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An Arrester Diagnosis by Measurement of Surface Temperature

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Abstract: A surface temperature of ZnO arresters as a function of ambient temperatures and leakage currents, and a variation of the leakage current according to the change of ambient temperatures as a seasonal characteristic were experimentally studied. The variations of the leakage current in range of -20 ℃ ~ 50 ℃ were below 10 ㎂, which comes about 4.5 % of the normal leakage current. Temperature difference between the ambient and the surface of arresters did not appear until 150 % to the normal leakage current, and appeared remarkably over 200 % of it. From the experimental results, we propose a polynomial to estimate the leakage current by measuring temperature difference of them. Tests on the used arresters showed the same results as the experimental ones.

Key-Words: ZnO arrester, Leakage current, Surface temperature, Ambient temperature, Diagnosis

1 Introduction

ZnO arresters are widely used to protect electric power facilities against overvoltages caused by lightning or switching surges. However, the arresters are deteriorated by commercial frequency overvoltages and/or lightning one. Deteriorated arresters could lead power failures, such as line to ground fault by a thermal runaway resulting from the increases in leakage current even in a nominal power system voltage [1~3].

Various arrester diagnostics have been proposed mainly based on leakage current analysis [4~6], and those have been being difficult in measurement of leakage current because of power system voltage harmonics and electromagnetic interferences [7]. Therefore, we have experimentally studied the leakage current vs. surface temperature of an arrester and the ambient temperature vs. leakage current of one to propose a new easy arrester diagnostic technique.

2 Experiments

Figure 1 shows the configuration of the experimental apparatus to analyze the correlation between deterioration of arresters and leakage currents, and surface temperature of one. A new gapless ZnO arrester (18 kV, 5 kA class) was used as a test sample. A data acquisition system (KEITHLEY, DAS-TC) with 10-thermocouple inputs was used to measure the ambient and surface temperature of arresters.

AC voltage applied to the arrester, and leakage currents were measured by using a high voltage probe (Tektronix, P6015A) and digital multi-meter (Fluke, 45).

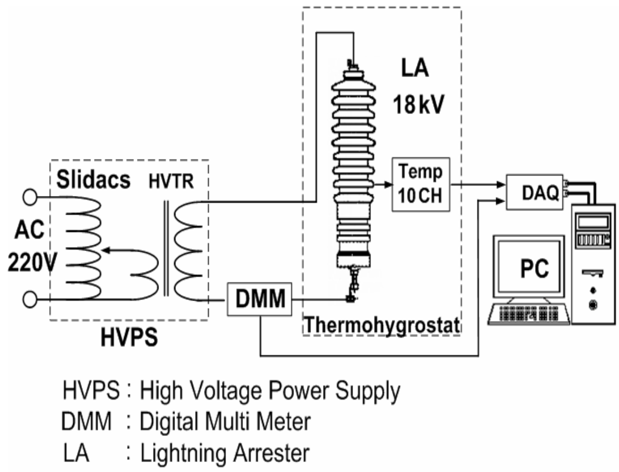

Fig. 1. Configuration of the experimental apparatus

Two ways of experiment were carried out: a) changes of leakage current as a function of ambient temperature, b) correlation between leakage current and surface temperature of an arrester. For the experiment, an arrester was set in a thermo-hygrostat and kept at a required temperature for over 2 hours.

The experiment on changes of leakage current as a function of ambient temperature started at 50 ℃ and then stepped down by 5 ℃ to -20 ℃.

Correlation between leakage current and surface temperature of an arrester was analyzed by every 10 ℃ in ranges from 35 ℃ to -15 ℃, increasing the leakage current up to 500 % of normal one. Also, the same types of arresters which were deteriorated in a power system (# 1) 340 μA_{rms} (155 %), (# 2) 430 μA_{rms} (195 %), (# 3) 640 μA_{rms} (290 %), were tested and compared with the results of the new one.

A photograph of the experimental apparatus is shown in Fig. 2. The ambient temperature was 25 ℃, and the surface temperature was measured two hours after applying 13.2 kV_{rms} AC voltage to the arrester.

