Winter 2001

DIAGNOSTIC NEWS

The Newsletter on Monitoring the Reliability of Electrical Equipment

Iris Power Engineering

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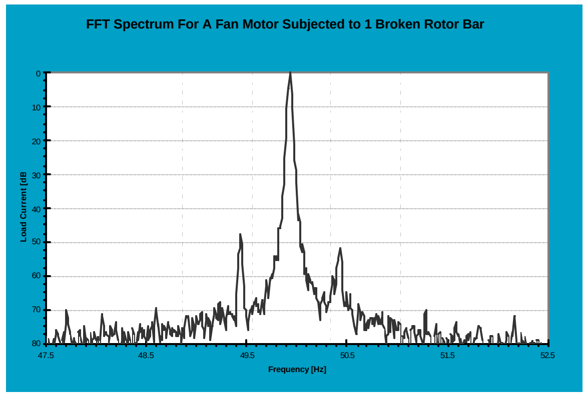
CSA for Motor Rotor Fault Detection

BY: MARK FENGER & BLAKE A. LLOYD

Low voltage and high voltage induction motors operating in industrial and utility plants often suffer premature failures caused by phenomena such as broken rotor bars, air gap eccentricity, bearing problems, etc. In fact, in an EPRI survey that included several thousand motors, findings indicated that 37 per cent of all in-service failures were caused by stator winding problems, and 42 per cent of these failures were caused by bearing problems. Thus, a significant number of motor problems can be attributed to phenomena that affects the rotating part of a motor, namely, the rotor.

It is well known that any phenomena causing a magnetic flux disturbance in the air gap between the rotor and the stator also produce induced current components in the stator. Specifically, a phenomenon such as broken rotor bars creates a change in the current distribution through the rotor winding which, again produces a non-symmetrical distortion of the magnetic field in the air gap. Historically, these phenomena have been studied analytically, and formulae predicting the frequency content of current components induced in the stator due to, for instance, broken rotor bars, have been produced.

This leads to the application of Current Signature Analysis (CSA) on induction motors, operating in industry and utility plants. Primarily, CSA is geared towards the detection of broken rotor bars but is capable of assessing other problems as well. CSA is based on obtaining frequency-resolved traces of the supply current in a motor, and then analyzes these traces for the presence, and magnitude, of certain frequency components.



Typical frequency spectrum of a motor under load with a large fundamental 60Hz component and sidebands at the motor slip frequency.

During the past 15 years, various instruments that relied on CSA technology have become available in the marketplace, and have been applied in predictive maintenance pro-

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New Texas Office

On Oct. 1, 2001, Iris opened its new regional office in Stafford, Texas. Situated just southwest of Houston, this office will provide services for customers in Texas and Louisiana. The office is currently staffed by Clinton Roache and Janet Hinrichs.

Clinton has had an illustrious career with Iris in Toronto, being the first member of the sales team and one of the first employees in the company. He has spent the last couple of years leading the five-member domestic application and sales team and now has undertaken the task of expanding our business in the above-mentioned territories. Janet Hinrichs joined Iris as a Field Service Specialist. She comes to Iris from the Public Service of Colorado where she served in various capacities working her way up to Journeyman Electrical Equipment Tester. In that position she performed testing on major equipment in power plants and substations, as well as testing cables and locating underground cable faults. Clinton and Janet may be reached in Houston at (281) 207-5322 or by fax at (281) 207-5323.

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New Tools for Continuous and Automated PD Measurement - the *Trac*: Early Successes

Although portable, on-line partial discharge testing has been used for many years, Iris has now taken this technology to a new level by pioneering the application and development of automated PD test equipment through its *GenGuard*, and, most recently, *Trac* lines of products.

The most recent innovation - *HydroTrac* - developed by Iris with support from EPRI and the New York Power Authority, allows hydro generator users to apply automated, continuous, on-line PD testing to their machines. Utilizing state-of-the-art electronics and software, the *HydroTrac* instrument has revolutionized PD testing by allowing each generator to be outfitted with a cost-effective, permanently-installed, PD monitoring system. To achieve this performance in a continuous monitor, *HydroTrac* employs radical component reduction through the use of programmable logic arrays and surface mount electronics. Recently, R&D Magazine recognized this innovative product by selecting *HydroTrac* as one of the top 100 products of this past year.

To meet the broadest range of applications, *HydroTrac* has been designed with a comprehensive list of interface and communications alternatives. The unit itself contains a micro controller, tactile panel, and local LCD display allowing it to operate in a standalone fashion, collecting and archiving PD data to local memory, and providing external alarm contacts on high PD readings. A local RS232 serial port is available to download the PD history for archiving and trending on an external computer.

Alternatively, *HydroTrac* can be configured with an analog output option, which generates current loop, or DC voltages that are proportional to the measured PD levels on the generator. These outputs can then be hardwired to existing SCADA, DCS, or PLC inputs, for trending, archiving, and alarming, utilizing software and interfaces familiar to the operator on existing plant systems.

