Development of a Monitoring Equipment of Current and Potential on Power Transmission Line for 66kV

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Abstract: We propose portable equipment that monitors current and voltage of high-potential power transmission lines. In the equipment, a current and voltage sensor are attached to an insulator that supports a power transmission line: A clamped to the power line and the detected current signal is transmitted to the ground station by a wireless optical link using transmission line is detected by a high resistance element, zinc oxide (ZnO). That acts as a potential divider between the power line and ground. We make an experimental device for 66kV power line and demonstrate that it can monitor currents proposed equipment is small-sized, light, and inexpensive in comparison with the conventional CT (current transformer) and PT (potential transformer) since it does not require high potential insulators and magnetic cores, further, the equipment is easily installed owing to its small size and its simple structure.

Keywords: Rogouski coil, Current sensor, Distributed generation, Electric power system, Energy-Network, Optical signal link, Remote current and voltage measurement, Voltage sensor LED, Zinc oxide (ZnO)

1. INTRODUCTION

For the sake of stable control of electric power systems or the estimation of breakdown points, it is necessary to monitor a current and voltage (potential) of power transmission lines. Current Transformer (CT) and Potential Transformer (PT) have been widely used for the measurement of current and voltage (potentials), respectively, of power transmission lines. They include high potential insulators and magnetic cores which are so heavy, large-sized, and expensive. Magnetic cores further cause saturation effects in their irons under transient or fault currents. CT and PT also consume much electricity, e.g., a rated output of CT and PT are 5-amp and 100-volt (standard value). Therefore, alternative techniques to CT and PT have been developed for the measurement of current and voltage of power transmission or distribution lines. In this paper we propose portable equipment without magnetic cores and high potential insulator for monitoring a current and voltage of power transmission lines as shown in Fig. 1. The equipment consists of three components: a current sensor, a voltage sensor, and a hollow insulator that supports a power transmission line. We pick up a current of a power transmission line by Rogouski coil. We transmit the detected current signal to the ground station by a wireless optical link using Voltage –Frequency conversion of an LED light. To detect the potential of a power transmission line we use a high gradient resistor ZnO which functions as a potential divider between the power line and the ground.

The proposed equipment is portable since the current sensor is attached to the hollow insulator supporting a power line and the voltage one is embedded in the insulator. Further, the equipment does not require high-potential line since current information is transmitted with a wireless (optical) signal link; and a voltage detector ZnO used here is a high gradient resistor of the order of 60 M ohm. The detected signals from the current and voltage sensor are processed using an electronic circuit which brings them to signals suitable for transmitting and monitoring purposes. This enables us to monitor the current and voltage of power lines over a wide dynamic range We apply communication and

solid-state technologies to the measurement of a current and voltage in power systems. As a result, the proposed equipment can be miniaturized and operated under low electricity consumption in comparison with the conventional CT and PT.

2. PPROPOSED CURRENT AND VOLTAGE SENSOR

In this section we describe a current and voltage sensor that detect a current of a power transmission line and a potential between the line and the ground.

$$e_l(t) = -\mu_0 lN \ln \frac{b}{a} \frac{di(t)}{dt}. \quad (1)$$

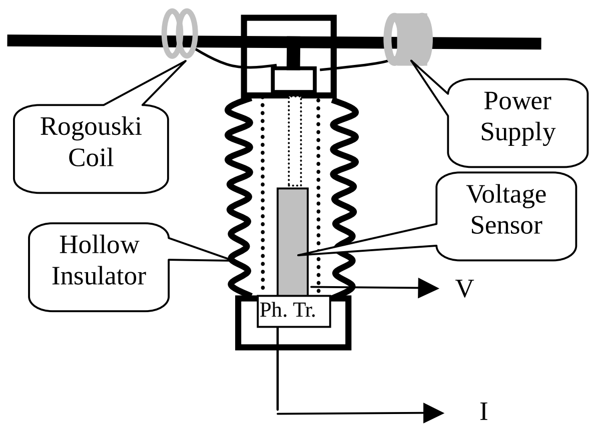

Fig. 1 Proposed equipment.

Here, μ_0 is permeability of the air, N is the number of turns of the coil, and a, b, and l are its geometrical parameters illustrated in Fig. 2.

The induced voltage $e_l(t)$ is integrated by a negative feedback circuit consisting of an Op-Amp. The integrated signal is then transmitted to the local station on the ground with an optical data link. After the integrated signal is converted into frequency in which the centre is 100 KHz (by using IC MAX 038 Voltage-Frequency converter), the signal is used for red LED irradiation and direct modulation. The intensity-modulated LED light travels through the hollow of insulator. The receiver consists of a phototransistor, preamplifier, Frequency-Voltage converter (IC LM2907), and Low pass filter. The current $i(t)$ is observed as the output of the receiver $e_i(t)$.

As will be shown later the current sensor ensures high linearity of signal level with respect to the measured current and provides a wide dynamic range from a stationary current level of power lines to fault one. Power supply for active devices including in integrator and transmitter of the current sensor is provided from a part of transmission power of the power line. This self-powered supply is described in paper [8].

