Diagnostic News

Inside this issue:

January 2014

Are we at the start of an Electrical Insulation Revolution: Nanodielectrics

By: Greg Stone

There has been no radical change in the insulation materials used in motor and generator windings since the 1960s. Epoxy-mica, aramid papers (Nomex^{TM}), epoxy glass laminates and polyamide-imides, the main insulating materials found in today's rotor and stator windings, have in fact been in general commercial use for over 50 years. Of course, there have been some improvements in the properties of these materials over time, and even some creepage of material thermal ratings, but the basic materials remain the same. What advances there have been have largely been due to manufacturing methods – such as the large scale adoption of global VPI and the widespread application of robotics for applying tapes and processing [1].

Revolutionary change may be on the way with the commercial introduction of "nanodielectrics". The recent issue of the IEEE Electrical Insulation Magazine was devoted to nanodielectrics [2]. This is a term, first coined by Dr. Michel Frechette of Hydro Quebec, for polymers that have nano particles dispersed within the polymer. " Nano" refers to the size of these particles, their largest dimension is in the order of 10s or perhaps 100s of nanometers (nm). Nanodielectrics are insulation materials where the nano-sized particles have been evenly dispersed throughout the polymer. The nano particles to date have usually been silicon dioxide (sand), alumina or similar oxides. The promise of nanodielectrics is that they can produce a 10 to 100 times improvement in voltage endurance – that is, they seem to be exceptionally resistant to partial discharge (PD). In applications such as power cable and transformers, this means the insulation can be made much thinner for the same lifetime. For high voltage stator windings, the development of effective dielectrics may permit the elimination of mica from the ground and turn insulation, which may greatly reduce the complexity of manufacturing bars and coils. Nanodielectrics also tend to have much lower thermal impedance - which means it is easier to conduct the I^2R heat to the stator core, lowering the conductor temperature (or less copper can be used for the same temperature).

Research on nanodielectrics has been ongoing for over 20 years – with few commercial products to show for it. In the first decade, research was concentrated on how nanodielectrics worked, since it was not initially clear why such a small amount of very tiny particles creates such a big effect (usually the nano particles make up less than 5% or so of the insulation material by weight). And researchers needed to understand why if the particles were larger (in the more common micrometer scale), the voltage endurance improvement essentially disappeared. More recently research has concentrated on ensuring the nano particles are evenly dispersed – that is they do not agglomerate together to make a micro-sized particle, where the voltage endurance properties are lost. This latter aspect has been a great challenge, and involves considerable proprietary technology. It is probably why nanodielectrics have not been widely applied on a commercial scale to date.

The first application of nano technology in the rotating machine field was as magnet wire insulation for inverter duty (variable speed) motor stator windings. Invertors of the voltage source, pulse width modulated type generate short risetime voltage surges that applied a high voltage to the turn–to-turn insulation.

Continued on page 2...

Are we at the start of an Electrical Insulation Revolution: Nanodielectrics

Continued from page 1...

Even 440 V motors were found to have PD in small voids between the magnet wires due to these voltage surges. Since the magnet wire film insulation is usually purely organic, it had very little PD resistance, and winding failure occurred quickly. Nanodioelectrics, a natural for this application, imparting much longer life due to its much higher PD resistance.

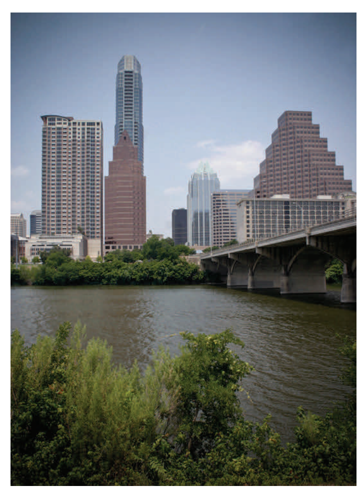
However, application of nanodielectrics to the main groundwall insulation of high voltage stators is still not commercial. Unlike the very thin film on magnet wire, the groundwall of a high voltage coil is several mm thick, and getting good dispersal of the nanodielectrics resin is probably the main challenge. Recently Siemens published work they have been doing to introduce a nano particle filled epoxy as an impregnating material in VPI bars and coils [3]. What is surprising is that they indicate the filler may be about 25% by weight, which should make for a viscous VPI impregnation material. At this stage, the nanodielectric is not used to replace the mica paper tape, but instead is just used to bond the tapes together with a much more PD-resistant material than pure epoxy. Siemens is now making full scale coils to evaluate the new material (and the processing required). If the new groundwall insulation demonstrates the huge increase in voltage endurance that small experimental coils yielded - and assuming the cost is reasonable – we will likely see in the near future the biggest change in motor and generator insulation technology in over 50 years.

