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A Review on Electrical and Electronics Measuring Devices

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***Abstract*: This paper describes different measuring devices used in electrical system. A measuring instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The electrical quantity such as voltage, current, power, power factor, energy and electronic quantity such as resistance, capacitance, inductance are measured with the help of different measuring devices. These papers introduce different measuring instruments with their working principal.**

***Keywords*: Permanent Magnet Moving Coil (PMMC), Permanent Magnet Moving Iron (MI), Deflecting Torque (Td), Controlling Torque (Tc), Alternating Current (A.C), Direct Current (D.C)**

1. Introduction

Generally, instruments are classified in to two categories.

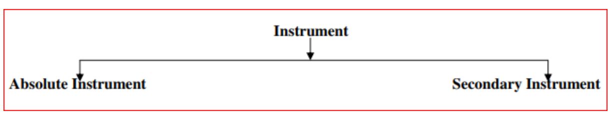

Fig. 1. Classification of instruments

A. *Absolute instrument*

An absolute instrument determines the magnitude of the quantity to be measured in terms of the instrument parameter. This instrument is really used, because each time the value of the measuring quantities varies. So we have to calculate the magnitude of the measuring quantity, analytically which is time consuming. These types of instruments are suitable for laboratory use. Example: Tangent galvanometer.

B. *Secondary instrument*

This instrument determines the value of the quantity to be measured directly. Generally, these instruments are calibrated by comparing with another standard secondary instrument. Examples of such instruments are voltmeter, ammeter and wattmeter etc. Practically secondary instruments are suitable for measurement.

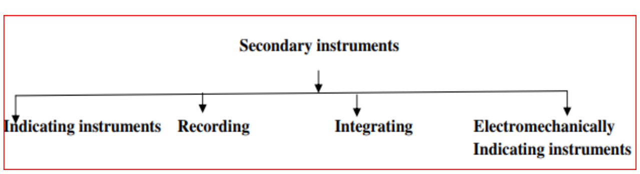

Fig. 2. Classification of secondary instruments

Indicating instrument: This instrument uses a dial and pointer to determine the value of measuring quantity. The pointer indication gives the magnitude of measuring quantity.
Recording instrument: This types of instruments records the magnitude of the quantity to be measured continuously over a specified period of time.
Integrating instrument: This type of instrument gives the total amount of the quantity to be measured over a specified period of time.
Electromechanical indicating instrument: for satisfactory operation electromechanical indicating instrument, three forces are necessary. They are (a) Deflecting force (b) Controlling force (c) Damping force
(A) Deflecting force: To deflect the pointer from its zero position, a force is necessary which is known as deflecting force. A system which produces the deflecting force is known as a deflecting system. When there is no input signal to the instrument, the pointer will be at its zero position. Generally, a deflecting system converts an electrical signal to a mechanical force.

For producing deflecting torque different effect are utilized such as Magnitude effect, thermal effect, force between a permanent magnet and a current carrying coil, Force between two current carrying coil (capacitance effect), electromagnetic effect etc.
(B) Controlling force: To control the deflection of pointer a force is necessary which will be acting in the opposite direction to the deflecting force. This force is known as controlling force. A system which produces this force is known as a controlled system. When the external signal to be measured by the instrument is removed, the pointer should return back to the zero position. This is possibly due to the controlling force and the pointer will be indicating a steady (constant) value when the deflecting torque is equal to controlling torque. i.e. Td = Tc

The controlling force is produce by different methods such as spring control and gravity control.
(C) Damping force: Due to inertia produced by this system, the pointer oscillates about it final steady position before coming to rest. The time required to take the measurement is more. To damp out the oscillation is quickly, a damping force is necessary.

This force is produced by different systems Air friction damping, Fluid friction damping and Eddy current damping.

2. Electrical measurement

For measurement of current, voltage, Power and Energy following instruments are used.

A. Permanent Magnet Moving Coil (PMMC) instrument

PMMC is one of the most accurate types of instrument used for D.C. measurements of current and voltage.

It works on the principal of “when D.C. supply is given to the moving coil, D.C. current flows through it. When the current carrying coil is kept in the magnetic field, it experiences a force”. This force produces a torque and the former rotates. The pointer is attached with the spindle. When the former rotates, the pointer moves over the calibrated scale. When the polarity is reversed a torque is produced in the opposite direction. The mechanical stopper does not allow the deflection in the opposite direction. Therefore, the polarity should be maintained with PMMC instrument.

If A.C. is supplied, a reversing torque is produced. This cannot produce a continuous deflection. Therefore, this instrument cannot be used in A.C.

