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Pulse Sequence Analysis of Partial Discharge during Accelerated Aging of Generated Bars

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Abstract

In this work, PD monitoring during accelerated aging of generator bars is experimented, pulse sequence analysis of the PD signals is applied for data processing and the aging process of the generator bars is studied. The results show that the method is capable to clarify the aging phase of the test objects containing multiple PD sites.

Keywords: Partial discharge Monitoring, Pulse Sequence Analysis, Generator Insulation, Aging

Introduction

Insulation aging of an electrical machine is influenced by electrical, thermal, mechanical and environmental stresses. The mechanical, thermal and resulting thermo-mechanical processes have an excessive influence on the service life of the insulation. Partial Discharge (PD) can cause erosion of insulation materials and accelerate aging processes. On the other hand, they give information about the insulation condition and degradation mechanism of the insulation. PD analysis is an effective tool to study the aging process. The aim of PD monitoring is to assess the aging phases and fault developments of the insulation. Data processing of the recorded PD signals can show a correlation between the PD activities and aging levels of the insulation [1].

Accelerated aging tests on machine insulation at machine production phase [2] and at aged insulation during normal operation are favorable. There are different accelerated aging test standards to be used before introducing, selecting or purchasing a new machine or a new insulation [3]. The results obtained during the aging tests can be used for the assessment of machine condition or for estimating the remaining life for the maintenance purposes during the normal machine operation [4].

Intelligent systems are implemented in the off-line and on-line tests for diagnostic and assessment of the test results. Some intelligent methods which are used for monitoring and decision making of PD activity in machine insulation are phase resolved partial discharge analysis (PRPDA) [5], pulse shape analysis and pulse sequence analysis (PSA) [6]. Most new monitoring systems use these methods for data analysis. In addition, noise rejection during on-line monitoring can also be performed.

Pulse Sequence Analysis Method

Pulse sequence of partial discharge at the site of the PD occurrence has been marked by a procedure that is associated with the condition and type of insulation degradation. Charges stored in the insulated cavity surface due to pre discharges have large influence on the pulse sequence of PD in the cavity. So unlike the primary knowledge, the sequence of partial discharges cannot be denoted as an accidental phenomenon. In some insulation systems which have high inductance, the detected partial discharges could be damped up to tens of percent, and amplitude analysis of the partial discharge cannot lead to a correct conclusion. The main parameter of the pulse sequence analysis is the time interval between the occurrences of successive partial discharges and can also be expressed either as a voltage difference or as a phase angle difference between successive partial discharges.

Fig.1 shows the characteristic parameters for 3 consecutive partial discharges based on the signal sequence analysis. Three PD signals are detected at times t_{n-1}, t_n and t_{n+1}. The time differences and corresponding voltage- and phase angle- differences can be presented as the following equations:

$$\Delta t_{n-1}=t_n-t_{n-1} \quad (1)$$
$$\Delta t_n=t_{n+1}-t_n \quad (2)$$
$$\Delta U_{n-1}=U_n-U_{n-1} \quad (3)$$
$$\Delta U_n=U_{n+1}-U_n \quad (4)$$

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$$\Delta\varphi_{n-1}=\varphi_n-\varphi_{n-1} \quad (5)$$
$$\Delta\varphi_n=\varphi_{n+1}-\varphi_n \quad (6)$$
$$E_{n-1}=\Delta U_{n-1}/\Delta\varphi_{n-1} \quad (7)$$
$$E_n=\Delta U_n/\Delta\varphi_n \quad (8)$$

For each PD test at machine insulation the diagrams E_n/E_{n-1} and $\Delta U_n/\Delta U_{n-1}$ will be presented [7].

