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Behaviour of Zinc Oxide Surge Arresters Under Pollution

K. Feser, W. Köhler, D. Qiu
University of Stuttgart
Federal Republic of Germany

K. Chrzan
Technical University of Wrocław
Poland

Abstract - This paper presents results of pollution tests with A.C. voltages which were carried out with a multi-unit zinc oxide arrester. The interaction between the polluted porcelain housing and the inner varistor column due to capacitive coupling has been found to be responsible for the temperature rise of varistor elements. The different voltage distribution between inside and outside of the arrester also causes a high radial electric field which can lead to internal discharges if the radial insulation system is not properly designed. These internal discharges may damage varistor elements which are not adequately coated and may cause a total destruction of the arrester.

The shape of the internal and external currents due to discharges is analysed. A test method to compare different arrester constructions under severe pollution is proposed. The method can also be applied to demonstrate the absence of discharges for a certain arrester design under extreme conditions of pollution during type tests.

Keywords: Pollution testing, metal oxide arrester, internal discharges, simulation model

1 INTRODUCTION

Zinc oxide surge arresters are exposed to heavy thermal and electrical stresses if the porcelain housings of the arrester units are polluted. Together with other environmental stresses such as temporary overvoltages or high temperatures this can lead to thermal runaway of the metal oxide arrester (MOA).

In the past in pollution research of MOAs a lot of attention was paid to the coupling in of currents at the flanges of a multi unit arrester with the porcelain housings nonuniformly polluted. This effect has also been taken into account in the testing standard /4/ for pollution tests of MOAs. The effect of coupling in currents at the flanges due to inhomogeneously polluted housings can be avoided if the total varistor column is included in a single housing /6/. Another problem caused by pollution of MOAs is the partial discharge phenomena inside the MO arresters /1/,/2/. These discharges have been responsible for the destruction of a complete arrester /3/.

Although there is no generally agreed standard for pollution testing of MOAs most pollution tests are carried out according to the test procedures given in IEC 507 /5/. This standard has been proved to be suitable to test the pollution performance of standard insulators. Dealing with the pollution performance of MOAs several effects have to be considered. This paper describes tests performed to understand in more detail the behaviour of polluted MOAs. As a result of these tests a new test procedure for MOAs installed in areas with a high pollution severity is proposed. The method can also be applied during type tests to demonstrate the absence of partial discharges in arrester units /8/.

2 TEST ARRANGEMENT AND MEASURING EQUIPMENT

The arrester units used for the investigations have the following specifications:

maximum continuous operating voltage	68 kV
overall length (with flanges)	1270 mm
core diameter of porcelain	150 mm
inner diameter of porcelain	110 mm
diameter of varistor elements	75 mm
length of varistor column	1100 mm
shed diameter (large/small)	265/235 mm
number of sheds (large/small)	17/16
leakage distance	3620 mm
specific creepage distance	38 mm/kV

The varistor column is mounted inside of the porcelain housing and is fixed to the housing using different constructions depending on the manufacturer. In most industrial designs there is an air insulation between the porcelain housing and the arrester column. Figure 1 shows the principal construction.

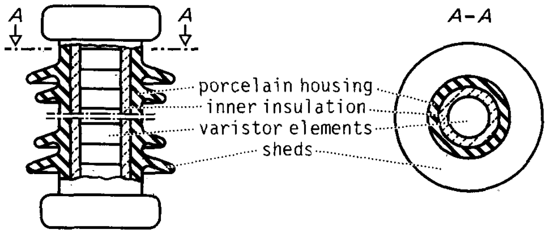

Figure 1: Principal construction of an arrester unit

For the measurement of the temperature distribution along the varistor column a special sensor was fixed to the arrester discs. The sensor was battery operated and its position along the varistor column could be changed. The transmission of the temperature to the recording system was done via a fibre optic link. This method could be used for temperatures up to 80 °C. To measure the temperatures during the same test at many different points small adhesive thermostrips were used which indicate the highest temperature during the test by a change of their colour.

The measurement of the voltage, of internal and external currents via shunts and of the temperature of the varistor column during the pollution tests was accomplished by use of a 16 channel fibre optic transmission and recording system with a memory of 60 kByte per channel, a maximum sampling rate of 10 kHz and a vertical resolution of 8 bit.

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3 PHENOMENA CAUSED BY POLLUTION AND DRY BAND FORMATION

3.1 Power Frequency Coupling Phenomena

During tests carried out according to the solid layer method it was observed that the formation of dry bands influenced the amplitude of the measured internal currents. Especially when there was only one dry zone near to one of the flanges of an arrester unit the temperature rise of the varistor column near the dry band was high. This was nearly independent of the presence of partial arcs across the dry zone. To investigate the influence of dry band formation on the stresses of the zinc oxide material (rise of internal current due to capacitive coupling) a special test has been carried out with a single arrester unit. First the arrester housing was polluted and dried. Afterwards at a certain location on the porcelain housing a dry zone of about 10 % of the total creepage length was formed artificially which was just large enough to prevent arcing across the dry zone. The A.C. test voltage of 68 kV was applied for several hours. During this test the internal and external currents were recorded.

