BASIC ELECTRICAL TECHNOLOGY LAB MANUAL

(COMMON TO ALL BRANCHES OF ENGG)

Subject: Basic Electrical Technology

Subject Code: ESC 107-A

B.Tech 1st /2nd Semester

Department of Electrical Engineering
J. C. Bose University of Science and Technology
YMCA, Faridabad-121 006

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION OF THE DEPARTMENT

Electrical Engineering Department congregates the challenges of new technological advancements to provide comprehensively trained, career-focused, morally strong accomplished graduates, cutting-edge researchers by experimental learning which contribute to ever-changing global society and serve as competent engineers.

MISSION OF THE DEPARTMENT

- To commit excellence in imparting knowledge through incubation and execution of high-quality innovative educational programs.
- To develop the Research-oriented culture to build national capabilities for excellent power management.
- To inculcate and harvest the moral values and ethical behavior in the students through exposure of self -discipline and personal integrity.
- To develop a Centre of Research and Education generating knowledge and technologies which lay ground work in shaping the future in the field of electrical engineering.

PROGRAM OUTCOMES (POs)

Graduates of the Electrical Engineering program at JCBUST, YMCA will be able to:

PO1. Apply knowledge of mathematics, science, engineering fundamentals, and electrical engineering specialization to the solution of engineering problems.

PO2. Identify, formulate, review literature, and analyze electrical engineering problems to design, conduct experiments, analyze data, and interpret data.

PO3. Design solutions for electrical engineering problems and design system components of processes that meet the desired needs with appropriate consideration for public health and safety and cultural, societal, and environmental considerations.

PO4. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions in electrical engineering.

PO5. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to electrical engineering activities with an understanding of the limitations.

PO6. Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

PO7. Understand the impact of electrical engineering solutions in societal and environmental contexts, and demonstrate the knowledge and need for sustainable development.

PO8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. Communicate effectively on complex engineering activities with the engineering committee and with society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations in electrical engineering.

PO11. Demonstrate knowledge and understanding of the engineering principles and management principles and apply these to one‘s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Recognize the need for, and the preparation and ability to engage in independent research and lifelong learning in the broadest context of technological changes in electrical engineering.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. To apply state-of-the-art knowledge in analysis design and complex problem solving with effective implementation in the multidisciplinary area of Electrical Engineering with due regard to environmental and social concerns.

PSO2. To prepare graduates for continuous self-learning to apply technical knowledge and pursue research in advanced areas in the field of Electrical Engineering for a successful professional career to serve society ethically.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce competent electrical engineering graduates with a strong foundation design, analytics and problem-solving skills for successful professional careers in industry, research and public service.

PEO2. To provide a stimulating research environment so as to motivate the students for higher studies and innovation in the specific and allied domains of electrical engineering.

PEO3. To encourage the graduates to practice the profession following ethical codes, social responsibility and accountability.

PEO4. To train students to communicate effectively in multidisciplinary environment.

PEO5. To imbibe an attitude in the graduates for life-long learning process.

Syllabus

Electrical Machines Lab-I (ELPC-353)

L-T-P **Internal Marks-15**
0-0-2 **ExternalMarks-35**
Total-50

List of Experiments

1. To study various types of measuring instruments.
2. To verify KCL and KVL
3. To verify Thevenin’s theorem.
4. To verify Norton's theorem.
5. To verify superposition theorem.
6. To study frequency response of series R-L-C circuit and determine resonance frequency.
7. To study frequency response of parallel R-L-C circuit and determine resonance frequency.
8. To study and plot the transient response of RL circuit
9. To study and plot the transient response of RC circuit.
10. To find the polarity and turns ratio of a single-phase transformer.
11. Speed control of DC shunt motor by armature voltage control method.
12. Speed control of DC shunt motor by field current control method.
13. To study the constructional features and working of three phase induction motor.
14. To study the constructional features and working of DC motor
15. To study the constructional features and working of synchronous motor.

COURSE OUTCOMES

Course Outcomes:

At the end of the course the student will be able to:

- **CO1.** Students will be able to get an exposure to common electrical components and their ratings.
- **CO2.** Students will be able to make electrical connections by wires of appropriate ratings.
- **CO3.** Students will be able to understand the usage of common electrical measuring instruments.
- **CO4.** Students will be able to understand the basic characteristics of transformers and electrical machine

Mapping of Course Outcomes (COs) with POs and PSOs

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2	1	2	1	1	1	1	1	1	1	2	1
CO2	2	3	2	1	3	1	1	1	1	1	2	1	2	1
CO3	3	2	1	2	1	1	1	1	1	1	1	1	2	1
CO4	3	2	2	2	2	1	2	1	1	1	1	2	3	1

||General Instructions||

1. Students should come well-prepared for the experiment they will be conducting.
2. Usage of mobile phones in the laboratory is strictly prohibited.
3. In the lab, wear shoes and avoid loose-fitting clothes.
4. Read and understand the experiment manual thoroughly before starting the experiment. Know the objectives, procedures, and safety precautions.
5. Before starting the experiment, check the condition of the equipment, wiring, and connections. Report any damaged or malfunctioning equipment to the lab instructor immediately.
6. Ensure all connections are made as per the circuit diagram. Double-check all connections before powering the equipment.
7. Do not switch on the power supply until the instructor has approved your setup. Always start with the minimum voltage/current required and gradually increase as needed.
8. Do not overload machines beyond their rated capacity. Overloading can damage the equipment and pose safety risks.
9. Familiarize yourself with the lab's emergency shutdown procedures, including the location of emergency switches and fire extinguishers.
10. Do not bring food or drinks into the lab to avoid accidental spills, which can lead to electrical hazards.
11. Stay attentive during the experiment. Avoid distractions like mobile phones, and do not engage in unnecessary conversation during lab work.
12. Accurately record all measurements and observations during the experiment. Ensure that all data is properly noted in your lab report.
13. If you are unsure about any procedure or face difficulties during the experiment, do not hesitate to ask the lab instructor for guidance.
14. After completing the experiment, switch off the power supply, disconnect the setup, and return all equipment to its proper place. Ensure the workspace is clean and organized.

Basic Electrical Technology Lab
(ESC-107A)

Index

EXPERIMENT NO. 1

Aim: To study various types of measuring instruments.

Apparatus Required:

- Ammeter
- Voltmeter
- Wattmeter
- Resistance ohmmeter
- Capacitor
- Inductor
- Function generator
- Multimeter
- CRO (Cathode Ray Oscilloscope)

Theory:

Electrical Instruments-: The instruments which are used to measure electrical quantities are called electrical instruments. Such as ammeter, voltmeter, wattmeter, energy meter etc.

Types of Electrical Instruments-:

The electrical instruments may be broadly classified as-:

- **Primary Instruments:** The instruments which give the value of the quantity to be measured in terms of the constants of the instruments are called primary instruments. The common example is tangent galvanometer.
- **Secondary Instruments:** The instruments which determine the electrical quantity to be measured directly in terms of deflection are called secondary instruments.These instruments are called secondary instruments. These instruments are generally used in practical.The secondary instruments are further classified as:-

- **Indicating Instruments**
- **Integrating Instruments**
- **Recording Instruments**

A. **Ammeter:** An ammeter is a measuring instrument used to measure current flowing through a circuit. The main principle of ammeter is that it must have very low resistance and also inductive reactance. It has very low impedance because it must have very low amount of voltage drop across it and must be connected in series connection because current is same in series circuit setting the ammeter up in parallel will create a short circuit and will not measure the current correctly.

Types of Ammeters

1. **Moving Coil Ammeter:** It uses magnetic deflection, where current passing through coil cause the coil to move in magnetic field.

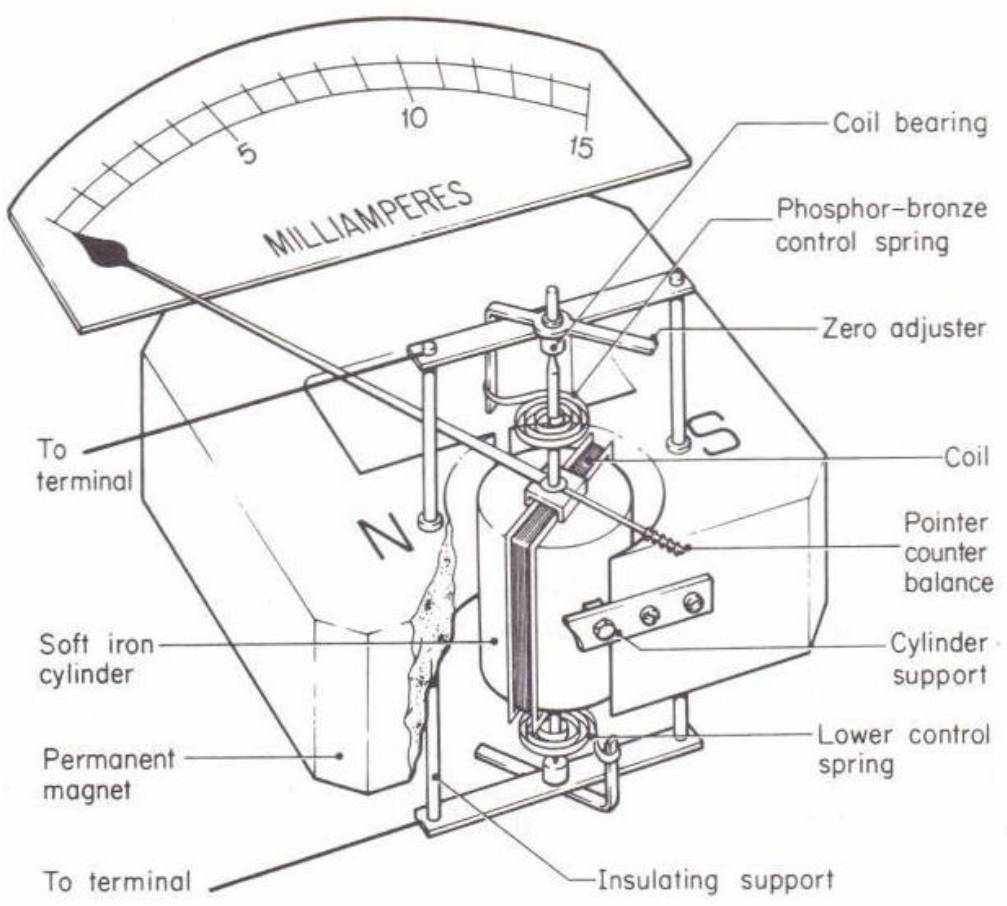


Fig: Cut section view of the Moving Coil Ammeter

Electrodynamic Ammeter: An electrodynamic movement uses an electromagnet instead of permanent magnet.

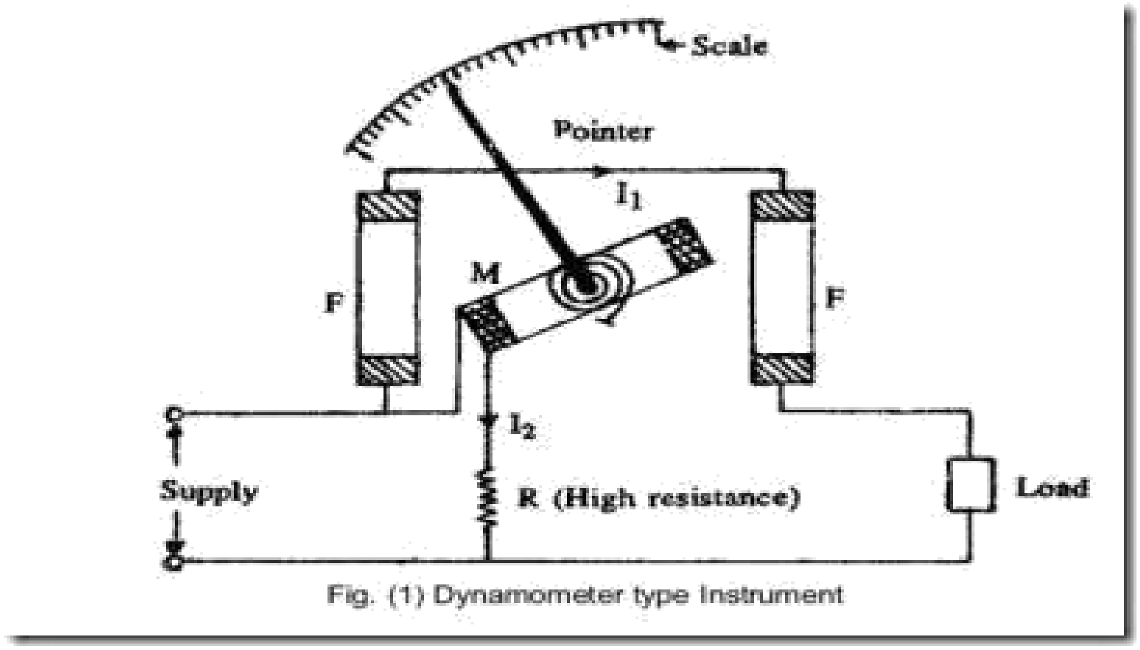


Fig: Cut section view of the Moving Coil Ammeter

Moving Iron Ammeter: Moving iron ammeter uses a piece of iron which moves when acted upon by electromagnetic force of a fixed coil of wire.

