An Application of the Novel Techniques Detecting Partial Discharge Employable to GIS Using Optical Sensor

Cheol-Hwi Ryu†, Seung-Yong Jung*, Ja-Yoon Koo* and Man-Seung Yeon**

Abstract – A novel technique has been proposed and related experimental works have been performed in order to detect the partial discharges and the location of the possible defects introduced into the Gas Insulated Switchgear. For this purpose, a prototype HY Pockels sensor has been developed and then employed in order to investigate its field applicability for finding the location of the defects using a 170kV GIS mock-up. Our proposed sensor enables us to measure the electric field variation due to the PD occurrence. In addition, the different PD patterns are observed, which might be dependant on the location and the distance of the sensor with respect to the PD source. Throughout this work, its linear response has been proved to be admissible as a function of the applied voltage. And also the position of the PD source might be distinguished by comparing the PD patterns.

Keywords: Pockels, Partial discharge, GIS

1. Introduction

For more than two decades, various techniques have been employed in order to detect partial discharges occurring inside power apparatus. They have been based on the conventional direct detecting systems by means of electrical or ultrasonic sensors. For the former, there are different types of current measurements using neutral lines of the transformer in order to detect the current pulses accompanied by the PDs generated at the bushing. In addition, ultrasonic sensors conglutinated on the enclosure of power apparatuses are used for the latter. Regardless of their acceptable sensitivity, certain technical inconveniences have been reported as follows: multistage amplification, large volume, external noise susceptibility, high price, and low on-site applicability.

On the other hand, optical measurement techniques are currently used globally in the field of high voltage engineering due to the following advantages: immune to external EMI noise and broad band response of the Pockels cell covering from DC to GHz. However, the reliability of several proposed techniques has not yet been approved regarding electric field measurement and PD detection inside the large high power apparatus [3-7].

In this regard, an optical measuring system with the Pockels sensor has been proposed, based on electrio-optic effect, in order to measure the distortion of the electric field that could take place inside the large power apparatus due to the PDs from various defects. For this purpose, the variation of the electric field due to the corona discharge, generated from the needle electrode on the conductor in the GIS, is detected by our proposed optical sensor.

Throughout this work, it is likely that the variation of the electric field due to corona discharge could be measured by use of the Pockels sensor.

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2. Experimental Setup

For this experimental work, the general view of the measuring system using the laser is described in Fig. 1, where a needle electrode was attached on the conductor surface in order to simulate the protrusion that could be formed on the conductor in a real scaled 170kV single-phase GIS mock-up. The application of voltage was realized by use of the H.V Test transformer (Hipotronics, AC 100kV) to generate corona discharges at the tip of the artificial needle with its length of 60mm. Different radiuses of curvature (5㎛, 10㎛, 100㎛, 200㎛) have been employed to choose an appropriate radius but little influence on the PD magnitude has been observed. And thus, with fixed radius curvature of 100㎛, only the effect of two important parameters has been considered such as the distance from the needle and the direction of the location of the sensor. All the data presented in this work are mean values after 30 times of repetition.

In order to investigate the possibility to detect the PD, the response of the sensor to the applied voltage was compared with that of other conventional methods using

CT. Thus, artificially generated partial discharges have been detected at the same time by our optical sensor as well as by the commercialized CT (Power Diagnostix, 20MHz ~ 25MHz) according to IEC60270. The former was installed inside the test mock-up of which the ground wire is connected with the latter. All the tests have been done without any SF6 at the indoor laboratory.

The HY-Pockels probe sensor, shown in Fig. 2, consists of mainly three parts, assembled into one piece by the UV curing epoxy, such as a y-cut LiNbO3 crystal (5×5×5mm cubic shape) for the transverse-mode application, a polarizer and an analyzer. The Linear Polarized Laser, launched into the Pockels sensor through the single mode optical fiber, is modulated by the electric field applied on the sensor.

