LABORATORY MANUAL

ELECTRICAL MACHINE LAB-II LAB

B.Tech. (Electrical Engineering), 4th Semester

Department of Electrical Engineering
Veer Surendra Sai University of Technology,
BURLA

Vision

To be recognized as a center of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

Mission

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

M1. Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.

M2. Fortifying collaboration with world class R& D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make in India' policy of the Government.

M3. Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

Program Educational Objectives

The program educational objectives of B.Tech. in Electrical Engineering program of VSSUT Burla are to prepare its graduates:

1. To have basic and advanced knowledge in Electrical Engineering with specialized knowledge in design and commissioning of electrical systems/renewable energy systems comprising of generation, transmission and distribution to become eminent, excellent and skilful engineers.
2. To succeed in getting engineering position with electrical design, manufacturing industries or in software and hardware industries, in private or government sectors, at Indian and in Multinational organizations.
3. To have a well-rounded education that includes excellent communication skills, working effectively on team-based projects, ethical and social responsibility.
4. To have the ability to pursue study in specific area of interest and be able to become successful entrepreneur.
5. To have broad knowledge serving as foundation for lifelong learning in multidisciplinary areas to enable career and professional growth in top academic, industrial and government/corporate organizations.

LIST OF EXPERIMENTS

2nd Cycle

1. Determination of power angle characteristics of an Alternator.
2. Load test of 3-Phase Induction Motor.
3. Determination of Parameters of single phase induction motor.
4. Separation of hysteresis and eddy current losses of single phase transformer.
5. Voltage regulation of 3-phase alternator by ZPF method.
6. Determination of Parameters of 3-phase three winding transformer and trace the waveform of Magnetising Current & Induced e.m.f.

COURSE OUTCOMES

Upon completion of this course, students will demonstrate the ability to:

CO1. Perform various tests on synchronous machines and to determine their characteristics.

CO2. Synchronize a given alternator to infinite bus.

CO3. Determine parameters of three phase and single phase induction motors.

CO4. Describe different losses of single phase transformer.

CO5. Determine characteristics, parameters and connections of three phase transformers.

Experiment 1

AIM OF THE EXPERIMENT:

To determine the power angle characteristics of a synchronous generator (Alternator).

OBJECTIVE:

To plot power angle characteristic of alternator at different excitations.

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

MACHINE SPECIFICATION:

DC Compound/shunt Motor: 16 HP, 220 V, 58 A, 1500 RPM

3-Ph Alternator: 8 KVA, 400/231 V, 11.5 A, 1500 RPM

THEORY:

The power angle characteristic is the relation between armature power and power angle of a synchronous machine at constant terminal voltage, frequency and excitation. The electrical power neglecting armature copper loss is

$$P = \frac{E_0 V}{X_d} Sin\delta$$

for cylindrical rotor machine and for a salient pole machine.

$$P = \frac{E_0 V}{X_d} Sin\delta + \frac{V^2}{2}\left(\frac{1}{X_d} - \frac{1}{X_q}\right) Sin\delta$$

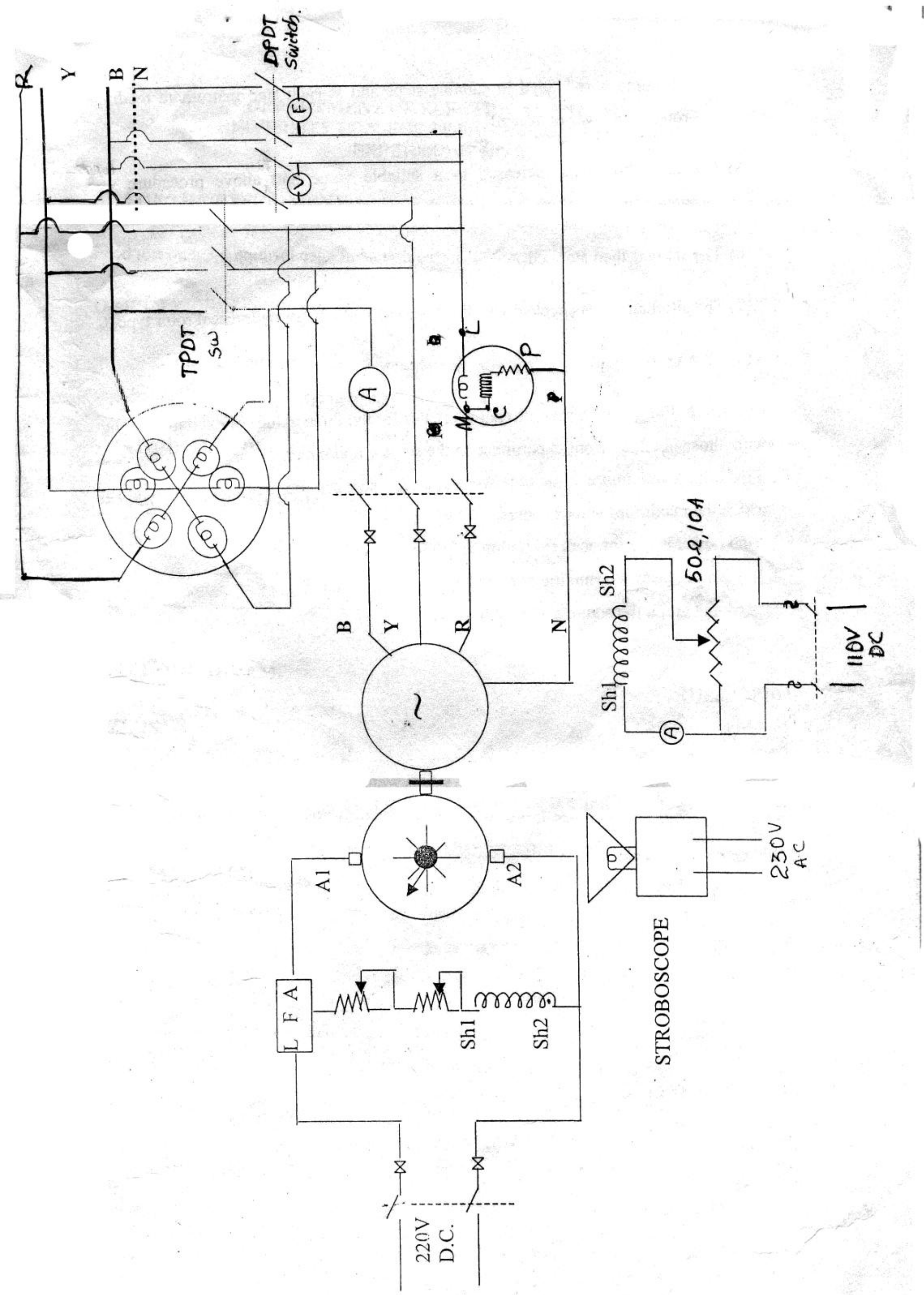
PROCEDURE:

(1) The instruments were connected as per circuit diagram.

(2) The alternator was synchronized with the bus bar.

(3) The initial position of the rotor was measured with the help of stroboscope.

CIRCUIT DIAGRAM:



(4) The machine was loaded in suitable steps and at each steps instrument readings and rotor angle was measured.

(5) The excitation was increased to a suitable value and above procedure was repeated and also the excitation was decreased below the no load value.

(6) The set was then stopped.

(7) The alternator was checked whether it was salient pole or cylindrical rotor type.

CALCULATION:

1. Calculate & Plot the power angle characteristics for the three values of excitation along with those obtained from experiment on the same graph paper.
2. Find out the maximum value of power output for each excitation and power angle at which the maximum values occurs.
3. Find power angle for each excitation at full load.
4. Determine the synchronizing coefficient for each excitation.
5. Mark the graph the stable and unstable region on the graph.

TABULTAION (for normal excitation, Under Excitation & Over Excitation)

Sl. No.	Excitation Field Current	Wattmeter Reading	Line Current	Power Angle

DISCUSSION:

CONCLUSION:

Experiment 2

AIM OF THE EXPERIMENT:

Load test on a 3-Phase squirrel cage induction motor.

OBJECTIVE:

To measure current, input, output, torque, slip, p.f. and efficiency of a 3-Phase squirrel cage induction motor on varying loads.

MACHINE SPECIFICATION:

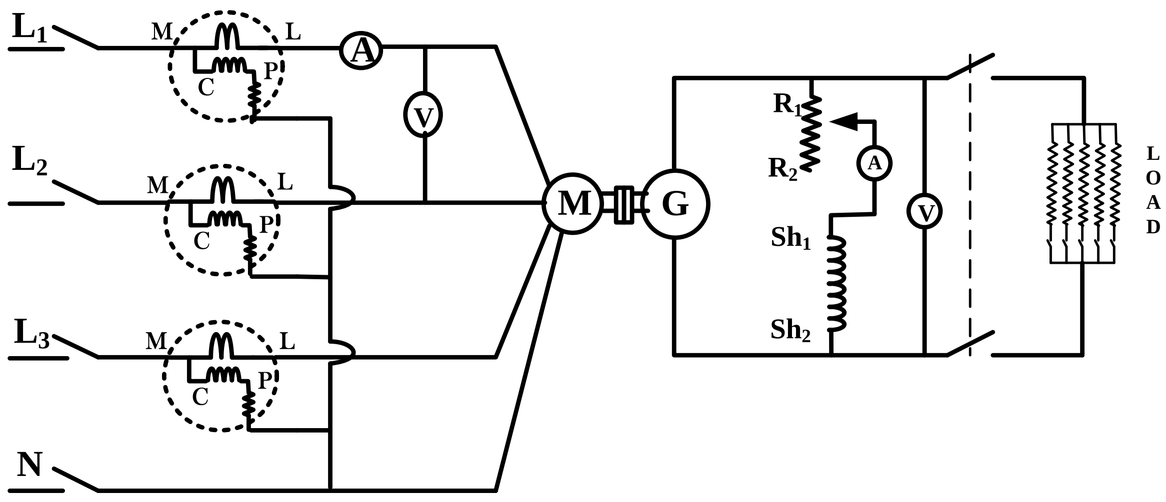
3-Ph Induction Motor: 15HP, 440 V, 21.7 A, 1450 RPM

DC Compound Generator: 7.5 KW, 220/230 V, 32 A, 1400 RPM

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

CIRCUIT DIAGRAM:-



THEORY:

Load test is carried out to know the performance of the m/c at different loads. It also helps to determine the performance and efficiency of the motor at difference temp.

Neglecting friction and wind-age losses, the power input of the motor = power developed in the motor. Again power output of the induction motor is power input to the generator. Assuming a suitable efficiency value of the DC generator and knowing the output of the generator, the output of the motor can be evaluated.

