NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE

(Accredited by NAAC, Approved by AICTE New Delhi, Affiliated to APJKTU)

Pampady, Thiruvilwamala(PO), Thrissur(DT), Kerala 680 588

DEPARTMENT OF MECHATRONICS

LAB MANUAL

EE 235 ELECTRICAL TECHNOLOGY LABORATORY

VISION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2013
- Course offered: B.Tech Mechatronics Engineering
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

To develop professionally ethical and socially responsible Mechatronics engineers to serve the humanity through quality professional education.

DEPARTMENT MISSION

MD 1: The department is committed to impart the right blend of knowledge and quality education to create professionally ethical and socially responsible graduates.

MD 2: The department is committed to impart the awareness to meet the current challenges in technology.

MD 3: Establish state-of-the-art laboratories to promote practical knowledge of mechatronics to meet the needs of the society.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates shall have the ability to work in multidisciplinary environment with good professional and commitment.

PEO2: Graduates shall have the ability to solve the complex engineering problems by applying electrical, mechanical, electronics and computer knowledge and engage in lifelong learning in their profession.

PEO3: Graduates shall have the ability to lead and contribute in a team with entrepreneur skills, professional, social and ethical responsibilities.

PEO4: Graduates shall have ability to acquire scientific and engineering fundamentals necessary for higher studies and research.

PROGRAM OUTCOMES (PO'S)

Engineering Graduates will be able to:

PO 1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO 2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO 3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO 4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO 5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO 6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO 7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO 8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO 9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO 10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO 11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO 12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO'S)

PSO 1: Design and develop Mechatronics systems to solve the complex engineering problem by integrating electronics, mechanical and control systems.

PSO 2: Apply the engineering knowledge to conduct investigations of complex engineering problem related to instrumentation, control, automation, robotics and provide solutions.

COURSE OUTCOME

C208.1	Acquire the basic knowledge in electric circuit theorems by experimental verification.
C208.2	Understand 3 phase balanced and unbalanced, star and delta connected supply and load and to measure power in 3 phase circuits
C208.3	Experimentally test the characteristics of DC machines under load and no load condition.
C208.4	Acquire knowledge about the speed control of DC motors.
C208.5	Demonstrate the Swinburne's test and acquire the knowledge in separation of losses in DC machines.
C208.6	Examine testing of the characteristics of single phase transformers under load condition, Three phase Induction Motors under load and no load condition.

CO VS PO'S AND PSO'S MAPPING

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PS0 1	PSO 2
C208.1	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C208.2	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C208.3	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C208.4	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C208.5	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C208.6	3	3	2	2	-	-	-	-	3	-	-	2	-	2
C 208	**3.00**	**3.00**	**2.00**	**2.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.00**	**0.00**	**0.00**	**2.00**	**0.00**	**2.00**

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

PREPARATION FOR THE LABORATORY SESSION

GENERAL INSTRUCTIONS TO STUDENTS

1. Read carefully and understand the description of the experiment in the lab manual. You may go to the lab at an earlier date to look at the experimental facility and understand it better. Consult the appropriate references to be completely familiar with the concepts and hardware.

2. Make sure that your observation for previous week experiment is evaluated by the faculty member and your have transferred all the contents to your record before entering to the lab/workshop.

3. At the beginning of the class, if the faculty or the instructor finds that a student is not adequately prepared, they will be marked as absent and not be allowed to perform the experiment.

4. Bring necessary material needed (writing materials, graphs, calculators, etc.) to perform the required preliminary analysis. It is a good idea to do sample calculations and as much of the analysis as possible during the session. Faculty help will be available. Errors in the procedure may thus be easily detected and rectified.

5. Please actively participate in class and don't hesitate to ask questions. Please utilize the teaching assistants fully. To encourage you to be prepared and to read the lab manual before coming to the laboratory, unannounced questions may be asked at any time during the lab.

6. Carelessness in personal conduct or in handling equipment may result in serious injury to the individual or the equipment. Do not run near moving machinery/equipment's. Always be on the alert for strange sounds. Guard against entangling clothes in moving parts of machinery.

7. Students must follow the proper dress code inside the laboratory. To protect clothing from dirt, wear a lab coat. Long hair should be tied back. Shoes covering the whole foot will have to be worn.

8. In performing the experiments, please proceed carefully to minimize any water spills, especially on the electric circuits and wire.

9. Maintain silence, order and discipline inside the lab. Don't use cell phones inside the laboratory.

10. Any injury no matter how small must be reported to the instructor immediately.

11. Check with faculty members one week before the experiment to make sure that you have the handout for that experiment and all the apparatus.

AFTER THE LABORATORY SESSION

1. Clean up your work area.

2. Check with the technician before you leave.

3. Make sure you understand what kind of report is to be prepared and due submission of record is next lab class.

4. Do sample calculations and some preliminary work to verify that the experiment was successful

MAKE-UPS AND LATE WORK

Students must participate in all laboratory exercises as scheduled. They must obtain permissionfrom the faculty member for absence, which would be gran ted only under justifiable circumstances. In such an event, a student must make arrangements for a make-up laboratory, which will be scheduled when the time is available after completing one cycle. Late submission will be awarded less mark for record and internals and zero in worst cases.

LABORATORY POLICIES

1. Food, beverages & mobile phones are not allowed in the laboratory at any time.

2. Do not sit or place anything on instrument benches.

3. Organizing laboratory experiments requires the help of laboratory technicians and staff. Be punctual.

SYLLABUS

Course code	Course Name	L-T-P - Credits	Year of Introduction
EE235	Electrical Technology lab	0-0-3-1	2016

Prerequisite : EE209 Electrical technology

Course Objectives

- To impart working knowledge on electrical circuits, A C machines, DC machines and transformers.

List of Exercises/Experiments : (Minimum 10 experiments are mandatory)

1. Verification of Thevenin's theorem
2. Verification of Norton's theorem
3. Verification of Superposition theorem
4. Verification of Maximum power transfer theorem
5. Power measurement in 3 phase balanced circuits
6. Power measurement in 3 phase unbalanced circuits
7. Load test on DC shunt motor
8. Load test on DC series motor
9. Speed control of DC shunt motor
10. Open circuit characteristics of DC series motor.
11. Open circuit characteristics of dc shunt motors
12. Swinburne's test and separation of losses in DC machine.
13. Load test on single phase transformer
14. Load test on 3-phase induction motor
15. No load test on 3- phase induction motors.

List of major equipment

DC shunt motor, DC series motor, DC series motor, single phase transformer, 3-phase induction motor, Watt meters, Ammeters, voltmeters, Tachometers.

Expected outcome.

- On completion of this lab course, the students will be able to understand the concept of electric circuits and the performance characteristics of electrical machines.

Text Book:

Theraja B.L., Theraja A.K. *A Text Book of Electrical Technology*, Vol.II "AC & DC Machines", publication division of Nirja construction & development (p) Ltd., New Delhi.

INDEX

1. VERIFICATION OF THEVENIN'S THEOREM

AIM

To verify Thevenin's theorem.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-1) A MC	1 No.
2	Linear Rheostat	10Ω, 8.5A 12Ω, 8.5A 11Ω, 8.5A	1 No. 2 Nos. 1 No.
3	Variable voltage source	(0-30)V DC	1 No.
4	Voltmeter	(0-30)V MC	1 No.

PRINCIPLE

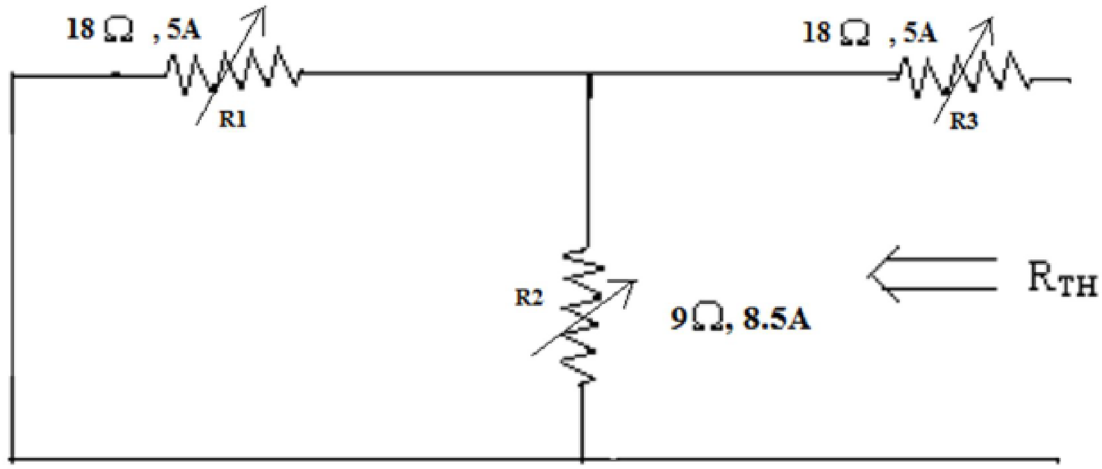
Thevenin's theorem states that any two output terminals of an active linear network containing independent sources (including current and voltage sources) can be replaced by a single voltage source of magnitude Vth in series with a single resistor Rth where Rth is the equivalent resistance of the network when looking from the output terminals with all sources (voltage and current) removed and replaced by their internal resistances and the magnitude of Vth is equal to the open circuit voltage across the terminals.

