



BEE
LABARATORY MANUAL

DEPARTMENT OF ELECTRICAL ENGINEERING

PREFACE

Engineering institutions have been modernizing and updating their curriculum to keep pace with the continuously developing technological trends so as to meet the correspondingly changing educational demands of the industry. As the years passed by, multi-disciplinary education system also has become more and more relevant in the present global industrial development. Thus, just as Computer Systems & Applications, *Basic Electrical & Electronics Engineering* also has become an integral part of all the industrial and engineering sectors be it infrastructure, power generation, minor & major Industries, Industrial Safety or process industries where automation has become an inherent part. Accordingly, several universities have been bringing in a significant change in their graduate programs of engineering starting from the first year to meet the needs of these important industrial sectors to enhance the employability of their graduates. Thus, at college entry level itself *Basic Electrical & Electronics Engineering* has become the first Multidisciplinary core engineering subject for almost all the other core engineering branches like Civil, Mechanical, Production engineering, Industrial Engineering, Aeronautical, Instrumentation, Control Systems and Computer Engineering. As a further impetus, since for understanding of this subject a practical knowledge is equally important, a laboratory course is also added in the curriculum. The experiments are so chosen that the student comprehends all the important theoretical concepts with good practical insight.

This handbook of Laboratory manual cum Observations for *Basic Electrical and Electronics Engineering* is brought out in a simple and lucid manner highlighting the important underlying concepts & objectives along with sequential steps to conduct the experiment. Every experiment is further provided with format of test results and most importantly the safety precautions to be taken.

INSTRUCTIONS TO STUDENTS

1. Before entering the lab, the student should carry the following things.
 - Identity card issued by the college.
 - Class notes.
 - Lab observation book/ Lab Manual.
 - Lab Record.
2. Student must sign in and sign out in the register provided when attending the lab session without fail. Students need to maintain 100% attendance in lab if not a strict action will be.
3. Come to the laboratory in time. Students, who are late more than 15 min., will not be allowed to attend the lab.
4. All students must follow a **Dress Code** while in the laboratory
5. Foods, drinks are NOT allowed and all bags must be left at the indicated place.
6. The objective of the laboratory is learning. The experiments/ demonstrations are designed to illustrate the need and operation of an equipment/ machine and to expose you, how to use different measuring instruments in industry or our daily life, conduct the experiments with interest and an attitude of learning
7. Students must take care of their valuable things, Work quietly and carefully.
8. Be honest in recording and representing your data.
9. If a particular reading appears wrong repeat the measurement carefully, to get a better fit for a graph
10. All presentations of data, tables and graphs calculations should be neatly and carefully done
11. If you finish early, spend the remaining time to complete the calculations and drawing graphs. Graphs should be neatly drawn with pencil. Always label graphs and the axes and display units.
12. Come equipped with calculator, scales, pencils etc. Before entering to lab, must **prepare for Viva** for which they are going to conduct experiment.
13. Do not fiddle with apparatus. Handle instruments with care. Report any breakage to the Instructor.
14. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.
15. Any damage of the equipment or burn-out of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.

DO'S AND DON'TS

DO'S:

- Proper Dress Has to Be Maintained While Entering in The Lab. (Boys Tuck in And Shoes, Girls with Apron).
- Students Should Carry Observation Notes and Record Completed in All Aspects.
- Correct Specifications of The Equipment Have to Be Mentioned in The Circuit Diagram.
- Student Should Be Aware of Operating Equipment.
- Students Should Be at Their Concerned Experiment Table, Unnecessary Moment Is Restricted.
- Student Should Follow the Indent Procedure to Receive and Deposit the Equipment from The Lab Store Room.
- After Completing the Connections Students Should Verify the Circuits by The Lab Instructor.
- The Readings Must Be Shown to The Lecturer In-Charge for Verification.
- Before Leaving the Lab, Students Must Ensure That All Switches Are in The Off Position and All the Connections Are Removed.
- All Patch Cords and Stools Should Be Placed at Their Original Positions.

DON'Ts:

- **Don't** Come Late to The Lab.
- **Don't** Enter into The Lab with Golden Rings, Bracelets and Bangles.
- **Don't** Make or Remove the Connections with Power On.
- **Don't** Switch on The Supply Without Verifying by The Staff Member.
- **Don't** Switch Off the Machine with Load.
- **Don't** Leave the Lab Without the Permission of The Lecturer In- Charge.

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Experiment No. 1 (A)

Aim:

Basic safety precaution, Introduction and use of measuring instruments – voltmeter, ammeter, multi-meter. Real-life resistors, capacitors and inductors.

APPARATUS REQUIRED:

S. No.	Name of apparatus	Type	Range	Quality
1.	Ammeter	MI, MC	(0-2)A AC, (0-1) A DC	As required
2.	Voltmeter	MI, MC	(0-300)V AC, (0-20) V DC	As required
3.	Multimeter	DIGITAL	-	1
4.	Resistors	Fixed, Variable	-	As required
5.	Capacitors	Fixed, Variable	-	As required
6	Inductors	Fixed, Variable	-	As required

THEORY

Ammeter:

Ammeter is an electronic instruments device used to determine the electric current flowing through a circuit. Ammeters measuring current in milli-ampere range is known as milli-ammeters. Common types of ammeters are moving-coil ammeter and moving-iron ammeter. Ammeters are connected in series to the circuit whose current is to be measured. Hence this electronic instruments are designed to have as minimum resistance/loading as possible.

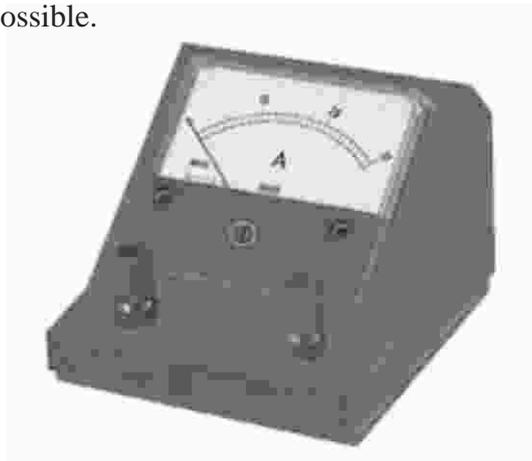
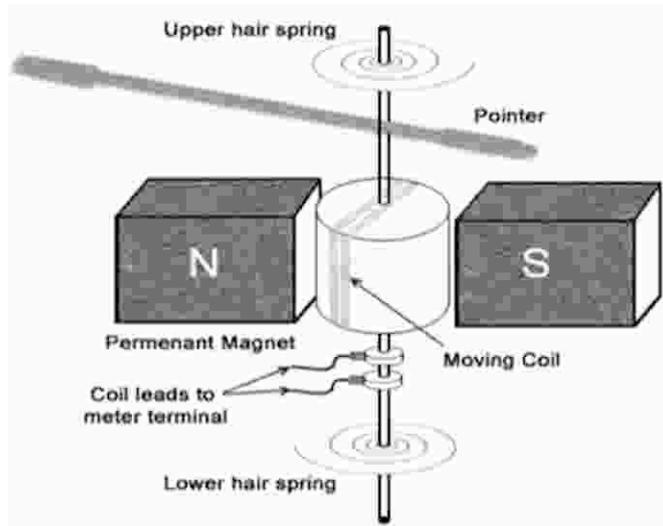


Fig. 1(a).1 Ammeter- Electronic Instruments

Moving Coil Ammeter:

Moving coil ammeters are used to measure DC Currents. This electronic instruments consists of a coil suspended by two hair springs. This coil is placed in a magnetic field created by a fixed permanent magnet. A torque is experienced when current passes through this coil which is proportional to the current. When the coil turns, the springs will exert a restoring force proportional to the angle turned. By these two forces, the coil



will stop at some point and the angular deflection will be proportional to the current.

Fig. 1(a).2 Moving coil ammeter

Moving Iron Ammeter:

Moving iron ammeters as electronic instruments can be used for measuring both direct and alternating currents in electronics lab. In this type of ammeter, a piece of soft iron is used. This iron piece constitutes of a moving vane and a fixed vane. Current to be checked flows through a fixed coil placed around the iron piece. This coil produces a magnetic field proportional to the current. So the iron pieces will get magnetized with the same polarity. The movable vane turns away from the fixed vane due to magnetic repulsion. As the iron turns, the spring of the electronic instruments will exert a restoring force and stop the vane, when both the forces become equal. The pointer of the ammeter is attached to the movable vane, which will point to the proper current reading using a calibrated scale.

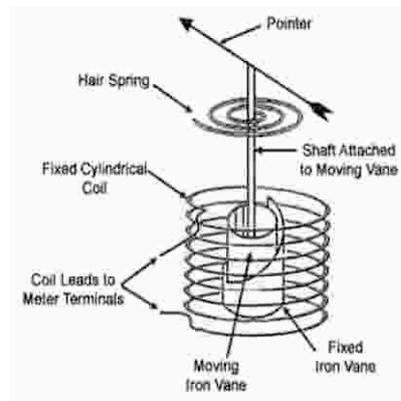


Fig. 1(a).3 Moving Iron Ammeter

Voltmeter:

Voltmeter is an electronic instruments used in an electric circuit to determine the potential difference or voltage between two different points. Digital and analog voltmeters are available in electronics lab. They are usually connected in parallel (shunt) to the circuit. Hence they are designed to have maximum resistance as possible to reduce the loading effect. This device is also common in electronics lab.



Fig.1 (a).4 (i) Analog Voltmeter

(ii) Digital Voltmeter

Analog Voltmeter:

Analog voltmeter is a type of voltmeter and electronic instruments with an extra connection of a series resistor (high resistance). It consists of a movable coil placed in a magnetic field. The coil ends are connected to the measuring terminals. As current flows across the coil, it will start turning due to magnetic force exerted on the coil and thus the hair spring will stop the coil by an equal and opposite restoring force. Angular rotation will be proportional to the voltage in this electronic instruments.

Digital Voltmeter

Digital voltmeters can measure both AC and DC measurements with high accuracy as an electronics instrument. It can measure a high voltage up to 1 kV. Main component of a digital voltmeter is an Analog to Digital Converter (ADC). Voltage to be measured is amplified or attenuated properly by the circuit and the output is sent to an Analog to Digital Converter (ADC) IC. This IC will convert the analog signal input to digital signal output. A digital display driven by this IC will display the proper voltage value.

Digital Multi Meter (DMM)

A multimeter or a multimeter, also known as a VOM (Volt-Ohm meter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter would include basic features such as the ability to measure voltage, current, and resistance. Analog multimeters use a micro ammeter whose pointer moves over a scale calibrated for all the different measurements that can be made. Digital multimeters (DMM, DVOM) display the measured value in numerals, and may also display a bar of a length proportional to the quantity being measured. Digital multimeters are now far more common than analog ones, but analog multimeters are still preferable in some cases, for example when monitoring a rapidly-varying value.

A multimeter can be a hand-held device useful for basic fault finding and field service work, or a bench

instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as electronic equipment, motor controls, Domestic appliances, power supplies, and wiring systems.

Operation:

A multimeter is a combination of a multi range DC voltmeter, multi range AC voltmeter, multi range ammeter, and multi range ohmmeter. An un-amplified analog multimeter combines a meter movement,

range resistors and switches.

For an analog meter movement, DC voltage is measured with a series resistor connected between the meter movement and the circuit under test. A set of switches allows greater resistance to be inserted for higher voltage ranges. The product of the basic full-scale deflection current of the movement, and the sum of the series resistance and the movement's own resistance, gives the full-scale voltage of the range. As an example, a meter movement that required 1 mill ampere for full scale deflection, with an internal resistance of 500 ohms, would, on a 10-volt range of the multimeter, have 9,500 ohms of series resistance. For analog current ranges, low-resistance shunts are connected in parallel with the meter movement to divert most of the current around the coil. Again for the case of a hypothetical 1 mA, 500 ohm movement on a 1 Ampere range, the shunt resistance would be just over 0.5 ohms.

Moving coil instruments respond only to the average value of the current through them. To measure alternating current, a rectifier diode is inserted in the circuit so that the average value of current is non-zero. Since the rectified average value and the root-mean-square value of a waveform need not be the same, simple rectifier-type circuits may only be accurate for sinusoidal waveforms. Other wave shapes require a different calibration factor to relate RMS and average value. Since practical rectifiers have non-zero voltage drop, accuracy and sensitivity is poor at low values.

To measure resistance, a small battery within the instrument passes a current through the device under test and the meter coil. Since the current available depends on the state of charge of the battery, a multimeter usually has an adjustment for the ohms scale to zero it. In the usual circuit found in analog multimeters, the meter deflection is inversely proportional to the resistance; so full-scale is 0 ohms, and high resistance corresponds to smaller deflections. The ohms scale is compressed, so resolution is better at lower resistance values.

Amplified instruments simplify the design of the series and shunt resistor networks. The internal resistance of

the coil is decoupled from the selection of the series and shunt range resistors; the series network becomes a voltage divider. Where AC measurements are required, the rectifier can be placed after the amplifier stage, improving precision at low range.



Fig 1(a).5 Digital Multi meter

Digital instruments, which necessarily incorporate amplifiers, use the same principles as analog instruments for range resistors. For resistance measurements, usually a small constant current is passed through the device under test and the digital multimeter reads the resultant voltage drop; this eliminates the scale compression found in analog meters, but requires a source of significant current. An auto ranging digital multimeter can automatically adjust the scaling network so that the measurement uses the full precision of the A/D converter.

In all types of multimeters, the quality of the switching elements is critical to stable and accurate

measurements. Stability of the resistors is a limiting factor in the long-term accuracy and precision of the instrument.

Quantities measured

Contemporary multimeters can measure many quantities. The common ones are:

- Voltage, alternating and direct, in volts.
- Current alternating and direct in amperes.

The frequency range for which AC measurements are accurate must be specified.

- Resistance in ohms.

Additionally, some multimeters measure:

- Capacitance in farads.
- Conductance in Siemens.
- Decibels.
- Duty cycle as a percentage.
- Frequency in hertz.
- Inductance in henrys.
- Temperature in degrees Celsius or Fahrenheit, with an appropriate temperature test probe, often a thermocouple.

Digital multimeters may also include circuits for:

- Continuity tester; sounds when a circuit conducts
- Diodes (measuring forward drop of diode junctions), and transistors (measuring current gain and other parameters)
- Battery checking for simple 1.5 volt and 9 volt batteries. This is a current loaded voltage scale which simulates in-use voltage measurement.

RESISTANCE & RESISTOR

The electrical resistance of an electrical element measures its opposition to the passage of an electric current; the inverse quantity is electrical conductance, measuring how easily electricity flows along a certain path. Electrical resistance shares some conceptual parallels with the mechanical notion of friction. The SI unit of electrical resistance is the ohm (Ω), while electrical conductance is measured in Siemens (S).

An object of uniform cross section has a resistance proportional to its resistivity and length and inversely

proportional to its cross-sectional area. All materials show some resistance, except for superconductors, which have a resistance of zero.

The resistance of an object is defined as the ratio of voltage across it to current through it:

$$R = \frac{V}{I}$$

Such materials are called Ohmic materials. For objects made of ohmic materials the definition of the resistance, with R being a constant for that resistor, is known as Ohm's law. In the case of a nonlinear conductor (not obeying Ohm's law), this ratio can change as current or voltage changes; the inverse slope of a chord to an I–V curve is sometimes referred to as a "chordal resistance" or "static resistance".



Fig. 1(a).6 Resistor

DC resistance

The resistance of a given resistor or conductor grows with the length of conductor and specific resistivity of the material, and decreases for larger cross-sectional area. The resistance R and conductance G of a conductor of uniform cross section, therefore, can be computed as

$$R = \rho \frac{L}{A}$$

$$G = \sigma \frac{A}{L}$$

where L is the length of the conductor, measured in meters [m], A is the cross-section area of the conductor measured in square meters [m²], σ (sigma) is the electrical conductivity measured in Siemens per meter (Sm⁻¹), and ρ (rho) is the electrical resistivity (also called specific electrical resistance) of the material, measured in ohm-meters (Ω m). Resistivity is a measure of the material's ability to oppose electric current. For purely resistive circuits conductance is related to resistance R by:

$$G = \frac{1}{R}$$

For practical reasons, any connections to a real conductor will almost certainly mean the current density is not totally uniform. However, this formula still provides a good approximation for long thin conductors such as wires.

AC resistance

A wire carrying alternating current has a reduced effective cross sectional area because of the skin effect.

Adjacent conductors carrying alternating current have a higher resistance than they would in isolation or when carrying direct current, due to the proximity effect. At commercial power frequency, these effects significant for large conductors carrying large currents, such as bus bars in an electrical substation, or large power cables carrying more than a few hundred amperes.

When an alternating current flows through the circuit, its flow is not opposed only by the circuit resistance, but

also by the opposition of electric and magnetic fields to the current change. That effect is measured by electrical reactance. The combined effects of reactance and resistance are expressed by electrical impedance.

Measuring resistance

An instrument for measuring resistance is called an ohmmeter. Simple ohmmeters cannot measure low resistances accurately because the resistance of their measuring leads causes a voltage drop that interferes with the measurement, so more accurate devices use four-terminal sensing.

Temperature dependence

Near room temperature, the electric resistance of a typical metal increases linearly with rising temperature, while the electrical resistance of a typical semiconductor decreases with rising temperature. The amount of that change in resistance can be calculated using the temperature coefficient of resistivity of the material using the following formula:

$$R(T) = R_0[1 + \alpha(T - T_0)]$$

Where T is its temperature, T_0 is a reference temperature (usually room temperature), R_0 is the resistance at T_0 , and α is the percentage change in resistivity per unit temperature. The constant α depends only on the material being considered. The relationship stated is actually only an approximate one, the true physics being somewhat non-linear, or looking at it another way, α itself varies with temperature. For this reason it is usual to specify the temperature that α was measured at with a suffix, such as α_{15} and the relationship only holds in a range of temperatures around the reference.

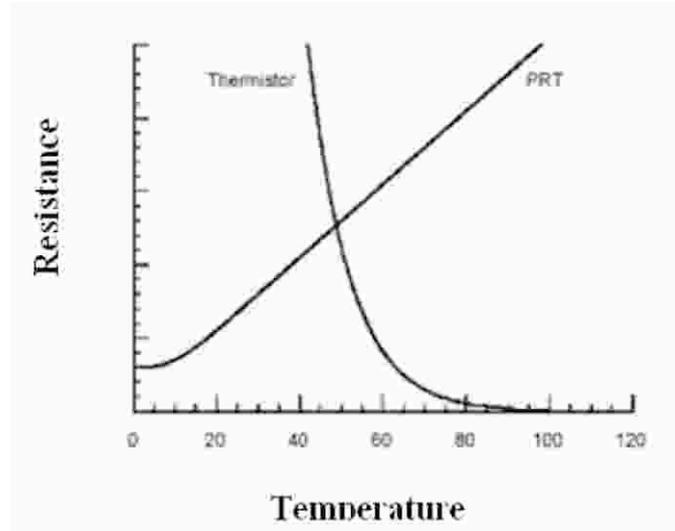


Fig. 1(a).7: Temperature characteristics of resistance

INDUCTANCE AND INDUCTOR

I. Elementary Characteristics

The coil in the figure simulates an inductor. The main issue is how the magnetic field lines go across the inductor (lines with arrows). There is some magnetic field at the top bottom of the coil too.

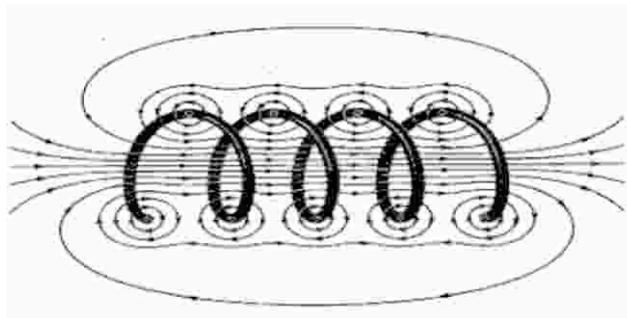


Fig. 1(a).8 Elementary characteristics

The current I going through the inductor generate a magnetic field which is perpendicular to I . The Magnetic Field H is given by the loops that surround the current I . The direction of the Magnetic Field is given by the arrows around the loops. If the current was to flow in the opposite direction the Magnetic



Field arrows would be reversed. For a practical display of this phenomena see: Magnetic field on wire.

Fig. 1(a).8 Magnetic field on wire

It is the Magnetic Field which contains the current through the coil which by the principle called Self-Induction will induce a voltage V . More specifically speaking, the voltage V across the inductor L is given by: $V = \Delta\Phi/\Delta T$ which reads – the voltage V is caused by the change in flux over the correspondent change in time, but since the change in flux is given by the inductance L and the change in current across the coil ΔI , the voltage V becomes:

$$V = L \frac{\Delta I}{\Delta T} \text{(Electrical definition for inductance)}$$

On the other hand the physical definition of inductance L is given by:

$$L = \mu N^2 \frac{A}{l} \text{(Physical definition for inductance)}$$

where μ stands for the relative ease with which current flows through the inductor or Permeability of the medium. N stands for the number of turns in the coil, A stands for its cross-sectional area, and the length of the coil is given by l . Hence this formula tells us that the more number of turns the larger the inductance (i.e.: current can be contained better), also the larger the cross-sectional area the larger the inductance (since there is more flux of current that can be contained) and the longer the coil the smaller the inductance (since more current can be lost through the turns). L is also proportional to μ , since the better the permeability current will flow with more ease.

Inductance and Energy

By containing the current via the magnetic field the inductor is capable of storing Energy. A Transformer such as the one on the Figure will certainly remind us of the ability of storing Energy associated with Inductors. Whereas for a capacitor the Energy stored depends on the Voltage across it, for the inductor the

$$W = \frac{1}{2} LI^2 \text{ Where } W \text{ stands for the energy on the inductor}$$

Basic Inductor Circuit

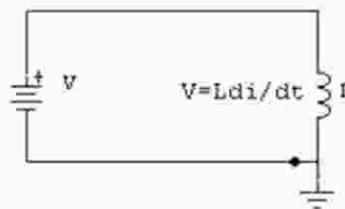


Fig. 1(a).9 Basic inductor circuit

The electrical parameters V and L (the inductance -measured in Henrys-H - review DC Basics or go to are given. The current I is implicitly given by the relationship:

$$V = L \frac{di}{dt}$$

Energy stored depends on the current being held, such that:

In a similar case as with the basic capacitor circuit we are implying that at time 0 a switch closes connecting the battery to the coil and the inductor starts to get charged. Also, in all real cases there will be a small resistance in series with the inductor, but we will get to this case in the discussion of R-L circuits.

At a specific point of time the voltage across the inductor is expressed by $V = L di/dt$ which is basically the

electrical definition of inductance, except that since we are just focusing at a point in time and not at an interval of time ΔT we will need to use the term dt and similarly for the current di instead of ΔI . The electrical definition still holds, since all we are saying is that the flux or change in current over time times the inductance is the Induced Voltage across the Inductor.

CAPACITOR

A capacitor is a passive electrical component that can store energy in the electric field between a pair of conductors (called "plates"). The process of storing energy in the capacitor is known as "charging", and involves electric charges of equal magnitude, but opposite polarity, building up on each plate. A capacitor's ability to store charge is measured by its capacitance, in units of farads.

Capacitors are often used in electric and electronic circuits as energy-storage devices. They can also be used to differentiate between high-frequency and low-frequency signals.



Fig 1(a).10 Capacitor

Theory of Operation

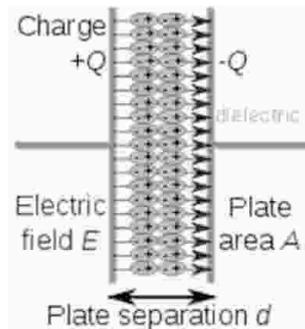


Fig 1(a).11 Parallel-Plate capacitor

Charge separation in a parallel-plate capacitor causes an internal electric field. A dielectric (orange) reduces the field and increases the capacitance.

A capacitor consists of two conductors separated by a non-conductive region. The non-conductive region is called the dielectric or sometimes the dielectric medium. In simpler terms, the dielectric is just an electrical insulator. Examples of dielectric mediums are glass, air, paper, vacuum, and even a semiconductor depletion region chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with no net electric charge and no influence from any external electric field. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, a capacitance of one farad means that one coulomb of charge on each conductor causes a voltage of one volt across the device.



Fig 1(a).12 Demonstration of a parallel-plate capacitor

The capacitor is a reasonably general model for electric fields within electric circuits. An ideal capacitor

is wholly characterized by a constant capacitance C , defined as the ratio of charge $\pm Q$ on each conductor to the voltage V between them:

Sometimes charge build-up affects the capacitor mechanically, causing its capacitance to vary. In this case, capacitance is defined in terms of incremental changes:

$$C = \frac{dq}{dt}$$

Energy storage

Work must be done by an external influence to "move" charge between the conductors in a capacitor. When the external influence is removed the charge separation persists in the electric field and energy is stored to be released when the charge is allowed to return to its equilibrium position. The work done in establishing the electric field, and hence the amount of energy stored, is given by:

$$W \int_{q=0}^Q V dq = \int_{q=0}^Q \frac{q}{C} dq = \frac{1}{2} \frac{Q^2}{C} = \frac{1}{2} CV^2 = \frac{1}{2} VQ$$

OBSERVATION TABLE

S.No.	Components for identification/Testing	Type	Measured Value		Quality
			By multimeter	By Color Coding	
1.	Resistors	i.			
		ii.			
2.	Capacitors	i.			
		ii.			
3.	Inductors	i.			
		ii.			

