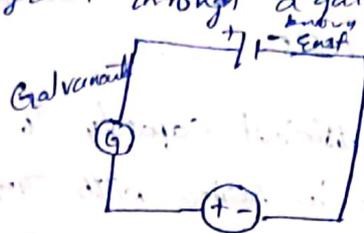


Principle of potentiometer

The potentiometer works on the principle of opposing the unknown emf by a known emf with the negative terminals of both the emf connected together while the positive terminals connected together through a galvanometer.

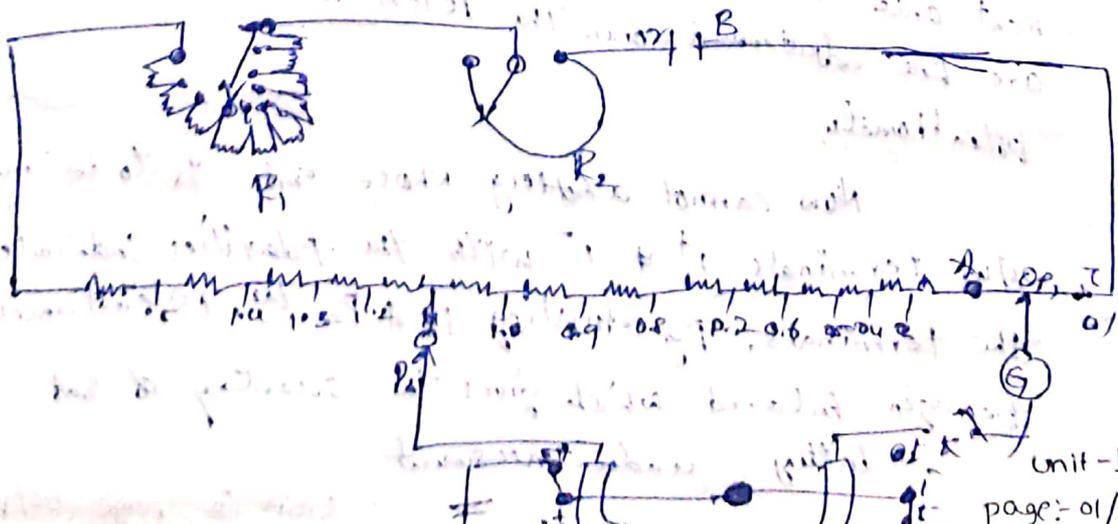


when the emf are of same value there is no deflection on galvanometer.

Crompton's DC potentiometer

The basic slide wire potentiometer considered is not the practical form of the DC potentiometer. The main drawback of the basic slide wire is that the length illustrated can not be read with greater precision. The DC potentiometer size is reduced as instead of long slide wire calibrated dial resistors of small circular wires of one or more turns are used.

A basic slide wire potentiometer was first modified by the scientist R.E. Crompton to a general term known as Crompton's D.C. potentiometer.



this potentiometer consists of a graduated slide wire AC which is connected in series with large number of coils. The coil resistance is equal to the slide wire resistance. Basically the sliding contact used in the basic slide wire potentiometer, but here two sliding contacts P_1 & P_2 are used. In that first (P_1) sliding contact slides over the slide wire and with the second (P_2) over the studs of the resistance coils.

The battery B is of sufficient capacity to provide working current and it is connected in series with regulating resistance. The resistance R_1 & R_2 where R_1 consists of number of resistance coils while R_2 is the turn of slide wire.

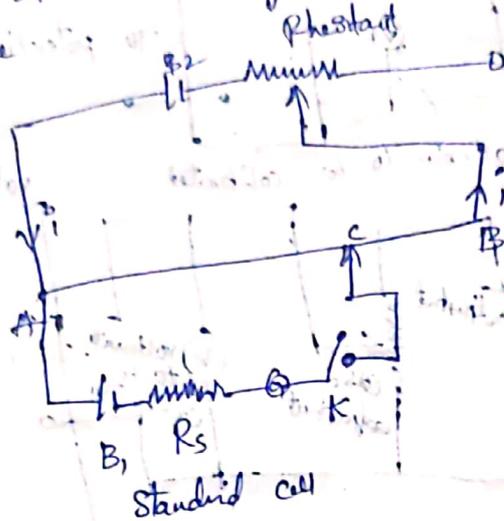
The galvanometer G, a and switch K are connected in series. Also points P_1 & P_2 through multiple circuit switch can change over switch. The main advantage of the multiple circuit switch is that we can connect a standard cell's, also S^+ & S^- of the battery whose e.m.f. are to be measured & as the terminals 1^+ & 1^- by 2^+ & 2^- .