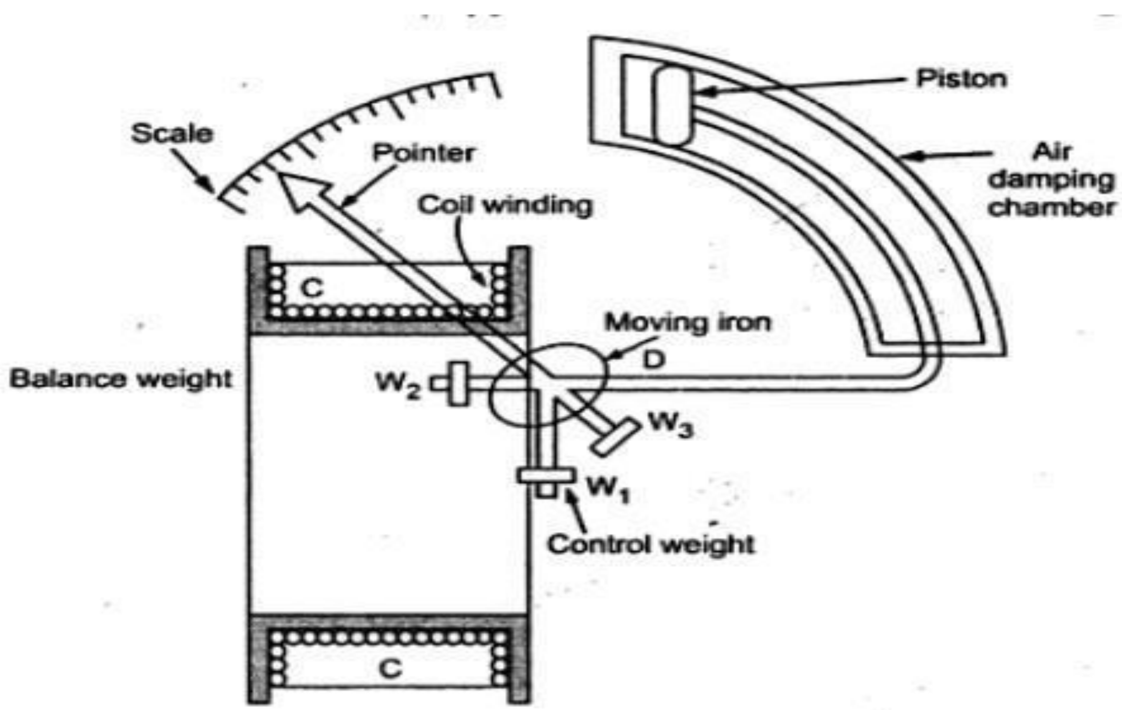


Fig: Cut section view of the Moving Iron Ammeter

B. Voltmeter: The instrument which measures the voltage or potential difference in volts. Voltmeter is always connected in parallel because if it is connected in series with the circuit, it minimizes the current which flows, also in parallel potential remain same and having high resistance.

Voltmeter works on the principle of ohm's law, which states that the voltage across a resistance is a directly proportional to the current passing through it.

C. Wattmeter: Wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in 'watts', of any given circuit. Electromagnetic Wattmeter's are used for measurements of utility frequency and audio frequency power, other types are required for radio frequency measurements. This work by using three coils, two fixed in series with the electrical load and a moving coil in parallel with it. The series coil measure current flowing through the circuit and the parallel coils measure voltage. It is situated between the two fixed coils and is attached to an indicator needle

Types of Wattmeter's

1. **Dynamometer type Wattmeter**

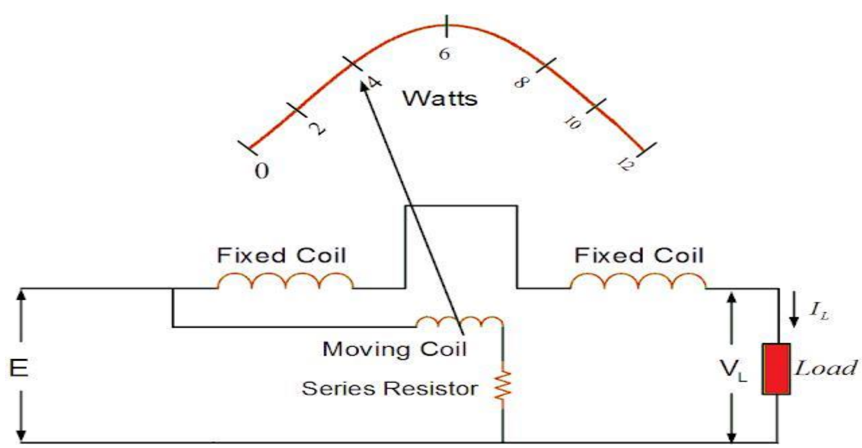


Fig: Cut section view of the Moving Iron Ammeter

2. **Induction type Wattmeter**

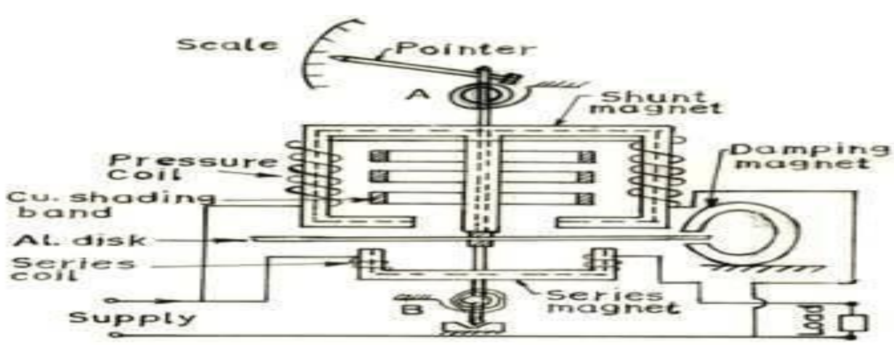


Fig: Cut section view of the Induction Ammeter

D. (Resistor) Ohmmeter:

A Resistor is a passive two terminal electrical component that implement electrical resistance at a circuit element. Resistor are used to reduce current flow adjust signal levels, to divide voltage & terminate transmission lines, the value of resistance measured by ohm-meter. It can be connected in both series and parallel.

E. Capacitor:

A Capacitor is a passive two terminal electronic component that stores electrical energy in form of electric field. The plates accumulate electric charge when connected to power source one plate accumulates position charge & the other plate accumulates negative charge. The capacitance is the amount of electric charge i.e. stored in the capacitor at a voltage of 1 volt. The capacitance is measured in units of farad (F). The capacitor disconnects current in alternating current (AC)circuits.

F. Inductor:

An inductor is a passive electronic component that stores energy in the form of magnetic field. An inductor consists of wire loop or coil. Inductor can be used in motors by creating mechanical energy from its electrical and magnetic energy. Inductor blocks AC by allowing DC to flow because it only resists the change in current. The growth of current flowing through the inductor is not instant but it is determined by inductors on self-induced or back emf value. In inductor current will lack the voltage by full 90 degree. Since there is no active energy involved or no work is done so power factor will always be 0.

G. Function Generator

A function generator is usually a piece of electronic list equipment or software used t0 generate different types of electrical wave form over a wide range of frequencies. Most function generator allows us to generate line, square or triangular AC function signals. Function generator creates a change in voltage under some function of time. It is used for testing the response of circuits to the common place input signals, produces various voltage pattern at different frequencies and amplitude.

H. **Multimeter**

A multimeter is a multiplex also known as VOM (volt-ohm-milliammeter) is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current and resistance. Analog multimeter uses a micrometer with a moving pointer to display rating. Digital millimetres are now for more common due to their lower cost and more accuracy but analog multimeter are still preferable in some cases. A multimeter can be a handheld device useful for basic fault finding and field service work or a bench

EXPERIMENT NO. 2

Aim: To verify KCL and KVL.

Apparatus Required: DC network kit and connecting wires.

Theory: KCL and KVL are used to solve the electrical networks

KCL: It states that in any electrical network the algebraic sum of currents meeting at a point is zero. Consider the case of few conductors meeting at a point A in the fig. Assuming incoming currents to be positive and the outgoing currents to be negative.

Incoming current=outgoing current

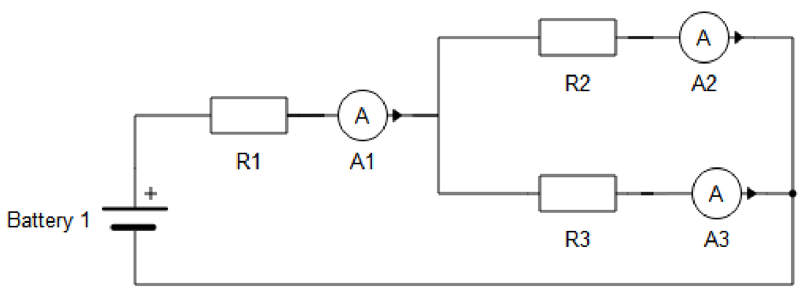


Fig: Circuit diagram for verifying KCL

KVL: It states that the algebraic sum of product of current and resistance in each of the conductors in any closed path in a network plus the algebraic sum of the e.m.f in the closed path is zero.

$$\Sigma IR + \Sigma E.M.F. = 0$$

Circuit Diagram:

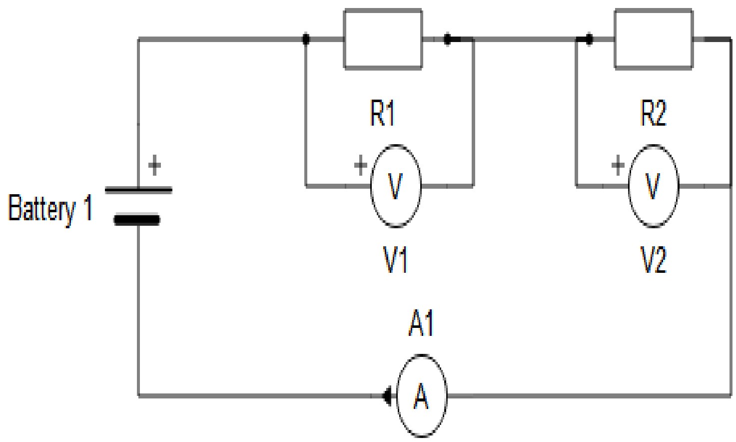


Fig: Circuit diagram for verifying KVL

Procedure:

KCL:

1. Make the connection according to the ckt diagram
2. Set the three rheostats to their max value.
3. Switch on the power supply
4. Change the setting of the rheostats to get different readings in all the three ammeters.
5. Measure the current in the three ammeters
6. Check that at every time current in the main branch is equal to the sum of currents in the two branches. repeat the setting of the rheostat
7. Switch off the power supply.

