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Lab Manual:

AC MACHINES LABORATORY(AEEC13)

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INTRODUCTION

Introduction

AC machines laboratory is intended to enhance the learning experience of the student about alternating current machines. Students are expected to gain experience in hands on training as well as knowledge to analyze electro-mechanical characteristics for industrial and agricultural applications. How the student performs in the lab depends on his/her preparation, participation, and teamwork. Each team member must participate in all aspects of the lab to ensure a thorough understanding of the equipment and concepts. The student, lab teaching assistant, and faculty coordinator all have certain responsibilities toward successful completion of the labs goals and objectives.

Student Responsibilities

The student is expected tocome prepared for each lab.Lab preparation includes understanding the labexperiment from the lab manual and reading the related textbook material.

Students have to write the allotted experiment for that particular week in the work sheets given and carry them to the Lab. In case of any questions or problems with the preparation, students can contact the Faculty Teaching the Lab course, but in a timely manner.

Students have to be in formal dress code, wear shoes and lab coat for the Laboratory Class.

After the demonstration of experiment by the faculty, student has to perform the experiment individually. They have to note down the observations in the observation Tables drawn in work sheets, do the calculations and analyze the results.

Active participation by each student in lab activities is expected. The student is expected to ask the Faculty any questions they may have related to the experiment.

The student should remain alert and use commonsense while performing the lab experiment.They are also responsible for keeping a professional and accurate record of the labexperiments in the files provided.

Responsibilities of Faculty Teaching the Lab Course

The Faculty shall be completely familiar with each labprior to the laboratory. He/She shall provide the students with details regarding the syllabus and safety review during the first week.Lab experiments should be checked in advance to make sure that everything is in working order.The Faculty should demonstrate and explain the experiment and answer any questions posed by the students.Faculty have to supervise the students while they perform the lab experiments. The Faculty is expected to evaluate the lab worksheets and grade them based on their practical skills and understanding of the experiment by taking Viva Voce. Evaluation of work sheets has to be done in a fair and timely manner to enable the students, for uploading them online through their CMS login within the stipulated time.

Laboratory In-charge Responsibilities

The Laboratory In-charge should ensure that the laboratory is properly equipped, i.e., the Faculty teaching the lab receive any equipment/components necessary to perform the experiments.He/She is responsible for ensuring that all the necessary equipment for the lab is available and in working condition. The Laboratory In-charge is responsible for resolving any problems that are identified by the teaching Faculty or the students.

Course Coordinator Responsibilities

The course coordinator is responsible fo rmaking any necessary corrections in Course Description and lab manual. He/She has to ensure that it is continually updated and available to the students in the CMS learning Portal.

Lab Policy and Grading

The student should understand the following policy:

ATTENDANCE: Attendance is mandatory as per the academic regulations.

LAB RECORD's: The student must:

1. Write the work sheets for the allotted experiment and keep them ready before the beginning of eachlab.
2. Keep all work in preparation of and obtained during lab.
3. Perform the experiment and record the observations in the worksheets.
4. Analyze the resultsand get the work sheets evaluated by the Faculty.
5. Upload the evaluated reports online from CMS LOGIN within the stipulated time.

Grading Policy:

The final grade of this course is awarded using the criterion detailed in the academic regulations. A large portion of the student's grade is determined in the comprehensive final exam of the Laboratory course (SEE PRACTICALS),resulting in a requirement of understanding the concepts and procedure of each lab experiment for successful completion of the lab course.

Pre-Requistes and Co-Requisties:

The lab course is to be taken during the same semester as AEEB15, but receives a separate grade. Students are required to have completed AHSB04,AHSB11 and AEE002 with minimum passing grade or better grade in each.

Course Goals and Objectives

AC machines laboratory is intended to enhance the learning experience of the student about alternating current machines. Students are expected to gain experience in hands on training as well as knowledge to analyze electro-mechanical characteristics for industrial and agricultural applications. In addition, the student should learn how to record experimental results effectively and present these results in a written report. More explicitly, the class objectives are:

1. To gain proficiency in the use of common measuring instruments.

2. To enhance understanding of performance characteristics:

• Single phase transformer,
• Three phase induction motor,
• Single phase induction motor,
• Synchronous generator;

3. To develop communication skills through:

• Maintenance of succinct but complete laboratory notebooks as permanent, written descriptions of procedures, results, and analyses.
• Verbal interchanges with the laboratory instructor and other students.
• Preparation of succinct but complete laboratory reports.

4. To compare theoretical predictions with experimental results and to determine the source of any apparent differences.

The experiments are designed to complement the concepts introduced in AEEC11. In addition, the student should learn how to record experimental results effectively and present these results in a written report.

Use of Laboratory Instruments

One of the major goals of this lab is to familiarize the student with the proper equipment andtechniques for conducting experiments. Some understanding of the lab instruments is necessaryto avoid personal or equipment damage.By understanding the devices purpose and following a fewsimple rules, costly mistakes can be avoided.

The following rules provide a guideline for instrument protection.

Instrument Protection Rules

1. Set instrument scales to the highest range before turning on the power/source.
2. Be sure instrument grounds are connected properly. Avoid accidental grounding of "hot" leads, i.e., those that are above ground potential.
3. Check polarity markings and connections of instruments carefully before connecting power.
4. Never connect an ammeter across a voltage source. Only connect ammeters in series with loads.
5. Do not exceed the voltage and current ratings of instruments or other circuit elements. This particularly applies to wattmeters since the current or voltage rating may be exceeded with the needle still on the scale.
6. Be sure the fuse and circuit breakers are of suitable value. When connecting electrical elements to make up a network in the laboratory, it is easy to lose track of various points in the network and accidentally connect a wire to the wrong place. A procedure to follow that helps to avoid this is to connect the main series part of the network first, then go back and add the elements in parallel. As an element is added, place a small check by it

on your circuit diagram. Then go back and verify all connections before turning on the power. One day someone's life may depend upon your making sure that all has been done correctly.

Data Recording and Reports

The Laboratory Worksheets

Students must record their experimental values in the provided tables in this laboratory manual and reproduce them in the lab worksheets. Worksheets are integral to recording the methodology and results of an experiment. In engineering practice, the laboratory notebook serves as an invaluable reference to the technique used in the lab and is essential when trying to duplicate a result or write a report. Therefore, it is important to learn to keep accurate data. Make plots of data and sketches when these are appropriate in the recording and analysis of observations. Note that the data collected will be an accurate and permanent record of the data obtained during the experiment and the analysis of the results. You will need this record when you are ready to prepare a lab report i.e worksheets.

The Laboratory Files/Reports

Worksheets are the primary means of communicating your experience and conclusions to other professionals. In this course you will use the lab worksheets to inform your faculty coordinator about what you did and what you have learned from the experience. Engineering results are meaningless unless they can be communicated to others. You will be directed by your faculty coordinator to prepare a lab report on a few selected lab experiments during the semester.

Your laboratory report should be clear and concise. The lab report shall be student hand written on a work sheets provided by the college. As a guide, use the format on the next page. Use tables, diagrams, sketches, and plots, as necessary to show what you did, what was observed, and what conclusions you can draw from this by using pencil and scale. Free hand diagrams and tables will reduce your marks. Even though you will work with one or more lab partners, your report will be the result of your individual effort in order to provide you with practice in technical communication.

LAB-1 ORIENTATION

1.1 Introduction

In the first lab period, the students should become familiar with the location of equipment and components in the lab, the course requirements, and the teaching instructor. Students should also make sure that they have all of the co-requisites and pre-requisites for the course at this time.

1.2 Objective

To familiarize the students with the lab facilities, equipment, standard operating procedures, lab safety, and the course requirements.

1.3 Prelab Preparation:

Read the Introduction and procedure of the experiment of respective experiments which are given this manual

1.4 Equipment needed

AEEB 17 lab manual

1.5 Procedure

1. During the first laboratory period, the instructor will provide the students with a general idea of what is expected from them in this course. Each student will receive a copy of the syllabus, stating the instructor's contact information. In addition, the instructor will review the safety concepts of the course.
2. During this period, the instructor will briefly review the equipment which will be used throughout the semester. The location of instruments, equipment, and components (e.g., Ammeters, voltmeter, watt meter, AC machines and connecting wiring) will be indicated. The guidelines for instrument use will be reviewed.

PROBING FURTHER EXPERIMENTS: - Questions pertaining to this lab must be answered at the end of laboratory report.

LAB-2 OPEN AND SHORT CIRCUIT TEST ON A SINGLE PHASE TRANSFORMER

2.1 Introduction

To predict the performance of a transformer at various loadings by knowing all the equivalent circuit parameters. These circuit parameters are supplied from Open Circuit (OC) and Short Circuit (SC) test data of a transformer without actually loading the transformer, these two assessed tests give the test results which are used to determine the equivalent circuit parameters.

2.2 Objective

By the end of this lab, the student should learn how to determine the equivalent circuit parameters, voltage regulation and efficiency of single phase transformer.

2.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

2.4 Equipment needed

1. Single phase transformer (2 KVA)
2. Single phase auto transformer
3. Ammeter (0-2 A) MI
4. Ammeter (0-20 A) MI
5. Voltmeter (0-60 V) MI
6. Voltmeter (0-150 V) MI
7. Watt meter (150/300 V, 1/2 A) LPF
8. Watt meter (150/300 V, 10/0 A) UPF
9. Connecting Wires.

2.5 Background

Open Circuit Test: The main purpose of this test is to find the iron loss and no-load current which are useful in calculating core loss resistance and magnetizing reactance of the transformer. In O.C. test primary winding is connected to AC supply, keeping secondary open. Sometimes a voltmeter may be connected across secondary as voltmeter resistance is very high and voltmeter current is negligibly small so that secondary is treated as open circuit. When primary voltage is adjusted to its rated value with the help of variac, readings of ammeter and wattmeter are to be recorded. Ammeter gives no load current. Transformer no load current is always very small, 2 to 5 percentage of its full load current. As secondary is open, I2 = 0, hence secondary copper losses are zero. And I1 = I0 is very low hence copper losses on primary are also very low. Thus, the total copper losses in O.C. test are negligibly small, hence neglected. Therefore, the wattmeter reading in O.C. test gives iron losses which remain constant for all the loads.

Short Circuit Test: The main purpose of this test is to find full load copper loss and winding parameters (R01, X01 or R02, X02) which are helpful for finding regulation of transformer. In this test, secondary is short circuited with the help of ammeter. As secondary is shorted, its resistance is very small and on rated voltage it may draw very large current. Such large current can cause overheating and burning of the transformer. To limit this short circuit current, primary is supplied with low/reduced voltage (5 – 15 percentage of the rated voltage) which is just enough to cause rated current to flow through primary which can be observed on an ammeter. The reduced voltage can be adjusted with the help of variac. The wattmeter reading as well as voltmeter, ammeter readings are recorded. As the voltage applied is low which is a small fraction of the rated voltage and iron losses are function of applied voltage, hence iron losses are negligibly small. Since the currents flowing through the windings are rated currents hence the total copper loss is full load copper loss. Hence the wattmeter reading is the power loss which is equal to full load copper losses.

2.6 Procedure

Open circuit test 1. Make the connections as per the circuit diagram.

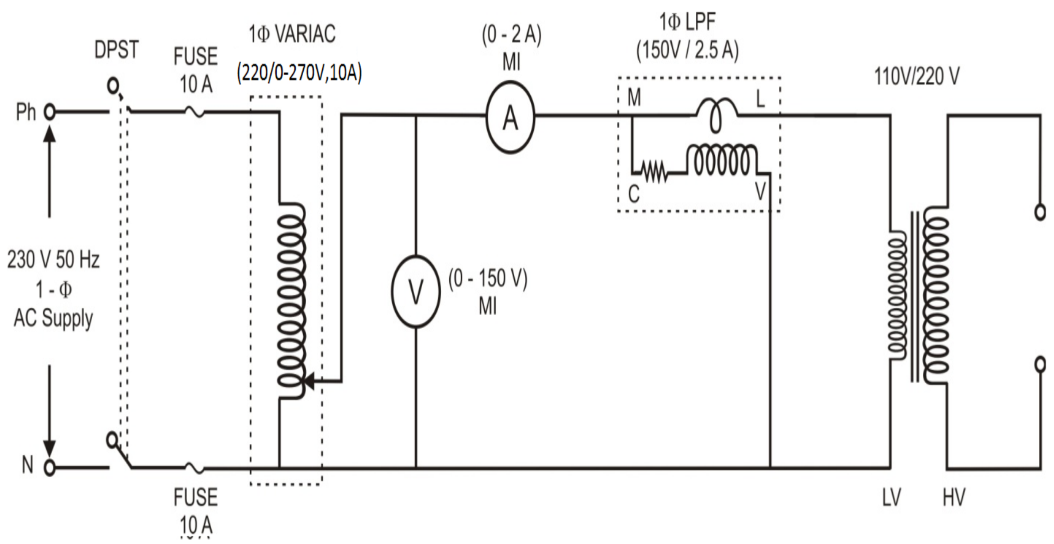


Figure 2.1 Open circuit test Circuit

2. Apply rated voltage with the help of autotransformer across LV winding, with the HV winding as open circuited.
3. Note down the readings of voltmeter (V), Ammeter (Io) and wattmeter (Po).

S. No	V_{oc}	I_0	W_0
1.			

Table 2.1 Open Circuit Measured Values

Short circuit test:

1. Make the connections as per the circuit diagram.

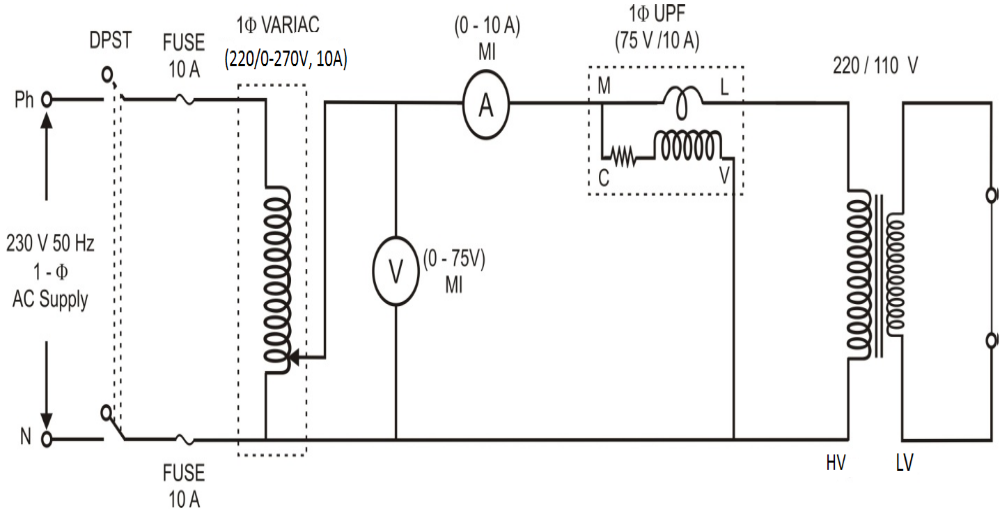


Figure 2.2 Short circuit test Circuit

2. Adjust supply voltage by single phase auto transformer such that the current through the transformer is the rated value and note down all meter readings.