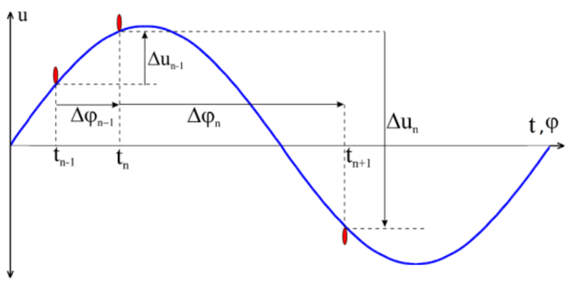


Fig. 1: Characteristic parameters for 3 consecutive partial discharges

Test Samples and Test Procedures

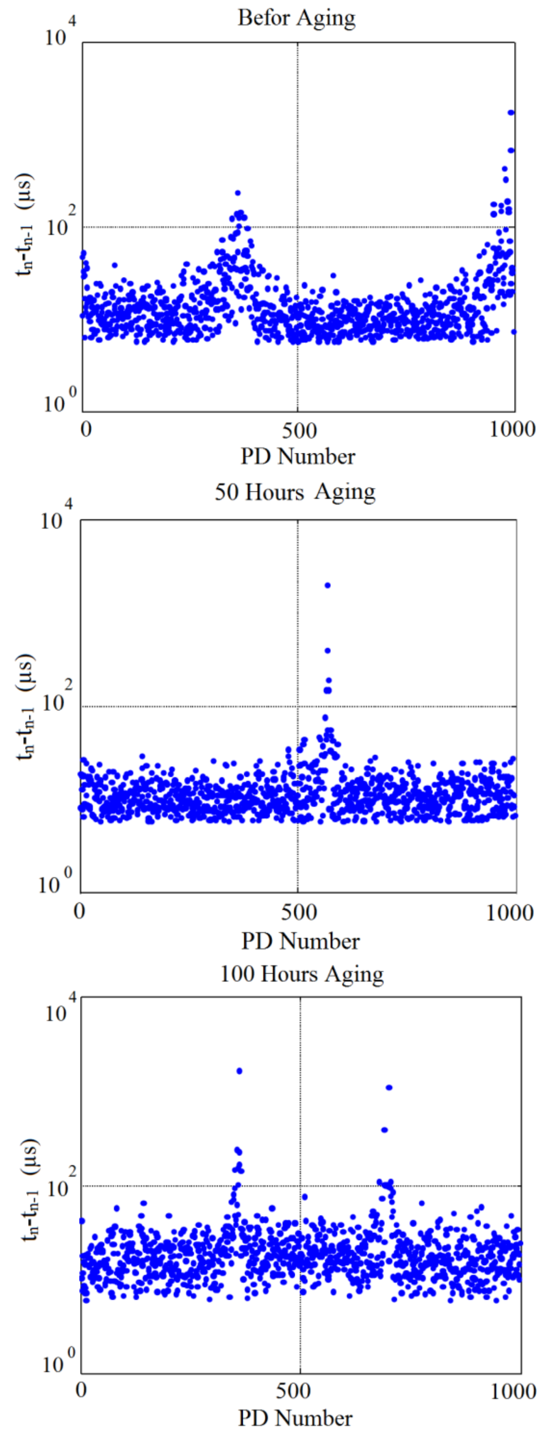
The test samples are new generator bars with 18 kV nominal voltages. They are produced for the generators of a hydro power plant in Iran. The tests are carried out on the samples according to the IEEE Std 1553 and IEEE Std 1043 standards. The bars are inserted between hot surfaces as shown in Fig.2 and the temperature is controlled and remains constant at 110^{O}C [8]. The test voltage is also constant at 39kV, 50 Hz.

Partial discharges of the bars are detected at 0, 50, 100 and 200 hours aging. The partial discharge measuring system has 50-800 kHz frequency band and the coupling capacitor has 1200 pF capacitance. The test duration is 1000 ms for each PD test.

Fig. 2: Generator bars located between hot surfaces

Test Results

The tests results of a bar which is failed after 218 hours aging are presented in Fig.3, 4 and 5. Fig.3 shows the variation of time interval between consecutive partial discharges of the generator bar before aging and after 50 hours, 100 hours and 200 hours aging respectively. Because of the enlargement of PD sites (cavities), the time interval between PD events increases.