Figure 2 shows the test arrangement with the estimated voltage distribution along the pollution layer and the inner varistor column for three locations of the dry zone. At an A.C. test voltage of 68 kV no partial arcs were burning arcross the dry zone and at the pollution layer. The wetting of the dried pollution layer was accomplished by an relative air humidity in the test room of more than 85 %.

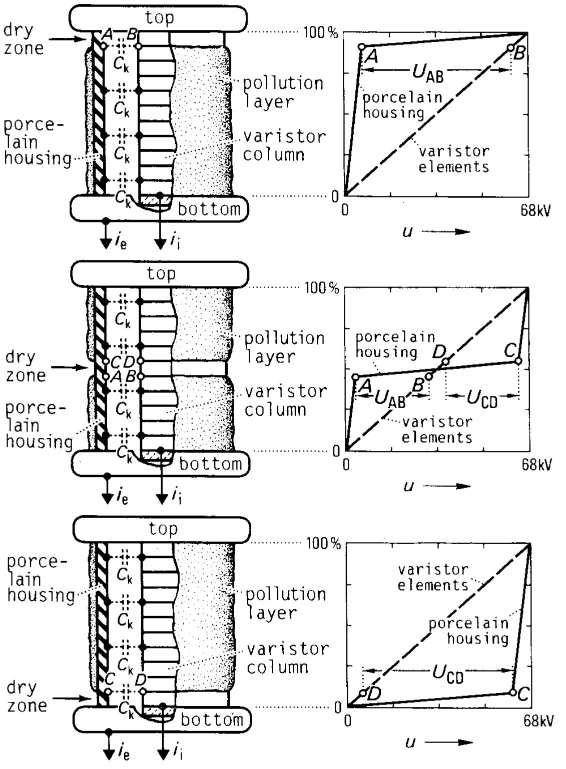


Figure 2: Influence of dry band position on the internal radial electric field

Because of the capacitive coupling between the varistor column and the pollution layer the current in the arrester discs is influenced by the voltage distribution along the external pollution layer. This leads to locally higher stresses of varistor elements near the dry zone.

In figure 3 the corresponding internal and external currents measured at the earth side of the arrester unit are shown. It can be seen that in the case of the dry zone at the bottom of the arrester the recorded peak value of the internal A.C. current reaches about 7 mA which is about 4 times higher than the corresponding value measured at the clean arrester unit (fig. 3d). The A.C. currents are accompanied by impulsive current spikes of both polarities (fig. 3c). With the dry zone at the top the sum of the amplitudes of both currents is again about 7 mA but this time 6 mA are measured outside and 1 mA inside. With the dry zone in the middle the sum of the amplitudes of the A.C. currents measured at the bottom is only about 3.5 mA (2 mA outside, 1.5 mA inside). No impulsive current could be observed.

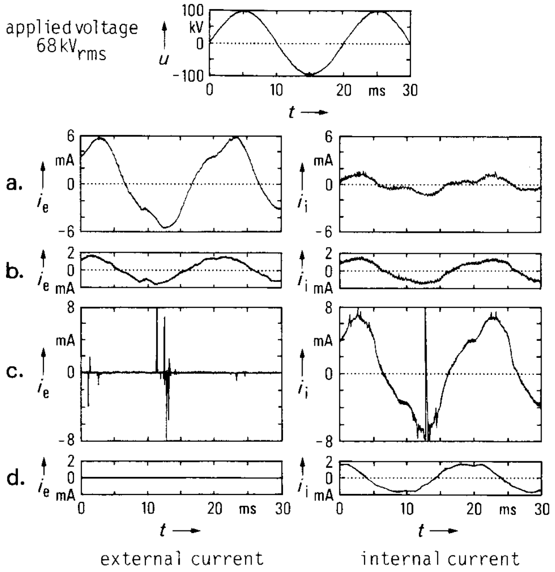


Figure 3: Influence of dry band position on the shape of internal and external currents

- a. dry zone at the top
- b. dry zone in the middle
- c. dry zone at the bottom
- d. clean arrester housing

In Figure 4 the influence of the dry band position on the measured peak amplitudes of the internal A.C. current is shown.

