

Instrument Transformers



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Instrument Transformers

What is an Instrument Transformer ?:

- It is a transformer that is used in conjunction with any measuring instrument (i.e., Ammeter, Voltmeter, Wattmeter, Watt-hour-meter, ...etc.) or protective equipment (i.e., Relays).
- It utilizes the current-transformation and voltage transformation properties to measure high ac current and voltage.

Instrument Transformers

Types of instrument transformers :

These instrument transformers are of two types:-

1. Current transformers
2. Potential transformers

Instrument Transformers

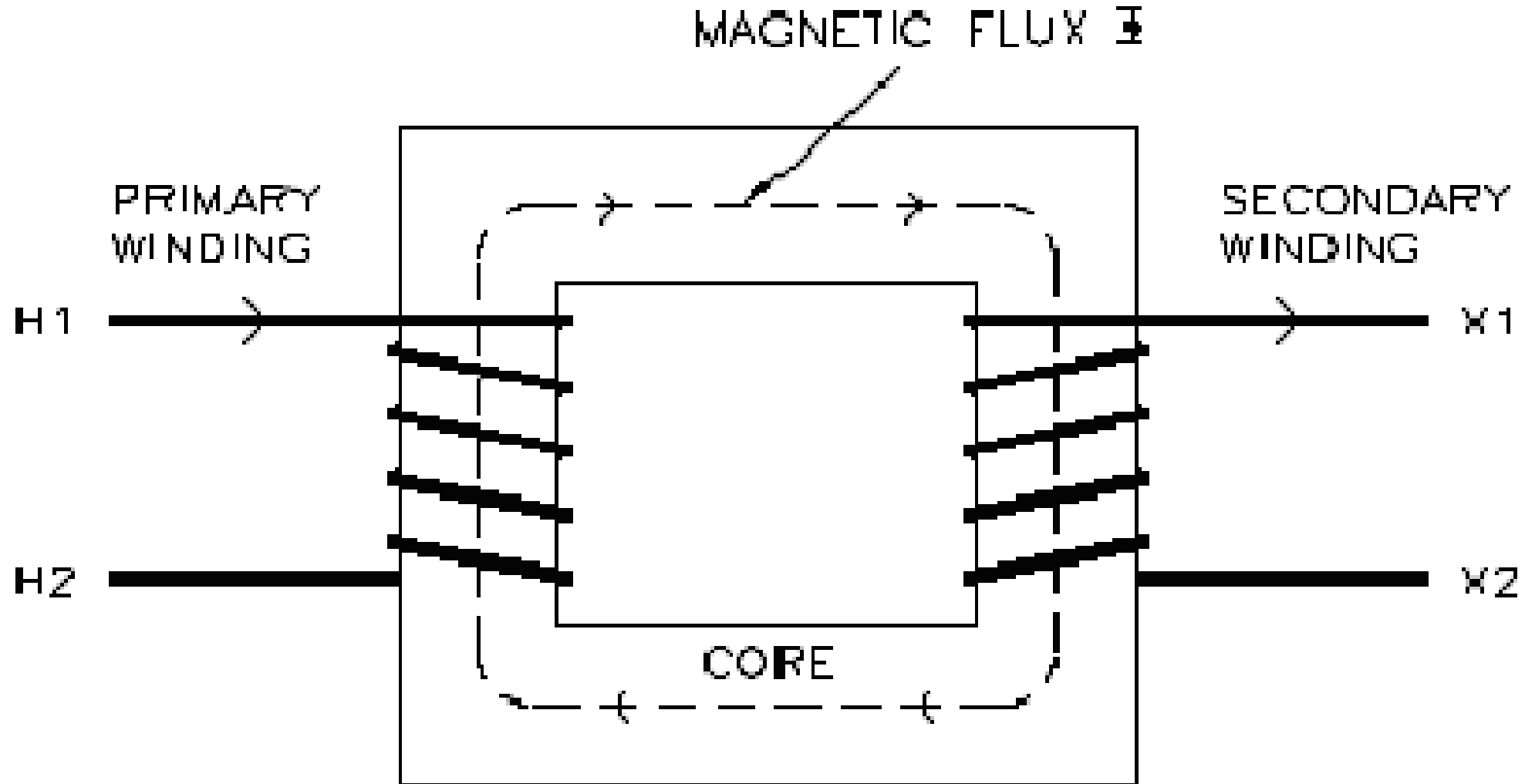
Applications of Instrument Transformers:

- For measurement of high ac current, it is usual to use low range ac ammeter with suitable shunt.
- For measurement of high ac voltage, low range ac voltmeters are used with high resistances connected in series.
- For measurement of very high ac current and voltage, we cannot use these methods. Instead, we use specially constructed HV instrument transformers to insulate the high voltage circuit from the measuring circuit in order to protect the measuring instruments from burning.

Instrument Transformers

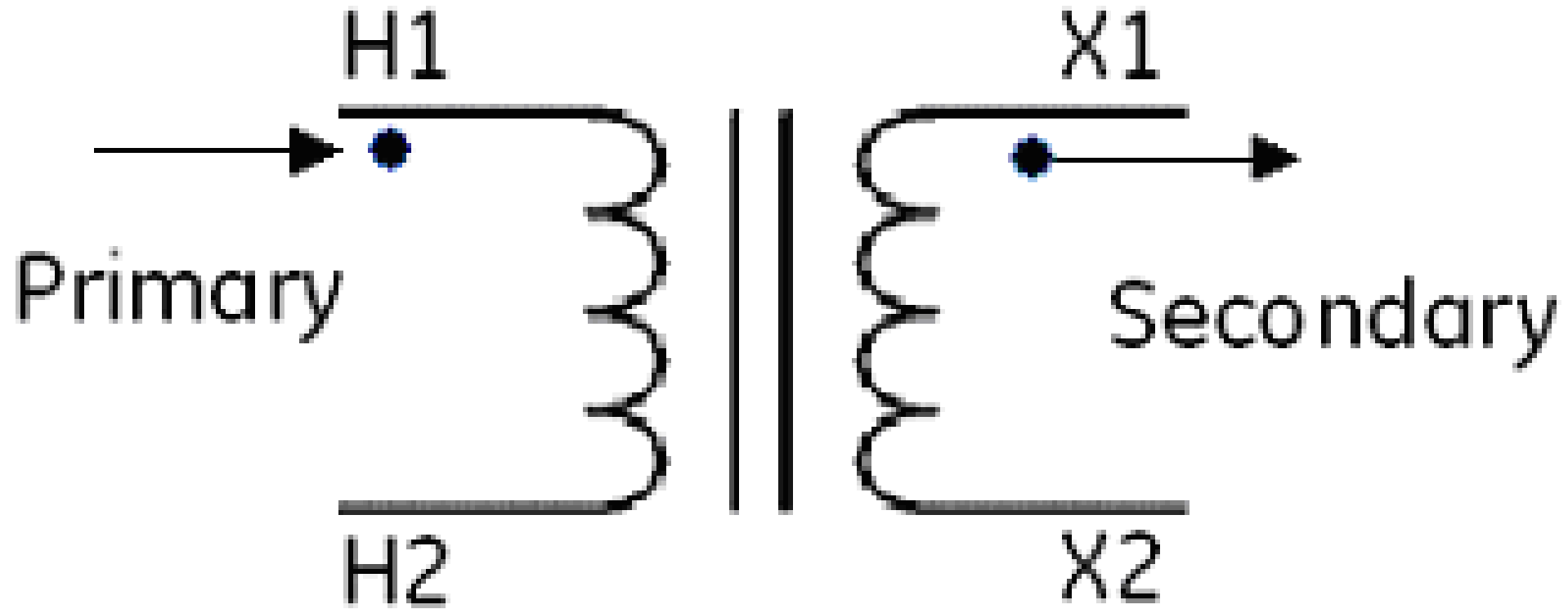
- Application of Instrumentation Transformers In dc circuits for current and voltage measurement, we use low range dc ammeters and voltmeters with rectifiers connected in their secondary circuits.
- The vast primary application of Instrument Transformers is for the protection and control of power system and power equipment of high and very high ratings.
- The working of these instrument transformers are similar to those of the ordinary transformers.