KVL:

1. Connect the circuit as per the circuit diagram
2. Switch on the power supply
3. Note down the readings of the voltmeters
4. Change the value of the rheostat and repeat the step several times and switch off the power supply.

Observation Table:

KCL:

S.N.O	Applied Voltage (volts)	I_1 (mA)	I_2 (mA)	I (mA)	$I = I_1+I_2$ (mA)	REMARK

KVL:

S.N.O	Applied Voltage E (volts)	V_1(volts)	V_2(volts)	Battery	Result Battery=V1+V2 (volts)	Remarks

Results:

1. The incoming current is found to be equal to the outgoing current.
2. The total input voltage is equal to the total voltage drop in the circuit.

Conclusion: KCL and KVL are very important in solving the circuits where direct formula can't be applied.

Viva Questions:

Q.1 What is the statement of Kirchhoff's first law?

Q.2 According to Kirchhoff's second law, the algebraic sum of all IR drops and emf's in any closed loop of a network is equal to…

Q.3 What is the internal resistance of an ideal voltage source?

Q.4 What is higher, the terminal voltage or the emf?

Q.5 What is the internal resistance of the current source ideally?

Q.6 What is the active network?

Q.7 What is the bilateral network?

Q.8 What is the difference between a node and a branch?

Q.9 What is the non-linear circuit?

EXPERIMENT NO. 3

Aim: To verify Thevenin's theorem.

Apparatus Required: DC network kit and connecting wires.

Theory: Thevenin's theorem as applied to the dc network circuit may be stated as the current flowing through a load resistance R_L connected across any two terminals A and B of a linear bilateral network is given by V_{TH} / R_{TH}+R_L where V_{TH} is the open circuit voltage and R_{TH} is the internal resistance of the network from terminal A to B with all voltage sources replaced with their internal resistances and current sources with infinite resistance.

Circuit Diagram:

Find current in R_L

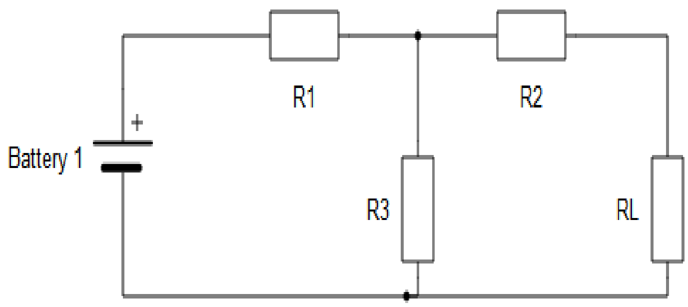


Fig: Circuit diagram for verifying Thevenin's Theorem

STEP I   Open circuit R_L, Find Vth

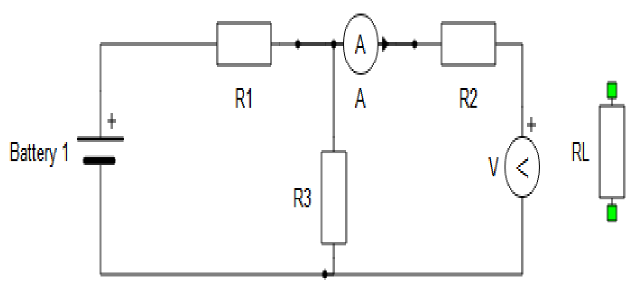


Fig: Circuit diagram for finding Vth

STEP II Find R_{th}

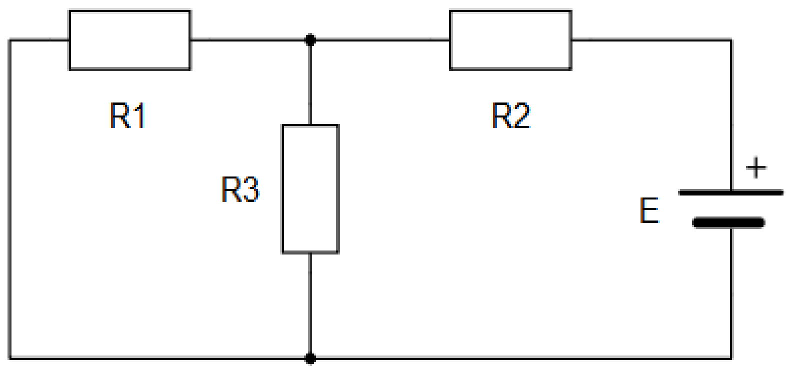


Fig: Circuit diagram for finding Rth

STEP III Equivalent Circuit

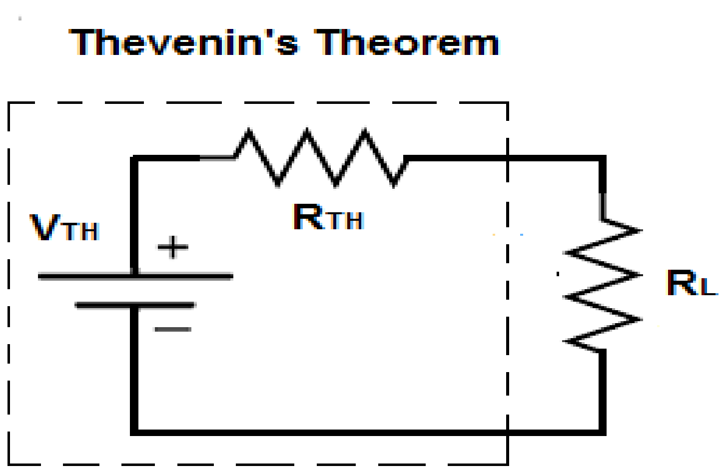


Fig: Thevenin's Equivalent Circuit

Procedure:

1. To find the current flowing through the load resistance R_L as shown in Fig. Remove R_L from the circuit temporarily and leave the terminals A and B open circuited.

2. Calculate the open circuit voltage V_{TH} which appears across terminal A and B.

$$V_{TH} = I.R_{TH}$$

This is called Thevenin's voltage.

3. Now calculate $R_{TH}=R_1 R_2 /R_1+R_2$. This is called Thevenin's resistance.

4. Calculate $I_L= V_{TH}/(R_L+R_{TH})$.

5. Calculate $V_{TH}= E R_2/R_1+R_2$

Observation Table:

SNO	Applied Voltage (Volts)	V_{TH} (volts) Theoretical	V_{TH} (volts) Practical	(Ohms)	I_L (mA) Practical	Result

Result: Thevenin's theorem has been verified.

Conclusion: In Thevenin's equivalent circuit Thevenin's equivalent voltage is in series with Thevenin's resistance and the load resistance.

Viva Questions:

Q.1 To what type of circuit Thevenin's theorem is applicable
Q.2 What is the use of Thevenin's theorem?
Q.3 How R_{TH} is connected with the circuit?
Q.4 How is R_{TH} connected with the load resistance?
Q.5 What modification is done in galvanometer to convert it into a ammeter?
Q.6 What modification is done in the galvanometer to convert it into a voltmeter?
Q.7 Resistance is an active element or the passive?
Q.8 How will you calculate the R_{TH}?
Q.9 In place of current source, what is placed while calculating R_{TH}?

Q.10 In place of voltage source which electrical parameters is placed?

EXPERIMENT NO. 4

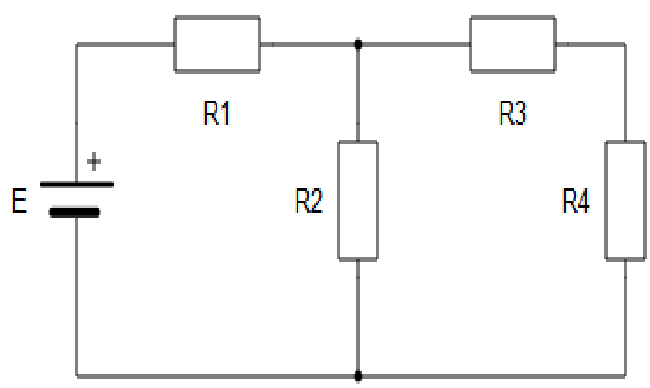
Aim: To verify Norton's theorem.

Apparatus Required: DC network kit and connecting wires.

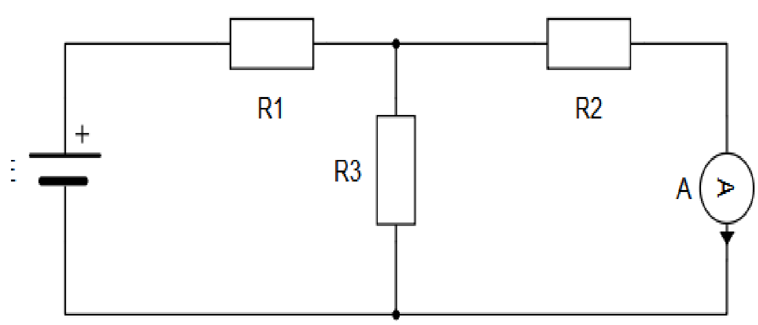
Theory: Norton's theorem replaces the electrical network by an equivalent constant current source and a parallel resistance. Norton's equivalent resistance $R_N=R_1*R_2/R_1+R_2$ Actual load current in the circuit I_{L1} Theoretical load current $I_{L2}=I_{SC}*R_N/(R_N+R_L)$, I_{SC} is the short circuit current.

Circuit Diagram:

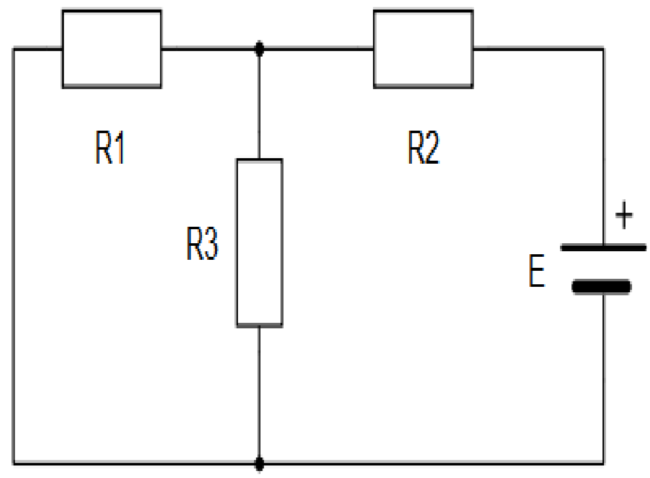
Find current in R_L



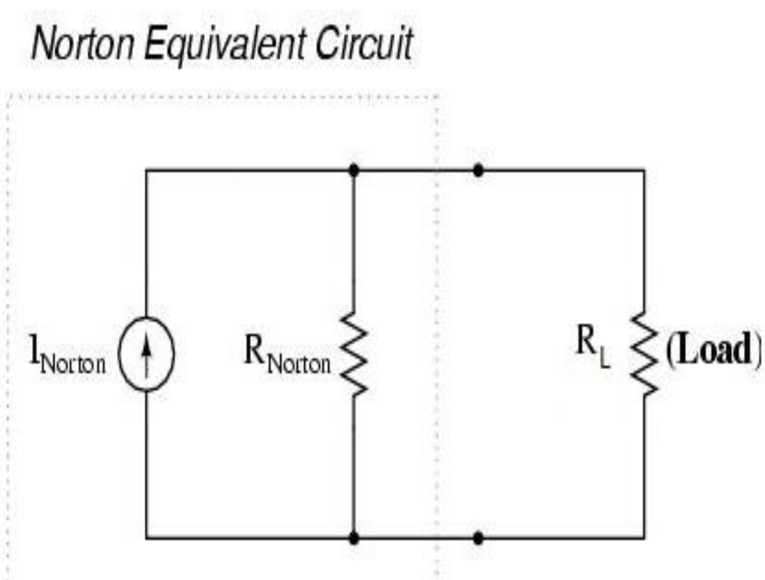
STEP I Short circuit R_L and Find current in AB



STEP II Find R_N



Step III Draw equivalent circuit and Find current in R_L



Observation Table:

SNO	Applied Voltage (volts)	I_N (mA)	R_N (Ω)	I_{L1} (mA)	I_{L2} (mA)	Error I_{L1} - I_{L2}	Result

Procedure:

1. Connect the circuit as per the circuit diagram
2. Remove the load resistance
3. Find the Norton's resistance R_N
4. Measure the Norton's current I_N
5. Now measure the current in the load resistance directly
6. Find out the current in the load
7. Using formula find out the current in the load resistance
8. Verify that these two are equal.