The Extension of range of PMMC instrument is possible by using shunt and multiplier.

For providing damping torque eddy current damping are used and for providing controlling torque spring control are used.

B. Moving Iron (MI) instruments

One of the most accurate instruments used for both AC and DC measurement is moving iron instrument. There are two types of moving iron instrument.

- Attraction type
- Repulsion type

The attraction type MI instrument works on the principle of “When the current is being measured is passed through the fixed coil. As the current is flow through the fixed coil, a magnetic field is produced”. By magnetic induction the moving iron gets magnetized. Thus the deflecting force is produced due to force of attraction. Since the moving iron is attached with the spindle, the spindle rotates and the pointer moves over the calibrated scale. But the force of attraction depends on the current flowing through the coil. Here air friction damping is used to reduce the oscillation.

Whereas the repulsion type MI instrument works on the principle of when the current flows through the coil, a magnetic field is produced by it. So both fixed iron and moving iron are magnetized with the same polarity, since they are kept in the same magnetic field. Similar poles of fixed and moving iron get repelled. Thus the deflecting torque is produced due to magnetic repulsion. Since moving iron is attached to spindle, the spindle will move. So that pointer moves over the calibrated scale.

Air friction damping is used to reduce the oscillation and controlling torque are provided through Spring control.

C. Dynamometer (or) Electromagnetic moving coil instrument (EMMC)

This instrument can be used for the measurement of voltage, current and power. The difference between the PMMC and dynamometer type instrument is that the permanent magnet is replaced by an electromagnet.

This type of instrument consists of three coils, out of these two coils are fixed coil and one is moving coil. All these coils are connected in series manner. This instrument works on the principle of when the current flows through the fixed coil; it produced a magnetic field, whose flux density is proportional to the current through the fixed coil. The moving coil is kept in between the fixed coil. When the current passes through the moving coil, a magnetic field is produced by this coil.

This instrument works on AC and DC. When AC voltage is applied, alternating current flows through the fixed coil and moving coil. When the current in the fixed coil reverses, the current in the moving coil also reverses. Torque remains in the same direction. This is because the fixed and moving coils are connected in series.

For providing controlling torque spring control is used and for damping torque Air friction damping is used.

D. Induction type instrument

This instrument works on the principal of electromagnetic induction principal. When the alternating quantity is passed through the conductor it produces the field. If the other conductor placed in this field the force is applied on this conductor which produces rotating motion in fixed coil which rotate the pointer on calibrated scale. This instrument only used for the A.C quantity.

For providing controlling torque spring control is used and for damping torque eddy current damping is used.

E. Electrostatic instrument

This instrument works on the principal of electrostatic principal. The instrument is generally used for measuring medium and high voltage. The voltage is reduced to low value by using capacitor potential divider. The force of attraction is proportional to the square of the voltage.

Table 1
Comparative study of entire instruments

Type of instrument	Effect used	Suitable for	Application	Sclae
Permanent Magnet Moving Coil Instrument (PMMC)	Magnetic Effect	D.C only	Ammeter, Voltmeter	Uniform Scale
Permanent Magnet Moving Iron Instrument (MI)	Magnetic Effect	A.C and D.C	Ammeter, Voltmeter	Non Uniform Scale
Dynamometer Instrument	Electro Dynamic Effect	A.C and D.C	Ammeter, Voltmeter, Wattmeter	Non Uniform Scale
Induction Type Instrument	Electromagnetic Effect	A.C only	Ammeter, Voltmeter, Wattmeter, Energy meter	Non Uniform Scale
Electrostatic Instrument	Electrostatic Effect	A.C and D.C	Voltage Only	Non Uniform Scale

The voltage is to be measured is applied between the two plates of capacitor. The force of attraction between these plates produces a deflecting torque.

Controlling torque is produced by spring control. Air friction damping is used.

3. Electronic measurement

The electronic component such as resistance, capacitance, inductance and frequency are measured with help of bridges. Bridge Circuit is a null method, operates on the principle of comparison. That is a known (standard) value is adjusted until it is equal to the unknown value. There are two types of bridges A.C bridges and D.C bridges.

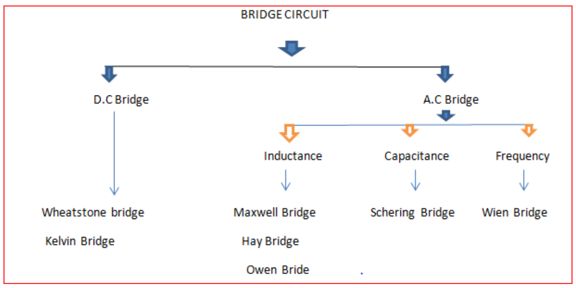

Fig. 3. Classification of bridge circuits

Measurement of Resistance: There are different methods are used for measurement of low, medium and high resistance.

