LABORATORY MANUAL

Electrical and Electronic Measurement Lab

FOR B. Tech. (EE/EIE)

Prepared By:

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(Asst. Prof. EIE)

DEPARTMENT OF ELECTRICAL AND INSTRUMENTATION ENGINEERING

Sant Longowal Institute of Engineering and Technology,

Longowal, Punjab-148106

(Deemed to be University, Under MHRD, Govt. of India)

VISION OF DEPARTMENT

Electrical and Instrumentation Engineering Department shall strive to act as a podium for the development and transfer of technical competence in academics, entrepreneurship and research in the field of Electrical and Instrumentation Engineering to meet the changing need of society.

MISSION

1. To provide modular programmes from skill development to the research level.
2. To impart education and training in innovative state-of-the-art technology in the field of Electrical and Instrumentation Engineering.
3. To promote holistic development among the students.
4. To provide extension services to rural society, industry professionals, institutions of research and higher learning in the field of Electrical and Instrumentation Engineering.
5. To interact with the industry, educational and research organizations, and alumni in the fields of curriculum development, training and research for sustainable social development and changing needs of society.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO):

The following Programme Educational Objectives are designed based on the department mission. The graduates of Instrumentation and Control Engineering should be able to demonstrate

1. Skill in professional / academic career using the knowledge of mathematical, scientific and engineering principles.
2. Expertise in solving real life problems, designing innovative products and systems that are techno-economically and socially sustainable.
3. Sustained learning and adaptation to modern engineering tools, techniques and practices through instruction, group activity and self-study.
4. Leadership and team work while working with diverse multidisciplinary / interdisciplinary groups.
5. Professional ethics and commitment to organizational goals.

PROGRAM OUTCOMES

Engineering Graduates will be able to:

Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

Conduct investigations of complex problems: 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.

Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

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

Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

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

Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

Project management and finance: Demonstrate knowledge and understanding of the engineering 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.

Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

1. Understand and analyze the existing techniques for measurement, instrumentation, process control and automation in real-time problems.
2. Develop innovative solutions for measurement, instrumentation, control and automation of real- time applications by utilizing the latest technological developments.

LABORATORY PRACTICE

SAFETY RULES

SAFETY is of paramount importance in the Electrical Engineering Laboratories.

1. Electricity NEVER EXCUSES careless persons. So, exercise enough care and attention in handling electrical equipment and follow safety practices in the laboratory. (Electricity is a good servant but a bad master).
2. Avoid direct contact with any voltage source and power line voltages. (Otherwise, any such contact may subject you to electrical shock)
3. Switch on the power to your circuit and equipment only after getting them checked up and approved by the staff member.
4. Ensure that the power is OFF before you start connecting up the circuit. (Otherwise, you will be touching the live parts in the circuit).
5. Wear rubber-soled shoes. (To insulate you from the earth so that even if you accidentally contact a live point, current will not flow through your body to the earth and hence you will be protected from electrical shock)
6. Avoid loose clothing. (Loose clothing may get caught on an equipment/instrument, and this may lead to an accident, particularly if the equipment happens to be a rotating machine)
7. Girl students should have their hair tucked under their coat or have it in a knot.
8. Do not wear any metallic rings, bangles, bracelets, wristwatches and neck chains.
9. Be certain that your hands are dry and that you are not standing on the wet floor. (Wet parts of the body reduce the contact resistance, thereby increasing the severity of the shock)
10. Get your circuit diagram approved by the staff member and strictly connect the circuit as per the approved circuit diagram.
11. Check power chords for any sign of damage, and be certain that the chords use safety plugs and do not defeat these plugs' safety feature by using ungrounded plugs.
12. When using connection leads, check for any insulation damage in the leads and avoid such defective leads.
13. Do not defeat any safety devices such as fuse or circuit breaker by shorting across it. Safety devices protect YOU and your equipment.
14. In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up etc.), switch off the power to your circuit immediately and inform the staff member.
15. After completing the experiment show your readings to the staff member and switch off the power to your circuit after getting approval from the staff member.
16. Some students have been found to damage meters by mishandling in the following ways:
    a. Keeping unnecessary material like books, lab records, unused meters etc., causing meters to fall down the table.
    b. Putting pressure on the meter (especially glass) while making connections or while talking or listening to somebody.

About Laboratory Manual

This manual is intended for the Second year students of engineering branches in the subject of Electrical and Electronic Measurement. This manual typically contains practical/Lab Sessions related Electrical Measurement covering various aspects related to the subject to enhance understanding.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

DO’S and DON’TS in Laboratory

1. Come fully prepared for the experiment in the laboratory.
2. Check for appropriate power supply before connecting to the equipment.
3. Decide the appropriate range of the measuring instruments on the basis of quantity to be measured.
4. Make the connections without connecting the leads to the supply.
5. Re-check the connections and show it to the teacher /instructor before switching-on the power supply to the circuit.
6. Energize the circuit only with the permission of the teacher/instructor.
7. After the experiment, disconnect the connections and put back the connecting wires/leads at appropriate place.
8. Return all the apparatus to the lab-staff.
9. In case of shock, switch-off the power supply immediately.
10. Strictly follow the procedure given with the respective experiments.
11. Avoid loose connections.
12. Don’t touch the main power supply leads with bare hand and avoid body earth.
13. Don’t use the mobile phones during laboratory.

ELECTRICAL MEASUREMENTS LABORATORY

LIST OF EXPERIMENTS

1. To study the construction and working principle of PMMC and moving iron instrument.
2. To study about the range extension of ammeter and voltmeter devices by using shunt and multipliers.
3. To measure the parameters of a choke coil using three voltmeter method.
4. To determine accurate Quality Factor of an unknown coil.
5. To study the Three phase power measurement by using two wattmeter method.
6. Calibration and testing of single phase energy meter by direct loading.
7. To measure medium resister by the voltmeter and ammeter method.
8. To study and perform an experiment to measure the unknown Resistance by Wheatstone's bridge.
9. To understand the construction and working mechanism of CRO.

   To perform amplitude, frequency, and phase measurements using a calibrated cathode ray oscilloscope and to make use of Lissajous figures for phase and frequency measurements.
10. To study the measurement of Self-Inductance by Maxwell's inductance capacitance Bridge.
11. To study the measurement of Self-Inductance by Anderson's Bridge.

TROUBLE SHOOTING HINTS

1. Be Sure that the power is turned ON
2. Be sure the ground connections are common
3. Be sure the circuit you build is identical to your circuit diagram (Do a node by node check).
4. Be sure that the supply voltages are correct
5. Be sure that the equipment is set up correctly and you are measuring the correct parameters

   If steps 1 through 5 are correct then you probably have used a component with the wrong value or one that doesn't work. It is also possible that the equipment does not work (although this is not probable) or the protoboard you are using may have some unwanted paths between nodes. To find your problem you must trace through the voltages in your circuit node by node and compare the signal you expect to have. Then if they are different use your engineering judgment to decide what is causing the different or ask your lab assistant.

Experiment-1

Aim: To study the construction and working principle of PMMC and moving iron instrument.

Apparatus: Meter Demonstration ckt, Connecting Wire, D.C Power supply

Theory:

PMMC: A Permanent Magnet Moving Coil **(**PMMC**)** meter – also known as a D'Arsonval meter or galvanometer – is an instrument that allows you to measure the current through a coil by observing the coil's angular deflection in a uniform magnetic field.

Construction

A PMMC Equipment consists of two main parts; moving coil and a permanent magnet along with other parts. These parts are explained below:

1. **Magnet System**

   The instrument consists of two high intensity, high coercive force magnets or a big U-shape magnet based on design. These magnets are made up of Alcomax and Alnico for higher coercive force and better field intensity.

   In many designs, an additional soft iron cylinder is placed in between the magnetic poles to make the field uniform; while reducing air reluctance to increasing field strength.

2. **Moving Coil**

   It is one of the main components of permanent magnet moving coil equipment; and is made up of copper coils wounded to a rectangular block in between the magnetic poles. Made up of Aluminium; the rectangular block is called Aluminium former pivoted to the jewelled bearing. It is what allows the coil to rotate freely.

   Non-metallic former like that of aluminium is used for current measurement; while metallic former with high electromagnetic damping is used to measure voltage.

3. **Control**

   Two spring made of phosphorus bronze acts as a control system for the permanent magnet moving coil. These springs are mounted on the jewel bearing of PMMC; providing the essential controlling torque. The controlling torque produced is mainly due to ribbon suspension. They oppose the force of deflection; so the electromagnetic force (of Moving Coil) came in equilibrium with the spring tension.

   This helps in keeping the pointer at a fixed position after an initial deflection. These control springs also serve the purpose of providing lead current paths in and out of the system.

4. **Damping System**
   Damping torque is produced in the PMMC equipment by the movement of aluminium core in the magnetic field. It keeps the pointer at rest after the initial deflection. This helps in proper measurement without fluctuations.

Due to the movement of the coil in the magnetic field; eddy current is produced in the aluminium former. this produces the damping force / Torque which opposes the further motion of the coil. Slowly the pointer deflection reduces and finally stop's at a fixed position.

5. **Scale and Pointer**

The pointer connected to the moving coil moves over a marked scale. The pointer moves along with the coil deflection to show readings marked on the scale. A pointer is a simple construction with light weight design and twisted section to reduce parallax error.

A Parallax error can be further reduced by proper alignment of pointer blades to the initial scale.

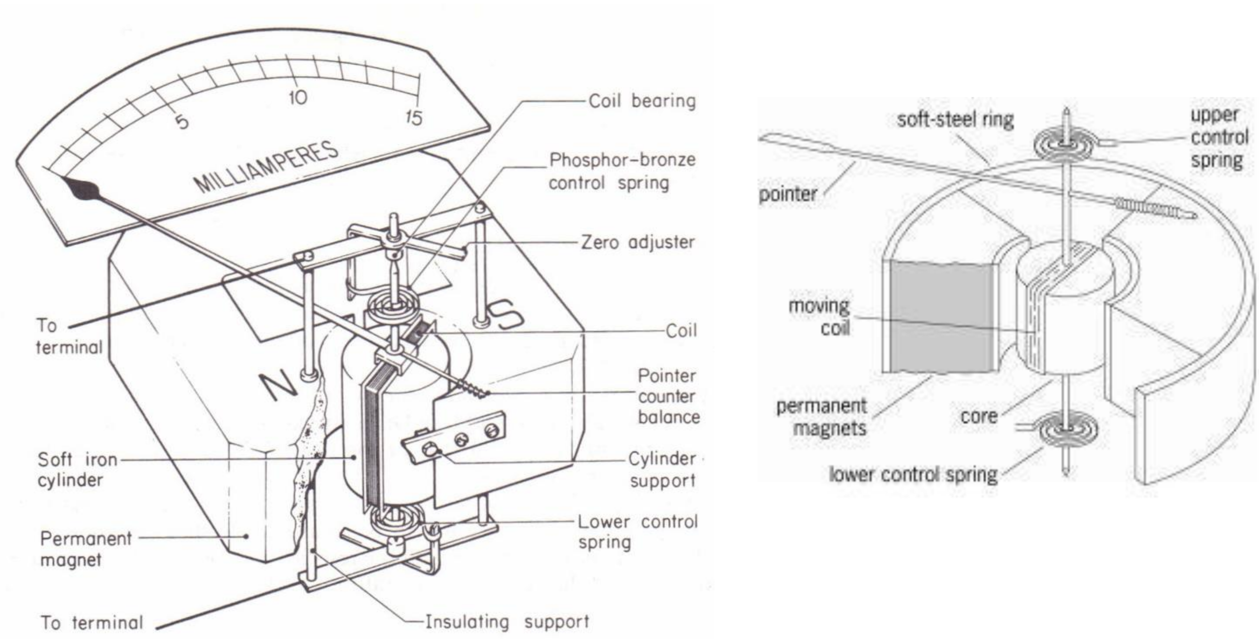


Fig: construction of PMMC Instrument

Working Principle of a PMMC Instrument

When a current caring conductor is placed in a magnetic field; it experiences a force perpendicular to the field and the current *(Fleming Left Hand Rule).* This force tends to move the conductor. According to Fleming left-hand rule; if your left-hand thumb, fore finger, and middle finger are at 90 degrees to each other. Then the magnetic field would be along with the fore finger, current across the middle while the force along with the thumb.