Hence knowing the power developed in the motor, the torque developed in the motor can be evaluated.

So torque $= \dfrac{P_m}{2\pi_r} N - m$

Where Pm = mechanical power output in watt

n_r = Rotor speed in rps

% age slip = $\dfrac{n_s - n}{n_s} x\ 100\%$

Where n_s = synchronous speed

n_r = rotor speed

TABULATION FOR LOAD TEST ON 3-PHASE SQUIRREL CAGE INDUCTION MOTOR:

Sl. No.	Supply Voltage (In Volts)	Line Current (In Amp)	Wattmeter Reading (In Kw)	Generator Voltage in Volts	Generator Current In Amp	Speed in rpm

PROCEDURE:

1. At first the circuit connection was made as per the circuit diagram.
2. Then the motor was started using Y-Δ Starter at no load. Then the different instrument readings were taken at no load.
3. The corresponding speed of the motor was noted by the help of stroboscope. The stroboscope was adjusted so that the motor looked like as if it was not moving.
4. Then the load was gradually increased by keeping the Vgen constant at 220V by moving the voltage adjustable wheel.
5. Then corresponding instrument reading and the speed of the motor by help of the stroboscope was noted down.
6. This procedure continued till the full load was applied on the motor.

TABULATION:

Sl. No.	V	I_L	W	V_g	I_g	N Rpm	P.F.	W O/p	T_L	Slip	η

SAMPLE CALCULATION:

DISCUSSION:

CONCLUSION:

Experiment 3

AIM OF THE EXPERIMENT:

To determine parameters of single phase induction motor (capacitor start induction motor) by performing no loads and block rotor test.

OBJECTIVE:

To measure input current, input power, output power, torque (both backward and forward) and efficiency of 1- Phase capacitor start induction motor.

MACHINE SPECIFICATION:

Induction Motor: 0.75 KW, 220 V, 6.9 A, 1400 RPM

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

THEORY:

For a 1-Phase induction motor, the equivalent circuit parameters can be measured from no load test, block rotor test and from measurement of stator winding resistance ‘r’.

(a) Block Rotor Test:

With the rotor at rest, 1-phase voltage applied to stator main winding is increased gradually from zero, so that rated current flows in the windings. Under these conditions, voltmeter, ammeter and wattmeter reading are noted, which are denoted by V_{SC}, I_{SC} and W_{SC} respectively.

$Z_{SC} = V_{SC}/I_{SC}$

Equivalent Resistance

$R_{SC} = W_{SC}/I^2_{SC}$

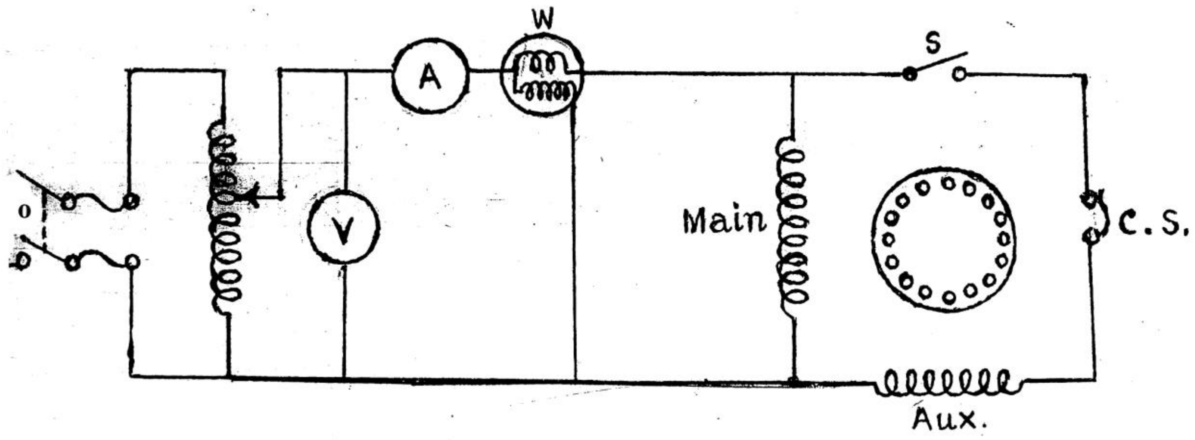
If r_1 = main stator winding resistance (measured previously)

Effective rotor resistance

$r_2 = R_{SC} - r_1$

Total reactance = $X_{SC} = X_1 + X_2$

CIRCUIT DIAGRAM:



SINGLE PHASE INDUCTION MOTOR

(b) No Load Test:

The 1-Phase induction motor under no load condition is run at rated voltage and frequency. Under these conditions slip is very less. So it may be assumed zero, so rotor resistance and inductance can be neglected.

Let the voltmeter, ammeter, wattmeter reading be V_1, I_{nl} and W_{nl} respectively then no load p.f.

$\cos\phi_{nl} = \dfrac{W_{nl}}{V_1 I_{nl}}$

No load equivalent impedance is

$Z_{nl} = V_1/I_{nl}$

$X_{nl} = Z_{nl}\sqrt{(1 - \cos^2\theta_{nl})} = Z_{nl}/\sin\theta_{nl}$

$Z_{nl} = \left(r_1 + \frac{r_2}{4}\right) + j[x_1 + ½(x_2 + x_m)]$

From above expression X_m can be found.