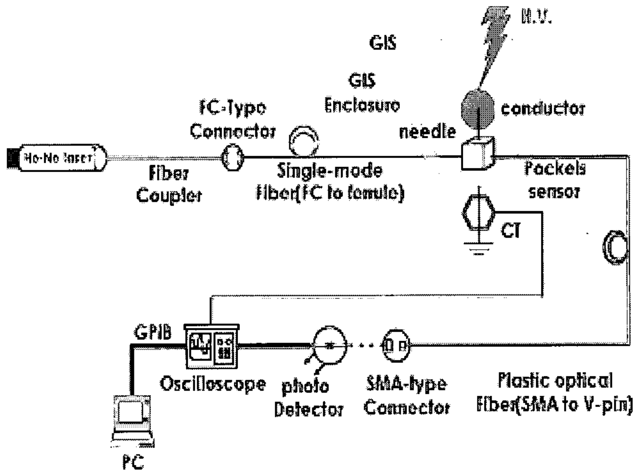
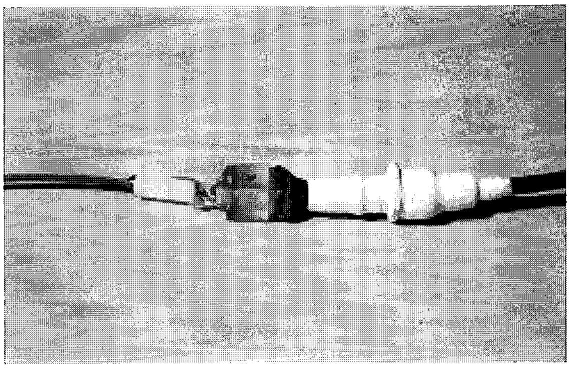


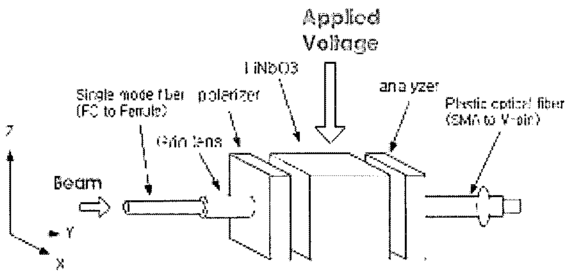
Fig. 1. Overview of the Experimental Setup

And then, after passing through the plastic optical fiber (core: 1000㎛), it is sent to the photo detector converting optical signals to electrical signals to be forwarded to the digital storage oscilloscope.

For the precise 3-D movement of the sensor without influencing the electric field distribution inside the GIS, a specially designed device is developed enabling us to change the sensor location with respect to the needle introduced on the conductor. Fig. 3 shows the schematic view inside the GIS including how the sensor is moved. In this work, the cylindrical coordinate system with respect to the conductor of the GIS was not adopted for the interpretation of the experimental results since the needle with 60mm has been introduced at the ending part of the conductor. And thus, the needle tip becomes the reference point, by which our results have been represented according to the rectangular coordinate system as show in Fig. 3.



(a) General view



(b) Structure

Fig. 2. HY-Pockels Probe Sensor

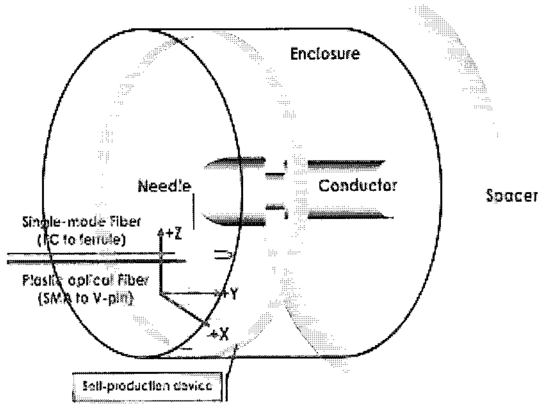


Fig. 3. Schematic view for the sensor location

3. Result and Discussion

3.1 Response of HY-Pockels sensor without needle

The distance in z axis between the conductor and the surface of the sensor was fixed to be 60mm and the voltage was applied to the conductor ranging from 1kV to 20kV without producing any corona discharges. Its response to the applied voltage shows a quasi-linearity as shown in Fig. 4, which might imply that the sensor could be used for detecting the PD.

