포켈스 소자를 이용한 PD 신호의 검출 및 비선형적 해석에 관한 연구

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A possible application of the PD detection technique using electro-optic Pockels cell with nonlinear characteristic analysis on the PD signals

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Abstract - In this paper, new Partial Discharge (PD) detection technique using Pockels cell was proposed and considerable apparent chaotic characteristics were discussed. For this purpose, PD was generated from needle-plane electrode in air and detected by optical measuring system using Pockels cell, based on Mach-Zehnder interferometer, consisting of He-Ne laser, single mode optical fiber, 50/50 beam splitter and photo detector.

A qualitative analysis was carried out by drawing Return map for the normalized time series of the detected PD signals. The results are as follows :

(a) Fixed points, between 0.7 and 1.0, are appeared clearly in the right upper area of the return map as the increase in the number of obtained data.
(b) Considerable periodicity have been remarked even though exact period and length can not be determined.
(c) The self-similarity can be also observed inasmuch as the late paths do not follow the previous ones.

Accordingly, exact quantitative analysis such as embedding dimension, fractal dimension, and Lyapunov exponents should be carried out for deducing the quantitative properties regarding PD phenomena.

1. Introduction

Since more than two decades, various techniques have been employed in order to detect the partial discharges occurring inside the power apparatus. They have been based on the conventional direct detecting system through electrical and/or ultrasonic sensors. Regardless of their acceptable sensitivity, a certain number of technical inconveniences have been disclosed as follows : multistage amplification, large volume, susceptible to external noise, high price and low on-site applicability[1-2].

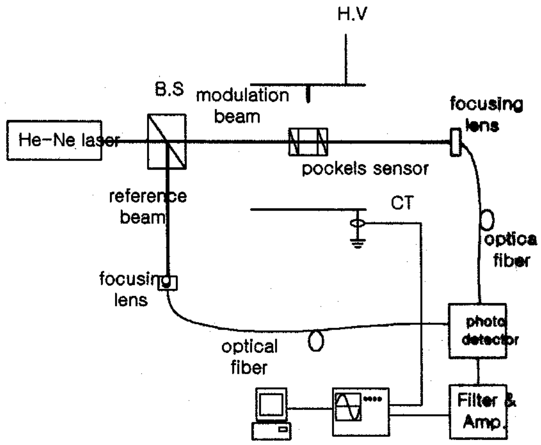
In this respect, an optical measuring system based on the electro-optic effect has been proposed and realized using Pockels cell with a view to detecting PD taking place at the needle plane electrode system. This system has the following advantages : nonmetallic probe sensor, immune to external EMI noise and broad band response of the Pockels cell from DC to GHz[3-4].

The voltage application was made by the PD free test transformer(Haefely PZTL-100-0.25) and measurement has been carried out inside the shielded room. PD signals have been detected simultaneously through both the commercial CT and Pockels cell. And then, PC based software using Labview™ has been developed for data treatment including statistical ϕ-q-n characteristics of PD signal.

Throughout this work, in order to understand possible correlation between those two detecting techniques, a comparison between their results has been discussed in connection with the PD information. Furthermore, optically detected PD signals have been analyzed in order to find certain possible chaotic characteristics.

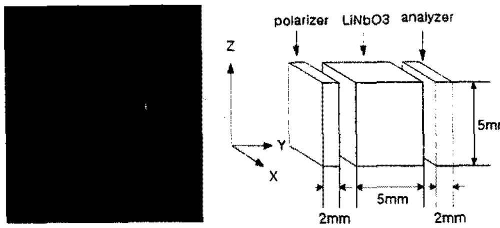
2. Experimental setup

Fig. 1 describes the realized optical measuring system based on the Mach-Zehnder interferometer and Pockels cell was put into high electric field in order to detect PD signals. In this system, PD sensor consists of Pockels cell (Y-cut $LiNbO_3$, 5×5×5㎜ cubic shape) polarizer and analyzer as shown in Fig. 2.



