Instrument Transformers

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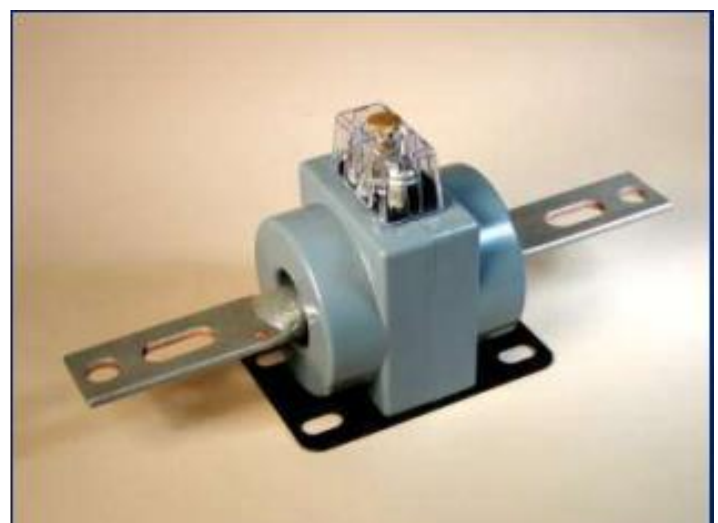

Topics

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Topics

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Introduction

- In power system, the currents and voltages are very large – Therefore, their direct measurements are not possible.
- It might appear that the extension of range could be conveniently done by the use of shunts for currents and multiplier for voltage measurement, as in DC. – But this method is suitable only for small values of current and voltage.

Current Transformer :

Line current 200A

5A or 1A

Introduction

- Difficult to achieve accuracy with a shunt on AC
- Capability of having shunt of large range is not possible
- The power consumed by multipliers become large as the voltage increases
- The measuring circuit is not isolated electrically from the power circuit

Introduction

- The solution is to step -down these currents/voltages with the help of Instrument Transformer – So that, they could be metered with instruments of moderate size

Introduction

These are special type of transformers used for the measurement of voltage, current, power and energy. As the name suggests, these transformers are used in conjunction with the relevant instruments such as ammeters, voltmeters, watt meters and energy meters.

Introduction

- **Instrument Transformers** are used in AC system for measurement of electrical quantities i.e. voltage, current, power, energy, power factor, frequency.
- **Instrument transformers** are also used with protective relays for protection of power system.

Introduction

- Basic function of **Instrument transformers** is to step down the AC System voltage and current.
- The voltage and current level of power system is very high.
- It is very difficult and costly to design the measuring instruments for measurement of such high level voltage and current.
- Generally measuring instruments are designed for 5 A and 110 V.

Introduction

- The measurement of such very large electrical quantities, can be made possible by using the Instrument transformers with these small rating measuring instruments.
- Therefore these instrument transformers are very popular in modern power system.

Types of Instrument Transformer

Such transformers are of two types :

1. Current Transformer (or Series Transformer)
2. Potential Transformer (or Parallel Transformer)

Current transformers are used when the magnitude of AC currents exceeds the safe value of current of measuring instruments.

Potential transformers are used where the voltage of an AC circuit exceeds 750 V as it is not possible to provide adequate insulation on measuring instruments for voltage more than this.

Uses of Instrument Transformer

It is used for the following two as:

1. To insulate the high voltage circuit from the measuring circuit in order to protect the measuring instruments from burning
2. To make it possible to measure the high voltage with low range voltmeter and high current with low range ammeter.

These instrument transformers are also used in controlling and protecting circuits, to operate relays, circuit breakers etc. The working of these transformers are similar as that of ordinary transformers.

Primary applications

- Instrument transformers are used: metering (for energy billing and transaction purposes)
- Protection control (for system protection and protective relaying purposes)
- Load survey (for economic management of industrial loads)

Use of Instrument Transformer

Measurement of current as CT

The primary winding is so connected that the current to be measured passes through it and the secondary is connected to the ammeter .

The function of CT is to step down the current.

Use of Instrument Transformer

- Depending on the requirements for those applications, the IT design and construction can be quite different.
- Protection ITs require linearity in a wide range of voltages and currents.
- Typical output levels of instrument transformers are 1-5 amperes and 115-120 volts for CTs and VTs, respectively.

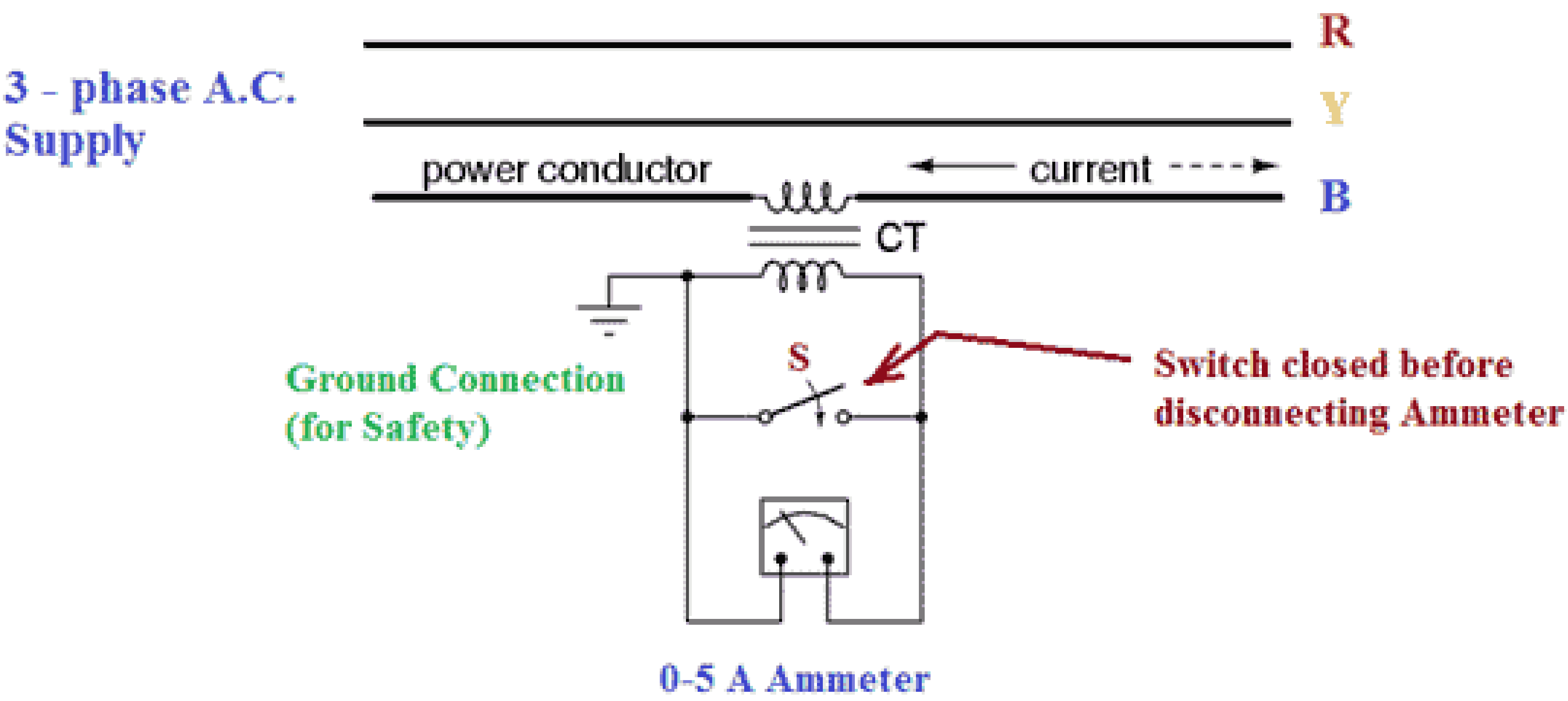
Use of Instrument Transformer

- During a disturbance, such as system fault or overvoltage transients, the output of the IT is used by a protective relay to initiate an appropriate action (open or close a breaker, reconfigure the system, etc.) to mitigate the disturbance and protect the rest of the power system.
- Instrument transformers are the most common and economic way to detect a disturbance.

