INTEGRATED ELECTRONIC METERING INSULATOR FOR MEDIUM VOLTAGE OVERHEAD LINES

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ABSTRACT

In order to integrate primary equipment to digitized integrated substation systems; the digitizing procedure of instrument transformers is essential. In this paper, we describe design and construction and test procedure of a line post insulator that monitors (&Records) current and voltage information of 20kV overhead distribution lines. In the equipment a voltage and current sensor are attached to an epoxy resin molded insulator with silicon rubber sheaths. Voltage on overhead line is detected by a special arrangement of resistive divider and a low signal current transformer detects current on overhead line. Voltage and current signals are monitored with 7-segment digital module by radio remote control. Equipment has analogue output terminals too for connect to RTU. Voltage and current information are recorded for long-time operation examination such as data logger systems. We demonstrate experimentally that the proposed equipment measures ranging from 0 up to 24kV and 0 to 500A, then experimental results are presented.

INTRODUCTION

Current and voltage transformers have been used for decades to step down T&D network high current and voltage which are suitable for metering and relaying. These conventional instrument transformers provide suitable signals to feed conventional measuring and protection equipments. Recent progress in information technology and competitive power market requirements necessitates substation information terminal to acquire precise and sophisticated substation primary equipment can be acquired [1]. With the development of the computerized and digital technology of measurement and protection devices, present traditional electromagnetic type instrument transformer will not be suitable. The new age devices only need analogue or digital signal in mV level. In order to match instrument transformer with these equipments, it is necessary to develop some new kinds of electronic voltage-current transducers with low voltage signals. Thus the possibility of using new sensors would be improved with low weight, small dimensions, free of electromagnetic interferences, simpler insulation and better accuracy. So, for nearly two decades now, electronic CTs (ECT) and VTs (EVT) has been the subject of considerable research, development and evaluation by manufacturers and potential users [2]. The ECTs and EVTs play a sensing and digitizing role for current and voltage information with the processing capabilities of digital electronics. This paper discusses the design and manufacture of electronic instrument transformer such as a line-post insulator with analogue and digital outputs. Test results are discussed.

2. ELECTRONIC MEASURING INSULATOR

2-1. General configuration

Electronic measuring insulator system configuration is shown in figure 1. It is based on low power current transformer principle. As for the voltage detection sensor, high reliability and simple insulated structure resistive voltage divider is applied. current and voltage sensor outputs are sent to electronic processing unit (EPU) by double shield twisted pair cable for 7-seg display, analogue output and digital recording of voltage and current information real RMS, respectively .

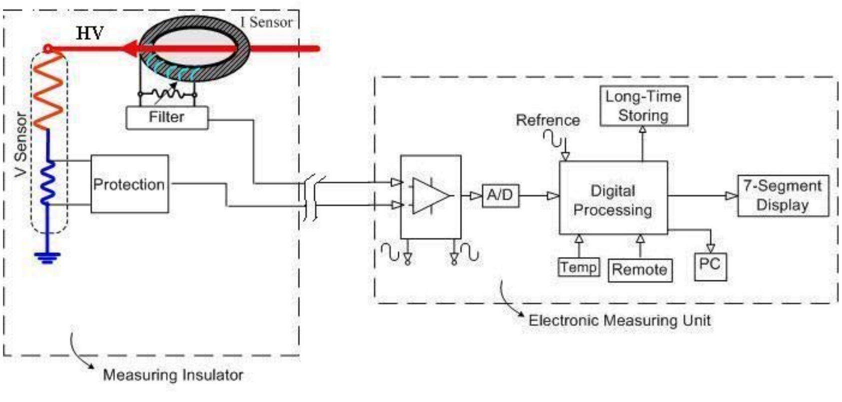

Figure 1. Basic configuration of electronic monitoring insulator

2-2. Proposed Voltage sensor

A high voltage non-inductive resistor in resistive divider is used to measure 20kV overhead lines voltage. The proposed divider provides a high impedance resistive voltage divider, include:

- high voltage resistances with 6 low TC and low VC resistors equal to R1
- low voltage resistance
- metal fitting to mitigate divider effect
- capacitive coupling
- low voltage resistance shield case

High voltage resistors consist of two stage series together with three parallel resistors in every stage. Top, middle and bottom of high voltage element (R1) is equipped with three metal special curve discs to optimize voltage gradient of R1 surrounding insulation. These metal fittings with low voltage shield case mitigate installation conditions error [3]. Fig1 shows the principles of resistive voltage divider. Fig2 shows the proposed voltage sensor characteristics. Divider Ratio is 10000/1. Since there is not separation isolation between high voltage and low voltage parts, a low voltage surge arrester is installed at divider output to avoid voltage rising in low voltage parts.