PROCEDURE

For Resistors

1. Identify the type of element and write in observation table.
2. Find different value of resistor using color coding and multi meter, note down in observation table
3. Using multi meter test given resistor for open and short conditions.

For Inductors

1. Identify the type of element and write in observation table.
2. Find different value of resistor using color coding and multi meter, note down in observation table.
3. Using multi meter test given resistor for open and short conditions.

For Capacitor

1. Identify the type of element and write in observation table.
2. Find different value of resistor using color coding and multi meter, note down in observation table
3. Using multi meter test given resistor for open and short conditions.

RESULT

Study of various passive components viz. resistor, capacitor, inductor and their testing and identification has done.

PRECAUTIONS

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.
4. Get the experimental readings checked by the teacher.
5. Don't touch directly the live parts of equipment and circuit.
6. Wear leather shoes in the lab.

VIVA VOICE:

- 1) What are the various uses of multimeter?
- 2) What is a capacitor?
- 3) Which device is use to measure ac current?
- 4) What is a voltmeter?

OBJECTIVE:

Introduction and use of oscilloscope.

APPARATUS REQUIRED:

S.No	Name of the equipment	Quantities	Type
1.	Function Generator	1	
2.	CRO	1	
3.	Connecting Probe	As Required	

THEORY

CATHODE RAY OSCILLOSCOPE

The cathode-ray oscilloscope (CRO) is a common laboratory instrument that provides accurate time and amplitude measurements of voltage signals over a wide range of frequencies. Its reliability, stability, and ease of operation make it suitable as a general purpose laboratory instrument. The heart of the CRO is a cathode-ray tube shown schematically in Fig.2.1

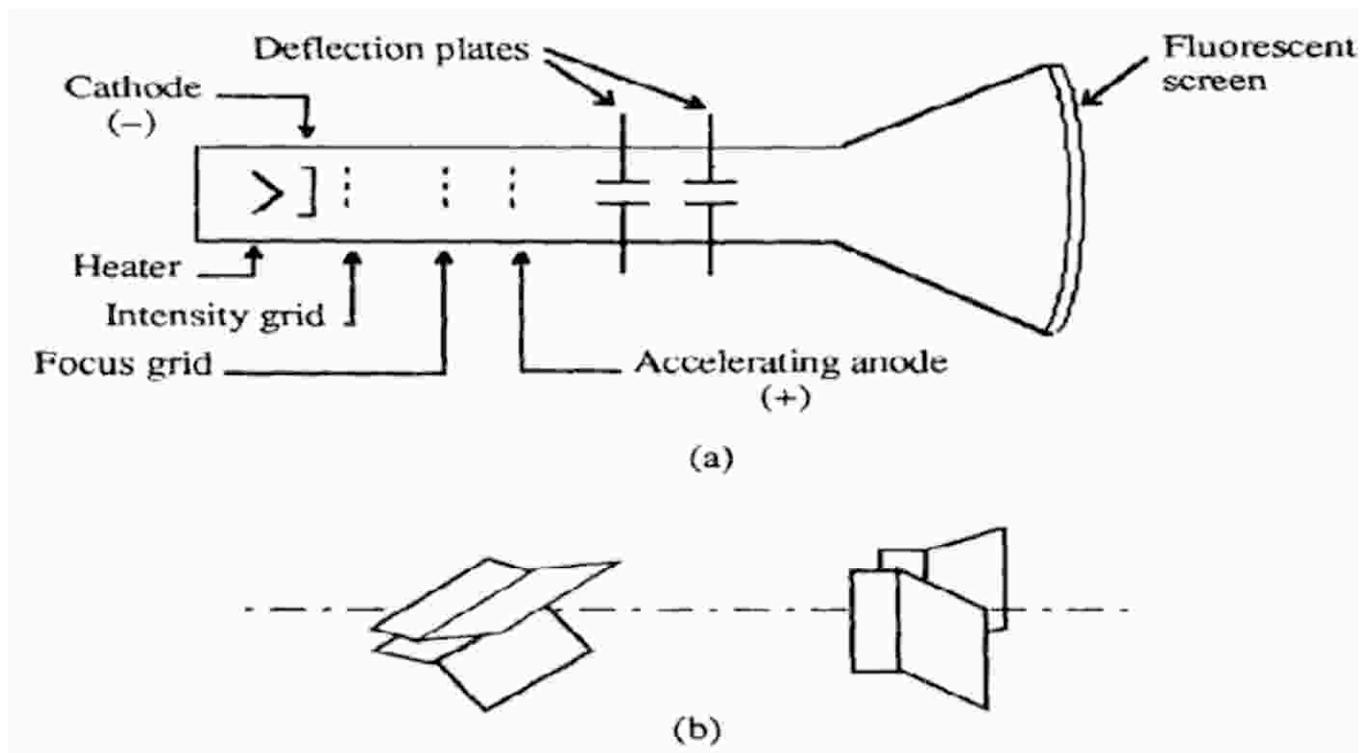


Fig: 1(b).1 Cathode-ray oscilloscopes (CRO) (a) Schematic (b) Details of deflection Plate

The cathode ray is a beam of electrons which are emitted by the heated cathode (negative electrode) and accelerated toward the fluorescent screen. The assembly of the cathode, intensity grid, focus grid, and accelerating anode (positive electrode) is called an electron gun. Its purpose is to generate the electron beam and control its intensity and focus. Between the electron gun and the fluorescent screen are two pair of metal plates - one oriented to provide horizontal deflection of the beam and one pair oriented to give vertical deflection to the beam.

These plates are thus referred to as the horizontal and vertical deflection plates. The combination of these two deflections allows the beam to reach any portion of the fluorescent screen. Wherever the electron beam hits the screen, the phosphor is excited and light is emitted from that point. This conversion of electron energy into light allows us to write with points or lines of light on an otherwise darkened screen.

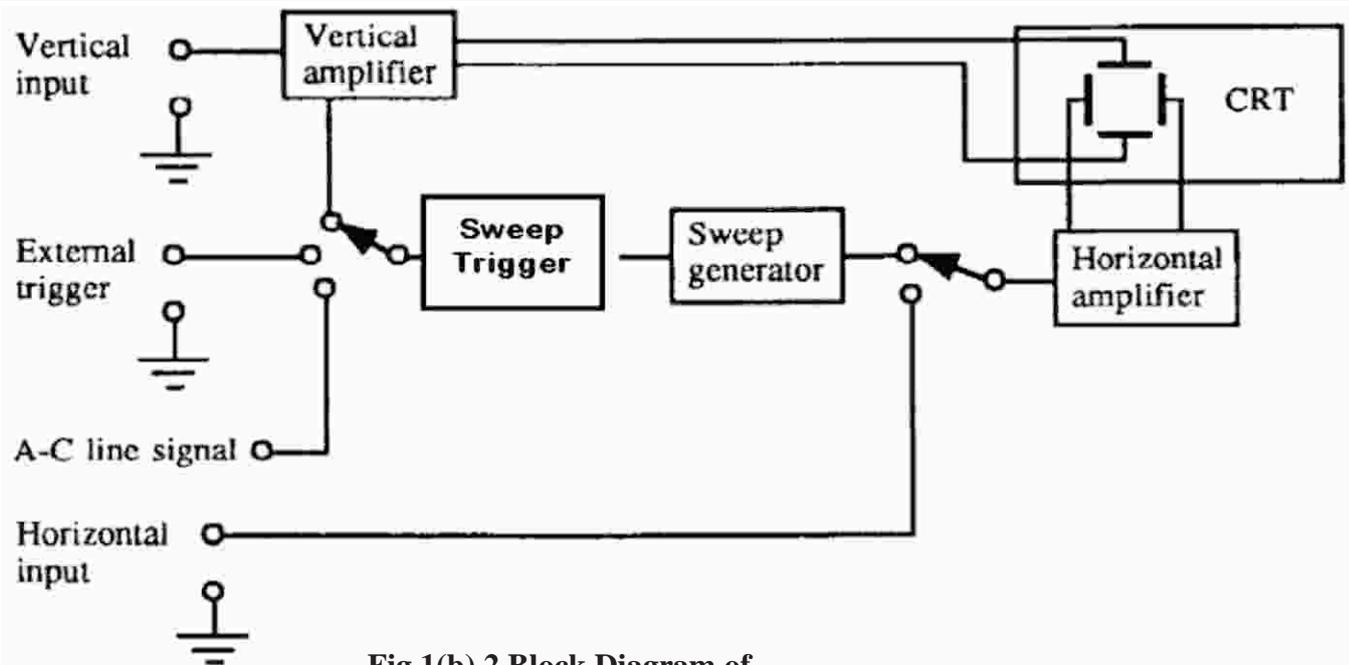


Fig 1(b).2 Block Diagram of

Oscilloscope CONNECTIONS FOR THE OSCILLOSCOPE

Vertical Input A pair of jacks for connecting the signal under study to the Y (or vertical) amplifier. The lower jack is grounded to the case.

Horizontal Input A pair of jacks for connecting an external signal to the horizontal amplifier. The lower terminal

is grounded to the case of the oscilloscope.

External Trigger Input Input connector for external trigger signal.

Cal. Out Provides amplitude calibrated square waves of 25 and 500 milli volts for use in calibrating the gain of the amplifiers.

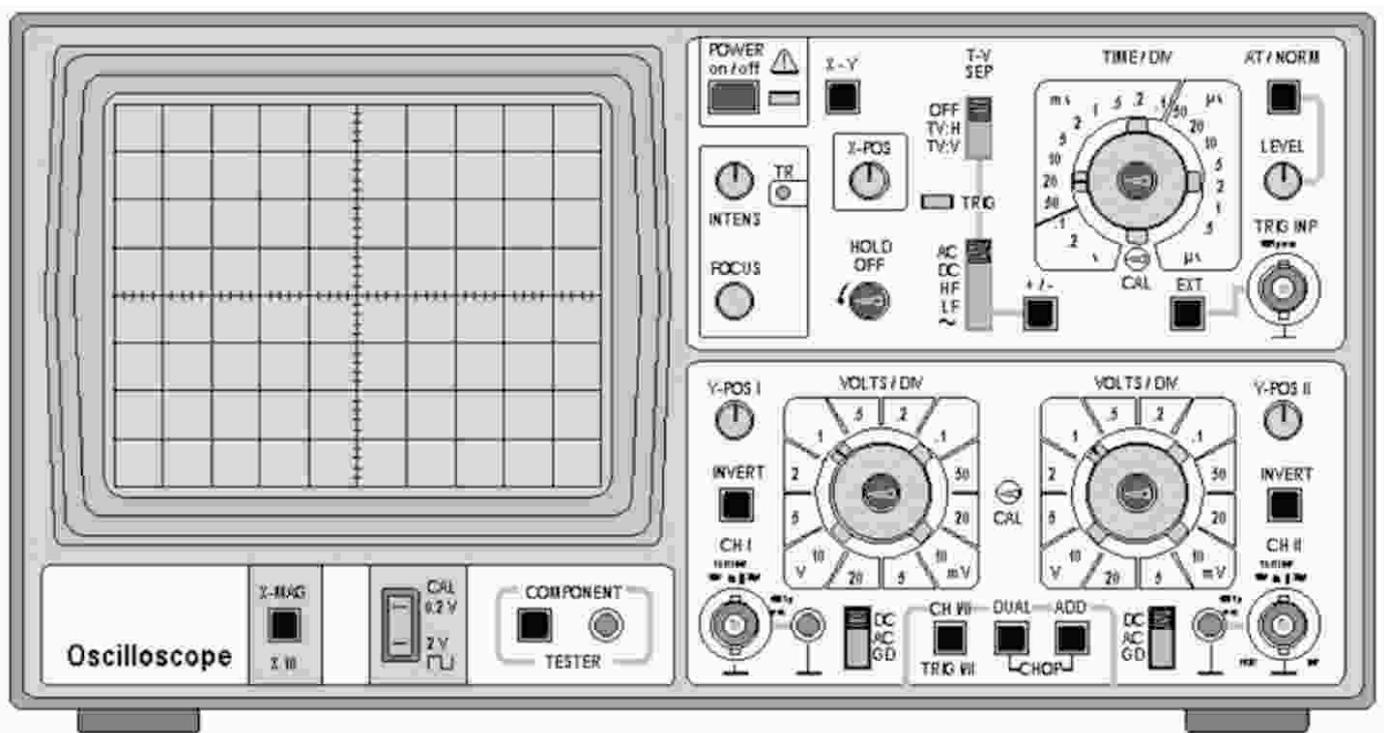


Fig 1(b).3 Cathode Ray Oscilloscope

Accuracy of the vertical deflection is + 3%. Sensitivity is variable.

Horizontal sweep should be accurate to within 3%. Range of sweep is variable

Operating Instructions: Before plugging the oscilloscope into a wall receptacle, set the controls as follows:

- (a) Power switch at off
- (b) Intensity fully counters clockwise
- (c) Vertical centering in the center of range
- (d) Horizontal centering in the center of range
- (e) Vertical at 0.2
- (f) Sweep times 1

WARNING Never advance the Intensity Control so far that an excessively bright spot appears. Bright spots simply burning of the screen. A sharp focused spot of high intensity (great brightness) should never be allowed to remain fixed in one position on the screen for any length of time as damage to the screen may occur.

PROCEDURE

I. Set the signal generator to a frequency of 1000 cycles per second. Connect the output from the generator to the vertical input of the oscilloscope. Establish a steady trace of this input signal on the scope. Adjust (play with) all of the scope and signal generator controls until you become familiar with the function of each.

II. Measurements of Voltage: By adjusting the Horizontal Sweep time/cm and trigger, a steady trace of the sine wave may be displayed on the screen. The trace represents a plot of voltage vs. time, where the vertical deflection of the trace about the line of symmetry CD is proportional to the magnitude of the voltage at any instant of time.

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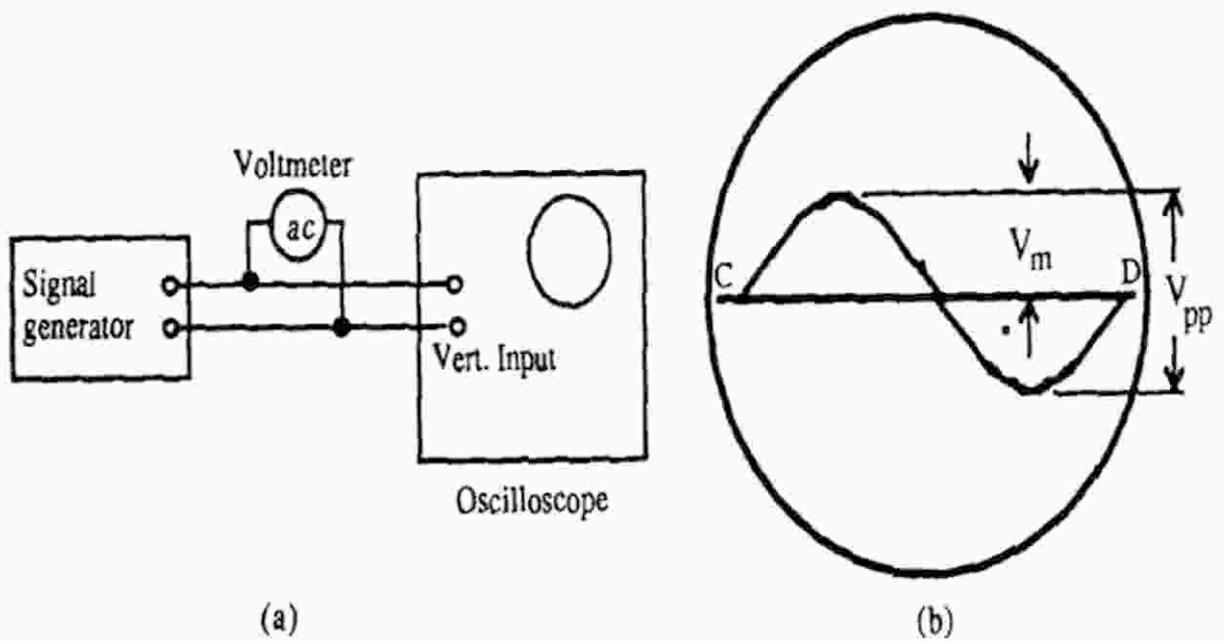


Fig 1(b).4 (a) Circuit for Procedure (b) Trace Seen on Scope

The relationship between the magnitude of the peak voltage displayed on the scope and the effective or RMS voltage (V_{RMS}) read on the AC voltmeter is

$V_{RMS} = 0.707 V_m$ (for a sine or cosine wave).

$$V_m = \frac{V_{rms}}{0.707}$$

Thus

III. Frequency Measurements: When the horizontal sweep voltage is applied, voltage measurements can still be taken from the vertical deflection. Moreover, the signal is displayed as a function of time. If the

time base (i.e. sweep) is calibrated, such measurements as pulse duration or signal period can be made. Frequencies can then be determined as reciprocal of the periods.

IV. Lissajous Figures: When sine-wave signals of different frequencies are input to the horizontal and vertical

amplifiers a stationary pattern is formed on the CRT when the ratio of the two frequencies is an integral fraction such as $1/2$, $2/3$, $4/3$, $1/5$, etc. These stationary patterns are known as Lissajous figures and can be used for comparison measurement of frequencies.

Use two oscillators to generate some simple Lissajous figures like those shown in Fig. You will find it difficult to

maintain the Lissajous figures in a fixed configuration because the two oscillators are not phase and frequency locked. Their frequencies and phase drift slowly causing the two different signals to change slightly with respect to each other.

FUNCTION GENERATOR

A function generator is a device that can produce various patterns of voltage at a variety of frequencies and amplitudes. It is used to test the response of circuits to common input signals.

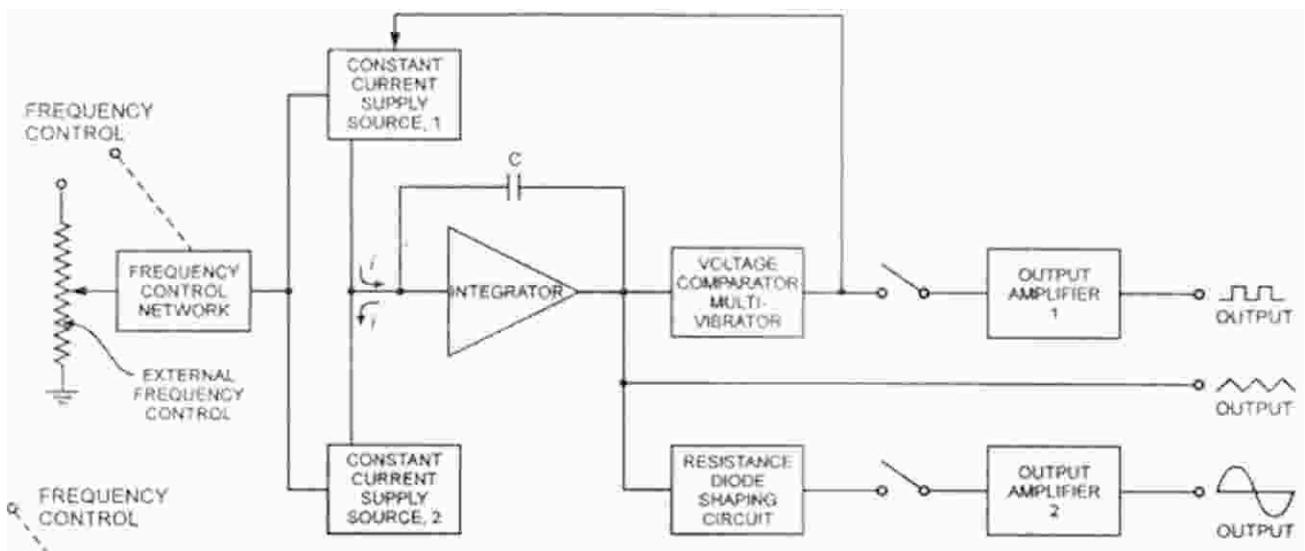


Fig 1(b).5 Function Generator

A function generator is usually a piece of electronic test equipment or software used to generate different types of electrical waveforms over a wide range of frequencies. Some of the most common waveforms produced by the function generator are the sine, square, triangular and saw tooth shapes. These waveforms can be either repetitive or single-shot (which requires an internal or external trigger source) Integrated circuits used to generate waveforms may also be described as function generator ICs. Although function generators cover both audio and RF frequencies, they are usually not suitable for applications that need low distortion or stable frequency signals. When those traits are required, other signal generators would be more appropriate.

Some function generators can be phase-locked to an external signal source (which may be a frequency reference) or another function generator. Function generators are used in the development, test and repair of electronic equipment. For example, they may be used as a signal source to test amplifiers or to introduce an error signal into a control loop.

Working

Simple function generators usually generate triangular waveform whose frequency can be controlled smoothly as well as in steps. This triangular wave is used as the basis for all of its other outputs. The triangular wave is generated by repeatedly charging and discharging a capacitor from a constant current source. This produces a linearly ascending or descending voltage ramp. As the output voltage reaches

upper and lower limits, the charging and discharging is reversed using a comparator, producing the linear triangle wave. By varying the current and the size of the capacitor, different frequencies may be obtained. Saw tooth waves can be produced by charging the capacitor slowly, using a current, but using a diode over the current source to discharge quickly - the polarity of the diode changes the polarity of the resulting saw tooth, i.e. slow rise and fast fall, or fast rise and slow fall.

A 50% duty cycle square wave is easily obtained by noting whether the capacitor is being charged or discharged, which is reflected in the current switching comparator output. Other duty cycles (theoretically from 0% to 100%) can be obtained by using a comparator and the saw tooth or triangle signal. Most function generators also contain a non-linear diode shaping circuit that can convert the triangle wave into a reasonably accurate sine wave by rounding off the corners of the triangle wave in a process similar to clipping in audiosystems.

A typical function generator can provide frequencies up to 20 MHz RF generators for higher frequencies are

not function generators in the strict sense since they typically produce pure or modulated sine signals only. Function generators, like most signal generators, may also contain an attenuator, various means of modulating the output waveform, and often the ability to automatically and repetitively "sweep" the frequency of the output waveform (by means of a voltage-controlled oscillator) between two operator-determined limits. This capability makes it very easy to evaluate the frequency response of a given electronic circuit.

Some function generators can also generate white or pink noise.

More advanced function generators are called arbitrary waveform generators (AWG). They use direct digital synthesis (DDS) techniques to generate any waveform that can be described by a table of amplitudes.

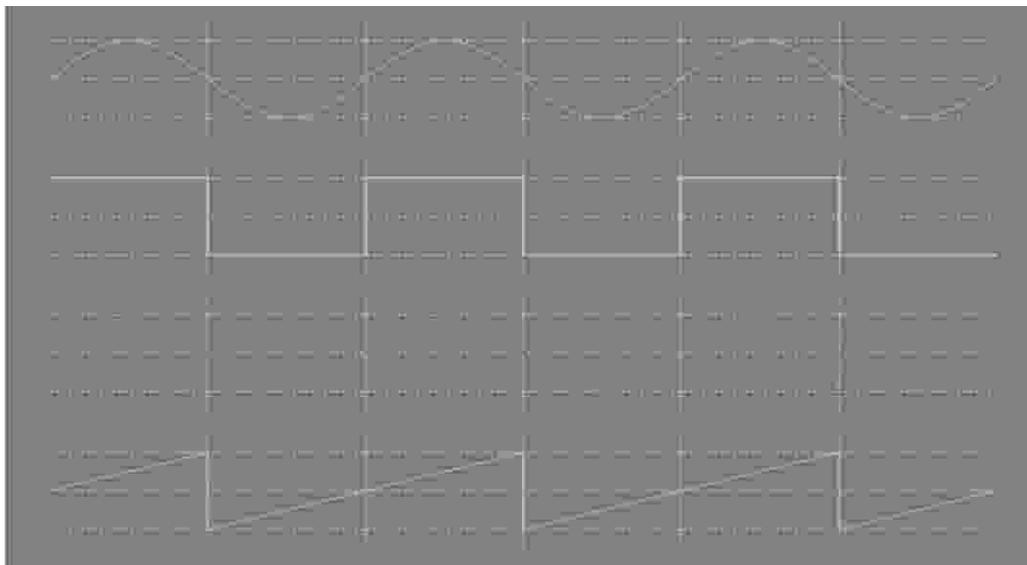


Fig. 1(b).6 Function generators output waveforms

RESULT

We have studied about the construction, working of CRO, function generator and learn how to measure frequency, voltage with the help of CRO.

PRECAUTIONS

1. All connection must be tight.
2. Get the circuit connections checked by the teacher before performing the experiment.
3. Power to the circuit must be switched on in the presence of the teacher.

