

University of Global Village (UGV), Barishal

Electrical Machine II Sessional

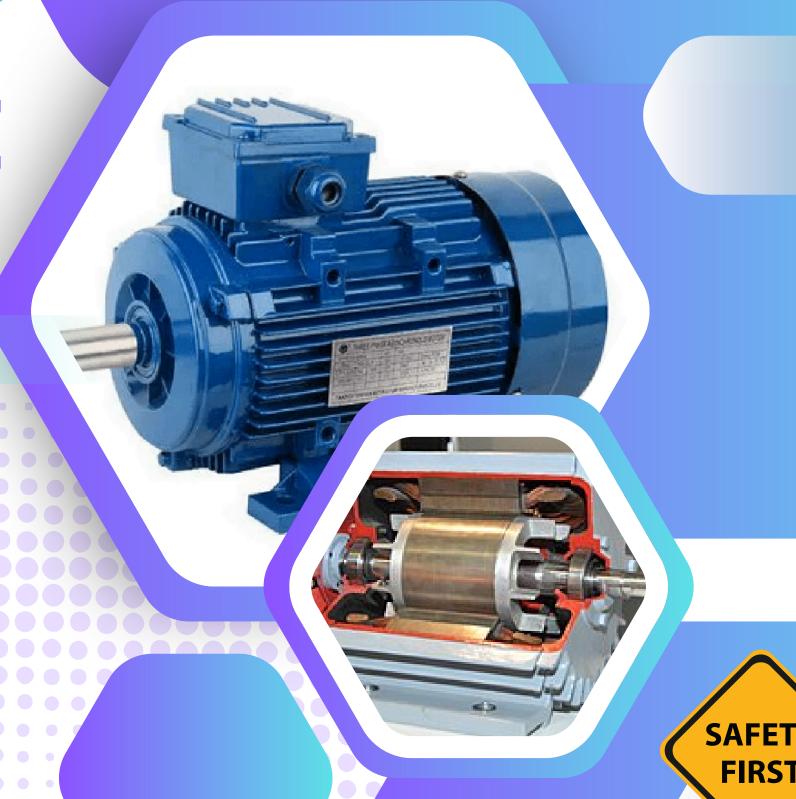
CONTENT OF THE SESSIONAL COURSE

Prepared by:

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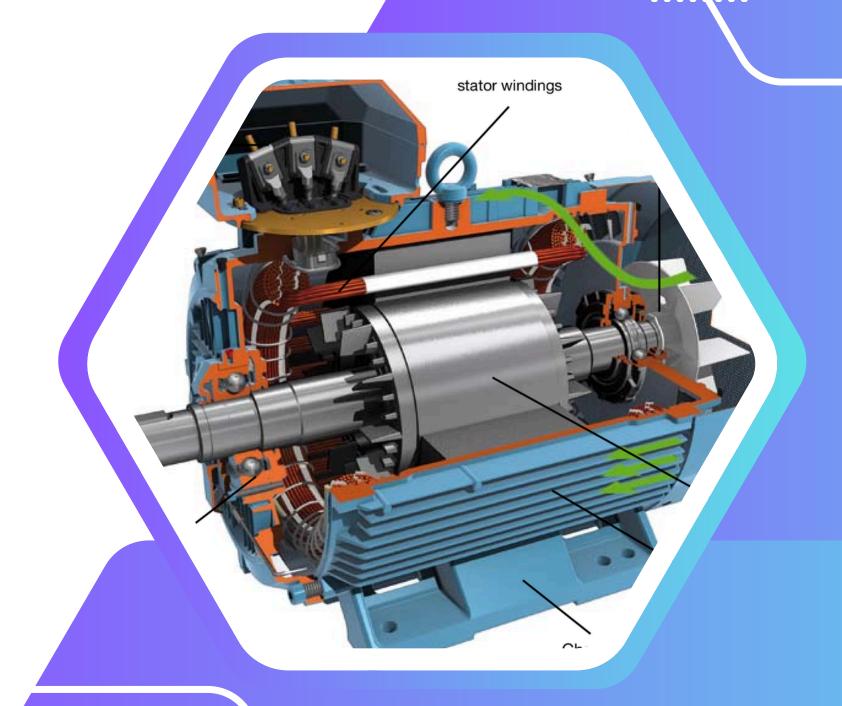
Basic Course Information



Course Title	Electrical Machine II Sessional			
Course Code	EEE 0714-2204			
Credits	01			
Marks	50			
Course Type	Sessional Course			
Level	4th & 6th Semester			
Academic Session	Winter 2025			

Course Rationale

This course will provide knowledge of AC machine such as Alternators, Synchronous motor, Induction motor that will bring them near to the practical applications. By understanding these machines' theoretical foundations and practical applications, students gain insights into efficient power generation, transmission, and utilization. Furthermore, the course equips learners with the skills to analyze, design, and troubleshoot synchronous and induction machines, fostering expertise crucial for electrical engineering and energy-related industries.



Course Objectives

This course has been projected for the students.

- To understand the construction and basic principle of AC machines.
- To analyze the properties of AC machines practically. To get required ideas for designing electrical machines.



Course Learning Outcomes (CLOs):



CLO 1

Analyze different machines with respect to theoretical knowledge.



CLO 2

Identify the performance of different machines experimentally.



CLO₃

Apply practical knowledge for designing Electrical machines.



CLO 4

Analyze the properties of Synchronous machines, Induction Motors.

Week No.	Experiment Name	Learning Outcomes	Theory Time (Hours)	Practical Time (Hours)	Alignment to CLO
1.	A GENERAL PROCEDURE FOR CONDUCTING EXPERIMENTS WITH DIFFERENT TYPES OF DC AND AC MACHINES	Students will gain a practical understanding of the operational principles, construction, and performance characteristics of various DC and AC machines.	02	03	CLO 1 CLO 2
2-3.	A) DETERMINATION OF PARAMETERS OF THE EQUIVALENT CIRCUIT OF A THREE-PHASE INDUCTION MOTOR. B) VERIFICATION OF THE EQUIVALENT CIRCUIT BY LOADING THE INDUCTION MOTOR.	Students will understand how to experimentally determine the parameters of the equivalent circuit	04	06	CLO 2 CLO 3
4-5.	NO LOAD AND BLOCKED ROTOR TEST ON A 3- φ INDUCTION MOTOR	Students will gain the ability to evaluate key performance parameters such as core losses, friction losses, and the equivalent circuit of the motor.	04	06	CLO 1 CLO 2

Week No.	Experiment Name	Learning Outcomes	Theory Time (Hours)	Practical Time (Hours)	Alignment to CLO
6-7.	BRAKE TEST ON 3- ф SQUIRREL CAGE INDUCTION MOTOR	After performing the brake test on a 3- \$\phi\$ squirrel cage induction motor, students will understand how to determine the motor's performance characteristics, such as torque, power, and efficiency, under various load conditions.	04	06	CLO 2 CLO 3
8-9.	LOAD TEST ON 3-PHASE AC SLIP RING INDUCTION MOTOR	Students will understand its performance characteristics, including torque, efficiency, and power factor under varying load conditions.	04	06	CLO 3 CLO 4
10.	LOAD TEST ON SINGLE PHASE INDUCTION MOTOR	Students will understand its performance characteristics, including efficiency and power factor under varying load conditions.		03	CLO 3 CLO 4

Week No.	Experiment Name	Learning Outcomes	Theory Time (Hours)	Practical Time (Hours)	Alignment to CLO
11 - 12.	EQUIVALENT CIRCUIT OF A SINGLE PHASE INDUCTION MOTOR	By conducting this experiment, students will understand how to derive the equivalent circuit parameters of a single-phase induction motor and analyze its performance characteristics.	04	06	CLO 2 CLO 3
13 -14.	REGULATION OF ALTERNATOR USING SYNCHRONOUS IMPEDANCE METHOD	Students will be able to determine the voltage regulation of an alternator using the synchronous impedance method and understand its significance in maintaining stable operation under varying load conditions.	04	06	CLO 2 CLO 3
AN EXPERIMENTAL STUDY ON A FAN MOTOR		Students will gain practical understanding of the working principles of a fan motor, analyze its electrical and mechanical performance, and evaluate key parameters	02	03	CLO 3 CLO 4

Week No.	Experiment Name	Learning Outcomes	Theory Time (Hours)	Practical Time (Hours)	Alignment to CLO
16-17	Designing a Project, where students could emphasize the knowledge and skills learned from lectures and experiments and utilize them to implement process control of an industry and voltage regulation and power factor control for a small power system.	Students will integrate theoretical concepts from lectures and practical skills from experiments to design a project focused on process control, voltage regulation, and power factor control for a small power system. They will demonstrate the ability to apply learned concepts to real-world industry scenarios, enhancing their practical knowledge and problemsolving skills in managing electrical systems effectively.	04	06	CLO 4

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 switching on 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 main panel 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 a cut.



WEEK 01

Page 12-16



EXPERIMENT 1— A general procedure for conducting experiments with different types of dc and ac machines



Pre Lab Work

- Motor and generator principles
- Types of motor and generator
- Identification whether a machine is generator or motor
- Common connections for a motor and a generator
- Loading arrangements for motor and generator
- Speed control of a motor

(To be written in the report)



1.1 Introduction: There are some common techniques to identify an electrical machine and to work with an electrical machine. The machine may be a motor or a generator. First of all, the students are required to identify a proper machine for their experiment. Then, in most cases, finding the characteristics of the motor or generator is required. In general, the characteristics are determined by loading the motor or generator. The general guidelines of identifying and loading of an electrical machine are given below.

1.2 Three phase Induction motor:

- 1.2.1 Identification of an induction motor: Based on rotor construction, there are two types of induction motor: squirrel cage and wound type. In a squirrel cage induction motor, only six stator terminals are available at outside and the rotor terminals are shorted inside. On the other hand, in a wound type, three rotor terminals are also available at outside along with six stator terminals. Hence, for a wound type nine terminals are available at outside whereas only six terminals are available for a squirrel cage motor.
- **1.2.2 Loading of an induction motor:** A dc machine (dc generator)/eddy current brake is connected in the laboratory for loading the induction motor, then the generator is loaded gradually and hence the motor is loaded gradually. The loading procedure of a generator will be discussed below.

1.3 Three phase synchronous machine:

- **1.3.1 Identification of a three phase synchronous machine**: A three phase synchronous machine has six armature terminals and two dc field terminals. A dc supply is applied to the field terminals. The synchronous machine may act as a generator (known as alternator) or a motor; it depends on the type of input and output. If the output is electrical and the input is mechanical force then the machine is a generator or alternator and vice versa for a motor. For an alternator, the input mechanical force is generated by an external dc/ac motor.
- **1.3.2 Loading of a three phase synchronous machine**: If the synchronous machine acts as an alternator, a three phase variable load (R/RL/RC) is connected in series with the armature of the machine to vary the armature/load current. Again, if the synchronous machine acts as a motor,

a dc generator (which acts as a load) is connected with its rotor to demonstrate the loading characteristics.