Instrument Transformers



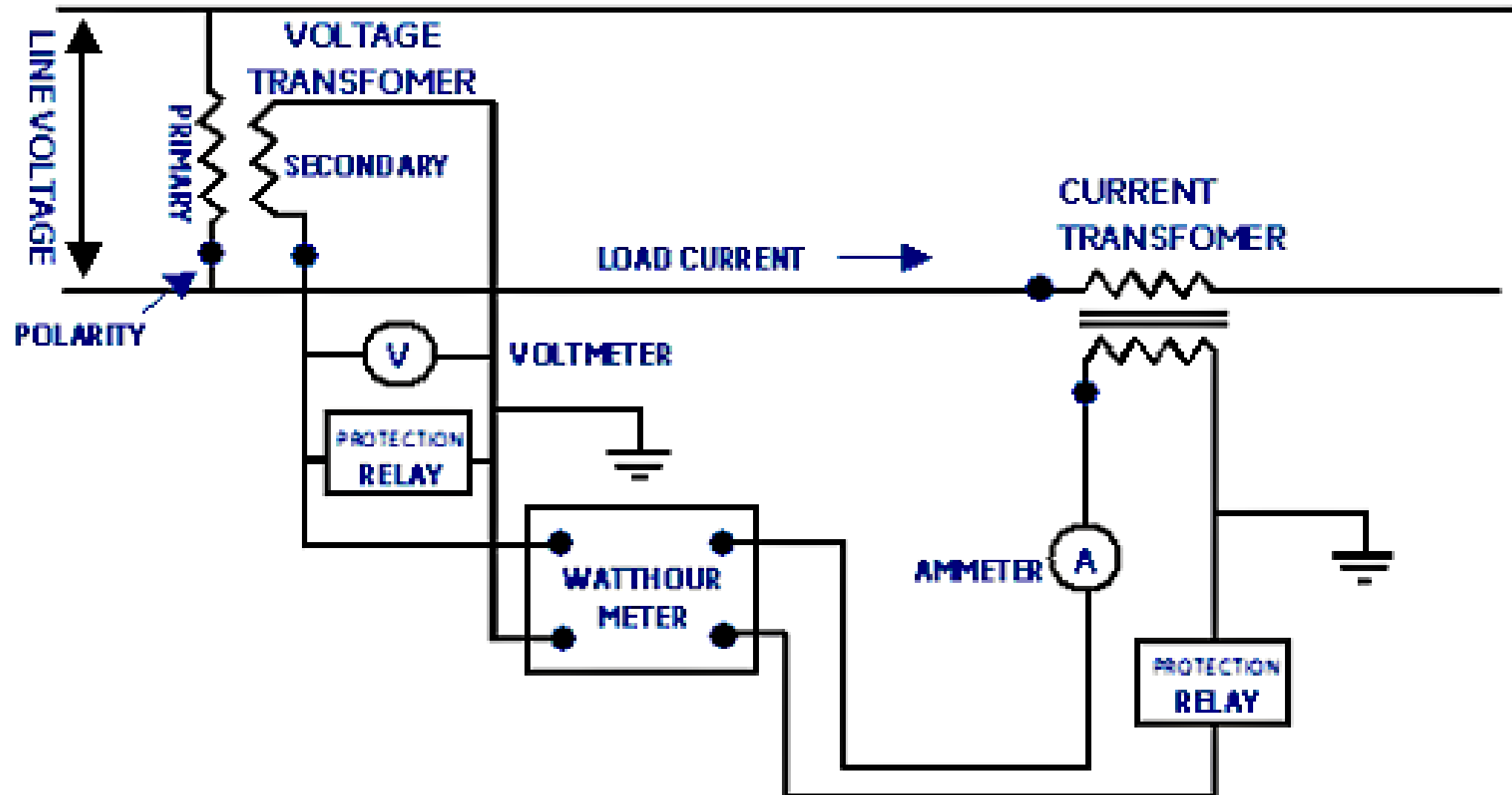
Basic Construction and Magnetic Circuit of Instrument Transformers

Instrument Transformers



Polarity of Instrument Transformers

Instrument Transformers



Common connections of instrument transformers

Current Transformers

What is current Transformer (CT)?:

- A current transformer is a transformer, which produces in its secondary winding low current, which is proportional to the high current flowing in its primary winding.
- The secondary current is usually much smaller in magnitude than the primary current.
- The design of CT depends on which type of instrument is connected to its secondary winding. **Measuring instrument OR Protective instrument.**
 - Measuring instrument CT** is expected to give accurate results up to a maximum of 125% of its normal full-load rated current.
 - Protective instrument CT** is expected to be accurate for up to 20 times of its normal full-load rated current (about 2000% of its full-load rated current!!..??).
- Based on the type of equipment for which the Ct is used for, its saturation point will vary. At the same time it is expected to be linear in the entire working range.

Current Transformers

Construction of C.T.:

- C.T. has a primary coil of one or more turns made of thick wire connected in series with the line whose current is to be measured.
- The secondary consists of a large number of turns made of fine wire and is connected across an ammeter or a relay's terminals.

Construction Types of Current Transformers



Window-type



Bar-type

Current Transformers

Function of CT:

- The principal function of a CT is to produce a proportional current at a level of magnitude, which is suitable for the operation of low-range measuring or protective devices such as indicating or recording instruments and relays.
- The primary and secondary currents are expressed as a ratio such as 100/5 or 1000/5 .
- With a 100/5 ratio CT, 100A flowing in the primary winding will result in 5A flowing in the secondary winding, provided that the correct rated burden is connected to the secondary winding.

Current Transformers

“Class” of a CT:

- The extent to which the actual secondary current magnitude differs from the calculated value, expected by the virtue of the CT ratio, is defined as the accuracy “Class” of the CT.
- The greater the number used to define the class, the greater the permissible “current error” [the deviation in the actual secondary current from the calculated value].

Current Transformers

Specifications of CT:

CTs should be specified as follow:

RATIO : Input / output current ratio

VA: Total burden (rating) including pilot wires.

Common burden ratings are 2.5, 5, 10, 15 and 30 VA. For example:

- Moving iron ammeter is 1-2 VA
- Moving coil rectifier ammeter is 1-2.5 VA
- Electro-dynamic instrument is 2.5-5 VA
- Maximum demand ammeter is 3-6 VA
- Recording ammeter or transducer is 1-2.5 VA

Current Transformers

CLASS : The accuracy required for the operation

DIMENSIONS: Maximum & minimum limits. For example:

- 0.1 or 0.2 for precision measurements.
- 0.5 for high grade kilowatt hour meters and commercial grade kilowatt hour meters.
- 3 for general industrial measurements.
- 3 or 5 for approximate measurements.

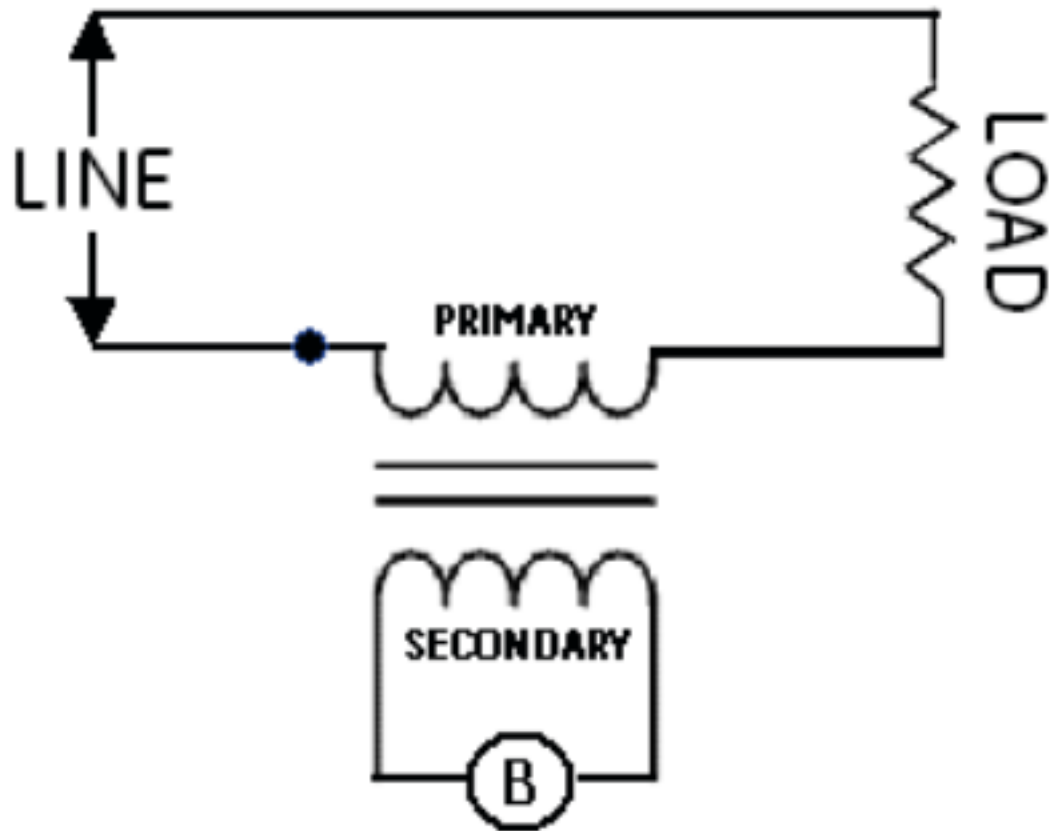
BURDEN (OHMIC): (Depending on pilot lead length)

