

DIAGNOSTIC NEWS

Your Source For Monitoring the Reliability of Electrical Equipment

Stator Winding Hipot Testing

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IRMC 2007

San Antonio, TX
June 3-7, 2007

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EVENTS

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Convention

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MAINTEC 2007

March 20-22, 2007

Birmingham, England

IRMC 2007

June 4-7, 2007

San Antonio, TX, USA

WaterPower XV

July 23-26, 2007

Chattanooga, TN, USA

The issue of hipot (or high potential) testing of stator windings was discussed about 10 years ago in this space, but it seems to be worthwhile to revisit the issue, since I get so many questions about it. If one buys a new motor or generator, or rewinds a stator, then by NEMA MG1 or IEC 60034-1, the stator insulation system must be given a hipot test. The preferred test for a new stator is an AC hipot - i.e. with the high voltage being 50 or 60 Hz, at twice the rated phase-phase voltage plus 1 kV, applied to the winding copper. Thus a 13.8 kV stator is tested at 28.6 kV, applied between the stator copper and the stator core. The NEMA and IEC standards also permit the commissioning hipot test to be done with DC voltage, where the voltage is applied at 1.7 times the AC hipot voltage (or 48.6 kV DC for a 13.8 kV rated stator). These recommendations are the same today as they were 50 years ago.

However, there are still a lot of recurring questions from machine owners:

- Should hipot testing be done on machines that have seen service - i.e. maintenance hipot testing?
- What are the pros and cons of AC vs. DC testing?
- Does hipot testing shorten the life of a winding?
- What about 0.1 Hz (or very low frequency - VLF) hipot testing?
- What about DC Ramp testing, where the DC voltage is automatically but slowly raised to the maximum test voltage, at the same time as the current is monitored?

The first three issues are dealt with in this article, and the last two in the next Diagnostic News.

Maintenance Hipot Testing

About 7 years ago, a survey conducted for EPRI found that about 50% of utilities do hipot testing on their critical motors and generators [1]. In surveys of students in maintenance classes that I have been involved in since then, it seems that the percentage of machine owners performing hipot testing may be increasing. Partly this may be driven by the more active involvement of insurance companies in suggesting that hipot testing be performed. (Although it is interesting to note that if the winding fails during such a hipot test, the insurance company will not permit an insurance claim due to this failure, in spite of the fact that the hipot failure will almost always delay the return to service of the motor or generator.) Or perhaps the anecdotal increase in popularity is due to the realization that hipot testing is an important tool in a predictive maintenance program to eliminate in-service failures.

With some caveats, I am a big believer in maintenance hipot tests. The hipot test will find gross flaws in the insulation, no matter where in the winding they occur, and gives one a strong assurance that stator winding failure will not occur when the motor or generator is returned to service. The test voltage usually simulates a worst case voltage transient that can occur at the stator terminals if a power system transient occurs, and thus assurance is given that a fault in the power system will not cause a second phase to fail (with its consequent much higher fault currents). The (out of circulation) IEEE 56 standard suggests the hipot test voltage be up to about 75% of the commissioning hipot voltage, or 21 kV



Stator Winding Hipot Testing Continued...

for AC and 36 kV with DC for the 13.8 kV example. However, the EPRI survey found that, at least in North America, the DC hipot maintenance test voltage is normally well less than this maximum, being about twice rated voltage, i.e. 28 kV DC for a 13.8 kV winding.)

One reason for not hipot testing is that some believe the test itself may degrade the stator insulation. In fact there is no evidence that maintenance hipot testing has ever failed a stator that would not have failed in service. The life that is 'removed' by hipotting is insignificant. The exceptions are perhaps direct water-cooled turbine generator stators that have some history of slow water leaks. Also, since motors are often hipotted from the switchgear, and thus the power cable is included in the hipot test, DC should be avoided in such cases. It is now well known that a DC hipot will significantly accelerate the water treeing cable failure mechanism. Thus if hipot testing is done from the switchgear, and the cables may run underground where there may be a water environment, only AC hipot testing should ever be contemplated.

Another important justification for not hipot testing is that if a failure occurs, then one must repair and/or remove the failed coil. This will delay the return to service of the machine, and will provoke some displeasure from plant management. It is inherent in hipot testing that such failures will inevitably occur. However, the risk of a hipot test failure can be greatly minimized if the machine owner has first done such diagnostic tests as insulation resistance, power factor tip-up or PD testing, all of which show the winding to be in good condition.

