

Changes in varistors properties after radial field test

M. Jaroszewski, P. Korycki*, K. Wieczorek, J. Zakrzewski
Wroclaw University of Technology, Wroclaw, Poland
* Electrotechnical Institute, Warszawa, Poland

Abstract: ZnO varistors are used in commercial surge arresters in high voltage application in the area of power engineering. Metal oxide arresters (MOA) operated in polluted areas may be subjected to an environmental stresses causing an internal partial discharges (PD), increased varistor temperature, increased leakage current, which may lead to “thermal run-a-way”. Internal PD, increased temperature and increased current may occur due to the uneven voltage distribution created by the surface leakage currents. It may be achieved when different voltage distribution between varistor column and porcelain housing becomes, especially when the stable dry zone occurs. The author, in this work, establishes uneven voltage distribution immersing arrester in tap water. This paper present changes in varistors properties after radial field test. It was shown, that changes in current-voltage characteristic can be result from degradation of insulating layer covering the varistors as result of the strong partial discharges created between internal surface of the porcelain housing and attentive surface of the varistors column.

1. Introduction

Zinc oxide (ZnO) varistors are devices with highly non-linear current voltage (I-V) characteristics. They are used as an active part of devices designed to protect electrical apparatus from transient overvoltages. One of the major applications of ZnO varistors is the high voltage surge arrester. Surge arresters are widely used for the protection of power system apparatus against the electrical system’s external or internal overvoltages.

As outdoor insulation, arresters are subject to pollution. Pollution phenomena on their porcelain housings belong to the primary causes of failures of surge arresters [1-6]. The phenomena occur when the contaminating layer on the porcelain housing becomes conductive.

When the surface leakage currents are very small (in comparison with the capacitive current), the capacitive voltage distribution is not significantly changed. This is the case in dry or slight pollution conditions. When the magnitude of the external leakage currents exceeds the arrester’s capacitive current (when the pollution is more severe), the transient voltage distribution on the housing surface may be markedly different from the normal capacitive distribution. Depending on the magnitude of the leakage current, the coupling to the ZnO varistor and

the duration of the pollution event, degradation of the varistor’s electrical properties may result. If the surface leakage current magnitude is large enough, a possible large voltage unbalance may force the voltage across the arrester to reach the inflection point of the latter’s voltage-current characteristics.

The distribution of voltage along the height of the arrester gets distorted because of:

- the development of areas with different surface conductances,
- the formation of dry bands separated by conductive regions as in barrel insulators,
- the bridging of the dry bands by partial arcs.

The potential of the column of varistors inside the arrester is then different from that of the polluted external surface and as a result, a radial electric field is generated. If the radial field gradient is high enough, very strong internal partial discharges (PD) may be initiated. Internal PDs are known to cause changes in the ambient gaseous medium inside the arrester which accelerate ageing and made changes of the varistor material properties [7-10]. The laboratory tests to check the withstand of the surge arresters to the radial field stress due to the non uniformity of the external pollutions have not been standardized yet. Ageing tests reproducing the kind of environmental stress generated by the radial field stress are necessary to gain insight into the arrester service performance.

2. Experimental

A new method of generating a high radial electric field by immersing the arrester in tap water is proposed. The test stand is shown in figure 1.

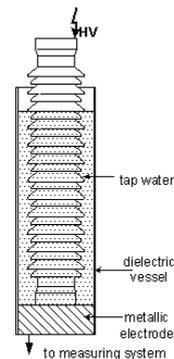


Figure 1: Test arrangement

Tests were performed on a surge arrester for the 110 kV AC system. The arrester's varistor column is mounted in the centre of the porcelain housing and there is air insulation between the varistors and the housing. The arrester was immersed in a cylindrical vessel made of a dielectric material and filled with tap water. The distance between the water level and the arrester's upper cover was set to about ¼ of the arrester's height to prevent arcing across the dry zone. The water has the potential of the bottom cover because of its direct contact with the latter. The bottom cover potential (almost the same as the ground potential) is transferred upwards to the water level. The voltage difference between the varistor column and the external surface of the porcelain housing is sufficient to start PDs inside the arrester enclosure. The test was conducted at an AC voltage equal to the continuous operating voltage U_c . The AC test voltage was applied to the arrester for 8 hours a day (figure 2). To avoid arrester "runaway", the internal current was recorded during the test.

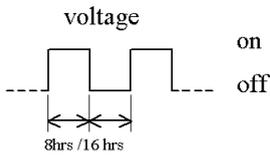


Figure 2: Pattern cycle

The following were measured before and after the radial field test:

- the resistive component of the leakage current at U_c voltage by a digital oscilloscope I_{rAC} ,
- the maximum total leakage current I_{maxAC} and the harmonics content at AC voltage I_h by a measuring system provided by the arrester manufacturer,
- the leakage current I_{DC} measured at DC voltage equal to the peak value of the U_c .

