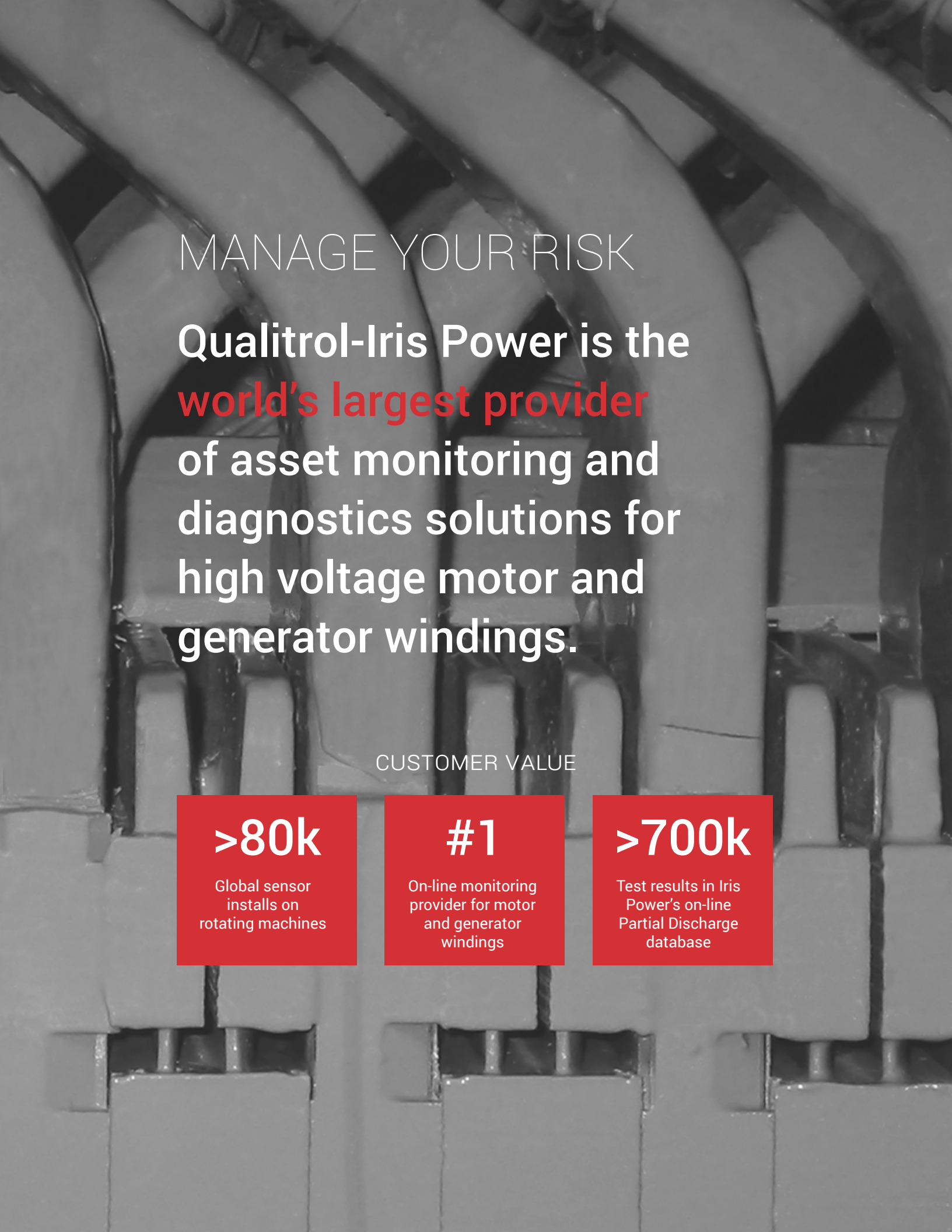
IRIS POWER

MOTOR CONDITION-BASED MAINTENANCE SOLUTIONS

QUALITROL
Defining Reliability

IRIS POWER
A QUALITROL Company
Defining Reliability



MANAGE YOUR RISK

Qualitrol-Iris Power is the world's largest provider of asset monitoring and diagnostics solutions for high voltage motor and generator windings.

