

DIAGNOSTIC NEWS

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Your Source For Monitoring the Reliability of Electrical Equipment

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CT CONCEPTS AND BASIC TESTING METHODS

by Ian Lawrie



CT BASICS

Current Transformers (CT) are used to reduce primary current of hundreds or thousands of amps to a nominal value of five or one amp. Most are of toroidal design consisting of a ring type core with many turns around the core comprising the secondary. The primary passes through the center of the ring.

The current ratio of the CT is related to its turns ratio. For example if the secondary winding has 600 turns and the primary has one turn (the conductor passing through the center of the core is effectively one turn) then the CT has a ratio of 600:1. If the center conductor is carrying 600 amps, the output from the 600 turn secondary winding is 1.0 amp.

Most protection CT's will have a classification that starts with the letter C followed by a number (10, 20, 50, 100, 200, 400, 800, 1200). The letter C is used for all toroidal CT's. The number specifies the voltage that can be developed at the full winding at 20 times secondary current. For example C-100 means that with a standard 1 ohm burden the CT can develop 100 volts. (1 ohm times 5 amps times 20 = 100).

CT's have an accuracy rating. CT's used for metering are far more accurate (for example 0.3%) than CT's used for protection (for example 2.5%). A metering CT need only maintain its accuracy in the range of 10% to 125% of rated nominal current. However, the protection must maintain its accuracy for all current levels up to 2000% of nominal current.

TYPES OF CTs

Many CT's have a secondary winding with many taps (typically up to five). The measurement of ratio on every tap is essential, but excitation is usually measured on one tap only -usually the full winding.

CT's are often "stand-alone" devices or may be part of switchgear, a circuit breaker or enclosed in the bushing of a power transformer.

UPCOMING EVENTS

501 F & G User Group Meeting	February 10, 2009 Glendale, AZ
LEMUG	January 29, 2009 Boca Raton, FL
SCE&G's 2008 Nuclear/Fossil Vendor Fair	January 29, 2009 Charlotte, NC
Energy Generation Ccnference	January 27-29, 2009 Bismarck, ND
NETA PowerTest 2008	March 9-12, 2009 San Antonio, TX
Western Turbine User Inc.	March 9-12, 2009 San Antonio, TX
Waterpower 2009	July 27-30, 2009 Spokane, WA



Terminals and Markings

CT terminals are usually marked to identify them. The high current/high voltage side of the CT is often marked as H1 and H2 in North America. In other parts of the world the designations P1 and P2 are used. The secondary winding or low current winding terminals are designated as X1 and X2 etc. in North America. They may be known as s1 and s2 etc. in other countries.

CT TESTING BASICS

Testing a CT and its circuit involves several important tests including:

Turns ratio: To verify that the output of the CT will be as indicated on the nameplate. The ideal method of testing CT's would be to apply nominal current on the primary and measure the current on the secondary. It is impractical to produce the nominal current for the testing purposes especially in "field" conditions. The conventional method of testing CT's is to apply voltage to the secondary and measure the induced primary voltage. The comparison of the voltages gives the CT turns ratio.

Polarity: To verify that the output current is in phase with the primary current.

Excitation/Saturation: This test serves two main purposes; the removal of Remanence flux, (demagnetizing) and verification of CT classification e.g. C-100. A CT core can become magnetized; when the current is interrupted and becomes zero but the flux may not become zero, or while performing DC tests such as winding resistance.

Before the ratio or excitation test is made and/or before the CT goes into service, the CT should be demagnetized.

The verification of the class of the CT is a bit more complicated to explain. Classes are explained above in CT basics. A C-100 CT must be able to develop 100 volts across its full winding at 20 times rated current. Rated current, in North America is 5 amps so 20 times that is 100 amps. So this means the CT must develop 100 volts into the burden of 1 ohm. (100 volts/100 amps = 1 ohm).

