SUN ZHENQUAN, GU CHAOMIN, ZHAO XUFENG, LI YANMING

State Key Laboratory of Electrical Insulation and Power Equipment, （School of Electrical Engineering Xi'an Jiaotong University）
Xi'an, 710049, China

Partial discharge activity in oil – paper insulated system under DC superimposed AC and harmonic voltage

Abstract. *In the present study, the partial-discharge activity under nonstandard voltage formed by ac, harmonic, and dc voltages was studied. It is identified that the negative dc voltage superposed with ac and high frequency harmonic enhances the discharge activity in the medium and if the negative dc voltage is superposed with ac and low frequency harmonic, it can mitigate the discharge activity. The signal of the partial discharges in oil-paper insulated systems under the composite voltage formed by dc superposed with ac and harmonic voltages, has a dominant frequency content at around 20 MHz.*

Streszczenie. *Analizowano wyładowania niezupełne przy niestandardowych napięciach złożonych z napięć AC i DC. Stwierdzono, że obecność napięcia stałego zwiększa prawdopodobieństwo wyładowań. Zbadano wyładowania niezupełne w izolacji papierowo-olejowej. (**Wyładowania niezupełne w izolacji papierowo-olejowej przy napięciu DC oraz składowej AC**)*

Keywords: Harmonic voltage ,composite voltage, oil-paper insulated system, partial discharge.
Słowa kluczowe: iziolacja olejowo-papierowa, wyładowania niezupełne.

Introduction

HVDC power transmission networks are widespread nowadays and converter transformers form key components of these systems. The insulation structure is same as in conventional power transformer but it is stressed with dc, ac, and harmonic voltages[1]. The major insulation in transformer is a combination of pressboard material and the transformer oil, which is a multi-dielectric system.[2, 3].The manufacturers estimate the quality of the insulation of the converter transformer by performing certain routine tests before installation, which includes AC voltage withstand test, DC voltage test with simultaneous partial discharge measurement, polarity reversal test with partial discharge (PD) measurement etc [4]. Considerable research work of PDs in oil-paper insulation system under ac or dc voltages have been performed for long time [5-9]. However, insulation systems are today more and more exposed to composite voltages such as dc superimposed ac voltage, and dc superimposed ac, harmonic voltage, etc. The literature on partial discharge activity under these composite voltages in oil-paper insulation system is scanty. Having known this, in the present work, a methodical experimental study was formulated to understand the partial-discharge activity under composite voltage formed by dc, ac and harmonic voltages in oil-paper insulation using the conventional technique for measuring PDs according to IEC 60270 [10]. The reliability of the oil-paper insulated system is adversely affected due to partial discharges produced by the presence of cavity in press board or protrusion in the surface of the conductor, leading to catastrophic failure of the insulation structure.

Experimental

The experimental setup used for the partial discharge measurement adopting pulse current method in oil-paper insulation system, under the composite voltage formed by dc, ac and harmonic voltages is shown in Fig. 1 and Fig.2. The synthetic glass, leak-proof chamber is of a cylindrical cross section with dimensions of diameter 150mm and height 300mm fitted with a high-voltage bushing at the top and the bottom ground plate and a viewing port around the chamber. The top brass electrode is the high-voltage electrode of diameter 50mm and a lead wire of diameter 8 mm is bolted to the electrode, and the undersurface electrode is ground electrode of diameter 50mm connected to the aluminum bottom of the chamber . The inner discharge model is designed using three layers paper boards are spliced together and the middle one with an artificial hole whose diameter is 8 mm The middle paper board is with 1mm thickness, the up and down press board is with 2mm thickness, respectively. the outline is square with 100 mm side length. R1,R2,R3 are water resistors with several MΩ which are used for limiting electric current.C1,C2 are blocking capacitors with 0.011μF blocking dc circuit. The rate of voltage divider is 3000:1.

To understand the influence of composite voltage on the discharge activity, a separate methodology is based on the assumption that a very large difference in frequency contents between the PDs and the applied voltage exists, which can then be used for separation between the PDs and the applied voltage was adopted. First, the ac voltage was increased at the rate of 500V/s up to the point of identification of the corona inception voltage. Then, the dc voltage was applied in steps of a 1-kV increase for every 1-min time up to 4 kV during the time period the PD signals were measured. The corona inception obtained under the ac voltage is 9 kV. The ambient temperature was maintained at 25 centi-degree for the study. In the present work, wide-band sensors were used with the frequency response in the range 100 kHz–1MHz and were used in the study. The gain of the integrated preamplifier was set to 60 dB with a 1-MHz bandwidth.

