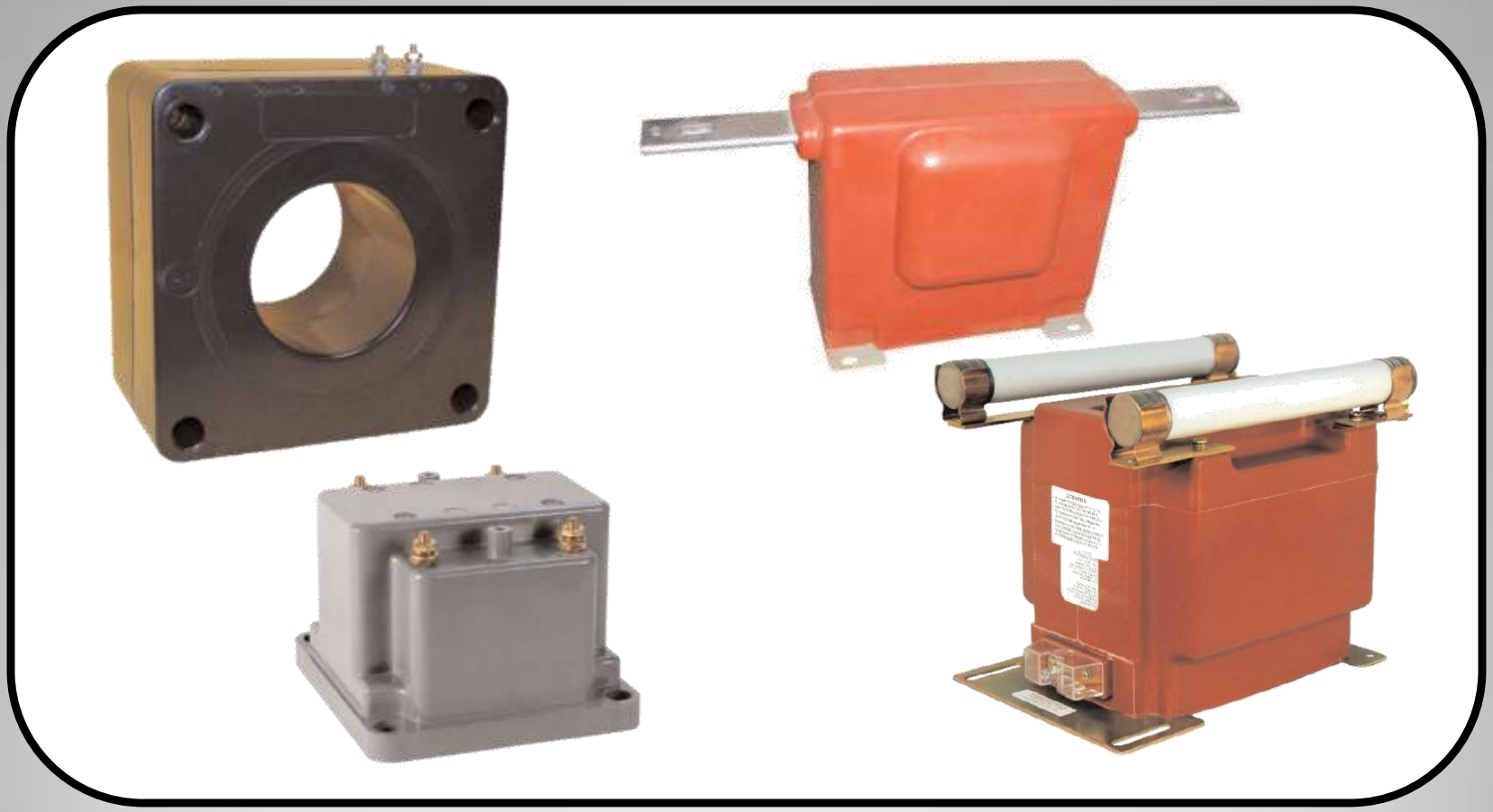
Instrument Transformer Basics



Kent Jones, P.E.
Line Power Manufacturing

Instrument Transformer Basics

What is an Instrument Transformer?

