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WHITE PAPER

"New Generation" Partial Discharge Monitoring

Applying the recommended International Standards is now a reality

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International Standard IEC60034-27-2 recommends to vary load and temperature during on-line Partial Discharges (PD) measurements in generators. This is not always possible at the time when the periodic on-line test is carried out.

The PDE Map makes continuous what is recommended by IEC standards, correlating PD with all operating conditions on-line and continuously, 24/7.

Intego GM and PDE Map suggests you the most appropriate way to operate the generator to extend its life and addressing the 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** recording and correlating PD with operating conditions in generators, and how it can help Asset Managers to better operate the machine to **mitigate Partial Discharge degradation process**.

The goal has been accomplished by using so-called **PDE Map**, which shows the PD Energy as a function of stator temperature and load. This tool allows to easily understand if PD activities are occurring in the monitored machine and **at which operating conditions**: low, medium, high load and/or low, medium, high temperature.

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

- Identify the dominant defect
- Plan inspection and corrective maintenance basing on condition
- Modify the operating conditions to stop degradation
- Compare similar machines and perform ranking
- Mitigate failure risk

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;
- Further measures 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 factor, 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" *particularly **the influence of load and temperature** on the specific PD behaviour can be efficiently **used to identify** the typical **deterioration mechanism** resulting in stator winding PD*.

International Standards IEC 60034-27-2 Recommendations

The following recommendations are done by IEC 60034-27-2: **PD readings should be taken under various load and temperature conditions**. The diagram shown in Fig 6 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:

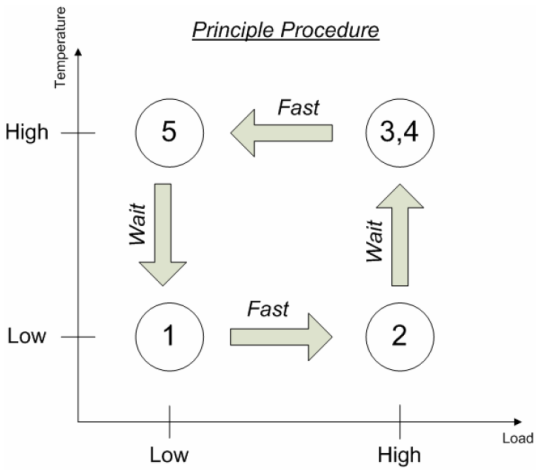


Figure 6 – Recommended test procedure with consecutive load and temperature conditions

- 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 of the time, not possible at all. 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 it:

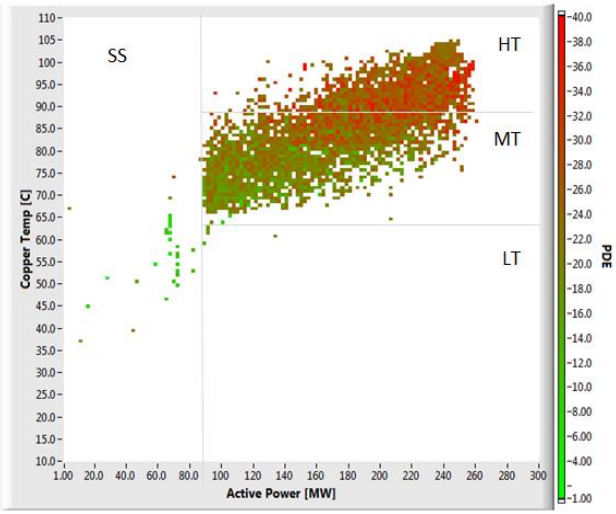
- Acquires PD data at all the different operating conditions
- Acquires signals during the machine start-up

- Allows meaningful trending aggregating results taken at homogeneous operating conditions
- **Generates outputs understandable by non PD expert (PDE Map)**
- Suggest, on such results, **the best way to operate the machine** avoiding excessive stress related to PD

PDE Map is a 2D representation of the machine status, load and temperature, where every ten minutes a dot in correspondence of the operating condition is shown and its color is related to the partial discharge energy index (from green to red based on the severity).