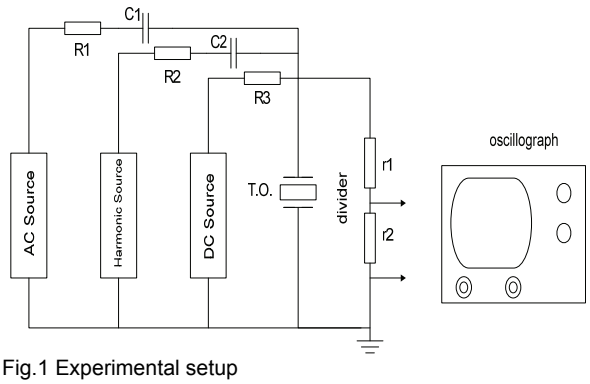
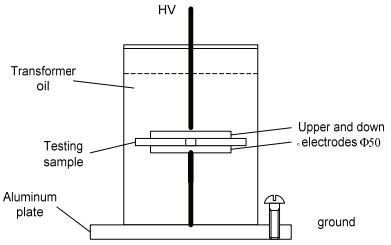
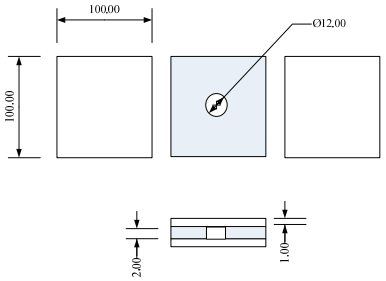


Fig.1 Experimental setup

The author tried to depict the typical PDs characteristic of the cavity in press board under dc, ac ,and harmonic voltages with different frequencies of 150,250,350 Hz. This principle involves the measurement of important parameters of the signal that crosses the threshold. The PD signal was sampled at the rate of 1 M samples/s. In the present work, the amplitude, energy, and counts of the signals were measured to identify and characterize the partial-discharges activities in oil-paper insulation using ORIGIN software.

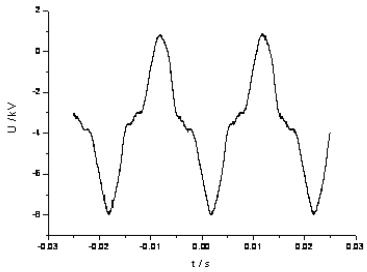


(a) Chamber

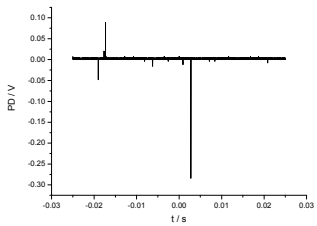


(b) Model of cavity in press board

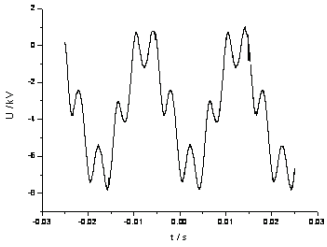
Fig.2 The testing sample system of cavity in press board



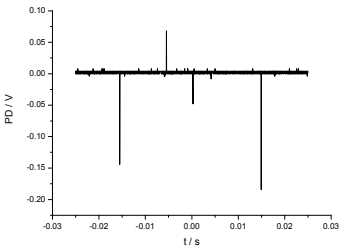
(a) The negative dc superposed with ac, and harmonic voltage of 150Hz



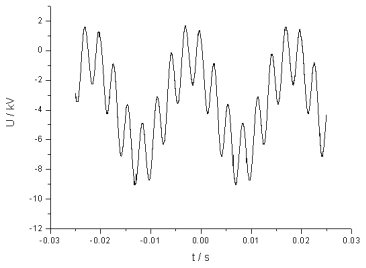
(b) PDs under composite voltage



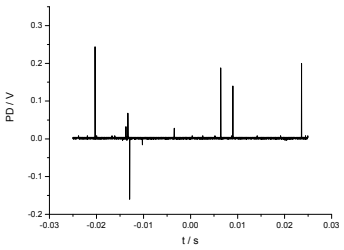
(c) The negative dc superposed with ac, and harmonic voltage of 250Hz



(d) PDs under composite voltage



(e) The negative dc superposed with ac, and harmonic voltage of 150Hz



(f) PDs under composite voltage

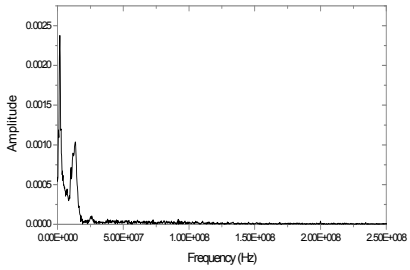
Fig. 3 The waveform of applied voltage and PDs

Results and discussion

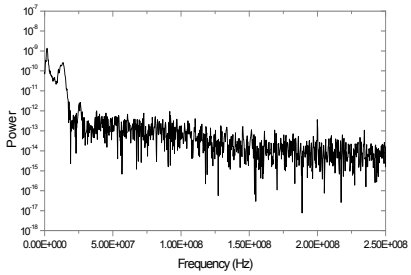
Fig. 3 shows a typical variation in the amplitude and numbers of the PD signals generated in cavity of press board in oil-paper insulation system under the composite voltages formed by dc, ac, and harmonic voltages. It is observed that under the composite voltage formed by the negative dc superposed with ac, and harmonic voltages, an increase in magnitude of dc voltages shows an increase in amplitude of the PD signal (Fig. 3(a)) and an increase in the frequency of harmonic shows an increase in the numbers of the PD signals (Fig. 3(b)). This indicates that under normal operation of oil-paper insulation system, the formation of composite voltage of the negative dc superposed over ac and high frequency harmonic can lead to the enhancement of partial-discharge activity from the defect site, leading to the initiation of catastrophic failure of the insulation system at lower voltages.

