Sensing the Partial Discharge in High Voltage Transformers

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***Abstract*- Considering the number of failures in high voltage ' power transformers caused by problems in bushing and winding insulation, it is important to study means for diagnosing incipient failures, to avoid long unavailability periods and its consequences. The aim of this study is to study investigation and measurement procedures, concerning the evaluation of position of partial discharge inside the transformer, in order to evaluate the degree of danger for the equipment. The methodology is based on a noninvasive measurement of partial discharges from the transformer bushing. The position of the partial discharge source is investigated considering the winding model in transformer, and the measurement of the response to the pulses of partial discharge waveform.**

I. INTRODUCTION

Insulation failure is one of the major causes of power apparatus failure. Insulation of power apparatus deteriorates during service period and leads to final failure. This deterioration depends on many factors like moisture content, temperature and partial discharges. Partial discharges are electrical discharges in the high voltage equipment that only partially bridge the insulation. If left unnoticed over a long time period they can result in complete electrical breakdown. Partial discharges can be of different types, produced from different faults and have different discharges. Partial discharges are also considered as symptoms of problems within electrical equipment. Condition monitoring is the process of sensing, identifying and locating partial discharges within electrical equipment[1,2].

Partial discharge pulse extraction is the process of sensing the presence of partial discharges in electrical equipment. Pulse extraction is also known as pulse separation and this process entails locating partial discharge pulses from within the electrical signal. These methods are usually tested on signals created in laboratories which are specifically created to have partial discharge presence in them with less amount of noise in them. The actual grid data however has low frequencies and the signal to noise ratio is much lower than the signals created in the laboratories.

A full discharge would be a complete fault between line potential and ground. The possible locations of voids within the insulation system are illustrated in Fig.1. The other area of PD, is insulation tracking. It usually occurs on the insulation surface. These discharges can bridge the potential gradient between the applied voltage and ground through cracks or contaminated paths on the insulation surface. Besides, surface discharges are readily detected in term of the ultraviolet radiation emitted by the discharges, using remote direction UV detection devices. Partial discharges that occur when there is a stress component present parallel to a dielectric surface are surface discharges. Surface discharges usually occur in bushings, ends of cables, the overheating of generator windings and if a discharge hits the surface from outside.

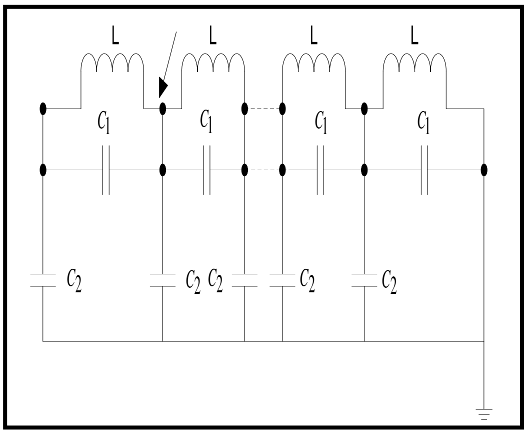

Fig.1 Transformer winding equivalent circuit

II. Partial discharge background

The standard PD detection systems rely on electrical voltage or current pulse detection. Electrical pulse detection equipment is commercially available and can be installed in HV labs. Pulse detection method has its own advantages and disadvantages. The advantages for this method are electromagnetic noise immunity, non-destructive and non-intrusive, high sensitivity sensor, frequency spectrum has high range, sensor installation not affected by shielding construction, robust mechanical strength, excellent electrical resistivity and more cost effective compared to other sensors. However, the disadvantages of this method are signal attenuation, measurement sensitivity affected by temperature, cannot detect PD level, highly complex calibration required, and limited capability when handling equipment with air insulation. Electrical pulse detection has become the common standard in PD detection, however, in recent years, the acoustic detection has gained some popularity and quite a number of research had been done using acoustic methods.

This study proposes that as our knowledge base evolves and matures, and the linkage between the cause and effect of the PD phenomenon becomes more established and better understood, this domain knowledge can be retained and embedded within a knowledge-based system facilitating future PD defect diagnosis and location. A knowledge-based decision support system is proposed as a means of providing a practical diagnostic explanation of PD behavior and defect geometry to end-users. The most important is parameter m, which is the relationship of the capacitive coupling between windings and between windings and neutral.

$$m = \sqrt{\frac{C_1}{C_2}} \quad (1)$$

with C2 denoting winding equivalent series capacitance and C1 equivalent capacitance between winding and transformer core as shown in Fig.1 Determination of equivalent capacitances C1and C2 can be done by using known methods, for example by considering the geometry of transformer (winding, core and tank) and dielectric properties of insulating oil and paper.

