Development and Application of Surge Measuring System for 550kV Substations

T.Yamada, T.Shioda, T.Narita
Tokyo Electric Power Company, Inc.
Tokyo, Japan

T.Chiba, N.Harigaya, R.Tsuge, Y.Sato
Toshiba Corporation
Kawasaki, Japan

Abstract - **The automatic measuring system of transient overvoltage was developed and applied to the actual substation in service. The surge voltage sensor has the frequency bandwidth from 0.1Hz to 10MHz, and can measure transient overvoltage, such as lightning surge. This system was installed and now operating at 550kV substation which is connected to 1000kV design transmission line. Up to the present, several records were successfully obtained.**

Keywords: Lightning surge, 1000kV design transmission line, Surge voltage sensor, Fiber optical link, Digitizer

I.INTRODUCTION

Lowering insulation level is a theme presently attracting a lot of attention around the world. Supporting this research are technological advances in related areas, such as high-performance metal-oxide surge arresters [1] and EMTP analysis technique. Recently, EMTP analysis, in particular, has been playing an important role in insulation coordination designing.

Current EMTP analysis accuracy improvements are achieved by applying the improvements made on circuit models for transmission lines and towers. However the accuracy depends on data of many parameters, therefore the calculated overvoltage values is preferred to be validated by measurements.

Measured field data have been gradually accumulated [2][3], however measured field data are very few for the transmission lines and towers designed for 1000kV transmission. These transmission lines are operated at 550kV now, and the particular phenomenon such as direct lightning stroke has been measured because of 1000kV design. The purpose of this study is to accumulate data which is useful for rational insulation coordination design in view of lightning.

This paper reports the development and application of the measuring system for the above purpose and the typical measured data until now.

II.MEASURING SYSTEM

The measuring system was developed and improved based on the previous experience for the overvoltage measurement of 550kV system [2][3].

A. Requirements

The following requirements were taken into account in designing this measuring system.

1) A frequency bandwidth of 0.1Hz to 10MHz was required for the voltage sensor. In order to measure the power frequency component accurately, the lower frequency limit was set 0.1Hz.

2) An automatic and continuous operation was required for the system.

3) The ability to record repetitive surges was required for the system. They include, for example, the repetitive lightning.

4) The time recording function was required in order to clarify the relation among the repetitive surges. The relative time resolution was set 1 micro second.

5) Multi(six) phase simultaneous trigger function was required in order to analyze the relation among phases, phase-to-phase surges and the symmetrical components.

B. System diagram

The configuration of the overall system is shown in Fig.1. The voltage wave form is measured with the capacitive divider using an insulating spacer of 550kV GIS, which is connected to 1000kV design transmission line. The fiber optical link is employed for signal transmission because it works under severe electro-magnetic environments, and long signal transmission (approximately 350 meters) is required. The measuring panels are equipped with digitizers, CPU (computer) and O/E (Opto-Electrical converter), and are arranged inside the relay room of the station. The CPU continuously operates the digitizer and the GPS time-stamping unit, these data are stored in a harddisk.