References

1. G.C. Stone, G.H. Miller, "Progress in Rotating Machine Insulation Systems and Processing", IEEE Electrical Insulation Magazine, July 2013, pp 45-51.
2. IEEE Electrical Insulation Magazine, November 2013 Issue.
3. P. Gropper et al, "Nanotechnology in high voltage insulation systems for large electrical machinery – first results", *CIGRE* Paper A1-103, August 2012.§

IRMC—COMET: December 2-4, 2014

The Iris Rotating Machine Conference is taking on a new look! The 2014 conference, to be known as the **Conference on Online Monitoring of Electric Assets** (COMET), will be held in Austin, Texas in affiliation with the University of Texas Center for Electromechanics! After 16 years, the IRMC program will change to provide attendees with parallel sessions on Rotating Machines, Gas Insulated Switchgear, and Transformers. This conference will be devoted not just to presentations on condition monitoring tools, but also to educating attendees on the practical aspects of implementing condition-based maintenance in transformers, switchgear, large motors and generators.



The first Conference will be held in Austin, Texas, December 2-4, 2014.

Mark your calendars for what will prove to be an exciting event covering all aspects of electrical equipment condition monitoring. Monitor http://www.utexas.edu/research/cem/comet/comet.html for more information!

Stator Core Testing: Pros and Cons of Using High Frequency

By: Mladen Sasic

Traditionally, both High Power Core Test (loop or ring flux test) and Low Power Core Test (EL CID) were conducted using network frequency 50/60 Hz power supplies as the excitation source. However, with advancement in variable frequency power supplies it became possible to conduct these tests at frequencies different from network frequency. Since the main excitation impedance is inductive, it is expected that the excitation current would reduce substantially as the frequency is raised ($I = V/(2\Pi fL)$, where f is frequency and L is the winding inductance. EL CID excitation cables are portable and easily installed in turbogenerators, however, the excitation winding complexity in hydro-generators can be quite significant, and a reduction in excitation source and winding weight is desirable and should be possible with an increase in test frequency. This reduction is, of course, much more important in conducting high flux tests, where power requirements are in the range of 1-3 MVA, and some OEMs recently started offering such a test, using 500 Hz power supply. A 500 Hz test would be conducted at up to ten times lower flux density than nominal (Flux = V/(4.44Nf)) for the same axial voltage along the length of the core, as the power frequency test. The flux could be generated at approximately five times lower magnetizing force H [A/m].

The EL CID testing at higher frequency theoretically also could allow faster scanning of the stator core. For a good resolution of the PHASE/QUAD signals without risk of harmonic errors, it is preferred to perform an analysis for 1 full AC cycle at each test point (2 mm normally). This naturally limits the speed of testing to 100-120 mm/sec at 50-60 Hz, whereas operation at (say) 500 Hz would potentially allow scan speeds of up to 1m/sec.

In 2001, Adwel International, now part of Iris Power, started a research project to investigate High Frequency EL CID potential benefits and the effect on measurement results. One of the reasons for the evaluation of a high frequency EL CID was based on expectation that existing diagnostic methods may be improved. Testing at high frequency and low flux was expected to have the advantage of providing the required test voltage along the core at a much reduced core excitation current level, resulting in considerably improved ratio of fault (QUAD) signal to excitation (PHASE) signals. Since potential benefits were expected, initial applications were made for UK and USA patents on this technique, with all priorities dated 4th December 2001. In 2005, both patents were granted, GB 2383878 and US 6903556.

The first step in our research was to evaluate chattock frequency response and determine possible frequency bandwidth for the new method. Tests on standard chattocks indicated that they had virtually error-free frequency response with only a 3% reduction in expected signal from 50 to 2000 Hz, so there was no need for a different type of chattock for this high frequency work. Since the chattock is an air-cored coil, it has a rising frequency response, i.e. voltage induced is proportional to frequency. Therefore, to enable a correct comparison with 50/60 Hz tests, high frequency test results were compensated in the analyses by applying a 1/f factor. The desired effect of increasing the test frequency (f) was that the excitation PHASE signal should reduce at a rate of 1/f, or by 40 times with frequency increase from 50 to

Continued on page 4...

Pros and Cons of Using High Frequency

Continued from page 3...