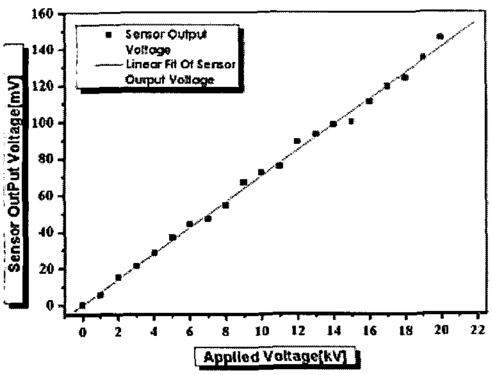
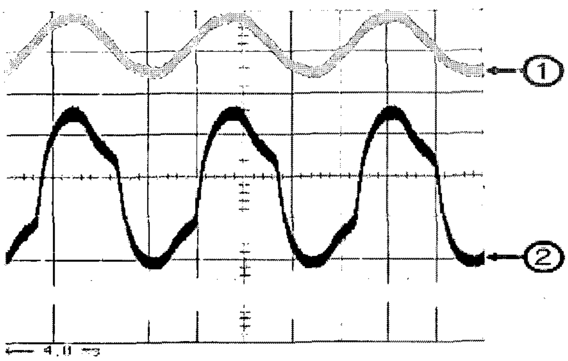


Fig. 4. Response to the applied voltage without needle

3.2 Comparison of the response with needle

A needle was introduced. The distance in -z axis from the needle tip to the surface of the sensor was fixed to be 5mm and the voltage applied to the conductor was 10kV for producing the corona discharges of which the measurement was made through the voltage divider (10000:1).



① Applied voltage ② HY-Pockels sensor ③ CT

Fig. 5. Response of sensor and CT to Vapp (10kV)

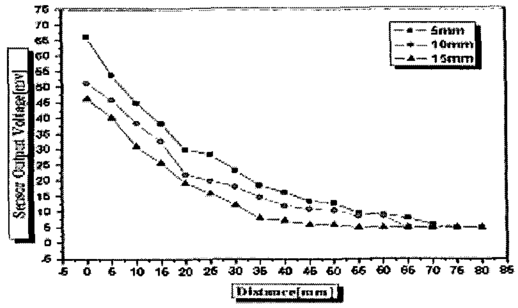
Two different responses, shown in Fig. 5, demonstrate that the PD occurrences have been detected at the same time, which supports the fact that HY-Pockels sensor could replace the conventional CT in terms of PD detection.

3.3 The effect of the distance from the needle

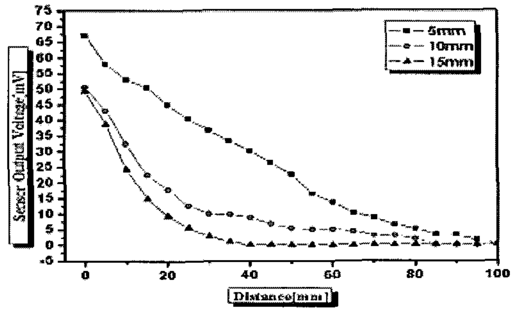
For Fig. 6 (a), (b), and (c), the position of the sensor in the x-y plane has been changed every 5mm in each axis by our moving device while the Vapp is 10kV. The distances are 5mm, 10mm and 15mm in -z direction from the needle to the x-y plane. For Fig. 6(d), the sensor has been moved only along the -z direction below the needle.

a) Movement along the '-Y' direction

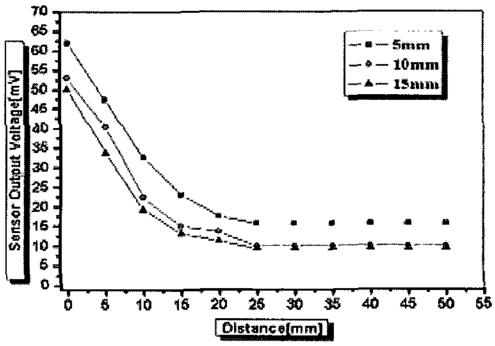
Along this direction, the conductor does not exist in the z direction from the sensor. The response of the sensor is decreased and reaches nearly zero as the distance is sufficiently increased.



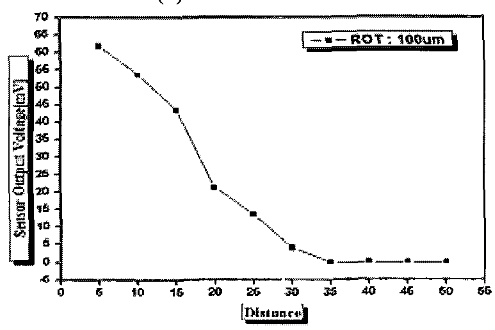
(a) '-Y' direction



(b) '±X' direction



(c) '+Y' direction



(d) '-Z' direction

5mm distance 10mm distance 15mm distance

Fig. 6. Response as a function of the distance between the needle and the sensor

b) Movement along the '±X' direction

The sensor output decreases linearly and remains as a small limited value as the distance is sufficiently increased.

