

# DIAGNOSTIC NEWS

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Your Source For Monitoring the Reliability of Electrical Equipment

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## Repairing Mechanical Damage to Stator Windings

*Earl Goodeve and Ron Wheeler*

While generally very reliable, with infrequent failures in operation, from time to time the insulation of generator and motor stator windings can be subjected to localized physical damage. This damage can occur from debris striking the winding during operation, or damage can occur during the course of a maintenance outage. The physical and intrusive nature of machine inspection, maintenance and repair exposes the stator winding insulation to inadvertent localized damage. This potential damage becomes even more likely during a stator rewedge operation because the removal of old wedges and installation of the new wedges takes place directly on the exposed coil insulation surfaces. Similarly the removal and re-insertion of endwinding blocking and ties that may have become loose, or have abraded the groundwall insulation, can cause damage away from the core.

Fortunately, it is often possible to repair certain types of localized stator winding insulation damage in-situ, with a reasonable expectation of it providing reliable service for the remainder of its originally expected life. This, and following articles, will hopefully provide insight into the decision-making process for such repairs along with some guidance as to how such localized repairs are made. Not all damage can be repaired, or at least not repaired for any extended period of operation. Hence, part of the evaluation process must recognize and accept that there are times when localized insulation damage should not be repaired. One other important note is that hydrogenerator stators are more likely to be able to be repairable than similar damage in a turbogenerator stator. This occurs because it is possible, in most hydrogenerators, to bypass or 'cut-out' coils that cannot be repaired and reconnect the affected circuit. In a turbo-generator stator, this is not an option.

### FACTORS TO CONSIDER WHEN DECIDING IF AN IN-SITU REPAIR IS POSSIBLE

There are a myriad of considerations to evaluate prior to attempting an in-situ repair procedure as opposed to other options such as cutting out the coil or doing a rewind. Here, we will consider a "repair" any attempt to return an existing winding to service that requires the restoration of groundwall insulation integrity. Failure to achieve that integrity, or the complete inability to do so, may result in an escalation to cutting out a coil or a rewind.

Whatever has caused a winding to become damaged, the following factors should be considered and evaluated to arrive at a go/no go decision to repair the groundwall insulation.



*Impact damage: It may be possible to successfully repair damage of this nature.*

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## UPCOMING EVENTS

EPRI - TGUG	Jan 18-20, 2010 Williamsburg, VA
SCE&G Nuclear Fossil Vendor Fair	Jan 20-21, 2010 Charlotte, NC
Energy Generation Conference	Jan 26-28, 2010 Bismarck, ND
501 F&G User Group Meeting	Feb 22, 2010 Orlando, FL
NETA PowerTest 2010	Feb 15-16, 2010 Long Beach, CA
Western Turbine User Inc.	Mar 14-17, 2010 San Diego, CA
IRMC 2010	June 21-24, 2010 Orlando, FL



## Repairing Mechanical Damage to Stator Windings ...

**Cost:** If there is anything that will resolve whether to repair or not, it is cost. Cost is not only the cost of mobilization and carrying out a repair; it is the consequential cost of not repairing. Loss of production usually far outweighs any direct cost of insulation repairs and can range from a few hundred dollars a day to thousands of dollars per hour. Needless to say, if in the latter range, then repair options generally increase since more effort and resources can be justified to carry out the work.

**Criticality:** If a machine is defined as "critical" then there is often a substantial economic impact, or the potential for one, if it is not readily available. In this case decisions are governed as discussed above. However, at times the nature of the machine and its role may be such that it is in reserve, but must be readily available. It may be required for safety which places a high premium on repair.

While the above two criteria will often be the leading factors in the repair decision, other factors entering the "fix versus do not fix" equation are:

**Extent of Damage:** The greater the portion of the winding that is suspect or visibly damaged, the more difficult, time consuming and expensive the repair. Repairs to large winding areas take more time, have a greater risk of being unsuccessful and may not be of much advantage over simple replacement. Re-insulation may not be practical where extensive groundwall damage is present.

**Space and Accessibility:** If there is not enough room to access the damaged area to carry out repairs, then repair ceases to be an option. However, ingenious work methods and special tools, often fabricated exclusively for the job at hand, do permit repairs to be carried out that at first glance appear "impossible". Generally, the more difficult the access and space within which to work, the longer the repair process and the more difficult to achieve reliability. In the worst cases, bottom coil sides with damage in the core (slot) involve access that requires coil/bar removal, if they must be worked on in order to return a machine to service.

**Spare:** In many cases, damage to an individual bar or coil can usually be repaired with minimal materials. For greater damage requiring removal of coils or bars to gain access to carry out repairs, it is necessary to have spare coils or bars to utilize as replacement parts. In addition to simple replacement, coil or bar removal to access damage is risky and sufficient spares are necessary to cover for consequential damage inflicted by the repair process itself.

