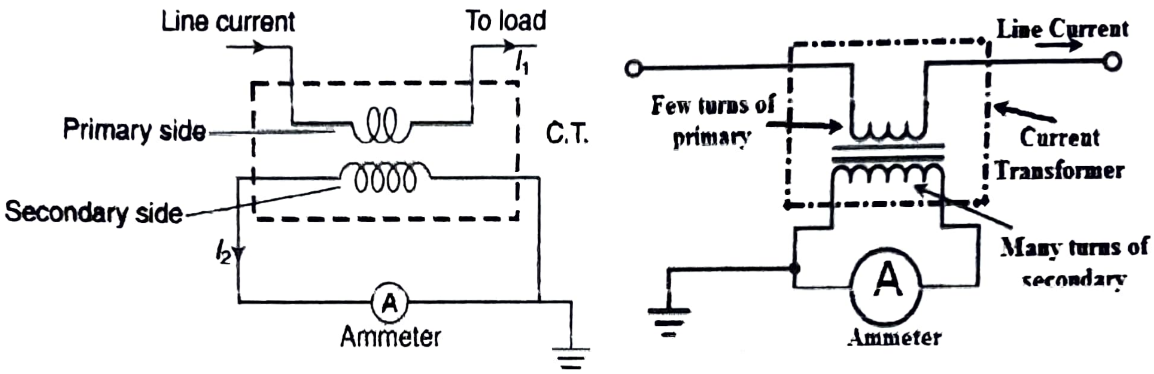
MODULE IV

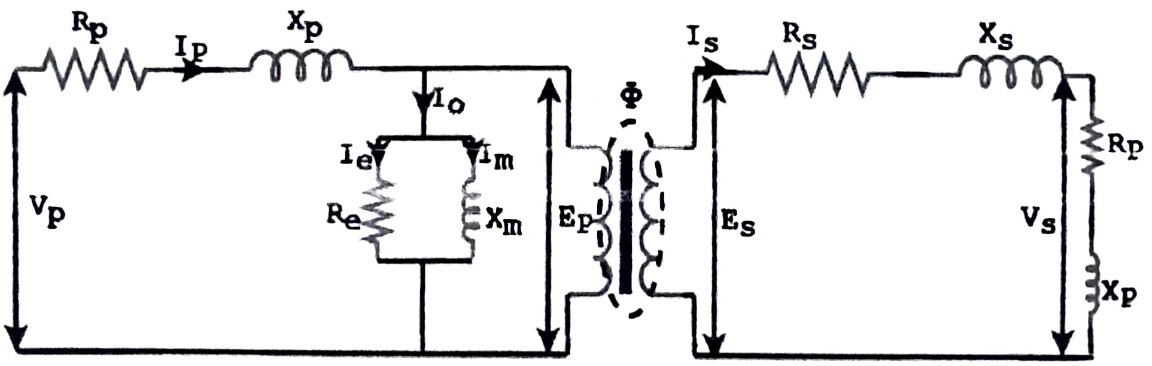
CURRENT TRANSFORMERS (CT):-

- The primary winding of a current transformer is connected in series with the line carrying the main current.
- The secondary winding of the CT, where the current is many times stepped down, is directly connected across an ammeter, for measurement of current; or across the current coil of a wattmeter, for measurement of power; or across the current coil of a watt-hour meter for measurement of energy; or across a relay coil.
- The primary winding of a CT has only few turns, such that there is no appreciable voltage drop across it, and the main circuit is not disturbed.
- The current flowing through the primary coil of a CT, i.e., the main circuit current is primarily determined by the load connected to the main circuit and not by the load
- One of the terminals of the CT is normally earthed to prevent any accidental damage to the operating personnel in the event of any incumbent insulation breakdown.



- When a typical name plate rating of a CT shows 500/5 A 10VA 5P20, it indicates that the CT rated primary and secondary currents are 500 A and 5 A respectively, its rated secondary burden is 5 VA, it is designed to have 5% accuracy and it can carry up to 20 times higher current than its rated value while connected in line to detect fault conditions,etc.urden) connected to the CT secondary.

Equivalent Circuit of Current Transformer(CT) :-



The CT primary has few turns, and it has very little resistance. Rp and Xp, respectively, denote the primary winding resistance and reactance. The secondary winding resistance and reactance are denoted by R_s and X_s, respectively. The magnetization components of the current transformer are Rc and X_m. R_c is responsible for the core loss component, and X_m is the magnetization reactance of CT.

Where,

n = *Turn ratio*

r_s = *Secondary winding resistance*

X_s = *Secondary winding reactance*

r_e = *Burden connected to CT secondary*

X_e = *Burden reactance connected to CT secondary*

E_p = *Induced EMF in CT primary*

E_s = *Induced EMF in CT secondary*

N_p = *Primary turns of CT*

N_s = *Secondary turns of CT*

I_p = *CT primary current*

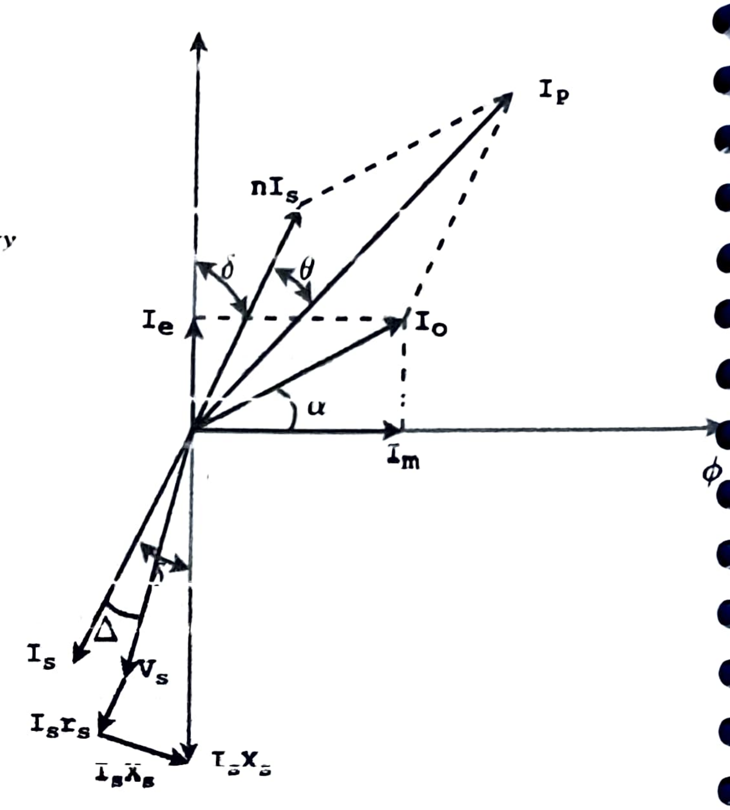
I_s = *CT secondary current*

I_m = *CT Magnetizing current*

I_o = *CT excitation current*

ϕ = *Flux in CT core*

θ = *Phase angle of CT*



The current transformer has two types of errors.