Kelvin double bridge method: This method is used for to measure unknown low resistance. Circuit connection for kelvin double bridge shown in below figure.

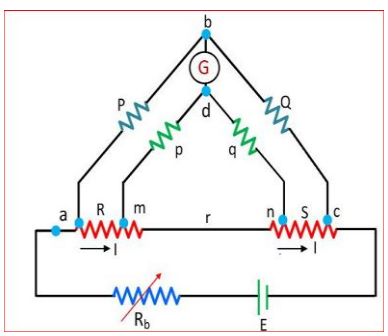

Fig. 4. Kelvin double bridge method

The unknown resistance is calculated by using following equation.

$$R=\frac{P}{Q}.S$$

Wheatstone Bridge: The device uses for the measurement of minimum resistance with the help of comparison method is known as the Wheatstone bridge. The value of unknown resistance is determined by comparing it with the known resistance. The Wheatstone bridge works on the principle of null deflection, i.e. the ratio of their resistances are equal, and no current flows through the galvanometer. The bridge is very reliable and gives an accurate result.

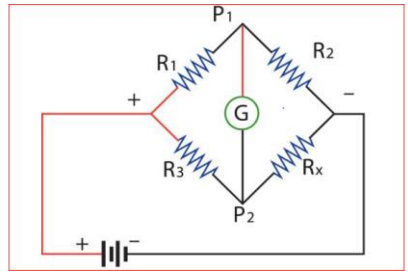

Fig. 5. Wheatstone Bridge

The unknown resistance is calculated by using following equation.

$$R_X=\frac{R2}{R3}.R_1$$

Measurement of Inductance: Following different types of bridges are used for measurement of inductance.

Maxwell's Inductance Bridge: In such type of bridges, the value of unknown resistance is determined by comparing it with the known value of the standard self-inductance. The connection diagram for the balance Maxwell bridge is shown in the figure below.

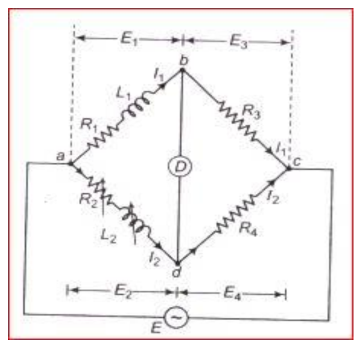

Fig. 6. Maxwell's Inductance Bridge

The unknown inductance is calculated by using following equation.

$$L_1=\frac{R3L2}{R4}$$

Maxwell's Inductance Capacitance Bridge: In this type of bridges, the unknown resistance is measured with the help of the standard variable capacitance. The connection diagram of the Maxwell Bridge is shown in the figure below.

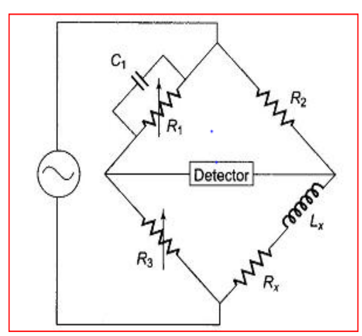

Fig. 7. Maxwell's Inductance Capacitance Bridge

The unknown inductance is calculated by using following equation.

$$L_X = R_2R_3C_1$$

Hay's Bridge: The Hay's bridge is used for determining the self-inductance of the circuit. The bridge is the advanced form of Maxwell's bridge. The Maxwell's bridge is only appropriate for measuring the medium quality factor. Hence, for measuring the high-quality factor the Hays Bridge is used in the circuit.

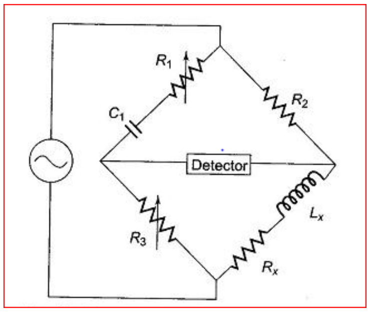

Fig. 8. Hay's bridge

The unknown inductance is calculated by using following equation.

$$L_X = \frac{R2R3C1}{1+(\frac{1}{Q})2}$$

For greater value of Q the 1/Q is neglected and hence the equation become $L_X = R_2R_3C_1$

Anderson Bridge: The Anderson's bridge gives the accurate measurement of self-inductance of the circuit. The bridge is the advanced form of Maxwell's inductance capacitance bridge. In Anderson Bridge, the unknown inductance is compared with the standard fixed capacitance which is connected between the two arms of the bridge.