We verify the class of the CT by performing an excitation test. The test involves applying increasing voltage while recording voltage and current. The point at which a small change in voltage will result in a large change in current indicates the "knee point" or "saturation voltage". This knee point voltage should be of a value that is higher than the CT class.

Winding resistance: This is the internal resistance of the CT winding.

Burden: This is the resistance of leads and devices that are connected to the CT. In order to confirm that the class of the CT (C-100) is adequate, its winding resistance (internal) and the burden (external) including lead and device resistance must be known.

Equipment and Instrumentation for Testing:

Traditional methods of testing CTs were cumbersome and inefficient. The excitation test required a variable transformer and a step up transformer, sometimes greater than 1200 volts, and of course suitable voltage and current meters. A lot of data points need to be recorded and plotted to verify the knee point properly.

Ratio could be measured with the use of an additional meter and comparing the X and H meters. But this was inaccurate. The development of turns-ratio testers helped this but often the range and resolution were not suitable.

Polarity was tested using a battery and a DC meter.

Winding resistance was either not checked or was measured with an ohmmeter.

The same was true for circuit burden. Ideally this should be measured as AC impedance.

The whole task was even more labor intensive when testing multi-ratio CT's. Most multi-ratio CTs have five taps which make for up to ten separate ratios. The whole process could involve an hour of testing per CT and a similar amount of time to compile the report.

Fortunately with the development of microprocessor based instruments, this task is reduced to a few minutes.

A year ago, Adwel (an Iris Power Company) introduced the DCT-2000, which automates the test process using a test-plan-driven functionality. The use of this product can reduce test and report time by up to 90%.

For more information on this product please visit our website or write to DCT@adwel.com.



STATOR WINDING TURN INSULATION

GREG STONE

Failure of the turn insulation in a stator winding will normally lead to a stator winding ground fault within seconds to minutes (Figure 1). Good turn insulation is therefore essential to the life of a motor or generator. Most motors and generators rated <50 MW use multi-turn coils, and thus have turn insulation. The following describes some of the alternatives available with turn insulation, plus some information on how to test it. I also address the differences in turn insulation designs in different parts of the world.

NORTH AMERICAN DESIGN VS. OTHERS

Perhaps one of the main differences between most stator windings made in North America, and those made in the rest of the world, revolves around the turn insulation design. In North America, most machine manufacturers will use a “dedicated” turn insulation – that is, each copper strand will have its own insulation, but there will be a separate turn insulation applied to the bundle of copper strands in a turn. Instead, most European and Asian-made machines will have an upgraded strand insulation that also serves as the turn insulation. The latter design started appearing in the 1970s as a way to reduce the amount of insulation in the slot, as well as to eliminate the manufacturing step of taping the turn insulation. The early experience with eliminating the turn insulation was not good in North America. Many premature motor and small generator failures seemed to be occurring. As a result, many utilities and petrochemical companies modified their purchase specifications to require turn insulation in addition to the strand insulation. Users in Asia and Europe seemed to have been more forgiving, and continued to allow a combined strand/turn insulation.

Another difference between North America and the rest of the world is in the nature of the tape used to make the turn (or strand) insulation. Originally, the “mica paper” tape used for the turn insulation had a woven Dacron™ and glass backing material. In the 1970s, material suppliers introduced a polyester film backing material for the mica paper. The advantage of the film-backed mica paper is that it had a much more consistent thickness, and thus it allowed tighter tolerances on coil insulation thickness. However, early experience in North America was again not good with film-backed tape. It seemed that epoxy did not “stick” as well to the tape as it did to the more porous woven backing. Thus there were a number of premature stator failures due to large voids adjacent to the turn insulation. Again, the response of many users was to exclude the use of film-backed tapes.

