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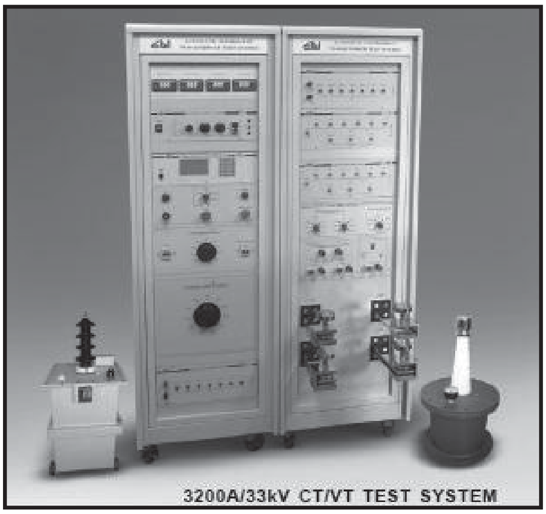
PRACTICAL ASPECT OF CT TESTING



This memorandum outlines many of the important aspects of assembling CT test equipment and using the same to test production CTs.

The important items of a CT test assembly include the following:

- A Reference Standard CT.
- A CT Comparator.
- A CT Burden Set.
- CT Demagnetizer.
- Connecting Leads.
- A Current Source.

REFERENCE STANDARD CT

The choice of the reference standard CT is very important. The CT must cover the expected ratio range and exhibit adequate accuracy for the CTs to be tested. In many instances users will equip themselves with toroidal CTs whose ratio can be changed at will by adding or subtracting turns from the primary winding. These become even more useful when there are several taps available on the secondary windings of such CTs.

It is very important to select a reference CT of adequate accuracy. Normally a reference CT of 10 times higher accuracy class than the test CT is used. Thus one would use a reference CT of 0.05% Class to test CTs of 0.5% Class. The use of such accurate CT allows one to use the results from the comparator directly, that is without correcting the readings for the errors of the standard CT. One may also use less accurate CT Standards, but then one must apply corrections to the observed readings in order to obtain accurate and correct test results. This would, for example, allow one to use a Class 0.1% or even Class 0.2% CT to test a Class 0.5% CT. It should be pointed out if the test CT is very close to meeting or failing its accuracy class all relevant corrections must be applied, including those of very accurate standards.

CT COMPARATOR

The "comparator" measures the deviation of the test CT from that of the reference CT. For most commercial applications a comparator should be capable of measuring errors from about 0.01% to about 4%. For special applications a wider measuring range than the above may be required. Thus for comparing standard CTs one would like to measure errors as low as 0.001% or even 0.0001% (1 part per million). For measuring CTs of not exactly the same ratio, one should consider ratio ranges of 20% or maybe even higher.

Another important characteristic of the comparator is the burden that it imposes on the reference CT. Modern comparators, typically using electronics, impose a rather low burden (typically < 1 VA) while some of the older manual comparators impose burdens in the order of 5 VA, or even as high as 15 VA. As a rule, a comparator exhibiting low burden is preferred, as a typical CT will exhibit lower errors at a lower burden. The only exception to this rule are compensated CTs. These are meant to be used at a prescribed burden and are typically not recommended or used as reference standard CTs.

Typical comparators will have connections for testing 5 Ampere and 1 Ampere CTs. Some may offer 2 Ampere or even other input current ranges. Comparators with multiple inputs will allow one to test 1 Ampere CTs while using a 5 Ampere standard. Typically the reverse is also true. Such features are desirable as CTs of several secondary current rating can be tested with only one standard CT, be it 5 or 1 Ampere. Comparators with multiple inputs will provide identical test results regardless of the inputs that are used.

CT BURDEN SET

A burden is always necessary when testing CTs to National or International Specifications. Typical burden specifications require them to exhibit certain impedance at a certain power factor (typically 0.8 lagging).

The accuracy of burdens is typically 3%. The accuracy of the burden may or may not be important depending on the burden sensitivity of the CT under test. CTs that exhibit high burden sensitivity, that is low accuracy or compensated CTs, should be tested at precisely the specified burdens if accurate and repeatable results are to obtained.

It is the normal practice in some jurisdictions to have the "physical burden" as per applicable specifications. This practice forces one to test the CTs at somewhat higher burden, as the test burden will include the "physical burden", the comparator and connecting leads. In other jurisdictions the CT is required to be tested at the 'specified' burden, therefore the value of the physical burden must be smaller by the impedance of the comparator and connecting leads.

CT DEMAGNETIZER

Most CTs will exhibit a change in accuracy if their core is magnetized. For this reason most National and International CT standards specify the test CT to be demagnetized before being tested. Large, high current and high accuracy CTs will typically exhibit more error influence due to magnetization than will small, low ratio CTs of modest accuracy.

CTs can be demagnetized by exciting the primary of the CT with the secondary open circuited or by using a dedicated CT Demagnetizers. It is safer to use dedicated demagnetizers, as they apply very low voltage to the CT as compared to the "open secondary" demagnetizing method.

CONNECTING LEADS

PRIMARY connecting leads are usually not very important in regards to accurate measurements. They should be of adequate gauge, however, so as not to heat up and cause a fall of current during the test. It should be also remembered that in high current circuits (>1000 A) it will be the inductance of the primary connecting leads that will control the current. Leads for the high current testing should be kept close to each other, thereby reducing the inductance in the circuit.

SECONDARY connecting leads are very important in an accuracy test installation. It must be remembered that the impedance of these leads will add to the burden of the test and standard CT and therefore affect the readings and accuracy. As the reference CT is typically of higher accuracy and higher burden rating, its lead length and therefore its lead resistance is usually not as important as the length and resistance of the test CT leads.