1.4 Single phase dc/ac machine:

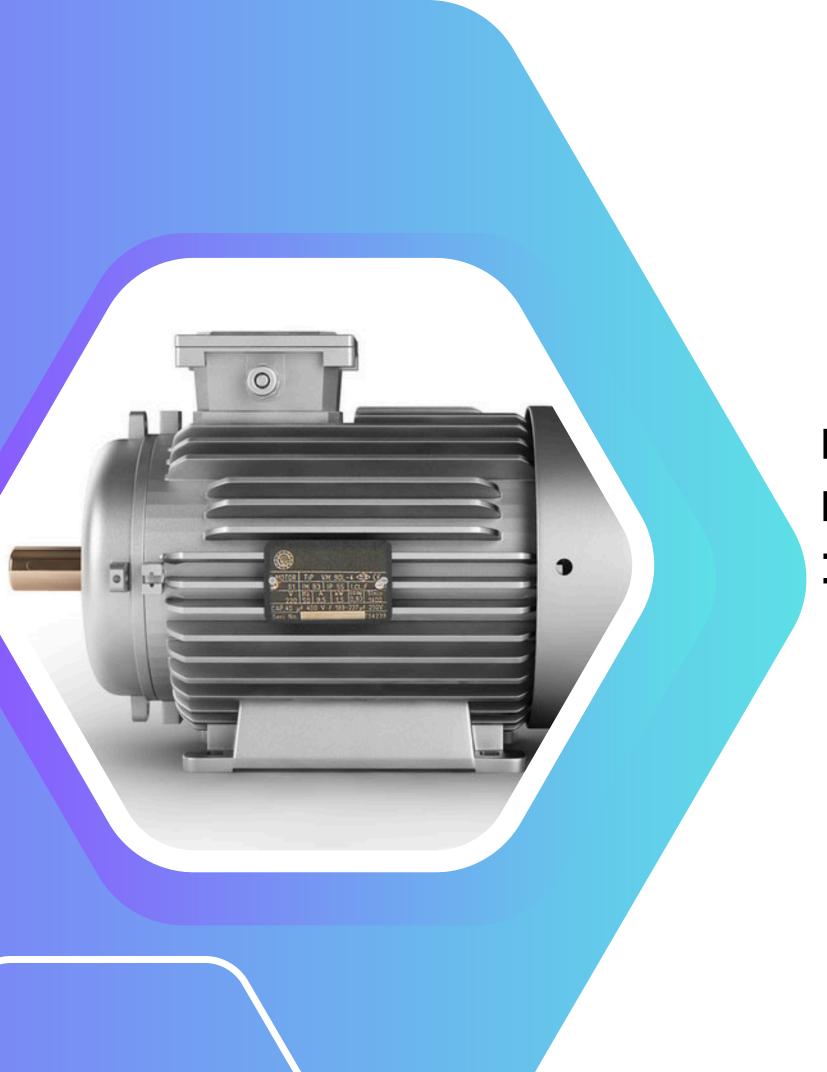
- **1.4.1 Identification of a single phase ac motor:** In our laboratory, it is confusing to identify a single phase ac motor using the terminals. The ac motors look like a dc motor. Hence, it is suggested to identify the motor using the nameplate of the motor.
- **1.4.1 Loading of a single phase ac motor:** A dc generator with variable external resistor will be used for loading the single phase ac motor.

The students are also advised to follow the following instructions during experiment:

- 1. Read the voltage and current ratings of a machine. Never apply the current and voltage that exceed the values written in the nameplate of the machine.
- 2. Don't close/open any switch until you know the function of the switch. It is better to ask a teacher/officer to open/close the switch of power supply.
- 3. Disconnect all connections that you made during experiment carefully.
- 4. Tidy up the experimental desk once you finish the experiment.
- 5. Don't discuss with other group member without any concern of a teacher.
- 6. Ask a teacher before you leave the laboratory.

WEEK 2-3

Page 18-28



EXPERIMENT 2— PARAMETERS OF THE EQUIVALENT CIRCUIT OF A THREE PHASE INDUCTION MOTOR



Pre Lab Work

- 1) If the no load test results of an induction machine are given as: 3-phase real power Pnl, line-line voltage Vnl, and stator current Inl, how to calculate magnetising impedance?
- 2) If the block-test results are given as: 3-phase real power Pbl, line-line voltage Vbl, and stator current Ibl, how to calculate leakage reactance of stator and rotor?
- 3) Derive the torque, output power, and efficiency of the induction machine based on the equivalent circuit.
- induction machine and describe the similarities and differences.

4) Compare the per phase equivalent circuit of a transformer and an



(To be written in the report)

2.1 Aims

- Determining the parameters of the equivalent circuit of a three-phase induction motor, by means of a no-load test and a blocked rotor test which are similar to the open circuit and short circuit tests used to measure the parameters of a transformer.
- The carrying out of a full load test, i.e. the experimental determination of real power drawn by the induction machine at full load slip.
- Verifying the equivalent circuit.

2.2 Theory

The stator of a 3-phase induction motor is fitted with three windings, each connected to one phase of a 3-phase supply. The rotor has a squirrel cage construction which is effectively short circuited. For normal operation, the stator and rotor currents set up a magnetic field distribution which rotates around the air gap at "synchronous speed" proportional to supply frequency (synchronous speed is 1500 rpm for the 50 Hz, 4-pole laboratory machines). Currents are induced in the predominantly resistive rotor due to it slipping behind the rotating magnetic field. These induced currents create a rotating magnetic field at the synchronous speed but which trails the stator field by 90 "electrical" degrees, thus creating motoring torque. In the theory of induction machines, the mechanical speed of the rotor (ω_r) and of the rotating magnetic field (ω_s) is of great importance. This is usually expressed as the "slip" (s), defined as:

$$S = (\omega_s - \omega_r)/\omega_s \tag{3.1}$$

Note that s=1 corresponds to standstill and s=0 corresponds to running at synchronous speed. The normal running speed of an induction motor is typically 5% below synchronous speed, which corresponds to a slip of 0.05. Fig. 1 shows a per phase equivalent circuit for an induction machine, referred to the stator side.

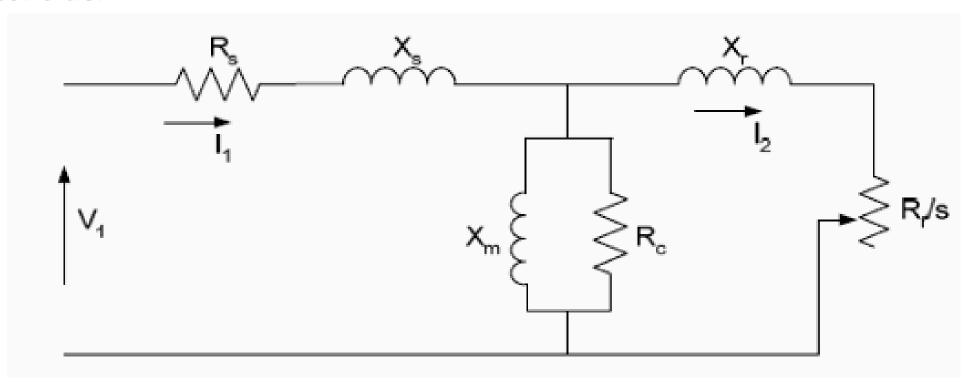


Fig. 1 Induction machine per-phase equivalent circuit, referred to the supply side.

The equivalent circuit is just like that for a transformer but, on an equal mass basis, the induction motor circuit has lower magnetising reactance because the magnetic circuit has the higher reluctance of two air gaps per pole pair. Provided magnetic saturation is not localised we may assume that the two leakage reactance are equal. Thus it is common for an unloaded induction

motor to have a no-load current 35% of rated current whereas for a transformer it may be only 10%. Obviously R_c accounts for the magnetising power loss and R_s represents the resistance of the stator. R_r is the rotor resistance referred to the stator side and R_r /s accounts for the power transferred across the air gaps to the rotor. This resistor can be split into R_r , accounting for the resistive heating in the rotor and R_r *(1-s)/s representing the mechanical power.

2.4 Experimental Work

Check the ratings of the induction motor on the nameplate and record in your report.

2.4.1 Stator resistance measurement R_s:

Using a multimeter, measure the DC resistance of each of the stator windings; then average the measurements as R_s.

2.4.2 Blocked-rotor test (short-circuit test):

Fig. 2 shows the connection diagram of an induction motor for the block-rotor test. The variable AC supply is used to power on the 3-phase squirrel cage induction machine. Make sure the power supply is **OFF** before starting to connect the circuit. Ask a teacher/officer to check the wirings.

- 1) Hold the rotor end with the hand to run a blocked rotor test.
- 2) Ensure that the variac is set to zero volts. Switch on the three-phase AC supply. Apply reduced voltage to the stator slowly using variac, sufficient to cause the rated current of 1.8 A (no more than 1.8 A shown on the ammeter). Measure and record the real power per phase (P_{bl}), voltage (V_{bl}) and currents (I_{bl}).
- 3) Turn the variac back to zero and then switch off the AC supply.

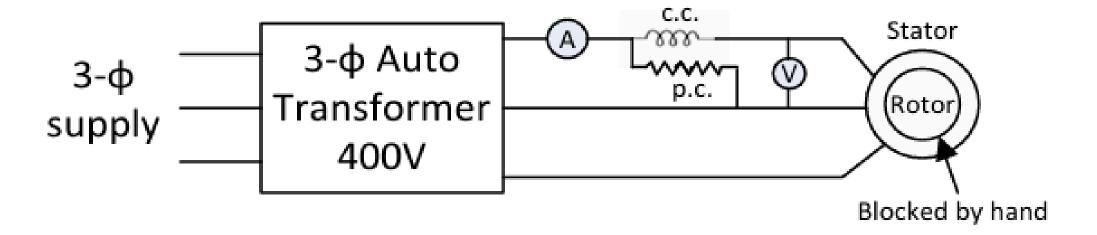


Fig. 2 Connection diagram for blocked-rotor test.

2.4.3 No-load test (open-circuit test):

The circuit connection diagram remains the same as Fig. 2. The induction machine stays without using hand; only friction load remains. Ask a teacher/officer to check the wirings.

- Turn on the AC supply. Start the motor by slowly increasing the variac voltage from zero. Do this slowly enough to ensure that the machine rated current (1.8 A) drawn from supply is at no stage exceeded. Please note the current readings on the ammeter. Why are the current readings increased, then decreased, and increasing again with consistently increasing the voltage?
- 2) When the motor has run up to speed, measure the no-load current (I_{nl}), active power (P_{nl}) and speed ω_r for the rated voltage of 400 V line-line. Note that Wattmeter register total power over the balanced three phases.
- Turn the variac back to zero and then switch off the variable AC supply.

2.4.4 Calculation of equivalent circuit parameters:

The average stator resistance R_s previously measured by a multimeter and can be considered to be the DC value. Due to the skin effect, an extra 20% should be considered for the stator AC resistance. Like the open-circuit test on a transformer, the no-load test on an induction motor gives information with respect to exciting current and no-load losses. At no-load, the rotor current is a very small value required to produce sufficient torque to overcome friction and windage, and the slip is very small so that the reflected rotor resistance (R_r/s) is very large. Hence the no-load input power is dissipated only at R_s and R_c . Subtracting stator copper loss of $R_s I_{nl}^2$ from no-load input power, will give core and rotational losses of the induction motor as:

$$P_r = P_{nl} - R_s I_{nl}^2 (2.2)$$

Now, magnetising branch resistance of Rc can be estimated as:

$$R_c = \frac{V^2}{P_r} \tag{2.3}$$

The total reactive power Q_{nl} at no-load is absorbed by self-reactance X_{11} of the stator, which is the series combination of stator reactance X_s and magnetising reactance X_m , i.e. $X_{11}=X_s+X_m$.