Result: Norton's theorem is verified

Conclusion: In Norton's equivalent circuit the Norton's current source is in parallel with NORTON'S resistance and the load resistance.

Viva Questions:

Q.1 To what type of network Norton's theorem applicable?
Q.2 How is R_N connected to I_N?
Q.3 What is placed in place of voltage sources while calculating the R_N?
Q.4 Give an example of unilateral circuit?
Q.5 What is unilateral circuit?
Q.6 Give one example of the bilateral n/w?
Q.7 What is the limitation of Ohm's law?
Q.8 What is the reason that ground pin is made of greater diameter in the plugs?
Q.9 Where is the voltage divider rule applicable?
Q.10 Where is the current divider rule applicable

EXPERIMENT NO. 5

Aim: To verify superposition theorem.

Apparatus Required:

S.No.	Name of the Apparatus Required	Specification/Rating/Range	Type	Quantity
1	Power Supply			
2	Resistance (wire wound)			
3	Digital multi-meter			
4	Connecting Wires			

Theory:

Superposition theorem states that in a linear network containing several independent sources, the overall response at any point in the network equals the sum of responses due to each independent source considered separately with all other independently sources made inoperative(short circuited). To make a source inoperative, it is short circuited leaving behind its internal resistance if it is a voltage source, and it is open circuited leaving behind its internal resistance if it is a current source.In most electrical circuit analysis problems, a circuit is energized by a single independent energy source. In such cases, it is quite easy to find the response (i.e., current, voltage, power) in a particular branch of the circuit using simple network reduction techniques (i.e., series parallel combination, star delta transformation, etc.).However, in the presence of more than one independent source in the circuit, the response cannot be determined by direct application of network reduction techniques. In such a situation, the principle of superposition may be applied to a linear network, to find the resultant response due to all the sources acting simultaneously.

The superposition theorem is based on the principle of superposition. The principle of Superposition states that the response (a desired current or the voltage) at any point in the linear network having more than one independent source can be obtained as the sum of responses caused by the separate independent sources acting alone. The validity of principle of superposition means that the presence of one excitation sources does not affect the response due to other excitations.

Circuit Diagram:

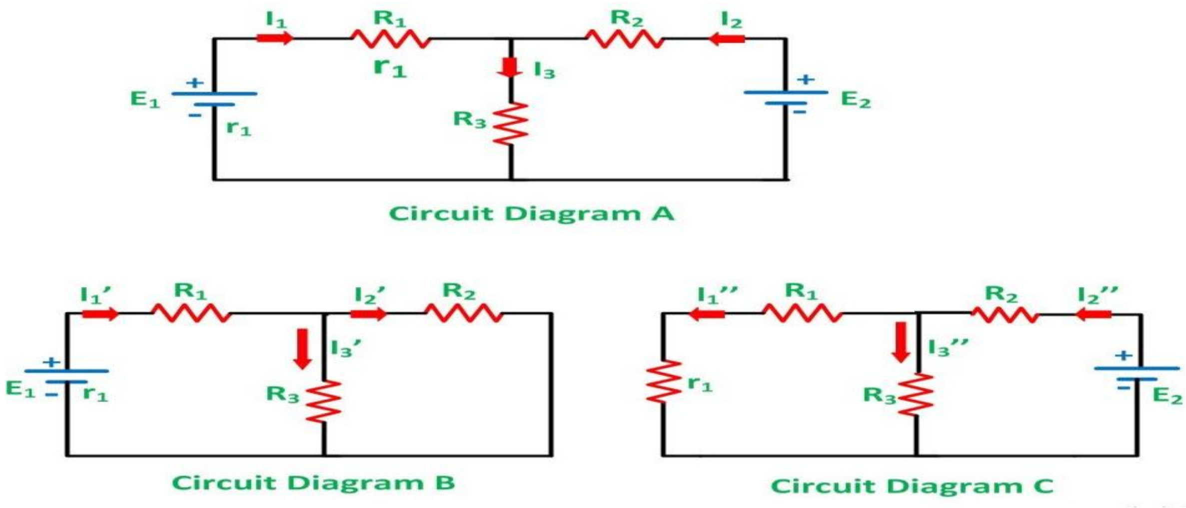


Fig: (A) Circuit Diagram for verifying Superposition Theorem (B) Circuit Diagram for finding the current in the circuit due to E1 (C) Circuit Diagram for finding the current in the circuit due to E2

Procedure:

1. Connect the DC power supply to resistance R1.Adjust voltage of supply to E1=10V.
2. Connect another DC supply to resistance R2. Adjust voltage to E2=5 V.
3. Connect the DC ammeter(mA) to resistance R3.
4. Now remove the left hand side of supply and measure and record the current through R3.
   I_3'= ma
5. Remove another supply and measure and record the current through R3.
   I_3''= ma.
6. Now apply both the supplies and measure the current in R3 i.e. I_3''.
   Now $I_3 = I_3'' + I_3'$

Observation Table:

Calculated Values

I_3	I_3'	I_3''

Observed Values

V_1= V_2=	V_2= V_1=	V_1= V_2=
$I_{3=}$	I_3'=	I_3''=

Calculations:

I_3(Observed) = $I_{3'}$+$I_{3'}$

I_3(Calculated)= (by solving using KVL)

% Error= (Observed Value-Calculated Value)/Calculated Value

Result: The percentage error is found to be__%.

Discussion: The % error is found to be in the range within 10%. The percentage error is due to observational errors, tolerance errors, calibration of instruments, etc. However, superposition theorem cannot be applied to non-linear network and network containing only dependent sources.

Conclusion: The superposition theorem is verified.

Question/Answers:

Q.1 Can the Superposition Theorem be used in AC circuits?

Q.2 What is a practical example where the Superposition Theorem is used?

Q.3 What type of elements does the superposition theorem apply to in a circuit?

Q.4 What is meant by a linear circuit?

Q.5 Can the superposition theorem be used for power calculations directly?

Q.6 Can the superposition theorem be applied to solve for the voltage across a capacitor in a linear circuit?

Q.7 What is an example of a linear component where the superposition theorem is valid?

Q.8 When applying the superposition theorem to an AC circuit, how are different sources handled?

Q.9 What is the internal resistance of an ideal voltage source when turned off?

Q.10 What is the internal resistance of an ideal current source when turned off?

Q.11 Can the Superposition Theorem be applied to non-linear circuits?

EXPERIMENT NO. 6

Aim: To study frequency response of series R-L-C circuit and determine resonance frequency.

Apparatus Required: CRO, Audio frequency generator, Multimeter and connecting wires.

Theory: In the series resonance circuit, the net reactance

$X=X_L-X_C$

So, impedance of the circuit is

$Z = \sqrt{(R^2+ (X_L-X_C)^2)}$

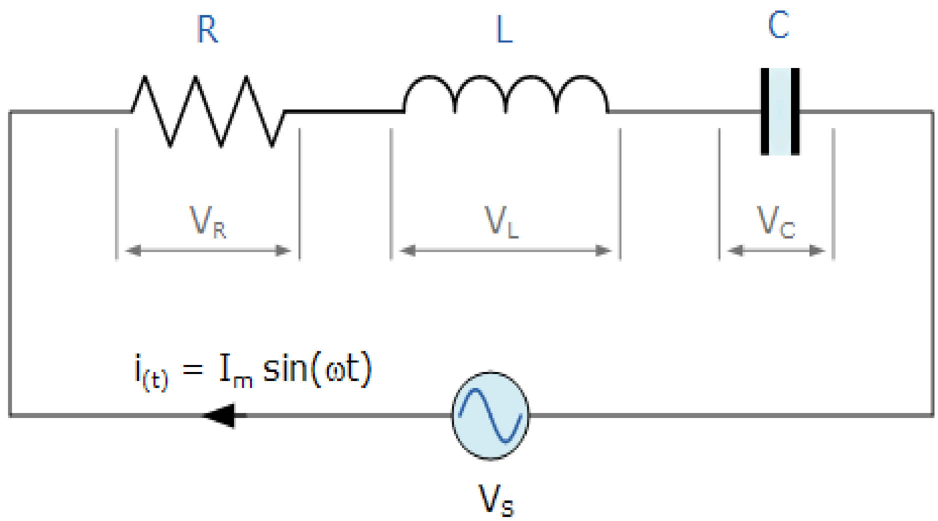
At the resonance frequency the capacitive reactance becomes equal to the inductive reactance.

$X_L = X_C$

$w_0L=1/w_0C$

$f_0=1/2\pi\sqrt{LC}$

Circuit Diagram:



Procedure:

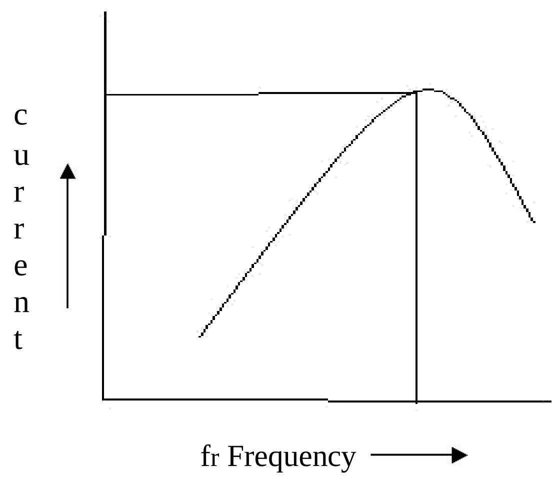
1. Make the connections shown in fig.
2. Frequency is given by audio frequency generator.
3. Change the frequency and note the reading carefully.
4. At certain frequency the voltage becomes maximum after which the voltage decreases. This is the resonance frequency.

5. Plot a graph between frequency and voltage.

Observation Table:

S.No	Frequency (Khz)	Current(Amp)

Graph:



Result: The resonance frequency is found to be……kHz

Conclusion: Impedance is minimum at resonance frequency.

Quiz Questions:

Q1. If frequency is 50 Hz, what is the angular frequency?
Q.2 If time period is 1/50 sec, what is the frequency?
Q.3 If I=200sin 100πt, at which time it will have the value of 100A?
Q.4 What is the average value of a square wave of peak value 200V?
Q.5 What is the relation between the max value and the average value of the square wave?
Q.6 What is the form factor?
Q.7 What is the form factor for a sine wave?

Q.8 What is the impedance for a series resonance circuit?

Q.9 What is the condition for resonance in a series RLC circuit?

Q.10 What is the quality factor?

EXPERIMENT NO. 7

Aim: To study frequency response of parallel R-L-C circuit and determine resonance frequency.

Apparatus: CRO, Audio frequency generator, Multi meters and connecting wires.

