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Detection and Localization of Partial Discharge in Transformer Oil and Winding using UHF Method

Ammu Anna Mathew, Anoop J R, S. Vivekanandan

***Abstract*: *Transformers are important part in power transmission. One of the serious faults that is seen in transformers is electrical insulation failure. Insulation failure is usually initiated by partial discharges (PD). Due to high voltage stress, the fluid insulation in electrical system or a small solid portion can get dielectric breakdown, this is known as partial discharge and this does not create a space between the conductors. The accurate location of PD is an effective method for assessing the existing electrical insulation condition and preventing future accidents. PD is detected by many methods, but for onsite detection of PD, one of the efficient methods is sensing the electromagnetic waves radiated by the discharge source with a frequency range that can go up to 3GHz. In this technique Ultra High Frequency (UHF) sensors are mounted on the transformer tank to measure these waves. This provides a suitable solution for on-site detection of insulation failure in power transformers*.**

Keywords: Oil, Partial discharge, transformer, UHF method, winding.

I. INTRODUCTION

Power transformers are the most important and expensive piece of equipment in a sub-station. To introduce a new transformer it cost millions of dollars. Mainly a transformer is designed for 2030 years. This is only the normal life cycle, if we do proper maintenance, then the life can be increased to 60 years. The problems mainly transformers face are, their internal conditions will degrade which will increase the risk of failures. Due to the large capital investment and its role in electrical energy network it is important to diagnose and monitor the transformer's working condition. If we are looking for the problem associated with transformers; the common problem that can be seen in the transformers are the insulation problems. The problem associated with insulation is known as Partial Discharge. [1]

The definition provided by International Electro technical Commission, definition of Partial Discharge is "An electrical discharge that makes a partial link in the insulation between adjacently placed conductors ".

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***** Correspondence Author

Ammu Anna Mathew*, Research Scholar, School of Electrical Engineering, Vellore Institute of Technology, Vellore, India, E-mail: ammumelekuttu@gmail.com

Anoop J R, M-TECH in Electrical Machines, APJ Abdul Kalam Technological University, E-mail: anoopjohnson92@gmail.com

Dr. S. Vivekanandan*, Associate Professor, School of Electrical Engineering, Vellore Institute of Technology, Vellore, India E-mail: svivekanandan@vit.ac.in

[2] In most of the cases PD starts with small cracks and voids or inclusions within the solid dielectric at conductor-dielectric interfaces placed in liquid or solid dielectrics or in bubbles within liquid dielectrics. The possible causes are it will lead to an incipient weakness in the insulation introduced during manufacturing or deterioration to the insulation [1]. There is chances for occurring Partial Discharge in the sharp points present in the transformers mostly in the high voltage side Discharges.

So detection of Partial Discharge is an important factor in the case of electrical network. So Partial Discharge detection can be done in many ways. There are methods such as Electrical and Non electrical Methods for the detection of Partial Discharge. The importance is in many methods they can be only done with the help of a laboratory set up. But the transformer placed in a yard, we can detect and inspect partial discharge in that by onsite [2]. For that the best method for sensing partial Discharge in onsite is UHF method. UHF technique offers the possibility to locate and identify the Partial Discharge Source [3]. During a partial Discharge pulse, electrons initially at rest are stripped from atoms and are accelerated by electric field (increasing current) and within a short time it comes to rest that is current is decreasing. PD means it is sudden increase of a single discharge current. The single discharge current can be expressed as

$$i(t) = \frac{I}{T} t e^{(1-\frac{t}{T})} \quad (1)$$

Where I,T and t are the peak current ,rise time of current pulse and time [3]. The total amount of charge is q is;

$$q = eIT \quad (2)$$

The value of e is 2.7183 and the graph can be plotted.

II. TYPES OF PARTIAL DISCHARGE

There are mainly four types of Partial Discharge such as Internal Discharge, Surface Discharge, Corona Discharge and discharge in electrical trees [3].

A. Internal Discharges

This mainly occurs in media of low dielectric strength such as gas filled or oil filled cavities show in fig.1 [3]. Partial Discharge occurs or start at any particular voltage level. In this the voltage at which discharge take s place depend on the stress. That means discharge depends on the stress and breakdown strength of cavity. The stress depends on the electric field applied and the cavities shape.

The breakdown strength of the cavity is determined by the dimension and the gas present in it.

