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High Field Electrical Conduction and Breakdown in Solid Dielectrics: A Signal Denoising Techniques by Wavelet Transform

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Abstract: One of the most important challenges of on-site partial discharge measurement is to capture the original signal in a noisy environment. The different sources of noise which includes thermal or resister noise added by the measuring circuit, signals due to electromagnetic interferences. Sophisticated and proper methods are required to detect and measured the partial discharge signals. Fortunately, due to the advancement in the analog to digital conversion techniques, signals can be easily captured with the help of interfacing devices. The signal can be extracted and converted into Excel sheets. This paper deals with de-noising of partial discharge signals during the breakdown phenomena in solid dielectrics. Several techniques are investigated and applied to the captured partial discharge signals. For the enhancement the insulation quality of the dielectric media, diagnosis plays a very important role in a power system. For diagnostic test such as detection, location and identification are used to find defects or faults and assess the ageing degree of the dielectric material. Wavelet Transform technique used to suppress a noise from partial discharge signal requires reasonable mother wavelet, amount of scales and thresholds to produce its best result. Results indicate that this technique not only attain better dancing effect, but also improve the sensitivity of partial discharge detection.

Keywords: Partial Discharge (PD), Discrete Wavelet Transform (DWT), Noise rejection, Signal denoising, Signal extraction.

I. INTRODUCTION

When high voltages are applied across the dielectric material with defects, the dielectric material may either totally breakdown, or partial discharges (PDs may occur. The partial discharges are localized discharges confined to the insulation system. They are caused due to the weak spots, such as void or cavities in the insulation where degradation takes place. It is well known that PD measurements are widely employed in testing power apparatus manufacture. However, there are recent trends to extend them to on-site measurements, where the major problem is encountered is the strong coupling of external noise, particularly discrete spectral interference (DSI). For the sensitive PD measurement. These disturbing signals to be rejected. In this paper, different denoising techniques are applied to the captured signal.[1-3]

Partial discharge detection involves the capture and storage of partial discharge data, processing of partial discharge signals, diagnosis and assessment of insulation. Partial discharge monitoring is approved the most effective technique for the insulation assessment. Partial discharge signals occurred in the form of individual or series of electrical pulses. They are small and likely to be submerged in noises. So electromagnetic interference is a major difficulty in partial discharge measurement. Rejection or filtering the noise from partial discharge signals is a precondition to analyze the characteristics of partial discharge signals.[2]

Partial discharge signals are always non-periodic and fast transient. It is unbalanced. So traditional signal processing methods such as Fourier Transform are limited for partial discharge signal extraction. Wavelet and its transform techniques can realize the local analysis and has been widely used in signal processing.[1-5]

II. PARTIAL DISCHARGE MODELING-THREE CAPACITANCE MODELS

A partial Discharge model using a three-capacitor circuit model or it is also known as 'a-b-c' model representing an isolated cavity within a dielectric material has been developed. Discharge is represented by an instantaneous change in the charging of a capacitance in the test object. A similar model has been used to study Partial Discharge behavior. The statistical behavior of this three-capacitance circuit is very complex, even though the circuit is Simple and deterministic. However, this model is not realistic in describing cavity properties because in a real cavity, there is surface charge accumulation on the cavity surface after a discharge occurs and the cavity surface is an unequal potential distributed surface. There is an improved ‘a-b-c’ model which has considered charging accumulation on the

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cavity surface after a discharge. The discharge is simulated as a time and voltage dependent resistance, which represents the discharge event as a change in the cavity from being insulating to conducting.

The figure-1 shows the typical three-capacitance equivalent circuit or 'a-b-c' model of a void within insulating material. In the model Ca' and Ca" which represents the capacitance in the material which is cavity-free, similarly Cb' and Cb" shows the capacitance in the material fall in series with the void and Cc represents the actual capacitance of the void.

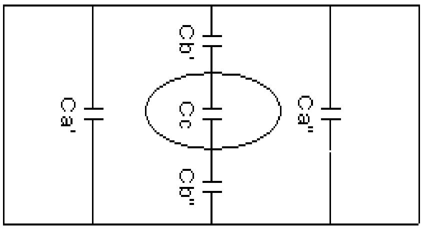

Figure-1: Typical three-capacitance equivalent circuit or 'a-b-c' model

The simplified equivalent circuit can be derived from the geometry, as shown in Figure-4, where Ca is the overall equivalent capacitance of Ca' and Ca", similarly Cb is the equivalent series capacitance of Cb' and Cb" and Vc is the voltage across the cavity. Discharge is assumed to occur when the voltage across the cavity capacitance Vc is higher than the inception voltage, $V_{inc.}$ stops when it is less than the extinction voltage, $V_{ext.}$ When a discharge occurs, Cc is short circuited, causing a fast transient current to flow in the circuit due to the voltage difference between the voltage source and across Cb. A fast transient voltage signal is created due to sudden voltage drop due to the impedance of the external circuit. Although this model is simple, it can represent the transient related to a discharge.