First the potentiometer is standard by using a standard cell's. Say Weston cell with e.m.f. of 1.0186 V. The multiple circuit switch is thrown to the terminals S^+ and S^- . The sliding contact P_1 & P_2 are set at 0.0186 along the slide wire and 1.0 on the standard respectively. The switch K is closed and the null deflection is the galvanometer is obtained by varying R_1 & R_2 here R_1 is used for coarse adjustment while R_2 is used for fine adjustment. Once the potentiometer is standardised resistance R_1 & R_2 are fine adjusted. Once the potentiometer is done standardising potentiometer.

Now cannot a battery whose e.m.f. is to be measured. Thus terminals 1^+ & 1^- with the polarities indicated by the terminals. By adjusting P_1 & P_2 the potentiometer can be again balanced which gives the reading of e.m.f. of the battery under measurement.

Standardisation of potentiometer:-

The standardisation of a potentiometer is a process of adjusting the working current supplied by the battery such that the voltage portion of sliding wire matches with the standard reference source.



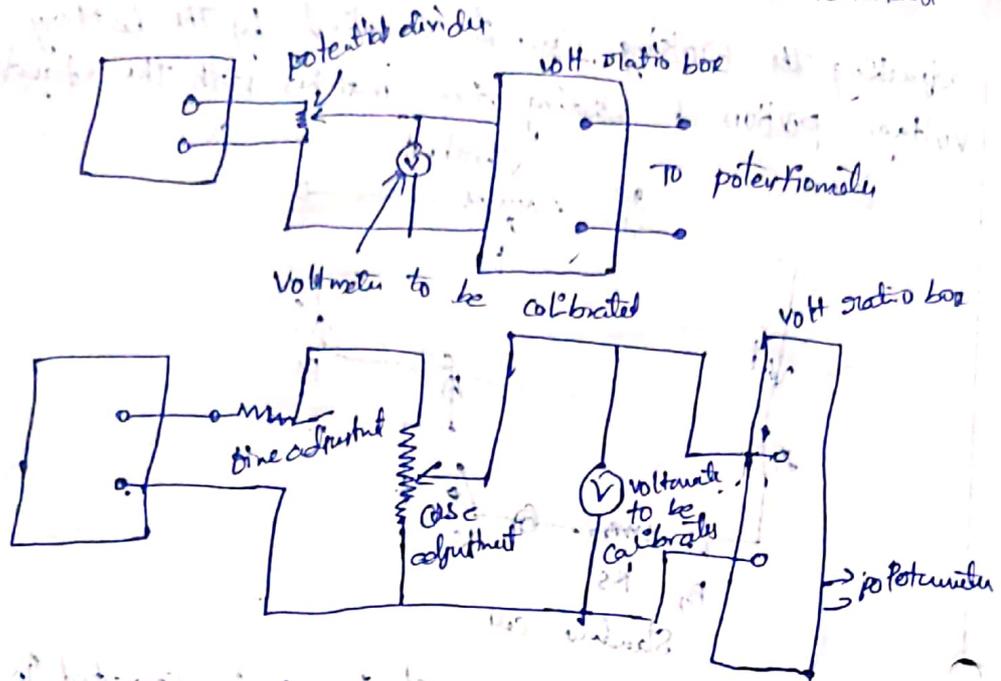
A battery of sufficient capacity i.e. B_1 is connected in series with a rheostat R_2 which regulates the working current flowing through the slide wire. A standard cell B_2 , usually a Weston standard cell of emf 1.0186 volts is connected to galvanometer and switch through a series resistance R_3 . By properly adjusting R_2 full sensitivity of the galvanometer can be obtained.