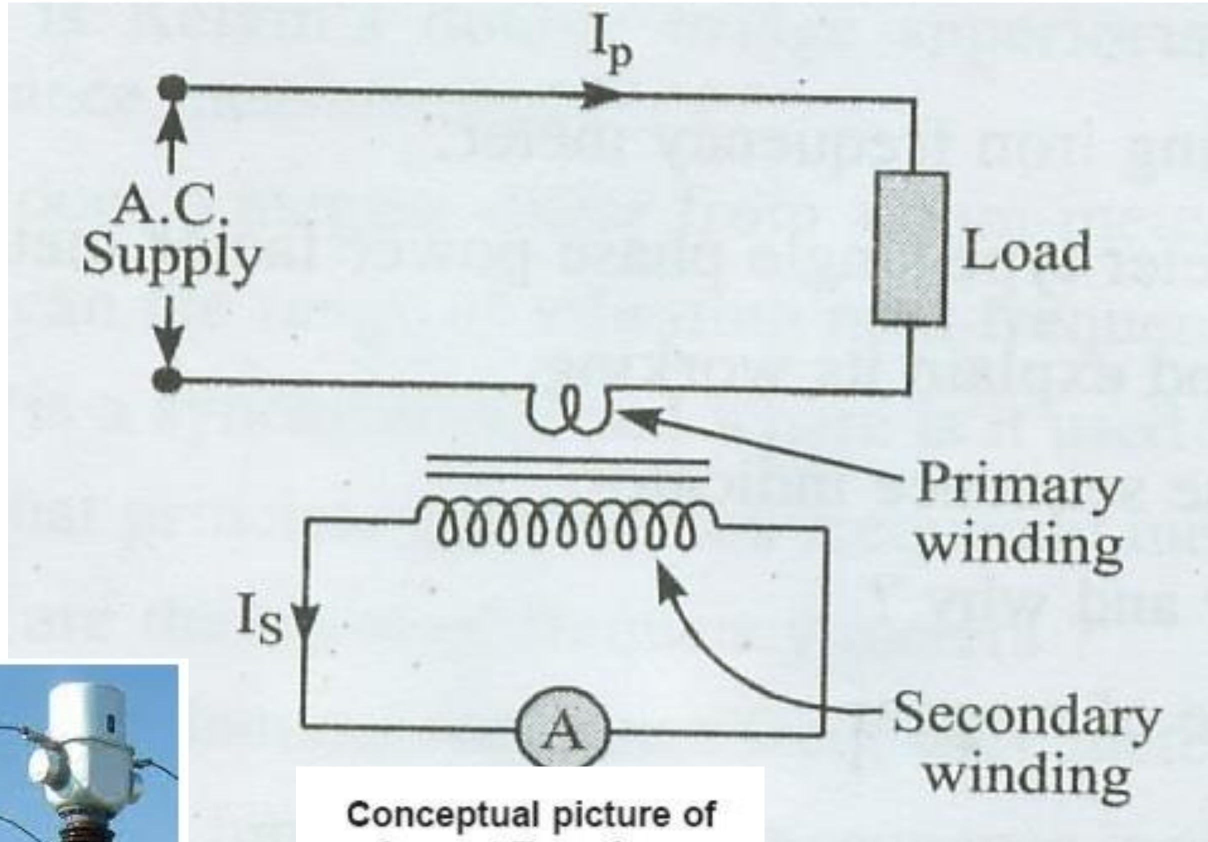
Current Transformers

- Current transformer is used to step down the current of power system to a lower level to make it feasible to be measured by small rating Ammeter (i.e. 5A ammeter). A typical connection diagram of a current transformer is shown in figure below.

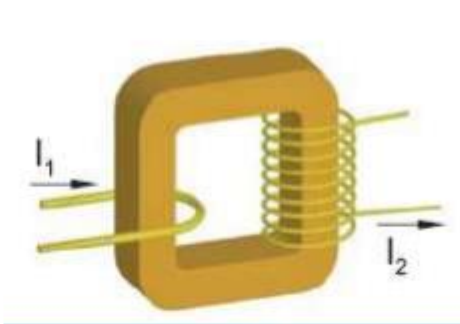
Connection diagram of a Current Transformers



Instrument Transformer as CT



Conceptual picture of
a Current Transformer



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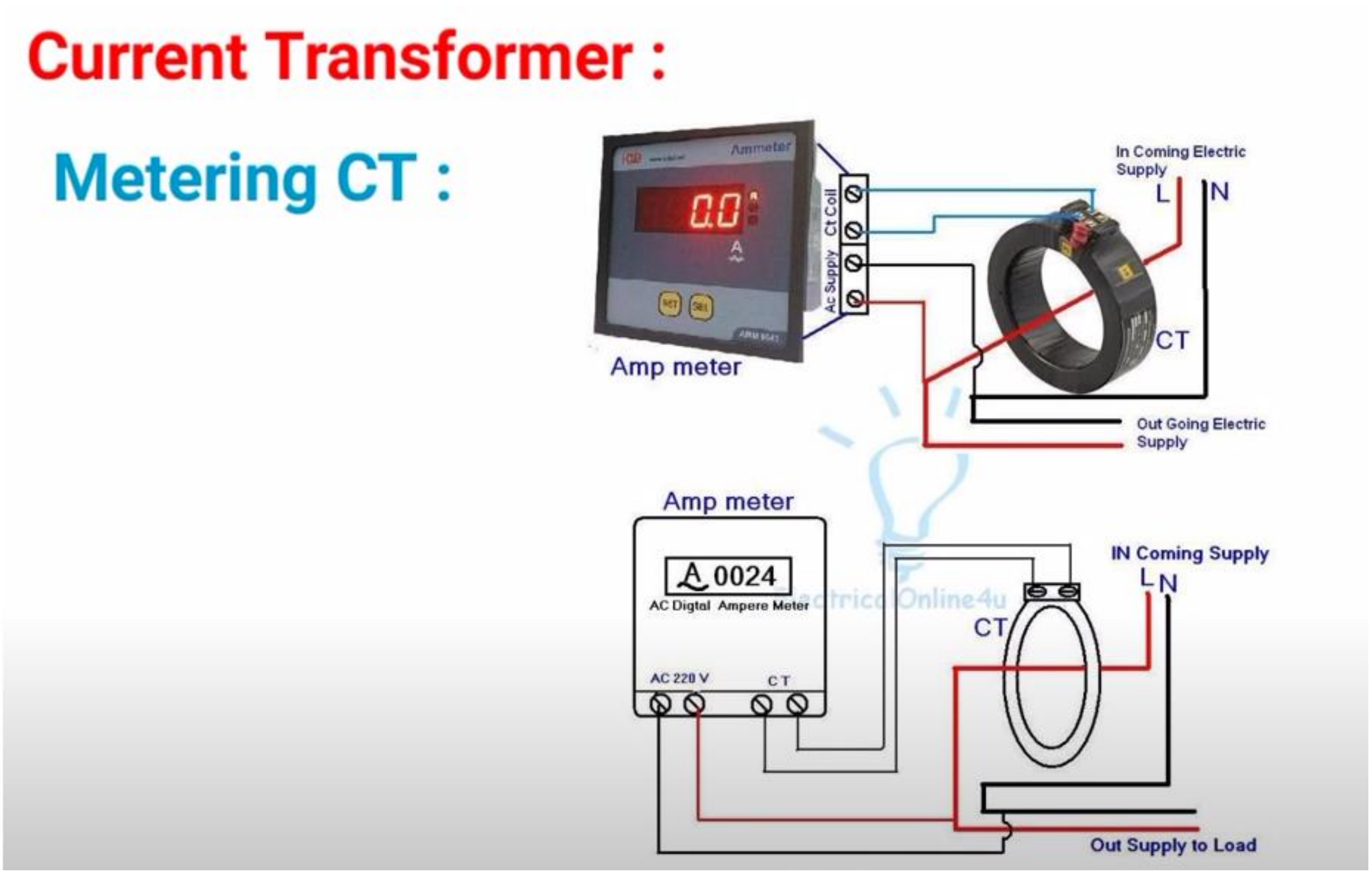
Current Transformers

- Primary of C.T. is having very few turns. Sometimes bar primary is also used.
- Primary is connected in series with the power circuit.
- Therefore, sometimes it also called **series transformer**.
- The secondary is having large no. of turns. Secondary is connected directly to an ammeter.
- As the ammeter is having very small resistance.
- Hence, the secondary of current transformer operates almost in short circuited condition.

Current Transformers

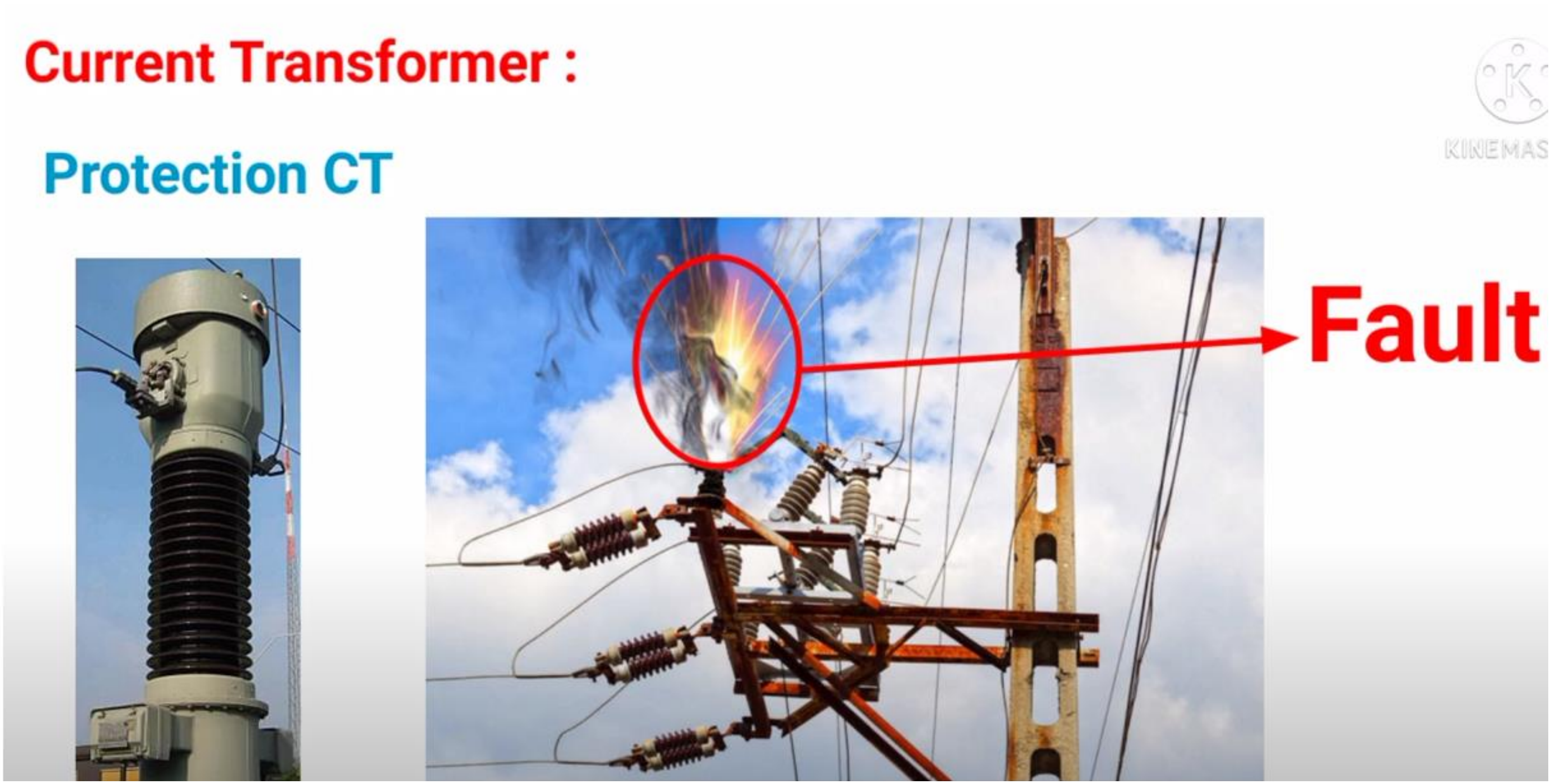
- One terminal of secondary is earthed to avoid the large voltage on secondary with respect to earth. Which in turns reduce the chances of insulation breakdown and also protect the operator against high voltage.
- More ever before disconnecting the ammeter, secondary is short circuited through a switch 'S' as shown in figure above to avoid the high voltage build up across the secondary.