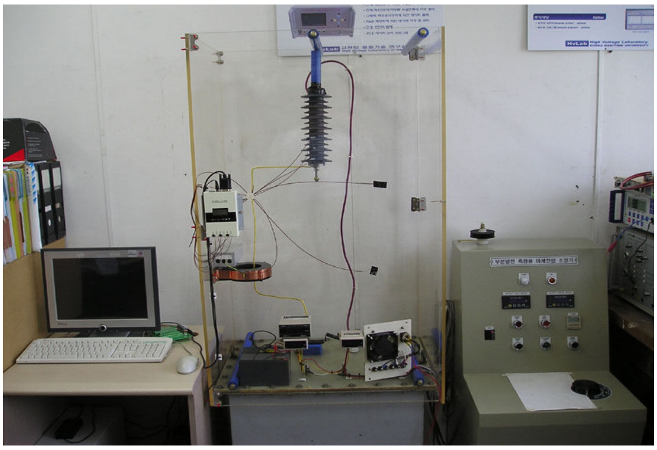

Fig. 2. Photograph of the experimental apparatus

3 Results and Discussion

3.1 Ambient temperature vs. leakage current

Figure 3 shows a relationship between ambient temperature and leakage current when 13.2 kV_{rms} of power system voltage is applied to the new arrester. Leakage current is about 222 ㎂ at 25 ℃ and maximum variation is 10 ㎂ (217 ㎂ ~ 227 ㎂) in ranges from 50 ℃ to -20 ℃. This comes about 4.5 % of the normal leakage current which flows in the application of power system voltage, and is less variation than the difference by arresters' characteristics. Consequently, it may not be necessary to consider the changes of leakage current to ambient temperature in arrester diagnostics.

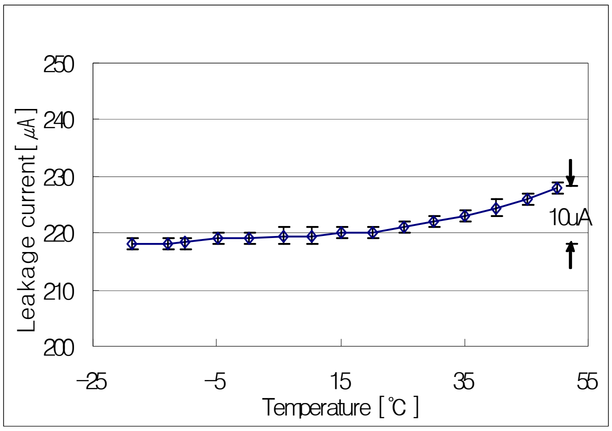

Fig. 3. Leakage current variations as a function of ambient temperature

3.2 Correlation between leakage current and surface temperature of arresters

Leakage current of an arrester increases as its ages, and the surface temperature of it also rises. This means the surface temperature is a function of leakage current and ambient temperature.

Figure 4 shows the correlation between leakage current and surface temperature at each steps of an ambient temperature when the leakage current increases in range of 100 % ~ 500 % of the normal leakage current with increasing the applied voltage.

Temperature difference between the ambient and the surface of arresters did not appear until 150 % of the normal leakage current, and appeared remarkably over 200 % of it. This difference increases with increasing the ambient temperature.

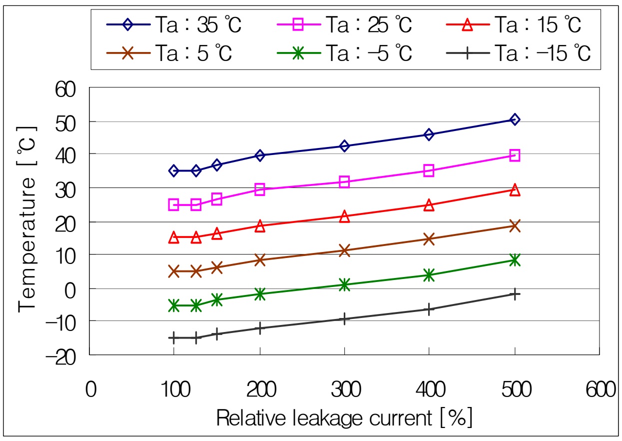

Fig. 4. Correlation between leakage currents and surface temperatures

The correlation between temperature difference and leakage current rearranged from the Fig. 4 is shown in Fig. 5. Temperature difference between the both is 1 ℃ ~ 2 ℃, 3 ℃ ~ 5 ℃, 6 ℃ ~ 7 ℃, 9 ℃ ~ 11 ℃, and at least of 15 ℃ at 150 %, 200 %, 300 %, 400 %, and 500 % of the normal leakage current, respectively. These results enable us to estimate the leakage current flowing them or to diagnose arresters by measuring the surface temperature of arresters.

The correlation between the temperature difference and the leakage current can be shown as a polynomial representation depending on ambient temperature from the Fig. 5.

In the ambient temperature range > 0 ℃, the polynomial is :

$$y = -0.0015x^3 + 0.0338x^2 + 0.0862x + 1.2475 \ [\%] \quad (1)$$

and for temperature ≤ 0 ℃,

$$y = -0.0016x^3 + 0.0307x^2 + 0.1616x + 1.2482 \ [\%] \quad (2)$$

where, y is the relative magnitude of the normal leakage current, and x is the temperature difference between the ambient and surface of the arrester.

