ELECTRICAL MEASUREMENT AND INSTRUMAINTATION [TH-3]

4TH SEM ELECTRICAL ENGG.

Under SCTE&VT, Odisha

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CHAPTER 1
MEASURING INSTRUMENTS

MEASURING INSTRUMENTS
INTRODUCTION

- Measurement is the act, or the result, of a quantitative comparison between a given quantity and a quantity of the same kind chosen as a unit. The result of the measurement is expressed by a pointer deflection over a predefined scale or a number representing the ratio between the unknown quantity and the standard.
- A standard is defined as the physical personification of the unit of measurement or its sub-multiple or multiple values.
- The device or instrument used for comparing the unknown quantity with the unit of measurement or a standard quantity is called a *measuring instrument.*
- The value of the unknown quantity can be measured by direct or indirect methods.
- In direct measurement methods, the unknown quantity is measured directly instead of comparing it with a standard. Examples of direct measurement are current by ammeter, voltage by voltmeter, resistance by ohmmeter, power by wattmeter, etc.
- In indirect measurement methods, the value of the unknown quantity is determined by measuring the functionally related quantity and calculating the desired quantity rather than measuring it directly. Suppose the resistance as (*R*) of a conductor can be measured by measuring the voltage drop across the conductor and dividing the voltage (*V*) by the current (*I*) through the conductors, by Ohm's law. $R = \frac{V}{I}$

DEFINITIONS OF SOME STATIC CHARACTERISTICS

Accuracy:

Accuracy is the closeness with which the instrument reading approaches the true value of the variable under measurement. Accuracy is determined as the maximum amount by which the result differs from the true value. It is almost impossible to determine experimentally the true value. The true value is not indicated by any measurement system due to the loading effect, lags and mechanical problems (e.g., wear, hysteresis, noise, etc.).

Accuracy of the measured signal depends upon the following factors:

- Intrinsic accuracy of the instrument itself;
- Accuracy of the observer;
- Variation of the signal to be measured; and
- Whether or not the quantity is being truly impressed upon the instrument.

Precision:

Precision is a measure of the reproducibility of the measurements, i.e., precision is a measure of the degree to which successive measurements differ from one another. Precision is indicated from the number of significant figures in which it is expressed. Significant figures actually convey the information regarding the magnitude and the measurement precision of a quantity. More significant figures imply greater precision of the measurement

Resolution:

If the input is slowly increased from some arbitrary value it will be noticed that the output does not change at all until the increment exceeds a certain value called the resolution or discrimi instrument. Thus, the resolution or discrimination of any instrument is the smallest input signal (quantity under measurement) which can be detected by the instrumen expressed as an accrual value or as a fraction or percentage of the full scale value. Resolution is sometimes referred as sensitivity. The largest change of input quantity for which there is no output of the instrument is called the dead zone of that instrument.

The sensitivity gives the relation between the input signal to an instrument or a part of the instrument system and the output. Thus, the sensitivity is defined as the ratio of output signal or response of the instrument to a change of input signal or the quantity under measurement.

Speed of Response

The quickness of an instrument to read the measurand variable is called the speed of response. Alternately, speed of response is defined as the time elapsed between the start of the measurement to the reading taken. This time depends upon the mechanical moving system, friction, etc.

MEASUREMENT OF ERRORS

In practice, it is impossible to measure the exact value of the measurand. There is always some difference between the measured value and the absolute or true value of the unknown quantity (measurand), which may be very small or may be large. The difference between the true or exact value and the measured value of the unknown quantity is known as the absolute error of the measurement.

If δA be the absolute error of the measurement, A_m and A be the measured and absolute value of the unknown quantity then δA may be expressed as

$$\delta A = A_m - A$$

Sometimes, δA is denoted by ε_0.

The relative error is the ratio of absolute error to the true value of the unknown quantity to be measured,

$$\text{i.e., relative error, } \varepsilon_r = \frac{\delta A}{A} = \frac{\varepsilon_0}{A} = \frac{\text{Absolute error}}{\text{True value}}$$