A slide wire with total length of 200 cm and resistance of 200 Ω is connected which is indicated by points A & B. During standardisation process switch K is closed and the sliding contact is placed at the mark of 101.86 cm along the slide wire as indicated by point C. Then we can observe some deflection on the galvanometer. Now by adjusting the value of rheostat R_2 we can get deflection in the galvanometer.

Under the condition of null deflection the voltage drop along 101.86 cm portion of the slide wire equals to the emf of standard Weston cell. This is nothing but the standardisation of a potentiometer. Once the potentiometer is standardised, the rheostat R_2 is not disturbed & working current remains constant.

Measurement of Voltage :-

The practical set up for calibration of voltmeter



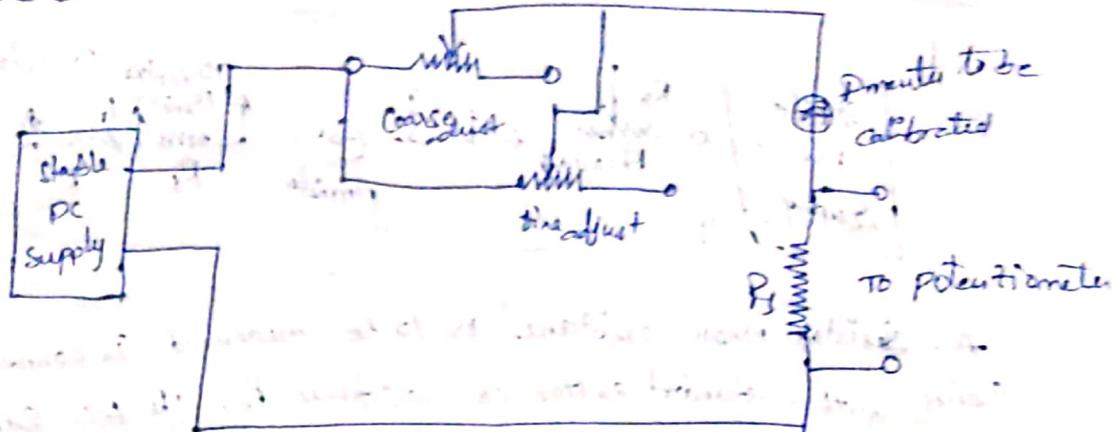
In both the circuit the concept used is of potential divider. The main important requirement of these circuit is the use of very stabilized D.C. Supply the only difference is that in the second circuit two rheostats used which are useful is coarse and fine adjuster with the adjustment it is possible to adjust a voltage such that the pointer of voltmeter exactly coincides the major division the voltage across voltmeter is stepped down using volt ratio box. for high accuracy is advisable to measure voltages near the maximum range of potentiometer.

Let the actual measured using potentiometer is

$$V_{act} = \frac{\text{potentiometer reading}}{(V.R \text{ box Ratio})}$$

$$\% \text{ error} = \frac{V_{ind} - V_{act}}{V_{ind}} \times 100$$

Calibration of Ammeter :



An ammeter to be calibrated is connected in series with a standard resistance \$R_s\$ to suitable value. The current supplied by a DC supply passes through ammeter as well as standard resistance \$R_s\$. Using dc potentiometer, voltage across across standard resistance can be measured. Thus current flowing through \$R_s\$ is.

$$I = \frac{V_s}{R_s}$$

\$V_s\$ = voltage across \$R_s\$

\$R_s\$ = Resistance of standard resistance

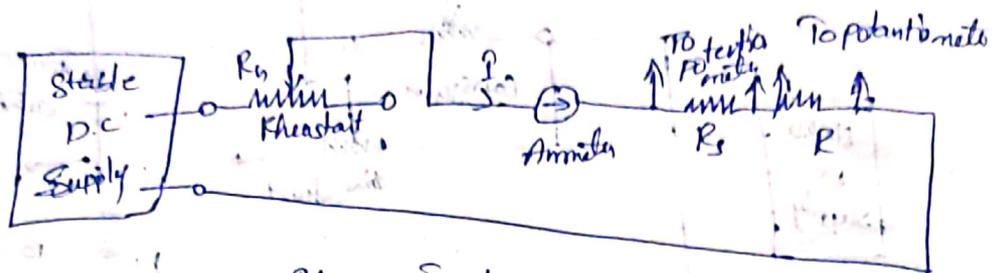
As the actual current \$I_{act}\$ and the current indicated by ammeter are not matching error is indicated