S. No	Vsc	Isc	Wsc
1.			

Table 2.2 Short Circuit Measured Values

2.7 Calculations

Open circuit test

Iron losses, $P_I = P_o$ watts.

No load P.f., $\text{Cos}\,\phi_o = \dfrac{P_o}{VI_o}$

Magnetizing current, $I_m = I_0\ \text{Sin}\phi_o$

Loss component of no load current, $I_w = I_0\ \text{Cos}\phi_o$

Magnetizing reactance, $X_0 = \dfrac{V}{I_m}$

Equivalent resistance of iron losses, $R_0 = \dfrac{V}{Iw}$

Short circuit test:

Full load copper losses $P_{Cu} = P_{SC}$ Watts.

Power factor on short circuit, $\text{Cos}\,\phi_{SC} = \dfrac{P_{sc}}{V_{sc} I_{sc}}$

Short circuit impedance $Z_{01} = \dfrac{V_{sc}}{I_{sc}}\ \Omega$.

Referred to primary:

HT equivalent resistance, $R_{01} = \dfrac{Psc}{I_{sc}^2}$.

HT equivalent reactance, $X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$

a) Efficiency: At X times full load and power factor cosϕ, output, P_0= X*S cos ϕ KW

Where S = KVA rating of the transformer.

Input = Output +Iron Loss+ x^2 *P_{Cu}

Efficiency (%η) = Output power / Input power *100

1. Calculate the efficiency of the transformer at Unity, 0.8 and 0.6 Power factors for 1/4, 1/2,3/4, full load and draw the output characteristics.
2. Calculate the maximum efficiency corresponding to the maximum load.

b) Regulation: Regulation is defined as percentage drop in voltage from no load to full load at any power factor due to voltage drops in resistance and leakage reactance of the transformer.

1. Calculate the percentage resistance voltage drop (%V_R) = $I_1 R_1/V_1$ x 110
2. Calculate the percentage reactance voltage drop (%V_x) = $I_1 X_1/V_1$ x 110.
3. Calculate the percent regulation, = %V_R Cos ϕ+ %V_x Sinϕ at Unity,0.8,0.6 leading and lagging power factors

2.8 Tabular column

PART - I: Efficiency

S. No.	Fraction of load (X)	Po	Pi	η
1	0.25			
2	0.5			
3	0.75			
4	1			

Table 2.3 Calculated efficiency values

PART - II: Regulation

S. No.	Power Factor	Regulation
1.		
2		
3		

Table 2.4 Calculated regulation valuess

2.9 Model graphs

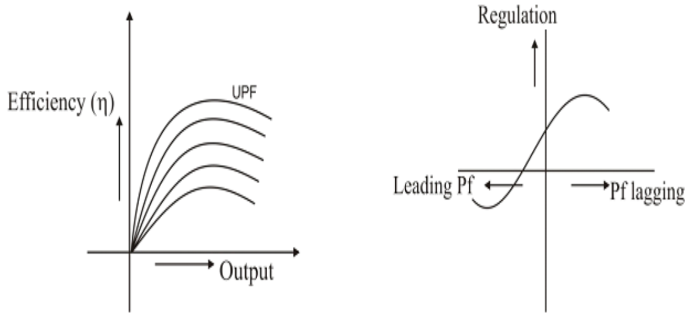


Figure 2.3: Efficiency and regulation curves under different power factor loading conditions

2.10 Probing Further Experiments

Q1. Plot efficiency curves of single phase transformer under different loading conditions using digital simulations.

Q2. Design open circuit and short circuit test on single phase transformer using LabVIEW

LAB-3 SUMPNERS TEST ON A PAIR OF SINGLE PHASE TRANSFORMERS

3.1 Introduction

Sumpner's test or back-to-back test on transformer is another method for determining transformer efficiency and voltage regulation loaded conditions. Short circuit and open circuit tests on transformer can give us parameters of equivalent circuit of transformer, but they cannot help us in finding the heating information. Unlike O.C. and S.C. tests, actual loading is simulated in Sumpner's test. Thus, the Sumpner's test give more accurate results of regulation and efficiency than O.C. and S.C. tests.

3.2 Objective

By the end of this lab, the student should learn how to determine the transformer efficiency and voltage regulation

3.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

3.4 Equipment needed

1. Two single phase transformers (2 KVA)
2. Two single phase auto transformers
3. Ammeter (0-2 A) MI
4. Ammeter (0-20 A) MI.
5. Voltmeter (0-60 V) MI.
6. Voltmeter (0-600 V) MI.
7. Voltmeter (0-150/300 V) MI.
8. Watt meter (150/300 V, 1/2 A) LPF.
9. Watt meter (150/300 V, 10/20 A) UPF.
10. Connecting Wires.

3.5 Background

Sumpner's test or back-to-back test can be employed only when two identical transformers are available. Both transformers are connected to supply such that one transformer is loaded on another. Primaries of the two identical transformers are connected in parallel across a supply. Secondaries are connected in series such that emf's of them are opposite to each other. Another low voltage supply is connected in series with secondaries to get the readings Secondaries of them are connected in voltage opposition, i.e., EEF and EGH. Both the emf's cancel each other, as transformers are identical. In this case, as per superposition theorem, no current flows through secondary. And thus, the no load test is simulated. The current drawn from V1 is 2I0, where I0 is equal to no load current of each transformer. Thus, input power measured by wattmeter W1 is equal to iron losses of both transformers. i.e., iron loss per transformer Pi = W1/2 Now, a small voltage V2 is injected into secondary with the help of a low voltage transformer. The voltage V2 is adjusted so that, the rated current I2 flows through the secondary. In this case, both primaries and secondaries carry rated current. Thus, short circuit test is simulated and wattmeter W2 shows total full load copper losses of both transformers i.e., copper loss per transformer PCu = W2/2.

3.6 Procedure

Open circuit test 1. Connect the circuit as per the circuit diagram .

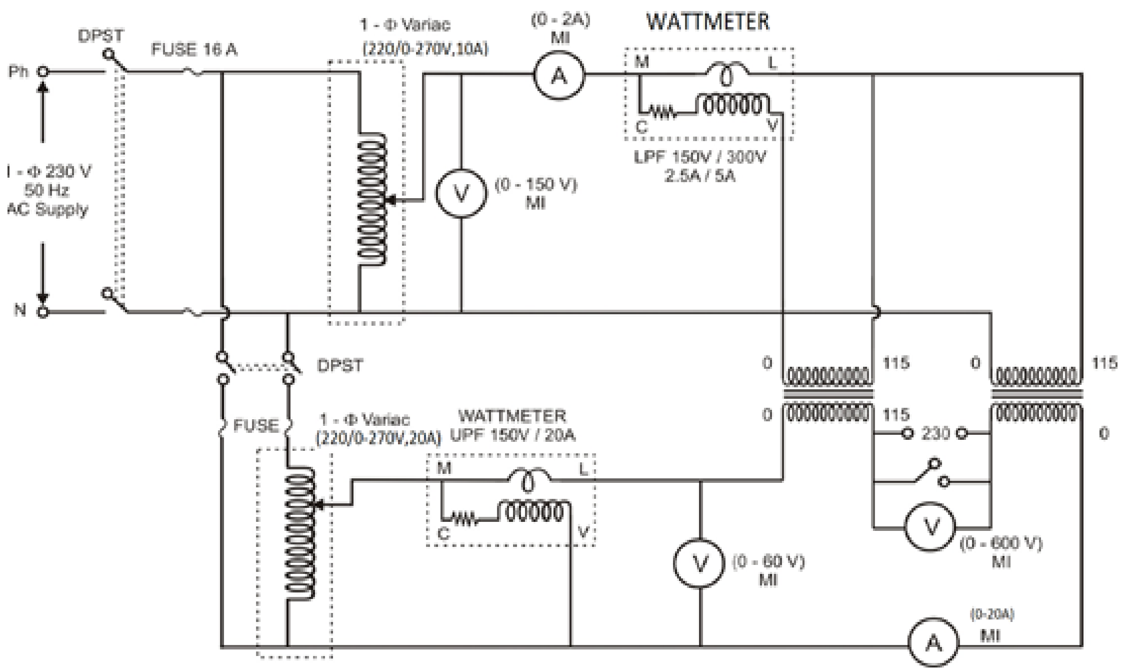


Figure 3.1 Sumpners test on a pair of single phase Transformerst

2. The primaries are connected in parallel to the 115V supply, keeping switch (S1) open.
3. If the polarities are appropriate, V3 should read Zero (otherwise it will read two times the rated secondary voltage; then one of the Secondary's has to be reverse connected).
4. When V3 reads zero, switch (S1) is closed and a low voltage is injected into the secondary winding, such that rated current is circulated.
5. This is only a circulation current in the secondary and does not cause any equivalent current to be drawn by the primaries from the supply.
6. The reflected current in the primaries flows as the circulating current in the closed loop

formed by two primaries. This reflected current does not flow from the supply. It is to be noted that the net power drawn from the supply is only power corresponding to no load losses.
7. Tabulate meter readings and calculate the circuit parameters.

S. No	V_0	I_0	W_0	V_2	I_2	W_2
1.						

Table 3.1 Measured Values

3.7 Calculations

Predetermination of Efficiency:

$$\text{No load losses} = \frac{W_o}{2} \text{ -------------- for each Transformer}$$

$$\text{Copper losses} = \frac{W_{sc}}{2} \text{ ------------- for each Transformer}$$

$$\eta_{At\,FL} = \frac{FL\ power}{(FL\ power + No\,load\,lossess + FL\ Copper\,lossess)}$$

$$\eta_{At\,\frac{1}{2}FL} = \frac{\frac{1}{2} FL\ power}{\frac{1}{2} FL\ power + No\ load\ lossess + \left(\frac{1}{2}\right)^2 FL\ copper\ lossess}$$

$$\text{No load current} = \frac{I_o}{2} \text{ per transformer}$$

Voltage applied = V_0

Using these values, the Values of R_o & X_o are calculated as in the OC test

$W_o = V_o I_o \cos\theta_o$

i.e., $\cos\theta_o = (W_o/2)/(V_o * [I_o/2])$ ------ for each transformer)

$I_w = [I_o/2] \cos\theta_o$

$I_m = [I_o/2] \sin\theta_o$

$R_o = V_o/I_w$

$X_o = V_o/I_m$

SC current = $I_2 = I_{sc}$

SC voltage = $V_2/2 = V_{sc}$

SC power = $W_2/2 = W_{sc}$

Using these values, the series parameters R_{o2} and X_{o2} (referred to secondary) are calculated as in the SC test.

$W_{sc} = I_{sc}^2 R_{o1}$

$R_{o1} = W_{sc}/I_{sc}^2$

$Z_{o1} = V_{sc}/I_{sc}$

$X_{o1} = \sqrt{(Z_{o1}^2 - R_{o1}^2)}$

$R_{o2} = R_{o1}K^2$

$X_{o2} = X_{o1}K^2$

3.8 Model graphs

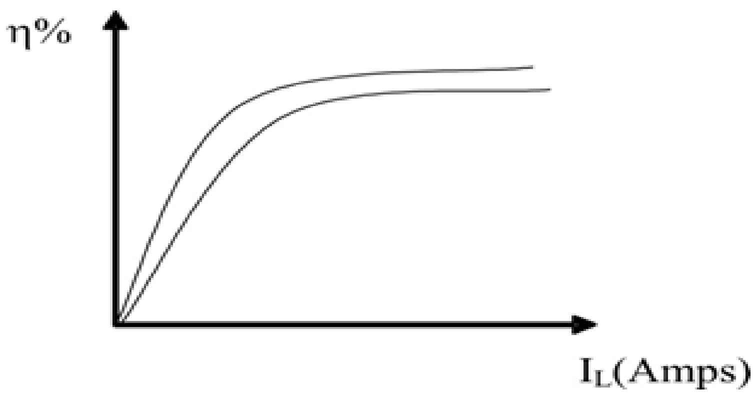


Figure 3.2: Performances on a Pair of single phase Transformers

3.9 Probing Further Experiments

Q1. Design back to back test for three phase transformers using digital simulation.
Q2. Design back to back test for three phase transformers using LabVIEW.

LAB-4 SCOTT CONNECTION

4.1 Introduction

The Scott-T Connection is the method of connecting two single phase transformers to perform the 3-phase to 2-phase conversion and vice-versa. The two transformers are connected electrically but not magnetically. One of the transformers is called the main transformer, and the other is called the auxiliary or teaser transformer. The Scott-T connection permits conversions of a 3-phase system to a two-phase system and vice versa. But since 2-phase generators are not available, the converters from two phases to three phases are not used in practice.

4.2 Objective

By the end of this lab, the student should learn how to convert three phase system to two phase system using two single phase transformers

4.3 Prelab Preparation:

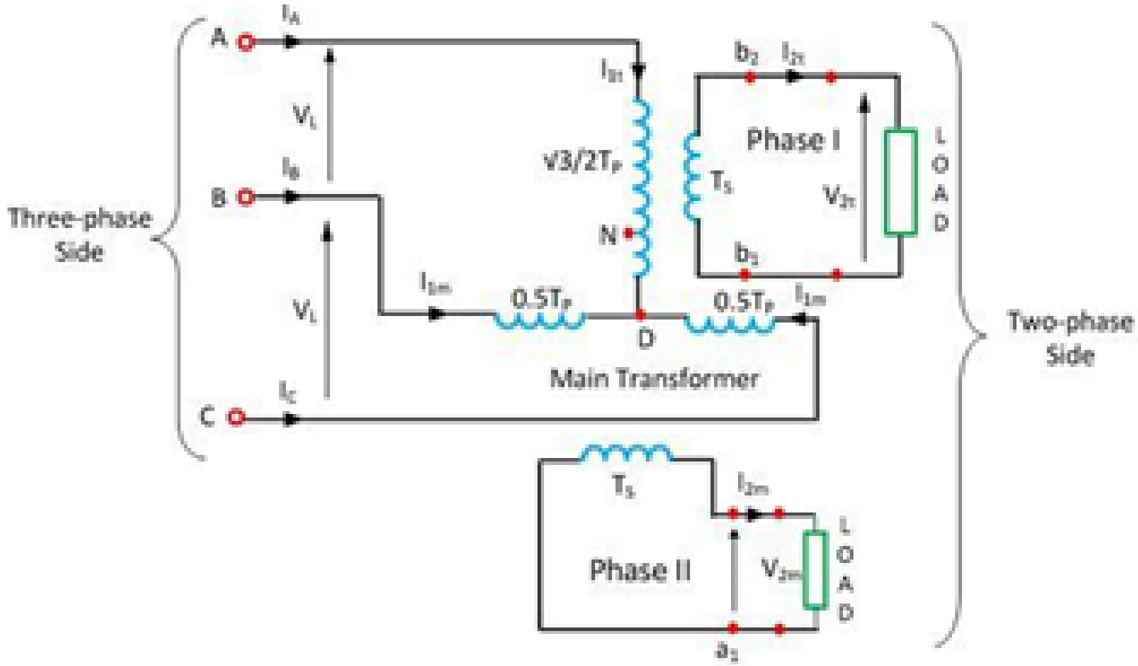
Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

4.4 Equipment needed

1. Two single phase transformers with tapping at 86.66 percentage (2 KVA)
2. Three phase auto transformer
3. Three Ammeters (0-10 A) MI
4. Two Ammeters (0-20 A) MI.
5. Two Voltmeters (0-600 V) MI.
6. Two Voltmeters (0-300 V) MI.
7. Two resistive loads
8. Connecting Wires.