Current Transformer (Sometimes called CTs)
It is simply a device unused to measure current by producing a smaller current that is proportional to the current that is to measured.

Current transformers are always connected in series. I.e. the main current carrying conductor must pass through it.

Instrument Transformer Basics

Instrument Transformer Basics

What is an instrument transformer?

Voltage Transformer (Sometimes called Potential Transformers, VTs, or PTs)
It is simply a device unused to measure voltage by producing a smaller voltage that is proportional to the voltage that is to measured.

Voltage transformers are always connected in parallel.
I.e. the transformer must be connected phase to phase or phase to Neutral.

Instrument Transformer Basics

Instrument Transformer Basics

LINE POWER

Understanding the terminology

Reading the Label

Right sizing

Do’s and Don’ts

Checking it Out

Inspecting

Instrument Transformer Basics

The Rule Book:

IEEE C57.13 – 2008

Standard Requirements for Instrument Transformers

Instrument Transformer Basics

Understanding the Terminology

Turns Ratio (Also called TTR, TR, or Ratio)

Current Transformer
TR= Primary Current/ Secondary Current
Example: What is the TR of a CT marked 600:5?
TR=600/5= 120

Voltage Transformer
TR= Primary Voltage/ Secondary Voltage
Example: What is the TR of a PT marked 13200:120?
TR=13200/120=110
Example: What is the TR of a PT marked 110:1?
TR= 110/1=110

Instrument Transformer Basics

Understanding the Terminology

Polarity

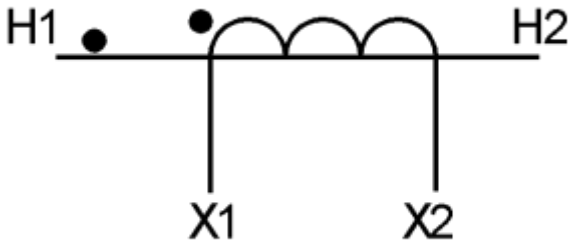
The Primary Terminals of an instrument transformer is marked H1 and H2. The secondary side is marked X1 and X2.

The rule is that whenever the AC wave shape of the H1 is high, then the X1 will also be high.

Some transformers use dots in lieu of characters. In this case H1 and X1 are marked with a dot. H2 and X2 have no marking.

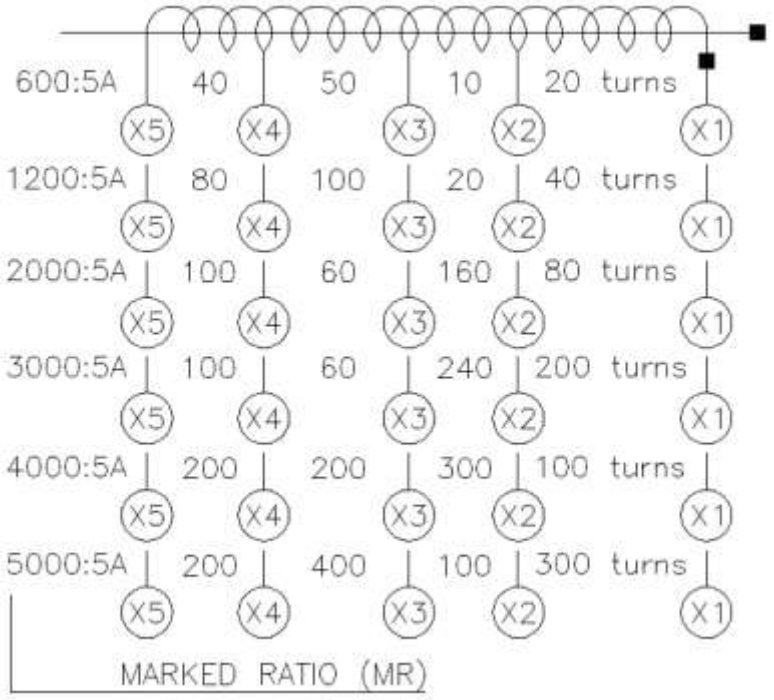
Instrument Transformer Basics

Polarity



Instrument Transformer Basics

Polarity- A multi-ratio



Instrument Transformer Basics

Understanding the Terminology

CT Rating Factor (RF)

The RF is the number of times the name plate current that can pass through the CT without over heating.