Uses of CT

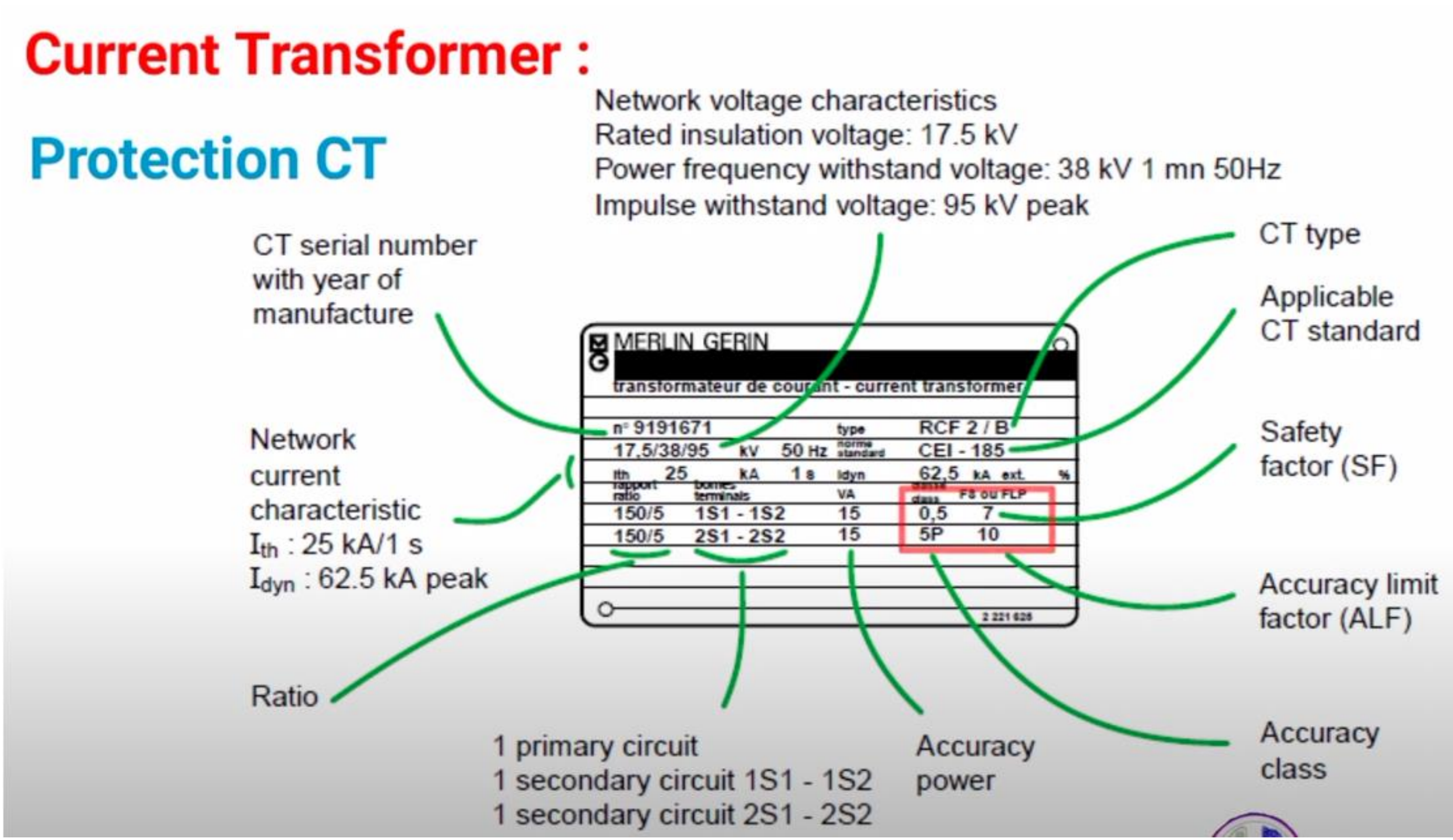


Current Transformer :
Metering CT :
Ammeter
0.0
A
Ct Coil
Ac Supply
Amp meter
In Coming Electric Supply
L
N
CT
Out Going Electric Supply
Amp meter
0024
AC Digtal Ampere Meter
AC 220 V
C T
CT
IN Coming Supply
L
N
Out Supply to Load

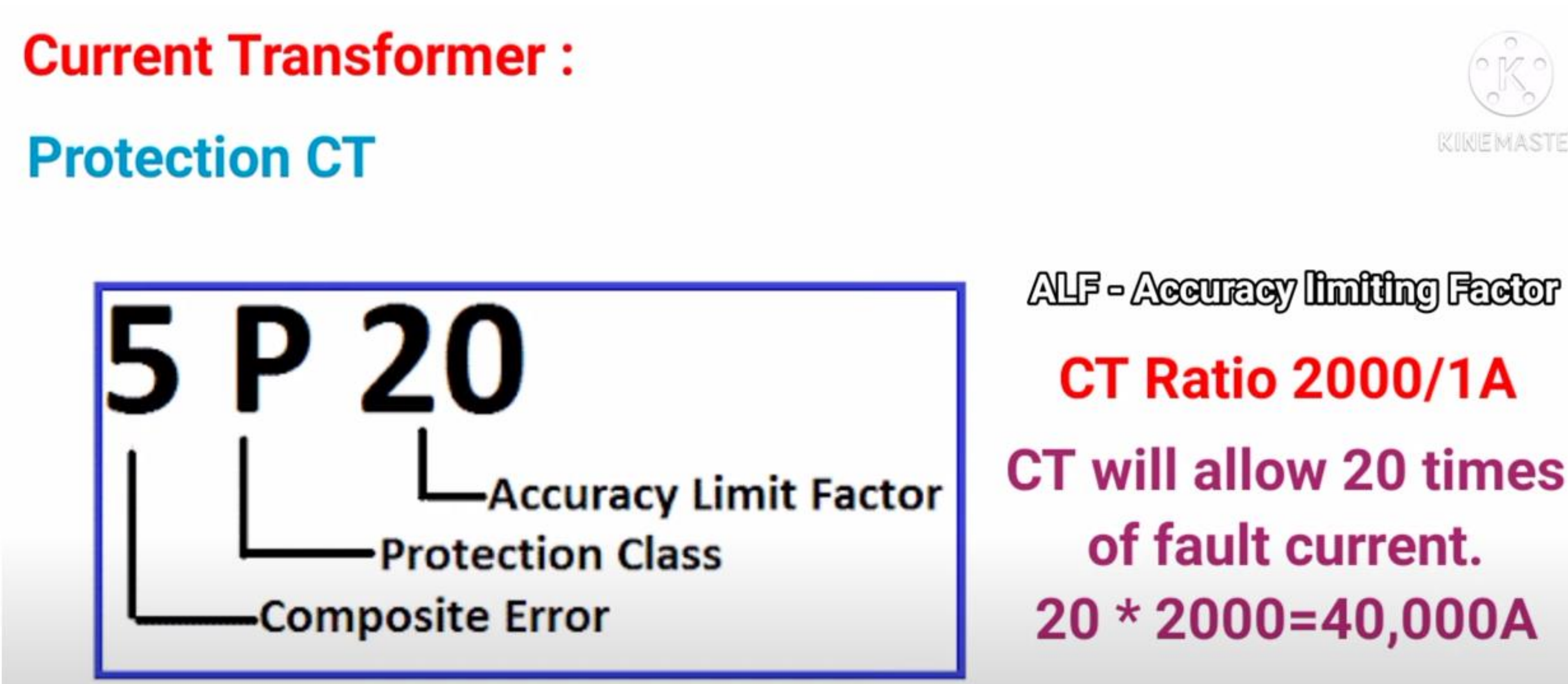
Uses of CT



How to identify protection CT?



How to identify protection CT?



How to identify meteringCT?