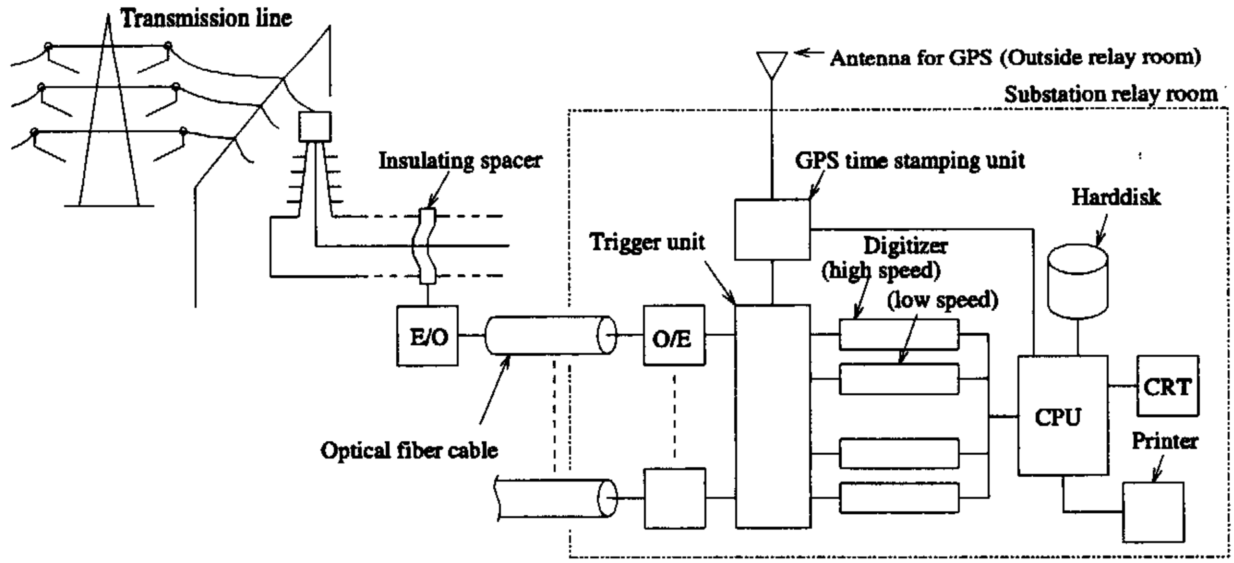


Fig. 1. System diagram

C. Surge voltage sensor

The construction of capacitive voltage divider and E/O (Electro-Optical converter) is schematically shown in Fig. 2. The stray capacitance between the high voltage conductor and the embedded electrode of an insulating spacers is utilized as primary capacitance of the divider. The parallel connection of low-inductance ceramic-type capacitors is used for the secondary capacitance.

In this study, to measure the power frequency component accurately, the capacitively divided voltage is further divided by C-R divider. The divided voltage is input to the buffer amplifier with high input impedance. It drives the E/O, and the voltage signal is converted to optical signal and transmitted through an optical fiber cable. The resistance of the C-R divider is approximately 500MOhms, which enables the lower frequency limit approximately 0.1Hz. This is sufficient to measure the power frequency component.

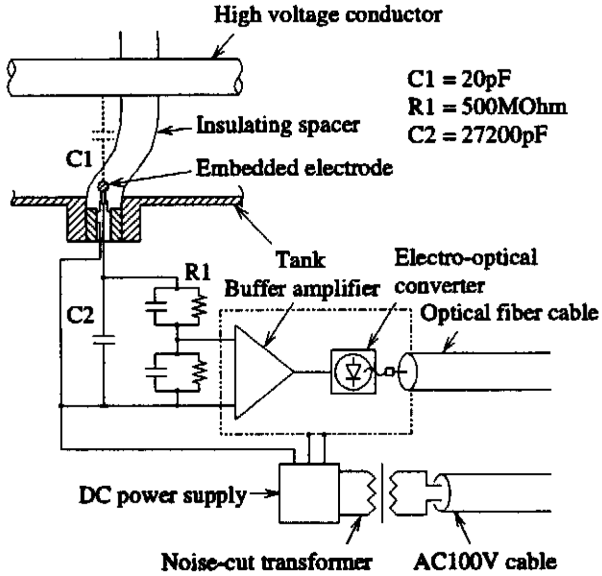


Fig. 2. Schematic diagram of surge voltage sensor

Table 1 and 2 show the specification of optical fiber link and C-R divider.

Table 1. Specification of optical fiber link

Frequency bandwidth	from DC to 60MHz (-3dB)
Range of output voltage	1Vo-p
Ratio of input voltage to output voltage	1:1

Table 2. Specification of C-R divider

Type of optical fiber	Parasitic-clad-multi-mode fiber
Input impedance	500MOhm
Frequency bandwidth	from DC to 100MHz (-3dB)
Ratio of input voltage to output voltage	1000:1

The measurable maximum voltage was set 1500kVp which is close to the LIWV (lightning impulse withstand voltage; 1425kVp) of the station where this system is installed.

D. Recording and Control System

Digitizer features pre-trigger and divided memory. This function enables measurement of the repetitive stroke, such as the repetitive lightning. In order to record detailed and overall wave shape effectively, simultaneous recording method is used.

Detailed wave shape is recorded by high speed digitizer (100 ns/point) and overall one is recorded by low speed digitizer (10 us/point).

We developed and used the trigger-unit which begin to record all channels of high and low speed digitizer when one of the phases satisfy the trigger condition. This function enables measurement of the relation among phases, phase-to-phase surges and the symmetrical components. A differential-trigger method is used because it can measure the surge around zero point. At present, the trigger level is set at 0.3 times the maximum phase-to-earth operating voltage $(550kV/\sqrt{3}\times\sqrt{2}=449kVp)$ for high frequency more than 1kHz.

The time stamp function using a GPS enables to analyze the relation among other stations.

III. APPLICATION AND RESULTS

A. Installation of Measuring System

End in May 1998, the measuring system unit was installed in a 550kV station of The Tokyo Electric Power Co.,Inc (Nishi-Gunma Switching Station) and is operating at present.

Fig. 4 and 5 show the external appearance of the installation of surge voltage sensor and the measuring panel.

B. Outline of Measurement Results

Several records were obtained up to December 1998 and typical, classified waveforms are summarized in Table 3.

Fig. 6 shows a waveform obtained from a induced lightning surge. The surge of the three phases have the same polarity and there is not much difference in the amplitude among them. The wave rise is slow and the magnitude is small.