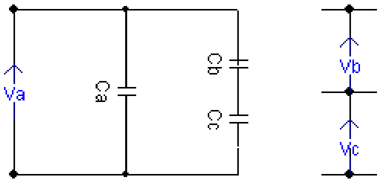

Figure-2: The Experimental arrangement of the simplified equivalent circuit

The three capacitance equivalent circuit diagram representing Partial Discharge in a cavity. The Partial Discharge current pulse and apparent charge magnitude as a function of time, which results from a voltage across the cavity and the current flowing through the cavity due to the partial discharge.

III. THE WAVELET TRANSFORM

Signal processing methods such as Fourier Transform, Wavelet Transform are usually used in the detection of break points, incipient frequencies in the signals and detecting the edges in the images, removal of noise, etc. Traditionally, techniques used for signal processing have been realized in either time or frequency domain to analyze and extract partial discharge events. In case the frequency domain the Fourier Transform assumes that any signal could be decomposed into a series of sine and cosine waveforms with the signal under analysis localized arbitrarily throughout the frequency domain but the information in the time may be is lost. With regard to the partial discharge pulse structure, there always exist non-periodic and fast transient features in the partial discharge signals detected, which tend to be ignored and cannot be revealed efficiently and explicitly by this kind conventional transform. Therefor, the Fourier Transform applied to partial discharge analysis has serious limitations. The Wavelet Transform is a linear operation that decomposes a signal into components that appear with different scales. The wavelet Transform plots a time-domain signal into a two dimensional array of coefficients, thus concentrating the signal in both time and frequency domain instantaneously. The wavelet Transform is useful in analyzing the transient, irregular and non-periodic signals in phase-space, which are time-scale and frequency domains as against the Fourier Transform which considers phenomena in an infinite interval.

Wavelet analysis employs a prototype function called the Mother Wavelet. This function has a mean zero and sharply decay is an oscillatory fashion, i.e., it sharply falls to zero on either side of its path. The wavelet Transform can be able in two different ways depending on what information is required out of this transformation process. The first method is the continuous wavelet transform (CWT), where one obtains a surface of wavelet coefficients, CWT (b, a), for different values of scaling 'a' and translation is discretize, but not are independent variables of the original signal.

The discrete wavelet transform (DWT), on the other hand, provides sufficient information both for analysis and synthesis of the original signal, with a significant reduction in the computation time.

IV. EXPERIMENTAL SETUP

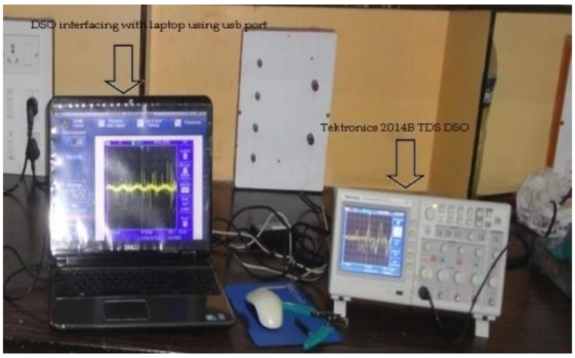

Figure 3: Experimental setup arrangement with PC interface

Figure 4: Experimental arrangement with 100 KV HV source

V. RESULTS AND DISCUSSION

In this process the Tektronix DSO, TPS 2014 B, with 100MHz bandwidth and adjustable sampling rate of 1 GHz is used to capture the current signal. The Tektronix current probe of rating 100 mv/A, input range of 0 to 70 Amps. AC RMS, 100 A peak and frequency range DC to 100 KHz are used for experimental purpose. The denoising method has been evaluated by applying the real practical experimental data. This technique analyzes the signal both in time and frequency domain simultaneously. A wavelet transform is a linear transform, which can treat non-stationary signals. Just as Fourier transforms decompose a signal into sinusoidal waves of various frequencies, wavelet transform breaks up a signal into shifted and dilated versions of what is called a mother wavelet. The fixed time, frequency resolutions of short time Fourier transform (STFT), which can be thought of as a possible method of analysis, has certain constraints in regard to analysis of non-stationary signals. Also, significant possibility of generating fast and computationally better algorithms of Decimated Wavelet Transform (DWT) makes it more suitable for the present purpose than STFT. The mother wavelet is a window function, whose extent enlarges in time (or reduction in frequency), while resolving low- frequency component and shrinks while analyzing high frequency components.

