

Research Article

Analysis of PD Pulses in Transmission Wire Line Network

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Abstract: The aim of study is to understand Partial discharge, in order to locate this phenomenon within an HV system. Voltages 110 kV and above are regarded as transmission level voltages. In long lines with light loads, lower voltages like 66 kV and 33 kV are frequently used. These lower voltages are known as sub transmission voltages. For distribution, voltages less than 33 kV are generally used. Voltages above 230 kV are regarded extra high voltage and above 765 kV are considered ultra high voltages. The equipment used at higher voltages is of different design when compared to the equipment used at lower voltages. It is necessary to design and develop a compact and cost effective insulation structure for a proper power transmission at higher voltages. Due to mechanical, thermal and electrical stress, the insulation may breakdown which leads to catastrophic failure of the device. Hence it is necessary for the users to have a warning device which gives advance notice about the potential insulation problems so that they may be repaired during a scheduled shutdown.

Keywords: BPA, flashover, HV system, insulator, PD signal, S-Transform

INTRODUCTION

This study presents an approach for outdoor ceramic insulator pollution can be gauged based on partial discharge detection and analysis. Laboratory tests and results of the monitoring activity carried out on some insulators of transmission lines are reported. They support the effectiveness of partial discharge detection and analysis as a tool to carry out condition-based maintenance of insulators of overhead lines. The use of Ceramic and polymeric insulators in power transmission and distribution systems are widely distributed. Nowadays, the silicone rubber polymeric insulators are highly preferred because of its superior insulation and surface hydrophobicity properties. The reason is that hydrophobicity of silicone rubber material offers high electrical surface resistance. Gorur *et al.* (2001) suggested the maintenance of the hydrophobicity of silicone rubber insulator is in long term. The reason is because the chemical stability and diffusion of low molecular weight contents for bulk volume to the surface of the material. Pollution starts builds up gradually on the surface of the insulator. When these pervert insulators are installed near industrial, agricultural or coastal areas, it results in the flow of Leakage Current (LC) under wet conditions and finally causes arcing and flashover. Flashover of outdoor insulators will lead to power outages and equipment damage. To determine the performance of

polymeric insulators in polluted environment, hydrophobicity properties are used. The surface of the insulator ages due to the electric activity caused by wetting and pollution. This insulator ageing leads to the reduction of its hydrophobic property. However, it is retrieved during the resting time in air. The insulators with high value of hydrophobicity recovery show better performance. By using an accelerated ageing method in laboratory, polymeric insulators of different materials and leakage distances can be evaluated.

According to the earlier reported investigations, it is understandable that under the lightly and heavily polluted conditions, the LC follows different pattern during the enlargement of the flashover. Meyer *et al.* (2004), there was a good correlation exists between the harmonic power components of dry band arcing and the surface temperature of silicone rubber samples. For evaluating the surface condition of polymeric insulators, it is necessary to have proper understanding of different LC pattern and its time-frequency characteristics.

In this study, Polydimethylsiloxane (PDMS) is used for high voltage insulation an application is examined as to the ageing behavior at different temperatures in air. Three models according to ISO 11346, to Moghadam *et al.* (2013) were applied to determine endurance limits in terms of a time-to-failure after ageing in hot air. Ageing was carried out in air from 150 to 170°C. Shihua *et al.* (2013) shows on

unaged and aged PDMS specimen's tensile tests were conducted at ambient temperature using strain-to-break values as a performance indicator for the degree of aging. The effects of aging were found to depend strongly on the aging conditions for PDMS. Kumagai *et al.* (2006) Insulation degradation is an effect of Partial discharge. Inside the insulation, discharges occur due to presence of voids or cracks or impurities. Depending on the nature and location of source of discharge different types of partial discharges occurring in the insulation system. Delamination, void discharge, end winding discharge, surface discharge is the commonly observed discharge types in rotating machines. Different Phase Resolved Partial Discharge (PRPD) patterns are produced by different discharge sources. This varying behavior is due to the physical processes taking place at different locations with different intensities during occurrence of partial discharges.

MATERIALS AND METHODS

Occurrence of PD: Partial Discharge can be outlined as an electrical pulse or discharge in a gas-filled vacuum or on a dielectric surface of a solid or liquid insulation system. This pulse or discharge only partially bridges the gap between phase insulation to ground, phase to phase insulation. In any void between the copper conductor and the grounded motor frame reference these discharges may occur. Between the copper conductor and insulation wall, or internal to the insulation itself, between the outer insulation wall and the grounded frame, or along the surface of the insulation Suwarno (2006) proposed these voids may be located. They attenuate quickly as they pass to ground, when the pulses occur at high frequencies. Montoya *et al.* (2004) the discharges are small arcs occurring within the insulation system. These discharges therefore, deteriorate the insulation and can result in eventual complete insulation failure. The other area of partial discharge is insulation tracking. It generally occurs on the insulation surface. These discharges can bridge the potential gradient between the applied voltage and ground by cracks or contaminated paths on the insulation surface.

