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Performance evaluation of noise reduction method during on-line monitoring of MV switchgear for PD measurements by non-intrusive sensors

Ghulam Amjad Hussain [a,*], Muhammad Shafiq [a], Lauri Kumpulainen [b], Farhan Mahmood [a], Matti Lehtonen [a]

[a] *Department of Electrical Engineering, Aalto University, Finland*
[b] *University of Vaasa, Vaasa, Finland*

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ABSTRACT

Partial Discharge (PD) measurement is a globally accepted method for insulation diagnosis of electrical assets. The consequences of insulation breakdown are well known. The trend is to move from conventional offline testing to online monitoring for insulation life prediction, which results in the inclusion of high frequency noise in the captured signals. Therefore de-noising is of paramount importance in online monitoring to obtain useful information from the signal.

In this research, a 20 kV switchgear panel has been subjected to PD faults in the laboratory and measurements have been carried out by using different non-intrusive sensors including a novel sensor, the *D*-dot sensor and recorded by a high frequency oscilloscope. The measured results show the effective applicability of sensors for switchgear. The Discrete Wavelet Transform (DWT) has been used to de-noise PD signals in this paper. Time domain and frequency domain comparison of original and de-noised PD signals reveals the significance of this technique for online monitoring of Medium Voltage (MV) switchgear. Finally, an adaptive online de-noising concept, based on automatic de-noising is also proposed in this paper.

Introduction

Medium Voltage (MV) switchgear is an integral component of distribution network. Any electrical fault occurring in the switchgear, may lead to equipment damage, interruption of power supply and various costs (maintenance and power interruption cost) on the utility companies. Metal-clad switchgear suffer from several insulation failure processes such as electrical treeing on insulation surfaces, electrical treeing of potential transformers (PT) and current transformer (CT) within the switchgear due to poor manufacturing or cracks, surface discharges over the bus-bar insulation, bad connections and terminations, etc. [1–4]. Many accidents have been reported due to the breakdown of insulation and arc-flash in switchgear [5,6]. To the best of our knowledge, diagnostic testing has not been applied on switchgear widely, possibly because of relatively low fault rate. However economic loss caused by a severe fault such as arc-flash in switchgear is very high.

Partial Discharge (PD) is a phenomenon of partial breakdown inside or across the insulation, confined to a small crack or void (inside the insulation) or over the surface [7]. PDs may not appear for years, depending on its root cause but once it starts, equipment may operate for months or longer before the failure is likely to take place. During on-line monitoring, based on the presence of PD activity through the operation, conclusions may be made about the actual dielectric insulation status. PD measurement is considered as the most reliable and acceptable source of information about the insulation degradation. Once it starts, the damage always increases. Hence, online monitoring and early detection of PD provide a mean of pro-active protection.

There are two major techniques for PD measurements, i.e. conventional and non-conventional. Conventional method is also called as an electrical method which measures current or voltage pulse (PD pulse). It involves conventional sensors like coupling capacitor, shunts, pulse transformer, etc. which are directly in contact with the equipment. The equipment is usually isolated from the power network and is tested stand alone during periodic maintenance. Non-conventional method involves non-intrusive sensors which measure physical parameters like electromagnetic signals,

* Corresponding author. Address: Department of Electrical Engineering, Aalto University, P.O. Box 13000, FI-00076 Aalto, Espoo, Finland.
E-mail address: amjad.hussain@aalto.fi (G.A. Hussain).

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ultrasonic, infrared and ultraviolet emissions. They can be installed near the equipment during its normal operation and sense the airborne physical parameters. Therefore, they are best suited for online monitoring [8,9]. The major problem with such type of monitoring is the interference of various types of external airborne noise. Hence, de-noising is of paramount importance, in order to extract useful features to make correct decision.

In this research work, non-intrusive sensors (*D*-dot sensor, loop antenna and Rogowski coil) have been developed and used for PD measurements of MV switchgear in the laboratory. *D*-dot sensor is a new sensor technology, which has not been used for online condition monitoring of switchgear so far. The application of the sensor for switchgear provides satisfactory results. Based on various advantages of this sensor over other sensors, it has been recommended for the PD measurements in air insulated switchgear [10]. An efficient de-noising technique based on Discrete Wavelet Transform (DWT) has been used in this paper. The performance of the proposed de-noising technique has been evaluated by comparing the original signal with the de-noised signals, captured through various sensors. A brief procedure for the implementation and integration of automatic de-noising technique based on DWT in online monitoring system has also been proposed in this paper. This paper is an extended version of our previous work in which signal processing of PD measurements was conducted [11]. Sections 'Sensors used for measurements', 'De-noising of modelled signal having typical on-site disturbances' and 'Self adaptive de-noising approach in automated on-line diagnosis' are the new additions. Measurements data has been revised and replaced. Sections 'External noise during on-line measurements' and 'Signal processing of laboratory measurements' have been enhanced significantly.

