Notes on Current Transformers

A current transformer is a transformer, which produces in its secondary winding a current, which is proportional to the current flowing in its primary winding. The secondary current is usually smaller in magnitude than the primary current.

The principal function of a CT is to produce a proportional current at a level of magnitude, which is suitable for the operation of measuring or protective devices such as indicating or recording instruments and relays.

The rated secondary current is commonly 5A or 1A, though lower currents such as 0.5A are not uncommon. It flows in the rated secondary load, usually called the burden, when the rated primary current flows in the primary winding.

The primary winding can consist merely of the primary current conductor passing once through an aperture in the current transformer core or it may consist of two or more turns wound on the core together with the secondary winding.

These are two basic CT types. The first is commonly called a “ring” type CT as the core is usually annular, but in some cases it may be square or rectangular in shape. The second is usually known as a “wound primary” type CT.

The primary and secondary currents are expressed as a ratio such as 100/5. With a 100/5 ratio CT, 100A flowing in the primary winding will result in 5A flowing in the secondary winding, provided the correct rated burden is connected to the secondary winding. Similarly, for lesser primary currents, the secondary currents are proportionately lower.

It should be noted that a 100/5 CT would not fulfil the function of a 20/1 or a 10/0.5 CT as the ratio expresses the current rating of the CT, not merely the ratio of the primary to the secondary currents.

The extent to which the secondary current magnitude differs from the calculated value expected by virtue of the CT ratio is defined by the [accuracy] “Class” of the CT. The greater the number used to define the class, the greater the permissible “current error” [the deviation in the secondary current from the calculated value].

Except for the least accurate classes, the accuracy class also defines the permissible phase angle displacement between primary and secondary currents. This latter point is important with measuring instruments influenced both by magnitude of current and by the phase angle difference between the supply voltage and the load current, such as kWh meters, wattmeter’s, var meters and power factor meters.

Common burden ratings are 2.5, 5, 10, 15 and 30VA.

Current transformers are usually either “measuring” or “protective” types, these descriptions being indicative of their functions. The principal requirements of a measuring CT are that, for primary currents up to 120% or 125% of the rated current, its secondary current is proportional to its primary current to a degree of accuracy as defined by its “Class” and, in the case of the more accurate types, that a specified maximum phase angle displacement is not exceeded.

A desirable characteristic of a measuring CT is that it should “saturate” when the primary current exceeds the percentage of rated current specified as the upper limit to which the accuracy provisions apply. This means that at these higher levels of primary current the secondary current is less than proportionate. The effect of this is to reduce the extent to which any measuring device connected to the CT secondary is subjected to current overload.

On the other hand the reverse is required of the protective type CT, the principal purpose of which is to provide a secondary current proportional to the primary current when it is several, or many, times the rated primary current. The measure of this characteristic is known as the “Accuracy Limit Factor” (A.L.F.). A protection type CT with an A.L.F. of 10 will produce a proportional current in the secondary winding [subject to the allowable current error] with primary currents up to a maximum of 10 times the rated current.

Preferred primary and secondary current ratings [and therefore ratios], classes, burdens and accuracy limit factors are defined in BS3938 and other comparable national standards, together with other minimum performance requirements, physical construction requirements, etc.

It should be remembered when using a CT that where there are two or more devices to be operated by the secondary winding, they must be connected in series across the winding. This is exactly the opposite of the method used to connect two or more loads to be supplied by a voltage or power transformer where the devices are paralleled across the secondary winding.

With a CT, an increase in the burden will result in an increase in the CT secondary output voltage. This is automatic and necessary to maintain the current to the correct magnitude. Conversely, a reduction in the burden will result in a reduction in the CT secondary output voltage.

This rise in secondary voltage output with an increase in burden means that, theoretically, with infinite burden as is the case with the secondary load open circuit, an infinitely high voltage appears across the secondary terminals. For practical reasons this voltage is not infinitely high, but can be high enough to cause a breakdown in the insulation between primary and secondary windings or between either or both windings and the core. For this reason, primary current should never be allowed to flow with no load or with a high resistance load connected across the secondary winding.

When considering the application of a CT it should be remembered that the total burden imposed on the secondary winding is not only the sum of the burden(s) of the individual device(s) connected to the winding but that it also includes the burden imposed by the connecting cable and the resistance of the connections.