The self-reactance can be determined by

$$X_{11} = \frac{V^2}{Q_{nl}}$$
, where $Q_{nl} = V_{nl}I_{nl}\sin(\theta_{nl})$ and $\theta_{nl} = \cos^{-1}(\frac{P_{nl}}{V_{nl}I_{nl}})$ (2.4)

Hence the magnetising reactance can be estimated as

$$X_m = X_{11} - X_s (2.5)$$

Like the short-circuit test on a transformer, the blocked-rotor test on an induction motor gives information with respect to the leakage impedances. If exciting current at blocked rotor test is neglected (as the stator current is much greater than exciting current), from the total reactive power absorbed by the induction motor, determine the sum of stator and rotor reactance as

$$X_s + X_r = \frac{Q_{bl}}{I_{bl}^2}$$
, where $Q_{bl} = V_{bl}I_{bl}\sin(\theta_{bl})$ and $\theta_{bl} = \cos^{-1}(\frac{P_{bl}}{V_{bl}I_{bl}})$ (2.6)

Assuming equal distribution of leakage reactance in the induction motors, stator and rotor reactance can be determined as: $X_s = X_r = \frac{X_s + X_r}{2}$ (2.7)

At blocked-rotor test, the input power is dissipated on R_s and R_r as the slip is 1. The sum of stator and rotor resistance can be determined by

$$R_s + R_r = \frac{P_{bl}}{I_{bl}^2}$$
 (2.8)

Substituting R_s measured before the rotor resistance can be worked out.

Now all the parameters in the equivalent circuit of Fig.1 are determined. Make a sketch of the per phase equivalent circuit of the induction motor and show on it the values of the parameters determined.

2.4.5 Load test:

Fig. 3 shows the connection diagram of the induction motor load test. Use an eddy-current brake as a load for the induction machine. Ask a teacher/officer to connect eddy current brake to the induction motor.

 Make sure the power supply is OFF before connecting the circuit. Ask a teacher/officer to check your connection before energising it.

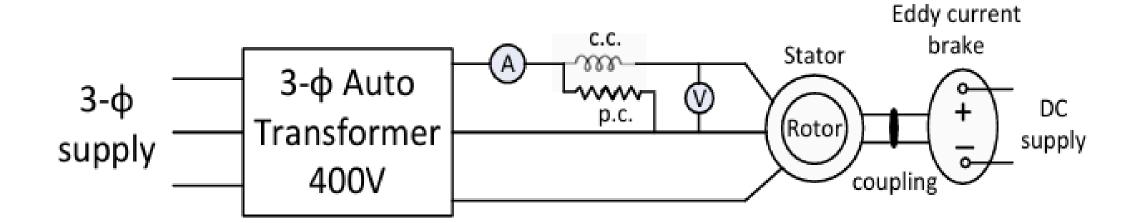


Fig. 3 Connection diagram for load test.

- 2) Switch on the AC power. Slowly increase the variac till the voltage reaches 400 V on the Voltmeter. Measure and record the current, real power and speed. Make sure the dc supply applied to the eddy current brake is OFF.
- Turn ON the dc supply. Slowly increase the dc current applied to the eddy current brake till the input motor current reaches 1.8 A.

Record the voltage, current, real power, and the speed. Compare the measurements with the calculations respectively in Section 2.5 below.

2.5 Comparison with Results from Equivalent Circuit

- With the rated voltage (V_{I-I}= 400 V), use the equivalent circuit worked out from the no-load and blocked rotor tests to calculate:
 - Per phase current from the supply
 - Total real power from the supply
 - Total reactive power from the supply
 - Power factor
 - Efficiency
- Compare these calculations with the measurements in the load test Section 2.4.5. Comment on the accuracy of the equivalent circuit.

WEEK 4-5

Page 30-39



EXPERIMENT 3— NO LOAD AND BLOCKED ROTOR TEST ON A 3- ϕ INDUCTION MOTOR



Pre Lab Work

- Study the working principle of a 3-phase induction motor and understand its equivalent circuit.
- Understand the purpose of the no-load and blocked rotor tests for determining motor parameters such as efficiency, starting torque, and voltage regulation.
- Familiarize yourself with the procedure of performing the no-load and blocked rotor tests.
- Review the necessary equipment, including the induction motor, wattmeter, ammeter, voltmeter, and tachometer.
- Prepare a datasheet to record the test results and calculate the motor's performance characteristics



(To be written in the report)

AIM:

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

APPARATUS REQUIRED:

Sl.				
No.	Equipment	Type	Range	Quantity
1	Voltmeter	MI	(0-600)V	1 no
2	Ammeter	MI	(0-10)A	1 no
			10A/600V UPF	1 no
3	Wattmeter	Electro dynamo meter type	10A/600V LPF	1 no
4	Tachometer	Digital	(0-10000)RPM	1 no
5	Connecting Wires		(0-20)A	Required

NAME PLATE DETAILS:

Power rating 5Hp

Voltage 400V

Current 6.8A

Speed (RPM) 150

Frequency 50Hz

PF Lagging

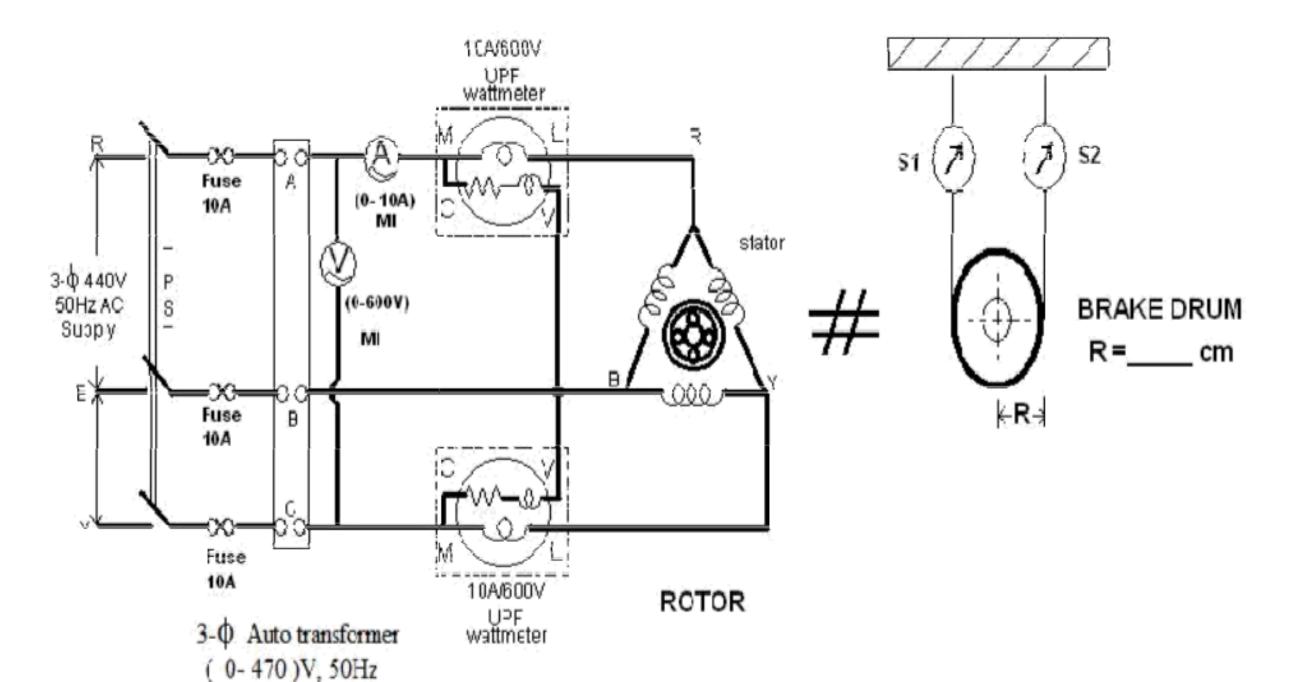
3- φ Auto transformer Details:

Input Voltage: 415 (Volt)

Output Voltage: (0-470) (Volt)

Current:_____(Amp.)

CIRCUIT DIAGRAM:



PROCEDURE:

NO- LOAD TEST:

- 1. Connections are made as per the circuit diagram.
- 2. Ensure that the 3- φ variac is kept at minimum output voltage position and belt is freely suspended.
- 3. Switch ON the supply. Increase the variac output voltage gradually until rated voltage is observed in voltmeter. Note that the induction motor takes large current initially, so, keep an eye on the ammeter such that the starting current current should not exceed 7 Amp.
- 4. By the time speed gains rated value, note down the readings of voltmeter, ammeter, and wattmeter.

5. Bring back the variac to zero output voltage position and switch OFF the supply.

BLOCKED ROTOR TEST:

- 1. Connections are as per the circuit diagram.
- 2. The rotor is blocked by tightening the belt.
- 3. A small voltage is applied using 3- ϕ variac to the stator so that a rated current flows in the induction motor.
- 4. Note down the readings of Voltmeter, Ammeter and Wattmeter in a tabular column.
- 5. Bring back the Variac to zero output voltage position and switch OFF the supply.

OBSERVATIONS:

No Load Test:

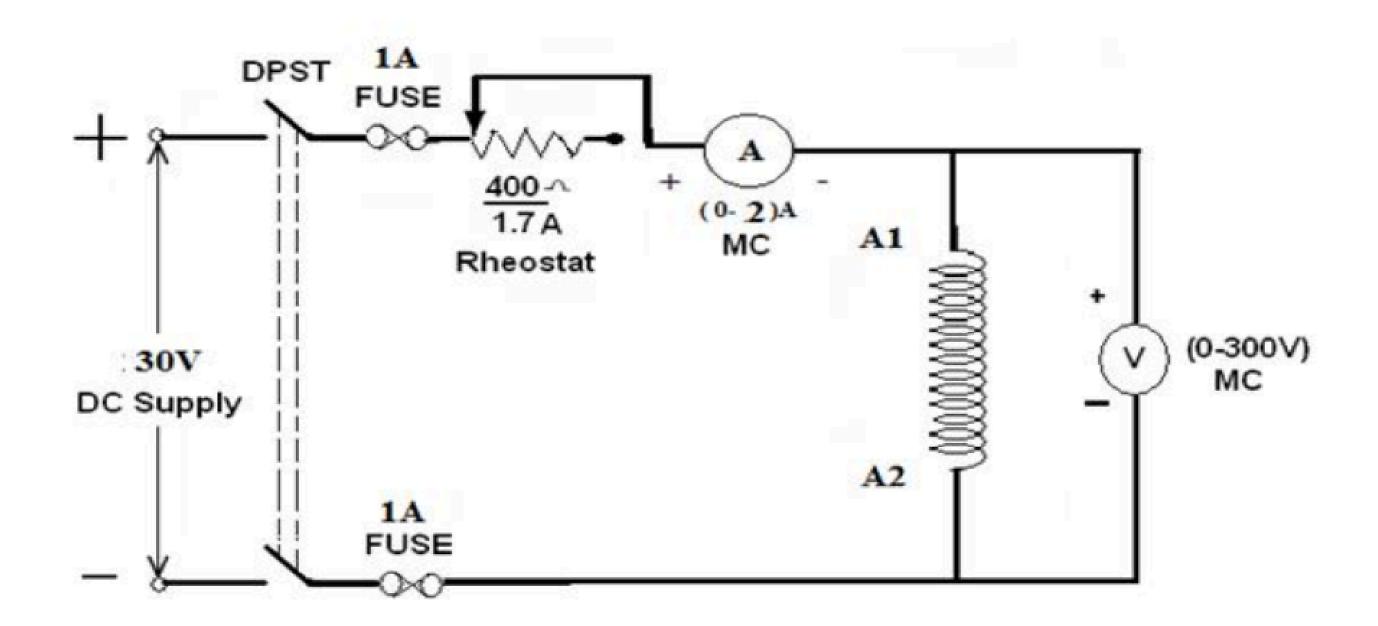
S No.	Voltmeter reading	reading	Wattmeter reading		Wnl (Pnl) (W)
	V nl (V)	Inl (A)	W ₁ (W)	W ₂ (W)	$\mathbf{W_1} + \mathbf{W_2}$
1	420	1	60	98	158*2=316