TABULATION

FOR OPEN CIRCUIT TEST

Sl. No.	Input Voltage	I/P Current	Input Power	Speed (rpm)

FOR BLOCK ROTOR TEST

Sl. No.	Input Current	Input Voltage	Input Power

FOR MEASUREMENT OF (STATOR) ARMATURE RESISTANCE

Sl. No.	Voltmeter Reading	Ammeter Reading	Resistance	Mean Resistance

PROCEDURE:

1. First for O.C. test circuit connection was done as per the circuit diagram. In this case LPF wattmeter was used.
2. The power supply was given to panel and the motor was switched on. Then the voltage was increased upto the rated voltage using variac gradually.
3. The rotor of motor was twisted by hand, so that it will not move, then voltage was decreased at regular interval and corresponding reading were taken from all the instruments.
4. Finally the voltage was made zero by the variac and the motor was switched off.
5. Then, for S.C. test circuit connection was done as per the circuit diagram. In this case u.p.f. wattmeter was used.
6. The motor was switched on and then the voltage was increased by the variac until the ammeter shows rated current reading. Then readings of all the instruments were taken.
7. The motor was switched off after reduction of voltage to zero.
8. Then, DC stator resistance was measured by giving DC supply to any two terminal of stator winding from DC panel.
9. By adjusting the current of circuit by the load box, different reading of voltmeter and ammeter were taken.
10. Finally DC resistance was calculated.

CALCULATION:

DISCUSSION:

CONCLUSION:

Experiment 4

AIM OF THE EXPERIMENT:

To separate the hysteresis and eddy-current losses of single phase transformer.

OBJECTIVE:

To determine the core loss at various voltages & frequency.

MACHINE SPECIFICATION:

DC Shunt motor (Prime-mover): 2.5 KW, 220 V (DC), 10 A, 1450 RPM

3-Ph Alternator/ Synchronous Generator: 3 KVA, 400 V, 4.5 A, 1500 RPM

Transformer: 230/115 V (2:1), 3 KVA

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

THEORY:

(A) At constant flux density in the core

Iron loss = $W_e = A_1 f + A_2 f^2$, f – frequency

or

$$\frac{W_e}{f} = A_1 + A_2 \text{ f}$$

Which is the equation of a straight line

Flux density will be constant if V/f is kept constant.

(B) The core loss depends upon flux density at constant frequency and the flux density depends upon applied voltage. Hence, the core loss will vary with voltage, if frequency is maintained constant.

PROCEDURE:

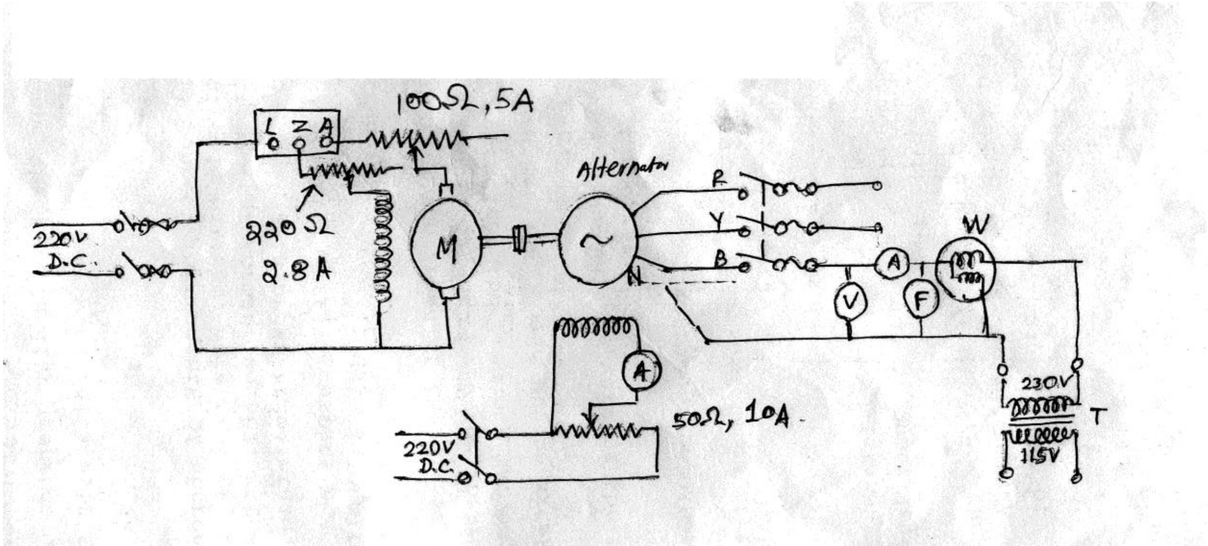
1. Connect instruments of appropriate ratings as per the circuit diagram. Note that the secondary is to be kept open. Transformer is supplied from an alternator in the laboratory in order to maintain V/f constant.

2. Adjust the field current and speed of the alternator so that the transformer is supplied with a voltage & f, such that v/f is constant. Note the instrument reading.

3. Vary the speed of the alternator keeping its field current constant. Note the instrument reading at various frequencies. The frequency may be varied from 25 to 60Hz.
4. Adjust the speed of the alternator to rated speed.
5. Vary the voltage varying the field current keeping the speed constant.
6. Record the instrument readings at various voltage.
7. Measure the d.c. resistance of the primary winding of the transformer.

