Measurement Method of the Resistive Leakage Current for Lightning Arrester Diagnosis

Gyung-Suk Kil[a], Ju-Seop Han, Jae-Yong Song, and Hwang-Dong Seo
Division of Electrical and Electronics Engineering, College of Engineering,
Korea Maritime University, 1 Dongsam-dong, Yeongdo-gu, Busan 606-791, Korea

[a]E-mail : kilgs@hhu.ac.kr

(Received February 3 2005, Accepted April 8 2005)

Several ways for monitoring the soundness of ZnO lightning arresters have been suggested, and all of which are based on the measurement of leakage current since it is well known that the resistive leakage current is a main indicator of arrester deterioration. In this paper, we proposed an algorithm to measure the resistive leakage current, which is quite different from the conventional method that eliminates capacitive current from the total leakage current. The proposed algorithm is based on that the magnitudes of the resistive leakage current are equal at the same applied voltage levels. To confirm the reliability of the algorithm, we fabricated a leakage current detector and designed an analysis program. Experimental results showed that the method does not need a complex circuitry and is useful to analyze the resistive leakage current.

Keywords : Lightning arrester, Resistive leakage current, Algorithm, Arrester diagnosis

1. INTRODUCTION

Lightning arresters are the best protective device in electrical power systems against transient overvoltages generated by lightning discharges and switching operations, but the arresters are deteriorated by the repetition of protective operations, the absorption of moisture, and defects at the time of manufacturing. The deteriorated arresters may lead to a power failure. Therefore, to diagnose arresters' soundness in online state is necessary[1-3].

As well known, the resistive leakage current is the most important parameter in arrester diagnostics, but total leakage current and/or the third harmonic component flowing through an arrester are widely employed as an ageing indicator because a complicated hardware configuration and an algorithm are needed to separate resistive leakage current from the total leakage current.

This paper proposes a method of measuring resistive leakage current. We designed an algorithm to measure resistive leakage current by a theoretical analysis on characteristics of the leakage current components. The algorithm proposed in this paper is expected to be widely employed to the related fields because of the simplicity of hardware and algorithm.

2. PRINCIPLE

There are several ways of monitoring resistive leakage current flowing arrester, and all of which eliminates the capacitive leakage current from the total leakage current to detect the resistive leakage current[3,4]. This also requires a complicated hardware and an algorithm.

The proposed algorithm is quite different from the conventional method and is based on the theory that the magnitudes of resistive leakage current are equal at the same level of applied voltage to an arrester. To understand the above algorithm, knowledge on an electrical equivalent circuit of the ZnO arresters must be acquired. The equivalent circuit of ZnO arresters is shown in Fig. 1.

The total leakage current flowing through the arrester is composed of the resistive leakage current I_r and the capacitive leakage current I_c. The resistive leakage current is produced due to the changes of schottky barrier which are formed between the ZnO grains, and increases with arrester deterioration[5].

Figure 2 shows waveforms of the leakage current components when a rated operating voltage is applied to arresters. As well known, the capacitive leakage current leads 90 ° and the resistive leakage current is the same phase to the applied voltage, respectively.

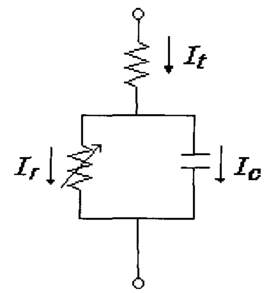


Fig. 1. Electrical equivalent circuit of arresters.

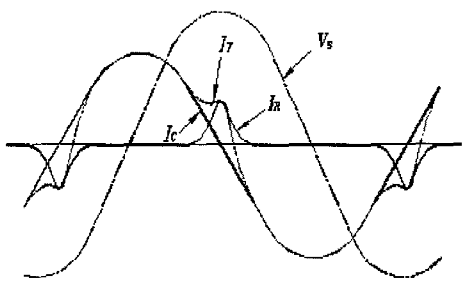


Fig. 2. Waveforms of the applied voltage and the leakage current components.

As shown in Fig. 3, also the leakage current components at each time, i and j can be written as;

$$I_r(i)+I_c(i)=I_t(i) \tag{1}$$

$$I_r(j)+I_c(j)=I_t(j) \tag{2}$$

If the magnitude of the voltages applied to the arrester at i and j, are equal, $V(i)=V(j)$, the resistive and the capacitive leakage currents are expressed as;

$$I_r(i)=I_r(j)=I_r \tag{3}$$

$$I_c(i)=-I_c(j) \tag{4}$$

This allows simplification;

$$I_r(i)+I_r(j)=I_t(i)+I_t(j) \tag{5}$$

$$2I_r=I_t(i)+I_t(j) \tag{6}$$

$$I_r=\frac{I_t(i)+I_t(j)}{2} \tag{7}$$

These equations are used to calculate the magnitude of the resistive leakage current flowing through an arrester and to reproduce the resistive leakage current waveform.

