As test equipment becomes more sophisticated with better features and accuracy, we risk turning our field personnel into test-set operators instead of skilled field service technicians. A test-set operator connects the leads, pushes the buttons, and records the results, hoping the numbers he records are good. A test technician connects the leads, pushes the buttons, and records the results. However, the test technician understands what the test set was doing while all the lights were flashing, and why. The technician can also evaluate the results and determine if a retest is necessary with different connections or substitute external equipment for tests when the test equipment malfunctions. The purpose of this article is to help a test-set operator understand the tests he performs, reinforce a test technique, or add it to his repertoire.

Description of Operation

During normal operation, a current transformer (CT) transforms higher current into a more manageable secondary current. This transformation is made possible by copper coils wrapped around an iron core, with the ratio between primary and secondary currents determined by the ratio between the number of primary and secondary turns. Bar- and window-type CTs do not have a physical primary winding and are considered to have one primary turn. When current flows through the primary winding, the following actions occur:

- The iron core inside the transformer is magnetized.
- The magnetic field in the iron core induces a voltage in the secondary coils.
- If the secondary circuit is closed, a current flows through the secondary circuit in proportion to the CT ratio.

The current transformation requires a small amount of energy to magnetize the iron core that creates small energy losses such as eddy currents, and heat caused by current flowing through the windings. Therefore, the secondary current is not a perfect representation of the primary current. All CTs that are built to ANSI standards have an accuracy class to outline what effect the losses have on the secondary current under normal conditions. The accuracy class is the minimum accuracy guaranteed by the manufacturer, although the CT may be built to higher standards.

Like every other transformer, CTs can only transform a finite amount of energy. This is usually the voltampere rating for normal transformers. The CTs energy limitation is included in the accuracy class but is shown as a maximum burden. The CT burden is the amount of impedance (ac resistance) connected to the CT secondaries and is usually rated in ohms or volts. The manufacturer only guarantees CT accuracy up to a maximum burden rating, and CT performance will degrade if the secondary burden is larger than rated.
Visual and Mechanical Inspections

Equipment Specifications

While performing visual and mechanical inspections, always compare equipment nameplate data with drawings and specifications. Every CT test sheet should include the following information:

**Serial Number** (when possible): The serial number is important to organize test results and allow a reference when comparing test results to manufacturer’s specifications. The serial number can also be used when ordering replacement or new CTs from manufacturers.

**Model Number** (when possible): The model number is important when comparing test results to manufacturer’s literature and ordering replacement, new, or spare CTs from manufacturers.

**Ratio**: The CT ratio is the most important piece of information regarding the CT and must be recorded from the nameplate or the design criteria. The ratio determines the CT’s operating characteristics and is used as reference for tests. If the CT has multiple taps (different possible ratio combinations), all taps should be recorded for future reference in case a new ratio is required for the application. This will allow a review of the options without visiting the site beforehand.

**Accuracy Class**: The CT accuracy class comprises a number-letter-number combination and indicates the CT’s ability to perform accurately under different conditions. In other words, the CT accuracy class indicates the CT’s performance characteristics and the maximum burden allowable on the CT secondaries. CTs can be separated into two distinct groups: metering and protection or relay. A CT can have ratings for both groups. See Figure 1 for a list of typical accuracy classes.

The CT accuracy class is made up of three parts, which are described in conjunction with Figure 2.

### Table: Standard Burdens for Standard 5-AMP / 60 Hz Secondary Current Transformers

<table>
<thead>
<tr>
<th>Burden Designation</th>
<th>Standard Secondary Burden Ratings</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Impedance (Ohms)</td>
</tr>
<tr>
<td>B-0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>B-0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>B-0.5</td>
<td>0.5</td>
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<td>B-4</td>
<td>4</td>
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<tr>
<td>B-8</td>
<td>8</td>
</tr>
</tbody>
</table>

**Accuracy**: The first number in the CT accuracy class is the rated ratio accuracy in percent. For example, the ratio of a 0.3B0.1 metering-class CT is accurate within 0.3 percent as long as the CT burden rating is not exceeded. The ratio of a 2.5C100 protection-class CT is accurate within 2.5 percent if the CT burden rating is not exceeded.

**Current-Transformer Class**: The second part of the accuracy class is a letter. The letter distinguishes for what application the CT is rated. A CT can have dual ratings and be used in metering or protection applications, if both ratings are listed on the nameplate.

Metering-class CTs have the letter B in the accuracy-class rating. They are designed for maximum accuracy from very low currents to the maximum CT rating. These CTs are often used to record power consumption and are the basis for electrical bills, hence the need for accuracy. A typical metering-class CT has an accuracy class similar to 0.3B0.1.

Protection-class CTs have the letters C, H, L, or T to indicate the protection-class rating.