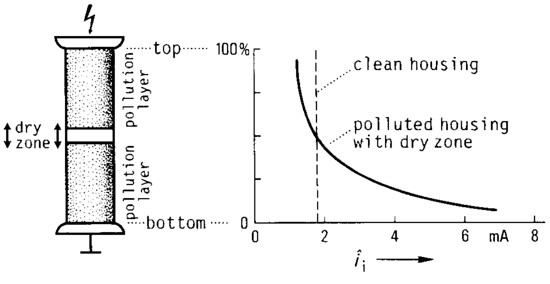


Figure 4: Influence of dry band position on the peak amplitude of the internal A.C. current

It can be seen that depending on the location of the dry band the amplitude of the internal A.C. current varies between a value that is smaller than under clean conditions and a maximum value being about 4 times higher. The current amplitudes depend on the construction of the arrester but the relative values will be similar for different designs.

This shows that due to the capacitive coupling between the pollution layer and the zinc oxide column the amplitude of the measured internal A.C. current depends on the location of the external dry zone of the pollution layer. Therefore under polluted conditions it is not possible to estimate the state of an arrester in service just by recording and evaluating the internal A.C. current at the bottom flange.

3.2 Thermal Stresses

In addition to the measurements of currents the maximum temperatures during the above described tests were recorded by means of thermostrips attached at different locations along the varistor column. In figure 5 the temperature distribution along the varistor column is shown after a test duration of 2 hours. The pollution layer was formed by a coating consisting of 5 g NaCl and 100 g Bentonite per litre of water and was allowed to dry for one day. During the test it was rewetted by a relative air humidity of approximately 85 % at an ambient temperature of 30 °C.

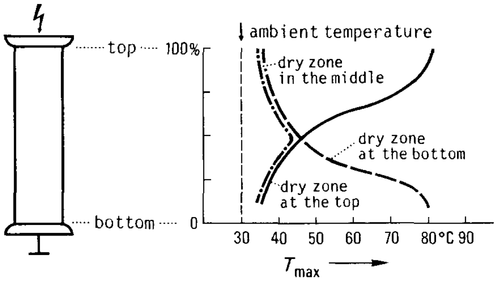


Figure 5: Temperature distribution along the varistor column of a single arrester unit with different dry band positions

It can be seen that with the dry zones at the flanges the temperature of the surrounding varistor elements can reach a value of about 85 °C. The maximum temperature of the varistor elements with the dry zone in the middle is only about 45 °C. The symmetry of the temperature profiles should be noted with the dry zone at the flanges. These results confirm that the A.C. currents are responsible for the temperature rise. A single dry zone near to one of the flanges results in the highest A.C. currents through that part of the arrester elements and therefore in a high local temperature rise near the dry zone.

To check whether the results obtained with a single arrester unit are also valid for a multi unit arrester the same test was carried out with two arrester units connected in series. The result of this test is shown in Figure 6. The highest temperature of the varistor elements was obtained with the dry zone of the upper arrester unit being at its bottom and the dry zone of the lower arrester unit at its top. A value as high as 105 °C was obtained at both varistor columns which is remarkably higher than the values obtained in the standard test procedures /4/,/5/. During the tests no partial arcs were burning across the dry zones.

To get the most severe condition for a certain design it is important to have no additional dry band formation during this test due to the A.C. current flowing in the pollution layer. To achieve this it might be necessary to enlarge the artificially modelled dry zone or to increase the amount of salt used for the pollution suspension which will decrease power dissipation in the pollution layer and prevent additional dry band formation. This will be necessary in case of longer arrester units or in case of a high coupling capacitance between the varistor column and the porcelain housing leading to a higher current in the pollution layer.

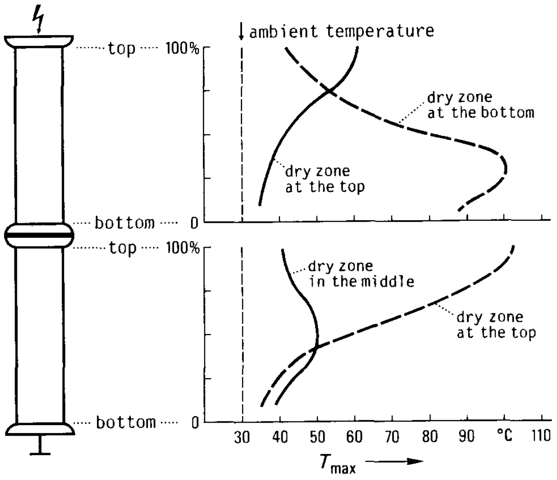


Figure 6: Temperature distribution along the varistor columns of two arrester units in series with different dry zone positions

3.3 Impulsive Currents due to External or Internal Discharges

Besides the A.C. currents responsible for the thermal stresses of the varistor elements impulsive currents were recorded during the pollution tests as shown in figure 3c. In general these current spikes can be observed on both the internal and the external current signals. They are caused by discharges on the porcellain surface (ignition of partial arcs, corona discharges) or by internal discharges between porcelain and arrester elements.