CUSTOMER VALUE

>80k
Global sensor installs on rotating machines

#1
On-line monitoring provider for motor and generator windings

>700k
Test results in Iris Power's on-line Partial Discharge database

CONDITION BASED MAINTENANCE

Predictive Maintenance, also called Condition-Based Maintenance (CBM), has rapidly become the best approach to minimize overall maintenance costs of large High Voltage (HV) motors. CBM is an approach to planning maintenance where equipment is removed from service when, and only when an on-line monitor gives an indication that some failure mechanism may be imminent. Thus, equipment shutdowns are NOT based on operating hours, the number of stop/starts, or the elapsed time since the last maintenance shut-down. With CBM, the time between maintenance outages can be significantly increased in well-made motors. CBM also reduces the risk of in-service failures, with the accompanying higher repair costs.

Having confidence in planning maintenance, based on the actual condition of the motor, involves the following prerequisites:

On-line monitors that are able to detect most of the failure mechanisms that are likely. If not, unanticipated failures may occur, which undermine confidence in the CBM approach.

There must be few false alarms. That is, if a monitor indicates a problem, an actual problem must be present.

The sensors and the monitor itself should not lead to a failure, and the monitoring cost must be a small percentage of the motor cost.

BENEFITS OF CONDITION BASED MAINTENANCE ON LARGE HV MOTORS

- The time between motor shut-downs can be extended if monitoring reveals that the rotor and stator are in good condition. This increases availability and helps to avoid the failures caused inadvertently during the shut-down inspections (such as leaving a tool in the machine).
- Problems can be found at early stages, allowing for a maintenance shut-down to be planned at a convenient time. Experience also shows that if most problems are detected at an early stage, repair costs are often less than 1% of the rewind cost that would be incurred if the failure were permitted to occur in-service.
- Rewinds and other major repairs are based on need rather than the calendar or operating hours – or the desire of machine manufacturers and service organizations to generate after-market revenue.

Historically, vibration analysis, lubrication oil analysis, and thermography have been used as CBM tools on the mechanical components of machines. However, in the past, the rotor and stator windings have generally required regular shutdowns of the machine for off-line tests and inspections to be performed.

Off-line testing includes insulation resistance, polarization index, stator core loss, stator wedge tests, capacitance and dissipation (power) factor tests for the stator winding, and the pole drop test for salient pole motors. The pole drop test would not be applicable for squirrel cage rotors.

Over the past 35 years, our extensive research (primarily funded by machine users or organizations representing machine users, such as EPRI and CEA) has developed and/or refined several technologies that can detect most rotor and stator winding problems in large electric motors during normal service.

THESE MONITORING TECHNOLOGIES INCLUDE:

- Reliable measurement of stator winding partial discharges (PD) using on-line methods.
- Detection of shorted turns in synchronous motor rotor windings using magnetic flux monitoring.
- Detection of broken rotor bars in induction motors
- Detection of stator endwinding vibration.
- Rotor shaft ground brush current and voltage monitoring.

The Iris Power GuardII+ monitor has been designed to be a continuous monitoring platform to incorporate one or more of the above monitors into a single, flexible format with a common hardware platform, database, and interface.

With all these on-line monitoring technologies, as well as temperature monitoring, the majority of motor aging problems can be detected and addressed well before in-service failures occur. Qualitrol-Iris Power and its staff have been at the forefront in bringing these new monitoring technologies to utilities and industrial users.

In addition to the on-line condition monitors, Qualitrol-Iris Power is the world's leading manufacturer of off-line testing tools that can be used to confirm the existence and determine the severity of any issues found by on-line monitoring.