Theory: For the parallel R-L-C circuit

$I_C = I_L \sin\Phi_L$

$I_L = V/Z$,

$\sin\Phi_L = X_L/Z$

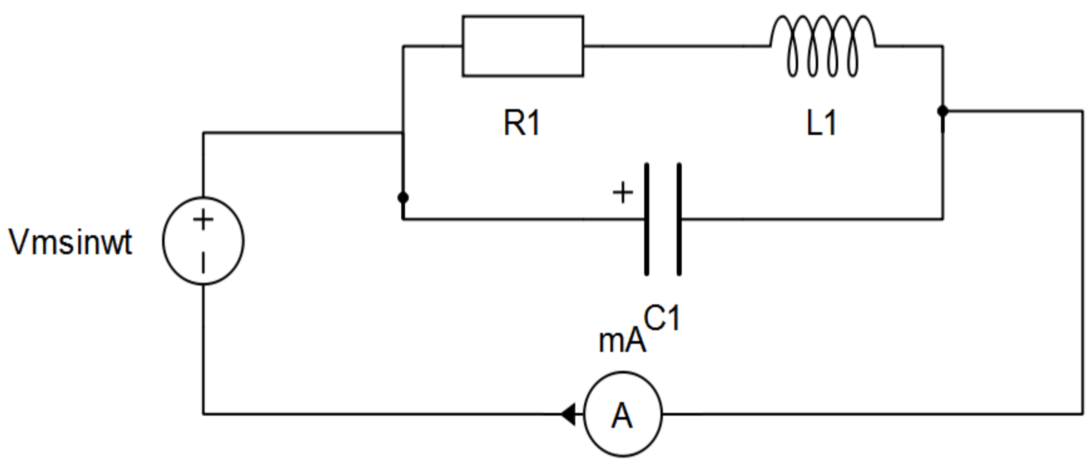
$V/Z * X_L / Z = V/X_C$

$X_L * X_C = Z^2$

$L/C = Z^2$

$L/C = R^2 + X_L^2$ $f_0 = 1/2\pi *$
$\sqrt{1/LC - R^2/L^2}$

Circuit Diagram:



Procedure:

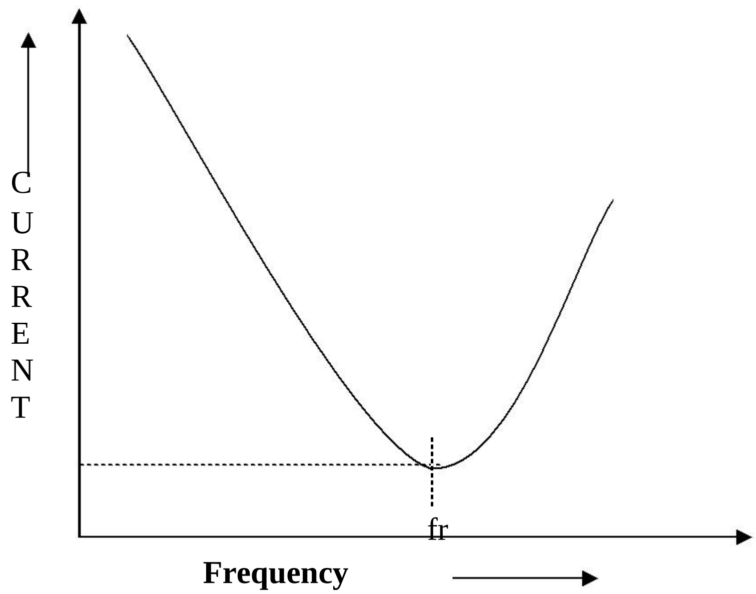
- Make the connections shown in fig.
- Frequency is given by audio frequency generator.
- Change the frequency and note the reading carefully

- At certain frequency the voltage becomes minimum after which the voltage increases. This is the resonance frequency
- Plot a graph between frequency and voltage.

Observation Table:

Sr.No	Frequency (Khz)	Current (Amp)

Graph:



Result: The resonance frequency is found to be……kHz.

Conclusion: Impedance is maximum at resonance frequency

Quiz Questions:

Q.1 **W**hat is the power factor of the resistance circuit?

Q.2 What is the power factor of the inductive or the capacitive circuit?

Q.3 What is the effect of the inductance on the time constant in any inductive circuit?

Q.4 What is the effect of dc flow on the dc?

Q.5 Can all the laws of the dc be applied to the ac circuit having resistance?

Q.6 What is the time constant of the capacitive circuit?

Q.7 What is the effect of length of iron path on inductance?

Q.8 If two signals having same frequency have opposite phase, what is the phase angle between them?

Q.9 For least power consumption what should be the phase angle between current and voltage?

Q.10 What is magnified by the parallel RLC circuit?

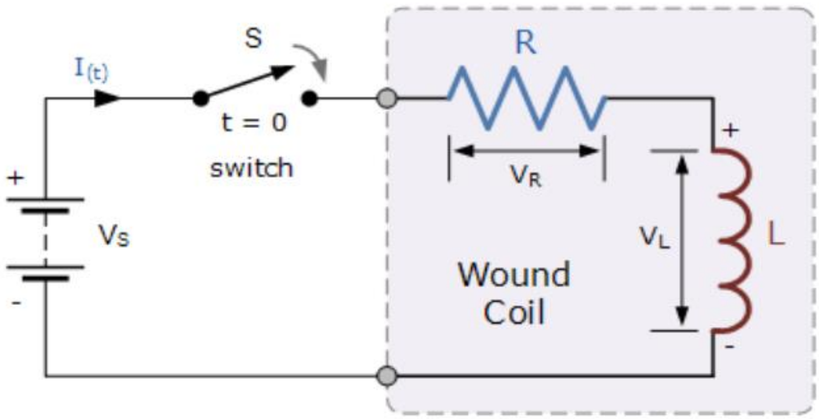
EXPERIMENT NO. 8

Aim: To study and plot the transient response of RL circuit

Apparatus Required: Power Supply, Circuit Board Kit., CRO, Function Generator, Connecting Leads.

Introduction: The Transient Response (also known as the Natural Response) is the way the circuit responds to energies stored in storage elements, such as capacitors and inductors. If an inductor has energy stored within it, then that energy can be dissipiated/absorbed by a resistor. How that energy is dissipated is the transient Response**.**

Circuit Diagram:



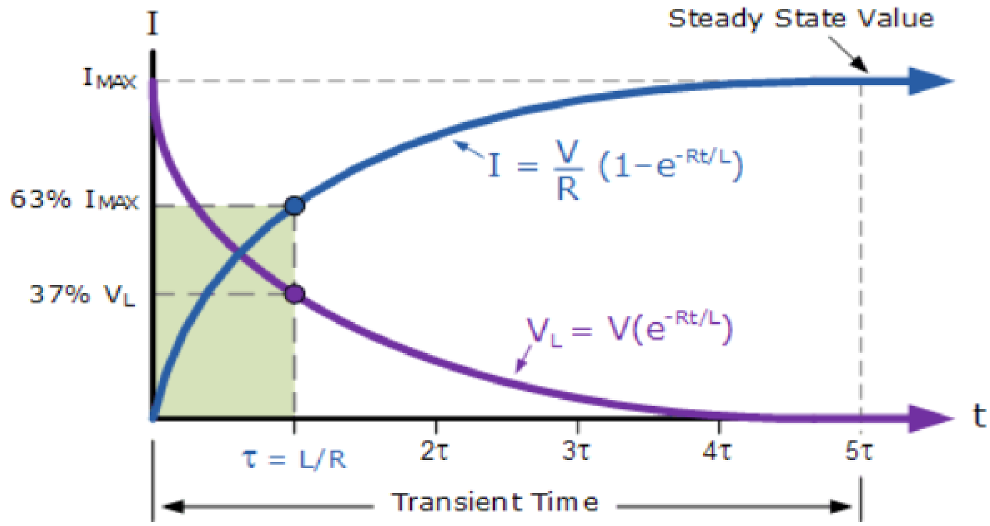
Theory: In an R-L circuit, voltage across the inductor decreases with time.The expression for the current build-up across the Inductor is given by

$$i_L(t) = \frac{V}{R}\left(1 - e^{-(R/L)t} \right) \qquad t \geq 0$$

where, V is the applied source voltage to the circuit for t ≥ 0. The response curve is increasing. The expression for the current decay across the Inductor is given by:

$$i_L(t) = i_0\, e^{-(R/L)t} \qquad t \geq 0$$

The **Time Constant**, (τ) of the LR series circuit is given as L/R and in which V/R represents the final steady state current value after five time constant values. Once the current reaches this maximum steady state value at 5τ, the inductance of the coil has reduced to zero acting more like a short circuit and effectively removing it from the circuit.



Since the voltage drop across the resistor, V_R is equal to I*R (Ohms Law), it will have the same exponential growth and shape as the current. However, the voltage drop across the inductor, V_L will have a value equal to: $Ve^{(-Rt/L)}$. Then the voltage across the inductor, V_L will have an initial value equal to the battery voltage at time t = 0 or when the switch is first closed and then decays exponentially to zero as represented in the above curves.

The time required for the current flowing in the LR series circuit to reach its maximum steady state value is equivalent to about 5 times constants or 5τ. This time constant τ, is measured by τ = L/R, in seconds, where R is the value of the resistor in ohms and L is the value of the inductor in Henries. This then forms the basis of an RL charging circuit were 5τ can also be thought of as "5*(L/R)" or the *transient time* of the circuit.

Procedure:

1. Connect the circuit according to the fig. & switch 'ON' the Supply.
2. Feed square wave from function generator to the I/P terminal of the circuit
3. Connect the CRO to the O/P terminal & note down the O/P wave.
4. Draw the Input & Output wave on the graph paper.

Result/Conclusions: Transient response of RL circuit has been studied and the results obtained are shown on the graph.

Precautions:

1. Make the connections according to the circuit diagram. Power supply should be switched off.
2. Connections should be tight.
3. Handle the CRO carefully.

4. Note the readings carefully.

Viva Questions:

Q.1 Define transient and steady state response of system.
Q.2 Define natural response and forced response of a system.
Q.3 Why transient occurs in electric circuits?
Q.4 Define time constant of RL circuit.

EXPERIMENT NO. 9

Aim: To study and plot the transient response of RC circuit.

Apparatus Required: Power Supply, Circuit Board Kit., CRO, Function Generator,

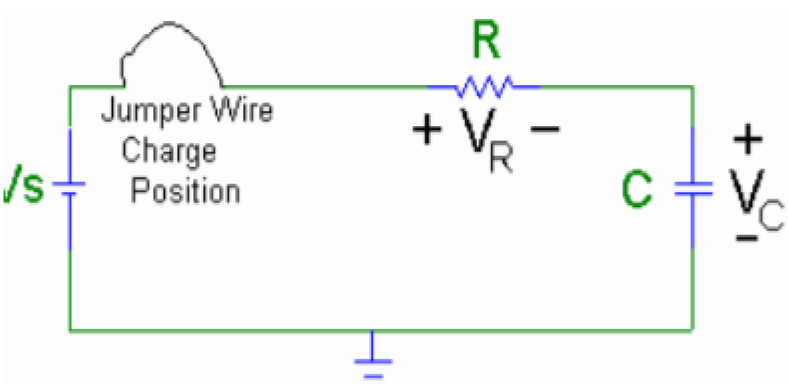
Connecting Leads.

Brief Theory: A capacitor has the ability to store an electrical charge and energy. The voltage across the capacitor is related to the charge by the equation V=Q/C for steady state values, or expressed as an instantaneous value, dv=dq/C

By definition i = dq/dt or dq = idt. Therefore

$$dv = \frac{1}{C} idt \quad or \quad v = \frac{1}{C}\int idt$$

The derivation of the transient responses of both the capacitor current and voltage in an RC circuit when a source voltage is suddenly applied to that circuit is shown below. Note that the time constant (t = τ = RC). The step response of an RC circuit can be analyzed using the following circuit:



$$V_S = Ri + \frac{1}{C}\int_0^t idt + V_C(0)$$

Immediately after the switch closes, KVL requires thatIf we differentiate (1) with respect to t, we get

$$R\frac{di}{dt}+\frac{i}{C}=0$$

The other two terms drop out because they are constants. Now divide thru by R-

$$\frac{di}{dt}+\frac{i}{RC}=0 \quad \Rightarrow \quad \frac{di}{dt}=-\frac{i}{RC} \quad \Rightarrow \quad \int_{I_0}^{i(t)}\frac{di}{i}=-\frac{1}{RC}\int_0^t dt$$

The voltage across the capacitor at t = 0 (Vo) will be zero because there cannot be an instantaneous change in voltage across the capacitor. Therefore, the initial current in the circuit will be as follows

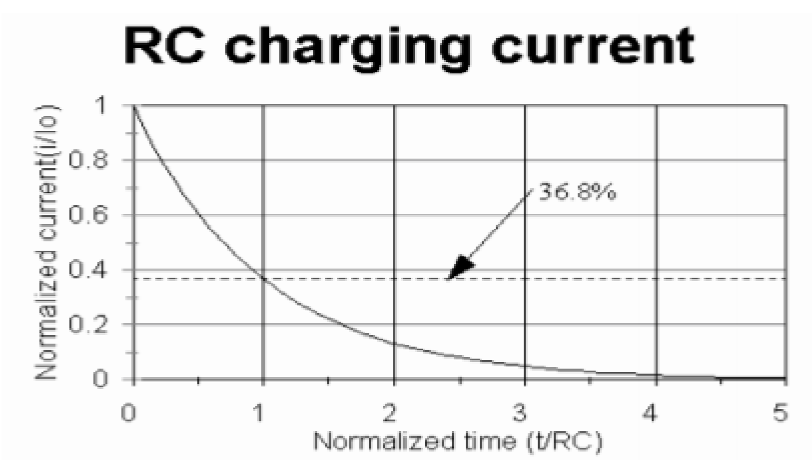
$$\ln i-\ln I_0=-\frac{t}{RC}$$

$$\ln i\,\Big|_{I_0}^{i(t)}=-\frac{1}{RC}t\,\Big|_0^t$$

$$\frac{i(t)}{I_0}=e^{-\frac{t}{RC}} \quad \Rightarrow \quad i(t)=I_0e^{-\frac{t}{RC}}$$

$$i(0)=I_0=\frac{V_S}{R}$$

Normalized current = i(t)/Io ,versus Normalized time = t/RC.