Typical values are 1.0, 1.33, 1.5, 2.0, 3.0 or 4.0

Example: A CT is marked 1200:5, RF=2.0
This CT can be applied at 1200*2.0= 2400 amps continuously without over heating!

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Metering accuracy

Expressed in a form like: 0.3 B 1.8

The first number is the accuracy class.
This is usually 0.3%, 0.6%, 1.2%, or 2.4%

The second number this the maximum burden (load) that you can put on the transformer and still get the accuracy percent!

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Metering accuracy

The IEEE C57.13 standard burdens:

	Burden Designation	Impedance (Ohms)	VA @ 5 amps	Power Factor
Metering	B0.1	0.1	2.5	0.9
	B0.2	0.2	5	0.9
	B0.5	0.5	12.5	0.9
	B0.9	0.9	22.5	0.9
	B1.8	1.8	45	0.9

Instrument Transformer Basics

Understanding the Terminology

Voltage Transformer Metering accuracy

The IEEE C57.13 standard burdens:

Burden Designation	Burden (VA)	Power Factor
W	12.5	0.10
X	25	0.70
M	35	0.20
Y	75	0.85
Z	200	0.85
ZZ	400	0.85

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Relay accuracy

Expressed in a form like: C50 or T50

Where the number represents the maximum amount of voltage that the CT can produce at 20 times over current with no more than a 10% error in transformation.

Instrument Transformer Basics

Understanding the Terminology

Selecting a CT
Both of these CTs are rated 600:5
How do you decide which one is right for you?

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Relay accuracy

Example:

A 600:5 CT is rated C20, 0.3 B 0.9. Can it produce enough voltage to trip a relay 50 feet away if connected to the relay with #14 awg. wire?

The voltage required is the sum of the voltage drop in the wire plus the relay burden (but most electronic relays have near zero burden), so lets look a the wire resistance:

Wire resistance= 50* 2* .0025 ohms/ ft = .25 ohms

Required voltage= I*R= 5*20*.25= 25 volts

25 volts > 20 volts

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Relay accuracy

Example:

A 600:5 CT is rated C20. Can it produce enough voltage to trip a relay 50 feet away if connected to the relay with #14 awg. wire?

25 volts > 20 volts, so this CT is to small!!

How could this be fixed?

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Relay accuracy

Aside: CT accuracy can more accurately be determined with the use on a CT Excitation curve.

