A Comparison on Leakage Current of 22 kV Porcelain Insulator Using High Voltage AC and Impulse Voltage via a Rotating Wheel Dip Test

B. Banhthasit, K. Tonmitra, A. Suksri, A. Kaewrawang, and M. Leeparkobboon

Abstract—**This paper presents the leakage current (LC) on porcelain insulator surface evaluated by the rotating wheel tester. The experiments have been studied under the conditions of severe environmental impact with surface contamination on specimens and then excited by electrical stresses for accelerated aging. The experiments were divided in two cases – high voltage alternating current and impulse excitation voltage. The result of the experiments showed that the LC on surface of specimen in both cases gradually increases almost exactly the same results for the first 100 cycles after that it rapidly increases with rotating wheel more than 100 cycles.**

Index Terms—**Leakage current, Aging, High voltage AC, Impulse, Rotating wheel tester**

I. Introduction

Outdoor insulators have an important function as vital equipment in overhead transmission lines and substations. Their performance as outdoor applications is greatly influenced by the action of environmental parameters [1]. They are always suffering from severe conditions such as surge lightning, electrical stresses, pollution and dust. The contaminants are deposited on the insulator surface forming as a dry layer later it becomes conductive when exposed to the light rain or morning dews [2, 3]. In this case, a flashover can occur even though operations are under the normal voltage stress and often followed by a long duration power outage [4, 5]. Consequently, the influence of pollution and electrical stresses are vital parameters to be considered in order to maintain the power quality a transmission line.

The processes of flashover consisted of three main steps [6]: (1) Formation of conductive pollution film covering of insulator surface with pollution layer and wetting of pollution layer by humidity, (2) Formation of pre-discharge along dry band and (3) Propagation of pre-discharge along dry surface and leading short circuited eventually.

Currently, there are many investigations on the leakage current (LC) characteristics of porcelain insulator [6-10]. The LC depends on type of voltage excitation [7] and it does not increase linearly with non-uniform electric field distribution [8]. The location of an insulator structure also has significant effect on the growth of erosions and tracking. Zhou and Mao [6] reported that specimen's surfaces have no obvious crack and dilapidation, even though, there are many electrical activities passed the surface. Han-Goo et al. [9] tested insulators by rotating wheel dip test (RWDT) with flashover test and impulse test after aging test. The results show erosion occurred in parting line on the surface of insulator. Suksri [10] presented that the LC has relationship with saline conductivity and rate of excitation voltage and it depends on shape of an insulator.

In this work, the study on effects of HVAC and impulse excitation voltage on contamination surface of 22 kV porcelain post type insulators by using RWDT are evaluated. In addition, the characteristics of LC and discharge performance on specimen surface have been considered.

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II. Experiments

The rotating wheel dip tester (RWDT) is used for aging insulator test in this work. The RWDT rotates in 4 steps and 40 s at each position: the first position of specimen is dipped into saline water (NaCl solution with 0.5 mS/cm), the second position is at horizontal position after dip into saline water, the third position has been excited by electrical stresses and the fourth position of specimen rests at a horizontal position as shown in Fig. 1.

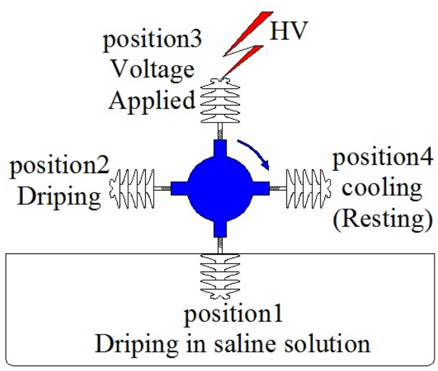

Fig 1. Rotating wheel dip test.

There are two excitation voltage types: HVAC 17.9 kV excitation voltages and HVAC 17.9 kV alternate with impulse negative polarity 1.2/50 μS, 110 kV excitation voltages. The excitation voltage types are alternated every 20 cycles. The leakage current had been recorded. Main equipments were arranged as shown in Figs. 2 and 3.

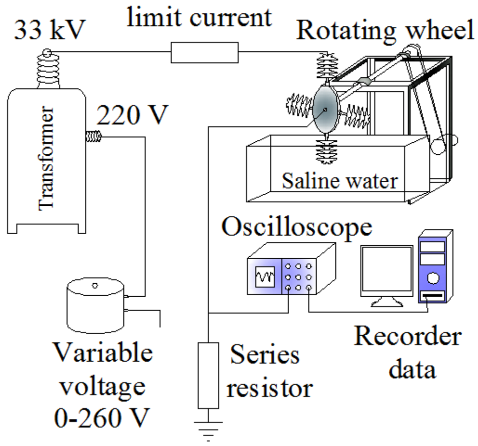

Fig. 2. HVAC excitation voltage equipment set up.