The measurements were performed after the arrester had been taken out of the water bath, cleaning the external surface and cooling to the ambient temperature.

3. Results

During the test internal PDs were recorded as the short impulse component in the leakage current. The internal PD activity was also observed in a darkroom after removing the arrester's upper cover. The results are shown in figure 3. The magnitude of the total AC current is not significantly changed. It was found that the arrester varistor leakage current resistive component changed during the test. Detailed

examination of the inner elements revealed other degradation mechanisms triggered by the erosion of the varistor's surface (fig 4).

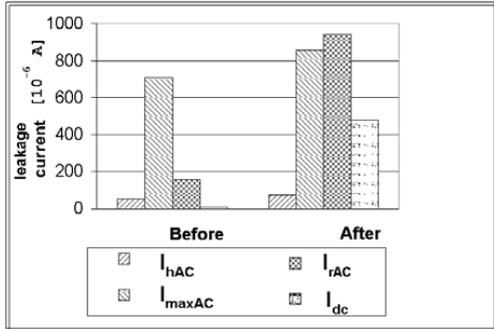


Figure 3: Test results

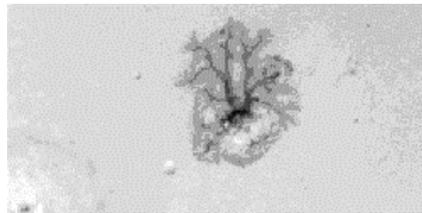


Figure 4: Surface erosion due to PD

4. Conclusions

The main goal of this research was to develop a simple radial electric field test for assessing the effect of partial discharges on ZnO varistors. During the test internal PDs are generated which results in varistor column leakage current instability due to varistor material degradation and varistor side surface erosion. After the radial field test the arrester showed significant changes in its voltage-current characteristic, an increase in the third harmonic of the leakage current, an increase of resistive component of the leakage current. The increase in the current may be due to varistor erosion caused by partial discharges.

The proposed method of assessing the performance of arrestors in real pollution conditions is simple, useful and low-cost. It can be used to verify arrester designs.

5. References

- [1] E.G. Maier, R.M. Rudolph, W. Schmidt, F. Hunziker, „Voltage Distribution and Pollution Performance of Metal-Oxide Arresters”, Session of CIGRE 1986, Paris

- [2] A. Bargigia, M. De Nigris, A. Pigini, A. Sironi, "Definition of Testing Procedures to Check the Performance of ZnO Surge Arresters in Different Environmental Conditions", Session of CIGRE, 1992, Paris
- [3] S. Harasym, H.G. Brosz, S.S. Shur, T. Shelepeten, W. Janiszewskyj, "Pollution Performance and Voltage Distribution in Surge Arresters Enclosed in Porcelain Housings – Measured and Calculated", 10th ISH, 1997, Montreal, Canada
- [4] S. Vitet, M. Louis, A. Schei, L. Stenström, J. Lunquist, „Thermal Behaviour of ZnO Surge Arresters in Polluted Conditions“, Session of CIGRE, 1992, Paris
- [5] L.J. Sparrow, R.M. Doone, "UK Experience in the Investigation of the Pollution Performance of Metal Oxide Surge Arresters", Session of CIGRE, 1988, Paris
- [6] S. Harasym, S.S. Shur, "Behaviour of Metal Oxide Surge Arresters Under Pollution", 10th ISH, 1997, Montreal, Canada
- [7] M. Jaroszewski, "Partial discharges in high voltage arresters", Przegląd Elektrotechniczny, Vol 2000, No 12, pp.297-300, in polish
- [8] A. Bui, A. Loubiere, M. Hassanzadeh „Electrical characteristic degradation of ZnO varistors subjected to partial discharges“, J.Appl.Phys.65(10), 15 May 1989, pp.4048-4050.
- [9] M.B. Kourdi, A. Bui, A.Loubiere, A.Khedim, „Behaviour of metal-oxide-based varistors subjected to partial discharges“, J.Appl.Phys.25 (1992), 548-551.
- [10] K.Izumi, H.Honama, J. Tanaka, „Deterioration of metal oxide surge arrester element caused by internal discharges under polluted conditions” – International Conference on Properties and Applications of dielectric Materials; July 8-12, 1991, Tokyo, Japan, pp.517-520.

Author address: Maciej Jaroszewski
 Wrocław University of Technology
 Institute of Electrical Engineering Fundamentals
 Wybrzeże Wyspiańskiego 27
 50-370 Wrocław, Poland
 e-mail: maciej.jaroszewski@pwr.wroc.pl

Author address: Piotr Korycki
 Electrotechnical Institute,
 ul. Pożaryskiego 28
 Warszawa, Poland
 e-mail: pkorycki@iel.waw.pl

This study was financially support by the State Committee for Scientific Research (Grant No. 4 T10B 037 22)