Dynamic characteristics:

The set of criteria defined for the instruments, which are changes rapidly with time, is called 'dynamic characteristics'.

The various static characteristics are:

i) Speed of response
ii) Measuring lag
iii) Fidelity
iv) Dynamic error

Speed of response:

It is defined as the rapidity with which a measurement system responds to changes in the measured quantity.

Measuring lag:

It is the retardation or delay in the response of a measurement system to changes in the measured quantity.

The measuring lags are of two types:

1) Retardation type:

In this case the response of the measurement system begins immediately after the change in measured quantity has occurred.

2) Time delay lag:

In this case the response of the measurement system begins after a dead time after the application of the input.

Fidelity:

It is defined as the degree to which a measurement system indicates changes in the measure and quantity without dynamic error.

Dynamic error:

It is the difference between the true value of the quantity changing with time & the value indicated by the measurement system if no static error is assumed. It is also called measurement error.

ERRORS IN MEASUREMENT

The types of errors are follows

i) Gross errors

ii) Systematic errors

iii) Random errors

Gross Errors

The gross errors mainly occur due to carelessness or lack of experience of a human begin. These errors also occur due to incorrect adjustments of instruments these errors cannot be treated mathematically

These errors are also called 'personal errors'.

Ways to minimize gross errors:

The complete elimination of gross errors is not possible but one can minimize them by the following ways:

Taking great care while taking the reading, recording the reading &calculating the result without depending on only one reading, at least three or more readings must be taken preferably by different persons.

Systematic errors

A constant uniform deviation of the operation of an instrument is known as Systematic error. The Systematic errors are mainly due to the short comings of the instrument & the characteristics of the material used in the instrument, such as defective or worn parts, ageing effects, environmental effects, etc.

Types of Systematic errors:

There are three types of Systematic errors as:

i) Instrumental errors

ii) Environmental errors

iii) Observational errors

Instrumental errors:

These errors can be mainly due to the following three reasons:

a) Short coming of instruments:

These are because of the mechanical structure of the instruments. For example friction in the bearings of various moving parts; irregular spring tensions, reductions in due to improper handling , hysteresis, gear backlash, stretching of spring, variations in air gap, etc ., Ways to minimize this error:

These errors can be avoided by the following methods:

Selecting a proper instrument and planning the proper procedure for the measurement recognizing the effect of such errors a n d applying t h e proper correction factors calibrating the instrument carefully against a standard

b) Misuse of instruments:

A good instrument if used in abnormal way gives misleading results. Poor initial adjustment, Improper zero setting, using leads of high resistance etc., are the examples of misusing a good instrument. Such things do not cause the permanent damage to the instruments but definitely cause the serious errors.

c) Loading effects

Loading effects due to improper way of using the instrument cause the serious errors. The best ex ample of such loading effect error is connecting a w ell calibrated volt meter across the two points of high resistance circuit. The same volt meter connected in a low resistance circuit gives accurate reading.

Ways to minimize this error:

Thus the errors due to the loading effect can be avoided by using an instrument intelligently and correctly.

Environmental errors:

These errors are due to the conditions external to the measuring instrument. The various factors resulting these environmental errors are temperature changes,pressure changes, thermal emf, and ageing of equipment and frequency sensitivity of an instrument

Ways to minimize this error:

The various methods which can be used to reduce these errors are:

i) Using the proper correction factors and using the information supplied by the manufacturer of the instrument

ii) Using the arrangement which will keep thesurrounding conditions Constant

iii) Reducing the effect of dust ,humidity on the components by hermetically sealing the components in the instruments

iv) The effects of external fields can be minimized by using the magnetic or electro static shields or screens

v) Using the equipment which is immune to such environmental effects.

Observational errors:

These are the errors introduced by the observer.

These are many sources of observational errors such as parallax error while reading a meter, wrong scale selection, etc.

Ways to minimize this error

To eliminate such errors one should use the instruments with mirrors, knife edged pointers, etc. The systematic errors can be subdivided as static and dynamic errors. The static errors are caused by the limitations of the measuring device while the dynamic errors are caused by the instrument not responding fast enough to follow the changes in the variable to be measured.

Random errors

Some errors still result, though the systematic and instrumental errors are reduced or at least accounted for. The causes of such errors are unknown and hence the errors are called random errors.

Ways to minimize this error

The only way to reduce these errors is by increasing the number of observations and using the statistical methods to obtain the best approximation of the reading.

MEASUREMENTS

The measurement of a given quantity is essentially an act or the result of comparison between the quantity (whose magnitude is unknown) & a predefined standard. Since two quantities are compared, the result is expressed in numerical values.