Benefits of the Condition Monitoring System

Condition Assessment by Machine Owners

Due to technology for reducing noise, and advanced algorithms to convert sensor signals to information, most end-users can interpret the data themselves, free of the commercial bias of rotating machines manufacturers and machine repair companies. Iris Power was created by the utility industry to provide third-party tools and technical advice that has the interest of machine owners in mind.

Turnkey solution

Where facilities have existing sensors for PD, flux, endwinding vibration, shaft monitoring and/or air gap, a continuous monitor installation does not require an outage, and the installation effort is limited to providing power to the monitor, configuration, and if desired, running a communication link to a remote Windows™ computer. Combined with the Iris Application Manager (IAM), one can collect data from multiple rotating machines which can be monitored continuously at the same time. This lowers the burden on plant personnel to collect data.

Reliable prediction

GuardII+ system has undergone unique and rigorously researched methods to overcome the electrical interference (noise) which is typical in most plant environments. This ensures reliable and repeatable measurements with a low probability of false alarms.

Customer education

The data can be easily interpreted by a maintenance professional after participating in a training seminar offered by Qualitrol-Iris Power's experienced engineering staff and world-class motors experts.

Monitor motor condition remotely

Via a company's intranet, experts located anywhere can determine the need for maintenance without having to travel to the plant. PDTracII and GuardII+ systems have been specifically designed to interface with central condition monitoring centers that many organizations are setting up.

Customized Data Storage

The GuardII+ software enables continuous data collection and storage (which creates a lot of, often redundant, data) or storing only critical data using sophisticated triggers based on operating conditions or events (such as a rapid increase in endwinding vibration).

Cybersecurity

Unlike monitoring systems developed by machine manufacturers which usually require the monitor output to be transmitted to the manufacturer's facilities for analysis, IRIS continuous monitoring system has been designed to allow the data to be contained entirely within the end-users company, and needs no connection to the outside world, as long as the plants are connected by their own secure intranet.

Ease of configuration

The GuardII+ monitors can be configured and upgraded with additional technologies, such as synchronous motor rotor flux or shaft voltage and current monitoring.

STATOR WINDING PARTIAL DISCHARGE MODULE

Partial discharges (PD) are small electrical sparks that occur within aging electrical insulation in stator windings rated 3kV and above. The PD occurs whenever there are small air gaps or voids in or on the surface of the insulation. Normally, well- made stator windings that are in good condition display little PD activity.

Industrial and utility motors rated 3.3 kV and above are monitored for partial discharge activity using 80pF epoxy mica capacitive couplers installed at the high voltage terminals of the machines. Typically, only three 6.9 kV or 16 kV rated sensors are installed because most motors are supplied by significant lengths of power cable, which attenuates and distorts any noise pulses from the power system, thereby making it unlikely that the signal is confused with the PD signals from the stator.

The sensors are fitted inside the motor termination enclosure, and the coaxial cables from the sensors are terminated in a separate enclosure to be used in conjunction with either the TGA-B™ portable PD analyzer, or directly plugged into a PDTracII™4208 continuous monitor.

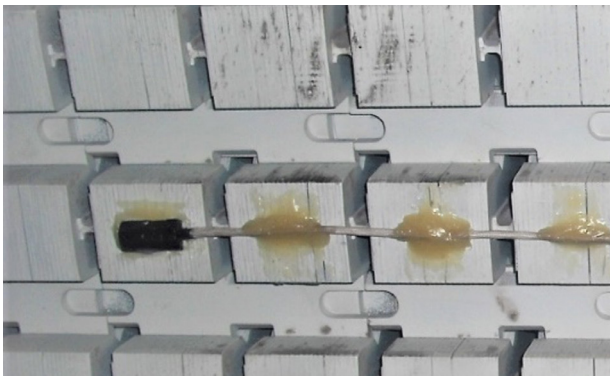
The choice of periodic monitoring using the TGA-B or continuous monitoring using the PDTracII depends on the maintenance practices of the facility, and, to some extent, on the voltage class of the motor. Machines rated 3.3 kV and 4 kV have shorter times to failure, so once insulation problems become a concern, continuous monitoring using the PDTracII is a prudent choice for these applications. Hazardous area and radiation certification are available for motor PD monitoring systems.

