of synchronization of two alternators?

2) What are the possible effects of wrong synchronization?

3) What are the different methods for synchronization?

4) Why a lamp pair is required in this experiment?

5) After synchronizing what is the effect of changing the excitation of the alternators.

6) Why the incoming m/c in parallel operation is operated at slightly higher speed then thesynchronous speed during synchronization.

7) In parallel operation of generator, for which condition circulating current develop even no load onthe machine.

8) What will happen, if synchronization takes place without proper phase sequence?

Load Test on Universal Motor

Aim: To perform load test on Universal motor operating both DC AND AC and to obtain the performance characteristics.

Apparatus :

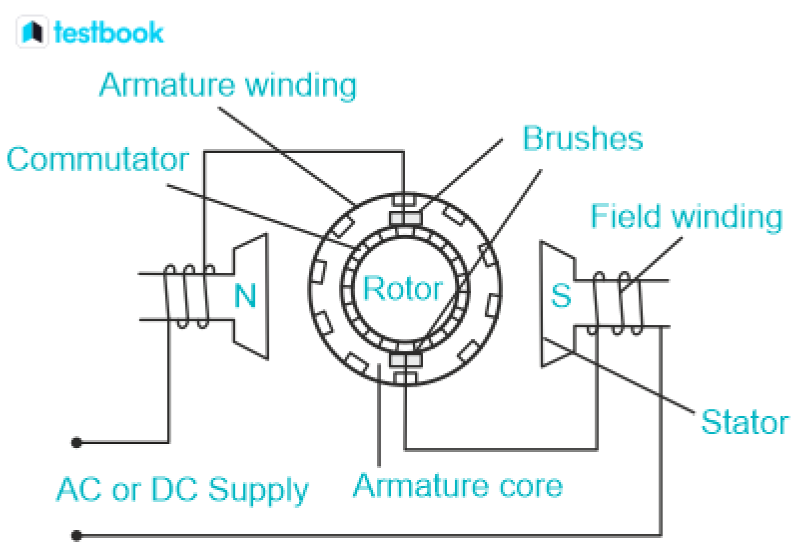
Sl No	Apparatus Name	Specification	Quantity
1)	Ammeter		
2)	Voltmeter		
3)	Wattmeter		
4)	Auto Transformer		
5)	Tachometer		

Electrical Machine Specifications:

The universal motor is a unique type of motor which runs on either DC or single-phase AC supply. These motors are usually series wound and produce high starting torque. Hence, universal motors are built into the devices meant to drive.

Universal motors operate at high speeds up to 3500 RPM. However, they run at low speed on AC supply than on DC supply of similar voltage due to a drop in reactance voltage, which is seen in AC but not in DC.

Universal Motor Diagram



Universal Motor Working Principle

A universal motor works similarly to the DC series motor. When the current passes into the field winding, the motor generates an electric field. The same current emanates from the armature conductors.When the current-carrying conductor is placed in a magnetic field, an electromagnetic field is produced, and the rotor starts to spin. The direction of this force is based on Fleming's left-hand rule.The motor also generates unidirectional torque when an AC supply is provided.Armature and field winding are in sequence and the same process. Hence, the polarity of the AC changes constantly, and the direction of the current in the armature and field winding is reversed simultaneously.The direction of the magnetic field and the armature current are reversed so that the direction of force found by the armature conductors remains the same.

Operation of Universal Motor

The operation of a universal motor is based on the interaction between a magnetic field and an electric field.A universal motor works on both single-phase AC and DC supply. When the DC motor is fed with a DC supply it works as a series DC motor. Current flows in the winding produce an electromagnetic field and the same current also flows through the armature conductors. When it is placed in an electromagnetic field it experiences a mechanical force and due to the mechanical force the torque starts to rotate producing a unidirectional torque.The armature winding and the field winding are connected in series and hence they are in the same phase.For an AC power supply, the direction of current in the armature and field winding reverses everytime, hence, the polarity of AC changes.

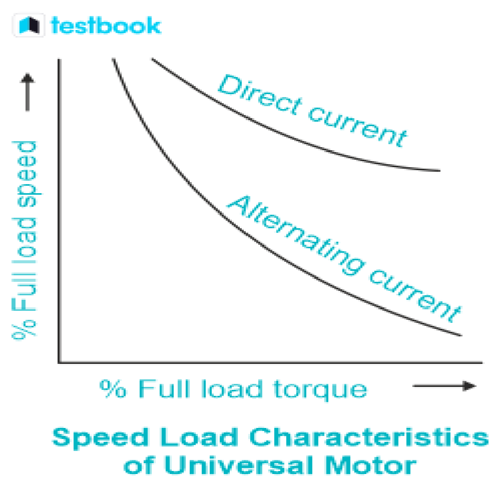
Characteristics of Universal Motor

Universal motors have high starting torque, and the speed increases with a decrease in the load.

- Small universal motors have significant no-load losses and limit the speed to 1500 to 20000 RPM.
- The power factor at full load is 90%, and the power factor at the beginning or overloading is low.

Speed-Load Characteristics

The speed load characteristics of universal motors are similar to that of DC series motors. However, the speed of a universal motor is inversely proportional to the load; that is, the speed is low at full load and high at no load due to low field flux. Hence, these motors are connected with permanent loads to avoid their operation at no load.



The figure shows the torque-speed characteristics of the universal motor for both AC and DC operations.

Procedure:

1. Connect the circuit as shown in Fig.
2. Set 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.
7. Calculate the various quantities and draw the various curves as stated above.

Observation Table :

SL NO	Input Voltage V (volt)	Input Current I (amp)	Input Power W (watt)	Force (Kgf) S1	S2	F = S1 – S2	Speed N_r (rpm)
1							
2							
3							
4							
5							

Diameter of pulley, d =___ m.

Calculation :

SL NO	Input Power P_{in} (watt)	Total Force F (Kgf)	Output Torque T (Nw-m)	Output Power P_o (watt)	Slip (%)	Power Factor cosΦ	Efficiency (%)
1							
2							
3							
4							
5							

Precautions:

4. All connections should be neat and tight.
5. Special attention should be given for cooling of the break pully, otherwise the wearing out of belt may be very rapid.
6. The current ratings should be-given special care while selecting wattmeters.

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.

RESULT:

Thus load test on the Universal motor has been conducted and its performance characteristics determined.

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