Partial Discharge Detection using Transient Earth Voltage & Ultrasound Testing

1. INTRODUCTION

Partial Discharge (PD) is an electrical phenomenon which causes insulation to deteriorate and frequently is the reason for breakdown of an insulation system resulting in failure of the equipment.

Partial Discharge can be described as an electrical pulse or discharge in a gas-filled void or on a dielectric surface of a solid or liquid insulation system. This pulse or discharge would partially bridge phase to ground insulation or phase to phase insulation in an electrical apparatus, thus causing the electrical equipment to fail.

Partial Discharges can occur for a number of different reasons. For example, PD can occur when high voltage structures have sharp projections, internal discharge can occur in voids and contact noise can occur if the ground connection to a bushing is poor.

Partial discharge in high voltage metal-clad switchgear can result in catastrophic failure of the individual plant and in some cases, of the substation (HV) plant. Conventional Partial Discharge Equipment is very expensive and difficult to use, and requires the equipment under test to be de-energised.

Through the use of modern techniques, it is now possible to detect and locate Partial Discharge with the equipment ON LINE, without the need to make direct connections to high voltage terminations, and hence, no necessity to shut down essential equipment.

2. PARTIAL DISCHARGE

Partial discharge in MV Switchgear can be considered to take two forms, surface discharge where tracking occurs across the surface of the insulation, exacerbated by airborne contamination and moisture, and internal discharge within the insulation which, if allowed to continue, eventually causes the insulation to break down catastrophically.

Surface Discharge

Surface discharges are often best detected using an ultrasonic listening instrument. However, there must be an uninterrupted air path between the discharge site and the instrument to allow the ultrasound waves to be detected.
Surface discharges tends to occur between the particles of a contaminant, producing heat, light, sound, electromagnetic radiation, Ozone and Nitrogen gasses. In the early stages of this type of degradation process, and if an air path from the discharge site to outside of the equipment is present, the high frequency sound waves generated by the partial discharge are readily detected using ultrasonic detection equipment in the 40 KHz range. Often moisture combines with the NOx gasses to produce Nitric acid, which attacks both the insulation and surrounding metalwork, which can become seriously rusted. Insulation surfaces affected by such an acid attack produce an ideal surface for tracking to occur. Tracking is the result of carbonization of the surface of insulation often brought on in the early stages by the breakdown of contaminates. These carbon tracks electrically shorten the insulation causing the process to accelerate to eventual flashover.

Solid Insulation Internal Discharge

Within all insulation material, however manufactured, there are small voids, often microscopic. In use, the insulator has one end connected to HV and the other to earth, which cause these voids to charge up like small capacitors. When sufficiently charged they discharge with a small spark across the air void as the breakdown strength of the air is lower than that of the surrounding insulation and the electric stress across the void is high. These sparks produce heat, light, noise and electromagnetic radiation. Only the electromagnetic radiation can escape. The discharge action also erodes the voids making them bigger, and as they get bigger the discharge energy dissipated with each discharge increases in magnitude. During this process carbonization of the inner surface also occurs, which progressively builds up to make the void conductive. This increases the electrical stress on the next void and the process repeats itself. Eventually there are sufficient conductive voids throughout the insulation large enough to cause the insulation to fail.

The electromagnetic pulses produced by partial discharges are in large part conducted away by the surrounding metalwork but a small proportion impinges onto the inner surface of the casing. These small charges (between 0.1 mV to 1 V) escape through joints in the metalwork, or a gasket on a gas insulated switch, and pass, as local raised voltages, across the surface of the switch to earth. These pulses of charge were first researched at EA Technology in 1974 by a Dr John Reeves, who named them Transient Earth Voltages (TEV).

It was found that the level of these TEV signals are proportional to the condition of the insulation for switchgear of the same type and model, measured at the same point. This produced a very powerful comparative technique for non-invasively checking the condition of switches of the same type and manufacture.

3. METHOD OF TESTING

By utilizing the EA Technology's UltraTEV Plus+ and the Partial Discharge Locator Model PDL1 a comprehensive partial discharge testing service can be achieved.

The UltraTEV Plus+ detects and measures both Transient Earth Voltage (TEV) and Ultrasound, hence allowing surface and solid insulation discharge to be analyzed.

The Partial Discharge Locator Model PDL1 is a two probes instrument capable of locating the source of TEV signal, thereby allowing the operator to accurately identifying the switchboard at fault.

It is to be noted that Partial Discharge levels can sometimes very significantly with time. External sources of high Partial Discharge may sometimes envelope the Partial Discharge activities within equipment which are required to be measured. In such situations, the Partial Discharge Monitor model PDM03 has been developed to overcome such problems.

The Transient Earth Voltage (TEV) measurement technique operates within a bandwidth of 3 to 70MHz, to detect and locate the PD source from the phase terminations to earth, up to 66kV usually caused by internal air solid insulation. The Ultrasound detector operates at 40kHz to detect airborne ultrasound voids in at low surface discharges, from the terminations. Both are non-invasive diagnostic techniques which have proven their worth in a lot of Electric Utilities like the CEGB of UK, PUB of Singapore, New Zealand Supply Authorities, etc.

The advantage of both these methods is that it is unnecessary to shutdown and de-energizes the equipment under test.