Note that the time constant (t = τ = RC) occurs at 36.8% of Io or 0.368 Vs/R. We also know that

$$i_C(t) = C\frac{dV_C}{dt} \quad \Rightarrow \quad V_C(t) = \frac{1}{C}\int_0^t i_C(x)dx + V_C(0)$$

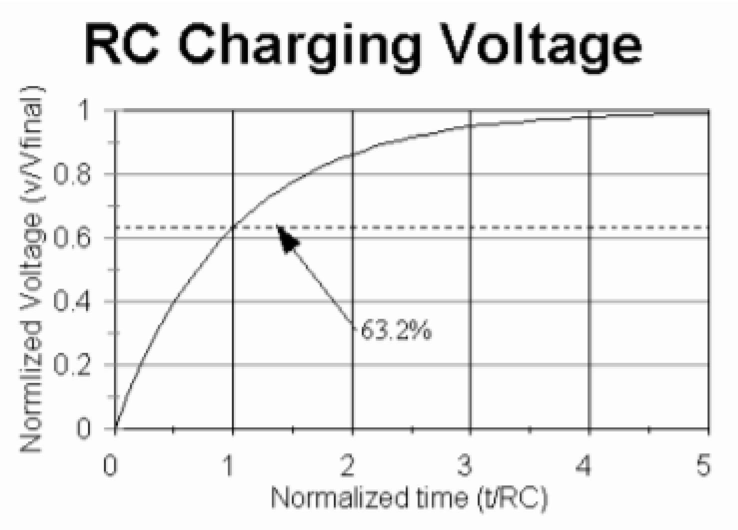
Substituting i from (7) and Io from (8) into (9), Putting in limits and simplifying gives:

$$V_C(t) = \frac{V_S}{RC}\left[-RCe^{-\frac{t}{RC}} + RC\right] = V_S - V_S e^{-\frac{t}{RC}}$$

$V_C(t) = V_S\left(1 - e^{-\frac{t}{RC}}\right)$ Capacitor voltage at any time t when charging from zero

$V_C(t) = V_i e$ Capacitor voltage at any time t when discharging to zero

Plotting normalized voltage (Vc /VS) versus normalized time (t/RC)



Note that the time constant (t = τ = RC) occurs at 0.632 Vs

Procedure:

1. Connect the circuit according to the fig. & switch 'ON' the supply.
2. Feed square wave from function generator to the Input terminal of the circuit.
3. Connect the CRO to the O/P terminal & note down the O/P wave
4. Draw the Input & Output wave on the graph paper.

Result: Transient response of RC circuit has been studied and the results obtained are shown on the graph.

Discussion: The capacitor charges and discharges within one minute.

Precautions:

1. Make the connections according to the circuit diagram. Power supply should be switched off.
2. Connections should be tight.
3. Handle the CRO carefully.
4. Note the readings carefully.

Viva Questions

Q.1 Define time constant of RC circuit.

Q.2 Voltage across capacitor cannot change instantaneously. Justify.

EXPERIMENT NO. 10

Aim: To find the polarity and turns ratio of a single-phase transformer.

Apparatus Required: One transformer, two voltmeters, one autotransformer

Theory:

It is essential to know the relative polarity at any instant of primary and secondary terminals for making correct connections. When the two transformers are to be connected in parallel to share the load on the system. The marking is correct if voltage E3 (E1+E2 OR E1-E2) is less than E1,such a polarity is termed as subtractive polarity. The standard practice is to have subtractive polarity because it reduces the voltage stress between adjacent loads. In case E3 > E1 the emf induced in primary and secondary have additive relation and transformer is said to have additive polarity.

Circuit Diagram:

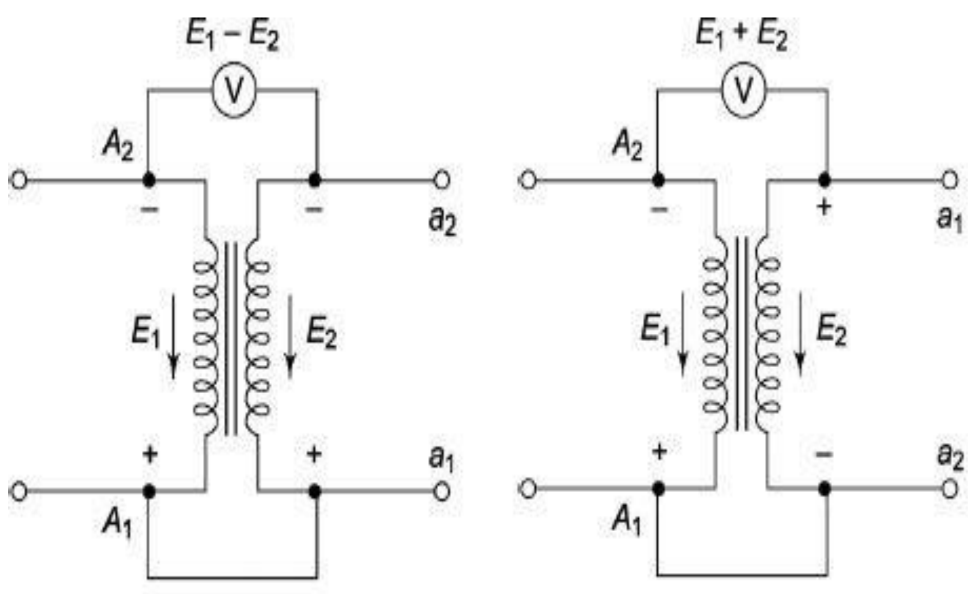


Fig: Circuit Diagram for subtractive and additive polarity

Procedure:

Polarity test:

1. Connect the circuit as shown in the diagram.
2. Switch on the single-phase a.c. supply.
3. Record the voltages E1, E2 and E3. In case E3<E1, the polarity is subtractive.
4. Repeat the step 3 after connecting terminals A1 and a2. In case E3> E1, the polarity is additive.
5. Switch off the a.c supply.

Turn Ratio Test:

1. Connect the circuit as shown in the diagram.
2. Switch on the a.c. supply.
3. Record voltage E1 across primary and E2 across various tapping's of the secondary.
4. If E1>E2 then the transformer is stepdown.
5. If E2> E1 then the transformer is step-up.
6. Switch off a.c supply.

Observation Table:

Subtractive Polarity:

S.NO	E1	E2	E3=E2-E1

Additive Polarity:

S.NO	E1	E2	E3=E1+E2

Results:

If E2>E1 then the transformer is step up otherwise the transformer is stepdown.

Viva Questions:

Q.1 What is the purpose of a polarity test on a single-phase transformer?
Q.2 What does the polarity of a transformer indicate?
Q.3 What are the two types of polarity in transformers?
Q.4 Can polarity be checked using a DC power source?

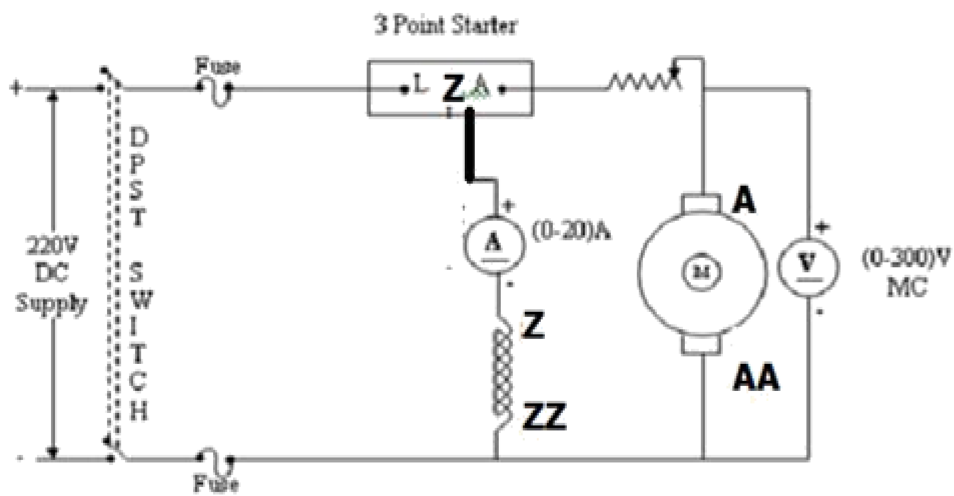
EXPERIMENT NO. 11

Aim: Speed control of DC shunt motor by armature voltage control method.

Apparatus Required:

S.No.	Name of the Apparatus Required	Specification/Rating/ Range	Type	Quantity

Circuit Diagram:



Theory:

The armature voltage control method of speed control of DC shunt motor is used for controlling speed below base speed. As its used for below base speed hence its also called as constant torque control method as our torque remains constant in this region. This method is used when speeds below the no-load speed are required. As the supply voltage is normally constant, the voltage across the armature is varied by inserting a variable rheostat in series with the armature circuit. As controller resistance is increased, voltage across the armature is decreased, thereby decreasing the armature speed. For a load constant torque, speed is approximately proportional to the voltage across the armature.

N = K{V-Ia. (Ra+R)}/ Flux

Procedure:

1. Connections are made as per the circuit diagram.
2. After checking the maximum position of armature rheostat and minimum position of field rheostat, DPST switch is closed

Armature Control:

Field current is fixed to various values and for each fixed value, by varying the armature rheostat, speed is noted for various voltages across the armature.

Observation Table:

Armature Voltage Control:

S.No.	Va =	
	Field Current If (A)	Speed N (rpm)

Result: Thus, the speed control characteristic curve of DC Shunt motor is obtained.

Precautions:

1. Field Rheostat should be kept in the minimum resistance position at the time of starting and stopping the motor.
2. Armature Rheostat should be kept in the maximum resistance position at the time of starting and stopping the motor

Viva Questions

Q.1 What is the armature voltage control method in DC shunt motors?
Q.2 What is dc shunt motor
Q.3 How does changing the armature voltage affect the speed of a DC shunt motor?
Q.4 What are the advantages of using the armature voltage control method?
Q.5 Are there any disadvantages to the armature voltage control method?

Q.6 Can the armature voltage control method be used for both increasing and decreasing the speed of the motor?

Q.7 How does the armature voltage control method affect the speed of a DC shunt motor?

Q.8 What are the typical applications of armature voltage control in DC shunt motors?