When current flows in the coil on the aluminium former; a magnetic field is produced in the coil in proportion to the current flow. This electromagnetic force along with a static magnetic field from the permanent magnet produces the deflection force in the coil. The spring then produces the controlling force to oppose further deflection; thus helps in balancing the pointer.

Then damping force is produced in the system by the movement of aluminium core in the magnetic field. It keeps the pointer fixed to a position after it reaches equilibrium with the controlling and deflection torque; providing better precision in measurement.

Torque Equation

As we know that torque is defined as:

Torque = force * perpendicular distance

In case of an electromagnetic circuit, force is given by NBIL

where,

N = No. of turns in coil; B = Flux density;

L = length of the coil; I = current flowing across the coil

Therefore now torque becomes T = NBIL * D

or T = NBI * A A - Area

or T = G * I G = NBA (constant)

As we know that deflecting torque T_d = controlling torque T_c.

and $T_c = K * \theta$

$GI = K\theta$ ► $\theta = G/K * I$

This equation shows that the deflection of a PMMC instrument is directly proportional to the electric current flowing across the coil.

Error in PMMC Equipment

1. **Error due to magnetism**

   Permanent magnet loses their magnetism with time; this is called magnet aging. With plenty of heat and vibration on the ship (especially Engine Room); There is a reduction of magnetism due to accelerated aging. This decrease in magnetic strength reduce the coil deflection affecting the readings.

2. **Error due to Temperature Difference**

   Moving Coil of PMMC instrument is made up of copper wires; the temperature coefficients of copper wire is known to be 0.004 per degree Celsius. So with increase in temperature, there will be a high increase in its resistance altering the actual reading.

3. **Error due to Spring**

   Aging leads to weakening of spring tension; this results in decreased deflection of the moving coil. This error is opposite to that of the error due to magnetic aging and sometimes cancel each other to reduce much difference in the final readings.

Advantages of PMMC Equipment

1. High weight to torque ratio.
2. It has pointer deflection proportional to the current; which makes the scale more uniform over an arc of 270 degrees.
3. It consumes much less power than other alternatives.
4. No hysteresis loss.
5. Unaffected by a stray magnetic field; perfect equipment for on-board applications.
6. All-purpose equipment; can be used as an ammeter, voltmeter, and galvanometer.

Disadvantages of PMMC Equipment

1. It only works for Direct current (D.C).
2. It's costly than its other alternatives.
3. It can show false reading due to the above stated reasons (cause of errors in permanent magnet moving coil instrument).

Moving Iron: The instrument in which the moving iron is used for measuring the flow of current or voltage is known as the moving iron instrument.

It works on the principle that the iron place near the magnet attracts towards it. The force of attraction depends on the strength of the magnet field. The magnetic field induces by the electromagnet whose strength depends on the magnitude of the current passes through it.

Construction and Working

In Moving Iron Instruments, a plate or van of soft iron or of high permeability steel forms the moving element of the system. The iron van is so situated that it can move in the magnetic field produced by a stationary coil.

The stationary coil is excited by the current or voltage under measurement. When the coil is excited, it becomes an electromagnet and the iron van moves in direction of offering low reluctance path. Thus the force of attraction is always produced in a direction to increase the inductance of coil. Mind that as the van follows the low reluctance path, the net flux in air gap will increase which means increased flux linkage of coil and hence inductance of coil will increase. It shall also be noticed that, the inductance of coil is variable and depends on the position of iron van.

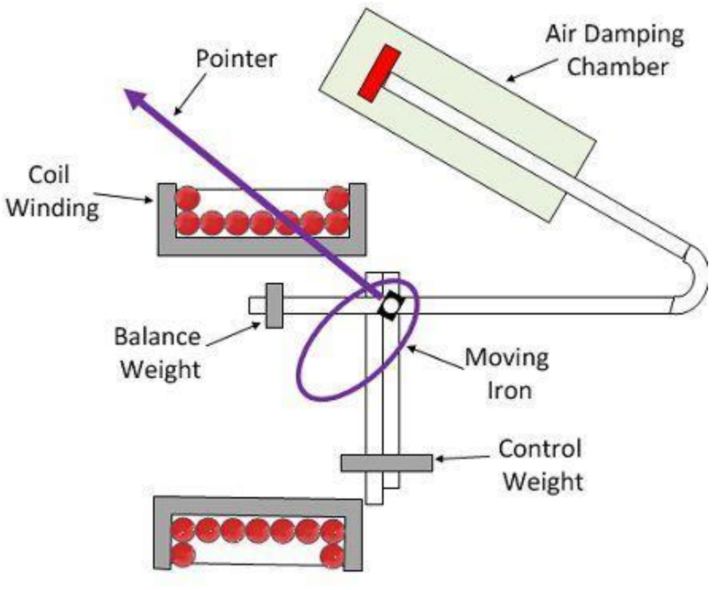
Classification

There are two types of moving iron instrument, Attraction and Repulsion type.

1. **Attraction Type:** The instrument in which the iron plate attracts from the weaker field towards the stronger field such type of instrument is known as the attraction type instrument.

Construction of Attraction Type Instrument: The stationary coil of the attraction type instrument is flat and has a narrow opening. The moving element is the flat disc of the iron core. The current flow through the stationary coil produced the magnetic field which attracts the iron coil. The iron vane deflects from the low magnetic field to the high magnetic field, and the strength of the deflection is directly proportional to the magnitude of the current flow through it. In short, we can say that the iron coil attracts towards in.

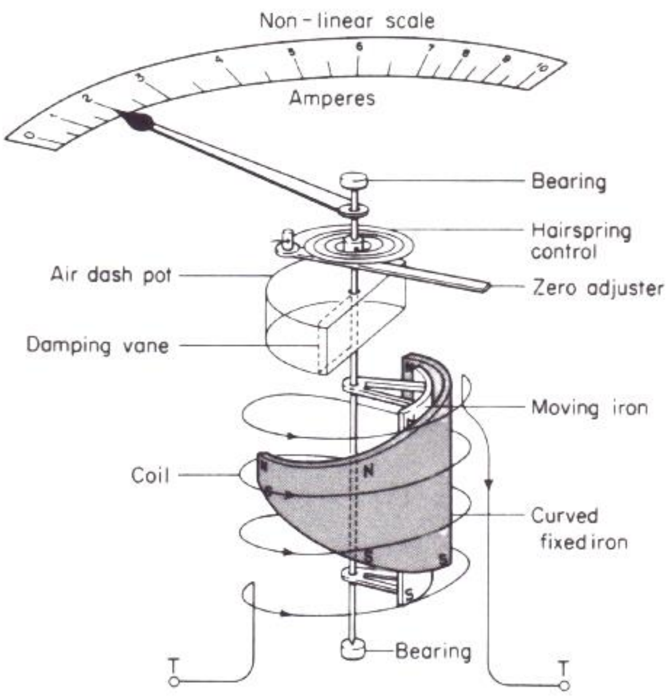
The attraction type instruments use spring, which provided the controlling torque. The deflection of the coil is reduced by the aluminium piston which is attached to the moving coil.

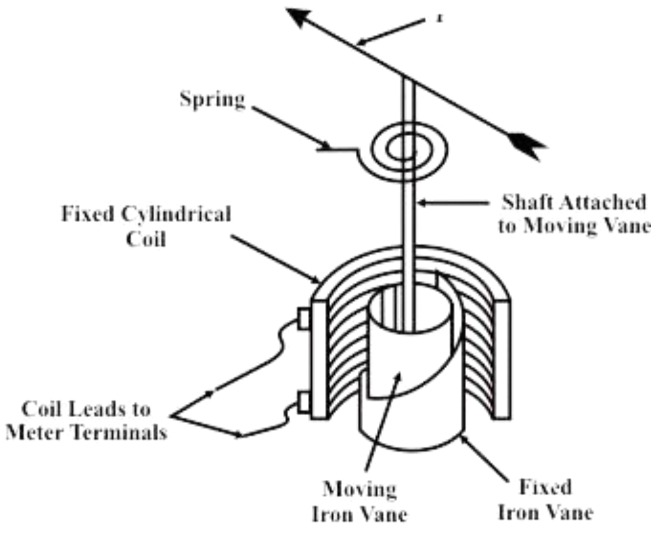


Attraction Type Moving Coil Instrument

2. Repulsion Type Instruments – The repulsion type instrument has two vanes or iron plates. One is fixed, and the other one is movable. The vanes become magnetised when the current passes through the stationary coil and the force of repulsion occur between them. Because of a repulsive force, the moving coil starts moving away from the fixed vane.

The spring provides the controlling torque. The air friction induces the damping torque, which opposes the movement of the coil. The repulsion type instrument is a non-polarized instrument, i.e., free from the direction of current passes through it. Thus, it is used for both AC and DC.





Torque Equation*:*

Suppose that, at any instant of time current flowing in the coil is I. Thus the energy stored in the coil in the form of magnetic field = $(1/2)LI^2$.

As soon as the current changes to (I+dI), deflection in the pointer becomes dϴ resulting into change in inductance of coil from L to (L+dL). Let this deflection in pointer is due to deflection torque Td.

Thus mechanical work done = $T_d * d\theta$ (1)

Energy stored in Coil = $(1/2)(L+dL)(I+dI)^2$

Change in stored energy of coil = Final Stored Energy – Initial Stored Energy

$= 1/2)(L+dL)(I+dI)^2 - (1/2)LI^2$

$= (1/2)[(L+dL)(I+dI)^2 - I^2L]$

$= (1/2)[(L+dL)(I^2 + 2IdI + (dI)^2 - I^2L]$

$= (1/2)[LI^2 + 2LIdI + L(dI)^2 + dLI^2 + 2IdI * dL + dL * (dI)^2 - I^2L]$

Neglecting second order and higher terms of differential quantities i.e. $L(dI)^2$, $2IdI * dL$ and $dL * (dI)^2$

$= (1/2)[2LIdI + dL * I^2]$

$= LIdI + (1/2)dL * I^2$ (2)

Again, just think, when there is a change of current from I to (I+dI), this change change of current must be accompanied by change in emf of coil. Thus we can write as

$E = d(LI)/dt$

$= IdL/dt + LdI/dt$

But electrical energy supplied by the source = eIdt

$= (IdL + LdI) * I$

$= I^2dL + LIdI$

According to law of conservation of energy, this electrical energy supplied by the source is converted into stored energy in the coil and mechanical work done for deflection of needle of Moving Iron Instruments.