QUALITROL-IRIS POWER IS, BY ANY MEASURE, THE WORLD'S LARGEST SUPPLIER OF ON-LINE PARTIAL DISCHARGE MONITORING SYSTEMS FOR GENERATOR AND MOTOR STATOR WINDINGS. THE KEY REASON FOR OUR SUCCESS IS A MEASUREMENT METHOD THAT IS RELIABLE, OBJECTIVE, AND EASY TO USE.

The technology explicitly separates stator winding PD from other similar types of electrical signals, called noise. Noise, which is usually relatively harmless, comes from power system corona, brush sparking on slip rings and shaft grounding arrangements, power tool operation, variable speed drives, etc. Other PD technologies require considerable human expertise to separate PD from noise or need expertise to continuously adjust filters, clusters, and gates to separate PD and noise. The Qualitrol-Iris Power digital noise separation technology allows automatic, unsupervised noise suppression. False indications of stator winding problems are tracked by Qualitrol-Iris Power and have been shown to be <1.5% of machines where high PD is suspected.

The Qualitrol-Iris Power system allows for an objective interpretation of the test results by technicians who have received as little as two days of classroom training. The primary reason for this can be attributed to the extensive database of test results that Iris Power has collected and updates frequently. In most cases, it is easy for a machine user to determine in minutes if the stator winding has insulation problems.

Qualitrol-Iris Power's customers have published dozens of technical papers with well over 200 case studies on the effectiveness of the technology.



TFPROBE MOUNTED ON THE STATOR CORE

ON-LINE ROTOR FLUX MONITORING

In 2004, Iris Power embarked on a major R&D program to develop better methods to warn of impending rotor winding failure in salient pole rotor windings. Some of this R&D was funded by EPRI and the New York Power Authority.

As with stator winding PD monitoring, the goal has been the development of tools that can be used and interpreted by plant personnel (if desired), yet still have a low risk of false indications.

Each pole in a salient pole rotor is a self-contained electromagnet, with a laminated steel core around which magnet wire or copper strips are formed into a coil. The copper conductors are insulated from one another (turn insulation), and from the rotor pole body (ground insulation). The rotor winding insulation will degrade during operation due to thermal aging, rotor current cycling and/or partly conductive contamination in combination with high mechanical compression stress caused by centrifugal forces. Usually, the turn insulation ages faster than the ground insulation because it is much thinner than the ground insulation, and is exposed directly to both higher compression forces and higher temperatures.

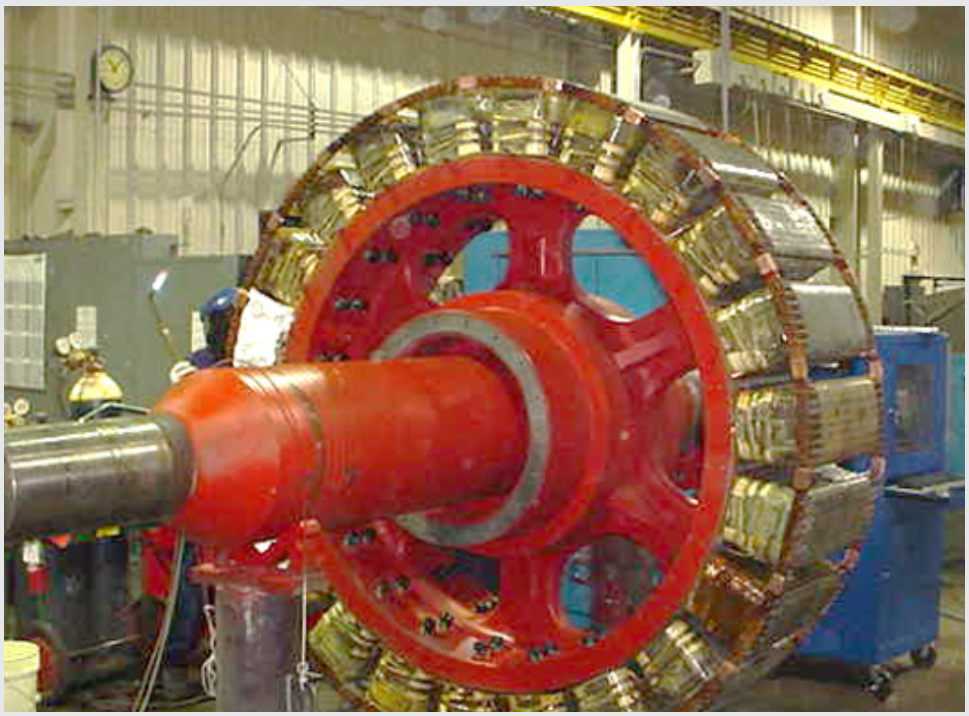
Thus, more and more turn shorts are likely to occur before a ground fault occurs. Generally, turn insulation shorts on a motor will not cause operational difficulties. However, if the number and severity of turn shorts increase over time, it is an indication that general insulation aging is occurring, and a ground fault may be imminent.