3.3.1 Impulsive Currents Caused by Internal Discharges

In case of only one dry zone at the bottom flange of the arrester housing there is a high radial electric field strength between the pollution layer and the varistor elements. This electric field is caused by the full applied test voltage only reduced by a small voltage drop along the outside pollution layer and the voltage drop along a few bottom varistor elements (see fig. 2). This voltage between the varistor elements and the pollution layer is distributed between the porcelain housing and the internal insulation system according to the geometrical arrangement and the dielectric permittivity of the materials used. If the internal insulation system between porcelain and arrester elements is not properly designed discharges may occur.

A slight corona discharge at the surface of the varistor elements or on the internal porcelain housing results in a small apparent charge in the pC range. In this case no spikes on the measured current signals can be seen. However, if there are observed complete flashovers in the insulation system between the internal porcelain housing and the varistor elements, the corresponding charge is in the nC range and causes spikes on the measured internal and external current signals (fig. 7). In most cases only one internal discharge during a 50 Hz half period could be observed. These internal discharges can occur in the positive and in the negative half period.

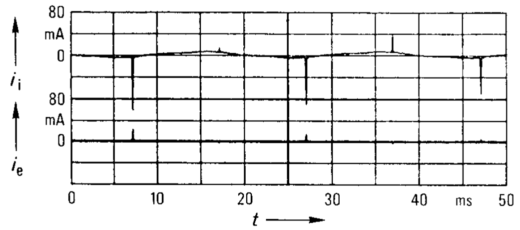


Figure 7: Impulsive currents caused by internal discharges (Dry zone at the bottom of the porcelain housing)

It can be seen (fig. 7) that the amplitudes of the negative spikes of the internal current signal are higher than the positive ones. This phenomena can be explained with the different breakdown voltages of inhomogeneous gaps.

If the dry zone is in the upper part of the arrester unit no current spikes can be measured with a measuring shunt at the bottom of the arrester unit (see fig. 3).

3.3.2 Impulsive Currents Caused by External Discharges

Current pulses on the measured internal and external currents due to external discharges are caused by the ignition of partial arcs on the pollution layer but also by glow discharges on the porcelain surface. To ensure that there are only external discharges when investigating their influence on the current signals the internal air volume of the arrester under test was filled with SF_6. Due to the 3 times higher dielectric strength of SF_6 compared to air internal discharges did not occur and the influence of external discharges on the current signals could be studied. Figure 8 shows the internal and external currents measured at the bottom flange obtained with glow discharges near to the dry zone. These external glow discharges result in small current spikes of a few milliamperes. For MO arresters these small current spikes are not dangerous because their contribution to the internal power dissipation is negligible compared to the 50 Hz currents caused by capacitive coupling between the porcelain housing and the varistor column.

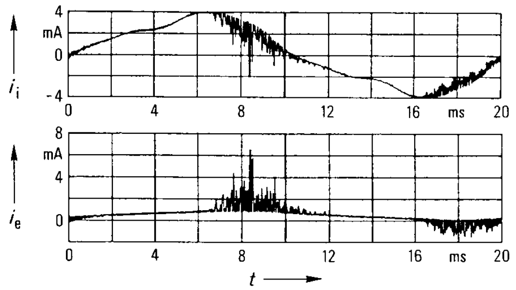
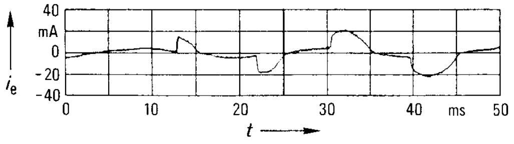
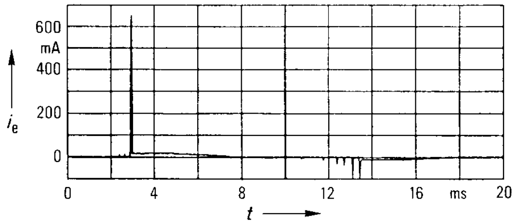


Figure 8: Current spikes caused by external glow discharges (Dry zone at the bottom of the porcelain housing)

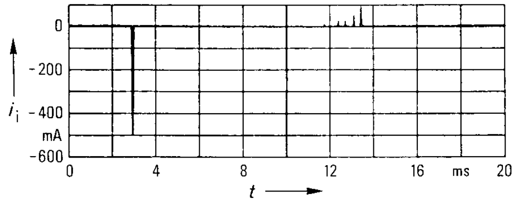
The impulsive currents caused by single partial arcs (fig. 9) can have a much higher amplitude than that ones caused by external glow discharges. During pollution tests with single arcs across dry zones current pulses in the internal and external current signal up to 1 A could be measured if the dry zones were at the bottom flange (fig. 9b). Again these current spikes could only be measured if the dry zone was at the bottom flange. In addition the shape and the amplitude of these currents is quite similar to the current pulses caused by internal discharges. It should be noted that under natural pollution arcing across a dry zone is a rather unstable process. A single arc across a dry zone will occur rather seldom for a longer time. It can only exist if the surface conductivity is small and the wetting rate of the pollution layer has a certain value. Under natural pollution normally glow discharges will occur.