PROCEDURE

1. Connections are made as shown in figure 1.
2. To prove the theorem, vary the voltage from the source and note the readings on the ammeter.
3. Then the load is removed and the voltmeter is connected so as to obtain the value of Vth as shown in figure 2.
4. After finding Rth using figure 3, the load current is calculated.
5. According to the theorem, the value of current obtained from the Thevenin equivalent circuit should be equal to the calculated value.

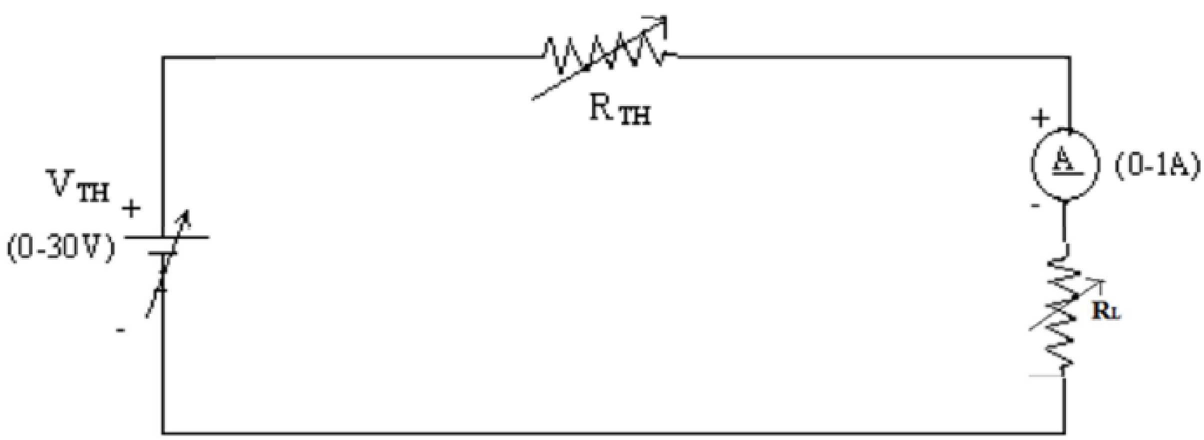
CIRCUIT DIAGRAM

To find R_{TH}



$$Rth = \frac{R_1 R_2}{(R_1 + R_2)} + R_3$$

Thevenin's Equivalent circuit



OBSERVATIONS

Table 1

SL NO	Voltage(volts)V	Measured current (I_L) A

Table 2

SL NO	Voltage(volts)V	Vth From Experiment

Table 3

SL NO	Voltage(volts)Vth	Ith (A)

Table 4

SL NO	Measured Current I_L (A)	I_{TH} (A)

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. What is Thevenin’s theorem?
2. What are the advantages of Thevenin’s theorem?
3. What is the difference between Thevenin’s and Norton’s theorem.
4. Differentiate between MI and MC meters.
5. What is source transformation technique?

2. VERIFICATION OF SUPERPOSITION THEOREM

AIM

To verify superposition theorem.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-1) A MC	3 Nos.
2	Linear Rheostat	10Ω, 8.5A 12Ω, 8.5A	2 Nos. 1 No.
3	Variable voltage source	(0-5)V DC (0-10)V DC	1 No. 1 No.

PRINCIPLE

In any linear bilateral network containing two or more independent sources, the resultant current or voltage is the algebraic sum of currents or voltages caused by each independent sources acting alone, with all other independent sources being replaced meanwhile by their respective internal resistances. Each independent source is considered at a time while all other sources are turned off or killed. To kill a voltage source means that it is replaced by its internal resistance.

PROCEDURE

1. Connections are made as shown in figure 1.

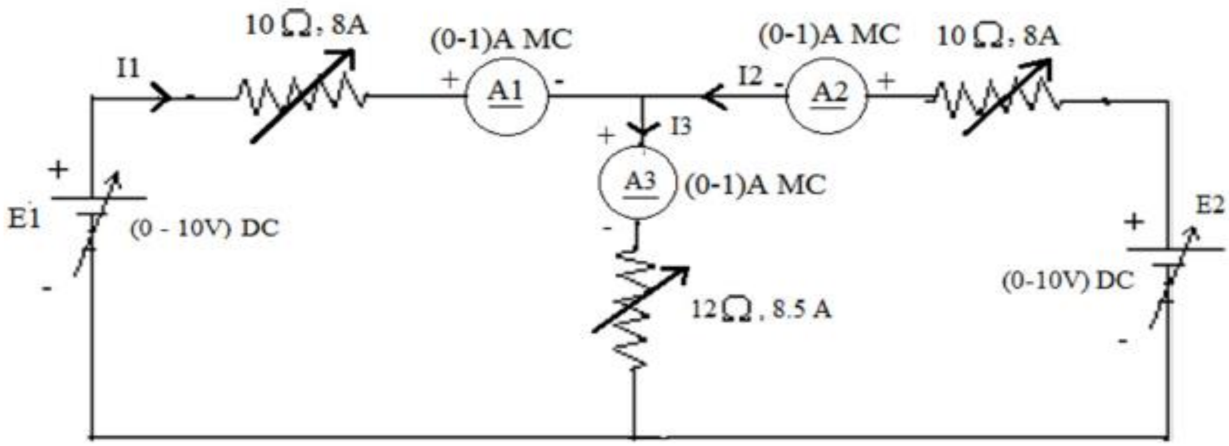
2. Keeping E1 and E2 as shown in figure, measure currents indicated by A1, A2 and A3 for various values of E1 and E2.

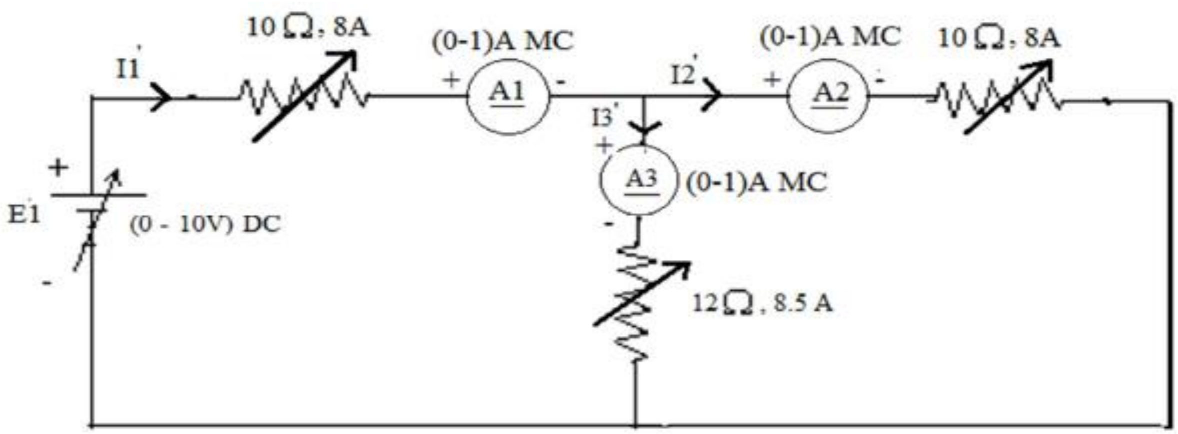
3. E1 and E2 are increased by noting that any of the ammeter reading does not exceed 1A.

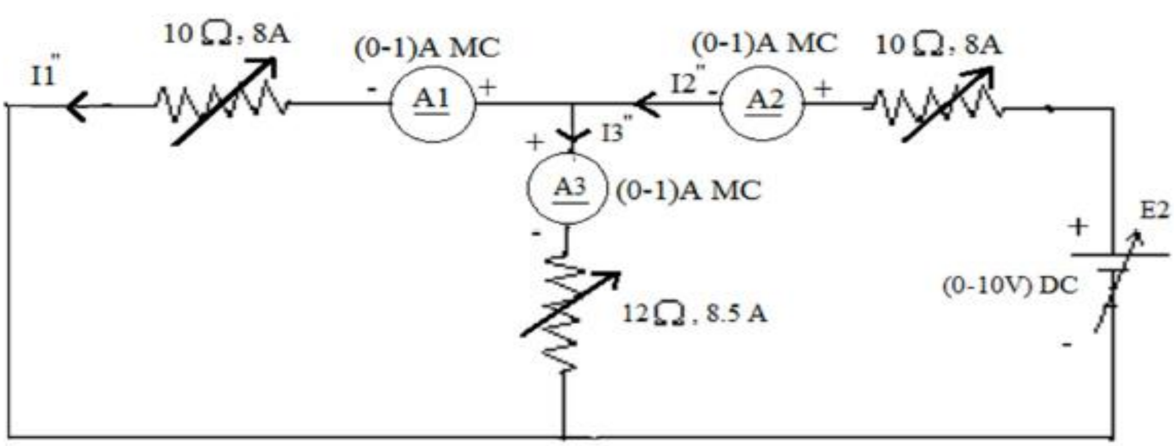
4. Replace E2 with internal resistance and note down various ammeter readings as in figure 2.

