Ukrainian Journal, Techniczna Elektrodinamika, 2002, part 8, pp. 93-96

INTERNAL PARTIAL DISCHARGES TEST FOR METAL OXIDE SURGE ARRESTERS

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***Key words* – pollution, degradation, metal oxide varistors**

INTRODUCTION

Pollution on a porcelain housing of metal oxide surge arrester when wetted can cause:

- development of electrical discharges and external pollution flashover,
- increase of varistor temperature, especially in the case of multi unit arresters
- ignition of internal partial discharges and varistor degradation.
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The pollution flashover voltage can be measured in the artificial test according to the salt fog method or solid layer method [1]. The temperature processes shall be tested according to salt fog method or solid layer method with prolonged time (e.g. up to 6 hours) because the temperature time constant of metal oxide arresters with porcelain housing amounts about 1,5 h. Besides these methods, the simpler procedures without wetting the test object are applied (slurry method [2], ANSI method [3]).

Partial discharges inside the surge arrester ignite when a high enough potential difference occur between varistor column and pollution layer on the porcelain housing. The formation of single, dry band at the flange is the most dangerous situation because in this case the highest potential differences arise [4]. The varistor diameter in surge arresters with porcelain housing is few centimetres smaller than the internal diameter of the housing. The empty space called discharge channel, together with special diaphragms and nozzles at the flanges protect the porcelain housing against explosive damage. This critical situation is possible when power arc will burn inside the housing as a consequence of surge arrester overloading [5]. The metal oxide arresters with polymer housing have usually another construction. The distribution type surge arresters and often and often high voltage surge arresters are produced using the direct curing of silicon rubber on varistors under the pressure.
There is not discharge channel and diaphragms in these arresters [6]. The internal partial discharges can here (similarly like in underground cables) burn only in small air cavities. The intensity of such partial discharges is small and they are not dangerous for metal oxide varistors. Therefore this paper desribes the internal partial discharges test for metal oxide surge arresters with porcelain housing.

IMPACT OF INTERNAL PARTIAL DISCHARGES DISCHARGES. TEST PROPOSALS

The first internal ionisation test of metal oxide surge arrester was carried out just at the beginning of gaples arresters application for high voltages [7]. Unfortunately, the test was performed on 48 kV rated arrester with test voltage of 39 kV. A grounded metallic band was placed half way up the porcelain housing. This caused audible external corona and associated internal ionisation. The arrester was energised in this manner for a period of three months. No detectable electrical deterioration of metal oxide varistors had occurred. On the basis of this experiment the conclusion was drawn that the metal oxide arresters did not suffer significant deterioration as a result of internal discharges caused by operation under severely contaminated conditions. But in the case of greater 96 kVrated arrester at test voltage of 70 kV the internal ionisation develops to internal discharges which break down the air channel [8]. So strong discharges can severely damage the varistors.

The internal arcing test [4, 8] and radial field test [9] were proposed as a procedure for checking the resistance of varistors against internal partial discharges. Internal arcing test model the critical conditions by formation of single artificial dry band representing approximately 10% of the leakage path. The test duration can last for only few days. Every day the surge arrester voltage-current characteristics shall be prove to detect the possible degradation changes. The simple diagnostics method consist in current measurement under dc voltage.

The radial field test represents a long duration (2000 or 1000 h) salt fog test with low water salinity of 1 or 10 g/litre. This procedure was criticised mainly due to a very long test duration. As a result, the IEC working group WG4 TC 37 began to compare different ideas to find out not so expensive and therefore a more acceptable method. The alternative procedures are listed in the table 1. The majority of proposals are in fact modifications of internal arcing test.

In all methods listed in the table 1 the high radial field is produced inside the housing. The varistor column can be treated as high voltage electrode, the grounded electrode is the wetted pollution layer, graphite layer, water or metallic bands. Breakdown occur when the potential difference between varistor column and grounded electrode (internal wall of the housing) exceeds the electrical strength of air channel (fig. 1).