Current Transformers

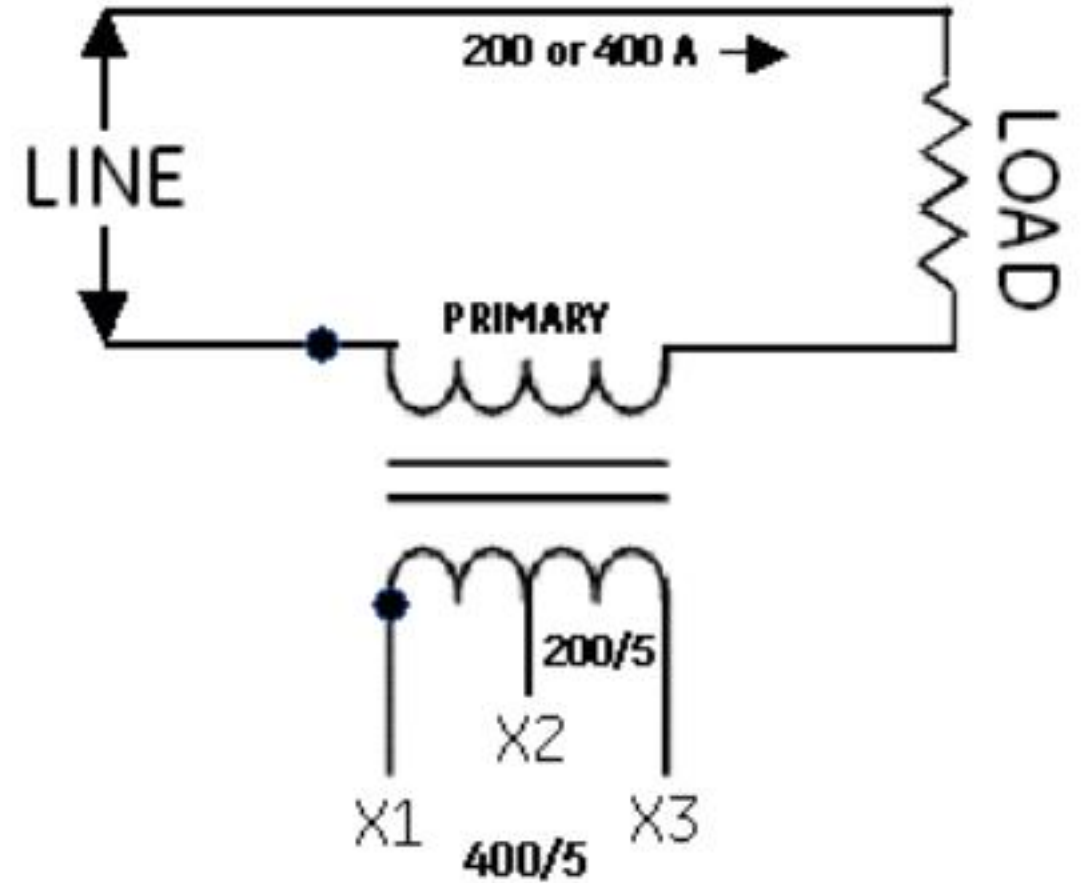
Current Transformers Stepping:

- These are used with low range ammeters to measure current in high voltage alternating circuits where it is not practical to connect instrument and meters directly to lines.
- They are step-up transformers (**voltage ratio**) because when we step-up the voltage the current decreases.
- The current is a step-down in a known ratio called the **current ratio** .

Connections of Current Transformers



Single-Ratio CT



Multi-Ratio CT

Multi-ratio CT:

- As indicated in the previous Figure, current transformers having a center tapped secondary are referred to as a dual ratio CT.
- Dual ratio CT are used in applications where it is necessary to have available two ratios of primary to secondary current from the same secondary winding of the CT.
- This may be accomplished by adding a tap in the secondary winding to get a second ratio.
- The ratio obtained by the tap is usually one-half the ratio obtained by the full secondary winding.
- A schematic example is previously shown with 200 amperes flowing in the primary, a connection X2 – X3 will produce 5 amperes out of the secondary. As the load grows to 400 amperes, the secondary circuit will be reconnected to X1 – X3 to still produce 5 amperes in the secondary circuit.

Current Transformers

Working (Measurement):

- If a current transformer has primary to secondary current ratio of 100:5 then it steps up the voltage 20 times and step down the current 1/20 times of its actual value.
- If we know the current ratio and the reading of an a.c. ammeter, the primary current can be calculated as:

$$\text{Primary Current} = \text{CT ratio} \times \text{ammeter reading}$$

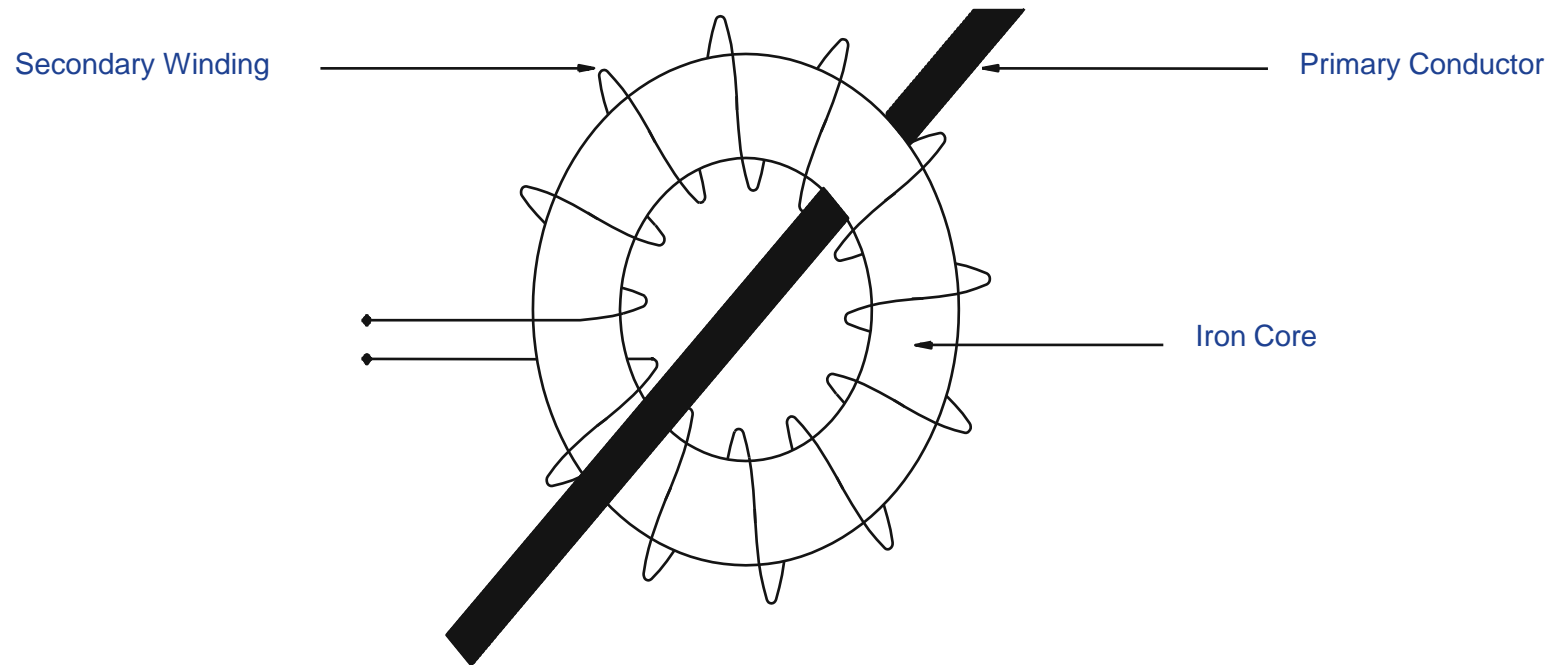
Current Transformers

Why CT secondary should never be open ?:

- Ammeter resistance is very low ,the current transformer normally works as a short-circuited instrument.
- If for any reason the ammeter is taken out of secondary winding then the secondary winding must be short-circuited with the help of a short-circuit switch.
- If this is not done, then a high Ampere-turns will set up a high flux in the magnetic core and it will produce excessive core loss which produce heat and high voltage across the secondary terminals .
- The high voltage can damage any electronic components in secondary side.
- Hence the secondary of any current transformer should never be left open.

