Current Transformers

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  - Steve Laslo
    - For the Hands On Relay School (3-13)
      - Revision 1.1 (Basic)
Objective of the presentation:

For participants to increase their knowledge level of Current Transformers in the following areas:

- CT Theory
  - Basic Operation
  - CT Polarity
  - CT Connections
- Safety Hazards
- Basic Safe Work Practices
Examples of CT’s
Examples of CT’s

Note Current Path

Free-Standing CT’s
Examples of CT’s

Free-Standing CT’s
Examples of CT’s
Basic Theory:

CT as a Voltage Transformer
CT as a Voltage Transformer
Working Range of (relative) flux levels on core:

Saturation Curves
CT with varying burden
CT with varying burden
CT with varying burden
Secondary open circuit wave shapes

Rapid flux state change causes high voltage spikes

Secondary Induced Voltage Spike
- $I_p$ - Primary Current
- $E_s$ - Induced e.m.f.
- $\phi_p$ - Core Flux

Core Flux During Saturation
A CT can easily supply currents above lethal levels!
The open circuit situation resolves to high voltages and lethal currents… WATCH THIS!!
CT Polarity

- Shows instantaneous current flow
- Polarity Mark generally indicates H1/X1 terminals.
Instrument Transformers are almost universally ‘Subtractive’ polarity
Another view on polarity:
Current flows as if there is a physical connection.
Some pictures of CT’s with polarity marks:

Bar-type CT
• Some pictures of CT’s with polarity marks:

Small Window CT
Some pictures of CT’s with polarity marks:
CT Polarity is critical when CT’s are being used together in single-phase or three-phase applications.
• CT’s in series act together to reduce burden per CT, and increase overall performance.
CT Polarity

- Basic Differential circuit.
  - Correct polarity is critical to proper circuit operation.
CT Polarity marks are almost universally installed with the polarity marks ‘away’ from the equipment they are installed on.
CT Polarity – Brain Teaser

- Which picture's have correct polarity and which are wrong?
- What would be the effect of the 'wrong' polarity?
Which picture's have correct polarity and which are wrong?
What would be the effect of the ‘wrong’ polarity?
There are 3 fundamental connections possible with CT’s in 3-Phase circuits.

- Wye
- Delta: a-c
- Delta: a-b
CURRENT SCHEMATIC

Schematic and Current path for ABB Flexi-test switches – Switches 'Closed'
‘Jack’ point for in-service readings.

‘Make before Break’ switch with contact to shorting bar.
‘Make before Break’ switch with contact to shorting bar.
‘Jack’ point for in-service readings.
Blade pulled slightly out makes contact with bar before separating from relay circuit.
Westinghouse-ABB Case/Switches
GE/Basler Style Case

- Shorting Bar
- Test Plug
GE/Basler Style Case

Shorting Bar

Spring Loaded Contacts
‘Isolated’ CT Circuits are typically single-point grounded.
- Since most CT connections are ‘Wye’, this ground is typically placed at the neutral connection.
- The ground keeps the whole CT winding at a reasonably low potential to ground.
- This is especially important in high-voltage environments where capacitive voltage dividers can be formed which can elevate the entire CT winding to an unsafe level.
Floating Secondary Issues

HV Conductor(s)

Capacitance between HV Conductor and Secondary Winding

Capacitance between Secondary Winding and Ground
• Working around CT Circuits:
  ◦ **Circuit Identification**
    • Wiring Diagram / AC Schematic Information.
  ◦ **Testing for Energized Circuits**
    • Secondary Current measurement.
    • Audible/Visual arcing check.
  ◦ **Safe work practices**
  ◦ **Job Briefings**
  ◦ **Methods of shorting at CT Shorting Blocks**
• Wiring Diagrams and/or Layout Prints should show actual placement of Terminal Blocks seen on Schematic Diagrams.
• Schematic Diagrams show Circuit Functionality and may have some Wiring Diagram information shown on them.
• Schematics and Wiring Diagrams should agree with each other.
• Your company may have standards for typical CT configurations that may aid in the identification process.
Diagram shows physical location of CT’s relative to the PCB and each other.

Example of ‘Clues’ to physical location of CT Circuits.
LOCALED LEFT SIDE OF THREE PHASE CAB. (SH. 3)

Example of critical information pertinent to physical location of CT Circuits.
CT Secondary Wires should be lifted slowly while listening for arcing as a final verification check.

The visual/audible Arcing Check is also not 100% reliable as a test for an open-circuit CT condition.

- In brightly lit and/or noisy areas, it may be difficult to detect the arcing condition.
- With low values of CT secondary current, there may be little-to-no arcing when wiring is lifted.
Using Test Instruments

Fluke Current Measuring Devices
Care should be taken to keep yourself from becoming a possible current path for the CT should it become open-circuited.

- Since CT Circuits are typically grounded (Wye), if you are touching Termination Frames or Relay Racks you may become part of the current path if you contact the CT conductor during an open-circuit incident.
Re-enactment of 1st Contact Accident

Quote from the Accident Report:

“The Electrician said he could smell his flesh burning”
When shorting CT secondaries at CT Shorting Blocks, care must be taken to properly short the CT Circuit.

- Depending on the connection made at the block it may take anywhere from 2 to 6 shorting screws to fully short the CT secondaries.
‘Single-Phase’ Type CT Shorting Block

- CT ratio tap wiring from one individual CT
- Note that a minimum of two screws are needed to short this 1 CT – if the full winding is shorted (Y1-Y5 in this case).
- Single-Phase wiring from individual CT to relays, instruments, etc.
- Ground screw connection normally left in-place.
- Shorting Block Ground
Single-Phase短路块示例
‘Three-Phase’ Type CT Shorting Block

CT wiring from three single-phase individual CT’s (three pairs)

Shorting Block Ground

Ground screw connection normally left in-place.

Three-Phase wiring to relays, instruments, etc.

Note that it takes a minimum of four screws to short this set of 3 CT’s – (2Y1, 4Y1, 6Y1, and one of 2Y5, 4Y5, and 6Y5 in this case) – as long as the Wye connection is intact – white wiring here.
Three-Phase Block Analysis
• Make sure necessary wiring is in place to effectively short ‘Three-Phase’ type blocks.

❤ Whenever using less than 6 shorting screws for a 3-phase circuit, the ‘Wye’ or ‘Delta’ connections MUST be intact or some CT’s may not be properly shorted.
Questions?