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Degradation Characteristics on MOV of Surge Arrester used for 6.6kV Power Distribution Line

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***Abstract*— In Japan, porcelain-housed internally gapped lightning surge arresters are applied for 6.6kV distribution lines. A lightning surge arrester is composed of Metal Oxide Varistors (MOVs) and an internal gap, which are installed in a porcelain housing having sealing structure. It is well known that a dominant degradation factor of a surge arrester is follow current interrupting ability of a MOV. This paper is focused on follow current interrupting ability of a degraded MOV due to lightning current. The degradation characteristics of a MOV due to lightning surge is examined by measuring the reference voltage of the MOV after lightning impulse currents are applied to a MOV. The variation of the reference voltage in the negative direction voltage was bigger than that of the positive direction voltage. Therefore, it should be evaluated by checking the reference voltage using both positive and negative direction during the degradation test.**

Keywords- lightning surge arrester, lightning protection, reference voltage, MOV, degradation characteristics

I. INTRODUCTION

Porcelain-housed lightning surge arresters for 6.6kV distribution lines are consisted of a series gap and a MOV as shown in Figure 1. Those constructional elements are installed in a porcelain housing having a sealing structure. Figure 2 shows the MOV. Degradation factors of electrical characteristics of lightning surge arresters are summarized in Figure 3.

In terms of components, possible causes which relate to lightning surge arrester degradation are shown as follows;

- Degradation of the follow current interrupting ability of a MOV.
- Degradation of the discharge characteristics of a series gap.
- Degradation of internal insulation performance caused by deterioration of a sealing structure.

In order to examine the degradation of the follow current interrupting ability of a MOV, measuring the terminal voltage of a MOV in the small current region of DC 1mA (hereafter, reference voltage) is effective.

To examine the degradation of a series gap in a lightning surge arrester, discharge voltage should be measured by a dedicated measuring device.

The degradation of the internal insulation performance due to the degradation of a sealing structure can be examined by visual inspection and insulation resistance measurement. In addition, the degradation of a lightning surge arrester that is used for long term can be examined by checking the year of manufacture and the compression set of a sealing rubber of a lightning surge arrester.

This paper is focused on the degradation of a MOV and follow current interrupting ability of lightning surge arresters installing a degraded MOV. Moreover, the degradation characteristics of a MOV due to lightning currents are examined by measuring the reference voltage of the MOV after applying lightning impulse currents.

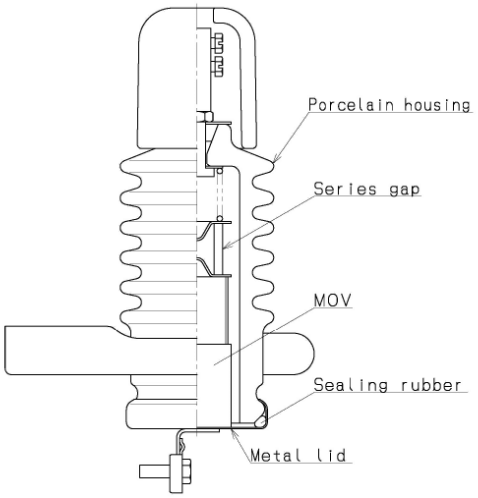


Figure 1. Structure of lightning surge arrester

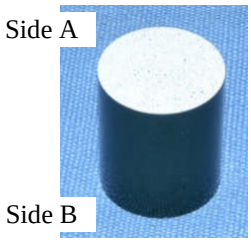


Figure 2. Appearance of a MOV

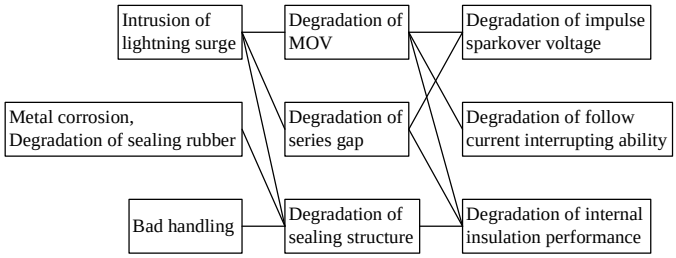


Figure 3. Flowchart of electrical degradation for a gapped surge arrester

II. TEST METHOD

A. The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 30kA.

As shown in Figure 4, high current lightning impulses (4/10 microseconds, 30kA, 37A/mm^2) are applied twice to three MOV samples with 5 minutes interval respectively. After the cooling down to the ambient temperature, reference voltages of samples are measured. Positive and negative direction of a lightning impulse current and measuring methods of a reference voltage are shown in Figure 5 and Figure 6.