External noise during on-line measurements

Due to switch-over from periodic maintenance to condition based maintenance, on-line measurement techniques have become more popular over the last two decades. In case of periodic maintenance, most of the time, the measurements were done in shielded laboratories, with filtered power supply, where the effect of external noise is negligible. In contrary, the on-line testing and measurement faces a large amount of external noise in measured signals. Extracting useful low-level (amplitude) signals from noisy backgrounds is a major challenge for on-line condition monitoring. In some situations, the background noise signals have very high amplitude compared to the PD signal. This directly affects the sensitivity and reliability of the acquired PD data. Digital signal processing (DSP) techniques must be applied to on-line PD measurements in order to recognize PD pulses within the electromagnetic interference (EMI) background, which often swamps the PD signal on-site. The identification and separation of PD signal from noise requires the knowledge of both the PDs and the noise. In general, noise sources may be divided into the following categories as shown in Fig. 1. [12,13]:

- Discrete Spectral Interference (DSI).
- Periodical pulses.
- Random pulses.
- White noise.
- Reflections.

Discrete Spectral Interference (DSI) is a narrow-band interference caused by radio (AM/FM) or TV broadcasts and other mobile communication networks. Periodical pulsed shaped disturbances are due to power electronic equipment. Random pulses are caused by lightning or switching operations, whereas white noise is electromagnetic (EM) interference caused by the measuring system or surrounding equipment [12,13]. DSI has a narrowband spectrum which is centred at certain dominant frequencies. The DSI can be easily blocked by band stop filtering of such frequencies. Periodical pulses can also be removed by implementing a gating circuit [14]. However, it is very difficult to eliminate the remaining two types of noise because they are more similar to PD pulses [13]. Switchgear has an additional source of noise resulting from the reflections of PD signals from the walls of switchgear and disturbs the air borne EM signal produced by the initial signal.

Fig. 2 presents an approximate spectrum distribution of various types of noise and PD signal in the air insulated switchgear [9]. Periodic pulses are usually low frequency noise (in kHz), whereas radio/TV broadband signals vary from few kHz to MHz. White noises are usually very high frequency (VHF) or ultra high frequency (UHF) noises. DSI and periodic pulses have higher amplitude than the white noise. From Fig. 2, it can be clearly

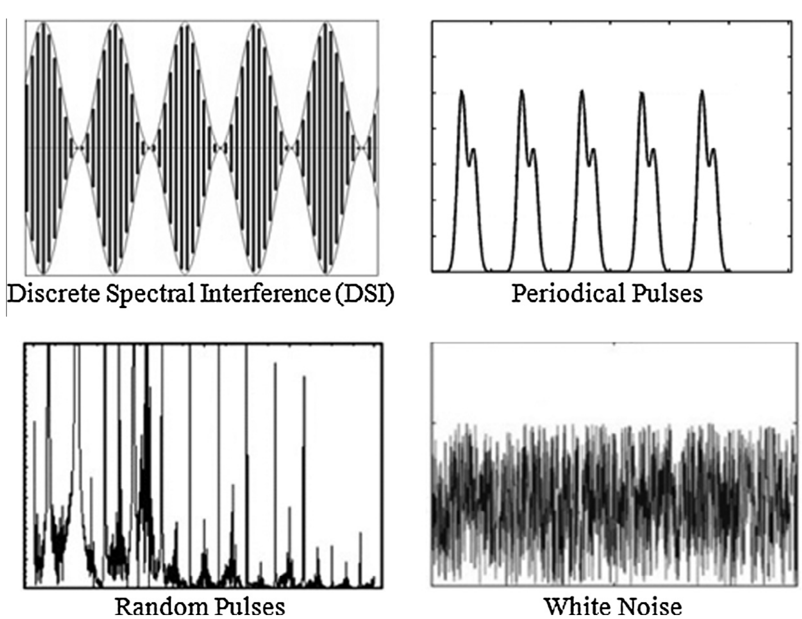

Fig. 1. External noises.