$$\% \text{ error} = \frac{I_{ind} - I_{act}}{I_{ind}} \times 100$$

\$I_{ind}\$ = current indicated by ammeter

$$I_{act} = I_s = \frac{V_s}{R_s}$$

Measurement of Resistance



A resistor whose resistance is to be measured is connected in series with a standard resistor of resistance R_s . The DC supply is controlled by a rheostat R_h . The current is adjusted such that the drop across each resistor is of the order of 1V. Due to the current I , voltages are developed across R_s and R both are then measured by using a dc potentiometer.

Let the voltage across standard resistance be V_{R_s}

$$V_{R_s} = I R_s \quad \text{--- (1)}$$

Voltage across unknown resistance be V_R

$$V_R = I R \quad \text{--- (2)}$$

dividing eqn

$$\frac{V_R}{V_{R_s}} = \frac{R}{R_s}$$

unknown resistance is given by

$$R_s = R \left(\frac{V_{R_s}}{V_R} \right)$$

A.C. Potentiometer

The basic principle of operation of d.c. potentiometer and a.c. potentiometer is exactly same. But in a d.c. potentiometer the balance e.m.f. voltage drop across the slide wire and the magnitude of unknown voltage is in magnitude as well as phase.

A.c. potentiometers are two types

→ polar type a.c. potentiometer :-

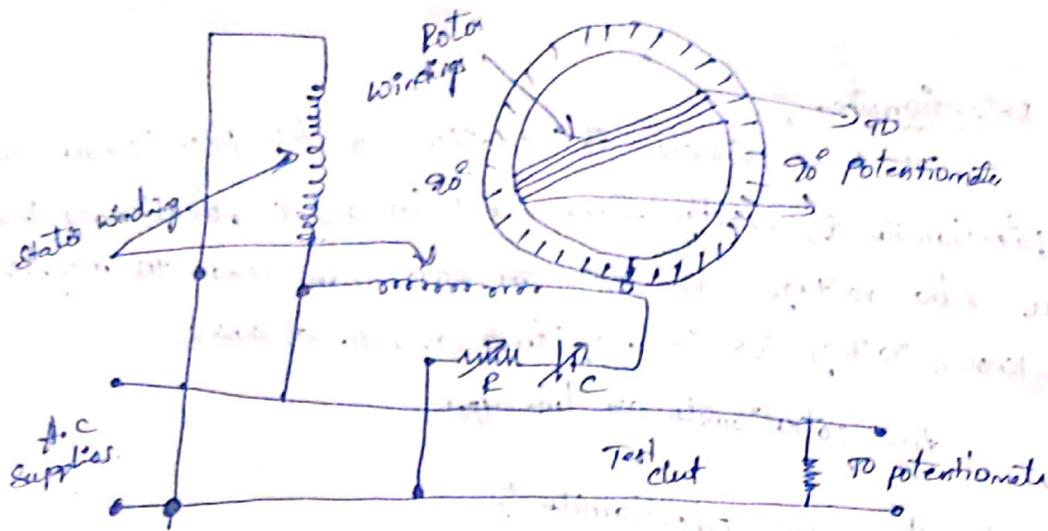
→ co-ordinate type a.c. potentiometer :-

Polar type A.C. Potentiometer

polar type a.c. potentiometer in which the magnitude and phase angle of unknown voltage are measured on different scales directly. The phase angle is measured with respect to some reference phase. As the voltage measured is represented in polar form as $V \angle \theta$, the a.c. potentiometer is called polar type a.c. potentiometer.

Being a polar type, Drysdale type a.c. potentiometer measures unknown e.m.f. in terms of its magnitude and phase angle. It consists of basic d.c. potentiometer along with some auxiliary components such as Drysdale phase shifter and electrodynamic type ammeter.

