Comparison Study of Sensitivity Between Three Sensors to Detect Partial Discharge on Natural Palm Oil

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Abstract: High-voltage transformer is the most critical and expensive component in a power system network in order to ensure the stability of the system. Partial discharge (PD) detection is a technique widely used for high voltage equipment insulation condition monitoring and assessment. Many researchers have used acoustic emissions (AE) at the vicinity of the discharge zones to detect PD. This paper compares the sensitivity of multimode fiber optical sensor step-index (MMF-SI)and multimode fiber optical sensor graded-index (MMF-GI) with piezoelectric film sensor (PZT). The fiber optical sensor (FOS) and PZT sensors were immersed in an oil tank fitted with two steel electrodes which were connected to different values of high voltage source. The experimental results show that three sensors have peculiar characteristics for the detection of AE and could be used as alternative detection devices.
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1. Introduction

PD has attracted much attention due to the high financial outlay needed to repair the damage it causes. A high voltage network system (HVNS) has a number of heavy transformer installations which continuously work to distribute electricity to substations. Stability of any power system network determines the life time of the high voltage equipment installed in the network. The expensive components of the high voltage equipment are the power transformers which are expensive and can incur high repair costs. Each fault on a single unit of the heavy transformer installations has a huge financial impact on the maintenance cost of the installations. Hence, continuous operational monitoring is very important. Failures due to PD cause deterioration of the HVNS performance and result in breakdown, fires and damage to the system. PD detection technique is widely used for high voltage equipment protection, insulation condition monitoring and general high voltage network assessment. Hence, a good understanding of PD mechanisms, its characteristics and development processes are important. Insulation of the HVNS has a high risk for dielectric stability when PD occurs. Therefore, continuous measurement and monitoring of PD is important so that preventive actions can be taken to avoid equipment damage. At the present moment, modern testing procedures are available to monitor high voltage insulation in the HVNS. There is now a new trend to monitor high voltage insulation using sensitive predictive diagnostic tools. PD results in many different physical phenomena such as electromagnetic emission (in the form of radio wave, light or heat), acoustic emission (in the audible and ultra-sonic ranges), ozone formation and nitrous oxide gas discharges. PD occurs when the insulation of HVNS deteriorates or degrades. For this reason, it has been used as a tool to predict and detect possible insulation failure of the system (Tenbohlen, 2008). The frequency and intensity of PD are the main quality criteria to estimate the life span of the HVNS. In this paper comparison study of sensitivity between three sensor have been described.

2. Acoustic and optical methods for PD detection

2.1 The Acoustic Method

Acoustic method takes advantage of the fact that all PDs result in localized and nearly instantaneous release of energy, appearing as a small 'explosions', which are point sources of acoustic waves. When the wave propagates in all directions, it can be detected and analyzed by a suitable sensor with the help of data acquisition equipment. One of the most obvious advantages of acoustic PD detection is that it is a real-time and on-line method. In the acoustic method, the detector locates the site of PD by studying the amplitude attenuation or phase delay of the acoustic waves. PD generates mechanical wave (acoustic wave) which is propagated in a radial manner along the medium from the site of discharge. The acoustic wave is produced by the explosion of mechanical energy due to the vaporization of material inside the transformer tank forming a pressure field (Smith, 2004), (Lundgaard, 1993), (Tilman, 2000), (Harrold,1979), (L. M.,1992).

The acoustic wave which travels in the transformer oil can be detected using acoustic sensors. For the acoustic method the acoustic wave is capture and detected using piezoelectric (PZT) acoustic sensors. PZT sensors are normally placed inside the oil tank to reduce interfering noise in the acoustic wave and to minimize the attenuation of the received signal (Wang, 2007). The acoustic method can be used to estimate the location of the source of PD signals by measuring the time of arrival of the acoustic wave with the help of sensors at multiple locations.

The acoustic method provides information regarding the strength and position of PD in real time. Due to the sensitivity of the acoustic method, interfering environmental noise can be pick up easily. Environmental noise can cause problem in the detection of the acoustic signal (Howells,1981), (Eleftherion, 1995).

2.2 The Optical Method

Optical method using optical fiber sensor can measure a wide range of chemical and physical parameters due to its small size, high sensitivity, light weight, high frequency response and its immunity to electromagnetic interference. Optical fiber acoustic sensors have been used in many applications, such as underwater hydrophones, civil structure non-destructive diagnosis, material property analysis (K. A. M.,1995), traffic monitoring, vehicle detection and PD detection (Furstenau, 1997). Optical detection technique makes use of fiber optic intrinsic interferometers such as Michelson interferometers or multimode fiber and fiber optic extrinsic interferometers such as Fabry–Perot interferometric sensors. It also uses Mach–Zehnder interferometer sensors which have been known to suffer from fringe fading problems caused by random polarization rotation. Fabry–Perot interferometric sensors are more compact than Michelson and Mach–Zehnder fibre sensors, and therefore achieve virtually single-point measurement. Until now, use of optical method for PD detection has limitations due to low measurement sensitivity of sensors.