- Ratio Error
- Phase Angle Error

CT Transformation Ratio

To find the transformation ratio, we need to calculate the primary current Ip, as per the definition, and divide it by the secondary current Is.

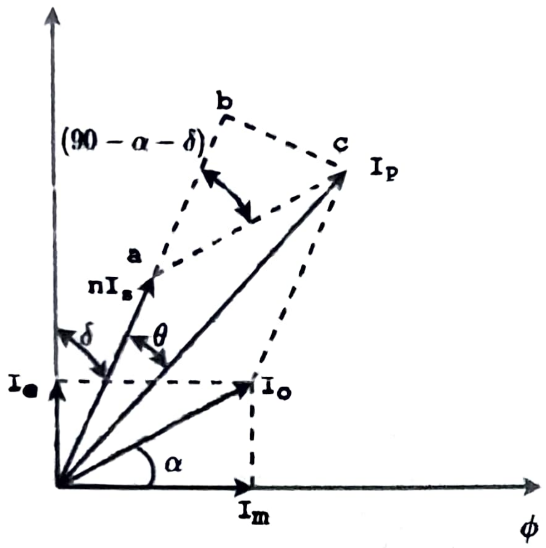
$$n = \frac{I_p}{I_s}$$

Ratio Error of Current Transformer

In an ideal current transformer, the primary current (Ip) should equal the multiplication of the secondary current and the turns ratio of CT. However, the secondary current does not vary in the same proportion as the increase in primary current and secondary current is less than the nominal secondary current. The error in the CT due to the difference in the current from its rated nominal ratio is called the current error or ratio error. The ratio error in a current transformer is due to magnetizing current, core loss current, leakage reactance, and burden impedance.

The CT ratio Error is defined as the per unit deviation in transformation ratio from its nominal ratio. Ratio error is expressed in percentage.

$$Ratio\ error = \frac{Nominal\ ratio - Transformation\ ratio}{Transformation\ ratio} X\ 100$$



From the above phasor, the primary current Ip is the phasor sum of nI_s and I_0. The CT primary current Ip can be calculated using the vector addition formula.

$$I_p = \sqrt{I_0^2 + (nI_s)^2 + 2\,I_o\,nI_s\,Cos(90 - \alpha - \delta)}$$

$$I_p = \sqrt{I_0^2 + (nI_s)^2 + 2\,I_o\,nI_s\,Sin(\alpha + \delta)}$$

The CT Ratio is equal to ratio of I_p / Is

$$R = \frac{I_p}{Is}$$

$$R = \frac{\sqrt{I_0^2 + (nI_s)^2 + 2\,I_o\,nI_s\,Sin(\alpha + \delta)}}{I_s}$$

The magnetizing current Io is very small compared to the primary current I_p. Therefore, the above expression can be simplified as follows.

$$R = \frac{\sqrt{I_0^2 + (nI_s)^2 + 2\,I_o\,nI_s\,Sin(\alpha + \delta)}}{I_s}$$

$$R = \frac{\sqrt{[(nI_s)^2 + \left(I_0 Sin(\alpha + \delta)\right)^2 + (2\,I_o\,nI_s\,Sin(\alpha + \delta)]}}{I_s}$$

$$R = \frac{\sqrt{\left[nI_s + \left(I_0 Sin(\alpha + \delta)\right)\right]^2}}{I_s}$$

$$R = \frac{nI_s + I_0 Sin(\alpha + \delta)}{I_s}$$

$$R = n + \frac{I_0 Sin(\alpha + \delta)}{I_s}$$

$$R = n + \frac{I_o}{I_s}\,Sin(\alpha + \delta)$$

From the above expression, it is clear that the transformation ratio is not equal to the turn ratio. The transformation ratio and turn ratio will be equal if α=0 and δ=0.This condition can be achieved **if the core loss is equal to zero and the burden is purely resistive.** This is an **ideal condition. However**, this condition is practically impossible.

#Ratio Error of Current Transformer for Resistive Burden

Since the burden of the CT is generally resistive. Therefore, the power factor of the burden is unity, and hence δ=0