Experiment No. 1(b)

Aim:

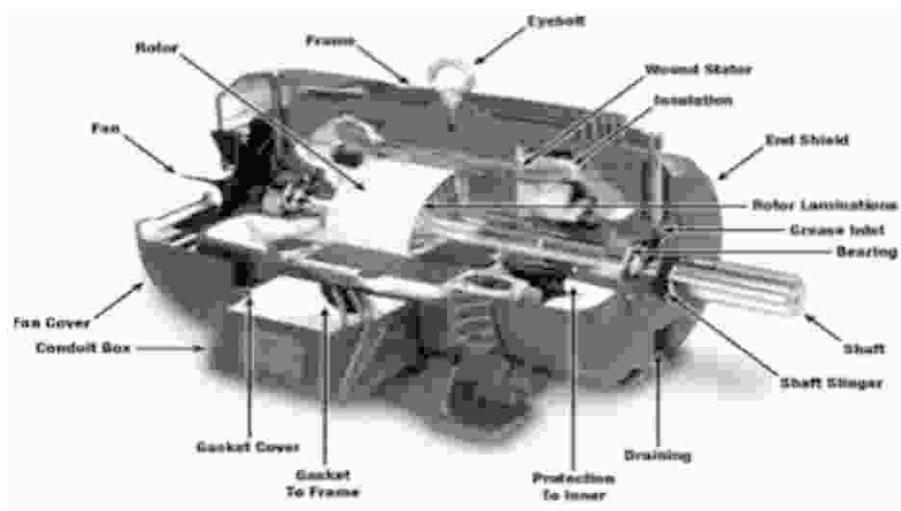
Demonstration of cut-out sections of machines: dc machine (Commutator brush arrangement), induction machine (squirrel cage rotor), synchronous machine (field winding - slip ring arrangement) and single-phase induction machine.

DC Machine: Construction and their Applications

The DC machine can be classified into two types namely DC motors as well as DC generators. Most of the DC machines are equivalent to AC machines because they include AC currents as well as AC voltages in them. The output of the DC machine is DC output because they convert AC voltage to DC voltage. The conversion of this mechanism is known as the commutator, thus these machines are also named as commutating machines. DC machine is most frequently used for a motor. The main benefits of this machine include torque regulation as well as easy speed. The applications of the DC machine is limited to trains, mills, and mines. As examples, underground subway cars, as well as trolleys, may utilize DC motors. In the past, automobiles were designed with DC dynamos for charging their batteries.

What is a DC Machine?

A DC machine is an electromechanical energy alteration device. The working principle of a DC machine is when electric current flows through a coil within a magnetic field, and then the magnetic force generates a torque which rotates the dc motor. The DC machines are classified into two types such as DC generator as well as DC motor. The main function of the DC generator is to convert mechanical power to DC electrical power, whereas a DC motor converts DC power to mechanical power. The AC motor is frequently used in the industrial applications for altering electrical energy to mechanical energy.



However, a DC motor is applicable where the good speed regulation & ample range of speeds are necessary like in electric-transaction systems.

Fig 4.1: DC machine

Construction of DC Machine

The construction of DC machine can be done using some of the essential parts like Yoke, Pole core & pole shoes, Pole coil & field coil, Armature core, Armature winding otherwise conductor, commutator, brushes & bearings. Some of the parts of the DC machine is discussed below.

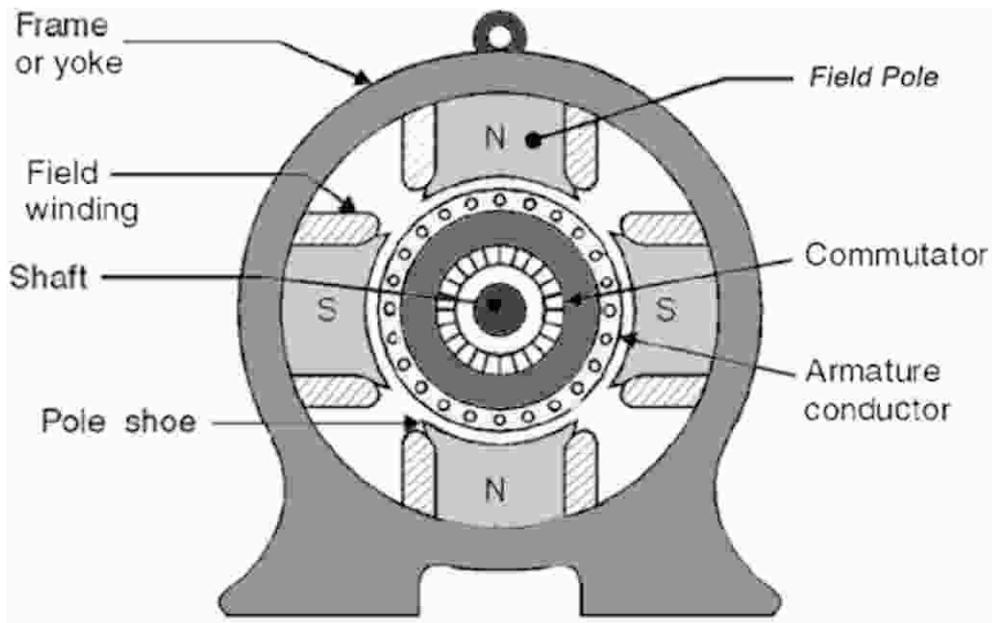


Fig 4.2 : parts of dc machine

Yoke

Another name of a yoke is the frame. The main function of the yoke in the machine is to offer mechanical support intended for poles and protects the entire machine from the moisture, dust, etc. The materials used in the yoke are designed with cast iron, cast steel otherwise rolled steel.

Pole and Pole Core

The pole of the DC machine is an electromagnet and the field winding is winding among pole. Whenever field winding is energized then the pole gives magnetic flux. The materials used for this are cast steel, cast iron otherwise pole core. It can be built with the annealed steel laminations for reducing the power drop because of the eddy currents.

Pole Shoe

Pole shoe in DC machine is an extensive part as well as enlarge the region of the pole. Because of this region, flux can be spread out within the air-gap as well as extra flux can be passed through the air space toward armature. The materials used to build pole shoe is cast iron otherwise cast steel, and also used annealed steel lamination to reduce the loss of power because of eddy currents.

Field Windings

In this, the windings are wound in the region of pole core & named as field coil. Whenever current is supplied through field winding then it electromagnetics the poles which generate required flux. The material used for field windings is copper.

Armature Core

Armature core includes the huge number of slots within its edge. Armature conductor is located in these slots

It provides the low-reluctance path toward the flux generated with field winding. The materials used in this core are permeability low-reluctance materials like iron otherwise cast. The lamination is used to decrease the loss because of the eddy current.

Armature Winding

The armature winding can be formed by interconnecting the armature conductor. Whenever an armature winding is turned with the help of prime mover then the voltage, as well as magnetic flux, gets induced within it. This winding is allied to an exterior circuit. The materials used for this winding are conducting material like copper.

Commutator

The main function of the commutator in the DC machine is to collect the current from the armature

conductor as well as supplies the current to the load using brushes. And also provides uni-directional torque for DC- motor. The commutator can be built with a huge number of segments in the edge form of hard drawn copper. The Segments in the commutator are protected from thin mica layer.

Brushes

Brushes in the DC machine gather the current from commutator and supplies it to exterior load. Brushes wear with time to inspect frequently. The materials used in brushes are graphite otherwise carbon which is in rectangular form.

AC Machine: Construction and working of squirrel cage induction motor.

A 3 phase squirrel cage induction motor is a type of three phase induction motor which functions based on the principle of electromagnetism. It is called a 'squirrel cage' motor because the rotor inside of it – known as a 'squirrel cage rotor' – looks like a squirrel cage.

This rotor is a cylinder of steel laminations, with highly conductive metal (typically aluminum or copper) embedded into its surface. When an alternating current is run through the stator windings, a rotating magnetic field is produced.

This induces a current in the rotor winding, which produces its own magnetic field. The interaction of the magnetic fields produced by the stator and rotor windings produces a torque on the squirrel cage rotor. One big advantage of a squirrel cage motor is how easily you can change its speed-torque characteristics. This can be done by simply adjusting the shape of the bars in the rotor. Squirrel cage induction motors are used a lot in industry – as they are reliable, self-starting, and easy to adjust.

Squirrel Cage Induction Motor Working Principle

When a 3 phase supply is given to the stator winding it sets up a rotating magnetic field in space. This rotating magnetic field has a speed which is known as the synchronous speed.

This rotating magnetic field induces the voltage in rotor bars and hence short-circuit currents start flowing in

the rotor bars. These rotor currents generate their self-magnetic field which will interact with the field of the stator. Now the rotor field will try to oppose its cause, and hence rotor starts following the rotating magnetic field.

The moment rotor catches the rotating magnetic field the rotor current drops to zero as there is no more relative motion between the rotating magnetic field and rotor. Hence, at that moment the rotor experiences zero tangential force hence the rotor decelerates for the moment.

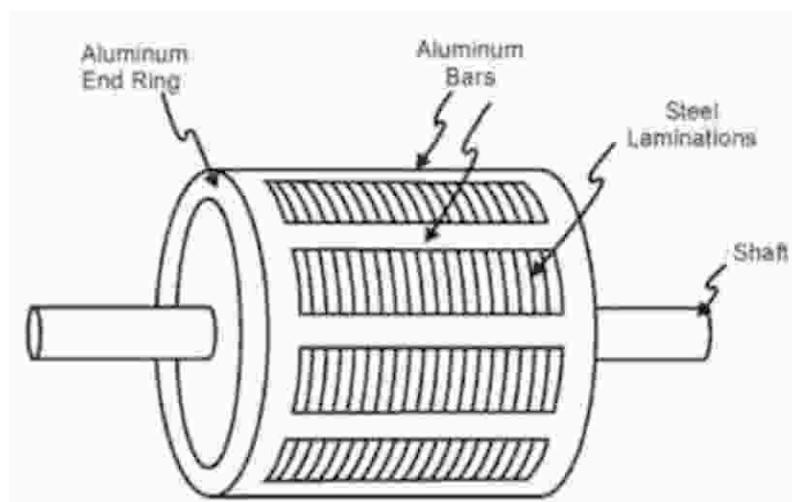


Fig 4.3 rotor

After deceleration of the rotor, the relative motion between the rotor and the rotating magnetic field reestablishes hence rotor current again being induced. So again, the tangential force for rotation of the rotor is restored, and therefore again the rotor starts following rotating magnetic field, and in this

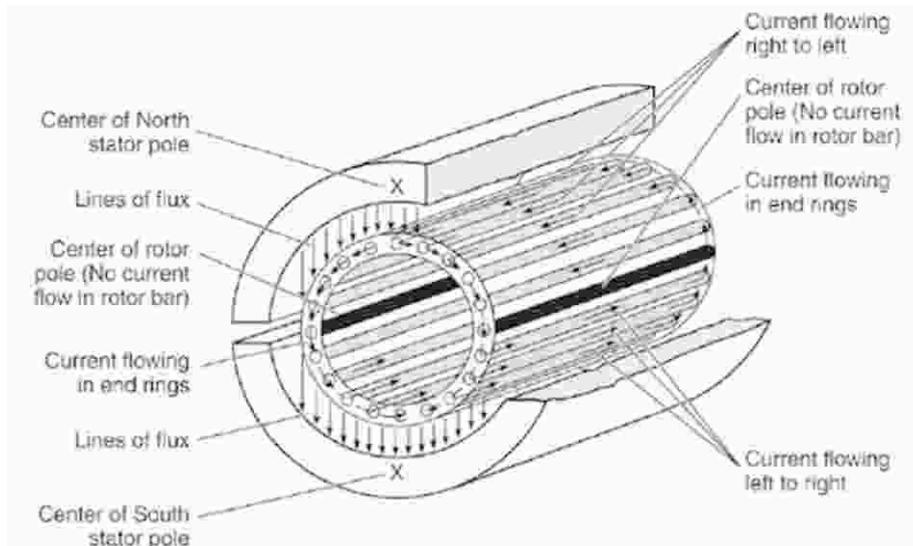
way, the rotor maintains a constant speed which is just less than the speed of rotating magnetic field or synchronous speed. Slip is a measure of the difference between the speed of the rotating magnetic field and rotor speed. The frequency of the rotor current = slip \times supply frequency

Squirrel Cage Induction Motor Construction

A squirrel cage induction motor consists of the following parts:

- Stator
- Rotor
- Fan

Bearings



Stator

It consists of a 3 phase winding with a core and metal housing. Windings are such placed that they are electrically and mechanically 120° apart from in space. The winding is mounted on the laminated iron core to provide low reluctance path for generated flux by AC currents.

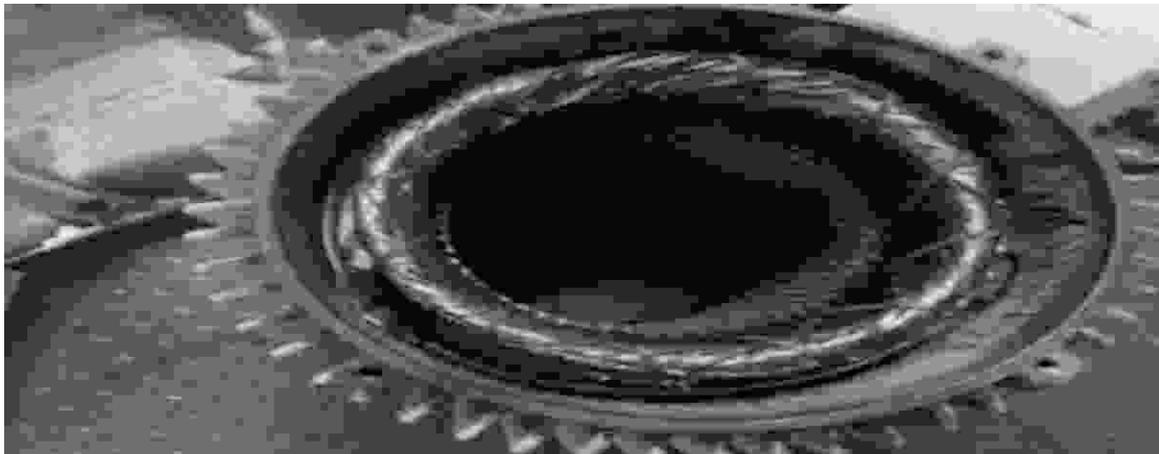


Fig 4.5:stator

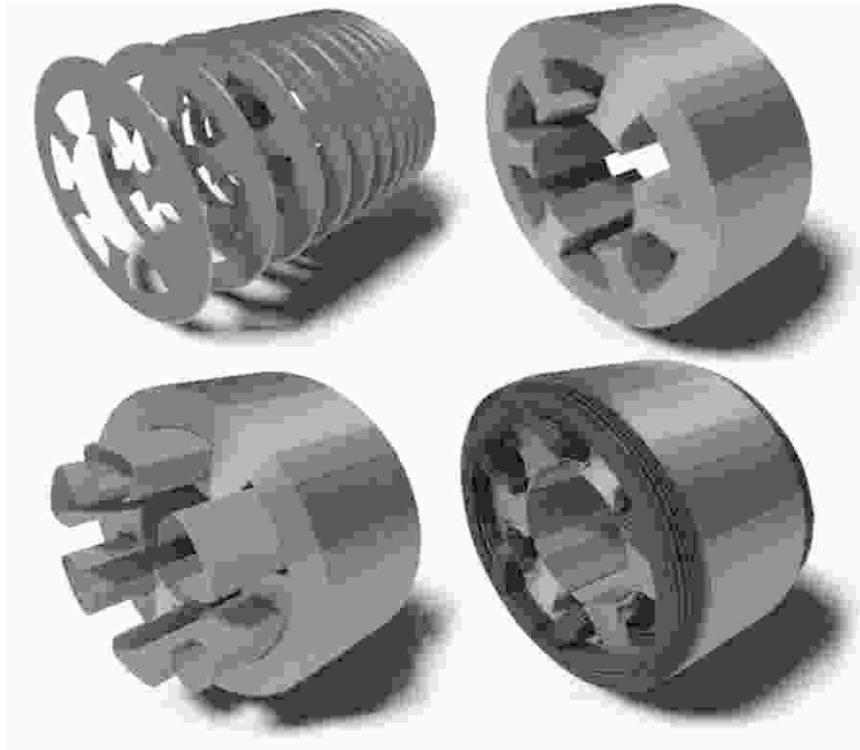


Fig 4.6:stator

Rotor

It is the part of the motor which will be in a rotation to give mechanical output for a given amount of electrical energy. The rated output of the motor is mentioned on the nameplate in horsepower. It consists of a shaft, short-circuited copper/aluminum bars, and a core.

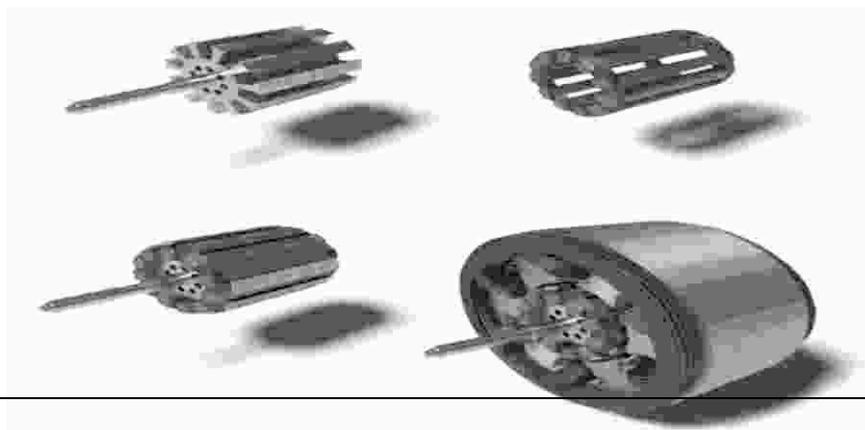
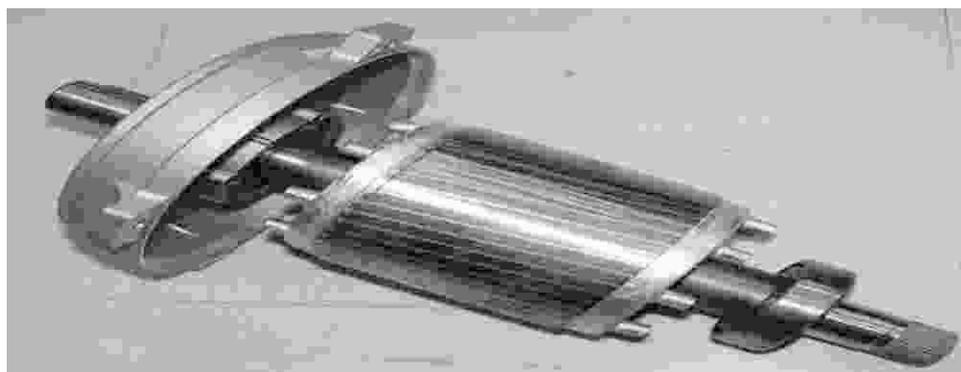


Fig 4.6:Rotor

The rotor core is laminated to avoid power loss from eddy currents and hysteresis. Conductors are skewed to prevent cogging during starting operation and gives better transformation ratio between stator and rotor.

Fan

A fan is attached to the back side of the rotor to provide heat exchange, and hence it maintains the temperature of the motor under a limit.

Bearings

Bearings are provided as the base for rotor motion, and the bearings keep the smooth rotation of the motor.

Application of Squirrel Cage Induction Motor

Squirrel cage induction motors are commonly used in many industrial applications. They are particularly suited for applications where the motor must maintain a constant speed, be self-starting, or there is a desire for low maintenance.

These motors are commonly used in:

- Centrifugal pumps
- Industrial drives (e.g. to run conveyor belts)
- Large blowers and fans
- Machine tools
- Lathes and other turning equipment

Advantages of Squirrel Cage Induction Motor

Some advantages of squirrel cage induction motors are:

- They are low cost
- Require less maintenance (as there are no slip rings or brushes)
- Good speed regulation (they are able to maintain a constant speed)
- High efficiency in converting electrical energy to mechanical energy (while running, not during startup)
- Have better heat regulation (i.e. don't get as hot)
- Small and lightweight
- Explosion proof (as there are no brushes which eliminate the risks of sparking)

Disadvantages of Squirrel Cage Induction Motor

Although squirrel cage motors are very popular and have many advantages – they also have some downsides. Some disadvantages of squirrel cage induction motors are:

- Very poor speed control
- Although they are energy efficient while running at full load current, they consume a lot of energy on startup
- They are more sensitive to fluctuations in the supply voltage. When the supply voltage is reduced, induction motor draws more current. During voltage surges, increase in voltage saturates the magnetic components of the squirrel cage induction motor
- They have high starting current and poor starting torque (the starting current can be 5-9 times the full load current; the starting torque can be 1.5-2 times the full load torque)

Construction of Synchronous Machines

Synchronous machines run at synchronous speed. The synchronous speed is given by

$$N_s = \frac{120f}{p}$$

Where, N_s = synchronous speed, f = supply frequency and p = number of poles. As we can see from the equation, the synchronous speed depends on the frequency of the supply and the number of poles. The construction of a synchronous machine is very similar to the construction of an alternator. Both are synchronous machines where one we use as a motor and the other as a generator. Just like any other motor, the synchronous motor also has a stator and a rotor. We will look into the construction details of the various part in one detail.

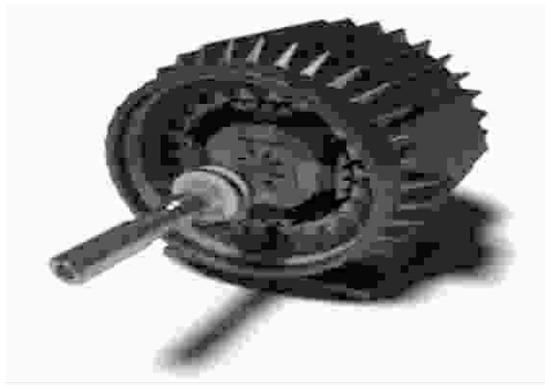


Fig 4.7: Stator of Synchronous Motor

The main stationary part of the machine is stator. The stator consists of the following parts.

Stator Frame

The stator frame is the outer part of the machine and is made up of cast iron. It protects the enter inner partsof the machine.



Fig 4.8: Stator frame of Synchronous Motor

Stator Core

The stator core is made up of thin silicon laminations. It is insulated by a surface coating to minimize hysteresis and eddy current losses. Its main purpose is to provide a path of low reluctance for the magnetic lines of force and accommodate the stator windings.



Fig 4.9: Stator core of Synchronous Motor

Stator Winding

The stator core has cuts on the inner periphery to accommodate the stator windings. The stator windings could be either three-phase windings or single phase windings.



Fig 4.10: Stator winding of Synchronous Motor

Enamelled copper is used as the winding material. In the case of 3 phase windings, the windings are distributed over several slots. This is done to produce a sinusoidal distribution of EMF.

Rotor of Synchronous Motor

The rotor is the moving part of the machine. Rotors are available in two types:

- Salient Pole Type
- Cylindrical Rotor Type

The salient pole type rotor consists of poles projecting out from the rotor surface. It is made up of steel laminations to reduce eddy current losses.



Fig 4.11: Rotor of Synchronous Motor

A salient pole machine has a non-uniform air gap. The gap is maximum between the poles and is minimum at the pole centres. They are generally used for medium and low-speed operations as they have a large number of poles. They contain damper windings which are used for starting the motor.

A cylindrical rotor is made from solid forgings of high-grade nickel chrome molybdenum steel forgings of high-

grade nickel chrome molybdenum steel. The poles are created by the current flowing through the windings. They are used for high-speed applications as they have less number of poles. They also produce less noise and windage losses as they have a uniform air gap. DC supply is given to the rotor windings via slip-rings. Once the rotor windings are excited, they act like poles.

Single Phase Induction Motor

We use the single-phase power system more widely than three phase system for domestic purposes, commercial purposes and some extent in industrial uses. Because, the single-phase system is more economical than a three-phase system and the power requirement in most of the houses, shops, offices are small, which can be easily met by a single phase system.

The single phase motors are simple in construction, cheap in cost, reliable and easy to repair and maintain. Due to all these advantages, the single phase motor finds its application in vacuum cleaners, fans, washing machines, centrifugal pumps, blowers, washing machines, etc.

The single phase AC motors are further classified as:

1. Single phase induction motors or asynchronous motors.
2. Single phase synchronous motors.
3. Commutator motors.

This article will provide fundamentals, description and working principle of single phase induction motor. Construction of Single Phase Induction Motor

Like any other electrical motor asynchronous motor also have two main parts namely rotor and stator.

Stator:

As its name indicates stator is a stationary part of induction motor. A single phase AC supply is given to the stator of single phase induction motor.

Rotor:

The rotor is a rotating part of an induction motor. The rotor connects the mechanical load through the shaft.

The rotor in the single-phase induction motor is of squirrel cage rotor type.

The construction of single phase induction motor is almost similar to the squirrel cage three-phase induction

motor. But in case of a single phase induction motor, the stator has two windings instead of one three-phase winding in three phase induction motor.