EXCITATION CURVE

Part #: 780-102
Core: 780 1L
Ratio: 1000:5
DCR: 0.32

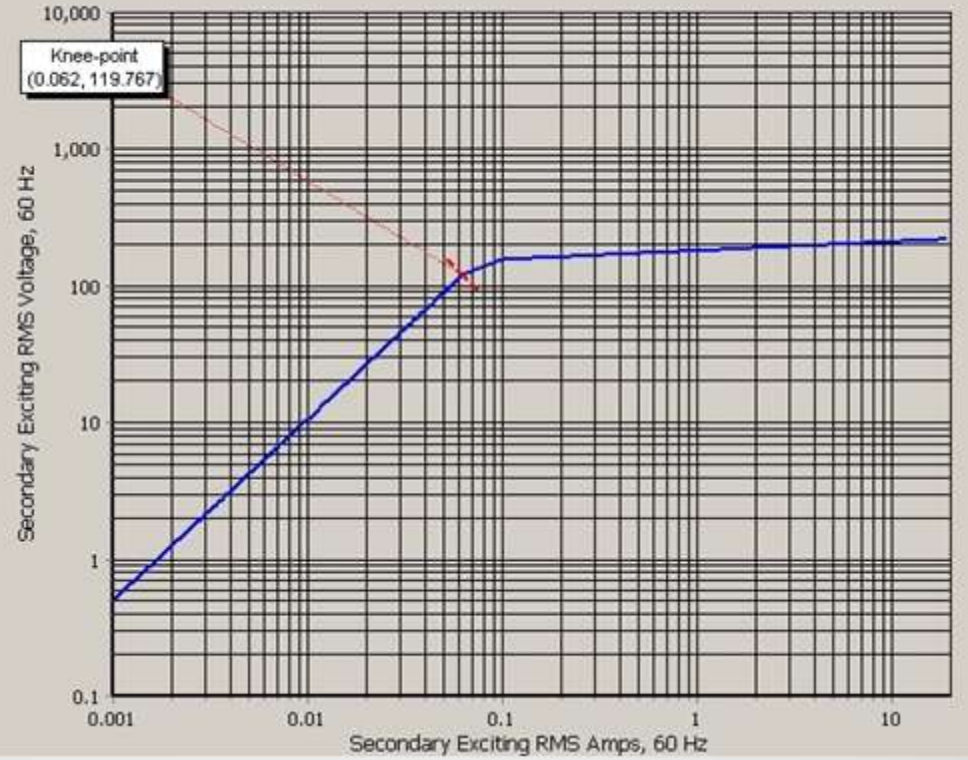
Plotting Coordinates

Current	Voltage
0.005	4.25
0.010	10.65
0.050	89.95
0.100	155.40
0.500	172.44
1.000	180.35
5.000	200.13
10.000	209.31

Ex Test Amps	Ex Test Volts
0.0620	119.77

Based on M4 steel

☐ Show Additional Ratios



Instrument Transformer Basics

Understanding the Terminology

Current Transformer Metering Accuracy

Example:

A 600:5 CT is rated C20, 0.3 B 0.9. Can it produce enough voltage to meter 50 feet away if connected to the relay with #14 awg. Wire?

The voltage required is the sum of the voltage drop in the wire plus the relay burden (but most electronic relays have near zero burden), so lets look a the wire resistance:

Wire resistance= 50* 2* .0025 ohms/ ft = 0.25 ohms

Instrument Transformer Basics

Understanding the Terminology

Current Transformer Metering Accuracy

Example:

A 600:5 CT is rated C20, 0.3 B 0.9. Can it produce enough voltage to meter 50 feet away if connected to the relay with #14 awg. Wire?

Since 0.25 ohms < 0.9 ohms

Even with the addition of a small meter burden, the CTs will perform fine.

Instrument Transformer Basics

Reading The Label

Actual Transformer Label

INSTRUMENT TRANSFOMERS,INC.
CURRENT TRANSFORMER
RATIO 1200:5 A. CAT 623-122MR
RF 1.33 ACC CLASS C100
50-400 HZ 600V INS CLASS 10kV BIL

Instrument Transformer Basics

Reading The Label

Actual Transformer Label

INSTRUMENT TRANSFOMERS,INC.
CURRENT TRANSFORMER
RATIO 400:5 A. CAT 115-401
RF 2.0 ACC CLASS 0.3B0.9 C50
50-400 HZ 600V INS CLASS 10kV BIL

Instrument Transformer Basics

Reading The Label

Actual Transformer Label

INSTRUMENT TRANSFOMERS,INC.
VOLTAGE TRANSFORMER PRI 2400V.
20:1 BIL 60kV 60 HZ 0.3Y
750VA @ 30 DEG C PTG3-2-60-SD0331

Instrument Transformer Basics

Reading The Label

Transformer Label

INSTRUMENT TRANSFOMERS,INC.
VOLTAGE TRANSFORMER PRI 12000V.
100:1 BIL 110kV 60 HZ 0.3WXMYZ 1.2ZZ
1200VA @ 30 DEG C PTG5-2-110-SDXXXXXFF

Instrument Transformer Basics

Do's and Don'ts

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…

Instrument Transformer Basics

Do's and Don'ts

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.

Instrument Transformer Basics

Checking Instrument Transformers
Is my transformer good?

