IRIS POWER
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1990 - 2015 IRIS POWER A QUALITROL Company 25 YEARS

Diagnostic News

April 2015

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EPRI Generation European Workshop	April 20-24, Madrid, Spain
IEEE—EIC	June 7-10, Seattle, WA
EASA	June 14-16, San Antonio, TX

30 Years of PD Testing of Hydrogenerator Stator Windings

By: Greg Stone

The Iris Power PDA test has been commercially available for almost 30 years. This article traces its origin to the Research Division of Ontario Hydro, and through the various commercial stages at FES and Iris Power. The PDA test refers to the instrument called the Partial Discharge Analyzer (PDA). The purpose of the PDA test is to measure PD during normal operation of the hydrogenerator, since PD is a symptom of many of the most common causes of stator winding insulation deterioration, such as:

- Loose coils in the slot
- Thermal deterioration of the insulation
- Winding contamination leading to electrical tracking
- Various stator winding manufacturing issues.

On-line PD testing services were available from a number of hydrogenerator manufacturers in the 1950s and 1960s. Such tests had proven to be effective in finding stator winding problems, especially slot discharges caused by loose windings in the slot. In addition, a few utilities such as TVA and Ontario Hydro (now called Ontario Power Generation) had developed their own test methods. All the available methods used capacitive couplers or high frequency current transformers (HFCTs) to detect the PD. Usually an oscilloscope displayed the PD pulses with respect to the AC cycle. A common aspect of these tests was the requirement of a human expert to look at the scope screen to determine what pulses were caused by stator winding PD, and what pulses were due to electrical sources outside of the generator. Such noise sources include transients caused by the static exciters, rotor winding slip ring sparking, poor electrical connections anywhere in the power house, arcing from the isolated phase bus, substation corona, etc. Without an expert to interpret the signals on the oscilloscope screen, the noise could be interpreted as a stator PD signal, and the stator winding diagnosed as in poor condition, when in fact the winding insulation was healthy.

In the mid 1970s after some very high profile hydrogenerator failures in Canada, the Canadian Electrical Association (CEA) decided to fund a research project to develop a less-subjective on-line PD test for hydrogenerator stators that could be performed by utility personnel. The motivation was to reduce test costs since utility personnel would do the tests instead of external experts. In addition, the utilities could determine the PD activity free of any perceived conflict of interest that some test service providers may have based on the severity of the PD. The Research Division of Ontario Hydro submitted a proposal to do the research based on finding ways to separate the stator PD from all other signals (noise). A contract was awarded, with Mr. Mo Kurtz as project leader and myself as the engineer. Dr. Ray Bartnikas (Hydro Quebec), Mr. George Dang (BC Hydro) and Mr. Bill McDermid (Manitoba Hydro) were the external advisors. As discussed later, key outcomes from the research was an 80 pF capacitive coupler made from a short length of power cable that is permanently connected to the stator winding (Figure 1); a differential method to separate PD from noise and analog/digital instrumentation (called the Partial Discharge Analyzer or PDA) to record the PD pulse magnitude and repetition rate. The research project resulted in prototype instruments that were used in the early 1980s by several Canadian utilities who installed the necessary capacitive couplers. Early technical papers on the PDA test are in references [1-3]. Following a request for proposals issued in 1985 (30 years ago), the cable couplers and the PDA-H

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IRMC 2015—Join us in Nashville, TN

June 22— 25, 2015—DoubleTree by Hilton

The 18th Annual IRMC will take place in Nashville and will be attended by industry professionals from around the world. Topics include operation and maintenance of stator cores; advanced groundwall insulation systems for stator windings; recent motor and generator failures; diagnostic testing and winding repair methods. Tutorials are available for further learning and offered by world experts on the topics. There will be ample time for participants to take in the local sites as well as network with colleagues.

Tutorials offered at this year's IRMC include:

- Stator Winding Partial Discharge Theory—Vicki Warren
- Introduction to Stator Winding Partial Discharge Interpretation—Vicki Warren
- Advanced Stator Winding Parial Discharge Interpretation—Greg Stone
- Partial Discharge Testing of Cables & Switchgear—Howard Sedding
- Shaft Voltages and Currents Monitoring—Mladen Sasic
- Condition Assessment, Repair & Testing for Induction and Synchronous Motors—Ian Culbert

The DoubleTree room rate of $189 is available until May 31st! Visit the Iris Power website for the full technical program and registration information, or contact Karen Howard at

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30 Years of PD Testing of Hydrogenerator Stator Windings

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Figure 1: A photograph of an 80 pF "cable-type" coupler (in the process of being installed) that was widely used in the 1980s to detect the PD on hydrogenerators.

instrument were formally licensed in 1986 by Ontario Hydro and CEA to FES International, a fore-runner of Adwel, which later merged with Iris Power Engineering.