The two methods of measurement can be described as follows:

i) *How Transient Earth Voltage (TEV) Measurement Works*

If a Partial Discharge occurs in the phase to earth insulation of an item of high voltage plant such as a metal-clad switchboard or a cable termination, a small quantity of electrical charge is transferred capacitively from the high voltage conductor system to the earthed metal-cladding. The quantity of charge transferred is very small and is normally measured in pico-coulombs. The transfer occurs typically, in a few nanoseconds.

When the partial discharge occurs, electromagnetic waves propagate away from the discharge site. Due to the skin effect, the transient voltages on the inside of the metalwork cannot be directly detected outside the switchgear. However, at an opening in the metal cladding such as the gasketted joints, the electromagnetic wave can propagate out into free space. The wave then generates a transient earth voltage on the metal surface. Hence, the technique is called TEV for Transient Earth Voltage.

ii) *How Ultrasound Electrical Detection Works*

Arcing, tracking and corona all produce some form of ionization which disturbs the air molecules around it. The UltraTEV Plus+ detects the ultrasound frequency noise produced by this effect and translates it, via heterodyning, down into the audible ranges. The specific sound quality of each type of emission is heard in headphones while the intensity of the signal is observed on a meter. Normally, electrical equipment should be silent; although some may produce a constant 50-cycle hum or some steady mechanical noises. These should not be confused with the erratic, sizzling, frying, uneven and popping sounds of an electrical discharge.

Low levels of Partial Discharge which emit very low levels of electromagnetic signals have been found in dry termination cable boxes. The electromagnetic signals are below the sensitivity of the Partial Discharge Locator PDL1 and if this Instrument is made more sensitive to detect such signals, the signals would be in the background noise level of most Substations. Hence, the UltraTEV Plus+ would be able to detect such low surface discharges from the airborne ultrasound signals generated.

4. POSSIBLE DEFECTS WHICH MAY BE DETECTED FROM PARTIAL DISCHARGE

Some examples of causes of Partial Discharge resulting in failure are:-

- Incorrect usage & installation of cable termination kits
  e.g. - Poor cutbacks on cable terminations & splices
  - No stress control tubes or insufficient length installed
  - Insufficient clearance between cores in a cross-core configuration
- Air voids created by inconsistent heat shrinkage of sleevings
- Air voids within cable insulation caused by manufacturing defects
- Sharp edges, or nicks left on conductors
- Insufficient clearance between conductors and surrounding insulation
- No angle boots installed to cover bare high voltage conductors in VT boxes
- Strong odor of Ozone, presence of whitish to bluish green powder due to formation of nitrous acid from ionization
- Colour fading and dark tracks on insulation near conductors, usually with a "treeing" pattern

Records by Power Utilities indicate that the main power outages in the electrical grid are caused by defective cable terminations and joints.

5. REMEDIAL ACTION

Upon detection of possible defect, the equipment must be shutdown and the potential fault area has to be carefully inspected visually to assess the seriousness of the problem. In most instances the affected components need to be replaced.

Partial Discharge Detection

Examples

Equipment: Bushings at VT Terminal

Partial Discharge Locator Reading: 24dB

Defects: Discolouration on Bushings & Busbar

Possible Cause: Ionization due to surface discharge

Equipment: Busbar Termination at VT Terminal

Partial Discharge Locator Reading: 32dB

Defects: Discolouration on Busbar & Insulator Surface

Possible Cause: Surface Ionization due to sharp corners on busbar

Equipment: 11kV HV Cable Base plate

Partial Discharge Locator Reading: 35dB

Defects: Bubbling of paintwork on baseplate

Possible Cause: Corrosion caused by Nitric acid produced from Ozone

Ref: Nt_server\UltraS-Pd/Pd Examples/Example Gallery

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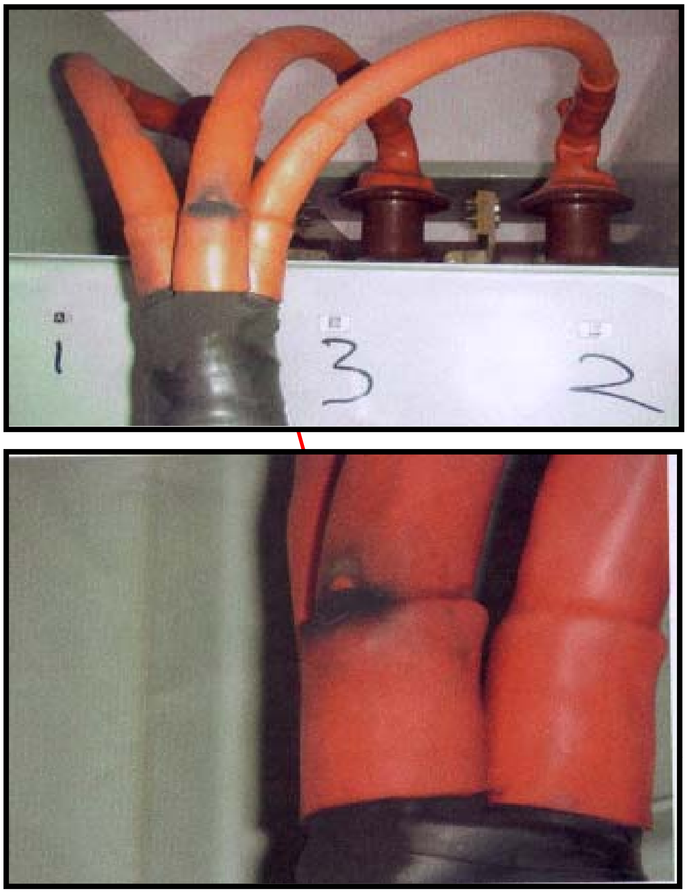
Partial Discharge Detection