Randy Brawley (Chelan PUD) with Randy Wallman (Iris) in front of a completed HydroTrac installation at Rock Island Dam

In locations with more centralized or automated generator monitoring, *HydroTrac* also contains a multi-drop RS485 (fiber or twisted pair) or 10Base-T Ethernet network connection. By utilizing these interfaces, multiple *HydroTrac* units can be remotely controlled via a Windows™-based software application. Interfacing this application to your plant DCS or SCADA will also allow *HydroTrac*'s PD data collection to be triggered based on generator operator conditions. In this configuration, pulse height analysis and summary PD data are collected by the remote computer and saved in a ODBC compliant database for viewing, trending, and analyzing.

Future versions of *HydroTrac* are being developed and will provide Web-Embedded capabilities allowing each *HydroTrac* unit to act as a mini Web Server. In this configuration, simple control, alarming, and data viewing will be available as Web pages, using just your Internet browser. For access to *HydroTracs* through the company internet firewall, *HydroTrac* will accept e-mailed commands, returning data or status information via a reply e-mail. The "EAlarm" feature lets *HydroTrac* e-mail PD alarms to any valid e-mail address in the world.

Following the successful verification and field trials of *HydroTrac* at several New York Power Authority plants, full-scale installation and the integration of 16 units at the St. Lawrence plant began last fall. Since the product has become commercially available this year, many utilities have already embraced the technology and are taking advantage of the flexible communications architecture to integrate continuous, automated PD monitoring into their generator maintenance strategy. A case in point is on the West coast of the U.S., where the Public Utility District No. 1 of Chelan County, located in Wenatchee, WA., is in the final stages of outfitting and integrating a network of 18 *HydroTracs* spread between two powerhouses, inter-connected via a fiber optic link. Avista, another western utility, has installed *HydroTrac* at two power stations: Cabinet Gorge, and Noxon Rapids. The *HydroTrac* unit at Noxon Rapids is controlled from an existing computer running the Zoom air gap and vibration monitoring system from VibroSystM.

Similar client response and interest has been shown for the *BusTrac* continuous monitor for turbine generators, fitted with Bus Couplers. Our users are eagerly awaiting the latest *PDTrac* instrument for motors due to appear in early 2002.

CSA for Motor Rotor Fault Detection

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grams throughout the industrial world. However, reliability problems have plagued many of these devices. Since the current signature spectrum frequency components and magnitudes are highly dependent on motor loading, (and therefore, the slip) as well as external influences such as the presence of mechanically-induced components from gearboxes, and factors such as rotor eccentricity, the accurate evaluation of rotor condition often requires expert knowledge and interpretation - without which, improper diagnostics can be made.

The most significant factor necessary for proper data interpretation is determining the operating slip of the motor. This is considered to be a key feature of CSA technology since all mathematical equations derived through the analysis of the dynamic rotor/stator magnetic interaction require the knowledge of the operating slip, expressed in the difference between the synchronous speed and the operating speed of a motor. Although the measurement of the operating slip can be obtained through the direct measurement of the operating speed via a tachometer or a stroboscope, this crucial task can significantly complicate the general application of CSA. Thus, it is desirable to be able to predict the slip as a function of known motor design information, such as nameplate data.

Identifying mechanically-related current components in the current spectrum ensures that healthy motors are not misdiagnosed.

The operating slip is a design parameter, which implies that each machine design has its own unique slip-versus-load relationship. Using the knowledge of the relationship between various machine parameters, as expressed by the nameplate data and the empirical slip design formulae, it is possible to develop an algorithm that deduces the operating speed, and thus, the slip, from a frequency-resolved trace of the supply current.

Furthermore, the ability to predict the position of current components caused by mechanical drives, such as gearboxes, and identifying their presence in the current spectrum, greatly enhance the quality of the CSA analysis. These components may appear at frequencies close to those where the current components, resulting in broken rotor bars, may occur. Thus, identifying these mechanically-related current components in the current spectrum ensures that healthy motors are not misdiagnosed.

Utilizing such advanced techniques allows for the development and the implementation of a fully diagnostic, autonomous CSA instrument, which only requires a simple non-invasive measurement of the supply current to a motor. Even when utilizing such advanced analysis, limitations of motor ratings, where slip predictions can be made, and on exact prediction of factors, such as the number of broken rotor bars given certain frequency component magnitudes, continue to exist. Research surrounding these problems continues today at Iris and at many other leading laboratories throughout the world.

CALLING ALL PAPERS!

Iris' Fifth Annual IRMC (Iris Rotating Machine Conference) is scheduled for June 10-13, 2002 in San Antonio, Texas. The Call for Papers is currently available on hard copy and on the Iris website at www.irispower.com.