The Rule Book:

ANSI/ NETA MTS-
STANDARD FOR MAINTENANCE TESTING SPECIFICATIONS

Instrument Transformer Basics

Checking Instrument Transformers
Is my transformer good?

Test number #1- Physical Observation

Sight
Do you see any damage?
Burn marks
Cracks
Blown fuse (PT only)

Sound
Does it rattle?

Smell
If you suspect a recent event, sniff the CT or PT. An internally shorted transformer can produce a lot of heat that can burn insulation. And, by all means, do not re-energize a transformer that does not pass the sniff test- even if it tests good!
Caution: Don't sniff test PVC dipped CTs

Instrument Transformer Basics

Checking Instrument Transformers

Is my PT good?

<u>Test #2</u>
<u>Continuity test to look for broken internal wires</u>

Measure the resistance from X1 to X2 and H1 to H2.

You should always see some resistance, but the H1 to H2 might be high on medium voltage transformers.

The resistance from X1 to X2 should always be less than H1 to H2!

If you can't measure resistance the PT is bad, don't do any more testing!

Instrument Transformer Basics

Checking Instrument Transformers

Is my CT good?

<u>Test #2</u>
<u>Continuity test to look for broken internal wires</u>

Measure the resistance from X1 to X2. Make sure all leads and shorting wires are removed form the terminals.

If resistance can't be measured or it shows very high, the CT is bad.
All 5 amp secondary CTs have a low secondary resistance. The exact value can be found on the manufactures specification sheet.

If you can't measure resistance the CT is bad, don't do any more testing!

Instrument Transformer Basics

Checking Instrument Transformers
Is my CT good?

<u>Test #3 (the ratio test)</u>

Buy a small bench top Variac (A variable voltage output transformer) and a small 120:12v transformer. Connect the transformer so that you have a variable 0-12 volt power source.

1. **Connect the variac leads to the X1 and X2 terminals of the CT and very slowly raise the voltage**
   Rules of thumb:
   - **Apply no more than ½ the relay class on a relay class CT**
     - **I.e. if the relay class is C50, then apply no more than 50/2=25 volts**
   - **Apply no more than 5 * burden class on a metering CT**
     - **I.e. if the burden is B0.5, then apply no more than 0.5*5=2.5volt**
2. **Loop a wire through the CT window one or more times and measure the voltage.**
   - **The voltage measured should be: $V_{(X1 \text{ to } X2)}$ * # of loops / Turns ratio**

Instrument Transformer Basics

Checking Instrument Transformers
Is my PT good?

<u>Test #3 (Ratio test)</u>

1. Remove all wires from the PT terminals.
2. Connect your variac across the H1 and H2 terminals.

> **STOP: NEVER connect the variac across the X1 to X2 terminals. Very high voltage may be present across H1 and H2 if this is done!**

3. Slowly raise the voltage on the variac to about 50 volts maximum. You don't need more!
4. Measure voltage across H1 to H2, and then across X1 to X2.
5. $V_{(H1\ to\ H2)}$/ $V_{(X1\ to\ X2)}$ should equal the Transformer Turns Ratio

Instrument Transformer Basics

Checking Instrument Transformers

Is my Instrument Transformer good?

<u>Test #4 (the insulation test)</u>

Perform insulation resistance testing per NETA/ ANSI MTS

Insulation resistance test levels and test values are recorded in Table 100.1 of the NETA/ANSI MTS standard.
For example 1000v rated equipment should be tested with 1000VDC and 100 Megohms should be the lowest acceptable resistance.

Instrument Transformer Basics

Inspecting Instrument Transformers

In theory, instrument transformers require little service, but….

Keep them Clean
Wipe them clean when you inspect them with a clean dry cloth.

If you have transformers on medium voltage systems, look for treeing.
(Treeing is carbon tracks that forms on the surface of the transformer due to partial discharge and/or corona.)
Clean it off!! The tracks will only grow larger, and can eventually break down.

Instrument Transformer Basics

LINE POWER

Questions?