In the 1990s several developments occurred. One was the creation of the "epoxy mica coupler" or EMC as an alternative to the cable-type coupler. Another was the development of an all-digital instrument (called the PDA-IV) that had superior noise separation as well as the ability to view the PD with respect to the 50 or 60 Hz AC cycle. Finally, with partial sponsorship from the New York Power Authority (NYPA) and the Electric Power Research Institute (EPRI), continuous PD monitoring systems were developed based on the PDA method. Both the HydroTrac and HydroGuard continuous monitors were introduced.

The PDA technology has been implemented by hydro plant owners around the world. Over 60,000 epoxy mica couplers have now been installed, and machines have been equipped with over 3500 continuous monitors. Canada, the USA, the UK and Italy were early adopters, as was Brazil. Now most developed countries having significant hydro generation are using PDA testing to greater or lesser extents and the technology is rapidly being implemented in China and the rest of Asia.

References

1. M. Kurtz, G.C. Stone, "In-service Partial Discharge testing of Generator Insulation", IEEE Trans Electrical Insulation, April 1979, pp 94-100. Also presented to the 1978 International Symposium on Electrical Insulation.
2. M. Kurtz, J.F. Lyles, G.C. Stone, "Application of Partial Discharge Testing to Hydro Generator Maintenance", IEEE Trans Power Apparatus and Systems, Aug 1984, pp 2148-2157.
3. J.C. Bromley, W. McDermid, "Application of CEA Partial Discharge Analyzer", Doble Client Conference, April 1982.§

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Iris Power Celebrates 25 Years

Iris Power was incorporated in early 1990 and started operations in November 1990. Thus we are proud to have reached our 25th anniversary. We are now the world's largest manufacturer of condition monitoring sensors and instrumentation of the electrical windings in motors and generators. In fact our roots go back further than 25 years, since Iris Power merged with Adwel in 2008. Adwel and its predecessor (FES International) started operations in 1986. We are still based in the Toronto area, but we are now complemented by a world-wide network of Sales Engineers and Field Service Specialists. Since 2010 Iris Power has been part of Qualitrol.

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How to Ensure Long Life from a Stator Endwinding Vibration Monitoring System

For on-line endwinding vibration monitoring, it is necessary to permanently install fiber optic accelerometers on the motor or generator stator endwindings. Typical endwinding vibration accelerometer kits include accelerometers with fiber optic cables, generator frame feedthrough with hydrogen tight penetration for hydrogen-cooled generators, and electro-optical converters. The type of accelerometers used should be rated 100mV/g, 5-1000Hz (±1dB), 0-50g. This will ensure sufficient signal output sensitivity, frequency range, and amplitude range to obtain meaningful results. The following design features should be incorporated to ensure signal accuracy:

1. The accelerometer design should have extremely low cross axis sensitivity meaning that the influence of the vibration perpendicular to the direction of measurement is limited.
2. The accelerometer cables should not be sensitive to vibration. A cable effect test can be performed on a fiber optic cable design to ensure erroneous data is not being introduced into the signal.
3. The fiber optic signal needs to be converted to a voltage in order for the data to be processed. Electronics used to perform this conversion should be located outside of the hydrogen seal to ensure longer life and easier maintenance. A test point allows access for calibration verifications to be performed.

Since the accelerometers are permanently connected to the endwindings, assurance is required that they will not in themselves pose a risk of stator endwinding failure. In addition, they must be very reliable. The following tests should be performed to ensure an extremely low risk of failure.

A **Partial Discharge (PD) test** should be performed on the accelerometers because they are installed on high voltage windings. The results of the test should show no PD activity up to 34 kV AC which would indicate that the materials of the accelerometer are not sensitive to magnetic and electrical fields.