CALCULATION AND GRAPHS:

1. Calculate the a.c. resistance of the primary winding.
2. Subtract the primary copper loss from the measured power to get the iron loss.
3. Plot a graph W/f Vs. F from the first set of readings. Determine the constants A_1 and A_2. Separate the hysteresis and eddy current losses and plot them taking frequency as the base.
4. Plot a no load current and Iron loss from the second set of readings, taking voltage along the x axis.
5. Find the values of hysteresis and eddy current loss at rate voltage and frequency.
6. Calculated the error in losses found graphically & from Instrument.



SEPARATION OF IRON LOSS OF A SINGLE PHASE TRANSFORMER

DISCUSSION:

1. Discuss the effect of magnetic saturation on the no load current and iron loss.
2. Explain why iron loss is less if the core is laminated.

CONCLUSION:

Experiment 5

AIM OF THE EXPERIMENT:

To determine the voltage regulation of a synchronous Generator by Zero power factor method (or Potier Triangle method)

OBJECTIVE:

To find voltage regulation at different p.f. of a synchronous generator by ZPF method.

MACHINE SPECIFICATION:

3-Ph Alternator/ Synchronous Generator: 400/440 V, 13 A ;

Excitation Circuit: 110 V(DC), Current(Max)- 6 A

DC Compound Motor: 15 HP, 58 A, 220 V, 1500 RPM

APPARATUS REQUIRED:

Sl. No.	Item	No. of Items	Rating

THEORY:

The two main factors which determine voltage regulations of an alternator are leakage reactance drop and drop due to armature reaction mmf. In this method the leakage reactance drop and armature reaction mmf can be separately determined. Therefore, this method is more accurate than the synchronous impedance method of determining the voltage regulation.

The reactive load for ZPF may be realized by using,

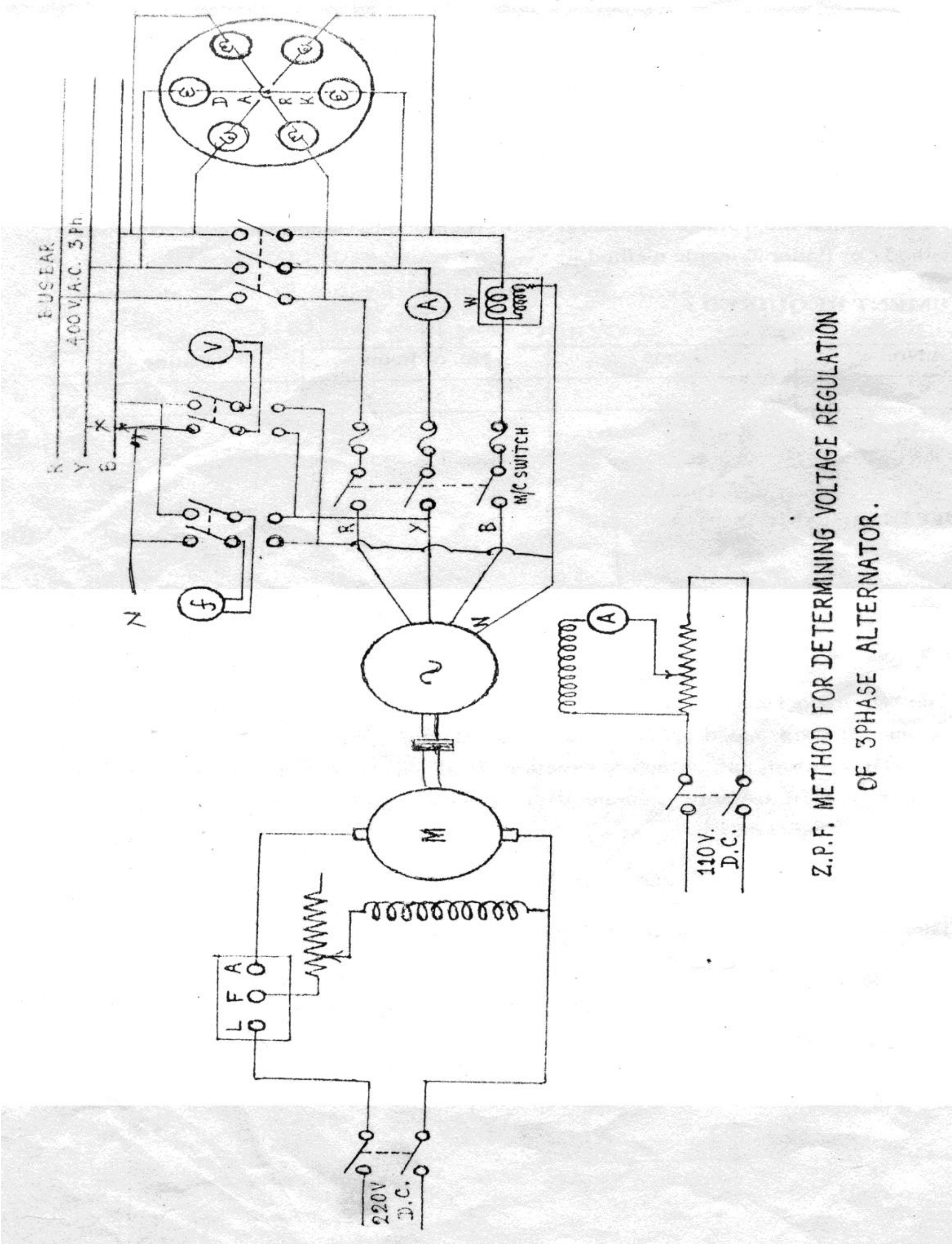
i) Three phase inductive load consisting of three choke coils, Or