Basic requirements of measurement

1) The standard used for comparison purposes must be accurately defined & should be commonly accepted
2) The apparatus used & the method adopted must be provable.

Measuring instrument

It may be defined as a device for determining the value or magnitude of a quantity or variable.

FUNCTIONAL ELEMENTS OF AN INSTRUMENT:

Most of the measurement systems contain three main functional elements.

They are:

i) Primary sensing element
ii) Variable conversion element &
iii) Data presentation element.

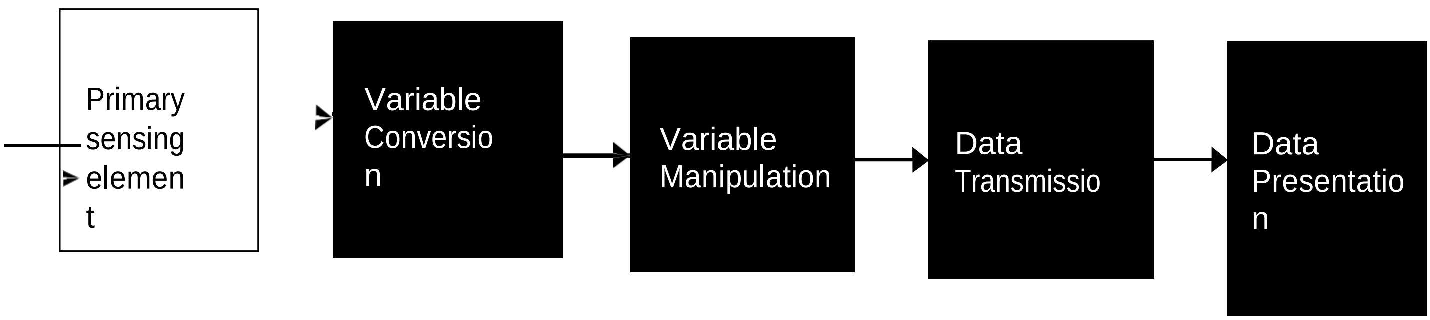

Fig 1.1 Functional Elements of an Instrument

Primary sensing element:

The quantity under measurement makes its first contact with the primary sensing element of a measurement system. i.e., the measured- (the unknown quantity which is to be measured) is first detected by primary sensor which gives the output in a different analogous form This output is then converted into an electrical signal by a transducer - (which converts energy from one form to another). The first stage of an measurement system is known as a detector transducer stage'.

Variable conversion element:

The output of the primary sensing element may be electrical signal of any form, it may be voltage, a frequency or some other electrical parameter. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form.

Variable manipulation element:

The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. It is not necessary that a variable manipulation element should follow the variable conversion element some non -linear processes like modulation, detection, sampling, filtering, chopping etc., are performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system This process of conversion is called 'signal conditioning'

The term signal conditioning includes many other functions in addition to Variable conversion & Variable manipulation In fact the element that follows the primary sensing element in any instrument or measurement system is called conditioning element'

NOTE: When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function is called a data transmission element'.

Data presentation element:

The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. This function is done by data presentation element

In case data is to be monitored, visual display devices are needed these devices may be analog or digital indicating instruments like ammeters, voltmeters etc. In case data is to be recorded, recorders like magnetic tapes, high speed camera & TV equipment, CRT, printers may be used. For control & analysis is purpose microprocessor or computers may be used. The final stage in a measurement system is known as **terminating stage'**

STATISTICAL EVALUATION OF MEASUREMENT DATA

Out of the various possible errors, the random errors cannot be determined in the ordinary process of measurements. Such errors are treated mathematically.
The mathematical analysis of the various measurements is called statistical analysis of the data'.

For such statistical analysis, the same reading is taken number of times, generally u sing different observers, different instruments & by different ways of measurement. The statistical analysis helps to determine analytically the uncertainty of the final test results.

Arithmetic mean & median:

When the n umber of readings of the same measurement are taken, the most likely value from the set of measured value is the arithmetic mean of the number of readings taken. The arithmetic mean value can be mathematically obtained as,

$$\overline{X} = \frac{X_1 \quad X_2 \quad .... \quad X_n}{n}$$

This mean is very close to true value, if number of readings is very large. But when the number of readings is large, calculation of mean value is complicated. In such a case, a median value is obtained which is obtained which is a close approximation to the arithmetic mean value. For a set of µ Q measurements X1, X2, X3.Xn written down in the ascending order of magnitudes, the median value is given by,

X median=X (n+1)/2

Average deviation:

The deviation tells us about the departure of a given reading from the arithmetic mean of the data set.

