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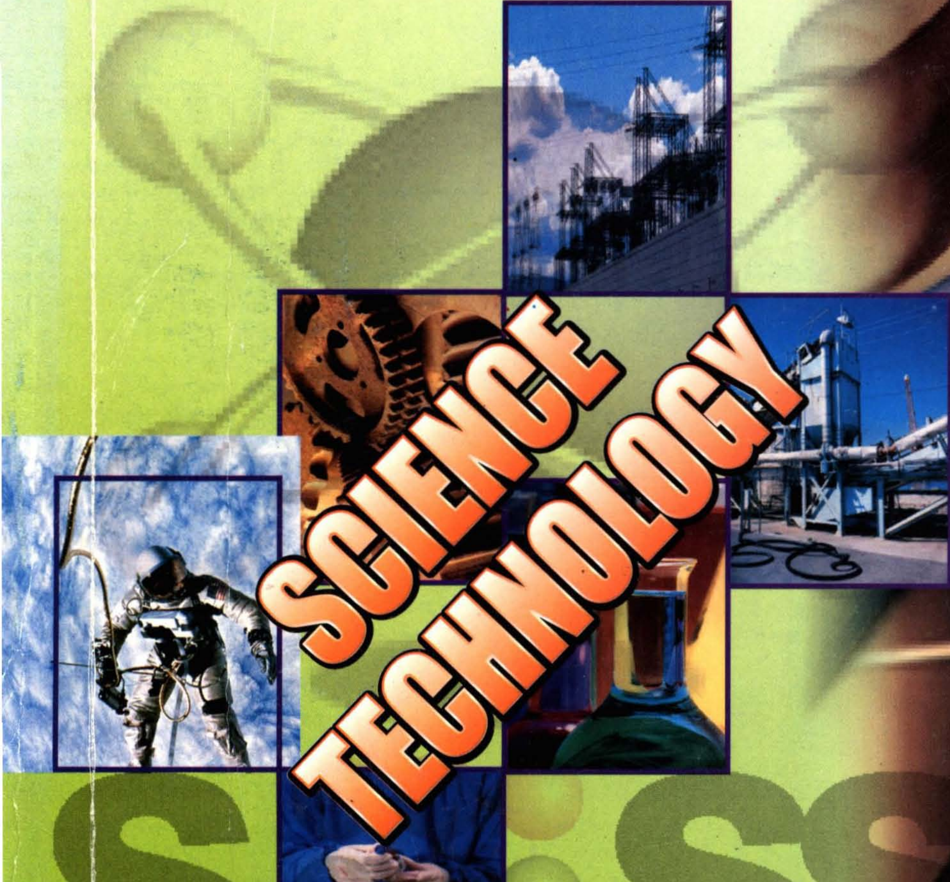

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Improving the Realibility of Zinc Oxide Surge Arrester

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ABSTRACT

Reliable surge arresters can avoid unnecessary costs associated with equipment damage and ineffective lightning protection techniques. The most recent advance in the arrester is the Zinc Oxide arrester. However, some of the arresters can be damaged during their operation. The major cause of failure of the arresters is the surface flashover. This study aims to examine the surface flashover effect on ZnO arresters and develop method to reduce its effect and enhance the performance of the arrester. The experiment was designed to study the surface flashover effects. The ZnO blocks supplied by manufacturers were tested under different environments during multipulse currents. The observed degradation was qualitatively explained in terms of physical changes on the blocks and their electrical characteristics. The study found that the environments surrounding the ZnO blocks had no impact on surface flashover. The major finding leads to the possible contribution of the quality of surface material coating in protecting the blocks from surface flashover.

Keywords: *Arrester, Surface Flashover, Multiple Impulse Currents.*

Introduction

The electrical power system has to be reliable and protected against overvoltage stresses. The lightning effects have been reported as the major cause of overvoltage stresses in the distribution system (Gosden 1974). The surge arresters play a vital role in protecting the system from the lightning fault. Nowadays, the surge arresters are indispensable and important product since the need for high power transmission is increasing. The characterization of the lightning and the design of the arresters determine the performance of the power system.

The most recent advances in the arrester used to prevent lightning damage are the Zinc Oxide arresters. They are also known as the Metal Oxide surge arrester (MOSA) or Metal Oxide Varistor (MOV). The reliable surge arrester must remain stable at its original value during usage and after experiencing the electrical stresses that result from absorbing the oncoming surges (Darveniza & Mercer 1993). In service, some of the arresters were damaged by lightning strikes during their operation and they were no longer reliable to be used. The study conducted by Tumma on the effects of multipulse impulse currents on ZnO arresters revealed that the ZnO arresters could fail when the arresters are subjected to multipulse currents, which are not evident during single impulse current (Darveniza & Mercer 1993). It was found that majority of the arresters failed because of the surface flashover. Prior tests (Tumma 1994) had been also made on gapped silicon-carbide arresters and the same effect had been demonstrated as in Darveniza & Mercer (1993).