2000 Hz, while the fault current (QUAD) signal should remain constant for constant core excitation voltage. This should provide a potential 40:1 improvement in "signal to excitation" ratio. However, since frequency response at very low flux levels is not specified by core steel manufacturers, the results from a variety of cores tested did not provide the expected improvement - the excitation current at 2000 Hz was 4 times higher than expected, as shown in Figure 1. The next step in research was to evaluate effects of core loss and fault inductance at various frequencies. The results clearly showed that testing at higher frequencies will be an issue for major faults, while there should be little impact on smaller faults. For example, the 1000 mA fault reduced to just 500 mA at 2 kHz, indicating that a lesser frequency may be optimal to avoid interpretation problems. At lower frequencies there is better discrimination between smaller and bigger faults. Based on the results from these tests, it appeared that the 300-600 Hz frequency region might be an acceptable choice for high frequency core testing.

There is still good discrimination between faults up to 1 A with only 25% reduction in apparent amplitude. The larger 1.4A – 2A faults are attenuated more, but still appear as major faults (~1A), as shown in Figure

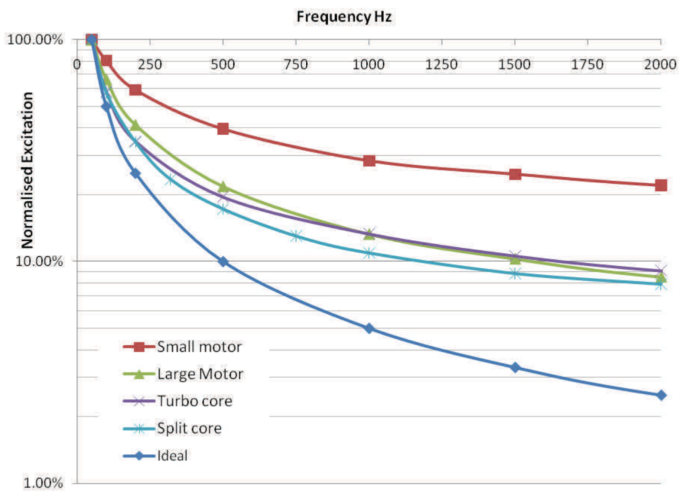


Figure 1. Reduction of excitation current with frequency increase, 50-2000 Hz

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Iris Power MDSP3—Detecting motor rotor cage-winding faults and air gap eccentricity

Previously introduced as IMCA, the new MDSP3 portable instrument detects rotor cagewinding faults i.e. broken rotor bars, cracked shorting rings, die-cast manufacturing faults, and unequal air gaps as they are the causes of many mechanical and electrical failure mechanisms in induction motors.

The MDSP3 measures the motor current in one phase and employs current signature analysis to determine if any of the above problems are present

While simple to use with a single clamp-on current sensor, MDSP3 is, as with all other Iris Power products, highly reliable and is designed to significantly reduce the risk of false indications using third generation technology.

All testing is done on-line in less than 40 seconds under varying load conditions.

Contact your sales team member for a demonstration.§

UPCOMING EVENTS 2014

EPRI TGUG	Jan 20-24 Dallas, TX
PCIC Middle East	Feb 4-5 Abu Dhabi, UAE
NETA Power Test	March 3-6 Denver, CO
Russia Power	Mar 4-6 Moscow, Russia
ST & GUG	Mar 25-26 Coventry, UK

2014 Training Program

Partial Discharge Course
March 25-27
Atlanta, GA, USA

EL CID Training Seminar
April 8-10
September 23-25
Toronto, Canada

Hydrogenerator Maintenance Course
October 21-23
Sacramento, CA, USA

For more information, contact:
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Pros and Cons of Using High Frequency

Continued from page 4...

2. The results in Figure 2 clearly show that there is a very significant saturation effect for faults, where by 2000 Hz it is almost totally impossible to discriminate between severe and modest 30 mm faults. They all asymptote to ~400 mA, even faults measured as 2A at 50 Hz.

Another series of tests was performed with faults of different resistivity and location to better evaluate the effectiveness of testing at 500 Hz, which based on previous work looked the most attractive compromise frequency. This time the response was evaluated at 50 Hz and 500 Hz (using the fixed frequency HF EL CID Signal Processing Unit), with the QUAD value determined by differencing against a no-fault scan of the same slot. Faults of different length at the tooth tip and slot base were applied, scanning along the length of the fault in conventional fashion. The research results indicated that the sensitivity of 500 Hz measurements for the 10 mm long severe faults is much lower than 50 Hz, and this effect is visible, but not so pronounced for the longer 30 mm faults. Figure 3 indicates 50 Hz and 500 Hz test result of 10 mm long fault on the tooth tip.

