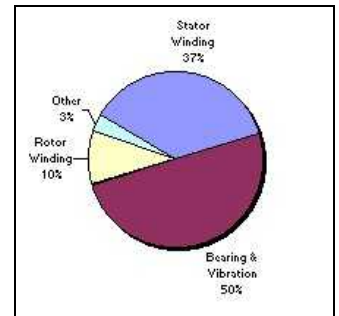


APPLICATIONS & BENEFITS

PARTIAL DISCHARGE TESTING FOR LARGE TURBINE GENERATORS

Introduction

Partial Discharge testing is a predictive maintenance tool for motor and generator stator windings. It is the only on-line electrical test that correctly identifies and warns of pending stator winding failure mechanisms such as loose windings, contamination, thermal deterioration, poor manufacture, problems due to load cycling and more! The test can be applied to any stator winding 3kV to 26kV. Industry statistics by IEEE and EPRI (Electrical Power Research Institute) indicate that approximately 40% of all rotating machine failures occur due to failure of the stator winding insulation. (See chart to right)



Defining Partial Discharge

Partial Discharges (PD) are basically tiny sparks that occur inside motors and generators. They occur within voids and on the surface of the stator winding insulation and out in the endwinding between phases. What we want to do is count the number of partial discharges inside the machine and quantify them. Essentially, if we see the PD activity increasing (more pulses and bigger pulses) over time, then we know that the stator winding insulation is aging. Knowing this, one can predict the severity of the insulation condition well in advance of a catastrophic failure. All this information is coming to you while the machine is running (on-line).

The reason it is called a "partial" discharge is simply because it's not a complete discharge (breakdown). It is not a breakdown from HV to ground, but rather a breakdown between some intermediate voltage and another intermediate voltage within the insulation. At 1 atmosphere (psig) the dielectric strength of a gas is ~3kV/mm. Hence the reason for not being able to PD test machines operating under ~3kV.

Iris Power Engineering is the worldwide leader in employing Partial Discharge monitoring techniques for predictive maintenance on rotating machines (motors and generators) rated 3kV and above. Our equipment is installed on more than 5,000 machines around the world!

Benefits of Partial Discharge Testing

Partial Discharge testing WILL provide users a huge benefit in the form of one or more of the following:

- Avoid unnecessary rewinds on older machines by maximizing the operating hours from a stator winding
- Avoid unexpected in-service failures of the stator winding; and extend up-time between outages
- Find a problem and correct it before it has a chance to fail the winding
- Find problems on new machines which may still be under warranty
- Assess the quality of maintenance repairs and/or rewinds with before and after readings
- Compare results from similar machines to focus maintenance on those with higher levels of PD
- Identify specific failure mechanisms in the stator winding to allow for corrective action prior to an outage
- Some insurance companies recognize the PD test and may give rebates
- Improve the overall reliability of motors & generators
- Accomplish all this while the machine remains in operation (On-Line)

In some cases, users have replaced such offline tests as Doble and HiPot testing with the on-line Partial Discharge test. We don't normally market our test with the intention to replace other forms of electrical testing as most are good tests to perform when given the chance. However, why take an operating machine out of service or extend an outage to do these tests when on-line Partial Discharge testing indicates a healthy stator winding. Iris does recommend that if a problem is identified with the on-line PD testing that users perform

various off-line tests (Corona Probe, Megger, etc...) to confirm the problems existence. This will provide a solid "second opinion" for which to base future maintenance.

Studies show that most stator windings are very reliable (about 95%) at any given time. Knowing this, it is important for users of large machines to know or at least have an idea if they are one of the 5% or not. There are advantages to knowing that there are no problems. Some machines are known to be more reliable than others because of their design and how they are operated. However, eventually these machines will fail, if for no other reason, due to gradual thermal aging of the stator winding insulation. Users of the partial discharge test will be able to find problems while on line and also identify machines that are in good condition enabling them to extend the time between major outages. On-line Partial Discharge testing is the only electrical test that allows you to do this.

On-Line PD Testing Applications

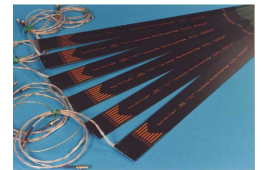
The Partial Discharge technology Iris offers was designed with plant staff in mind. That is, anyone can use it. Users don't have to rely on some expert with a PhD to come to site and interpret the signals shown on the screen. The way the system works is by creating a 'user friendly' environment where unwanted noise signals are separated, but not discarded, from machine Partial Discharge.

In accomplishing this, Iris offers its clients several options:

1. Purchase their own portable **TGA-B™** or **TGA-S™** instrument for routine periodic testing;
2. Rent a portable **TGA-B™** or **TGA-S™** instrument and have Iris do the analysis;
3. Purchase a Continuous On-Line Monitor (**BusTrac™** or **TurboGuard™**) to operate in either stand alone mode with alarm or analog outputs, remote control mode or automated mode;
4. Testing Services – Have Iris come to site and perform periodic routine testing



In any of the above cases, permanently installed PD sensors, Bus Couplers (shown to the left) or Stator Slot Couplers™ (shown to the right) specifically designed to work with partial discharge frequencies (50MHz-250MHz typically) need to be installed. The Bus Couplers are high voltage 80pF Epoxy Mica Capacitors. When installed they create a high pass filter to allow PD signals through for measurement. Iris has sold over 25,000 of these sensors around the world. Worthy of mention is that not one has ever failed. In fact, the



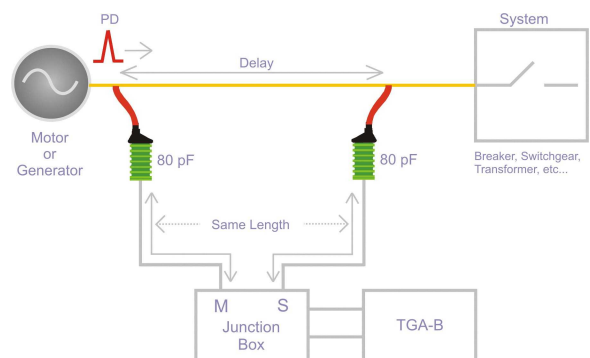
IEEE has specified a theoretical operating life of about 60,000 years!!! We'll all be retired by then... The Stator Slot Couplers™ are high frequency directional radio antennas. They are coated with an epoxy glass laminate to withstand the operating environment within a generator. Iris has sold over 3,500 individual SSCs to date.

With only 2 days worth of training, clients can become their own "expert" on partial discharge testing and interpretation. It's that easy. The reason is simple. Iris's patented noise separation techniques that are built into the system (sensor installation and instrument) objectively separate signals based on where they originate. Thus, eliminating false indications. Here's how 2 of Iris' systems work:

1. Bus Coupler Installation - Directional Noise Separation (Units <200MW)

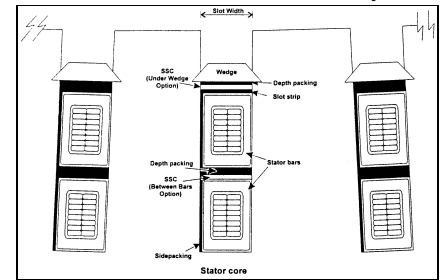
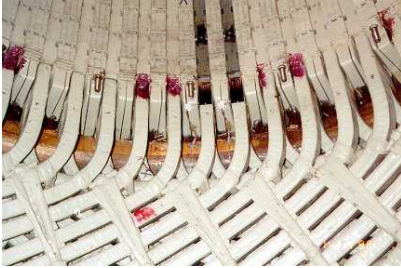
The figure shown here describes how our Bus Coupler system works in separating noise signals from the system and partial discharge signals from a generator. The portable **TGA-B™** instrument is able to tell which direction the signals originate from, thus also giving the unique benefit of being able to see any PD activity from the connected system. It determines if the PD detected came from the generator, between the bus coupler pair, or from the connected system.

Bus couplers are installed in pairs: 2 sensors per phase with at least 6' but no more than 50' of bus between them. A typical installation takes two days to complete per generator. Iris offers installation supervision and calibration services to clients who prefer assistance.



2. Stator Slot Coupler™ Installation (Units >200MW)

Stator Slot Couplers™ (SSCs) are by far the most sensitive partial discharge sensor in the world since they are installed directly underneath the wedges in high voltage stator slots (See picture to the right). They reliably eliminate both internal and external noise to provide consistent trendable readings. Although mainly sold and installed as a PD sensor for larger (>200MW) H-cooled turbogenerators, some clients have installed them on smaller air-cooled turbos, hydros, and even motors. They effectively distinguish between internal noise and machine PD, which can become a nuisance on the larger machines. Whereas the bus couplers do not have the capability of separating internal noise and PD. However, internal noise is only an issue on older larger (>200MW) turbine generators.



Iris Recommends

As a basis for new clients, Iris recommends PD testing every 6 months for the first 2 years. This will provide a good solid baseline trend for future comparison. From there, depending on the levels of Partial Discharge and how it is changing, Iris recommends, as a minimum, testing no less than once per year.

Alternatively, some clients opt to purchase a continuous on-line monitor to continually “track” and trend the PD activity. This eliminates the need for on-site visits. Our Trac instruments **BusTrac™** will provide maximum warning of increasing PD activity in order for maintenance personnel to act accordingly. They come equipped with alarm relays and optional analog (4-20mA) signal outputs for connection to a DCS or SCADA. Users can also remotely communicate with the Trac monitors via Ethernet, RS485, fibre-optic or wireless. **PDTrac™** also comes equipped with analog input modules to allow condition based triggering on stator winding temp, ambient temp, or humidity.



The **BusTrac™** on-line monitor make life much simpler since the user knows that PD measurements are always being collected.

The Iris Partial Discharge Database

Iris has an extensive statistical PD database of results. Currently, there are over 47,000 records in the database. Each year Iris breaks it down and summarizes it in various ways making it more practical. To date, comparisons by type of sensor, stator voltage, type of machine, vintage, hydrogen pressure and OEM have been completed with very interesting conclusions. Having such an extensive database provides the following benefits:

- Allows the comparison of similar machines, focusing maintenance time and expenditure on machines with excessive deterioration (higher PD magnitudes)
- Informs users of what a good, and bad level really are when it comes to PD levels, rather than guessing
- Indicates further that Iris Power Engineering is the leader in partial discharge theory and application

Iris Profile – (brief)

Iris Power Engineering's roots stem from the utility industry. The PD test we market today was developed in conjunction by Ontario Hydro (now Ontario Power Generation) the Canadian Electrical Association and EPRI. The key personnel involved in the research and development of this on-line PD testing system from Ontario Hydro left in 1990 to form Iris Power Engineering, Inc. Their goal: To provide users of large motors and generators with high-quality products and services to improve maintenance capabilities. As an ISO9001 registered company, Iris customers can expect to receive quality products and continued professional service. Currently Iris employs 75 people with continued growth in mind. Iris Power's extensive client list contains customers from around the world.