Partial Discharge Monitoring Technology

Retain for future use.

Introduction

Partial Discharge (PD) is a precursor to complete insulation breakdown in electrical equipment. PD is a proven science and phenomena, with research dating back to the early 1950s.

As insulation systems in electrical equipment age or if the equipment is poorly maintained, the potential for failure and downtime increases. Continuously monitoring the entire electrical system for partial discharge provides valuable information relative to equipment insulation condition, equipment repairs, preventive maintenance, budget allocations and maintenance planning/scheduling.

The analysis and reports may be used as a predictive technology to show that proactive measures are being taken to mitigate catastrophic failures which, in turn, may reduce insurance premiums.

What is Partial Discharge?

In technical terms, Partial Discharge (PD) is an electrical discharge that occurs in an insulation system that does not completely bridge the electrodes. A discharge would be analogous to lightning that occurs in our atmosphere. Particles that move rapidly within clouds cause the electrons to become excited where a charge begins to build to the point that a discharge of energy will occur in the form of lightning.

When expressed in non-technical terminology, the words “electrical discharge” means an ‘arc’ or ‘spark’. The electrodes referred to above would be phase voltage (+) to ground (-) or phase (+) to phase (+). Partial discharge is an arc or spark that does not go between phase and ground or between adjacent phases. The spark gets dissipated through air.

There are other phenomena that are closely related or could be considered as forms of partial discharge:

Corona Discharge

An electrical discharge characterized by a corona, occurring when one of two conducting surfaces (such as electrodes) of differing voltages has a pointed shape, resulting in a highly concentrated electric field at its tip that ionizes the air (or other gas) around it. Corona discharge can result in power loss in the transmission of electric power.

Surface Tracking or Electrical Treeing

Electrical treeing first occurs and propagates when a dry dielectric material is subjected to high and divergent electrical field stress over a long period of time. Electrical treeing is observed to originate at points where impurities, gas voids, mechanical defects, or conducting projections cause excessive electrical field stress within small regions of the dielectric. This can ionize gases within voids inside the bulk dielectric, creating small electrical discharges between the walls of the void. An impurity or defect may even result in the partial breakdown of the solid dielectric itself. Ultraviolet light and ozone from these partial discharges (PD) then react with the nearby dielectric, decomposing and further degrading its insulating capability. Gases are often liberated as the dielectric degrades, creating new voids and cracks. These defects further weaken the dielectric strength of the material, enhance the electrical stress, and accelerate the PD process.
Partial Discharge (PD) Monitoring Technology
Schneider Electric Services

How Does PD Affect Electrical Equipment?

Once started, PD may result in equipment failure. PD can occur in new equipment or develop over time. Electrical equipment and components contained within switchgear can easily be affected by a voltage surge that can increase PD activity.

From a timing perspective of the breakdown of insulation, many factors must be considered including voltage level; size, shape and location of the defect; ambient conditions such as temperature and humidity; and mechanical factors such as vibration, cooling, equipment construction; age of the insulation, etc.

A partial discharge can take years to develop into a complete breakdown or take only a matter of months. The challenge is to detect the level of PD. This requires specialized sensing and monitoring equipment.

What Happens When Equipment Fails?

An electrical equipment arc fault due to PD is a result of complete insulation breakdown. A path has been established either phase to phase or phase to ground as a “full discharge” of energy. Both methods can be potentially catastrophic and cause significant damage to equipment and often interruption to production.

The path of electricity within electrical equipment can be controlled by design and construction. PD Monitoring Technology can monitor and predict a system malfunction, ie, electric current seeking a path to ground.

Will PD Monitoring Replace Preventive Maintenance?

There is a need for both PD monitoring and a preventive maintenance program. Electrical testing has been an industry standard for performance evaluation. Preventive maintenance work scopes incorporate both electrical testing and inspections for mechanical functionality of a device. The mechanical inspection checks for proper lubrication, spring tension, and contact wear of the device. Adjustments are then made to the mechanism to meet the OEM specifications. As part of maintenance, cleaning and housekeeping of switchgear should also be performed.

When used in conjunction with a preventive maintenance program, PD Monitoring is a predictive maintenance tool that can greatly minimize the potential for equipment phase faults and identify areas that need special attention. PD Monitoring should be considered as advanced technology that can predict an insulation breakdown before the PD escalates to a phase to phase or phase to ground fault.

An example application of PD monitoring is in metal clad switchgear where the line-side bus section is rarely, if ever, inspected or cleaned due to the design of the equipment. Similar to how infrared thermography is utilized to identify “hot spots” in between maintenance outages, PD monitoring would be able to identify a problem with insulation integrity in the switchgear. However, with continuous PD monitoring, warnings of a failure are more timely than a once a year scan via hand-held devices. Once a problem is identified, services are performed during the next outage opportunity to rectify the situation.
What Type of Equipment Can be Monitored?

Over the last half century, most PD monitoring was in large, MV rotating machines* (motors and generators). In the late 1980s, new technology was introduced that pioneered the expansion of PD measurements in field conditions to switchgear, bus duct, transformers and cable systems and accessories. Schneider Electric Services can provide the sensors, monitoring equipment, installation, analysis and reporting of partial discharge activity on this type of equipment rated 4,160 volts and above.

*Many customers already use Resistance Temperature Detectors (RTDs) on rotating equipment and the question is often asked, ‘Are additional sensors needed to detect partial discharge?’

The RTDs that are embedded in the windings, often installed by the OEM motor manufacturer, can be utilized as PD sensors. As a PD pulse travels through a winding, the pulse will attenuate in magnitude and frequency quite quickly. Partial Discharge activity can be detected via the RTDs as these “sensors” will now provide a zone of coverage within the winding and thus enables analysis toward the type, location and size of a potential defect.

As an alternative to RTDs, Coupling capacitors and/or Radio Frequency Current Transformers (RFCTs) could be installed at the line terminals/cable connection. In this case, there would be a limited zone of coverage for PD detection. By utilizing the existing RTDs on a non-intrusive basis (wired in series), enhanced detection of PD is utilized in the analysis to determine the PD signature. This method of detection provides a cost savings (due to existing sensors) while increasing the amount of useful data for analytical purposes.

What Are Applicable Voltage Levels?

The higher the voltage level the more destructive the discharge energy that results from a complete insulation breakdown. Theoretically, PD can occur as low as 300-volt equipment under ideal conditions. Practical applications of the technology would be to install sensors and monitor PD in MV equipment rated 4,160 volts and above. Schneider Electric Services can continuously monitor PD on a variety of electrical equipment types with a variety of applications from 4,160-volt equipment on up to 1.1 million volts.

Can Cables Be Tested?

Yes. PD activity typically occurs where there is a connection point in the cable: taped or booting insulation over a connection; splice joints; stress cone installations, etc. Measurements of PD on cables will provide more information on the condition of the terminations and splices when compared to an off-line insulation resistance test.

PD activity can be detected in cables by installing a RFCT around the ground shield of the cable termination. As a PD pulse tracks down the cable, the pulse will attenuate in magnitude and frequency. The distance where PD detection can be effectively monitored is highly dependent upon the type of cable insulation that was installed on the conductor as well as the type and condition of the shield.

Types of cables that can be monitored for PD follow, along with the maximum monitoring distance for each type: PILC (1,000 ft); HMWPE (1,000 ft); XLPE (1,000 ft); EPR (300 ft).
How Does the PD Monitor Communicate?

The Switchgear and Cable Monitor (SCM) is mounted either within the electrical equipment or in its own enclosure within the respective location. Multiple sets of couplers/sensors are wired into the Monitor (up to 90 channels for input). Included in each enclosure provided by Schneider Electric Services are sensors for monitoring ambient temperature and humidity, both of which are correlated to PD activity.

A basic software package is included as part of the PD Monitoring system. The software gathers the data and provides graphics to represent the various monitored parameters, which allows for establishing alarm parameters. The installed system will be configured with a wired set of contacts to a visible and/or audio alarm device(s). Three relay contacts are available, two for separate alarm stages and one for system health. When an alarm is initiated, the software package can be used to collect data for sending to Schneider Electric Services for analysis (or Schneider Electric Services field representatives can be scheduled to come on-site and download the data).

A ModBus RTU or TCP ModBus connection is provided by the customer/end user if the system is to be connected into their plant network.

Switchgear Layout Examples

Two High Example

Single High Example

All Systems can be networked together via ModBus RTU 485 or TCP ModBus

Each Monitor has a Yellow, Red and Device Alarm Relay Contacts
Switchgear Layout Examples

13.8kV – 4.16 kV

13.8kV – 480 v

13.8kV – 480 v

Left: If Power Centers are close to each other (Max Cable length - 150 feet)
One Monitor can be used

Below: Monitors Incoming Bus Duct, Switchgear and RFCTs on cable termination shield ground

Switchgear Installation Examples

Coupling Capacitor Installation
With all investments, there should be a payback or return on investment. Based on data provided in IEEE Standard 493-2997 (also known as the Gold Book), the following general algorithms have been developed to determine a simple payback based on various types of equipment typically found in facilities. The only parameter you need to provide is the cost per hour to your company for a particular piece of equipment to be out of service.

<table>
<thead>
<tr>
<th>Equipment Description</th>
<th>Investment</th>
<th>Payback Algorithm (Yrs)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Power Transformers - Primary &amp; Secondary</td>
<td>$25,000</td>
<td>$25,000 / 11.75 x Outage Cost per Hour</td>
<td>SCM (Wall Mounted) Requires 90-265 VAC</td>
</tr>
<tr>
<td>Three (3) Unit Substations Close Together Consisting of Switch &amp; Transformer (each)</td>
<td>$8,500 / unit sub</td>
<td>$8,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous Monitoring with SCM. One SCM cam can monitor up to 5 units.</td>
</tr>
<tr>
<td>Ten (10) Cubicles of MV Switchgear</td>
<td>$28,500</td>
<td>$28,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous Monitoring with SCM.</td>
</tr>
<tr>
<td>Bus Duct - 30 Feet</td>
<td>$17,000</td>
<td>$17,000 / 11.75 x Outage Cost per Hour</td>
<td>Continuous monitoring with RMM.</td>
</tr>
<tr>
<td>Large MV Induction Motor</td>
<td>$18,500</td>
<td>$18,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous monitoring with RMM.</td>
</tr>
<tr>
<td>Large MV Synchronous Motor</td>
<td>$18,500</td>
<td>$18,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous monitoring with RMM.</td>
</tr>
<tr>
<td>Steam Turbine Generator</td>
<td>$23,500</td>
<td>$23,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous monitoring with RMM.</td>
</tr>
<tr>
<td>Gas Turbine Generator</td>
<td>$21,500</td>
<td>$21,500 / 11.75 x Outage Cost per Hour</td>
<td>Continuous monitoring with RMM.</td>
</tr>
</tbody>
</table>

* Typical investment in hardware, installation costs and 3 years of remote monitoring and diagnostic service.
Contact Schneider Electric Services to request a quote for Partial Discharge Monitoring. Depending upon the equipment to be monitored, the following information will be needed.

**MetalClad Switchgear or Unit Substation Installation**
- Sketch of switchgear line-up or plan view of line-up identifying total number of vertical sections
- Quantity of incoming main circuit breaker sections (typically, 2 utility feeds)
- Quantity of two high breaker construction and single breaker sections
- Indicate whether connections are taped or booted
- Monitor switchgear (couplers only) or switchgear and feeder cables* (couplers w/ RFCTs)
  * Identifying Cable Type

**Large Power Transformers**
- MVA Rating
- Primary & Secondary Voltages
- Mounting Location of Monitoring Unit
- Bussing Type
- Existing Bushing Test Connection (Y/N)

**MV Bus Duct or IsoPhase Bus Duct**
- Voltage
- Length of Duct
- Photos
  * Depending on design, only one set of sensors may be required.

**MV Rotating Equipment**
- Information related to existing RTDs including type, quantity, and location
- Type of connection inside the connection box
- Type of cables feeding the motor (if RFCTs are to be installed for cable monitoring)

**Scope of Work**
Schneider Electric Services will provide labor, materials and equipment to install the components and perform system start-up and commissioning. The initial data for analysis will be downloaded and based upon the initial data sample; Schneider Electric Services will generate a report of findings and recommended action(s). The report will include a recommended schedule of visits to download stored data from the monitoring units for analysis. In addition, Schneider Electric Services is available to respond to alarm conditions. The data can either be retrieved on-site or sent by the customer via CD for analysis.

**Recommendations**
1. Use all available resources to make informed decisions.
2. Recognize the potential to affect production (along with a major financial expenditure) should the data, analysis and report indicate an imminent insulation failure.