5. Replace E1 with internal resistance and also note down various ammeter readings as in figure.

CIRCUIT DIAGRAM







OBSERVATIONS

Sl. No.	E_1 (V)	$I_{1'}$ (A)	$I_{2'}$(A)	$I_{3'}$(A)

SAMPLE CALCULATION

$$I_1 = I_1' - I_1''$$
$$I_2 = I_2'' - I_2'$$
$$I_3 = I_3' + I_3''$$

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. Explain superposition theorem.
2. What do you mean by killing a voltage source?
3. Explain Kirchhoff's voltage law.
4. Explain Kirchhoff's current law.

5. What do you mean by a linear bilateral network?

3. POWER MEASUREMENT IN THREE PHASE BALANCED CIRCUIT

AIM

To measure the power and power factor of three phase balanced load by two wattmeter method.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-10)A, MI	1 No.
2	Voltmeter	(0-500)V, MI	1 No.
3	Wattmeter	500V,10A,UPF	2 Nos.
4	Autotransformer	415/(0-415)V	1 No.

PRINCIPLE

In two wattmeter method the current coils of two watt meters are connected in two phases and the potential coils between the corresponding phase and the third phase. It can be proved that the sum of the wattmeter readings gives the total power.

From the phasor diagram

Reading of Wattmeter 1, $W1 = VRY\ IR \cos(30 + \phi)$

Reading of Wattmeter 2, $W2 = VBY\ IB \cos(30 - \phi)$

$W1 + W2 = VRY\ IR(\cos 30 \cos \phi - \sin 30 \sin \phi) + VBY\ IB(\cos 30 \cos \phi + \sin 30 \sin \phi)$

$= VRY\ IR (\cos 30 \cos \phi) + VBY\ IB(\cos 30 \cos \phi)$

Assuming balanced load

$VRY = VBY = VBR = VL$ & $IR = IB = IY = IL$

Where VL and IL are the line values of voltage and current.

$= VLIL \cos 30 \cos \phi + VLIL \cos 30 \cos \phi$

$= 2VLIL\ \sqrt{3}/2 \cos \phi$

$= \sqrt{3} VLIL \cos \phi$

W2-W1 = VLIL(cos(30 - ϕ) - cos (30 + ϕ))

= VLILsin ϕ

(W2-W1/ W1 +W2)=(1/√3)tan ϕ

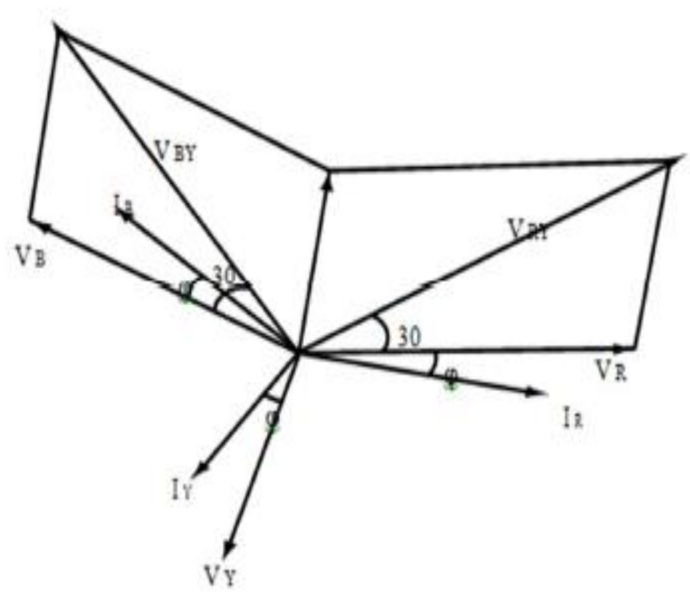
tan ϕ=√3(W2-W1/ W1 +W2)

ϕ=(tan-1(√3(W2-W1/ W1 +W2)))

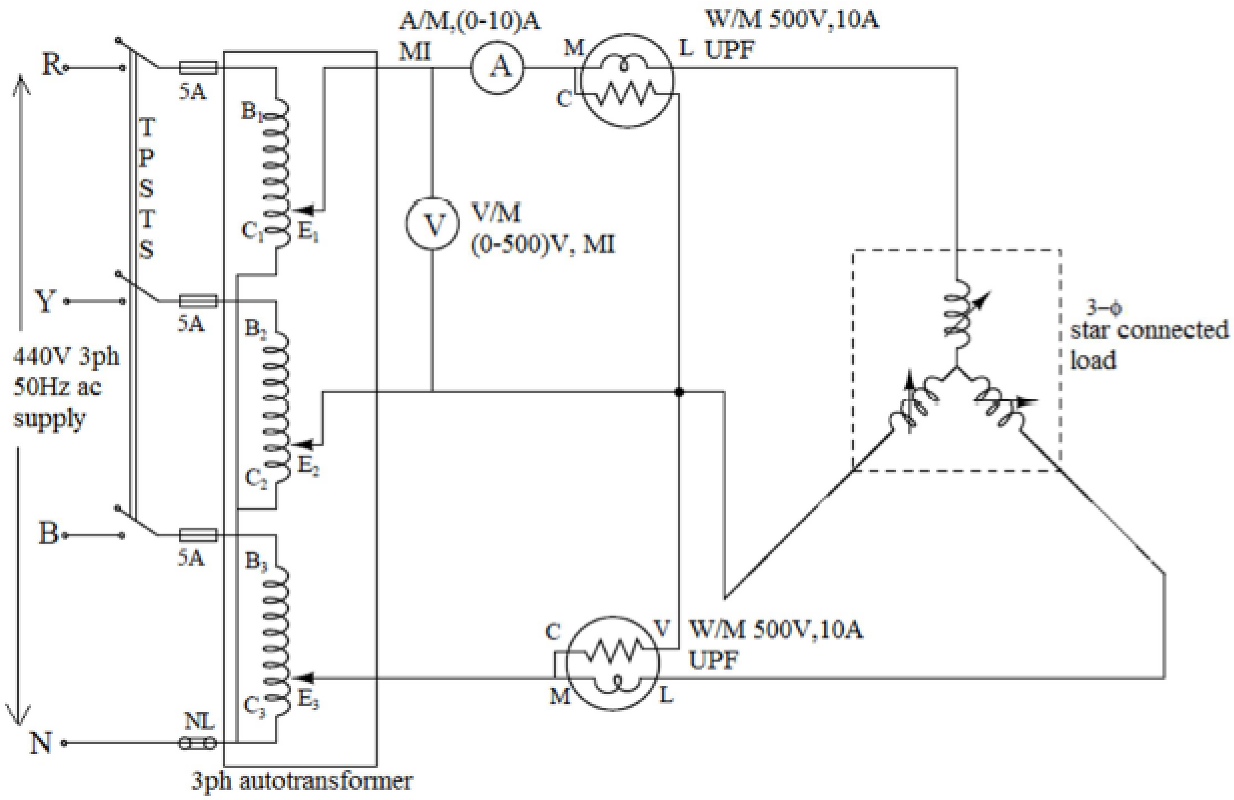
PROCEDURE

1. Connections are made as shown in figure.
2. Supply is switched on by keeping the autotransformer at minimum position.
3. Then the autotransformer is varied till the voltmeter shows rated voltage.
4. Note the ammeter and wattmeter readings.
5. Then the load is varied and the wattmeter, voltmeter and ammeter readings are noted.
6. The above procedure is repeated for different load conditions.

PHASOR DIAGRAM



CIRCUIT DIAGRAM



OBSERVATIONS

Sl. No.	Vin(V)	Iin(A)	Wattmeter Reading		P = W1+W2	$\phi = \tan^{-1}\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$	Cos ϕ
			W1	W2			

SAMPLE CALCULATION

Voltage V = ...

Current I = ...

Wattmeter reading W1 = ...

Wattmeter reading W2 = ...

Total power P = W1 +W2 = ...

Phase angle $\phi = \tan^{-1}\dfrac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$ = ...

Power factor = cos ϕ = ...

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. What is the expression for power in a 3ϕ circuit?
2. Derive the expression for power factor in terms of the wattmeter readings.
3. What are the other methods of measuring 3ϕ power?
4. What does a zero reading in one of the watt meters signify?

4. LOAD TEST ON DC SERIES MOTOR

AIM

To conduct Load test on DC series motor and plot the performance characteristics.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-15)A, MC	1 No.
2	Voltmeter	(0-250)V, MC	1 No.
3	Tachometer		1 No.

MACHINE DETAILS

Take down the name plate ratings of motor

Sl. No.	Name Plate details
1	
2	
3	

PRINCIPLE

In a series motor, the field winding is connected in series with the armature winding. Thus the same current flows through the field and armature windings. Speed of a dc series motor.

$$N = \frac{V - I_a(R_a + R_{se})}{K_e \times \phi}$$

Where Ia is the armature current, Ra is the armature resistance, Rse is the series field resistance, ϕ is the flux per pole and N is the speed in rpm.