III. EXPERIMENT

A specially adapted power transformer, with accessible taps along the windings (figures 2and 3) was used in the tests. Pulses with period of about 70 nanoseconds, for simulating partial discharge along the winding, were injected in the winding taps. In the transformer bushings, those pulses were measured by means of a partial discharge detector. For the measurements, the conventional detection technique proposed by IEC 270 Standard was used, complemented by digitalization equipment.

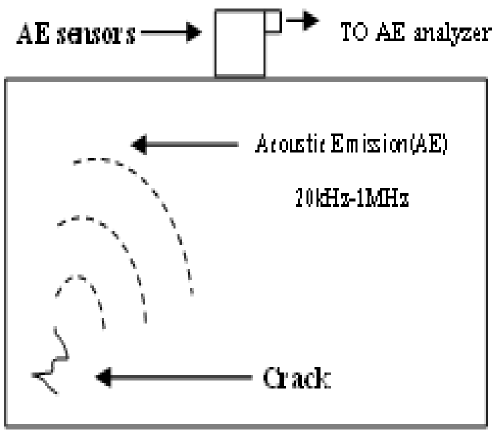

Fig.2 Acoustic Emission System

Acoustic Emission System was used to detect the energy in transient elastic wave form that was emitted from material cracking. Probe was detected to transform energy from sound wave energy to electrical wave. Electrical wave was amplified by amplifier though filter circuit. The signal was analyzed to compare crack track. The signal can be used analyzed in both of time domain and frequency domain. The frequency ranging are 20 kHz to1 MHz. Typical signals are shown in Fig.3.