Hence,

$I^2dL + LIdI$ = Change in stored energy + Work done

⇒ $I^2dL + LIdI = LIdI + (1/2)dL * I^2 + Tdx\, d\Theta$ [from (1) and (2)]

⇒ $Tdx\, d\Theta = (1/2)dLxI^2$

⇒ $\boldsymbol{Td = (1/2)I^2(dL/d\Theta)}$

Thus deflecting torque in Moving iron Instruments is given as

$$\boldsymbol{Td = (1/2)I^2(dL/d\Theta)}$$

From the above torque equation, we observe that the deflecting torque is dependent on the rate of change of inductance with the angular position of iron van and square of rms current flowing through the coil.

In moving iron instruments, the controlling torque is provided by spring. Controlling torque due to spring is given as

$Tc = K\Theta$

Where K = Spring constant; ϴ = Deflection in the needle

In equilibrium state, deflecting and controlling torque shall be equal as below.
Deflecting Torque = Controlling Torque

⇒ $T_d = T_c$

⇒ $(1/2)I^2(dL/d\Theta) = K\Theta$

⇒ $\boldsymbol{\Theta = (1/2)(I^2/K)(dL/d\Theta)}$

From the above torque equation, we observe that the angular deflection of needle of moving iron instruments is square of rms current flowing through the coil. Therefore, the deflection of moving iron instruments is independent of direction of current.

Advantages of the MI Instruments

The following are the advantages of the moving iron instruments.

1. **Universal use**: The MI instrument is independent of the direction of current and hence used for both AC and DC.
2. **Less Friction Error:** The friction error is very less in the moving iron instrument because their torque weight ratio is high. The torque weight ratio is high because their current carrying part is stationary and the moving parts are lighter in weight.
3. **Cheapness**: The MI instruments require less number of turns as compared to PMMC instrument. Thus, it is cheaper.
4. **Robustness**: The instrument is robust because of their simple construction. And also because their current carrying part is stationary.

Disadvantages of Moving Iron Instruments.

The following are the disadvantages of Moving Iron Instrument.

1. **Accuracy:** The scale of the moving iron instruments is not uniform, and hence the accurate result is not possible.
2. **Errors:** Some serious error occurs in the instruments because of the hysteresis, frequency and stray magnetic field.
3. **Waveform Error:** In MI instrument the deflection torque is not directly proportional to the square of the current. Because of which the waveforms error occurs in the instrument.
4. **Difference between AC and DC calibration:** The calibration of the AC and DC are differed because of the effect of the inductance of meter and the eddy current which is used on AC. The AC is calibrated on the frequency at which they use.

Two type of error occurs in the MI instruments i.e., the error which occurs on both AC and DC and the error which only occur on AC.

Experiment-2

Aim: To study about the range extension of ammeter and voltmeter devices by using shunt and multipliers.

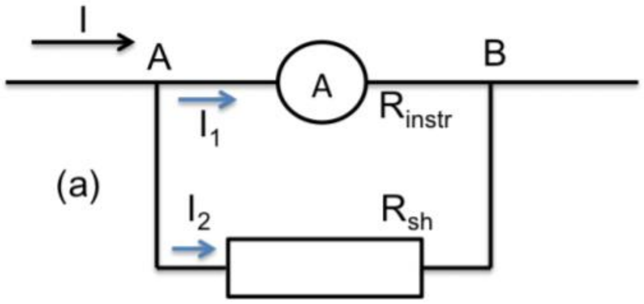
Apparatus:

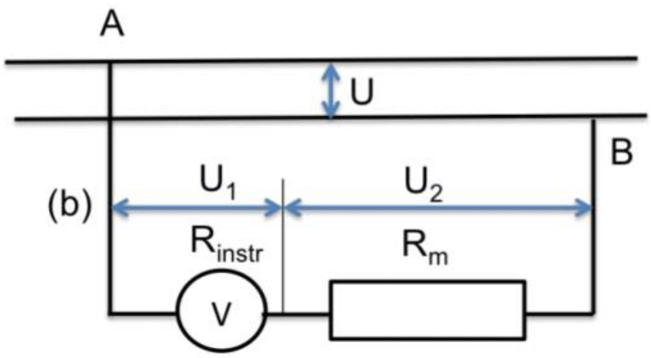
Theory:

The ranges of electrical measuring instruments (whether ammeter, voltmeter, or any other type of meters) are limited by currents, which may be carried by the coils of the instruments safely. For example, the moving coils of the instruments can carry maximum current of about 50 mA safely and the potential drop across the moving coil is about 50 mV. Hence, it becomes necessary that the current and voltage being measured be reduced and brought within the range of instrument.

Common devices used for extending the range of the instruments are

a) Shunts
b) Multipliers

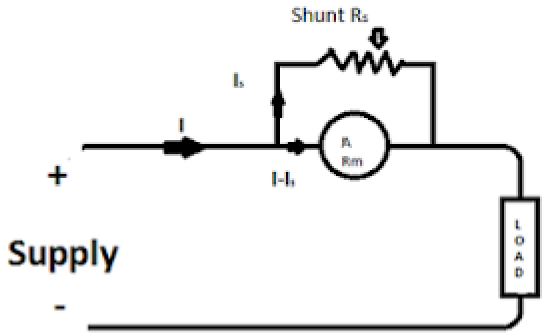




Shunts

The range of an ammeter can be extended by connecting a low resistance, called shunt, connected in parallel with ammeter. So, the current will be distributed between the two branches in such a way that an appropriate (i.e., safe) amount would go through the ammeter, and the over range (i.e., extra) current would be bypassed through the shunt resistance. (Figure 2(a)).

The shunt resistance can be determined as,



where I = Current to be Measured

Im = Full Scale Deflection Current

Is = Shunt Current

Rm = Resistance of ammeter

Rs = Shunt Resistance

We have,

$$I = Im + Is$$

$$Is = I - Im$$

$$(I - Im)\, Rs = Im\, Rm$$

$$Rs = \frac{Im\ Rm}{(I - Im)}$$

$$Rs = \frac{Rm}{(I - 1)} * Im$$

$$Rs = \frac{Rm}{(N - 1)}$$

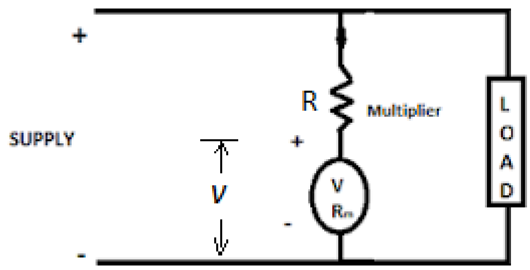
The ratio of total Current to be measured to the full scale Deflection current is Called the multiplying power of the shunt. it may be denoted by **N**.

A measuring instrument together with a shunt resistor becomes a ‘new’ device with an extended measurement range. The resistance of a ‘new’ ammeter is always less than the resistance of an initial device by a factor of n.

Multipliers

The range of voltmeter can be extended by connecting a high resistance, called multiplier in series with the voltmeter (Figure 2(b)). The multiplier limits the voltage drop so that it does not exceed the value of full scale and thus prevents from being damaged.

The multiplier resistance can be determined as:



Where, V = Voltage to be measured

v = Voltage across the meter

I_m = Full scale deflection current

R = Resistance in series with coil to extend the range.

R_m = Voltmeter resistance.

$$V = I_m (R + R_m)$$

$$V = I_m R + I_m R_m$$

$$I_m R = V - I_m R_m$$

$$R = \frac{V - I_m R_m}{I_m}$$

$$R = \frac{V}{I_m} - R_m$$

OR

The ratio of total Voltage to be measured to the voltage across the voltmeter for which it is actually designed is known as multiplying factor. it may be denoted by **m**.

$$m = V / v$$

$$\frac{V}{v} = \frac{I_m (R + R_m)}{I_m R_m}$$

$$m = \frac{R}{R_m} + 1$$

$$R = R_m (m - 1)$$

Hence for the measurement of voltage ***m*** times the voltage range of instrument, the series multiplying resistance R should be (m - 1) times the meter resistance Rm.

The voltmeter together with the multiplier transforms to a ‘new’ instrument with an extended measuring range and an increased internal resistance by a factor of n. Multifunctional devices that combine an ammeter and a voltmeter contain both a set of multipliers and a set of shunts.

Experiment - 3

Aim: To measure the parameters of a choke coil using three voltmeter method.

Apparatus:

S.No	Name of components	Type	Range	Qty
1.	Ammeter	MI		3
2.	Voltmeter	MI		1
3.	1-phase variac			1
4.	Choke Coil			1
5.	Rheostat			1

Theory:

A choke coil is a part used in electrical circuits to allow DC current to flow through while blocking AC current from passing. These coils are used in a number of electrical devices. When used as part of a radio's circuitry, it falls into one of two frequency classes: audio or radio.

The choke coil parameters we are going to measure in this 3-voltmeter method are the inductance, resistance as all choke coils have inherent resistance in addition to their inductance. We also measure the quality factor and power absorbed by the given choke coil.

A given choke coil is usually represented by a pure inductance (L) in series with equivalent resistance (r). This equivalent resistance takes into effect the iron losses in the core of the choke coil and the inherent resistance of the choke coil. 3-Voltmeter method and 3-Ammeter method are two of the best ways to measure these two parameters. Thus the equivalent resistance accounts for the copper loses in the choke coil and the iron loses in the iron core.

The following figures represent the circuit diagram of 3-voltmeter, equivalent circuit of choke coil.