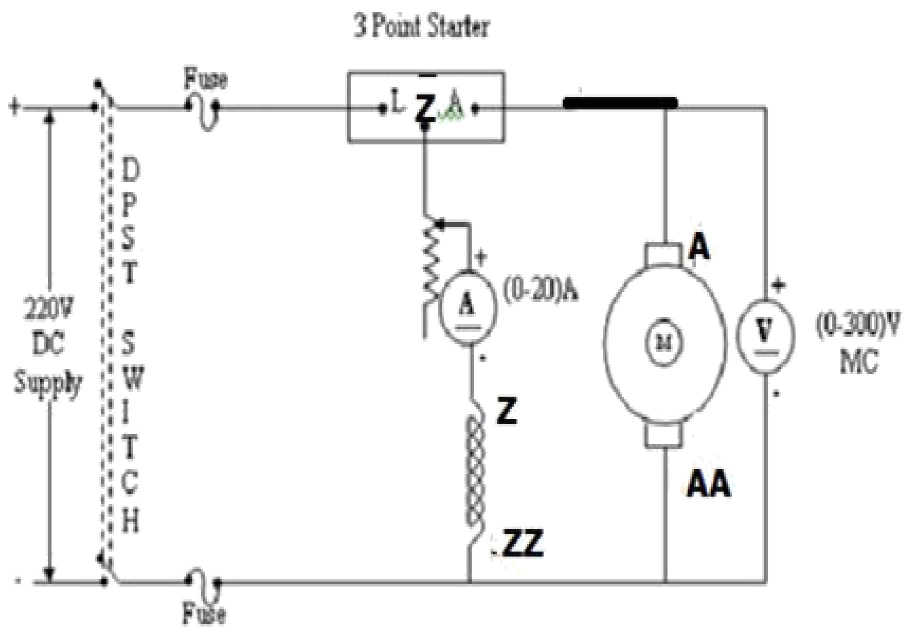
EXPERIMENT NO. 12

Aim: Speed control of DC shunt motor by field current control method.

Apparatus Required:

S.No.	Name of the apparatus required	Specification/Rating	Type	Quantity

Circuit Diagram:



Theory:

Speed control of DC shunt motor by the help of field flux control is carried out above the base speed. As its used for above base speed hence it is also called as constant power control method as our power remains constant in this region By decreasing the flux, the speed can be increased and vice versa. The flux of a dc motor can be changed by changing I_{sh} with help of a shunt field rheostat. Since I_{sh} is relatively small, shunt field rheostat has to carry only a small current, which means $I_{sh}R$ loss is small, so that rheostat is small in size.

Procedure:

1. Connections are made as per the circuit diagram.
2. After checking the maximum position of armature rheostat and minimum position of field rheostat, DPST switch is closed.

Field Control:

1. Armature voltage is fixed to various values and for each fixed value by adjusting the field rheostat, speed is noted for various field currents.
2. Bringing field rheostat to minimum position and armature rheostat to maximum position DPST switch is opened.

Observation Table:

S.N.O	Va =	
	Field current (A)	Speed N (rpm)

Result:

Thus, the speed control characteristic curve of DC Shunt motor is obtained.

Precautions:

1. Field Rheostat should be kept in the minimum resistance position at the time of starting and stopping the motor.
2. Armature Rheostat should be kept in the maximum resistance position at the time of starting and stopping the motor.

Viva Questions:

Q.1 How does the speed of a DC shunt motor vary with armature voltage and field current?

Q.2 Compare the resistance of the armature and field winding.

Q.3 What is the importance of speed control of DC motor in industrial applications?

Q.4 What are the applications of a DC shunt motor?

Q.5 Which is of the two methods of speed control is better and why?

Q.6 Why is the speed of DC shunt motor practically constant under normal load condition?

Q.7 What are the factors affecting the speed of a DC shunt motor?

Q.8 What is the field control method for speed control of a DC shunt motor?

Q.9 How does changing the field resistance affect the speed of a DC shunt motor?

Q.10 What are the advantages of using the field control method for speed control?

Q.11 What are the limitations of the field control method?

Q.12 Can the field control method be used for both increasing and decreasing the speed of a DC shunt motor?

EXPERIMENT NO. 13

Aim: To study the constructional features and working of three phase induction motor.

Construction details:

Stator:

It is stationary part of induction motor. It consists stator winding. It is housed on the motor frame. It is made from casting materials.

Rotor:

It is the rotating part of the induction motor. It is housed on the shaft of induction motor. It has two ends, one is called driving end and another is called non driving end. Mechanical load is connected on driving end while cooling fan is connected on non-driving end. Both the ends are connected with bearings for free rotation means of reduced friction losses.

Stator Windings:

1. Star connected
2. Delta connected.

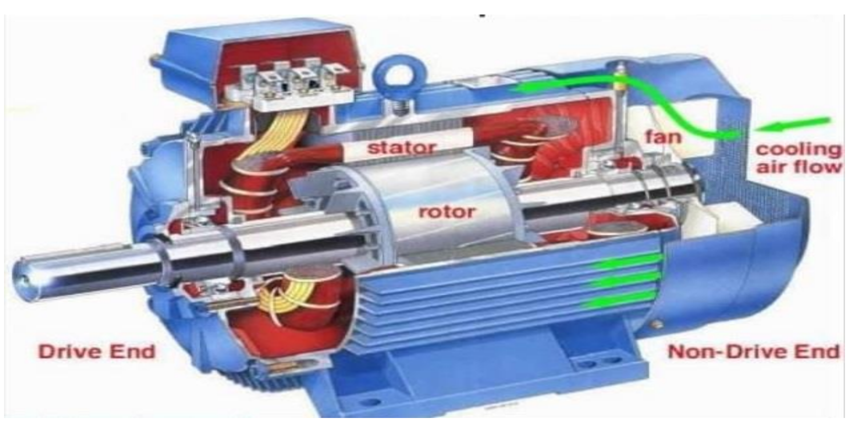
Rotor Windings:

It is wound as rotor bars and short circuited at both the ends through end rings.

According to rotor construction it can be classified

1. Squirrel cage induction motor.
2. Slip ring induction motor.

Cut Section View of 2-Phase Induction Motor:



Working of Three Phase Induction Motor:

1. **Production of Rotating Magnetic Field**

The stator of the motor consists of overlapping winding offset by an electrical angle of 120°. When the primary winding or the stator is connected to a 3 phase AC source, it establishes a rotating magnetic field which rotates at the synchronous speed.

2. **Rotation**

According to Faraday's law an emf induced in any circuit is due to the rate of change of magnetic flux linkage through the circuit. As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring, and cut the stator rotating magnetic field, an emf is induced in the rotor copper bar and due to this emf a current flows through the rotor conductor. Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation; hence as per Lenz's law the rotor will rotate in the same direction to reduce the cause i.e. the relative velocity.

Thus, from the working principle of three phase induction motor it may observed that the rotor speed should not reach the synchronous speed produced by the stator. If the speeds equals, there would be no such relative speed, so no emf induced in the rotor, & no current would be flowing, and therefore no torque would be generated. Consequently, the rotor cannot reach the synchronous speed. The difference between the stator (synchronous speed) and rotor speeds is called the slip. The rotation of the magnetic field in an induction motor has the advantage that no electrical connections need to be made to the rotor.

Thus, the three phase induction motor **is:**

- Self-starting.
- Less armature reaction and brush sparking because of the absence of commutators and brushes that may cause sparks.
- Robust in construction.
- Economical.
- Easier to maintain.

Induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed. Like any other electrical motor, induction motor have two main parts namely rotor and stator.

Viva Questions:

Q.1 What is the difference between a squirrel-cage rotor and a wound rotor?

Q.2 What is slip in an induction motor?

Q.3 What are the types of rotors used in induction machines?

Q.4 Why is an induction motor called a 'self-starting' motor?

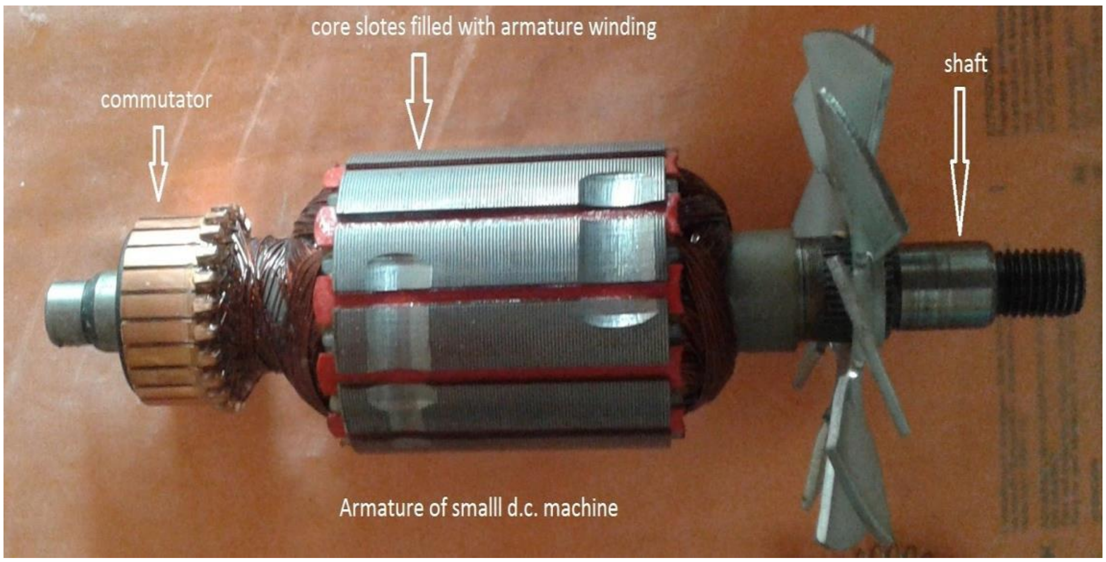
Q.5 Why is the induction machine widely used in industrial applications?

EXPERIMENT NO. 14

Aim: To study the constructional features and working of DC motor.

Construction details:

- **Yoke:** It supports the entire machine and acts as protective cover, supports the poles. It offers flux path completion through it. Therefore, it should be good ferromagnetic material. In large machine yoke are made of cast steel. When DC machine operate with power electronic converter & control system application, laminated yokes are preferred
- **Armature Core:** To reduces the eddy current either laminate the core or put silicon in steel called "Stalloy" or electrical steel in 3.5% to 4%.



- **Commutator:** It is made up of hard drawn copper and insulated by "Mica". It is a rotating switch which converts AC into DC. The thickness of insulation is 0.8mm.
- **Brushes:** These are stationary sliding contacts which offer a good electrical connection between rotating commentator and stationary loads.
- **Shaft:** The armature core and commentator are mount and keyed to the shaft for the exchanged of mechanical power.

Cut Section View of the DC Machine

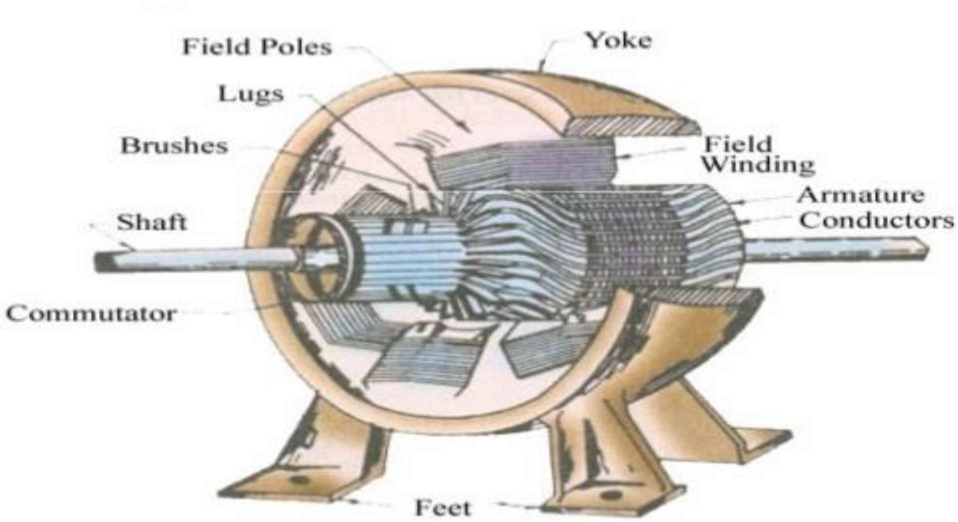


Fig: Cut Section View of the DC Machine

Theory: Electrical motors are everywhere around us. Almost all the electro-mechanical movements we see around us are caused either by a AC or a DC motor. Here we will be exploring DC motors. This is a device that converts DC electrical energy to a mechanical energy.