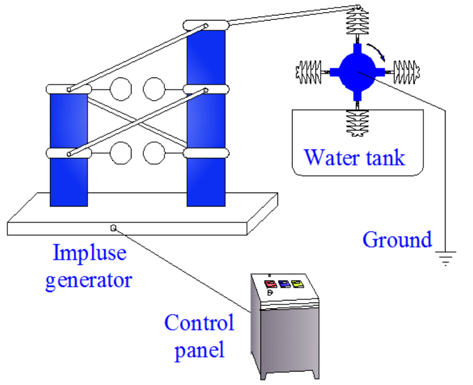

Fig. 3. HV impulse excitation voltage equipment set up.

III. Experimental Results And Discussion

Fig. 4 shows the LC recorded within four days with various cycles. On the first 100 cycles, both of LC obtained from two excitation voltage types gradually increases almost the same trend and less than 1 mA on wet condition. In this period, the LC is not sufficient enough to aging surface and the saline resistance layer has not yet been formatted completely [6]. However, the LC rapidly increases during 100 - 450 cycles. The peak amplitude of LC occurs at the initial excited voltage and rapidly decreases after 5 seconds. This phenomenon occurs due to thin pollution layer has been dried rapidly causes by heat which generates by LC. In this condition, it presents a low surface resistance on wet condition. After 450 cycles the LC gradually increases but duration of the peak LC is longer than 20 seconds. In this period, the longer LC caused by accumulation of saline on surface have been formatted thickness conductivity layer. Furthermore, the results show different effects on excitation voltage after 315 cycles. It might be contributed by the impulse effect. The partial discharge at dry band of insulator has been occurred during excitation HV voltage when the LC exceeds over 1 mA.

The distortion in original waveform indicates as discharge activity on the specimen's surface. This performance is generated harmonics which it contains in LC signal and the amplitudes of harmonics component is depended on discharge severity [11].

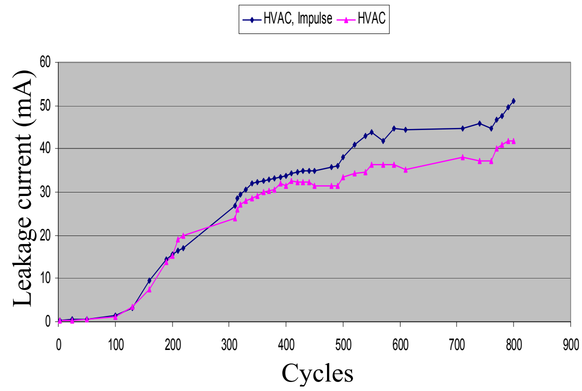

Fig. 4. Leakage current with various cycles.

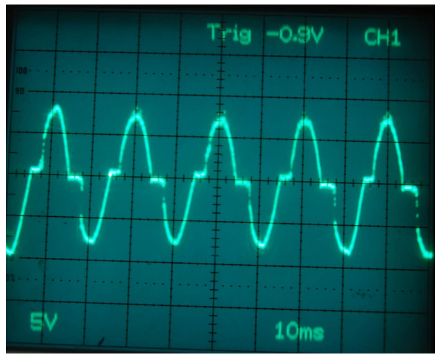

Fig. 5. Waveform of leakage current with HVAC excitation voltage.

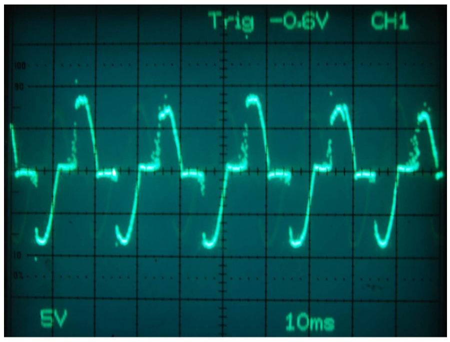

Fig. 6. Waveform of leakage current with HVAC and impulse excitation voltage.

Consequently, degradation specimen surface can be observed by severe discharge which indicates on the term dominant harmonics component.

Figs. 7 and 8 show the order harmonics component on LC signal at the same current from different excitation voltages. We have found that the fundamental LC, I_1, at frequency of 50 Hz is the highest amplitude. It means that I_1 is dominant current component of LC and the percent of total harmonics distortion which calculates from equation (1) is clearly shown on the HVAC alternate with impulse voltage excitation. All results and discussion revealed that severe effect of insulator were resulted from an excitation of impulse more than high voltage AC excitation voltage.

$$\%THD = \sqrt{\frac{\sum_{n=2}^{\infty}(I_n)^2}{I_1^2}} \times 100 \qquad (1)$$

where I_n for n=2, 3, 4,… is the harmonic amplitude of nth order of the harmonics and I_1 is the fundamental LC.

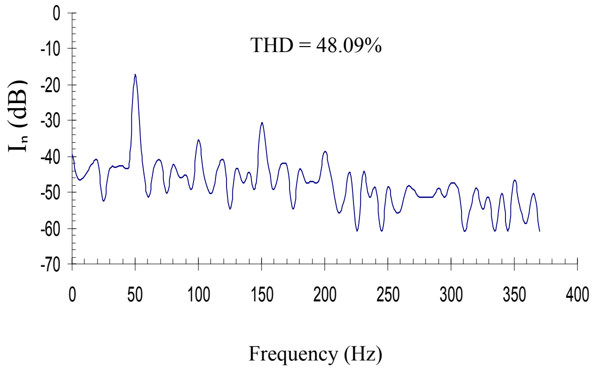

Fig. 7. Harmonics component of LC on HVAC excitation voltage condition.