B.S : plate type beam splitter
CT : current transformer

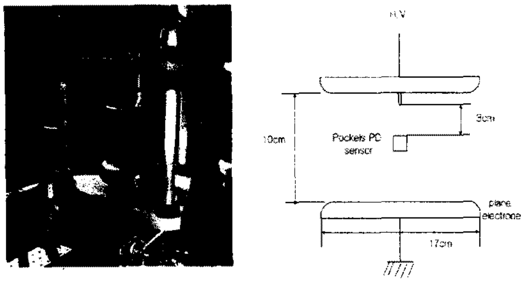
Fig. 1 Experimental setup



(a) A Photo of Pockels sensor (b) Structure of Pockels sensor

Fig. 2 General view of fabricated Pockels sensor

PD were generated from the needle-plane electrode on which the application of the voltage was realized by the PD free transformer. In order to detect PD, the Pockels cell was put below 3㎝ from the needle-electrode as shown in Fig. 3 (b).



(a) A photo of electrode (b) Structure of electrode

Fig. 3 Construction of electrode

Laser beam from He-Ne laser source is splitted into the beams of which are modulated by the electric field applied on the Pockels cell and the other one is reference. And they are transmitted through single mode optical fiber to photo detector for their conversion to electric signals respectively before amplifying.

A part from the above optical measurement, CT has been also employed to detect directly PD signals.

Afterwards, all the detected analogue signals are transformed into digitized ones by use of the digital storage oscilloscope, and then saved for their analysis by the PC based software.

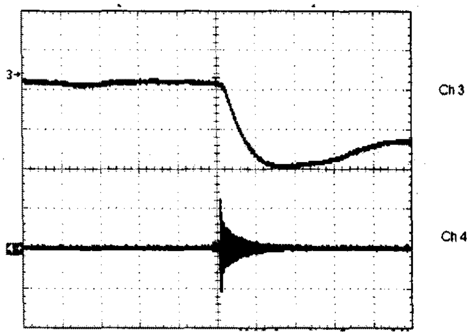
3. Chaotic Analysis.

3.1 PD signal analysis

The synchronized one single pulse of PD signals, detected through CT and Pockels sensor, are shown respectively in Fig. 4, from which the rising time is measured to be about 8[μs].

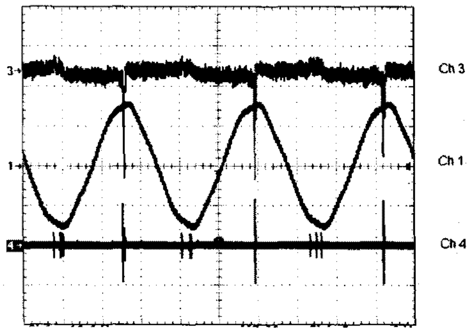
Fig. 5 shows the PD signals detected both by the CT for the Ch. 4 and by the Pockels cell for the Ch. 3 during the three periods of the applied voltage represented by Ch. 1.

However, it could be pointed out that the PD signals during the negative half cycle of the applied voltage are nearly undetected through the Pockels cell . This might be ascribed to the response characteristics and the relating low sensitivity of our optical measuring system.



Ch 3 : Pockels sensor, Ch 4 : CT

Fig. 4 Synchronized single PD pulse for CT and Pockels sensor



Ch 1: Applied voltage, Ch 3 : Pockels sensor, Ch 4 : CT

Fig. 5 Measured signal for PD

3.2 Data Preparation

In order to investigate chaotic characteristics, the data storage related to the PD signals has been done consecutively during 1300[㎳] for which scala time series can be represented as the equation (1).

$$x(t+1) = x(t+\Delta t) \quad (1)$$

Δt : the sampling time step.

$x(t)$: sampled data as time evolution with sampling time step Δt.

Normalization[5] of the signals should be made according to the equation (2), by which the values are taken between 0 and 1 in order to compare every data with other one measured at different sequential moment.

$$x^*(t) = \frac{(x(t) - x_{\min})}{(x_{\max} - x_{\min})} \quad (2)$$

$x^*(t)$: normalized sampled data

3.2 Results and Discussion

The normalized time series of PD signals detected through Pockels sensor during 1300[ms] is shown in Fig. 6 where apparently aperiodic and random characteristics seems to be observed. However, it is recommended to embed the results in one-dimensional time series into the those in larger dimensional phase space.

