



Inside this Issue:

Is On-Line PD Testing Useful for Hydrogen-Cooled Turbine	1,2
Remembering Ian	2
Shaft Monitoring Instruments Now Offered by Iris Power	3,4
Iris 1990 + 25 Years	4
IRMC 2015/2016	4

**UPCOMING EVENTS
2015/2016**

COMET	Nov 10-12, 2015 Austin, TX
IRMC	June 13-16, 2016 Scottsdale, AZ

Is On-Line PD Testing Useful for Hydrogen-Cooled Turbine Generators?

By: Greg Stone

Turbine generators (TGs) in nuclear, coal, oil and some gas-fired plants tend to be rated above a few hundred megawatts. Such machines tend to be hydrogen cooled (and above 500 MW or so, both direct water- and hydrogen-cooled). Hydrogen-cooled TGs have many advantages. Due to the small mass of the hydrogen molecule, the efficiency of a hydrogen-cooled machine is higher than an air-cooled machine, since there is less “windage” loss created by the spinning rotor. The absence of oxygen in the machine also means that aging processes that include oxidation do not occur and thus thermal aging is much slower. High pressure hydrogen is also much more effective than air in removing heat due to I²R losses in the rotor (and stator).

An important side effect of the use of high pressure (15 - 60 psi-g, or 100 – 400 kPa-g) hydrogen in TGs is that it will strongly suppress partial discharge (PD). The electrical breakdown strength of air and hydrogen are close. What makes the breakdown strength of the hydrogen so much higher is the pressure effect. It has been known for more than a century that electrical breakdown is strongly affected by the pressure of the gas. Most gasses have an electrical breakdown strength of about 3 kV/mm when dry and at 100 kPa. In contrast, if the pressure is 3 times higher, the breakdown strength is 9 kV/mm. The dramatic effect of pressure on breakdown results in the suppression of PD in high pressure hydrogen-cooled machines. So the questions often asked are:

1. is PD a cause of insulation failure, and
2. is on-line PD testing useful?

The short answer is no and yes, respectively.

PD is still sometimes present in hydrogen-cooled TGs in spite of the pressure effect. One reason PD still occurs is because such machines often are designed to run at higher operating voltage (up to 27 kV) and higher design average electrical stress (typically >3 kV/mm compared to air-cooled machines). That is, the manufacturers take advantage of the PD suppression properties of high pressure hydrogen, and reduce clearances compared to air-cooled machines. Also, certain types of degradation will still result in the electric fields needed to breakdown high pressure hydrogen. But unlike in air-cooled machines, the PD itself will not meaningfully degrade the insulation. The larger PD normally measured in air-cooled machines can slowly degrade epoxy (although it may take decades) – but more importantly, PD in air creates nitric acid that can chemically attack the insulation. This chemical attack phenomena is absent in hydrogen-cooled machines. In my experience, PD has never been the direct cause of failure in hydrogen-cooled machines.

So, is PD monitoring useful in hydrogen-cooled machines? Over 50 years of experience



Continued on page 2...

Remembering our friend—IAN CULBERT



Ian Culbert
1943-2015

Ian Culbert, a long time machine specialist at Iris Power, died suddenly on Tuesday, September 8th, 2015 after a short illness. He was well known to customers for giving courses and providing technical support.

Ian was born in Scotland and started his career as an apprentice at Parson's Peebles - an important supplier of motors to the petrochemical, utility and shipping industries. During this stage he became qualified as an Electrical Engineer, specifically in the design of electrical machines. He and his wife Anne decided to immigrate to Canada 7 years later, where he obtained a job as a machine designer in the Stratford, Canada plant of Reliance (now part of the ABB group), a high voltage motor supplier.

After 4 years at Reliance Ian moved to Toronto where he became the motor specialist in Ontario Hydro's (now OPG) Design and Development Division. He was particularly involved with the critical motors in their nuclear generating stations. During this time he became involved with his first external group - the Electric Power Research Institute's (EPRI) Large Electrical Motor User Group (LEMUG). He would attend their conferences twice per year - giving papers and participating in working groups to write common specifications for nuclear plant motors. Ian elected to take early retirement after 24 years at Hydro, and he joined Iris Power.