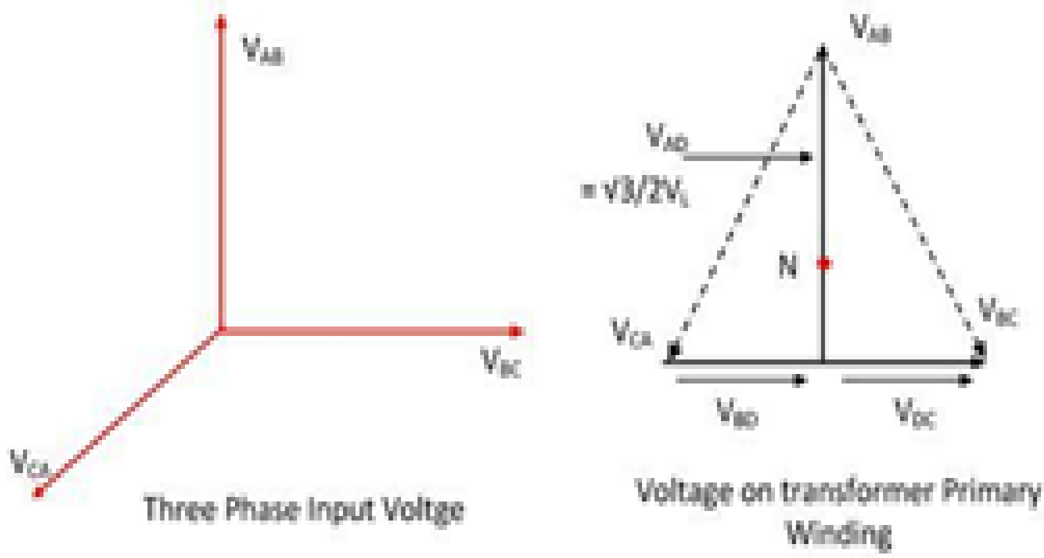
4.5 Background

The figure below shows the Scott-T transformer connection. The main transformer is centre tapped at D and is connected to the line B and C of the 3-phase side. It has primary BC and secondary a1a2. The teaser transformer is connected to the line terminal A and the centre tapping D. It has primary AD and the secondary b1b2



The identical, interchangeable transformers are used for Scott-T connection in which each transformer has a primary winding of Tp turns and is provided with tapping at 0.289Tp , 0.5Tpand 0.866 Tp.

Phasor Diagram of Scott Connection Transformer: The line voltages of the 3-phase system VAB, VBC, and VCA which are balanced are shown in the figure below. The same voltage is shown as a closed equilateral triangle. The figure below shows the primary windings of the main and the teaser transformer.



The D divides the primary BC of the main transformers into two halves and hence the number of turns in portion BD = the number of turns in portion DC = Tp/2. The voltage VBD and VDC are equal, and they are in phase with VBC.

$$V_{BD} = V_{DC} = \frac{1}{2}V_{BC} = \frac{1}{2}V_L < 0°$$

The voltage between A and D is

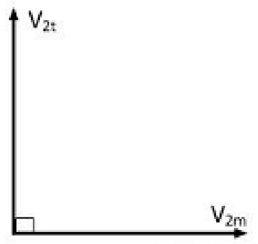
$$V_{BD} = V_{DC} = \frac{1}{2}V_{BC} = \frac{1}{2}V_L < 0°$$

$$V_{AD} = V_{AB} + V_{BD}$$

$$V_{AD} = V_L\left(-\frac{1}{2} + j\frac{\sqrt{3}}{2}\right) + \frac{1}{2}V_L$$

$$V_{AD} = V_L\left(j\frac{\sqrt{3}}{2}\right) = 0.866V_L < 90°$$

The teaser transformer has the primary voltage rating that is 0.866 of the voltage ratings of the main transformer. Voltage VAD is applied to the primary of the teaser transformer and therefore the secondary of the voltage V2t of the teaser transformer will lead the secondary terminal voltage V2m of the main transformer by 90º as shown in the figure below.



$$\frac{V_{S_1}}{V_{AD}} = \frac{T_S}{T_{AD}}$$

$$V_{2t} = \frac{T_S}{T_{AD}}V_{AD} = \frac{T_S}{\frac{\sqrt{3}}{2}T_P} \times \frac{\sqrt{3}V_t}{2}$$

$$\frac{T_S}{T_P}V_L = v_{2m}$$

For keeping the voltage per turn same in the primary of the main transformer and the primary of the teaser transformer, the number of turns in the primary of the teaser transformer should be equal to 0.866 Tp. Thus, the secondaries of both transformers should have equal voltage ratings. The V2t and V2m are equal in magnitude and 90º apart in time; they result in the balanced 2-phase system. Position of Neutral Point N The primary of the two transformers may have a four-wire connection to a 3-phase supply if the tapping N is provided on the primary of the teaser transformer such that The voltage across AN = VAN = phase voltage Since the voltage across the portion AD.

$$V_{AD} = \frac{\sqrt{3}}{2} V_L$$

The voltage across the portion ND

$$V_{ND} = V_{AD} - V_{AN} = \frac{\sqrt{3}}{2} V_L - \frac{V_L}{\sqrt{3}} = \frac{V_L}{2\sqrt{3}}$$

The same voltage turns in portion AN, ND and AD are shown by the equations,

$$T_{AN} = \frac{T_P}{\sqrt{3}} = 0.577T_P$$

$$T_{ND} = \frac{T_P}{2\sqrt{3}} = 0.288T_P$$

$$T_{ND} = \frac{\sqrt{3}T_P}{2} = 0.866T_P$$

$$\frac{T_{AN}}{T_{ND}} = \frac{T_P}{\sqrt{3}} + \left(\frac{T_P}{2\sqrt{3}}\right) = 2$$

The equation above shows that the neutral point N divides the primary of the teaser transformer in ratio. AN: ND = 2:

4.6 Procedure

1. Make the connections as per the circuit diagram with meters of suitable ranges.

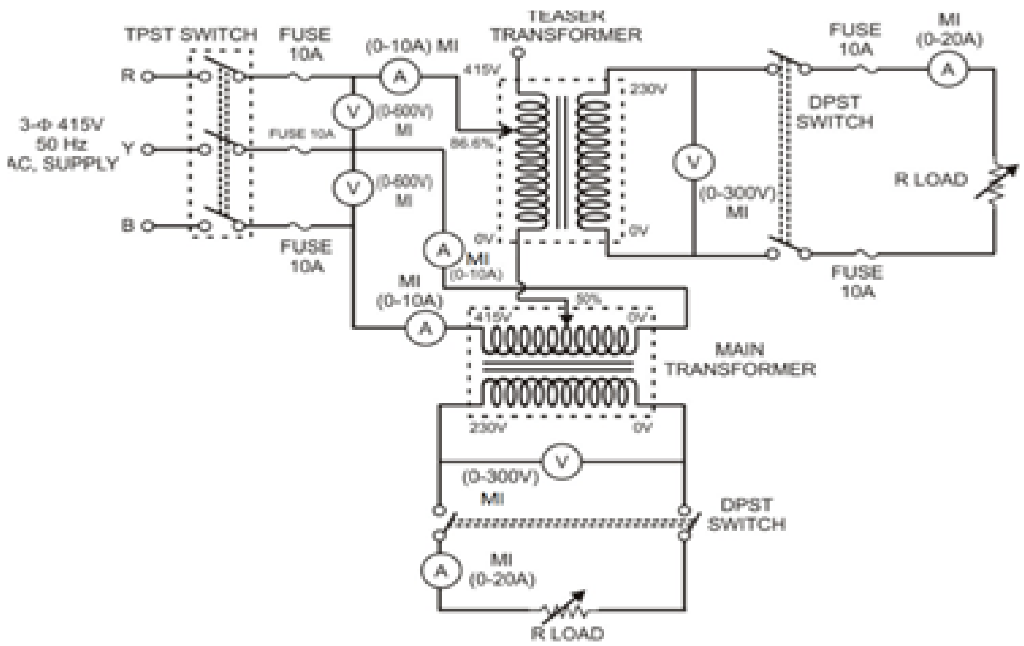


Figure 4.1 Scott Connections of Transformers

2.Connect loads to the secondary side of the two transformers.
3.Gradually increase the load current on both transformers and note the readings of load currents and voltages.

S. No	I_R	I_Y	I_B	V_{RY}	V_{YB}	V_{TS}	I_{TS}	V_{MS}	I_{MS}
1.									
2									
3									

Table 4.1 Measured Values

4.7 Probing Further Experiments

Q1. Convert two phase to three phase system using two single phase transformers
Q2. Design three phase transformer using three single phase transformers

LAB-5 SEPARATION OF CORE LOSSES IN SINGLE PHASE TRANSFORMER

5.1 Introduction

The iron losses in the transformer core can be separated by supplying variable frequency supply to the transformer by keeping v/f ratio constant. From this test iron losses are separated into hysteresis and eddy current losses. This test is helpful in the design of core

5.2 Objective

By the end of this lab, the student should learn how to separate iron losses into hysteresis and eddy current losses in single phase transformers

5.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

5.4 Equipment needed

1. DC Shunt motor (5 HP)
2. Alternator (3 KVA)
3. Two rheostats (0-370 Ohms/ 1.7 A)
4. Ammeter (0-2 A) MC
5. Ammeter (0-10 A) MI
6. Voltmeter (0-150 V) MI.
7. Watt meter (150/300 V, 1/2 A) LPF
8. Tachometer
9. Connecting Wires.

5.5 Background

Iron Losses Iron losses are caused by the alternating flux in the core of the transformer as this loss occurs in the core it is also known as Core loss. Iron loss is further divided into hysteresis and eddy current loss. Hysteresis Loss The core of the transformer is subjected to an alternating magnetizing force, and for each cycle of emf, a hysteresis loop is traced out. Power is dissipated in the form of heat known as hysteresis loss and given by the equation shown below:

$$P_h = K\eta B_{max}^{1.6} f V \quad \text{watts}$$

The iron or core losses can be minimized by using silicon steel material for the construction of the core of the transformer.

Eddy Current Loss When the flux links with a closed circuit, an emf is induced in the circuit and the current flows, the value of the current depends upon the amount of emf around the circuit and the resistance of the circuit.

Since the core is made of conducting material, these EMFs circulate currents within the body of the material. These circulating currents are called Eddy Currents. They will occur when the conductor experiences a changing magnetic field. As these currents are not responsible for doing any useful work, and it produces a loss (I2R loss) in the magnetic material known as an Eddy Current Loss.

The eddy current loss is minimized by making the core with thin laminations.

The equation of the eddy current loss is given as

$$P_h = K\eta B_{max}^{1.6} f V \quad \text{watts}$$

Where,

- Ke – coefficient of eddy current. Its value depends upon the nature of magnetic material like volume and resistivity of core material, the thickness of laminations
- Bm – maximum value of flux density in wb/m2
- T – thickness of lamination in meters
- F – frequency of reversal of the magnetic field in Hz
- V – the volume of magnetic material in m3

5.6 Procedure

1. Make the connections as per the circuit diagram.

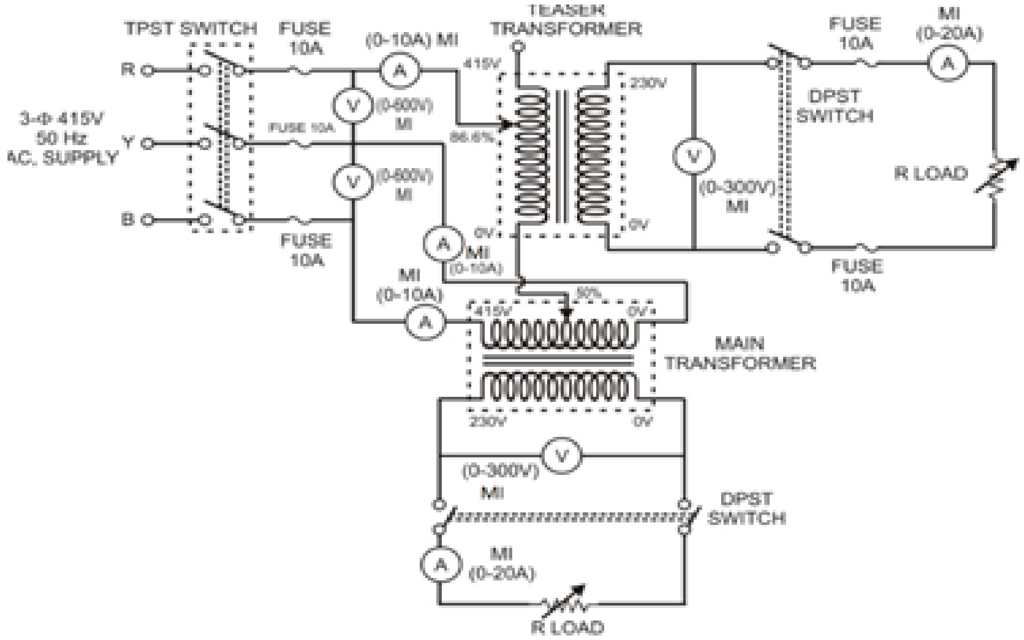


Figure 5.1 Separations of Core Losses of a single phase Transformer

2. Start the alternator with the help of prime mover (DC Motor).
3. Adjust the speed of the prime mover so that the alternator frequency should be 50 Hz.
4. Vary the excitation of the alternator so that the required voltage builds across the armature (Say 230 V between line and neutral).
5. Note down all meter readings.
6. Repeat the above steps for different frequencies by changing the speed of the prime mover (With Speed control of DC Shunt motor by Armature control or Field Control).
7. Repeat step 6 for different frequencies of the alternator by varying the speed of DC motor so that V / f ratio is maintained constant.
8. Plot the graph between W/f and frequency of the transformer

S. No.	Speed	Frequency	Voc	W/f	Io	Wo
1						
2						
3						
4						

Table 5.1 Measured Values

5.7 Calculations

Hysteresis loss and eddy current loss are the components of the iron losses. For the applied fl ux density Bmax to the core, we have
Hysteresis loss = Af
and Eddy current loss = Bf2

The no load loss can be expressed as
Wc=Af+Bf2
where A and B are constants.

