Development of an Equipment for Monitoring Current and Voltage on a Power Transmission Line

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Abstract: A portable equipment that measures a current and voltage waveform of power transmission lines is proposed. In the equipment, the current and voltage, respectively, are detected by a loop coil and a capacitor clamped around the power lines. The detected data is transmitted by an FM wave to the receiver on the ground station. Since the receiver is isolated from the power lines, we do not require high potential insulators for the measurement of current and voltage. The proposed equipment is therefore, small-sized, light, and low in the cost of production. Experimental results presented here show that the equipment can monitor the current flowing in single wire over a ground plane and the potential of the wire.

1. Introduction

For the sake of stable control of electric power systems or the estimation of breakdown points on power transmission lines, it is necessary to monitor currents and voltages of the power lines. CT(Current Transformer) and PT(Potential Transformer) have been widely used for the measurement of the current and potential, respectively. The conventional CT and PT include magnetic cores and high potential insulators, which are so heavy, large-sized, and expensive. Therefore, novel monitoring systems of power transmission lines have been developed [1-3].

We here propose a portable monitoring equipment without magnetic cores and high potential insulators. In the equipment, we use a loop coil to detect a current and a capacitor to detect a voltage (potential) of a power transmission line, and then transmit the detected data to the local station on the ground by an FM wave. The proposed equipment is small-sized, light, and low in the cost of production, in comparison with the conventional CT and PT since it is not necessary to use magnetic cores and high potential insulators. In what follows, we first describe each component of the equipment and then show experimental results such as current and voltage waveforms of single wire measured by it.

2. Current and Voltage Monitoring Equipment

We here explain the equipment that monitors the current flowing in power transmission lines and the potential of the power line. Figure 1 shows the block diagram of the proposed monitoring system. The system consists of three components: a) Detector, b) Transmitter and Receiver, and c) Signal processor.

2.1 Detector

We denote by i(t) and v(t), respectively, the current and potential of single wire over a ground plane. Figure 2 de-

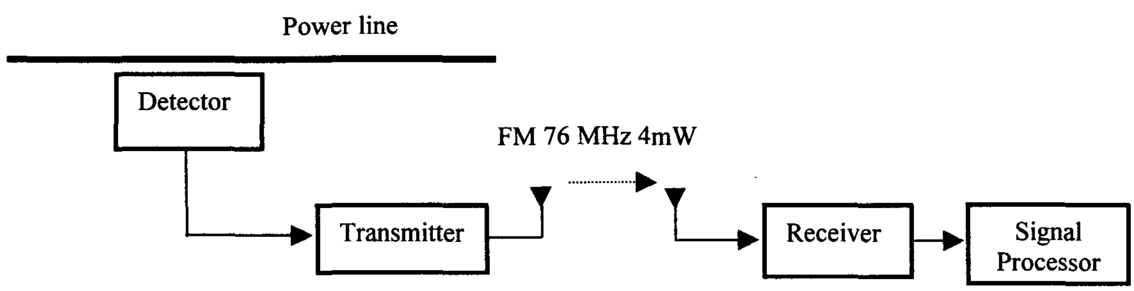

Fig.1 Proposed monitoring system

notes a schematic representation of the detector component of the current and potential.

2.1.1 Current Detector

As a detector of the current we use a rectangular loop coil which picks up magnetic fields radiated by the current i(t). The induced voltage of the loop coil $e_\ell(t)$ is given by

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

where μ_0 is permeability of air, and a, b, and ℓ are shown in Fig.3. The induced voltage is integrated by the negative feedback integrator. The output signal $e_i(t)$ from the integrator is proportional to the current i(t) to be monitored.

2.1.2 Voltage Detector

We detect the potential v(t) by a tubular capacitor by which the single wire is surrounded as shown in Fig. 2. An equivalent circuit of the voltage detector is approximately given in Fig. 4 where C_{12} is capacitance of the tubular capacitor, C_{pl} denotes distributed capacitance between single wire and Conductor ①, and C_{20} is one between Conductor ② and a ground plane in Fig. 2. The potential v(t) is calculated from the voltage of the tubular capacitor v(t) by the following equation:

$$\mathbf{v(t)} = \frac{1/C_{pl} + 1/C_{12} + 1/C_{20}}{1/C_{12}}\, v_{12} \quad (2)$$

Hence, we can monitor v(t) by detecting $v_{12}(t)$ provided that the capacitance C_{12}, C_{pl}, and C_{20} are constants. The values of the capacitances are investigated from theoretical and experimental points of view.