- A C-rating indicates that the CT accuracy can be calculated before construction because there is no appreciable leakage flux in the CT design.
- A T-rating indicates that the CT can have significant leakage flux, and the CT accuracy must be obtained by testing in the factory.
- An H-rating indicates that the CT accuracy rating is applicable within the entire range of secondary currents from five to 20 times the nominal CT rating. These are typically wound CTs.
- An L-rating indicates that the CT accuracy applies at the maximum-rated secondary burden at 20 times rated only. The ratio accuracy can be up to four
times greater than the listed value, depending on the connected burden and fault current. These are typically window, bushing, or bar-type CTs.

Protection-class CTs are not as accurate as metering-class CTs but are designed to operate over a wider range of current. This wider range is necessary to allow the protective relay to operate at different fault levels. Protection-class CTs are typically rated to operate accurately up to 20 times the CT rating. A typical protection-class CT has an accuracy class similar to 2.5C100.

**Burden:** The third part of the accuracy-class rating follows the letter and indicates the maximum burden allowed. If the CT secondary-burden rating is exceeded, CT accuracy is not guaranteed.

Metering-class CT burdens are displayed as secondary ohms. For example, the ratio of a 0.3B0.1 rated CT is accurate to 0.3 percent if the connected secondary burden impedance does not exceed 0.1 ohms. A 0.6B8 rated metering-class CT will operate within 0.6 percent accuracy if the secondary burden does not exceed 8.0 ohms.

Protection-class CT burdens are displayed as the maximum secondary volts allowable if 20 times (100 amperes with a five-ampere nominal CT secondary) the CT rating were to flow through the secondary circuit. For example, a 2.5C100 protection-class CT is accurate within 2.5 percent if the secondary burden is less than 1.0 ohm (100 volts / 100 amperes).

**CT Type:** The four typical CT types include window, bushing, bar, and wound.

- Window CTs are the most common. They are constructed with no primary winding and are installed around the primary conductor. The electric field created by current flowing through the conductor interacts with the CT core to transform the current to the appropriate secondary output. Window CTs can be of solid or split core construction. The primary conductor must be disconnected when installing solid window CTs. However, split core CTs can be installed around the primary conductor without disconnecting the primary conductor.

- Bushing CTs are window CTs specially constructed to fit around a bushing. Usually they cannot be accessed, and their nameplates are found on the transformer or circuit-breaker control cabinets.

- Bar-type CTs operate on the same principle of window CTs but have a permanent bar installed as a primary conductor.

- Wound CTs have a primary and secondary winding like a normal transformer. These CTs are rare and are usually used at very low ratios and currents, typically in CT secondary circuits to compensate for low currents, to match different CT ratios in summing applications, or to isolate different CT circuits. Wound CTs have very high burdens, and special attention to the source CT burden should be applied when wound CTs are used.

**Voltage Class:** The CT voltage class determines the maximum voltage with which a CT can be in direct contact. For example, a 600-volt window CT cannot be installed on or around a bare 2400-volt conductor. However, a 600-volt window CT can be installed around a 2400-volt cable if the CT is installed around the insulated portion of the cable and the insulation is rated correctly.
Physical and Mechanical Condition

Verify the physical and mechanical condition of the CT. When possible, the CT should be inspected for shipping damage, incorrect bracing, cracks, and general overall condition. The CT should be permanently mounted and not supported by the primary conductor.

Correct Connection of Transformers

Verify the correct connection of transformers with system requirements. This step is often the most critical step performed. Incorrect CT connections can cause significant problems on any polarity-sensitive metering or protection scheme such as generator protection (IEEE 32, 40, 67), line protection (IEEE 21, 67, 78), or differential elements (IEEE 87). In many instances, the connection is as important as the CT polarity. If the primary polarity of a CT is reversed, the secondary wiring can also be reversed to achieve the desired overall polarity. Two wrongs often make a right when working with CT connections.

Adequate Clearances

Verify that adequate clearances exist between primary and secondary circuit wiring. Inspect the space between the CT phases, ground, and secondary conductor to ensure adequate clearance. (Quick rule-of-thumb: one inch per kilovolt plus one inch.) Remember that line-to-line voltages apply between phases. Also check that the secondary wiring is not run parallel and/or close to the primary conductor to prevent any current from being induced into the secondary path. All wiring above the primary conductor should be permanently affixed to the structure to prevent the wiring from falling onto the primary conductors in the future. (Sticky backs are not considered permanent.)

Grounding and Shorting Connection

Verify that all required grounding and shorting connections provide contact. CTs are always shipped with shorting devices installed if the burden circuit cannot be completed at the factory. Measure the resistance between both sides of the terminal block to ground before removing the shorting device to ensure the device is operating correctly. The measured resistance should be negligible. The CTs should remain shorted until the secondary wiring is complete and loop-tested. Always check to ensure that the shorting devices are removed on in-service CTs just prior to energization.

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