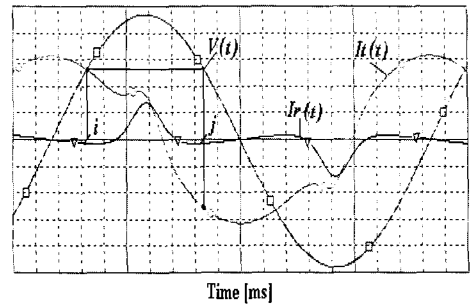


Fig. 3. Waveforms of applied voltage and leakage current component.

3. EXPERIMENTAL SET-UP

The proposed method requires the measurement of the voltage applied to an arrester and the current flowing through the arrester. In this study, we measured the voltage by using a high voltage probe (P6015A, Tek.) and designed a leakage current detector which is composed with a clamp-type ZCT (Zero-phase Current Transformer), a differential amplifier, a low-pass filter, and an impedance converter. The leakage current detector has a sensitivity of 1 mV/uA, an effective measurement range of 50 uA~5 mA, and a frequency bandwidth of 7 Hz~2.8 kHz (-3 dB) as shown in Fig. 4.

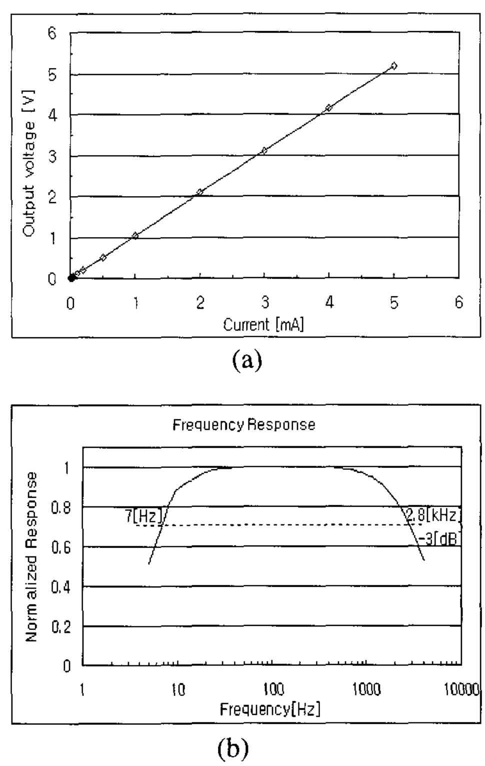


Fig. 4. Electrical characteristics of the leakage current detector: (a) input current vs. output voltage and (b) frequency bandwidth.

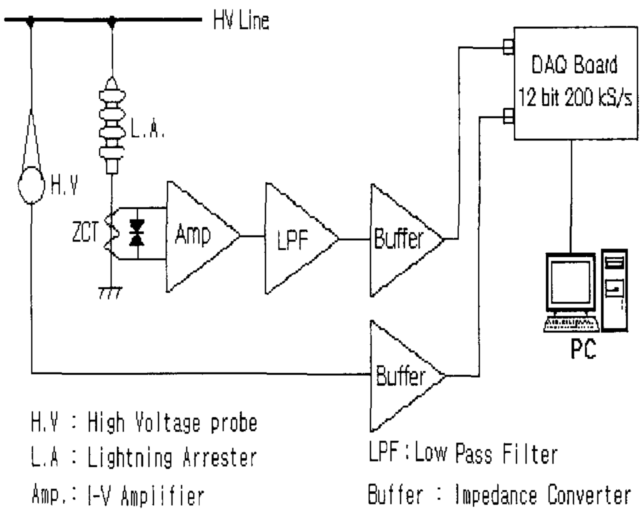
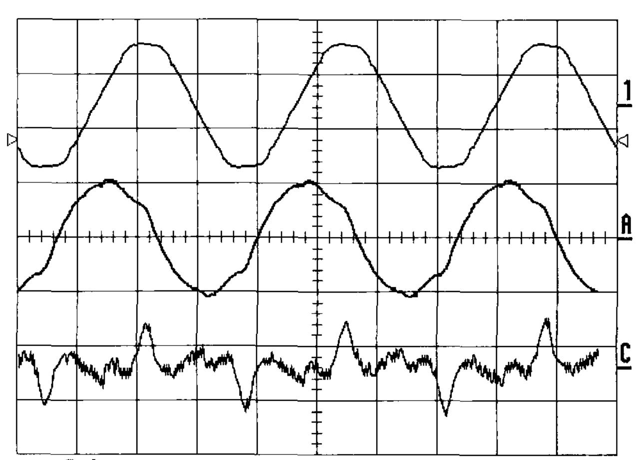


Fig. 5. Configuration of the experimental set-up.