Blocked Rotor Test

			Wattmeter reading		
S No.	Voltmeter Reading V br	Ammeter reading Ibr	W ₁ (W)	W ₂ (W)	W _{br} (P _{br}) W ₁ +W ₂
1	20.5				120*2=2
1	38.5	8	56	64	12

Measurement of stator winding resistance (r_1) :

CIRCUIT DIAGRAM:



TABULAR COLUMN:

S no.	Voltage (v)	Ammeter (I)	Resistance (R)

Procedure to find r 1:

- 1. Connections are made as per the circuit diagram
- 2. Switch ON the supply. By varying the rheostat, take different readings of ammeter and voltmeter in a tabular column.
- 3. From the above readings, average resistance r_1 of a stator is found

Measurement of Stator resistance

- 1. Connect the circuit as per the circuit diagram shown in fig (2).
- 2. Keeping rheostat in maximum resistance position switch on the 220 V Dc supply.
- 3. Using volt-ammeter method measure the resistance of the stator winding.
- 4. After finding the stator resistance, R_{dc} must be multiplied with 1.6 so as to account for skin effect i.e. $R_{ac} = 1.6 R_{dc}$.

MODEL CALCULATIONS:

$$G=W_0/3V_2$$
,

$$Y_0 = I_0/V$$

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

$$Z_{01}=V_{sc}/I_{sc}$$

$$R=W_{sc}/3xI_{sc}^2$$

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

For circle diagrm:

$$\cos\Phi_0=W_0/\sqrt{3}\ V_0I_0$$
,

$$\Phi_0 = \cos^{-1}(W_0/\sqrt{3} V_0 I_0)$$

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

$$I_{sn}=I_{sc}(V/V_{sc});$$

PRECAUTIONS:

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

RESULT:

No load and blocked rotor tests are performed on 3-Φ Induction motor.

WEEK 6-7

Page 41-48



EXPERIMENT 4 — BRAKE TEST ON 3- φ
SQUIRREL CAGE INDUCTION MOTOR



Pre Lab Work

Understanding the principles of the brake test, which is used to determine the motor's mechanical losses and efficiency. Familiarize yourself with the setup, including the motor's key components such as the stator, rotor, and the brake drum. Study the working of the motor under no-load and varying-load conditions. Prepare to measure parameters such as input power, output power, torque, and speed. Ensure the correct calibration of instruments like tachometers and dynamometers to accurately record results.

(To be written in the report)

AIM:

To determine the efficiency of 3- ϕ induction motor by performing load test. To obtain the performance curves for the same.

APPARATUS REQUIRED:

Sl. No.	Equipment	Type	Range	Quantity
1	Voltmeter	MI	(0-600)V	1 no
2	Ammeter	MI	(0-10)A	1 no
			10A/600V UPF	1 no
3	Wattmeter	Electro dynamo meter type	10A/600V LPF	1 no
4	Tachometer	Digital	0-9999 RPM	1 no
5	Connecting Wires	****	****	Required

3- φ Auto transformer Details:

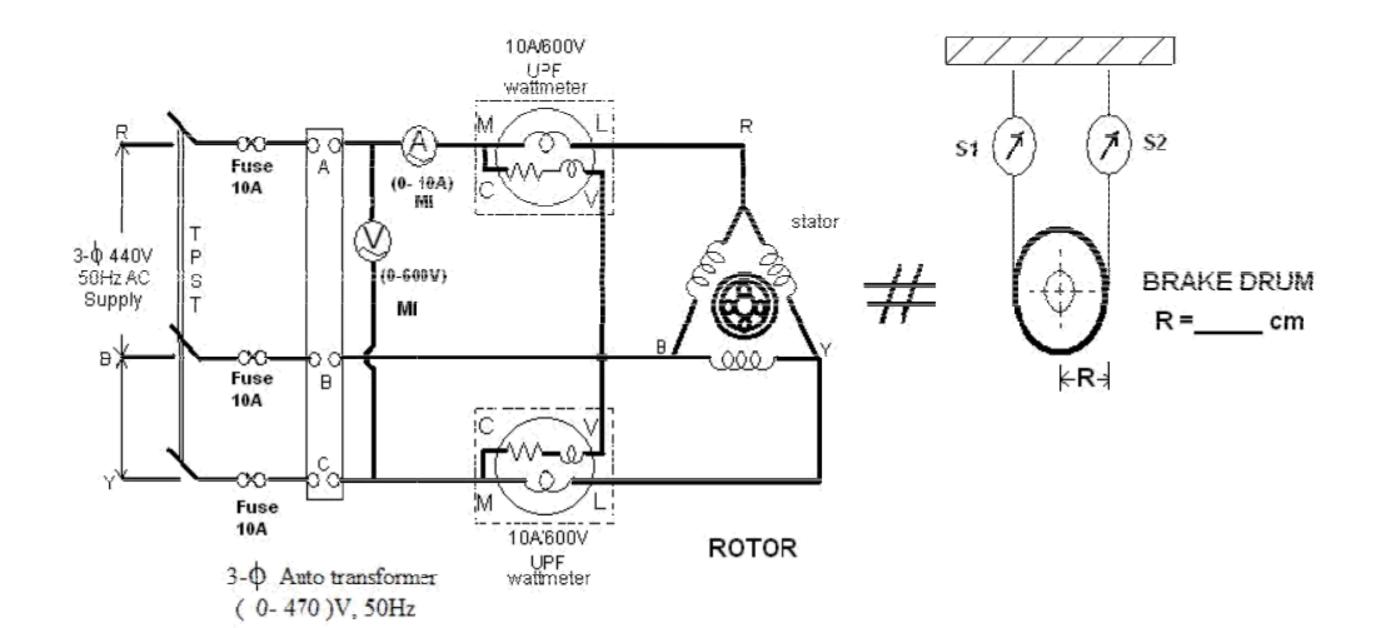
Input Voltage: 415 (Volt)

Output Voltage: _____(0-470)______(Volt)

Current:_____(Amp.)

Freq.:_____(Hz)

CIRCUIT DIAGRAM:



PROCEDURE:

- 1. Connections are made as per the circuit diagram.
- 2. Ensure that the 3- ϕ variac is kept at minimum output voltage position and belt is freely suspended.
- 3. Switch ON the supply. Increase the variac output voltage gradually until rated voltage is observed in voltmeter. Note that the induction motor takes large current initially, so, keep an eye on the ammeter such that the starting current current should not exceed 7 Amp.
- 4. By the time speed gains rated value, note down the readings of voltmeter, ammeter, and wattmeter at no-load.
- Now the increase the mechanical load by tightening the belt around the brake drum gradually in steps.
- 6. Note down the various meters readings at different values of load till the ammeter shows the rated current.
- 7. Reduce the load on the motor finally, and switch OFF the supply.

TABULAR COLUMN:

S. N	Volt age(Curre nt(A)	Wattn readin		I/P power	Sprii (kg)	ng bal	lance	Speed (N)	% Slip	Power factor	Torque (Nm)	Pout(W)	%η
	V)		W1	W2	W1+W2	S1	S2	(S1- S2)	rpm	cosΦ= w₁+w2 /√3vi				
1	400	1.2	240	240	480	0	0	0	1498	0.13	0.57	0	0	0
2	400	2.2	880	240	1160	1.5	6. 5	5	1485	1	0.76	5.49	853.74	76.31
3	400	3	1120	480	1600	2.5	10	7.5	1454	3.06	0.76	8.24	1254.64	78.41
4	400	3.6	1440	640	2080	3.5	14	10.5	1424	5.06	0.83	11.53	1720.85	827.3
5	400	4	1600	720	2320	4.5	16 .5	12	1398	6.8	0.83	13.18	1929.52	83.16
6	400	5	1960	880	2840	5.5	19	13.5	1382	7.8	0.81	14.83	2146.23	75.57
7	400	6	2000	960	2960	6.0	20	14	1268	7.54	0.7	15.38	2093.76	70.23

MODEL CALCULATIONS:

Input power drawn by the motor $W = (W_1 \pm W_2)$ watts

Shaft Torque,
$$T_{sh} = 9.81 (S_1 \sim S_2) R N-m$$

Output power in watts =
$$\frac{2\pi N T_{sh}}{60}$$
 watts

1. efficiency =
$$\underbrace{output\ power\ in\ watts}_{Input\ power\ in\ watts} x\ 100$$

Calculations:

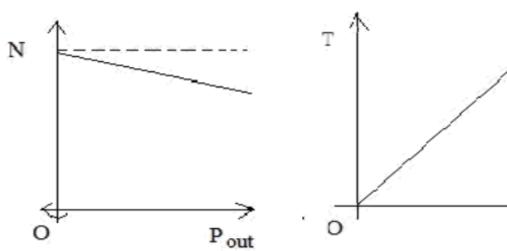
$$% Slip = (Ns-N)/NS*100$$

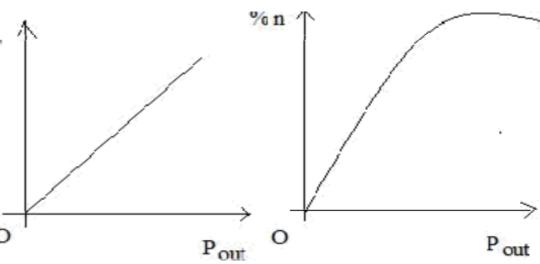
$$=120f/P$$

Power factor of the induction motor $\cos\Theta=W/\sqrt{3} \ V_L I_L$

MODEL GRAPHS:

- 1. Speed or slip Vs output power
- 2. Torque Vs output power
- 3. % efficiency Vs output power





PRECAUTIONS:

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

RESULT:

The load test on 3- Φ squirrel cage induction motor conducted and the characteristics of torque, speed, efficiency versus output power were drawn.

WEEK8 Page 50-56



EXPERIMENT 5 — LOAD TEST ON 3-PHASE AC SLIP RING INDUCTION MOTOR



Pre Lab Work

- Review the working principles and construction of a 3-phase slip ring induction motor.
- Understand the significance of performing a load test to determine the motor's performance under varying load conditions.
- Familiarize yourself with the connection diagram and test setup for the load test, ensuring correct wiring and equipment placement.
- Study the parameters to be measured, such as current, voltage, power, and torque, during different load conditions.
- Prepare to calculate the motor's efficiency, slip, and power factor based on the data obtained during the experiment.