2.2 Transmitter and Receiver

Since the detected analog signals $e_i(t)$ and $v_{12}(t)$ are transmitted with a radio (wireless) link to the receiver on the ground, the receiver is electrically isolated from the high potential line. As a result, the proposed system does not require insulators which are used in the conventional CT and PT. We employ the data transmission by an FM wave whose carrier frequency is 76 MHz and radiation power is 4 mW.

2.3 Signal Processor

The receiver is connected to a personal computer through a signal processor unit including an A/D converter. The signal processor is in the process of development now.

3. Experimental Result

As an experimental example, we monitor the current and potential of a copper wire over a metallic plane. Figure 5 shows a view of experimental setup for measuring current. A sinusoidal voltage of commercial frequency (60 Hz) is applied to the wire. The effective value of the current and potential of the wire are denoted by I and V, respectively.

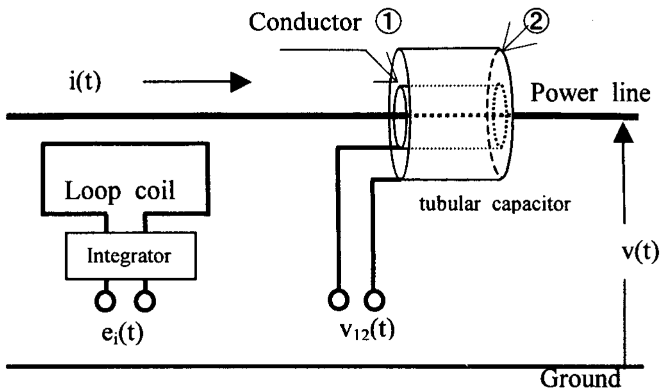

Fig.2 Detector Component

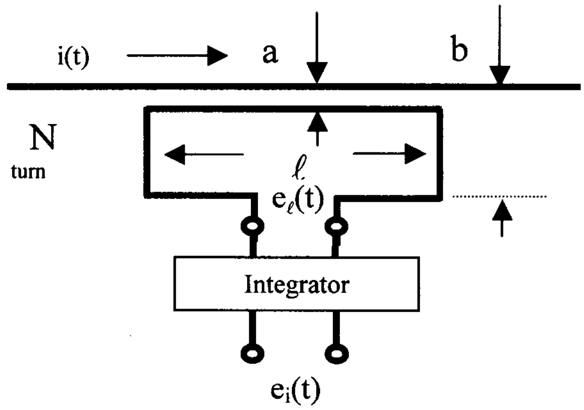

Fig.3 Current Detector

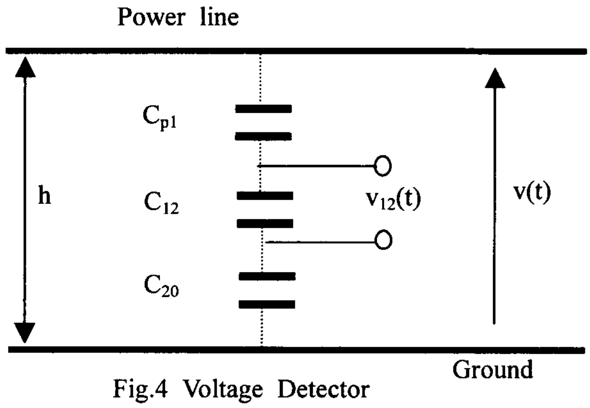

Fig.4 Voltage Detector

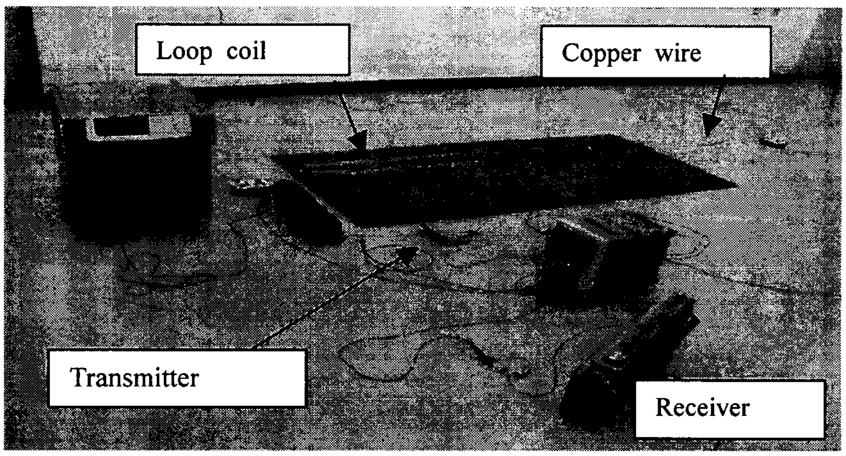

Fig.5 A view of experimental setup for measuring current

3.1 Preparation

It is necessary to measure not only a fundamental wave of 60 Hz but also its harmonic components in the case of the monitoring purpose of the electric power system such as the estimation of breakdown points. We, therefore, investigate the frequency characteristics of the proposed monitoring equipment before measuring current or potential waveforms. Figure 6 shows the output voltage from the receiver