Electrical characteristics (T vs Ia):- It shows the variation of torque with the armature current.

We have

T α ϕIa where ϕ is the flux/pole

α IaIa (as ϕ α Ia up to the point of magnetic saturation)

Thus T α Ia2

However after magnetic saturation ϕ remains almost constant, Hence Tα Ia. Thus the curve is a parabola up to magnetic saturation and shows a linear variation after the point.

Mechanical Characteristics (N1 vs T): It shows the variation of speed with torque.

We have $N \propto \frac{Eb}{\emptyset} \propto \frac{1}{\emptyset}$ as Eb is almost constant where Eb is back emf.

In a series motor $\emptyset \alpha$ Ia. So $N \propto \frac{1}{Ia}$

That is, as Ia increases, Speed decreases. The same pattern is followed in the N-T characteristics. The curve traced is a rectangular hyperbola. A series motor should never be started at no load. At no load, Ia is very small, hence the speed of the motor becomes dangerously high as N α 1/Ia

The efficiency of a small motor can be measured directly by brake test. The motor is loaded directly by a belt placed on a pulley mounted on the shaft of the motor. The desired load is put by tightening belt. The tension applied on the belt is measured by using spring balance.

Output Torque = (S1-S2) x R x 9.81 Nm.

Where W1 is the tension on the tight side of brake in Kg. W2 is the tension on the slack side of the brake in Kg. R is the radius of the pulley in m. If N is the speed of the motor in rpm, then

Power Output = ((S1-S2) x R x 9.81x 2πN)/60

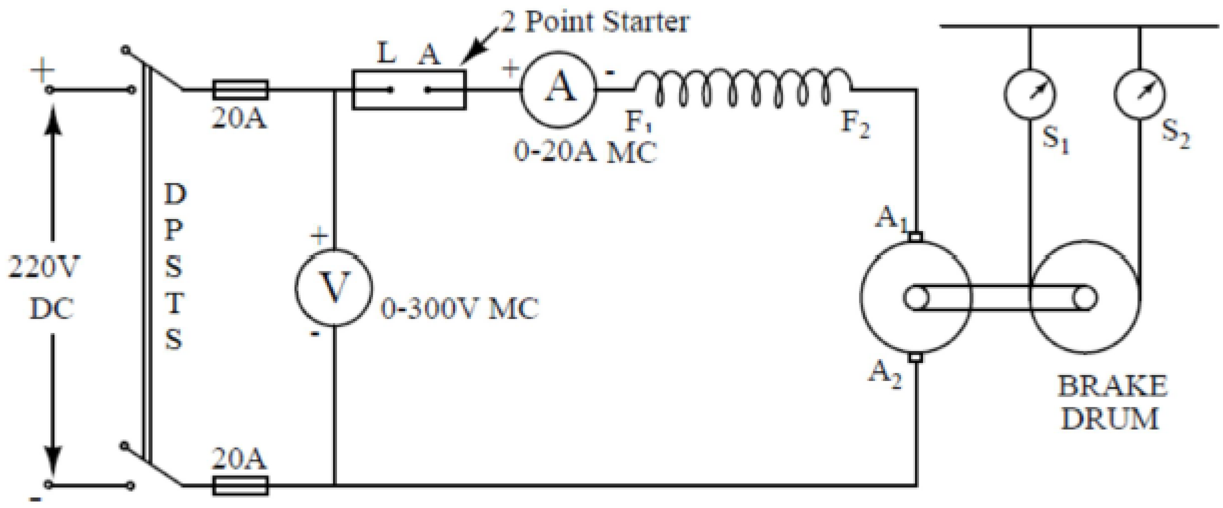
PROCEDURE

1. Connections are made as per the circuit diagram.
2. Apply some load to the motor using spring and break drum.
3. Switch on the motor using the starter.
4. Note down the motor voltmeter reading and keep it at rated value.
5. Note down the current and spring balance readings.
6. The experiment is repeated for different loads till the rated current of the machine is reached.

7. During the experiment when the machine gets heated up, it is cooled by pouring water into the brake-drum.

8. The load is then reduced till the current reaches a small value and the supply is switched off.

CONNECTION DIAGRAM



OBSERVATIONS

Sl. No.	Vin(V)	Iin(A)			Speed (rpm)	Torque (Nm)	Output (Watts)	Input (Watts)	% Efficiency
			S_1(Kg)	S_2(Kg)					

SAMPLE CALCULATIONS

Sample Calculation (set no. . . .)

Voltmeter reading (V) = ...

Current (I) = ...

Spring balance readings, S1 = ... S2 = ...

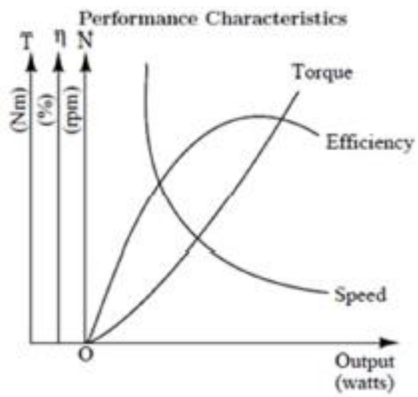
Speed (N) = ...

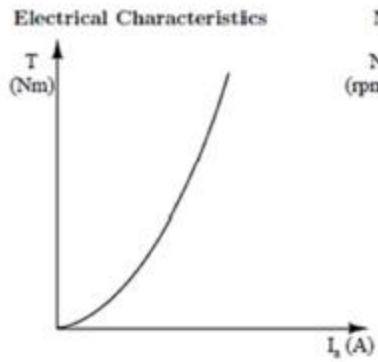
Torque (T) = 9.81 (S1 − S2) R = ... Where R is the radius of brake drum.

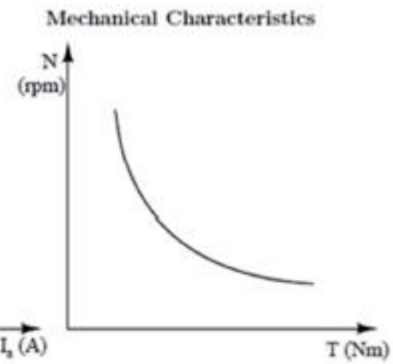
Output power = = ... $(2\pi NT)/60$

Input power = V I = ...

Efficiency = Output power/ Input power = ...







RESULTS AND DISCUSSIONS

CONCLUSION

VIVA QUESTIONS

1. What is the precaution to be taken when working with a d-c series motor?
2. What is the need for starter with a d-c motor?
3. What is the condition for maximum efficiency in a d-c motor?
4. What are the different losses occurring in a d-c machine?
5. Give some applications of d-c series motor.

5. LOAD TEST ON SINGLE PHASE TRANSFORMER

AIM

To conduct load test on the given single phase transformer at unity power factor and determine the efficiency and regulation curve.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-10)A,MI (0-5)A,MI	1 No. 1 No.
2	Voltmeter	(0-250)V, MI (0-150)V, MI	1 No. 1 No.
3	Wattmeter	150V,10A,UPF 300V, 5A, UPF	1 No. 1 No.
4	Autotransformer	230/(0-230)V	1 No.

PRINCIPLE

Regulation of a transformer is defined as the drop in terminal voltage of a transformer expressed as a percentage of the no-load terminal voltage.

$$\% \text{ Voltage Regulation} = \frac{V \text{ no load} - V \text{ on load}}{V \text{ no load}}$$

When a purely resistive load is connected across the secondary, the transformer will be working at unity power factor.

$$\text{Terminal voltage, } V = \text{Induced emf } [E_2] - I_2 r_2 - I_2 x_2$$

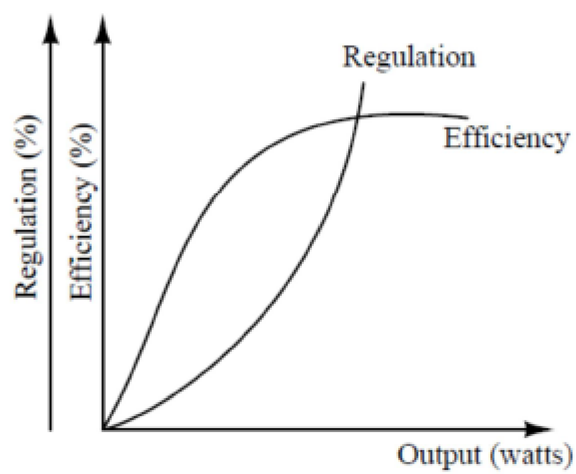
Where r2 and x2 are the secondary winding resistance and leakage reactance respectively and I2 is the secondary load current. The efficiency of transformer is defined as (output/input) x 100. As the load current increases the power output increases.

The iron loss remains constant from no load to full load. The copper loss increases as the square of the load current. Thus the efficiency curve starts from zero, increases to a maximum value
(When iron loss = Cu loss) and thereafter starts decreasing.