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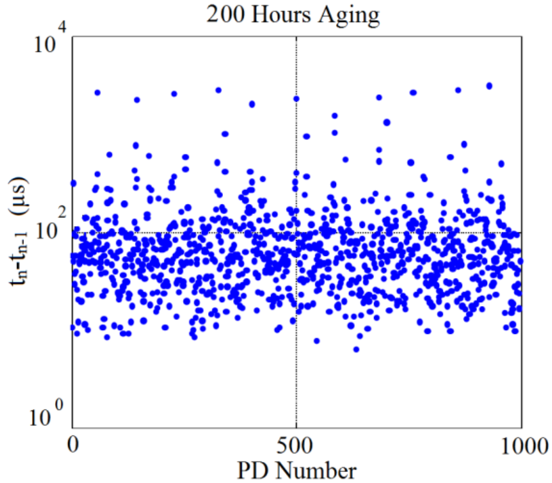
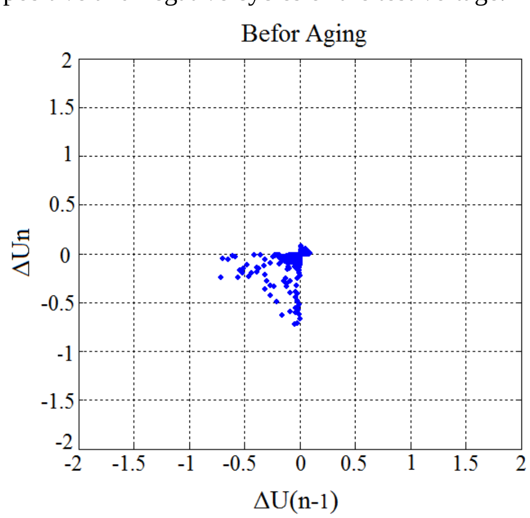


Fig.3: (t_n-t_{n-1}) patterns of 1000 consecutive PD signals of the bar during the aging

The bar has a few negative PD before the aging and clusters are concentrated in 3rd quarter of the $\Delta U_n/\Delta U_{n-1}$ pattern (see Fig.4). The E_n/E_{n-1} pattern has a narrow diagonal cluster (see Fig. 5).

As the aging duration becomes longer, the clusters in $\Delta U_n/\Delta U_{n-1}$ pattern grows up and is presented in the first quarter too. At the beginning of the aging the PD activity of the bar is concentrated between copper conductor and insulation; therefore the clusters in E_n/E_{n-1} pattern become thicker and grow up from the end point of diagonal line in anti clockwise direction [9]. After 200 hours (18 hours before electrical puncture), the high amplitude and low quantity partial discharges produce an elliptical form around the main diagonal cluster. Now the high intensity partial discharges are activated in both positive and negative cycles of the test voltage.



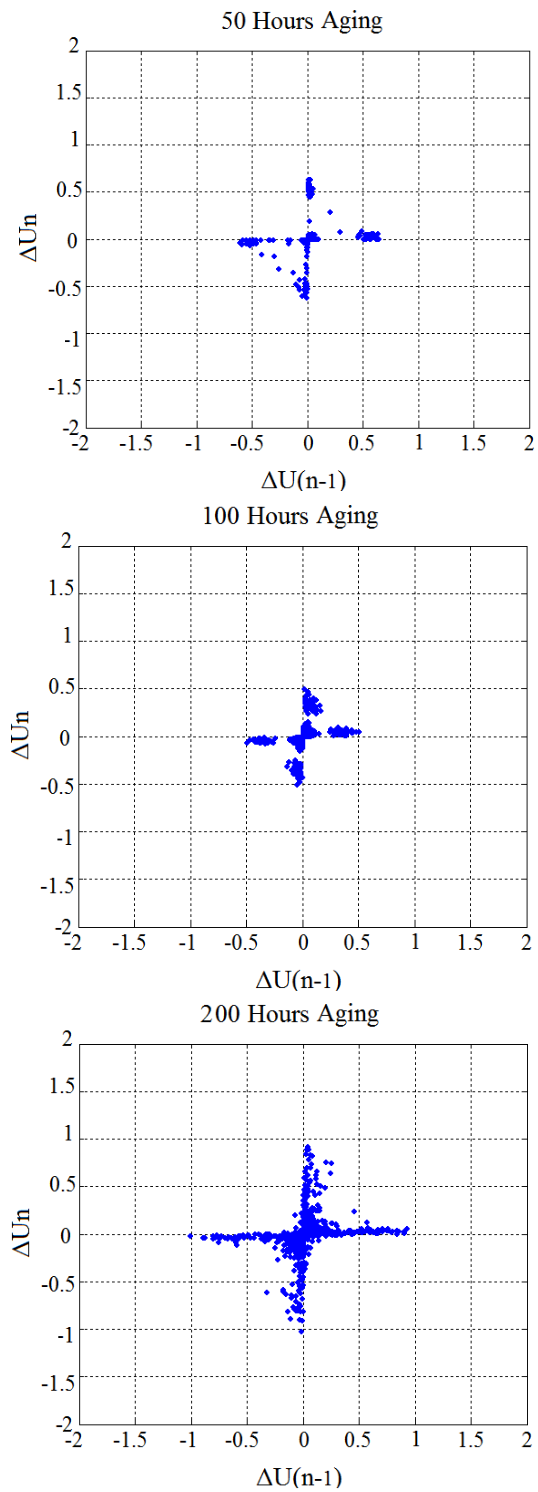


Fig.4: $\Delta U_n/\Delta U_{n-1}$ patterns of PD activity of the bar during aging