Construction of the DOUGHNUT Type C.T. :

The most common type of C.T. construction is the “**DOUGHNUT**” type. It is constructed of an iron toroid, which forms the core of the transformer, and is wound with many secondary turns.



- The 'doughnut' fits over the primary conductor, which constitutes one primary turn. If the toroid is wound with 240 secondary turns, then the ratio of the C.T. is 240 : 1 or 1200 : 5A
- The continuous rating of the secondary winding is normally 1 AMP or 0.5 AMP in many parts of the world.
- This type of 'doughnut' C.T. is most commonly used in circuit breakers and power transformers. The C.T. fits into the bushing, and the porcelain bushing fits through the centre of the 'doughnut'.
- Up to four C.T.'s of this type can be installed around each bushing of an oil circuit breaker. This arrangement is shown in a following diagram.

Substation Class Circuit Breakers' CTs



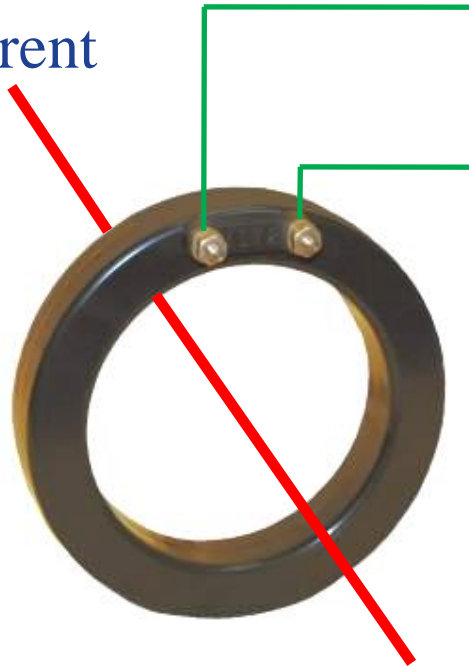
Polyester Taped Bushing CT on
Outdoor Circuit Breaker

CT Turns-ratio (TR)

$$\text{Transformer Ratio} = \frac{\text{Primary Current}}{\text{Secondary Current}}$$

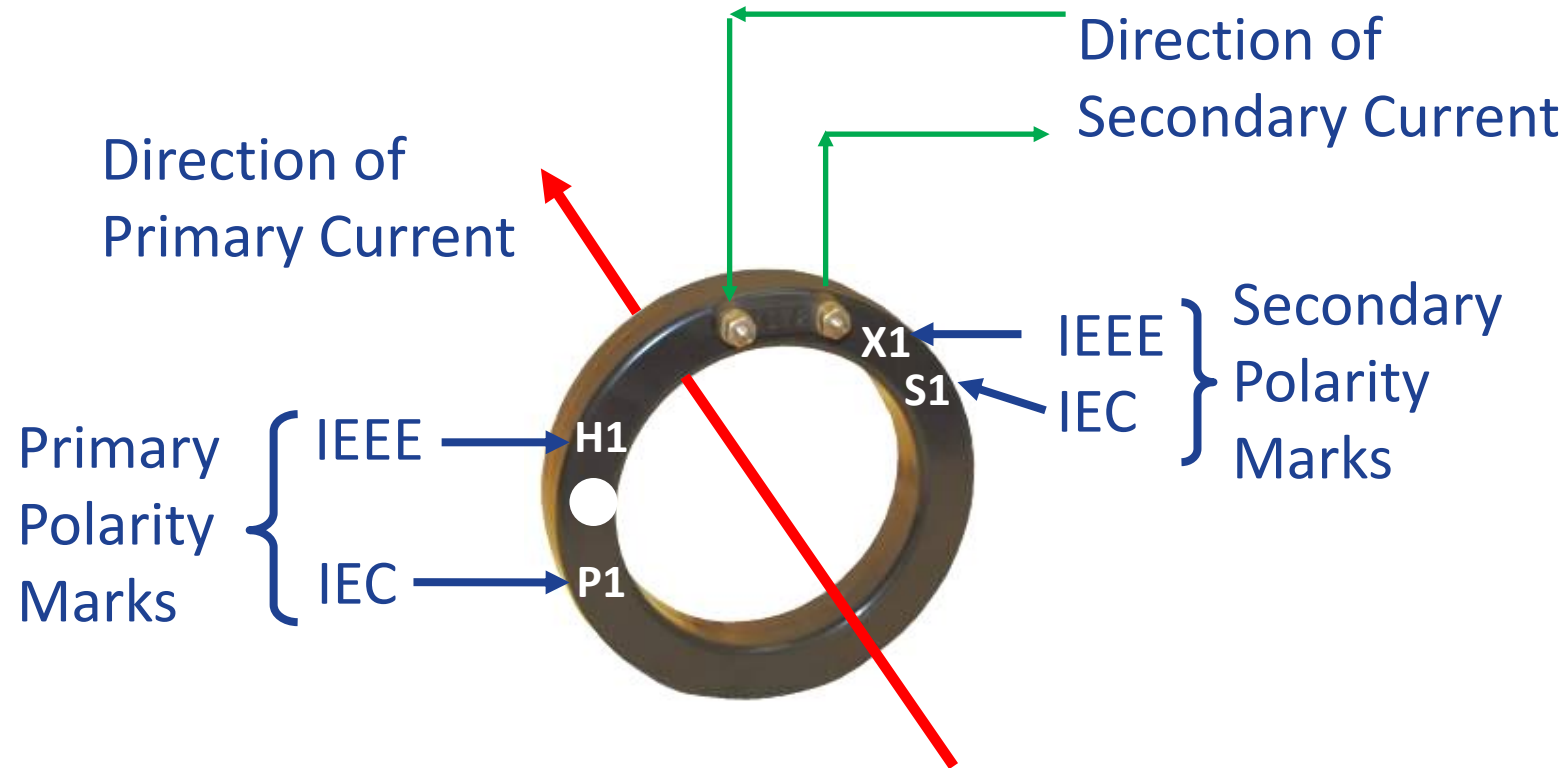
Primary Current
(100 amps)

Secondary Current
(5 amps)



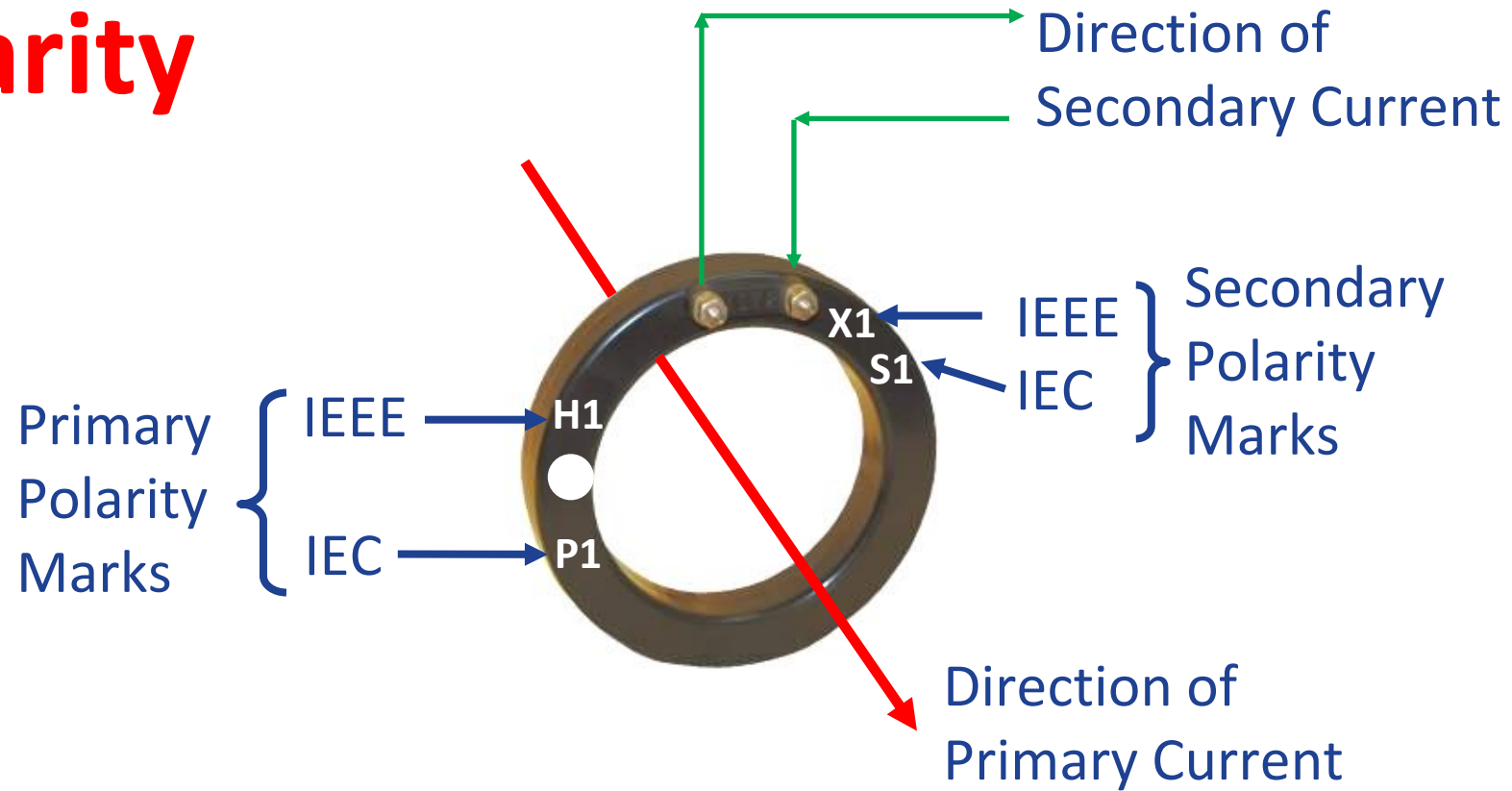
$$\frac{100}{5} = 100:5 \text{ or } 20:1$$