Examples



Equipment: Cable Termination at 11kv HV Panel

Partial Discharge Locator Reading: 32dB

Defects: Burn marks on cable insulation

Possible Cause: Air voids within cable sleeves caused by defective termination

Equipment: Cable Termination at 11kV HV Panel

Partial Discharge Locator Reading: 35dB

Defects: Discolouration on cable insulation

Possible Cause: Ozone from ionization attack on cable surface

Ref: Nt_server\UltraS-Pd/Pd Examples/Example Gallery

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Partial Discharge Detection

Examples

Equipment:	Cable Termination at 11kV Transformer Compartment
Partial Discharge Locator Reading:	35dB
Defects:	Burn Marks between the B & R phase cables
Possible Cause:	Arcing between the phases due to insufficient spacing between phase cables

Close up of anomaly

Ref: Nt_server\UltraS-Pd/Pd Examples/Example Gallery

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Partial Discharge Detection

Examples

Equipment:	Cable termination at 33kV transformer panel
Partial Discharge Locator Reading:	20dB on outside panel surface but 35-40 DB on surface of internal panel close to fault
Defects:	Heavy discolouration of cable surface, slight burn marks
Possible Cause:	Voids within internal insulation

Ref: Nt_server\UltraS-Pd/Pd Examples/Example Gallery

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BENEFITS AND EXPERIENCES OF NON-INTRUSIVE PARTIAL DISCHARGE MEASUREMENTS ON MV SWITCHGEAR

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ABSTRACT

Partial discharge activity has long been accepted as a major cause of failure of Medium Voltage (MV) switchgear. Traditional techniques for the detection of partial discharge involved taking plant out of service and energising via a discharge free power supply and measuring signals using coupling capacitors and conventional PD detectors according to IEC 60270. Over the last 25 years or so instrumentation has been developed that enables the detection of partial discharge activity with the plant in normal service.

This paper will show the how two power utility companies have successfully introduced the widespread use of partial discharge testing, what their main drivers are behind the adoption and the practical results, experiences and benefits gained as a result.

INTRODUCTION

Over recent years the popularity of non-intrusive partial discharge testing has increased as network operators have started to appreciate the need for regular testing and realised the benefits that can be gained from the approach. However, until recently there was still a major barrier to wholesale adoption of partial discharge testing for MV switchgear and that was the capital cost of the test equipment coupled with the requirement for skilled engineers to carry out the testing in the days of downsized workforces.

The recent introduction to the market of low-cost, simple to use instruments that combine the ability to detect discharge activity using electromagnetic and ultrasonic methods has effectively removed this barrier to adoption. This is resulting in changes to the way power utility companies are approaching the condition assessment and management of switchgear assets and at the same time enhancing the safety of operators working on the system.

Partial Discharge

Partial discharge in MV Switchgear can be considered to take two forms, **surface discharge** where tracking occurs across the surface of the insulation, exacerbated by airborne contamination and moisture, and **internal discharge** within the insulation which, if allowed to continue, eventually causes the insulation to break down catastrophically.

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The electromagnetic pulses produced by partial discharges are in large part conducted away by the surrounding metalwork but a small proportion impinges onto the inner surface of the casing. These small charges (between 0.1 mV to 1 V) escape through joints in the metalwork, or a gasket on a gas insulated switch, and pass, as local raised voltages, across the surface of the switch to earth. These pulses of charge were first researched at EA Technology in 1974 by a Dr John Reeves, who named them Transient Earth Voltages (TEV).

It was found that the level of these TEV signals are proportional to the condition of the insulation for switchgear of the same type and model, measured at the same point. This produced a very powerful comparative technique for non-invasively checking the condition of switches of the same type and manufacture.

Since 1983, EA Technology has assembled, with the co-operation of the UK Electricity Companies, a database of substation partial discharge survey results with over 15,000 entries covering all different manufacturers, types of MV switchgear, and associated equipment. It is from this large body of results that EA Technology was able to determine appropriate threshold levels for a simple to use instrument called the UltraTEV.

UltraTEV

The UltraTEV detects the presence of both surface and TEV discharges and indicates, using different coloured LEDs, if further investigation is required. This instrument is designed for use by staff with minimal training and is used extensively for a first pass indicator for the presence of partial discharge.

The UltraTEV Instrument

This low cost instrument, the first to combine both electromagnetic and ultrasonic testing capabilities, has changed the way in which a number of power utility companies throughout the world approach the condition assessment and management of switchgear assets and at the same time enhances the safety of operators working on the system.

THE CLP EXPERIENCE

CLP Power Hong Kong (CLP) is a vertically integrated power company with total installed generation capacity of over 8,000 MW and total transmission and distribution transformer capacity of over 54 thousand MVA. Its annual local energy consumption is in excess of 30 thousand GWh.

Installed at more than 12,000 customer substations, there are over 43,000 11kV switchgear panels (70% VCB with air-insulated busbars) connecting more than 16,000 distribution transformers, distributing electricity to over 2.2 million customers. Condition monitoring of such a large asset group becomes an important task in response to the increasing expectation of stakeholders on higher equipment availability and reliability, greater safety, longer life span and lower O&M costs.