a. external current



external current



b. internal current

Figure 9: Current spikes caused by external discharges
a. Dry zone at the top of the housing
b. Dry zone at the bottom of the housing

In summary of the observations, it can be concluded that internal current spikes produced by either external or internal discharges are similar. If external and internal discharges occur at the same time it is impossible to decide which spikes in the internal current signal were caused by internal and which were caused by external discharges. Therefore it is necessary to avoid external discharges if an arrester has to be checked for internal discharges. This can be performed during type tests. Then this procedure is an excellent method to compare different constructions of internal insulation systems and to prove for a certain design the absence of internal discharges under extreme conditions.

3.3.3 Theoretical Investigations

To prove the afore mentioned behaviour a model of a MO arrester unit under pollution was developed. For the calculation of the internal and external currents the equivalent circuit shown in figure 10 was used. The total arrester unit is modeled by a series connection of 5 single arrester elements considering the electrical characteristics of the MO material (R(i), C_a), the coupling capacitances between the pollution layer and the varistor column (C_p, C_k) and the influences of the pollution layer and the dry zone (R_p, R_c).

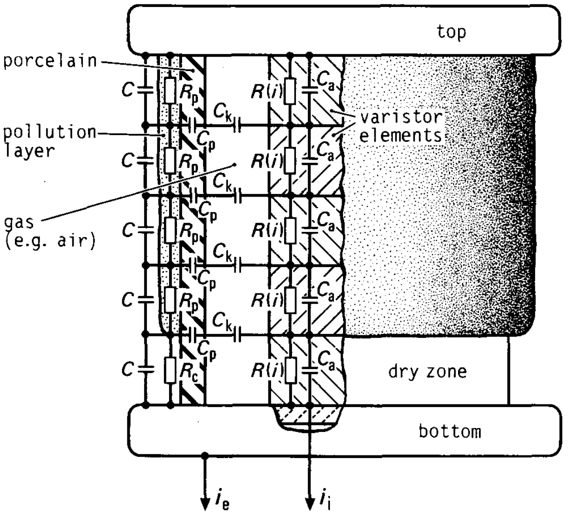
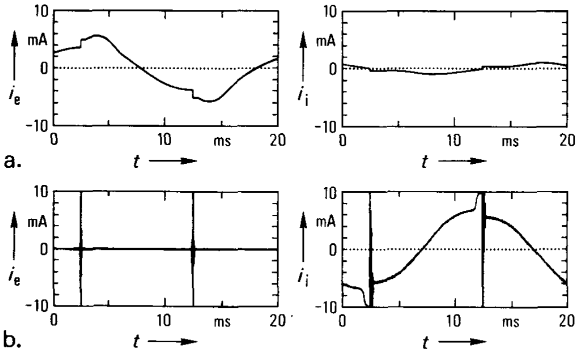


Figure 10: Model of an arrester unit under pollution
R(i) - nonlinear resistor
C_a - capacitance of varistor material
C_k - coupling capacitance of internal insulation system (e.g. air)
C_p - coupling capacitance of porcelain
R_p - pollution resistance
R_c - restistance of dry zone
C - longitudinal capacitance

Assuming different breakdown positions, e.g. across the dry zone or between the porcelain housing and the varistor elements (capacitance C_k), the internal and external currents at the bottom were calculated and compared to the measurement. In figure 11 the calculated current signals are shown for an internal breakdown across C_k. These signals have to be compared to the results of the measurement in figure 3.

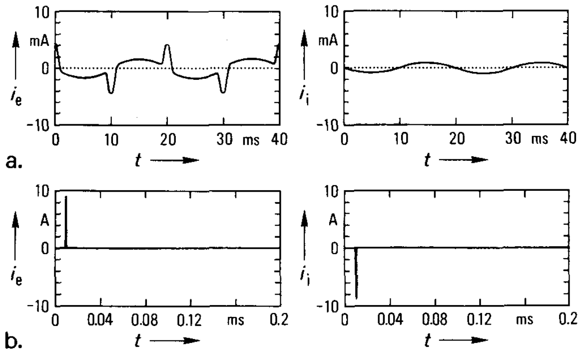


external current internal current

Figure 11: Influence of the dry band position on the calculated shape of internal and external currents with an internal breakdown (across C_k)
a. dry zone at the top
b. dry zone at the bottom

The comparison results in a rather good agreement and confirms the assumptions for the model. The first peak in the internal current (fig. 11b) is due to the nonlinear resistor, the breakdown of the inner insulation system results in the high current spikes. Similar shapes of current signals can be observed in fig. 3c. Also the internal breakdown with a dry zone at the top (fig. 11a and fig. 3a) results in comparable current signals.