Mechanism of PD initiation: In an insulator a partial discharge occurs when the electric field in localized area changes in such a way that a localized arcing is created. This localized arcing proves itself as an electrical pulse that is large enough to be measured. Voids are defined as gaps in a dielectric material, such as gas bubbles in oil or cracks and fissures in the paper insulation. For creating a capacitance, the void region must have a lower dielectric constant than the surrounding material. When the electric field difference across the void exceeds minimum breakdown field strength, then partial discharge can occur. But reaching

this minimum field strength does not guarantee an immediate partial discharge. Two criteria must be met for a PD to occur. First, the electric field difference across the void must be higher than the breakdown value, which is determined by the field's ability to speed up an electron to the point that if it impacts an additional molecule, more electrons are knocked loose than are absorbed. Second, there must be a free electron existing within a specific volume, whose size is proportional to the voltage across the void, to accelerate within the field. When these conditions are met, the build-up of electrons in motion grows exponentially and a streamer, or electron channel, is created and current can flow across the void and return the voltage across the void to zero. However, the presence and location of a free electron is a random process dominated by the presence of ambient radiation knocking electrons loose from surrounding materials. Cosmic rays which is the largest source of ambient radiation, creates very few electrons. A free electron must be present within a voltage dependent volume while the electric field strength is high enough to cause a cascading flow of electrons from the movement of a single free accelerated electron for a PD to occur. This needs for free electrons, makes the PD phenomenon very unforeseeable and a PD can occur within minutes or within hours of reaching the breakdown field strength within the void. The resulting discharge proves itself as a noticeable electrical, acoustic and sometimes optical signal. It should be noted at this time that the exact mechanisms and resulting signal characteristics of a partial discharge are not completely understood, though there are loose instructions that device fabricators can use in building detection systems.

Phase resolved partial discharge pattern: The first conception to assessment is the characteristic attribute that partial discharges occur only during the first and third quarter of each cycle. This is the inceptive rising positive signal and the inceptive rising negative signal. During the initial rising positive signal, all the capacitive components are being charged until the partial discharge inception voltage is reached across each specific void and partial discharges start. As the positive wave cycle commences to decrease, the positive voltage across each void is reduced because some capacitive charge remains.

Since the voltage across a capacitor cannot be changed instantaneously, Some level of charge must exist. Figure 1 shows the typical PRPD pattern of insulation system under 0 to 360°. We are creating a positive charge and the resultant partial discharges during the first quarter cycle. This positive charge is effectively reversed during the third quarter cycle resulting in a positive charge in the reverse direction and the resultant partial discharges. The second concept to review is that partial discharges are measured as voltage pulses; therefore, during the positive waveform

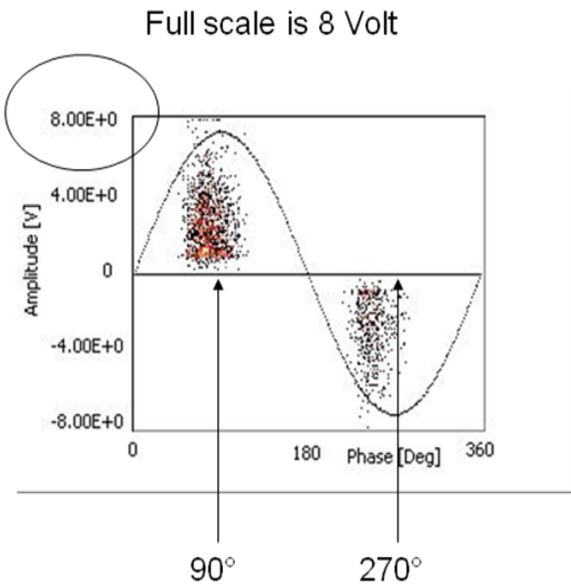


Fig. 1: Typical PRPD pattern of insulation system

cycle, a discharge, or a partial short-circuit, results in a negative, downward oriented pulse. This is referred to as a partial discharge with a negative polarity and occurs during the first quarter-cycle of increasing positive voltage applied to the void. During the third quarter-cycle, a partial short-circuit results in a positive, upward oriented pulse. This is referred to as a partial discharge with a positive polarity and occurs during the third quarter-cycle of the increasing negative voltage applied. These partial discharges, which are measured as a high frequency change in the power signal in millivolts to a few volts, cannot be observed with a standard scope.