Where

$$di = xi - \overline{X}$$

di = deviation of ith reading

Xi= value of ith reading

$\overline{X}$ = arithmetic mean

The average deviation is defined as the sum of the absolute values of deviations divided by the number of readings. This is also called mean deviation

STATIC CHARACTERISTICS

The performance characteristics of an instrument are mainly divided into two categories:

1) Static characteristics
2) Dynamic characteristics

Static characteristics:

The set of criteria defined for the instruments, which are used to measure the quantities which are slowly varying with time or mostly constant, i.e., do not vary with time, is called 'static characteristics'.

The various static characteristics are:

i) Accuracy
ii) Precision
iii) Sensitivity
iv) Linearity
v) Reproducibility
vi) Repeatability
vii) Resolution
viii) Threshold
ix) Drift
x) Stability
xi) Tolerance
xii) Range or span

Accuracy:

It is the degree of closeness with which the reading approaches the true value of the quantity to be measured. The accuracy can be expressed in following ways:

a) Point accuracy:

Such accuracy is specified at only one particular point of scale. It does not give any information about the accuracy at any other point on the scale.

b) Accuracy as percentage of scale span:

When an instrument as uniform scale, its accuracy may be expressed in terms of scale range.

c) Accuracy as percentage of true value:

The best way to conceive the idea of accuracy is to specify it in terms of the true value of the quantity being measured.

Precision:

It is the measure of reproducibility i.e., given a fixed value of a quantity, precision is a measure of the degree of agreement within a group of measurements. The precision is composed of two characteristics:

a) Conformity:

Consider a resistor having true value as 2385692, which is being measured by an ohmmeter. But the reader can read consistently, a value as 2.4 Due to the nonavailability of proper scale. The error created due to the limitation of the scale reading is a precision error.

b) Number of significant figures:

The precision of the measurement is obtained from the number of significant figures, in which the reading is expressed. The significant figures convey the actual information about the magnitude & the measurement precision of the quantity.

The precision can be mathematically expressed as: P=1-

$$\left|\frac{X_n - \overline{X_n}}{\overline{X_n}}\right|$$

Where, P = precision

X_n = Value of nth measurement

$\overline{X_n}$ = Average value the set of measurement values

Sensitivity:

The sensitivity denotes the smallest change in the measured variable to which the instrument responds. It is defined as the ratio of the changes in the output ofan instrument to a change in the value of the quantity to be measured.

Mathematically it is expressed as,

$$\text{Sensitivity} = \frac{\text{Infinitesimal change in output}}{\text{Infinitesimal change in input}}$$

=qo/qi

Thus, if the calibration curve is liner, as shown, the sensitivity of the instrument is the slope of the calibration curve. If the calibration curve is not linear as shown, then the sensitivity varies with the input.

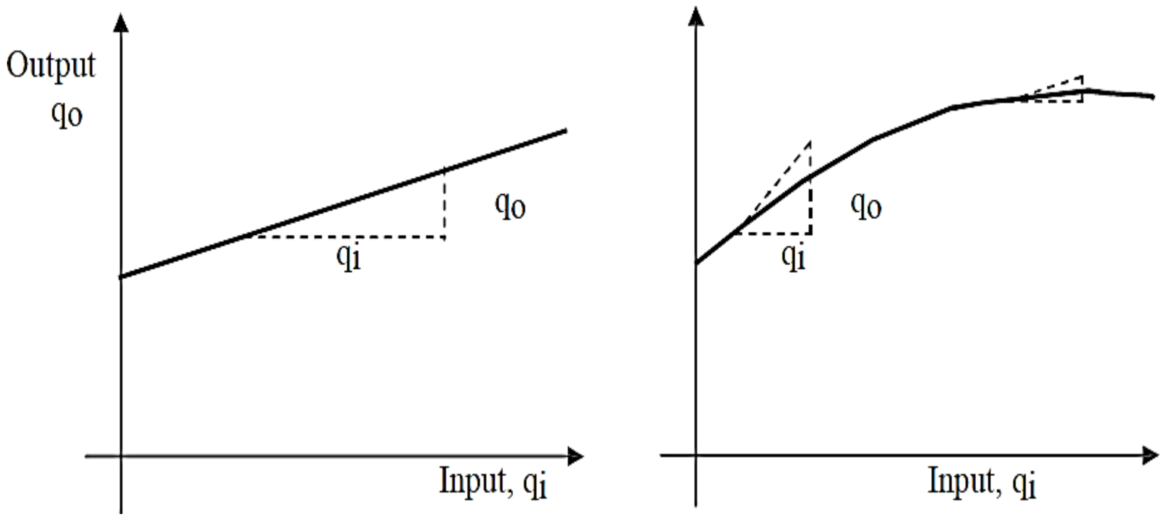

Fig1.2Sensitivity Curve

Inverse sensitivity or deflection factor is defined as the reciprocal of sensitivity.