The test is performed on the same type three samples of a MOV whose diameter is 32 mm.

B. The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 100kA.

This test is performed as shown Figure 7.

A high current lightning impulse (4/10microseconds, 100kA, 75A/mm^2) is applied twice to three MOV samples. The same as Test A, reference voltages of samples are measured after cooling down to the ambient temperature.

The test is performed on the same type three samples of a MOV whose diameter is 41mm.

C. Operating duty test of lightning surge arresters installing degraded MOVs.

The test procedure and test circuit are shown in Figure 8 and Figure 9.

Lightning impulse current (8/20microseconds, 2.5kA) is applied to a lightning surge arrester, which installs a degraded MOV and a series gap. In this test, lightning impulse currents are added to 8.4kV power frequency voltage. The decreasing rate of reference voltage of a MOV is about 8%, 11%, 14%, 17% and 20%.

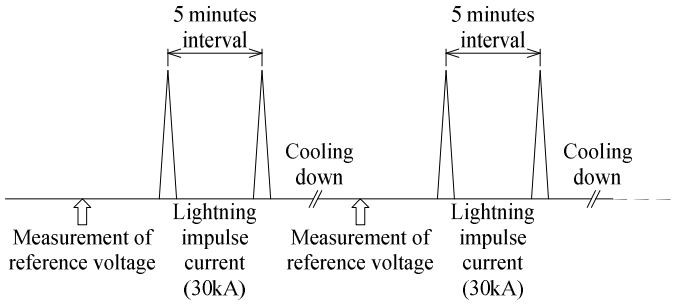


Figure 4. Test procedure of applying lightning impulse currents of 30kA (Test A)

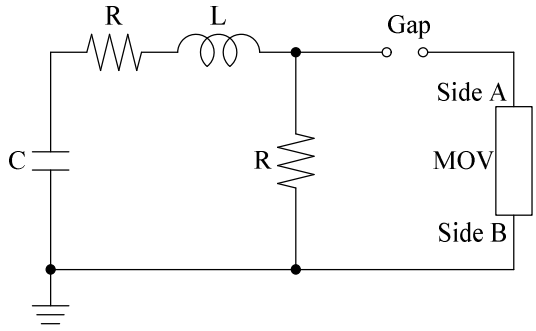
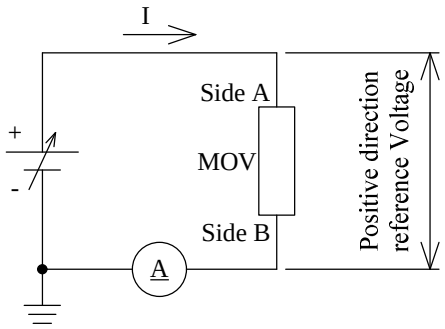
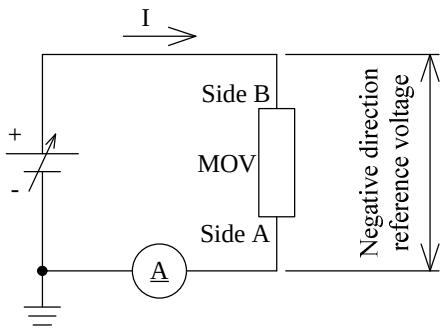


Figure 5. Direction of a lightning impulse current



(a) Positive direction



(b) Negative direction

Figure 6. Measurement methods of a reference voltage

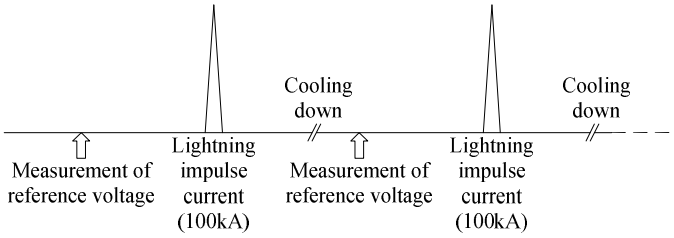
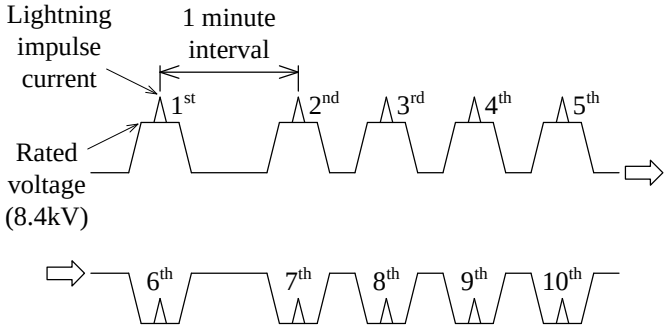