So far no steps were taken to minimize the effect of surface flashover on the arresters. The aims of the study are to examine the surface flashover effect on ZnO arrester and develop method to reduce its effect, which in turns will improve the performance of the arrester. The experiment was designed to study the surface flashover effects on several makes of ZnO blocks. The ZnO blocks supplied by manufacturers were tested under various environments during multipulse currents test. These environments include the normal lab air, sulfurhexaflouride gas, vacuum condition and various relative humidity in the range of 65% to 98%. The observed degradation can be qualitatively explained in terms of physical changes on the blocks and their electrical characteristics.

Materials and Methods

In this experiment, the lightning multiple impulse generator developed by Darverniza et al. (1989) was used to generate multiple impulse currents similar to the currents produced during lightning. The method used in this work was to first demonstrate that the arresters are stable and can discharge lightning surge without failure by conducting the voltage tests on the ZnO arresters. The arresters were then subjected under the multiple current tests to investigate the capacity of the ZnO arresters to withstand these tests. Diagnostic tests were also conducted to the arresters before and after the multiple impulse current to observe any degradation or damage to the blocks in terms of physical changes and also electrical characteristics.

Test Samples

A typical gapless ZnO arrester is shown in Figure 1. The ZnO block is the main element of the arrester. Twenty-one ZnO blocks from six different manufacturers were used in this experiment. The arrester voltage ratings were in the range of 10kV to 12.5kV. Current ratings were 5kA to 10kA. All samples were 3.15 cm in height and 3.30 cm in diameter. Four conditions were used to represent various environments the blocks were subjected to during the multipulse currents test. The conditions include normal, vacuum, sulfurhexaflouride and humidity in the range of 60% to 98%. Three blocks were tested under each four conditions to ensure replication. Therefore, an accurate result and assumption can be made.

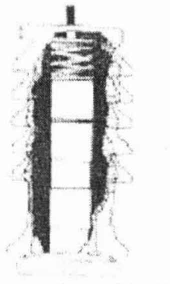


Fig. 1: A gapless ZnO arrester

Voltage Test

A 1.2/50 μs voltage test was conducted on a nylon block before the multiple impulse current tests to predict the breakdown level of the gap surrounding the block under vacuum, normal and sulfur hexaflouride gas conditions. This is important to demonstrate that the arresters are stable and can discharge lightning surge without failure. The nylon block that resembled the ZnO block was used. The voltage test was applied on the nylon block for each condition until the block experienced breakdown.

Multiple Impulse Currents

The multipulse impulse test demonstrates the stability and robustness of the ZnO arrester. All twenty-one blocks were subjected to multiple impulse tests at peak currents varied between 5 to 13 kA (with 10% accuracy). A group of quintuple 8/20 μs lightning current impulses was applied to the blocks increasing from 5kA until the blocks experience breakdown or surface flashover. The level breakdown for normal, SF6 gas, humidity and vacuum were then recorded. This level represent the withstand capability of the blocks to various conditions as the blocks were subjected to the current test. The 8/20 μs current waveshape was used to simulate the effects of a direct lightning return stroke to overhead power transmission and distribution lines. The 8/20 μs waveform was specified under short ciruit conditions, therefore it was chosen in this experiment to observe the surface flashover when the applied current is short circuited through the ZnO block. However, +10% for both the 8 μs front time and 20 μs time to half-value is well within acceptable values.

Diagnostic Tests

Before and after diagnostics tests were conducted on the ZnO blocks to observe subtle changes in the electrical characteristics. The test criteria for the tests are measurement of the 1.0 mA a.c. reference voltage and residual voltage at rated 8/20 μs discharge current before and after the multiple impulse current tests. The changes of characteristic were identified by the ratio of the after to the before values for both voltages. The changes must be in the range of 0.9 to 1.1 according to the standards defined in (Anon, 1987). The criteria for assessing the capability of the blocks with the impulse current tests are based on the gross effects of the block such as physical damage or marked changes to the block or significant abnormalities in the current and voltage oscillograms recorded during the tests and after to before ratio of reference and residual voltage not greater than + 10%.

Results and Discussion

The results of the voltage test in Table 1 show that the breakdown level for the SF6 gas was higher than other conditions. The lowest breakdown level occurred during the vacuum condition.

Table 1: Summary of the Voltage Test Results

Condition	Breakdown Level (kV)
Vacuum	35
Normal	41
SF6 Gas	105

Condition Breakdown Level (kV)

The results of multiple impulse current indicated that the use of humidity, SF6 and normal did not significantly influence the block's breakdown level. Small burn marks were observed on block A11 and A15 which were subjected to hum 62% and 79% respectively as shown in Figure 2. Apart from these two blocks no physical damage was observed. A lower surface flashover was produced during vacuum condition at the level of 10.1 kA on average in comparison with other conditions which experienced surface flashover above 11 kA.