as functions of frequency when the input level to the transmitter is kept constant. We observe in the figure that the output is flat over the region from 50 Hz to 2 KHz. The equipment, thus, enable us to measure the harmonic components of current or potential.

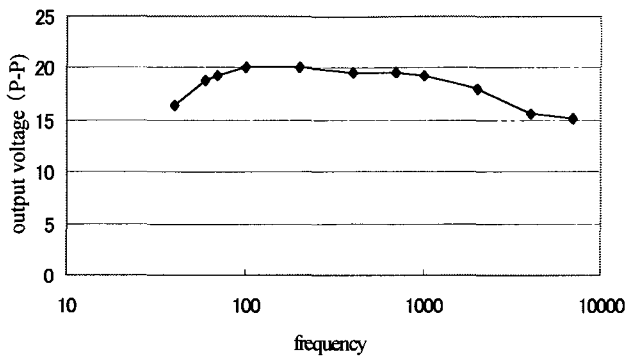

Fig.6 Frequency characteristic of Transmitter and Receiver

3.2 Current monitoring

Table 1 indicates the size of a loop coil detecting the current of the effecting value I (5A, 100A).

Figure 7 shows experimental results in case of the loop coil A; (a) the waveform of a current on a wire i(t); (b) the induced voltage $e_\ell(t)$; (c) the output from integrator $e_i(t)$; and (d) the current waveform from Receiver.

Figure 8 shows the waveform of each component of the current monitoring equipment when I=0. This figure indicates an influence of noise in these components. Detector differentiates the current waveform of the power line, so the detected waveform includes high frequency noises. On the other hand, Integrator reduces high frequency noises because it functions as a low pass filter. The transmitter and receiver also reduces the noise as confirmed from the waveform (c) and (d).

Figure 9 shows the integrated waveform detected by Coil B when I=100A. It shows the effect of noise reduction through Integrator.

Table 1 Size of loop coil (f=60Hz)

Coil	I[A]	a[cm]	b[cm]	l[cm]	N[turn]
A	5	2	10	170	30
B	100	1	11	20	50

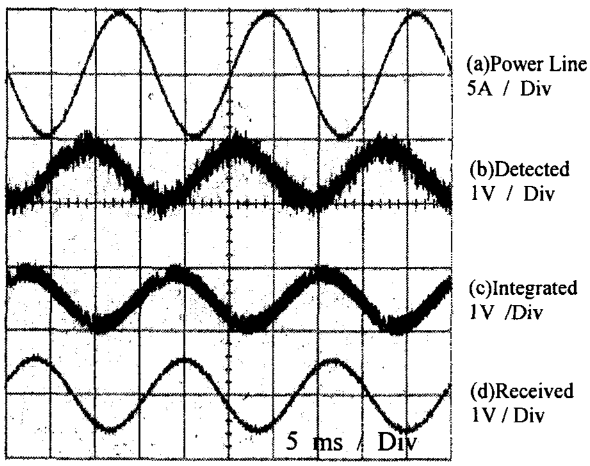

Fig.7 Waveforms of each component when I = 5A(Coil A)

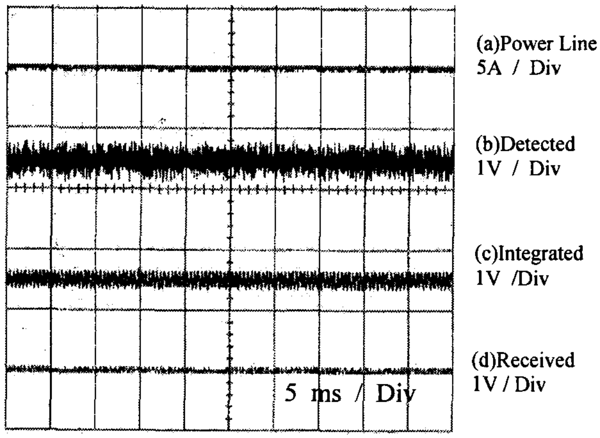

Fig.8 Waveforms of each component when I = 0A(Coil A)

3.3 Voltage monitoring

Figure 10 shows an obtained voltage waveform by the detector when V=60(V).