If, for example, the resistance of the connecting cable and the connections is 0.1 ohm and the secondary rating of the CT is 5A, the burden of the cable and connections (RI2) is 0.1 x 5 x 5 = 2.5VA. This must be added to the burden(s) of the connected device(s) when determining whether the CT has an adequately large burden rating to supply the required device(s) and the burden imposed by the connections.

Should the burden imposed on the CT secondary winding by the connected device(s) and the connections exceed the rated burden of the CT the CT may partly or fully saturate and therefore not have a secondary current adequately linear with the primary current.

The burden imposed by a given resistance in ohms [such as the resistance of a connecting cable] is proportional to the square

Notes on Current Transformers (continued)

of the rated secondary current. Therefore, where long runs of cable between CT and the connected device(s) are involved, the use of a 1A secondary CT and a 1A device rather than 5A will result in a 25-fold reduction in the burden of the connecting cables and connections.

All burden ratings and calculations are at rated secondary current.

Because of the foregoing, when a relatively long [more than a very few metres] cable run is required to connect a CT to its burden [such as a remote ammeter] a calculation should be made to determine the cable burden. This is proportional to the "round trip" resistance, i.e. twice the resistance of the length of twin cable used. Cable tables provide information on the resistance values of different sizes of conductors at 20o C per unit length. The calculated resistance is then multiplied by the square of the CT secondary current rating [25 for 5A, 1 for 1A]. If the VA burden as calculated by this method and added to the rated burden(s) of the device(s) to be driven by the CT exceeds the CT burden rating, the cable size must be increased [to reduce the resistance and thus the burden] or a CT with a higher VA burden rating must be used, or a lower CT secondary current rating [with matching change in the current rating of the device(s) to be driven] should be substituted.

Burden (VA) of copper wires between instrument and current transformer for 1A and 5A secondaries

Cross section mm^2	Table for 1A Secondaries					
	Burden in VA (twin wires) Distance in metres					
	Distance					
	10m	20m	40m	60m	80m	100m
1.0	0.36	0.71	1.43	2.14	2.85	3.57
1.5	0.23	0.46	0.92	1.39	1.85	2.31
2.5	0.14	0.29	0.57	0.86	1.14	1.43
4.0	0.09	0.18	0.36	0.54	0.71	0.89
6.0	0.06	0.12	0.24	0.36	0.48	0.60

Cross section mm^2	Table for 5A Secondaries					
	Burden in VA (twin wires) Distance in metres					
	Distance					
	1m	2m	4m	6m	8m	10m
1.5	0.58	1.15	2.31	3.46	4.62	5.77
2.5	0.36	0.71	1.43	2.14	2.86	3.57
4.0	0.22	0.45	0.89	1.34	1.79	2.24
6.0	0.15	0.30	0.60	0.89	1.19	1.49
10.0	0.09	0.18	0.36	0.54	0.71	0.89

General

CTs should be specified as follows:

RATIO: input / output current ratio
VA: total burden including pilot wires.
CLASS: accuracy required for operation
DIMENSIONS: maximum & minimum limits

Metering CTs

In general, the following applies:

CLASS

- 0.1 or 0.2 for precision measurements
- 0.5 for high grade kilowatt hour meters for commercial grade kilowatt hour meters
- 3 for general industrial measurements
- 3 or 5 for approximate measurements

BURDEN (depending on pilot lead length)

- Moving iron ammeter 1-2VA
- Moving coil rectifier ammeter 1-2.5VA
- Electrodynamic instrument 2.5-5VA
- Maximum demand ammeter 3-6VA
- Recording ammeter or transducer 1-2.5VA

Protection CTs

In addition to the general specification required for CT design, protection CT's require an Accuracy Limit Factor (ALF). This is the multiple of rated current up to which the CT will operate while complying with the accuracy class requirements.

In general the following applies:

- Instantaneous overcurrent relays & trip coils - 2.5VA Class 10P5
- Thermal inverse time relays - 7.5VA Class 10P10
- Low consumption Relay - 2.5VA Class 10P10
- Inverse definite min. time relays (IDMT) overcurrent - 15VA Class 10P10/15
- IDMT Earth fault relays with approximate time grading - 15VA Class 10P10
- IDMT Earth fault relays with phase fault stability or accurate time grading required - 15VA Class 5P10

Class X CTs

Class X CTs are special CTs used mainly in balanced protection systems (including restricted earth fault) where the system is sensitively dependent on CT accuracy. Further to the general CT specifications, the manufacturer needs to know:

- Vkp - Voltage knee point
- Io - Maximum magnetising current at Vkp
- Rs - Maximum resistance of the secondary winding