Fig. 7 shows a waveform obtained from a direct lightning surge. In Fig. 7 (b), the polarity of the upper phase (black-phase, in this case) is negative and others are positive. The difference of upper phase is

Table 3. Summary of Waveform Records

Figure	Date	Maximum surge voltage	Cause
6	23:10:28 98/08/21	+145kV	Induced lightning
7	23:50:06 98/08/21	-246kV	Direct ligntning

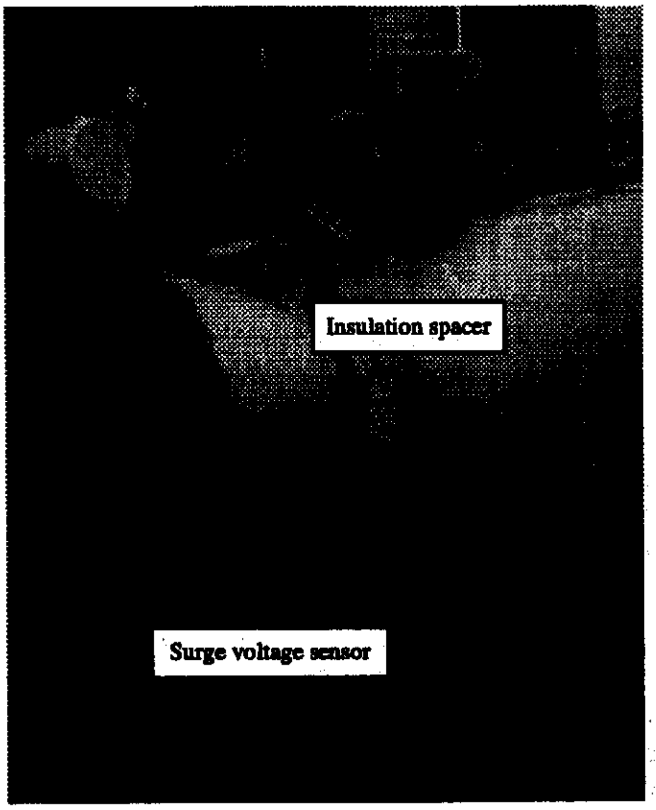


Fig. 4. External appearance of the surge voltage sensor

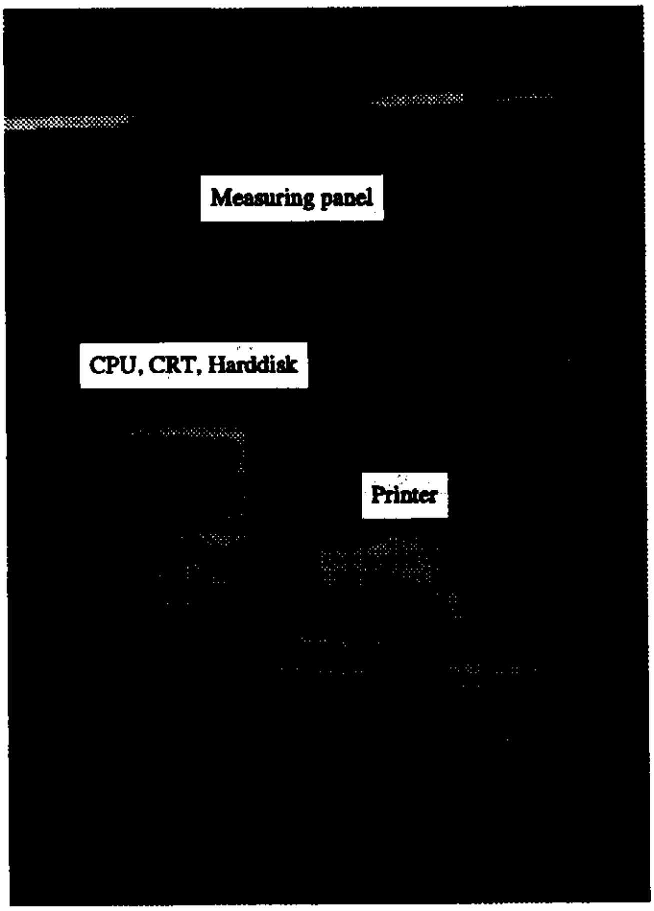


Fig. 5. External appearance of the measuring panel

larger than other phases. After surge incoming, the reduction of the power frequency voltage can't be seen. Therefore it seemed that the direct lightning to upper phase didn't lead to fault and was transmitted into the station.

IV.CONCLUSION

The automatic measuring system was developed for measuring overvoltage and applied to the actual 550kV substation, which is connected to 1000kV design transmission line, in service. This system has been in operation since June 1998, and up to the present several records have been obtained. The results of this study are summarized as below.