If the operating voltage formed is of the negative dc superposed with ac and low frequency harmonic voltage, an decrease in frequency of the harmonic voltage mitigates the partial-discharge activity in oil-paper insulation system, suggesting that the composite voltage profile formed by the negative dc superposed with ac and low frequency harmonic voltage could be adopted to suppress the discharge activity in the oil-paper insulation system.

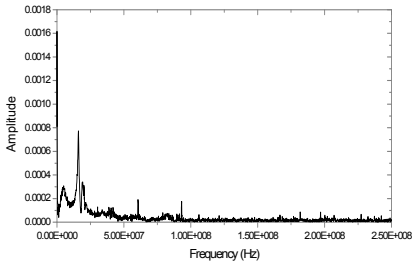
Fig.3 shows the characteristic change in PD counts under the composite voltage. It clearly shows that the under the composite voltage formed by the negative dc ,ac and harmonic voltage, the number of counts of the PD signal increased with the increase of harmonic voltage frenquency. In the case of negative dc superposed with only ac voltage, the discharges in the medium are completely mitigated and no PD signal could be measured. Fig. 4 shows the typical single PD pulse signal generated by the application of the composite voltages formed by dc, ac, and harmonic voltage and their corresponding fast Fourier transform (FFT) analysis of the signal. It is observed that the dominant frequency content of the PD signals produced in oil-paper insulation system is at around 20 MHz, irrespective of the voltage profile namely dc, ac, and dc superposed with ac, and harmonic voltage.



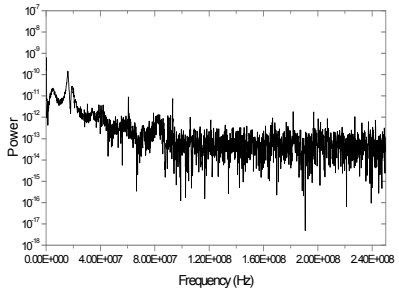
(a) The amplitude characteristics under composite voltage including 150Hz



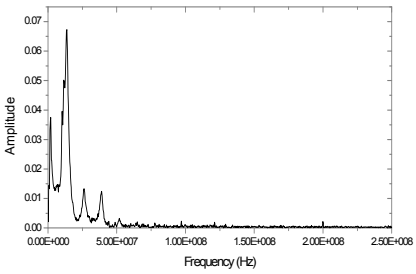
(b) The power characteristics under composite voltage including 150Hz



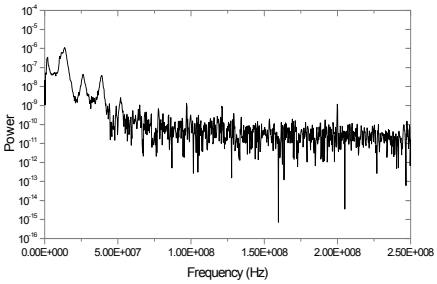
(c) The amplitude characteristics under composite voltage including 250Hz



(d) The power characteristics under composite voltage including 250Hz



(e) The amplitude characteristics under composite voltage including 350Hz



(f) The power characteristics under composite voltage including 350Hz

Fig.4 The amplitude and power characteristics of single PD under composite voltage

Conclusion

The formation of composite voltage of the negative dc superposed with ac and high frequency harmonic voltage can enhance the partial-discharge activity in oil-paper insulation system. The composite voltage of the negative dc superposed with ac and low frequency harmonic voltage diminishes; the partial-discharge activity in oil-paper insulation. The FFT analysis of the PD signal indicates that the dominant frequency content of the PD signals in oil-paper insulation under composite voltage formed by dc ac, and harmonic voltage is at around 20 MHz. The oil-paper insulation property of converter transformer meet the requirement of not only dc and ac voltage but also the composite voltage formed by dc, ac, and harmonic voltages.

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A***uthors****: Doctor Sun Zhenquan, member CIGRE. State Key Laboratory of Electrical Insulation and Power Equipment, （School of Electrical Engineering Xi’an Jiaotong University,）No. 28 XIANNING West Road ,Xian , China. E-mail: Sun.1120@stu.xjtu.edu.cn; Professor LI Yanming , State Key Laboratory of Electrical Insulation and Power Equipment, （School of Electrical Engineering Xi’an Jiaotong University,）No. 28 XIANNING West Road ,Xian , China.*