The IRMC is one of the few non-commercial conferences dealing exclusively with practical problems in operating and maintaining motors and generators. We are soliciting abstracts for papers discussing recent innovations in machines and testing, as well as papers given by machine users on problems they have experienced and repair methods. In addition to the technical program, we also offer several tutorials that educate plant maintenance personnel on predictive maintenance and test methods. Usually over 125 people attend this conference - it is an excellent forum for exchanging ideas.

Iris Rotating Machine Conference

To submit a paper or for more information, contact: Kim Zarb at 416-5600 X 240 or fax: 416-620-1995 or e-mail: kzarb@irispower.com

Motor Maintenance Tips

(recently published on reliabilityweb.com)

BY: GREG STONE

1. IEEE has recently extensively revised the criteria for what is a “good” reading for motor stator windings. Modern form-wound motors should have a minimum insulation resistance of 100 Megohms, rather than the (kV+1) Megohms minimum previously used. See IEEE 43-2000.

2. If a motor is to be operated in a very humid environment, or if it is likely that contaminants such as insects, coal dust, chemicals, etc. will be in the environment, then consider installing a totally-enclosed, fan-cooled (TEFC) motor, rather than a WP2 motor. The initial capital cost will be a bit higher, but the costs of cleaning the motor, as well as reducing the likelihood of stator winding failure due to contamination will reduce life cycle costs.

3. All squirrel cage induction motors have limits on how many motor starts a particular motor should see in a fixed time period (an hour or a day). Follow the manufacturer’s recommendations on starting frequency, otherwise motor life will be reduced due to rotor and stator winding over-heating. If you know an application will require frequent starting, make sure the motor vendor knows this, so they can supply a more robust design.

4. A Class F motor does not imply that you can operate the motor at 155°C and expect 20 or 30 year's life. In fact, Class F materials are only required to operate for 20,000 hours (about 3 years) at 155°C before failure can be expected.

5. Within reason, every 10°C rise in winding temperature will decrease the life of a motor by 50 per cent. To maximize motor life, allow the motor to run as cool as possible by keeping the winding clean (to maximize heat transfer) and keeping the cooling system operating effectively, for example, by making sure any filters are clean.

6. Industry statistics show that bearings and related mechanical problems are the

UPCOMING EVENTS

Conferences

Jan. 22-24: **Energy Generation Conference**, Bismark, ND

March: IEEE **Cement Industry Conference**, Jacksonville, FL

June 10-13: **IRMC**, San Antonio, TX

Courses

April 1-4: **Motor & Generator Maintenance Course**, San Onofre, CA

Tradeshows

Jan. 29-31: **EXFOR**, Montreal, PQ

Growth in Field Service Activities

I am sure many of our clients would join us in saluting the dedicated members of the Field Service group. Despite more than 30 per cent growth in our service business year over the years, many members have dedicated a considerable amount of time working on the launch of our new Condition Assessment Service.

An example of this dedication is the recent installation of our new *BusTrac* continuous PD monitors on the generators servicing Hibernia, one of the largest off-shore platforms in the world.

Not only did Dave Quinn put our system through its paces in this harsh environment, but, as part of his safety training, he had to climb out of an overturned helicopter cabin that was submerged in the cold waters of the Atlantic.

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most common causes of motor failure. Almost all such problems can be easily detected well before failure with an effective vibration monitoring program. Since this can be done on-line, there is no interruption to motor operation, making vibration monitoring an effective predictive maintenance tool.

7. After bearing problems, the stator winding and the rotor winding are the most common causes of motor failure. Two on-line ways to assess the condition of the stator and rotor windings are partial discharge monitoring and current signature analysis, respectively. To avoid in-service motor failures, and at the same time, to minimize motor shutdowns for testing - vibration, partial discharge and current signature monitoring are important predictive maintenance tools.

8. If three-phase motor stator windings seem to be burning up much more quickly than expected, check the phase-to-ground voltage on each phase. If the voltage on each phase differs by more than 3 per cent, then significant circulating currents are flowing in the stator, which overheat the windings. The cause of the "voltage imbalance" is almost always unequal loading of the power source somewhere else in the plant.

9. When rewinding a stator where the coils have to be burned out, have the service shop do a core loss test on the stator before and after the burnout. The stator core losses should not increase by more than about 5 per cent. If the core loss increases by more than 5 per cent, the service shop may have done the "burn out" at too high a temperature, and thus damaged the insulation between the steel laminations.

10. If a motor has been retrofitted with an inverter to allow for variable speed operation, and the stator winding fails, then the cause may be over heating or voltage surges from the drive. IFD motors tend to run at higher temperatures due to harmonics and less-effective air-cooling when operating at low speeds. IFDs create thousands of fast rise-time, high-magnitude voltage surges per second, which may degrade the turn and ground insulation. You may need to upgrade the motor to one especially intended for IFD operation.

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