$$R = n + \frac{I_o Sin(\alpha + \delta)}{I_s}$$

$$\delta = 0 \; for \; resitive \; burden$$

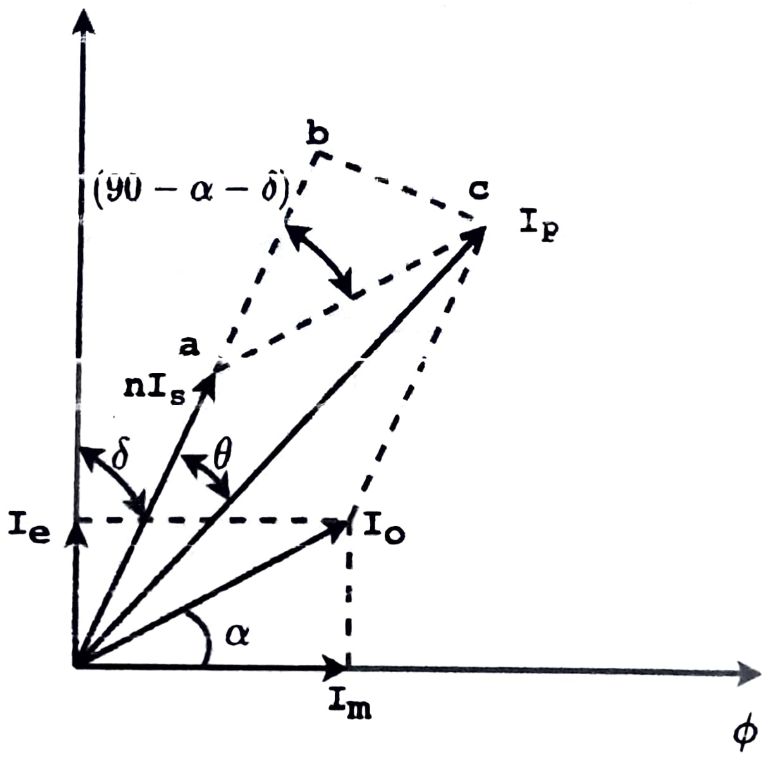
$$R = n + \frac{I_o Sin\alpha}{I_s}$$

$$R = n + \frac{I_e}{i_s} \qquad Since \; [\, I_o Sin\alpha = I_e \,]$$

Phase Angle Error of the Current Transformer:-

The primary and secondary current of the CT should be out of phase, meaning the phase angle between the primary and secondary must be 180 degrees. Any deviation in the phase angle from 180 degrees is called the **phase angle error of the CT.**

The phase angle of the current transformer is defined as the angle between the primary current Ip and secondary current I_s. In the above phasor diagram, θ is the phase angle.



Consider the right angle triangle ABC in the above phasor diagram.

$$\tan\theta = \frac{bc}{ob}$$

$$= \frac{I_0 Sin(90 - \alpha - \delta)}{oa + ab}$$

$$= \frac{I_0 Cos(\alpha + \delta)}{[nI_s + I_0 Sin(\alpha + \delta)]}$$

Since θ is very small, so $\tan\theta = \theta$

$$\theta = \frac{I_0 Cos(\alpha + \delta)}{[nI_s + I_0 Sin(\alpha + \delta)]}$$

Also I_0 *is very small and,* $I_0 Sin(\alpha + \delta) \lll nI_s$

hence $I_0 Sin(\alpha + \delta)$ *can be neglected*

$$\theta = \frac{I_0 Cos(\alpha + \delta)}{nI_s}$$

$$\theta = \frac{I_0 (Cos\alpha\, Cos\delta - Sin\alpha\, Sin\delta)}{nI_s}$$

$$\theta = \frac{I_0\, Cos\alpha\, Cos\delta - I_0 Sin\alpha\, Sin\delta}{nI_s}$$

From Phasor, $I_0 Cos\alpha = I_m$ *and* $I_0 Sin\alpha = I_e$

$$\theta = \frac{I_m\, Cos\delta - I_e\, Sin\delta}{nI_s}\ Radians$$

$$\theta = 180/\pi \frac{(I_m\, Cos\delta - I_e\, Sin\delta)}{nI_s}\ Degree$$

Phase Angle Error of Current Transformer For Resistive Burden

The phase angle between the primary and secondary of the current transformer must be 180 degrees. The primary and secondary current must be out of phase. The phase angle error is the deviation in the phase angle of the primary and secondary current. The phase angle between the primary and secondary current of the CT is denoted by angle θ.

Since the CT burden is generally resistive, the power factor of the burden is unity, and hence δ=0. The following expression gives the phase angle error of CT.

$$\theta = 180/\pi \frac{(I_m\, Cos\delta - I_e\, Sin\delta)}{nI_s}$$

$$\theta = 180/\pi \frac{(I_m\, Cos0 - I_e\, Sin0)}{nI_s}$$

$$\theta = \left(\frac{180}{\pi}\right)\frac{I_m}{nI_s}\ Degree$$

Causes of Errors in CT:-

In an ideal CT, the actual transformation ratio should have been exactly equal to the turns ratio andthe phase angle should have been zero. However, due to inherent physical limitations to the electric and magnetic circuits of the CT, practical performance deviates from these ideal behaviors and errors are introduced in measurement. The reasons for these errors are given here.

- Primary winding always needs some magnetising MMF to produce flux and, therefore, the CT draws the magnetising current IM.
- CT no-load current must have a component Ic that has to supply the core losses, i.e., the eddy current loss and the hysteresis loss.
- Once the CT core becomes saturated, the flux density in the core no longer remains a linear function of the magnetising force, this may introduce further errors.
- Primary and secondary flux linkages differ due to unavoidable flux leakages.

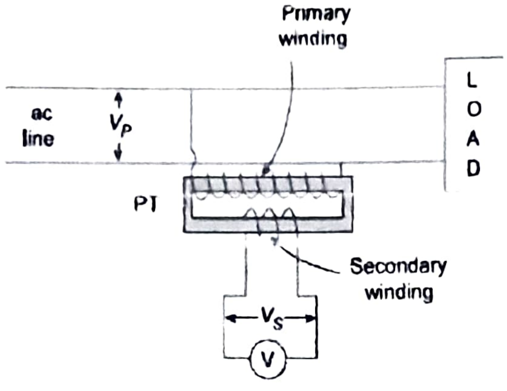
Reducing Errors in CT:-

Errors are produced in the ratio and phase angle of a CT owing to the presence of the no-load component of the primary current. Improvement of accuracy, then, depends upon minimizing this component or nullifying in some way its effects in introducing errors. The most obvious idea would be to attempt to keep the magnetizing current component as small as possible. This can be achieved by a combination of the following schemes:

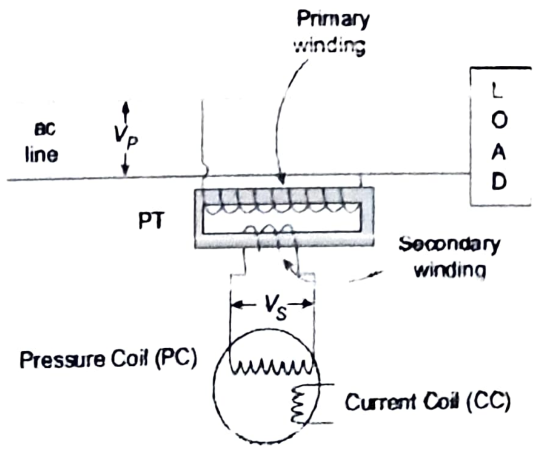
- **Low Flux Density**
  The magnetising component of current may be restricted by using low values of flux density. This may be achieved by using large cross-section for core. For this reason, CTs are normally designed with much lower flux densities as compared to a normal power transformer.
- **High Permeability Core Material**
  The magnetising component of current may be made small by the use of high permeability core material. 50% Fe + 50% Ni has high permeability at low flux densities along with reasonably high saturation density value. It is used frequently as core material for manufacturing CTs.
- **Modification of Turns Ratio**
  The accuracy of current transformers may be improved, at least in terms of transformation ratio, by suitably modifying the actual number of turns.
- **Use of Shunts**
- If the secondary current is found to be too high, it may be reduced by a shunt placed across the primary or secondary. Use of shunts can also help in reducing the phase-angle error.
- **Wound-Core Construction**
  An improvement in the magnetisation characteristics of the CT core may be achieved by the use of wound-core construction. This type of construction for the core has been in use for some time in distribution transformers. By special treatment of the silicon steel to be used as core material, and by using it to carry flux always in the direction of grain orientation (rolling the sheet steel in proper way), magnetic properties of the core can be largely improved. This improvement may be utilised in CTs to reduce the ratio and phase angle errors.

POTENTIAL TRANSFORMERS (PT):-

- The primary winding of the PT is connected across the high-voltage line whose voltage is to be measured and the measuring instruments are connected across the secondary of the PT.

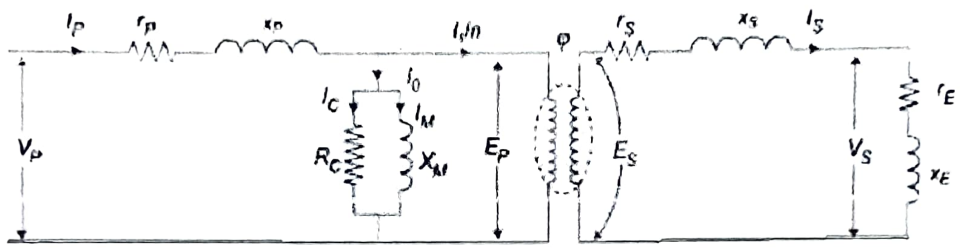


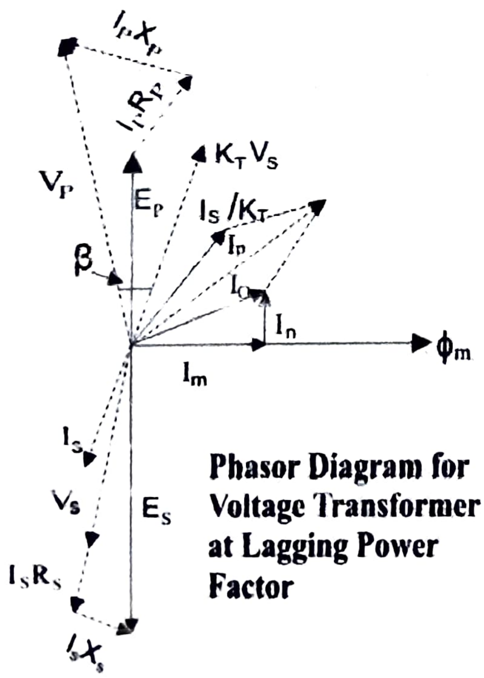
(a)



(b)

Equivalent circuit:-

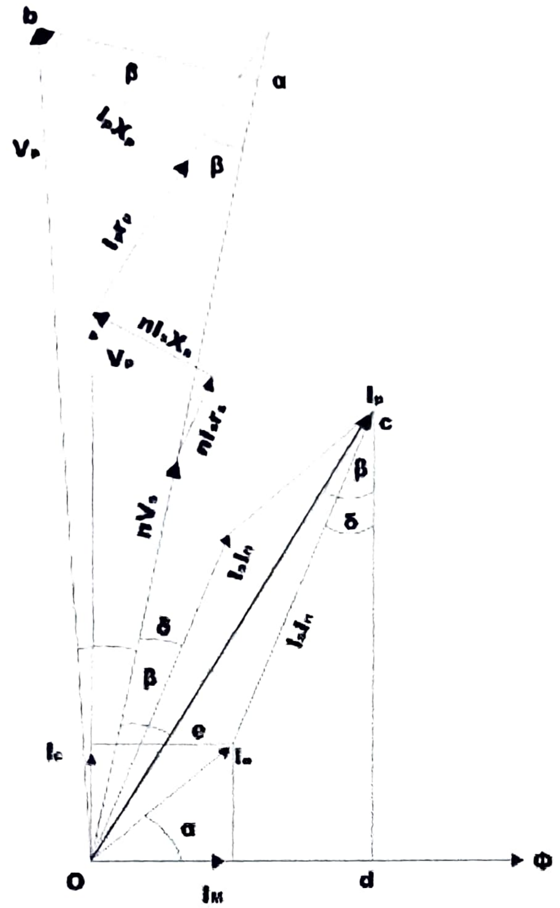




Phasor Diagram for Voltage Transformer at Lagging Power Factor

I_s = Secondary current.
E_s – Secondary induced emf.
V_s – Secondary terminal voltage.
R_s – Secondary winding resistance.
X_s – Secondary winding reactance.
I_p – Primary current.
E_p – Primary induced emf.
V_p – Primary terminal voltage.
R_p – Primary winding resistance.
X_p – Primary winding reactance.
K_T – Turns ratio = Numbers of primary turns/number of secondary turns.
I_0 – Excitation current.
I_m – Magnetizing component of I_0.
I_w – Core loss component of I_0.
Φ_m – Main flux.
β – Phase angle error.

Expanded view of Phasor Diagram



The phase angle between the primary voltage and the secondary voltage is called the phase angle of PT. *This phase angle is ideally equal to zero because these two phasors are in* same phase.

