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Q6: What is preventing online PD monitoring becoming widely accepted? Where do the challenges remain to push this technique forward?

The author of this contribution is the convenor of WG D1.66. D1.66 is tasked with defining gas-insulated switchger (GIS) PD monitoring (PDM) system requirements to ensure that signals from incipient PD defects are reliably detected, monitored and interpreted so that asset managers can take prompt and appropriate actions to prevent equipment malfunction. This technical guidance will help users to choose a PDM system best fitting to their particular needs and their level of PD know-how. At CIGRE 2022, the WG D1.66 has presented a paper (ID_10883) where the present status of WG activity is shown. A CIGRE TB will be published in the near future as well

The Ultra High Frequency (UHF) method was introduced in the late 1980's for PD measurements and is now widely accepted, being used by GIS manufacturers for routine testing in the factory, during on-site acceptance tests, and by utilities for online PD monitoring.

In the last 10 years, more than 700 PDM systems based on the UHF method have been installed on GIS throughout the world, monitoring a total of more than 85,000 UHF sensors. Many utilities are fitting PDMs due to heightened sensitivity to outages from customers and stakeholders, thus redirecting the primary motivation for PDM towards condition assurance and the more general trend towards digitized asset management.

Many online PDM systems have been developed to date and are typically operated as individual 'island' solutions within a customer's asset management of GIS. The process has been reliant on individual specialist knowledge of PD phenomenon and GIS failure modes. The dearth of sufficient numbers of such specialist personnel is having the effect of requiring more diagnostic capability from the PDM systems themselves along with internet connectivity to remotely access support of external expertise.

However, since the technical requirements of PDMs are not standardized, the related recommendations derived from the different application cases vary significantly. There is a strong need for a versatile PDM system that is able to provide all information requested in the international documents to assure that incipient PD defects are detected, and their evolution is monitored so that asset managers can derive prompt actions.

The current PDM systems on GIS have many technical weaknesses :

- External noise discrimination is very challenging, often leading to false alarms being generated.
- Expert systems are not yet sufficiently effective or accurate.
- Alert/warning procedure does not consider results from the sensitivity check and from the signal-profile evaluation.

Other non-technical weaknesses include :

- Factory Acceptance Tests (FAT) for PDM systems are not defined or standardized, making it difficult to assign and assess pass/fail criteria.
- Data format and displayed information (graphs, trends, PD patterns, etc.) are not standardized and not compatible between systems of different vendors.
- PD amplitude reference points are not clearly specified.
- Computers and some data acquisition boards of PDM systems have to be replaced after several years of operation ; long-time quality and robustness are limited, component obsolescence (a problem intrinsic to electronic hardware).

CIGRE WG D1.66 proposes to eliminate main deficiencies of PDM systems. In particular:

- **A novel warning/alert procedure is proposed** as one of the most pressing challenges facing GIS PDM systems is to significantly reduce the number of false alarms. As part of this, a proposal is that the results from the UHF Sensitivity Check (CIGRE TB 654) and from approximate PD Signal Attenuation Profile evaluation are used to set the optimum signal amplitude threshold value for all connected UHF sensors, and to define the response of the PDM system when those pre-set threshold levels are exceeded.

- After detection of PD activity, further steps are necessary and PDM systems should provide users with an **efficient and automated evaluation of the PD defects** type. This plays a pivotal role in both reducing false alarms and revealing defects that actually pose operational risk. A set of data files representing five typical GIS PD defects is proposed to test the efficacy of the available pattern recognition algorithms. The results of the round robin test are compared with the results from human experts. The recognition algorithms tested show a wide variation in performance and indicate that there is much room for improvement of the different classification algorithms. Other tests for PD identification are also proposed, such as e.g., applying real-size GIS test setups by inserting well-known PD defects together with typical interference signals, or using just compact test cells containing the usual well-known PD defects and combining them with typical interference signals.
- **Rapid, efficient, and effective risk assessment based on PD diagnostics is mandatory** and must take technical as well as non-technical parameters into consideration. The technical impact parameters estimate the probability of a failure in the GIS, and the non-technical impact parameters estimate the consequences in case a failure occurs. The goal of this process is to formulate a risk index which can provide a reliable guidance as to which action should be taken. The most preferred approach - the concept of traffic signals (green, yellow, red) - is recommended. Practical examples confirm the advantage of defect localization performed by Time-off-Flight (ToF) measurements or signal profile measurements. The former requires an additional measuring system, while the latter necessitates a very structured evaluation of the sensitivity verification. The special challenges encountered when applying PDM systems to three-phase encapsulated GIS are also covered.

The improved PDM systems for GIS that will fulfil the proposed requirements will create more clear benefits for the users.