Accuracy Class	% Ratio error at % rated Current			
	5	20	100	120
0.2	0.75	0.35	0.2	0.2
0.2S	0.75	0.2	0.2	0.2

CT Ratio 200/1A

±0.2 → 0.8A or 1.2A

Why CT Secondary Should not be Open ??
Why CT Secondary Side Should be Shorted??
SVERKER 650
HIOKI
S1
S2

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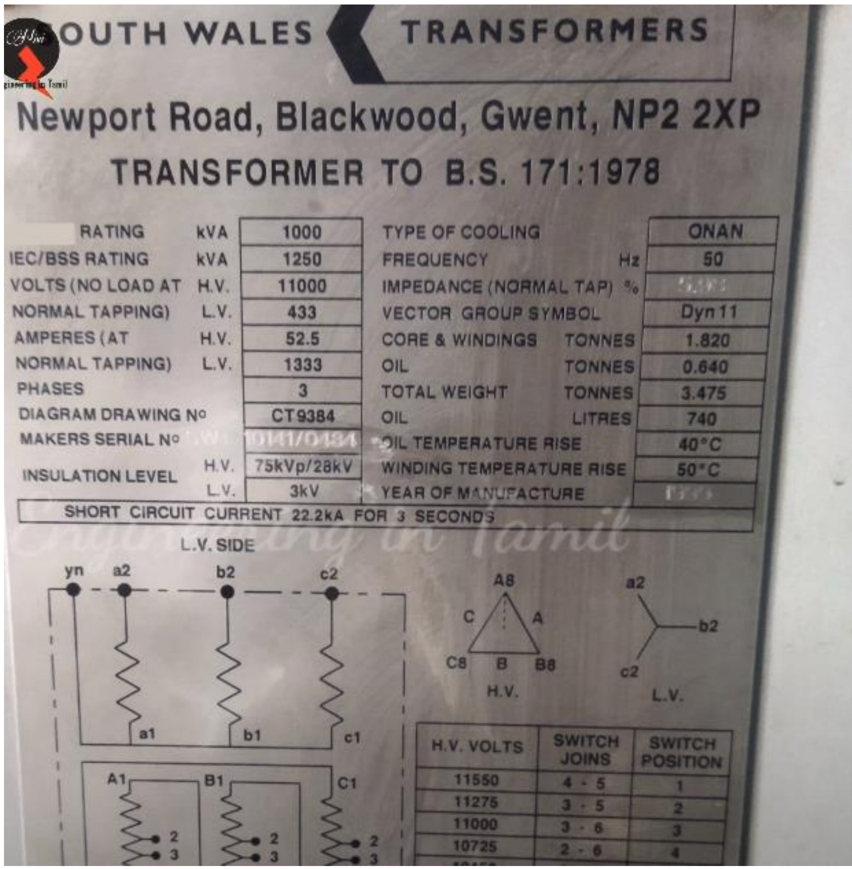


1000 KVA 11Kv/433V

Primary voltage - 11000(11kv)

Primary current - 52.2 A

Secondary voltage - 433 V

Secondary current - 1333 A

Primary = Secondary

VA VA

$$11000 \times 52.5 = 433 \times 1333$$

$$577500 = 577189$$

Current Transformer Ratio 100/1 A

Rated voltage - 11Kv

Primary voltage - 11000 V

Primary current - 100 A

Secondary - Voltage ??

Secondary - 1A

Primary = Secondary

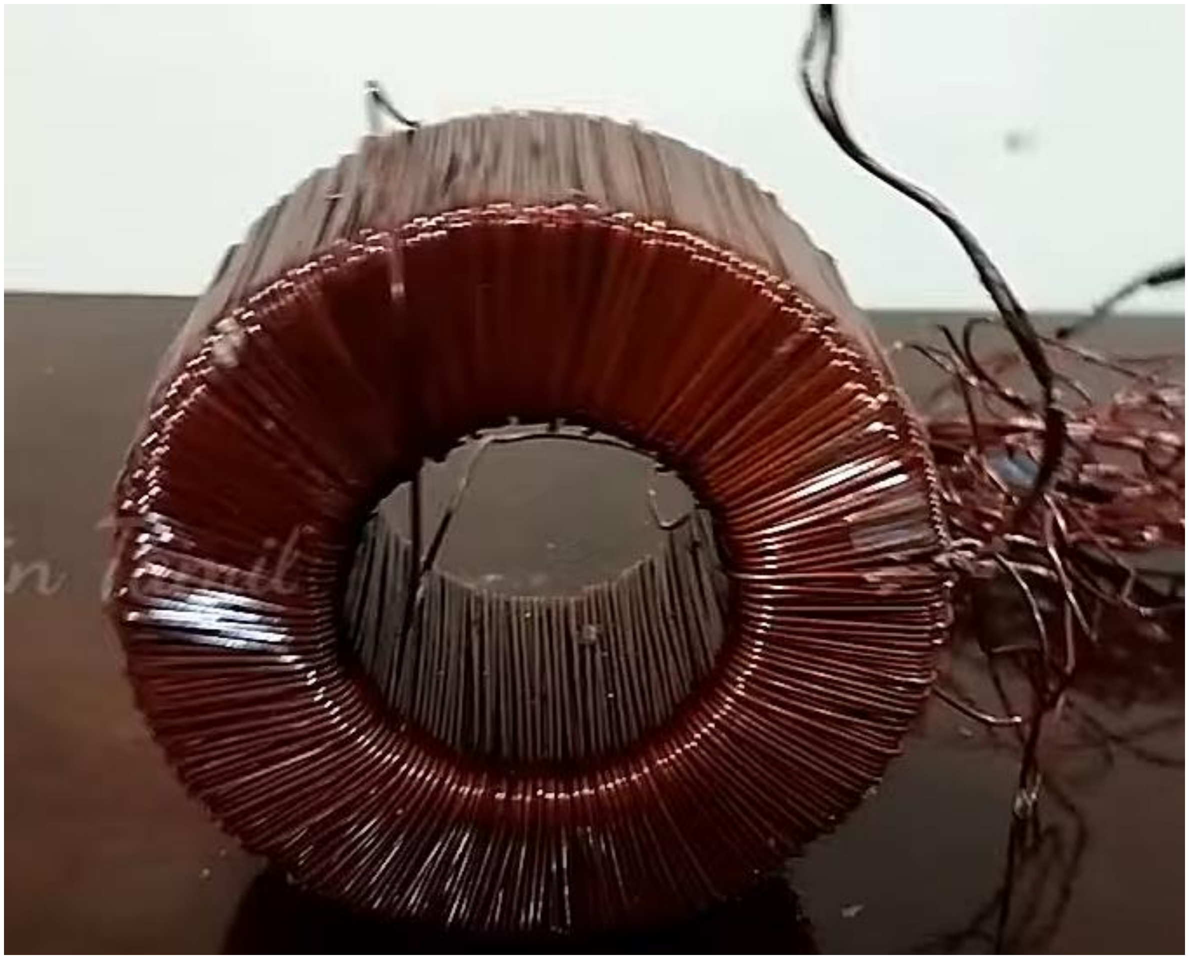
VA VA

11000x100 = Vs x1

1100000 = Vs

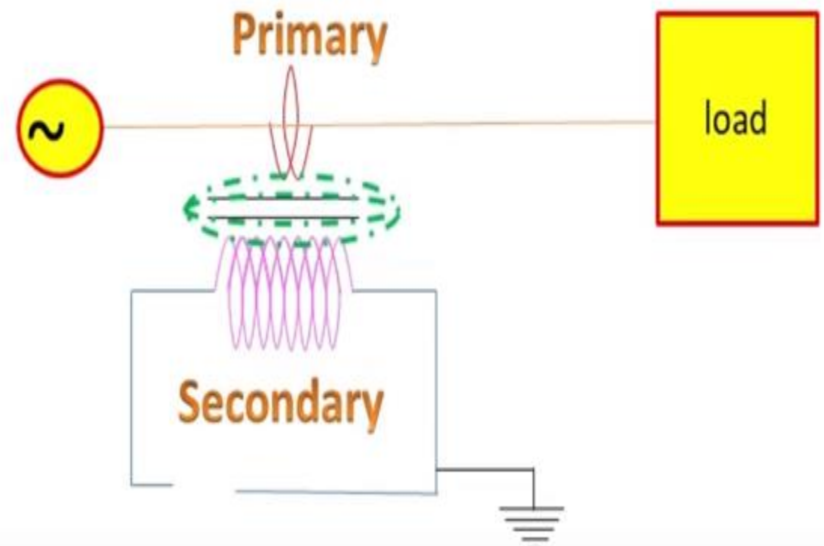
Ct Secondary - 1100000 V

CT Winding – low voltage insulation design



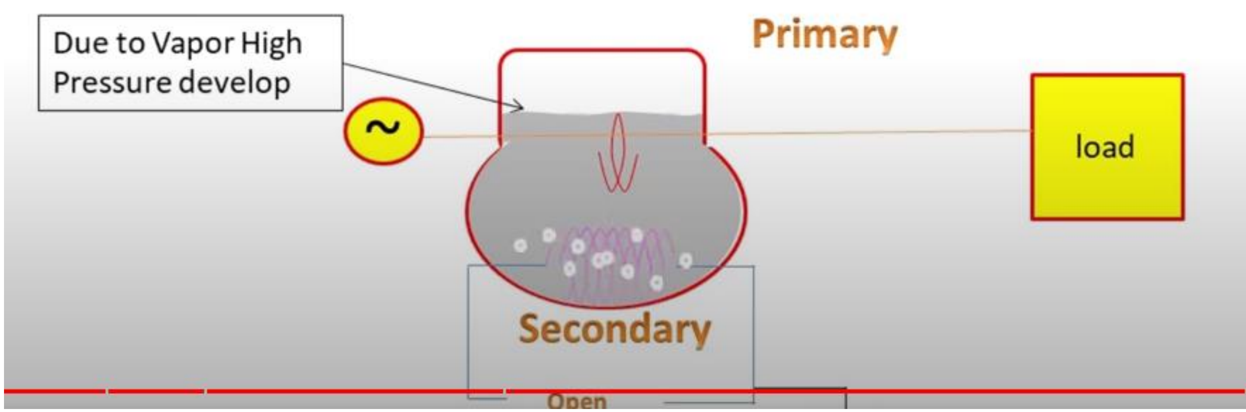
Effect of CT Secondary open

1. More Heat will produced in CT due to Core losses
2. During any fault condition Secondary Voltage will become very high and CT get Saturated
3. During high load CT secondary TB will get spark and melt
4. Due to high Voltage Insulation in CT get damage.
5. Due to Insulation Damage fire can produce
6. Mal-operation in Protection relay.