The experimental set-up for measuring the applied voltage and the leakage current is shown in Fig. 5. The measured voltage and the current are input to a DAQ (12 bit 200 ks/S) input, and the resistive leakage current is analyzed by using the proposed algorithm.

4. RESULTS AND DISCUSSION

Figure 6 shows the waveforms of the applied voltages, the total leakage current, and the resistive leakage current calculated by a mathematical function equipped in a digital oscilloscope (9240C, Lecroy).



Ch.1 applied voltage [5kV/div, 5ms/div]
Ch.A total leakage current [800uA/div, 5ms/div]
Ch.C resistive leakage current [500uA/div, 5ms/div]

Fig. 6. Waveforms of the voltage and the leakage current components.

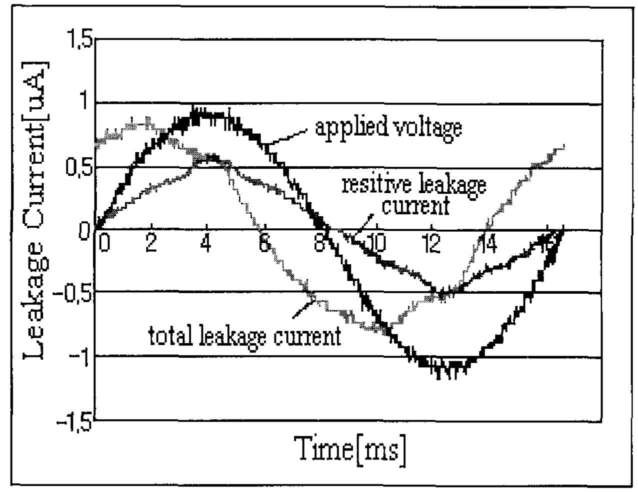


Fig. 7. Analyzed resistive leakage current waveform.

The RMS value of the applied voltage is 2.6 kV, and the maximum value of the total leakage current is 810 uA. The maximum value of the resistive leakage current is 510 uA.

The resistive leakage current analyzed by the algorithm is shown in Fig. 7. The maximum value of the resistive leakage current is 530 uA. There are differences of 20 uA in the two results. This is resulted from an error caused by manual operation for calculating the resistive leakage current in the oscilloscope.

5. CONCLUSIONS

In this paper, we proposed a method to analyze the resistive leakage current which stands for an indicator of the arrester deterioration. The possibility of the algorithm is experimentally tested by using an arrester block, and it is confirmed that the algorithm can calculate the magnitude of the resistive leakage current and reproduce the resistive leakage current waveform.

The major advantage of the proposed method is that it does not require a complex circuitry and is easy to completion.

ACKNOWLEGMENT

This work has been supported by KESRI(R-2005-B-138), which is funded by MOCIE(Ministry of Commerce Industry and Energy).

REFERENCES

[1] C. Yue, "The research of methods of determining condition of ZnO surge arresters", High Voltage

Technology(in Chinese), Vol. 24, No 4, p. 35, 1995.
[2] H. Zhu and M. R. Raghuveer, "Influence of harmonics in system voltage on metal oxide surge arrester diagnostics", Proceeding of the 1999 Annual Report Conference on Electrical Insulation and Dielectric Phenomena, p. 542, 1999.
[3] S. Shirakawa, F. Endo, S. Kobayashi, K. Kurita, K. Koto, and M. Sakai, "Maintenance of surge arrester leakage current detector", IEEE Transaction on Power Delivery, Vol. 3, No. 3, p. 998, 1988.
[4] J. Lundquist, L. Stenstrom, A. Schei, and B. Hansen, "New method for measurement of the resistive leakage currents of metal-oxide surge arresters in service", IEEE Transaction on Power Delivery, Vol. 5, No. 4, p. 1811, 1990.
[5] T. K. Gupta, "Application of zinc oxide varistors", Journal of the American Ceramic Society, Vol. 73, No. 7, p. 1817, 1990.