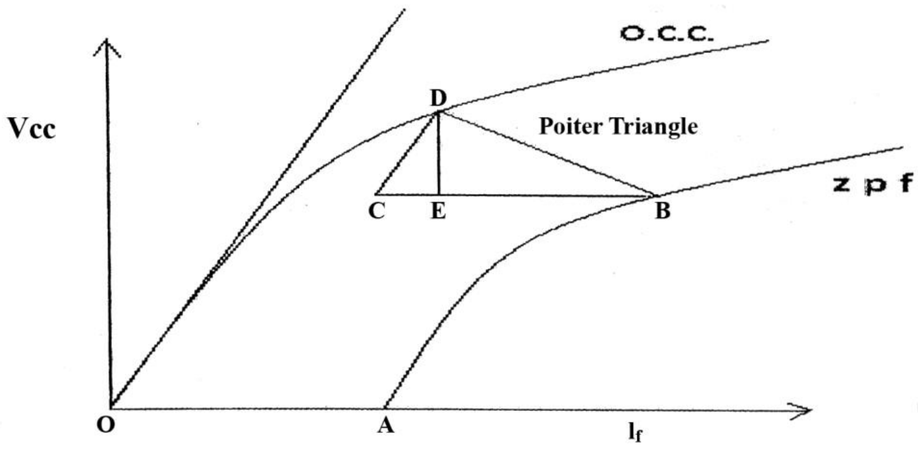
ii) An under excited synchronous machine to be tested is run as an over excited synchronous motor. This method is used in the Lab.

PROCEDURE:

1. Run the machine as generator and perform the OC & SC test. In the OC test the excitation should be increased to a value till the terminal voltage is about 1.25 times of the rated value. SC test is conducted at F.L. rating of the machine.
2. Adjust the frequency & the voltage and phase sequence of the machine with the bus bar then synchronise the machine to the infinite bus bar.
3. Disconnect the prime mover. The machine is running as a Synchronous motor.
4. Adjust the field excitation of the DC motor and make the power to zero. Increase the excitation of the machine until the rated current is obtained. Note the instruments reading and stop the set.

CIRCUIT DIAGRAM:-





CALCULATION:

- The resistance of the armature is measured and "IR_a" value is calculated.
- From the Potier Triangle "DE" gives the value of armature leakage reactance i.e. "IX_1". This value along with the resistive drop is added vectorially. This gives the value of "E".
- From the O.C.C. determine the respective field current for "E". Vectorially draw it 90^0 leading to "E". Now draw "BE" at an angle of "90+ θ" to "OD" and add them vectorially this give "OF".
- Now determine the terminal voltage at the field current obtained above from O.C.C. This gives the value the no-load terminal voltage i.e. "E_0".
- Now the voltage regulation can be calculated by using the formulae:

$$\%\eta = \left[\frac{(E_0 - V)}{V}\right] \times 100$$

Considering the case of the 0.8 pf lag:-

$$E^/ = ((V \cos ø + IRa)^2 + (V \sin ø + IX_1)^2)^{½}$$

The corresponding field current is OI_1

Therefore, the total field current is –

$$I = ((BE)^2 + (OI_1)^2 + 2 \text{ x } BE \text{ x } OI_1 \text{ x } \cos ø)^{½}$$

Voltage corresponding to the above value of "I" from O.C.C. graph is E_0.

% voltage regulation is = $\left(\frac{(E_0 - V)}{V}\right) \times 100$

Similarly the value of voltage regulation for 0.8 pf lead and unity pf is calculated.

GRAPH & DISCUSSION:

1. Plot the open circuit characteristics using p.u. values.
2. On the same graph paper and using the results of SC test and Z.P.F. test draw the Potier triangle and hence plot the zero power factor characteristic.
3. Obtain the leakage reactance drop and excitation necessary to overcome armature reaction mmf.
4. Calculate regulation at 0.8 lagging, unity and 0.8 leading power factor at full load.

NOTE:

The following basis may be used to convert actual quantity into PU values.

Rated voltage = 1.0 Rated current = 1.0 pu.

Excitation necessary to generate normal rated voltage at no load = 1.0 pu.

DISCUSSION

1. Discuss the difference between potier reactance and leakage reactance.
2. Discuss the accuracy of method of finding voltage regulation.
3. Explain how a synchronous motor operating at zero leading power factor is equivalent to a synchronous generator working at zero lagging power factor.

For no load and SC test keep synchronizing switch off. Open connection with dotted lines are for the S.C. the test.

For Z.P.F. test remove the short circuit and connect the ammeter to read line current.

PRECAUTION:

CONCLUSION:

Experiment 6

AIM OF THE EXPERIMENT:

Determination of parameter of a 3-phase 3-winding transformer and trace the waveform of magnetizing current and induced emf.

OBJECTIVE:

(i) To study the waveform of magnetizing current and induced emf.
(ii) To determine the parameter of star equivalent circuit.
(iii) To find voltage regulation of a 3 phase and 3 winding transformer connected in star/star/delta.