The development of a reliable on-line method to detect the shorted turns has, for the first time, allowed operators to trend the number of poles with shorts and their severity during normal operation. In addition, the need to perform the off-line pole drop test to detect rotor shorted turns is eliminated. The pole drop test has been widely recognized as an unreliable way of finding shorted rotor turns, since the test can only be performed when the rotor is at standstill, where shorts may clear or shorts may form, that are not present under rotation.

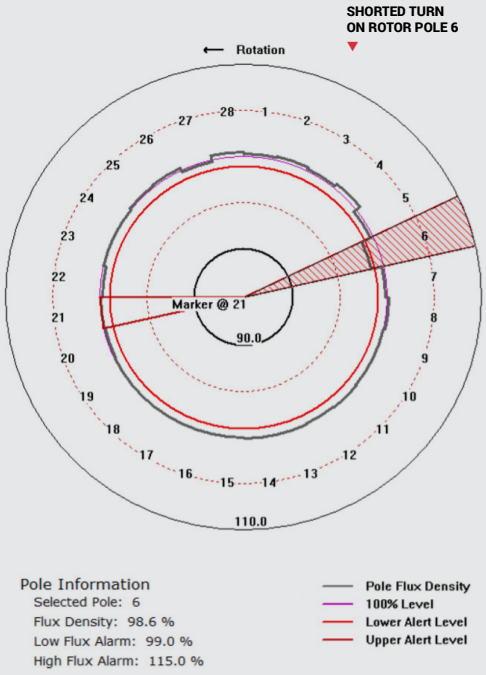
Qualitrol-Iris Power introduced the world's first commercial on-line monitor to detect shorted turns in salient pole rotor windings in 2005. The Iris Power technology requires the measurement of the main magnetic flux in the air gap between the rotor and the stator. The magnetic flux is detected by means of a single sensor called the TFProbe™ that is permanently installed by gluing it to a stator core tooth during a suitable, short outage. Usually, the TFProbe is retrofitted with the rotor in place. The output of the probe is a voltage that is proportional to the main magnetic flux crossing the air gap, as the rotor rotates. A reduction in magnetic flux as a pole passes the sensor implies a shorted turn may be present.

Algorithms unique to salient pole rotors have been developed and implemented in the dedicated monitor, FluxTracII 4208. Three algorithms are used to reduce the influence of air gap variations on the readings. If a shaft sync signal is provided, the rotor pole containing the short can be identified. All measurements and calculations are done within the rotor flux module.

The TFProbe signals can also be analyzed by means of the portable Iris Power RFA-S instrument. The GuardII+ with the rotor flux module provides polar plots showing the shape of the rotor and poles with likely shorts. It also trends the short severity vs time, which can provide information suggesting that the rotor ground insulation is also deteriorating and may fail.