The two measurements illustrated on the 2-D graph are partial discharge Maximum Magnitude, is generally represented in millivolts and Pulse Repetition Rate, which is represented by the number of partial discharge pulses during one cycle of an AC waveform. The partial discharge magnitude is related to the extent of damaging discharges occurring, therefore related to the amount of damage being inflicted into the insulation. The pulse repetition rate specifies the amount of discharges occurring, at the various maximum magnitude levels. Both play a role in finding the condition of the insulation under test. Whereas seldom possible with on-line motors, the maximum magnitude level should be marked with the standard scale to reflect the actual charge, measured in pico-coulombs. The advantages of such calibration are offset by the relative collation of homogeneous motors and more importantly by trending of the partial discharge activity over time. On-line partial discharge testing allows for such trending and analysis of the electrical apparatus. The exemplification of the partial discharge activity relative to the 360 degrees of an AC cycle allows for

pin pointing the prominent cause of partial discharges, therefore suitable corrective actions can be executed.

RESULTS AND DISCUSSION

Feature extraction from repetition rate analysis of PD pulses: Repetition rate of the PD pulses (pulses/sec) is a good indicator of flashover on the surface of the insulator. It is contingently a measure of surface degradation of the polymeric insulators. The PD appears in pulse bursts and their repetition rate is irregular in the case of outdoor polymeric insulators. Figure 2 shows the plot between repetition rate and pollution level of polymeric insulators at different relative humidity conditions.

In common, the repetition rate of the PD pulses increases with increase in pollution level and relative humidity level. Once the partial discharge inception starts, the repetition rate rises gradually with respect to increase in pollution and when the pollution level reaches the maximum to 0.12 ESDD, it shows a reduction in repetition rate. Identical trend is obtained for both virgin and thermal aged specimens. The magnitude of repetition rate is considerably higher for thermal aged specimens when compared with virgin specimens. Rate of rise of repetition rate is higher for 100% RH level when compared with 80% RH level. The reason for rapid decrease in repetition rate at high pollution may be due to the evolution of long partial arcs along the surface which warm up the surface and causes a time lag for the formation of next partial arc. This clearly shows that PD repetition rate can be used as accessory information to forecast the flashover.

Feature extraction from equivalent time length-equivalent band width: It is important to understand the the time and frequency domain characteristics of PD signal in order to extract major qualities and flourish a better diagnostic system for the flashover forecast of polymeric insulators. During the present experimental studies, discrete PD pulses were also encapsulated concurrently at different pollution conditions and stored in PC for frequency domain analysis. Typical PD pulses and its equivalent frequency spectrum of thermal aged insulators obtained at different surface pollution conditions are shown in Fig. 3 Under lightly polluted conditions, Short duration discharges (Fig. 3a and 3b) are mostly observed. whereas long duration discharges are observed at heavily polluted conditions (Fig. 3c). Time length and rise time of PD pulses increases greatly with respect to growth in pollution level. At lightly polluted conditions (0.06 ESDD), the high frequency content (15-25 MHz) is also observed in the frequency spectrum of the PD signal. With respect to rise in pollution level from 0.06 ESDD to 0.12 ESDD, the measure of high frequency content (15-25 MHz) notably decreases and the dominant frequency content

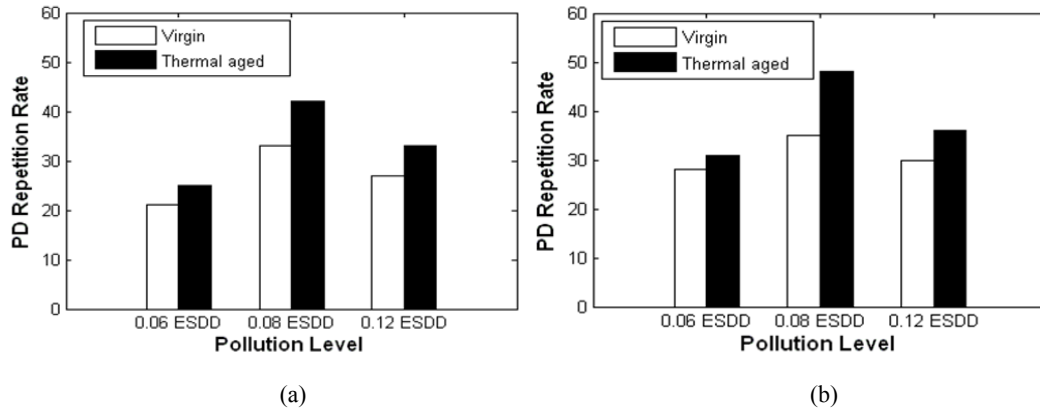


Fig. 2: PD repetition rate of virgin and thermal aged polymeric insulator at; (a): 80% RH and (b): 100 % RH