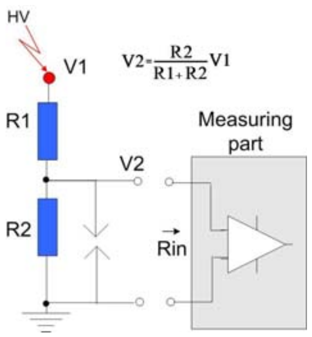

Figure 2. Resistive voltage divider structure

2-3. Proposed current sensor

Proposed monitoring insulator detects distribution line current by low power current transformer. This sensor consists of small core iron cored inductive current transformer and secondary winding with minimized losses, which is connected to internal shunt resistor R_{sh}. secondary current i_2 produces voltage u_2 across low internal resistance, which is directly proportional to primary current. Low power current transformer is shown in Figure 1.

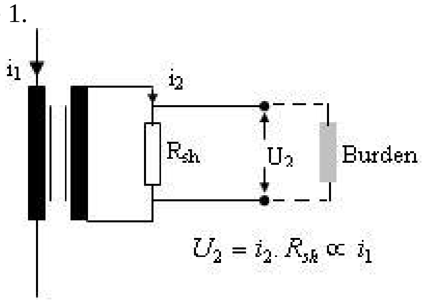

Figure 3. Low power current transformer

These types of current transducers are classified as 0.5 accuracy class. Better accuracy can be achieved over a wide nominal current range. Further, low power current transformer voltage output allows electronic signal processing adaptation as well as automation purposes.

2-4. Electronic and Remote

The six Instrument amplifiers are used in input circuit for three phase voltage and current signal conditioning. A/D part converts three voltage and current signals to digital signal to process, record and monitor by 200 samples at one cycle. Recording procedure is done for long time in three phase 20kV distribution overhead line. Three phase Voltages and currents in addition to environment temperature are monitored on 7-segment panel by a radio remote control at the bottom of 20kV pole.

3. ELECTRIC FIELD ANALYZE

The design of high voltage elements and insulation body of insulator and voltage and current sensors was done by goal of reaching maximum reliability with a minimal need of material and space. a substantial prerequisite in order to reach this goal is an optimal electric field strength distribution on proposed sample elements and dielectric boundaries. It is necessary to generate the geometry to be optimized. By changing geometry parameters, we optimized the design procedure.

Geometry of Insulator, voltage and current sensor are simulated to identify critical areas (see Fig.4) [4]. Insulator inner electric field critical value is considered 1kV/mm. In this work, it seems reasonable to keep inner insulator electric field below 1kV/mm. it can be seen that electric field magnitude along insulator is less than critical value (see figure 5). But maximum electric field in electrodes and insulation edges is about 1.9kV/mm. therefore edges were cut to soft curve to reduce electric field strength.