SALIENT POLE
MOTOR ROTOR



RFAII-S™: PORTABLE SHORTED TURN DETECTOR FOR SALIENT POLE ROTORS

Algorithms unique to salient pole rotors have been developed and implemented in the RFAII-S to detect the perturbations in the magnetic flux caused by shorted turns. If a shaft sync signal is provided to the RFAII-S, the rotor pole containing the short can be identified. All measurements and calculations are done within the RFAII-S, and the instrument can collect data without a connection to a laptop computer. A computer is only needed for set-up and downloading of data. The test takes a few minutes and is normally repeated twice per year. The software that displays the results clearly indicates (both in a schematic and in tables), if shorts are present and on what poles they are occurring. The display software can also display rotor shape.

FLUXTRACII-S™: CONTINUOUS FLUX MONITOR FOR SALIENT POLE ROTORS

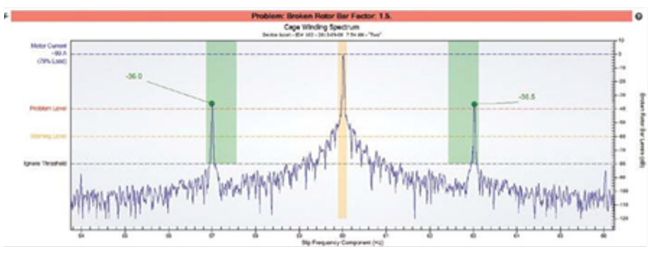
The FluxTracII-S instrument is a continuous on-line rotor flux monitor for rotor winding shorted turn detection in salient pole machines such as hydrogenerators, motor generators in reversible pump turbines, and salient pole motors. The FluxTracII-S instrument can monitor and evaluate up to four machines at the same time, so that when a rotor shorted turn is detected, an alert relay is activated. The instrument stores the base line measurements, the latest set of alerted measurements, and the latest set of non-alerted measurements. The data can be locally or remotely downloaded or can be automatically transmitted through Modbus over TCP/IP protocol to a plant SCADA system.

ON-LINE CURRENT SIGNATURE ANALYSIS TO FIND DEFECTIVE INDUCTION MOTOR ROTORS AND ROTOR ECCENTRICITY

The squirrel cage rotors in induction motors do not contain any insulation. Although such squirrel cage induction motor rotors are extremely reliable (which is why they are used in >99% of all AC motors), they sometimes fail due to "broken" rotor bars and cracked shorting rings. Such failures are most likely to occur on motors that see frequent starting, or high starting torque applications. The small current that flows in the rotor winding during normal operation is prevented or reduced in a rotor bar that is cracked or broken. This, in turn, distorts the magnetic field from the rotor. Since the spinning rotor's magnetic field induces a current into the stator winding, it is possible to detect broken rotor bars by measuring the current that comes from the motor's stator winding.

Current Signature Analysis (CSA) was originally invented by Professor Bill Thomson of Robert Gordon University in Scotland. Although the earlier versions of this technology were prone to false indications, Professor Thomson continued his research and developed many improvements to the CSA technology. In 2002, Iris Power introduced the first generation CSMeter™ which incorporated Professor Thomson's ideas in a portable, easy to use instrument. In 2014, Iris Power introduced the third generation MDSP3™. The MDSP3 detects the motor current in one of the three phases by means of a clamp-on current transformer, either on the main feed in low voltage motors or on a CT secondary for high voltage motors. After just a minute or so, the MDSP3 displays if the motor rotor contains any broken bars, or if the rotor has any eccentricity due to unequal air gaps between the rotor and the stator. Many years of experience has shown the algorithms to have a low probability of false indications that have plagued other CSA tools.

