DEVELOPMENT OF CAPACITIVE SENSOR TECHNIQUE FOR PARTIAL DISCHARGE DETECTION IN HIGH VOLTAGE CABLE

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ABSTRACT

The phenomenon of partial discharge (PD) is a hidden activity that happens in insulators due to stresses of high voltages. Furthermore, due to aging effect it may lead to breakdown of insulation, and it is also a main cause of severe failure of electrical appliances and instruments installed in the grid power station. The earlier detection of PD can save a huge amount so its detection and localization is important. In current scenario, the conventional techniques of detection for partial discharges are expensive and have many drawbacks regarding its accuracy. In this study, a simple capacitive sensor technique has been developed for the detection of the partial discharge phenomenon in high-voltage cables. The capacitive sensor could be of any size and shape that could be easily mounted on the high-voltage cables. The designed capacitor was mounted on high-voltage cable, and it was capable to pick the partial discharge signal successfully through the high-pass filter. The partial discharge data was captured along with high-voltage discharge parameters using digital oscilloscopes. The data was then processed and analysed in the time domain to deduce the information about the level of partial discharge. The results show that the PD signal is prominent in the range of 100 nsec, which has many peaks similar to oscillatory motion than the other explored ranges. The capacitive sensor was also used for the detection of high-voltage signal and compared with the high-voltage probe signal. The attenuation factors for the four sensors have been determined and compared. The results show that as the high voltage increases the attenuation factor decreases and in some cases the attenuation curve has a crinkle for the sensors, which may be due to change of position on the cable. The results show linear behaviour in the explored range that suggests the capacitive sensor might be useful for the measurements of high voltage without high-voltage probe. In the comparison of the attenuation factors without high-pass filter results show that attenuation factor decreases as the high-voltage increases but for two samples of sensors, the trend was very close to linear behaviour. These results suggest that capacitive sensor could be used as an alternative cost effective approach for the detection of both high voltage and monitoring the PD signal in high-voltage cables.

ABSTRAK

Fenomena discas separa (PD) adalah suatu aktiviti terlindung yang berlaku dalam penebat di sebabkan oleh bebanan voltan tinggi. Ia juga di sebabkan kesan penuaan yang boleh menjurus kepada kegagalan penebat dan menjadi punca utama kegagalan teruk kepada perkakasan elektrik dan instrumentasi yang di bekalkan kepada stesen kuasa grid. Untuk senario ini, penentuan discas separa secara teknik konvensional adalah sangat mahal dan kebanyakannya mempunyai masalah tentang kejituannya. Dalam kajian ini suatu kaedah mudah sensor kapasitif telah di bangunkan untuk menentukan fenomena discas separa di dalam kabel bervoltan tinggi. Sensor kapasitif dari pelbagai saiz dan bentuk, mudah di pasang pada kabel bervoltan tinggi. Kapasitor yang direkabentuk apabila di pasang pada kabel voltan tinggi, boleh mengesan isyarat separa discas dengan berkesan melalui tapisan laluan tinggi. Data discas separa dikumpul bersama parameter discas voltan tinggi dengan menggunakan osiloskop digital. Kemudian data ini di proses dan di analisa dalam domain masa untuk menentukan informasi mengenai tahap discas separa. Keputusan kajian menunjukan isyarat PD adalah sangat ketara di dalam julat 100 nsaat, yang mana terdapat banyak puncak seperti pergerakan osilatori daripada julat lain yang di kaji. Sensor kapasitif juga di gunakan untuk menentukan isyarat bervoltan tinggi dan di bandingkan dengan kuar isyarat voltan tinggi. Faktor faktor pengecilan untuk keempat-empat sensor telah di kenalpasti dan di bandingkan. Keputusan menunjukan apabila voltan tinggi meningkat faktor pengecilan menurun dan dalam kebanyakan kes sensor sensor mengalami kedutan pada lengkung pengecilan, dimana ia adalah di sebabkan pertukaran kedudukan pada kabel. Keputusan kajian menunjukan sifat linear dalam julat di kaji mencadangkan sensor kapasitif dijangkakan sangat berguna untuk mengukur voltan tinggi tanpa kuar voltan tinggi. Di dalam perbandingan di antara faktor pengecilan tanpa tapisan laluan tinggi, keputusan menunjukan faktor pengecilan berkurang apabila voltan tinggi meningkat tetapi untuk dua sampel sensor, sifatnya hampir sama seperti sifat linear. Keputusan keputusan ini menunjukan sensor kapasitif boleh di gunakan sebagai pendekatan berkesan kos alternatif untuk mengesan kedua-dua voltan tinggi dan pengawasan isyarat PD dalam kabel voltan tinggi.