Polarity



Primary current into “polarity” forces
Secondary current out of “polarity”

Polarity



Primary current into “non-polarity” forces

Secondary current out of “non-polarity”

CT Metering Accuracy

Since **actual** secondary current \neq **Rated** secondary current

Then:

The difference in % is known as the
“**Accuracy**” or “**Class**”
of the CT

Burden

Load connected to CT secondary

Includes devices & connecting leads

Expressed in ohms

Standard values = B0.1, B0.2, B0.5, B0.9, B1.8
E0.04, E0.2

CT accurate Burden Calculation



$$Z_T = R_{CT} + R_L + Z_B$$

Z_T = Total burden in ohms (vector summation of resistance and inductance components)

R_{CT} = CT secondary resistance in ohms @75 deg C

R_L = Resistance of leads in ohms (Total loop distance)

Z_B = Device impedance in ohms

CT Saturation

Factors Affecting Degree and Time to Saturation

1. High DC offset

2. High fault current Magnitude (symmetrical current)

Example:

- 100 to 5 CT@20 times= 2000 amps.
- Also @20,000 amps we have 200 times CT

3. Low CT Turns Ratios

4. High secondary burden

5. Low CT Accuracy (Class)

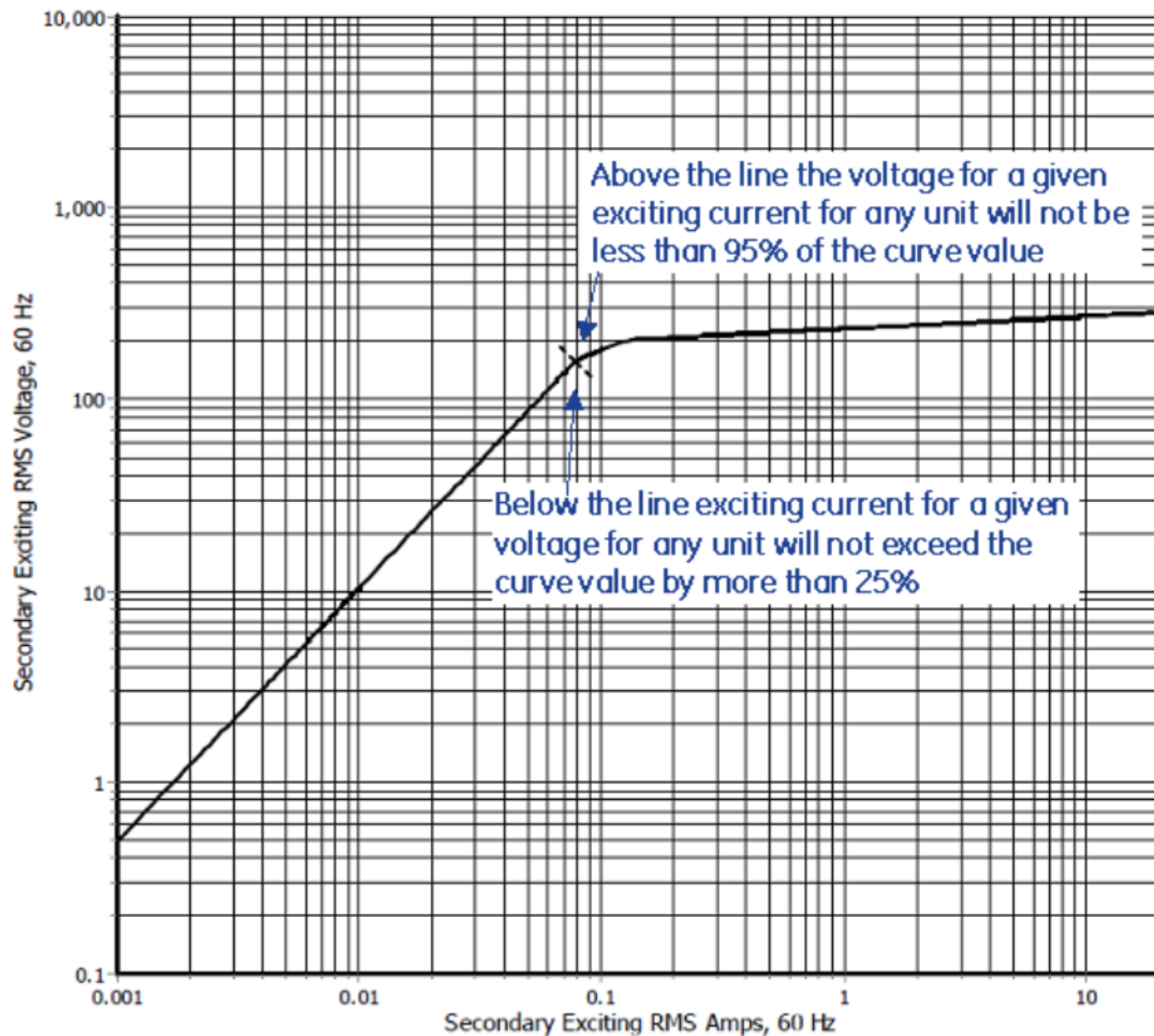
6. High reminance flux

- Can occur if current interrupted when core is saturated
- If DC flows in windings during testing
- Need a voltage above 60% of knee point to reduce the Reminance to less than 10% of saturation flux density.

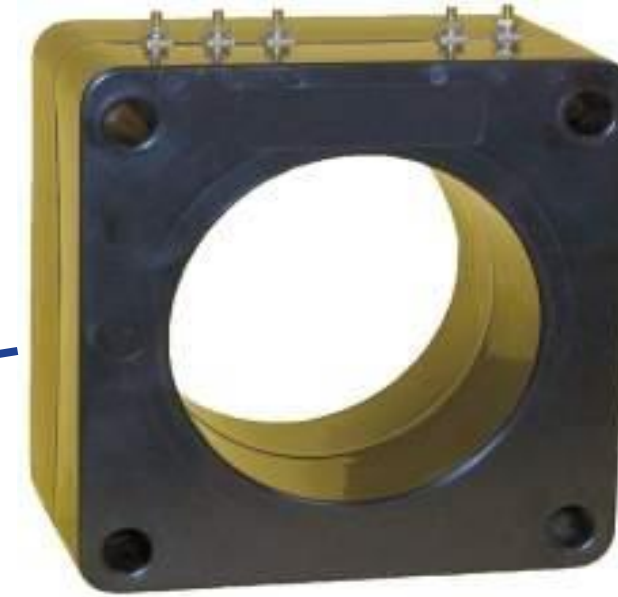
Tips for Avoiding CT Saturation

1. Use higher ratio CTs
2. Use separate set of high ratio CTs for high fault current tripping
3. Reduce secondary burden by:
 - Selecting low burden relays & meters
 - Distributing single phase burdens among phases
 - Increasing the size of secondary leads
 - Reducing the length of secondary leads
 - Using “step down” auxiliary CTs

