Specifying and using Current Transformers for Power Measurements

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Current transformers (CT) are simple and reliable devices which make it possible to make accurate measurements of alternating current flowing in a conductor without making any electrical contact. This characteristic makes the current transformer, or CT an invaluable tool for the power utility industry.

The principle of operation of a CT is the sensing of the magnetomotive force around a current-carrying conductor. The CT contains a high permeability magnetic core, and a multiple turn secondary winding. This secondary winding links all the magnetic flux generated in the core by the magnetomotive force (mmf) caused by the current in the primary conductor.

The CT therefore resembles other transformers. The goal in designing a CT is to approach the behavior of an ideal transformer, where the permeability of the core can be considered infinite; the resistance of the windings is zero, and both windings link exactly the same magnetic flux. To the extent these conditions are met, the transformer will have two properties:

1. The voltage per turn will be equal on both the primary and the secondary windings, so that the ratio V (sec)/V (pri) = N (sec)/N (pri).

2. The net magnetizing current is zero, so I (pri) x N(pri) + I (sec) x N (sec)=0, or

I (sec)/N(pri)= -I (pri)/N(sec).

It can be seen that an ideal transformer can be described by one number, the ratio N (sec)/N (pri). For the CT, N (pri) is usually 1, so that I (sec) = I (pri}/N (sec), or, as is usually written, I(pri)/N. (the negative sign can usually be ignored, unless the phase relationship between I(pri) and I(sec) is of importance in the measurement).

For most measurements, the CT secondary winding is permanently connected to a low value resistor, called the burden resistor. The voltage across this resistor is then

V= [I (pri)/N] x R. The value of R is determined by the maximum value of I (pri) to be measured, the number of secondary turns (N), and the full scale voltage of the measuring or recording device.

The value of R is then equal to (V x N) / I (pri). As an example, if V = 0.333 volts.

N = 5000, and I (pri) = 100 Amps, R will be16.65 ohms, and its full scale power dissipation will be 0.0067 watts.

It should be noted that a CT such as this one should never be operated with an open secondary winding. If this happens, and a current step is applied to the primary, the CT will briefly act as an N: 1 step up transformer, and a dangerous voltage surge will result. For applications where the burden resistor may be switched or removed, a permanently connected bi-directional zener diode (10 volts is usually OK) will eliminate the hazard.

Construction of the CT is determined by the application. For permanent installation a silicon iron toroidal core, usually offers the combination of high accuracy and small size at a reasonable cost. The main disadvantage is the necessity for interrupting the circuit during installation or removal.

To overcome this problem, several openable designs are in use. Some use tape wound cut cores mounted in a hand-operated clamp, so they can be installed with one hand. Other designs use plastic or metal clips to hold the core structure together. Yet another solution might be to make the core interleaving to minimize the air gap. All of these approaches require careful design and construction to maintain the integrity of the magnetic flux path, i.e., they do not introduce significant air gaps into the flux path.

The accuracy of a CT is of course affected in by turn count errors, and burden resistor tolerance. Other errors, which affect the phase error between I (pri) and the voltage across the burden resistor. This is caused by the fact that the CT is not an ideal transformer, but has a finite inductance, and a non-zero winding resistance (and burden resistance). This is the reason accuracy is a bigger problem either opening CT designs: the added air gap, no matter how small, lowers the inductance.

The phase error is generally not significant where only the amplitude of the current is important, but matters significantly when the CT is used in measuring power, when voltage and current signals are multiplied together. Accordingly, applications requiring accurate power measurements should use a CT with low phase error. For highest accuracy, a non-opening nickel iron alloy toroidal core provides the most inductance, and therefore the least error.

There is one disadvantage to the CT concept: The presence of a DC component in the current being measured will tend to saturate the core, and seriously affect the accuracy.

For higher frequency applications a ferrite core can be used. This makes the CT configuration usable up to 100 kHz and possibly more. This makes possible CT devices, which can be used on high frequency power conversion equipment.

The advantage of the CT can be summarized:

1. Isolation from circuit under test
2. High accuracy over a wide current range
3. No adjustments or recalibration required
4. Passive device – no power source required
5. Immune to overloads

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