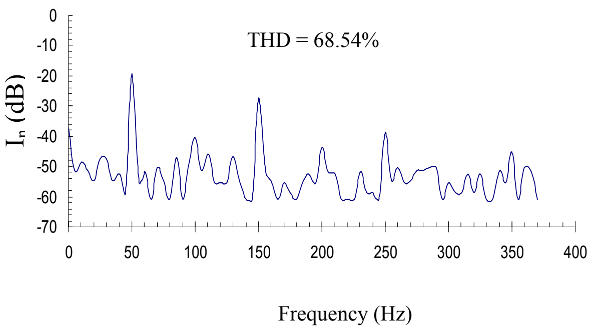

Fig 8. Harmonics component of LC on HVAC alternate with impulse excitation voltage condition.

In addition, increasing LC indicates the degradation of insulator surface because of electrical stresses on contamination surfaces. We have also found that the insulator surface losses hydrophobicity, which express in term of appearance discoloration and crazing which caused by activity of discharge [5, 7, 12] as shown in Fig. 9.

(a) Discoloration (b) Crazing

Fig. 9. Insulator surface after experiment.

IV. Conclusion

The aging on HVAC and HVAC alternate with impulse on contamination porcelain surface have been carried out. Degradation on porcelain surface insulator with negative polarity impulse excitation is higher than high voltage AC excitation voltage. The further extension of dry band area due to partial discharge accelerates the aging when specimen is excited by HVAC or impulse excitation voltage. The deterioration significantly on specimen surface will be indicated the details when investigate not only on amplitude of LC, but very significant necessary to investigate with harmonics component content in LC signal.

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References

[1] W. S. Z. E. Kuffel, J. Kuffel, "High Voltage Engineering", Second edition, Oxford Auckland Boston Johannesburg Melbourne New Delhi, 2000, pp. 509-513.
[2] M. T. Gençoglu and M. Cebeci, "The pollution flashover on high voltage insulators", Electr. Electr. Power Syst. Res., Vol. 78, No. 11, 2008, pp. 1914-1921.
[3] R. M. Claude de Tourreil, Wallace Vosloo, Franck Schmuck, "Guide for the establishment of naturally polluted insulator testing station", CIGRE, 2007, paper 333.
[4] S. Chandrasekar, C. Kalaivanan, A. Cavallini, and G. Montanari, "Investigations on leakage current and phase angle characteristics of porcelain and polymeric insulator under contaminated conditions", *Dieectrics and Electrical Insulation, IEEE Trans, Dielectr. Electrical Insulat.*, Vol. 16, No. 2, 2009, pp. 574-583.
[5] J. P. Holtzhausen and W. L. Vosloo, "The pollution flashover of ac energized post type insulators", *IEEE Trans. Dielectr. Electrical Insulat.*, Vol. 8, No.2, 2001, pp. 191-194.
[6] J. Zhou, S. C. Mao, L. M. Wang, and Z. C. Guan, "Circle tests of tracking and erosion of the composite insulator", *Electrical Insulat. Dielectr Phen. Annual Rep Conf.*, 2003.
[7] B. S. Limbo, "Insulator Ageing Test with HVAC and HVDC Excitation using the Tracking Wheel Tester", *University of Stellenbosch.*, 2009, pp. 27-28.
[8] Y. Yin, X. Liang, Y. Zhou, and X. Li, "Study of tracking wheel test method under DC voltage", *Proc. Propertie. Applic of Dielectric Materials*. Vol. 1, 2003, pp. 439-442.
[9] S.-W. H. Han-Goo Cho, Un-Yong Lee, "Tracking Resistance by the RWDT and Flashover Characteristics of Polymeric Materials of Outdoor HV Insulator", *Inter. Conf. Propertie Applic Dielectric Materials.*, 25-30 May 2002.
[10] A. Suksri, K. Tonmitr, K. Boontun, "Electrical Leakage Current on 22kV Porcelain Insulators Tested under Saline Solution", *J. KKU Eng.*, Vol. 30, 2003, pp. 379-389.
[11] M. I. a. C. K. S.Chandrasekar, "Investigations on Harmonic Contents of Leakage Current of Porcelain Insulator under Polluted Conditions", *15th National Power Systems Conference (NPSC)*, 2008, pp. 340-344.
[12] M. S. Muhamad Amin, "Ageing of Polymeric Insulator (Overview)", *Rev. Adv. Mater. Sci.* Vol.13, 2006, pp. 93-116.

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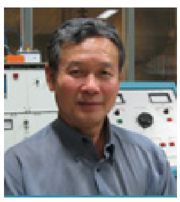

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