ABSTRACT

Transformers, as crucial part of the electric network, ensure reliable and safe energy exchange over wide areas between consumers and suppliers, and they also represent a large capital value. With the growing demand of power, power quality and power availability the stringent need for system reliability is inevitable. Hence, a general growing focus on cost-effective condition-based maintenance (CBM) strategies, instead of time-based approaches, can be seen. CBM tactics may require a whole set of monitoring and diagnostic techniques. Beside several established methods to gather information about the current condition of a transformer on a temporal basis, there is an increased need for possibilities of conducting the diagnostics in an on-line manner. In view of the general advantages of on-line measurements, as there are (a) realistic stresses for the measurements and (b) permanent monitoring and inspection capabilities, this is quite comprehensible.

The diagnostic examination of partial discharges (PD) is regarded as a powerful, nondestructive and sensitive diagnostic tool for the condition assessment of insulating systems at factory. Electric PD measurements, conducted according to the IEC 60270 standard, are often referred to as 'conventional method'. If performed on-site and on-line measurements on transformers show certain limitations, regarding the applicability of sensors and the receptivity for several disturbances. In contrast, the 'non-conventional' electromagnetic Ultra High Frequency Antenna (UHF), High Frequency Current Transformer (HFCT) and Acoustic Emission (AE) PD measuring
methods have advantages for on-site/on-line applications. However, the sensitivity and repeatability of these methods are questionable compared the conventional methods. AE & UHF methods have advantages such as non-invasive measurements, immune to interferences and no need of shutdown of transformer in case of AE technique, whereas UHF is still prone to all kinds of electromagnetic disturbances. An additional benefit of these methods is the inherent possibility of a 3-dimensional determination of the failure location using arrival times of these PD signals. However, the electrical method needs the geometrical information for location of PD source and commercialization of these methods has various drawbacks such as interferences, difficulty in instrumentation and interferences.

A comparative sensitivity investigations of acoustic and electrical PD signals revealed a moderate damping of the AE signals in oil and in the solid insulations, compared to the resulting attenuation of the electric signals. Especially for hidden PD defects in windings a significantly higher sensitivity may be reached with the electrical method as a consequence. Results of experiments with AE PD signals, concerning the damping characteristics of different materials and structures commonly used in transformer manufacturing lead to the assumption that AE PD signals get attenuated when they propagate within the whole transformer. Several AE propagation paths for PD occurring within transformer tank are seen, leading to difficulty in identification and classification of source in case of multiple PD sources.
However, UHF method is a sensitive method of PD detection, which is also prone to electromagnetic interference during the testing due to nearby electrical components. Hence its design and application have seen major changes in adapting to invasive sensor measurement (Sacha Markalous) with improved location accuracy.

Owing to the sensitivity differences between these non-conventional methods, an advantageous combination of any two methods is reasonable. Two aspects of the combination can be pointed out: (a) the detection sensitivity is enhanced and (b) the plausibility and credibility of a finding a potential PD activity is increased.

In the practical applications of condition assessment of on-site transformers, there are many online partial discharge detection and location systems employing AE and UHF techniques, whereas the usage of electrical method is not yet commercialized as a product. In-spite of the inbuilt sensitivity problem of acoustic emission technique, its commercialization is due to its immunity towards external noise and lack of practically proven on-site electrical application. There are many algorithms proposed for the electrical method for partial discharge location, but the most feasible technique is terminal measurement-based algorithm which is considered for implementation in practice.

In this work these three methods of non-conventional PD measurements are studied for their basic capability of online PD measurement by conducting preliminary tests for better understanding of each method.
Further each method is individually compared with the conventional method of PD measurement for their sensitivity to various types of PD models such as corona gap, voids and floating electrodes. This study gives a fair understanding of each method with respect to their detection capabilities.

To compare these methods based on their location accuracy, each method is utilized to locate a known PD source designed for variable intensity and location. In each method an individual proven method is used and denoising techniques are utilized as and when needed. Extensive tests on lab size insulation PD models, lab transformers and in-service transformers are conducted. Results are summarized as an overall comparison of each non-conventional technique based on their online transformer PD detection and location capabilities.

The research outcome indicates the need of design review and analysis along with the site measurements to improve the online assessment of transformer health index.