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포켈스 소자를 이용한 고전압 임펄스 및 미소신호 측정기술 개발

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Development of Measuring Techniques for High Voltage Impulse and Small Signals using Pockels Cell

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ABSTRACT

In order to substitute for the conventional measuring system which could bring about technical inconveiences, measuring techiques for the fast transient high voltage upto 100 kV and small signals less than 1 V are developed by use of Laser Source with Pockels cell.

for the former, capacitive voltage divider was specially designed for reducing the impulse voltage less than the half-wave voltage of Pockels cell.

For the latter, interferometer type was employed as a mean to removing the fluctuation of Laser output intensity. And also the main beam through the Pockels cell and the reference beam from the Laser source are seperated before being detected respectively by photo diodes. And then, these two signals are amplified and compared for detecting only the small signals applied across the Pockels cell.

Throughout this work, Laser-based measuring system is likely to enable us, at this moment, to detect correctly lightning impulse voltage upto 100 kV and the small signals less than 1 V upto the 2 MHz. Such a system could be employed as a possible diagnostic measuring system at the substation.

I. INTRODUCTION

A recent increase in electric power demand requires stable power supply, which could be achieved by improving the diagnostic and preventive methods for the power apparatus. For this purpose, it is highly necessary to develop better measuring techniques for not only the fast transient impulse voltages but small signals. Because the former, comming into the substation, are produced by the overvoltages taken place at the power energy system. Regarding the latter, their patterns should be recognized since the pulse-type small signals could indicate actual insulation condition of electric power apparatus in which partial discharges are generated.

Conventional measuring system using potential transformer (PT) has shown mainly three technical inconveniences such as, decreased accuracy due to the effects of higher harmonics, large volume and high cost ascribed to safe insulation, and inaccurate measurement for fast transient voltages.[1] In transmitting, through the coaxial cable, partial discharge signals detected by the transducer, the minimum measurable voltages are practically limitted due to the noise from the electromagnetic interference and damping of the signal amplitude.

On the other hand, optically based measuring system shows the high signal-noise ratio (SNR) by seperating electrically the measuring system from noise sources of the power system.[2] And thus, various investigations have been devoted in its progressive devolopment with highly growing interests.

In this work, optical measuring system was constructed in view of measuring high voltage impulse and pulse type small signals by use of the KDP and Lithium niobate Pockels cell respectively. Transverse mode was adopted for the application of the voltage to be measured, since it is possible to obtain different half wave voltage by controlling the minute dimensional variation of the crystal in use.[3] And, the characterization of the constructed system was also performed.

II. EXPERIMENTALS

As well described above, the response of our system is determined by the changes in voltage-induced polarzation occuring by the optical radiation passing through an appropriate Pockels crystal.[3,4] In consequence, the measurable voltage is practically limitted by the half-wave voltage of the crystal in use and the linearity of irradiance throughout the applicable voltage range as well.

Regarding the longuitudinal mode, all the Pockels cell have their own characteristic half wave voltage within which the measuable voltage range is required to be located. On the contrary, transverse mode could be better way in putting the half-wave voltage in appropriate range by varying the dimension of crystal.[2]

Considering the fact that peak-to-peak voltages from less than 1 V to higher than 100 kV could be measured accurately in transverse mode, the dimensions of KDP and $LiNbO_3$ crystals were accurately selected and then were put into our system in transverse mode in order to measure both the high voltage impulses and small signals respectively.

Optical system arrangement

Fig. 1 shows schematically the optical arrangement in which light intensity difference method [5] were adopted by splitting the incident beam, as a mean to prevent the signal distortion caused by fluctuation of laser source intensity. This method permits to compare modulated beam by applied signal (beam 1) with the reference beam (beam 2), so that their

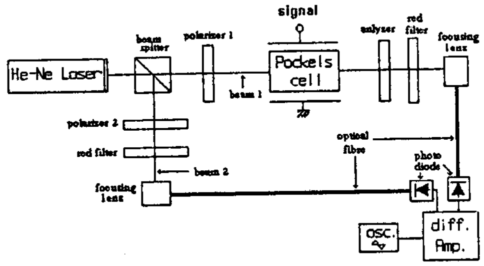

Fig. 1 schematic block diagram for voltage measurement

difference converted to the electric signal could be amplified by difference amplifer.