**Cleanliness:** The general state of contamination in a winding will have a bearing on the probability of success of a repair. A winding saturated with oil and covered in carbon or brake dust means operating in an unclean environment and attempting to insure that no contaminant enters the repair area. Undesired or unintentional foreign matter in a repair may lead to immediate failure during hipot testing or to premature failure once returned to service. Extra effort is required to clean the area to be worked on and to maintain a clean environment. This is easier said than done.

**Location:** The physical location of the damage within the stator, as well as the electrical position, or voltage, at which the damaged area normally operates, will affect repair decisions. Line-end repairs must be able to continuously withstand the electrical stresses imposed by that voltage and the proximity to surrounding stator winding circuits or machine components (ground). The same damage in a coil or bar near the winding neutral point does have the advantage of operating at lower voltage stress levels. In some cases there may be some opportunity to carry out a repair and ease up on acceptance testing in order to return a machine to service. However, it must be appreciated that under certain fault conditions, the neutral coils of a machine may approach full rated voltage. Therefore, any repair that has not been tested to suggested or recommended high voltage levels is an unknown and should not be considered as reliable.

**High Potential Testing:** Regardless of the type or extent of a stator winding repair, once the work has been completed there must be some proof testing to confirm that it is safe to energize the machine with minimal risk of an in-service failure. There is often a reluctance to apply recommended hipot test voltages (IEEE 4, IEEE 56, IEEE 95) to a sound winding let alone one that has been repaired. However, one should weigh very carefully the consequences of an in-service failure compared to finding a weakness under test conditions. In addition, any deficiencies found while testing can be immediately addressed as the machine is in some state of disassembly for the work being carried out. Failure on return to service, in addition to possible more extensive damage, necessitates machine disassembly again and the consequential extended forced outage.

The above illustrate points in the thought process when evaluating repair options. These focus on costs and general accessibility and spares. We have not yet discussed what types of mechanical damage might be repairable. Our next articles will look at different types of stator winding damage and how repairs to these may be approached.

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*This article is abstracted from the report "Guide for Stator Winding Coil Insulation Repair", published by EPRI as Final Report 1014909 in 2007. EPRI members can order the full report from EPRI as a CD Rom, which contains hundreds of photos.*



*Major electrical fault: "Repair" of this type of damage may not be reasonable or practical*



## FOCUS ON IRIS SALES TEAM



### **Rajiv Sharma, Manager Global Sales Operations**

Our Sales efforts and business opportunities continue to grow. In terms of Sales numbers we have experienced a very encouraging year so far; this is largely due to customers who believe in our technology and its benefits. We continue to remain focused and committed to our approach of consistently providing solutions that will assist customers to enhance their maintenance programs.

Recognizing the demand for future growth and awareness of Iris products and services globally; we have opened our Brazil Operations. We have also hired new team members who will be supporting our Agents and customers. I would like to take this opportunity to welcome and introduce to you the following Sales team members.



**Julian Bellotti** - Middle East & Northern Africa International Project Manager. Julian has been a successful business manager for over 20 years with diversified international experience in the manufacture, distribution, sales and marketing areas. He has experience with automation systems and knowledge-based high technology. Julian holds a Bachelor of Arts Degree, Psychology from Wilfrid Laurier University,

Waterloo, Ontario, an Electronics (Instruments) Engineering Diploma from George Brown College, Toronto, and a Business Management Diploma from Humber Business School, Toronto. He speaks English, Spanish, Italian and French.

**Sunny Gaidhu** joined Iris as a student engineer in 2005. He became part of the sales team in May 2009 and is responsible for Iris products North America. Prior to joining the sales team he was a summer co-op student working in the manufacturing department since 2005. Sunny has an Electronics Engineering Technologists degree from Sheridan College and a B.Eng from McMaster University in Electrical Engineering.



**Ghughur Kumar Jha** joined Iris in August 2009 as Product Manager – India Operations. Ghughur has a long, distinguished career in the Indian Air Force where he received his education as an electrical engineer in power plants. Prior to joining Iris, he was an Area Sales Manager with a product portfolio including Steinel cupancy sensors, Altenburger Dimming Solutions, Railway Platform lighting Solutions and PEHA wireless switches. He is now working on an MBA through ICFAI, Hyderabad (India).



**Serge Unga** joined us as an Applications Engineer North America in May 2009. Prior to joining Iris, Serge was a sales engineer with an electronics company working with the steel, automotive, pulp & paper, textile, petro-chemical, electrical power generation & service industries. Serge obtained his Electrical Engineering Degree (with a major in Power Systems) at the University of Moncton (New Brunswick) in 2004 and is presently working on completing a Master in Business Administration (MBA) at University Laval (Quebec). He speaks French and English.



The Sales team is ably supported by (left to right) Madge Wozniczka, Olga Aviles and Reena Chadha.