Circuit Diagram:

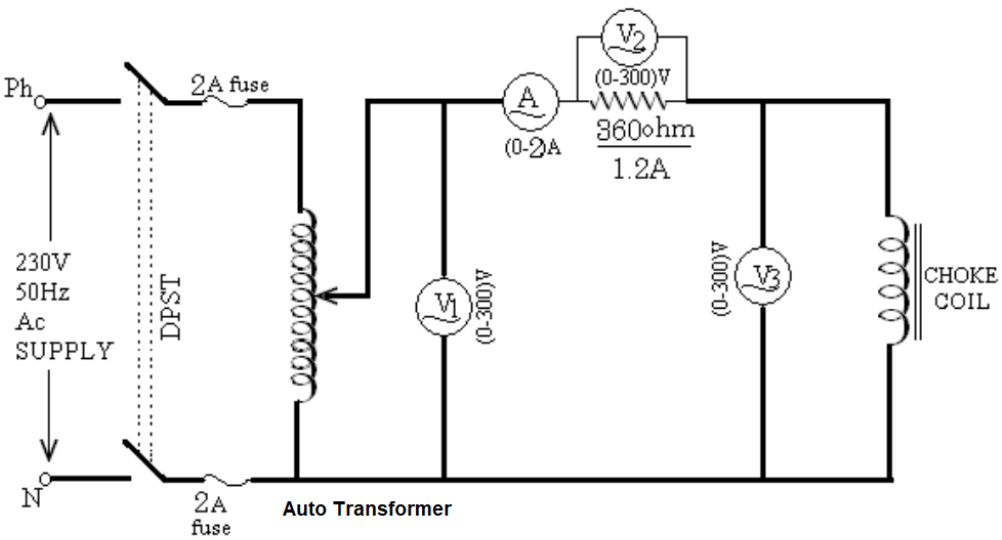


Fig: connection for measurement of parameters of a choke coil using three voltmeter method

Procedure:

1. Connections are made as per the circuit diagram.
2. Initially variac is kept at minimum position or zero output voltage position and Close the DPST switch.
3. Vary the variac to apply the rated voltage of 230 volts, note down the readings of ammeter and three Voltmeters.
4. Adjust the inductive load to particular load current (1A or 2A).
5. Note down the Readings of Ammeter and 3 Voltmeter.
6. Reduce the supply voltage in steps by varying the variac.
7. At each step note down the readings of ammeter and 3voltmeterS then tabulate the Readings in tabular column
8. Reduce the supply voltage to zero by bringing the variac to zero output voltage Position and Open the DPST main switch

Observation Table:

S.No	I (amp)	V_1 (volts)	V_2 (volts)	V_3 (volts)	$P = \frac{(V_1 - V_2 - V_3)}{2r}$	Cos ϕ	r (ohms)	L (mH)
1. .								
2.								

Calculations:

$$V1 = V_2+V_3-2V_2V_3\cos\phi$$

From the phasor diagram

$$\text{Cos}\,\varphi = \frac{(V_1 - V_2 - V_3)}{2V_2V_3}$$

Power in the coil=P=V_3I Cosϕ

Power loss in the choke coil = I r

$$V_3\text{I COS}\phi = \text{I r}$$

Choke coil resistance => r = V_3/I (Cos ϕ)

Impedance of the coil => Z = V_3/I

But we know Z = r+X_L

Coil reactance X_L = Z-r

Coil inductance => L = X_L/2f Henry

Precautions:

1. Initially set the variac to minimum position
2. Vary the variac such that the current and voltage are within the rated values.

Results

Experiment - 4

Aim: To determine accurate Quality Factor of an unknown coil.

Apparatus:

Theory:

The determination of the storage factor Q is one of the most widely used means in the laboratory for testing radio frequency coils, inductors and capacitors. The storage factor is equal to $Q = (\omega_0 L) / R$ where ω_0 is the resonant frequency, L is the inductance and R is the effective resistance of the a coil. The effective resistance R, is never determined directly since its value depends upon the value of frequency.

Working Principle:

The principle of working of this useful laboratory instrument is based upon the well-known characteristics of a resonant series R-L-C circuit.

At resonant frequency f_0, we have $X_C = X_L$

where,

Capacitive reactance $X_C = 1/(2 \pi f_0 C)$

Inductive reactance $X_L = 2 \pi f_0 L$

Resonant frequency $f_0 = 1/(2 \pi \sqrt{LC})$

and current at resonance $I_0 = E/R$

The voltage across the capacitor $E_C = I_0 * X_C = I_0 * X_L = I_0 * \omega_0 L$ and input voltage $E = I_0 * R$ then $E_C / E = (\omega_0 L) / R = Q$ and $E_C = QE$.

If the input voltage is kept constant the voltage across capacitor is Q times E and a voltmeter connected across the capacitor can be calibrated to read the value of Q directly.

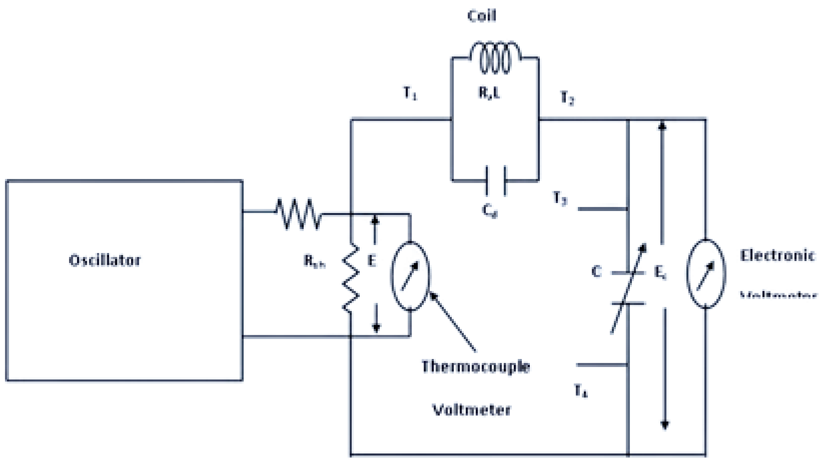


Fig: practical circuit of unknown coil

Practical Circuit

The practical circuit is shown in Figure 1. It consists of self-contained variable frequency RF oscillator. This oscillator delivers current to a low value shunt resistance R_{sh}: value may be 0.02 Ohm. The small value of input voltage E is injected into circuit that would be measured by thermocouple voltmeter. An electronic voltmeter is connected across this capacitor. The coil under test is connected to terminals T_1 and T_2.

Measurement of Q

The circuit for measurement of Q shown in Figure 1. The oscillator is set to the desired frequency and then the tuning capacitor is adjusted for maximum value E_0. The input voltage E is kept constant then the voltage across capacitor is calibrated to read the value of Q directly. The measured value of Q is defined whole circuit not of the coil. There are errors caused due to shunt resistance and distributed capacitance of the circuit.

Correction of Shunt Resistance

$$Q(meas) = \frac{\omega_0 L}{R + R_{sh}} \quad (1)$$

$$\text{True value, } Q_{true} = \frac{\omega_0 L}{R} = Q_{meas}\left(1 + \frac{R_{sh}}{R}\right)$$

Correction of Distributed Capacitance

$$Q(true) = Q_{meas}\left(1 + \frac{C_d}{C}\right) \quad (2)$$

where, C_d = distributed capacitance and C = tuning capacitance.

Measurement of Self Capacitance

The value of Inductance is given by

$$L = \frac{1}{4\pi^2 f_0^2 C} \quad (3)$$

The values of f_0 and C are known and therefore the value of inductance may be calculated.

Measurement of Effective Resistance

The value of effective resistance may be computed from the relation

$$R = \frac{\omega_0 L}{Q_{(true)}} \quad (4)$$

Measurement of Self Capacitance

The self-capacitance is measured by making two measurements at different frequencies. The capacitor is set to a high value and the circuit is resonated by adjustment of the oscillator frequency. Resonance is indicated by the circuit Q meter. Let the values of tuning capacitor be C_1 and that of frequency be f_1 under these condition. Therefore,

$$f_1 = \frac{1}{2\pi \sqrt{L(C_1 + C_d)}} \quad (5)$$

The frequency is now increased to twice its initial value and the circuit is resonated again this time with the help of the tuning capacitor. Let the values of tuning capacitor be C_2 and that of frequency be f_2 under these condition. Therefore,

$$f_2 = 1 / (2\pi \sqrt{L(C_2 + C_d)}) \tag{6}$$

Now, $f_2 = 2 * f_1$

The distributed capacitance,

$$C_d = (C_1 - 4C_2) / 3 \tag{7}$$

Procedure:

The experiment can also be performed on virtual lab platform. The web link is:

http://vlabs.iitkgp.ernet.in/asnm/exp14/index.html

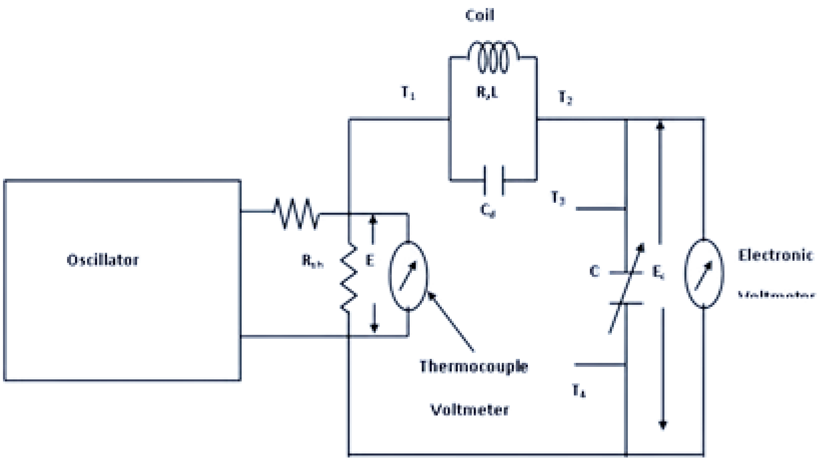


Fig: Circuit Diagram for Q meter experiment

1. Set the Shunt Resistance (Rsh) value as small as possible (Say 0.02 Ohm). Set all the parameters (R, L, C) by yourself.
2. Set the voltage value of the oscillator (E = 10 V).
3. At f = 100 Hz. Check the value of voltage drop across capacitor. (EC).
4. Change the frequency until EC reach at the maximum value. Then calculate the value Q measured using this formula `Q_(meas) = (omega_0L) / (R + R_(sh))`.
5. Calculate the true value of unknown coil by using this formula `Q_(true) = (omega_0L) / R`
6. First resonance occurs due to frequency (say f1). Note down the value of tuning capacitor C. (say C1). Double the input frequency (f1) (say f2 = 2 * f1). Change the tuning capacitor value until resonance occurs. Note down the value of tuning capacitor C. (say C2). Discharge capacitance (Cd) would be = (C1-4 * C2) / 3.

Experiment - 5

Aim: To study the Three phase power measurement by using two wattmeter method.

Apparatus:

Theory:

Two wattmeter method

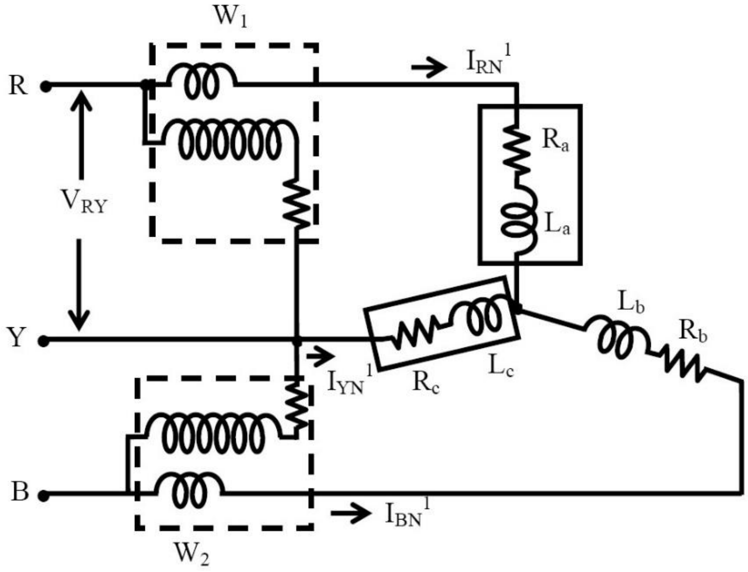


Fig : Connection diagram for three phase power measurement using two wattmeter method

The connection diagram for the measurement of power in three phase power measurement circuit using two wattmeter's method is shown in figure 1. This is irrespective of the circuit connection star or delta. The circuit may be taken as balanced or unbalanced one, balanced type being only a special case. Please not the connection of two wattmeter's. The current coil of the wattmeter's 1 and 2 in series with R and B phase with the pressure voltage coils being connected across R-Y and B-Y respectively. Y is the third phase in which no current coil is connected.