Only pure laser beam transmitted, through the optical fibre without any stray light, could be detected by the photo diode using a red filter put before light sensing. Hence, in order to supress the external noise, the focusing lens, red filter and optical fiber were put into one housing

Construction of the light sensing system

The circuit for light sensing system is shown in Fig. 2, which is well shielded in one metallic case and also grounded in order to detect only pure signals.

Each current begins to flow through the resistor at the moment of detecting two splitted beams by photodiodes and then is converted to the voltage for being amplified and differentiated by op-amp.

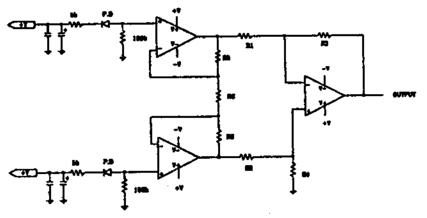

Fig. 2 Circuit diagram for the light sensor

Design of the Capacitive Voltage Divider

It is practically necessary, for measuring high impulse voltages, to provide voltage divider in order to reduce their magnitude to the order in measurable range of Pockels cell. Hence a capacitive divider was designed consisting of two parts : upper part with low capacitance shown in Fig. 3, through which high voltage is applied and lower part using several ceramic capacitors whose number depends on the level of high voltage. Since the upper part is stressed by most of applied high voltage, the voltage in measurable range can be obtained across the ceramic capacitors for being applied to Pockels cells.

In order to avoid creeping discharge on the upper part of the designed divider, FEM was employed to solve the governing equaton for the two-dimensional analysis, since the structure of the divider is symmetric cylindrical type.

Fig. 4 describes the distribution of equi-potential lines for the case with the application of 300 kV. Since the electric field is distributed uniformly at the outer part of the skirt, as shown in Fig. 4, it could be expected that creeping discharge is hardly taken place due to the field concentration.

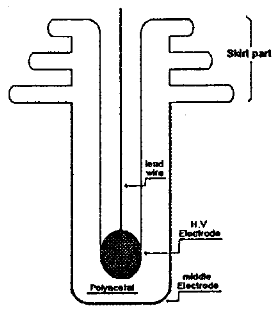

Fig. 3 Cross-sectional view for of the upper part of capacitive voltage divider

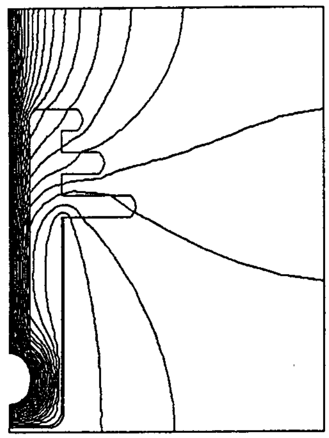

Fig. 4 Equi-potential lines the voltage divider

III. RESULTS AND DISCUSSION

High voltage impulse measurement

Table 1 Comparision of irradiance between theoretical and experimental values

Applied Voltage (kV)	Calculated Amplitude (V)	Measured Amplitude (V)
100	1.59	1.5
170	3.08	3.2
250	4.57	4.8

The typical lightning impulse with different magnitudes was produced by impulse generator (HAFELEY Multi Test Set) and then its magnitude was reduced by the specially designed capacitive voltage divider to the order of measurable range. Afterwards, the reduced impulse voltage was applied to KDP Pockels cell for being detected through optical measuring system in Fig 1.

Fig. 5 shows the results by the application of impulse voltages upto 250 kV, in which it could be pointed out that the upper signals from the high voltage probe are well coincident with those below measured through the designed optical measuring system.

The comparision of irradiances between theoretical and experimental values for each applied impulse was summerized in table 1, by which it could be confirmed that calculated magnitudes correspond well to the measured ones.