Drysdale phase shifter is also called phase shifting transformer. It consists of a ring shaped laminated steel stator. This stator is wound with either a two phase or three phase winding. Inside the stator, keeping some air gap, is the stator rotor. The rotor consists of a winding provided in the slot which supplies voltage to slide wire circuit of potentiometer.



When current flows through stator winding, a rotating field is produced inducing e.m.f. in the rotor. The phase of rotor current can be changed through any angle relative to stator supply voltage by rotating rotor thus the change in the phase of secondary e.m.f. is equal to the angle through which rotor is moved from its original zero position. It is very important to arrange windings such that although the magnitude of e.m.f. induced in rotor is changed, phase remains unchanged. Thus we can directly read the phase angle with the help of scale fixed on top of the instrument.

Co-ordinate type A.C. Potentiometer :-

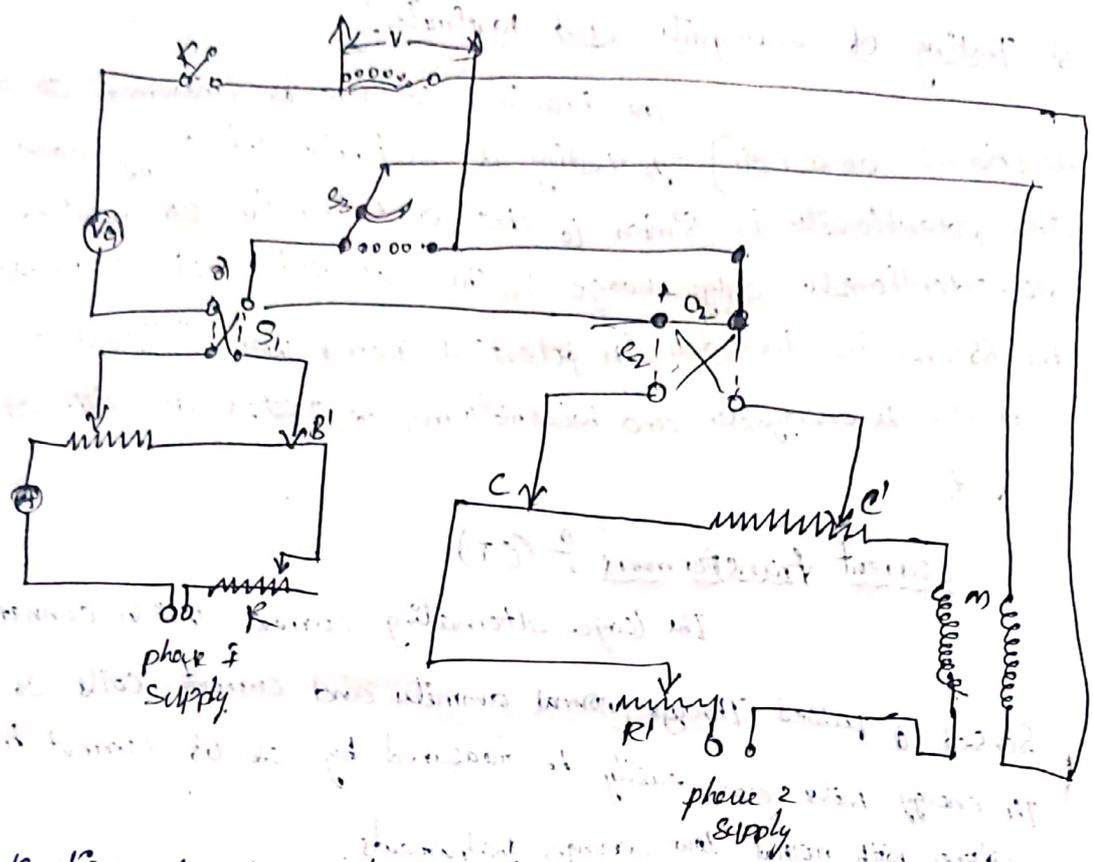
This potentiometer consists of two separate potentiometers enclosed in some common case. The inphase and quadrature potentiometer consists of sliding contacts BB' and cd respectively. The ratiostats R and R' are also provided in the respective potentiometer for the adjustment of current. By using different supplies for the potentiometers are obtained.