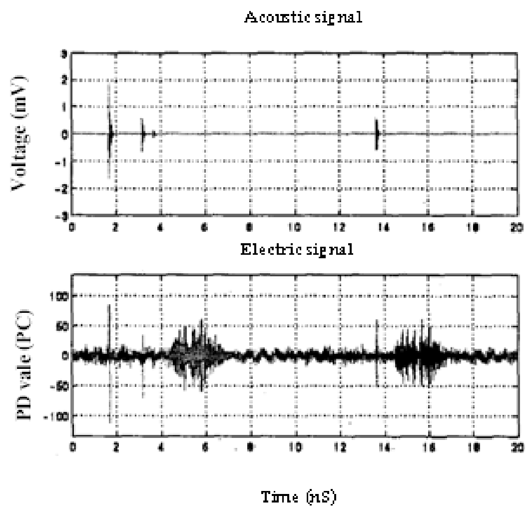

Fig.3 Typical acoustic signal and electrical signal

IV. Results and Discussions

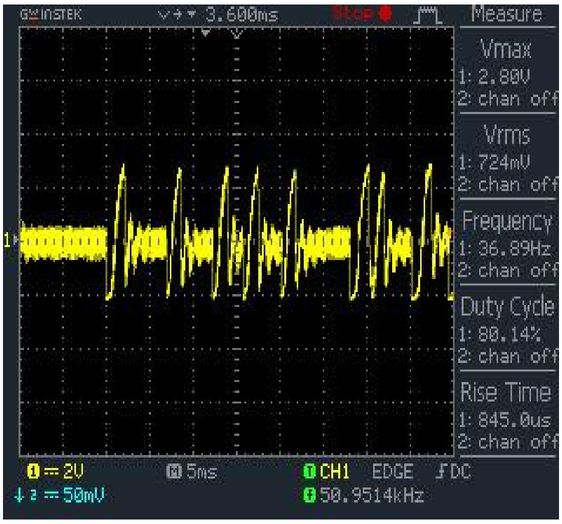

Fig.4.Typical waveform as stainless sparking gap

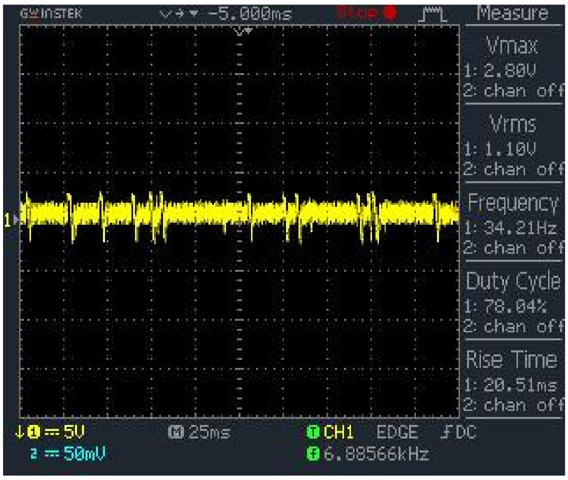

Fig.5.Typical waveform as copper sparking gap

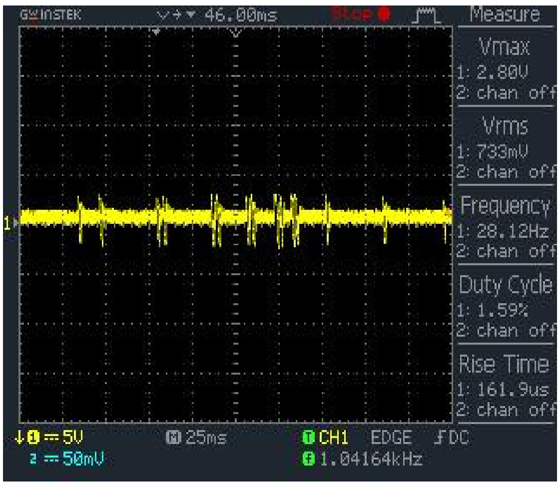

Fig.6.Typical waveform as Aluminum sparking gap

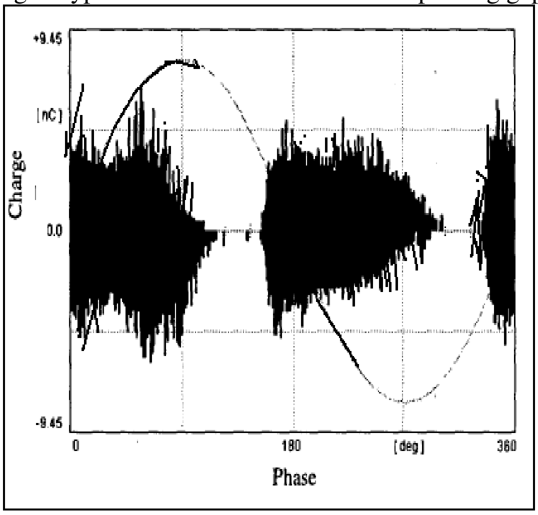

Fig.7 Phase and Position of PD

V. CONCLUSIONS

Both of used and new transformer oil are performed with various conditions. It was found that the partial discharge from used oil type was more appear than the new oil type. The condenser microphone frequencies are ranging 1.02 kHz to 1.06 kHz. The output frequency of stainless sparking gap are 36.9 -37.09 Hz. The results show the trend of good agreement between the theoretical expectations and discharge position. The partial discharge occur along the winding taps same as expected good agreement values, indicating the winding electrical model. The method shows better results for discharges located in regions near the central part of the winding. In this way, this methodology can be used for the location of PDs inside the transformer.

REFERENCES

[1] G. Paoletti and A. Golubev, "Partial discharge theory and technologies related to medium-voltage electrical equipment", IEEE Transactions on Industry Application, Vol.37, No.1, pp. 90-103, Jan/Feb 2001.

[2] F.H. Kreuger, "Partial Discharge Detection in High-Voltage Equipment", Butterworth&Co. (Publishers) Ltd, 1989.

[3] R. Bartnikas, "Partial discharges, their mechanism, detection and measurement", IEEE Transactions on Dielectrics and Electrical Insulation, Vol.9, No.5, pp. 763-807, October 2002.

[4] R.E. Lee, D.E. Fritz, P.H. Stiller, D.F. Shankle, "Prevention of covered conductor burndown on distribution circuits -Arcing Protection devices" IEEE Transaction on PAS Vol. 101 No.8, pp. 2434-2438, August 1982.

[5] M. Washino, A. Fukuyama, K. Kito., K. Kato, “Development of current limiting arcing horn for prevention of lightning faults on distribution lines” IEEE Paper 86 SM 363-6,1986.

[6] R.E. Lee, D.E. Fritz, P.H. Stiller, L.A, Killar, D.F. D.F. Shankle “New device reduces conductor burndown on distribution circuits” Electric Light and Power, pp.52-54, August 1980.

[7] K. Nakamura, P.J. Mckenny, M.S. A.A. Hamman, G. Adams, R. Fernandes, F. Rushen, “Impulse Breakdown characteristic of 13.2 kV. covered conductor insulator/tie configurations” IEEE Transaction on Power Delivery, Vol. PWRD-1 No.4, pp. 250-258, October 1986.

[8] Provincial Electricity Authority, “The Standard of Distribution System Construction”.

[9] M.D. Judd, S.D.J. McArthur, J.R. McDonald and O. Frish, "Intellingent Condition Monitoring and Asset Mangement: Partial Disharge Mointoring for Power Transformer",IEE Power Eng. J., pp. 297-304, 2002

[10] S. Meijer, P.D. Agoris, J.J Smit, MD Judd and L. Yang, "Application of UHF diagnostics to detect PD during power transformer acceptance test" IEEE Int. Symp. Electr. Insul.(ISEI), pp. 416-419, Toronto, Cananda, 2006

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