If star connected circuit is taken as an example the total instantaneous power consumed in the circuit is,

$$W = I_{RN} \cdot V_{(RN)} + I_{YN} \cdot V_{(YN)} + I_{BN} \cdot V_{BN} \qquad (1)$$

Each of the terms in the above expression equation (1) is the instantaneous power consumed by the phases. From the connection diagram, the circuit in and the voltages across the respective (current, pressure or voltage) coils in the wattmeter,

W1 are IRN and VRY = VRN − VYNVRY = VRN - VYN.

So, the instantaneous power measured by the wattmeter W1 is $W1 = I_{RN} \cdot V_{RY}$

Similarly the instantaneous power measured by the wattmeter W2 is,

$$W2 = I_{BN} \cdot VBY = IBN \cdot (VBN - VYN)$$

Some of the two readings as given above is,

$$W_1 + W_2 = I_{RN}(V_{RN} - V_{YN}) + I_{BN}(V_{BN} - V_{YN})$$
$$= I_{RN}V_{RN} + I_{BN}V_{BN} - V_{YN}(I_{RN} + I_{BN}) \quad ------(2)$$

and $I_{RN} + I_{BN} + I_{YN} = 0$
applying in equation (2),

$$W_1 + W_2 = I_{RN}V_{RN} + I_{BN}V_{BN} + V_{YN}\, I_{YN} \quad --------(3)$$

Equation (1) is compared with equation (3) to give the total instantaneous power consumed in the circuit. They are found to be same.

The phasor diagram of three phase balanced star connected circuit is shown in figure 2.

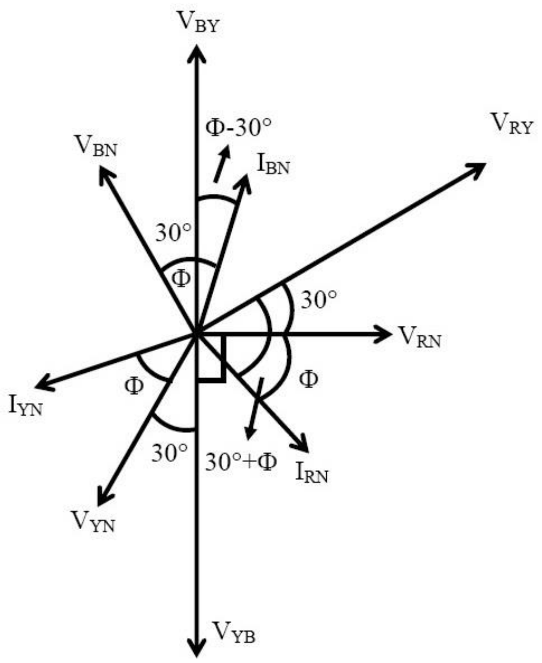


Fig 2: Phasor diagram of three phase balanced star connected circuit

Procedure

Balanced Load:

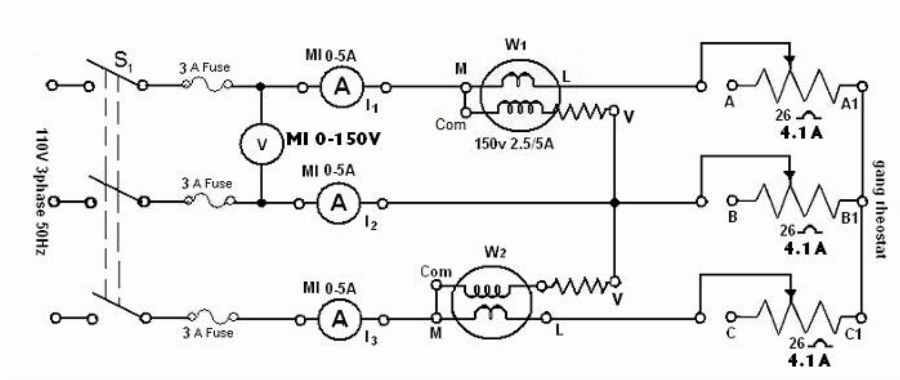


Fig. 1. Three phase power measurement circuit under balance condition

1. Connect the circuit as shown in Fig. 1.
2. Adjust the ganged rheostat for the maximum resistance.
3. Switch on the supply.
4. Close switch S1S1.
5. Read the meters to obtain VL, I1, I2VL, I1, I2 and I3I3. Note the wattmeter reading W1W1 and W2 W2 (Note the multiplying factor on the wattmeter).
6. Vary the load resistance and obtain at least five sets of observations, the current should not exceed the limit (4.1 A).

Unbalanced Load:

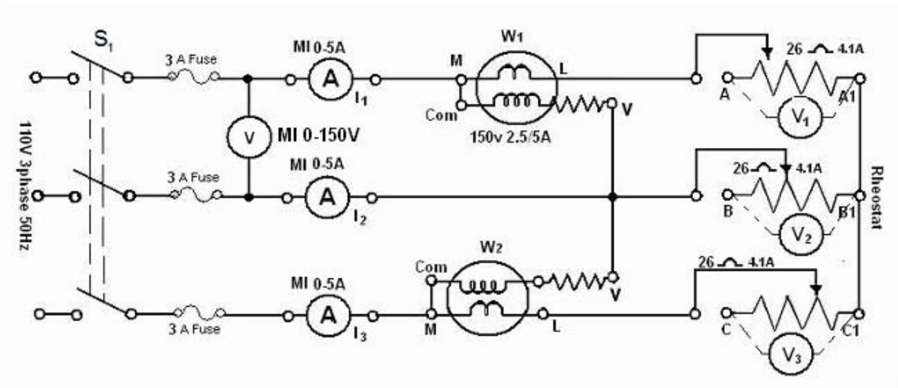


Fig. 2. Three phase power measurement circuit under unbalance condition

1. Connect the circuit as shown in Fig. 2.
2. Replace the ganged rheostat by three separate rheostats of 26 Ω, 4.1 A and connect in a star.
3. Adjust the three rheostats at the maximum values.
4. Switch on the supply and set the autotransformer to 110 V.
5. Close switch S1 and take five sets of observation for different rheostat settings such that the reading of I1I1, I2I2and I3I3 in each set is appreciably different to create unbalanced loading condition. The current should not exceed the limits in each arm.

Experiment 6

Aim: Calibration and testing of single phase energy meter by direct loading.

Apparatus required:

S.No	Name of components	Type	Range	Qty
1.	Single phase energy meter			01
2.	wattmeter			01
3.	Voltmeter	MI	(0-150/300)V	01
4.	Ammeter	MI	(0-5/10)A	01
5.	Resistive load			01
6.	Stop watch			01

Energy meter specifications:

Meter constant: ________________________

Rated voltage:______________________ Current:_________________________

Frequency:_________________________ Type:___DISK_________________________

Theory:

Experiment 7

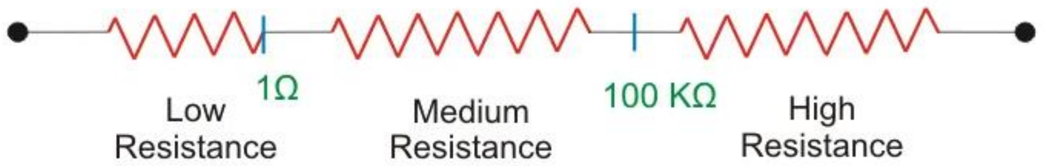
Aim: To measure medium resister by the voltmeter and ammeter method.

Apparatus: DC ammeter (0-500mA), DC Voltmeter (0-5V), Dc power supply (0-30V), Variable Resistance -100 ohm. Connecting wires.

Theory

Resistance is one of the most basic elements encountered in electrical and electronics engineering. The value of resistance in engineering varies from very small value like, resistance of a transformer winding, to very high values like, insulation resistance of that same transformer winding. Although a multimeter works quite well if we need a rough value of resistance, but for accurate values and that too at very low and very high values we need specific methods.

Resistance is classified into three categories as low, medium, and high resistance. Medium resistance range from 1 Ω to 100 KΩ.



Voltmeter and ammeter are connected in series as shown in fig, where ammeter measures the total current flowing through the circuit and voltmeter measures the voltage across the unknown resistance .The voltmeter should have ideally infinite resistance and ammeter should have ideally zero resistance so that it will measure total current flowing through the unknown resistance. But practically it is not possible and measured value Rm of the resistance is the sum of resistance of ammeter and actual resistance.

$Rm=R_1+R_a$ Where

where R_1=actual resistance and R_a=resistance of the ammeter.

It is clear from the expression that the value of measured resistance is equal to actual resistance when ammeter has zero resistance.

Theory:

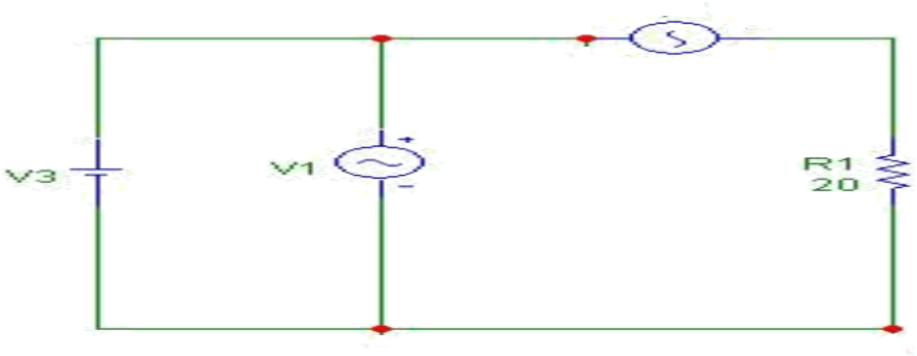


Fig: voltmeter and ammeter method

Procedure:-

1. Make the connections as per circuit diagram.
2. Switch on the supply and note down the readings of ammeter and voltmeter.
3. Calculate the value of the unknown resistance by ohms low.
4. Perform the procedure for the other case similarly.

Observation Table:-

S.No.	**Volatge (volts)**	**Current (Amp)**	**Resistance A_T (Actual)**	**Resistance A_M (Measured)**	**% Error**

Result: - Hence we study the measured and the actual value of the unknown resistance ____________is found.

Precautions :

1. Connections should be tight.
2. Instrument should be handled carefully.

Experiment 8

Aim: To study and perform an experiment to measure the unknown Resistance by Wheatstone's bridge.

Apparatus: Portable Wheatstone bridge kit, Light Spot DC Galvanometer, Various Medium Resistors, Multimeter, Connecting leads.

Theory:

A bridge circuit in its simplest form consists of network of four resistance arms forming a closed circuit, with a dc source of current applied to two opposite junctions and a current detector connected to the other two junctions.