Today there has been several decades of apparently suc-

cessful experience with both combined strand/turn insulation and film-backed mica paper turn insulation on machines made in Europe. Thus it seems that there is perhaps no need for users to maintain specifications that require a separate turn insulation layer and/or ban the use of film-backed tapes. However, both requirements will probably result in longer motor and generator life, since the turn insulation is so critical to the life of the stator, and end of life is often determined by the turn insulation.

TURN INSULATION TESTING

The only direct test of the condition of the turn insulation is a surge voltage test (using for example testers from Baker and PJ). The surge test is really a hipot test for the turn insulation – and of course if the test fails, then the coil is damaged and must be replaced. All manufacturers do surge testing during stator manufacture. However, surge testing of complete windings has always been controversial, since detecting a turn fault can be difficult given there is only a small change in the waveform between a good winding, and a winding with one shorted turn (caused by the high voltage surge). Although modern surge testers which compare a low voltage waveform with a high voltage waveform on the same phase are more sensitive than before, there is still a risk of failing the turn insulation with the surge voltage and not detecting it.

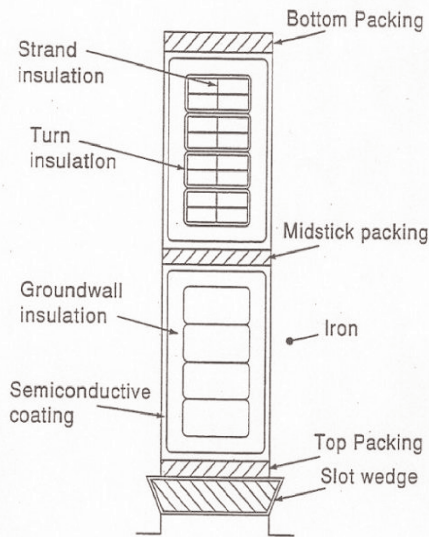
Contrary to some marketing claims, low voltage tests on form wound stators using inductance and/or impedance analyzers will NOT find deteriorated (but unfailed) turn insulation – since there is no change in inductance or impedance until the turn is shorted. Of course once the turn is shorted in service, a ground fault almost immediately follows due to the extremely high circulating current that flows through the shorted turn.

Indirectly, a partial discharge (PD) test may sometimes find deteriorated (but unfailed) turn insulation. If the deterioration process (say due to thermal aging or turns moving relative to one another) creates air spaces between the outer circumference of the conductor stack and the ground insulation – then PD will occur in the air spaces adjacent to the turn insulation. PD occurs because on the outside surface of the conductor stack, the turn insulation is exposed to the main phase to ground voltage- and thus PD will occur in any voids there. However, if air pockets only exist between the turns (and not on the outside conductor surface), there will not be enough voltage across the voids to trigger PD in the voids, and thus such voids remain undetectable.



Stator Winding Turn Insulation Continued...

In conclusion, detecting weaknesses in the turn insulation in motors and small generators, without inducing a failure, continues to be a challenge.



SPOTLIGHT ON MANUFACTURING



Meet our manufacturing team. These are the individuals who help put together our line of superior testing and monitoring products.

The team is headed by Claude Silveira and is a highly skilled group, consisting of 30 individuals willing to meet and exceed demanding deadlines.

Our sincerest thanks for all of their hard work in 2008.

UPCOMING EVENTS

IRIS ROTATING MACHINE CONFERENCE 2009 (IRMC)

Join us for the 2009 IRMC in
New Orleans, Louisiana
May 11-14, 2008

Venue:



InterContinental New Orleans
444 St. Charles Ave.
New Orleans, LA 70130

COURSES

Iris will be running the following courses in 2009:

ACE Course

February 18-20, 2009
& September 15-17, 2009 Toronto, ON

Motor Maintenance Course

March 17-19, 2009 Long Beach, California

Partial Discharge Course

February 24-26, 2009 Long Beach, California

Hydrogenerator Maintenance Course

April 28 - 30, 2009 The Coeur d'Alene Resort

For more information, or to register, please contact Michelle Mathias at mmathias@irispower.com.