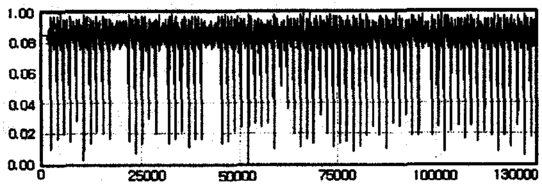


Fig. 6 Normalized time series through Pockels sensor(1300[ms])

Prior exact embedding, it is possible to investigate the presence of chaotic characteristics, such as self-similarity and periodicity by drawing return map based on the results in time series, which can be also represented by non-integer fractal dimension. Moreover, it is required to determine the dimension and delay time in order to come out the correct embedding[5-7].

Therefore, return map has been drawn for the PD signals measured through our optical sensor in order to investigate their fractal properties as shown in Fig. 7.

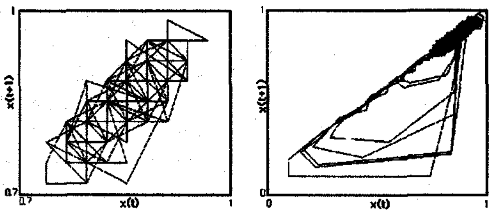
Several remarks can be pointed out from the four figures in Fig. 7. :

(a) Fixed points, between 0.7 and 1.0 as shown in Fig. 7(a), are appeared more clearly in the right upper area of the figure as the increase in the number of obtained data.

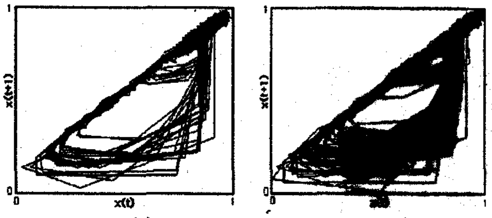
(b) Considerable periodicity have been remarked in Fig. 7(b)~(d) even though exact period and length can not be determined.

(c) The self-similarity can be also observed inasmuch as the late paths do not follow the previous ones.

Accordingly, it could be deduced that the return map of PD signals, measured through Pockels cell, shows noticeable aperiodic and self-similarity within their boundaries.



(a) (b)



(c) (d)

Fig. 7 Return map based on the results in time series shown in Fig. 6. (a)1800 points, (b) 10000 points, (c) 50000 points, (d) 130000 points

4. Concluding Remarks

Throughout this work, it is disclosed that optical measuring system using Pockels sensor seems to be capable of detecting PD. However, elaborate electronic devices and systems are required for amplifying and filtering unit before data acquisition in order to detect the small PD under 20pC.

In addition, Return map has been drawn in order to investigate the presence of chaotic characteristics in PD signals, detected through optical sensor, in the normalized time series. And thus, it could be deduced that the return map of PD signals, measured through Pockels cell, shows noticeable aperiodic and self-similarity within their boundaries.

However, further indispensible quantitative analysis such as embedding dimension, fractal dimension, and Lyapunov exponents should be carried out for determining more exact chaotic properties regarding PD phenomena.

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[REFERENCES]

[1] J.P. Steiner, IEEE EI Magazine, Vol. 1, No. 1, pp.20-33, 1991

[2] J.H.Capenter, J.S.Kresge, C.B.Musick, IEEE Trans. PAS Vol. 84(4), p. 647, 1965

[3] J.Y.Koo, Y.M.Chang, J.H.Lee, J.EEIS, Vol.1(3), pp 12-24, 1996

[4] J.Y.Koo, Y.M.Chang. S.S.Noh, "Partial discharge detection technique using electro-optic effect", CEDIP-IEEE, pp.254-257, 1997

[5]Y. S. Lim et al., " A Nonlinear Analysis of Partial Discharge Signal", Trans. KIEE. Vol. 49C, No. 3, pp. 169-176, 2000

[6]K. Alligood. T. Sauer and J. Yorke, "CHAOS - An introduction to dynamical systems", Springer, 1996

[7]D. Kaplan and L. Glass, "Understanding Nonlinear Dynamics", Springer, 1995