Wheatstone's bridge is used for accurate measurement of resistance. The circuit diagram of a typical Wheatstone's bridge is given in fig below:

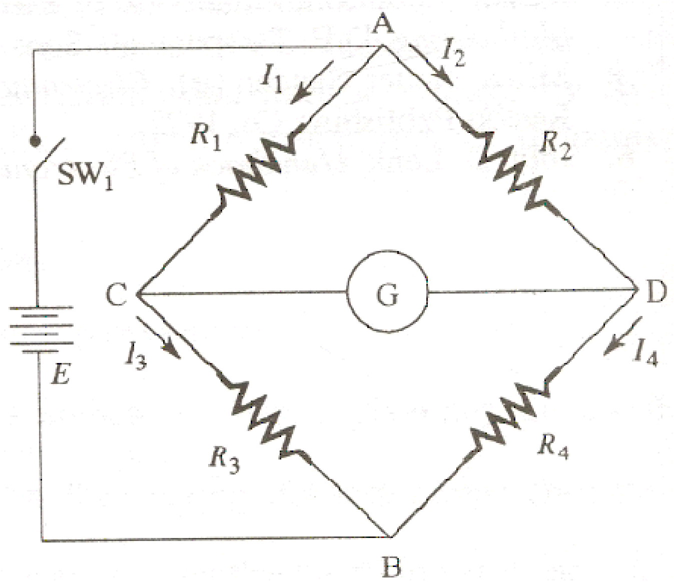


Fig: Wheatstone's bridge circuit diagram

When SW_1 is closed, current flows and divides into the two arms at point A, i.e. I_1 and I_2. The bridge is balanced when there is no current through the galvanometer, or when the potential difference at points C and D is equal, i.e. the potential across the galvanometer is zero.

To obtain the bridge balance equation, we have from the fig. above

$$I_1 R_1 = I_2 R_2 \qquad (1))$$

For the galvanometer current to be zero, the following conditions should be satisfied.

$$I_1 = I_3 = E/ (R_1 + R_3)$$

$$I2 = I4 = E/ (R_2 + R_4)$$

Substituting in Eq. (1)

$(E*R_1)/ (R_1+R_3) = (E*R_2)/ (R_2+R_4)$

$R_4 = (R_2*R_3) / R_1$

This is the equation for bridge to be balanced.

Circuit Diagram:

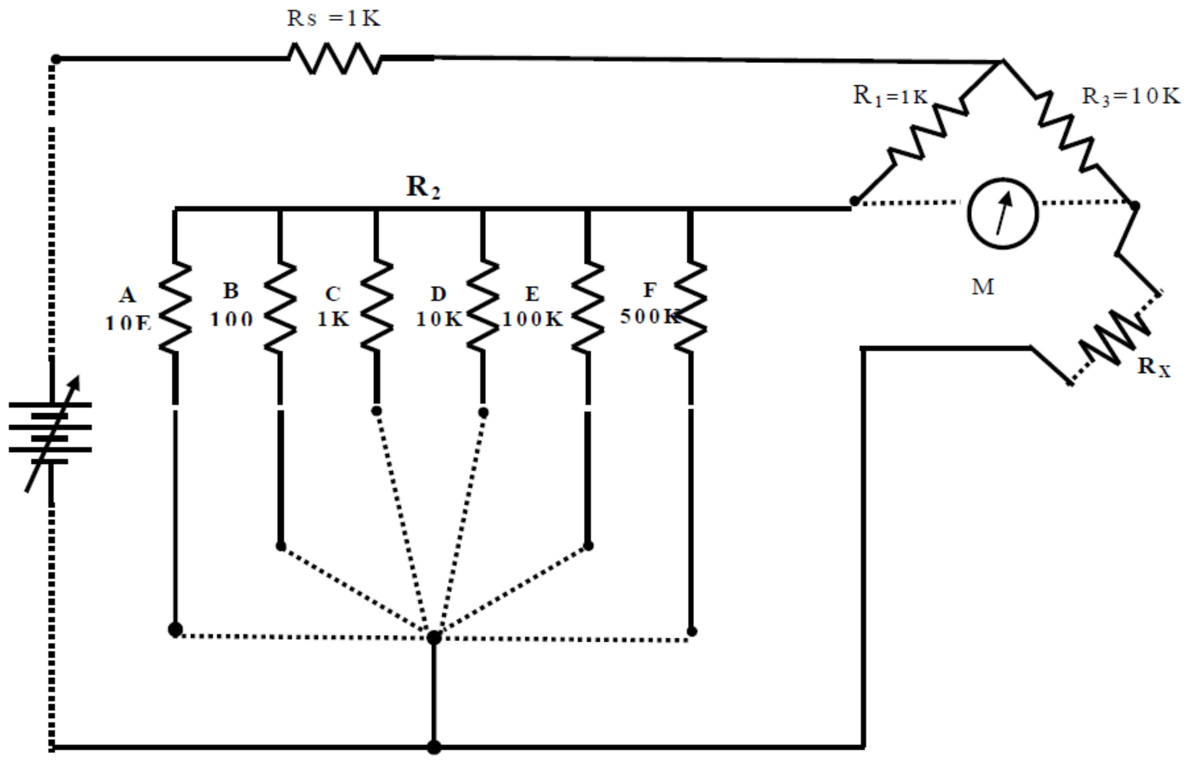


Fig: Wheatstone's bridge kit

Procedure

1. Take The Trainer kit. Measure resistors A, B, C, D, E, F, R1 and the variable pot R3 by adjusting "ADJ R3". Note down the values of each resistors.
2. Now insert its mains cord in mains 230 V supply plug and switch it 'ON‟. Measure the DC supply voltage. (It should be 12V DC)
3. Select the unknown resistor and measure its resistance Rx and note it down.
4. Connect the resistor to the terminal (Rx), and connect the power supply into the circuit. Connect the galvanometer to M of the bridge with the help of jumper.
5. Connect the S1 terminal to any resistor A, B, C, D, E, F. Adjust pot „R3‟ to get a null reading on the galvanometer.
6. Once the „Null, reading is found, remove all the jumpers and measure the value of R3. Put the value of R3 in the formula given below and calculate Rx practically.
7. Rx=R2*R3/R1 (R2=A or B or C….. or F)
8. Match the practical „Rx‟ with that of the Rx directly measured on multimeter.
9. Take four to five reading to find the unknown resistance i.e. Rx with different resistors.

Note: Use unknown resistors of values between 10 Ω to 10 KΩ for the better sensitivity.

Observation Table:-

S.No.	Resistance A_T (Actual)	Resistance A_M (Measured)	Error (A_T-A_M)	%Error

Result: - Hence we have studied the Wheatstone bridge and the actual value of the unknown resistance ____________is found.

Precautions:

1. Connections should be tight.
2. Instrument should be handled carefully

<u>Experiment 9</u>

Aim:

- To understand the construction and working mechanism of CRO.
- To perform amplitude, frequency, and phase measurements using a calibrated cathode ray oscilloscope and to make use of Lissajous figures for phase and frequency measurements.

Apparatus: CRO, connecting leads, function generator.

Theory:

The cathode ray oscilloscope (CRO) is a type of electrical instrument which is used for showing the measurement and analysis of waveforms and others electronic and electrical phenomenon. It is a very fast X-Y plotter shows the input signal versus another signal or versus time.

The CROs are used to analyse the waveforms, transient, phenomena, and other time-varying quantities from a very low-frequency range to the radio frequencies.

<u>Construction</u>

The main parts of the cathode ray oscilloscope are as follows.

1. Cathode Ray Tube
2. Electronic Gun Assembly
3. Deflecting Plate
4. Fluorescent Screen For CRT
5. Glass Envelop

1. Cathode Ray Tube

The cathode ray tube is the vacuum tube which converts the electrical signal into the visual signal. It mainly consists of an electron gun and the electrostatic deflection plates (vertical and horizontal).The electron gun produces a focused beam of the electron which is accelerated to high frequency.

The vertical deflection plate moves the beams up and down and the horizontal beam moved the electrons beams left to right. These movements are independent to each other and hence the beam may be positioned anywhere on the screen.

2. Electronic Gun Assembly

The electron gun emits the electrons and forms them into a beam. The electron gun mainly consists a heater, cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode. For gaining the high emission of electrons at the moderate temperature, the layers of barium and strontium is deposited on the end of the cathode.

After the emission of an electron from the cathode grid, it passes through the control grid. The control grid is usually a nickel cylinder with a centrally located co-axial with the CRT axis. It controls the intensity of the emitted electron from the cathode.

The electron while passing through the control grid is accelerated by a high positive potential which is applied to the pre-accelerating or accelerating nodes.

The electron beam is focused on focusing electrodes and then passes through the vertical and horizontal deflection plates and then goes on to the fluorescent lamp. The pre-accelerating and accelerating anode are connected to 1500v, and the focusing electrode is connected to 500 v. There are two methods of focusing on the electron beam. These methods are

- Electrostatic focusing
- Electromagnetic focusing.

The CRO uses an electrostatic focusing tube.

3. Deflecting Plate

The electron beam after leaving the electron gun passes through the two pairs of the deflecting plate. The pair of plate producing the vertical deflection is called a vertical deflecting plate or Y plates, and the pair of the plate which is used for horizontal deflection is called horizontal deflection plate or X plates.

4. Fluorescent Screen for CRT

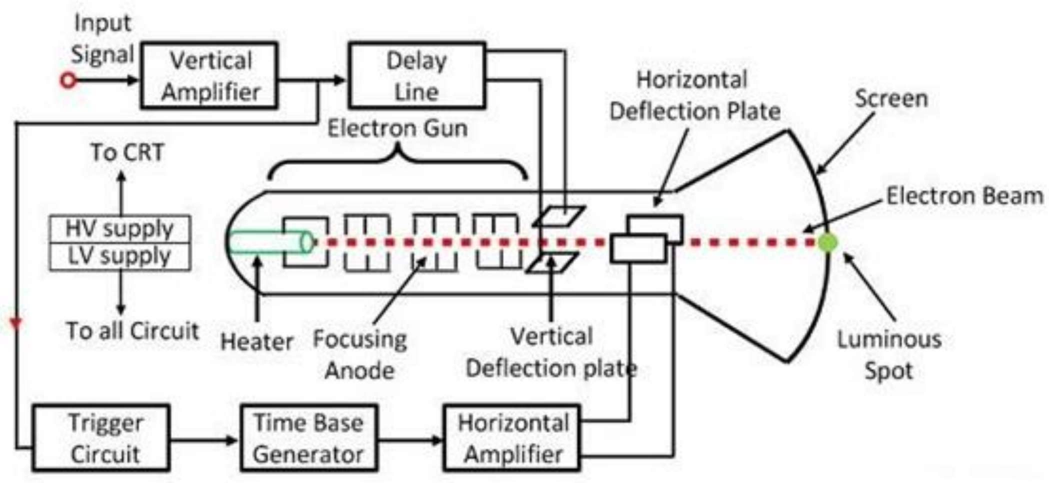
The front of the CRT is called the face plate. It is flat for screen sized up to about 100mm×100mm. The screen of the CRT is slightly curved for larger displays. The face plate is formed by pressing the molten glass into a mould and then annealing it.