Tab. 1. Procedure proposals for testing of surge arresters performance under internal partial discharge stress

Lp.	Author	Test object	Conducting layer	Test voltage	Test duration
1	Sakshaug [7] 1982	48 kV rated arrester	Grounded metalic band placed half way up the porcelain housing	39 kV	3 months
2	Chrzan, Feser, [4] 1989	The longest arrester unit	Bentonit - 100 g/l H_2O, NaCl – 5 g/l H_2O, 90% of leakage path, wetting in air with a relative humidity about 95%	U_c	5 days with p.d. stress lasted 8 h a day
3	Chrzan, [8] 1995	The longest arrester unit	Graphite layer with surface conductivity in the range of 20 µS, 90% of leakage path	U_c	5 days with p.d. stress lasted 8 h a day
4	Korycki, [10] 2001	The longest arrester unit	The arrester unit is placed in a vessel filled with tap water at 20 °C. 50 % of the housing height shall be immersed in water.	U_c	5 days with p.d. stress lasted 8 h a day
5	Chrzan, 2002	The longest arrester unit	Grounded metallic bands between sheds. The highest band is placed 10% of the housing height lower than the upper flange. The distance between upper metallic band and bottom metallic band amounts at least 50% of the housing height	1. Voltage high enough to cause internal corona. 2. Voltage high enough to breake-down the discharge channel	Duration shall be long enough to use up oxygen in the discharge channel and to allow the oxygen diffuse from varistor ceramics

U_C - continuous operating voltage

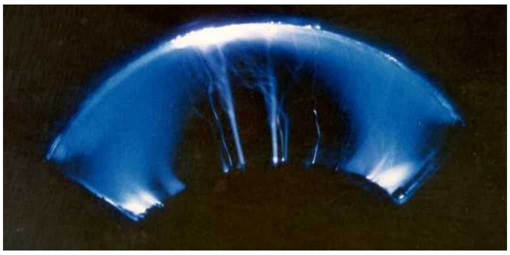


Fig. 1. Intensive partial discharges inside a non-uniformly polluted surge arrester. Test voltage 68 kV.

The basic problems in the laboratory simulation of the field conditions leading to the ignition of partial discharges inside of surge arresters are:

a) The building of conducting external layer, selection of surface conductivity, selection of dry (clean) band width, the wetting method,
b) The value of test voltage and test duration
c) Evaluation of test results

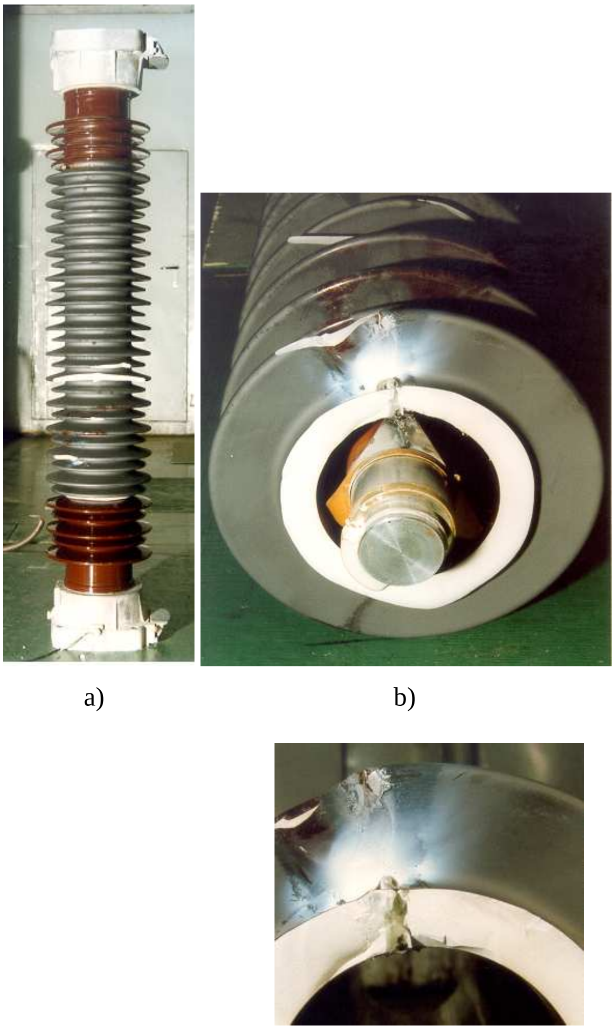
The diatomaceous earth (kaolin, bentonite, kieselguhr) used for standard pollution test of insulators according to solid layer method with an addition of NaCl or more hygroscopic $CaCl_2$ can be applied for formation of pollution layer [11]. A very convenient wetting method consists in availing of hygroscopic properties of salt. The test shall be carried out in a chamber with high air humidity e.g. 95%. The external electrode can also be formed from other materials like graphite, tap water, or metal. The dry (clean) band shall be wide enough to avoid external flashovers and narrow enough to cause the high radial field and internal partial discharges.