Figure 7. Test procedure of applying lightning impulse currents of 100kA (Test B)



1st to 5th :Same polarity as power frequency voltage
6th to 10th :Opposite polarity as power frequency voltage

Figure 8. Test procedure of operating duty test (test C)

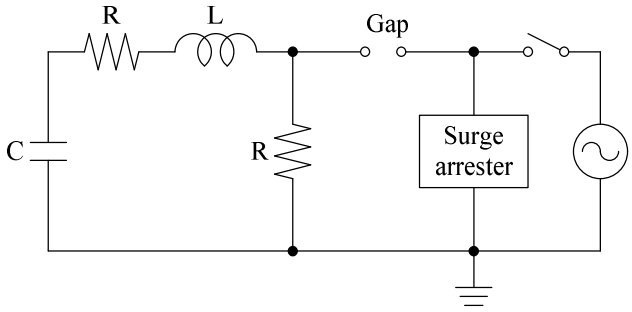


Figure 9. Test circuit of operation duty test (Test C)

III. TEST RESULTS

A. *The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 30kA.*

The variation of the reference voltage of a MOV with the number of high current lightning impulses is shown in Figure 10.

There is no change of the reference voltage after the application of impulse currents in the positive direction. However, the degradation tendency of a MOV is observed after the application of impulse currents in the negative direction. As a result, the variation of the reference voltage is decreased up to 8% compared to the initial reference voltage after 30 shots of lightning impulse currents are applied.

B. *The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 100kA.*

The variation of the reference voltage of a MOV with the number of high current lightning impulses is shown in Figure 11.

Impulse currents are applied to a MOV until the MOV is punctured. In this test, sample No.2 is punctured after 6 shots of lightning impulse currents and sample No.3 is punctured after 9 shots. The degradation tendency of a MOV in both positive and negative direction was observed in case of this test. As shown in Figure 11, the variation of the negative direction is bigger than that of the positive direction. The reference voltage was decreased up to 7% compared to initial reference voltage after 10 shots. On the other hand, the reference voltage was decreased up to 14% in case of negative direction.

C. *Operating duty test of lightning surge arresters installing degraded MOVs.*

Figure 12 shows the number of follow current interrupting failures in each MOV. Figure 13 shows the waveforms, when a follow current interrupting failure was observed.

In the case of the decreasing rate of the reference voltage less than 11%, follow current interrupting was successful. In the case of the decreasing rate of the reference voltage more than 14% and less than 17%, the probability of the follow current interrupting failure was 1%. In the case of the decreasing rate of the reference voltage more than 17% and less than 20%, the probability of the follow current interrupting failure was 14%. In the case of the decreasing rate of the reference voltage more than 20%, the probability of the follow current interrupting failure was 43%.

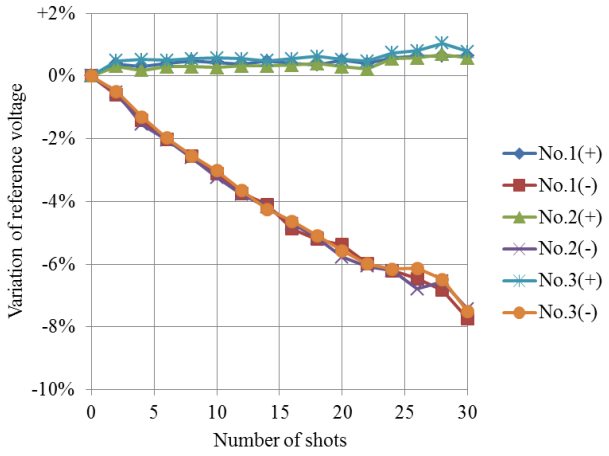


Figure 10. Variation of a reference voltage with the impulse current of 30kA (37A/mm^2)