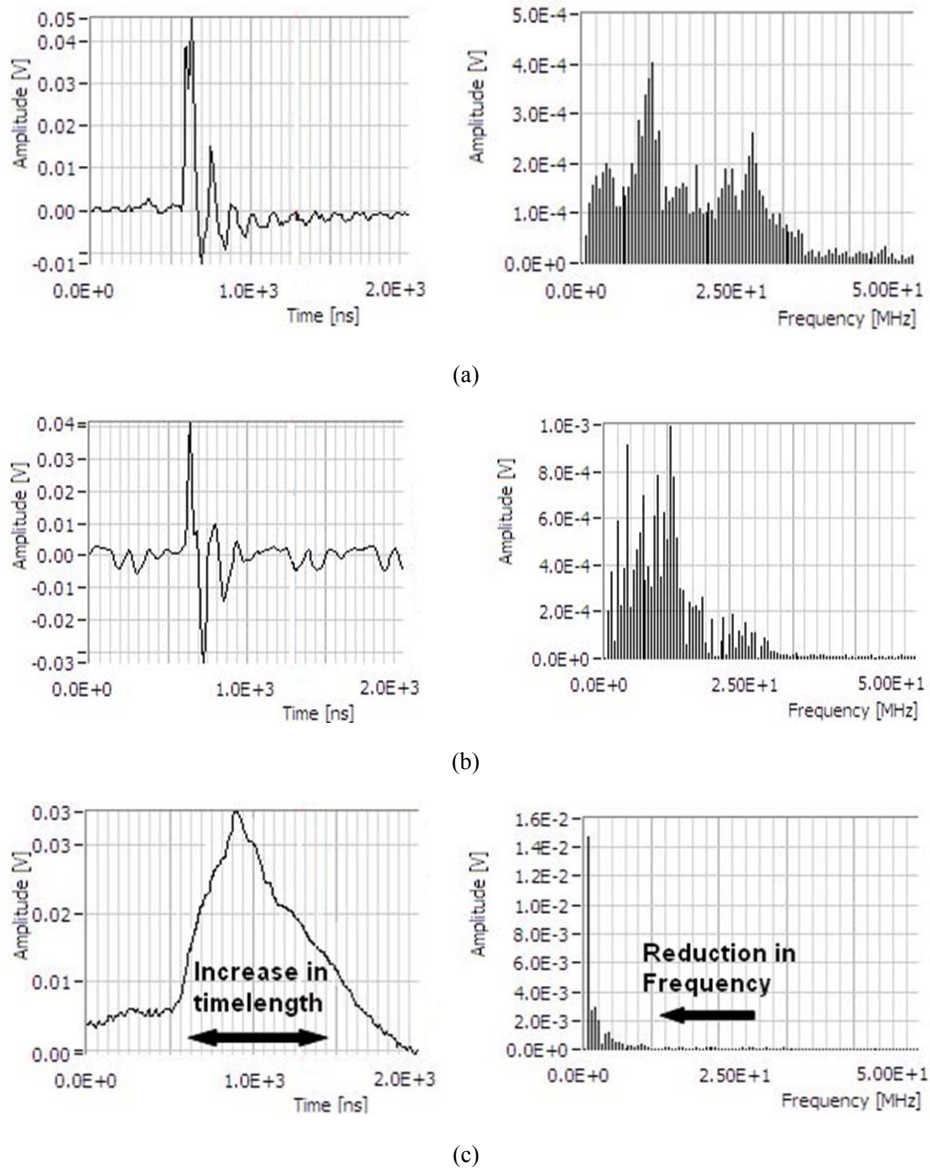


Fig. 3: PD pulse and frequency spectrum of thermal aged polymeric insulator obtained at 90 % RH; (a): 0.06 ESDD; (b): 0.08 ESDD; (c): 0.12 ESDD

relocate towards 5-10 MHz. Energy content of the PD signal increases at long arcs and this will increase the surface local temperature of the thermal aged specimens, which will lead to faster abrasion and degradation of the polymeric material.

CONCLUSION

Due to mechanical, thermal and electrical stress, the insulation may breakdown resulting in the catastrophic failure of the equipment. Hence it is necessary for the users to have a warning device which gives advance notice about the potential insulation problems so that they may be repaired during a scheduled shutdown. It is of great significance to understand Partial discharge, in order to locate this phenomenon within an HV system.

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