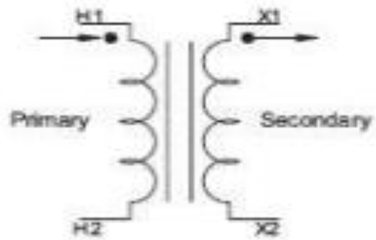
When secondary kept open?

1. More Heat will produced in CT due to Core losses.
2. Due to high voltage insulation will get damage and it have chance of burning.
3. Only in Oil fill CT have chance of blasting due Over heating by core losses and also may be insulation failure cause burning and heat which lead to oil boil and get vapor which lead to blast



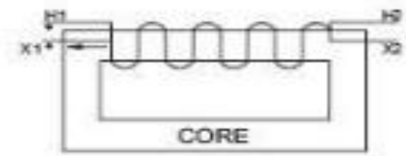
TYPES OF CONSTRUCTION

Current Transformer



Current Example
5.5 Amperes
Ratio 1:1

Voltage Transformer



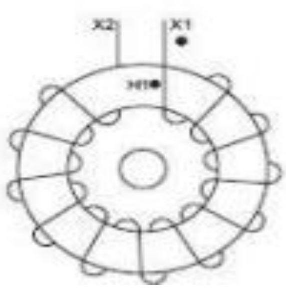
Voltage Example
Primary 7200 Volts
Ratio 60:1 or 7200:120 Volts