From the phasor diagram we have,

$$V_p = E_p + I_pR_p + I_pX_p = nE_s + I_pR_p + I_pX_p$$

$$V_p = n(V_s + I_sR_s + I_sX_s) + I_pR_p + I_pX_p = nV_s + nI_sR_s + nI_sX_s + I_pR_p + I_pX_p$$

$$O_a = V_p \cos \Theta$$

$$O_a = nV_s + nI_sR_s \cos \delta + nI_sX_s \sin \delta + I_pR_p \cos \beta + I_pX_p \sin \Theta$$

$$V_p \cos \Theta = nV_s + nI_sR_s \cos \delta + nI_sX_s \sin \delta + I_pR_p \cos \beta + I_pX_p \sin \beta$$

$$V_p \cos \Theta = nV_s + nI_s(R_s \cos \delta + X_s \sin \delta) + I_pR_p \cos \beta + I_pX_p \sin \beta \qquad (1)$$

But in reality, the phase angle is very small and the primary and secondary voltage are perpendicular to the flux and then;

<ocd = β and <ecd = δ

Then

$I_p \cos\beta = I_c + \frac{I_s}{n}\cos\delta$ *and* $I_p \sin\beta = I_M + \frac{I_s}{n}\sin\delta$ (2)

Hence $V_p\cos\Theta = V_p$

Then,

Substituting the above value from eq 1 we get

$V_p = nV_s + nI_s(R_s\cos\delta + X_s\sin\delta) + (I_c + \frac{I_s}{n}\cos\delta)R_p + \left(I_m + \frac{I_s}{n}\sin\delta\right)X_p$

Or

$$V_p = nV_s + I_s\cos\delta\left(nr_s + \frac{R_p}{n}\right) + I_s\sin\delta\left(nX_s + \frac{X_p}{n}\right) + (I_cR_p + I_mX_p) \quad (3)$$

Or

$$V_p = nV_s + \frac{I_s}{n}(R_p\cos\delta + X_p\sin\delta) + (I_cR_p + I_mX_p) \quad (4)$$

Where R_e is equivalent resistance of PT and X_e equivalent reactance of PT.

Phase Angle of Potential Transformer (PT)

From the phasor diagram the terms Ip and Is are less compared to large voltage and these terms are neglected thus we get:

$$\tan\theta = \frac{I_pX_p\cos\beta - I_pR_p\sin\beta + nI_sX_s\cos\delta - nI_sR_s\sin\delta}{nV_s} \quad (5)$$

$$\tan\theta = \frac{X_p\left(I_c + \frac{I_s}{n}\cos\delta\right) - R_p\left(I_m + \frac{I_s}{n}\sin\delta\right) + nI_sX_s\cos\delta}{nV_s}$$

$$\tan\theta = \frac{I_s\cos\delta\left(\frac{X_p}{n} + nX_s\right) - I_s\sin\delta\left(\frac{R_p}{n} + nR_s\right) + I_cX_p - I_mR_p}{nV_s}$$

$$\tan\theta = \frac{(\frac{I_s\cos\delta}{n}(X_p + n^2X_s) - \frac{I_s\sin\delta}{n}(R_p + n^2R_s) + I_cX_p - I_mR_p}{nV_s}$$

$$\tan\theta = \frac{\frac{I_s\cos\delta}{n}X_p - \frac{I_s\sin\delta}{n}R_p + I_cX_p - I_mR_p}{nV_s}$$

$$\tan\theta = \frac{\frac{I_s}{n}(X_p\cos\delta - R_p\sin\delta) + I_cX_p - I_mR_p}{nV_s}$$

Let tan o = o, then

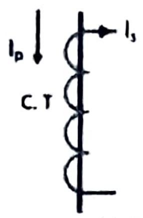
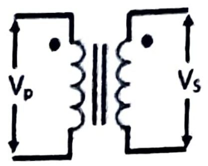
$$\theta = \frac{\frac{I_s}{n}(n^2 X_s \cos\delta - R_p \sin\delta) + I_c X_p - I_m R_p}{nV_s} \quad (6)$$

$$\theta = \frac{\frac{I_s}{n}(n^2 X_s \cos\delta - n^2 R_s \sin\delta) + I_c X_p - I_m R_p}{nV_s}$$

$$\theta = \frac{nI_s(X_s \cos\delta - R_s \sin\delta) + I_c X_p - I_m R_p}{nV_s}$$

So, the phase angle Θ is:

$$\theta = \frac{I_s}{V_s}(X_s \cos\delta - R_s \sin\delta) + \frac{I_c X_p - I_m R_p}{nV_s} \quad (7)$$

Basis for Comparison	**Current Transformer**	**Potential Transformer**
Definition	Transform the current from high value to the low value.	Transform the voltage from high value to the low value.
Circuit Symbol		
Core	Usually built up with lamination of silicon steel.	It is made up of with high quality steel operating at low flux densities
Primary Winding	It carries the current which is to be measured	It carries the voltage which is to be measured.
Secondary Winding	It is connected to the current winding of the instrument.	It is connected to the meter or instrument.
Connection	Connected in series with the instrument	Connected in parallel with the instrument.
Primary Circuit	Has a small number of turns	Has a large number of turns
Secondary Circuit	Has a large number of turns and cannot be open circuit.	Has a small number of turns and can be open circuit.
Range	5A or 1A	110v
Transformation Ratio	High	Low
Burden	Does not depends on secondary burden	Depends on the secondary burden
Input	Constant current	Constant Voltage
Full line current	The primary winding consists the full line current.	The primary winding consists the full line voltage.
Types	Two types (Wound and Closed Core)	Two types (Electromagnetic and Capacitor voltage)
Impedance	Low	High
Applications	Measuring current and power, monitoring the power grid operation, for operating protective relay,	Measurement, power source, operating protective relay,