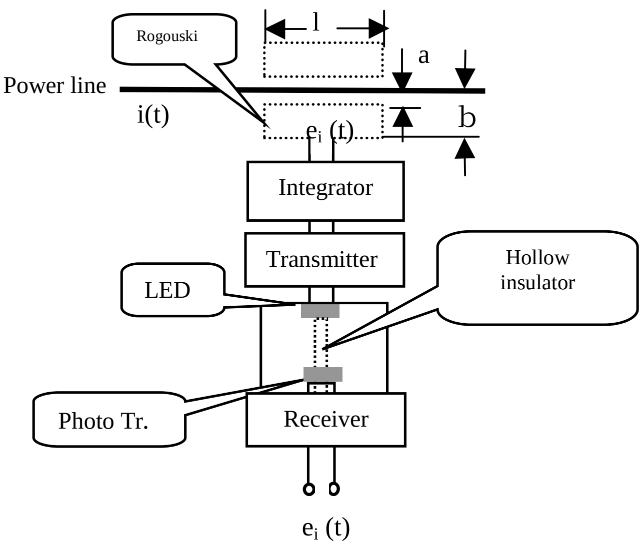

Fig. 2 Component of current sensor.

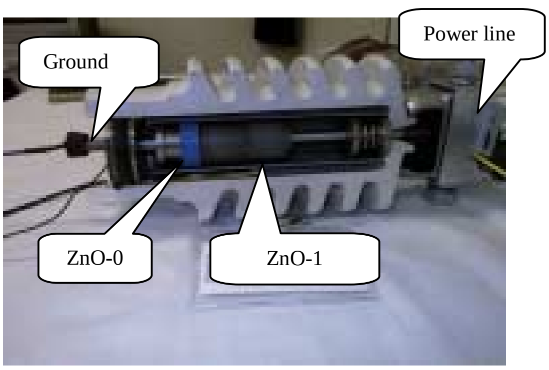

Fig. 3 Appearance of voltage sensor.

The proposed current sensor includes no high potential insulators except for a supporting insulator. Further magnetic cores also are not used in the current sensor. The proposed equipment is therefore totally free from saturation effects in irons under transient or fault currents when an accident on a power line occurs.

2.2 Potential Sensor

We use a high resistance element voltage sensor proposed by Y. Kuribayashi and H. Ueda to detect a potential of a power transmission line by using. As shown in Fig. 3, we connect two zinc oxide elements, ZnO-0 and ZnO-1, in series between a power line and the ground. The potential of a power line $V(t)$ is divided by the ZnO elements and given by

$$V(t) = \frac{Z_0 + Z_1}{Z_0} V_0(t). \qquad (2)$$

Here, Z_0 and Z_1 are the impedance of ZnO-0 and ZnO-1, respectively, and $Vo(t)$ is a terminal voltage of ZnO-0.

We measure the impedance of ZnO-0 and ZnO-1 that are used in the proposed voltage sensor. The experimental results are shown in Fig. 4 which is an equivalence circuit of the voltage sensor consisting of the ZnO elements. Note that the ZnO element is approximated by an RC parallel circuit. :We thus obtain a potential of a power transmission line by detecting the terminal voltage of ZnO-0. In order to evaluate an equivalence circuit of the voltage sensor consisting of the ZnO elements. an equivalence circuit of the voltage sensor consisting of the ZnO elements.

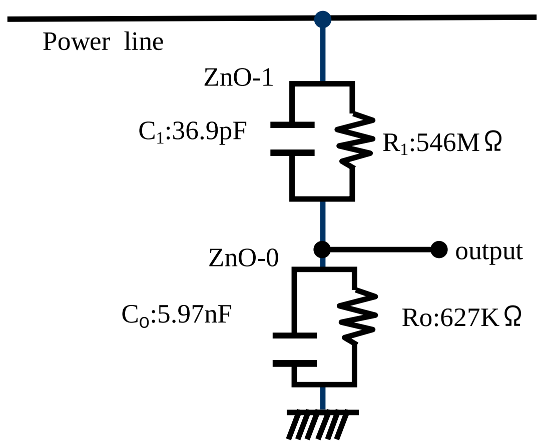

Fig. 4 Equivalent circuit of potential sensor.

3. EXPERIMENTAL RESULTS

We make an experimental device for monitoring a current and potential of 3-phase 6.6 KV power lines of 60 Hz. Figure 8 shows experimental set up for the proposed equipment. In this section we show experimental results measured by the proposed equipment.

3.1 Measurement of Current

We design the current sensor so that currents ranging from 0 to 600 A can be monitored. By this specification parameters of the air-core solenoidal coil used here are determined as follows: a=1.5 cm, b=4.5 cm, l=5 cm, and N=854.

We measure the current of a power line by the propos ed sensor and the usual CT. We denote by V_c the output of the proposed sensor and V_{CT} for CT.

Figure 9 shows V_c and V_{CT}, the induced voltage of the coil e_l when I_0 is 100 A. In this figure we observe that the two sensors detect the sinusoidal current signal. Note that the phase of the signal detected by the proposed sensor is same as that of CT although the amplitude is different to each other.