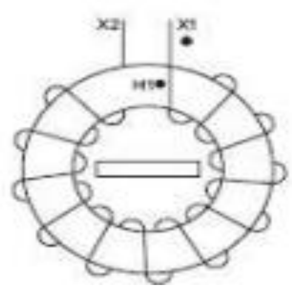
Construction Types

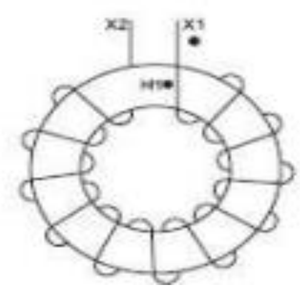
Window-type

Bar-type

Wound

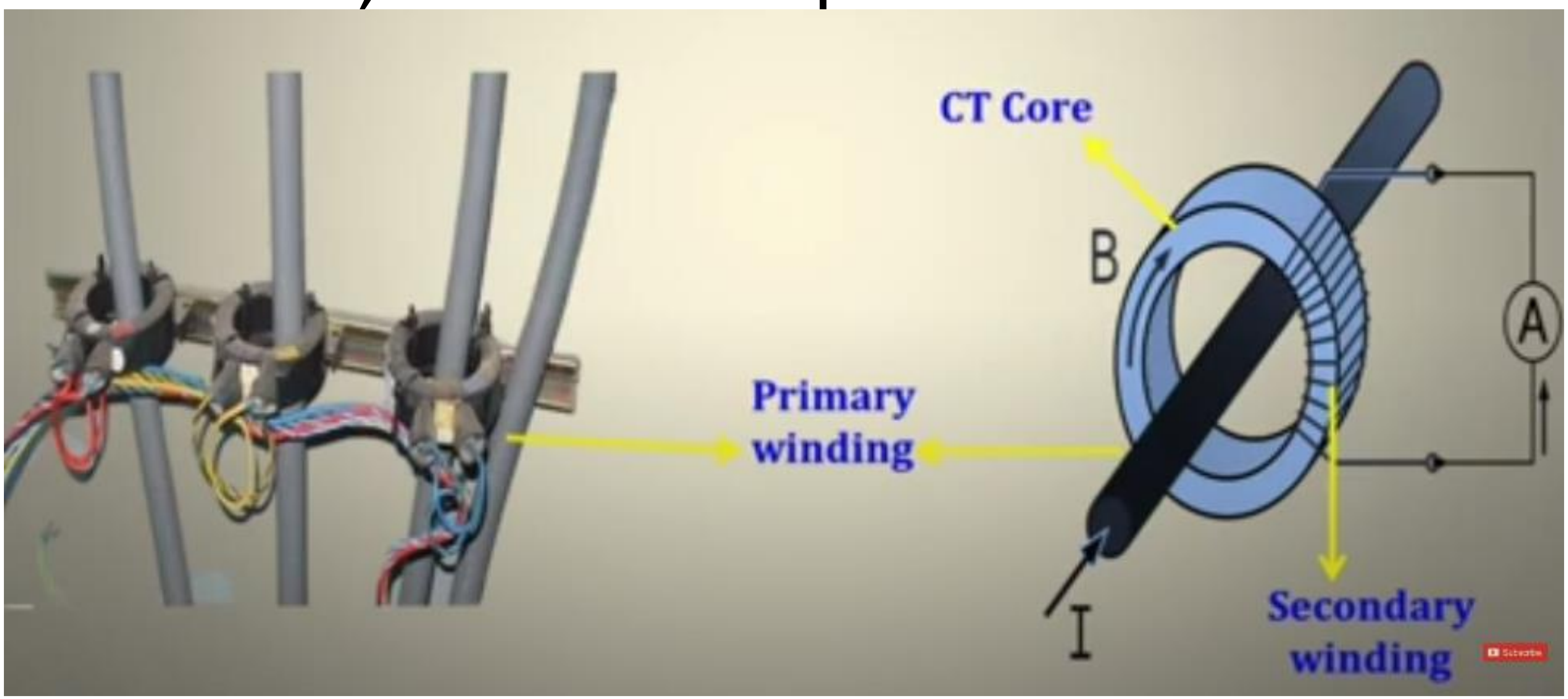






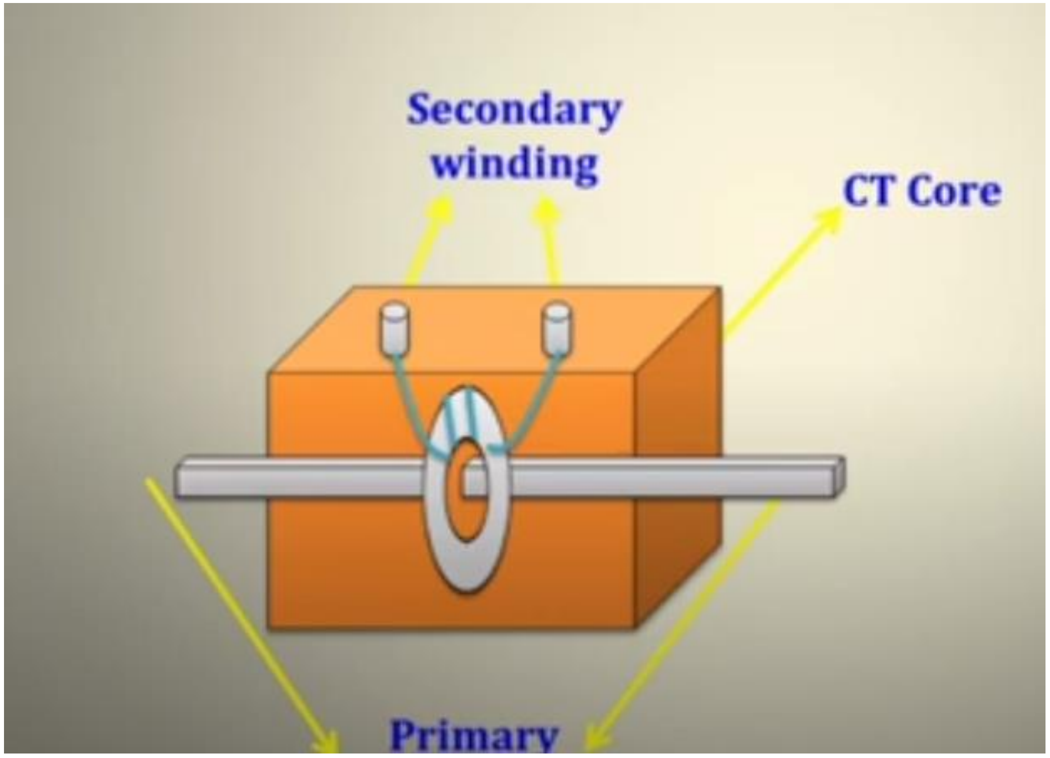
Window type

- Used in low voltage systems
- Ex: Starter, VFD control panels

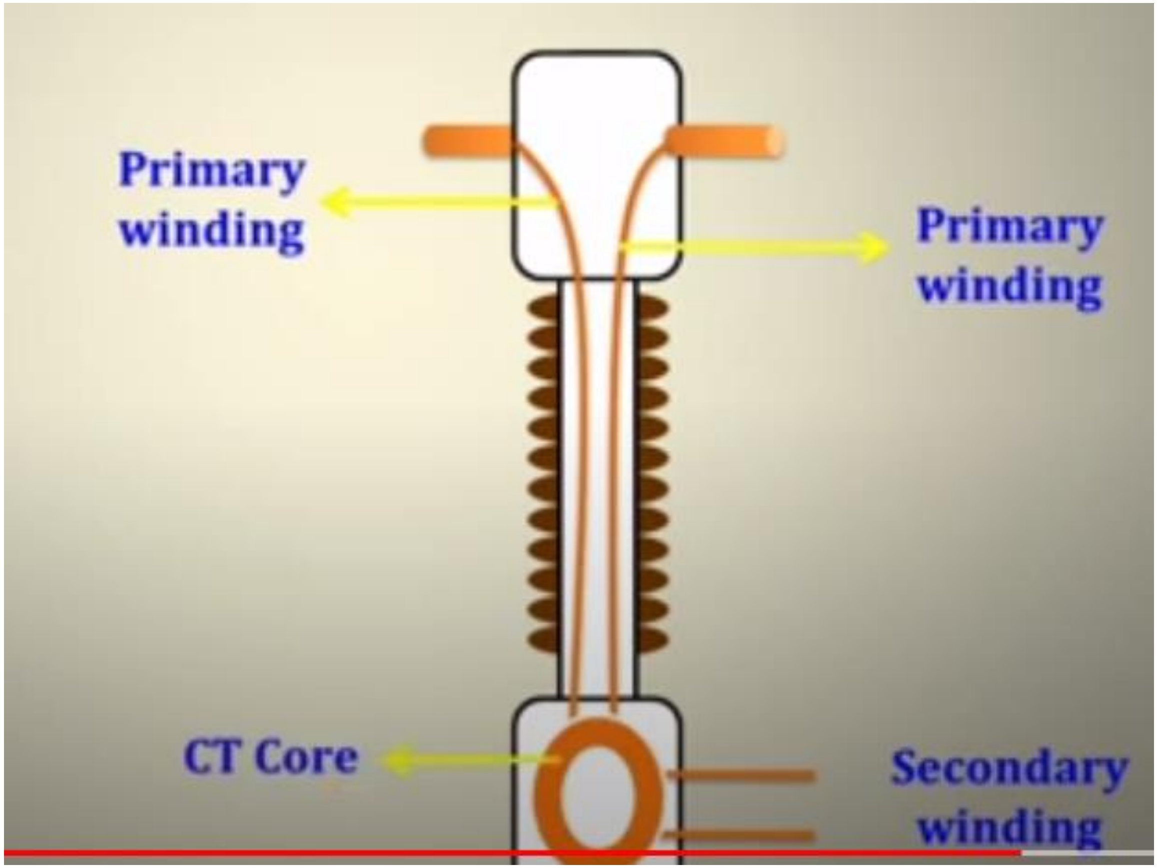


Bar type

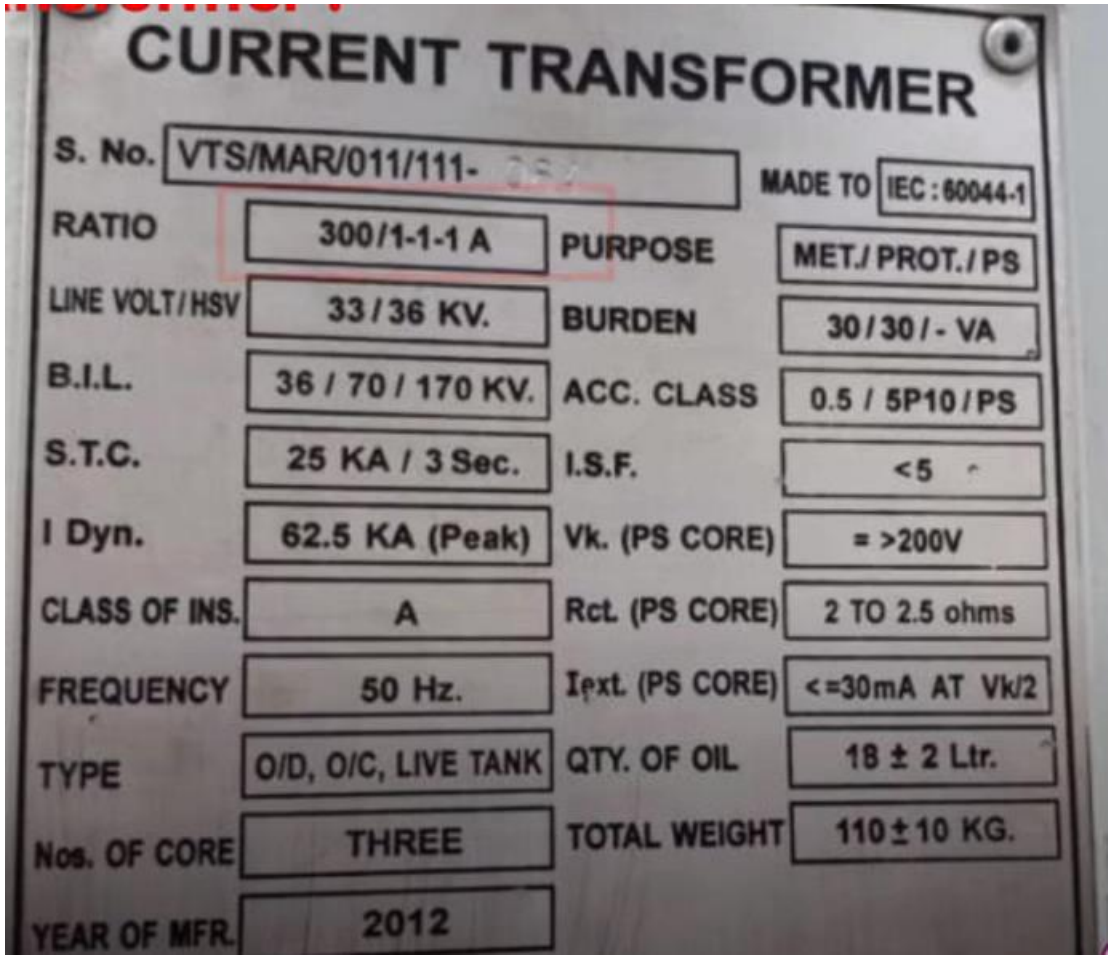
- Used in medium voltage systems
- Ex:Power distribution systems



Wound type
Used in high voltage systems
Ex:Switchyard



Name plate details



Current & Voltage Transformer Basics

Potential Transformer

- **Potential Transformer**is used to step down the voltage of power system to a lower level to make is feasible to be measured by small rating voltmeter i.e. 110 – 120 V voltmeter.
- A typical connection diagram of a **Potential Transformer** is showing figure below.

Potential Transformer

- The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.
- PT primary should be grounded, if not grounded,