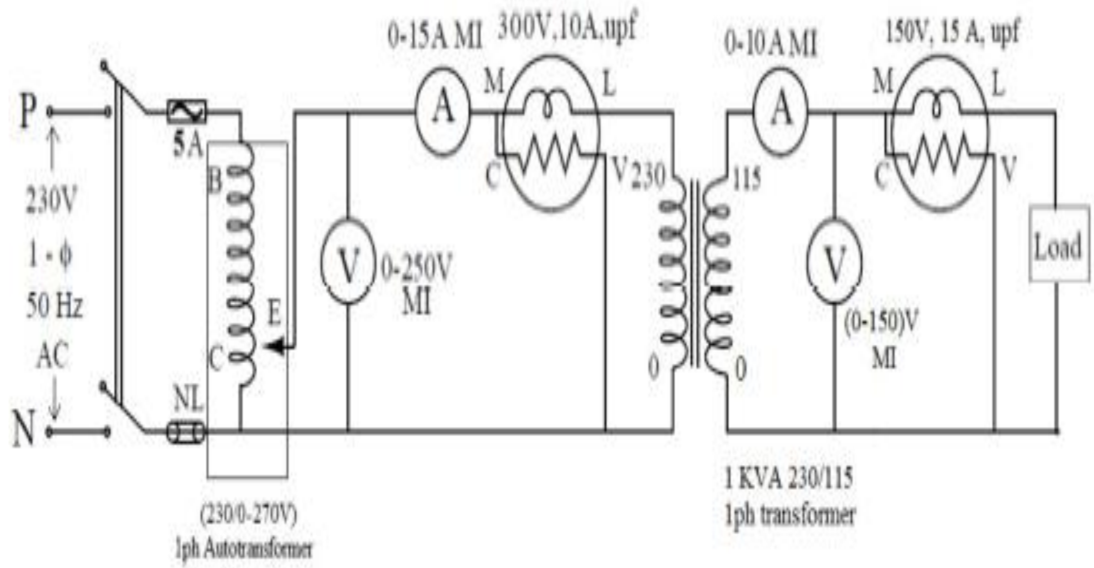
PROCEDURE

1. Connections are made as per the circuit diagram.
2. Auto transformer is kept at minimum position and supply was switched on.
3. Rated voltage is applied to the primary by varying the auto transformer.
4. The meter readings corresponding to no load was noted.
5. Load was applied gradually.
6. Each time the auto transformer is adjusted to maintain primary voltage.
7. The loading can be done up to 125% of the rated current of the load side.
8. The load is then reduced till the current reaches a small value and the supply is switched off.

REGULATION AND EFFICIENCY CURVES



CONNECTION DIAGRAM



OBSERVATIONS

Sl. No.	V_1(V)	I_1(A)	V_2(V)	I_2(A)	W_1(W)	W_2(W)	Efficiency (%)	Regulation (%)

SAMPLE CALCULATIONS

Sample Calculation (set no. . . .)

Primary Voltage (V1) = ...

Primary Current (I1) = ...

Wattmeter Reading (W1) = Input power = ...

Secondary Voltage (V2) = ...

Secondary Current (I2) = ...

Wattmeter Reading (W2) = Output power = ...

Efficiency = (Output power/Input power) ×100= . . . .

Regulation = (VNL – VL)/VNL ×100 = ...

VNL = V2NL

VL=V2FL

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. What do you understand by regulation of a transformer?
2. What are the other methods of testing transformers?
3. What is the disadvantage of testing a transformer using load test?
4. Is a high or low value of regulation preferred for a transformer? Give reasons.
5. What are the reasons for the drop in terminal voltage as the secondary current is increased?

6. VERIFICATION OF MAXIMUM POWER TRANSFER THEOREM

AIM

To verify maximum power transfer theorem for the given circuit.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-1) A MC	1 No.
2	Linear Rheostat	10Ω, 8.5A 12Ω, 8.5A 11Ω, 8.5A	1 No. 2 Nos. 1 No.
3	Variable voltage source	(0-30)V DC	1 No.
4	Voltmeter	(0-30)V MC	1 No.

PRINCIPLE

In a linear, bilateral circuit the maximum power will be transferred to the load when load resistance is equal to source resistance. Depending upon the conditions of the circuit, there are three cases:

CASE 1: (Purely Resistive circuit & Load resistance is variable) - "Maximum power is delivered from a source to a load when the load resistance is equal to the source resistance". (RL = RS)

CASE 2: (Reactants present & load resistance and reactance can be independently varied) - "Maximum power is delivered from a source to a load when the load impedance is the complex conjugate of source impedance". (XL = -XS & RL = RS)

CASE 3: (Reactants present but only the magnitude of the load resistance can be varied) - "Maximum power is delivered from a source to a load when the magnitude of the load impedance is equal to the magnitude of source impedance".

PROCEDURE

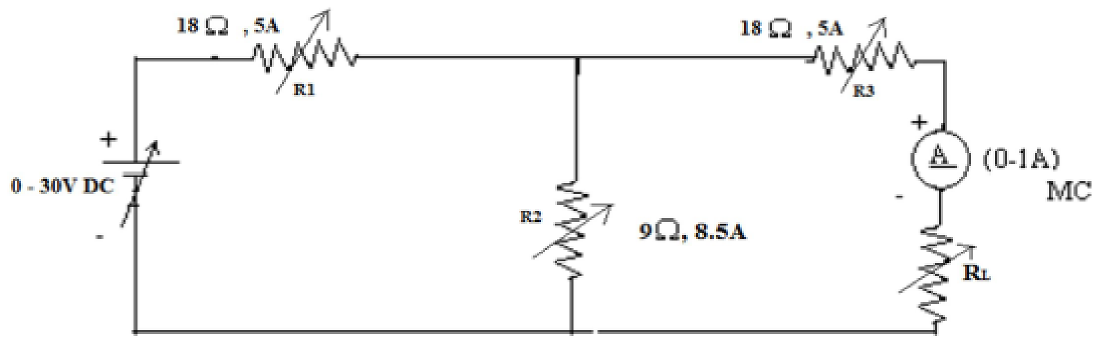
1.First find the Thevenin equivalent circuit for circuit shown in figure.

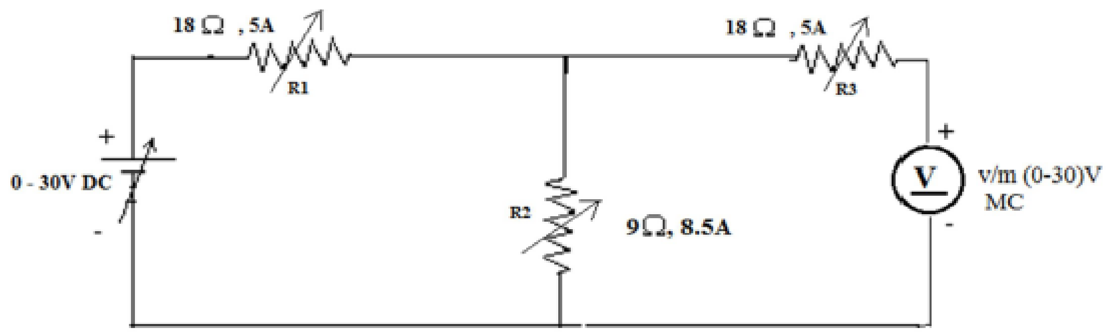
2. After finding RTH & VTH, vary the load resistance RL from the minimum value to maximum value.

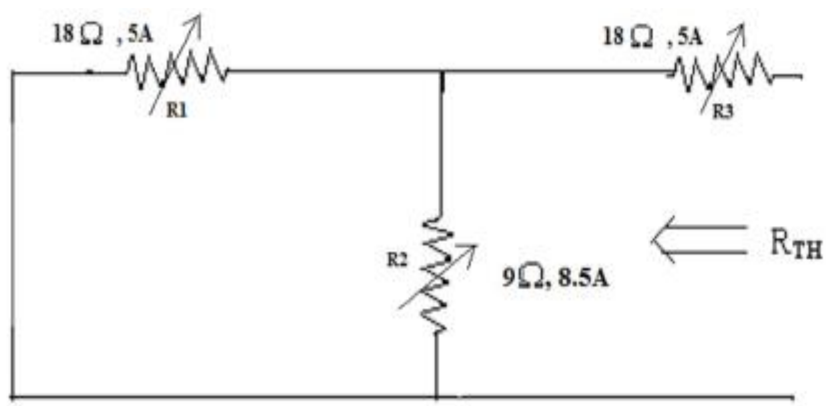
3. Plot the graph between RL & Power (IL^2R_L) where, theoretical IL = [VTH / (R_{TH}+R_L)]

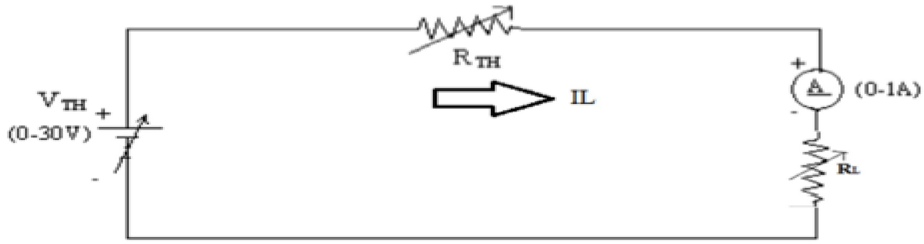
4. Finally verify that when RL = RTH, maximum power is delivered or not.