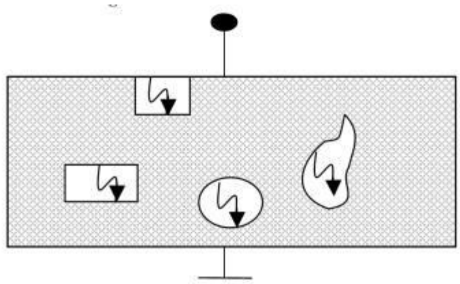

Fig.1. Internal Discharge

B. Surface Discharge

Surface discharge occurs when the stress component is parallel to the surface. The surface is dielectric; the occurrence of this discharge will cause problems to bushings and end of cables.

C. Corona Discharge

Partial Discharge cause problems to the sharp points present in the equipment there causing is corona. Corona can pollute the oil and cause decrease in breakdown stress. Commonly the sharp point at high voltage side is affected but there are chances to occur at the sharp edges at the earth potential. If we take the sulphur hexafluoride gas circuit breakers, if it contains any sharp points if it cause problems it may affect human beings also.

D. Discharge in Electrical Tree

Electrical trees are formed from the defects in the insulation materials. As the electrical tress are formed and become large the stem and the larger the branches became hollow. Discharge occurs in these hollow spaces and it will lead to an internal discharge.

III. DETECTION METHODS

The Non electrical Measuring methods include ultrasonic method, Light effect, and Gas chromatography. [4]

A. Gas Chromatography

Due to the oil space charges and discharges, breakdown gases are produced. By the comparison and quantity of produced gas one will be able to determine what type of partial fault detection occurred. The main gases present in this are Hydrogen and Methane. The specialty is it is cost effective. The main advantage for using this is cost effective and these all are chemicals so it has good sensitivity. But gas chromatography gives a qualitative analysis results. We didn't get a qualitative report by doing this test.

B. Ultrasonic Method

When a partial discharge or problems takes place, there will be a production of Ultrasonic sound waves. The frequency range should be in between 20 kHz to 100 kHz. These are produced due to Partial Discharge, arching or by corona. The frequency of ultra sounds will vary for each type of problem. For partial Discharge it is in the range of 20 kHz to 30 kHz. For corona and arcing it is 40 kHz. The important part is ultrasound waves can penetrate any opening or seals so we can identify the sound waves. So without removing the seals or the protective covers we can do measurements. Electrical Measuring methods include electric pulse detection method and UHF detection method.

a. UHF Detection

UHF method is the best way for testing the partial discharge in power transformer. The all other methods has the problem such that all are done in a laboratory set up. It is very difficult to test a transformer in onsite. For the discussed methods we have to de-energize the transformers for detecting Partial Discharge. But UHF is new method for testing Partial Discharge in onsite without de-energizing [5]. The UHF method is now used in gas insulated substation for testing of high voltage onsite commissioning test and condition monitoring during service. The specialty of this is when Partial discharge occur in transformers it cause multiple resonance in transformer tank. Due to the high speed Partial Discharge pulse it will result in an electromagnetic spectrum enabling certain resonances and these produced resonances and these produced resonances are in ultra-frequency range. The range can go up to 3 GHz. For testing this wave form we have to use sensors. UHF method provides good sensitivity and the great advantage of this technique is the high signal to noise ratio. If the sensed signal generated by Partial Discharge is transmitted to a spectrum analyzer, it can provide a good distinguished from the noise. We can provide UHF sensor externally or internally [6]. For the placing of sensors we can provide it in the dielectric apparatus. Dielectric windows can be built in new transformers but for the existing ones we can provide this because it is very expensive. So for the existing ones we can provide sensor to the transformer drain valve.

b. Design for internal sensor

The size of the drain valve varies with the transformers. For each manufacturers and specifications it will vary. For the design purpose it can consider that a drain valve of 2 inch and the antenna for that has to be designed [6]. The frequency range for detection Partial discharge was 300 MHz to 1.5 GHz. The ideal type of antennas for this purpose is low periodic or spiral antenna. According to specification of antenna monopole antenna has length range similar to the length of the drain valve. The length 100 mm is the acceptable as the comprisable antenna structure. The monopole antenna has good broadband characteristic from the computer stimulation results for different antenna structures can give the difference of each type of antenna structure. The selected antennas for the stimulation are straight wire, zig zag wire, flat plat and conical wire as shown in fig 2 [6]. From the result we get an idea about the effective area of different types of wires. From the computer stimulation the straight wire and the zig zag models appear to distribute the current along its length and they should receive better signals and the flat plate antenna has poor performance in comparison with other models. The result is shown in fig. 3 [6]. Result of the effective area and the frequency of the monopole antenna structure will give better idea about which will exhibit the smallest effective area.