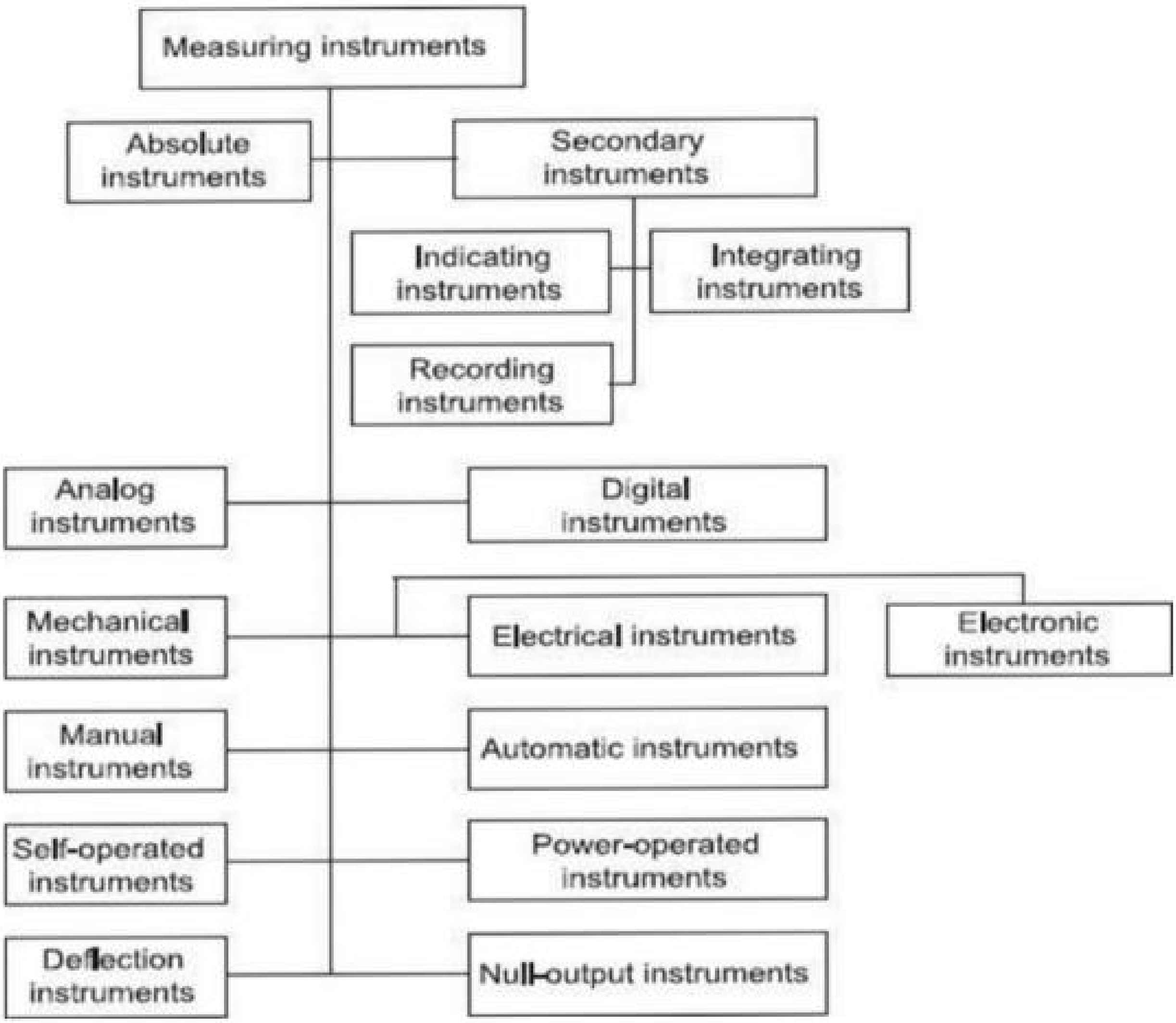
When the absolute error ε_0 ($=\delta A$) is negligible, i.e., when the difference between the true value A and the measured value A_m of the unknown quantity is very small or negligible then the relative error may be expressed as,

$$\varepsilon_r = \frac{\delta A}{A_m} = \frac{\varepsilon_0}{A_m}$$

The relative error is generally expressed as a fraction, i.e., 5 parts in 1000 or in percentage value,

$$\text{i.e., percentage error} = \varepsilon_r \times 100 = \frac{\varepsilon_0}{A_m} \times 100$$

CLASSIFICATION OF INSTRUMENTS



The measuring instruments may be classified as follows:

I. Absolute and Secondary Instruments

Absolute Instruments

The instruments of this type give the value of the measurand in terms of instrument constant and its deflection. Such instruments do not require comparison with any other standard. The example of this type of instrument is tangent galvanometer, which gives the value of the current to be measured in terms of tangent of the angle of deflection produced, the horizontal component of the earth's magnetic field, the radius and the number of turns of the wire used. Rayleigh current balance and absolute electrometer are other examples of absolute instruments. Absolute instruments are mostly used in standard laboratories and in similar institutions as standardizing.

Secondary Instruments

These instruments are so constructed that the deflection of such instruments gives the magnitude of the electrical quantity to be measured directly. These instruments are required to be calibrated by comparison with either an absolute instrument or with another secondary instrument, which has already been calibrated before the use. These instruments are generally used in practice.