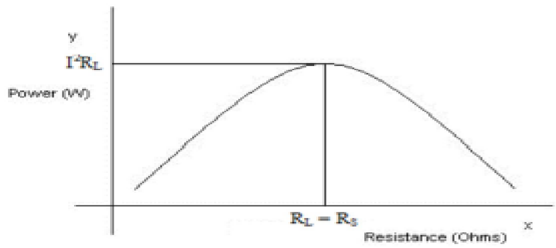
CONNECTION DIAGRAM











OBSERVATIONS

SL NO	V_{TH}(V)	Load current (I_L) (A)	Load Resistance(R_L) (Ω)	$P=I_L^2R_L$ (Watts)

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. What is maximum power transfer theorem?

2. Why do we replace current source with an open circuit and voltage source with a short circuit for calculating RTH ?

3. What do you mean by ideal voltage source and current source?

4. Why do we connect ammeter in series and voltmeter in parallel?

5. What is the efficiency in maximum power transfer condition?

7. VERIFICATION OF NORTON'S THEOREM

AIM

To find the Norton's equivalent circuit from the given circuit.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-1) A MC	1 No.
2	Linear Rheostat	10Ω, 8.5A 12Ω, 8.5A 11Ω, 8.5A	1 No. 2 Nos. 1 No.
3	Variable voltage source	(0-30)V DC	1 No.
4	Voltmeter	(0-30)V MC	1 No.

PRINCIPLE

Norton's theorem states that any two terminal linear network with current sources, voltage sources and resistances can be replaced by an equivalent circuit consisting of a current source in parallel with a resistance. The value of the current source is the short circuit current between the two terminals of the network and the resistance is equal to the equivalent resistance measured between the terminals with all the energy sources are replaced by their internal resistances.

PROCEDURE

1. Connection are made as per the circuit diagram shown in figure 1.
2. Vary the supply voltage V and take the corresponding reading IL from the ammeter.
3. Now connect the circuit diagram in figure 2 (Removing the load resistor RL and shorting the terminals).
4. Vary the supply voltage V in the same way as done in step 2 and note down the corresponding IN from the ammeter.
5. Find out the RN and draw the Norton's Equivalent circuit.
6. Now apply source transformation in the circuit diagram as shown in figure 3 and obtain the circuit as shown in figure 4.

7. Connect the circuit as shown in figure 4 and vary the supply voltage and note down the corresponding IL from the ammeter.

CIRCUIT DIAGRAM

To find load current (I_L)

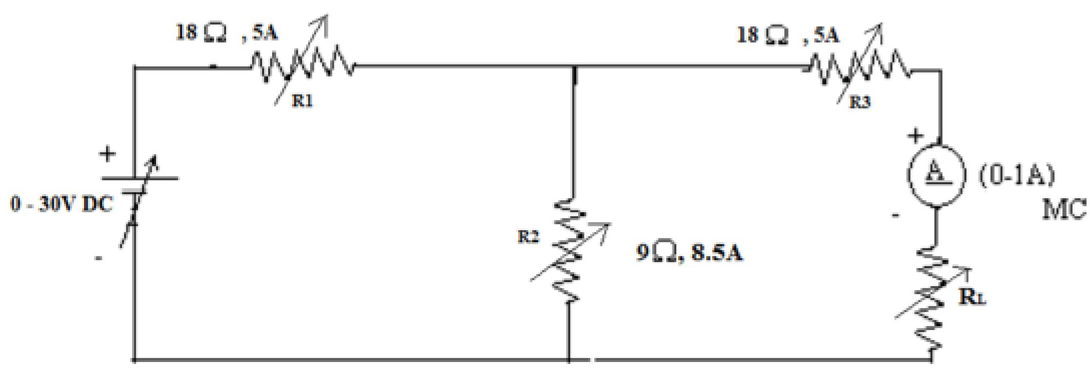


Fig 1

To find I_N

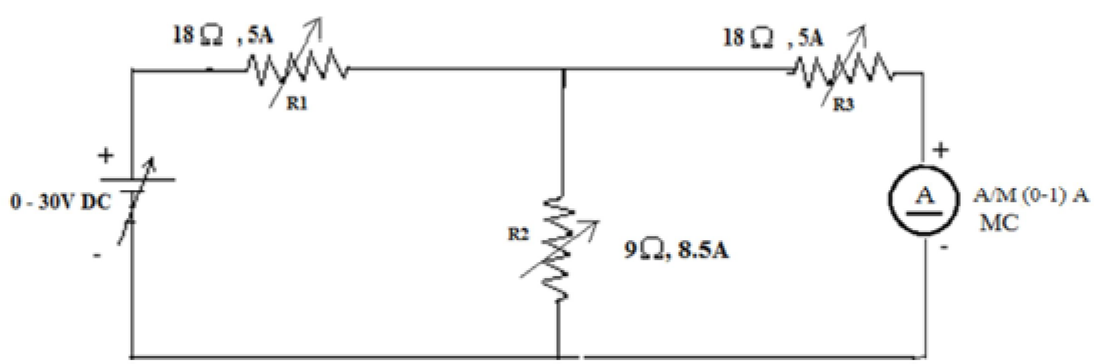
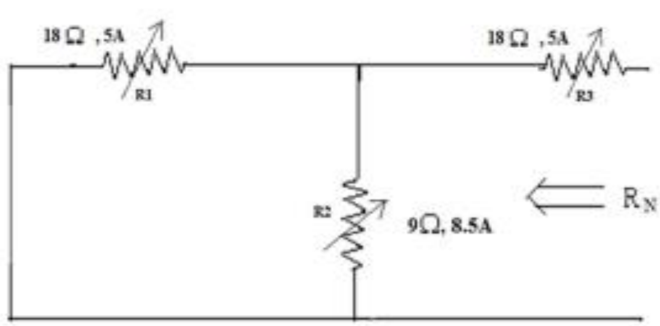


Fig 2

To find R_N



$$R_N = \frac{R_1 R_2}{(R_1 + R_2)} + R_3$$

Norton's Equivalent circuit

Fig 3

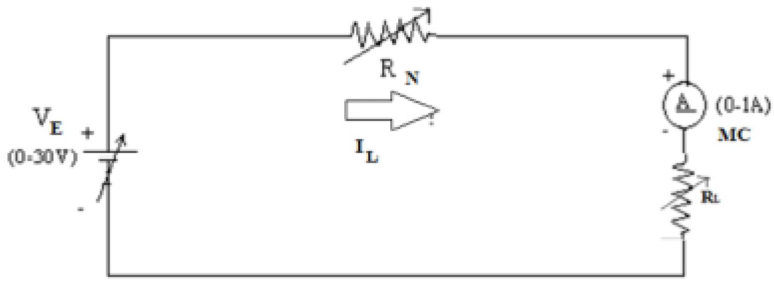


Fig 4

OBSERVATIONS

Table 1

SL NO	Voltage(volts)V	Measured current (I_L) A

Table 2

SL NO	Voltage(volts)V	Norton's Current (I_N) A

Table 3

SL NO	Norton's Current (I_N) A	Equivalent Voltage(volts) (V_E)

Table 4

SL NO	Equivalent Voltage(volts) (V_E)	I_L (A)

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1. What is Norton's theorem?
2. What are the advantages of Norton's theorem?
3. What is the difference between Thevenin's and Norton's theorem.
4. Differentiate between dependent and independent sources.
5. What is internal resistance of a source?

8.LOAD TEST ON DC SHUNT MOTOR

AIM

To conduct Load test on DC shunt motor and plot its performance characteristics.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-20)A, MC	1 No.
2	Voltmeter	(0-300)V, MC	1 No.
3	Rheostat	1300Ω; 1.5A	1 No.
4	Tachometer		1 No.

MACHINE DETAILS

Take down the name plate ratings of motor

Sl. No.	Name Plate details
1	
2	
3	

PRINCIPLE

A shunt DC motor connects the armature and field windings in parallel or shunt with a common D.C. power source. When electric voltage is supplied to the shunt DC motor, due to high resistance of the shunt winding, it draws very low current. The higher number of turns of the shunt winding helps in generating a strong magnetic field. The armature draws high current, thus also generating a high magnetic field. The motor starts rotating as the magnetic field of the armature and shunt winding interact. As the magnetic fields grow stronger, rotational torque will increase, thus resulting in an increase of rotational speed of the motor.

$$N = \frac{V - I_a R_a}{K_e \times \phi}$$

Where Ia is the armature current, Ra is the armature resistance, ϕ is the flux per pole and N is the speed in rpm.