There are three leads involved in the secondary circuit of a test CT. The lead from the CT to the burden; the lead from the burden to the comparator; and the lead from the comparator to the CT. The desirable condition is to maintain the burden in the secondary circuit at a particular known value. As IEC specifications specify the

MINIMUM test burden as 1VA, the installations, in many laboratories use this value as the minimum burden in the secondary circuit of the test CT. These laboratories make certain that the impedance of the comparator input plus the secondary leads add up to 1VA (circuit resistance of 0.040 ohms). To comply with this total resistance value, the lead length and wire gauge must be properly selected. The longer the lead length required, the larger the wire cross-section (smaller wire gauge number). It should be pointed out that most standards require burdens below 5 VA to be resistive (power factor 1.0).

If this is done, any tests at a selected burden will be conducted at the selected burden PLUS the minimum of 1 VA

CURRENT SOURCE

The current source for CT testing need not be elaborate. It must provide the desired current and power without overheating and be continuously adjustable from zero to the test current. It must be remembered that the test is to be conducted basically on a current of sinusoidal wave shape, say less then 3% harmonic distortion. This may be difficult to obtain for some test locations.

Test current containing harmonics will always affect the test result. The larger the errors (lower Class CT) the larger will be the effect of the harmonics on the test results. The tendency will be to have larger phase errors when the current wave is flat-topped, and smaller phase errors when the current wave is peaked. The opposite will tend to be true of the ratio errors. It must be pointed out that error influences due to harmonics are always due to the performance of the test CT rather than due to the reference CT or the comparator. Most, if not all, comparators measure the CT errors based only on the fundamental current, and therefore are not affected by harmonics.

In locations where the power system harmonic is substantial (>5%), it may be desirable to provide a harmonic filter in the power circuit. This filter need not be elaborate; a simple inductor of some milli henries will usually improve the waveform of the test current substantially. It should be pointed out that the harmonic distortion in India is typically in the order of 10% and because of this, a filter is recommended.

TESTING PROCEDURE:

CONNECTIONS

Safety is very important, both for the equipment as well as for the personnel. Before making connections, it is important to ascertain that the power to the current source is disconnected and cannot be turned on inadvertently. It must be remembered that open-circuited CTs step up the applied test voltage which in most cases will be of a magnitude that is dangerous to human life.

The connections on the high current side as well as those on the secondary side should be made using a wire gauge that is adequate for the current. It is especially desirable to make and have available leads for the secondary circuits whose resistance is known, as discussed above under "connecting leads". These leads would be preferably "calibrated" with the test set and thus the impedance of the standard as well as the secondary circuit would be known.

TESTING SEQUENCE

After making connections it is always desirable to check the proper connections and operation of the comparator. This is typically done by energizing the power source and increasing the current to a small value (2%<I<10%). If a proper reading can be taken at this value then a test sequence can be started at the highest current and the highest burden. Once a reading is obtained at this value, the current should be slowly reduced to the next lower test point, and so on. If a second set of readings is required, one at a lower burden, then the burden should be reduced while the current is at low value, then the current would be increased to the highest required value and a second set of readings started.

When conducting readings, it is usually important to pay attention to the current values being set by the current source. The question that is asked repeatedly is "how close should the set current values be to those specified in standards". Unfortunately most standards specify only the test current values without specifying the tolerance on these values. Therefore the practical answer is that the more accurate the test CT the less accurate need be the current settings. This also means that the current must be set more precisely whenever testing CTs that exhibit poor accuracy or burden regulation.

APPLYING CORRECTIONS

When conducting tests, it is usually necessary to apply corrections to the readings before assigning error readings to the test specimen. In many cases these corrections will be limited to the errors of the reference CT. As was discussed earlier, it may be desirable to apply correction even when the reference CT is of 10 times higher accuracy class than the test CT. This is especially important when the test CT will be tested by others and readings compared.

There may be also other corrections that need be applied. One of these is due to the test frequency. Whereas in many countries the power frequencies are maintained closely at 50 or 60 Hz, the power frequency in India varies regularly between 48 and 52 Hz, or even wider limits. Such frequency variation will affect the CT test result. The lower the frequency the higher the errors that will be measured. The magnitude of this effect depends on the accuracy of the test and reference CTs. The larger the errors (the lower the class) the larger the effect due to frequency variation. It should be pointed out that the frequency effect would be seen in both the ratio and phase errors of high accuracy CTs. It will be seen primarily in the phase errors of low accuracy CTs.

Examples of applying corrections.

The examples below provides a scenario of testing a 1% Class CT using a 0.2% Class standard CT.

I (%)	Test Readings		Standard CT		Corrected Result	
	Ratio	Phase	Ratio	Phase	Ratio	Phase
120	-0.543	15.5	-0.134	3.7	-0.677	19.2
100	-0.600	17.5	-0.156	4.0	-0.756	21.5
20	-0.950	25.8	-0.205	6.0	-1.155	31.8
5	-1.434	35.8	-0.356	8.0	-1.790	43.8

The example below is an example of testing a compensated 1% Class CT using a 0.2% Class standard CT

I (%)	Test Readings		Standard CT		Corrected Result	
	Ratio	Phase	Ratio	Phase	Ratio	Phase
120	+0.341	-28.8	-0.134	3.7	+0.201	-25.1
100	+0.237	-27.8	-0.156	4.0	+0.081	-23.8
20	-0.575	4.7	-0.205	6.0	-0.780	+10.7
5	-1.522	38.7	-0.356	8.0	-1.878	+46.7

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