5.8 Model graph

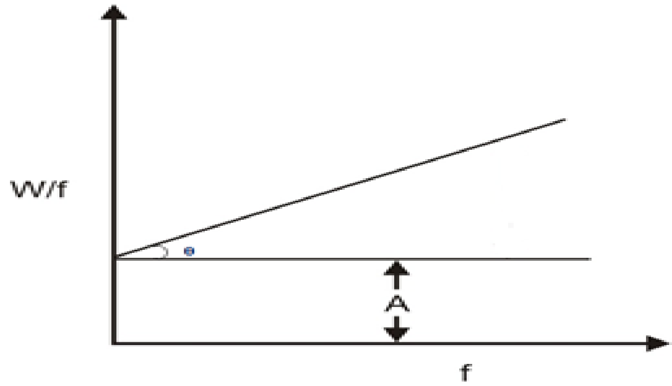


Figure 5.2 Graph plotted between W/f and core losses (WT)

5.9 Probing Further Experiments

Q1. Separate constant losses in three phase star connected transformer
Q2. Separate constant losses in three phase delta connected transformer

LAB-6 PARALLEL OPERATION OF A SINGLE PHASE TRANSFORMERS

6.1 Introduction

Parallel Operation of a single phase transformer means that the two or more transformers having the same polarities, same turn ratios, same phase sequence and the same voltage ratio are connected in parallel with each other to meet the load demand

6.2 Objective

By the end of this lab, the student should learn how to connect the two or more single phase transformers in parallel to meet the load demand

6.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

6.4 Equipment needed

1. Two single phase transformers (2 KVA)
2. Two auto transformers
3. Voltmeter (0-150 V) MI
4. Voltmeter (0-300 V) MI
5. Three Ammeters (0-10 A) MI
6. Ammeter (0-20 A) MI
7. Watt meter (150/300 V, 5/10 A) LPF
8. Two Watt meter (150/300 V, 10/20 A) UPF
9. Resistive load
10. Connecting wires

6.5 Background

Reasons for Parallel Operation Parallel operation of a transformer is necessary because of the following reasons are given below:
• It is impractical and uneconomical to have a single large transformer for heavy and large loads. Hence, it will be a wise decision to connect a number of transformers in parallel.
• In substations, the total load required may be supplied by an appropriate number of the transformer of standard size. As a result, this reduces the spare capacity of the substation.
• If the transformers are connected in parallel, so there will be scope in future, for expansion of a substation to supply a load beyond the capacity of the transformer already installed.
• If there will be any breakdown of a transformer in a system of transformers connected in parallel, there will be no interruption of power supply, for essential services.
• If any of the transformer from the system is taken out of service for its maintenance and inspection, the continuity of the supply will not get disturbed **Necessary conditions for parallel operation** For the satisfactory parallel operation of the transformer, the two main conditions are necessary. One is that the Polarities of the transformers must be the same. Another condition is that the Turn Ratio of the transformer should be equal.

The other two desirable conditions are as follows:
• The voltage at full load across the transformer internal impedance should be equal.
• The ratio of their winding resistances to reactance's should be equal for both the transformers. This condition ensures that both transformers operate at the same power factor, thus sharing their active power and reactive volt-amperes according to their ratings.

6.6 Procedure

1. Make the connections as per the circuit diagram.

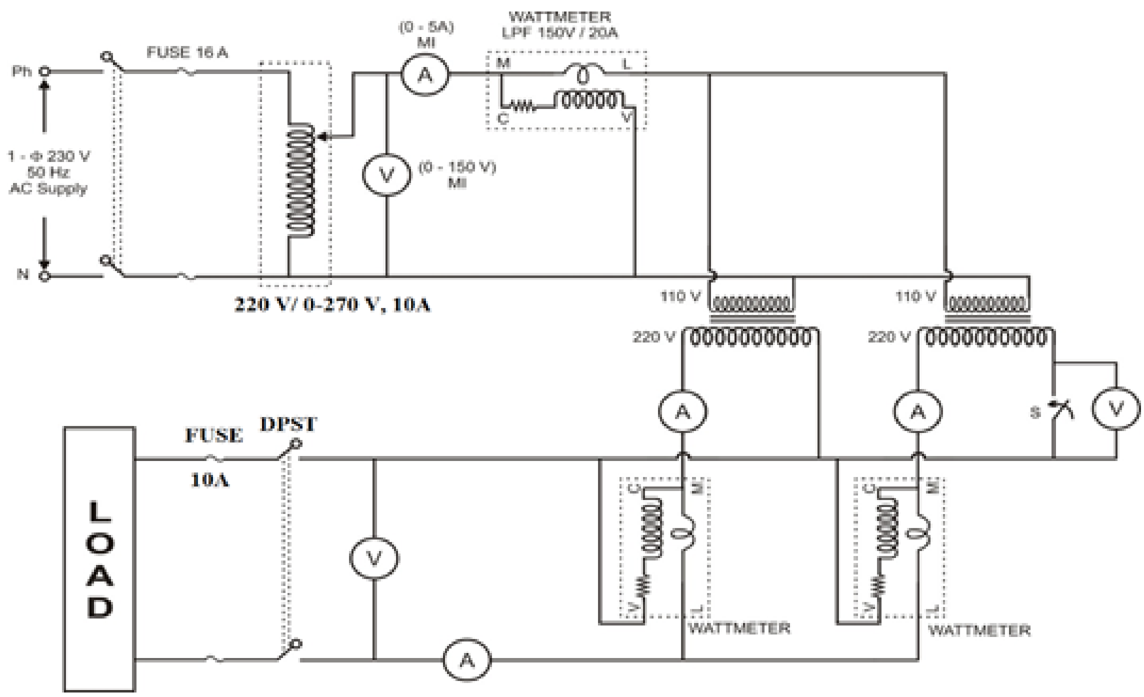


Figure 6.1: Parallel Operation of single phase Transformers

2. Set the auto transformer at the zero position and switch on the supply.
3. Apply the rated voltage across the primary winding of the transformer gradually with the help of auto transformer.

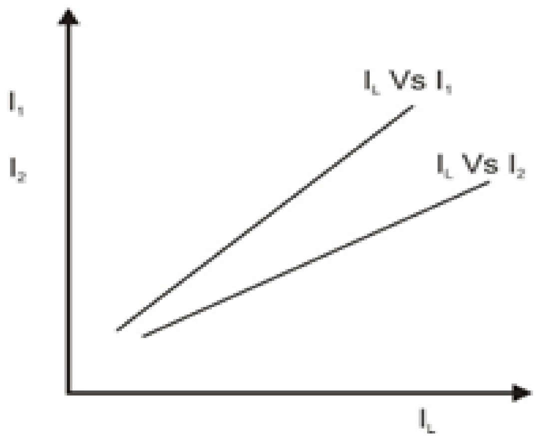
4. If V3 is showing zero reading then close the SPST switch 'S', otherwise reverse the transformer connection and close the switch S
5. Apply load in steps till the rated current and note down all meter readings.

S.No	I_L	V_1	V_2	I_1	I_2	W_1	W_2
1							
2							
3							
4							

Table 6.1: Measured values

6.Conduct the SC test on two single phase transformers and find the effective resistance and leakage reactance of each transformer.
7.Verify the practical values with theoretical values.
8.Draw the graphs of IL versus I1 and I2.

6.7 Model graph



6.8 Probing Further Experiments

Q1. Design a circuit for parallel operation of single phase transformers using MA LAB
Q2. Design a circuit for parallel operation of single phase transformers using LabVIEW

LAB-7 HEAT RUN TEST

7.1 Introduction

Heat run test or temperature rise test is one of the type tests on the power transformer. This test's results are really important for the operational economy to show the performance of the transformer in the fields. The mean purpose of this test is to check whether the oil and winding temperatures of the transformer meet the values specified in the standard and technical projects.

7.2 Objective

By the end of this lab, the student should learn how to measure the rise in temperature inside the winding of a 3- phase transformer using heat run test

7.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

7.4 Equipment needed

1. Three single phase transformers (2 KVA)
2. Three phase auto transformers
3. Single phase auto transformer
4. Two Voltmeters (0-600 V) MI
5. Two Ammeters (0-20 A) MI
6. Watt meter (150/300 V, 5/10 A) LPF
7. Watt meter (50/300 V, 10/20 A) UPF
8. Connecting Wires.

7.5 Background

Heat run test is similar to that of back to back test which can be conducted on the transformers. In heat run test, the watt meters are not required which are used in back to back test. Only a voltmeter is used to measure the primary applied voltage and ammeter to measure current in the secondary side. The primary side is excited at normal voltage and frequency. The secondary side is connected in open-delta. It is provided with a circulating current from an auxiliary single phase supply of any convenient frequency. The method gives the same results as that of back to back connection without the requirement of two identical transformers. It is possible to apply the method whatever the normal internal connections if temporary alterations can be made where necessary. The heat run test is continued until the windings and the oil in the tank attain a steady temperature. This temperature rise must be within permissible limits which is set by designer.

7.6 Procedure

1. Make the connections as per the circuit diagram.

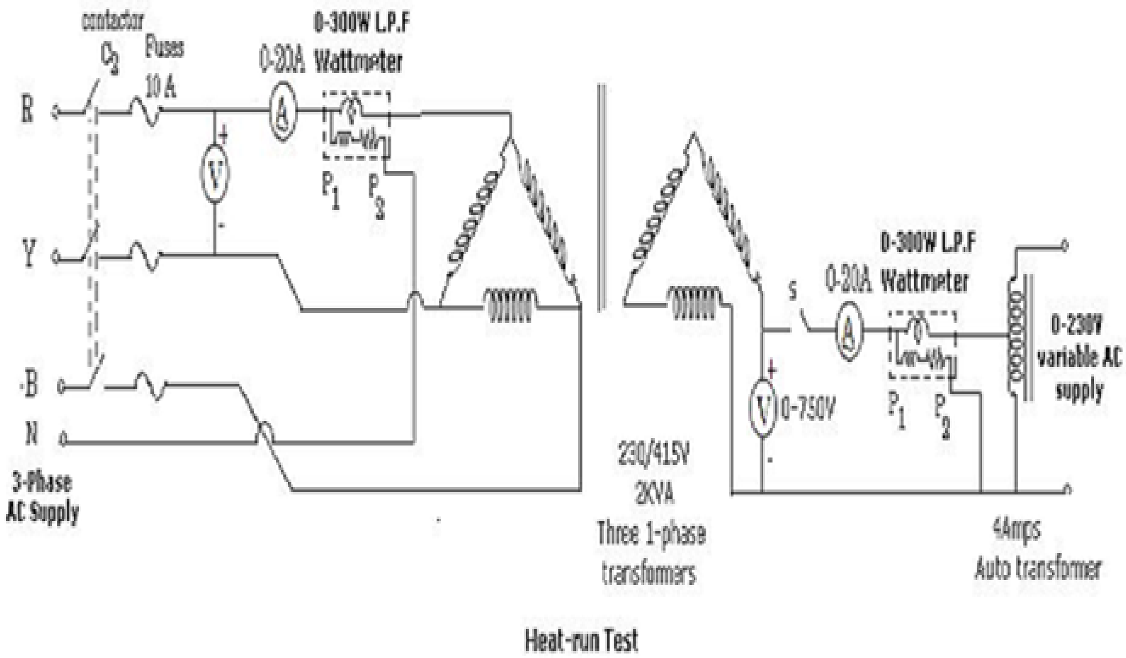


Figure 7.1: Heat run test

2. Connect the voltmeter across R1 and B2 on LV Side
3. Keep the switch in the off position.
4. Switch on the 3-phase power supply.
5. Record the Ammeter, Voltmeter readings on the primary side and observe the reading on the secondary side, which is connected between R1 and B2

S. No	V_1	I_1	V_2	I_2	W_1	W_2
1 2						
3						

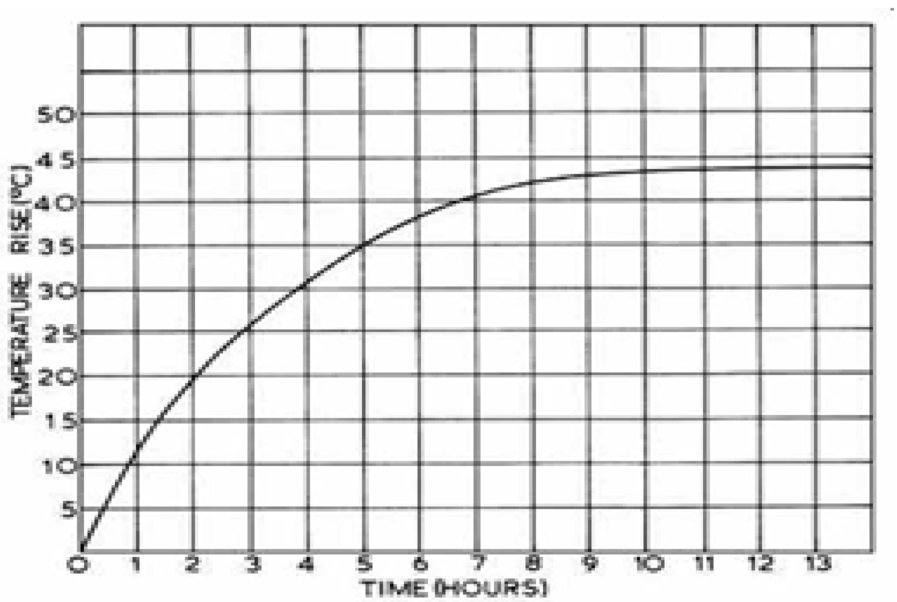
Table 7.1: Measured values

S. No	Time (Min)	Temperature (°C)
1		
2		
3		

Table 7.2: Measured values

6. If the voltmeter indicates high value, then conduct the polarity test and connect them as per the dot Convention.
7. If this voltmeter indicates zero, then switch ON Sw1 and slowly increase the auto transformer till the Ammeter indicates the rated current of the secondary winding 8.2 Amps.
8. Draw the graph between temperatures Vs. Time.

7.7 Model graph



Fgure 7.2: Temperature curve

7.8 Probing Further Experiments

Q1. Design heat run test using MATLAB
Q2. Design heat run test using LABVIEW

LAB-8 BRAKE TEST ON THREE PHASE SQUIRREL CAGE INDUCTION MOTOR

8.1 Introduction

Break test is basically blocked rotor test in which rotor and stator losses (mainly copper loss) found by this method. Due to blocked rotor, rotor can't able to move act like short circuit and as we know in short circuit condition voltage is almost zero. By this condition we got zero iron losses and can able to find only copper loss itself.