(To be written in the report)

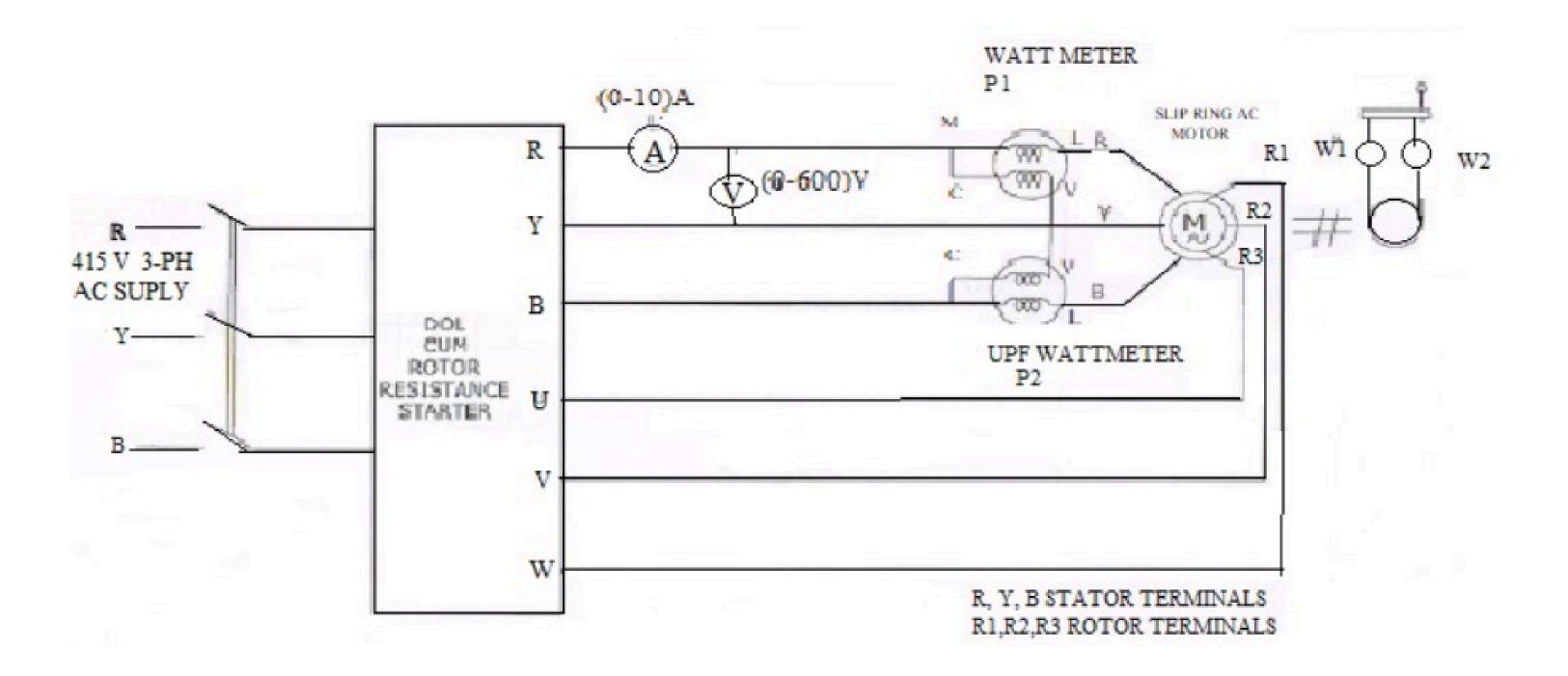
AIM:

To Perform Load Test on 3 Phase AC Slipring Induction Motor.

APPARATUS REQUIRED:

Sl. No.	Equipment	Туре	Range	Quantity
1	Ammeter	MI	(0-10) A	1 no
2	Voltmeter	MI	(0-500) V 10A/600V UPF	1 no 1 no
3	Wattmeter	Electro dynamo meter type	10A/600V UPF	1 no
4	Tachometer	Digital	(0-10000)RPM	1 no
5	Connecting Wires	****	(0-20)A	Required

CIRCUIT DIAGRAM:



PROCEDURE:

- 1. Connect circuit. as shown in diagram.
- 2. Adjust 'Zero set' for Balances.
- 3. Switch on Mains supply s/w.
- 4. To Start AC Motor, press START Push Button & Shift position of Rotor resistance s/w from 1 to 2 to 3 to 4. Resistance is cut out and rotor is short circuited at position 4.
- 5. Note down readings of voltmeter, Ammeter, Wattmeter's & load on balances W1 & W2 Kg.
- Using hand wheel of Brake drum arrangement load the motor in steps from no load to rated torque.
- 7. Rated torque T = (W1-W2) *A

A = Break drum Constant = Radius of Pulley (Meter) * 9.81

- 8. At each step repeat Step 5.
- 9. Calculate power output P = 2JINT/60.
- 10 .Calculate efficiency = output / input.

Observation Table:

S N O	Line Volt s V _L	Lin e Am ps.	Wattr	tts	I/P Powe r P1 +	Loa d W1	Loa d W2 Kg.	W1- W2	Spee d RP M	Tor que N-m	Output power	%η
1.	420	3.8	P1 0.24	P2	P2 0.53	Kg. 0	0	0	1472	0	0	0
1.	420	3.0	0.24	0.29	0.55	U	U	U	14/2	U	U	U
2.	420	4	0.32	0.19	0.51	4	0.5	3.5	1420	4.12	612.6	30.02
3.	420	4.2	0.34	0.09	0.43	4.5	1	3.5	1360	4.12	586.7	34.11
4.	420	4.4	0.38	0.04	0.42	6	1.5	4.5	1348	5.29	746.7	44.9

RESULT:

Load test is performed on 3-O A.C. Slip ring Induction motor, and characteristics performances are observed.

WEEK 9-10

Page 58-65



EXPERIMENT 6 — LOAD TEST ON SINGLE PHASE INDUCTION MOTOR



Pre Lab Work

- Review the basic working principles of a single-phase induction motor, including its construction and operation.
- Understand the purpose of a load test in determining the performance characteristics like efficiency, power factor, and torque.
- Familiarize yourself with the test setup, including the motor, load bank, and measuring instruments like ammeters, voltmeters, and wattmeters.
- Prepare calculations for expected motor performance at noload and full-load conditions.
- Ensure proper safety measures and motor insulation are verified before starting the experiment

(To be written in the report)



AIM:

To conduct the direct load test on the given single phase induction motor and to determine and plot its performance characteristics.

APPARATUS REQUIRED:

Sl. No.	Equipment	Туре	Range	Quantity
1	Voltmeter	MI	(0-300)V	1 no
2	Ammeter	MI	(0-10)A	1 no
3	Tachometer	Digital	0-9999 RPM	1 no
			(0-150)V UPF	
4	Wattmeter	Dynamo-type	(0-10)A	1 no
	Connecting			
5	Wires	****	(0-20)A	Required

NAME PLATE DETAILS:

1Ф Induction motor

Rated Voltage: 220V

Rated Current: 8A_

Rated Speed: <u>1500rpm</u>

Rated Power: 2HP_

Rated Frequency: ____<u>50Hz</u>_____

FORMULA USED:

Torque = $9.81 \times (S_1-S_2) \times R$ Nm, where R is the radius of the brake drum in meter.

Output power, $P_0 = 2\pi NT/60$ Watts

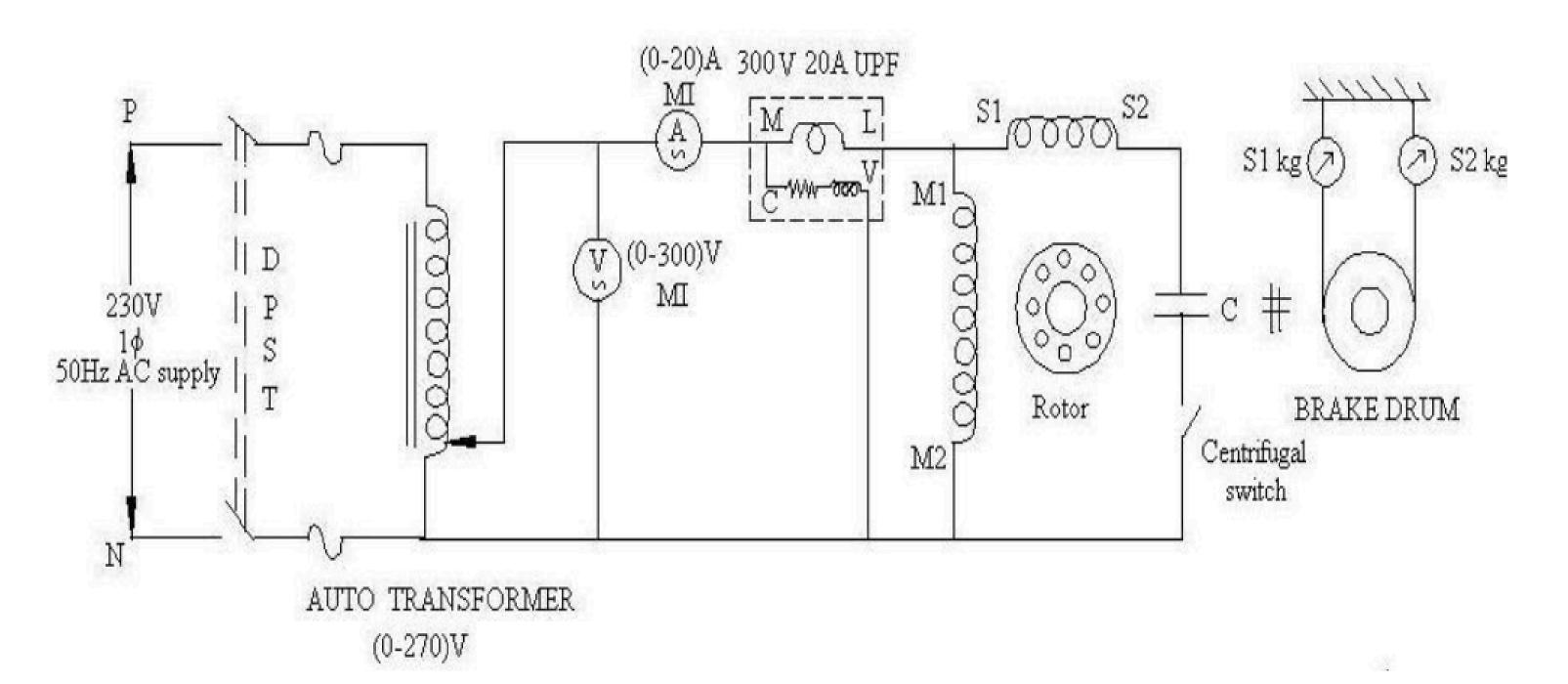
Input power, $P_i = W_1+W_2$ Watts

%Efficiency, $\%\eta = (\text{output power/input power}) \times 100$

$$% Slip = (Ns-N)/N \times 100$$

Power factor = $\cos \phi = W/VI$

CIRCUIT DIAGRAM:



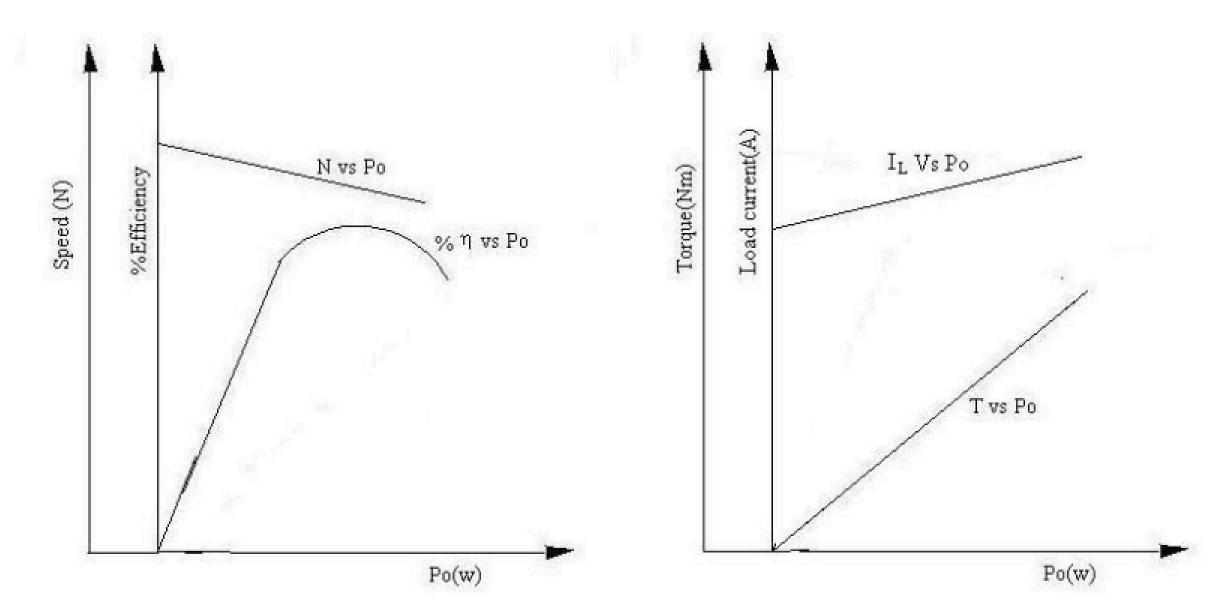
PROCEDURE:

- 1. Connections are given as per the circuit diagram.
- 2. Switch on the supply at no load condition.
- 3. Apply the rotor voltage to the motor using the variac and note down the readings at ammeter And wattmeter.
- 4. Vary the load in suitable steps and note down all the meter readings till fill load condition.

TABULAR COLUMN:

S. No		I _L Amps	S ₁ kg	S ₂ kg	S kg	W watts	Speed rpm	Torque Nm	Po watts	%η
1	220	2	0	0	0	480	1480	0	0	0
2	220	4	2	0.5	1.5	680	1460	1.65	252.142	37.09
3	220	5	4.5	1.5	2	960	1448	2.197	332.97	34.68
4	220	6	6.5	2	4.5	1120	1440	4.94	745.15	65.53
5	220	7	8.3	2.5	5.8	1440	1430	6.372	953.71	66.23

MODEL GRAPH:



RESULT:

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

WEEK 11-12

Page 67-76



EXPERIMENT 7 — EQUIVALENT CIRCUIT OF A SINGLE PHASE INDUCTION MOTOR



Pre Lab Work

The no-load test will help identify the magnetizing branch parameters, while the blocked rotor test will give us the resistance and reactance of the motor's equivalent circuit. Measurements of voltage, current, and power will be taken during both tests. The motor's equivalent circuit parameters will be calculated from the obtained data. This experiment will help in understanding the behavior and performance characteristics of a single-phase induction motor.



(To be written in the report)

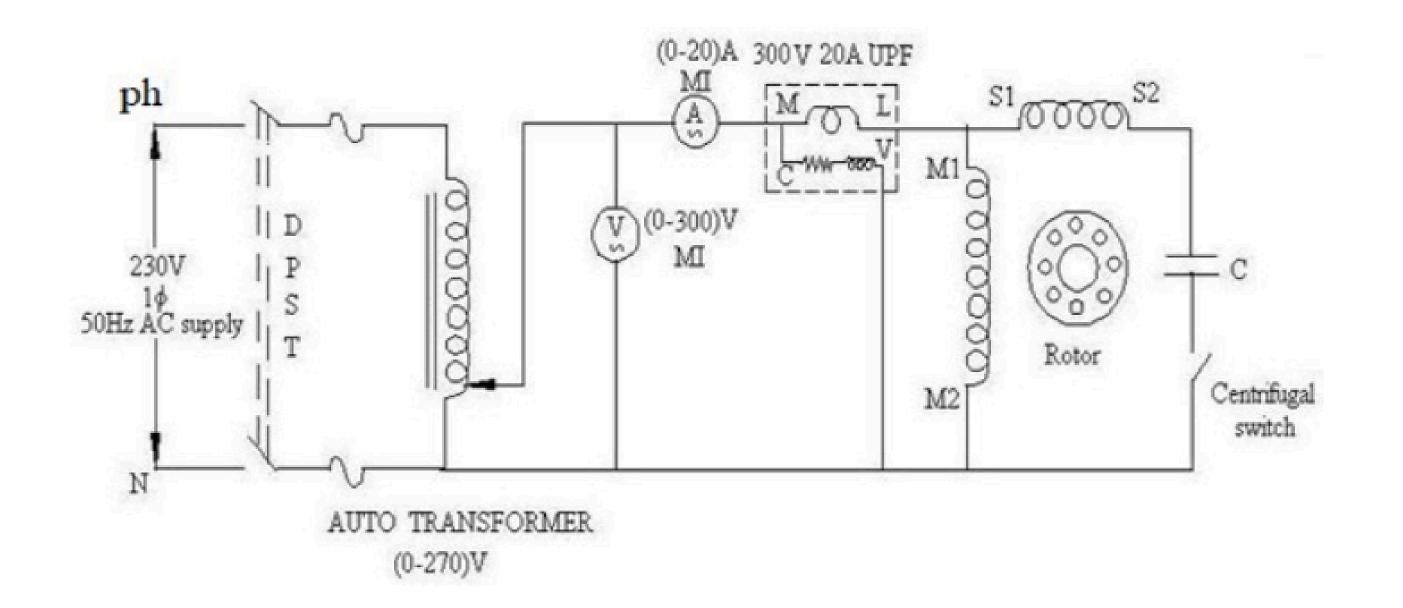
AIM:

To determine the equivalent circuit parameters of a single phase induction motor by performing the no- load and blocked rotor tests.

APPARATUS REQUIRED:

Sl. No.	Equipment	Туре	Range	Quantity
1	Voltmeter	MI	(0-300)V	1 no
2	Ammeter	MI	(0-10)A	1 no
3	Wattmeter	Dynamo-type	(0-300)V LPF (0-10)A	1 no
	vv attificter	Бупатто-турс	(0-10)X (0-150)V UPF	1110
4	Wattmeter	Dynamo-type	(0-10)A	1 no
5	Connecting Wires	****	(0-20)A	Required

CIRCUIT DIAGRAM:



PROCEDURE:

No load Test:

- 1. The circuit connections are made as per the circuit diagram.
- 2. Be sure that variac (auto transformer) is set to zero output voltage position before starting the experiment.
- 3. Now switch ON the supply and close the DPST switch.
- 4. The variac is varied slowly, until rated voltage is applied to motor and rated speed is obtained.
- 5. Take the readings of Ammeter, Voltmeter and wattmeter in a tabular column.
- 6. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.

Blocked Rotor Test:

- 1. To conduct blocked rotor test, necessary meters are connected to suit the full load conditions of the motor.
- 2. Connections are made as per the circuit diagram.
- Before starting the experiment variac (auto transformer) is set to zero output voltage position.
- 4. The rotor (shaft) of the motor is held tight with the rope around the brake drum.
- 5. Switch ON the supply, and variac is gradually varied till the rated current flows in the induction motor.
- 6. Readings of Voltmeter, Ammeter, and wattmeter are noted in a tabular column.
- 7. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.
- 8. Loosen the rope after the experiment is done.

Calculation for No-Load Test:

$$V_0 I_0 \cos \phi_0 = W_0$$
 $\cos \phi_0 = \frac{W_0}{V_0 I_0}$
 $Z_0 = \frac{V_0}{I_0}$
 $X_0 = Z_0 \sin \phi_0$
 $X_0 = X_1 + \frac{1}{2}(X_2 + X_m)$
 $X_m = 2(X_0 - X_1) - X_2$

Calculation For Blocked Rotor Test:

$$z_{sc} = \frac{v_{sc}}{v_{sc}}$$

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

r₁ is the DC resistance of stator of motor

$$\mathbf{r}_2 = \mathbf{R}_{sc} - \mathbf{r}_1$$

$$\mathbf{x_1} + \mathbf{x_2} = \mathbf{x_{sc}}$$

since leakage reactance can't be seperated out, it is common practice to to assume $\mathbf{X}_1 = \mathbf{X}_2$

$$x_1 = x_2 = \frac{x_{sc}}{2} = x_{sc} = \frac{1}{2} \sqrt{z_{sc}^2 - R_{sc}^2}$$

OBSERVATIONS:

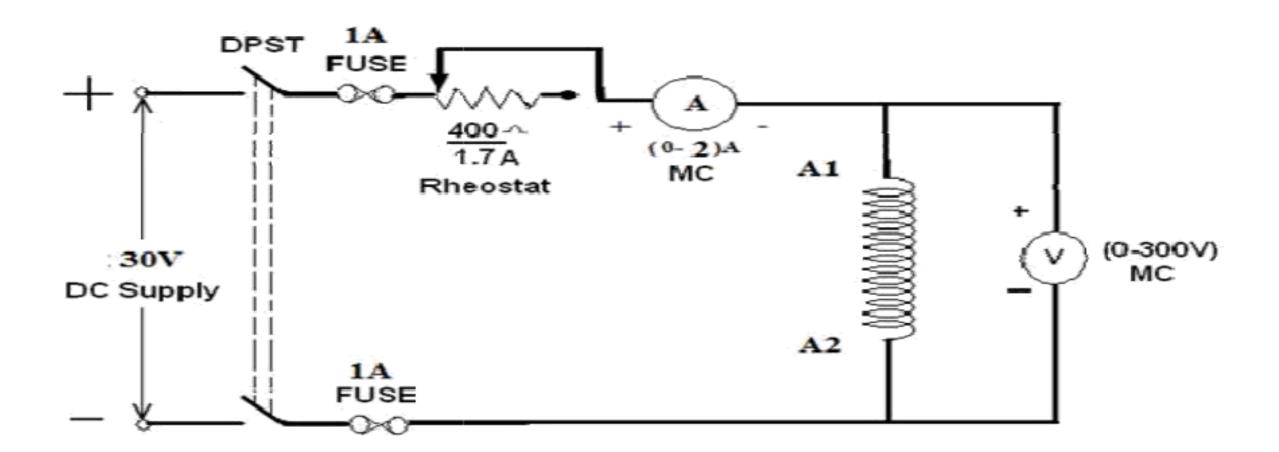
For No-Load Test:

Sl no.	$egin{aligned} \mathbf{Voltmeter} \\ \mathbf{reading} \\ \mathbf{V_o} \end{aligned}$	Ammeter reading I₀	Wattmeter reading Wo	cosΦ ₀ =W ₀ /V0I0
1	220	2	80*2=160	0.3636

For Blocked Rotor Test:

Sl no.	Voltmeter reading Vsc	Ammeter reading Isc	Wattmeter reading Wsc	cosΦ _{sc}
1	38	8	130*2=260	0.855

Circuit diagram for measurement of R₁:



PROCEDURE:

- 1. Connections are made as per the circuit diagram.
- 2. Initially rheostat is set at maximum resistance position.
- 3. Switch ON the supply, and vary the rheostat gradually and note down the readings of ammeter and voltmeter
- 4. For the corresponding values, average of r1 is take

To find stator Resistance:

S.NO.	V(volts)	I(Amps)	R=V/I Ω
1	5	4.76	1.05
2	10	9.09	1.1
3	15	13.39	1.12
4	18	15.65	1.15
5	20	18.18	1.1

Average Value: R_{dc} R_{ac} $R_{dc} = 1.1$

Comments:

- 1. Since IM is not self starting Machine, it is started by placing an auxiliary winding in the circuit.
- 2. Here no-load test is similar to open circuiting the load terminals and blocking the rotor is similar to conducting short circuit on the IM.