MODULE IV

POTENTIOMETER

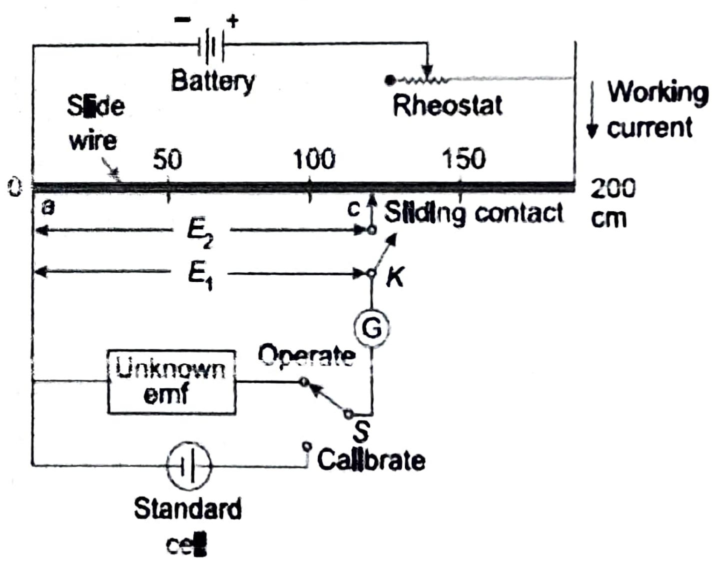
A potentiometer is an instrument which is used for measurement of potential difference across a known resistance or between two terminals of a circuit or network of known characteristics.

Some important characteristics of a potentiometer are the following:

1) A potentiometer measures the unknown voltage by comparing it with a known voltage source rather than by the actual deflection of the pointer. This ensures a high degree of accuracy.
2) As a potentiometer measures using null or balance condition, hence no power is required for the measurement.
3) Determination of voltage using a potentiometer is quite independent of the source resistance.
   - Since a potentiometer measures voltage by comparing it with a standard cell, it can be also used to measure the current simply by measuring the voltage drop produced by the unknown current passing through a known standard resistance.
   - By the potentiometer, power can also be calculated and if the time is also measured, energy can be determined by simply multiplying the power and time of measurement. Thus potentiometer is one of the most fundamental instruments of electrical measurement.

DC potentiometer :-

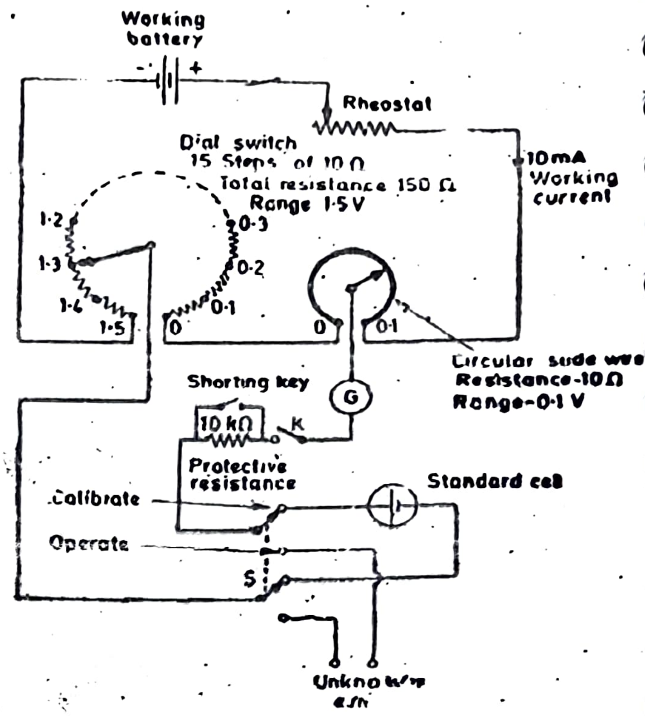
Operation:-



- First, the switch S is put in the 'operate' position and the galvanometer key K kept open, the battery supplies the working current through the rheostat and the slide wire. The working current through the slide wire may be varied by changing the rheostat setting.
- The method of measuring the unknown voltage, E1, depends upon the finding a position for the sliding contact such that the galvanometer shows zero deflection, i.e., indicates null condition, when the galvanometer key K is closed.
- Zero galvanometer deflection means that the unknown voltage E1 is equal to the voltage drop E2, across position a–c of the slide wire. Thus, determination of the values of unknown voltage now becomes a matter of evaluating the voltage drop E2 along the portion a–c of the slide wire.

- When the switch S is placed at ' calibrate' position, a standard or reference cell is connected to the circuit. This reference cell is used to standardize the potentiometer.

Laboratory-Type CROMPTON'S DC POTENTIOMETER:-



Basic slide wire dc potentiometer has the following disadvantages.

- The slide wire is linear and hence occupies more space which is not practical.
- If the length is decreased then resolution of the potentiometer decreases as voltage per unit length increases.
- So Crompton potentiometer is used in practice to decrease the size without compromising the resolution (smallest measurable voltage).
- It consists of a dial switch which has fifteen (or more) steps. Each steep has 10 Ω resistance. So the dial switch has total 150 Ω resistance.
- The working current of this potentiometer is 10 mA and therefore each step of the dial switch corresponds to 0.1 volt. So the range of the dial switch is 1.5 volt.
- The dial switch is connected in series with a circular slide wire. The circular slide wire has 10 Ω resistance. So the range of that slide wire is 0.1 volt. The slide wire calibrated with 200 scale divisions and since the total resistance of slide wire corresponds to a voltage drop of 0.1 volt, each division of the slide wire corresponds (0.1÷200)=0.0005 volt .
- With this Crompton's potentiometer it is possible to estimate the reading up to 0.0001 volt.

Procedure for Measurement of Unknown emf :-

- At first, the combination of the dial switch and the slide wire is set to the standard cell voltage. Let the standard sell voltage be 1.0175 volts, then the dial resistor is put in 1.0 volt and the slide wire at 0.0175 volts setting.
- The switch 'S' is thrown to the calibrate position and the galvanometer switch 'K' is pressed until the rheostat is adjusted for zero deflection on the galvanometer.
- The 10 kW protective resistance is kept in the circuit in the initial stages so as to protect the galvanometer from overload.
- After the null deflection on the galvanometer is approached the protective resistance is shorted so as to increase the sensitivity of the galvanometer. Final adjustment is made for the zero deflection with the help of the rheostat. This completes the standardisation process of the potentiometer.