In figure 12 the current signals for an external breakdown across the dry zone are shown. These calculated signals have to be compared with the measured signals of figure 9. Again the shape of the current signals are identical, confirming the correct modelling.



external current internal current

Figure 12: Influence of the dry band position on the calculated shape of internal and external currents with an external breakdown across the dry zone
a. dry zone at the top
b. dry zone at the bottom

Thus further investigations can be performed with computer model. The calculated shapes show that the relative high voltage across the dry zone may cause high currents in the adjacent arrester elements located in the nonlinear region of their voltage/current characteristic. This results in a higher power dissipation leading to an increased temperature. The characteristic shape of the current signals for external or internal breakdowns can be investigated and used for controlling the performance of arrester units in service.

4 RESULTS OF POLLUTION TESTS WITH STANDARD TEST PROCEDURES

For comparison to our tests described above pollution tests according to the ANSI test procedure /4/ and the solid layer test procedure /5/ were carried out.

4.1 Pollution Tests according to the ANSI Test Procedure

Figure 13 shows the temporal development of the temperatures measured in the middle of the varistor columns of a two unit zinc oxide arrester with a test voltage of 136 kV.

The one hour conditioning test resulted in a temperature rise of the upper arrester unit of about 2 °C. The following 15 minute test cycle with the pollution layer applied to the bottom porcelain housing causes an additional temperature rise of 18 °C and the second 15 minute test cycle gives another temperature rise of 12 °C. During the following 70 minutes the temperature of the varistor column decreases steadily which proves thermal stability of the arrester. Therefore the test voltage is switched off.

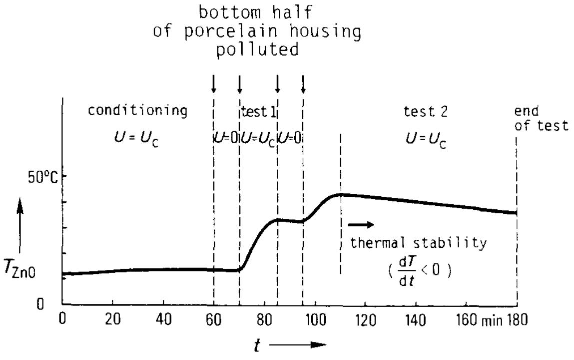


Figure 13: Temporal development of the temperature of the upper varistor column during an A.C. pollution test of a 136 kV two unit zinc oxide arrester according to the ANSI test procedure

The tests carried out with two arrester units in series showed a good reproducability and a small scatter of the obtained temperature rises. The temperature rise is caused by coupling in the leakage current of the bottom arrester unit to the varistor column of the upper arrester unit. Due to the clean housing of the upper unit there are no stresses due to a high radial electric field inside of the top arrester unit.

Tests with a single arrester unit with the lower 50 % of the porcelain housing polluted resulted in a smaller temperature rise of about 10 °C after a test duration of 3 hours. In case of a high air humidity of 95 % inside of the test room the temperature rise was up to 30 °C due to the wetting of the applied pollution layer.

In principle this test corresponds to the pollution tests described in section 3.1. The only differences are the larger dry zone and the other method used for the wetting of the pollution layer influencing the duration of the test. The results can be explained by the larger dry zone leading to a smaller radial electric field. As a consequence the A.C. currents coupled in the arrester will be reduced which results in a smaller temperature rise.

4.2 Pollution Test According to the Solid Layer Method

The suspension used for the pollution of the arresters consisted of 40 g Bentonite and 5 g sodium chloride (NaCl) per litre of water. The wetting of the pollution layer was done by steam fog. The maximum surface conductivity was about 10 µS. After the application of the test voltage the temperatures of the varistor elements of the arresters under test were measured by a small battery operated sensor inside of the arrester housing mounted in the middle of the varistor column, which transmitted the measured temperature values via an optical fibre to a receiver unit. The maximum temperatures were obtained 4 to 5 hours after the application of the A.C. test voltage and were in the range from 5 to 20 °C. The reproducability of these tests was bad indicated by a big scatter of the maximum temperatures.

As shown in figures 5 and 6 the thermal stress of the varistor elements is mainly caused by the coupling in of 50 Hz currents due to different voltage distributions inside and outside of the arrester. The maximum temperature rise and its position at the varistor column depends on the number and position of the dry zones on the porcelain housing which randomly varies during pollution tests according to the solid layer method. This is the reason for the big scatter in the test results. The same explanation may be valid for a large scatter reported on A.C pollution tests with the salt fog test procedure /3/.