8.2 Objective

By the end of this lab, the student should learn how to draw and analyze the performance characteristics of three phase squirrel cage induction motor

8.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

8.4 Equipment needed

1. Three phase squirrel cage induction motor (5 Hp)
2. Three phase auto transformers
3. Voltmeter (0-600 V) MI
4. Ammeter (0-20 A) MI
5. Two watt meter (150/300 V, 5/10 A) LPF
6. Two watt meter (50/300 V, 10/20 A) UPF
7. Tachometer
8. Connecting Wires.

8.5 Background

Tests are required to check the condition of the induction motor and to get the basic idea of malfunctioning of the motor. Now a day lots of techniques and tests are available which gives the complete health card of the induction motors. By monitoring some parameters like voltage, current, temperature, and vibration problem could be diagnosed and by correcting these faults

the overall efficiency of the machine can be improved. This will reduce the energy consumption and operational costs. **Tests for Induction Motor** Number of test is done on induction motor to check its different parameters. All the tests are divided into two parts: **Preliminary Tests** These tests are performed to check the electrical or mechanical defects of the induction motor.
1. Firstly, check the components of motor like
i. Broken rotor bars
ii. High resistance joints
iii. Cracked end rings
2. No-load running current test
3. High potential test
4. Air-gap measurement
5. Balancing of current
6. Temperature rise in bearing
7. Voltages in shaft
8. Direction of rotation
9. Level of noise
10. Strength of vibration
11. Air gap eccentricity
Performance Tests The purpose of these tests is to estimate the performance characteristics of the induction motor. Along with preliminary tests, these tests are also done on motor.
1. No load test
2. Locked rotor test
3. Breakdown torque load performance test
4. Temperature test
5. Stray load loss test
6. Determination of efficiency test

8.6 Procedure

1. Make the connections as per the circuit diagram.

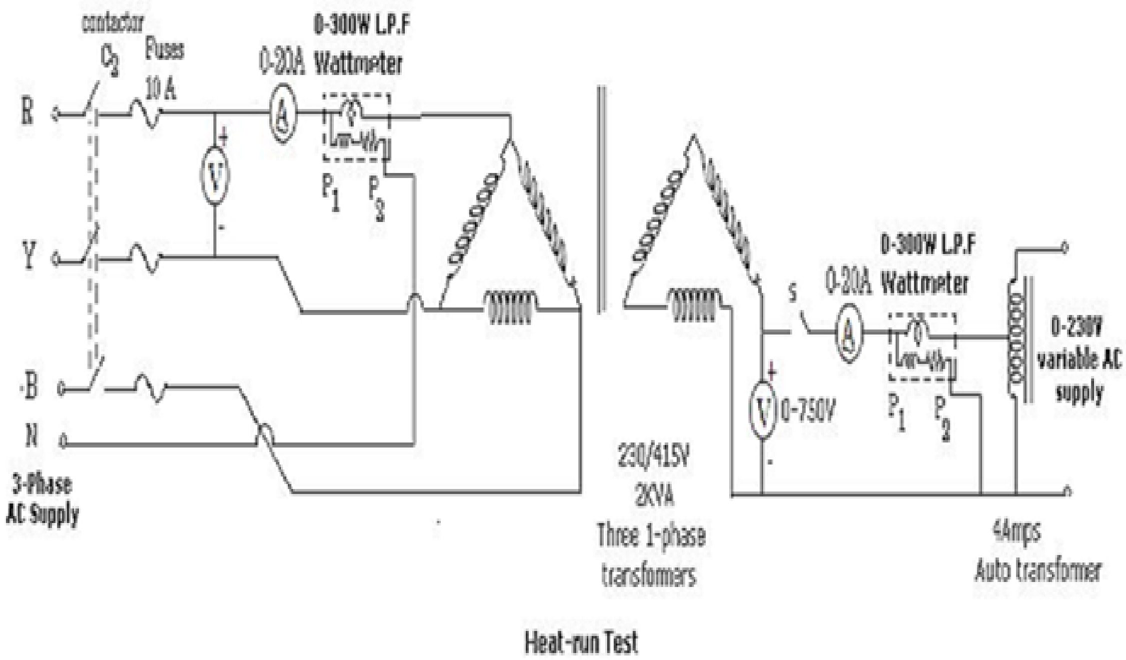


Figure 8.1 :Brake Test on three phase Induction Motor

2. Start the three phase IM on no load by means of three phase auto transformer 3. Note down all meters reading and the speed at no load.

S. No	V_L	I_L	W_1	W_2	S_1	S_2	Speed
1							
2							
3							
4							
5							

Table 8.1: Measured values

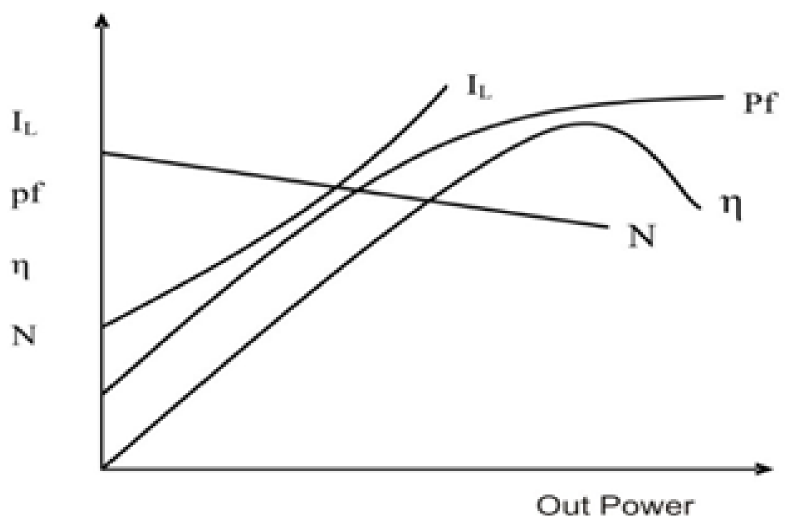
4. Apply mechanical load by tightening the belt on the brake drum and note down the readings of the meters, spring balances, and the speed. 5. Repeat the above step-4 until the motor draws full load current. 6. Calculate the torque, slip, output, efficiency and power factor for each set of readings as per the model calculations.

S. No	V_L	I_L	W_1	W_2	S_1	S_2	Speed	Torque	Output power	Input power	Efficiency
1											
2											
3											
4											
5											

Table 8.2 Calculated values of efficiency, torque and output power

7. Draw the performance curves

8.7 Model graph



Fgure 8.2 Performance curves of three phase Induction Motor

8.8 Probing Further Experiments

Q1. What are the different starting methods used to start induction motors?
Q2. What is the speed of an Induction motor for a) 4 percentage b) 10 percentage

LAB-9 NO LOAD AND BLOCKED ROTOR TEST ON THREE PHASE INDUCTION MOTOR

9.1 Introduction

To predict the performance of a three-phase induction motor by knowing all the equivalent circuit parameters. These circuit parameters are supplied from no load and blocked rotor test. Without actually loading the induction motor, these two assessed tests give the test results which are used to determine the equivalent circuit parameters.

9.2 Objective

By the end of this lab, the student should learn how to determine the equivalent circuit parameters of three phase squirrel cage induction motor

9.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

9.4 Equipment needed

1. Three phase squirrel cage induction motor (5 Hp)
2. Three phase auto transformers
3. Voltmeter (0-600 V) MI
4. Ammeter (0-20 A) MI
5. Two watt meter (150/300 V, 5/10 A) LPF
6. Two watt meter (50/300 V, 10/20 A) UPF
7. Tachometer
8. Connecting Wires.

9.5 Background

No load test: The efficiency of large motors can be determined by directly loading them and by measuring their input and output powers. For larger motors it may be difficult to arrange loads for them. Moreover, power loss will be large with direct loading tests. Thus, no load and blocked rotor tests are performed on the motors. As the name suggest no load test is performed when rotor rotates with synchronous speed and there is no load torque. This test is similar to the open circuit test on transformer. Actually, to achieve synchronous speed in an induction motor is impossible. The speed is assumed to be synchronized. The synchronous speed can be achieved by taking slip = 0 which creates infinite impedance in the rotor branch. This test gives the information regarding no-load losses such as core loss, friction loss and windage loss. Rotor copper loss at no load is very less that its value is negligible. Small current is required to produce adequate torque. This test is also well-known as running light test. This test is used to evaluate the resistance and impedance of the magnetizing path of induction motor.

Blocked rotor test: A blocked rotor test is normally performed on an induction motor to find out the leakage impedance. Apart from it, other parameters such as torque, motor, short-circuit current at normal voltage, and many more could be found from this test. Blocked rotor test is analogous to the short circuit test of transformer. Here shaft of the motor is clamped i.e., blocked so it cannot move and rotor winding is short circuited. In slip ring motor rotor winding is short circuited through slip rings and in cage motors, rotors bars are permanently short circuited. The testing of the induction motor is a little bit complex as the resultant value of leakage impedance may get affected by rotor position, rotor frequency and by magnetic dispersion of the leakage flux path. These effects could be minimized by conducting a block rotor current test on squirrel-cage rotors

9.6 Procedure

No load Test: 1. Make the connections as per the circuit diagram.

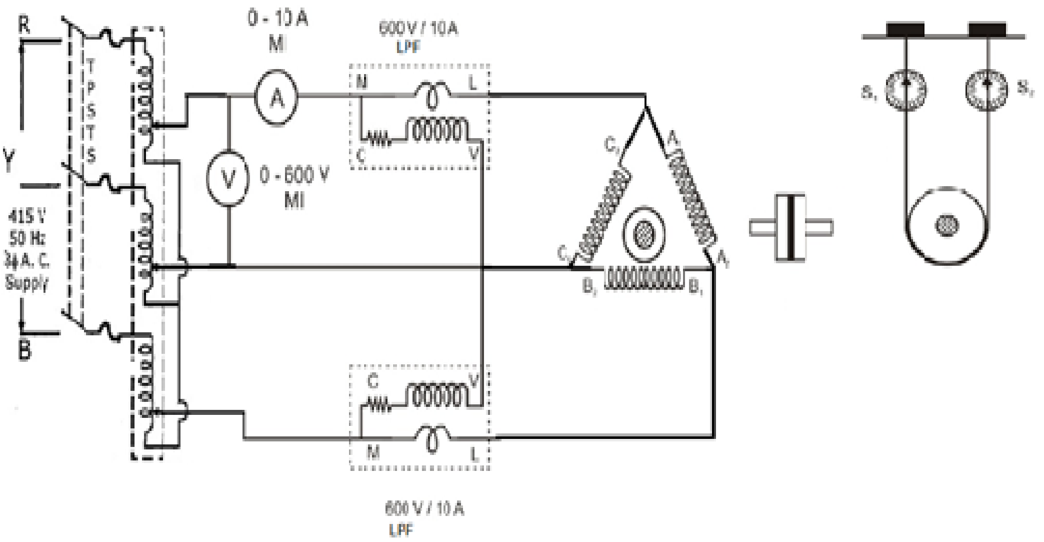


Figure 9.1: No load and blocked rotor test on three phase induction motor

2. Close the main switch and gradually increase the voltage applied to the stator through the auto transforme.
3. At rated voltage, take the values of the two watt meters (W1 and W2), stator current I0, Stator voltage

S. No	V_{oc}	I_0	W_1	W_2
1				

Table 9.1: Measured values

Blocked rotor test: 1. For the second figure Block the rotor and vary supply voltage until rated current flows through the circuit.

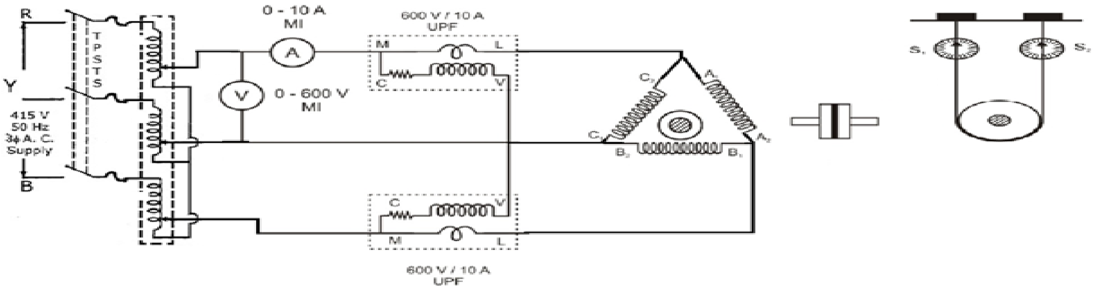


Figure 9.2: No load and Blocked rotor tests on three phase induction motor

2. Note the readings of voltmeter, ammeter and wattmeter's
3. Tabulate the observations and calculate the power input and power factor for each reading.
4. Measure the stator resistance and make the necessary temperature correction.

S. No	V_{sc}	I_{sc}	W_1	W_2
1				

Table 9.2: Measured values

9.7 Model graph

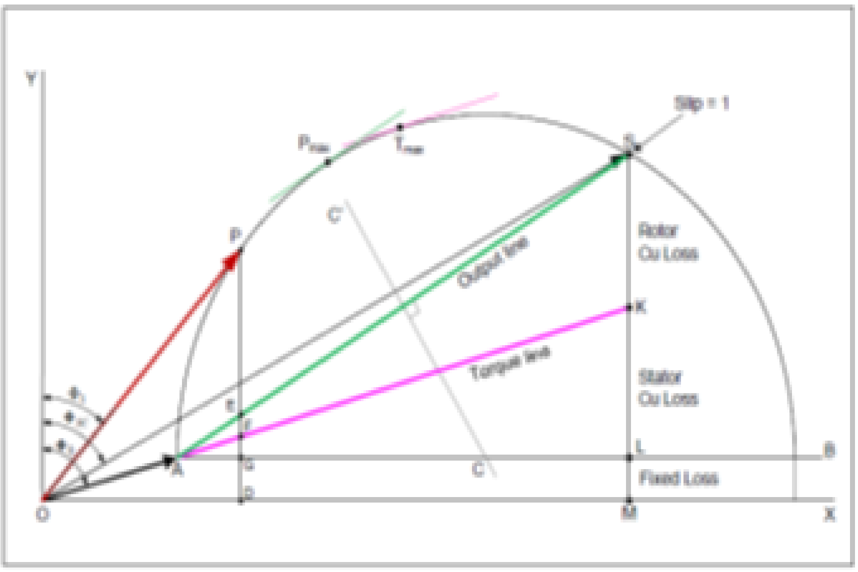


Figure 9.3: Circle diagram of three phase induction motor

9.8 Probing Further Experiments

Q1. What is the condition for maximum torque of 3 phase induction motor?
Q2. State the condition when induction motor acts as induction generator.

LAB-10 REGULATION OF THREE PHASE ALTERNATOR BY SYNCHRONOUS IMPEDANCE METHOD

10.1 Introduction

The voltage regulation of alternator by EMF method involves the EMF quantities of all the armature parameters (armature resistance, Armature leakage reactance, armature reaction). The drop due to armature reaction is not considered, because it does not occur due to any of the physical element but due to interaction of armature flux with main flux.