Figure 11 shows the dependence of V_{12} on h where V_{12} is the voltage of the detecting capacitor and h is the height from the ground to the wire. As shown in this figure, the detected voltage V_{12} decreases with the height h.

4. Conclusion

We have proposed the monitoring equipment that measures the current and voltage waveform of power transmission lines. It is experimentally confirmed that the equipment enables us to monitor the current flowing in single wire over a ground plane and the potential of the wire. The equipment has following advantages:

(a) The equipment consists of a loop coil, a tubular capacitor and electronic devices. It is small sized, light, and low in the cost of production compared with the conventional CT and PT.

(b) The equipment is able to monitor the waveform of an accident current since it has a broad range of measurement with respect to both frequency and intensity of current.

(c) The equipment consumes very little electricity since active elements are used just in an integrator and a transmitter.

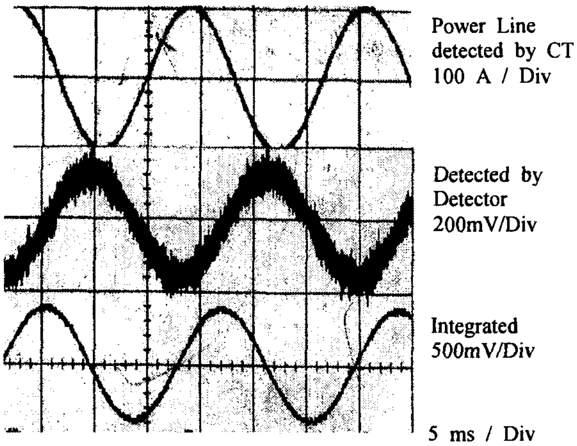

Fig.9 Detected waveform of the current of I = 100A(Coil B)

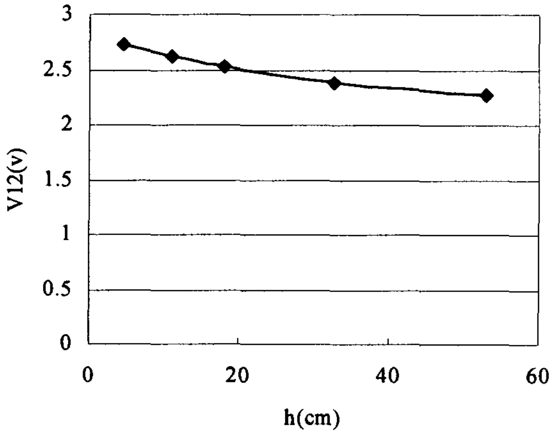

Fig.10 V as functions of h

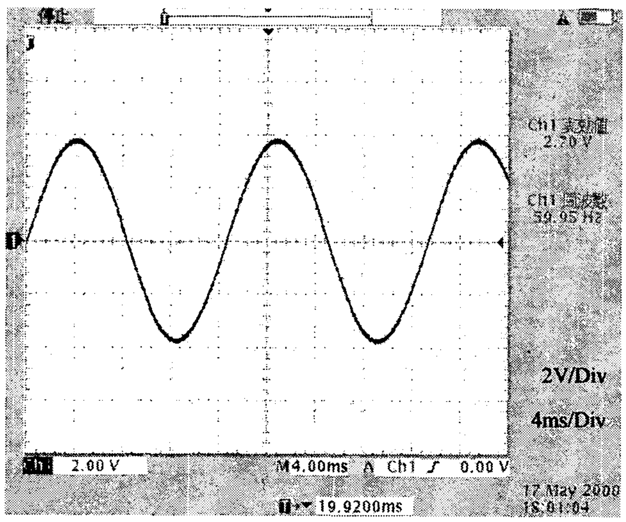

Fig.11 A monitored voltage waveform (V=60V, h=4.5cm)

Reference

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