Output Torque = (S1-S2) x R x 9.81 Nm

Where W1 is the tension on the tight side of brake in Kg. W2 is the tension on the slack side of the brake in Kg. R is the radius of the pulley in m. If N is the speed of the motor in rpm, then

Power Output = ((S1-S2) x R x 9.81x 2πN)/60

PRECAUTIONS:

1. DC shunt motor should be started and stopped under no load condition.
2. Field rheostat should be kept in the minimum position.
3. Brake drum should be cooled with water when it is under load.

PROCEDURE

1.Connections are made as per the circuit diagram.

2.After checking the no load condition, and minimum field rheostat position, DPST switch is closed and starter resistance is gradually removed.

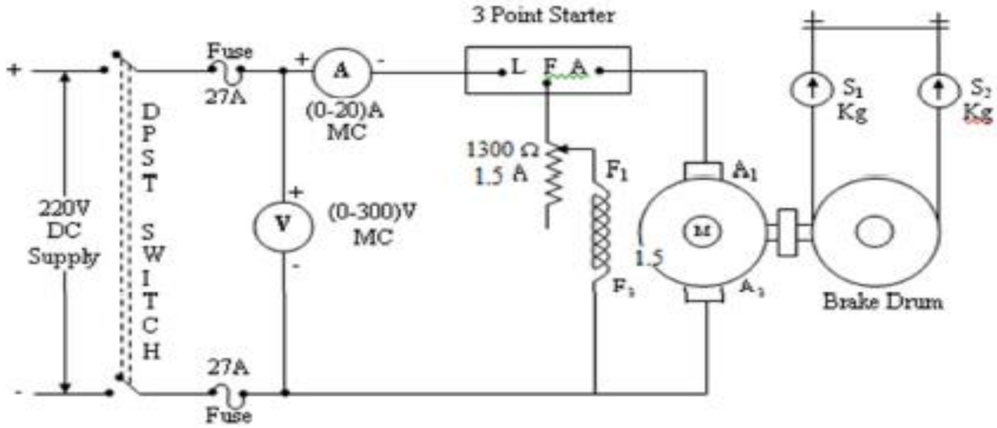
3.The motor is brought to its rated speed by adjusting the field rheostat.

4.Ammeter, Voltmeter readings, speed and spring balance readings are noted under no load condition.

5.The load is then added to the motor gradually and for each load, voltmeter, ammeter, spring balance readings and speed of the motor are noted.

6.The motor is then brought to no load condition and field rheostat to minimum position, then DPST switch is opened.

CONNECTION DIAGRAM



FUSE RATING:

125% of rated current

$$\frac{125 \times \text{rated current}}{100} =$$

NAME PLATE DETAILS:

Rated Voltage : 220V
Rated Current :
Rated Power :
Rated Speed :

OBSERVATIONS

Sl. No.	Vin(V)	Iin(A)			Speed (rpm)	Torque (Nm)	Output (Watts)	Input (Watts)	% Efficiency
			S_1(Kg)	S_2(Kg)					

SAMPLE CALCULATIONS

Sample Calculation (set no. . . .)

Voltmeter reading (V) = ...

Current (I) = ...

Spring balance readings, S1 = ... S2 = ...

Speed (N) = ...

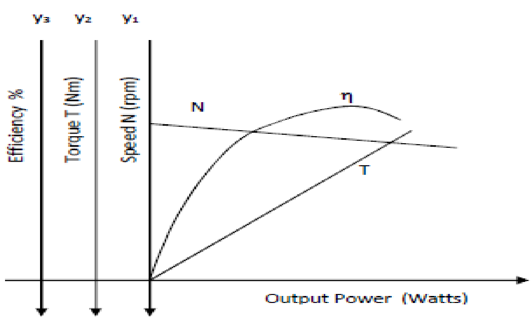
Torque (T) = 9.81 (S1 − S2) R = ... Where R is the radius of brake drum.

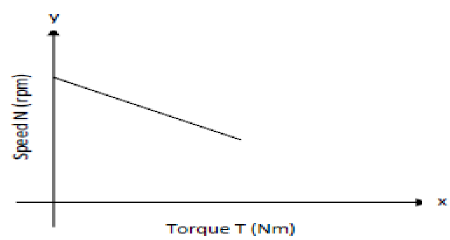
Output power = = ... (2πNT)/60

Input power = V I = ...

Efficiency = Output power/ Input power = ...

MODEL GRAPHS:





RESULTS AND DISCUSSIONS

CONCLUSION

VIVA QUESTIONS

1. What is the significance of back emf in a d-c motor?
2. What is the difference between a three point starter and a four point starter?
3. What are the different methods to control speed of a d-c shunt motor?
4. What are the different factors which make effects on efficiency of a d-c machine?
5. Give some applications of d-c shunt motor.

9.SWINBURNE'S TEST

AIM

To conduct Swinburne's test on DC machine to determine efficiency when working as generator and motor without actually loading the machine and predetermine the armature current and efficiency when the machine operates as a motor and as a generator at (1/4)th full load , (1/2) full load, (3/4)th full load, full load and (5/4)th full load.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-5)A, (0-2)A,MC	1 No., 1 No.
2	Voltmeter	(0-300)V,(0-30)V, MC	1 No., 1 No.
3	Rheostat	300Ω; 1.7A	1 No.
	Tachometer		1 No.

MACHINE DETAILS

Take down the name plate ratings of motor.

Sl. No.	Name Plate details
1	
2	
3	

PRINCIPLE

The Swinburnes test is a no load test. The given machine is run as a motor on no load at rated voltage and speed. The supply voltage, armature current and field current are to be measured. If the Ra is measured, the constant losses of the machine can be calculated as a no load input copper loss. If constant losses and armature copper loss are known, for any current the efficiency can be calculated.

No load input to the motor $=VI_0$ watts

Armature copper loss at no load= I_{a0}^2Ra

Constant loss of the machine , $Wc=VI_0-I_{a0}^2Ra-V_bI_{a0}$

Input to generator at full load= Output+Wc+Cu loss + brush loss

Input to motor at full load $=VI_l$

Efficiency= (Output/Input)*100

PROCEDURE

1. Connections are made as per the circuit diagram.
2. After checking the minimum position of field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. By adjusting the field rheostat, the machine is brought to its rated speed.
4. The armature current, field current and voltage readings are noted.
5. The field rheostat is then brought to minimum position DPST switch is opened.

CONNECTION DIAGRAM

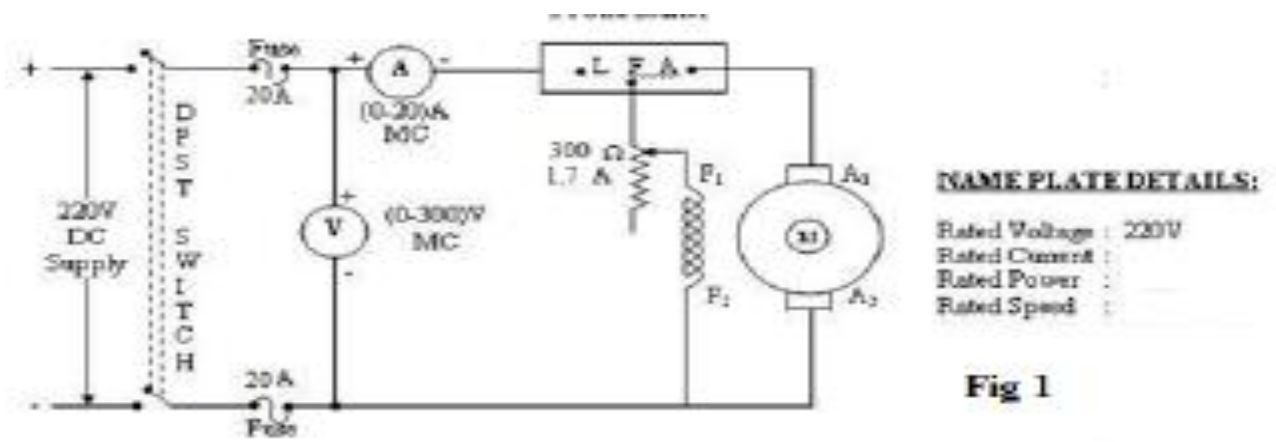


Fig 1

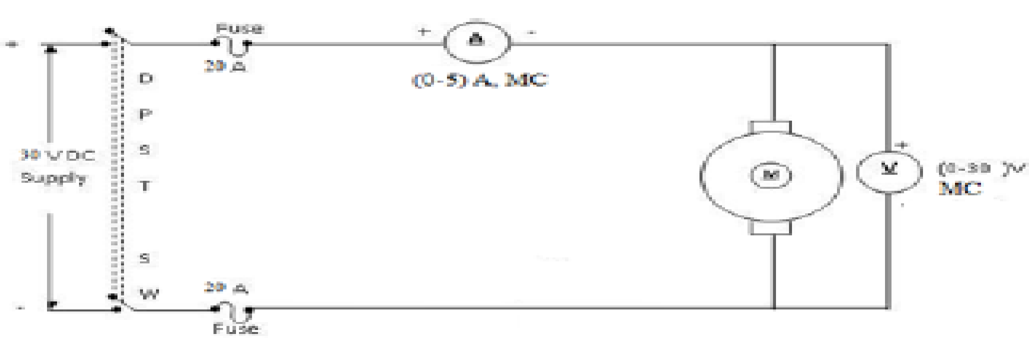


Fig 2: To measure Ra

OBSERVATIONS

Supply Voltage (V)	No Load Current I_0(A)	Field current I_f(A)	$I_{a0}= I_0 - I_f$ (A)	$W_c = VI_0 - I_{a0}^2R_a$ (W)