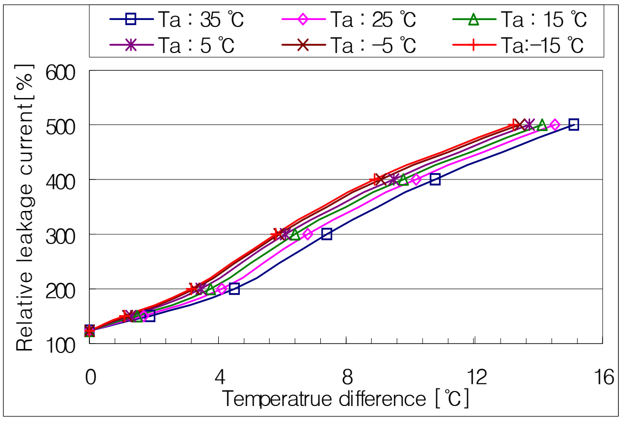

Fig. 5. Correlation between temperature differences and leakage currents

Figure 6 shows an example of a comparison between an experimental result and a calculation one by using the polynomial (1). The deviation between these two results appeared in only over 400 % of the normal leakage current and is bellow 0.5 %. Using the polynomial (1) and (2), we can calculate the leakage current flowing the arrester just put in temperature difference.

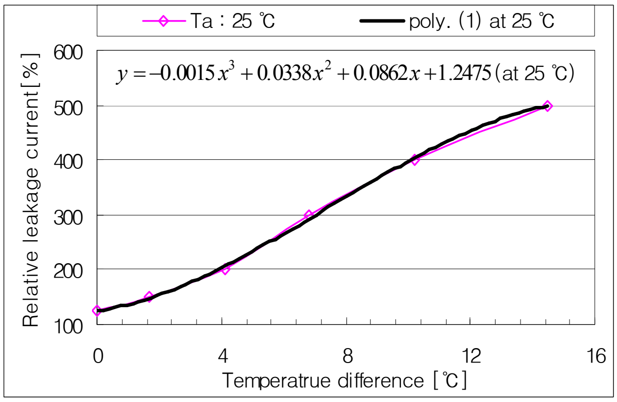

Fig. 6. Comparison between an experimental result and a calculated one by polynomial (1)

3.3 Tests on used arresters

Deteriorated arresters used in a high voltage distribution line were tested to compare with the results of Fig. 4 at the ambient temperature of 25 ℃, and the test result was shown in Fig. 6. Temperature differences were 2 ℃ in arrester # 1 (flowing 155 % of the normal leakage current), 4 ℃ in arrester # 2 (flowing 195 % of it), and 7 ℃ in arrester # 3 (flowing 195 % of it). This result accords with one of Fig. 4.

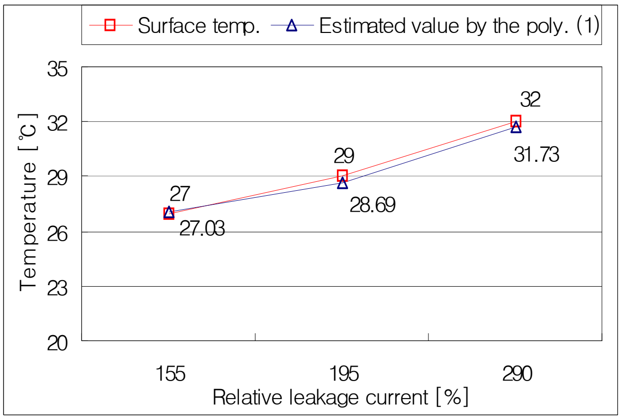

Fig. 7. Correlation between leakage current of used arresters and surface temperature

This experiment was not considered the influence of wind and radiant heat in a real environmental condition where the arresters are set in. Regardless the change of ambient temperature, the variation of leakage currents was little, and the temperature difference was shown over 3 ℃ remarkably from 200 % of the normal leakage current.

4 Conclusion

In this paper, the variation of leakage current as a seasonal temperature change and the correlation between the leakage current and the surface temperature of arresters were experimentally studied.

The variations of leakage current as the ambient temperature changes were below 10 ㎂ in the range of 50 ℃ ~ -20 ℃, which comes about 4.5 % of the normal leakage current and is less than the differences appeared by arresters' characteristics. Consequently, it may not be necessary to consider the influence of ambient temperature in arrester diagnostics.

Temperature difference between the ambient and the surface of arresters appeared remarkably over 200 % of the normal leakage current. We proposed a polynomial to estimate the leakage current flowing the arrester by measuring the surface temperature.

Tests on used arresters showed the same results as the experimental ones. From the results, we expect that a reliable arrester diagnosis is possible by measuring the surface temperature of them after more studies on the effect of wind, moisture penetration, and arrester types.

ACKNOWLEDGEMENT

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