It seems that the arrester maximum continuous operating voltage shall be used as the constant value of test voltage. On the other hands, it is very convenient to control the intensity of internal partial discharges by changing the value of test voltage. Of course, the test voltage shall be equal or lower than maximum continuous operating voltage. In particular it is interesting to use two values of test voltage: the higher value at which the breakdown of internal channel occur and the lower value at which only internal corona takes place. To properly select the test voltage value, the increase of electrical strength of air (as a result of chemical reactions) should be taken into account [12]. The test can consist of three cycles repeated each day:

1. Short cycle duration, e.g. 0,5 h. The breakdowns of internal channel occur at voltage equal to maximum continuous operating voltage,
2. Longer cycle duration, e.g. 8 h. Internal corona takes place in the channel at lower test voltage,
3. Long cycle, e.g. 15,5 h without internal corona. During this time the arrester diagnostics can be performed.

The cycles can be changed in different way, e.g. in the case of arrester polluted by diatomaceous earth, it can be controlled by the air humidity changes at the same voltage.

During the time without presence of partial discharges the varistor can be degraded due to oxygen diffusion from the varistor bulk to the internal channel. The oxygen partial pressure in the discharge channel decreases as a result of chemical reaction caused by partial discharges [12]. In author opinion the selection of first cycle duration is the most difficult problem because the phenomenon of concentrated discharges and dry bands on outdoor insulators is not sufficiently known [13]. This stress caused by intensive partial discharges and breakdowns can damage the varistors and even to cause the breakdown of porcelain housing (fig. 2).



a) b)

c)

Fig. 2. The damaged surge arrester during an internal arcing test with graphite layer
a) view of surge arrester, b) broken porcelain housing with visible tracking on internal polymer insulation
c) breakdown trace in porcelain

The second cycle duration shall be long enough to decrease the oxygen partial pressure nearly to zero. This time depends on the partial discharges intensity. It was estimated on 6 h for an gapped arrester unit contaminated by graphite layer and proved according to the internal arcing procedure [12]. The third cycle without internal partial discharges shall be obviously the longest. In the field it is nearly equal to the arrester operation time.

Degradation of varistors with removed epoxy covering and exposed to reducing atmosphere depends strongly on time and ambient temperature [14].On the other hands it has been found that, by suitable choice of the coating, metal oxide varistors can be produced which do not respond to operation in reducing atmospheres with an increase in the power loss [15]. The first cycle with strong internal discharges is therefore critical because these discharges are able to damage the varistor coating.

Diagnostics of arrester during the third cycles can be performed under dc voltage. This method is very convenient because the arrester housing has not to be cleaned before the measurements (there is no capacitive coupling between vaistor column and pollution layer). Additionally, the dc current represent the resistive component. The procedure for measurement of resistive current component under ac voltage is not so simply and can be influenced by considerable errors [16].

CONCLUSIONS

1. The basic phenomena which cause the varistor degradation due to the presence of partial discharges inside the arrester housing are well known.
2. For the properly selection of internal partial discharges test for surge arresters, kinetics investigation of chemical reaction in air channel, oxygen diffusion in varistors and influence of temperature on these processes in commercial arresters should be investigated.
3. In author opinion the test should consist of three cycles. The severe, three cycle test should be destined for arrester working in heavily polluted conditions and the two cycle test – for arrester working in light polluted areas.

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