10.2 Objective

By the end of this lab, the student should learn how to determine the voltage regulation of alternator by synchronous impedance method

10.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

10.4 Equipment needed

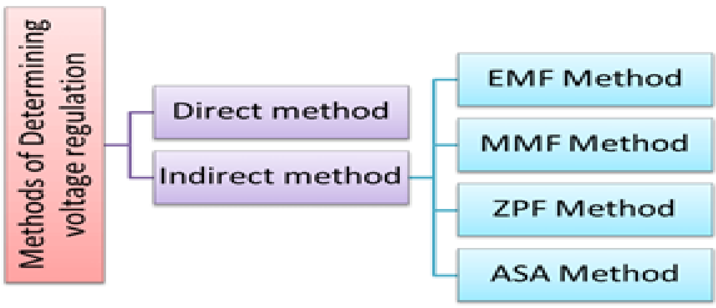
1. DC Shunt motor (5 HP)
2. Three phase alternator (3 KVA)
3. Two rheostats (0-370 Ω / 1.7 A)
4. Voltmeter (0-600 V) MI
5. Ammeter (0-2 A) MC
6. Ammeter (0-10 A) MI
7. Tachometer
8. Connecting Wires

10.5 Background

The voltage regulation of an alternator is defined as "the rise in voltage at the terminals, when the load is reduced from full load rated value to zero, speed and field current remaining constant". With the change in load, there is a change in terminal voltage of an alternator or synchronous generator. The magnitude of this change not only depends on the load but also on the load power factor. It is also defined as "the rise in voltage when full load is removed divided by the rated terminal voltage, when speed and field excitation remain the same." It is given by the formula,

$$\text{Percentage Voltage Regulation} = \frac{E_0 - V}{V} \times 100$$

Methods to determine voltage regulation:



Methods to determine Voltage Regulation: Direct method of determining the voltage regulation is employed for smaller machines.

In this direct method, a three phase load is connected to star connected alternator with the help of Triple Pole Single Throw switch. The field winding of alternator is excited using an external DC supply. A rheostat is connected in series with the field winding, to control the flux produced in the field winding.

Adjust the rheostat of the field winding so that, to produce the rated terminal voltage. Close the load switch, apply the full load and measure the voltage at full load V.

Then the entire load is thrown off while the speed and field excitation are kept constant. The open circuit or no load voltage is measured and now the regulation can be determined from the below equation.

$$\text{Percentage Voltage Regulation} = \frac{E_0 - V}{V} \times 100$$

But in the case of large machines, it becomes very difficult to determine the voltage regulation by direct loading method. So, it is very important to switch over to the indirect methods of determination.

10.6 Procedure

1. Make the connections as per the circuit diagram. Start the alternator with the help of prime mover (DC Shunt motor) and adjust speed to the synchronous speed. The speed of the alternator is to be kept constant throughout the experiment

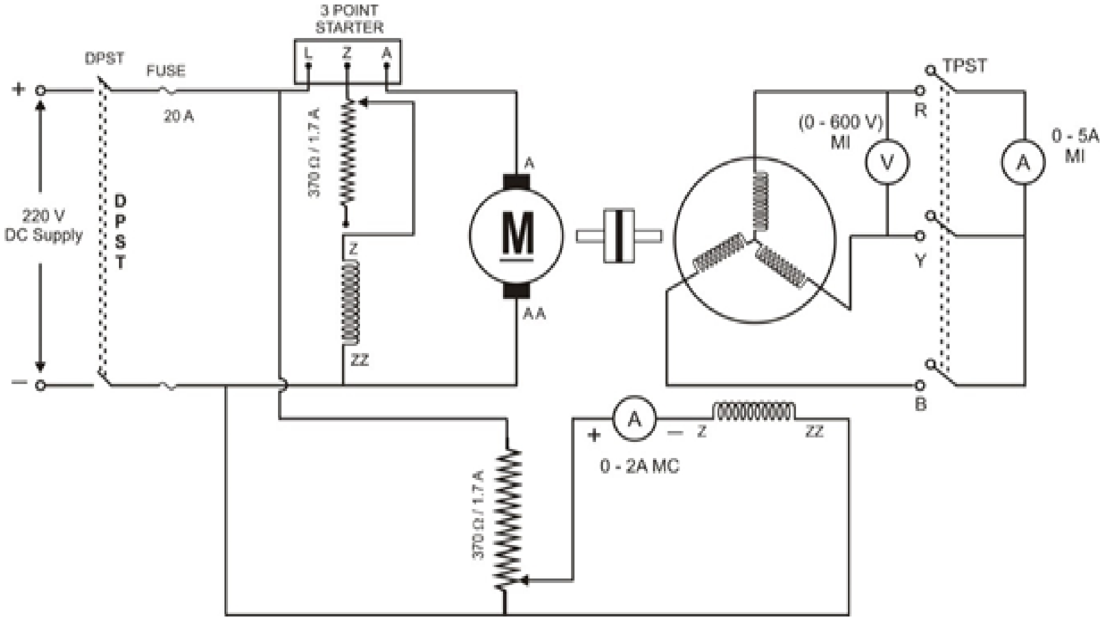


Figure 10.1: Regulations of three phase Alternator Synchronous Impedance Method

2. Excite the field winding alternator keeping armature open.
3. Note down the terminal voltage at different values of field currents.

S. No	I_f	E_g	I_f	I_{SC}
1				
2				
3				
4				

Table 10.1: Measured values

4. Draw the graph of armature voltage versus field current to get the open circuit characteristic (O.C.C) of the Alternator.
5. Close the TPST switch and excite the field winding of the alternator till the rated current flows through the armature.
6. Note down field current and short circuit current.
7. Draw the graph of the short circuit current versus field current to get the short circuit characteristic (SCC).

10.7 Model graph

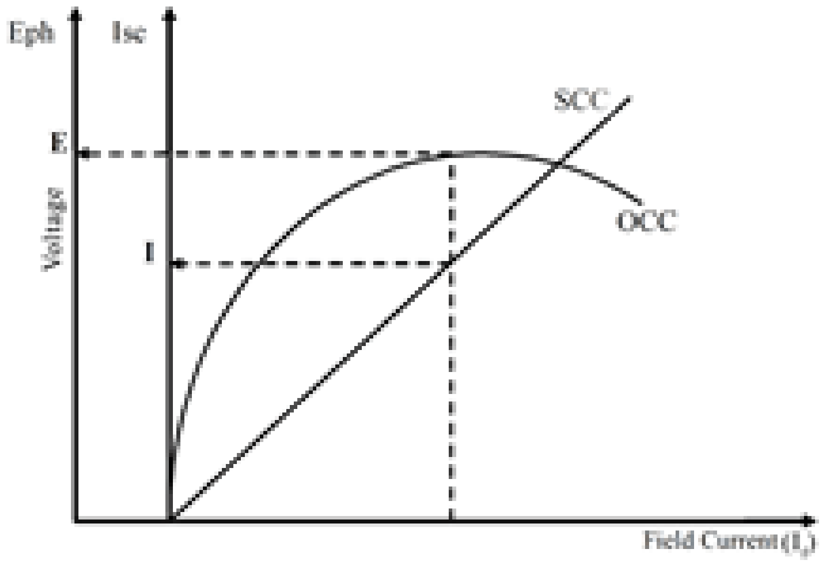


Figure 10.3: OC and SC Characteristics

8. Obtain the synchronous impedance corresponding to the rated voltage.

$$Z_s = \frac{V_{oc}}{I_{sc}}, I_f \text{ const}$$

9. Measure the armature resistance per phase by drop method. The a.c. resistance will be 20 percentage more than the D.C. Resistance: Ra = 1.2 Rdc
10. Calculate the synchronous reactance, Xs
11. Calculate the generated EMF with full load at a 0.8 lagging and leading power factor
E =[(V Cos¢ + I R a)2 (V Sin ¢ + I Xs)2]1/2
(+) sign for lagging power factor and (-) sign for leading power factors.
12. Calculate full load regulation at different power factors.
13. Draw the graph of regulation versus power factor

10.8 Probing Further Experiments

Q1. How the voltage regulation is affected by armature reaction?
Q2. State the condition for zero regulation

LAB-11 REGULATION OF THREE ALTERNATOR BY MMF OR AMPERE TURNS METHOD

11.1 Introduction

MMF method is used for determining the voltage regulation of an alternator or synchronous generator it is also called as Ampere turns method or Rothert's MMF method. This MMF method is based on the results of open circuit test and short circuit test on an alternator. For any synchronous generator or alternator, MMF is required, which is a product of field current and turns of the field winding for two separate purposes.

11.2 Objective

By the end of this lab, the student should learn how to determine the voltage regulation of alternator by MMF or Ampere turns method

11.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

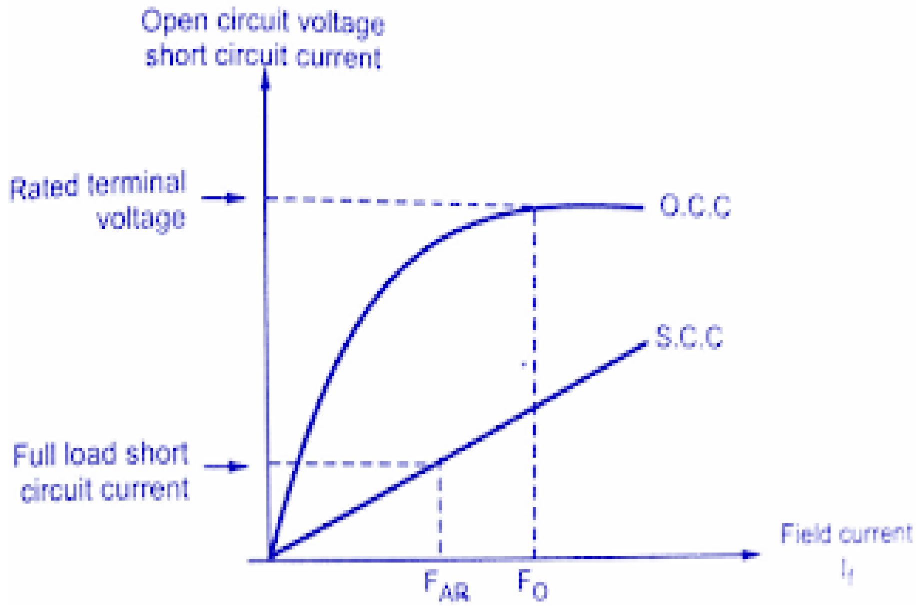
11.4 Equipment needed

1. DC Shunt motor (5 HP)
2. Three phase alternator (3 KVA)
3. Two rheostats (0-370 Ω / 1.7 A)
4. Voltmeter (0-600 V) MI
5. Ammeter (0-2 A) MC
6. Ammeter (0-10 A) MI
7. Tachometer
8. Connecting Wires

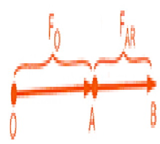
11.5 Background

The field MMF which is required for inducing the rated terminal voltage on the open circuit can be obtained from open circuit test results and open circuit characteristics. This is denoted as FO. Synchronous impedance consists of two components. They are armature resistance and

synchronous reactance. Now synchronous reactance also has two components, armature leakage reactance and armature reaction reactance. In the short-circuit test, field MMF is necessary to overcome drop across armature resistance and leakage reactance and also to overcome the effect of armature reaction.
But drop across armature resistance and leakage reactance is very small and can be neglected. Thus, in short circuit test, field MMF circulates the full load current balancing the armature reaction effect. The value of ampere-turns required to circulate full load current can be obtained from short circuit characteristics. This is denoted as FAR.
Under short circuit condition as resistance and leakage reactance of armature has no significant role, the armature reactance is dominating and hence the power factor of the purely reactive circuit is zero lagging. Hence FAR gives demagnetising ampere-turns. Thus, the field MMF is entirely used to overcome the armature reaction which is wholly demagnetising in nature.
The two components of total field MMF which are FO and FAR are indicated in OCC(open circuit characteristics) and SCC (short circuit characteristics) as shown in the below figure

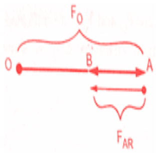


If the alternator is supplying full load, then total field MMF is the vector sum of its two components Fo and FAR. This depends on the power factor of the load which alternator is supplying. The resultant field MMF is denoted as FR. Let us consider the various power factors and the resultant FR.
Zero lagging power factor: As long as the power factor is zero lagging, the armature reaction is completely demagnetizing. Hence the resultant FR is the algebraic sum of the two components FO and FAR. Field MMF method is not only required to produce rated terminal voltage but also required to overcome completely demagnetizing armature reaction effect. It is shown if the below figure.

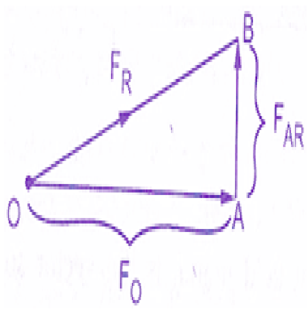


OA = FO
AB = FAR DEMAGNETISING
OB = FR = FO + FAR

Zero leading power factor: When the power factor is zero leading then the armature reaction is totally magnetising and helps main flux to induce rated terminal voltage. Hence net field required is less than that required to induce rated voltage normally, as part of its function is done by magnetizing armature reaction component. The net field MMF in this MMF method is the algebraic difference between the two components FO and FAR.
Total field MMF is greater than Fo



OA = FO
AB = FAR MAGNETISING
OB = FO - FAR = FR
Total MMF is less than FO. Total MMF is less than FO.
Unity power factor: Under unity power factor condition, the armature reaction is cross magnetising and its effect is to distort the main flux. Thus, FO and FAR are at right angles to each other and hence resultant MMF is the vector sum of FO and FAR in this MMF method. This is shown in the below figure.