A vibration galvanometer V_G is tuned to the supply frequency and it is connected in series with a switched X and electro-dynamometer type ammeter.

S_1 & S_2 are the sign changing switches which are necessary for reversing direction of unknown e.m.f. The unknown voltage is introduced using selector switch S_3 which is having 4 terminals.

⑤

The transformers T_1 & T_2 are step down transformers and they supply about 6 to 8 volts to potentiometer. By using variable resistor and capacitor, the supply for T_2 is obtained by adjusting R and C , quadrature is obtained.



Application of A.C. potentiometer :-

Similar to the d.c. potentiometer a.c. potentiometer can be used for the calibration of voltmeter, ammeter & used for testing of energy meter & wattmeter.

1. Calibration of voltmeter

The method of calibration with a.c. potentiometer is very much similar to that with d.c. potentiometer. If the working voltage is less than 1.5 v. it can be measured directly. If the voltage is very high than a.c. potentiometer must be used along with volt box (a) two capacitor in series for measurement of medium and high voltages respectively.

2) Calibration of ammeter:

The calibration of a.c. ammeter may be carried out by using non-inductive standard resistance and successively noting measurements of various alternating current through it. The process of calibrating ammeter using a.c. & d.c. potentiometer is same.

3) Testing of energy meter and wattmeter!

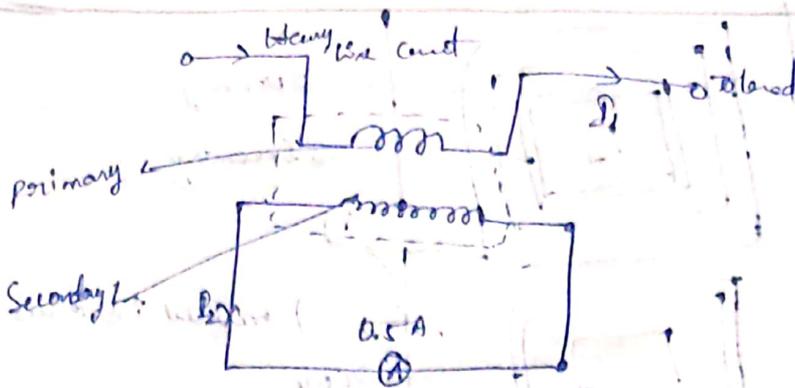
The practical set up for (measurement of self reactance of a coil) The testing of wattmeter and energy meter with a.c. potentiometer is similar to that of calibration of wattmeter with d.c. potentiometer only change in the set up is that a phase shifting transformer is included in potential varied with respect to the current. The energy meter and wattmeter may be tested at different power factor.

Current transformers (CT)

The large alternating current which cannot be sensed & passed through normal ammeter and current coils of wattmeter. The energy meter can easily be measured by use of current transformer along with normal low range instruments.

A transformer is a device which consists of two windings called primary and secondary. It transforms energy from one source to another with suitable change in the level of current (or) voltage. A current transformer basically has a primary coil of one or more turns of heavy cross sectional area. This is connected in series with the line carrying high current.

The secondary of the transformer is made up of a large number of turns of fine wire having small cross-sectional area. This is usually rated for 5A this is connected to the coil of normal range ammeter.



Working Principle:

These transformers are basically step up transformers, i.e. stepping up a voltage from primary to secondary. The current reduces from primary to secondary. So, from current point of view, they are step down transformers, stepping down the current value from primary to secondary.

N_1 = Primary turns

N_2 = Secondary turns

I_1 = Primary current

I_2 = Secondary current

$$\frac{I_1}{I_2} = \frac{N_2}{N_1}$$

Construction of current transformers:

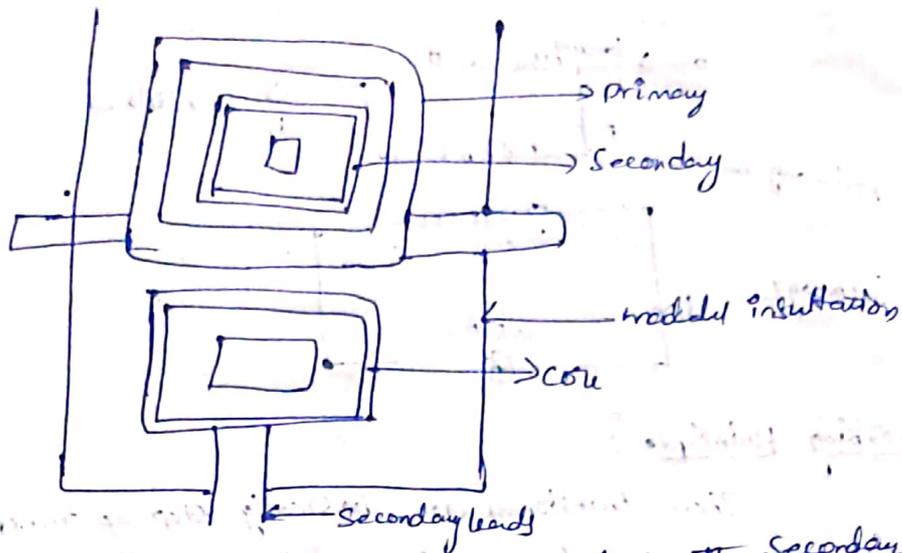
there are two types of construction

1) wound type

ii) Bar type

1) wound type current transformer

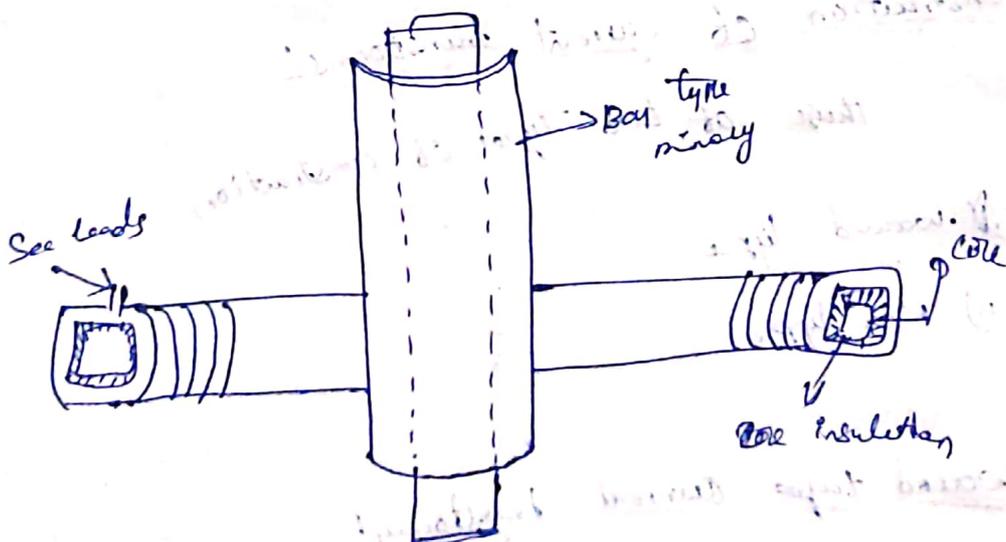
In wound type construction, the primary is wound more than the turns on the core.



In a low voltage sand type current transformer, the secondary winding is wound on a bakelite former. The heavy primary winding is directly wound on the top of the secondary winding with suitable insulation. In this case otherwise the primary is wound completely separately and then taped with suitable insulating material and assembled with the secondary on the core.

2) Bar type current transformer

In this type of CT the primary winding is nothing but a bar of suitable size.