4.3 A New Proposal for Pollution Testing of MOAs

The above test results have shown that the critical conditions for metal oxide arresters under pollution are not always covered by the conditions modelled by the standard test procedures. For this reason a test procedure for type testing of arrester units or for comparing different designs is proposed which should be used to substitute or at least to complete other procedures for pollution testing of MOAs.

The proposed test procedure consists of a check of thermal stability and of a test which allows to detect internal discharges under extreme conditions. The proposed test has to be carried out as follows:

- The arrester under test has to be polluted and dried as described in the solid layer method /5/. The suspension for the coating of the porcelain housing should consist of 5 g NaCl and 100 g Bentonite per litre of water.

- At the bottom flange of the arrester a dry zone of about 10 % of the creepage length has to be modelled. To prevent during the following test additional dry band formation on the pollution layer and arcing across the dry zone it might be necessary to increase the length of the modelled dry zone or the amount of salt used for the pollution layer.

- For the measurement of the temperatures along the varistor column serveral small adhesive thermostrips may be placed along the varistor column indicating the maximum temperature by a change of their colour.

- Afterwards the air humidity in the test room is increased to 85 % and the A.C. test voltage equal to the maximum continuous operating voltage of the arrester is applied for 5 hours.

- The arrester is checked for internal discharges by measuring the current through the varistor column at the bottom flange. The arrester under test is free of internal discharges if there are no current spikes superimposed to the registered A.C. current signal. It is important to have no external discharges near to the bottom flange during this test.

- The tested arrester has to be checked for internal damages by measuring its power dissipation before and after the pollution test under clean conditions at approximately the same temperature. The evaluated values should not differ by more than 10 %.

- The evaluation of the maximum temperature of the varistor elements obtained during this test, indicated by the thermostrips, gives additional information about the thermal stresses the arrester has been exposed to during this test.

It should be noted that for these tests it is not necessary to have a powerful test source as it is for the standard pollution test procedures because there are no high current partial arcs. Furthermore it has to be noticed that the test results are not much influenced by the degree of pollution in terms of ESDD or surface conductivity but mainly by a sufficient wetting of the applied layer. At a relative air humidity of more than 85 % this wetting is ensured and the reproducability of the procedure was found to be rather good.

5 CONCLUSIONS

Dry band formation on polluted metal oxide surge arresters at A.C. voltages may result in:

- rise of the internal A.C. current in the arrester column up to 4 times higher than under clean conditions due to the capacitive coupling between the pollution layer and the varistor column, if the dry band is near to one of the flanges.
- high local temperatures at the varistor column near to the dry band depending on the size and position of the dry band.
- discharges inside of the arrester due to a high radial electric field strength indicated by current spikes superimposed to the internal A.C. current.

The proposed test procedure is an extreme long duration test modelling worst conditions caused by artificial single dry band formation under high air humidity. It can be applied to check the thermal stability of arresters under extreme conditions. In addition the procedure can be used to compare different designs in respect to internal discharges. The protection of the arrester blocks against the effect of internal discharges can be investigated under controlled circumstances.

During the test internal discharges can be detected by measuring the internal current of the varistor elements at the bottom flange. This is possible due to the dry band at the bottom flange and the absence of external discharges. The test procedure has a good reproducability due to the absence of external partial arcs. The artificial modelling of a single dry zone result in a stable long time duration stress for the arrester under test.

ACKNOWLEDGEMENT

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REFERENCES

/1/ N.M. Vong, R. Miller, D.M. Ryder, R.M. Doone, L.J. Sparrow:"Deterioation in the Performance of Zinc Oxide Surge Arrester Elements Due to Partial Discharges", 6. Int. Symp. on High-Voltage Eng., New Orleans, USA, 1989, paper No. 27.22.

/2/ L.J. Sparrow, R.M. Doone:"UK Experience in the Investigation of Pollution Performance of MOSA", CIGRE Session 1988, Paris, paper 33-07.

/3/ A. Bargigia, G. Mazza, G. Le Roy, A. Rousseau, L.J. Sparrow:"Behaviour of MOSA under Different Environmental Conditions", CIGRE Session 1988, Paris, paper 33-14.

/4/ Standard for Metal Oxide Surge Arresters for Alternating Current Power Circuits, ANSI/IEEE C62.11-1987.

/5/ IEC Publ. 507:"Artificial Pollution Tests on High-Voltage Insulators to be used on A.C. Systems".

/6/ E.G. Maier, R.M. Rudolph, W. Schmidt, F. Hunziker: "Voltage Distribution and Pollution Performance of Metal Oxide Arresters". CIGRE Session 1986, Paris, paper 33-12.