Accelerated Life Test: Due to the permanent nature of the accelerometer installation in the endwinding area they must have a long life. An accelerated life test comprised of high temperature, thermal cycling, and vibration testing should be performed on a fiber optic accelerometer design to simulate at least 10 years of continuous service operation. A test procedure to achieve this can be:

- High Temperature Test: place accelerometer in an oven at +200 °C and maintain temperature for at least 450 hours.
- Thermal Fatigue Test: place accelerometer in an environmental chamber thermal cycling from +20 °C to +120 °C for at least 50 cycles at 1 cycle per hour.
- Vibration Test: place accelerometer on a shaker table and apply 150 m/s^2 at 120 Hz continuously for more than 12 hours.
- A performance check should be performed before and after the testing and result in minimal signal output change. This would indicate that the accelerometer would still be operational after 10 years of continuous service operation.

Accelerator Performance: In hydrogen cooled generators the accelerometers are installed in a pressurized environment. Accelerometer performance should be evaluated in a pressure chamber with minimal signal variation.

Feedthrough Pressure Test: For hydrogen-cooled generators a penetration and fiber optic feedthrough cable bundle are used to pass the signal through the hydrogen seal. Pressure testing of the feedthrough cable should show no leaks up to 2.75 MPa-g (400 psi-g). In addition, accelerated life testing similar to the accelerometers can be performed to simulate at least 10 years of continuous service operation. The following procedure to achieve this is modified from the accelerometer testing due to different environmental conditions:

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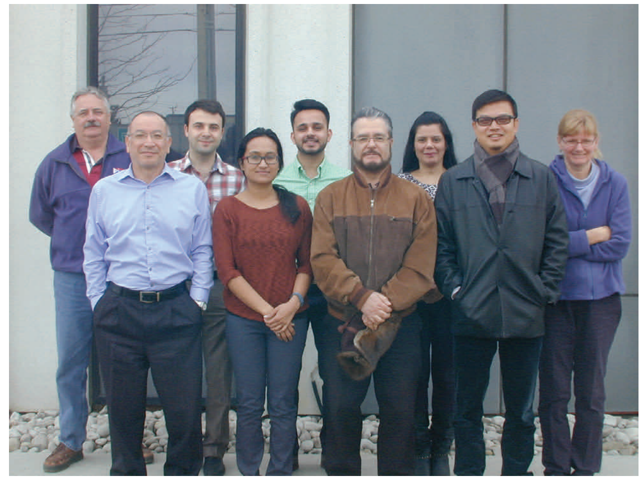
2015 Training Schedule

Turbogenerator Maintenance Course	April 21-23, Toronto, Canada
Partial Discharge Course	May 12-15, Houston, TX
Seminar on Hydrogenerator Monitoring	May 27-28, Houston, TX
EL CID Course	Sept 15-17, Toronto, Canada
Hydrogenerator Maintenance Course	Oct 20-22, Baltimore, MD
Large Turbine Generator & Motor Maintenance	Fall 2015, Toronto, Canada

Qualitrol-Iris Power Global Customer Service Team

Customer service (either pre-sales, on-site, or post-sales services) is the heart of our business model. The GCS team is in charge of pre-sales services, including:

- Identifying customer needs (requisitions, questionnaires, call conferences, etc)
- Offering solutions (technical descriptions, quotes)
- Explaining the solutions (flyers, brochures, manuals)
- Customizing solutions for special cases
- Promoting conferences and site visits by Sales representatives
- Receiving feedback as opportunities to improve



L-R (back row) Bob Ferguson (Technical Application), Emrah Arik (Inside Sales), Anil Kalia (Inside Sales), Reena Chadha (Sales Analyst), Madge Wozniczka (Sales Analyst)

L-R (front row) Pablo Rojas (Sales Support), Maurin Baroi (Technical Application), Byron Mazariegos (Sales Support), Kevin Wang (GCS Manager)

How to Ensure Long Life from a Stator Endwinding Vibration Monitoring System

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- High Temperature Test: place feedthrough in an oven at +150 °C and maintain temperature for at least 350 hours.
- Thermal Fatigue Test: place feedthrough in an environmental chamber thermal cycling from +20 °C to +150 °C for at least 35 hours at a rate of 1 cycle per hour.
- Vibration Test: place feedthrough on a shaker table and apply 220 m/s^2 at 120 Hz continuously for more than 85 hours.
- A leak check under pressure should be performed before and after the test procedure. No leaks would indicate that the feedthrough would still be operational after 10 years of continuous service operation.

Monitoring vibration in motor and generator stator endwindings requires the use of specialized sensing equipment. Certain design considerations should be made to ensure signal accuracy and rigorous testing should be performed to ensure that the sensors do not pose a risk of machine failure. §

IRIS Power EVAII sensors have passed these rigorous tests and meet these design requirements!

Ask your sales manager for EVAII durability documentation.