The inside surface of the faceplate is coated with phosphor crystal. The phosphor converts electrical energy into light energy. When an electronics beam strike phosphor crystal, it raises their energy level and hence light is emitted during phosphorous crystallisation. This phenomenon is called fluorescence.

5. Glass Envelope

It is a highly evacuated conical shape structure. The inner surface of the CRT between the neck and the screen is coated with the aquadag. The aquadag is a conducting material and act as a high-voltage electrode. The coating surface is electrically connected to the accelerating anode and hence help the electron to be the focus.

Working: When the electron is injected through the electron gun, it passes through the control grid.



The control grid controls the intensity of electron in the vacuum tube. If the control grid has high negative potential, then it allows only a few electrons to pass through it. Thus, the dim spot is produced on the lightning screen. If the negative potential on the control grid is low, then the bright spot is produced. Hence the intensity of light depends on the negative potential of the control grid.

After moving the control grid the electron beam passing through the focusing and accelerating anodes. The accelerating anodes are at a high positive potential and hence they converge the beam at a point on the screen.

After moving from the accelerating anode, the beam comes under the effect of the deflecting plates. When the deflecting plate is at zero potential, the beam produces a spot at the centre. If the voltage is applied to the vertical deflecting plate, the electron beam focuses at the upward and when the voltage is applied horizontally the spot of light will be deflected horizontally.

Amplitude, Phase and Frequency Measurement

Measurement of Voltage Using CRO

A voltage can be measured by noting the Y deflection produced by the voltage; using this deflection in conjunction with the Y-gain setting, the voltage can be calculated as follows:

V = (no. of boxes in cm.) x (selected Volts/cm scale)

Measurement of Current and Resistance Using a CRO:

Using the general method, a correctly calibrated CRO can be used in conjunction with a known value of resistance R to determine the current I flowing through the resistor.

Measurement of Frequency Using a CRO:

A simple method of determining the frequency of a signal is to estimate its periodic time from the trace on the screen of a CRT. However, this method has limited accuracy, and should only be used where other methods are not available. To calculate the frequency of the observed signal, one has to measure the period, i.e. the time taken for 1 complete cycle, using the calibrated sweep scale. The period could be calculated by

T = (no. of squares in cm) x (selected Time/cm scale)

Once the period T is known, the frequency is given by

f (Hz) = 1/T(sec)

Measurement of Phase:

The calibrated time scales can be used to calculate the phase shift between two sinusoidal signals of the same frequency. If a dual trace or beam CRO is available to display the two signals simultaneously (one of the signals is used for synchronization), both of the signals will appear in proper time perspective and the amount of time difference between the waveforms can be measured.

This, in turn can be utilized to calculate the phase angle *, between the two signals.

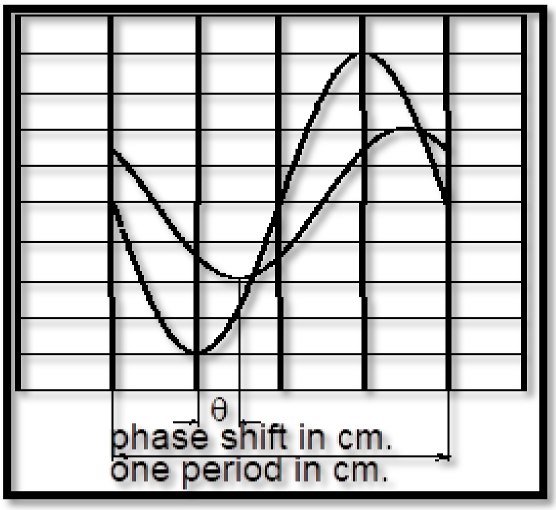


Figure1: Phase shift between two signals

Referring to figure 1, the phase shift can be calculated by the formula; Phase shift in cm.

$$\theta = \frac{\text{Phase shift in cm.}}{\text{One period in cm.}} \times 360^{o}$$

Note that the calculation does not involve the actual calibrated Time base setting. In fact, the observed waveforms can be varied using the horizontal amplifier venire adjustment to obtain as many boxes for one full scale as desired. Another method for fast calculation is to multiply the scale factor by the phase difference (in cm) where the scale factor is degrees per box or degrees per cm.

Use of Lissajous Patterns to Calculate Phase Shift:

Lissajous patterns are obtained on the scope simultaneously by applying the two sinusoidal inputs to be compared at the vertical and horizontal channels. The phase shift is then determined using measured values taken from resulting Lissajous pattern. This pattern on the CRT screen may be either a straight line or a circle or an ellipse depending on the amount of phase shift.

Figure 2 shows the resulting closed curve if the phase shift is between and. This pattern is an ellipse (inclined at if the two amplitudes are the same). The angle of inclination at which the ellipse is generated is of no importance in the phase angle calculation. Noting that the vertical signal amplitude at instant 1 is

N = ASin (θ), θ can be computed by

$\theta = 180^{o} - \sin^{-1}(N / M)$

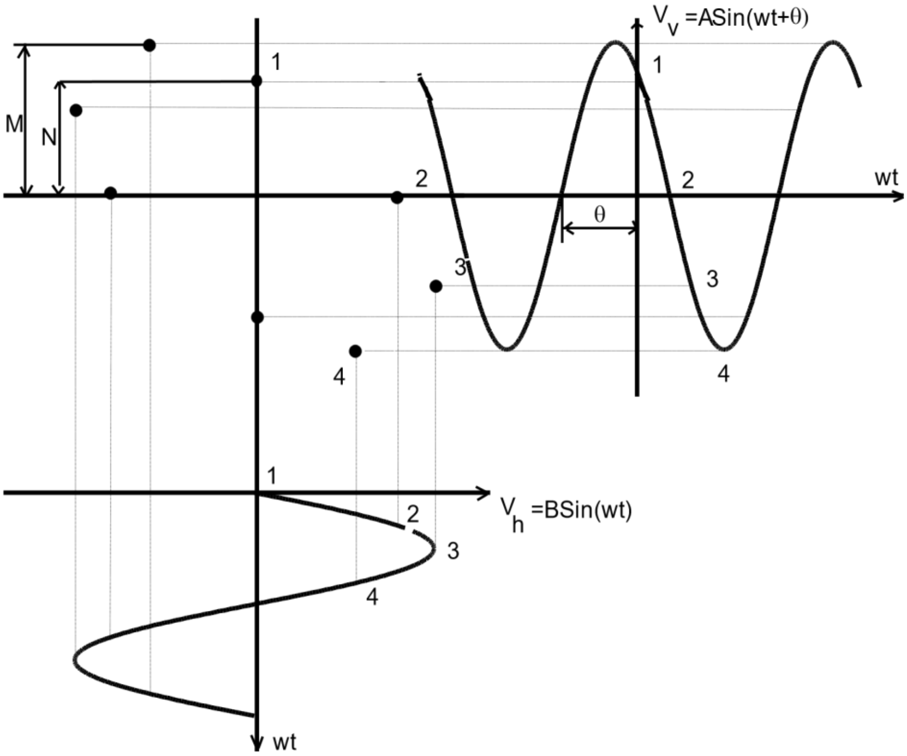


Figure 2: Lissajous Pattern

Phase angels between 0^{o} - 90^{o}, the ellipse has a positive slope and angle calculated by the following formula: $\theta = \sin^{-1}(N / M)$

The actual scale settings do not change the ratio (N/M). Hence try to get an ellipse of maximum possible size on the CRO for increased accuracy. For phase angles of 90^{o} □180^{o}, the ellipse has a negative slope and the angle calculated by the above method must be subtracted from 180^{o} to obtain the phase shift. Phase angles between 180^{o} - 270^{o} result in Lissajous patterns similar to those for θ : 90^{o} -180^{o}, and cannot be directly distinguished. One technique for determining, if the phase shift is less or more than 180^{o}, is to add an extra slight phase shift to the signal Vv. If the phase angle measured increases, then the angle is less than 180^{o}. If it decreases, the angle is greater than 180^{o}. Figure 3 shows how to compute the required phase angle.

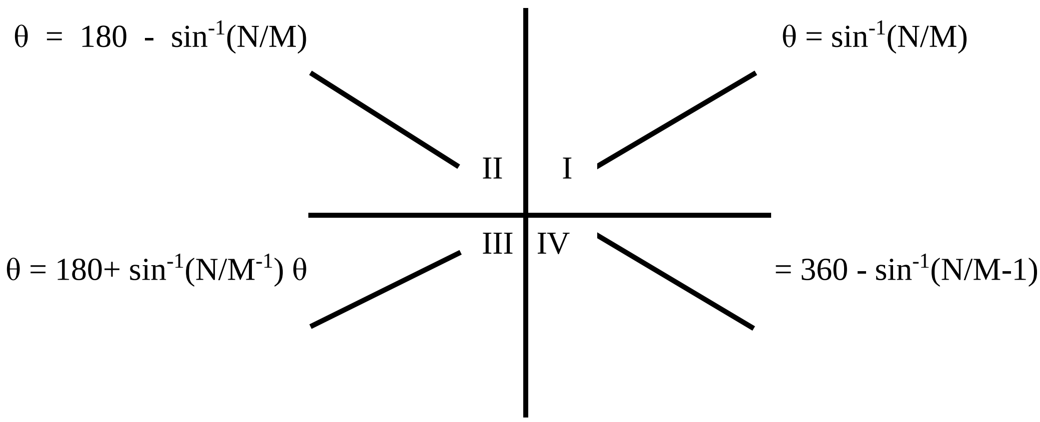


Figure 3 Phase angle calculation in 4 quadrants

Use of Lissajous Patterns for Frequency Measurements:

If a well calibrated CRO Timebase is not available, a signal generator can be used to measure the frequency of an unknown sinusoidal signal. It is connected to the vertical channel (or horizontal) and the calibrated signal source is fed to the horizontal channel (or vertical). The frequency of the signal generator is adjusted so that a steady Lissajous pattern is obtained. The Lissajous pattern can be very involved to analyze. However, for the frequency measurement, all that is needed is the number of tangencies (points at the edge of arcs) along the vertical and horizontal lines.

The frequency relationship between the horizontal and vertical inputs is given by:

$$F_h / F_v = \text{No. of tangencies (vertical)} / \text{No. of tangencies (horizontal)}$$

from which f_v, the unknown frequency can be calculated.

Experiment 10

Aim: To study the measurement of Self-Inductance by Maxwell's inductance capacitance Bridge.

Apparatus: Portable Maxwell's bridge kit, voltmeter, various electronics components, Digital Multimeter, Connecting leads.