<u>Small signal measurement</u>

In order to characterize the response of the designed system to the small signals, various signals in small amplitude were produced by function generator with various magnetudes and frequencies varying from 150 kHz to 2 MHz. The results in response to various amplitudes at 1 MHz are shown in Fig. 6 by which it could be remarked that the designed system is able to reproduce well the input signals whose amplitudes are reduced down to 1 V. And moreover, even though the response to the amplitudes of input signal below 0.2 V is a little distorted due to the external noise, the input signals are quite recognizable from the detected signals through measuring system due to its linearity considering the comparision of the magnitude between the calculated values and the measured ones in table 2.

Table 2 Comparision of irradiance between theoretical and experimental values in 1 MHz

Applied Voltage (V)	Calculated Amplitude (mV)	Measured Amplitude (mV)
0.2	25.6	23
1.4	179.3	154
2	259.7	273

The frequency characteristics shown in Fig. 7 prove that it is also possible to reproduce the applied signals larger than 1 V with relatively higher frequencies at 1.5 MHz as well as at 2 MHz respectively.

Ⅳ. CONCLUSION

Based on the obtained results, it is found that our designed measuring system employable for diagnosis of electric apparatus seems to be capable of detecting not only the fast transient voltage but the small signals at high frequency.

Particularity, for the latter, it is also proved that the light intensity difference method is likely effective. In addition, in transverse mode, it is possible to locate the half-wave voltage into measurable linear region by only the dimensional variation of the crystals, without any phase compensator

However, in order to reproduce the voltages in concern, further progress should be made such as the compensation of temperature characteristic of crystals and the reduction of half-wave voltage of Pockels cells for the small signals below 1 V at high frequency over 1 MHz.

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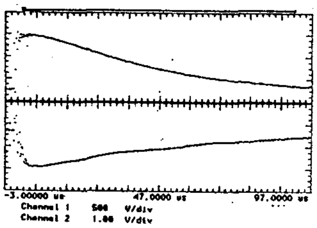
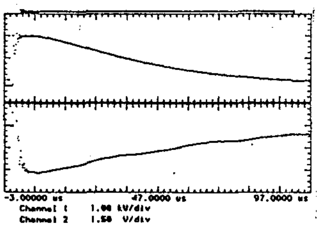
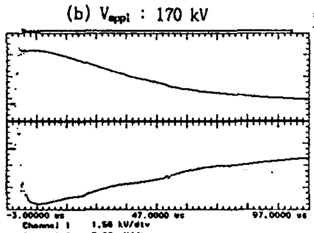


(a) V_{appl} : 100 kV

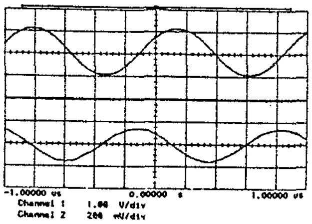


(b) V_{appl} : 170 kV

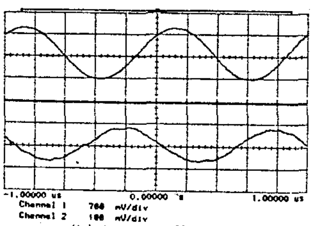


(c) V_{appl} : 250 kV

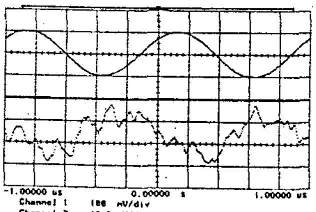
Fig. 5 Response wave-form for each applied voltages



(a) V_{appl} : 2 V

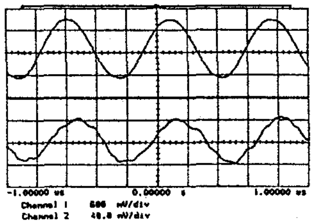


(b) V_{appl} : 1 V

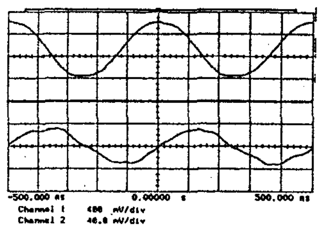


(c) V_{appl} : 0.2 V

Fig. 6 Response wave-form for each applied voltage in 1MHz



(a) 1.5 MHz



(b) 2 MHz

Fig. 7 Response wave-form for each frequencies in 1 V