Stator of Single Phase Induction Motor

The stator of the single-phase induction motor has laminated stamping to reduce eddy current losses on its periphery. The slots are provided on its stamping to carry stator or main winding. Stampings are made up of silicon steel to reduce the hysteresis losses. When we apply a single phase AC supply to the stator winding, the magnetic field gets produced, and the motor rotates at speed slightly less than the synchronous speed N_s .

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

Synchronous speed N_s is given by

Where, f = supply voltage frequency, P = No. of poles of the motor.

The construction of the stator of the single-phase induction motor is similar to that of three phase induction motor except there are two dissimilarities in the winding part of the single phase induction motor.

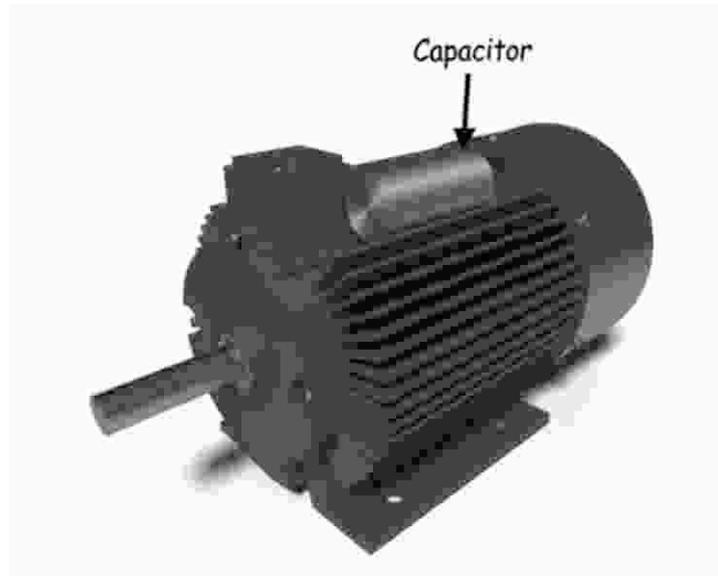
1. Firstly, the single-phase induction motors are mostly provided with concentric coils. We can easily adjust the number of turns per coil can with the help of concentric coils. The mmf distribution is almost sinusoidal.
2. Except for shaded pole motor, the asynchronous motor has two stator windings namely the main winding and the auxiliary winding. These two windings are placed in space quadrature to each other.

Rotor of Single Phase Induction Motor

The construction of the rotor of the single-phase induction motor is similar to the squirrel cage three-phase induction motor. The rotor is cylindrical and has slots all over its periphery. The slots are not made parallel to each other but are a little bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of induction motor more smooth and quieter (i.e. less noisy).

The squirrel cage rotor consists of aluminum, brass or copper bars. These aluminum or copper bars are called rotor conductors and placed in the slots on the periphery of the rotor. The copper or aluminum rings permanently short the rotor conductors called the end rings.

To provide mechanical strength, these rotor conductors are braced to the end ring and hence form a complete closed circuit resembling a cage and hence got its name as squirrel cage induction motor. As end rings permanently short the bars, the rotor electrical resistance is very small and it is not possible to add external resistance as the bars get permanently shorted. The absence of slip ring and brushes make the construction of single phase induction motor very simple and robust.



RESULT:

We have studied about DC machines, Squirrel cage induction motor, Synchronous machines, 1-ph induction motor.

VIVA VOICE:

1. Why 1-ph induction motor is not self-starting ?
2. What is the difference between dc machine and synchronous machine?
3. What is slip?
4. Write the types of dc machine?

1C. Components of LT switchgear:

Definition:

The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchgear.

The term 'switchgear' is a generic term that includes a wide range of switching devices like circuit breakers,

switches, switch fuse units, off-load isolators, HRC fuses, contactors, miniature circuit breakers, ELCBs, GFCIs etc.

It also includes the combination of these switching devices with associated control, measuring, protecting and regulating equipment. The switchgear devices and their assemblies are used in connection with the generation, transmission, distribution, and conversion of electrical energy.

We all are familiar with low voltage switches and re-wirable fuses in our homes. Switches are used for opening

and closing an electric circuit while fuses are used for over-current and short-circuit protection. In such a way, every electrical device wants a switching and a protecting device.

Various forms of switching and protective devices have been developed. Thus switchgear can be taken as a general term covering a wide range of equipment concerned with the switching, protection, and control of various electrical equipment.

Function of a Switchgear

Switchgear has to perform the functions of carrying, making and breaking the normal load current like a switch. In addition, it has to perform the function of clearing the fault current for which sensing devices like current transformers, potential transformers and various types of relays, depending on the application, are employed. There also has to be provision for metering, controlling and data, wherein innumerable devices are used for achieving the switching function.

Thus switchgear can include circuit breaker, current transformers, potential transformers, protective relays, measuring instruments, switches, fuses, MCBs, surge arrestors, isolators, and various associated types of equipment.

Now let's look into the components of switchgear in detail.

Components of Switchgear

Switchgear essentially consists of switching and protecting devices such as switches, fuses, isolators, circuit breakers, protective relays, control panels, lightning arrestors, current transformers, potential transformers, auto reclosures, and various associated equipment.

Some types of equipment are designed to operate under both normal and abnormal conditions. Some equipment is meant for switching and not sensing the fault.

During normal operation, switchgear permits to switch on or off generators, transmission lines, distributors and other electrical equipment. On the other hand, when a failure (e.g. short circuit) occurs on any part of the power system, heavy current flows through the equipment, threatening damage to the equipment and interruption of service to the customers.

However, the switchgear detects the fault and disconnects the unhealthy section from the system. (For more details visit working of a circuit breaker and protective relays.)

Similarly, switching and current interrupting devices play a significant role in the modern electrical network, right from generating stations, transmission sub-stations at different voltages, distribution substations, and

load centers. The switching device here is called a circuit breaker.

The circuit breaker, along with associated devices for protection, metering and control regulation, is

called as switchgear.

Read in detail about Components of Switchgear

Evolution of Switchgear

The switchgear equipment is essentially concerned with switching and interrupting currents either under normal or abnormal operating conditions.

The tumbler switch with ordinary fuse is the simplest form of switchgear and was used to control and protect

lights and other equipment in homes, offices, etc.

For circuits of a higher rating, a high-rupturing capacity (H.R.C.) fuse in conjunction with a switch may serve the purpose of controlling and protecting the circuit. However, such switchgear cannot be used profitably on a high voltage system (33 kV) for two reasons.

Firstly, when a fuse blows, it takes some time to replace it and consequently, there is an interruption of service

to the customers.

Secondly, the fuse cannot successfully interrupt large fault currents that result from the faults on high voltage system.

With the advancement of the power system, lines and other equipment operate at high voltages and carry large currents. When a short circuit occurs on the system, a heavy current flowing through the equipment may cause considerable damage.

In order to interrupt such heavy fault currents, automatic circuit breakers (or simply circuit breakers) are used. A circuit breaker is one switchgear which can open or close an electrical circuit under both normal and abnormal conditions.

Even in instances where a fuse is adequate, as regards to breaking capacity, a circuit breaker may be preferable. It is because a circuit breaker can close circuits, as well as break them without replacement and thus has a wider range of use altogether than a fuse.

Essential Features of Switchgear

The essential features of switchgear are :

1. Complete Reliability
2. Absolutely certain discrimination
3. Quick operation
4. Provision for manual control

1. Complete reliability

With the continued trend of interconnection and the increasing capacity of generating stations, the need for reliable switchgear has become of paramount importance.

This is not surprising because it is added to the power system to improve reliability. When a fault occurs on any

part of the power system, they must operate to isolate the faulty section from the remainder circuit.

2. Absolutely certain discrimination

When a fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section.

It should isolate the faulty section from the system without affecting the healthy section. This will ensure

continuity of supply.

3. Quick operation

When a fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents.

If the fault is not cleared quickly, it is likely to spread into healthy parts, thus endangering complete shut down

of the system

4. Provision for manual control

Switchgear must have provision for manual control. In case the electrical (or electronics) control fails, thenecessary operation can be carried out through manual control.

Classification of Switchgear

Switchgear can be classified on the basis of the voltage level into the following

1. Low voltage (LV) Switchgear
2. Medium voltage (MV) Switchgear
3. High voltage (HV) Switchgear

1. Low Voltage Switchgear

Switchgear for low voltage applications is generally rated up to 1000 V AC and 1500V DC.

The commonly used low voltage switchgear devices include oil circuit breakers(OCBs), air circuit breakers(ACBs), switch fuse units (SFUs), off-load isolators, HRC fuses, earth leakage circuit breakers (ELCBs), Residual Current Protective Devices (RCCB & RCBO), miniature circuit breakers (MCB) and moulded casecircuit breakers (MCCB) etc. i.e. all the accessories required to protect the LV system.

The most common use of this is in LV distribution board.

Read more about Low Voltage Switchgear.

2. Medium Voltage Switchgear

Switchgear for medium voltage applications is rated from 3.3 kV to 33 kV class.

Medium voltage switchgear is mainly used for the distribution of electrical energy connected to various electrical networks. They include most of the substation equipment such as minimum oil circuit breakers, bulkoil circuit breakers, air magnetic switchgear, SF₆ gas insulated switchgear, vacuum switchgear, and gas insulated switchgear.

They may metal enclosed indoor type, metal enclosed outdoor type, outdoor type without a metal enclosure, The interruption medium may be oil, SF₆, and vacuum etc..

The main requirement of MV power network is to interrupt the current during faulty condition irrespective of what type of CB is used in the system. Although it may be capable of functioning in other conditions also.

Medium voltage switchgear should be capable of,

- Normal ON/OFF switching operation.
- Short circuit current interruption.
- Switching of capacitive currents.
- Switching of inductive currents.
- Some special application.

3. High Voltage Switchgear

The power system deals with the voltage above 36kV are referred to as high voltage.

As the voltage level is high the arcing produced during switching operation is also very high. So, special care tobe taken during designing of high voltage switchgear.

High voltage circuit breakers (such as SF₆ Circuit breaker or Vacuum Circuit breaker) are the main component

of HV switchgear. Hence high voltage circuit breaker should have special features for safe and reliable operation.

Faulty tripping and switching operation of high voltage circuit breakers are comparatively very rare. Most of the

time these circuit breakers remain at ON condition and may be operated after a long period of time. So

Circuit Breakers must be reliable enough to ensure safe operation, as when required.

Read more about different Types of High Voltage Circuit Breakers.

Indoor and Outdoor Switchgear

The main components of switchgear are circuit breakers, switches, bus-bars, instruments and instrument transformers.

It is necessary to house the switchgear in power stations and sub-stations in such a way so as to safeguard personnel during operation and maintenance and to ensure that the effects of fault on any section of the gear are confined to a limited region.

Depending upon the voltage to be handled, switchgear may be broadly classified into

1. Outdoor type Switchgear
2. Indoor type Switchgear

Outdoor Switchgear

For voltages beyond 66 kV, switchgear equipment is installed outdoor.

It is because, for such voltages, the clearances between conductors and the space required for switches, circuit breakers, transformers, and other equipment become so great that it is not economical to install all such equipment indoor.

Experiment No-02

2(a): TRANSIENT RESPONSE OF R-C NETWORK

AIM:

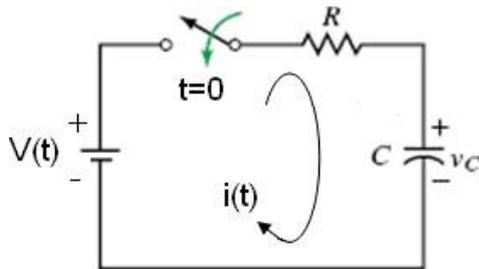
Study and obtain the transient response of a series R-C Network

APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Function Generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	Voltmeter			
6	Connecting wires			

CIRCUIT DIAGRAM:

THEORY: Let us consider the R-C circuit as shown below



Applying KVL, we obtain

$$v(t) = Ri(t) + \frac{1}{C} \int i(t) dt$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + \frac{1}{C} \left[\frac{I(s)}{s} + \frac{q(0_-)}{s} \right]$$

$$\text{or, } V(s) = RI(s) + \frac{I(s)}{sC} + \frac{v_C(0_-)}{s}$$

Now as all initial conditions set equal to zero, i.e. $v_C(0_-) = 0$, so the equation becomes

$$V(s) = RI(s) + \frac{I(s)}{sC}$$

$$\text{or, } V(s) = I(s) \left[R + \frac{1}{sC} \right]$$

Example:

To study the transient response of a series R-C circuit where $R=200\Omega$, $C=10\mu F$ for the following conditions

- 1) source voltage is 40V DC with all initial conditions set equal to zero.
- 2) source voltage is a pulse signal with a period of 0s, width of 5ms, rise and fall times of $1\mu s$, amplitude of 20V and an initial value of 0V and all initial conditions set equal to zero.

For Case - 1:-

$$v(t) = 40u(t) \quad \therefore V(s) = \frac{40}{s}$$

Therefore,

$$I(s) = \frac{sC}{RC(s + \frac{1}{RC})} \cdot \frac{40}{s} = \frac{40}{R} \cdot \frac{1}{(s + \frac{1}{RC})}$$

Taking Inverse Laplace transform on both sides of the above equation,

$$i(t) = \frac{40}{R} e^{-\frac{1}{RC}t}$$

Putting $R = 200\Omega$ and $C = 10\mu F$, we get

$$i(t) = \frac{40}{200} e^{-500t}$$

$$\text{At } t = 0, i(t) = \frac{40}{200} \text{ A} = 200\text{mA}$$

$$\text{At } t = \infty, i(t) = 0$$

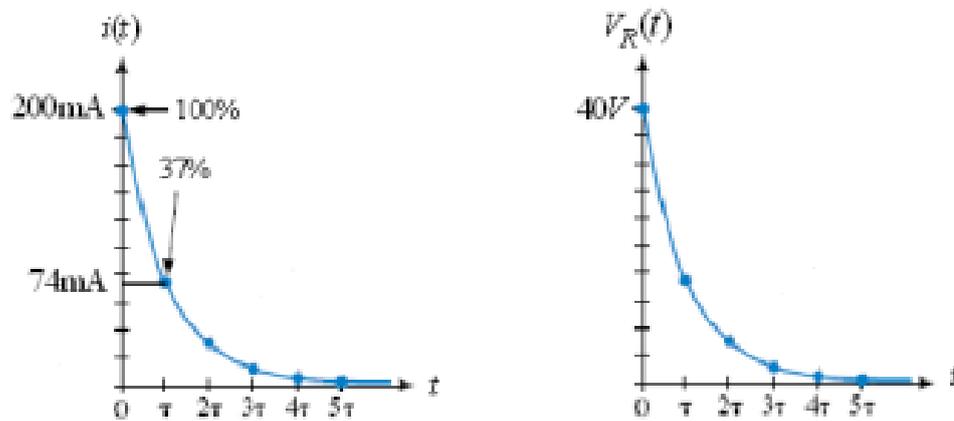
$$\text{At } t = \tau = RC = 2\text{ms}, i(t) = 200 \times (37\%) = 74\text{mA}$$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 200 \times \frac{40}{200} \cdot e^{-500t} = 40e^{-500t}$$

$$\text{At } t = 0, V_R(t) = 40\text{V}$$

$$\text{At } t = \infty, V_R(t) = 0$$



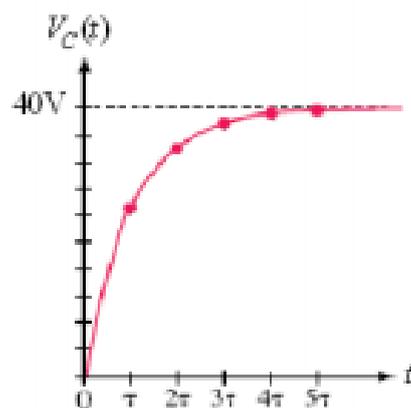
Voltage drop across the capacitor C is,

$$V_C(t) = v(t) - V_R(t) = 40(1 - e^{-500t})$$

At $t = 0$, $V_C(t) = 0$

At $t = \infty$, $V_C(t) = 40V$

The plot of $V_C(t)$ vs. t is as follows:



For Case - 2:-

$$v(t) = 20[u(t) - u(t-1)]$$

Therefore,
$$V(s) = \frac{20}{s}(1 - e^{-s})$$

and,
$$I(s) = \frac{20sC(1-e^{-s})}{sRC(s + \frac{1}{RC})} \cdot \frac{1}{s} = \frac{20}{R} \left[\frac{1}{(s + \frac{1}{RC})} - \frac{e^{-s}}{(s + \frac{1}{RC})} \right]$$

Taking Inverse Laplace transform on both sides of the above equation,

$$i(t) = \frac{20}{R} \left[e^{-\frac{1}{RC}t} u(t) - e^{-\frac{1}{RC}(t-1)} u(t-1) \right]$$

Putting $R = 200\Omega$ and $C = 10\mu F$, we get

$$i(t) = \frac{20}{200} \left[e^{-500t} u(t) - e^{-500(t-1)} u(t-1) \right]$$

At $t = 0$, $i(t) = \frac{20}{200} \text{ A} = 100\text{mA}$

At $t = \infty$, $i(t) = 0$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 200 \times \frac{20}{200} \left[e^{-500t} u(t) - e^{-500(t-1)} u(t-1) \right]$$

or,
$$V_R(t) = 20 \left[e^{-500t} u(t) - e^{-500(t-1)} u(t-1) \right]$$

At $t = 0$, $V_R(t) = 20\text{V}$

At $t = \infty$, $V_R(t) = 0$

Voltage drop across the capacitor C is,

$$V_C(t) = v(t) - V_R(t) = 20(1 - e^{-500t})u(t) - 20(1 - e^{-500(t-1)})u(t-1)$$

At $t = 0$, $V_C(t) = 0$

At $t = \infty$, $V_C(t) = 0$

At $t = T = 5\text{ms}$, $V_C(t) = 18.36\text{V}$

PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly Case 1 & Case 2.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.(response wave form is observed across Elements ,R C)
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet.

Observation Table

S. No	t(sec)	Ic (t)	Vc (t)	Vr(t)
1				
2				
3				
4				

RESULT: Transient response of a series R-C and series R-L circuit

EXPERIMENT – 2 (b)

TRANSIENT RESPONSE OF R-L NETWORK

AIM:

Study and obtain the transient response of a series R-L circuit

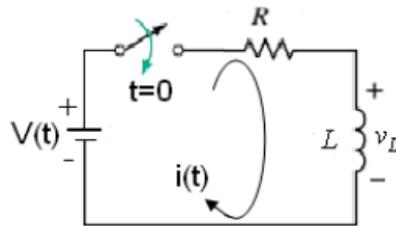
APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Function Generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	Voltmeter			
6	Connecting wires			

CIRCUIT DIAGRAM:

THEORY: Let us consider the R-L circuit as shown below

Let us consider the R-L circuit as shown below:



Applying KVL, we obtain

$$v(t) = Ri(t) + L \frac{di(t)}{dt}$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + L[sI(s) - i(0_-)]$$

Now as all initial conditions set equal to zero, i.e. $i(0_-) = 0$, so the equation becomes

$$V(s) = I(s)[R + sL]$$

or,

$$I(s) = \frac{V(s)}{R + sL} = \frac{1}{L} \cdot \frac{V(s)}{s + \frac{R}{L}}$$

To study the transient response of a series R-L circuit where $R=100\Omega$, $L=10\text{mH}$ for the following conditions:

1) Source voltage is 10V DC with all initial conditions set equal to zero.

2) Source voltage is 10V DC with initial condition $i_L(0_-) = 20\text{mA}$

For Case - 1:-

$$v(t) = 10u(t) \quad \therefore V(s) = \frac{10}{s}$$

Therefore,

$$I(s) = \frac{1}{L} \cdot \frac{\frac{10}{s}}{s + \frac{R}{L}} = \frac{1}{L} \left[\frac{10}{s(s + \frac{R}{L})} \right] = \frac{10}{R} \left[\frac{1}{s} - \frac{1}{s + \frac{R}{L}} \right]$$

Taking inverse Laplace transform on both sides of the above equation,

$$i(t) = \frac{10}{R} \left[1 - e^{-\frac{R}{L}t} \right]$$

Putting $R = 100\Omega$ and $L = 10\text{mH}$, we get

$$i(t) = \frac{10}{100} \left[1 - e^{-10^4 t} \right]$$

$$\text{At } t = 0, i(t) = 0$$

$$\text{At } t = \infty, i(t) = \frac{10}{100} \text{ A} = 100\text{mA}$$

$$\text{At } t = \tau = \frac{L}{R} = 100\mu\text{s}, i(t) = 100 \times (63\%) = 63\text{mA}$$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 100 \times \frac{10}{100} (1 - e^{-10^4 t}) = 10(1 - e^{-10^4 t})$$

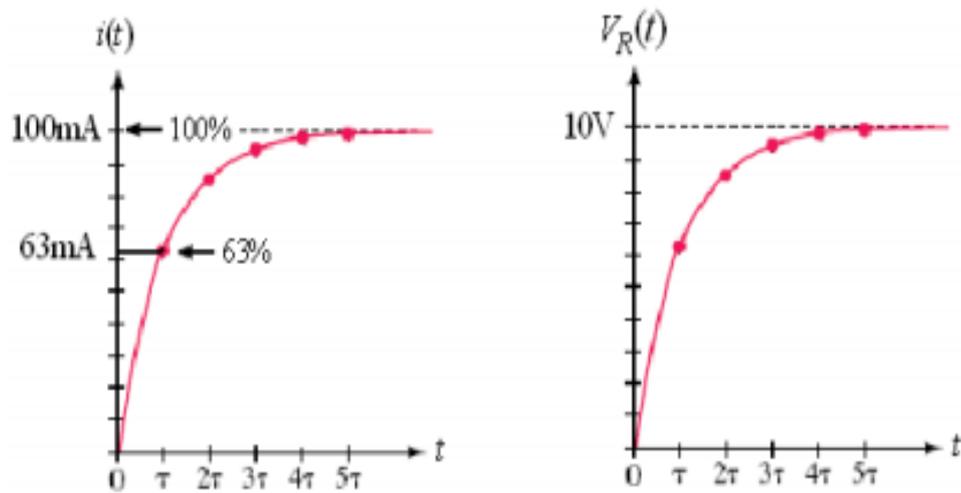
Voltage drop across the inductor L is,

$$V_L(t) = v(t) - V_R(t) = 10e^{-10^4 t}$$

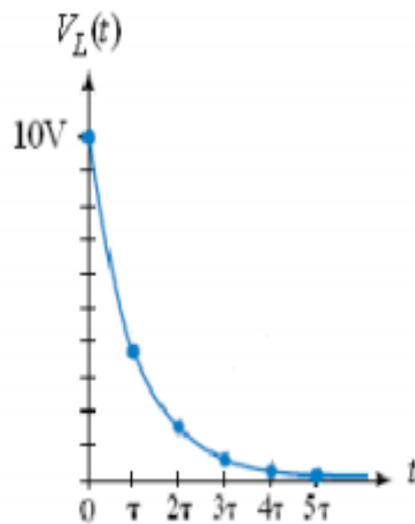
At $t = 0$, $V_L(t) = 10\text{V}$

At $t = \infty$, $V_L(t) = 0$

The plot of $i(t)$ vs. t and $V_R(t)$ vs. t are as follows:



The plot of $V_L(t)$ vs. t is as follows:



For Case - 2:-

$$v(t) = 10u(t) \quad \text{and} \quad i_L(0_-) = 20\text{mA}$$

$$\therefore V(s) = \frac{10}{s}$$

$$V(s) = RI(s) + L[sI(s) - 20 \times 10^{-3}]$$

$$\text{or,} \quad \frac{10}{s} + 20 \times 10^{-4} = LI(s) \left[s + \frac{R}{L} \right]$$

$$\text{or,} \quad I(s) = \frac{0.02}{s + 10^4} + \frac{10^3}{s(s + 10^4)}$$

Taking inverse Laplace transform on both sides of the above equation,

$$i(t) = 0.1 - 0.08e^{-10^4 t}$$

$$\text{At } t = 0, i(t) = 20\text{mA}$$

$$\text{At } t = \infty, i(t) = 100\text{mA}$$

Voltage drop across the resistor R is,

$$V_R(t) = Ri(t) = 100 \times i(t) = 100(0.1 - 0.08e^{-10^4 t}) = 10 - 8e^{-10^4 t}$$

$$\text{At } t = 0, V_R(t) = 2\text{V}$$

$$\text{At } t = \infty, V_R(t) = 10\text{V}$$

Voltage drop across the inductor L is,

$$V_L(t) = v(t) - V_R(t) = 8e^{-10^4 t}$$

$$\text{At } t = 0, V_L(t) = 8\text{V}$$

$$\text{At } t = \infty, V_L(t) = 0$$

PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly Case 1 & Case 2.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively. (response wave form is observed across Elements ,R C)
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet.