Theory: Maxwell's capacitance bridge

In this bridge, an inductance is measured by comparison with a standard variable capacitance. The connection is shown in Figure below:

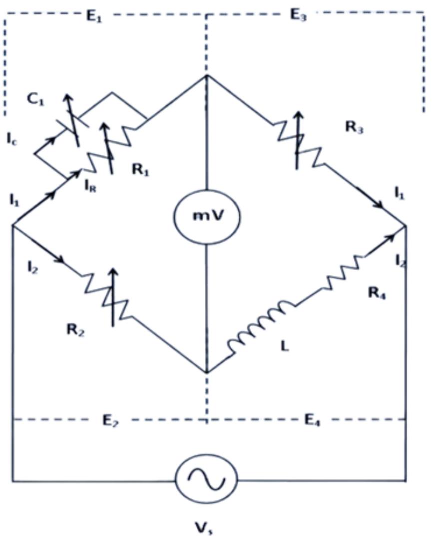
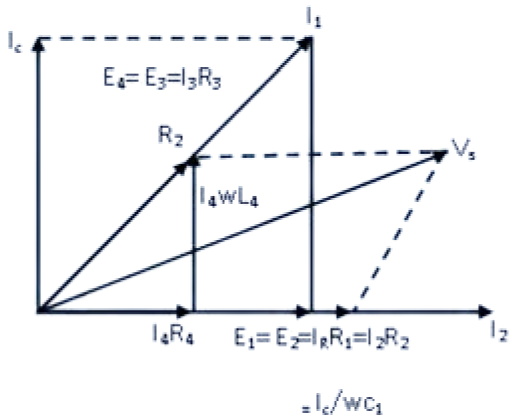


Fig 1: Circuit diagram for Maxwell's Bridge



Phasor diagram for the circuit shown in Figure 1

Here,

L = Unknown Inductance,

R_4 = Effective resistance of unknown Inductance coil,

R_1, R_2, R_3 = Known non inductive resistance,

C_1 = Standard variable capacitor.

The balance equation for the branch can be written as:

$$(R_4 + j\omega L) * (R_1 + j\omega C_1 R_1) = R_2 R_3$$

$$R_1 R_4 + j\omega L.R_1 = R_2 R_3 + j\omega R_2 R_3 C_1 R_1$$

Equating the real and imaginary parts,

$$R_4 = R_2 R_3 R_1 \qquad (1)$$

$$L = R_2 R_3 C_1 \qquad (2)$$

Two variables R_1 and C_1 which appear in one of the two balance equations (i.e. equation (1) and (2)) and hence the two equations are independent.

The expression for Q factor can be written as:

$$Q = \omega L R_4 = \omega C_1 R_1$$

Procedure:

The experiment can also be performed on virtual lab platform. The web link is:

http://vlabs.iitkgp.ernet.in/asnm/exp11/index.html

1. Connect all the components and the air cored coil as shown in the figure.
2. Set the product of R2R3 at a convenient value and obtain the balance by varying R1 and C1.
3. Decide the ranges for R1 and C1 through which they can varied without bringing database at noise C.R.O.
4. Repeat the procedure with different values of the product R2R3 and decide upon readings that permit maximum accuracy for the measurement.

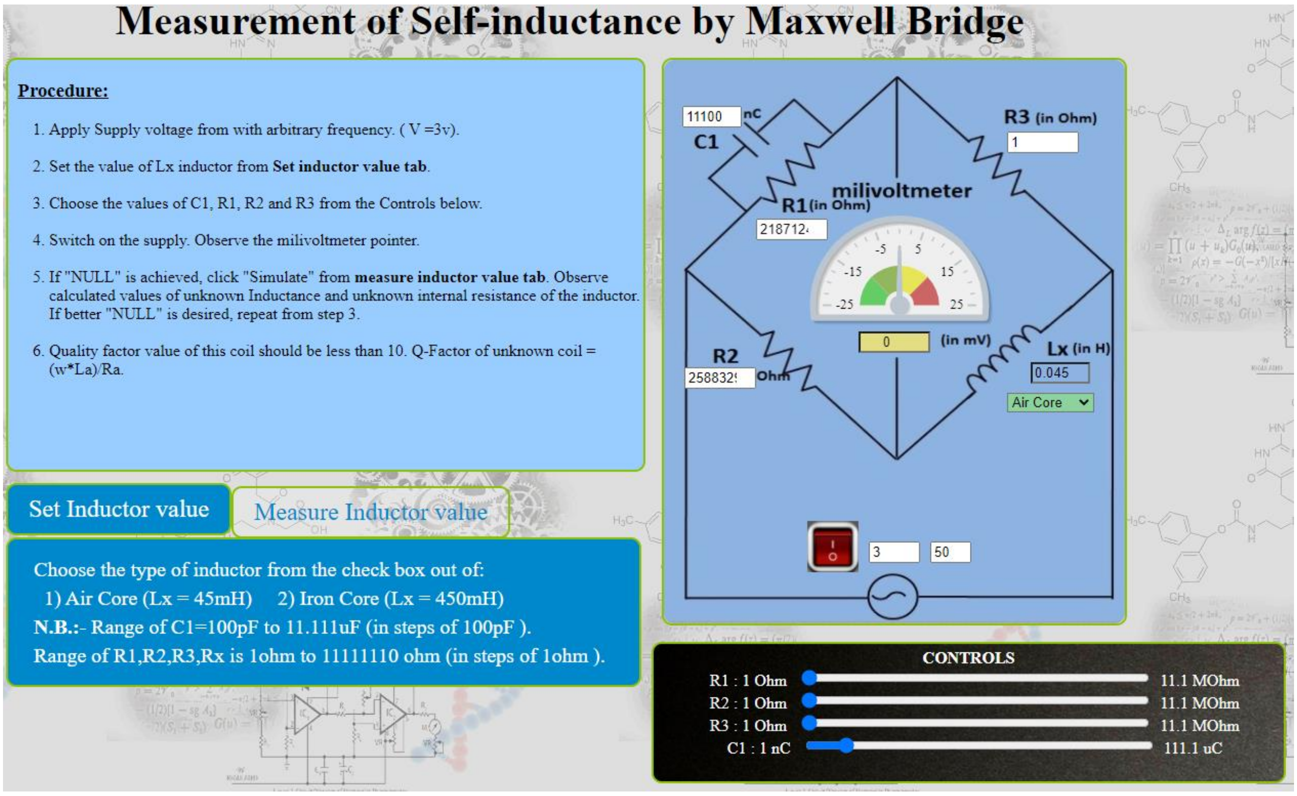


Fig : Experiment setup in VLAB platform

Result: - Hence we have studied the Maxwell's inductance Capacitance Bridge and unknown self inductance____________is found.

Precautions :

1. Connections should be tight.
2. Instrument should be handled carefully.

Experiment 11

Aim: To study the measurement of Self-Inductance by Anderson's Bridge.

Aim: To study the measurement of Self-Inductance by Maxwell’s inductance capacitance Bridge.

Apparatus: Portable Anderson's Bridge kit, voltmeter, various electronics components, Digital Multimeter, Connecting leads.

Theory:

This bridge is a modification of the Maxwell’s inductive and capacitive bridge. In this method, the self inductance is measured in terms of a standard capacitor. This method is applicable for precise measurement of self inductance over wide range of values. Figure 1 shows the circuit diagram of the bridge for balance conditions.

Circuit Diagram

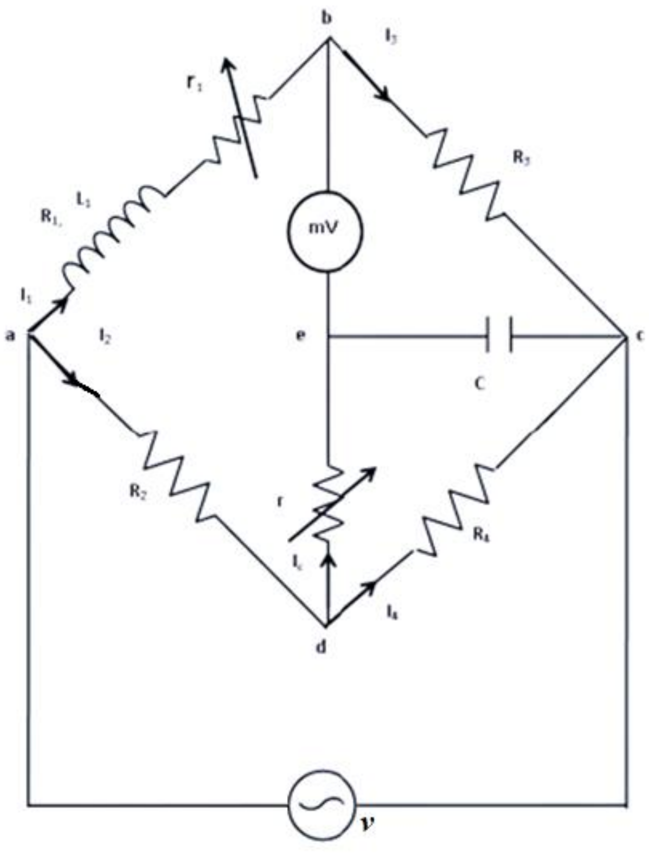


Fig 1: Circuit diagram for Measurement of Self Inductance by Anderson's Bridge

Let, L_1 =Self-inductance is to be measured.

R_1 = Resistance of self-inductor.
r_1 = Resistance connected in series with self-inductor.
r, R_2, R_3, R_4 = Known non inductive resistances.
C = Fixed standard capacitor.

At balance,

$I_1 = I_3$ and $I_2 = I_C + I_4$

now, $I_1R_3 = I_C / j\omega C$ then $I_C = I_1 j\omega CR_3$ (1)

Writing the other balance equations,

$$I_1 (r_1 + R_1 + j\omega L_1) = I_2R_2 + r.I_C \quad (2)$$

$$I_C(r + 1 / j\omega C) = (I_2 - I_C)R_4$$

Substituting the value of ICIC in equation (2), we get

$$I_1 (r_1+R_1+j\omega L_1) = I_2R_2 + I_1 j\omega C .(r.R)=$$

or, $I1 (r_1+R_1+j\omega L_1-j\omega C.r.R_3) = I_2R_2$ (3)

and $j\omega CR_3I_1 (r+1 / j\omega C) = (I_2-I_1 j\omega CR_3)R_4$

or, $I_1(j\omega CrR_3+j\omega CR_3R_4) = I_2R_4$ (4)

From equations (3) and (4), we get by equating real and imaginary parts,

$$R_1 = (R_2R_3 / R_4) - r_1 \quad (5)$$

$$L_1=C (R_3 / R_4) [r(R_4+R_2) + R_2R_4] \quad (6)$$

An examination of balance equation reveals that to obtain easy convergence of balance, alternate adjustments of r_1 and r should be done as they appear in only equation. (1) and (2).

Procedure

The experiment can also be performed on virtual lab platform. The web link is:

http://vlabs.iitkgp.ernet.in/asnm/exp23/index.html

1. Apply Supply voltage (3V) from the signal generator with arbitrary frequency. (say 50Hz). Also Set the value of the unknown air cored coil from 'Set Inductor Value' tab
2. Then switch on the supply to get milli-voltmeter deflection.
3. Choose the values of r_1, R_2, R_3, R_4, r, and C from the resistance and capacitance box. Varry the values to some particular values to achieve "Null".
4. Observe the milli-voltmeter pointer to achieve "NULL".
5. If "Null" is achieved, switch to 'Measure Inductor Value' tab and click on 'Simulate'. Observe calculated values of unknown Inductor (L_1) and it's Internal Resistance (R1).

Result: - Hence we have studied the Anderson's Bridge and unknown self inductance________is found.

Precautions :

1. Connections should be tight.
2. Instrument should be handled carefully.