The main reason for not hipot testing, other than cost, is that if a hipot failure occurs during the test, that such a failure may not occur for months or years if the unit was placed in service without a hipot test. That is, if one had avoided the hipot test, months or years of extra life may have resulted. This is true. And if the consequences of a failure during the hipot are the same as those of a failure in service, then there is no reason to hipot test. Thus whether one does a hipot test or not is really an economic or business decision. If the machine is critical and its failure will interrupt production, then perhaps hipot testing is worthwhile, since the damage and return to service will be shorter than the damage and loss of production costs of an in-service failure.

Reference

1. B. Gupta, G.C. Stone, J. Stein, "Use of Machine Hipot Testing in Electric Utilities, IEEE Electrical Insulation Conference," Cincinnati. Oct. 2001.

pC AS PD MEASURING UNIT

New versions of PDLitePro and PDView will be released, enabling the user to introduce calibration factors for purposes such as unit conversion of PD measurement, in capacitive objects.

Some standards (e.g. ASTM D1868 and IEC 60270) describe a method to calibrate PD measurements in picocoloumbs (pC), in which a fast rise time voltage step V is injected via a calibration capacitor C into the measuring circuit (charge $Q=CV$, in pC). If the measured value is X , the constant $k=Q/X$ is used as multiplying factor to convert mV PD readings in pC.

This calibration is applicable to a simple insulation system that can be represented as a two terminal capacitor (e.g. a stator bar or coil). The appeal of the measurement in pC for off-line testing is that the charge is independent of the capacitance of the measured object.

The new versions of both the PDLitePro controlling software and PDView viewing software used with IRIS' portable instruments will facilitate the change of PD measuring units from mV to pC. The user can introduce either a scaling factor per asset (measured object) or a multiplying factor per PD sensor set. The factor is obtained by the user from the above mentioned calibration process.

The scaling factor per asset and multiplying factor per sensor set can be used for other purposes too, such as to compensate attenuation produced by additional on-line noise filters; and to compensate attenuation produced by alternative PD sensors (e.g. RFCT instead of 80 pF EMC). For details please contact your IRIS' sales representative.

It is necessary to remind that PD readings on complete stator windings in terms of picocoloumbs (pC) are meaningless due to the presence of inductance (L) along the winding that introduces both resonance frequencies (LC ladder network) and significant attenuation of the pulses depending on the PD pulse location.

NEW STANDARD OF OFFLINE PD: IEC 60034-27

IRIS will offer the low frequency option for the popular portable instruments TGA-B and PDA-IV for off-line PD measurements, in the range 50 kHz to 5 MHz, compliant with newly published IEC 60034-27

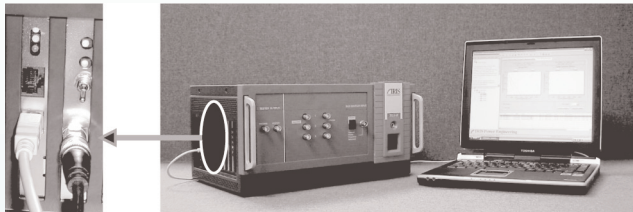
The portable instruments TGA-B and PDA-IV are used primarily for on-line PD testing of stator winding. Due to the significant role of the noise during on-line testing



IRIS has implemented effective noise discrimination/elimination methods including testing at high frequencies (over 40 MHz).

During the maintenance activities (with the machine out of service) several off-line tests may be done, including off-line PD testing of stator winding. The portable instruments TGA-B (turbogenerators and motors) and PDA-IV (hydro-generators) can be used to perform the off-line PD measurements at high frequencies, employing an external 50/60 Hz voltage source to energize the winding and the portable PD sensors. All the tested section of the winding is energized at the same voltage, including the neutral point (which is at zero voltage in normal operating conditions), so that PD activity could originate in any location along the winding. Due to the fact that noise during an off-line test is not significant and that at low frequencies the inductive impedance of the winding is lower, it is better to perform off-line tests at low frequencies.

Recently the new standard IEC 60034-27 "Off-line partial discharge measurements on the stator winding insulation of rotating electrical machines" has been released, requiring a low frequency PD test, with a lower cutoff frequency below 100 kHz for off-line PD measurement. The low frequency option available for the portable instruments TGA-B and PDA-IV, will be compliant with new standard. It enables off-line PD measurement in the frequency range 50 kHz to 5 MHz.



PDA-IV instrument with low frequency option. The laptop controls measurement process and stores test results

AUTOMATED CONTINUOUS PD MONITORING

Current trends in plant monitoring are towards continuous, on-line systems. Even for measurements like PD, which changes slowly, lack of staff to do periodic testing with portable instruments and the need for training to operate such instruments and collect trendable data have led to a move toward continuous PD data collecting. A continuous on-line system also has advantages in collecting data at consistent operating conditions, and the ability to integrate PD measurements with those from other monitors and sensors.

