Current Transformers

- Bonneville Power Administration
  - Steve Laslo
    - For the Hands On Relay School (3-12)
      - Revision 1.1
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
Single CT’s
CT’s in Series
Secondary open circuit wave shapes

Rapid flux state change causes high voltage spikes

Core Flux During Saturation

Secondary Induced Voltage Spike

$I_p$ - Primary Current

$E_s$ - Induced e.m.f.

$\phi_p$ - Core Flux
CT used was from a retired 500kV ITE SF6 PCB - BCT 3000/5 (Full Winding).
Test Equipment: TEK 20kV probe, ITE/Gould Digital Scope, Transrex high current supply.
Test Performed in EPA Mangan Lab - 7/16/02.
Note: Test Data are approximate values combined from two consecutive test runs.
- Added V/A Column 8-02 (SIL); formatting change (6-03).
## CT Open Circuit Voltage Test

7-16-02 Ron Denis / Steve Laslo

<table>
<thead>
<tr>
<th>Primary Current (Amps)</th>
<th>Secondary Output Voltage ($V_{PEAK}$)</th>
<th>$V_{PEAK}$/Amp</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>110</td>
<td>22</td>
<td>Sine Wave</td>
</tr>
<tr>
<td>49</td>
<td>900</td>
<td>18.37</td>
<td>Slight Distortion</td>
</tr>
<tr>
<td>167</td>
<td>1400</td>
<td>8.38</td>
<td>Marked Distortion</td>
</tr>
<tr>
<td>567</td>
<td>1800</td>
<td>3.17</td>
<td></td>
</tr>
<tr>
<td>813</td>
<td>2220</td>
<td>2.73</td>
<td>Saturated – CT making significant noise</td>
</tr>
<tr>
<td>1967</td>
<td>2600</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>2337</td>
<td>3600</td>
<td>1.54</td>
<td>Fully Saturated – Waveform primarily consisting of Voltage Spikes</td>
</tr>
<tr>
<td>3987</td>
<td>5000</td>
<td>1.25</td>
<td>Higher, Narrower Spikes</td>
</tr>
<tr>
<td>5047</td>
<td>5900</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>6487</td>
<td>8000</td>
<td>1.23</td>
<td>CT noise level very high Waveform extremely peaked</td>
</tr>
</tbody>
</table>
A CT can easily supply currents above lethal levels!
**Ratings of CT’s**

<table>
<thead>
<tr>
<th>Current Ratio</th>
<th>Catalog #</th>
<th>Meter Accuracy</th>
<th>Relay Accuracy</th>
<th>Rating Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200:5</td>
<td>D041200S1</td>
<td>0.3 B1.8</td>
<td>C300</td>
<td>2.0</td>
</tr>
</tbody>
</table>

- **Meter Accuracy:**
  - Secondary Current will be within 0.3% accuracy at rated current and Burden levels of 1.8 ohms or less.

- **Relay Accuracy:**
  - Secondary Current will be within 10% accuracy at 1-20 x rated current with burden levels of 3 ohms or less.
  - Full winding output of the CT is essentially 300V, which can drive 100A secondary current through a 3 ohm burden (or less).
  - ‘C’ indicates accuracy can be calculated based on design of this CT. ‘C’ ratings are the most common.
  - Less common letter classes: K, T, H, L

- **Rating Factor:**
  - Up to 2 x rated current can be applied continuously with the CT staying within it’s accuracy and thermal ratings.
By the IEEE Standard, does a 0.3% CT mean its 0.3% accurate?

IEEE Standard
Actual CT Accuracy
New supplement to IEEE Standard
- C57.13.6-2005
- Creates a new 0.15% accuracy class
  - With an extended, **consistent** range between 5% and TRF
Multi-ratio issues
• **Ratio Test**
  ◦ Two commonly used out-of-service methods to test:
    • **Voltage Method**
      ◦ CT is essentially tested as a voltage transformer by applying voltage to the CT Secondary and measuring the primary voltage.
      ◦ The turns ratio is approximately equal to the voltage ratio.

![Diagram of CT Ratio Test](image)
• **Ratio Test**
  ◦ **Current Method**
    ◦ Some form of ‘loading gear’ is used to push current through the CT primary. Secondary current is compared to primary current, usually through a ‘Reference CT’.
• Polarity Test
  ◦ Four commonly used out-of-service methods to test:
    • DC Flash Method
      ◦ A lantern battery or equivalent DC source is momentarily connected to the CT Secondary and the primary voltage is monitored with a voltmeter.
• Classical Polarity Test
  ◦ Voltage Method
    • This test is performed in the same manner as a voltage transformer polarity test.
Testing CT’s

- **Ratio/Polarity Test using voltage method:**
  - While performing ratio check, phase angle of both voltages is compared using phase angle meter(s).
Ratio/Polarity Test using Current Method

While performing ratio check, phase angle of both voltages is compared using phase angle meter(s).
Excitation Test

- Secondary Excitation Method
  - Secondary voltage is applied and exciting current is measured
  - Voltage / Current are plotted and compared to manufacturer’s information
Excitation Curves
Excitation Test using Primary Current Injection
- Primary Current is measured along with secondary voltage
- Primary exciting current is divided by the CT ratio to determine equivalent secondary exciting current to compare to manufacturer’s diagrams.
True-RMS Meter

'CTER' Meter

Average Response Meter
The easiest way to demagnetize a CT is to apply test current at a level that approaches its excitation ‘knee’, then slowly decrease the input current to zero. This can be done with secondary excitation or primary current injection.
A ground shield should be used on the unit as it is normally mounted in an area of high lightning incidence, the strike-over zone of the bushing or close to the bottom of the porcelain. The ground shield lead should be routed on the same side of the CT where the mounting hardware is located (see Figures 1, 2 & 3).

- If shield systems are improperly mounted, induced current will flow through the CT, causing ratio errors.

**Possible Ground Loop Traps**
Floating Secondary Issues

HV Conductor(s)

Capacitance between HV Conductor and Secondary Winding

Capacitance between Secondary Winding and Ground
Re-enactment of 1st Contact Accident

Quote from the Accident Report:
“The Electrician said he could smell his flesh burning”
‘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).

Shorting Block Ground

Single-Phase wiring from individual CT to relays, instruments, etc.

Ground screw connection normally left in-place.
Single-Phase Shorting Block Example
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.
CT Circuits can easily provide enough voltage and associated current to inflict lethal wounds if open-circuited while primary current is flowing.

- Before working on CT Circuitry a Job Briefing should be held, and the Circuits positively Identified and Tested.
- Good work practices can help avoid injury in the event a current circuit does become open-circuited.
- Take whatever time is necessary to perform the job properly and safely.

Safety Summary