Ian was most visible outside of Iris in his long participation in industry working groups writing standards on testing windings. In addition to his EPRI LEMUG activities, he was one of Iris's representatives on the IEEE Power and Energy Society's Electrical Machines committee preparing winding test standards. One of his major accomplishments was as Chair of the working group that revised IEEE 43 on insulation resistance - the most widely used rotating machine insulation test standard in the world. He was active on the working group that revised the IEC standard (60034-1) - the world's main standard on rotating machines. Ian was a huge contributor to the first and second editions of the book "Electrical Insulation for Rotating Machines, published by Wiley. In the past 18 months, Ian has written a book with Prof Bill Thomson on current signature analysis. With these standards and books, Ian's impact on the motor and generator business will be felt by new engineers and maintenance staff for many decades.

Ian's friends and colleagues in Iris and outside of Iris will remember his generous nature, his patience in explaining concepts and ideas, his depth of technical knowledge and his hard work in shaping the specification of machines from an end-user point of view. He made a huge contribution to the world of electrical machines in his long career. §

Is On-Line PD Testing Useful for Hydrogen-Cooled Turbine Generators?

Continued from page 1...

has shown that on-line PD testing can detect two important failure processes in hydrogen-cooled TGs:

- loose windings in the slot leading to slot discharge, and
- contamination of the stator end-windings by partly conductive materials such as oil mixed with dust/dirt that leads to electrical tracking.

In these cases PD is just a symptom that loose windings and contamination are present. Specifically, the PD is just a symptom, not a contributing factor to the rate of deterioration.

This ability to detect loose windings in the slot and contamination has been demonstrated in dozens of case studies published since the 1970s. PD being a symptom of these two deterioration processes is the reason that all major TG manufacturers offer on-line PD testing services (as well as Iris-Qualitrol). It should be noted, however, that on-line PD does not seem to be able to detect small water leaks into the insulation or endwinding vibration - two other important causes of start winding aging/failure. §

Shaft Monitoring Instruments Now Offered by IRIS

Although the phenomenon of voltages and currents on motor and generator shafts has been known for the last 100 years, there has been an increase in occurrences and intensity of shaft current damage as machines become larger, operate at higher speeds, and more magnetic-based non-destructive inspection tools are used. This problem may affect all types of rotating machines (electrical and non-electrical, such as compressors and pumps) but it is most frequently observed on 2- and 4-pole turbogenerators.

During the normal operation of electrical machines, AC and DC voltages can be induced in the shaft, or created by the rotating elements of the turbine, connected to the same shaft. If voltages are high enough, shaft currents can reach levels capable of causing bearing failures. The main sources of shaft voltages are:

- Asymmetry of magnetic fields (incomplete cancellation of three phase magnetic fields) caused by design, manufacturing, or by stator winding, rotor winding or core faults.
- Flux generated by magnetized turbine and generator parts in the vicinity of the shaft.
- Shaft off center position.
- Electrostatic effects caused by charged steam or lubricants.

In addition to pitting (mechanical damage resulting from arcing between shaft and bearing) or EDM (electrodischarge machining), shaft currents may also alter the chemical properties of lubricating oil. Although the shaft is less sensitive to sparking effects, compared to the bearing surface, a more serious effect of bearing currents on the shaft is the mechanical wear produced by the buildup of metallic debris. Without effective shaft grounding, bearings and oil films are the only insulation between the shaft and the grounded parts and as shaft currents are not confined, they cannot be controlled. The build-up of voltage on the shaft and the resulting currents may damage bearings and could result in catastrophic rotating machine failure.

To control and keep shaft voltages low, one or both of the generator shaft bearings are insulated and the shaft is grounded using one or more closely spaced grounding devices, usually carbon, silver or copper brush, or copper braid.