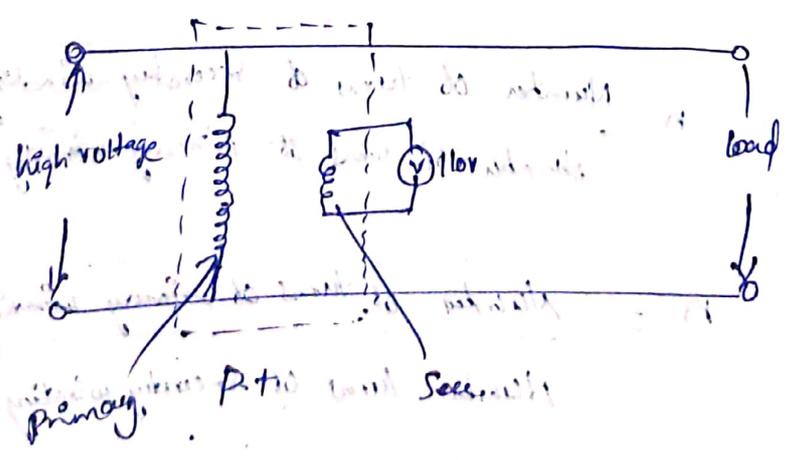


The insulation on the bar type primary is bit like paper tube or resin directly moulded on the bar. Such bar type primary is the integral part of the current transformer. The core and the secondary windings are same in bar type transformer. The stampings used to the laminations in current transformers must have high cross sectional area. than the ordinary transformer. The magnetizing current is also small. the windings are placed very close to each other so as to reduce the leakage reactance to avoid the core effect in bar type T/F

Potential Transformer :- (P.T)

The basic principle of these transformer is same as current transformers. the high alternating voltage are reduced in a fixed proportion to the measurement purpose with the help of potential transformer. The construction of these transformers the windings are low power rating windings. primary winding consists of large number of turns while secondary has less number of turns and usually rated for 110v. The primary is connected across the high voltage line while secondary is connected to the low range voltmeter coil. one end of the secondary is always grounded for safety purpose.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2}$$



Ratios of instrument transformer:

1) Actual ratio (R)

The actual transformation ratio is defined as the ratio of the magnitude of actual primary to the corresponding magnitude of actual secondary these.

$$R = \frac{\text{magnitude of actual primary current}}{\text{magnitude of actual secondary current}} \text{ for C.T}$$

$$R = \frac{\text{magnitude of actual primary voltage}}{\text{magnitude of actual secondary voltage}} \text{ for P.T}$$

the actual ratio is also called transformation ratio.

2) Nominal ratio (K_n)

The nominal ratio is defined as the ratio of rated primary quantity to the rated secondary quantity.

$$K_n = \frac{\text{Rated Primary Current}}{\text{Rated Secondary Current}} \text{ for C.T}$$

$$K_n = \frac{\text{Rated Primary Voltage}}{\text{Rated Secondary Voltage}} \text{ for P.T}$$

3) Turns ratio (n)

$$n = \frac{\text{Number of turns of secondary winding}}{\text{Number of turns of primary winding}} \text{ for C.T}$$

$$n = \frac{\text{Number of turns of primary winding}}{\text{Number turns of secondary winding}} \text{ for P.T}$$

Errors in CT :-

1) Ratio error

2) phase angle error

D. Ratio error :-

The current transformation ratio I_2/I_1 is equal to the turns to the turns ratio N_1/N_2 . But it is not so. The current ratio is not equal to turns ratio because of magnetizing and core loss components of the exciting current. It also get affected due to the secondary current and its power factor. The load current is not a constant fraction of the primary current.

Similarly in case of potential transformer, the voltage ratio V_2/V_1 is also not exactly equal to N_1/N_2 due to the factors mentioned above. The transformation ratio is not constant but depends on the load current power factor of load and exciting current of the transformer. Due to this fact large error is introduced in the measurements due by the CT. If such error is called ratio error.

$$\text{T Ratio error} = \frac{\text{Nominal ratio} - \text{Actual ratio}}{\text{Actual ratio}} \times 100$$

$$\% \text{ Ratio error} = \frac{k_n - R}{R} \times 100$$

Phase Angle error

In the power measurements, it is must that the phase of secondary current is to be displaced by exactly 180° from that of primary current to C.T while the phase of secondary voltage is to be displaced by exactly 180° from that of primary voltage to P.T but actually it is not. So the error introduced due to this fact is called phase angle error & denoted by angle θ by which the phase difference b/w primary and secondary is different from 180° .

The phase angle error is

$$\theta = \frac{180^\circ}{\pi} \left[\frac{I_m \cos \phi - I_c \sin \phi}{n I_s} \right]$$