Primary voltage will very high, to damage the PT

- PT placed parallel in electric circuit

PT Name plate

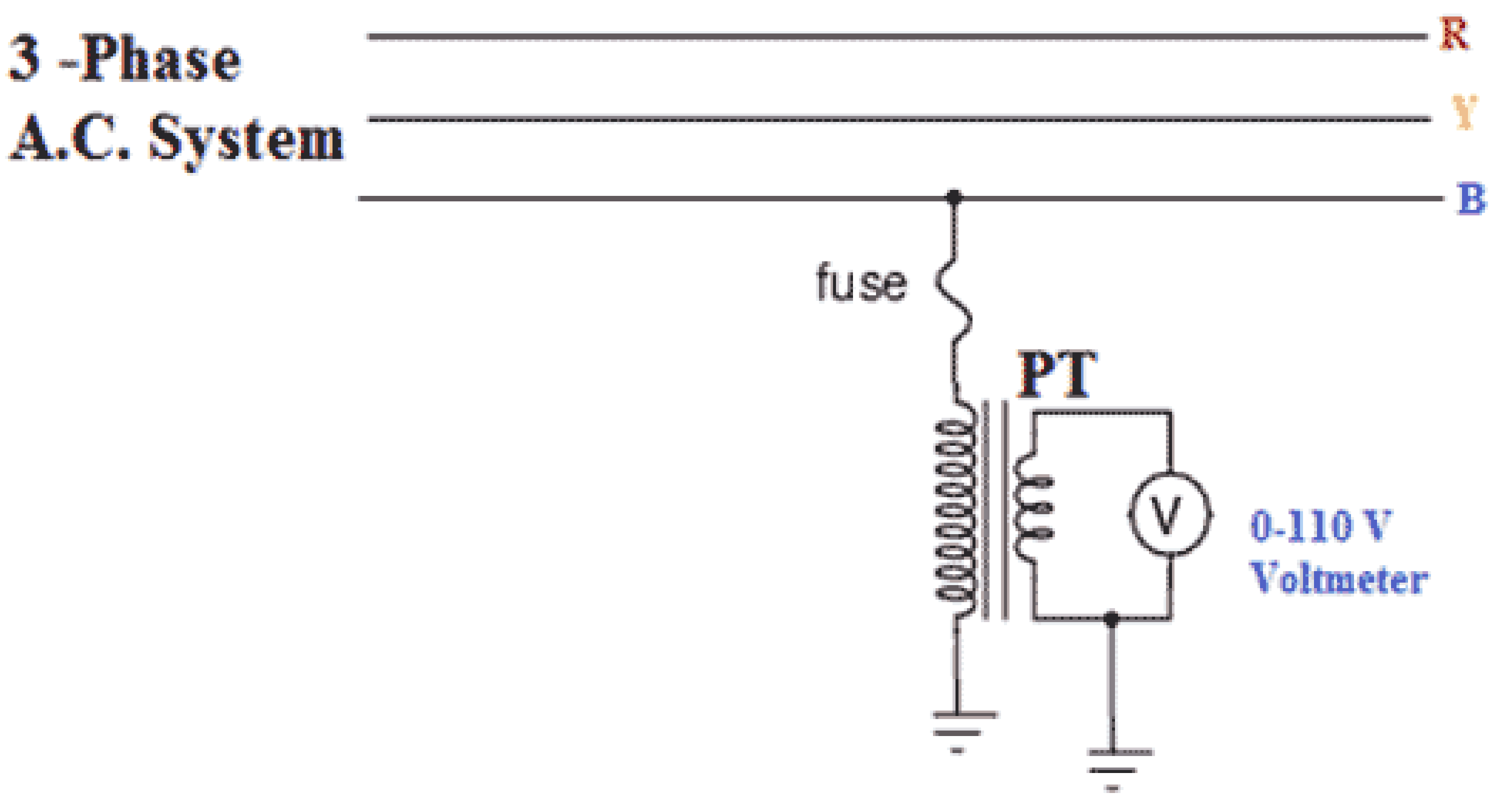
Potential Transformer

Measurement of voltage by PT

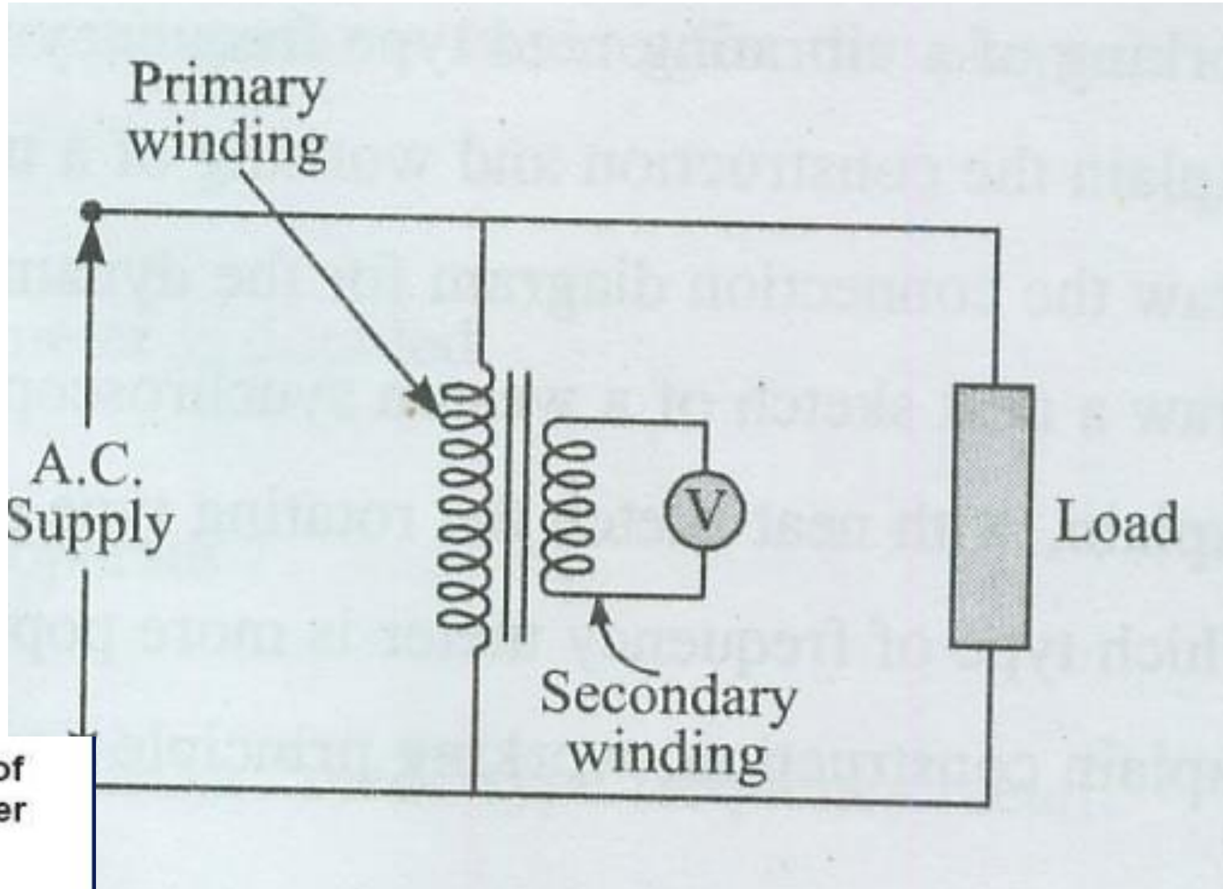
The primary winding is connected to the voltage side to be measured and secondary to the voltmeter.

The function of PT is to steps down the voltage to the level of voltmeter.

Connection diagram of a **Potential Transformer**



Instrument Transformer as PT



Conceptual picture of a Voltage Transformer

Potential Transformer

- Primary of P.T. is having large no. of turns. Primary is connected across the line (generally between on line and earth).
- Hence, sometimes it is also called the **parallel transformer**.
- Secondary of P.T. is having few turns and connected directly to a voltmeter.

Potential Transformer

- As the voltmeter is having large resistance. Hence the secondary of a P.T. operates almost in open circuited condition.
- One terminal of secondary of P.T. is earthed to maintain the secondary voltage with respect to earth. Which assures the safety of operators.

Advantages of Instrument Transformer

1. The measuring instruments can be placed for away from the high voltage side by connecting long wires to the instrument transformer. This ensures the safety of instruments as well as the operator.
2. This instrument transformers can be used to extend the range of measuring instruments like ammeters and voltmeters.

Advantages of Instrument Transformer

3. The power loss in instrument transformers is very small as compared to power loss due to the resistance of shunts and multipliers.
4. By using current transformer with tong tester, the current in a heavy current circuit can be measured.

Disadvantages of Instrument Transformer

1. The only main draw back is that these instruments can not be used in DC circuits.

Current Transformers

In order to minimise the exciting ampere turns required, the core must have a low reluctance and small iron losses.

The following three types of core constructions are generally employed :

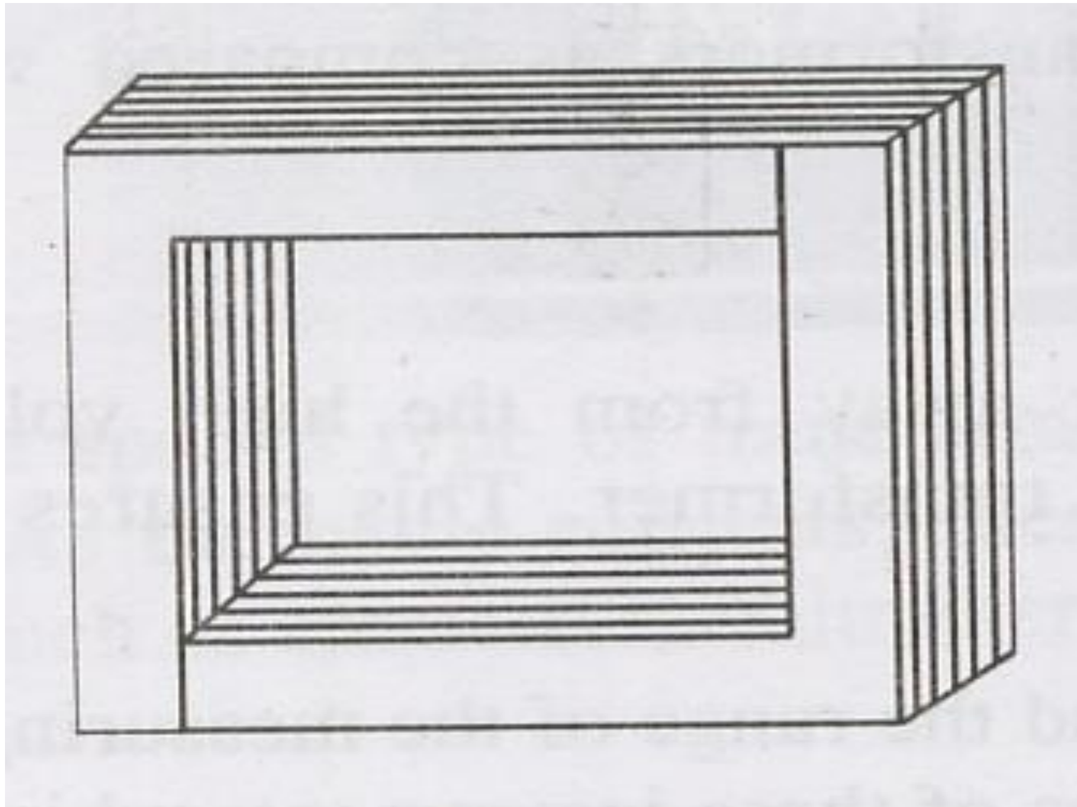
1. Core type
2. Shell type
3. Ring type

Core type

It is rectangular form core type. The laminations are of L shaped assembled together.

The winding are placed on one of the shorter limbs, with the primary usually wound over the secondary. The main advantage of this type of core is that sufficient space is available for insulation and is suitable for high voltage work.

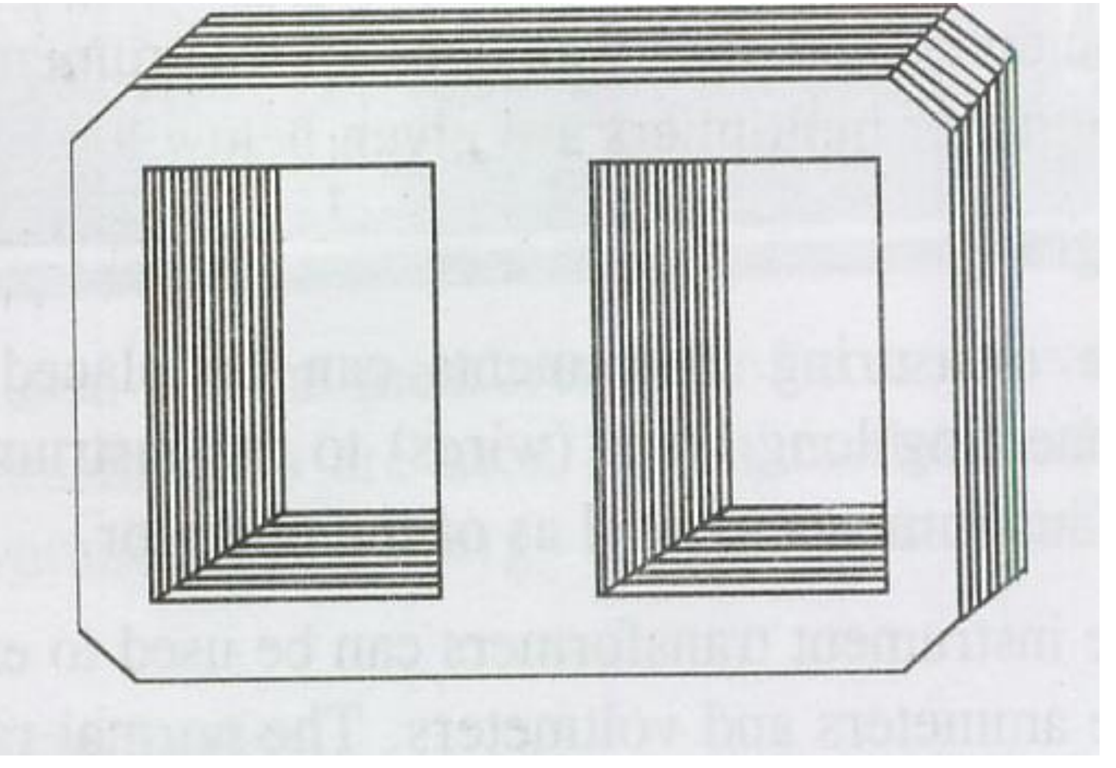
Core type



Shell type

- In shell type, the windings are placed at the central limb, thus it gives better protection to the windings.

