Preventing Rotating Machine Failure with On-line PD Monitoring

On-line partial discharge (PD) monitoring is an essential diagnostic tool for condition-based maintenance to ensure reliable operation and extended service life of motors and generators.

Executive Summary

With the increasing age of motors and generators, on-line partial discharge (PD) monitoring has become an essential asset management tool. Compared with routine off-line diagnostic tests, on-line PD monitoring provides asset managers with continuous insulation condition status while rotating machines are in operation. It indicates whenever operational stress and aging are damaging electrical insulation and putting your machines at risk of failure.

In this white paper, you will learn how on-line PD monitoring has significant benefits for your organization. Not only can you optimize maintenance schedules based on actual insulation condition, the reliable service life of your aging machines can be maximized to help you get the most out of your investment.

Introduction

Rotating machines are important components in power generation and industrial applications. As a result, machine reliability and availability are in high demand. Premature failure may lead to significant economical losses, due to unexpected outages and possible damage to the asset itself. The refurbishment or replacement of a machine due to a failure can last for months and result in high costs.

Motors and generators are routinely inspected and maintenance is conducted to avoid premature failures and to prolong their service life. To plan maintenance effectively, it is essential to have accurate condition information about when components need repairing or replacing.

Condition-based knowledge is key

The insulation of motors and generators has to withstand thermal, electrical, ambient and mechanical stresses during service. To detect insulation degradation at an early stage and to prevent severe failures in service, detailed information on the actual insulation condition is essential.

This information is used to help organizations move from a time-based to a condition-based maintenance. Diagnostic testing and monitoring is required to assess the condition of rotating machines, ensure their reliability, reduce maintenance costs, and to avoid unexpected outages.

Generators are important components in the power supply. Knowing their insulation condition at all times helps prevent failures.

Insulation degradation in rotating machines

Stator winding insulation faults are a common cause of failure in rotating machines. Deterioration of the stator insulation can cause shorts within the windings, between the phases or between phase and ground. Such serious errors can eventually result in a complete failure of the machine.

PD often identifies insulation defects

The rate of deterioration in stator winding insulation can be most reliably tracked by measuring partial discharge (PD) activity.

PD occurs in the stator winding insulation system of motors and generators, where local electric field stress exceeds the local electrical strength. PD activity can cause faults that lead to failure and serious consequent damage in rotating machines. Therefore it is mandatory to identify the presence of PD activities and to keep an eye on PD tendencies.

PD is a widely-accepted measuring parameter for insulation diagnosis. The measurement of PD is employed as a sensitive means of assessing the quality of new insulation as well as detecting PD activity in older electrical winding insulation arising from operational stresses in service.

Compared with other dielectric tests (i.e. the measurement of dissipation factor or insulation resistance), the differentiating character of PD measurements allows weak points (defects) to be identified in the insulation system.

Detecting harmful PD

The insulation materials typically used for rotating machines are resistant to a certain level of PD. Therefore, PD pulses can be expected in all phases under normal operating conditions. However, an increase of PD activity over time can indicate insulation degradation caused by operational stress and aging processes.

Therefore the key to successful PD measurement in stator windings is the separation of parallel active PD sources and the distinction between harmful PD, normal PD occurrences and external noise inevitably present in industrial surroundings. To achieve this, synchronous multi-channel PD measurement as well as advanced noise suppression and source separation techniques are applied.

Insulation breakdown caused by PD phenomena in rotating machines tends to extend over several years. However, sensitive PD measurements are able to detect developing insulation defects, even when the gradient of variation is very small. On the basis of periodic or continuous PD measurements, timely condition-based maintenance actions can be taken to minimize the risk of machine outage.

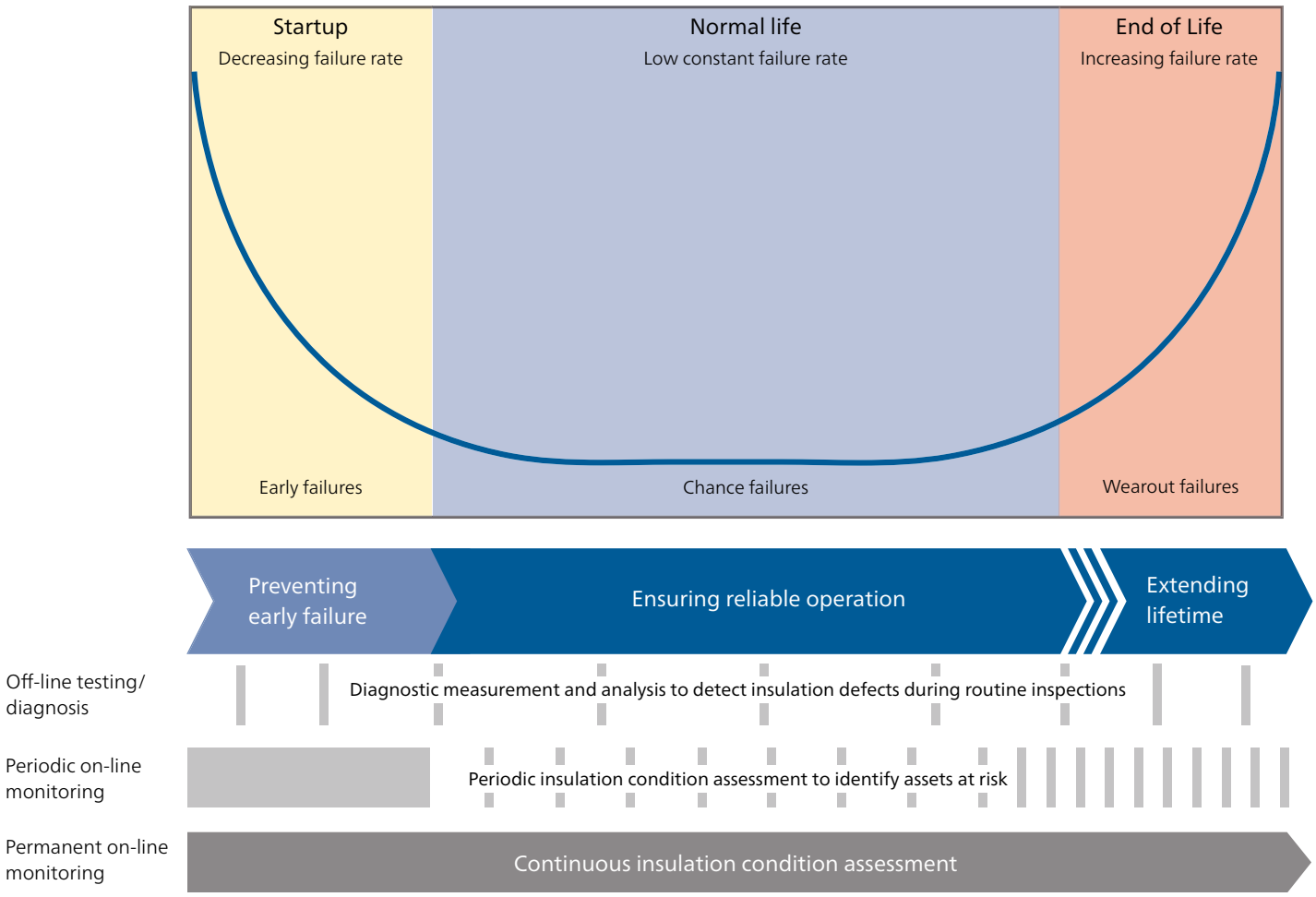
Off-line vs. on-line PD measurement

Off-line diagnostic PD measurements have been carried out for decades to detect insulation defects that could lead to unscheduled repairs and overhaul of motors and generators.

These measurements are only possible during planned outages. Significant cost pressure to keep machines running often results in reducing the frequency of such inspections and accepting greater operating risk.

In contrast to off-line tests, on-line PD monitoring continuously assesses the condition of stator winding insulation while the machine is running under real service conditions (load, operational stress).

As a result, measurement evaluations apply to actual machine operation. In addition, "blind" periods between routine off-line tests can be eliminated, during which



Failure rate during asset life and implementation of on-line PD monitoring
Periodic and permanent PD monitoring can be implemented across the complete life cycle of motors and generators to increase reliability, prevent premature failures and extend service life.

on-line stress conditions can result in or contribute to machine failure.

The aim of rotating machine condition monitoring is to know and understand the risk position at all times to allow timely and appropriate measures to be taken or planned.

The real-time and trend data gathered by PD monitoring systems can be used for precise condition assessment. Exact knowledge of insulation condition at any time saves money, as maintenance schedules can be specifically optimized.

Continuous on-line PD monitoring can therefore be used as a basis for the transition from expensive, time-based maintenance toward a more cost-effective, condition-based maintenance.

Periodic vs. permanent on-line monitoring

There are two types of on-line PD monitoring systems to choose from – either periodic or permanent. Both types of monitoring systems offer continuous on-line assessments of PD levels and insulation condition in stator windings during time intervals specified by the operator.

Periodic PD monitoring enables operators to observe changes in PD activity over short periods of time. Such a monitoring system is typically portable and can be used on different types of electrical assets. When one asset has been monitored for a period of time, the system can be easily moved for setup at the next asset to be monitored. Using the monitoring software, asset managers can reliably assess the current insulation condition and identify which asset is most at risk of failure.

For machines with increasing PD levels, as well as those with special availability requirements or with high loads, a permanent continuous monitoring system can be installed to keep a constant eye on the insulation condition state. Insulation condition status can be viewed anytime using a web interface to a secured server.

Alarm triggering when PD levels are too high

Both types of on-line PD monitoring systems record measurement data over time and visualize trends in PD activity. An alarm is triggered only in case of service-relevant PD activity that exceeds limits pre-selected by the user. When acquired PD values are below these pre-defined limits, they are colored in green (OK) in a dashboard style display. However when measured values are near or above user-defined threshold levels, they are colored either in yellow (warning) or red (alarm).

A list of events that triggered the warning or alarm is provided in an event log. The early detection of changes in PD activity enables asset managers to decide if and when to schedule downtime and make planned maintenance.

Reducing the frequency of off-line tests

Adding a permanent on-line PD monitoring system can therefore significantly reduce the requirement for frequent or routine off-line electrical testing. This saves not only time but also the expense associated with off-line tests and taking rotating machines off-line.

Ideally on-line PD monitoring should be used from the beginning when a motor or generator is put into operation to continuously check for symptoms or evidence of an abnormal insulation condition throughout its service life. Taking the necessary machine off-line can be planned in advance and based on necessity.

Benefits of on-line PD monitoring

On-line PD monitoring is an essential tool for effective maintenance and asset management with these benefits:

- On-line PD monitoring answers questions about the present condition of the equipment and its future performance.
- Real-time and trend data gathered by on-line PD monitoring systems can be used for precise insulation condition assessment.
- On-line PD monitoring systems enable the effective comparison of historical data and the visualization of trends.
- On-line PD monitoring systems trigger an alarm when activity exceeds user-defined thresholds.
- Continuous knowledge of the insulation state saves time and money as maintenance can be scheduled only when required.
- Timely maintenance and repair can help to extend the service life of assets.

Monitoring system components

Permanent PD monitoring systems

A permanently installed on-line PD monitoring system consists of PD sensors, a data acquisition unit, a central computer (or server) with software, which processes, archives, visualizes and analyzes the measurement results over an ongoing period of time. After installation, the monitoring system requires no human interaction and can be left for several years of reliable data collection.

Coupling capacitors are by far the most commonly-used PD sensors on rotating machines. They provide high sensitivity and scan larger areas of the stator winding. The star connection can also be measured if desired.

A coupling capacitor is mounted on each phase of the machine. The multi-channel acquisition unit is then placed as close as possible to the coupling capacitors to realize the shortest possible length of the measurement cables.

The central computer (or server) receives PD data from a single or from multiple acquisition unit(s) for analysis, display, and storage. The data is transmitted from the acquisition unit(s) to the central computer (or server) via a fiber optic cable to ensure complete electrical isolation.

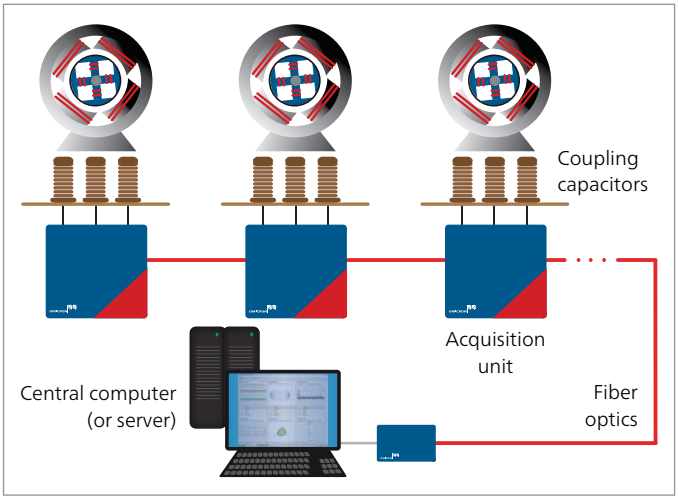
The advantage of such a central computer (or server)-based system is to have a single remote access point for several monitored machines that can be easily reached via a TCP/IP interface. Operators can view real-time and historical PD data anytime and anywhere via the web interface. This allows them to react quickly to detected problems and access the stored PD data from any remote location.

The monitoring software enables operators to set up and administer the system, including setting warning and alarm thresholds, as well as to adjust center frequency and bandwidth to ensure reliable measurements in environments with interference.

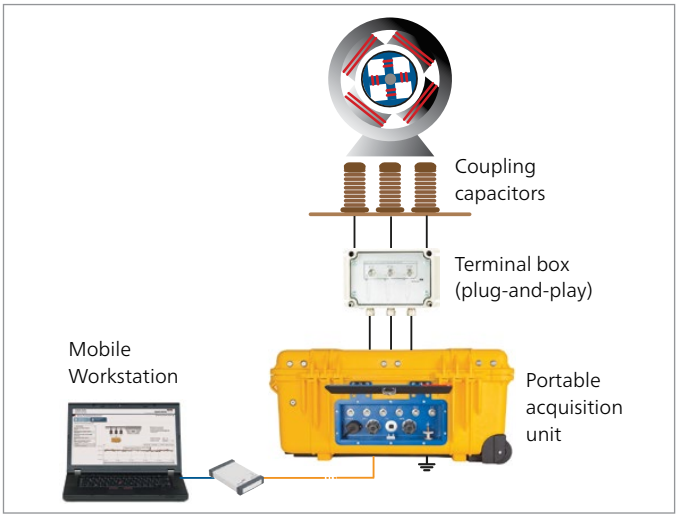
Periodic PD monitoring systems

A periodic monitoring system also consists of coupling capacitors, which can be permanently installed during a routine shutdown of the machine.

During periodic monitoring, a mobile data acquisition unit can be connected to the sensors via a terminal box for monitoring the machine while it is operating. This mobile unit is also connected via a fiber optic cable to a mobile workstation installed with the monitoring software for system setup, administration and data access. A pre-defined measurement configuration, which is stored in the software's database, allows easy setup and measurement consistency with prior PD measurements.



Permanent PD monitoring system



Periodic PD monitoring system

Economic benefits of on-line PD monitoring

It is often necessary for asset managers to economically justify this type of condition monitoring activity to their organization in terms of the benefits gained.

A PD monitoring system is an efficiency tool. Rather than contributing directly to increased revenue, it allows asset managers to detect abnormal conditions and to use the information to greatly minimize maintenance and repair costs as well as revenue loss due to outages.

A machine failure during operation causes a longer outage time and considerable cost expenditure for repair and replacement. The detection of pending faults is therefore essential in order to reduce the failure rate and thus decrease the outage time as much as possible.

In this respect, the purpose of on-line monitoring is to prevent major and catastrophic failures and to convert them into issues that can be repaired at a reduced cost during a planned outage.

Monitoring data also supports strategic decision making to ensure the safe, continued operation of rotating machines beyond the service life specified by the manufacturer. This enables asset managers to optimize their investment in the equipment.

Implementing an on-line PD monitoring system may add investment costs associated with an asset. However, considerably lower overall life cycle costs can be expected as a result of the information and the knowledge gained from using an on-line PD monitoring system.

Savings achieved

Calculating the costs of total asset ownership takes into account not only the purchase of the electrical asset itself, but also the costs associated with its installation, training and overall maintenance. Adding to these costs is the level of risk based on the probability of a premature failure actually occurring and the negative economic impact of such an event.

- Risk = Cost of consequences x Probability of a failure
- Benefit = Annual cost of risk without on-line monitoring vs. Annual cost of risk with on-line monitoring

The added cost of implementing on-line monitoring can be easily justified when one considers the costs incurred without monitoring for unexpected failure and outages.

The following table shows how the different cost factors are affected by the application of on-line PD monitoring systems:

Impact of on-line PD monitoring on asset life cycle costs

> Investment in an on-line monitoring system	(+)
> Costs for planned maintenance and repair	(–)
> Costs for unplanned maintenance and repair	(–)
> Outage costs due to maintenance	(–)
> Costs for off-line testing	(–)
> Insurance fees	(–)
> Pre-mature equipment replacement	(–)

Conclusion

Systems for periodic and permanent on-line PD monitoring identify mechanisms responsible for the deterioration of stator winding insulation in motors and generators throughout their service life.

This way, weak points in the insulation can be detected at an early stage and machine failures can be avoided through the early implementation of condition-based maintenance and repair measures. On-line insulation status information also helps to maximize machine performance, extend service life, and decrease operating costs. Most importantly, it provides asset managers with greater peace of mind.

How OMICRON can contribute to your on-line PD monitoring success

Advanced technology

The advanced technical features of our on-line monitoring systems enable the synchronous detection of partial discharge (PD) on all phases of rotating machines. They also allow the effective suppression of noise signals, as well as the separation and individual evaluation of singular PD sources within the stator winding of rotating machines. You are provided with actionable data to assess the risk of failure and to make condition-based maintenance decisions for greater efficiency and cost savings.

Customized solutions

Periodic and permanent PD monitoring systems for motors and generators:

Periodic on-line PD monitoring

OMS 605
Portable PD monitoring system for a variety of electrical assets
www.omicronenergy.com/oms605

- Three measurement channels for synchronized PD data acquisition
- Plus one measurement channel for an additional acquisition unit (i.e. at the star point)
- Wheeled case for easy transport to different monitoring locations
- Rugged system design for industrial environments (IP65)
- Compatible with a variety of PD sensors, including 80pF coupling capacitors
- Simple to use plug-and-play modules for fast system set-up
- Powerful software for PD analysis, trending and data visualization

Permanent on-line PD monitoring

MONGEMO
Permanent PD monitoring system for motors and generators
www.omicronenergy.com/mongemo

- Customized system approach to match specific monitoring requirements
- Synchronous, four-channel PD data acquisition for complete PD assessment
- Advanced noise suppression and fully automated PD cluster separation for convenient evaluation
- Recording of raw PD data at selected intervals for in-depth post analysis
- Seamless integration of third-party monitoring devices and SCADA systems

Knowledge and support

Expert assistance with system design, installation, training, data analysis and condition reporting.

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

Customers in more than 150 countries rely on the company's ability to supply leading edge technology of excellent quality. Service centers on all continents provide a broad base of knowledge and extraordinary customer support. All of this together with our strong network of sales partners is what has made our company a market leader in the electrical power industry.