3. Experimental Work

In this work, PZT and two multimode optical fiber sensors FOS (step-index and graded index) were used for PD detection. All these sensors were immersed in oil as in Fig. 1 High Voltage discharge which simulates PD produces acoustic emission between two steel electrodes which creates interference in the light passing through the optical fibre connected via PZT and two FOS to three channels of the multichannel oscilloscope. The simulated PD is generated using 5 kV, 10 kV and 15 kV power source in two round shape steel electrodes having 5 mm gap. A light source from tungsten halogen (wavelength 350-2200nm) is sent through an optical fiber. Output from two FOS is picked up by the photo detector (BPX65) which is connected to the optical fiber by means of a fiber adapter. The optical fiber used is a multimode (graded index and step index) fiber having core diameter of 50 µm. The cladding diameter of multimode fiber is 125 µm with coating layer plus soft coating such as acrylate based elastomers. The acrylate material has narrower band pass sensitivity to ultrasound of AE which gives good result in transformer PD detection. FOS is connected to a photo detector which converts light to electrical signal which is enhanced using low noise amplifier. The PZT sensor is placed inside the oil tank at the same distance from the electrodes as multimode fiber sensor, FOS. This distance (between the sensor and PD source) is set at 4 cm.

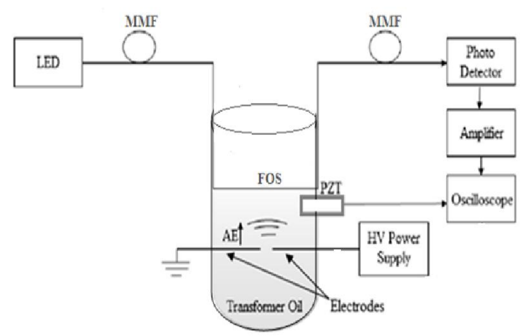

Figure1. Schematic setup for detection of acoustic emission phenomenon.

4. Results and Discussions

In this experiment, the sensitivities of the three sensors, MMF- SI, MMF- GI and PZT,were compared using the characteristics of responses (captured by the multichannel oscilloscope) caused by AE generated by PD. When electrodes are ignited by high voltage (15 kV), arc discharge is observed as ripple waves arriving at all sensors at the same time and in the same phase. The minima of the high voltage peaks of the acoustic signal picked up by the three sensors are different. Typical acoustic signals detected by both FOS (MMF-SI, MMF-GI) sensors and PZT are shown in Fig. 2. The distance of PZT sensor was 5cm while for FOS it was 4 cm. The velocity of sound in transformer oil is around 1.5 mm/µs. The amplitude of the sensors are shown in Fig. 3 Based on experimental results it could be concluded that the multimode optical fiber has the ability to act as acoustic sensor with sensitivity higher than PZT sensor. The frequency Domain Analysis the Fast Fourier Transform (FFT) calculation of stored data for all sensors are shown in Fig. 4. In Fig. 4. FFT spectrum of sensors of time domain waveform (Fig. 2). PZT sensor has a value of -62 dB with noise level of -84dB indicating that the resolution of signal is 22 dB above the noise floor. MMF-SI sensor has a value of -63 dB with noise level of -82 dB indicating that the resolution of signal is 19 dB above the noise floor. While the MMF-GI sensor has a value of -66 dB with noise level of -78dB indicating that the resolution of signal is 12 dB above the noise floor. The resolution of the sensors at different voltage have been shown in Table 1.