c) Movement along the '+Y' direction

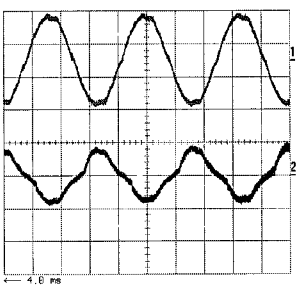
The conductor does exist in the z direction from the sensor along this direction, which implies that the influence from the conductor performs some role in response to the behavior of the sensor. Therefore, the response of the sensor displays the same form as the applied voltage by the influence of the conductor, which becomes important as the distance is increased.

d) Movement to the '-z' direction

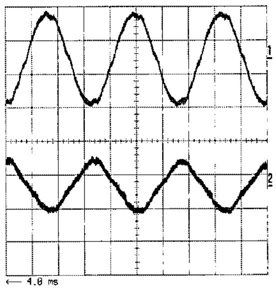
The magnitude of PD is reduced suddenly and is undetectable at the distance of about 50mm.

3.4 The effect of the direction of the sensor location

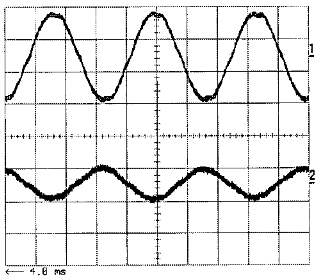
In this case, the distance from the needle in the -z direction is 5mm and the movement in the x-y plane is 15mm for each direction such as '-Y', '±X' and '+Y'.



(a) '-Y' direction



(b) '±X' direction



(c) '+Y' direction

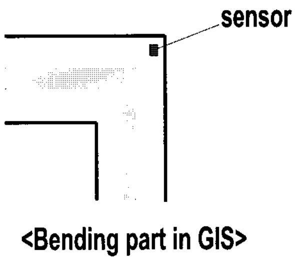
Vapp= 10kV — HY-Pockels Cell

Fig. 7. Response as a function of the direction between the needle and the sensor

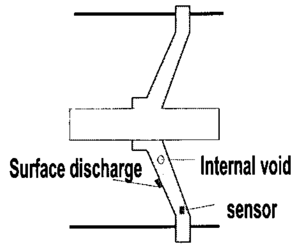
3.5 Possible position of protrusion in GIS

Based on the results in Fig. 7 and Fig. 8, the location of the possible defects introduced inside the GIS could be imagined by using our optical sensor, which could be summarized in Fig. 8 as follows:

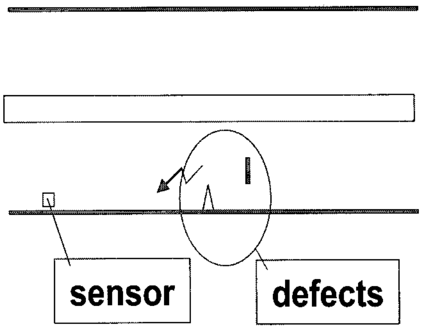
(a) Defects at the bending part of the conductor
(b) Internal void discharge or surface discharge in the spacer
(c) Defect on the enclosure or free moving particles



(a) '-Y' direction



(b) '±X' direction



(c) '+Y' direction

Fig. 8. Estimation of defect location in GIS

4. Conclusion

Throughout this work, our optical measurement system for detecting the electric field variation under high voltage in the GIS is proposed and realized. A possible application of this system for detecting and analyzing the PD has been considered by investigating the output characteristics of the HY-Pockels probe sensor. Important preliminary results under the non-uniform field are obtained as follows:

- Linear response of the sensor is proved.
- Possible application has been remarked to replace the commercialized CT.
- The location of the defects in GIS could be estimated.

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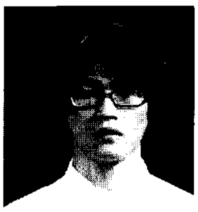

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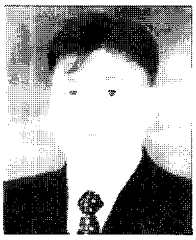

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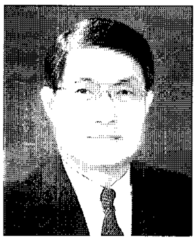

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