- *After completion of the standardisation, the switch 'S' is thrown to the operate* position thereby connecting the unknown emf into the potentiometer circuit. With the protective resistance in the circuit, the potentiometer is balanced by means of the main dial and the slide wire adjustment.
- As soon as the balanced is approached, the protective resistance is shorted and final adjustments are made to obtain true balance.
- After the final true balance is obtained, the value of the unknown emf is read off directly from the setting of the dial switch and the slide wire.
- The standardisation of the potentiometer is checked again by returning the switch 'S' to the calibrate position. The dial setting is kept exactly the same as in the original standardisation process. If the new reading does not agree with the old one, a second measurement of unknown emf must be made. The standardisation again should be made after the measurement.

AC POTENTIOMETER :-

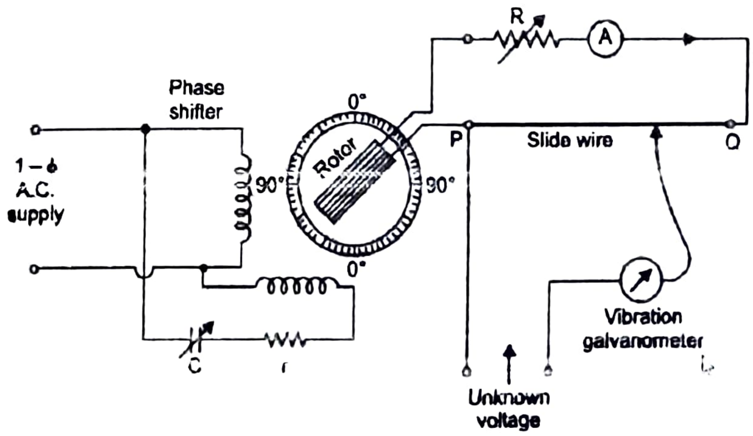
An ac potentiometer is same as dc potentiometer by principle. Only the main difference between the ac and dc potentiometer is that, in case of dc potentiometer, only the magnitude of the unknown emf is compared with the standard cell emf, but in ac potentiometer, the magnitude as well as phase angle of the unknown voltage is compared to achieve balance.

The following points need to be considered for the satisfactory operation of the ac potentiometer:

- To avoid error in reading, the slide wire and the resistance coil of an ac potentiometer should be non-inductive.
- The reading is affected by stray or external magnetic field, so in the time of measurement they must be eliminated or measured and corresponding correction factor should be introduced.
- The sources of ac supply should be free from harmonics, because in presence of harmonics the balance may not be achieved.
- The ac source should be as sinusoidal as possible.

Drysdale Polar Potentiometer :-

- The slide wire S1–S2 is supplied from a phase shifting circuit for ac measurement.
- The phase shifting circuit is so arranged that the magnitude of the voltage supplied by it remains constant while its phase can be varied through 360°. Consequently, slide wire current can be maintained constant in magnitude but varied in phase.



- *The phase shifting circuit consists of two stator coils connected in parallel supplied from the same source; their currents are made to differ by 90° by using very accurate phase shifting technique.*
- The two windings produce rotating flux which induces a secondary emf in the rotor winding which is of constant magnitude but the phase of which can be varied by rotating the rotor in any position. The phase of the rotor emf is read from the circular dial attached in the potentiometer.
- Before the ac measurement, the potentiometer is first calibrated by using dc supply for slide wire and standard cell for test terminals T1 and T2. The unknown alternating voltage to be measured is applied across test terminals and the balance is achieved by varying the slide wire contact and the position of the rotor.
- The ammeter connected in the slide wire circuit gives the magnitude of the unknown emf and the circular dial in the rotor circuit gives the phase angle of it.

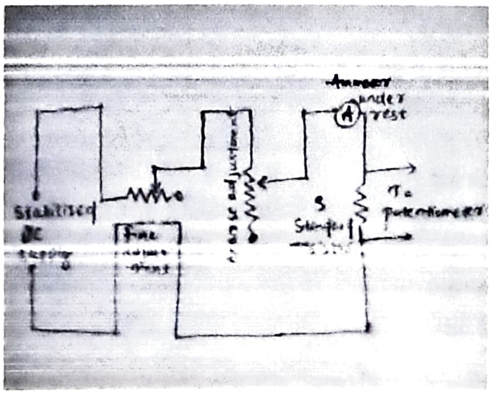
APPLICATIONS OF dc POTENTIOMETERS

Practical uses of dc potentiometers are

- Measurement of current
- Measurement of high voltage
- Measurement of resistance
- Measurement of power
- Calibration of voltmeter
- Calibration of ammeter
- Calibration of wattmeter

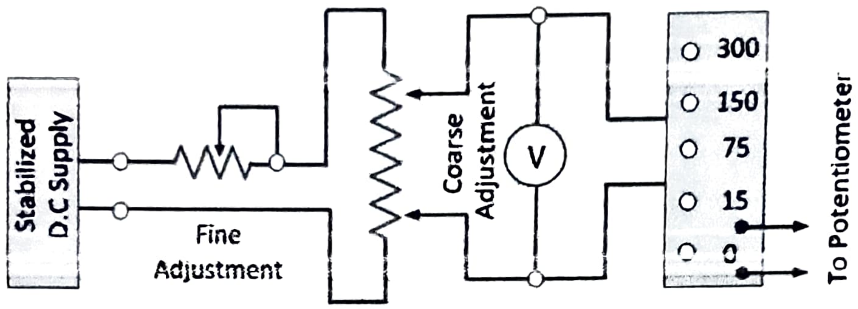
Calibration of Ammeter by Potentiometer :-

- Now, compare the reading of the ammeter with the current found by calculation. If they do not match, a positive or negative error will be induced.
- A calibration curve may be drawn between the ammeter reading and the true value of the current as indicated by the potentiometer reading.
- As the resistance of the standard resistor *S* is exactly known, the current through *S* is exactly calculated. This method of calibration of ammeter is very accurate.