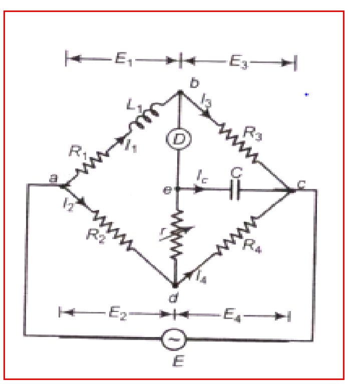

Fig. 9. Anderson Bridge

The unknown inductance is calculated by using following equation.

$$R_1 = \frac{R2.R3}{R4} \qquad L_1 = \frac{C.R3}{R4}(rR_2+R_2R_4+rR_4)$$

Owen's Bridge: The Bridge which measures the inductance in terms of standard capacitance is known as Owen's bridge. It works on the principle of comparison i.e., the value of the unknown inductor is compared with the standard capacitor. The connection diagram of Owen's bridge is shown in the figure.

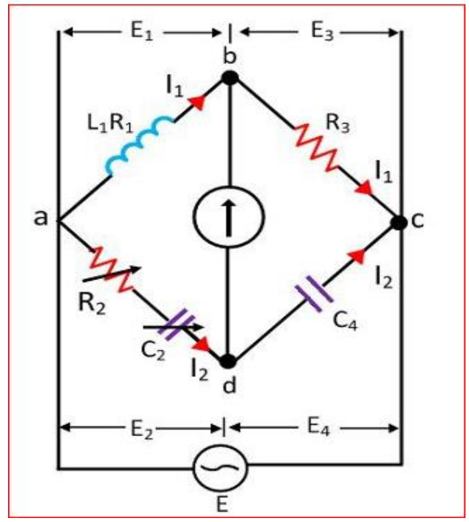

Fig. 10. Owen's Bridge

The unknown inductance is calculated by using following equation.

$$L1 = R2R3C4 \qquad R1 = R3.\frac{C4}{C2}$$

Measurement of Capacitance: For measurement of unknown capacitance Schering Bridge are used.

Schering Bridge: The Schering bridge use for measuring the capacitance of the capacitor, dissipation factor, properties of an insulator, capacitor bushing, insulating oil and other insulating materials. It is one of the most commonly used AC Bridge. The Schering Bridge works on the principle of balancing the load on its arm.

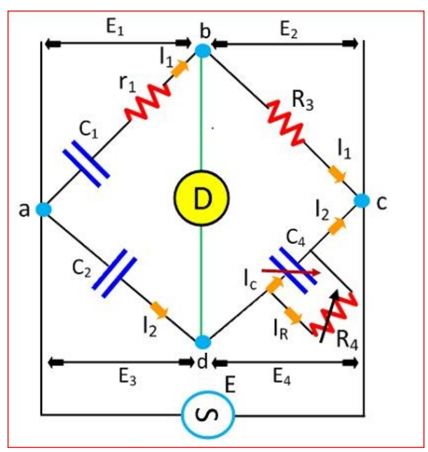

Fig. 11. Schering Bridge

The unknown capacitance is calculated by using following equation.

$$C1 = \frac{R4}{R3}C2$$

Measurement of Frequency:

Wien's Bridge: The Wien's bridge circuit diagram shown in below figure. It consists series RC combination in one arm and a parallel combination in the adjoining arm. Wien's bridge in designed to measure frequency. It can also be used for the measurement of an unknown capacitor with great frequency.

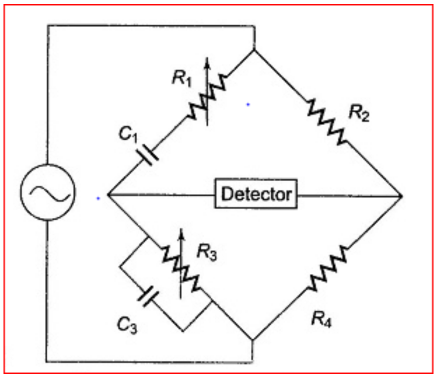

Fig. 12. Wien's Bridge

The unknown frequency is calculated by using following equation.

$$f = \frac{1}{2\pi\sqrt{C1R1C3R3}}$$

4. Conclusion

In this paper, different measuring devices are discussed for measurement of electrical and electronic quantity with their circuit connection and mathematical equation.

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