To find motor efficiency

Load in terms off F.L	Load Current I_L (A)	$I_a = I_L - I_f$ (A)	Armature cu loss $I_a^2R_a$ (W)	Total loss = $W_c + I_a^2R_a$ (W)	Input power (W)	Output Power = Input – Losses (W)	Efficiency (%)
¼							
½							
1							
¾							
5/4							

To find generator efficiency

Load in terms off F.L	Load Current I_L (A)	$I_a = I_L + I_f$ (A)	Armature cu loss $I_a^2R_a$ (W)	Total loss = $W_c + I_a^2R_a$ (W)	Output power (W)	Input Power = Output + Losses (W)	Efficiency (%)
¼							
½							
1							
¾							
5/4							

SAMPLE CALCULATIONS

Sample Calculation (set no. . . .)

No load input to the motor = ………

Armature copper loss at no load= $I_{a0}^2R_a$ = …………

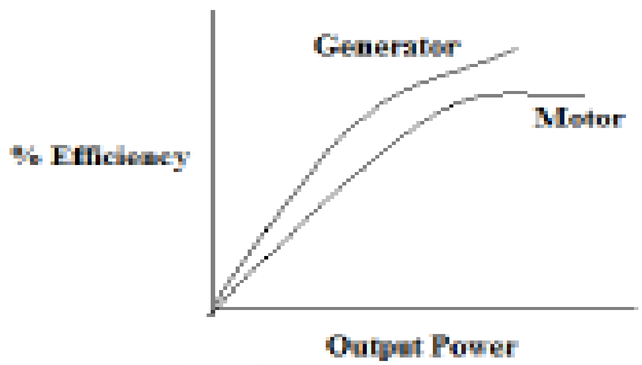
Constant loss of the machine , W_c= ………………………..

Input to generator at full load= ……………………..

Input to motor at full load = ………………..

Efficiency= (Output/Input)*100

MODEL GRAPH



RESULTS AND DISCUSSIONS

CONCLUSION

VIVA QUESTIONS

1. What are the assumptions made in Swinburne's test?
2. What is the purpose of Swinburne's test?
3. What are the constant losses in a DC machine?
4. Why is the indirect method preferred to the direct loading test?
5. The efficiency of DC machine is generally higher when it works as a generator than when it works as a motor. Is this statement true or false? Justify your answer with proper reasons.

10. LOAD TEST ON THREE PHASE INDUCTION MOTOR

AIM

To conduct load test on the given 3-ph squirrel cage induction motor and plot the performance characteristics.

APPARATUS REQUIRED

Sl. No.	Name of the instrument	Specification	Quantity
1	Ammeter	(0-15)A,MI	1 No.
2	Voltmeter	(0-500)V, MI	1 No.
3	Wattmeter	500V,15A,UPF	2 Nos.
4	Autotransformer	415/(0-415)V	1 No.
5	Tachometer		1 N0.

MACHINE DETAILS

Take down the name plate ratings of motor

Sl. No.	Name Plate details
1	
2	
3	

PRINCIPLE

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-ph 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-ph supply is given to a 3-ph winding displaced by 120 degree 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 current versus output.

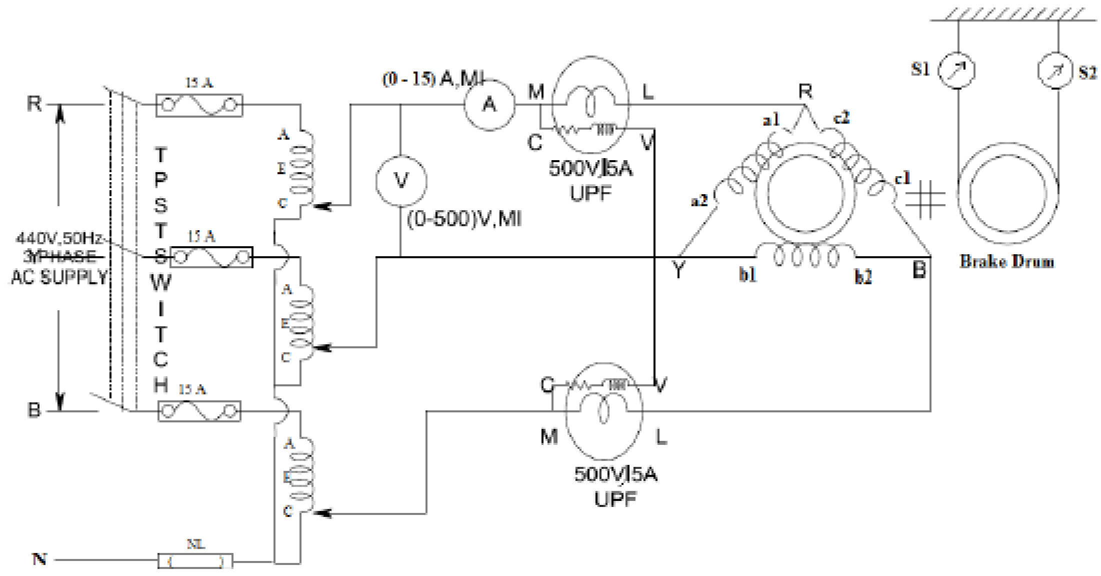
Current and torque increases with increase in output. The induction motor is essentially a constant speed motor. However speed reduces gradually with increase in output and slip increases gradually with increase in output. The pf is low at low

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. Connections are made as shown in figure.
2. Close the TPST switch.
3. Adjust the 3phase autotransformer till the voltmeter shows the rated line voltage of the induction motor.
4. Note down the line voltage, line current, power input and the speed indicated by the respective voltmeter, ammeter, wattmeter and tachometer under no load condition.
5. Load the machine by means of brake drum arrangement and note down the corresponding meter readings and speed.
6. Repeat the same procedure up to the rated current of the induction motor.

CONNECTION DIAGRAM

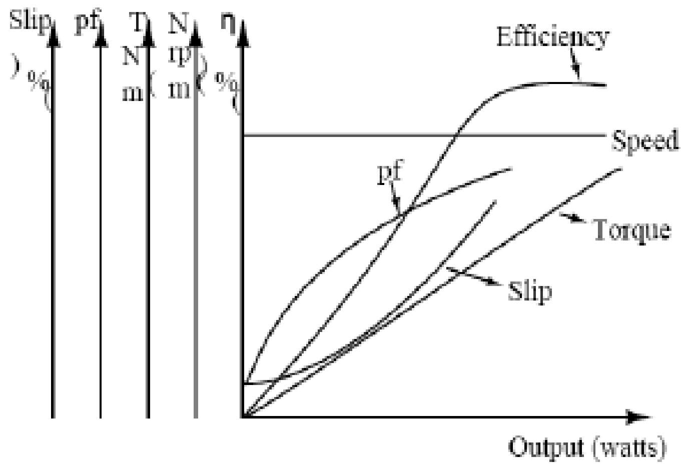


Voltage V	- 415 V
Current I	- 7.5A
Power	- 5HP
Connection	- Δ
Speed(*rpm*)	- 1440
Phase	- 3φ

OBSERVATIONS

Sl. No.	V (*volts*)	I (*Amp*)	W_1 (*watts*)	W_2 (*watts*)	S_1 (Kg)	S_2 (Kg)	N (*rpm*)	T (*Nm*)	Output (*watts*)	Input (*watts*)	slip (%)	*pf*	Efficiency (%)

Model Graph



SAMPLE CALCULATIONS

Voltage V = ...

Current I = ...

Wattmeter reading W1 = ...

Wattmeter reading W2 = ...

Input power P = W1 +W2 = ...

Spring balance Readings S1 = ... S2 = ...

Speed (N) = ...

Torque (T) = 9.8 (S1 − S2) R = ... Where R is the radius of brake drum.

Synchronous speed = 120 × fP

% slip = ((Ns – N)/Ns)∗100

46 NCERC, PAMPADY Prepared by Rajesh P & Sebin Joseph

Power factor = cos ϕ = (w1+w2) / (√3*VI) =…….

Output power = (2ΠNT) / 60 =…….

% Efficiency = (output power) / (input power) ∗ 100

RESULT AND DISCUSSION

CONCLUSION

VIVA QUESTIONS

1.What is ‘slip’ in an induction motor?

2. What are the two types of 3-ph induction motors and what is the difference between the two.

3. What is the value of slip at starting?

4. What are the advantages and disadvantages of squirrel cage induction motor?

5. Give some applications of 3-ph squirrel cage induction motor?