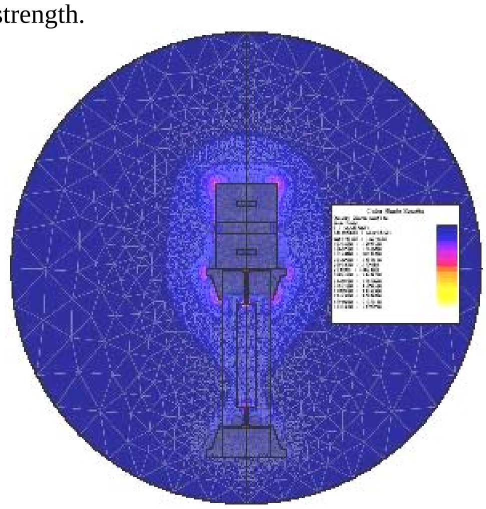

Figure 4. Electric field simulation for prototype sample

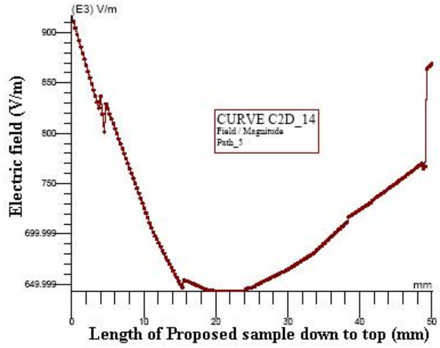

Figure 5. Electric field distribution inside insulator body

4. RESULTS

4-1. Voltage measurement results

The proposed equipment is able to measure up to 24kV corresponding to the +4 V full scale of A/D converter with good linearity. A reference 0.1% voltage divider was used to calibrate the system in voltage mode. Voltage measurement test setup is shown in figure 4. Test line high voltage value was varied from zero to 24kV and the measured voltage is compared with reference voltage divider output voltage. Fig5 shows that linearity in this range is more than ±0.5% .also; phase error in full scale is Less than 30 minutes. Thus accuracy class voltage measurement is 1 [5].

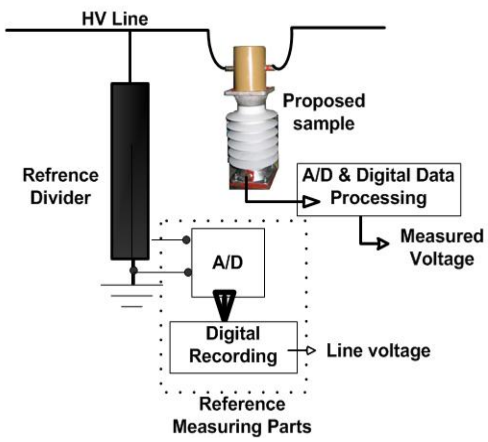

Figure 6. Voltage measurement test setup

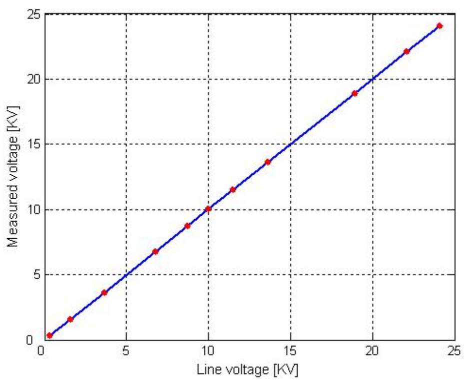

Figure 7. Voltage sensor linearity curve

4-2. Current measurement results

A test circuit is set up to investigate the proposed current sensor operation and accuracy. The test circuit current was measured by the offered current sensor and precise conventional CT (0.2 class). Figure6 shows the RMS value of the detected current by proposed current sensor. Test circuit current detected by the CT is varied from 0 to 500 A. the linearity between detected current by proposed current sensor and the test circuit current is confirmed in figure 6. It is seen that current magnitude and maximum phase errors are less than 1 % and maximum of 60 minutes in full scale, respectively. Thus accuracy class for current measurement is 1 [6].

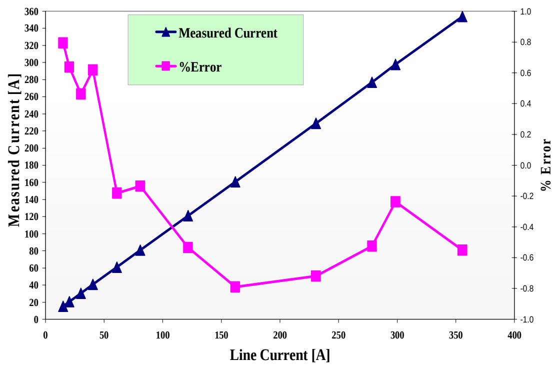

Figure 8. Linearity of current sensor

The monitoring insulator was installed on a 20 kV distribution line and line current is monitored by the proposed current sensor and common CT. Fig7 shows the circuit for measurement of the distribution line current I0. VCT waveform is voltage output of usual CT that is proportional to I0 and VS is proposed current sensor voltage. These waveforms are shown in fig8. It can be seen that both sensors detect sinusoidal current signal.