RESULT: Transient response of a series R-C and series R-L circuit

EXPERIMENT – 2 (c)

TRANSIENT RESPONSE OF R-L-C

AIM:

Study and obtain the transient response of a R-L-C circuit

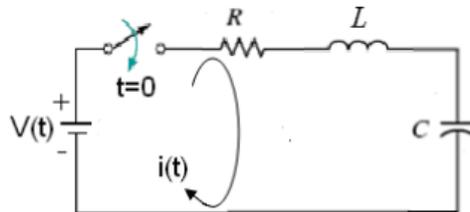
1. Transient response of a R-L-C circuit, excited by a unit step input

APPARATUS:

S. No.	Name of the Equipment	Range	Type	Quantity
1	Signal generator			
2	Required resistors			
3	Required Inductors			
4	Required capacitors			
5	CRO probes			
6	Connecting wires			

CIRCUIT DIAGRAM:

THEORY: Let us consider the R-L-C circuit as shown below:



Applying KVL, we obtain

$$v(t) = Ri(t) + L \frac{di(t)}{dt} + \frac{1}{C} \int i(t) dt$$

Taking Laplace transform on both sides of the above equation,

$$V(s) = RI(s) + L[sI(s) - i(0_-)] + \frac{I(s)}{sC} + \frac{v_C(0_-)}{s}$$

Now as all initial conditions set equal to zero, i.e. $i(0_-) = 0$ and $v_C(0_-) = 0$, so the equation becomes,

$$V(s) = I(s) \left[R + sL + \frac{1}{sC} \right]$$

Here, $v(t) = u(t)$ $\therefore V(s) = \frac{1}{s}$

Therefore, $\frac{1}{s} = I(s) \left[R + sL + \frac{1}{sC} \right]$

or, $I(s) = \frac{1/L}{s^2L + \frac{R}{L}s + \frac{1}{LC}}$

The roots of the denominator polynomial of the above equation are,

$$s^2L + \frac{R}{L}s + \frac{1}{LC} = 0$$

or, $s_1 = -\frac{R}{2L} + \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$ and

$$s_2 = -\frac{R}{2L} - \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

Let $\omega_0 = \frac{1}{\sqrt{LC}}$ and $\xi\omega_0 = \frac{R}{2L}$

$$\therefore \xi = \frac{R}{2} \sqrt{\frac{C}{L}}$$

Now,

$$I(s) = \frac{1/L}{(s-s_1)(s-s_2)} = \frac{1}{L(s_1-s_2)} \frac{1}{(s-s_1)} + \frac{1}{L(s_2-s_1)} \frac{1}{(s-s_2)}$$

or, $I(s) = \frac{1}{2\omega_0L\sqrt{\xi^2-1}} \left[\frac{1}{(s-s_1)} - \frac{1}{(s-s_2)} \right]$

Taking inverse Laplace Transform on both sides,

$$i(t) = \frac{1}{2\omega_0 L \sqrt{\xi^2 - 1}} e^{-\xi\omega_0 t} \left[e^{\omega_0 t \sqrt{\xi^2 - 1}} - e^{-\omega_0 t \sqrt{\xi^2 - 1}} \right]$$

Case - 1:-

$$R < 2\sqrt{\frac{L}{C}}$$

i.e. $\xi < 1$

$$i(t) = \frac{1}{\omega_0 L \sqrt{1 - \xi^2}} e^{-\xi\omega_0 t} \sin\left(\omega_0 t \sqrt{1 - \xi^2}\right)$$

The network is then said to be **Under Damped** or **Oscillatory**.

Case - 2:-

$$R = 2\sqrt{\frac{L}{C}}$$

i.e. $\xi = 1$

$$i(t) = \frac{1}{L} t e^{-\omega_0 t}$$

The network is then said to be **Critically Damped**.

Case - 3:-

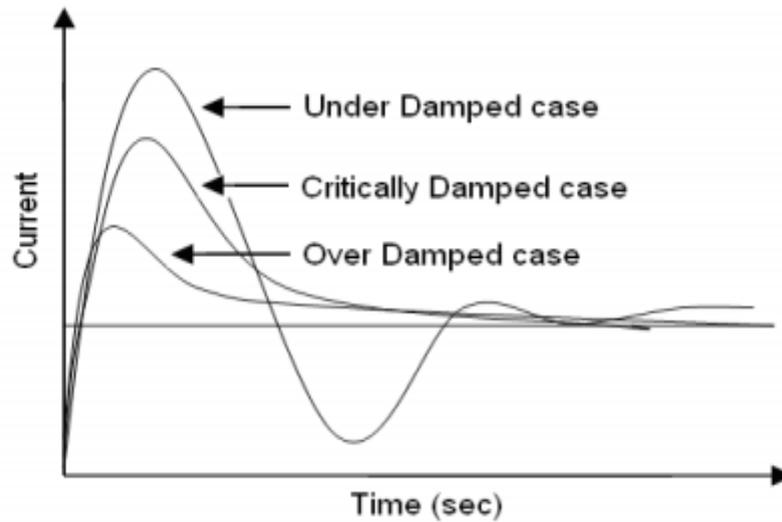
$$R > 2\sqrt{\frac{L}{C}}$$

i.e. $\xi > 1$

$$i(t) = \frac{1}{\omega_0 L \sqrt{\xi^2 - 1}} e^{-\xi\omega_0 t} \sinh\left(\omega_0 t \sqrt{\xi^2 - 1}\right)$$

The network is then said to be **Over Damped**.

The current response for the above three cases is shown in the figure below:



PROCEDURE:

1. Connect the circuit as shown in fig.
2. Set the voltage Accordingly.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.
4. Form the observation table between the time and magnitude of response in CRO.
5. Draw a graph between time and magnitude of response on the semi-log sheet

RESULT: Transient response of a R-L-C circuit is verified

ii) VERIFICATION OF SERIES RESONANCE

AIM:

To design the resonant frequency, quality factor and band width of a series resonant circuit.

APPARATUS:

S. No.	Name of the Equipment	Quantity
1.	Series resonance Trainer Kit	1
2.	Digital CRO	1
3.	CRO probes	As Required
4.	Connecting wires	As Required

CIRCUIT DIAGRAM:

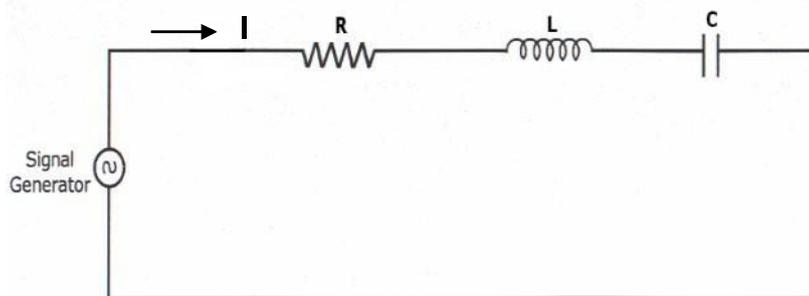


Fig – 12.1 Series Resonance

PROCEDURE:

1. Connect the circuit as shown in fig.12.1 for series resonant circuit
2. Set the voltage of the signal from function generator to 10V.
3. Vary the frequency of the signal in steps and note down the magnitude of response on CRO respectively.(response wave form is observed across element R)
4. Form the observation table between the frequency and magnitude of response in CRO for series resonance circuit.
5. Draw a graph between frequency and magnitude of response on the semi-log sheet and determine the resonant frequency, quality factor and bandwidth of series RLC circuit\.

THEORETICAL CALCULATIONS: Series Resonance

Resonant Frequency $(f_r) = 1/(2\pi\sqrt{LC})$ Lower cut off

frequency $(f_1) = f_r - R/4\pi L$

Upper cut off frequency $(f_2) = f_r + R/4\pi L$

Quality factor $Q_r = \omega_r L/R = 1/\omega_r RC$

Band Width $f_2 - f_1 = R/2\pi L$

TABULAR COLUMN:

S.No	Frequency (Hz)	Magnitude of response
.		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

MODEL GRAPH:

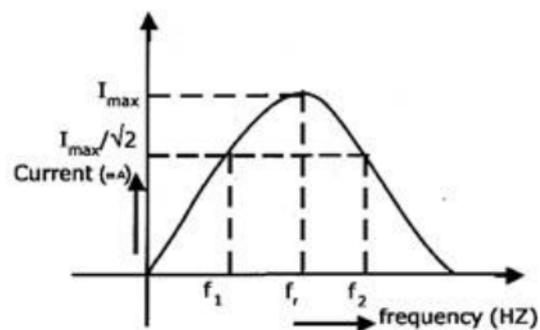


Fig – 12.2 Series Resonance

RESULT: Series Resonance is Verified

Experiment No. 03

Aim:

- a) Observation of the no-load current waveform for single phase transformer on CRO.
- b) To measure the voltages and currents, and power of a for single phase transformer for resistive load and calculate turn ratio.

Apparatus Required

S. No	Name of apparatus	Type	Specification	Quantity
1.	Single Phase Transformer	Core Type	2 KVA	1
2.	CRO	Dual channel	30 MHz	1
3.	Ammeter	MI	0-5 A	2
4.	Voltmeter	MI	0-300V	2
5.	Wattmeter	Electro Dynamic	0-1500W	2
6.	Load	Resistive	3KW	
7.	Connecting Leads		1.5 sq mm, 9A	

Introduction

Transformers are one of the most important components of any power system. It basically changes the level of voltages from one value to the other at constant frequency. Being a static machine the efficiency of a transformer could be as high as 99%. The transformer is a static device (means that has no moving parts) that consists of one, two or more windings which are magnetically coupled and electrically separated with or without a magnetic core. It transfers the electrical energy from one circuit to the other by electromagnetic induction principle. The winding connected to the AC main supply is called primary winding and the winding connected to the load or from which energy is drawn out is called as secondary winding. These two windings with proper insulation are wound on a laminated core which provides a magnetic path between windings.

When the primary winding is energized with alternating voltage source, an alternating magnetic flux or field will

be produced in the transformer core. This magnetic flux amplitude depends on the applied voltage magnitude, frequency of the supply and the number of turns on the primary side. This flux circulates through the core and hence links with the secondary winding. Based on the principle of electromagnetic induction, this magnetic linking induces a voltage in the secondary winding. This is called as mutual induction between two circuits. This secondary voltage depends on the number of turns on the secondary as well as magnetic flux and frequency. **Construction of single phase transformer**

Generally, the name associated with the construction of a transformer is dependent upon how the primary and secondary windings are wound around the central laminated steel core. The two most common and basic designs of transformer construction are the Closed-core Transformer and the Shell-core Transformer.

In the "closed-core" type (core form) transformer, the primary and secondary windings are wound outside and

surround the core ring. In the "shell type" (shell form) transformer, the primary and secondary windings pass inside the steel magnetic circuit (core) which forms a shell around the windings as shown below.

In both types of transformer core design, the magnetic flux linking the primary and secondary windings travels entirely within the core with no loss of magnetic flux through air. In the core type transformer construction, one half of each winding is wrapped around each leg (or limb) of the transformer's magnetic circuit as shown above. The coils are not arranged with the primary winding on one leg and the secondary on the other but instead half of the primary winding and half of the secondary winding are placed one over the other concentrically on each leg in order to increase magnetic coupling allowing practically all of the

magnetic lines of force go through both the primary and secondary windings at the same time. However, with this type of transformer construction, a small percentage of the magnetic lines of force flow outside of the core, and this is called “leakage flux”.

Shell type transformer cores overcome this leakage flux as both the primary and secondary windings are wound on the same centre leg or limb which has twice the cross-sectional area of the two outer limbs. The advantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils on both left and right hand sides before returning back to the central coils.

This means that the magnetic flux circulating around the outer limbs of this type of transformer construction is

equal to $\Phi/2$. As the magnetic flux has a closed path around the coils, this has the advantage of decreasing core losses and increasing overall efficiency.

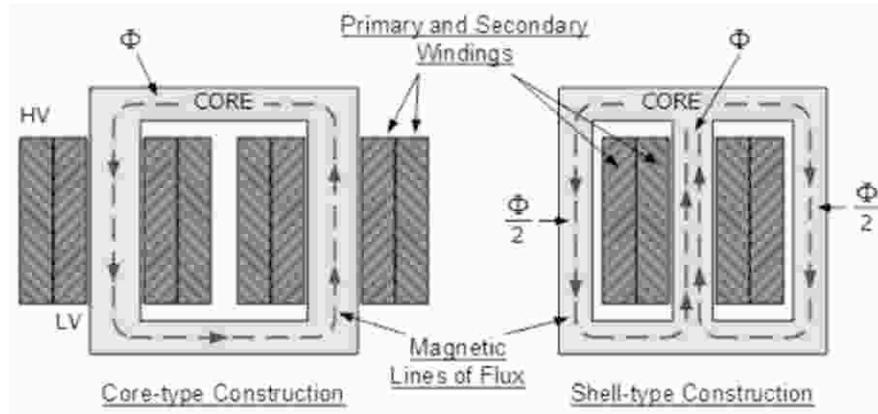


Fig 2(a).1 Core type and shell type transformer

Laminating the Iron Core

Eddy current losses within a transformer core cannot be eliminated completely, but they can be greatly reduced and controlled by reducing the thickness of the steel core. Instead of having one big solid iron core as the magnetic core material of the transformer or coil, the magnetic path is split up into many thin pressed steel shapes called “laminations”.

The laminations used in a transformer construction are very thin strips of insulated metal joined together to

produce a solid but laminated core as we saw above. These laminations are insulated from each other by a coat of varnish or paper to increase the effective resistivity of the core thereby increasing the overall resistance to limit the flow of the eddy currents.

The result of all this insulation is that the unwanted induced eddy current power-loss in the core is greatly

reduced, and it is for this reason why the magnetic iron circuit of every transformer and other electro-magnetic machines are all laminated. Using laminations in a transformer construction reduces eddy current losses.

The losses of energy, which appears as heat due both to hysteresis and to eddy currents in the magnetic path, is known commonly as “transformer core losses”. Since these losses occur in all magnetic materials as a result of alternating magnetic fields. Transformer core losses are always present in a transformer whenever the primary is energized, even if no load is connected to the secondary winding. Also these hysteresis and the eddy current losses are sometimes referred to as “transformer iron losses”, as the magnetic flux causing these losses is constant at all loads.

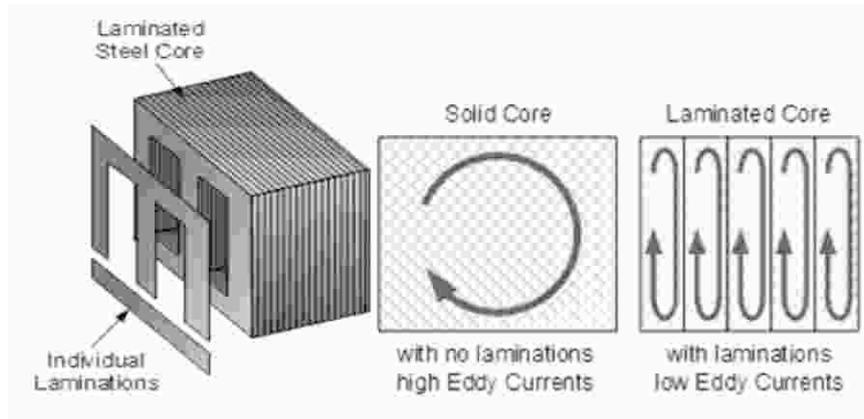


Fig. 2(a).2 Lamination of transformer core Principle of operation Ideal Transformer

A transformer is a device used to change voltages and currents of AC electric power by mutual induction principle. In the simplest version it consists of two windings wrapped around a magnetic core; windings are not electrically connected, but they are coupled by the magnetic field, as it shown in Figure 3.1. When one winding is connected to the AC electric power, the electric current is generated. This winding is called the primary winding. The primary current produces the magnetic field and the magnetic flux links the second winding, called the secondary winding. The AC flux through the secondary winding produces an AC voltage, so that if some impedance is connected to the terminals, an AC electric current is supplied.

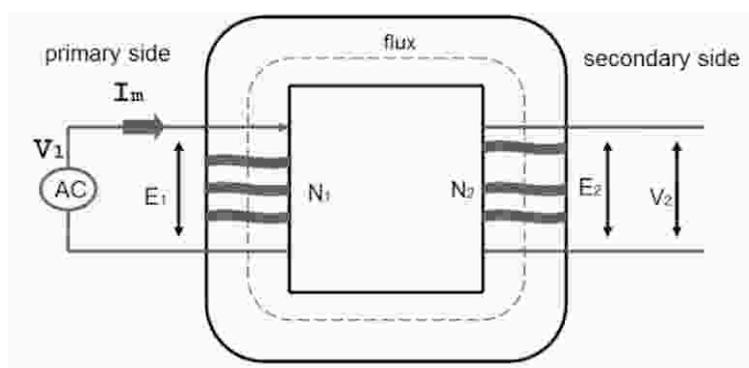


Fig 2(a).3 Ideal transformer on no load Transformer on No Load Condition

When the transformer is operating at no load, the secondary winding is open circuited, which means there is no load on the secondary side of the transformer and, therefore, current in the secondary will be zero, while primary winding carries a small current I_0 called no load current which is 2 to 10% of the rated current. This

current is responsible for supplying the iron losses (hysteresis and eddy current losses) in the core and a very small amount of copper losses in the primary winding. The angle of lag depends upon the losses in the transformer. The power factor is very low and varies from 0.1 to 0.15.

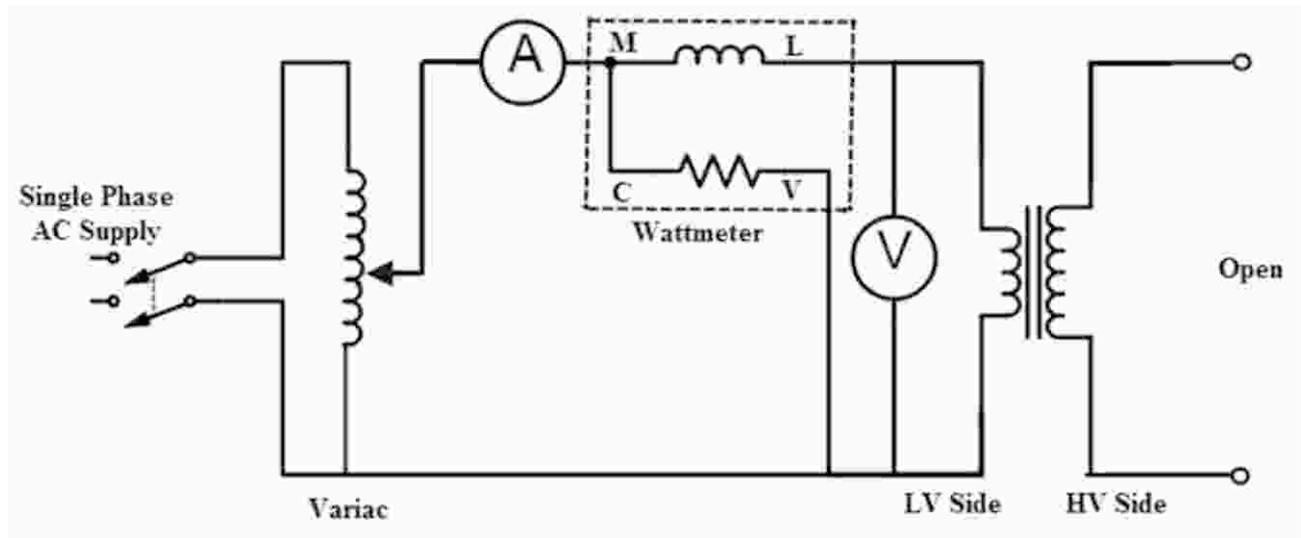


Fig 2(a).4 Single phase transformer on no load condition

The no load current consists of two components

- Reactive or magnetizing component I_m (It is in quadrature with the applied voltage V_1 . It produces flux in the core and does not consume any power)
- Active or power component I_w , also known as working component (It is in phase with the applied voltage V_1 . It supplies the iron losses and a small amount of primary copper

loss) The following steps are given below to draw the phasor diagram

1. The function of the magnetizing component is to produce the magnetizing flux, and thus, it will be in phase with the flux.
2. Induced emf in the primary and the secondary winding lags the flux ϕ by 90 degrees.
3. The primary copper loss is neglected, and secondary current losses are zero as $I_2 = 0$. Therefore, the current I_0 lags behind the voltage vector V_1 by an angle ϕ_0 called no-load power factor angle shown in the phasor diagram above.
4. The applied voltage V_1 is drawn equal and opposite to the induced emf E_1 because the difference between the two, at no load, is negligible.
5. Active component I_w is drawn in phase with the applied voltage V_1 .
6. The phasor sum of magnetizing current I_m and the working current I_w gives the no load current I_0 .

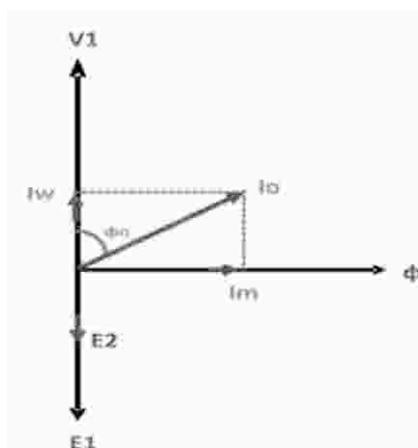


Fig 2(a).5 Phasor diagram of transformer no load condition

Observation of no load current in transformer

Method :-Oscilloscope typically doesn't measure current but instead it measures voltage. Thus to observe current waveform you could simply use current-to-voltage component like resistor, and probe the voltage across that resistor. The current information can be obtained by using Ohm Law formula: $V = I.R$ or $I = V/R$ which means current waveform will match exactly the observed voltage, despite the magnitude may be different.

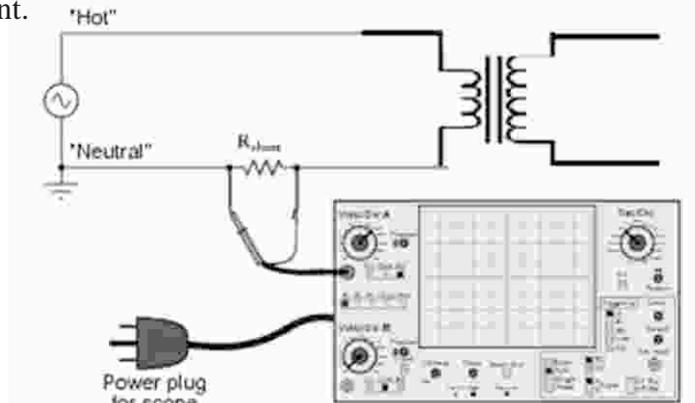


Fig 2(a).6 Observation of no load current in transformer

S. No	Current observed by Ammeter(A)	Current observed by CRO(A)
1.		
2.		
3.		
4.		

Transformer “On-load”

When an electrical load is connected to the secondary winding of a transformer and the transformer loading is therefore greater than zero, a current flows in the secondary winding and out to the load. This secondary current is due to the induced secondary voltage, set up by the magnetic flux created in the core from the primary current.

The secondary current, I_S which is determined by the characteristics of the load, creates a self-induced secondary magnetic field, Φ_S in the transformer core which flows in the exact opposite direction to the main primary field, Φ_P . These two magnetic fields oppose each other resulting in a combined magnetic field of less magnetic strength than the single field produced by the primary winding alone when the secondary circuit was open circuited.

This combined magnetic field reduces the back EMF of the primary winding causing the primary current, I_P to increase slightly. The primary current continues to increase until the core's magnetic field is back at its original strength, and for a transformer to operate correctly, a balanced condition must always exist between the primary and secondary magnetic fields. This results in the power to be balanced and the same on both the primary and secondary sides. Transformer “On-load”

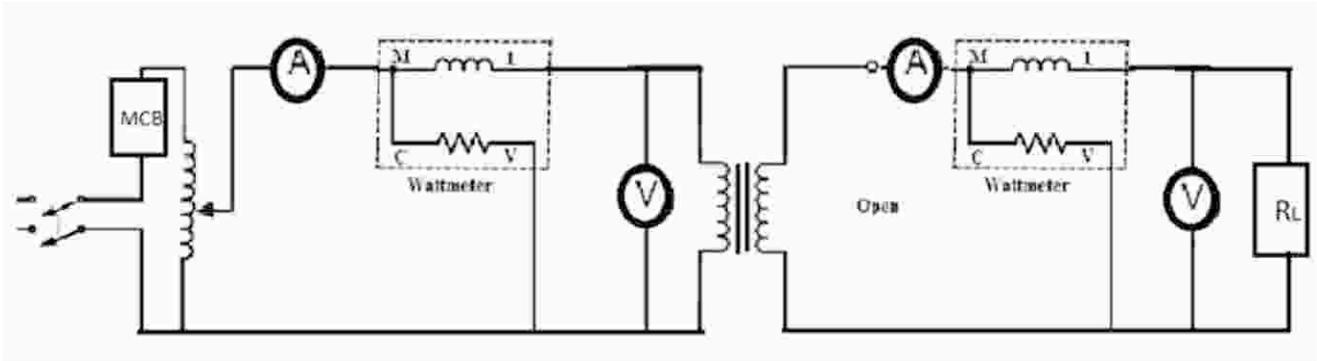


Fig2(b).1 Transformer On-load

We know that the turns ratio of a transformer states that the total induced voltage in each winding is proportional to the number of turns in that winding and also that the power output and power input of a transformer is equal to the volts times amperes, (V x I). Therefore:

$$(\text{Power})_{\text{primary}} = (\text{Power})_{\text{secondary}}$$

$$V_p * I_p = V_s * I_s$$

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

But we also know previously that the voltage ratio of a transformer is equal to the turns ratio of a transformer as: “voltage ratio = turns ratio”. Then the relationship between the voltage, current and number of turns in a transformer can be linked together and is therefore given as

Transformer Ratio(n)

$$\frac{N_s}{N_p} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

Where:

- $N_p/N_s = V_p/V_s$ - represents the voltage ratio
- $N_p/N_s = I_s/I_p$ - represents the current ratio

Note that the current is inversely proportional to both the voltage and the number of turns. This means that with a transformer loading on the secondary winding, in order to maintain a balanced power level across the transformers windings, if the voltage is stepped up, the current must be stepped down and vice versa. In other words, “higher voltage — lower current” or “lower voltage — higher current”.