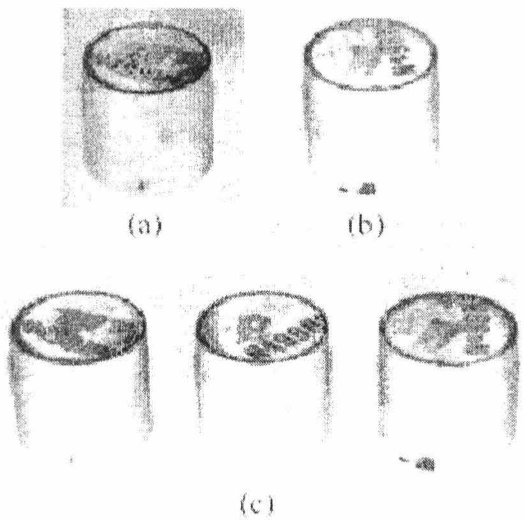
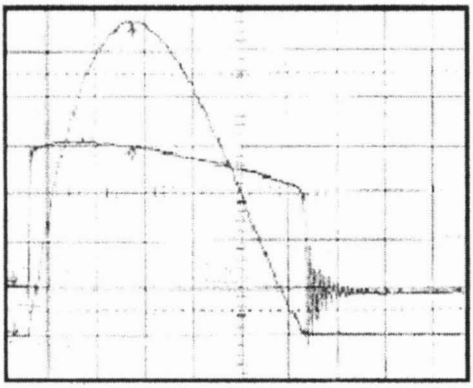
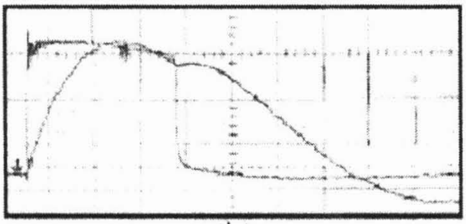


Fig. 2: (a) Block A11 and (b) Block A15 which failed by surface flashover during the multiple tests. (c) Comparison of blocks A11 and A15 with the normal block in the middle.

Based on the a.c. reference voltage ratio most of the blocks had large electrical characteristic changes. The blocks that were subjected to vacuum condition satisfied the a.c. ratio assessment. Block A20 also had small changes of approximately 5%. By contrast, most of the blocks experienced small changes under the residual voltage test. Two blocks under SF6 conditions experienced large residual changes. The largest changes of residual voltage (98%) were experienced by block A1 under normal conditions. One block under humidity conditions also had large changes on this voltage. Figure 3 represents an example of an abnormal and normal oscillogram.



(a)



(b)

Figure 3 (a) A normal oscillogram for the residual voltage (b) An abnormal oscillogram of block A11

Discussion

The voltage test results for nylon block demonstrated a significant difference between the effects caused by vacuum and SF6 gas on the gap surrounding the nylon block. The SF6 gas increased the breakdown level and thereby could improve the stability of the blocks. On the other hand, vacuum conditions reduced its breakdown level. Therefore, the vacuum condition was not preferred for use in the arrester design as it can easily initiate failure to the arrester at low surface flashover level. A very different result emerged from the multiple impulse test for the ZnO block. There was no significant difference between the effects caused by humidity and SF6 to the blocks. It is clear that the presence of SF6 and humidity did not influence the surface flashover level during the test. Three ZnO blocks failed at low current. level, 10.1 kA during vacuum conditions. The blocks also satisfied the a.c. reference voltage and residual voltage criteria. The results demonstrated that these blocks are stable. Hence, a vacuum environment can initiate the surface flashover at very low current. No significance difference can be seen from the results of humidity. Humidity created on the surface of ZnO blocks might be absorbed by the heat applied during the multiple test. Therefore the blocks acted as in normal conditions. No obvious damage appeared on most of the ZnO blocks. Small burn marks and cracked lines were observed on blocks A11 and A15. The gross damage on these blocks was caused by surface flashover as it appeared after the flashover was applied. The failure might have been initiated from the thermal effects when the blocks were stressed with multiple currents. In fact, there was an insufficient cool period between the quintuple of block A11 and A15. The lowest ratio of a.c. voltage and residual voltage was due to the highest current level, that is 12.5 kA, and the large number of eight continuous sequences of currents applied. It appeared that the heat produced during the tests accumulated along the brass block and ZnO blocks. The heat transferred to the ZnO blocks varied with the number of currents applied. Hence, this thermal instability of the blocks can lead to surface flashover.

Eventhough the majority of the blocks failed after the multiple tests and stressed with the heat developed during the tests, no gross effect was observed. The SF6 gas and humidity environments also did not influence the surface flashover level. Therefore, the dielectric behaviour of the block's surface coating has a major influence on the surface flashover. It was found that most of the ZnO blocks used in Darveniza & Mercer (1993) experienced major surface damage. By contrast, the ZnO blocks used in this experiment did not yield the same result. This discrepancy was due to the different surface coatings used in the blocks. It is likelihood that the surface material coating of the blocks played a major influence on the surface flashover phenomena.

Conclusion

It can be concluded that the humidity, SF6 and vacuum conditions did not cause any significant difference to the ZnO blocks. When there is a gas space surrounding the block and its coating, those three conditions have little influence on the surface flashover. It was found that the quality of surface material coating can protect the blocks from damage by surface flashover. A serious attention should be given on the manufacturing of the ZnO arresters' material coating to improve the reliability of ZnO arresters.

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