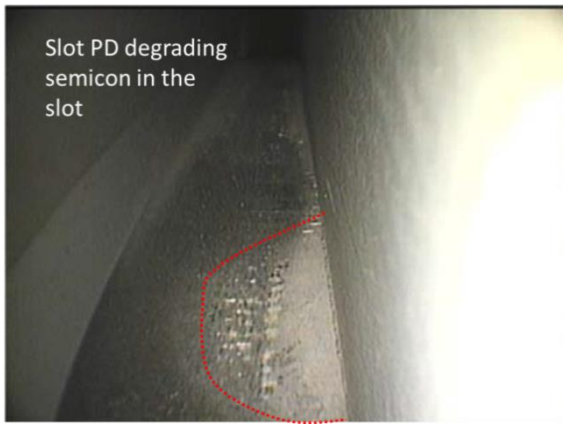
The overall distribution of the points within the obtained map represents a very intuitive graphical visualization tool which makes the user confident to identify:

- **What are the operating conditions of the machine**
- **In which operating condition PD are smaller and in which are higher**
- **What is the predominant degradation mechanism**



Looking at the beside Map, obtained from a 300 MVA VPI Turbo-Generator, concentrations of red dots are mainly occurring in the HT zone, which means at High Temperature. It is also clear that the red dots are occurring at any power level between 140 and 300 MW, which means that the PD mechanism is not directly dependent on load. As a matter of facts, red dots clearly start to occur above 85°C. This behaviour indicates the **presence of degradation at the semi-conductive coating in the slot portion of the winding** due to the increase of the semicon resistivity with the temperature.

The diagnosis was confirmed by the borescope inspection in the slots.

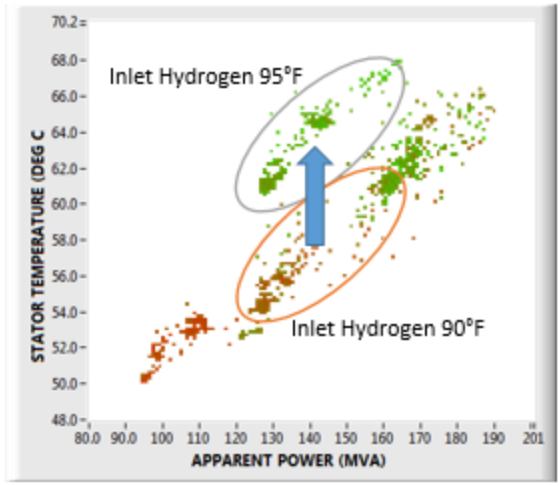


Poor cooling efficiency is suspected to be the cause of the overall temperature increase with consequent PD inception and stator slot coating degradation. The degradation phenomenon could be reduced, maybe stopped, by improving the cooling efficiency to reduce the overall temperature of 20°C.

The owner had not a clue of such a big difference in the condition of the machines from the periodic testing.

Indeed, it was not possible to play with load and temperature during the testing and make comparison of the results with generators in other plants.

Thanks to the on-line continuous monitoring and the PDE Map it did not take more than 5 minutes to realize what the problem was and what action had to be taken.



A PD monitoring system applied to a 200 MVA turbo-generator 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 genuine monitoring system as **INTEGO GM** allows the generation of graphical output, the **PDE Map** which performs automatically and continuously what is **recommended by the International Standard** 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 or not intensive PD
- At which operating condition the PD is higher
- What change in the operating condition would reduce the PD and stop degradation
- Which machines deserve special attention and maintenance

The above mentioned information can be obtained:

- Without any training on PD theory
- Without sending data to PD experts

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

- Defer the need for expert in data interpretation
- Providing intuitive graphical tools describing machine insulation status
- Allowing intuitive comparison between machines
- Provide meaningful trends at the same operating conditions
- Suggesting the best way to manage the generator operating condition to reduce insulation degradation and extending machine life
- **Mitigate failure risk**
- **More effectively target maintenance and re-investments**
- **Save operating expenditures for PD analysis and PD measurements**
- **Base critical decisions on International IEC Standards**

> Samuel Clemmons, Tennessee Valley Authority: Visual maps provide immediate understanding of PD behavior 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 Power

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

With a distinguished 30-year activity of innovation in the energy sector, along with a global sales and technical support infrastructure, Camlin Power continues to build on a unique innovation heritage, working collaboratively with customers around the world to offer solution driven products.

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

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