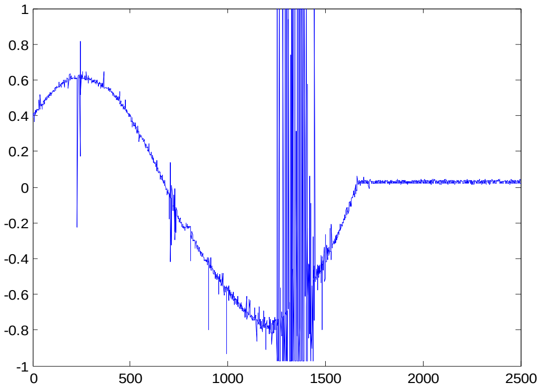

Figure 5: Signals with Partial Discharge and Noise plotted using MATLAB environment.

The method of denoising of a polluted signal involves two steps. In the first phase a desired mother wavelet is chosen according to the characteristics of the signal and then DWT coefficients are obtained. The second phase involves the modification of these wavelet coefficients using hard and soft Thresholding. The denoised signal is then reconstructed by taking inverse wavelet transforms of modified components. The following figures illustrate a denoising process by this method.

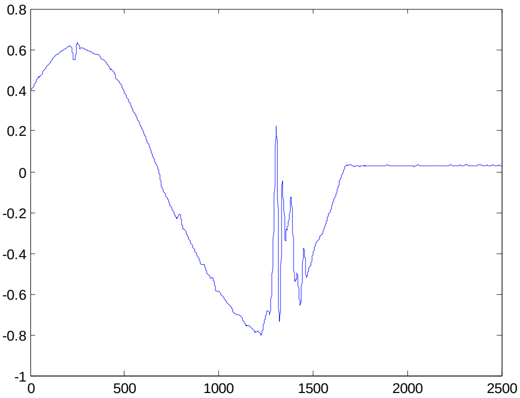

Figure 6: Denoised signal using db4 at level 4

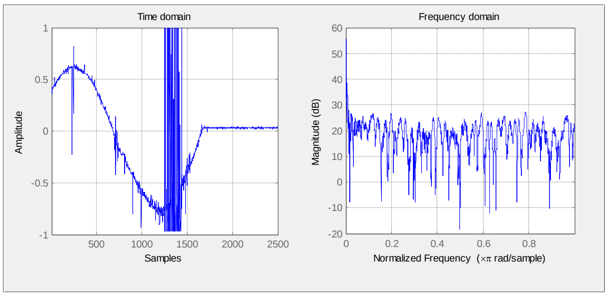

Figure 7: Time domain and frequency domain analysis of captured signal

VI. SIGNAL DENOISING TECHNIQUES

Sr. No	De-noising Techniques
1	Fast Fourier Transform (FFT), Constant threshold
2	Fast Fourier Transform (FFT), Frequency Dependent threshold
3	Low ass Filtering (Butterworth Filter)
4	Low ass Filtering (Chebyshev Filter)
5	Low ass Filtering (Inverse Chebyshev Filter)
6	Low ass Filtering (Elliptic Filter)
7	Winger- Ville Distribution (WVD)
8	Short Time Fourier Transform (STFT)
9	Least Mean squares (LMS)
10	Leaky LMS
11	Sign-error LMS
12	Sign-data LMS
13	Sign-Sign LMS
14	Normalized LMS
15	Kurtosis-driven LMS

16	Adaptive Recursive LMS
17	Cascade adaptive Filtering
18	Frequency –Domain Adaptive Filtering FDAF) using DFT
19	Frequency –Domain Adaptive Filtering FDAF) using DCT
20	Frequency –Domain Adaptive Filtering FDAF) using DWT
21	Recursive Least Squares (RLS)
22	Exponentially-weighted Recursive Least Squares (EWRLS)
23	Matched Filtering
24	Notch Filtering, Algorithm 1, Direct Implementation
25	Notch Filtering, Algorithm 1, Lattice Filter Implementation
26	Notch Filtering, Algorithm 2, Direct Implementation
27	Notch Filtering, Algorithm 2, Lattice Filter Implementation
28	Wavelet Based (Thresholding)
29	Wavelet Based (Mallat’s Algorithm)

VII. CONCLISION

In this paper, we looked at the problem associated with de-noising the partial discharge signals during the breakdown of solid dielectric material. Several de-noising methods were evaluated by applying different techniques. The methods were characterized on the basis of their mean square errors (MSE) and the time required for the execution. It was observed the wavelet based de-noising performs well based on real partial discharge data.

Mother Wavelet selection is associated with the partial discharge signal. The Wavelet based de-noising technique can extract the partial discharge signal well from high level noise circumstances. This novel technique is helpful for future research on signature analysis accompanied by some optimization techniques such as Neural Networks or Genetic Algorithm.

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BIOGRAPHIES

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