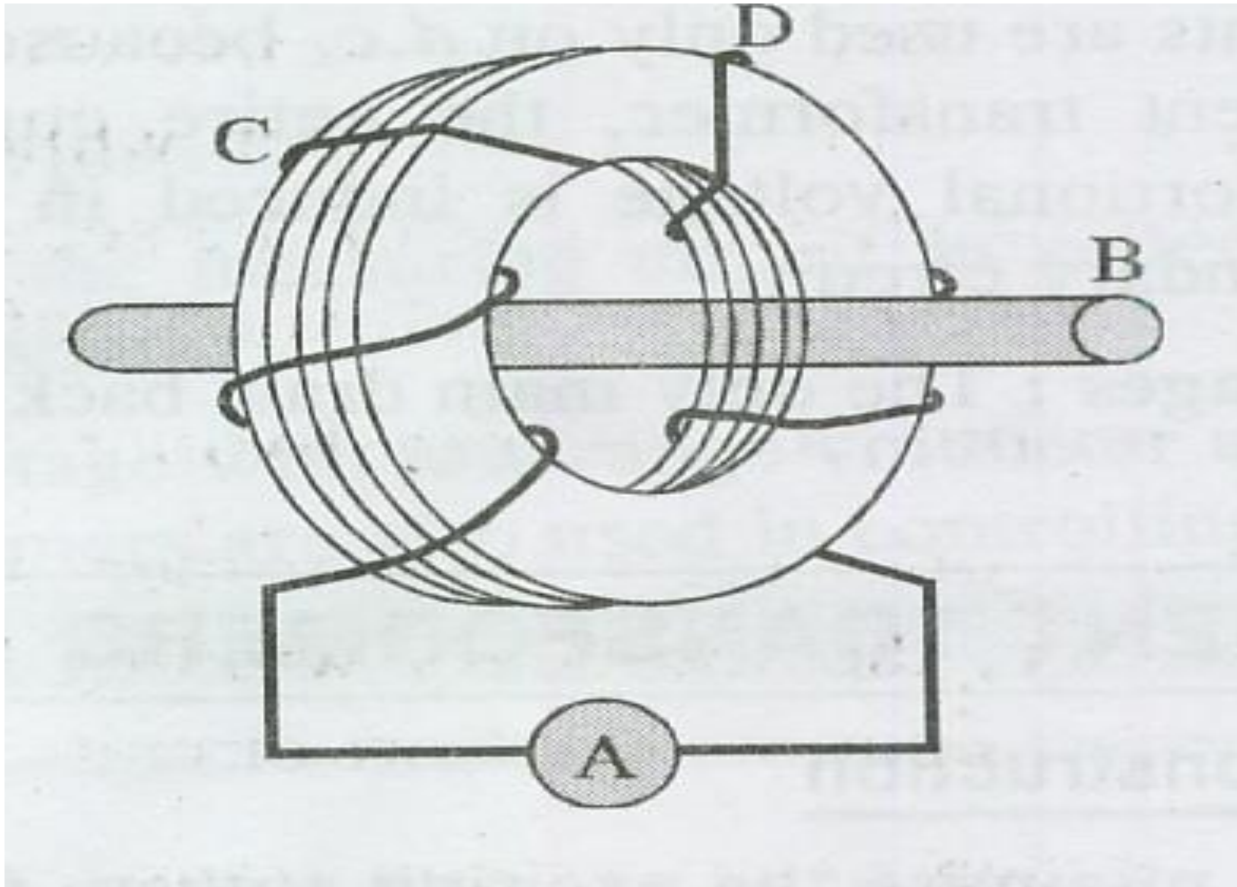
Shell type



Ring type

- Ring type core is commonly used when primary current is large. The secondary winding is distributed round the ring and the primary winding is a single bar.
- It is a joint less core and there is very small leakage reactance.

Ring type



Ratios of Instrument Transformers

Actual ratio [R]

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

$$R = \frac{\text{Magnitude of actual primary current}}{\text{Magnitude of actual secondary current}} \quad \text{... For C.T.}$$

$$R = \frac{\text{Magnitude of actual primary voltage}}{\text{Magnitude of actual secondary voltage}} \quad \text{... For P.T.}$$

The actual ratio is also called transformation ratio.

Ratios of Instrument Transformers

Nominal ratio [Kn]

The nominal ratio is defined as the ratio of rated primary quantity to the rated secondary quantity, cither current or voltage.

$$K_n = \frac{\text{Rated primary current}}{\text{Rated secondary current}} \quad \text{... For C.T.}$$

$$K_n = \frac{\text{Rated primary voltage}}{\text{Rated secondary voltage}} \quad \text{... For P.T.}$$

3. Turns ratio [n]

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

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

Ratios of Instrument Transformers

Ratio Correction Factor (RCF)

It is the ratio of transformation i.e. actual ratio to the nominal ratio.

$$\therefore \qquad \text{RCF} = \frac{R}{K_n}$$

$$\text{i.e.} \qquad \boxed{R = \text{RCF} \times K_n}$$

The ratio which is indicated on the name plate of a transformer is always Its nominal ratio.

Burden of an Instrument Transformer

- The nominal ratio of an instrument transformer does not remain constant in practice as the load on the secondary changes.
- It changes because of effect of secondary current, power factor and magnetizing as well as core loss components of current and this causes errors in the measurements.

Burden of an Instrument Transformer

- For the particular class of transformers the specific loading at rated secondary winding voltage is specified such that the errors do not exceed the limit. Such a permissible load is called burden of an instrument transformer

Burden of an Instrument Transformer

$$\text{Total secondary winding burden} = \frac{(\text{Secondary winding induced voltage})^2}{\text{Total impedance of secondary circuit including load and winding}}$$

$$= \begin{pmatrix}\text{Secondary winding}\\ \text{current}\end{pmatrix}^2 \times \begin{bmatrix}\text{Total impedance of secondary circuit}\\ \text{including load and winding}\end{bmatrix}$$

If only the impedance of the load is considered then burden due to only load can be obtained,

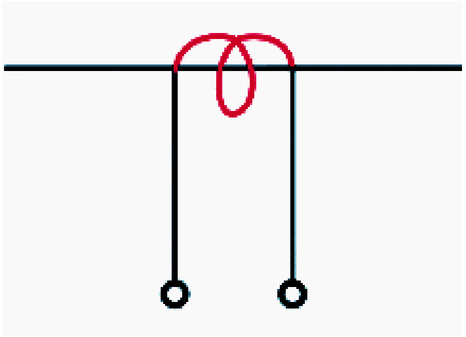
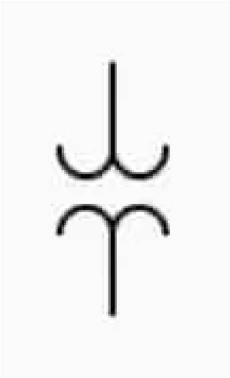
$$\text{Secondary winding burden due to load} = \frac{(\text{Secondary winding induced voltage})^2}{\text{Impedance of the load on secondary}}$$

$$= \begin{pmatrix}\text{Secondary winding}\\ \text{current}\end{pmatrix}^2 \times [\text{Impedance of the load on secondary}]$$

Comparison of current transformer and potential transformer

Property	Current transformer	Potential transformer/ Voltage transformer
Purpose	Transforms high current to low, measurable value.	Steps down high voltage to low, measurable value.
Windings	Primary: Typically Single turn. Secondary: A large number of turns.	Primary: A large number of turns. Secondary: Fewer turns.
Winding thickness	Primary: Heavy conductor capable of carrying high currents. Secondary: Thin conductor capable of carrying 5A-20A.	Primary: Thin conductor. Secondary: Thick conductor.
Primary Connection	The primary winding is connected in series to the current-carrying conductor	The primary of a potential transformer is connected across the conductor and earth.
Secondary rating	The secondary rated current can be either 1A or 5A	The secondary rated voltage can be $100/\sqrt{3} – 120/\sqrt{3}$ or $100/3 – 120/3$ V

Comparison of current transformer and potential transformer

Symbols		
Types	1. Window CT or toroidal CT 2. Bar CT 3. Wound CT	1. Electromagnetic induction type 2. Capacitive-coupled type 3. Optical type
Safety Consideration	The secondary terminals of a current transformer must never be open-circuited.	The secondary terminals of a voltage transformer must never be short-circuited.