The sensors utilized to provide signals for Shaft Voltage Monitoring consist of insulated shaft riding brushes for shaft voltage sensing and shunts installed on the shaft grounding brushes, for shaft current sensing. Different methods have been proposed to measure the effectiveness of the shaft ground brushes that are used to prevent excessive shaft voltage and currents. IEEE 112, Standard Test Procedure for Polyphase Induction Motors and Generators, provides a brief description of shaft current and voltage measurement methods, and a comparison of different techniques is given in IEEE 115, while IEEE 1129 gives a short summary of causes and instrumentation used. There is no standardized approach in the selection of sensors, their location or methods used for data collection. The most frequent lay-out is shown in Figure 1.

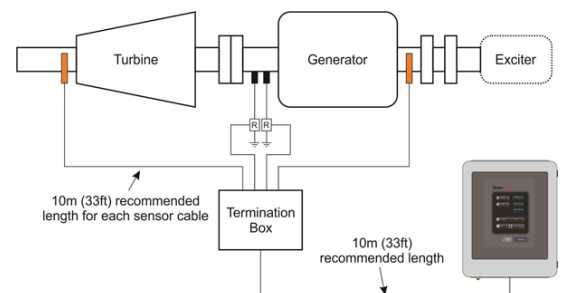


Figure 1. Typical shaft monitoring configuration on a turbogenerator

To overcome problems associated with periodic data collection and the use of portable instruments (non-consistent surface contact between shaft and a portable brush, and the inability of an ordinary digital voltmeter to accurately measure non-sinusoidal voltage shapes), Iris Power has developed a continuous Shaft Monitor.

Iris can provide two versions of the instrument, SMTraclI as a single technology Shaft Monitor, or it can be delivered as a part of a multi-technology GuardII, where up to three modules

Continued on page 4...



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2015/2016 Training Schedule

Hydrogenerator Maintenance Course	Oct 20-22, 2015 Baltimore, MD
Advance Partial Discharge Course	Jan 19-20, 2016 Singapore
Seminar on Hydrogenerator Monitoring	Feb 9-11, 2016

Iris 1990 + 25 Years !



Founders in 1991

Iris began its long history in November 1990 to commercialize new technology via an organization that shared the same interests as owners and operators of machines. Since its start, Iris Power has grown from the four founders to over 120 associates. Large generators and motors globally are now equipped with Iris technology to help plan stator and rotor winding maintenance and replacement.

Iris Power's success is due in large part to the support of our many customers world-wide together with the dedication of a loyal group of associates. Many of the original employees of Iris Power are still working here now. Thanks to all for a successful 25 years!



Iris Power Founders: Blake Lloyd, Steve Campbell, Greg Stone and Resi Zarb (left to right) 25 years later.

Iris Rotating Machine Conference

The 18th Annual Iris Power Conference was held in Nashville, TN last June.

Attendees from the US and Canada were joined by participants from Japan, Ireland, South Korea, Finland, Sweden, Brazil, Italy, Israel, South Africa, and Switzerland to make this, once again, a very successful conference for endusers of motors and generators.

Mark your calendars for IRMC 2016 which will be held in Scottsdale, Arizona the week of June 13-16!

If you have a topic to present, please contact Karen Howard, khoward@qualitrolcorp.com



Shaft Monitoring Instruments Now Offered by IRIS

Continued from page 3...

(Shaft Monitoring, Flux, Endwinding Vibration or Partial Discharge) can be used.

Shaft current and voltage signals are fed to an active termination box and then to a monitor to facilitate continuous monitoring and processing of the shaft grounding current and the shaft voltage. These continuously monitored signals are the keys to machine condition determination and can provide an early warning of developing unit problems.

The principal function of the instrument is to warn users about the following situations:

- Poor performance of grounding brush;
- Presence of additional grounds on the shaft;

- Presence of high voltage on the shaft.

In addition, the instrument will automatically collect and store a number of measurements in internal memory. The SMView software provides FFT analysis of the results and trending of data at different fixed and user selected frequencies. Modbus protocol can be used to communicate all measured and calculated values to a remote PC.

The installation of the Monitor can be performed without unit shutdown, but connection to the grounding brush might require the shutdown, depending on the type of brush installed.