OA = FO
AB = FAR CROSS MAGNETISING
OB = FR = FO + FAR
Here below is the following considerations for MMF or Ampere turn method for determining voltage regulation of Alternator. General Case: Now consider that the load power factor . In such case, the resultant MMF is to be determined by vector addition of FO and FAR.
Once FR is known, obtain a corresponding voltage which induced EMF Eph, required to get rated terminal voltage Vph. This is possible from open circuit characteristics drawn.
Once Eph is known then the voltage regulation can be obtained as,

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

11.6 Procedure

1. Make the connections as per the circuit diagram. Start the alternator with the help of prime mover (DC Shunt motor) and adjust speed to the synchronous speed. The speed of the alternator is to be kept constant throughout the experiment

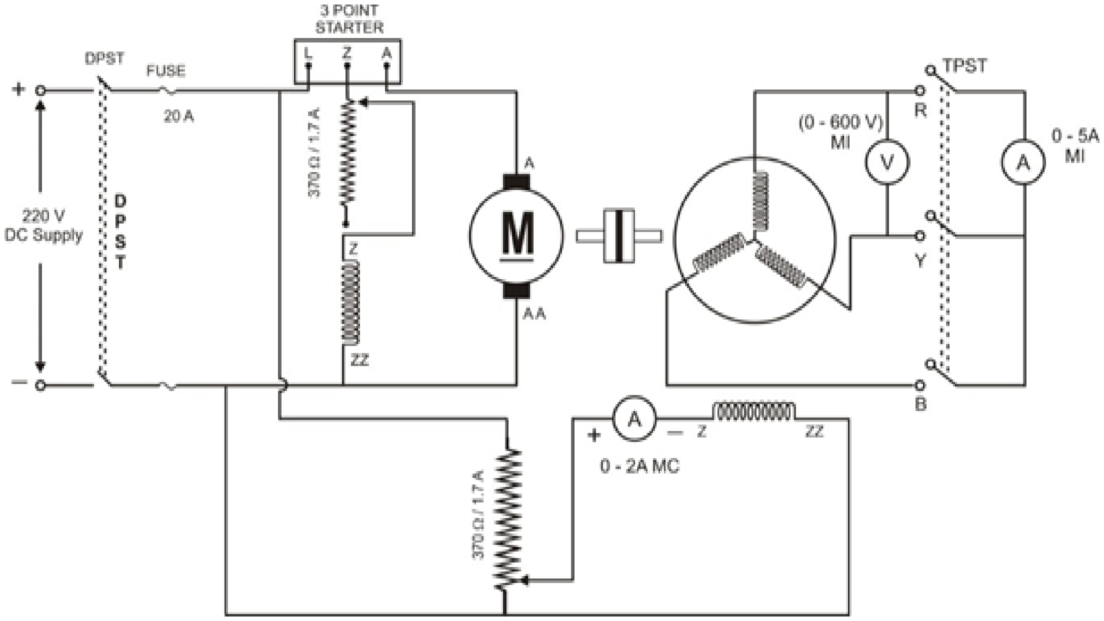


Figure 11.1: Regulations of three phase Alternator Synchronous Impedance Method

2. Excite the field winding alternator keeping armature open.
3. Note down the terminal voltage at different values of field currents.

S. No	I_f	E_g	I_f	I_{SC}
1				
2				
3				
4				

Table 11.1: Measured values

4. Draw the graph of armature voltage versus field current to get the open circuit characteristic (O.C.C) of the Alternator.
5. Close the TPST switch and excite the field winding of the alternator till the rated current flows through the armature.
6. Note down field current and short circuit current.
7. Draw the graph of the short circuit current versus field current to get the short circuit characteristic (SCC).

11.7 Model graph

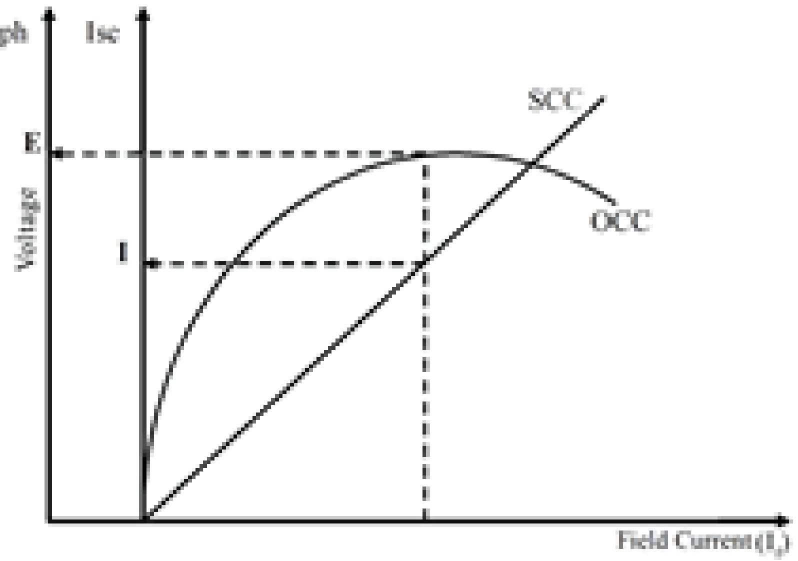


Figure 11.3: OC and SC Characteristics

11.8 Calculations

1. Find the value of induced emf with the resistance drop using the formula, if resistance is given

$$E_{oph} = V_{ph} + I_{aph} R_a \cos\phi$$

2. For the rated voltage (Eoph), draw a line that cuts the OCC curve, from that, draw a vertical line and find the field current If1 and mark it as A.
3. [If the resistance is not given, neglect it and hence for the rated voltage Vph, find the corresponding field current If1]
4. Find the field current If2, that is responsible to circulate the full load short circuit current (Isc) by balancing the armature reaction. This is obtained by drawing a line for full load short circuit current.
5. Now, With A as centre and If2 as radius, draw a semi-circle.
6. For Leading power factor, current leads the voltage, so considering AB as voltage phasor, draw the current phasor such that it leads the voltage by power angle inside the semi-circle (the angle between this current phasor and x-axis is (90-power angle) in anti-clockwise direction) and mark the point on the semi-circle as C.
7. Join OC, which is the resultant Field current (If) that is responsible for generating rated voltage with the drops.
8. Now, in order to find the corresponding voltage, with O as centre and OC as radius, draw an arc that cuts the x-axis at point D.
9. From this point D, draw a vertical line which cuts the OCC curve, from that draw a horizontal line to y-axis and find the no load voltage (Eph).

11.9 Probing Further Experiments

Q1. Calculate voltage regulation of alternator using zero power factor method.
Q1. Calculate voltage regulation of alternator by zero power factor method using LabVIEW.

LAB-12 V AND INVERTED V CURVES OF THREE PHASE SYNCHRONOUS MOTOR

12.1 Introduction

The performance characteristics of a synchronous motor are obtained by v-curves and inverted v-curves. Synchronous machines have parabolic type characteristics (The graph drawn is in the shape of parabolic). If the excitation is varied from low (Under-excitation) to high (Over-excitation) value, then the current Ia also changes i.e., becomes minimum at unity power factor. and then again increases. But at starting lagging current becomes unity and then becomes leading in nature. V-curves and inverted V-curves of a synchronous motor are used to analyse efficiency on no-load and on-load conditions.

12.2 Objective

By the end of this lab, the student should learn how the power factor, armature and field current currents effect the performance of synchronous motor

12.3 Prelab Preparation:

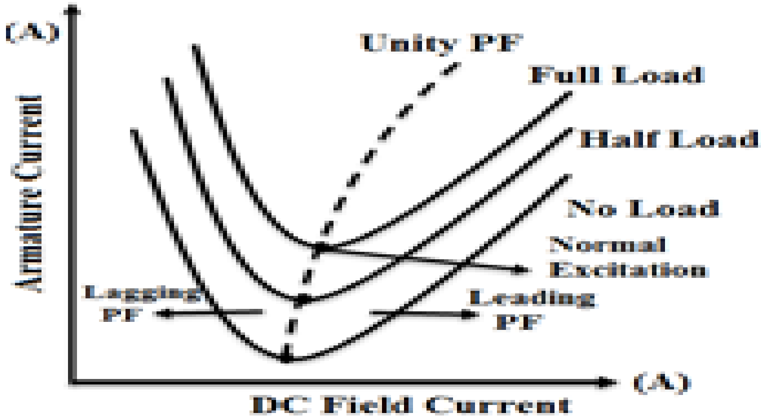
Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

12.4 Equipment needed

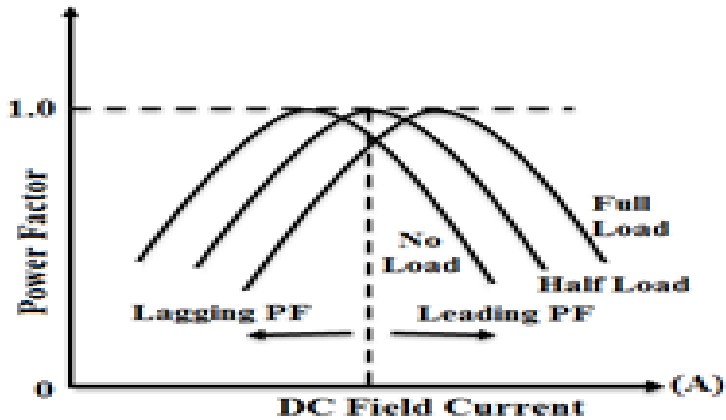
1. DC Shunt motor (5 HP)
2. Three phase synchronous motor (5 HP)
3. Three phase auto transformer
4. Rheostat (0-370 Ω / 1.7 A)
5. Voltmeter (0-600 V) MI
6. Ammeter (0-10 A) MI
7. Ammeter (0-2 A) MC
8. Two watt meters (0-300/600 V, 5/10 A) UPF
9. Resistive load
10. Tachometer
11. Connecting Wires.

12.5 Background

V-Curves of Synchronous Motor: If the armature current Ia is plotted against excitation or field current for various load conditions, we obtain a set of curves known as 'V-Curves' clue to their shape similar to english letter V. In the below figure V-Curve of a synchronous motor shows how armature current Ia changes with excitation for the same input, at no-load, half full-load, and full-load.



From V-Curves it is observed that the armature current has large values both for low and high values of excitation (though it is lagging for low excitation and leading for higher excitation). In between, it has a minimum value corresponding to the unity power factor (normal excitation
Inverted V-Curves of Synchronous Motor: If the power factor is plotted against excitation for various load conditions, we obtain a set of curves known as 'Inverted V-Curves



The inverted V-Curves of synchronous motor shows how the power factor varies with excitation. From inverted V-curves, it is observed that the power factor is lagging when the motor is under excited and leading when it is over-excited. In between, the power factor is unity.

12.6 Procedure

1. Make the connections as per the circuit diagram.

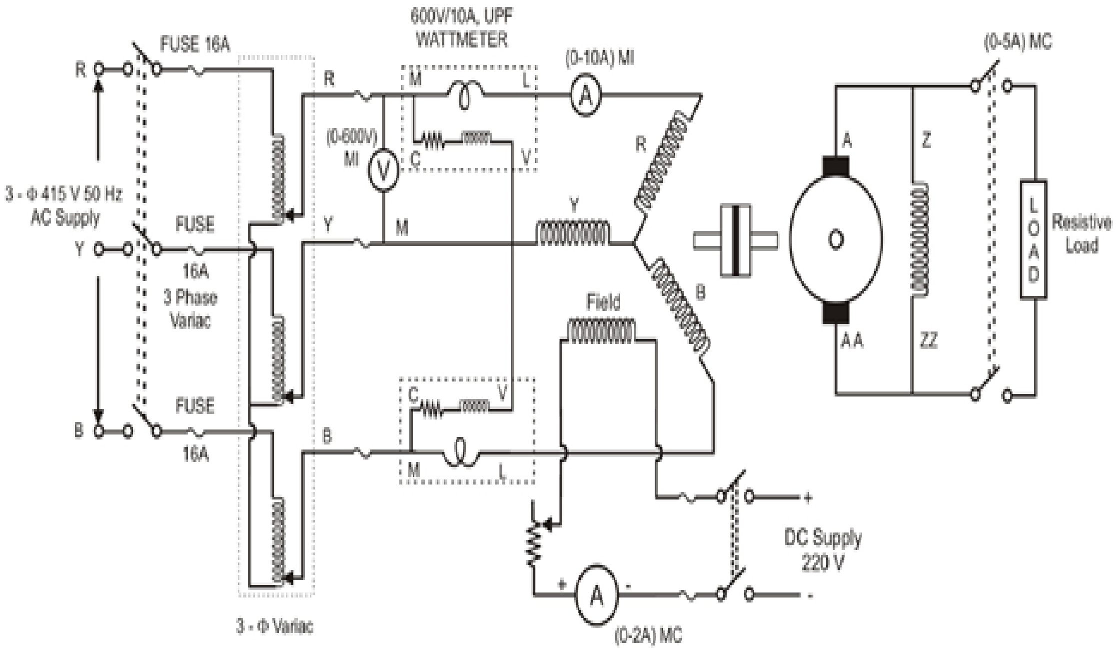


Figure 12.1: V and Inverted V-Curves of three phase Synchronous motor

2. Switch on the AC supply feeding to 3-phase synchronous motor and start the motor using 3-phase variac.
3. Ensure that the motor is running at no-load and synchronous Speed.
4. Now the field winding of the synchronous motor is exited with excitation unit.
5. Set the Rheostat of the field winding of the motor to the position of the normal excitation. (Here the armature current will draw the minimum current from the mains.)
6. Note down all meter readings at this position.
7. Decrease the excitation current in steps and note down ammeter and wattmeter readings. (Excitation current may be reduced till the rated armature current flows in the armature circuit of the synchronous motor) (If as Ia).
8. Again, set back rheostat position to normal excitation position, now increase the excitation in steps and note down all meter readings.
9. Repeat the step - 5, 6, 8, and 8 for half load and full load.

S. No	Fraction of Load	I_f	I_a	W_1	W_2	Cos Φ
1						
2						
3						
4						

Table 12.1: Measured values

10. Decrease the load on the motor and switch of the supply.

12.7 Model graph

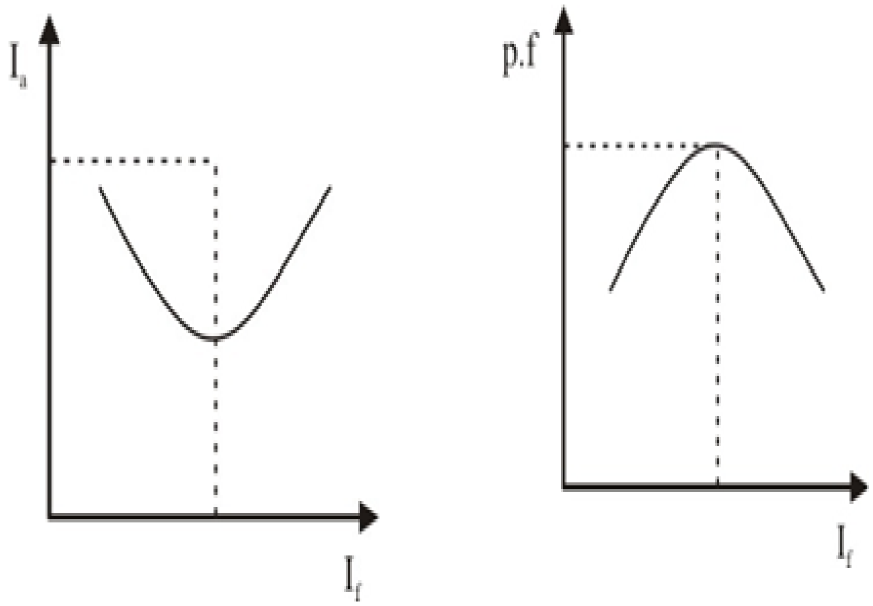


Figure 12.2: V and Inverted V-Curves of three phase Synchronous Motor

12.8 Probing Further Experiments

Q1. What could be the reason if a 3-phase synchronous motor fails to start
Q2. What is the significance of V and inverted V curve?