MDSP3 BENEFITS



- **Advanced algorithms**: MDSP3 has advanced current signature analysis (CSA) algorithms to accurately predict the operating slip from the measured current. Thus slip calculations can be done at different loads to accurately detect slip and hence detect cage winding frequencies.
- **Simplicity:** MDSP3 can detect cage winding faults and eccentricity with the use of a single clamp connected to the motor current transformer or around one of the phase leads.
- **Reliability:** In line with other Iris Power instruments, MDSP3 is designed to significantly reduce the risk of false indications by distinguishing between noise and legitimate rotor bar problems, with a noise floor greater than 100 dB.
- **On-line measurements:** All testing is done on-line, in less than 90 seconds, to find problems before they cause additional motor damage.
- **Range and accuracy:** MDSP3 can accurately test motors under varying load conditions where many other test systems give ambiguous results. MDPS uses two current probes to cover a wide range of current from 5 A to 1000 A.
- **Portable and safe:** MDSP3 needs only one input from a current probe clamped directly to one of the phase leads or the secondary side of a CT at the motor MCC or breaker. The MDSP3 processor is powered from a portable computer's USB connection. It does not need a separate battery or power supply.

Shaft Grounding Module

Because the motor shaft is spinning within different magnetic fields, it is possible that shaft voltages and currents can be induced. Asymmetry of magnetic fields caused by design, manufacturing or operational problems can also create shaft voltages and currents. The induced voltage on the motor shaft may be sufficient to breakdown the thin film of oil between the shaft and the bearings. If shaft current is high enough, arcing between the two components can result in pitting of the bearing surfaces and contamination of the lubricating oil, leading to a catastrophic bearing failure.

SHAFT GROUND BRUSH

Shaft voltage and current monitoring

The purpose of shaft grounding monitoring is to indicate the presence of high levels of shaft voltage and/or measure the current flowing through the shaft brush to ground. If the shaft voltages are high, or the currents through the brush are too low, then the shaft grounding system is not performing its task, and the risk of a bearing failure increases. Shaft brush monitoring may also provide additional benefits, including:

- Avoiding unexpected mechanical failures of the bearings by identifying poorly performing brushes for replacement.
- Identifying the quality of repairs or maintenance on brushes
- Prioritizing maintenance on machines in your fleet where it is most needed

On-line shaft brush monitoring using the GuardII+ requires the permanent installation or modification of one or two voltage brushes. In addition, resistive shunts can be inserted between the shaft grounding brush(es) and ground to measure the currents from one or two brushes. Shaft current and voltage signals are continuously measured by the GuardII+ shaft grounding module to trend and alert when grounding maintenance is required. Installation of the voltage brushes and connection to the shaft grounding brush may require a short motor shutdown, depending on the type of the brush installed.

The trend over time of the rms and peak-to-peak shaft voltages and brush currents will indicate when shaft ground brush maintenance is required. Further diagnostics are also possible by monitoring the change in voltage and current harmonics over time.

Beyond Continuous Monitoring Using GUARDII+

In addition to integrated periodic or continuous on-line monitoring of rotating machine rotor and stator windings, Qualitrol-Iris Power offers a complete selection of tools for motor condition assessment, including:

- Many tools to confirm the rotor and stator winding condition, including capacitance and dissipation factor tip-up testers, DC Ramp testers, polarization/depolarization current testers, RF corona probe testers and stator wedge tightness testers
- The EL CID low core flux tester to find damaged core lamination insulation in stators and rotors
- Specialized courses by some of the best known motor and generator experts in the world
- Winding condition assessment studies

To support customers in the use and interpretation of the GuardII+ monitoring system, Qualitrol-Iris Power has some of the most knowledgeable motor winding experts in the world on its staff. Iris staff have written two books on the subject (Electrical Insulation for Rotating Machines, 2nd Edition, published by Wiley/IEEE Press; and Condition Monitoring of Rotating Electrical Machines, published by the IET).

Our experts spent many years working for both rotating machines manufacturers and utilities in the design, testing, inspection and maintenance of motors, and have contributed to most of the relevant IEEE, IEC, and ISO standards.

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