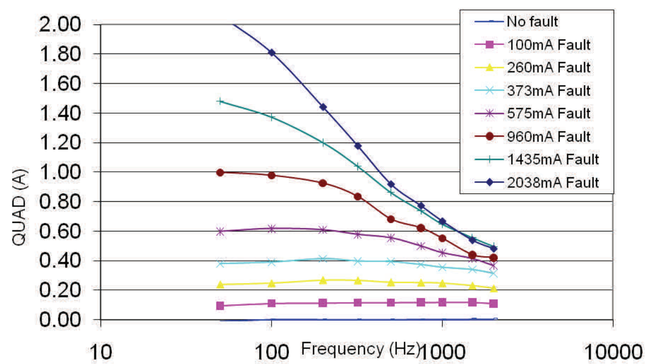

Figure 2. Measured fault current for various faults at different frequencies

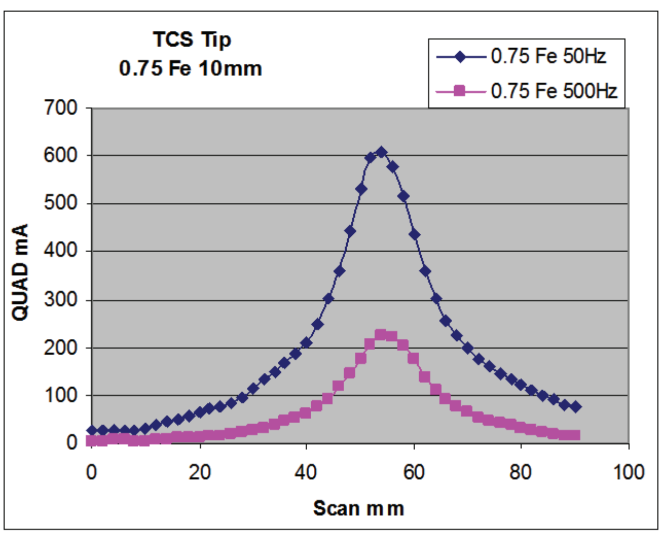

Figure 3. 10 mm long fault on tooth tip

CONCLUSIONS

The original objective to determine if the use of higher frequency excitation for EL CID testing has benefits has demonstrated that there are some excitation benefits in the use of frequencies of around 500 Hz.

However, there are no detectable improvements in the sensitivity to faults on the tooth surface or down the slot to the slot base surface at 500 Hz or any other higher frequency. Furthermore, there is significant reduction in the ability to discriminate between fault severities, since large faults are not visible anymore, and this will hinder repair decisions in these cases.

The modest benefits of higher scan speeds and lower excitation power are outweighed by the rising attenuation of more severe core faults leading to poorer fault interpretation.

It is believed that users would prefer to ship slightly heavier test equipment, (25 A, 240 V Variac is sufficient source even for the largest generators) to site and take a little longer to test to obtain more reliable results.§

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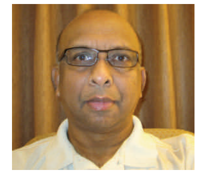

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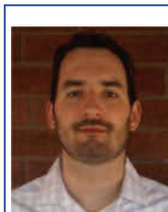


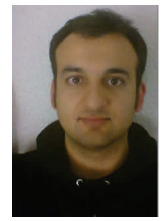
Qualitrol Generation / Iris Power Field Service has been installing, testing, & commissioning our customers' equipment since the beginning of Iris Power. From humble beginnings in Canada, we have now expanded to a team of 21 people located in 9 countries including USA, China, India, Brazil, Switzerland, UK, UAE, Canada, & Italy.

Some of our key services include:

- Installation of sensors – Partial Discharge, Flux, Endwinding Vibration, Air Gap & Shaft Brush.
- Commissioning of Qualitrol-Iris Power continuous monitors all the way back to the original MotrTrac to the 3-in-1 technology of the GuardII line.
- Online data collection and diagnosis.
- Offline machine testing with the DeltaMaxx, EL CID, SWA, and low frequency PD measurements.
- Provide customer training at site in all of our technology and equipment.

We collectively spend almost 20,000 hours a year at our customers' sites ensuring the reliable operation of their assets through on-line and off-line condition monitoring. We continue to grow and increase our presence in markets around the world, and look forward to the opportunity to work with you!

Brad Spacinsky
Manager, Field Service



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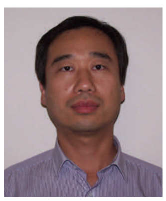

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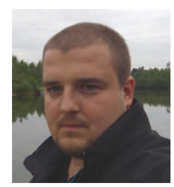

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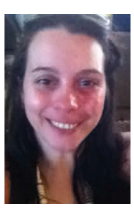

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