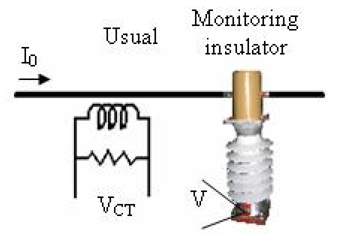

Figure 9. Current measurement test setup

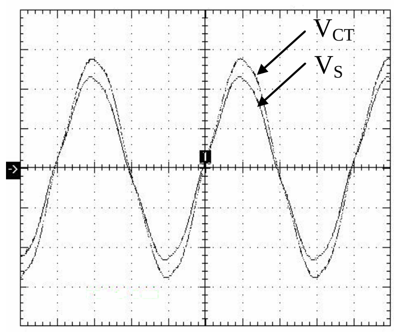

Figure 10. V_{CT} and V_S Waveforms

Figure 11. High voltage test of proposed samples

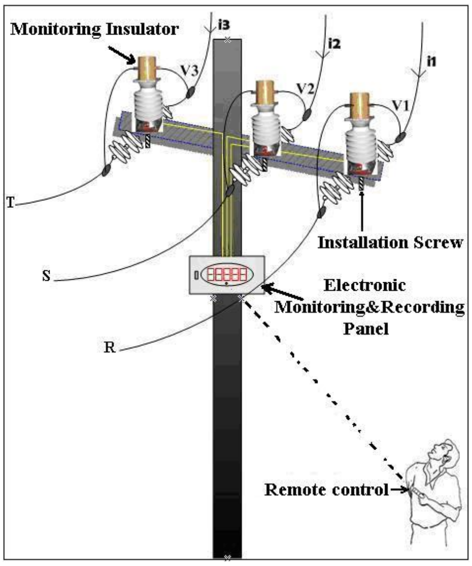

Figure 12. Operating structure of proposed system

Results of laboratory high voltage test (see Fig11) showed that proposed samples strength against 50kV (1min) power frequency and 125kV impulse voltage. The operating structure of proposed system showed in Fig12. After calibration and laboratory tests, the prototype samples are installed in field (see Fig13). Site test Results confirmed laboratory tests outcomes.

5. CONCLUSION

A system is introduced in this paper to measure and record voltage and current in 3 phase 20kV overhead distribution lines. The system has the following features.

(1) Overhead line current is detected by low power current transformer.

(2) Voltage is detected by special arrangement of resistive divider.

(3) Analogue outputs of sensors are compatible with RTU system.

(4) Voltage-current real RMS values for 3 phases are shown in digital display elements. It is possible to select and read three phase voltage and current by remote control at the bottom of overhead pole.

(5) Three phase currents and voltage samples are recorded in the device internal memory every 1 minute during long time operation and line information condition monitoring by a computer.

In future, voltage and current measurements experimental results would be shown.

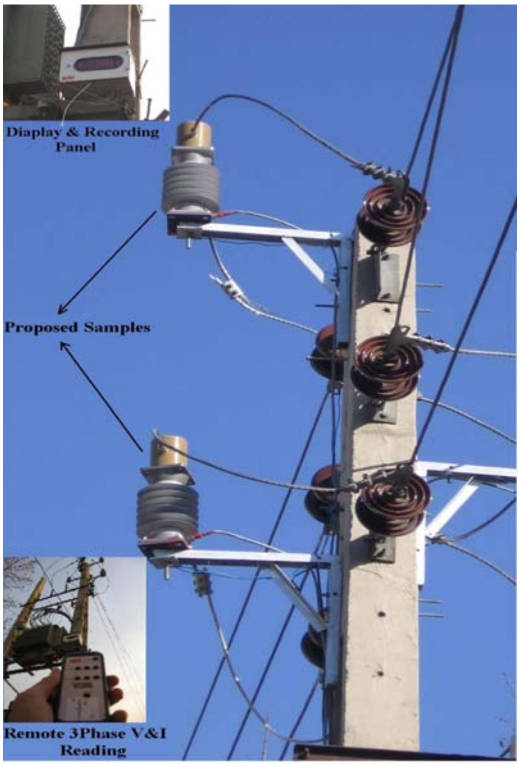

Figure 13. Site test of proposed samples

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