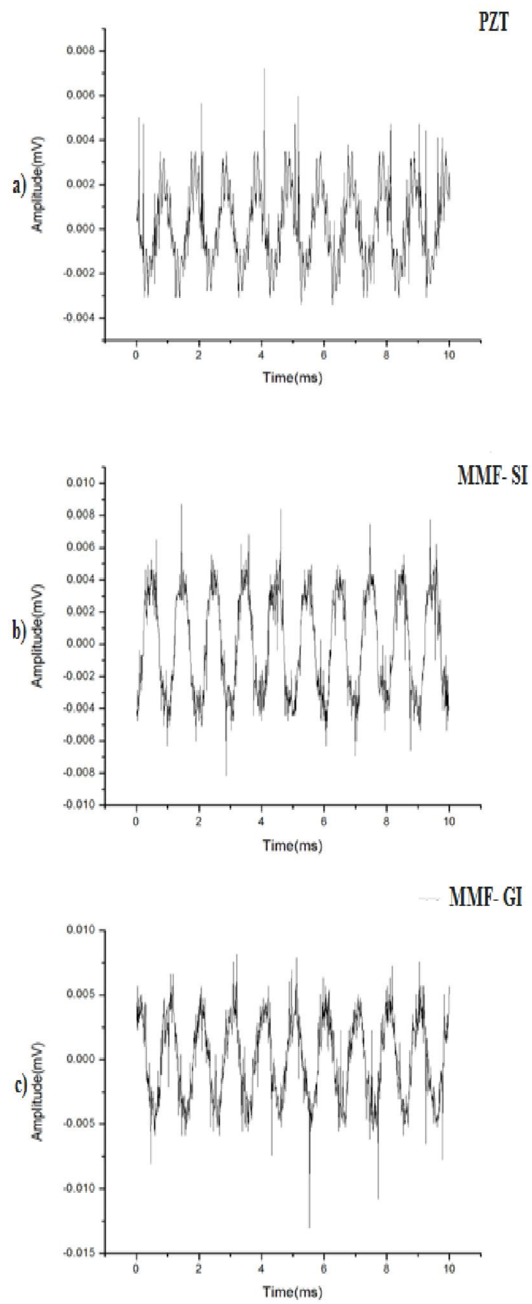

Figure 2. Typical waveform of PD acoustic signal detected by MMF- SI, MMF-GI sensor and PZT.

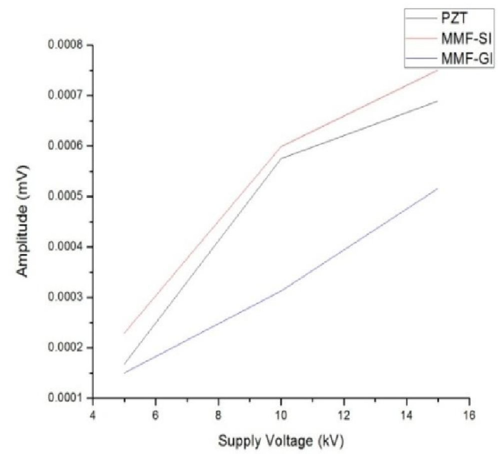

Figure 3. Shows the amplitude of three sensors at different voltages.

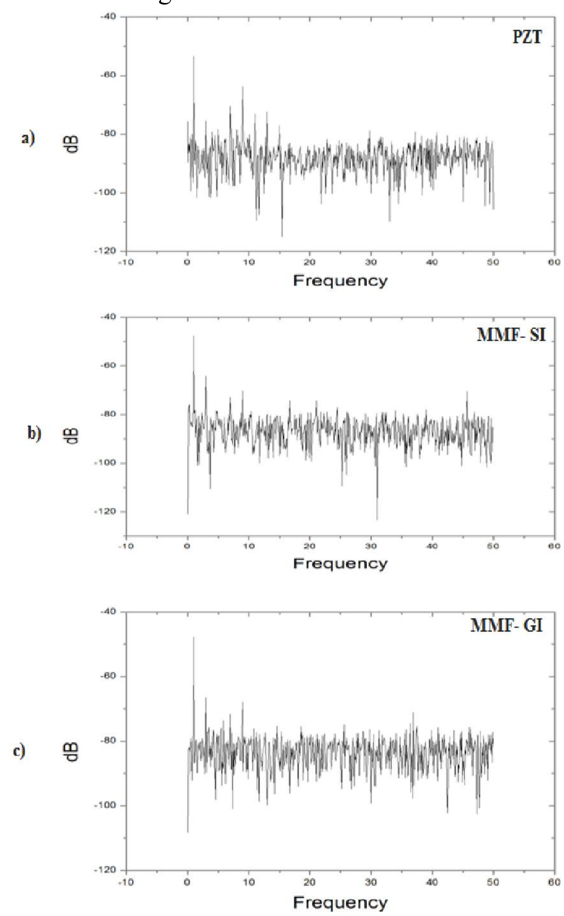

Figure 4. The FFT spectrum of output signal for FOS and PZT

Table 1. Shows the resolution of the three sensors at different voltage

S.	PZT			MMF- SI			MMF- GI		
V.	Va.	N.	R.	Va.	N	R.	Va.	N.	R.
5 kV	-75	-90	15 dB	-72	-84	12 dB	-74	-80	6 dB
10 kV	-64	-86	22 dB	-69	-82	13 dB	-70	-78	8 dB
15 kV	-62	-84	22 dB	-63	-82	19 dB	-66	-78	12 dB

5. Conclusin

Sensitivity of FOS and PZT for acoustic sensing were ascertained and measured. The data of all sensors were analyzed in time domain and compared through peak analysis. The results suggest that the multimode optical fiber was able to act as acoustic sensor with large wide band of signals. The time domain analyses show that FOS has been successfully used to capture acoustic signal with high amplitude. The FFT spectrum of MMF-SI have shows the higher resolution at different voltage. These experimental results are interesting and suggest that the three sensors have peculiar characteristics for the detection of AE and can be used for any PD detection requirements**.**

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