WEEK 13-14

Page 78-90



EXPERIMENT 8 — REGULATION OF ALTERNATOR USING SYNCHRONOUS IMPEDANCE METHOD



Pre Lab Work

- Review the principles of alternator operation, focusing on synchronous reactance and synchronous impedance.
- Understand the concept of voltage regulation in alternators and its importance for maintaining constant output voltage.
- Familiarize yourself with the synchronous impedance method for calculating voltage regulation.
- Study the open-circuit and short-circuit tests used to determine synchronous reactance and impedance.
- Prepare necessary calculations for the experiment, including determining the synchronous impedance and expected voltage regulation values.

(To be written in the report)

AIM:

To find the regulation of a 3 - ϕ alternator by using synchronous impedance method.

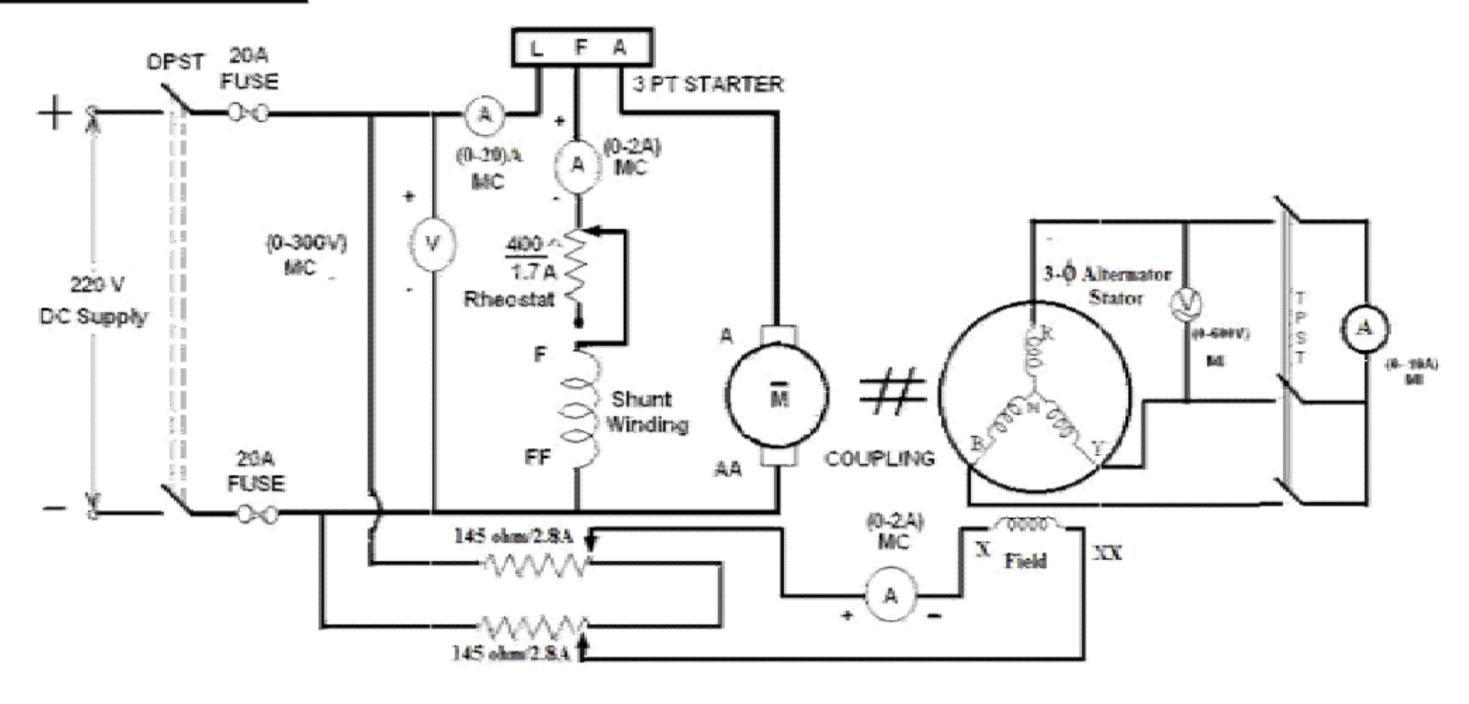
APPARATUS REQUIRED:

Sl.				
No.	Equipment	Type	Range	Quantity
1	Voltmeter	MI	(0-300/600)V	1 no
2	Ammeter	MI	(0-5/10)A	1 no
3	Ammeter	MI	(0-2.5/5)A	1 no
			400 Ω /1.7A	1 no
3	Rheostat	Wire-wound	145Ω /2A	2 no
4	Tachometer	Digital	(0-100000)RPM	1 no
5	Connecting Wires	****	(0-20)A	Required

NAME PLATE DETAILS:

DC Motor(prime mover)		3- ф Alternator	
Power rating : 5HP		Power Rating : 3KVA	
Armature Voltage	: 220V	Voltage : 415 V	
Current	: 19A	Rated Current: 3.8A	
Speed	: 1500rpm	Speed : 1500rpm	
Excitation	: Shunt	Excitation : DC Generator	

CIRCUIT DIAGRAM:



PROCEDURE:

Open Circuit Test:

- 1. Make the connections as per the circuit diagram.
- Before starting the experiment, the potential divider network in the alternator field circuit and field regulator rheostat of motor circuit is set minimum resistance position.
- 3. Switch ON the supply and close the DPST switch. The DC motor is started by moving starter handle.
- 4. Adjust the field rheostat of DC motor to attain rated speed (equal to synchronous speed of alternator)
- 5. By decreasing the field resistance of Alternator, the excitation current of alternator is increased gradually in steps.
- 6. Note the readings of field current, and its corresponding armature voltage in a tabular column.
- 7. The voltage readings are taken upto and 10% beyond the rated voltage of the machine.

Short Circuit Test:

- 1. For Short circuit test, before starting the experiment the potential divider is brought back to zero output position, i.e., resistance should be zero in value.
- 2. Now close the TPST switch.
- 3. The excitation of alternator is gradually increased in steps until rated current flows in the machine and note down the readings of excitation current and load current (short circuit current).
- 4. Switch OFF the supply.

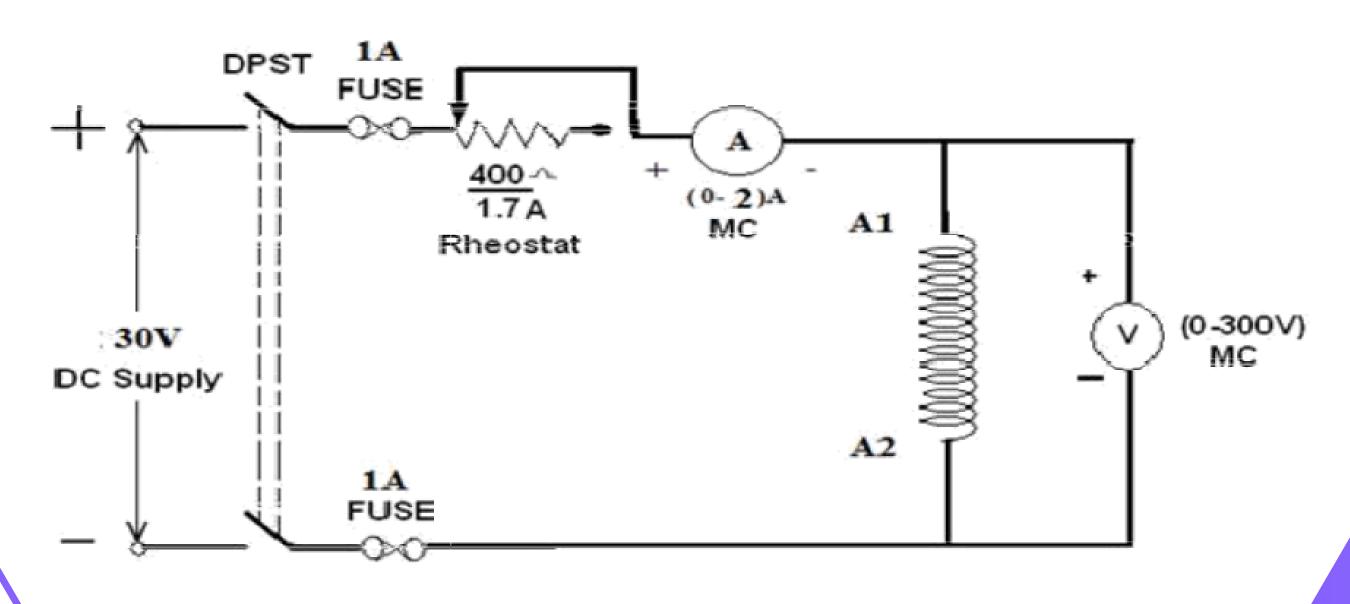
OBSERVATIONS:

	OC 1	test		S.C. test	
SL. No.	Field current in Amp.(I f)	OC voltage per phase (Vo)	SL. No.	Field current I _f (Amp.)	SC current I _{sc} Amp.
1	0.25	140	1	0.24	0.5
2	0.3	160	2	0.3	1
3	0.35	175	3	0.35	1.2
4	0.4	205	4	0.4	1.6
5	0.45	228	5	0.45	1.9
6	0.5	250	6	0.5	2.15
7	0.55	270	7	0.55	2.4
8	0.6	265	8	0.6	2.8
9	0.7	320	9	0.65	3.1
10	0.75	335	10	0.7	3.4

Procedure to find Armature resistance of Alternator:

- 1. Connections are made as per the circuit diagram.
- 2. Switch ON the supply. By varying the rheostat, take different readings of ammeter and voltmeter in a tabular column.
- 3. From the above readings, average resistance Ra of a armature is found out.

Connection diagram to find Ra:



OBSERVATIONS:

S No.	Armature current I(amp)	Armature voltage Va (volts)	R _{dc} =V/I

Procedure to find synchronous impedance from OC and SC tests:

- 1. Plot open circuit voltage, short circuit current verses field current on a graph sheet.
- 2. From the graph, the synchronous impedance for the rated value of excitation is calculated.
- 3. The excitation emf is calculated at full load current which is equal to the terminal voltage at No load.
- 4. The voltage regulation is calculated at rated terminal voltage.