In the evaluation of the antenna structures, evaluation

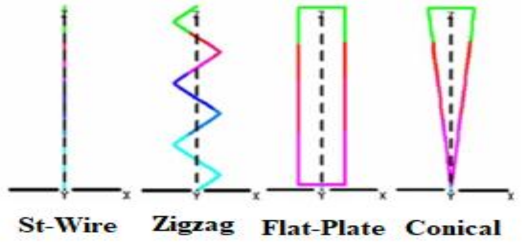

Fig.2. Antenna Structures

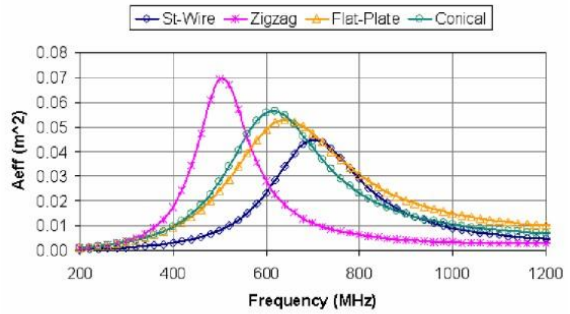

Fig.3. Comparison of Effective Area versus frequency

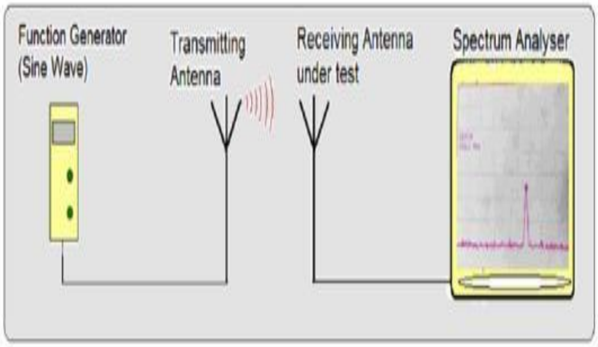

Fig 4. Frequency response test set up

is done in two ways: evaluation of the antenna performance in air and in oil.

In the evaluation of antenna purpose, behavior in air it can be done by frequency response test set up. That is a sine wave from the function generator is fed to transmitting antenna. By using a receiving antenna it is received from it and it is transmitted to a spectrum analyzer as shown in Fig.4 [6]. In the evaluation of behavior in the oil dielectric breakdown test for this there was an oil dielectric breakdown. For this there was an oil dielectric breakdown test used. This test consists of two spherical electrodes in a small volume of oil [7]. By changing the position of electrodes different types of partial discharge in oil was produced. The resultant electromagnetic pulses were transmitted to the antenna through air to the spectrum analyzer and the output can be observed from this as shown in fig. 5 [6]. Before connecting the spectrum analyzer it is connected to a 25 dB booster amplifier.From the result it is seen that the majority of the designs performed sustainably without too much differences in their gain. From the responses obtained conical monopole antenna was best design appeared. It has gain output which is slightly higher than the straight wire type. In the oil nature select a 66/11 kV, 10 MVA transformer and providing a 25v pulse signal as shown in fig. 6.

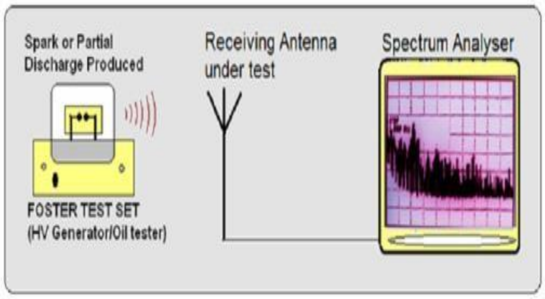

Fig.5. PD source test set up

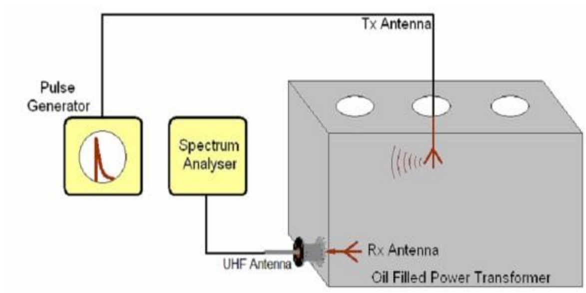

Fig.6. Evaluation in oil using a pulse generator

Fig.7. Insertion of antenna

Fig 8. Sensor placed in dielectric window

The testing- antenna was provide in the tank and it is connected to a spectrum analyzer. On computing the test results of the different antennas conical antenna perform the best result.The best result obtained on conical antenna which was encased in epoxy resin to increase its mechanical strength. Then antenna was placed in the drain valve of the transformer. The insertion of the antenna was shown in the fig. 7 [6].