Calibration of Voltmeter by Potentiometer :-

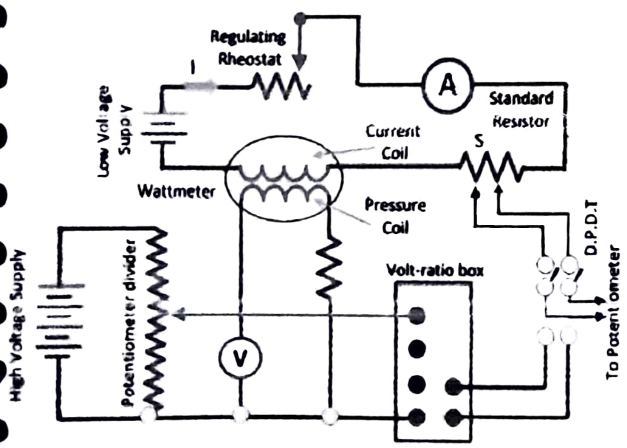
- The potential divider network consists of two rheostats. One for coarse and the other for fine control of calibrating voltage. The voltage across the voltmeter is steeped down to a value suitable for the potentiometer with the help of the volt–ratio box.
- *In order to get accurate measurements, it is necessary to measure voltages near the maximum range of the potentiometer, as far as possible.*
- The potentiometer measures the true value of the voltage. If the reading of the potentiometer does not match with the voltmeter reading, a positive or negative error is indicated. A calibration curve may be drawn with the help of the potentiometer and the voltmeter reading.



Calibration of Voltmeter with Potentiometer

Calibration of Wattmeter by Potentiometer :-

- The current coil of the wattmeter is supplied from low voltage supply and the potential coil from the normal supply through the potential divider.
- The voltage *V* across the potential coil of the wattmeter under calibration is measured *directly by the potentiometer. The current through the current coil is measured by* measuring the voltage across a standard resistor connected in series with the current coil divided by the value of the standard resistor.



Calibration of Wattmeter with a DC Pontentioemter

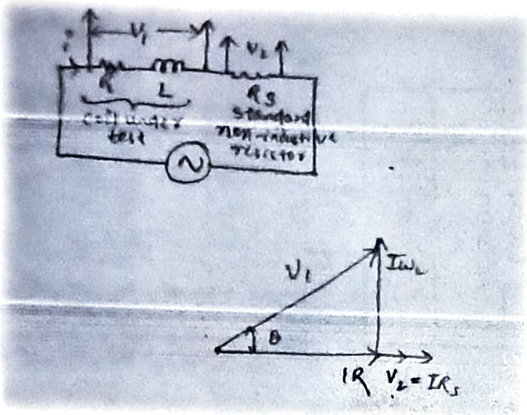
- The true power is then *VI*, where *V* is the voltage across the potential coil and *I* is the current through the current coil of the wattmeter. The wattmeter reading may be compared with this value, and a calibration curve may be drawn.

APPLICATIONS OF AC POTENTIOMETER :-

The major applications of the ac potentiometers are

1. Measurement of self-inductance
2. Calibration of voltmeter
3. Calibration of ammeter
4. Calibration of wattmeter

Measurement of Self-Inductance :-



or, $I = \frac{V_2}{R_S}$

Voltage drop across inductive coil = V_1

Phase angle between voltage across and current through the coil = θ

Voltage drop due to resistance of coil, $IR = V_1 \cos\theta$

$$\therefore \text{ resistance of the coil, } R = \frac{V_1 \cos\theta}{I} = \frac{V_1 \cos\theta}{\frac{V_2}{R_S}} = \frac{R_S V_1 \cos\theta}{V_2}$$

Voltage drop due to inductance of coil, $I\omega L = V_1 \sin\theta$

$$\therefore \text{ inductance of the coil, } L = \frac{V_1 \sin\theta}{I\omega} = \frac{V_1 \sin\theta}{\omega\left(\frac{V_2}{R_S}\right)} = \frac{R_S V_1 \sin\theta}{V_2 \omega}$$

Calibration of Wattmeter :-

- The current coil of the wattmeter is supplied through stepdown transformer and the potential coil from the secondary of a variable transformer whose primary is supplied from the rotor of a phase shifting transformer.

- *The voltage V across the potential coil of the wattmeter and the current I through the* current coil of wattmeter are measured by the potentiometer, introducing a volt–ratio box and a standard resistor.
- The power factor cos *q* is varied by rotating the phase shift rotor, the phase angle between voltage and current, F being given by the reading on the dial of the phase shifter.
- The power is then *VI* cos F and the wattmeter reading may be compared with this reading.
- A calibration curve may be drawn if necessary. A small mutual inductance *M* is included to ensure accuracy of measurement of zero power factor.

AC POTENTIOMETER

Advantages

1. An ac potentiometer is a very versatile instrument. By using shunt and volt–ratio box, it can measure wide range of voltage, current and resistances.
2. As it is able to measure phase as well as magnitude of two signals, it is used to measure power, inductance and phase angle of a coil, etc.
3. The principle of ac potentiometer is also incorporated in certain special application like Arnold circuit for the measurement of CT (Current Transformer) errors.

Disadvantages

1. A small difference in reading of the dynamometer instrument either in dc or ac calibration brings on error in the alternating current to be set at standard value.
2. *The normal value of the mutual inductance M is affected due to the introduction of mutual inductances of various potentiometer parts and so a slight difference is observed* in the magnitude of the current of quadrature wire with compared to that in the in–phase potentiometer wire.
3. Inaccuracy in the measured value of frequency will also result in the quadrature potentiometer wire current to differ from that of in–phase potentiometer wire.

PYQ'S ASKED IN MID & END SEMESTER EXAMINATIONS

MODULE IV

2MARKERS

1) Draw the phasor diagram of current transformer.
2) Why the secondary of CT is never kept open ?

4MARKERS

1) What is the role of current transformer ? Derive the expression for turns ratio error and phase angle error of CT?
2) Derive the expression for turns ratio error and phase angle error of PT?
3) Why Potentiometer is used ? Explain the working of Crompton potentiometer .
4) Differentiate between AC and DC potentiometer.

NUMERICALS (teacher special)

1) A CT has one turn primary and 200 turns secondary windings . The secondary carries a current of 5 A passing through a secondary burden of 1 ohm . The flux is set up in the core by the current of 80 A . The frequency is 50 Hz and area of cross section is 1000 sq-mm. calculate the actual transformation ratio and phase angle for the transformer.