Figure 10 shows linearity of current sensor. The amplitude of detected current has fine linearity with flowing current of power transmission line.

3.2 Measurement of Potential

We detect the potential, i.e., the voltage between a power line and the ground, by the ZnO sensor described in 2.B and the usual PT. We denote by V_{ZnO} the output of the ZnO sensor and V_{PT} for PT.

Figure 11 compares the waveform of V_{ZnO} with that of V_{PT} that the ZnO sensor detects the sinusoidal voltage signal of 60 Hz. We also observe the phase shift of the detected signal from that of CT associated with the reactance component of ZnO element. The phase shift can be corrected by using an appropriate electronic circuit.

Next we investigate the linearity between the detected signal by the ZnO sensor and the power line potential. Figure 11 shows the rms values of the detected potential when the power line potential is varied from 0 to 6000 V. The maximum error with respect to the magnitude of potential detected by the ZnO sensor is less than 4.4 %.

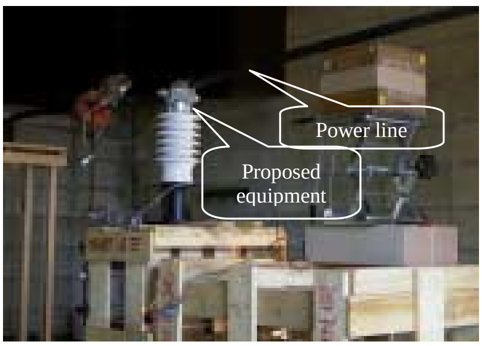

Fig. 5 View of experimental set up

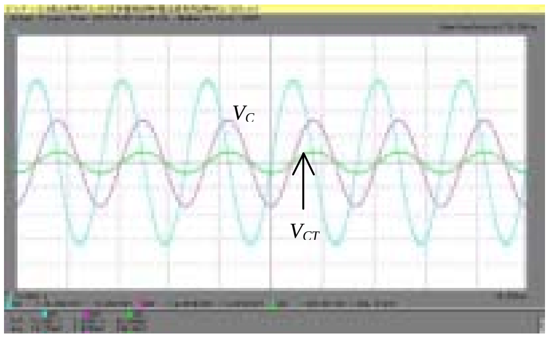

Fig. 6 Wave forms of V_c, V_{CT}, and e_l.

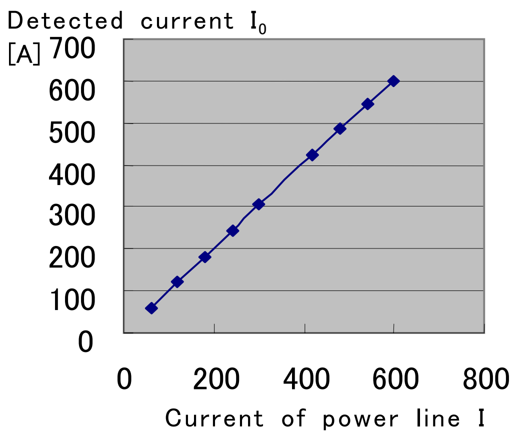

Fig. 7 Linearity of the current sensor

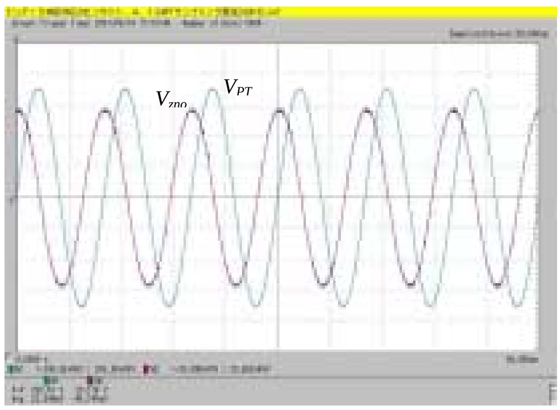

Fig. 8 Waveform of V_{ZnO} and V_{PT}.

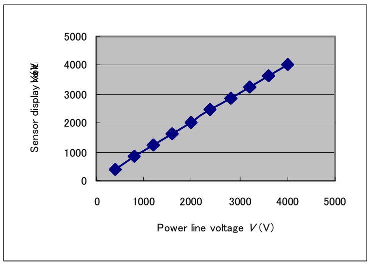

Fig. 9 Detected potential as functions of p ower line potentials.

4. CONCLUSION

We have carried on the following studies to develop a current and potential sensor for monitoring power transmission line:

A current on the power line is detected by a Rogouski coil clamped to the power line and the detected current signal is transmitted to the ground station through a modulated LED light;

A voltage is detected by a high gradient resistance element, zinc oxide (ZnO) that acts as a potential divider between the power line and the ground;

We made a trail model in which the current and voltage s ensor are embedded in a hollow insulator; and It is experiment ally demonstrated that the trial model measures the waveform of currents ranging from 0 to 600 A and potentials up to 6000 V.

We apply communication and solid-state technologies to the measurement of currents and voltages in power systems. As a result, the equipment can be miniaturized and operated under low electricity consumption in comparison with the conventional CT and PT.

AKNOLEGEMENT

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