## LEMUG GROUP VISIT TO IRIS

On August 25, 2009 about 60 attendees at the EPRI Large Electric Motor User Group (LEMUG) meeting visited Iris Power to see our facilities. LEMUG was in Toronto for their semi-annual meeting to discuss various issues with respect to large motors. The visit was organized by Wayne Johnson of the Electric Power Research Institute. The visitors saw demonstrations of the ELCID test on a motor stator core, as well as a partial discharge measurements on 60 Hz and inverter duty windings.



## JOHN F. LYLES



John Lyles, one of the pioneers in the interpretation of on-line PD data in stator windings, passed away on Saturday November 7, 2009. He was 77 when he died. John had spent most of his career as a hydrogenerator designer at General Electric, and then as the head of the group that looked after Ontario Hydro's 160 or so large hydrogenerators. John was well known throughout the hydrogenerator industry due to his many IEEE papers on the design and maintenance of hydrogenerators. He also gave courses on hydrogenerator winding maintenance, initially by himself, and then via either EPRI or Iris Power. His unique experience, both as a machine designer and a user, allowed him to make many contributions to the understanding of winding failure, and effective methods for repairing and rewinding. His success was manifest in the fact that toward the end of his tenure, Ontario Hydro's generators needed stator rewinds at about one fifth the rate of other comparable utilities. His ideas for achieving long stator winding life were published as a series of papers in the IEEE Transactions on Energy Conversion ("Parameters Required to Maximize Thermoset Hydrogenerator Stator Winding Life", IEEE Trans EC, September 1994). Even 15 years later, this series of papers is still "state of the art". On retirement from Ontario Hydro in 1993, John continued as a very active consultant to utilities around the world until his "second" retirement in 2007.

Of great interest to Iris Power customers, John developed the first rules for interpreting on-line partial discharge data which he published in various papers in the 1980s. His guidelines were practical and useful. In spite of the rapid improvements in partial discharge interpretation in the past decade, John's guidelines still form the basis of the most reliable means for determining which stator windings had insulation problems, and also the most likely cause of any problems.

John is survived by Valerie, his wife of 44 years, two children and many grand children.

## DEVELOPMENT NEWS

**Tech Tip - Tracs:** The Iris Trac monitors (BusTrac, HydroTrac and PDTrac) can store PD data summaries for up to 2 years. Attention codes are activated and an Attention LED on the front panel warns the user when memory reaches 90% capacity. On reaching 100% memory capacity, approximately one year's worth of data is automatically erased without user intervention. This means that data for trending, displaying and analysis will be irretrievably lost if not downloaded.

It is essential to periodically download PD data from your Trac and then purge memory. Purging the memory after each download inhibits the same measurements from being downloaded again and prevents the database from becoming unnecessarily large. We recommend data download every 6 months. Refer to the respective Trac user manual on instructions for downloading data and purging memory.

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**H<sub>2</sub> Pressure:** PD readings are affected by the operating conditions of the machine being tested (load, winding temperature, humidity, etc). For hydrogen cooled machines, hydrogen pressure is also important and thus our software provides a place to record the H<sub>2</sub> pressure at the time PD data is taken. There are several alternative units for pressure which our software allows (psi-g, psi-a, bars, kPa). Unfortunately, except for psi units where gauge and absolute are specifically called out, the current versions of our applications assume absolute pressure is being entered. For customers using bars and kPa, many may have assumed gauge values. This is not generally a problem, since what you put in, you get back out - thus if you are consistent there is no issue. However, in PDView, for example, you switch units from kPa to psi-g, the software assumes the kPa that was entered was absolute, and an incorrect units conversion will take place. To eliminate this confusion, new versions of PDGuardPro, PDLitePro, and PDView will be forthcoming which will specifically indicate the units with -a and -g postfix. The new units will then be explicitly psi-g, psi-a, bars-g, bars-a, kPa-a, kPa-g, and the addition of kg/cm<sup>2</sup>.

## UPCOMING EVENTS

### IRIS ROTATING MACHINE CONFERENCE 2010 (IRMC)

Join us for the 2010 IRMC in  
Orlando, Florida  
June 21-24, 2010

Venue:  
The Sheraton Safari  
Hotel & Suites  
Lake Buena Vista  
Orlando, FL 32836

**COURSES - for more information contact [mmathias@irispower.com](mailto:mmathias@irispower.com)**

#### Partial Discharge Course

February 2 - 4, 2010, Sweden

March 2 - 3, 2010, UK

November 16 - 18, 2010, Orlando, Florida, USA

#### ACE EL CID Course

March 23 - 25, 2010, Toronto, Ontario, Canada

#### Hydrogenerator Maintenance Course

April 13 - 15, 2010, Portland, Oregon, USA

#### Turbine Generator and Motor Maintenance Course

May 4 - 6, 2010, Houston, Texas, USA