/7/ A. Rousseau, P. Gourmet, H. Niklasch, F. Buret: "A New Use of Pollution Tests of ZnO Arresters", 6. Int. Symp. on High-Voltage Eng. New Orleans, USA, 1989, paper No. 27.17.

/8/ K. Chrzan, W. Köhler, K. Feser:"Behaviour of Zinc Oxide Surge Arresters Under Pollution", 6. Int. Symp. on High-Voltage Eng., New Orleans, USA, 1989, Paper No. 26.01.

Kurt Feser was born on December 10, 1938 in Garmisch-Partenkirchen, F.R. Germany. From 1958 to 1963 he studied Electrical Engineering at the Technical University of Munich, finishing with the "Diplom-Ingenieur". After a year with Brown Boveri and Cie AG in Mannheim, Germany, he joined the high-voltage institute of the University of Munich.

In 1970 he received his Dr.-Ing. from the University of Munich, and in 1971 he joined Haefely & Cie AG, Basel, Switzerland as chief development engineer for high-voltage test equipment. From 1980 he was responsible at Haefely & Cie for capacitors, high-voltage test equipment and accelerators and was as director member of the executive board of Haefely. During 1977 to 1980 Dr. Feser was member of the board of Directors of American High Voltage Test Systems, Accident, Maryland.

In April 1982 he joined the University of Stuttgart as head of the power transmission and high-voltage institute. Prof. Feser is fellow of IEEE, member of VDE and CIGRE, chairman of CIGRE WG 33-03 "High-voltage test technique" and author of about 100 papers.

Wolfgang Köhler was born on June 21, 1956 in Schwäbisch Hall, F.R. of Germany. From 1976 to 1981 he studied Electrical Engineering at the University of Stuttgart finishing with the "Diplom-Ingenieur" degree. Since 1981 he is with the power transmission and high-voltage institute of the University of Stuttgart, where he became chief of the high-voltage laboratory in 1984.

In 1988 he received his Dr.-Ing. from the University of Stuttgart.

His current research work deals with high-voltage test and measurement procedures.

Donggang Qiu was born on May 1, 1954 in Shanghai, China. He studied at the Technical University of Huanan, China and at the Shanghai Jiao Tong University, China. He received his Master degree in electrical engineering from Shanghai Jiao Tong University in 1981. In 1981, he joined the Institute of High-Voltage Technique of Shanghai Jiao Tong University.

Since November 1986, he is with the power transmission and high-voltage institute of the University of Stuttgart, F.R. Germany. His current researches are surge arresters and their simulation.

Kristian Chrzan was born on October 19, 1955 in Odolanow, Poland. From 1970 to 1983 he studied Electrical Engineering at the Technical University of Wrocław, Poland. Since 1983 he is with the high-voltage institute of the Technical University of Wrocław where he received his Dr.-Ing. in 1987.

From 1987 to 1989 he was a scholar of the Alexander von Humboldt Fellowship at the high-voltage laboratory of the University of Stuttgart.

Discussion

Y. I. Musa (AEPSc, Columbus, Ohio): The authors of the "Behavior of Zinc Oxide Surge Arrester Under Pollution" are to be congratulated for writing a fine paper. The authors concentrated on the arrester internal design which is important to the arrester stability when it is subjected to contamination. However, the authors didn't address the importance of the arrester external housing design, leakage distance and porcelain shed design. Also arrester contaminant washing during clean fog test and means to assure arrester contaminant wetting during their proposed tests.

The purpose of the contaminant test is to simulate field condition as much as possible which I didn't see in the paper. It is difficult to see the arrester contaminated in the field with a dry band at the bottom of the arrester. In my opinion, the contamination test specified in ANSI/IEEE C6211-1987 is only a partial wetting test and not a complete contamination test for the arrester. I believe that an overall contamination test for zinc oxide arrester should be investigated keeping in mind the arrester internal design as indicated in this paper.

Two main reasons for arrester contamination should be considered 1) arrester thermal runaway and 2) partial or complete arrester flashover. I would like the authors to respond to the following questions:

1) How does the new proposed method simulate field condition?
2) How does the new proposed method test the arrester design for partial or complete arrester flashover?
3) How does the new proposed test prevent contaminant washing during the test?

K. Feser: We would like to thank Mr. Musa for his discussion giving us the opportunity to clarify our intention. The proposed test procedure is recommended as a design test for an arrester and not as a routine test. It should show the correct internal construction under heavy conditions of contamination. Normally this condition is not given under field environment. The purpose of this test is to demonstrate even under severe conditions the absence of partial arcs inside the arrester. These partial arcs were responsible for complete arrester destruction under service condition in a polluted area. By comparing different designs or by assuming a certain severity of pollution the test can demonstrate the adequate internal construction and the thermal stability of arrester blocks. The test is not intended to replace any pollution test on the complete arrester, especially taking into account the external housing design or washing procedure.

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