Principle of DC Motor:

Direct current motor works on the principle, when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. This is known as motoring action. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact they produce a mechanical force, and based on that the working principle of DC motor is established.

The direction of rotation of a this motor is given by Fleming's left hand rule, which states that if the index finger, middle finger and thumb of your left hand are extended mutually perpendicular to each other and if the index finger represents the direction of magnetic field, middle finger indicates the direction of current, then the thumb represents the direction in which force is experienced by the shaft of the dc motor**.**

The back emf like in case of a generator is represented by

$$E_b = \frac{PNZ\emptyset}{60A} \qquad (1)$$

Where, P = no of poles
φ = flux per pole
Z= No. of conductors

A = No. of parallel paths

and N is the speed of the DC Motor.

So, from the above equation we can see E_b is proportional to speed 'N'. That is whenever a direct current motor rotates, it results in the generation of back Emf. Now lets represent the rotor speed by ω in rad/sec. So, E_b is proportional to ω.

So, when the speed of the motor is reduced by the application of load, E_b decreases. Thus the voltage difference between supply voltage and back emf increases that means $E - E_b$ increases. Due to this increased voltage difference, armature current will increase and therefore torque and hence speed increases. Thus a DC Motor is capable of maintaining the same speed under variable load.

Now armature current I_a is represented by

$$I_a = \frac{E - E_b}{R_a}$$

Now at starting, speed $\omega = 0$ so at starting $E_b = 0$.

$$\therefore \ I_a = \frac{E}{R_a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Now since the armature winding R_a is small, this motor has a very high starting current in the absence of back Emf. As a result we need to use a starter for starting a DC Motor. Now as the motor continues to rotate, the back Emf starts being generated and gradually the current decreases as the motor picks up speed.

Viva Questions

Q.1 What is the role of the commutator in a DC machine?
Q.2 What is the significance of back EMF in a DC motor?
Q.3 What is the purpose of brushes in a DC machine?
Q.4 What is the principle of operation of a DC motor?
Q.5 What is back EMF in a DC motor?
Q.6 How can the direction of rotation of a DC motor be reversed?

EXPERIMENT NO. 15

Aim: To study the constructional features and working of synchronous motor.

Construction Details:

Cut section View of the Synchronous Machine

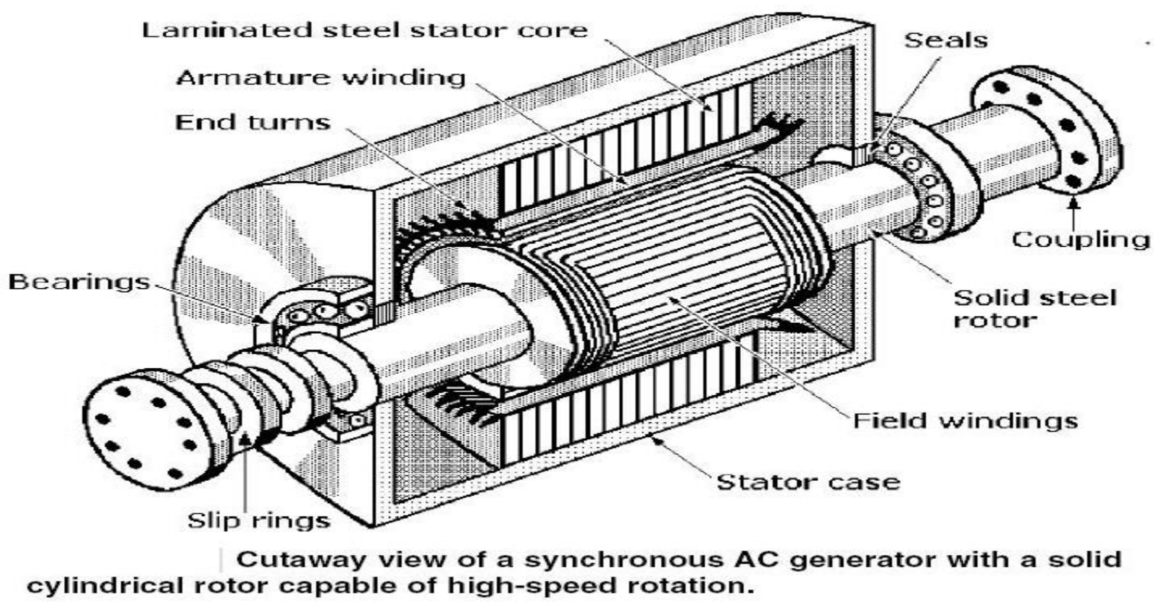


Fig: Cut section view of a synchronous AC generator with a cylindrical rotor

Stator:

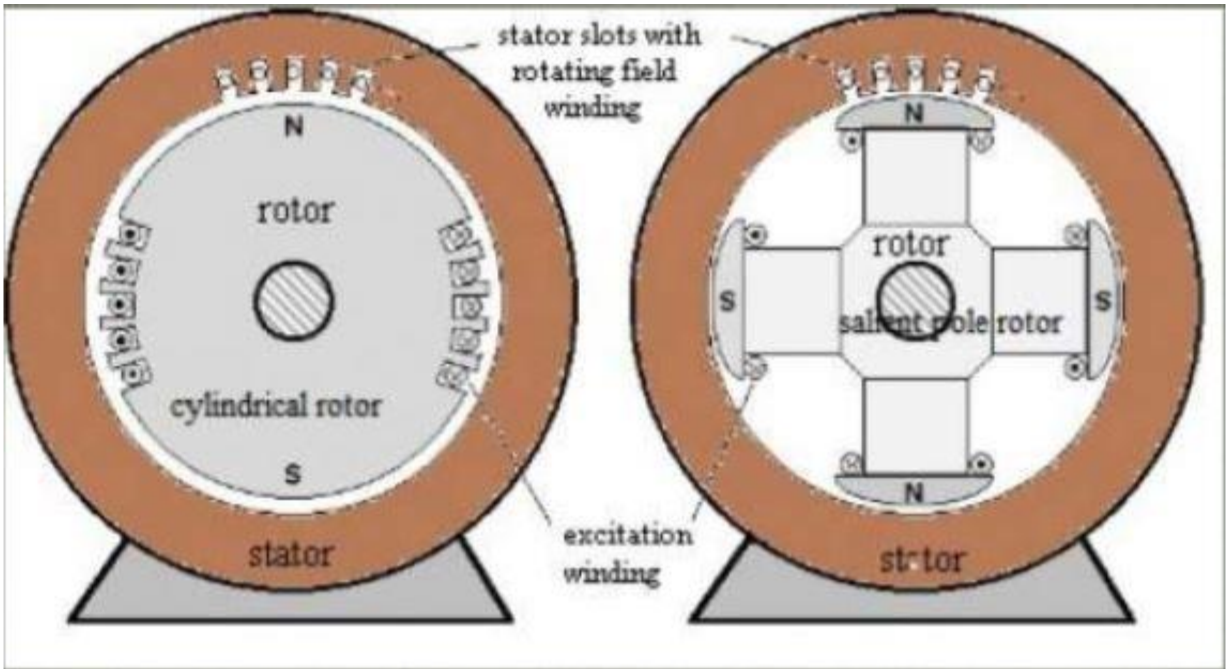
It provides mechanical support to the stator and rotor. It is made from casting materials. It is stationary part of induction motor.It consists stator winding.It is housed on the motor frame.

Rotor:

Rotor can be classified into two types.

1. Salient Pole type
2. Cylindrical type

Construction of the two are shown in the below given figure.



Salient pole type

In salient pole type air gap is minimum along d axis and maximum along q axis.It contains large diameter and small length also known as hydro electric type.

Cylindrical type

Air gap is uniform throughout the surface. It contains large length small diameter also known as Turbo electric type.

Slip rings (Brushes)

It is made of conductive material. Mostly graphite is used.

Theory: Electrical motor in general is an electro-mechanical device that converts energy from electrical domain to mechanical domain. Based on the type of input we have classified it into single phase and 3 phase motors. Among 3 phase induction motors and synchronous motors are more widely used. When a 3 phase electric conductors are placed in a certain geometrical positions (In certain angle from one another) then an electrical field is generated. Now the rotating magnetic field rotates at a certain speed, that speed is called synchronous speed. Now if an electromagnet is present in this rotating magnetic field, the electromagnet is magnetically locked with this rotating magnetic field and rotates with same speed of rotating field.

Synchronous motors is called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there or in other words it’s in synchronism with the supply frequency. Synchronous speed is given by

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

where, f = supply frequency & p = no. of poles

Normally it's construction is almost similar to that of a 3 phase induction motor, except the fact that the rotor is given dc supply, the reason of which is explained later. Now, let us first go through the basic construction of this type of motor

From the above picture, it is clear that how this type of motors are designed. The stator is given is given three phase supply and the rotor is given dc supply.

Main Features of Synchronous Motors:

1. Synchronous motors are inherently not self-starting. They require some external means to bring their speed close to synchronous speed to before they are synchronized.
2. The speed of operation is in synchronism with the supply frequency and hence for constant supply frequency they behave as constant speed motor irrespective of load condition
3. This motor has the unique characteristics of operating under any_electrical power factor. This makes it being used in electrical power factor improvement.

Principle of Operation Synchronous Motor:

Synchronous motor is a doubly excited machine i.e. two electrical inputs are provided to it. It’s stator winding which consists of a 3-phase winding is provided with 3 phase supply and rotor is provided with DC supply. The 3-phase stator winding carrying 3 phase currents produces 3 phase rotating magnetic flux. The rotor carrying DC supply also produces a constant flux. Considering the frequency to be 50 Hz, from the above relation we can see that the 3-phase rotating flux rotates about 3000 revolutions in 1 min or 50 revolutions in 1 sec. At a particular instant rotor and stator poles might be of same polarity (N-N or S-S) causing repulsive force on rotor and the very next second it will be N-S causing attractive force. But due to inertia of the rotor, it is unable to rotate in any direction due to attractive or repulsive force and remain in standstill condition. Hence it is not self-starting.

To overcome this inertia, rotor is initially fed some mechanical input which rotates it in same direction as magnetic field to a speed very close to synchronous speed. After some time magnetic locking occurs and the synchronous motor rotates in synchronism with the frequency.

: Methods of Starting of Synchronous Motor

1. **Motor starting with an external prime Mover:** Synchronous motors are mechanically coupled with another motor. It could be either 3 phase induction motor or DC shunt motor. DC excitation is not fed initially. It is rotated at speed very close to its synchronous speed and after that DC excitation is given. After some time when magnetic locking takes place supply to the external motor is cut off.
2. **Damper winding:** In case, synchronous motor is of salient pole type, additional winding is placed in rotor pole face. Initially when rotor is standstill, relative speed between damper winding and rotating air gap flux in large and an emf is induced in it which produces the required starting torque. As speed approaches synchronous speed, emf and torque is reduced and finally when magnetic locking takes place, torque also reduces to zero. Hence in this case synchronous is first run as three phase induction motor using additional winding and finally it is synchronized with the frequency.

Applications of Synchronous Motor:

1. Synchronous motor having no load connected to its shaft is used for power factor improvement. Owing to its characteristics to behave at any electrical power factor, it is used in power system in situations where static capacitors are expensive.
2. Synchronous motor finds application where operating speed is less (around 500 rpm) and high power is required. For power requirement from 35 kW to 2500 KW, the size, weight and cost of the corresponding three phase induction motor is very high.

Viva Questions:

Q.1 What are the two main types of rotors used in synchronous machines?
Q.2 What is a salient pole rotor, and where is it commonly used?
Q.3 What is a cylindrical rotor, and where is it typically used?
Q.4 Where are synchronous machines commonly used?
Q.5 What are the advantages of using a synchronous machine?
Q.6 What are the main types of windings used in the stator of a synchronous machine?
Q.7 What is the synchronous speed of a synchronous machine?
Q.8 What is the purpose of damper windings in a synchronous machine?
Q.9 How does a synchronous motor start?