LAB-13 SLIP TEST ON THREE SALIENT POLE SYNCHRONOUS MOTOR

13.1 Introduction

Slip test is performed on salient pole synchronous machine to determine the direct axis reactance and quadrature axis reactance.

13.2 Objective

By the end of this lab, the student should learn how to determine direct and quadrature axis reactance's of synchronous motor

13.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

13.4 Equipment needed

1. DC Shunt motor (5 HP)
2. Three phase synchronous machine (3 KVA)
3. Three phase auto transformer
4. Rheostat (0-370 Ω / 1.7 A)
5. Two voltmeters (0-600 V) MI
6. Ammeter (0-10 A) MI
7. Tachometer
8. Connecting Wires.

13.5 Background

Direct and quadrature axis reactance's of a salient-pole synchronous machine can be estimated by means of a test known as the slip test. The machine armature is connected to a 3-phase supply whose voltage is much less than the rated voltage of the machine, while the rotor is run at speed close to synchronous with the field winding left open-circuited (unexcited) as shown in below figure. Since the excitation emf is zero, heavy currents would be drawn by the armature if connected to the rated voltage supply.

The currents drawn by the armature set up an MMF wave rotating at synchronous speed as shown in Fig. Since the rotor is being run at a speed close to synchronous, the stator MMF moves slowly past the field poles at slip speed (ns n). When the stator MMF is aligned with the d-axis (field poles), direct axis flux is set up so that effective reactance offered by the machine is Xd. Similarly, when the stator MMF aligns with the q-axis, the flux set up is direct axis flux/pole and the machine reactance is Xq. The current drawn by the armature therefore varies cyclically at twice the slip frequency as shown by the current waveform drawn in Fig. the rms current is minimum when machine reactance is Xd and is maximum when it is Xq. Because of cyclic current variations and consequent voltage drop in the impedance of supply lines (behind the mains), the voltage at machine terminals also varies cyclically and has a minimum value at maximum current and maximum value at minimum current as shown by the voltage waveform of Fig. The machine reactance's can be found as

$$X_d = \frac{V_t \text{ (at } I_a \text{ (min)) (line)}}{\sqrt{3}\, I_a \text{ (min)}}$$

$$X_q = \frac{V_t \text{ (at } I_a \text{ (max)) (line)}}{\sqrt{3}\, I_a \text{ (max)}}$$

The phenomenon of armature current going through maximum and minimum values during the slip test is also easily seen from Eqs.with Ef= 0

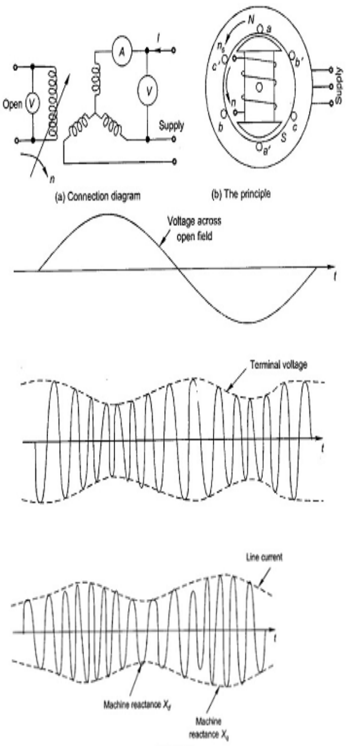
$$I_d = \frac{V_b}{X_d} \cos \delta, \qquad I_q = \frac{V_b}{X_q} \sin \delta$$

At $\delta = 0°$ (air-gap field axis oriented along d-axis),

$$I_a \text{ (min)} = I_d = \frac{V_b}{X_d}; \qquad I_q = 0$$

and at $\delta = 90°$ (air-gap field axis oriented along q-axis)

$$I_a \text{ (max)} = I_q = \frac{V_b}{X_q}; \qquad I_d = 0$$



Observation of the voltage induced in the field during the slip test is helpful in location of maxima/minima on current and voltage wave shapes. As the flux set up by armature currents moves past the rotor field, the flux linkage of the field vary and an emf of twice the slip frequency is induced in it. When the rotor field is aligned with the armature MMF, its flux linkages are maximum while the rate of change of flux linkage is zero, i.e. the voltage across the open field goes through zero at this instant which identifies Xd of the machine. It similarly follows that Xq is identified with the voltage maximum in the field. The wave of voltage across the open-field with reference to current and voltage waves at the armature is also shown in Fig.

Since current and voltage meters as connected in Fig. would oscillate at twice the slip frequency, the slip must be kept very small so that dynamics of the meters do not introduce errors in reading maximum/minimum values. Greater accuracy is achieved by using a recording oscillogram.

13.6 Procedure

1. Make the connections as per the circuit diagram.

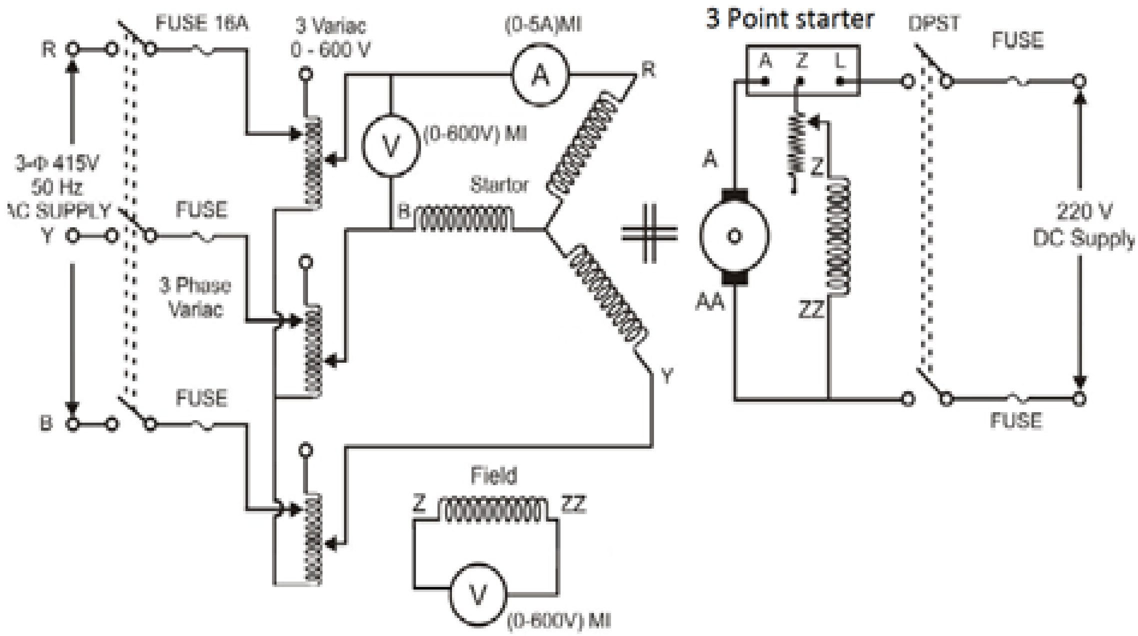


Figure 13.1: slip test

2. Run the alternator through the DC Motor at near synchronous speed, keeping the AC supply off. 3. Keeping the Variac output voltage at minimum, connect the AC supply to the variac. 4. Note that the field winding is to be kept open throughout. 5. Increase the Variac output voltage so that a reasonable current pass through the armature. 6. If the directions of rotation of the rotor and stator fields are the same, then a slight adjustment of speed causes significant oscillation of the armature current. Else reverse the direction of rotation of motor. 7. When the ammeter shows slow but wide oscillations note Imax and Imin and the corresponding voltages Vmin and Vmax and calculate Xd and Xq.

S. No	V_{min}	V_{max}	I_{min}	I_{max}	Xd	Xq
1						
2						
3						
4						

Table 13.1: Measured values

8. Using Xd and Xq, the regulation of the salient pole alternator at specified load condition can be determined using the appropriate phasor diagram.

13.7 Calculations:

$$X_d = \frac{Maximum\ Volts\ per\ phase}{Maximum\ Current\ per\ phase}$$

$$X_q = \frac{Minimum\ Voltage\ per\ phase}{Minimum\ Current\ per\ phase}$$

$$Tan\delta = \frac{I_a X_q\ Cos\phi - I_a R_a\ Sin\phi}{V + I_a R_a\ Cos\phi}$$

$$I_q = I_a Cos\psi$$

$$Id = Ia\ Sin\ \psi$$

$$\psi = \phi + \delta$$

$$Eo = V\ Cos\delta + I_q R_a + I_d X_d$$

$$\%\ \text{Regulation} = \frac{E_0 - V}{V}\ X\ 100$$

13.8 Probing Further Experiments

Q1. Explain the reason for oscillation in voltmeter reading during slip test?
Q2. What are the normal values of XQ XD for the two types of synchronous machine?

LAB-14 NO-LOAD AND BLOCKED ROTOR TEST ON SINGLE PHASE INDUCTION MOTOR

14.1 Introduction

To predict the performance of a single phase induction motor by knowing all the equivalent circuit parameters. These circuit parameters are supplied from no load and blocked rotor test. Without actually loading the induction motor, these two assessed tests give the test results which are used to determine the equivalent circuit parameters.

14.2 Objective

By the end of this lab, the student should learn how to determine the equivalent circuit parameters of single phase induction motor

14.3 Prelab Preparation:

Read the material in the textbook that describes open circuit and short circuit test. Prior to coming to the lab. Prior to coming to lab class, have glance of the Procedure.

14.4 Equipment needed

1. Single phase induction motor
2. Single phase auto transformer
3. Voltmeter (0-300 V) MI
4. Ammeter (0-10 A) MI
5. Watt meter (0-150/300 V, 5/10 A) LPF
6. Watt meter (0-150/300 V, 5/10 A) UPF
7. Tachometer
8. Connecting Wires

14.5 Background

The efficiency of small motors can be determined by directly loading them and by measuring the input and output powers. But in the case of large motors, it is difficult to arrange that much load for them. The power loss will be large if we directly test the load. Therefore, indirect methods are used to determine the efficiency of 3-phase induction motors.

We can perform the following test on the motor to find the efficiency:
1. No-Load test.
2. Blocked-rotor test.
No-Load test or Open-Circuit Test: The no-load test of an induction motor is similar to the open-circuit test of a transformer. The motor is not connected from its load, and the rated voltage at the rated frequency is applied to the stator to run the motor without a load. The 2-wattmeter method measures the input power of the system.
The voltmeter measures the standard-rated supply voltage and an ammeter measures the no-load current. Since the motor is running at no-load, total power is equal to the constant iron loss, friction and winding losses of the motor.
Pconstant = Pi = P1 + P2 = Sum of the two wattmeter readings.
Since the power factor of the induction motor under a no-load condition is generally less than 0.5, one wattmeter will show a negative reading. Therefore, it is, necessary to reverse the direction of current-coil terminals to take the reading.
Blocked Rotor or Short-Circuit Test: The blocked rotor test of an induction motor is same as the short-circuit test of a transformer. In this test, the shaft of the motor is connected so that it cannot move and rotor winding is short-circuited. In a slip-ring motor, the rotor winding is short-circuited through slip-rings and in cage motors, the rotor bars are permanently short-circuited. This test is also called the locked-Rotor test. When a reduced voltage at the reduced frequency is applied to the stator through a 3-phase auto-transformer so that full-load current flows in the stator, the following three readings are obtained.

14.6 Procedure

1. Make the connections as per the circuit diagram.

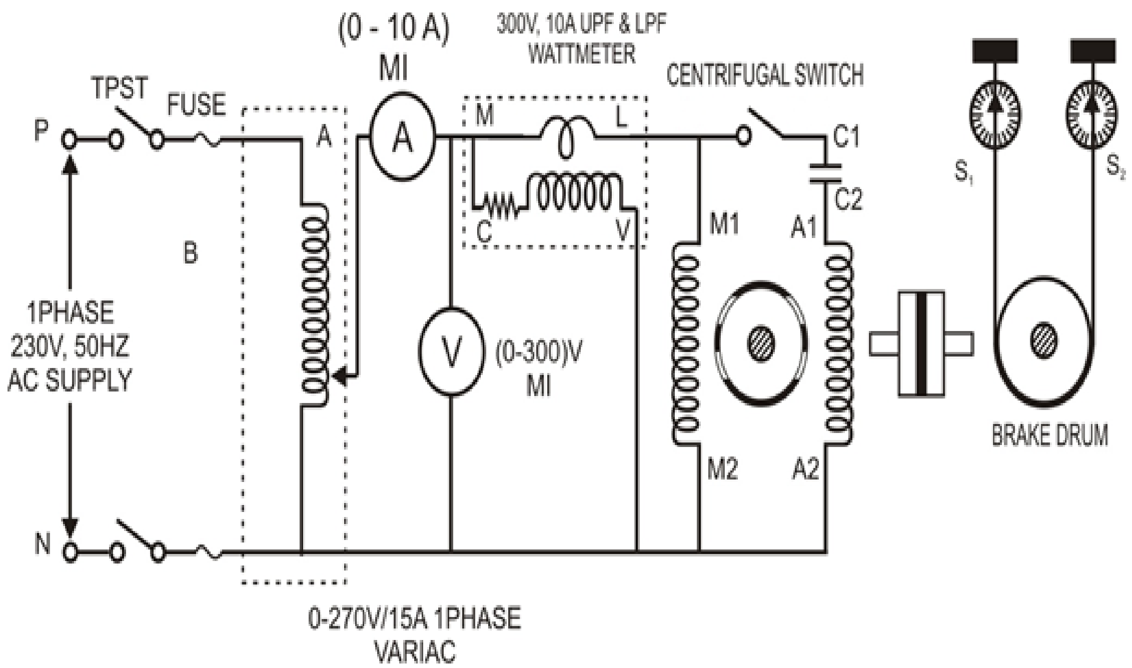


Figure 14.1:No load and blocked rotor test circuit

2. Apply the rated voltage to the induction motor by varying auto transformer, so that the machine runs at rated speed.
3. Note down the corresponding Ammeter, Voltmeter and Wattmeter readings.

S. No	V_0	I_0	W_0
1			

Table 14.1: Measured values

4. Restore the autotransformer to its initial position, and switch off the supply.

Blocked rotor test: 1. Connections are made as per the circuit diagram
2. Block the rotor with the help of brake drum arrangement.
3. Vary the supply voltage with the help of autotransformer so that the ammeter reads rated current and note down the corresponding Ammeter, Voltmeter and Wattmeter readings.

S. No	V_{sc}	I_{sc}	W_{sc}

Table 14.2: Measured values

4. Reduce voltage to zero with auto transformer and switch off the supply.

14.7 Probing Further Experiments

Q1. Does the motor start when supply lines are connected?
Q2. How can we reduce the starting current of an induction motor?