MODEL CALCULATIONS:

Zs= Voc/Isc for the same If and speed : $Xs = \sqrt{Zs^2-Ra^2}$ (Ra=Rdc)

Generated e.m.f. of alternator on no load is

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

- + for lagging p.f.
- for leading p.f.

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

1. Re
$$g = \frac{E - V}{V}$$
 x 100

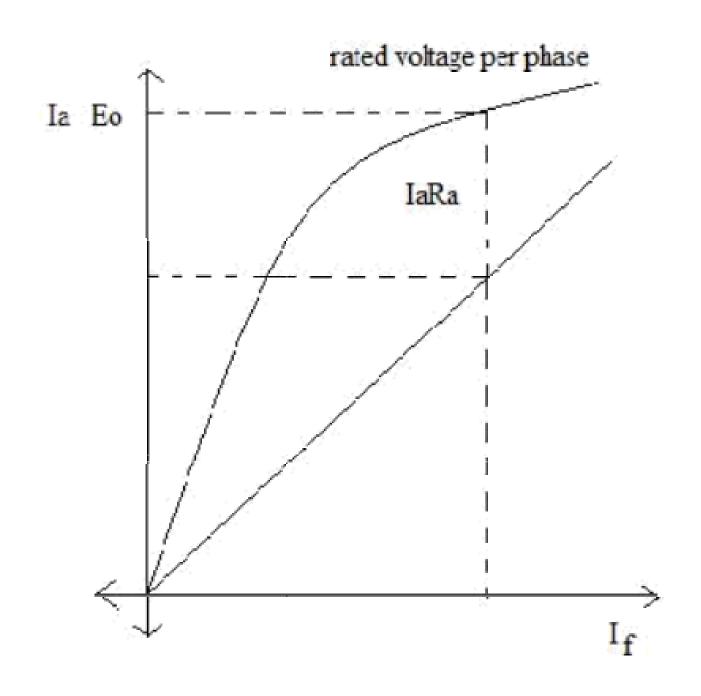
Where

 $\mathbf{E_0}$ – generated emf of alternator (or excitation voltage per phase)

V – full load, rated terminal voltage per phase.

MODEL GRAPHS:

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



PRECAUTIONS:

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

RESULT:

The O.C. and S.C. tests were conducted on the given 3-Φ Alternator and the regulation of Alternator was predetermined by e.m.f. and m.m.f. method.

WEEK 15

Page 92-96



EXPERIMENT 9 — EXPERIMENTAL STUDY ON A FAN MOTOR



Pre Lab Work

- 1) How to work out the equivalent circuit of a fan motor from the terminal voltage and current, considering that only one winding is present at a time?
- 2) What are the physical and thus the electrical differences between the main and auxiliary windings?
- 3) Is a fan motor still capable of rotating without a capacitor? Explain your opinion.
- 4) Does a capacitor increase the speed of a fan motor? Justify your answer.

(To be written in the report)



Aims

- Investigation of the construction of a fan motor Determining the parameters of the equivalent circuit of a fan motor
- To observe the role of the main and auxiliary windings and capacitor in a fan motor

Theory:

The fan motor is a permanent split capacitor motor. It has a cage rotor and the two windings named as main and auxiliary. The auxiliary winding has one capacitor connected in series. The capacitor is permanently connected in the circuit both at the starting and running conditions. That is why, a fan motor is called as capacitor start and capacitor run motor. It is also called as a single value capacitor motor. A typical fan motor has 36 slots and 18 poles in the stator. The connection diagram of a fan motor is shown in Fig. 1.

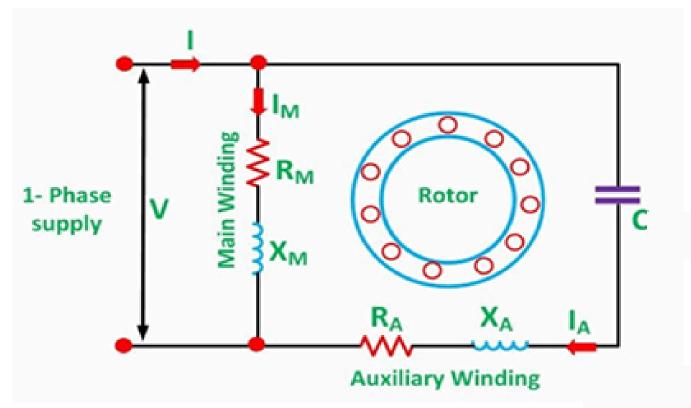


Fig. 1 Equivalent circuit of a fan motor.

In Fig. 1,

V and I are the supply voltage and current;

 I_M , R_M , and X_M are the main windings current, resistance, and inductance, respectively;

 I_A , R_A , and X_A are the auxiliary windings current, resistance, and inductance, respectively;

C is the capacitor.

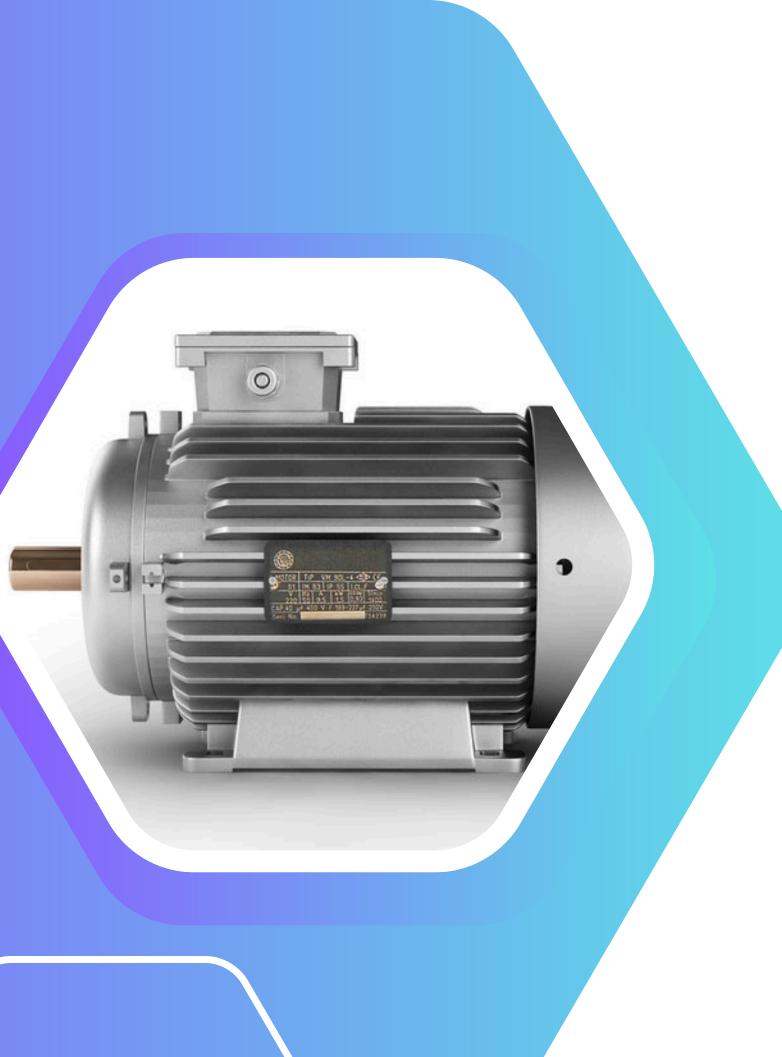
As the capacitor is always present in the circuit, this type of motor does not contain any starting switch. The auxiliary winding is always present in the circuit. Thus, the motor operates as the balanced two-phase motor.

Experimental Work

- 1) Take an exposed stator core of a fan motor where windings are visible. Then, count and note down the number of slots and poles in the stator.
- 2) Take an intact fan motor and disconnect the connection between the main and auxiliary windings. Identify the main and auxiliary windings by measuring the dc resistance. The winding with high resistance is the auxiliary winding.
- 3) Make sure the ac power supply is OFF, and the main and auxiliary windings are disconnected. Connect the ac supply to the main winding only. Ask a teacher/officer to check your connection.
- 4) Apply 220 V ac to the main winding and record the input current and rotor speed. Switch OFF the power supply. Calculate and record the main windings resistance RM and reactance XM.
- 5) Repeat the task 4) for auxiliary winding only. Calculate and record the auxiliary windings resistance RA and reactance XA.
- 6) Connect the main and auxiliary windings in parallel without a capacitor. Ask a teacher/officer to check your connection. Apply 220 V ac and record the input current and motor speed.
- 7) Now connect a capacitor in series in the auxiliary winding. Then, combine the auxiliary winding with the main winding in parallel. Ask a teacher/officer to check your connection. Apply 220 V ac and record the motor input current and speed.
- 8) Switch OFF the power supply.
- 9) Calculate the value of capacitor.

WEEK 16-17

Page 98-99

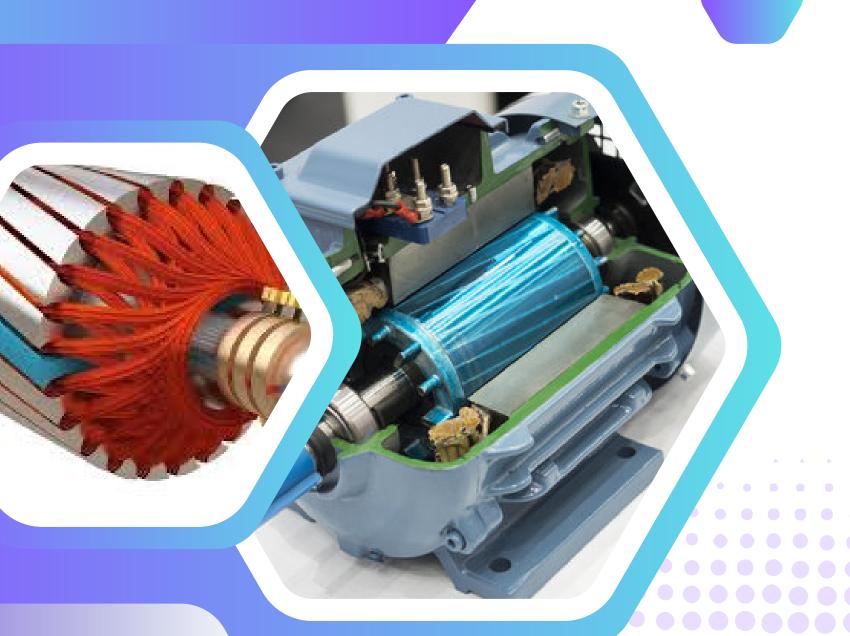


EXPERIMENT 10 — Designing a Project, where students could emphasize the knowledge and skills learned from lectures and experiments and utilize them to implement process control of an industry and voltage regulation and power factor control for a small power system.



What students should do?

- Each group of students will visit an industry where different types of electrical machines are being used.
- Students will try to understand how different tasks are being achieved by using the machines in the industry.
- Students will draw the block diagram of the process control. Students will calculate the total load of the industry.
- Students will recommend the reactive power compensation and voltage regulation techniques (if required) by observing the power factor.
- Students will give a power point presentation on their industry visit in front of course instructors.
- Finally, students will submit a group report.



Thank You For Your Attention