Of prime importance for any continuous monitor is reliability of the electronics and system doing the monitoring. In the case of PD, we are looking at motors and generators, which generally are very reliable machines, and may run decades without problems. Thus any continuous monitor must be designed to be robust, and at least as reliable as the machine it is monitoring.

So when selecting a continuous monitor, how can the user judge if it is going to be robust and reliable, and appropriate for the application. Some questions to ask, and key indicators that the instrument designer has done his homework would include:

- ◆ What certifications and standards testing has been done. Is the monitor UL or CSA rated, does it have additional ratings for Radiation environments, ATEX hazardous environment ratings.
- ◆ What enclosure is the instrument in, is it water tight, does it use sealed penetrations. If the instrument is to be mounted in a plant environment, does it include shock mounts, what is its operating temperature range, etc.
- ◆ Looking at the electronics itself can be a key indicator of robustness - are all the components soldered in, is wiring tied down, do headers include a locking mechanism, are screws and fasteners fixed with LockTight or lock washers.
- ◆ What is the operating range of the input power supply (frequency, voltage range, harmonics)? Is the instrument supply designed to withstand over-volt ages and/or power dips. During transient conditions such as these, will the instrument gracefully save data into non-volatile storage and recover when stability returns.
- ◆ If the monitor is to be connected to field sensors for example for measuring load or temperature, it is very important that these inputs are properly protected and isolated. What is the rated electrical isolation between ground and the sensor inputs? Do the inputs have a surge rating, and do they support all the sensor types you typically employ. If sensors must be changed in the future, can the input module in the instrument be easily substituted to match the new sensor without having to return it to the manufacturer?
- ◆ Does the instrument have diagnostics built into the firmware, and are you able to remotely monitor conditions such as the power supply levels, case temperature, and other critical instrument parameters?
- ◆ Does the instrument design include isolated terminations, so should the instrument fail in service, it is possible to remove the electronics for repair, without having to disconnect field sensors or require a machine outage?
- ◆ Are field upgrades of firmware and/or controlling software possible?



Automated Continuous PD Monitoring continued...

- ◆ Does the system rely on proprietary protocols for communication and control, or does it support standard automation protocols such as OPC? Is the data recorded by the system store in standard data bases such as Access, and are tools available to view, organize, and interpret your data.
- ◆ Does the supplier have a large installed base of customers and a reference list of applications in your type of environment?

Before venturing into a continuous monitoring application, you should assure yourself that each of these questions has been considered and answered.

UPCOMING EVENTS

UPCOMING COURSES

Hydrogenerator Maintenance Course

May 1-3, 2007
Coeur d'Alene, Idaho, USA

Turbo Generator Maintenance Course

July 10-12, 2007
St. Petersburg, FL, USA

Motor Maintenance Course

New Orleans, LA, USA
November 6-8, 2007

Partial Discharge Course

Orlando, FL, USA
November 13-15, 2007

A Memorial to Mo Kurtz



Mo Kurtz (left) and John Lyles surrounded by several generations of PDA at Iris's offices, 1995. John and Mo were both instrumental in the development of the PDA and TGA on-line partial discharge technology during their tenure at Ontario Hydro.

On Dec 24, 2006 Mo Kurtz died at the age of 83 in Toronto, Canada. Mo was a pioneer in the field of insulation system. Aside from military service during the Second World War, Mo worked his entire career at the Research Division of Ontario Hydro, at the time the largest electric power utility in North America. As Senior Dielectrics Engineer, it was Mo's job to perform failure investigations of power cables, rotating machines, transformers and switchgear. Since there were many failures, and many common causes - Mo went on to research ways of preventing such insulation failures. This lead him and his colleagues to develop more rigorous specifications for insulation systems, create qualification tests and better factory tests, as well as invent ways of assessing the insulation condition of power system equipment that was in service. Mo retired from Ontario Hydro Research in 1987.

Of particular importance to Iris customers, is the fact that Mo was the developer of the original on-line partial discharge test used by Ontario Hydro to assess stator winding insulation condition. Along with his colleague Bob Anderson, Mo was performing on-line PD tests on about 200 generators since the early 1950s. This experience lead naturally to the development of the PDA and TGA tests, also developed at Ontario Hydro. Iris Power is the exclusive licensee of these successor on-line PD tests for stators. Without Mo's insights, on-line PD testing would not be the routine procedure that is now applied to most of the world's large generators.

Mo is survived by his wife Toni, and his four children.