**Avoiding CT Saturation
with Linear Operation
(Knee limit of the Curve)**



CT Actual Connections



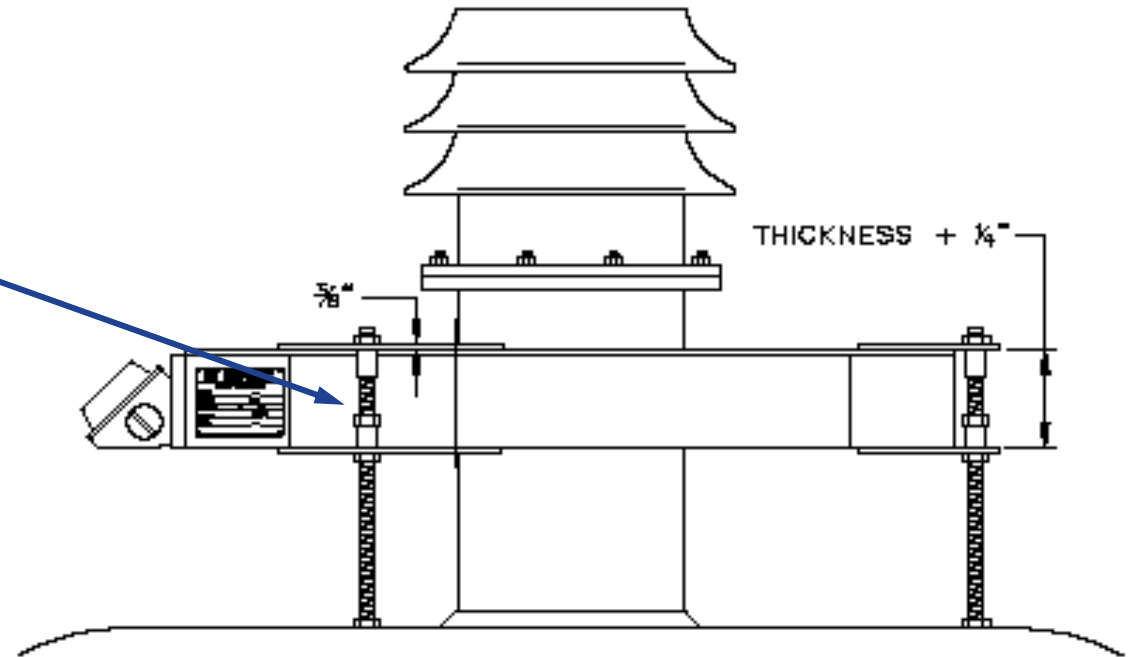
Typical window CT

Power Transformers' CT Connections

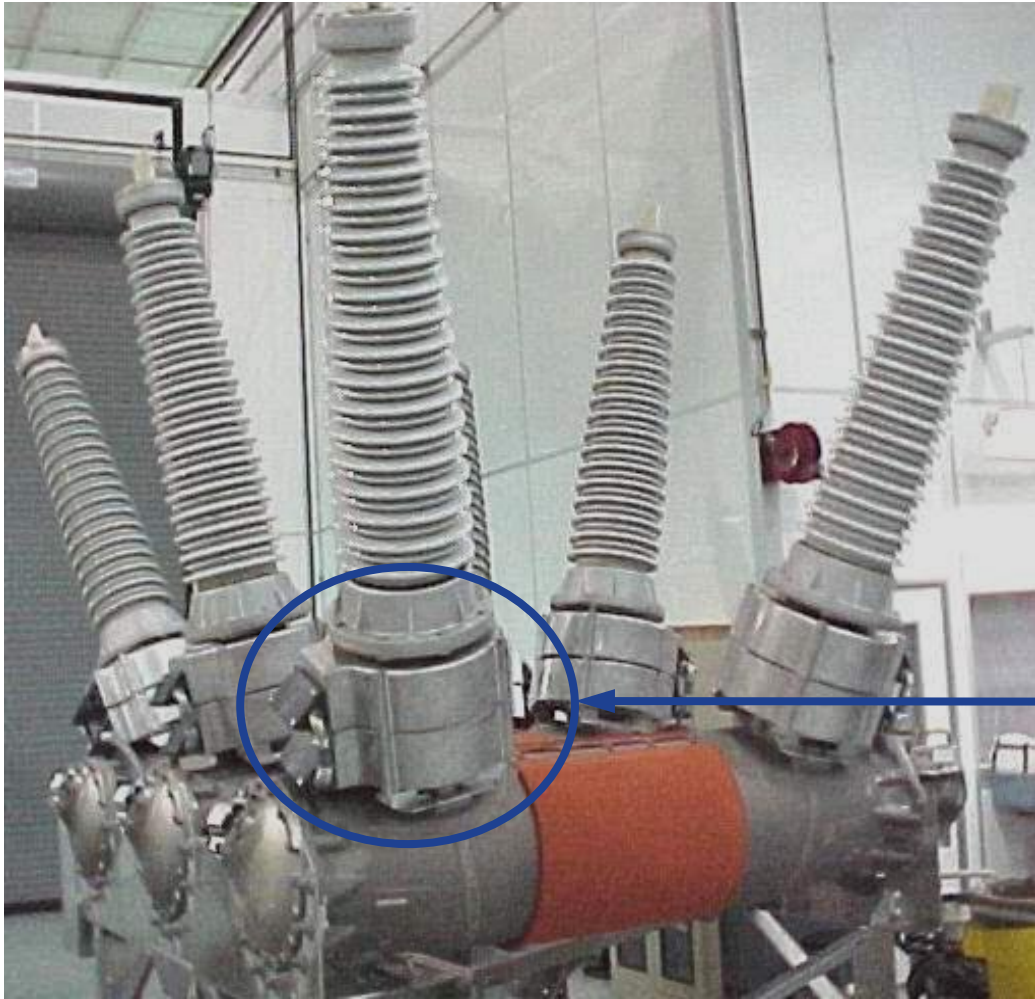
Slip over current transformer for installation over exterior of outdoor bushing



Outdoor Type B07 for Retrofit



Substation Class Circuit Breakers' CT's



Ground Shield



Outdoor BO7 - Replaces BCT's in shielded aluminum housing

Generators CT Connections



Board Mounted Generator CT

Potential Transformers

What is a Potential Transformer (PT) or (VT)?:

- A PT or sometimes called VT is a step-down transformer having many primary turns but few secondary turns.
- In a step-down transformer the voltage decreases and the current increases, thus voltage can be easily measured by using a low-range voltmeter instrument.
- The voltage is stepped-down in a known ratio called the **voltage ratio**.

Potential Transformers

Construction and working of P.T.:

Construction

- A potential transformer has many primary winding turns but few number of secondary winding turns that makes it a step-down transformer.
- A Voltmeter is connected to the secondary winding is usually a voltmeter of 150 V.

Working (Measurement):

- Primary terminals are connected in parallel across the line to which the voltage is to be measured.
- The voltmeter reading gives the transformed value of the voltage across the secondary terminals.
- The deflection of the voltmeter when divided by the transformed ratio gives the actual voltage across the primary winding as:

The Line voltage = deflection / transformation-Ratio

Where transformation ratio = V_2/V_1

Potential Transformers

Precaution for P.T.:

- Since the secondary of a p.t. is connected to relays, their ratings are usually 40 to 100 Watts.
- For safety purpose the secondary should be completely insulated from the high voltage primary and should be in addition grounded.

Potential Transformers

Types of P.T. :

Some types of p.t. are:

- Shell type
- Dry type
- Oil type

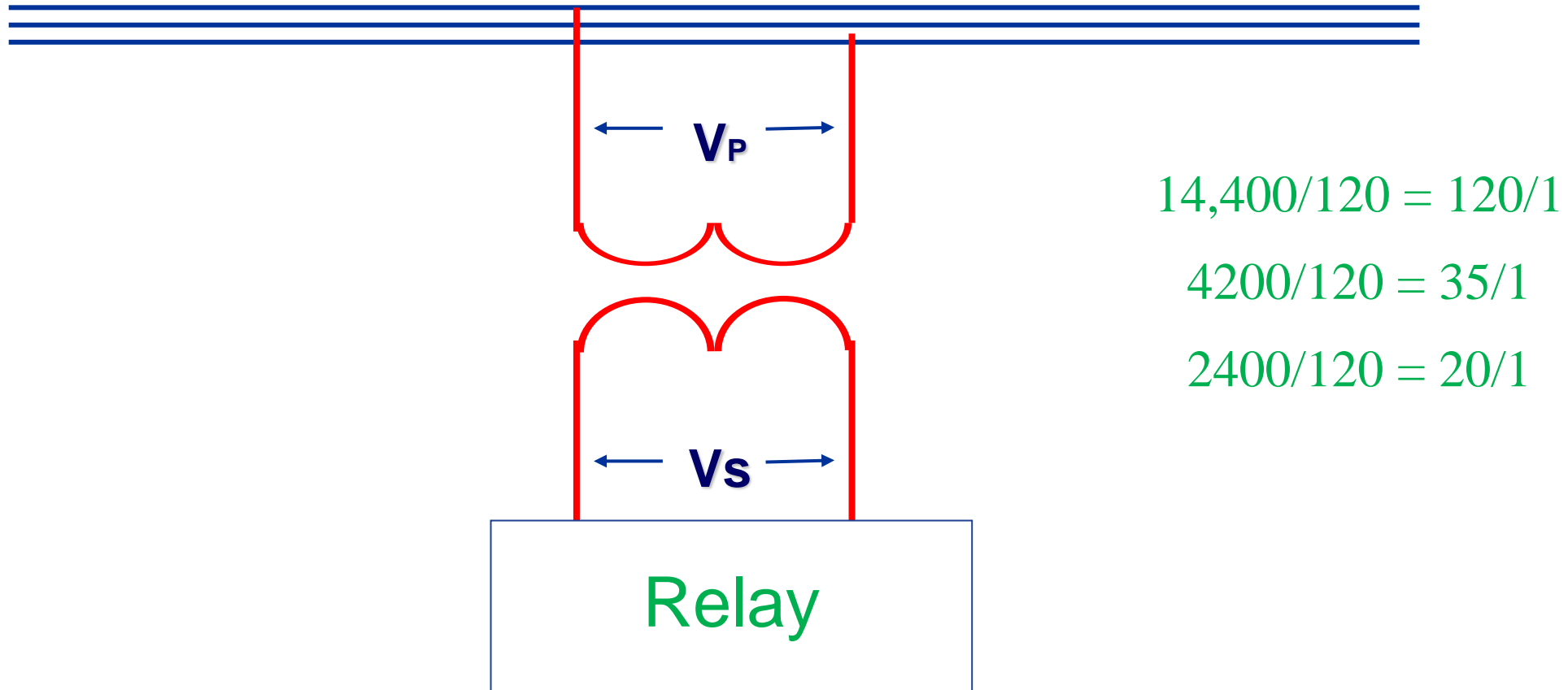
Rating

1. Below 5000 v
2. 5000-13800 v
3. Above 13800 v

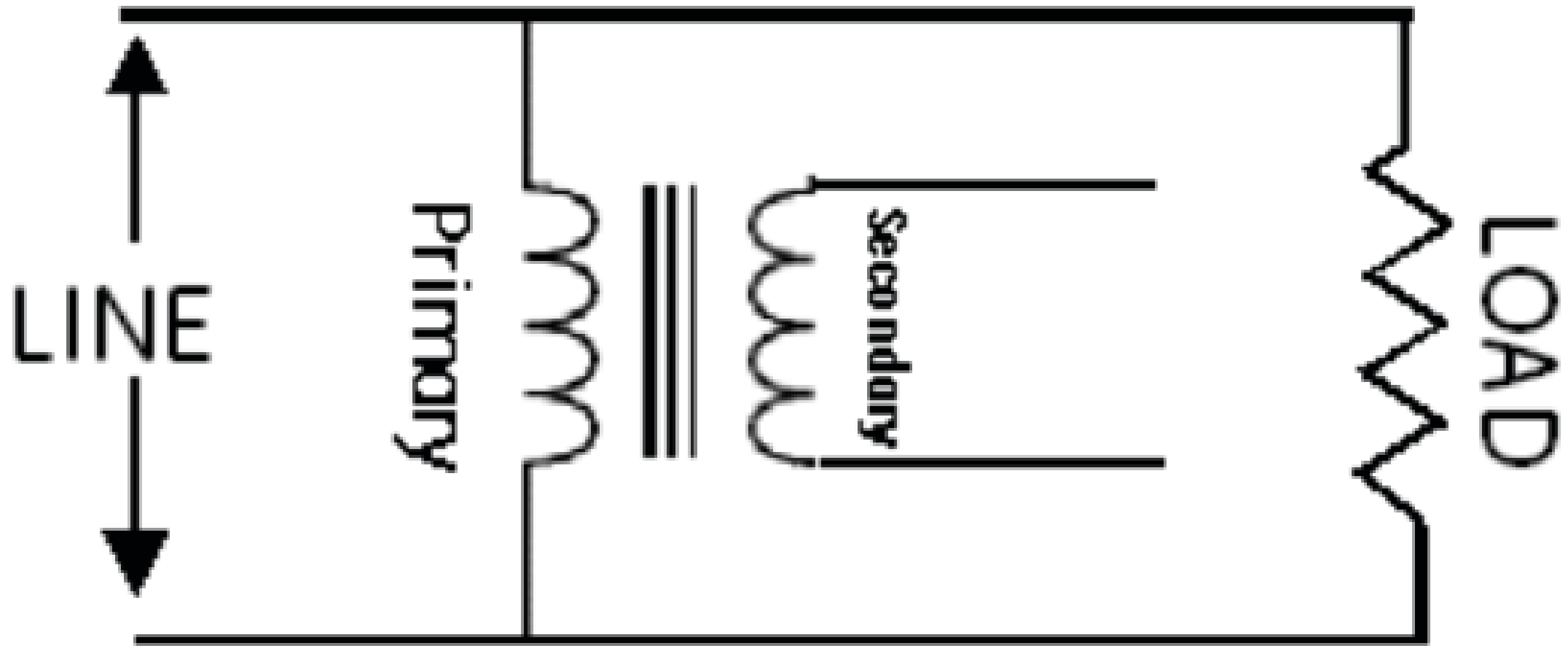
Type

Shell type
Dry type and oil type
only oil type

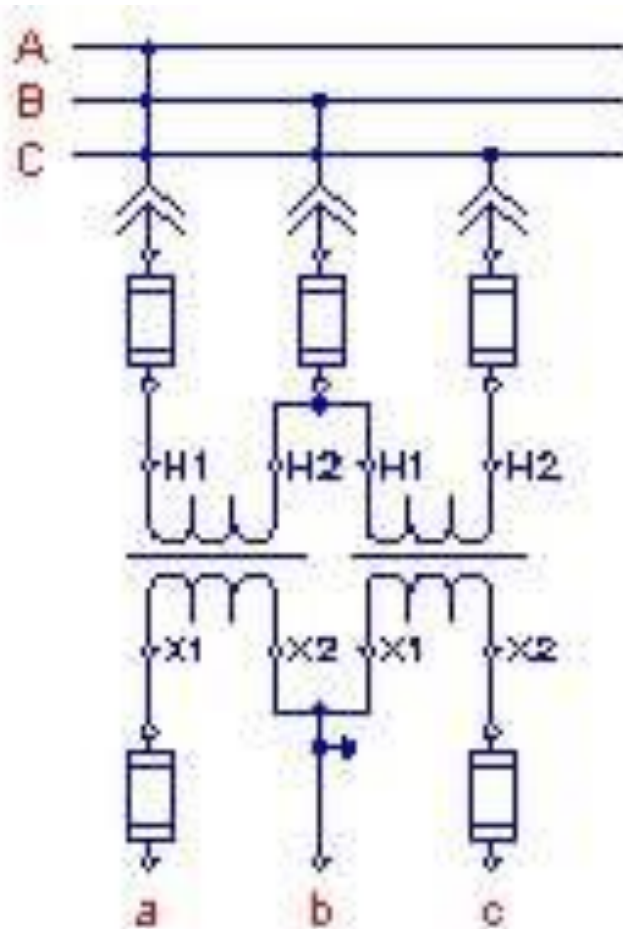
Potential Transformer Common Ratios



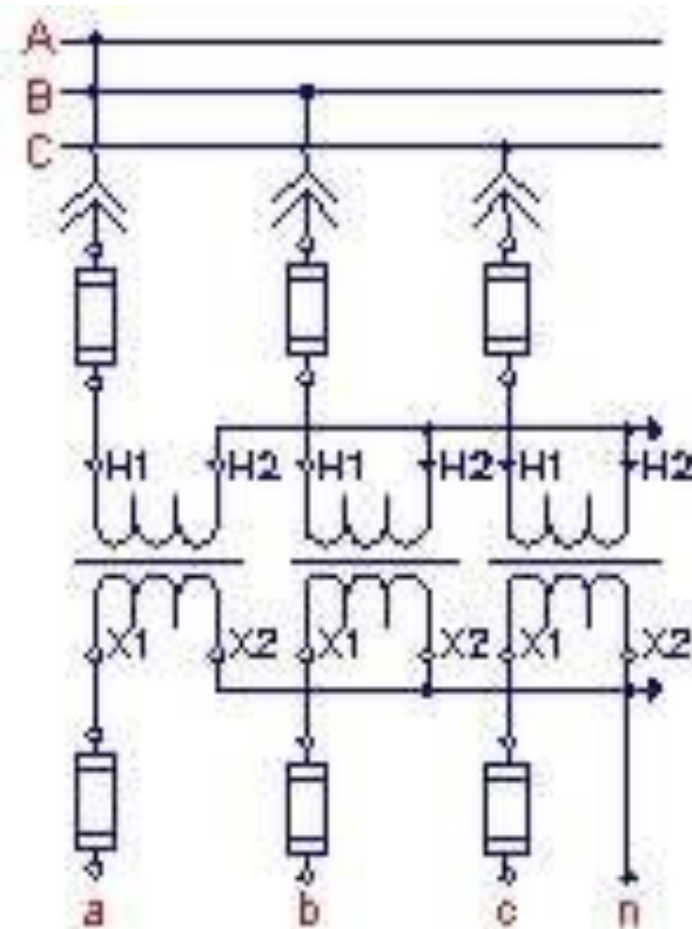
Connections of 1-Phase Potential Transformers