As a transformers ratio is the relationships between the number of turns in the primary and secondary, the voltage across each winding, and the current through the windings, we can rearrange the above transformerratio equation to find the value of any unknown voltage, (V) current, (I) or number of turns, (N) as shown.

The total current drawn from the supply by the primary winding is the vector sum of the no-load current, I_0 and

the additional supply current, I_1 as a result of the secondary transformer loading and which lags behind the supply voltage by an angle of Φ .

Observation Table:-

S. No.	Load	Primary Side			Secondary Side			Efficiency(%)
		V_p	I_p	W_p	V_s	I_s	W_s	$(W_s/W_p) * 100$
1								
2								
3								

Result:-

Observation of the no-load current waveform has been done on an oscilloscope.

Measurement of primary and secondary voltages and currents, and power is done after loading of a transformer with different resistive load condition.

Efficiency of transformer is calculate for direct loading condition.

VIVA VOICE:

1. What happen when Transformer is given DC supply?
2. For a transformer with primary turns 100, secondary turns 400, if 200 V is applied at primary what voltage we will get in secondary?
3. What is difference between transformer and amplifier?
4. How can eddy current loss be minimized?
5. What is auto transformer?
6. Does the transformer draw any current when its secondary is open?
7. What is current transformer?
8. What type of transformer a distribution transformer is? step-up or step-down.
9. What is transformer regulation?

Experiment No. 4

O.C and S.C tests on a single-phase transformer.

AIM:

To perform the open circuit and short circuit test on a single-phase transformer and to draw the equivalent circuit after determining its constants.

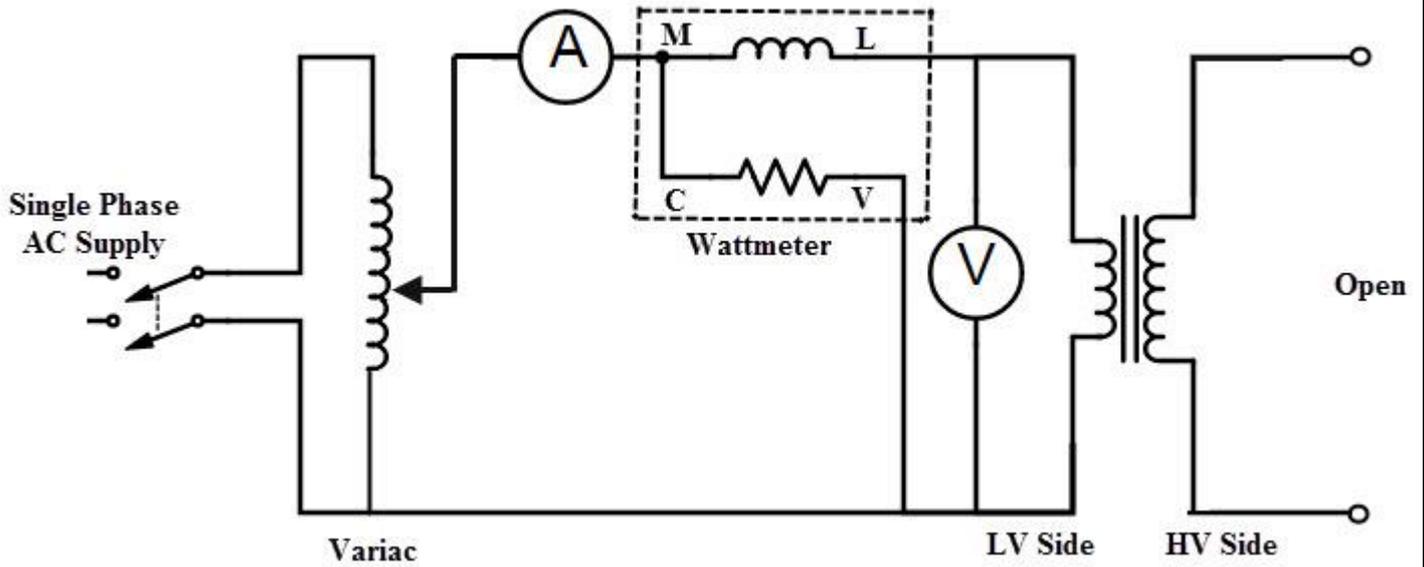
NAME PLATE DETAILS:

Voltage Ratio	220/110V
Full load Current	13.6A
KVA RATING	3KVA

EQUIPMENT REQUIRED:

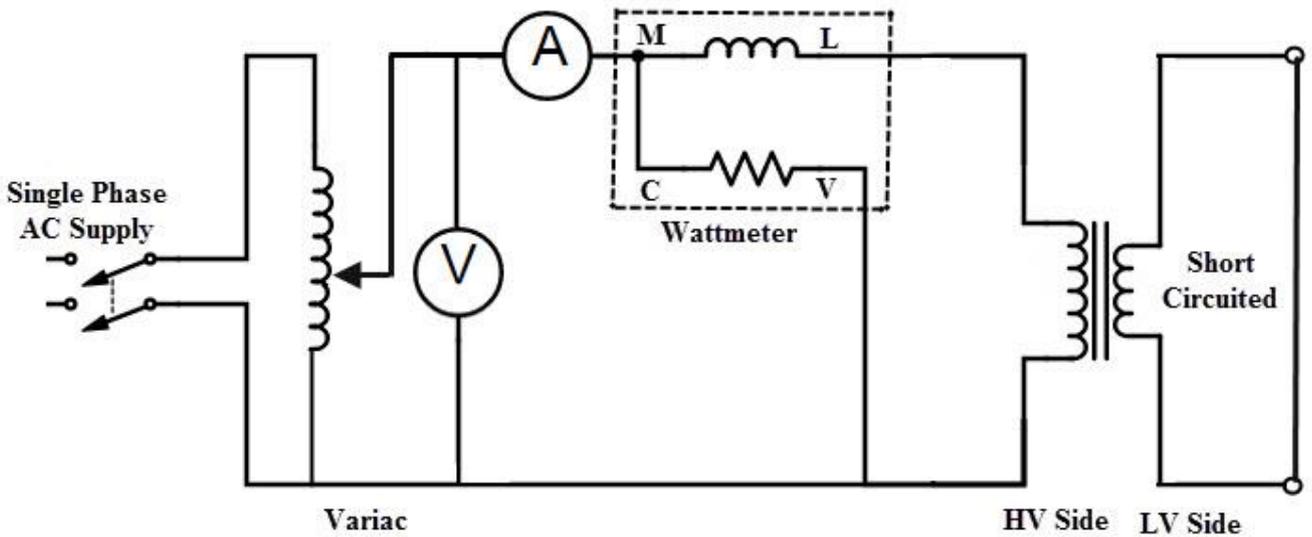
S.NO	NAME OF THE EQUIPMENT	RANGE	TYPE	QUANTITY
1	Single phase transformer	3KVA,230/230V,50 HZ		1
2	Wattmeter	2.5/5A LPF	LPF	1
3	Wattmeter	10/20A UPF	UPF	1
4	Ammeter	0-1A		1
5	Ammeter	0-20A		1
6	Voltmeter	0-300V		1
7	Voltmeter	0-30/75V		1
8	1ph Variac	0-300V,15A		1

OPEN CIRCUIT TEST:



Circuit Diagram: OC Test

SHORT CIRCUIT TEST:



Circuit Diagram: SC Test

THEORY:

The performance of a transformer can be calculated on the basis of its equivalent circuit which contains four main parameters, the equivalent resistance R_{01} as referred to primary (or secondary R_{02}), the equivalent leakage reactance X_{01} as referred to primary, the core-loss conductance G_0 and the

magnetizing susceptance B_0 . These constants or parameters can be easily determined by two test i.e. Open circuit test and short circuit test. These are very economical and convenient, because they furnish the required information without actually loading the transformer. In fact, the testing of very large a.c machinery consists of running two test similar to the open and short circuit test of a transformer.

The purpose of this test is to determine no load loss or core loss and no load I_0 which is helpful in finding X_0 and R_0 . One winding of the transformer whichever is convenient but usually high voltage winding is left open and the other is connected to its supply of normal voltage and frequency. A wattmeter (W), Voltmeter (V) and ammeter (A) are connected in the low voltage winding i.e. primary winding in the present case. With normal voltage applied to the primary, normal flux will be setup in the core, hence normal iron losses will occur which are recorded by the wattmeter. As the primary no load current I_0 is small, Cu loss is negligibly small in primary and nil in secondary. Hence, the wattmeter reading represents practically the core loss under no load condition.

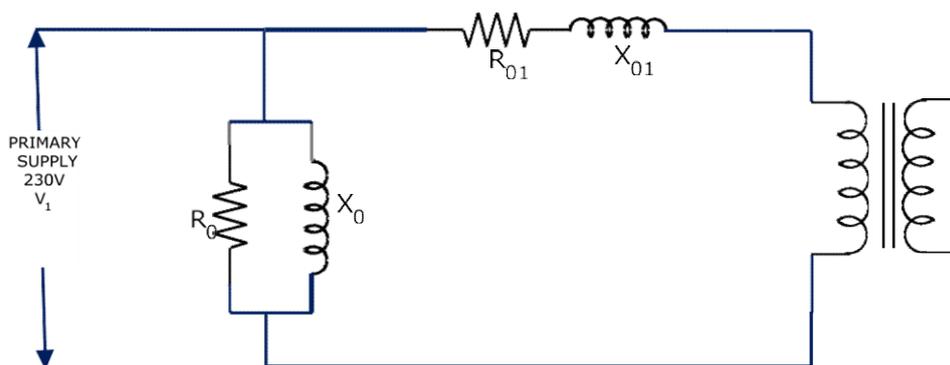
For short circuit test, one winding usually the low voltage winding, is solidly short-circuited by a thick conductor (or through an ammeter which may serve the additional purpose of indicating rated load current).

A low voltage (usually 5 to 10% of normal primary voltage) at correct frequency (though for Cu losses it is not essential) is applied to the primary and is cautiously increased till full- load current are flowing both in primary and secondary (as indicated by the respective ammeters).

Since, in this test, the applied voltage is a small percentage of the normal voltage, the mutual flux ϕ produced is also a small percentage of its normal value. Hence, core losses are very small with the result that the wattmeter reading represents the full load Cu loss or $i^2 R$ loss for the whole transformer i.e. both primary Cu loss and secondary Cu loss. The equivalent circuit of the transformer under short-

circuit condition. If V_{sc} is the voltage required to circulate rated load currents, then $Z_{01} = V_{sc}/I_1$

A two winding transformer can be represented by means of an equivalent circuit as shown below



PRECAUTIONS:

1. Don't switch on power supply without concerning respected teachers.
2. 1 ϕ Auto transformer must be kept at minimum potential point. Before switch on the experiment.

OPEN CIRCUIT TEST PROCEDURE:

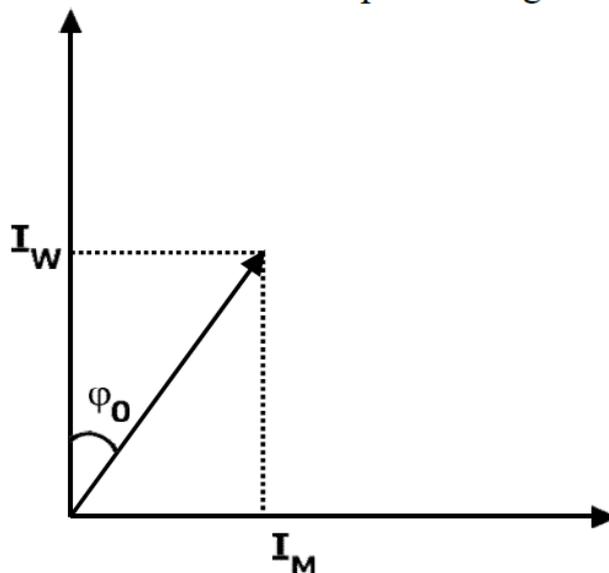
1. Connect circuit as shown in the circuit diagram. open circuit the secondary and apply full load voltage to the primary through a variac. The copper loss is negligible since there is only no load current is flowing. Hence power consumed is the core losses of the core.
2. Note voltmeter and ammeter and wattmeter reading.

OBSERVATION TABLE:

SLNO	V	I_0	W	$I_W = \frac{W}{V}$	$I_M = \sqrt{I_0^2 - I_W^2}$	$\cos\phi = \frac{W}{VI_0}$

CALCULATION:

See the no load phasor diagram below



$$W = VI_0 \cos \phi_0$$

$$I_W = \frac{W}{V}, \quad I_M = \sqrt{I_0^2 - I_W^2}, \quad R_0 = \frac{V}{I_W}, \quad X_0 = \frac{V}{I_M}$$

SHORT CIRCUIT TEST PROCEDURE:

1. Connect as shown in the circuit diagram. Short circuit the secondary and apply a low voltage to the primary through a auto transformer. The iron losses are negligible since the flux will be very low on account of the primary and secondary.
2. Increase the voltage gradually till full load current flows in the primary. Note voltmeter and ammeter and wattmeter reading.

OBSERVATION:

SL.NO.	V	I	W_c

CALCULATIONS:

Let the total equivalent resistance of primary and secondary referred to primary side be R_1 ohms and the total equivalent leakage reactance referred to primary side be X_1 ohms.

$$W_c = I^2 R_1$$

$$\text{Hence } R_1 = W_c / I^2 \quad \text{Also } V / I = Z_1 \text{ and } X_1 = \sqrt{Z_1^2 - R_1^2} \text{ ohms.}$$

CONCLUSION:

- Now draw the equivalent circuit.
- Plot a graph of copper loss versus load current (short circuit current). What is the shape of the curve?
- Determine the regulation of the transformer at various loads for an assumed load power factor of 0.8 lagging.

$$\text{Regulation percentage} = \frac{V_o - V_t}{V_t} \times 100$$

Where V_o = secondary no load voltage.

V_t = secondary full load voltage.

- Plot a curve of regulation versus load current.

RESULT:**POST LAB QUESTIONS:**

- Why iron is chosen as the material for the core of the transformer?
Why not use aluminium?
- What is normally the efficiency of a transformer to be?
- Why Transformers Are Rated In KVA?

Experiment No. 5

Three-phase transformers: Star and Delta connections

AIM:

Three-phase transformers: Star and Delta connections. Voltage and Current relationships (line-line voltage, phase-to-neutral voltage, line and phase currents). Phase-shifts between the primary and secondary side.

APPARATUS REQUIRED:-

S.No.	Name of apparatus	Type	Range	Quality
1.	Ammeter	MI	(0-5)A	02
2.	Voltmeter	MI	(0-500)V	03
3.	3 Phase Transformer		3 KVA,440/440 V-	01
4.	3 Phase Auto Transformer		8/16 A, 415/470 V	01

THEORY:-

Star Connection:

In a 3-phase AC circuit, line voltage is equal to 1.732 times of the phase voltage and line current is equal to the phase current .i.e.

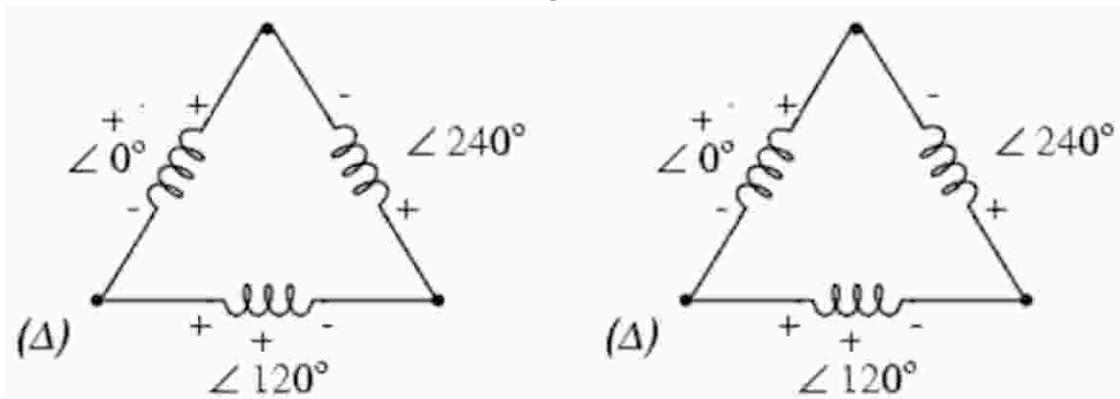
$$V_{Line} = \sqrt{3} V_{Ph}; I_{Line} = I_{Ph}$$

Delta Connection:

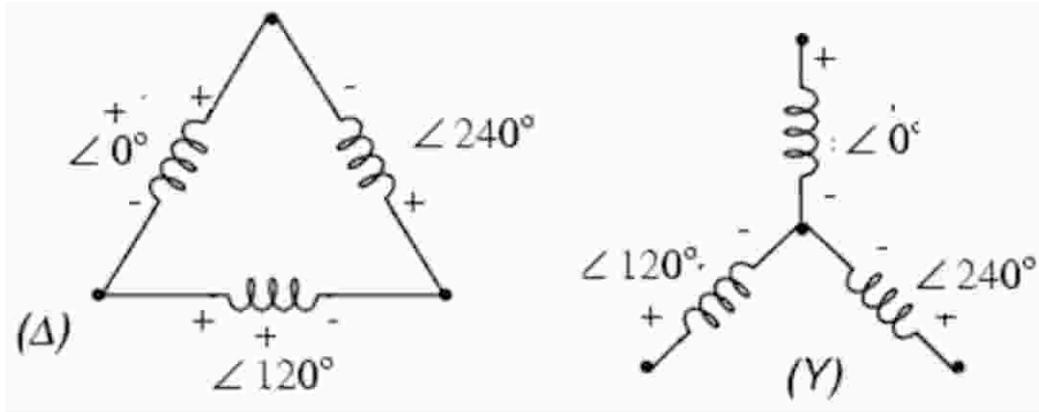
In a 3-phase delta connection line current is equal to 1.732 times of the phase current and line voltage is equal to phase voltage .i.e.

$$I_{Line} = \sqrt{3} I_{Ph}; V_{Line} = V_{Phase}$$

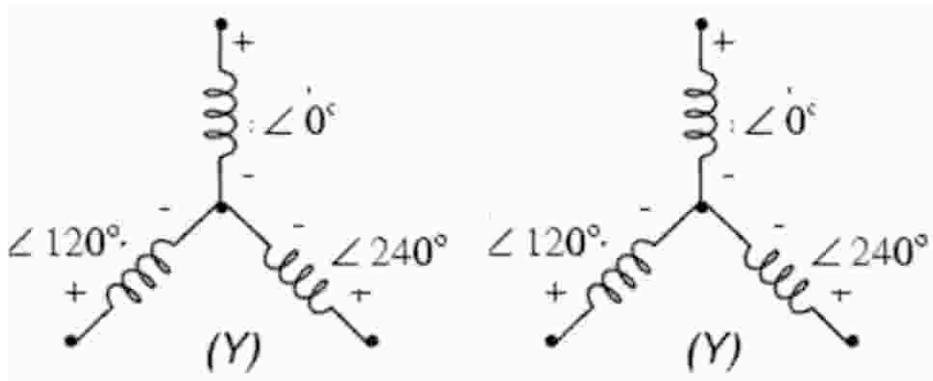
Delta/Delta Connection:- The ratio of primary to secondary line voltages remains equal to the ratio of transformation 'a'. The main advantage of this connection lies in that the system can still operate on 58% of its rated capacity even in case of failure of one of the transformers. The remaining two transformers work in open delta or V. This connection is favoured for voltages below 50 KV.



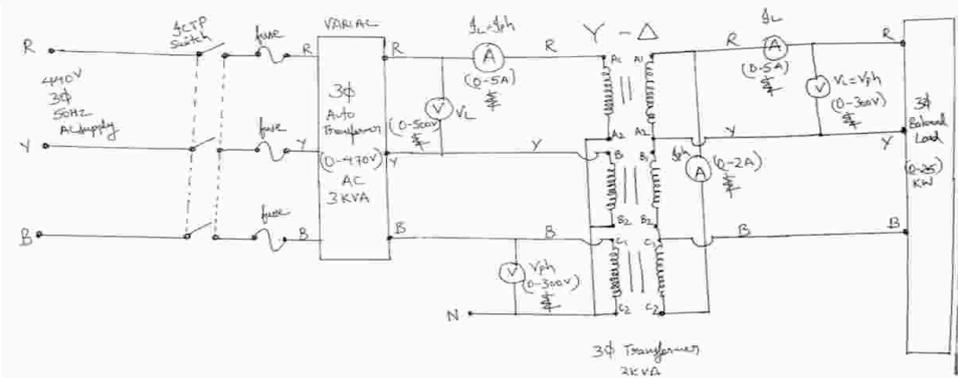
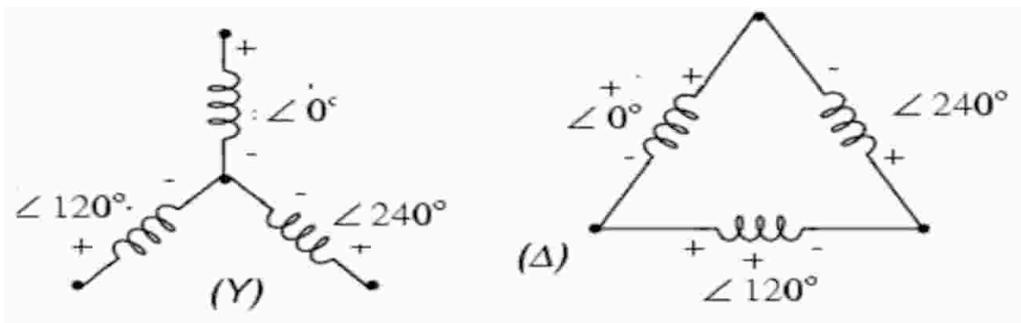
Delta/Star Connection:- This gives a higher secondary voltage for secondary for transmission purposes than connections with delta secondaries without increasing the strain on the insulation of the transformers. It is the connection commonly used at the generating end of transmission lines. The star neutral is generally grounded.



Star/Star Connection:- This permits the neutral points of both primary and secondary 3 phase circuits. When the primary neutral is not connected to the source neutral, it is necessary to use delta connected tertiary winding in order to avoid imbalance in the system.



Star/Delta Connection:- This connection is commonly used at the receiving ends of high voltage transmission lines.



PROCEDURE:-

Fig: 3.1 star delta connection of a 3-ph transformer

- (a) Connect the circuit as shown in figure.
- (b) Ensure that variac is at its minimum position.
- (c) Switch ON the supply by closing switch and apply the rated voltage slowly by increasing the position of variac.
- (d) Note down the reading of Ammeters & Voltmeters.
- (e) Now decrease the applied voltage up to zero by decreasing the position of variac.
- (f) Switch OFF the supply.

**OBSERVATION TABLE:-
(PRIMARY SIDE)**

(SECONDARY SIDE)

TYPE OF CONNECTION	I_{line}	I_{phase}	V_{line}	V_{phase}	I_{line}	I_{phase}	V_{line}	V_{phase}
star/star								
star/delta								
delta/star								
delta/delta								

RESULTS:-

We have studied about the construction, various connection of 3- Φ transformers and obtain the line and phase voltages on both sides (primary and secondary) of the transformer.

PRECAUTIONS:-

- 1. All connection must be tight.
- 2. Get the circuit connections checked by the teacher before performing the experiment.
- 3. Power to the circuit must be switched on in the presence of the teacher.
- 4. Get the experimental readings checked by the teacher.
- 5. Don't touch directly the live parts of equipment and circuit.
- 6. Wear leather shoes in the lab.

VIVA VOICE:

- 1) Explain line voltage, line current, phase voltage, phase current.
- 2) What is the relationship between line voltage and phase voltage in star connection?
- 3) Can a 3 ph transformer is used to step up 1 ph ac voltage?
- 4) What is a 3-ph auto transformer?

Experiment No-6

SPEED CONTROL OF DC SHUNT MOTOR

AIM:

To study the variation of speed of a. d. c. shunt motor.

- i) With armature voltage under constant field excitation, and
- ii) ii) With field excitation under constant armature voltage.