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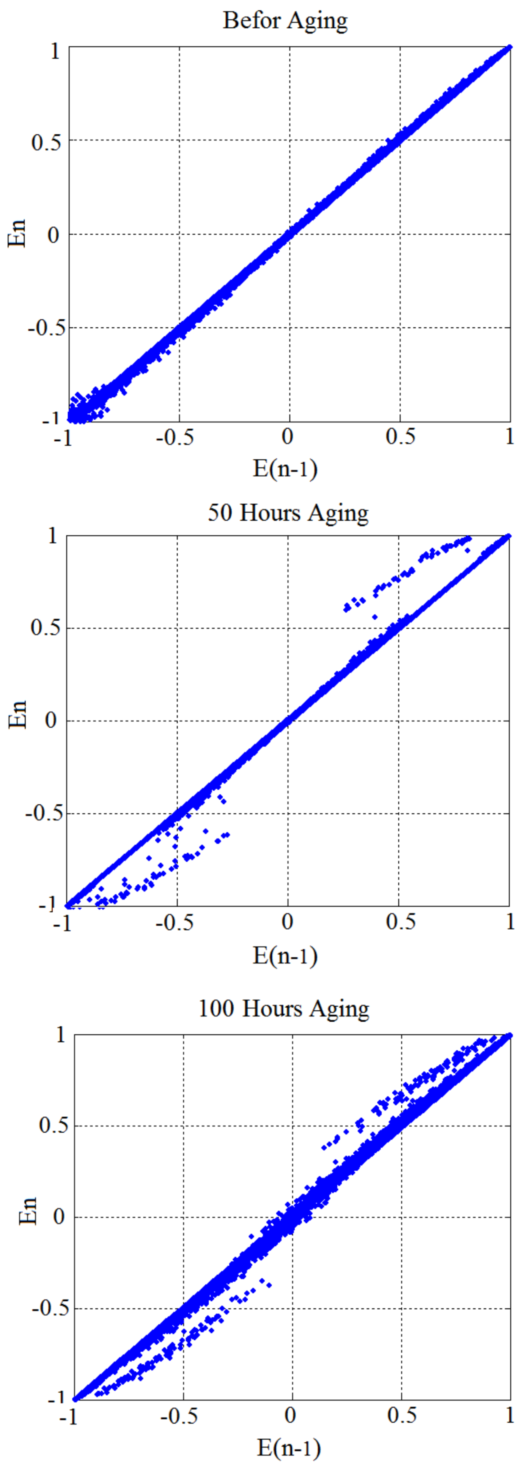

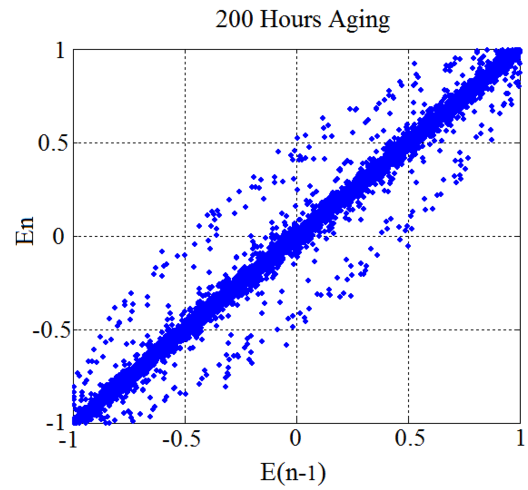

Fig.5: E_n/E_{n-1} patterns of PD activity of the bar during aging

Conclusion

Application of pulse sequence analysis during accelerated aging of generator bars is studied experimentally. The results show that the method can also be implemented in analysis of multiple PD sites. The aging process and the aging phase of the test object are clarified using pattern recognition of the test results. In PD monitoring of generator winding, the amplitude of receiving partial discharge signals from the remote bars are highly damped, this method does not need to PD amplitude measurement and may be used in aging assessment of the complete generator winding.

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Author Biblography

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