Secondary instruments are further classified as

- Indicating instruments
- Integrating instruments
- Recording instruments

(i) Indicating Instruments:

Indicating instruments are those which indicate the magnitude of an electrical quantity at the time when it is being measured. The indications are given by a pointer moving over a calibrated (pregraduated) scale. Ordinary ammeters, voltmeters, wattmeters, frequency meters, power factor meters, etc., fall into this category.

(ii) Integrating Instruments:

Integrating instruments are those which measure the total amount of either quantity of electricity (ampere-hours) or electrical energy supplied over a period of time. The summation, given by such an instrument, is the product of time and an electrical quantity under measurement. The ampere-hour meters and energy meters fall in this class.

(iii) Recording Instruments:

Recording instruments are those which keep a continuous record of the variation of the magnitude of an electrical quantity to be observed over a definite period of time. In such instruments, the moving system carries an inked pen which touches lightly a sheet of paper wrapped over a drum moving with uniform slow motion in a direction perpendicular to that of the direction of the pointer. Thus, a curve is traced which shows the variations in the magnitude of the electrical quantity under observation over a definite period of time. Such instruments are generally used in powerhouses where the current, voltage, power, etc., are to be maintained within certain acceptable limit.

II. Analog and Digital Instruments

1. Analog Instruments

The signals of an analog unit vary in a continuous fashion and can take on infinite number of values in a given range. Fuel gauge, ammeter and voltmeters, wrist watch, speedometer fall in this category.

2. Digital Instruments

Signals varying in discrete steps and taking on a finite number of different values in a given range are digital signals and the corresponding instruments are of digital type. Digital instruments have some advantages over analog meters, in that they have high accuracy and high speed of operation. It eliminates the human operational errors. Digital instruments can store the result for future purposes. A digital multimeter is the example of a digital instrument.

III. Mechanical, Electrical and Electronics Instruments

1. Mechanical Instruments

Mechanical instruments are very reliable for static and stable conditions. They are unable to respond rapidly to the measurement of dynamic and transient conditions due to the fact that they have moving parts that are rigid, heavy and bulky and consequently have a large mass. Mass presents inertia problems and hence these instruments cannot faithfully follow the rapid changes which are involved in dynamic instruments. Also, most of the mechanical instruments cause noise pollution.

Advantages of Mechanical Instruments

- Relatively cheaper in cost
- More durable due to rugged construction
- Simple in design and easy to use
- No external power supply required for operation
- Reliable and accurate for measurement of stable and time invariant quantity

VI. Deflection and Null Output Instruments

In a deflection-type instrument, the deflection of the instrument indicates the measurement of the unknown quantity. The measurand quantity produces some physical effect which deflects or produces a mechanical displacement in the moving system of the instrument. An opposite effect is built in the instrument which opposes the deflection or the mechanical displacement of the moving system. The balance is achieved when opposing effect equals the actuating cause producing the deflection or the mechanical displacement. The deflection or the mechanical displacement at this point gives the value of the unknown input quantity. These types of instruments are suited for measurement under dynamic condition. Permanent Magnet Moving Coil (PMMC), Moving Iron (MI), etc., type instruments are examples of this category.

In null-type instruments, a zero or null indication leads to determination of the magnitude of the measurand quantity. The null condition depends upon some other known conditions. These are more accurate and highly sensitive as compared to deflection-type instruments. A dc potentiometer is a null- type instrument.

OPERATING TORQUES

Three types of torques are needed for satisfactory operation of any indicating instrument. These are

1. Deflecting torque
2. Controlling torque
3. Damping torque

Deflecting Torque/Force

Any instrument's deflection is found by the total effect of the deflecting torque/force, control torque/ force and damping torque/force. The deflecting torque's value is dependent upon the electrical signal to be measured; this torque/force helps in rotating the instrument movement from its zero position. The system producing the deflecting torque is called the *deflecting system.*

Controlling Torque/Force

The act of this torque/force is opposite to the deflecting torque/force. When the deflecting and controlling torques are equal in magnitude then the movement will be in definite position or in equilibrium. Spiral springs or gravity is usually given to produce the controlling torque. The system which produces the controlling torque is called the *controlling system*.

The functions of the controlling system are

1. To produce a torque equal and opposite to the deflecting torque at the final steady position of the pointer in order to make the deflection of the pointer definite for a particular magnitude of current
2. To bring the moving system back to its zero position when the force causing the instrument moving system to deflect is removed

The controlling torque in indicating instruments is almost always obtained by a spring, much less commonly, by gravity.