APPARATUS:

Sl.NO.	Name of the equipment	Range	Type	Qty
1	DC Shunt motor expt setup			1
2	Ammeter	0-1A,0-5A	MC	1
3	Voltmeter	0-300	MC	1
4	Rehostats	185 Ω /1.5A,40 Ω /6.7A	wirewound	1 each
5	Connecting Wires	1sqmm		As Required

CIRCUIT DIAGRAM:

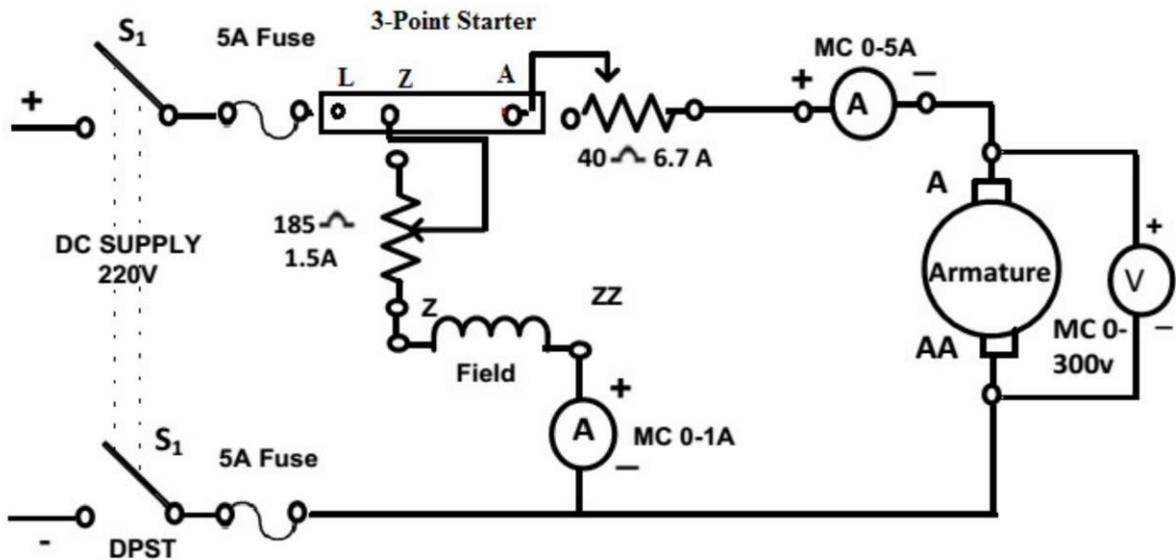


Fig 1. Speed Control of D.C. Shunt Motor

PROCEDURE:

- i) Connect the circuit as shown in figure – 1.
- ii) Start the motor with maximum resistance in the armature circuit and minimum resistance in the field circuit.
- iii) Bring the motor to the rated speed, first by decreasing the resistance in the armature circuit and then by increasing the resistance in the field circuit.
- iv) Vary the resistance in the field circuit and take readings of speed and field current, keeping the armature voltage constant at a particular value.
- v) Change armature voltage to another value and repeat the procedure given in(iv)
- vi) Then change the resistance in the armature circuit and take reading of speed and armature voltage, keeping the field current constant at a particular value.
- vii) Change the field current to another value, repeat the procedure given in (vi).
- viii) Take three sets of readings for each method of variation.

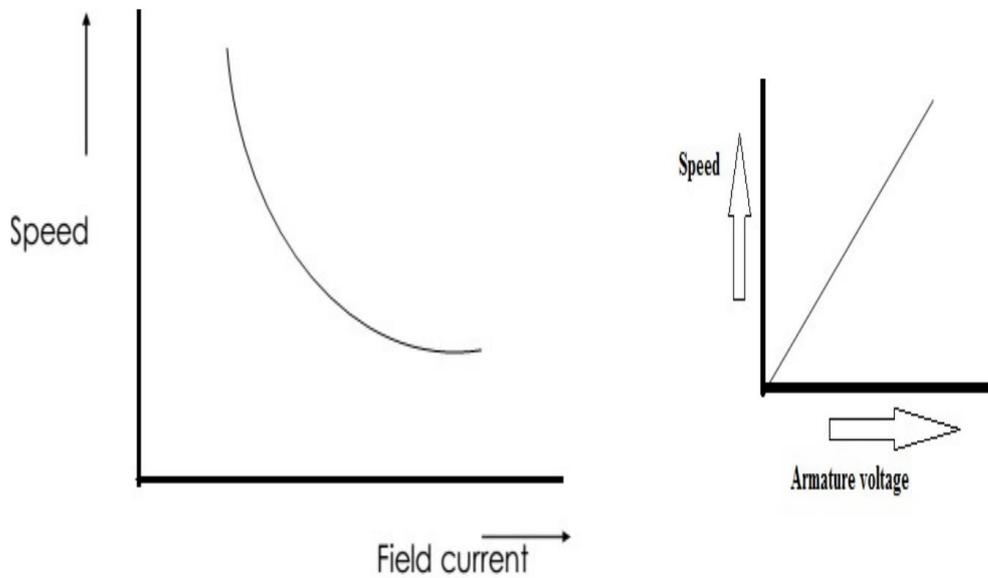
OBSERVATION :**Table I: Variation of speed with field excitation.**

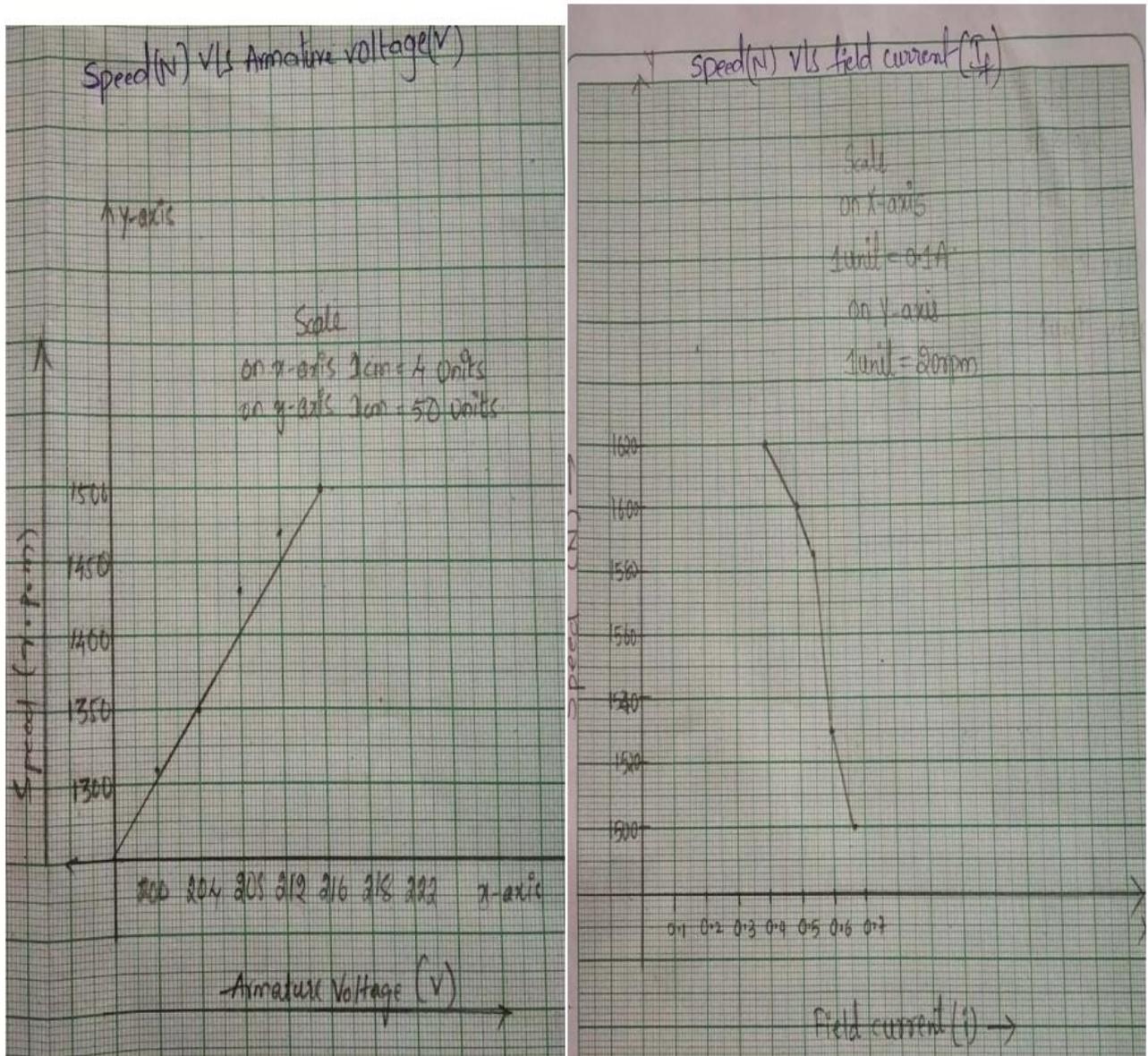
Sl.No	Field current (I_F amps)	Speed N (rpm)	Constant Armature Voltage(V)
1	0.67	1500	216
2	0.6	1530	216
3	0.55	1585	216
4	0.5	1600	216
5	0.4	1620	216

Table II. Variation of speed with armature voltage.

Sl.No	Armature Voltage(V)	Speed N(rpm)	Constant Field Current (I_F amps)
1	216	1500	0.66
2	212	1470	0.66
3	208	1430	0.66
4	204	1350	0.66
5	200	1310	0.66

MODEL GRAPH i) Plot speed against field current for different sets of constant armature voltage on a graph paper. ii) Plot speed against armature voltage for different sets of constant field current on another graph paper





RESULTS:

The field control method and armature control method on D.C shunt motor is studied.

DISCUSSION:

- i) Discuss and explain about the nature of the plots with relevant equations.
- ii) Discuss about the limitations and merits of the two methods of speed control.
- iii) Why do you keep the resistance in the armature circuit at a maximum, and resistance in the field circuit a minimum at start?
- iv) What will happen when the field circuit gets opened, while the machine is running.

Experiment No-07
TORQUE-SLIP Characteristics of an Induction Motor

AIM:

To determine the Torque vs. slip characteristics of an Induction motor.

APPARATUS :

Sl No	Apparatus Name	Apparatus Type	Specification / Range	Makers Name	Serial No
1	Induction Motor				
2	Ammeter				
3	Voltmeter				
4	Wattmeter				
4	Variac				
7	Tachometer				

THEORY:

In this test supply voltage is applied to motor and variable mechanical load is applied to the shaft of motor. Mechanical load can be provided by brake and pulley arrangement. The input current, input voltage, input power and speed of motor are observed from the experiment and various performance quantities are calculated as explain below.

SLIP:

Due to the three-phase supply given to stator of an induction motor, a rotating magnetic field of constant magnitude is set up in the stator of the motor. The speed with which this rotating magnetic field rotates is known as synchronous speed and is given by

$$N_s = 120f / P$$

Where

f =supply frequency. P =no of poles on the stator of the rotor. The actual speed of the rotor N_r is always less than the synchronous speed. So the slip of the motor is given by

$$s = \frac{N_s - N_r}{N_s} \times 100\%$$

This value of slip at full load lies between 2 to 5%.

TORQUE :

Mechanical loading is applied on induction motor by means of brake and pulley arrangement. The belt can be tightened or loosened by means of threaded rods with handles fixed on frame. Two spring balances are provided at the end of belt. The net force exerted at the brake drum can be obtained from the readings of the two spring balance i.e. F_1 and F_2

Net force exerted on drum, $F = (F_1 - F_2)$ Kgf

And Torque $T = F \times \frac{d}{2} \times 9.81$ Nw-m

Where d = effective diameter of brake drum in meter.

OUTPUT POWER :

The output power of induction motor can be calculated as $P_o = \frac{2\pi N_r T}{60}$

Where N_r = speed of induction motor in rpm.

INPUT POWER :

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

$$P_{in} = W$$

POWER FACTOR :

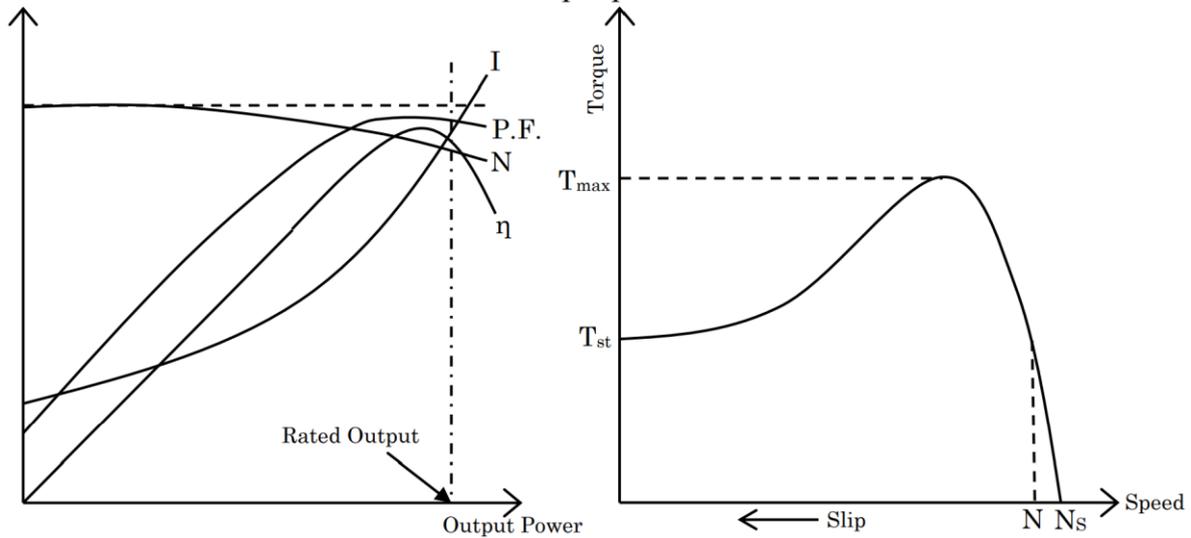
The power factor can be calculated from the following relation

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

EFFICIENCY :

The efficiency of induction motor can be calculated using the relation

$$\eta = \frac{\text{output power}}{\text{input power}} \times 100\%$$



CIRCUIT DIAGRAM :

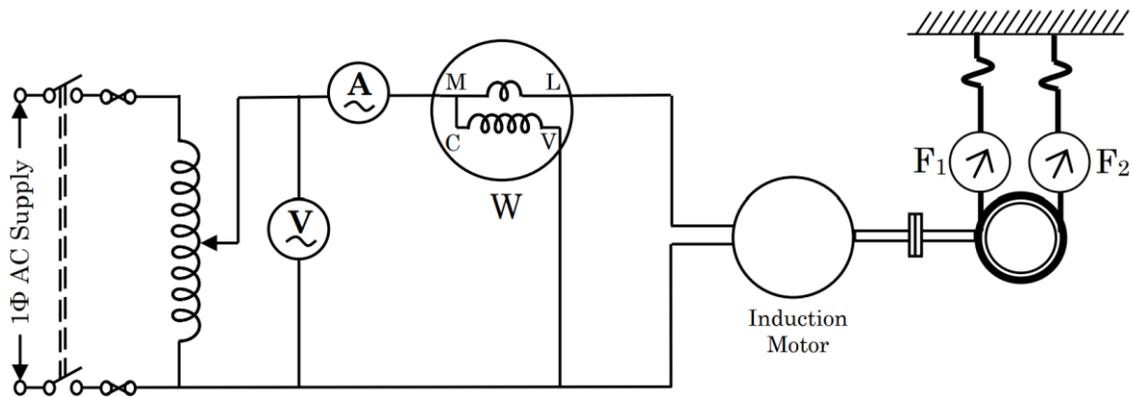


FIG : EXPERIMENTAL SET-UP FOR PERFORMING NO-LOAD AND BLOCK-ROTOR TEST OF SINGLE PHASE INDUCTION MOTOR

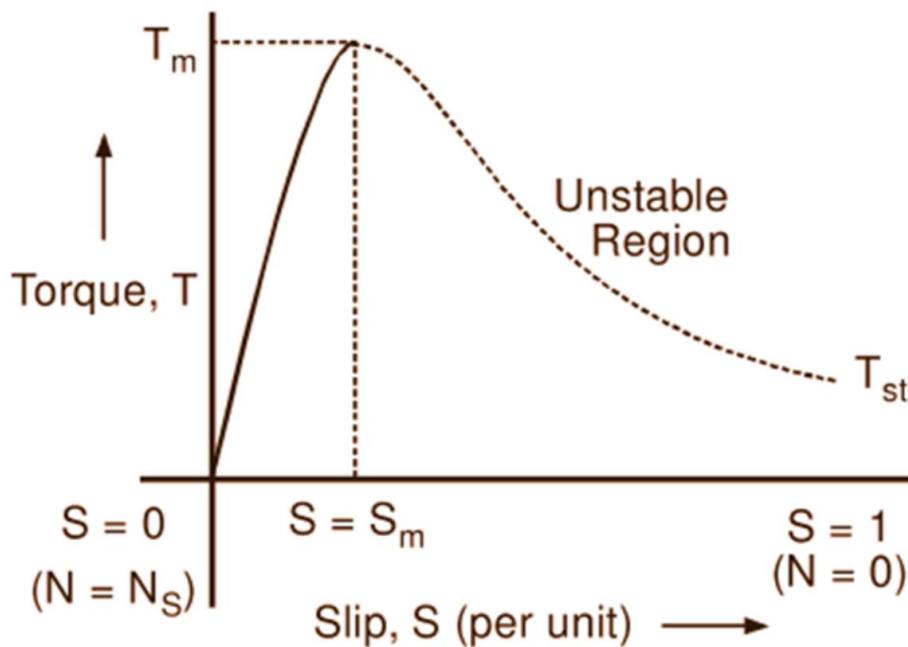
PROCEDURE :

- 1) Connect the circuit as shown in Fig.
- 2) Set the single-phase variac at minimum voltage and brake pulley arrangement at no load.
- 3) Switch ON the power supply and start the induction motor.
- 4) Now gradually increase the applied voltage by varying the variac very slowly up to the rated voltage.
- 5) Increase the mechanical load on motor step by step and note down the various reading for load.
- 6) Switch OFF the supply and disconnect the motor.
- 7) Calculate the various quantities and draw the various curves as stated above.

OBSERVATION TABLE :

SL NO	Input Voltage V (volt)	Input Current I (amp)	Input Power W (watt)	Force (Kgf)			Speed N_r (rpm)
				F_1	F_2	$F = F_1 - F_2$	
1							
2							
3							
4							
5							

Model Graph:



Result:

T-S characteristics of an induction motor obtained

Experiment No. 8
Demonstration of dc-dc converters.

APPARATUS REQUIRED:

Sr. No.	Name of apparatus	Specification	Quantity
1	buck, boost and buck- boost converters trainer kit	-	1
2	DC Voltmeter	0-50 V	2
3	CRO	20 MHz	1
4	CRO probe	1:10 type	1
5	Patch cords	-	As per required
6	AC power supply	1 phase, 230 V, 50 Hz	-

THEORY:

Operating principle:

Boost converter:

A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

Operating principle:

The operation of the boost converter is relatively straightforward.

When the switch is in ON position, the inductor output is connected to ground and the voltage V_{in} is placed across it. The inductor current increases at a rate equal to V_{in}/L .

When the switch is placed in the OFF position, the voltage across the inductor changes and is equal to $V_{out} - V_{in}$. Current that was flowing in the inductor decays at a rate equal to $(V_{o}-V_i)/L$.

In reality no boost converter will be lossless, but efficiency levels of around 85% and more are achievable in most supplies.

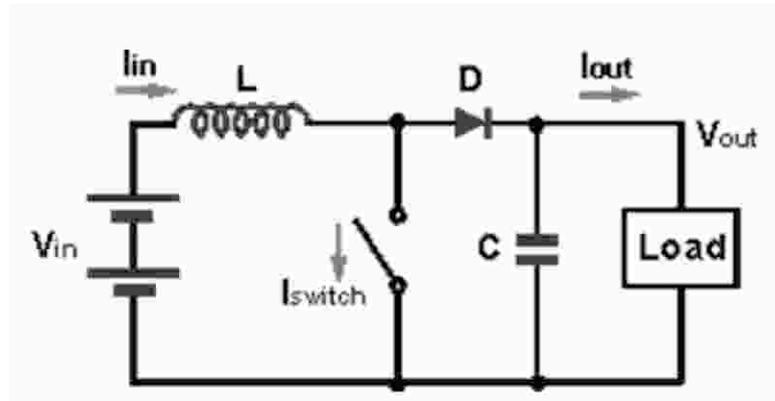


Fig. 6.2 Circuit diagram of boost converter

PROCEDURE:

For Boost converter:

1. Keep AC voltage selection switch in T2.
2. Keep P4 in most anticlockwise position.
3. Keep selector switch in P2.
4. Now connect test point marked as R1 to the test point marked as R1 on boost configuration.
5. Connect PSC1 (+ve) to PSC1 terminal in boost configuration.
6. Now check these connections carefully before switch ON the system.
7. Now slowly increase Pot P4 clockwise direction.
8. Observe the output carefully.

1. For Boost converter

Sr. No.	V_{in}	V_{OUT}

RESULT:

Thus we have studied the Boost Converter.

Experiment No-09

Calibration of Single-Phase Energy Meter

To study the connections of an energy meter.

To use it to measure Electrical energy and also to calibrate the given energy meter

APPARATUS:

Sl.NO.	Name of the equipment	Range	Type	Qty
1	Autotransformer	0-230V		1
2	Ammeter	0-10A	MI	1
3	Voltmeter	0-300v	MI	1
4	Resistive Load	10 amps	1- Φ	1
5	Energy meter		Dynamometer	1
6	Connecting wires	1sqmm		As required

CIRCUIT DIAGRAM:

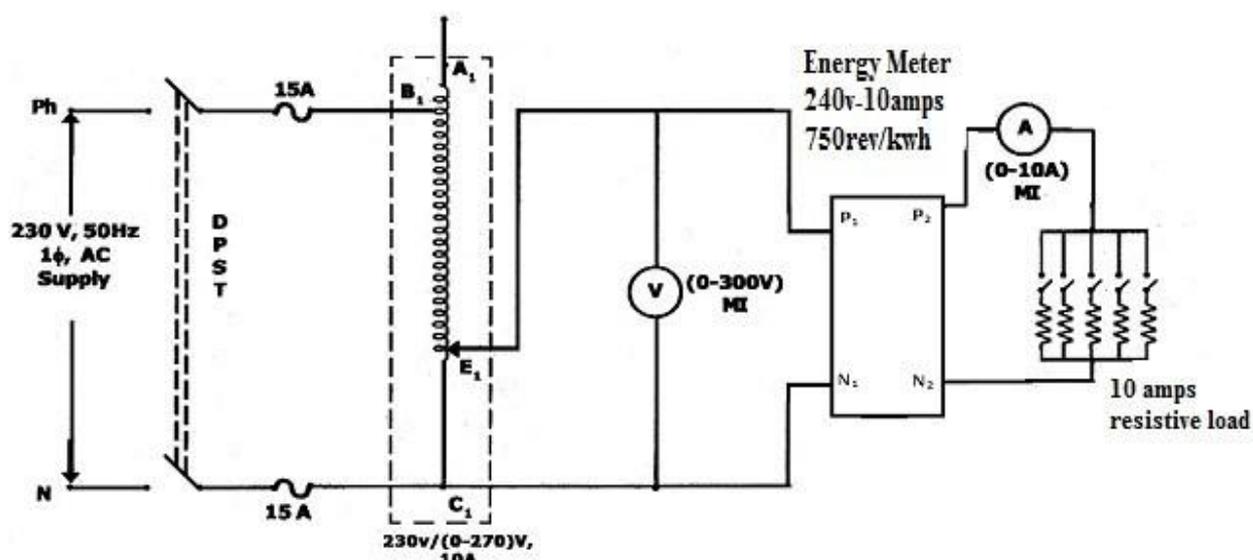


Fig.1- Φ Energy Meter Testing

M – Mains line)

N – Neutral(return)

L -- Load

PROCEDURE:

1. Note the specifications of the energy meter as given on its name plate.
2. suitable ranges of the ammeter and voltmeter such that energy meter can be tested over its complete range
3. Connect the circuit as shown in the diagram.
4. Before switching on the supply ,ensure that the loading rheostat switches (all)are open.
5. Note down the initial reading of the energy meter.
6. Set the desired load by selecting a suitable combination of Switches on the loadingrheostat.
7. Switch on the supply and wait for the red indicator of the energy meter disc to come in thefront. At this moment start the stopwatch. Note down the voltmeter and ammeter readings.
8. Measure the time (T) for (N) revolutions (say 20 revolutions) switch off the stopwatch immediately. Switch off the supply.
9. By adjusting the loading rheostat take 8 to 10 sets of readings covering the fullcurrent range of the energy meter and tabulate the observation asin table

OBSERVATION TABLE:

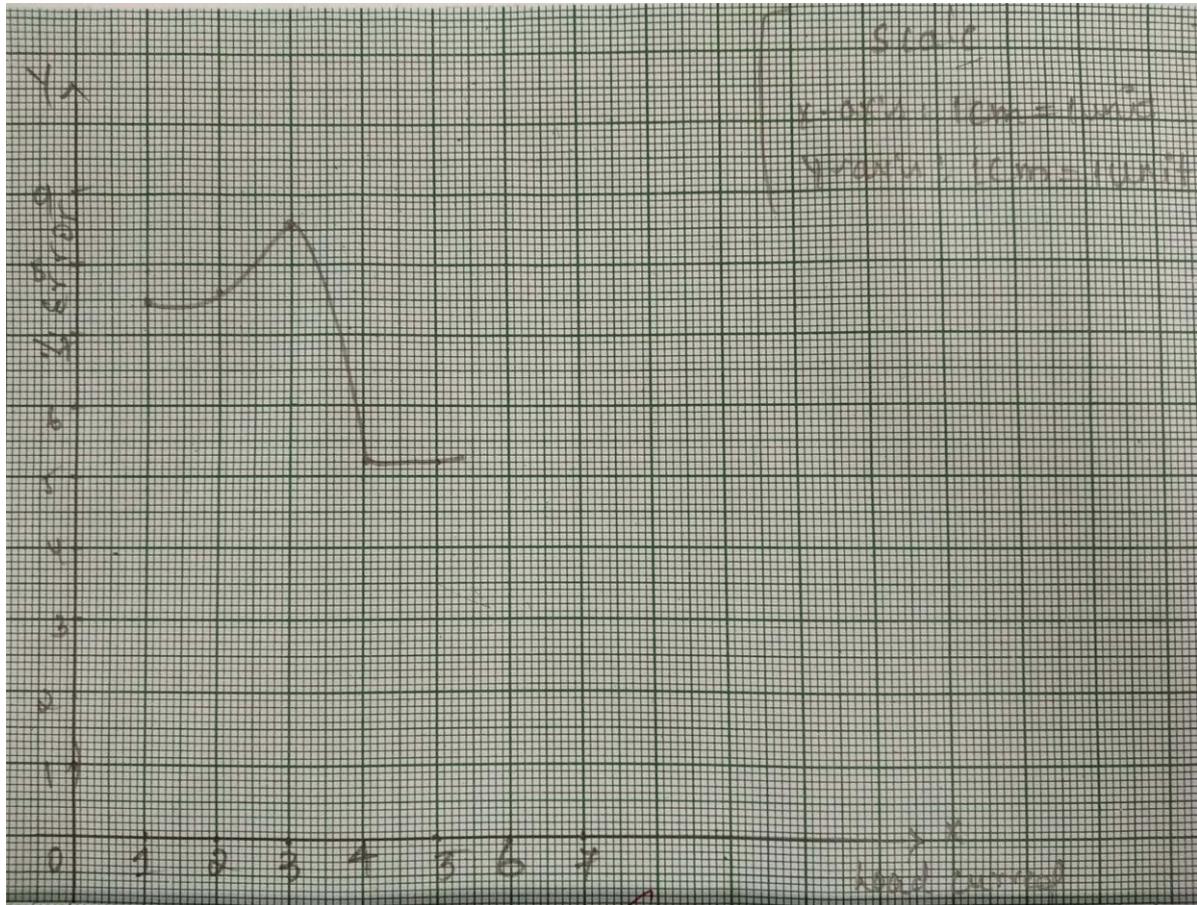
V_s	I_L (A)	Time T (s)	$E_m = \frac{N}{M}$	$E_a = \frac{V.I.T}{(1000 \times 3600)}$	% Error = $\frac{E_m - E_a}{E_a} \times 100$
230	1	48	6.66×10^{-3}	6.13×10^{-3}	7.66%
230	2	41	6.66×10^{-3}	6.19×10^{-3}	7.59%
230	3	32	6.66×10^{-3}	6.12×10^{-3}	8.64%
230	4	25	6.66×10^{-3}	6.33×10^{-3}	5.21%
230	5	20	6.66×10^{-3}	6.10×10^{-3}	5.20%

Meter constant M =750 revolutions/kWh

E_m =Energy Recorded by the meter E_a =Actual Energy Consumed During N rev.

Model graph:

Plot the graph % Error Vs Load Current curve:



Result: The given energy meter is calibrated, and also error calculated.

Discussion:

- ▶ Possible causes of error in the reading of an energy meter
- ▶ Methods for eliminating the errors.

Experiment No-10

THREE –PHASE POWER MEASUREMENT

AIM:

To measure power in a three phase circuit under

- i) Balanced resistive load condition
- ii) Unbalanced resistive load condition

APPARATUS REQUIRED:

S.No	Equipment Name	Range	Type	Quantity
1	Voltmeter	(0-150)V	MI	3No's
2	Ammeter	(0-5)A	MI	3No's
3	Wattmeter	5A,150V	Electrodynamometer type	2No's
4	TPST	-	-	1No's
5	Fuse	5A	-	3No's
6	Rheostat	26 Ω /4.1A	Wire wound(Variable)	3No's
7	Gang Rheostat	26 Ω /4.1A of each limb	Wire wound(Variable)	1No
8.	3 ph variaic	0-440V		1 No

BALANCED RESISTIVE LOAD

CIRCUIT DIAGRAM:

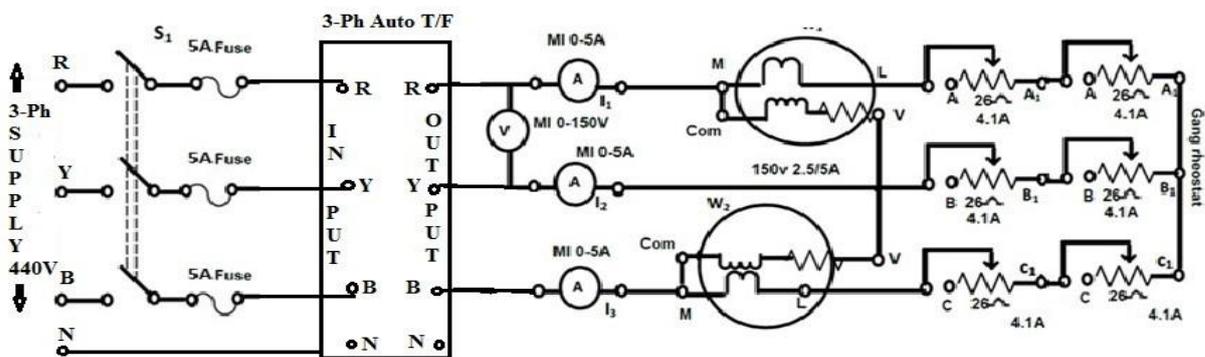


Fig.1 BALANCED RESISTIVE LOAD

PROCEDURE:

1. Connect the circuit as shown in Fig.1
2. Adjust the gang rheostat and Individual rheostats for the maximum resistance.
3. Switch on the supply and set the autotransformer to 120V.
4. Close switch S1.
5. Read the meters to obtain VL, I1, I2 and I3. Note the wattmeter reading W1 and W2 (Note the multiplying factor on the wattmeter).

6. Vary the Gang rheostat resistance and obtain at least five sets of observations, the current should not exceed the limit (4.1 A).
7. Tabulate the readings and check the results by completing the calculations

OBSERVATION TABLE -1:

(Three phase power in a balanced load)

S.No.	V _L	I ₁	I ₂	I ₃	W ₁	W ₂	W _C	W _M W ₁ + W ₂	%Error $\frac{W_M - W_C}{W_C} * 100$
1	120	1.25	1.4	1.4	160	133	280.59	293	4.42%
2	120	1.35	1.6	1.5	163	133	308.30	296	-3.98%
3	120	1.65	1.7	1.5	173	152	339.48	325.5	-4.11%
4	120	2.45	2.6	2.4	276	250	516.15	526	1.90%

UNBALANCED RESISTIVE LOAD

CIRCUIT DIAGRAM:

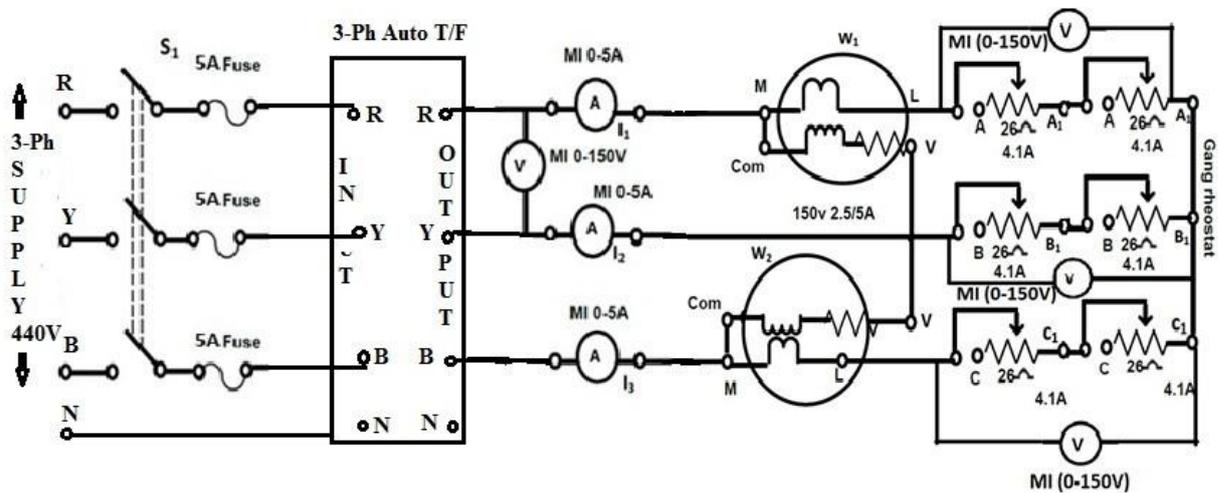


Fig.2 UNBALANCED RESISTIVE LOAD

PROCEDURE:

1. Connect the circuit as shown in Fig. 2.
2. Adjust the three rheostats and gang rheostat at the maximum values.
3. Switch on the supply and set the autotransformer to 120V.
4. Close switch S1 and take five sets of observation for different rheostat settings such that the reading of I1, I2 and I3 in each set is appreciably different to create unbalanced loading condition. (Don't vary the gang rheostat). The current should not exceed the limits in each arm.

5. Note down $I_1, I_2, I_3, V_1, V_2, V_3, W_1$ and W_2 . Check the result by completing the computations indicated in Table.2.

OBSERVATION TABLE -2

(Three phase power in an unbalanced load)

S.No.	V_1	V_2	V_3	I_1	I_2	I_3	W_1	W_2	W_C	W_M $W_1 + W_2$	%Error $\frac{W_M - W_C}{W_C} * 100$
1	85	72	54	1.4	1.9	2	210	150	368.05	360	-2.18%
2	75	55	80	1.8	2.1	1.4	210	142.5	362.5	352.5	-2.75
3	58	80	73	2.1	1.65	1.7	140	222.5	377.9	362.5	-4.07%
4	67	65	65	1.12	1.25	1.9	150	150	283.37	300	5.6%

RESULT:

The three phase power is measured by two wattmeter method is studied and error had been calculated.

Experiment No-11

Characteristics of Lamps

- a) Obtaining the V-I characteristics of the following nonlinear elements
Lamp (L1): 40W, 220V AC Tungsten Lamp

Lamp (L2): 18W, 220V AC, Compact Fluorescent Lamps (CFL).

APPARATUS:

Sl.NO.	Name of the equipment	Range	Type	Qty
1	Autotransformer	0-230V		1
2	Ammeter	0-0.2A	MI	2
3	Voltmeter	0-300v	MI	1
4	Incandisent lamp,CFL lamp	40w,18w		1

Circuit Diagram:

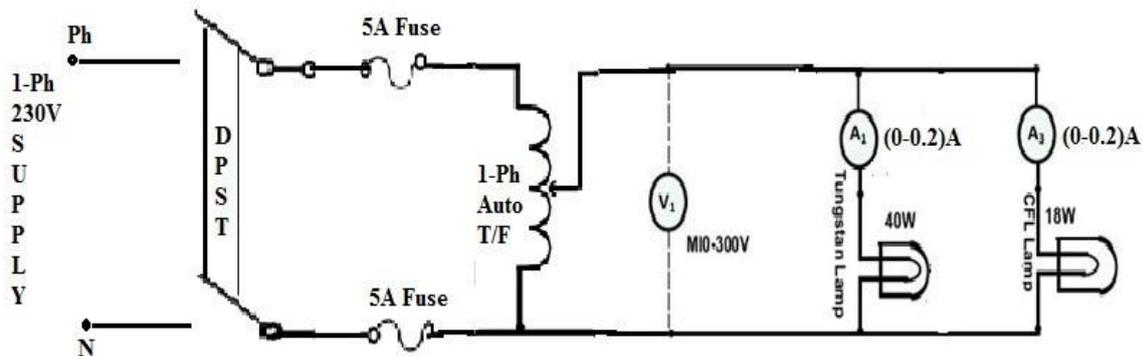


Fig.1 V-I characteristics of the Tungsten and CFL Lamp

Procedure for V-I characteristics of the Tungsten and CFL Lamp

- a) Choose the appropriate ratings of the Ammeters, Voltmeters and Fuse wire.
- b) Set up the circuit as shown in Fig 1 with the lamps and instruments as indicated. Keep the switch S open.
- c) Set the autotransformer for zero output voltage. Close the switch S.
- d) Increase the autotransformer output voltage in steps of 20/30 V, until the full voltage (i. e 230V) is obtained. At each step, note the readings of V_1 , A_1 , A_2 and record them in
- e) Table 1. Repeat step (d) decreasing output voltage of auto transformer from full to zero volts.

Observation Table :

S.No	V ₁ (V)	I ₁ (A) (Tungsten Lamp)			I ₂ (A) (CFL Lamp)		
		Inc	Dec	Mean	Inc	Dec	Mean
1.	40	0.08	0.076	0.078	0.08	0.076	0.078
2	80	0.086	0.102	0.094	0.09	0.086	0.088
3	120	0.11	0.124	0.117	0.086	0.084	0.085
4	160	0.132	0.144	0.138	0.082	0.08	0.081
5	200	0.15	0.162	0.156	0.078	0.078	0.078
6	230	0.16	0.166	0.163	0.074	0.074	0.074

Model graph

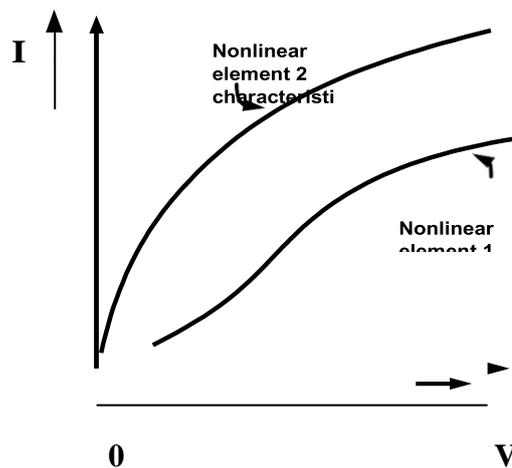


Fig.2 Model graph for V-I characteristics

RESULT:

V-I Characteristics of different lamps have been studied.

Discussion Questions:

1. How will you interpret the v-i characteristics of two different incandescent lamps?
2. Why do the readings differ for increasing and decreasing values of the lamp voltages? Discussion Questions:
 1. Account for the differences, if any, between the predicted and the observed steady state operating points of the circuit.

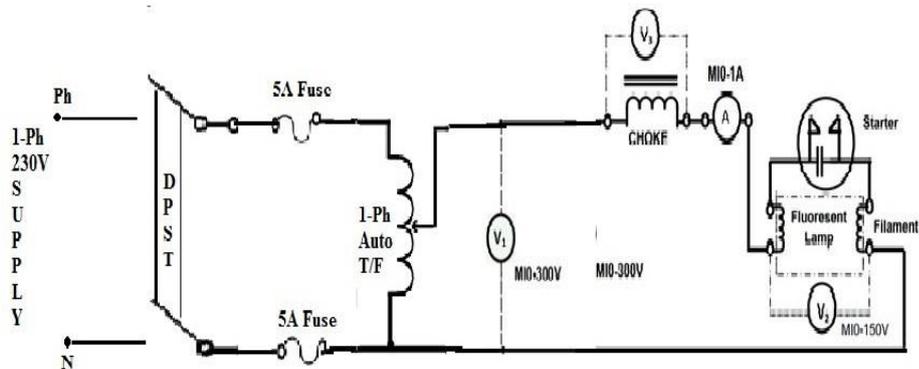
Why source characteristics will be referred as load line characteristics?

II.FLUORESCENT LAMP:

Aim: To obtain the V-I characteristics of a Fluorescent Lamp

APPARATUS:

Sl.NO.	Name of the equipment	Range	Type	Qty
1	Autotransformer	0-230V		1
2	Ammeter	0-0.2A	MI	2
3	Voltmeter	0-300v,0-150v	MI	2,1
4	Fluorescent lamp	36w		1



.0

Fig.7 Circuit diagram for testing of a Fluorescent Lamp

Procedure:

1. Set up the circuit as shown in Fig.7 Keep the switch S open.
2. With the autotransformer at zero output position, close the switch S.
3. Increase the autotransformer output gradually until the lamp lights up. Note the meter readings and enter them in the proper column in Table 3.

When the lamp starts to glow, increase the autotransformer output voltage in steps until the rated voltage is obtained. Enter the readings of the meters in Table 3.

4. Decrease the supply voltage in steps until the lamp extinguishes. Record the meter readings

Table 3: Fluorescent lamp characteristics.

S.NO.	V _s	V _L	V _c	I _L	Remarks
1	230	106	184	3.6	Full bright
2	210	114	150	2.4	Low bright
3	190	128	124	2.2	Dim
4	150	149	20	0	Light extinguish

V_s = Voltage across the supply = reading of the voltmeter V₁

V_L = Voltage across the lamp = reading of the voltmeter V₂

V_c = Voltage across the choke = reading of the voltmeter V₃

I_L = Current through the lamp = reading of the ammeter A

RESULT: The characteristics of fluorescent lamps are studied.

Discussion Questions:

1. Plot V_L versus I_L and V_c versus I_L on the same graph sheet.
2. Comment on the nature of the plots. How are V_L and V_c related?
3. Discuss the function of the choke in the lamp circuit. Can it be replaced by a resistor?
4. What is the necessity of a starter? Can a single- pole switch replace it?
5. The voltage needed for starting the glow of the lamp and the voltage when the lamp extinguishes, are not equal. Explain why?
6. If ac supply is replaced by dc, will the circuit work? If not, what changes are to be made?

Experiment No-12

Verification of Network Theorems

The objective of this experiment is to verify the

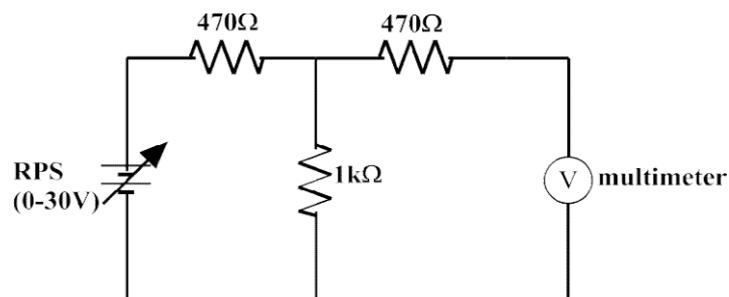
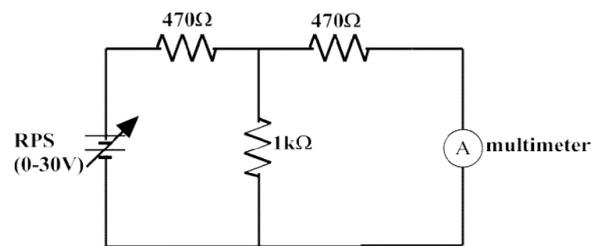
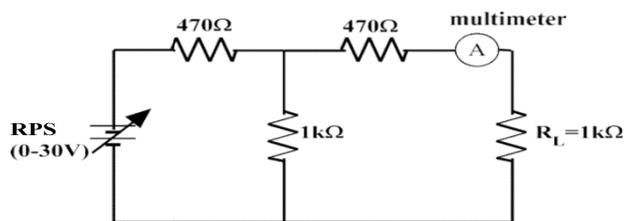
- a. Thevenin's Theorem
- b. Superposition Theorem

APPARATUS:

Sl.NO.	Name of the equipment	Range	Type	Qty
1	Resistors	470 Ω		1
		470 Ω		1
		1k Ω		1
		1k Ω		1
2	Bread board	-	-	1
3	Regulated power supply	0-30V	-	1
4	Multimeter	-	Digital	1
5	Single Stand Wires			As Required

a) Thevenin's Theorem

Circuit Diagrams:



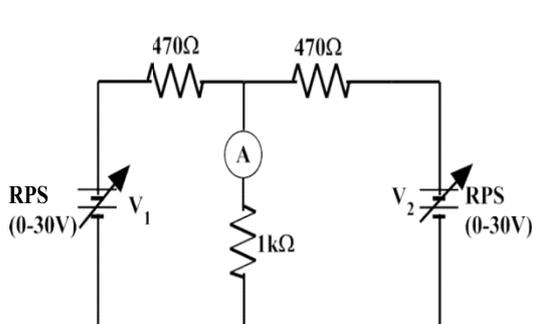
Procedure:

Fig1: Circuit Diagram for verification of thevenin's theorem

1. Connect the circuit as shown in fig1(a)
2. Switch on the RPS and apply some input voltage (say 30V), observe the load current I_L .
3. Now reconnect the circuit as shown in Fig1(b) and apply the same input voltage as in step 2 and observe the short circuit current (I_{SC}).
4. Now reconnect the circuit as shown in fig1(c) and apply the same input voltage as in step 2 and observe the voltage (V_{Th}), open circuit voltage which is nothing but the thevenin's
5. Now compute the thevenin's equivalent resistance ($R_{Th} = V_{Th} / I_{SC}$).
6. Compute the load current applying thevenin's theorem as $I_L = V_{Th} / (R_{Th} + R_L)$.
7. Compare the above load current with its observed value in step(2) and verify the theorem.
8. Adjust the input voltage to a new value and repeat the procedure from step(2) to step(7) (Take at least five sets of readings).

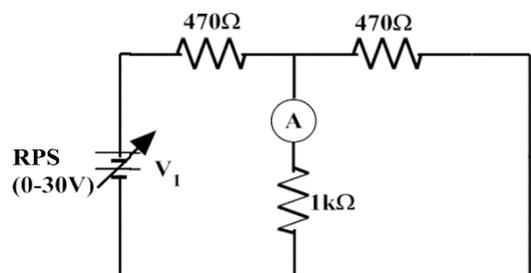
Table-I Thevenin's Theorem:

Sl.No	Source voltage V_s	Observed load current (I_L) ma	I_{SC} ma	V_{Th}	$R_{Th} = (V_{Th} / I_{SC})$ c	Computed load current $(V_{Th} / (R_{Th} + R_L)) = I_{Lm}$ a
1	10	3.8	8.3	6.75	0.813	3.72
2.	20	7.4	16.9	13.4	0.792	7.4



b) **Superposition Theorem:**

(a)



(b)

c) **Circuit Diagram:**

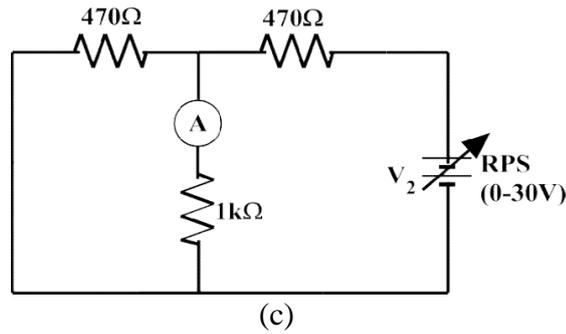


Fig2: Circuit Diagram for Superposition Theorem

Procedure:

1. Connect the circuit as shown in the Fig2(a), apply some input voltage V_1 and V_2 and observe the current (I) through the $1k\Omega$ resistor.
2. Connect the circuit as shown in fig2(b), and apply the same voltage V_1 as in step1 and observe the current (I_1) through the $1k\Omega$ resistor.
3. Connect the circuit as shown in fig2(c), and apply the same voltage V_2 as in step1 and observe the current (I_2) through the $1k\Omega$ resistor.
4. Compare I with (I_1+I_2) taking care of signs properly to verify the theorem.
5. Repeat the procedure from step1 to step4 for five different combinations of voltages V_1 and V_2

Table – II Superposition Theorem: For $V_s=10,20v$

Sl.No.	I_T ma	I_1 ma	I_2 ma	Computed current ($I_T=I_1+I_2$)ma	Error	%Error
1.	8.3	4.1	4.2	8.3	0	0
2	16.18	8.16	7.99	16.15	0.03	3

RESULT: Hence the Thevenin's and superposition theorems Are verified.

Discussion:

- 1) Can you suggest any alternative procedure for the determination of Thevenin's resistance R_{Th} ?
- 2) Is there any restriction for the choice of circuit elements?'
- 3) While considering the effect of a single source, the other source is short circuited why?How far is it justified?