Inverse sensitivity or deflection factor = 1/ sensitivity =qi/qo

Linearity

The linearity is defined as the ability to reproduce the input characteristics symmetrically & linearly. The curve shows the actual calibration curve & idealized straight line.

Idealized Straight line

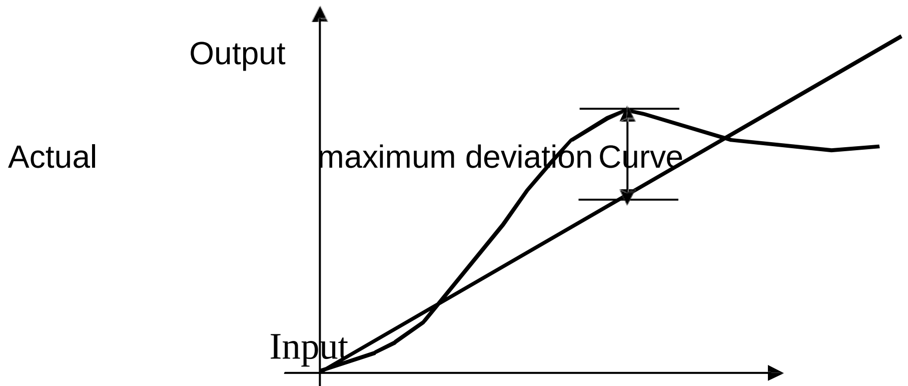

Fig 1.3 Actual calibration curve & idealized straight line Max.

% non-linearity= Deviation of output from idealized / Straight line Full scale reading

Reproducibility:

It is the degree of closeness with which a given value may be repeatedly measured. It is specified in terms of scale readings over a given period of time.

Repeatability:

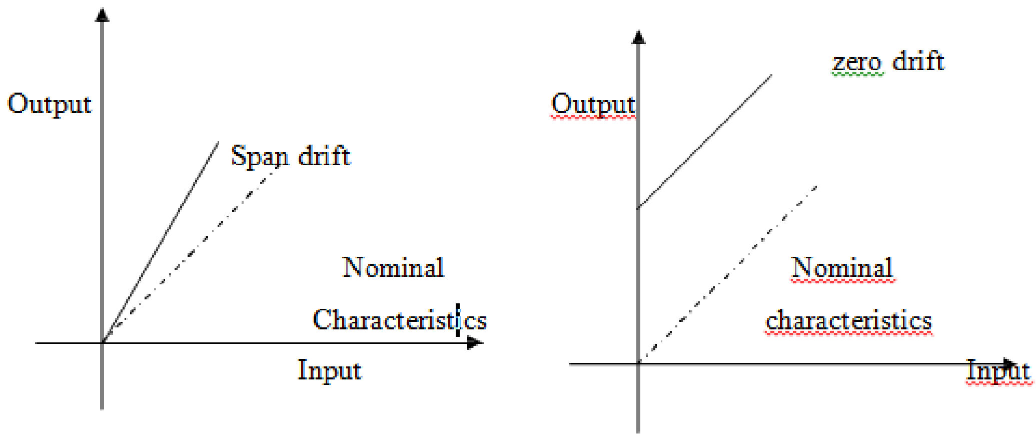

Fig1.5Drift Curve

Drift:

Drift may be classified into three categories:

a) Zero drift:

If the whole calibration gradually shifts due to slippage, permanent set, or due to undue warming up of electronic tube circuits, zero drift sets in.

b) Span drift or sensitivity drift

If there is proportional change in the indication all along the upward scale, the drifts is called span drift or sensitivity drift.

c) Zonal drift:

In case the drift occurs only a portion of span of an instrument, it is called zonal drift.

Resolution:

If the input is slowly increased from some arbitrary input value, it will again be found that output does not change at all until a certain increment is exceeded.

This increment is called resolution.

Threshold:

If the instrument input is increased very gradually from zero there will be some minimum value below which no output change can be detected. This minimum value defines the threshold of the instrument.

Stability:

It is the ability of an instrument to retain its performance throughout is specified operating life.

Tolerance:

The maximum allowable error in the measurement is specified in terms of some value which is called tolerance.

Rangeorspan:

The minimum & maximum value of a quantity for which an instrument is designed to measure is called its range or span.