Often, when relay technicians arrive at a customer’s job site, they have a specific task in mind — test relays. Many (certainly not all) technicians do not give instrument transformers a thought. It is not a minor point that the protective relays can be connected, calibrated and ready to go, but if the instrument transformers are not up to speed, those wonderfully engineered protective relays are about as much use as bus bar. I have gone to job sites where the relays were perfectly calibrated (by me, of course), but when the instrument transformers were checked, they had a number of problems that rendered the relays inoperative. Following is a short list of CT problems found at one customer’s site:

• Shorted CT secondaries
• Open-circuited CT secondaries
• Miswired CTs
• CTs that had not been wired
• CTs installed backwards
• Incorrect CTs
• Defective CTs
• CTs with incorrect ratios or on the wrong taps

Mind you, this was just at one site and had been in operation for years in this fashion. When teaching a course there, I spoke with their electrical engineer. He designed and installed a new part of their electrical system but had never heard of CT polarity. (I thought he was making that up.) After explaining instrument transformer polarity, he said, “So that’s why the directional relays were tripping.” I asked him how he finally resolved the problem, and he said, “I just switched wires until it worked.” I am not making this up — I wish I were. In the articles I wrote on transformer differential relaying (*NETA World*, 1989, Volume 11, Number 1) polarity of CTs was covered. If you missed this article, call me to send you a copy.

**Instrument Transformer Tests**

Besides the obvious doo-dah’s mentioned above, such as verifying that CTs are neither shorted nor open-circuited and the like, what tests should be performed? Part of the answer depends on whether it is a routine maintenance test interval, a major maintenance test interval, or acceptance testing. During acceptance testing, all aspects and characteristics of the device are tested; you want to be certain you received what you paid for and that the device can be used at all settings. Maintenance testing is performed to ensure the device is suitable for continued service and is usually only done at the existing taps or settings. For CTs, the most common field maintenance tests are:

• Ratio
• Saturation
• Insulation resistance
• Burden

For PTs/VTs:

• Ratio
• Insulation resistance
Figure 1 — Current Transformers

Figure 1 shows two types of current transformers: bar-type on the left and right and window-type in the center. Acceptance testing on a CT usually involves performing the above-listed tests on all ratios and taps plus a polarity test. NETA MTS-01 lists the burden and polarity tests as maintenance tests also. However, if the CTs have been tested in the past and correctly documented, there is not much chance that the polarity will change. The burden test is another story. Considering the problems an over-burdened instrument transformer can cause, the burden test should always be considered during maintenance testing. Unfortunately, this important test is neglected, even during acceptance testing.

He Ain’t Heavy….

You will often hear of relay burdens or coil burdens but may wonder exactly what that is. Burden is the amount of impedance a coil or other device has; it is expressed in ohms. This column will look at the amount of burden (or load) a CT can handle without saturating. This is calculated as

\[ Z_B = \frac{(N_p)(V_{\text{cl}}) - (I_{\text{ext}} - 100)(R_s)}{I_{\text{ext}}} \]

Where:

- \( Z_B \) = The allowable burden on the CT
- \( N_p \) = Proportion of CT turns in use (Turns in use / Total number of turns for multiratio CTs)
- \( V_{\text{cl}} \) = The ANSI voltage class of the CT
- \( I_{\text{ext}} \) = External fault current in CT secondary values.
- \( I_{\text{ext}} \) is considered to be 100 if the actual secondary current is less than 100 amperes.
- \( R_s \) = CT secondary winding resistance (in ohms). If \( I_{\text{ext}} \) is less than 100 amperes, \( R_s \) is zero.

CT performance (read that as accuracy) will be satisfactory if the calculated value of \( Z_B \) is less than the calculated or measured value for \( Z_T \), the total CT secondary burden. \( R_l \) can be measured using a DVM on an installed system and the result plugged into the calculation for \( Z_T \) (total impedance) or it can be estimated using standard wire resistances.

\( Z_T \) for wye-connected CT’s is:

- 3Ø Faults = 1.13 (\( R_l \)) + \( R_B \) + \( Z_A \)
- \( R \)-ground Faults = 1.13 (2\( R_l \)) + \( R_B \) + \( Z_A \)

\( Z_T \) for delta-connected CT’s is:

- 3Ø Faults = 3 \[ 1.13 (R_l) + R_B + Z_A \]
- \( R \)-ground Faults = 2 \[ 1.13 (R_l) + R_B + Z_A \]

Where:

- 1.13 = multiplier to account for temperature rise in the conductors during faults
- \( Z_T \) = Total CT secondary burden (in ohms)
- \( R_l \) = The one-way lead resistance @ 75⁰ (in ohms)
- \( Z_A \) = The burden of any other device or coil connected to the CT
- \( R_B \) = Burden of the relay coil

As an example:

Maximum calculated short-circuit current available (in primary amperes) — 12,000A

CT used — 1200:5 multiratio CT
800:5 tap used
ANSI Class — C200

Actual Circuit Burden — 3 ohms (\( R_B + R_l \))

\[ N_p = \frac{800}{1200} = 0.67 \]

\[ I_{\text{ext}} = I_p \]

\[ I_p = \frac{12000A}{1200} = 0.67 \]

\[ N = \frac{160}{75} = 75 \]

\( N_p \) is the proportion of turns in use, and \( N \) is the turns ratio of the CT turns in use (800/5). \( I_p \) is the primary current.

Enter the numbers into the formula for allowable burden:

\[ Z_B = 0.67 x 200 x (100-100) x 0 \]

\[ = 1.34 \text{ ohms} \]
The actual circuit burden is 3.0 ohms, which exceeds the allowable calculated burden of 1.34 ohms. In this situation, the CT would likely go into saturation during a short-circuit condition, causing the relay to misoperate or, possibly, not operate at all. The options here are:

1. Reduce the burden on the CT
2. Use a higher CT ratio tap
3. Use a higher ANSI class CT
4. Series two CTs (utilities often use this one)

At the beginning of this column, I mentioned the facility that had so many CT problems. It is probably worth mentioning that these problems were discovered when the system was given a primary injection functional trip test. A high-current test set was connected to each phase of a de-energized bus. Current was passed through the CTs, and relay operation was observed. Needless to say, due to the previously-mentioned problems, many of the relays did not function. Unfortunately, production managers seem to believe that if they never have a trip, everything is working just fine. We in the testing and maintenance industry know that that is often not true.

In summary, relays must have an accurate and proportional voltage or current to protect the system. Instrument transformers make up a large part of the protective scheme but are often neglected. As I have said in the past, part of our function is to educate our customers as to the consequences of neglecting their electrical system. Just because they do not see it does not mean it is not important or, in this case, critical.

There is a lot more information involving instrument transformers that I could cover in this column, if there is an interest. I am always interested in your opinions on past articles and ideas for new ones.

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