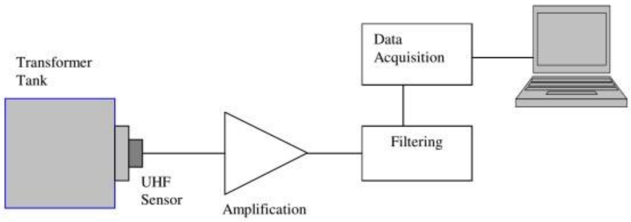

Fig. 9. Typical UHF PD Monitoring System

The external sensor can be placed externally at the dielectric window of the transformer, as shown in fig. 8 [8]. The connection of sensor is given to amplifier that one or more sensors are connected and their output is given to the amplifier for amplification and it is given to a filter circuit for the elimination of the harmonic element from the data [8] Block diagram representation is shown in fig. 10. [6] Then the output of the field is given to a Data acquisition system and it is given to the computer and the results are monitored.

IV. LOCATING PARTIAL DISCHARGES SOURCE

Locating the Partial discharge source is an important one in protection of transformers. That is to locate the exact position of the partial discharge. We are doing this to connect two or three sensors to the transfer unit [8]. The three time differences (Δt_{12}, Δt_{31}, Δt_{23}) for sensors are recorded. Propagation speed of electromagnetic waves is *V*. Then from the three equations we can locate the location of PD source.

V. RESULT AND DISCUSSION

The main defect in transformers is partial discharge and it leads to whole power loss. Here we can understand that partial discharge mainly occurring by various means such as internal discharge, surface discharge, electrical tree discharge or discharge due to corona effect. These problems can be identified and solved by proper inspection periodically. In the discussion with transformer manufactures the conclusion obtained is the testing for partial discharge is mainly done at the manufacturing time, after installing there is no proper inspection. The methods such as gas chromatography and ultrasonic technique can be used for checking but from the analysis we came to the conclusion of using UHF detection is best. By using this technique the main advantage is it is portable and can be tested at the installed locality.

VI. CONCLUSION

Partial discharge is one of the most important defects occurring in the transformers. Partial discharge will lead to the problems in transformer insulation nowadays only at the manufacturing time all the transformers are testing after that most of the manufacturers are not ready to check the transformers working condition because of the need for a laboratory set up. UHF method will be a good method that can resolve the above mentioned problems by using this onsite detection can be carried out. The best way for placing UHF sensor is also identified.

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AUTHORS PROFILE

Ammu Anna Mathew received her B.tech degree in Electrical and Electronics Engineering from Kerala University, India, in 2010 and M.E. degree in Applied Electronics from Sathyabama University, Chennai, India, in 2013. She worked as an Assistant Professor in Department of Electrical and Electronics Engineering at Lourdes Matha College of Science and Technology, Trivandrum, India. She is currently pursuing the Ph.D degree with School of Electrical Engineering from VIT University, Vellore, India. She is a life member of ISTE. Her current research interests include flexible wearable biosensor fabrication.

Anoop J R, received B.tech degree in Electrical and Electronics Engineering from Kerala University, India, in 2015 and M-TECH in Electrical Machines from APJ Abdul Kalam Kerala Technological University in 2017. He has various publications in International and National Journals related to solar power and booster circuits. He is also a member of the International Engineers Association.

Dr. S. Vivekanandan received his B.E. degree in Electronics and Instrumentation from Anna University, India and M.E. degree in Process Control Instrumentation from Annamalai University, India, in 2002 and 2004, respectively, and the Ph.D. degree from Vellore Institute of Technology, Vellore India, in 2015. He is currently working as Associate Professor in School of Electrical Engineering, VIT University,Vellore. He has authored more than 30 research articles which is published in different reputed International Journals. He is also a faculty coordinator of ISA Student Section District 14. He received best mentor award from ISA in 2017 from USA. He has also filed a patent on IoT based biosensor for chronic disease diagnosis. He is also a life member in IEEE, ISA and IETE. His current research interest includes biomedical devices and development of cascade control systems for biomedical applications.