MACHINE SPECIFICATION:

3-Ph Transformer: 7.6 KVA, 50 Hz, 400/230/110 V, 12.5/13.1/13 A

APPARATUS REQUIRED:

Sl. No.	Item	No. of Items	Rating

THEORY:

The leakage impedance of the star equivalent circuit of a 3-winding transformer shown below can be determined from the results of three-circuit test.

All the quantity is referred to say the primary winding.

The three short circuit tests are as follows:

Test	Winding excited	Winding short circuited	Applied Voltage	Current in the short circuited winding
1	Primary	Secondary	V1	I2’ (ref. To Pr.)
2	Primary	Tertiary	V1	I3’ (ref. To Pr.)
3	Secondary	Tertiary	V2	I3’ (ref. To Pr.)

If Z_{12} is the short circuit impedance of branches 1 and 2 of the equivalent circuit with branch 3 open then

$$Z_{12} = Z_1 + Z_2$$

$$= (r_1 + r_2) + j(x_1 + x_2) = V_1/I_2$$

$$Z_{13} = Z_1 + Z_3 = (r_1 + r_3) + j(x_1 + x_3) = V_1/I_3$$

$$Z_{23} = Z_2 + Z_3 = (r_2 + r_3) + j(x_2 + x_3) = V_2/I_3$$

Solution of the above equation gives:

$Z_1 = ½ (Z_{12} + Z_{13} – Z_{23})$

$Z_2 = ½ (Z_{12} + Z_{23} – Z_{13})$

$Z_3 = ½ (Z_{13} + Z_{23} – Z_{12})$

CALCULATION:

Find E_{r1}, E_{r2}, E_{r3} be p.u. resistive drops (w.r.t. primary) for winding 1,2, & 3.

and E_{x1}, E_{x2}, E_{x3} be p.u. reactance (w.r.t. primary) for winding 1, 2 & 3.

For 1^0 winding, the p.u. voltage regulation is

$$E_1 = K_1 (E_{r1} \cos \emptyset_1 + E_{x1} \sin \emptyset_1)$$

Where Cos $\emptyset_1$ operating power factor of winding 1 and K_1 = primary winding/ base KVA.

For secondary winding alone,

$$E_2 = K_2 (E_{r2} \cos \emptyset_2 + E_{x2} \text{Sin } \emptyset_2)$$

Where, Cos $\emptyset_2$ operating power factor of winding 2 and K_2 = secondary loading KVA/Base KVA

Similarly regulation can be found for tertiary winding alone also, with given Cos $\emptyset_3$ and K_2.

The voltage regulation for any pair of winding can be obtained by the algebraic sum of individual voltage regulation of this spare under consideration, if power flows from one to another.

Now, voltage regulation from secondary to tertiary

$$E_{23} = E_2 – E_3$$

And from tertiary to secondary is,

$$E_{32} = E_3 – E_2$$

As power doesn't flow from secondary to tertiary or from tertiary to secondary.

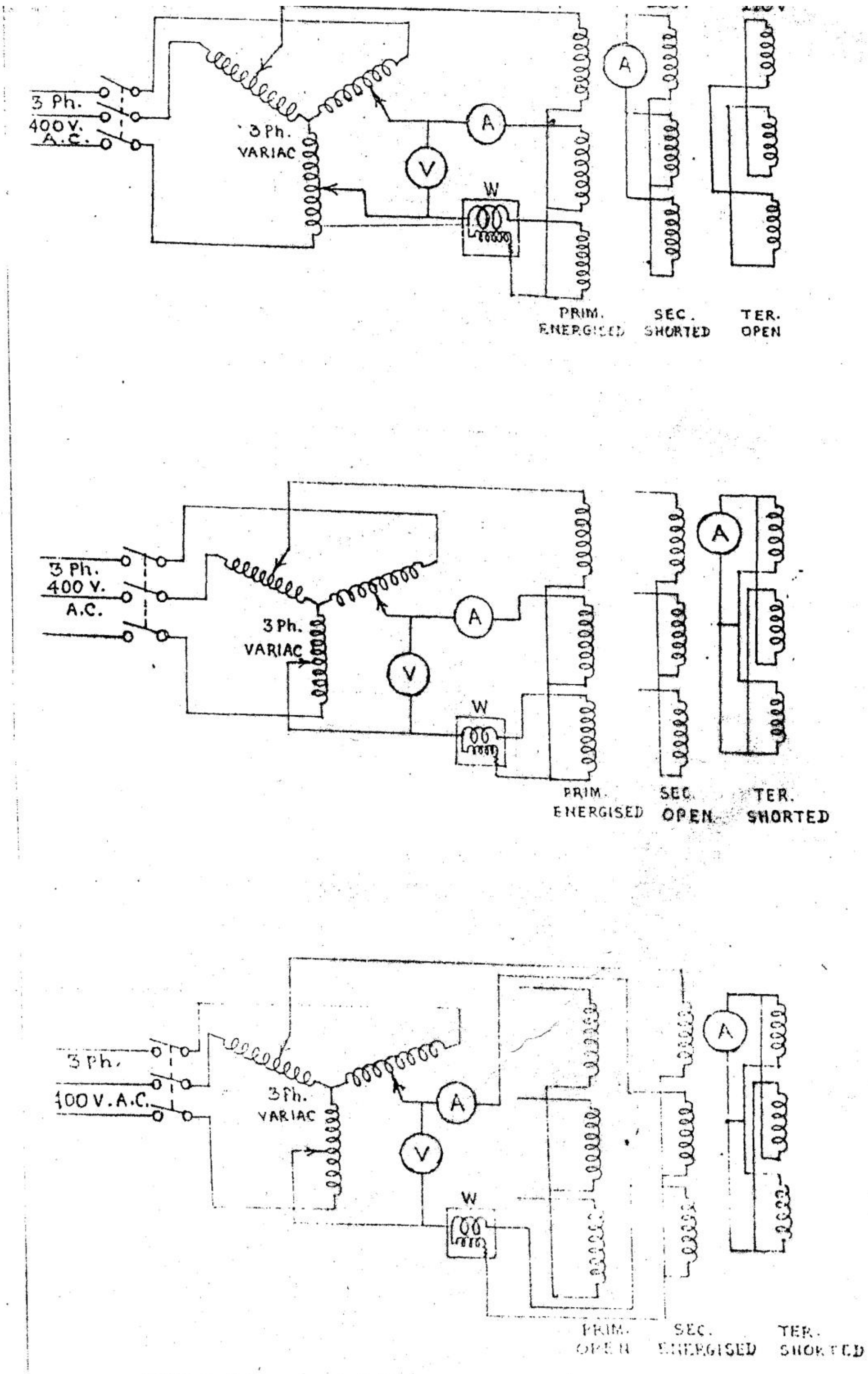
Voltage regulation from primary to secondary and from primary to tertiary are:

$E_{12} = E_1 + E_2$ $E_{13} = E_1 + E_3$

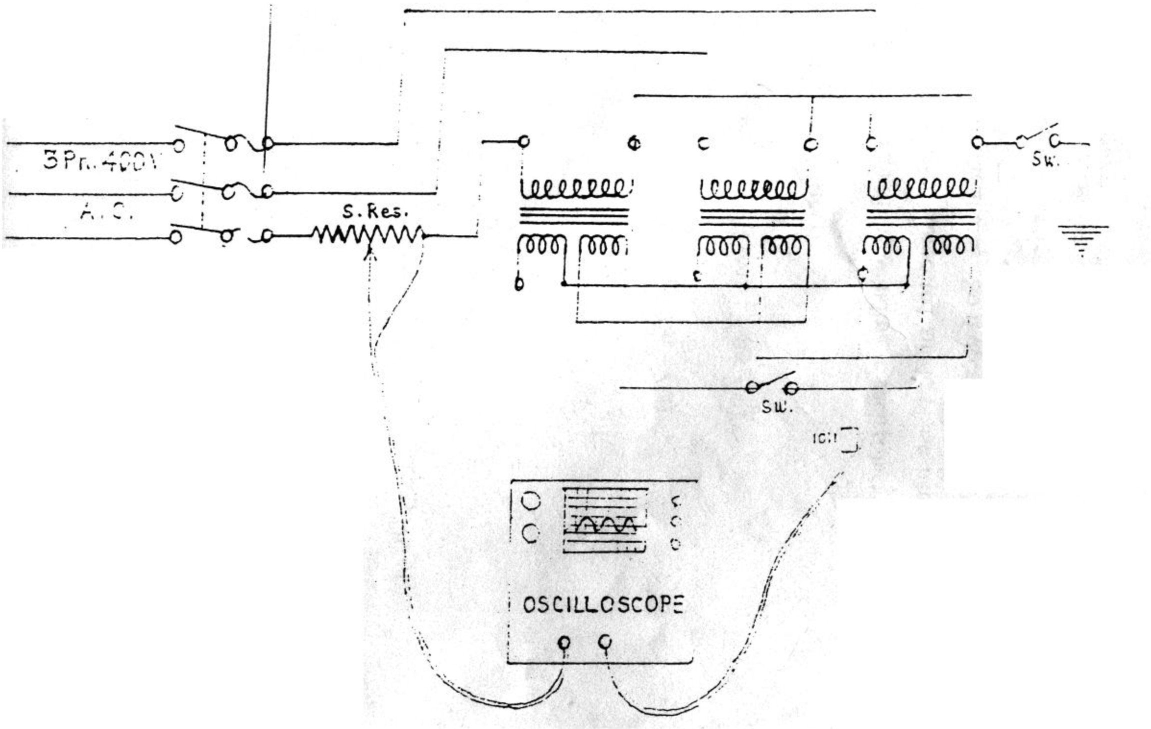
Similarly, regulation from secondary to primary and from tertiary to primary are

$E_{21} = -(E_1+E_2)$ $E_{31} = - (E_1, E_3)$

Negative sign is used here, as voltage regulation is determined from secondary to primary where as power flows from primary to secondary.



DETERMINATION OF EQUIVALENT CIRCUIT PARAMETERS OF A THREE PHASE THREE WINDING TRANSFORMER



STUDY OF MAGNETISING CURRENT AND SEC. INDUCEI VOLTAGE WAVE SHAPE OF A 3 Phase 3 WINDING TRANSFORMER

TERTIARY WINDING:

This is an auxiliary winding in each transformer connected in delta and applied to star-star or star-delta connected single phase banks to provide a closed path in which triple current can circulates. So it decreases the zero phase sequence impedance.

DISCUSSION:

CONCLUSION: