WHITE PAPER

Partial Discharge Monitoring for Generators

Enhancing PD Monitoring with the PDE Map

Applying recommended International Standards for PD monitoring is now a reality.

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International Standards IEC60034-27-2 and IEEE 1434 recommend varying load and temperature during online Partial Discharges (PD) measurements in generators. This is not always possible at the time when the periodic online test is carried out.

The PDE Map provides continuous monitoring as recommended by the international standards, correlating PD with all operating conditions on-line 24/7. INTEGO GM and the PDE Map provide you with information on the most appropriate way to operate the generator to extend its life and optimize your capital expenditure.

Executive Summary

This White Paper shows how a new approach to **Partial Discharge (PD)** monitoring can match the recommendation by International Standards **IEC 60034-27-2** and **IEEE 1434** recording for correlating PD with operating conditions in generators, and how this can help Asset Managers to better operate the machine to **mitigate Partial Discharge degradation process**.

The goal has been accomplished by using a so-called PDE Map, which provides visualization of the PD Energy as a function of stator temperature and load. This tool allows asset managers to easily interpret PD activity occurring in the monitored machine and at which operating conditions PDs occur; low, medium, high load and/or temperatures respectively.

The identification of the most critical operating condition allows Operation & Maintenance (O&M) to:

- Identify the defects producing PD
- Plan inspection and corrective maintenance based on condition
- Modify the operating conditions to mitigate degradation
- Compare similar machines and perform fleet ranking to prioritize maintenance
- Mitigate failure risks

Background

PD testing on rotating machines has gained widespread acceptance, being able to provide information on:

- Points of weakness in the insulation system
- Degradation process
- Maintenance planning for immediate action and intervals between overhauls.

It has been recognized that PD alone is not sufficient to assess the time to failure or the probability of failure, since degradation mechanisms mainly depend on other factors, such as design, age and, most importantly, machine operating condition. As indicated in International Standard IEC 60034-27-2 "Online Partial Discharge measurements on the stator winding insulation of rotating electrical machines", the influence of load and temperature *on the specific PD behavior can be efficiently* used to identify *the* defects and deterioration mechanisms *producing stator winding PD.*

International Standards IEC 60034-27-2 Recommendations

Online PD test procedures are recommended in IEC 60034-27-2, PD readings should be taken under various load and temperature conditions. The diagram shown in Fig 1 of the IEC document is a bi-dimensional plot where Load is on X-axis and Temperature is on Y-axis. This plot defines 4 operating areas, at which the PD measurements should be taken.

The following procedure according to Fig.6 of the IEC document should be observed:

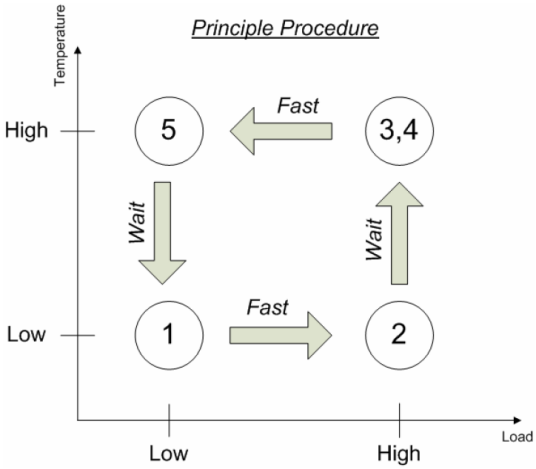


Figure 1 – Recommended test procedure with consecutive load and temperature conditions

- Step 1: Measurement at low load and thermally stable winding conditions
- Step 2: Measurement at high load directly after fast load increase
- Step 3: Measurement at high load and thermally stable winding conditions
- Step 4: Measurement at high load with significant change of reactive power and thermally stable winding conditions
- Step 5: Measurement at low load directly after fast load decrease

As said, following this procedure is time consuming and, most times it is not practical for the generating station to manipulate load changes in operation as prescribed. The result is that 90% of periodical PD tests are performed without varying the operating conditions. This makes the comparison of results over the time inconsistent and misleading.

Solution: The PDE Map

A monitoring system acquiring both PD and operating condition signals of the machine solves the above problems because the system:

- Acquires PD data at all the different operating conditions.
- Acquires signals during the machine start-up.
- Allows meaningful trending aggregating results taken at homogeneous operating conditions.
- Generates outputs easily interpreted by non-PD experts (PDE Map)
- Provides insights for managing the machine operation in order to avoid excessive stress, causing high PD.

The PDE Map is a 2D representation of the machine status, load and temperature, where every ten minutes a measurement point in correspondence with the operating condition is shown, and its colour is related to the partial discharge energy index (indicated as green points having low severity, and red points having high severity).

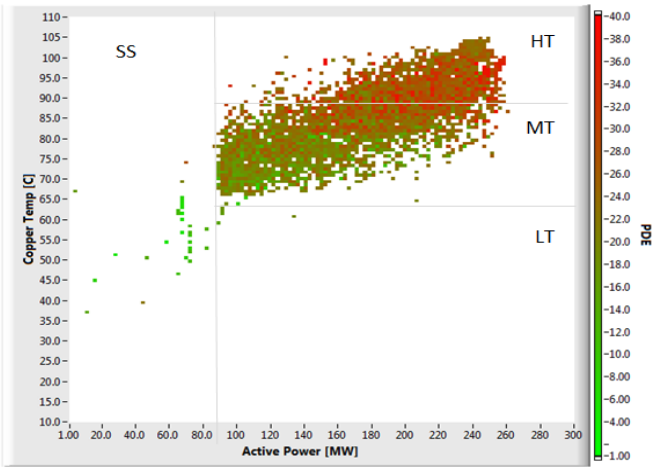


Figure 2 – PDE Map

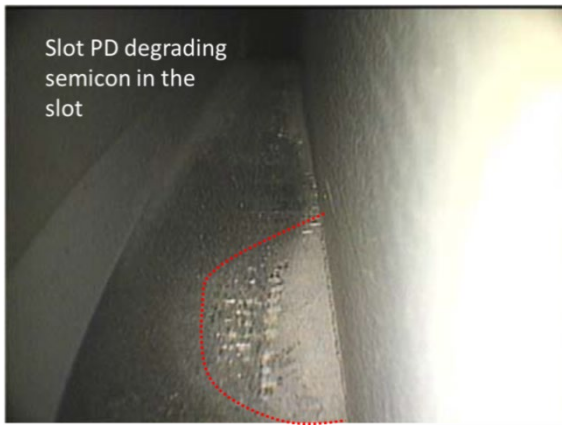
The overall distribution of the points within the obtained map represents a very intuitive graphical visualization tool which empowers the user to confidently identify:

- What are the operating conditions of the machine
- In which operating condition PD is most severe
- What the predominant degradation mechanism is

Case study 1

Looking at the PDE Map (figure 2), obtained from a 300 MVA, VPI, Turbo-Generator, concentrations of red points are mainly occurring in the High Temperature (HT) zone. It is also clear that the red dots are occurring at power levels between 140 and 300 MW, which means that the PD mechanism is not directly dependent on load. What is also clear is that the red dots start to occur above 85°C. This behavior indicates the presence of degradation at the semi-conductive coating in the slot portion of the winding due to the increase of the semi-conductive resistivity with temperature.

The diagnosis was confirmed with a borescope inspection in the slots during maintenance outage.



Poor cooling efficiency is suspected to be the likely cause of the overall temperature increase with consequent PD inception and stator slot coating degradation. The degradation phenomenon could be reduced, potentially stopped, by improving the cooling efficiency to reduce the overall temperature by 20°C.

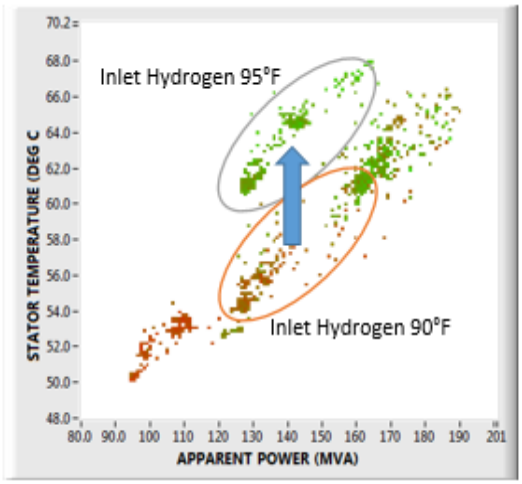
The customer was not aware of the stark differences in PD intensity from their periodic online PD testing approach used previously.

Part of the reason for their unawareness was that it was not possible to adjust load and temperature during the testing.

Thanks to the on-line continuous monitoring and the PDE Map the asset manager was able to identify what the defect producing PD was and determine what corrective actions had to be taken.

Case study 2

A PD monitoring system applied to a 200 MVA turbogenerator highlighted an inverse relation between PD activity and the machine temperature. Simply acting on the temperature regulator of the cooling hydrogen it was possible to avoid the stator core temperature to decrease below 59°C, defined as the boundary for acceptable PD level from the PDE Map. During the following weeks, the machine was operated in the same load range, but with a different regulation of the inlet hydrogen temperature, and the PDE Map has highlighted a substantial reduction of the PD activity between 120 and 160 MVA.



Conclusions

A novel online PD monitoring system for rotating machines, INTEGO GM, enables visualization of PD with respect to the operating conditions. The PDE Map automatically and continuously captures PD with operating load and temperature information as is recommended by International Standards for on-line PD measurements in generators.

For the first time, O&M Managers, Asset Managers, Field Service Engineers and Substations Operators can easily and quickly understand:

- If a machine has intensive PD.
- At which operating conditions PD becomes more severe.
- What change in the operating conditions would reduce the PD and limit degradation.
- Prioritization and maintenance on machines that deserve special attention due to PD severity and condition.

INTEGO GM and PDE Map represent the most effective tool for asset management enabling the users to:

- Utilize intuitive graphical tools describing machine insulation condition.
- Make comparisons between PD severity on sister machines
- Make meaningful comparisons of PD trends under the similar operating conditions
- Assist Asset Managers and Operators make decisions on generator operating conditions to reduce insulation degradation and extend machine life
- Mitigate failure risk
- More effectively target maintenance and re-investments
- Save operating expenditures for PD analysis and PD measurements

Samuel Clemmons, Tennessee Valley Authority: Visual maps provide immediate understanding of PD behaviour with respect to copper temperature and load. This comparison enables the machine owner to manage machine loading and cooling to extend insulation reliability.

About Camlin Energy

CAMLIN ENERGY provides innovative asset and network management products for power systems.

For almost 40 years, Camlin has been working collaboratively with our customers and partners across the Energy industry. We continue to build upon our long-standing history and heritage of innovation, providing asset monitoring solutions that help to optimize the energy networks we all rely upon.

From product design, sales, trainings, to technical support, customers are always at the heart of everything we do.

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