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LIST OF SYMBOLS AND ABBREVIATIONS

V	-	Volt
HV	-	High Voltage
PD	-	Partial Discharge
AF	-	Attenuation Factor
V_O	-	Output Voltage
V_i	-	Input Voltage
AE	-	Acoustic Emission
PZT	-	Piezoelectric
OFS	-	Optical Fiber Sensor
I	-	Ampere
DBD	-	Dielectric Barrier Discharge
LLD	-	Low Level Discriminator
ADC	-	Analogue to Digital Convertor
HFCT	-	High Frequency Current Transformer
Hz	-	Hertz
DGA	-	Dissolved Gas Analysis
GIS	-	Gas Insulated Substation
UHF	-	Ultra High Frequency
Sec	-	Second
mm	-	Millimeter
cm	-	Centimeter
µm	-	Micrometer
nm	-	Nanometer

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Partial discharge (PD) phenomenon is one of the reasons that happen in high voltage appliances and lead to failure of power transformer, leading to expensive repair and power outage. An acoustic emission (AE) phenomenon also happens near the discharge zone that can be used to detect PD. The sensors are dipped in the oil tank fitted with two steel electrodes which are connected to high voltage source. The experimental data of sensors and high voltage discharge parameters are recorded by the recording source. The main problem of high-voltage power equipment is degradation of isolation [1]. The main reason of degradation is partial discharge (PD) phenomena [2]. The PD is hidden activity of small electrical spark present in insulation as a result electrical breakdown occurs in the cable or equipment. The PD phenomenon occurs when the electric field exceed local ionization threshold of dielectric insulation [3]. In the PD phenomenon energy is emitted in the form of electromagnetic emission, radio waves, light and heat and also as acoustic emissions (AE) in the audible and ultrasonic ranges. The ultrasonic pressure waves can be used to detect the intensity and location of PD signal. The frequency band of discharge in oil has wideband range (10-500 kHz). PD signals have been detected and located using piezoelectric (PZT) ultrasound sensor for typical frequency about 150 kHz mounted on tank wall. The main problem of PZT sensor, it suffers from degeneration of signal-to-noise ratio due to environmental noises such as Electromagnetic interference. Another problem related with externally mounted PZT sensor is multi-path signal, due to the ultrasound signal transport from the source to the sensor along different speed and different path, this mean low level of precision is achieved. Therefore, the sensor must be located inside tank of transformer, close to PD source to overcome to this problem [4, 5]. This sensor which is electrically non-conductive, chemically inert, passive and small in size is the best choice for the detection of PD phenomenon. The optical fiber sensor (OFS) has been used which has some advantages like it has a simple structure, low power consumption, small size, light weight, immunity to electromagnetic interference noises, high sensitivity, corrosion resistance, low prices and large wideband. These advantages make OFS perfect candidate for acoustic detection. The use of interferometric OFS inside transformer can give very high level of sensitivity that can be achieved due to PD phenomenon [6, 7]. Recently single-mode OFS has been used based on interferometric measurement of AE inside transformer [8, 9]. The single-mode optical fiber sensor has high sensitivity by using long fiber in sensing arm, but the frequency response is a drawback in this case.

In this project a capacitive sensor would be developed for the diagnostic of PD phenomenon. Different samples of the capacitive sensor would be developed for the calibration purpose using metal foil. These sensors would be used for partial discharge detection in high voltage cable. The experimental data of both sensors and high voltage discharge parameters would be collected using digital oscilloscopes. The data of experimental results would be then analysed using origin pro software.

1.2 Problem Statement

As mentioned above, the convention techniques of detection for partial discharges are expensive and have drawbacks in accuracy. In this study capacitive sensor technique would be designed for the detection of partial discharge phenomenon in high voltage cables. Generally, the commercial high voltage probes are frequency sensitive and their insulating material is deteriorated after long time operation. This capacitive sensor would provide an alternative solution for the detection of high voltage instead of high voltage probe as well as the detection of partial discharge phenomenon.

Research Objectives

This study would focus on the following objectives:

1. To Design and develop of capacitive sensor for the detection of partial discharge.
2. To conduct an experiment and calibrate the sensor for high voltage use.
3. To acquire data of high voltage discharge using capacitive sensor.
4. To characterize the Partial discharges through waveform study.

1.4 Scope of Research

The scope of this work is described below:

This study would remain confined in the high voltage range up to 1-10 kV cables. Aluminium metal foil would be used as plate material of the capacitive sensor and commercial available polymer sheets would be used as spacer material. Breakdown voltage of insulating sheets would be determined and electrical properties of the sample material would be determined through IV characteristics.

1.5 Significance of the Study

As mentioned above, the convention techniques of detection for partial discharges are expensive and have drawbacks in accuracy.
The capacitive sensor technique can also be used instead of high voltage probe. Generally, the commercial high voltage probes are frequency sensitive and insulating material is deteriorated after long time operation.

The capacitive sensor technique is inexpensive as the material of sensor is inexpensive and techniques is safe and provide total isolation from the line high voltage.

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