Strategy for Equipment Condition Monitoring

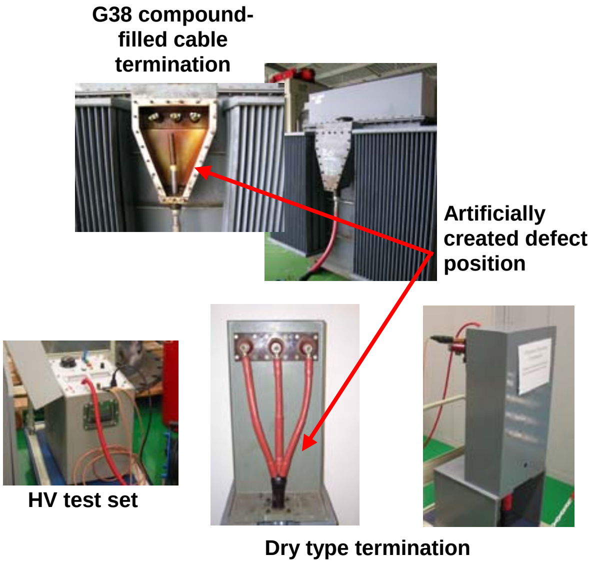
PD detection is one of the important condition monitoring tasks to ensure the operational integrity of substation MV equipment. Remedial actions could be taken at an early stage when PD signals are detected before developing into catastrophic failure. Before the introduction of the Transient Earth Voltage (TEV) technology, like many other power companies, CLP adopted traditional ultrasonic technology to detect the PD signal of MV equipment at 11kV level. Due to its high sensitivity characteristic, the ultrasonic detection device is capable of picking up small PD signals at its early stage of development. However, in CLP's operational experience, there are some limitations on using only ultrasonic detection, which include:

- Ultrasonic signal is easily influenced by high frequency noises from the environment;
- PD detection holes or openings must be available on the equipment to be tested;
- Ultrasonic detection is relatively directional and so the sensor must be pointed directly to the source for effective detection;
- Ultrasonic testing will only detect discharge activity occurring on the surface of insulation;
- Readings on the ultrasonic detector cannot be easily interpreted by site staff or tradesman.

With the introduction of TEV detection technology, PD signals could easily be detected with the detector placed on a convenient position of the metallic cover of the equipment. The "UltraTEV" detector possesses the advantages of both the ultrasonic and TEV detection and its green/red/yellow light indicator also provides simple and clear indication to site staff about the detection result.

Before full adoption of the UltraTEV, CLP conducted laboratory experiments and field trials to verify its effectiveness.

Tests on both G38 compound-filled and dry type cable boxes with the UltraTEV were concluded with positive results. Feedback from field trials were also satisfactory.



Testing Arrangement

Operational Experience

In order to enhance operational safety, the UltraTEV detector is being used for PD detection on switchgear panels and cable boxes when operational staff enter a substation. In addition, regular condition monitoring will be conducted with the UltraTEV as a first scan and further detailed investigation will be conducted whenever an abnormal condition is found.

In general, field staff members' feedback showed that the UltraTEV is an easy-to-use tool for PD detection. It increased their confidence on the integrity of equipment when working inside a substation.

Since the actual field use of the UltraTEV detector in March 2006, abnormal PD activities have been successfully identified at an 11kV primary substation installed with AIS panels aged over 30 years. Subsequent detailed investigation identified a PD source inside the CT chamber. The panel was then isolated for follow up remedial improvement work.

Further Application

After gaining the experience on 11kV switchboards, CLP is exploring the usage of UltraTEV detection on other equipment including cable uptake installed on overhead line poles and cable body etc. In order to achieve continuous monitoring on critical equipment, use of on-line TEV detection system to detect PD activities at 11kV primary substations will also be explored.

THE ESB EXPERIENCE

ESB Networks is the owner and operator of the electricity network in the Republic of Ireland. As the licensed Distribution System Operator it is responsible for maintaining all the sub-transmission, medium and low voltage electricity network infrastructure in the country. This includes all overhead electricity lines, poles, substations, and underground cables that are used to bring power to Ireland's 1.7 million Domestic, Commercial and Industrial customers. ESB Networks also owns and maintains the higher voltage Transmission system.

Operational Problem

In 2002 two unrelated but serious incidents occurred that brought safe working practices to the top of the ESB agenda. One of these incidents involved a cast resin 10kV ring main unit which catastrophically failed 30 minutes after a manual switching operation. Subsequent investigation indicated insulation failure. For this reason all 250 substations equipped with the same type of switchgear were placed under operational restriction requiring switching operations only to be carried out 'off-line'. Because of the customer supply disruption caused, ESB asked EA Technology to assist in developing an operational protocol to help remove the restriction.

As the incident was caused by insulation failure it is reasonable to consider that partial discharge within the insulation was occurring prior to failure and that with the proper detection equipment this could have been detected.

The Solution

EA Technology and ESB worked together developing a protocol that used the recently introduced UltraTEV instrument. Because the UltraTEV detects both internal and surface discharge activity and indicates with simple red and green lights the presence or absence of discharge, the instrument was ideal as a 'safe to operate'/ 'not safe to operate' indicator. The protocol required the threshold settings within the UltraTEV to accurately and demonstrably indicate when significant partial discharge was present or absent. It was proposed that a trial be undertaken to test the protocol. This would involve testing a selection of the suspect ring main units with the UltraTEV. Further checks would also be carried out using the MiniTEV instrument for internal discharges, and a sensitive ultrasonic detection instrument to check for surface discharge. The ring main unit would then be switched 'out' ('alive, or 'dead' as indicated by the instruments), racked out, and a detailed inspection undertaken for any signs of partial discharge.

If the UltraTEV instrument indicated the absence of discharge, and this was confirmed by a detailed visual inspection, and this was true for all the switches of the ring main unit, then the restriction could be lifted for that substation.

This protocol was agreed by the Safety Representatives of ESB and in November 2003, and later that month tested on a selection of substations in Cork.

Results of the Protocol Testing

Ten substations equipped with the ring main units in the City of Cork were subject to a full non-intrusive partial discharge survey followed by a comprehensive visual examination.

The results of the testing and inspections indicated that the protocol was viable and provided a basis for practical management of the 250 ring main units of this type on the network. It also determined that the threshold levels of the UltraTEV were correct, sensitive enough to detect dangerous levels of discharge but not over sensitive to result in unwarranted restriction to normal operation of the network.

Other Switches on the ESB Network

ESB also have over 5000 10kV fused cast resin to air switchgear on their network. This switchgear also suffered numerous disruptive failures and the opportunity arose during the Cork trials to survey 2 of these units. Both switchgear units exhibited red lights on the UltraTEV indicating the need for maintenance or replacement.

This result led ESB to consider incorporating the UltraTEV into routine working practices prior to operation of switchgear. This, it was argued, would significantly improve the safety and reliability of operational activities as well as target their resources to best effect.

The ESB network also includes some modern SF6 switchgear, oil filled ring main units, and open cubicle substations.

Adoption of the Protocol Across the ESB Network

The protocol developed and tested in Cork was adopted nationally and all operational switching and inspection staff were issued with an UltraTEV instrument for use prior to all switching operations. Over 400 instruments were issued between May 2004 and March 2005.

Operational Experience After 12 Months

During 2006 over 5,000 inspections were carried out using the UltraTEV. These results are split into 2 basic areas, Cast Resin, which account for 70% of the tests, and Others, which include terminations on SF6 switchgear, Oil Filled RMU terminations, and Open Cubicle equipment.

Cast Resin Switchgear: 93% Green 7% Red

This result was better than expected and is likely to improve as the causes of the red lights are removed from the system.

Others: 95% Green 5% Red

ESB are pleased with the overall results in that they have not been swamped by defective equipment as had been expected, and that operational staff are not being unknowingly exposed to dangerous situations.

CONCLUSIONS

Prior to adopting the widespread use of instruments for partial discharge surveying of MV plant, companies have an understandable concern that an unwarranted level of equipment would be highlighted as needing further investigation.

The laboratory and field trials carried out by CLP and ESB demonstrated the applicability of the UltraTEV instrument and validated the chosen threshold levels. These threshold levels were carefully selected by EA Technology based on many thousands of survey results from all types of switchgear operating between 3.3 and 33kV. Both companies have now further corroborated the threshold levels through comprehensive field experience.

The operational staff of CLP and ESB have embraced the newly available partial discharge technology and it has become 'business as normal' in both companies. Adoption of the simple to use UltraTEV as a first line tool for both condition assessment and enhancement of operational safety has been a success for both companies.

The strongest common message coming from the companies is that the use of the instrument has **increased operational staff confidence on the integrity of equipment when working inside a substation**.

Both companies have also found a clear commercial benefit in the widespread use of the UltraTEV through the reliable condition assessment of switchgear and the accurate targeting of maintenance and replacement resources towards plant in need of attention.

For ESB in particular further major benefits have been in the management of a significant operational problem, identification of switches that were not to be switched live, increased safety for operational staff and the removal of onerous operational restrictions.

ACKNOWLEDGMENTS

The authors would like to express their thanks to the respective companies for allowing them to publish the paper and acknowledge colleagues for their help in gathering the requisite field information.

INFRARED THERMOGRAPHIC WINDOWS

The H.VIR Infrared Window is a patented inspection window developed by Sorem for Infrared Thermographic inspections. These windows are made from special optical fluoride glass which is transparent to infrared rays as well as the visual wavelength. They have 95% transmissivity for the infrared wavelength and provide a large angle of view with minimum signal attenuation.

The windows can be permanently fitted onto switchboard and transformer panels , thus allowing permanent inspection of the internal critical components like connections, switches, etc. to be conducted with safety at any time.

Without an H.VIR window, the high voltage installations are normally inaccessible due to safety reasons. The H.VIR window allows monitoring to be carried out without the need to disrupt power supply.

The H.VIR window comes with a protective cover and O ring to prevent accidental impact damage and provides for water tightness.

This window has been tested & approved by the following Bodies:

(i) Underwriters Laboratories Inc.
(ii) Bureau Veritas
(iii) NEMKO - Norwegian Board of Testing and Approval of Electrical Equipment
(iv) Israel Standards Institution
(v) Elektrisitetstilsynet - Norwegian Electricity Inspectorate
(vi) ABB Finland - Internal arc fault of 20kA , 1 sec.(Fastened onto front of HV panel)

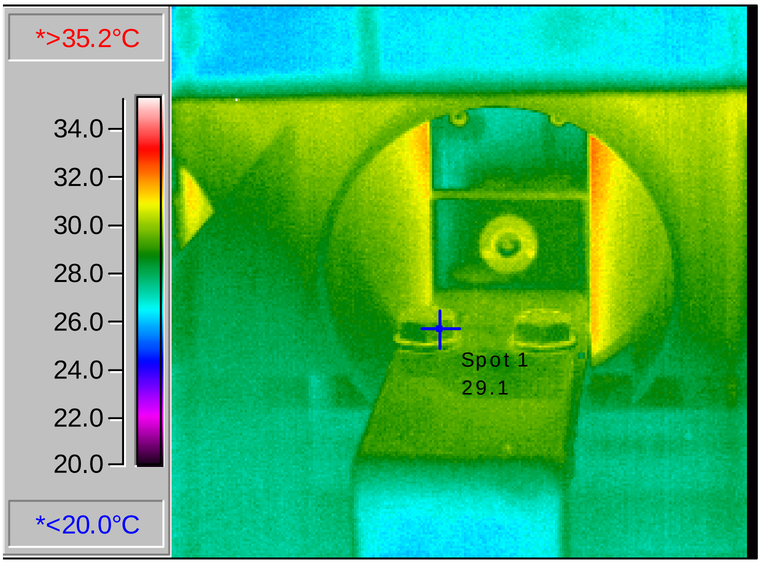
Windows have been successfully installed in oil rigs, which require very stringent inspection programs from Lloyds, etc.

Common Sizes	50mm, 72mm,95mm diameter.		
Wavelengths	Shortwave	-	0.3 to 5.5um
	Longwave	-	0.3 to 11um

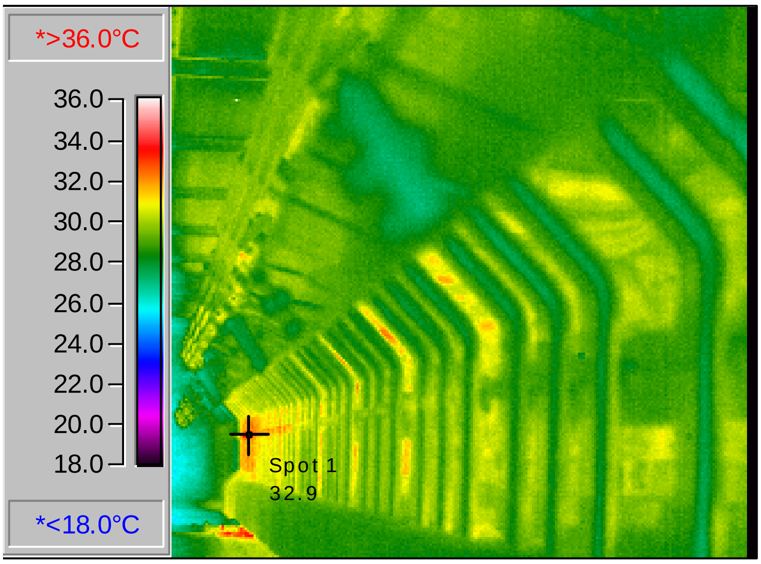
Applications

Electrical	-	High Voltage switchboards Transformer cable boxes Busways & junction boxes Motor armatures
Mechanical	-	Manifolds Scale deposit inspections Vessels & storage tanks

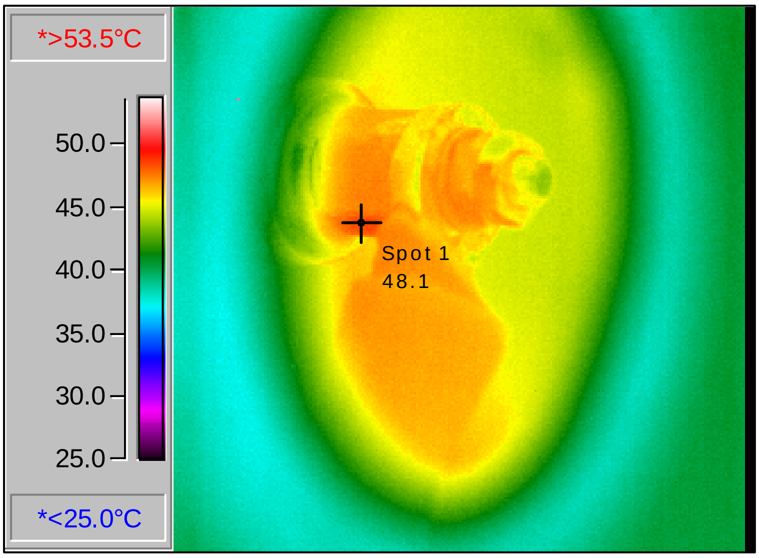
EXAMPLES OF HVIR INSTALLATIONS



Busbar Terminations of a Switchgear as seen thru the HVIR Window



Busbar Chamber of a Switchgear as seen thru HVIR Window installed at Busbar chamber



Transformer Terminations as seen thru HVIR Window

Ref: Ntserver/IRWindow/window examples

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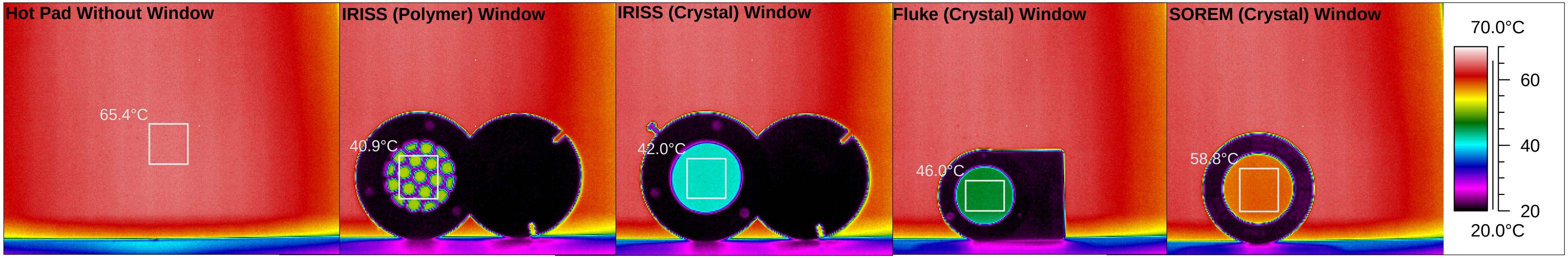

<u>Comparison of Temperatures between various type of Infrared Windows</u>

A Hot Pad is heated up to 65.4°C. Windows or various brands is put in between the hot Pad and the Infrared Thermal Camera. The settings on the Infrared Thermal camera remains constant throughout the test.

The temperatures through each type of windows is as follows:

IRISS Polymer Window = 40.9°C = 37% error from actual Hot Pad temperature
IRISS Crystal Window = 42.0°C = 36% error from actual Hot Pad temperature
Fluke Crystal Window = 46.0°C = 30% error from actual Hot Pad temperature
SOREM Crystal Window = 58.8°C= 10% error from actual Hot Pad temperature

As can be seen, temperatures through SOREM's Windows gives the closest reading to the actual temperature of the Hot Pad.

The errors on other brands range from 30 - 37% of the actual temperatures of objects seen through these Infrared Windows. As such, an electrical components seen through a IRISS Polymer Window could show a temperature of 63°C when the actual temperature is 100°C!!

<u>References of Past installations</u>

ABB Manufacturing
BP Chemicals
Cabot Malaysia
KLCC Convention Centre
Eastman Chemicals Malaysia
Cray Valley Malaysia
Kaneka Malaysia
Kapar Energy Ventures
Nestle Foods Factories
Seagate
Stats ChipPac
Western Digital
Titan Petchem
Intel
TNB Janamanjung

Philip Morris
ON Semiconductors
Fairchild Semiconductors
Capitaland (Gurney Plaza)
Dell Asia Pacific
Cabot Malaysia
Akzo Nobel Malaysia
Jabil Circuit
Renasas
Inokom
ABB Thailand
Secomex Malaysia
Cargill Malaysia
Tencate Geosynthesis
YTL Power Paiton, Indonesia

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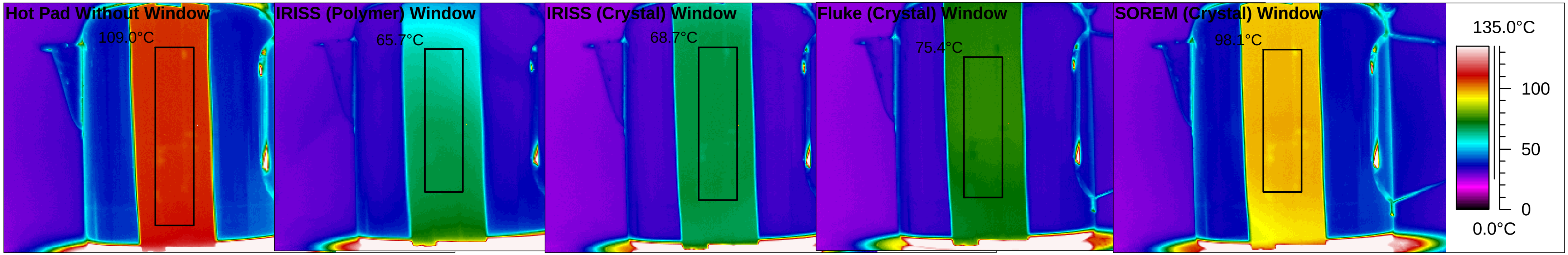

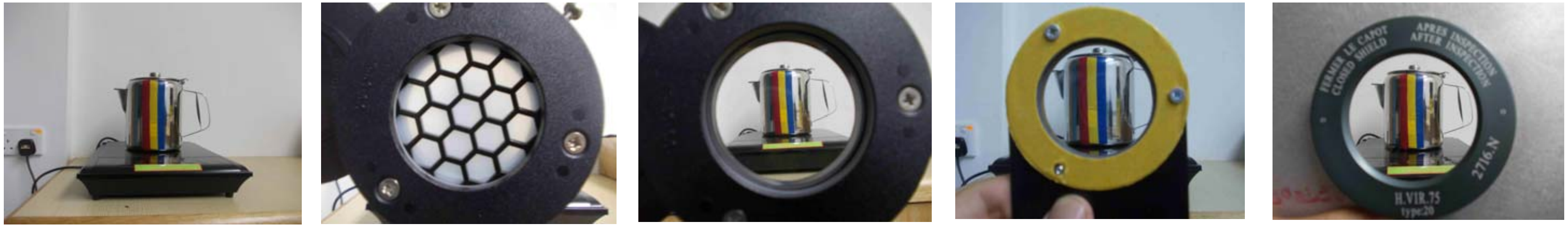

See-ing through the Infrared Windows

As can be seen above, Polymer type windows DO allow Infrared Cameras to 'see-through' with a slight thermal variation, BUT visually, it is opaque. Hence any evidence of Partial Discharge faults on High Voltage Switchgears and Transformers which do not produce any heat, will not be detected as polymer windows does not allow one to see through visually. This is seen as a disadvantage to the electrical engineer and his Condition Monitoring team.

Comparison of Technical Specification of Infrared Windows

	Type	IP Rating	Crystal Insert Diameter (mm)	Thickness	Attachment
SOREM	Crystal	**67**	2.0 inch	**3mm**	**1 big nut**
Fluke	Crystal	65	**1.7 inch**	2mm	3 small screws
IRISS	Crystal	65	2.0 inch	2mm	3 screws
IRISS	Polymer	65	2.0 inch	unknown	3 screws

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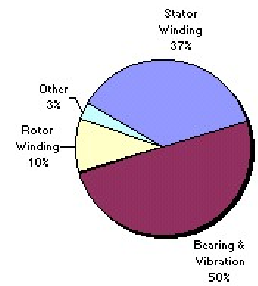
IRIS POWER ENGINEERING

APPLICATIONS & BENEFITS

PARTIAL DISCHARGE TESTING FOR MOTORS & 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 machine failures occur due to failure of the stator winding insulation. (See pie 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. Iris sensors are 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.

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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:

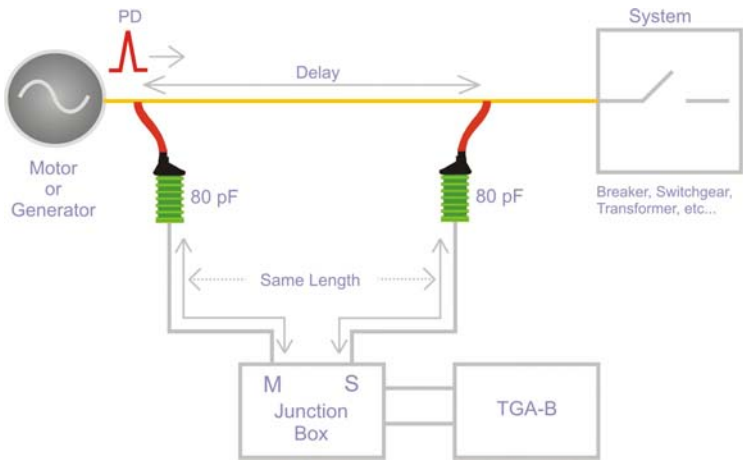
1. Purchase their own portable ***TGA-B™*** instrument for routine periodic testing;
2. Rent a portable ***TGA-B™*** instrument and have Iris do the analysis;
3. Purchase a Continuous On-Line Monitor (***BusTrac™*** or ***PDTrac™***) to operate in either stand alone mode with alarm or analog outputs, 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, 80pF capacitive Bus Couplers (shown to the left) specifically designed to work with partial discharge frequencies (50MHz-250MHz typically) need to be installed. These high voltage capacitors 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…

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 Iris' system works:

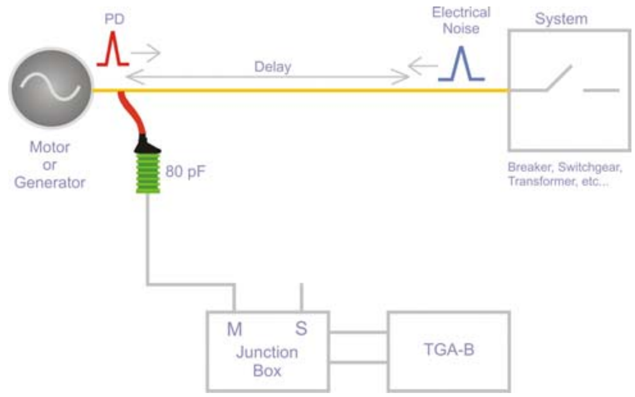
Bus Coupler Installation (Directional Noise Separation)

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.

In cases where the machine is connected to the system (breaker, switchgear, etc.) using power cable, AND there is at least 100 feet (straight run, no taps) of power cable between the machine terminals and connected system, one bus coupler per phase can be used. This type of installation is very typical for motors, but on occasion is applied on generators. The reason for only needing one bus coupler is that any High Frequency (HF) electrical noise signals traveling from the system will be significantly attenuated by the >100' of power cable. Since Iris' bus couplers operate at HF (>40MHz), noise signals don't pass through the bus couplers. If they were to operate at lower frequencies, more electrical noise would enter the system and make it difficult to separate the PD from electrical noise. Thus, PD testing at high frequencies provides a high Signal-To-Noise Ratio (SNR).



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 ***PDTrac™*** and ***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 ***PDTrac™*** is used with a 3-coupler installation and the ***BusTrac™*** is used with a 6c-oupler installation. The Trac instruments make life that much easier knowing 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 then 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.