(1) We developed the surge voltage sensor, which features the wide frequency bandwidth.

(2) We developed the automatic measuring system, which features multi phase simultaneous sweep and parallel usage of fast and slow digitizers.

(3) From May 1998 until December 1998, several recordings including direct stroke and induced lightning were successfully obtained. Most of all was caused lightning surges.

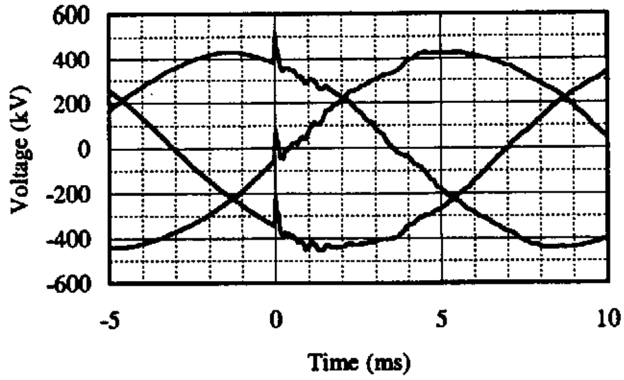
These measurements are planned to continue to March 2002, accumulate additional data and install this measuring system in a 550kV station of Minami-
Iwaki Switching Station which is connected to 1000kV transmission line.

V.REFERENCES

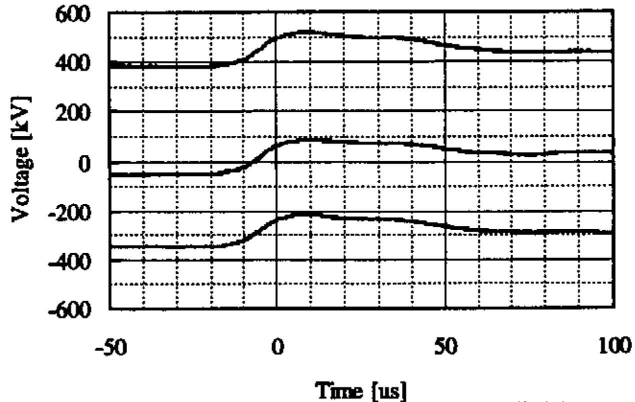
[1] T.Imai et al., "Development of High Gradient Zinc Oxide Nonlinear Resistors and Their Application to Surge Arresters", *IEEE Trans. Power Delivery*, Vol.13, No.4, 1998, pp.1182-1187

[2] T.Yorozuya et al., "Overvoltage Measurement at 550kV Substations," *IEEJ National Convention on Power and Energy*, Paper No.81 1990. (in Japanese)

[3] S.Okabe et al., "Analysis of Surges Measured at 550kV Substations," *IEEE Trans. Power Delivery*, Vol.6, No.4, 1991, pp.1462-1468.

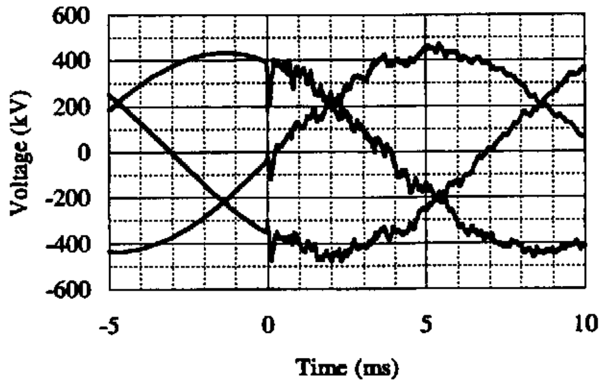


(a) Recorded by low speed mode digitizer

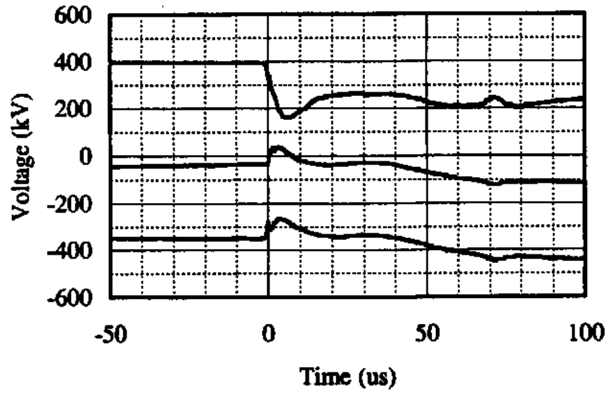


(b) Recorded by high speed mode digitizer

Fig. 6. Waveform example by a induced lightning surge



(a) Recorded by low speed mode digitizer



(b) Recorded by high speed mode digitizer

Fig. 7. Waveform example by direct lightning stroke