Other PT and 3-Phase Typical Connections

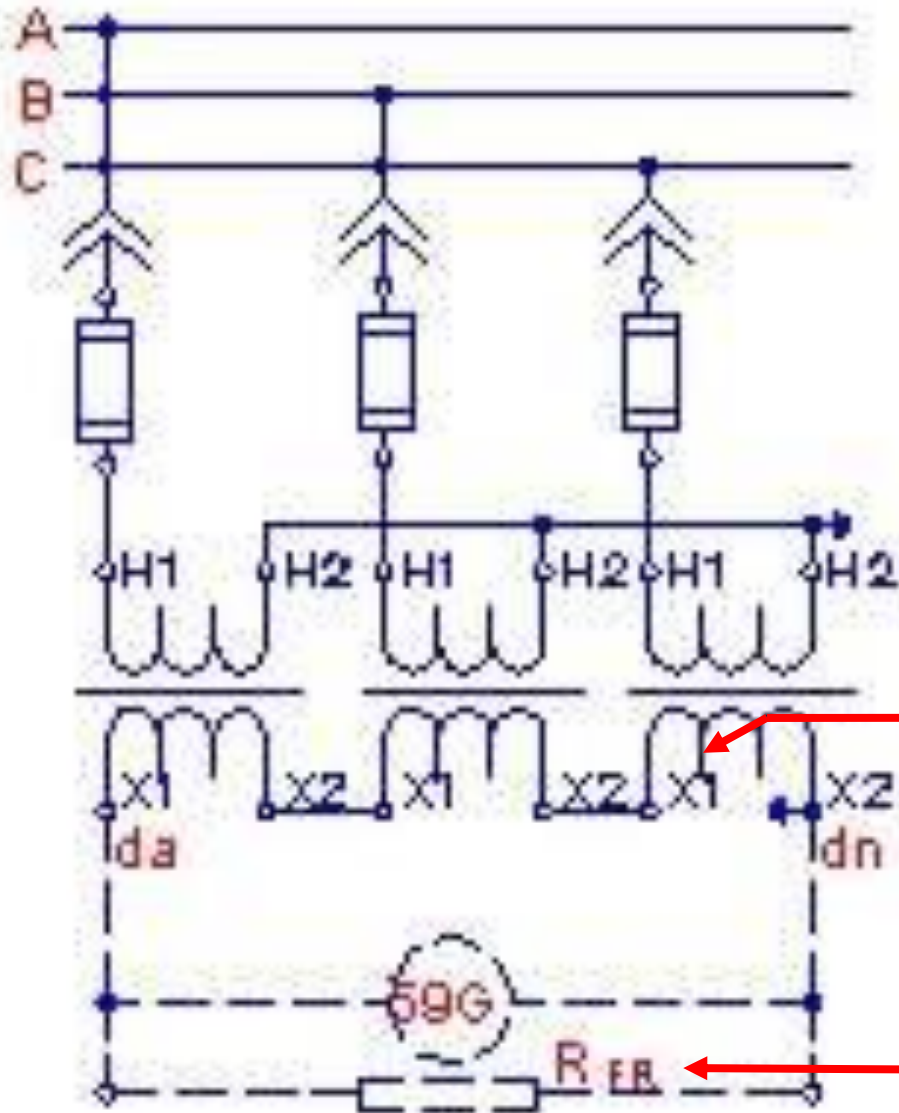


Open Delta Connection
(2) Double Bushing VTs



Y – Y Connection
(3) Single Bushing VTs

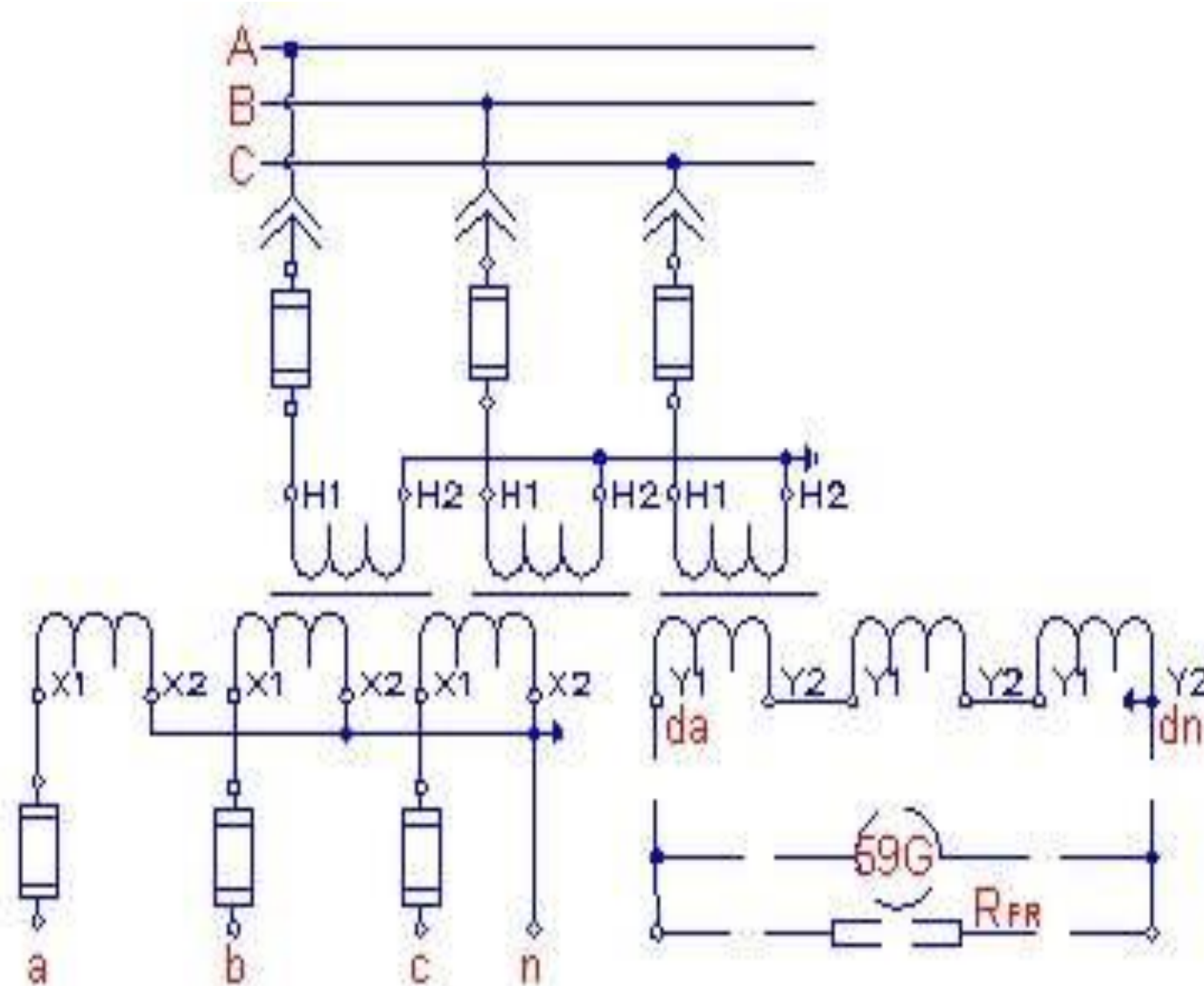
Other PT and 3-Phase Typical Connections



Y – Broken Corner Δ VT Connection

damping resistor R

Other PT and 3-Phase Typical Connections



Y-Y/Broken Corner Δ Connection

Basic important rules for Instrument Transformers

Rule # 1

Never open circuit a current transformer secondary while the primary is energized

CTs are intended to be proportional current devices. Very high voltages can result from open circuiting the secondary circuit of an energized CT. Even very small primary currents can cause damage.

Rule # 2

Never short circuit the secondary
of an energized VT

VTs are intended to be used as proportional voltage devices. Damaging current will result from short circuiting the secondary circuit of an energized VT.

Rule # 3

CT secondary leads must be
added to the CT burden

Electronic relays usually represent very little burden to the CT secondary circuit. In many cases the major burden is caused by the CT secondary leads.

Rule # 4

Never use a 60 Hz rated VT
on a 50 Hz System

60 Hz VTs may saturate at lower frequencies and exceed temperature limitations. VT failure is likely...severe equipment damage is possible.