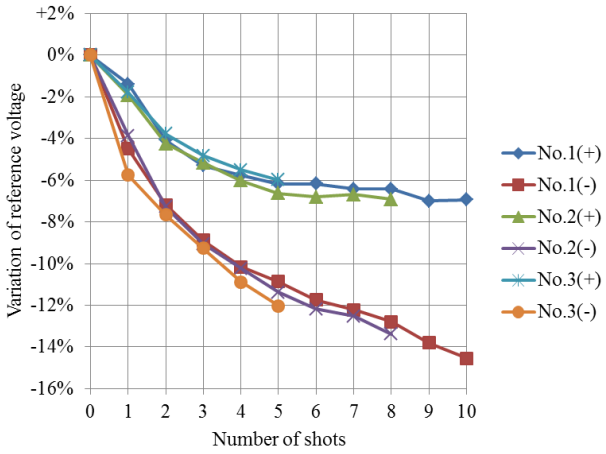


Figure 11. Variation of reference voltage with the impulse current of 100kA(70A/mm^2)

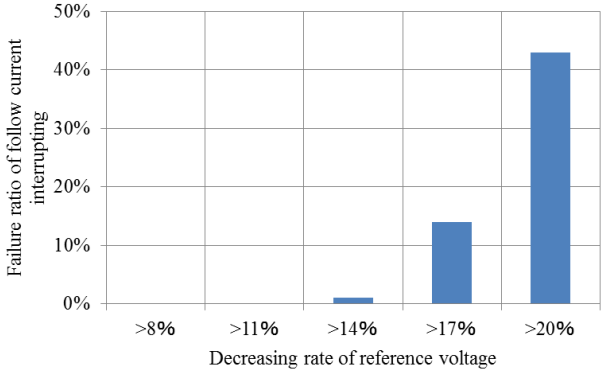


Figure 12. Relationship between decreasing rate of reference voltage of MOV and follow current interrupting failure count

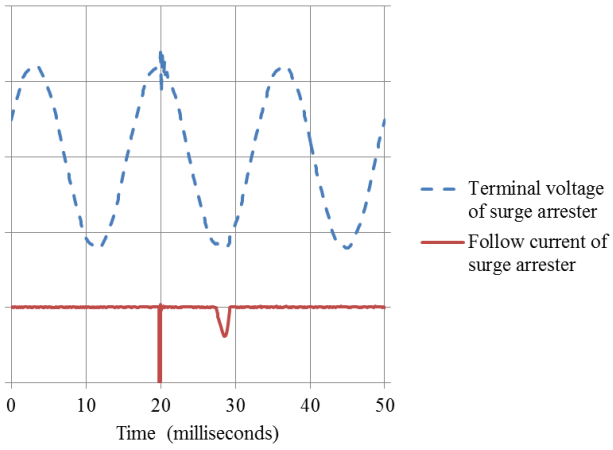


Figure 13. Waveform of follow current interrupting failure

IV. CONCLUSIONS

To examine the degradation of a MOV, that causes the degradation of electric characteristics of lightning surge arresters, the MOV was evaluated by measuring the reference voltage after applying lightning impulse currents.

Main results are shown as follows;

A. The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 30kA.

There is no change of reference voltage after the application of impulse currents in the positive direction. However, degradation tendency of a MOV, which is caused by decreasing the reference voltage, were observed for the application of impulse currents in the negative direction.

B. The degradation tendency of a MOV under lightning impulse currents of 4/10 microseconds, 100kA.

There are degradation tendencies of a MOV for the application of impulse currents in both positive and negative direction. The variation of reference voltage after the application of impulse currents in the negative direction was much higher than that of positive direction.

Therefore, it should be evaluated by checking the reference voltage after the application of impulse currents in both positive and negative direction when examining the degradation of a MOV.

C. Operating duty test of lightning surge arresters installing degraded MOVs.

In case of decreasing rate of a reference voltage more than 14%, follow current interrupting failures occurred. The larger the rate of a reference voltage decrease, the larger the probability of follow current interrupting failures.

In this paper, the degradation of a MOV due to lightning impulse currents were examined. But it is very difficult to measure the reference voltage of a MOV in-service lightning surge arresters, because there is a series gap between a terminal and a MOV. A new method to measure directly the reference voltage of surge arresters with series gap is needed.

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